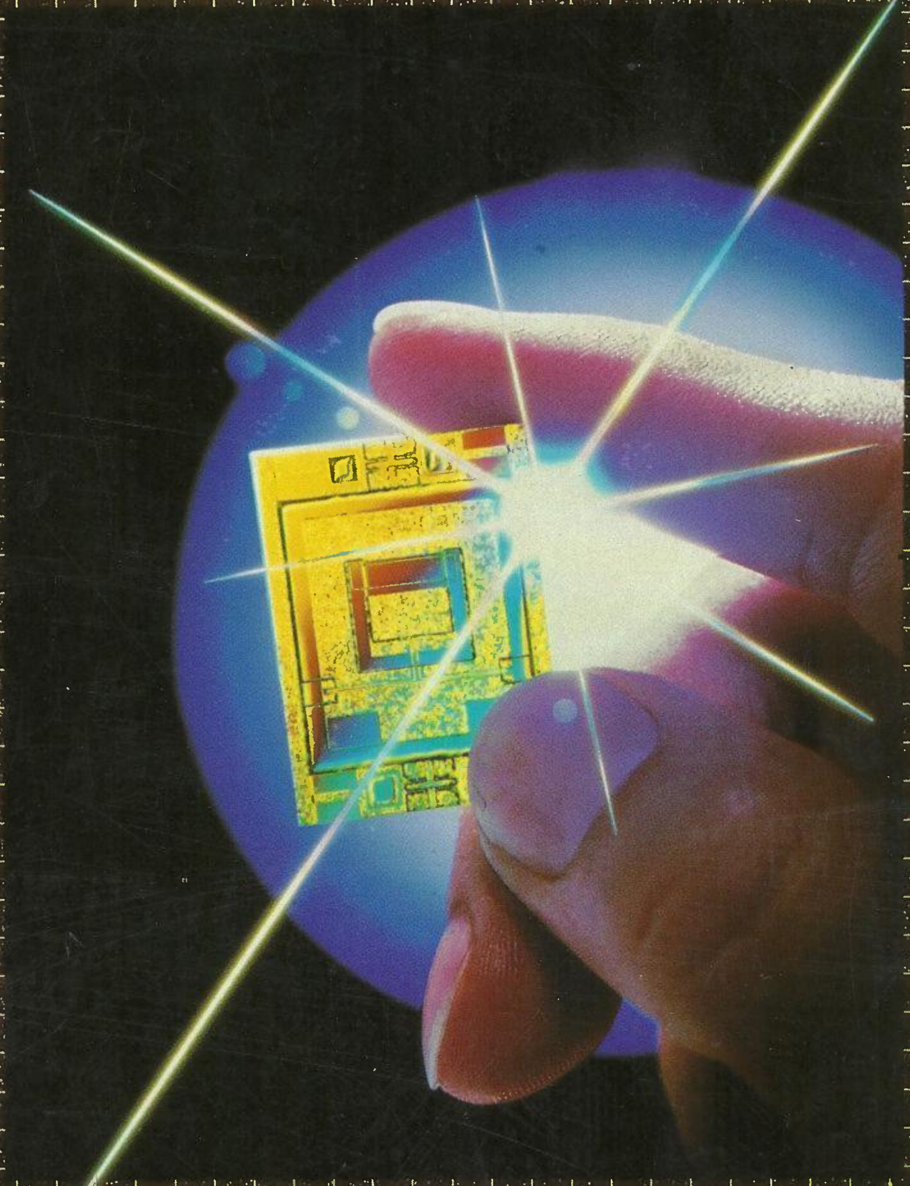
DARE TO DISCOVER



RESEARCH DEPARTMENT OPEN DAYS 1985

Telecom Australia

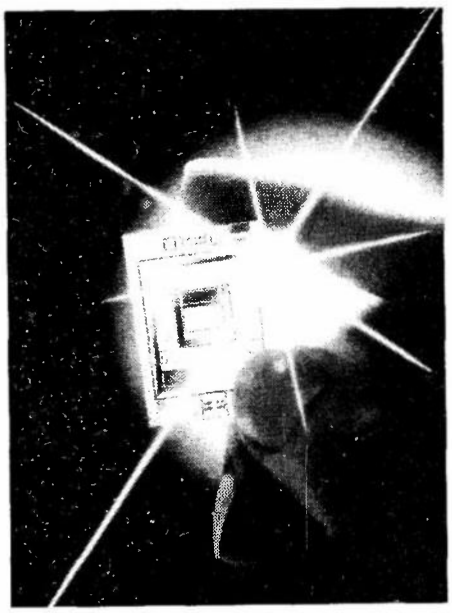
DARE TO DISCOVER

To discover is the essence of research. Discovery is the realization of vision.

Research can be expensive and achievement of a favourable outcome cannot be guaranteed. However, benefits from successful research can enormously outweigh the cost. Judgement in the choice and direction of research is crucial if the proportion of successful work is to be rewardingly high.

RESEARCH DEPARTMENT OPEN DAYS 1985

Telecom Australia



COVER PHOTOGRAPH:

A 100 times magnification of a two-dimensional, electron gas, field effect transistor (TEGFET) made in the Research Department. Telecom's Research Department is the only Australian laboratory capable of producing this revolutionary semiconductor device.

FOREWORD

This booklet has been prepared as a record of the highly successful Open Days conducted by the Research Department of Telecom Australia between 1 to 6 July 1985 (inclusive).
The Open Days were formally declared open by Mr R W Brack, Chairman, Australian Telecommunications Commission. During the week of Open Days, some 12 000 people from within Telecom Australia, the Australian telecommunications industry, other research institutions, academia and the community at large took the opportunity to visit the Research Department and to view and discuss a wide variety of projects, activities and facilities.
The spectrum of this work was demonstrated by just over 100 exhibits, each manned by staff and supported by short descriptive monographs on the topic of the exhibit. A large central display provided a focus for exhibits distributed throughout the Department's laboratory complex at 770 Blackburn Road, Clayton, providing a summary introduction to the six major themes under which most exhibits had been assembled.

This booklet gives a brief history of the Research Department and records the exhibits and the associated monographs in terms of the major themes, namely:
- Human Factors in Telecommunications
- Telematique Services
- Integrated Services Digital Network
- Optical Fibre Communications
- Satellite Communications
- Materials Science.

Other exhibits not recorded under the major themes are categorized as those relating to scientific reference standards, instrumentation and laboratory facilities.

H.S. Wragge
DIRECTOR, RESEARCH

CONTENTS

FUNCTIONS OF THE RESEARCH DEPARTMENT

The Department provides the technological research and development support needed to allow Telecom Australia to carry out its day-to-day activities and to prepare for the technological demands of the future. In general terms the research and development objectives of the Department are :

(a) to ensure that research and development are undertaken at an adequate intellectual level and in sufficient fields of work to satisfy its needs for new knowledge, new expertise and new developments,

(b) to assist the Australian telecommunication manufacturing industry in maintaining the required level of innovation and up-to-date manufacturing technology and

(c) to encourage universities and other tertiary education institutions to accord telecommunications research a prominence that will attract talented engineering and science students in sufficient numbers to meet future national needs.

CHARTER

With these objectives in mind the Research Department operates to the following charter:

(a) to conduct research and development in telecommunications theory and practice, particularly as applying to the Australian region,

(b) to appraise new developments in telecommunication equipment and in appropriate cases to conduct field trials,

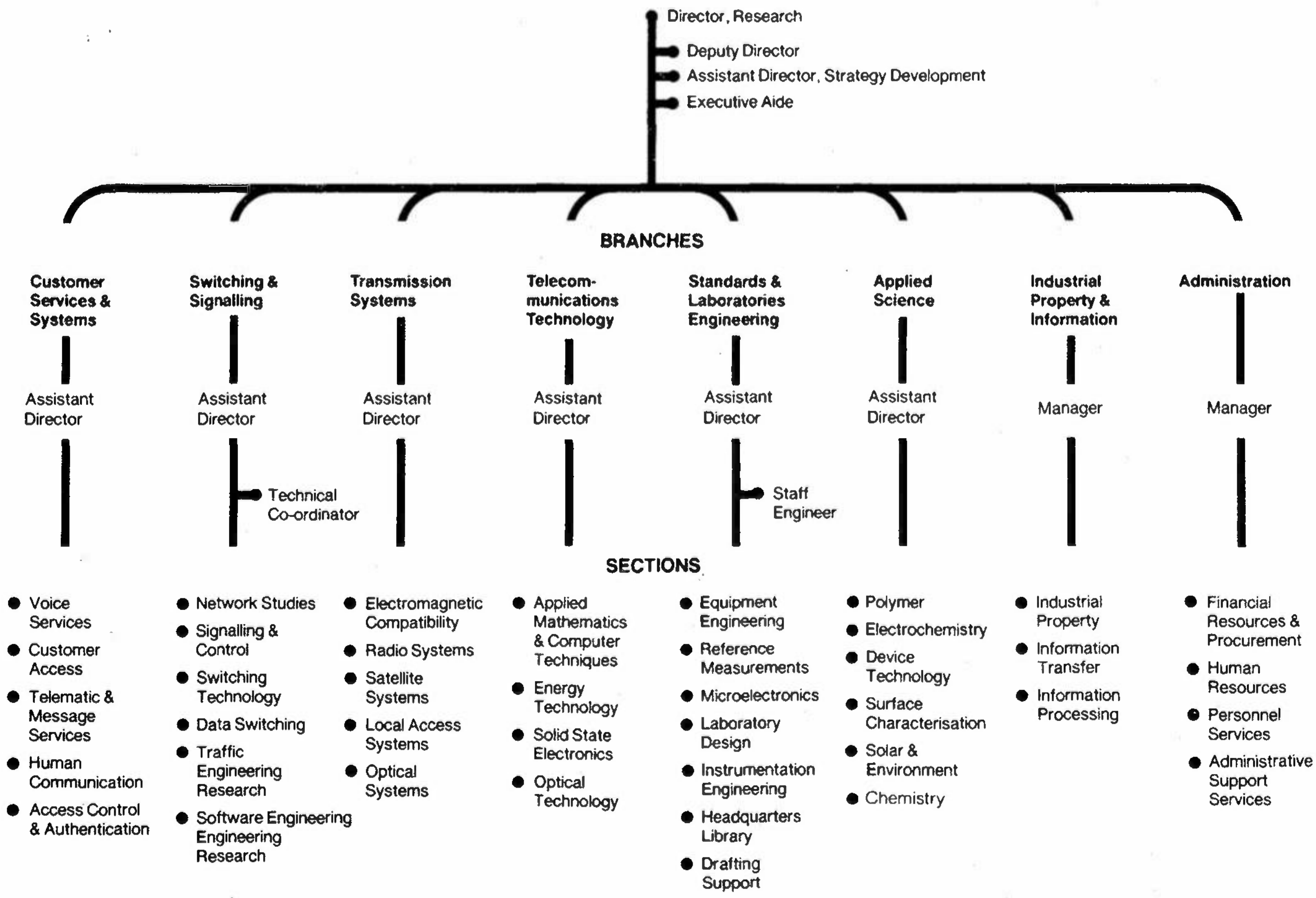
(c) to develop apparatus and systems that are required in the Australian communications network and are not available from commercial sources,

(d) to act as consultant on scientific and engineering matters to Telecom Australia,

(e) to participate in the work of national and international organizations associated with telecommunications research and to be represented on their committees and

(f) to encourage research and development in telecommunications and allied disciplines in tertiary education institutions and industrial laboratories.

RESEARCH DEPARTMENT ORGANIZATION



The Research Laboratories' Organisation

CONTRIBUTIONS TO RADIO BROADCASTING

From 1925 onwards, the Department's staff became involved in the transmission of radio broadcast programs over the trunk network, engineering in 1925 the first simultaneous interstate broadcast in Australia. The occasion of this broadcast was a promotion of a Commonwealth Conversion Loan by the Secretary to the Treasury, Mr. J.R. Collins, via a network hook-up of six radio stations — 2FC, 2BL, 3LO, 3AR, 4QG and 5CL. The Department went on to arrange the nation-wide broadcast in 1927 of the first opening in Canberra of the Commonwealth Parliament, by manning a similar transmission network for the radio broadcast stations of the day.

Between 1925 and 1927, the Department was equipped to conduct radio frequency field strength measurements and was carrying out these measurements on the medium frequency broadcast transmitters. At this time, decisions were made to extend and upgrade the National Broadcasting stations to provide a reliable service to 90% of the population and, in 1927 Mr Witt and several other of the Department's staff were seconded to plan the present National Broadcasting System. Following the planning phase, which lasted several years, the Department was closely involved with the implementation of the plan, going on to design broadcast transmitting equipment and antenna systems, evaluating studio equipment and the like during the years prior to World War II.

This direct involvement with the implementation of radio broadcasting has since ceased but it is of note in that it led from medium to high frequency (HF) broadcasting, the Department setting up the first Australian HF transmitter on an experimental basis at Lyndhurst, Victoria, in 1928 and later developing it until it provided a regular service. This early involvement with radio built up the expertise in transmitter design, antenna design, radio field strength measurements and propagation theory that was turned to VHF (very high frequency) radio telephony applications and investigations in the late 1930s. In 1938, when the submarine cable link to Tasmania was under repair, the staff of the Department were instrumental in establishing the first APO radio telephone system from Mount Tanybryn in Victoria to Stanley in Tasmania, a distance of 270 km across Bass

THE 1932 MOVE INTO SPACIOUS ACCOMMODATION

By 1932, the staff had increased to 35 and they had outgrown the 500 m^2 they then occupied in Melbourne House. (As another indicator of growth, the value of the Department's test equipment had risen from 3000 pounds in 1925 to 16 000 pounds in 1932). In this year they moved into what was then a spacious area of 2400 m^2 at 59 Little Collins Street, Melbourne, which remained the Head Office of the Research Department until 1978 when it was relocated to its present site at 770 Blackburn Road, Clayton. Before the complete relocation of the Department at Clayton at that time, the Department's activities had spilt over into a further six buildings at the eastern end of central Melbourne, and one at North Carlton.

THE 1940s — AND THEIR LINKS WITH CURRENT RESEARCH

The years of World War II saw the Department assisting in the development of radar systems and engaged in other work for the armed services. Following the war, the radio frequency activities of the Department turned more towards radio telephone systems. However, for a period after the war and as a preliminary to the introduction of television broadcasting into Australia, the Department was engaged on television propagation studies, as well as on a series of studies to determine the optimum parameters for a working television broadcast service. This latter work has now changed emphasis and is directed at studies of the coding of television signals for optimum bandwidth utilization, with particular attention being given to broadband digital systems of the future.

The extension of the radio telephony work at VHF and UHF has naturally involved the Department in the investigation of satellite systems and staff of the Department have participated in studies on the use of satellites for telecommunications purposes since 1960.

The post-war years have also seen an expansion of the Department's interest in broadband systems and guided transmission media — as might be expected with the addition of the newer video and high-speed data services to the older telephony and telegraphy services provided by the APO. The expertise developed by the Department

THE 1950s AND 1960s — SEMICONDUCTORS AND SYSTEMS

The invention of the transistor in 1948 led soon afterwards to the increasing use of these (and later generation) semiconductor devices in experimental systems in the Research Department. This was particularly evident in the growth of expertise and activity in the Department in the investigation and development of digital electronic switching and transmission techniques and systems. In particular, this advance was responsible for the Department becoming heavily committed in the technology of future generation all-electronic exchange systems. The Department set up its own facility for manufacturing micro-electronics prototypes in the early 1970s.

By contrast with the early preoccupation of the Department with the trunk network's individual transmission links, the evolution of Stored Program Controlled telecommunications networks since the late 1950s (and the evolution of mathematical systems theory since the 1940s) led, by a shift in conceptual emphasis, to the examination of the total network and its capacity to provide integrated services, telephony, data, facsimile, perhaps video — through a common network. Through research into Stored Program Controlled systems and networks and into advanced transmission, switching and signalling techniques, the Department was able to give informed advice to Telecom network planners on costs and facilities of networks and systems of the future.

PRINCIPAL THEMES OF THE 1985 OPEN DAYS

The work of the Research Department was summarized under six major themes, namely:

Human Factors in Telecommunications

Telematique Services

Integrated Services Digital Networks

Optical Fibre Communications

Satellite Communications

Materials Science.

Most exhibits for the Open Days were grouped under these major themes. Most exhibits were also manned by staff who were able to provide visitors with outlines of the work depicted. Monographs were also made available at most exhibits to provide visitors with brief written outlines of the work portrayed and its objectives.

Other exhibits displayed Departmental activities relating to scientific reference standards, instrumentation and special facilities provided by the Department in support of Telecom's operations.

The following pages record:

- the six major themes
- the exhibits grouped under each theme
- the monographs associated with the exhibits.

HUMAN FACTORS IN TELECOMMUNICATIONS

Introduction

People and their need to communicate provide the only reason for telecommunications. The need to communicate explains why huge resources have been spent to build a worldwide telecommunication service. Now people can communicate to almost anywhere using the spoken word, text or moving and static images. With telecommunications, people can seek information stored remotely in computer data banks or they can monitor the performance of some distant physical process. Telecommunication options are already numerous and more will eventuate as knowledge grows with research and experience.

However, there is a hidden cost to this proliferation of telecommunication possibilities. The cost lies in the increased complexity of the telecommunication service. People could face considerable difficulty in the choice and easy use of telecommunications, unless services are designed and implemented to match human capabilities.

The study of human factors in Telecom's Research Department aims at understanding the requirements placed on telecommunication facilities to enable human users to communicate easily and effectively. Human Factors research generates guidelines for designing services and systems that people find easy to use whatever their level of experience might be.

What is Human Factors Research in Telecommunications?

The term 'Human Factors', for the Research Department's purposes, refers to those attributes of people that are important when using telecommunication services. They are the factors that should be considered when designing the terminal equipment and procedures that people use for telecommunication and when specifying the desired overall performance of the communication service.

The factors of concern may be physical. The shape and dimensions of the human skull affect the optimal design of the telephone handset. The factors may be psychophysical. The human ability to understand speech depends upon both hearing — the level of sound in the telephone receiver — and on the ability to interpret the sounds heard as speech. The last factor determines the limits to the ways in which the speech signal can be processed for cheapness and ease of transmission between telephones. For some types of telecommunication the important human factors may be cognitive; the procedures for using text messaging services require the user to read and understand instructions written on a video display screen and to act upon them. The written instructions and the procedures they describe must be carefully matched to the human abilities in this type of performance.

An Historical Overview

The need for human factors studies has grown over the years, slowly at the start, but more recently with increased rapidity. For 100 years, telephony was the only telecommunication service used directly by a general population. (Telegrams required the intervention of the telegraphist, who actually used the technical system.)

At first, the telephone was a magical device but the customer had a simple procedure — just pick up the receiver, turn the handle and listen for the operator. The expert operator would use the complicated switchboard to connect the customers. The main human factors problem with telephony was, and is, ensuring that people can hear and understand speech correctly. The Research Department, since its foundation in 1923, has worked on this problem and has contributed much to the international understanding in this area of knowledge. The result is an Australian telephone network that is equal to any other in its quality of speech communication.

During the last two decades, new technology, made possible by semiconductor devices (the transistor and its offspring, the microchip), has opened the door to a vast range of new services for general use in the community. The new possibilities have brought with them a new set of human factors problems, some of which have been studied by the Research Department, but many of which have still to be solved.

Video and audio teleconferencing received considerable attention in the 1970s and early 1980s. Psychophysical studies of human vision produced information on the performance that would be required of television systems if they were to be suitable for video-conferencing. Research into the human factors of group communications led to several exploratory developments in audio teleconferencing, some of which have been offered commercially.

The advent of computers into telecommunication in the most recent years has brought about a new direction in human factors studies in the Research Department. The cognitive capabilities of humans to understand and operate computer based telecommunication services, such as telematique and message services, is an important area of study. It has been the focus of human factors research during the last two to three years and mirrors a growing concern in international laboratories. The demands of Telecom's customers for 'user friendly' telecommunications will lead to greater emphasis on this research in the future.

Telecom's Interest in Human Factors Research

The application of the results of the human factors research is an essential element in meeting Telecom's paramount commitment to provide up to date, affordable and efficient communications throughout Australia (Telecom Annual Report 1983-84). This is clearly seen in telephony, where the goal is that all telephone connections must enable speech communication to take place to a satisfactory standard. Human factors research aims at determining what is a satisfactory standard as seen by the Australian population in Australian conditions.

However, Telecom's commitment to providing up to date services means that our knowledge must grow beyond the human factors relevant to telephony and into the field of computer based telecommunications. The value added network services that telecomputing makes possible must match the users' capabilities if these offerings are to be acceptable to Telecom's customers.

The Research Department's Role and Contribution

The Research Department will continue with its human factors studies on speech. The future emphasis in the digital environment will be on the use of speech signal processing techniques, such as adaptive differential pulse code modulation encoding, the acceptability of their use in the telephony network and the acceptability of different types of synthetic voice used for voice announcements.

However a significant proportion of the Research Department's resources in human factors research will be directed to studies of the issues related to computer based telecommunications.

This is a new field that has been recognized as a significant problem area by the International Telegraph and Telephone Consultative Committee (CCITT). The VIIITH CCITT Plenary Assembly Meeting in October 1984 agreed to study a new set of questions dealing with the problems during the 1985-88 study period. The same problem area has arisen in computing where the spread of personal computers has brought untrained people, whose business is other than computer programming, face-to-face with the difficulties of controlling a complex logic machine.

Current understanding of human factors in computer based telecommunication is very pragmatic and based on experience of what works, particularly the experience and preferences of the expert software designer. Some general principles are agreed as being necessary but many questions still exist. Much of the knowledge reported in the literature is valuable for the designer and service provider, who must get services into the market place; however, more and better knowledge will help ensure that the most usable services become available to the customer.

The Research Department has built up a small, skilled, interdisciplinary team of psychologists, engineers and technical officers to investigate the area. This team is well equipped to contribute to developing our understanding of what will make Telecom's new computer based telecommunications easy for our customers to learn to use and to continue to use efficiently.

It is worth noting that the research does not take place exclusively in the laboratory. The results of laboratory experiments are as far as possible further tested in the field, with strong attempts being made to duplicate real life conditions.

The Benefit to the Customer

Most telecommunications users have had experience with modern products that are complicated to use. Many people have difficulties with the range of options available on some washing machines or the time clock mechanisms on stoves or video recorders. Hence it is fairly obvious that considerable effort is worthwhile in designing telecommunications to be readily usable. Most people want their telecommunications service as a tool, not a challenge. They want services that enable them to get on with their main business efficiently and effectively. Telecom's human factors research effort is aimed at providing just such a tool.

LIST OF EXHIBITS

In the English language there are approximately forty distinguishable, mutally-exclusive sounds. These basic linguistic elements are called phonemes and are shown in Table 1 below. Their manifold acoustic variations are called allophones.

Table 1. The Sounds of Speech

VOWELS

Front	Central	Back
/i/ heed	/ɜ/ bird	/u/ boot
/ɪ/ hit	/ɚ/ over	/ʊ/ foot
/e/ hate	/ʌ/ up	/ɒ/ pot
/ɛ/ met	/ə/ ado	/ɔ/ all
/æ/ at	/o/ boat	/a/ father

FRICATIVE CONSONANTS

Place of Articulation	Voiced	Unvoiced
Labio-Dental	/v/ vote	/f/ for
Dental	/ð/ then	/θ/ thin
Alveolar	/z/ zoo	/s/ sea
Palatal	/ʒ/ azure	/ʃ/ she
Glottal		/h/ he

	Stop Consonants		Nasals	Semi-Vowels	Glides
	Voiced	Unvoiced			
Labial	b/ be	/p pay	/m/ me	/j/ you	/r/ read
Alveolar	/d/ day	/t/ to	/n/ no	/w/ we	
Palatal	/g/ go	/k/ key	/ŋ/ sing		/l/ let

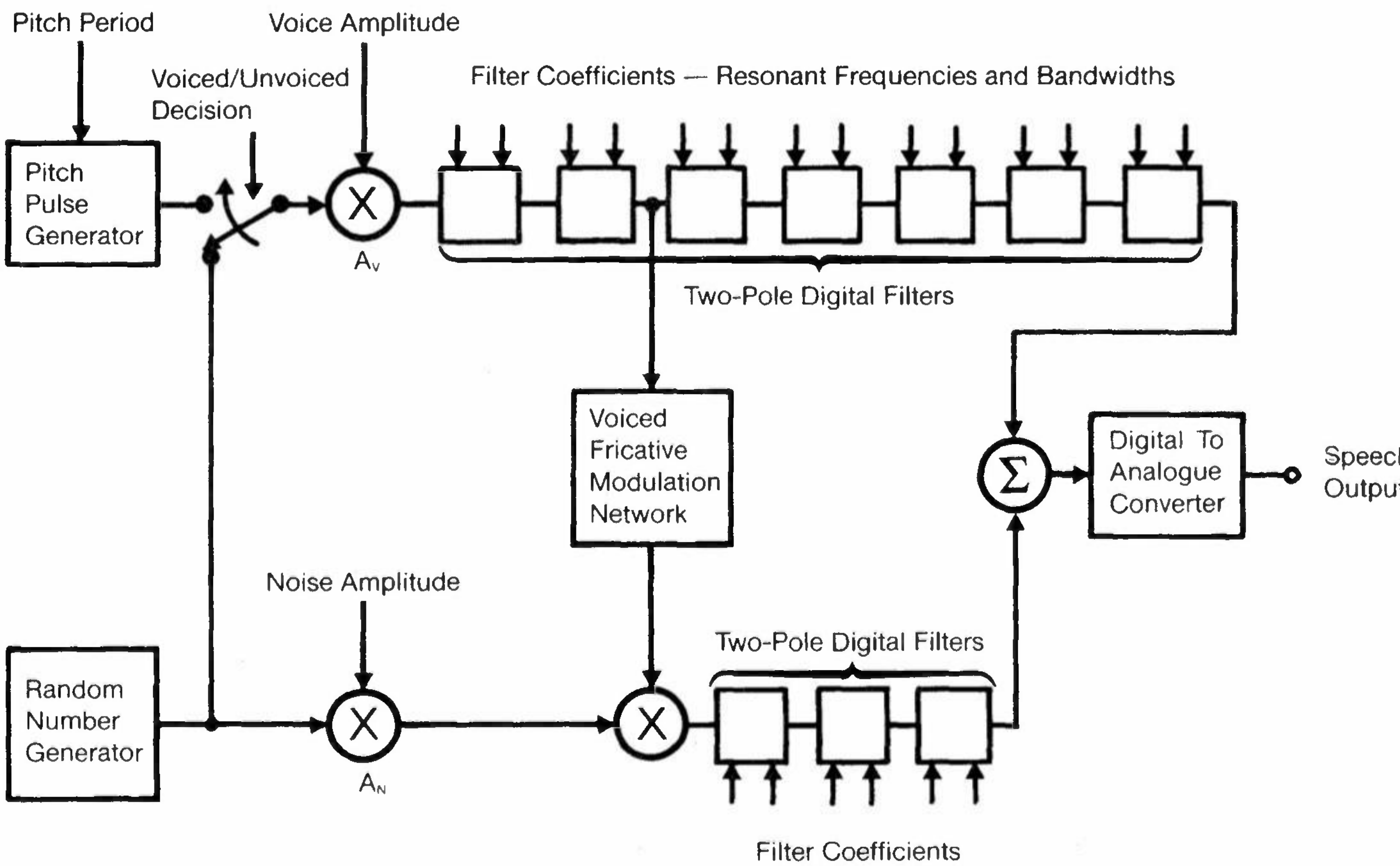


Fig. 2. A Digital Serial Formant Speech Synthesizer

A Text-To-Speech System

A complete text-to-speech system is depicted in Fig. 3 *(over)*. The preprocessor accepts textual input, identifies sentence length segments and isolates individual word units, which are checked against an inventory of non-lexical items (e.g. numbers such as 1000, money values such as $1.50 or abbreviations such as Dr.) for which a phonological representation is substituted.

The word units are then checked against a lexicon, which contains around 300 words and caters for approximately 80% of the most common words used in the English language, from which a phonetic transcription is determined. If the word unit is not contained in the lexicon, a set of rules must be applied to determine the phonetic transcription.

Once a phonetic transcription has been obtained, context sensitive rules are applied to the sentence as a whole to generate variation in stress and appropriate changes in pitch. The synthesis by rule component accepts these phonetic transcriptions and produces time-varying synthesizer parameters, from which speech can be synthesized.

Contact: Roland Seidl 03-541 6759

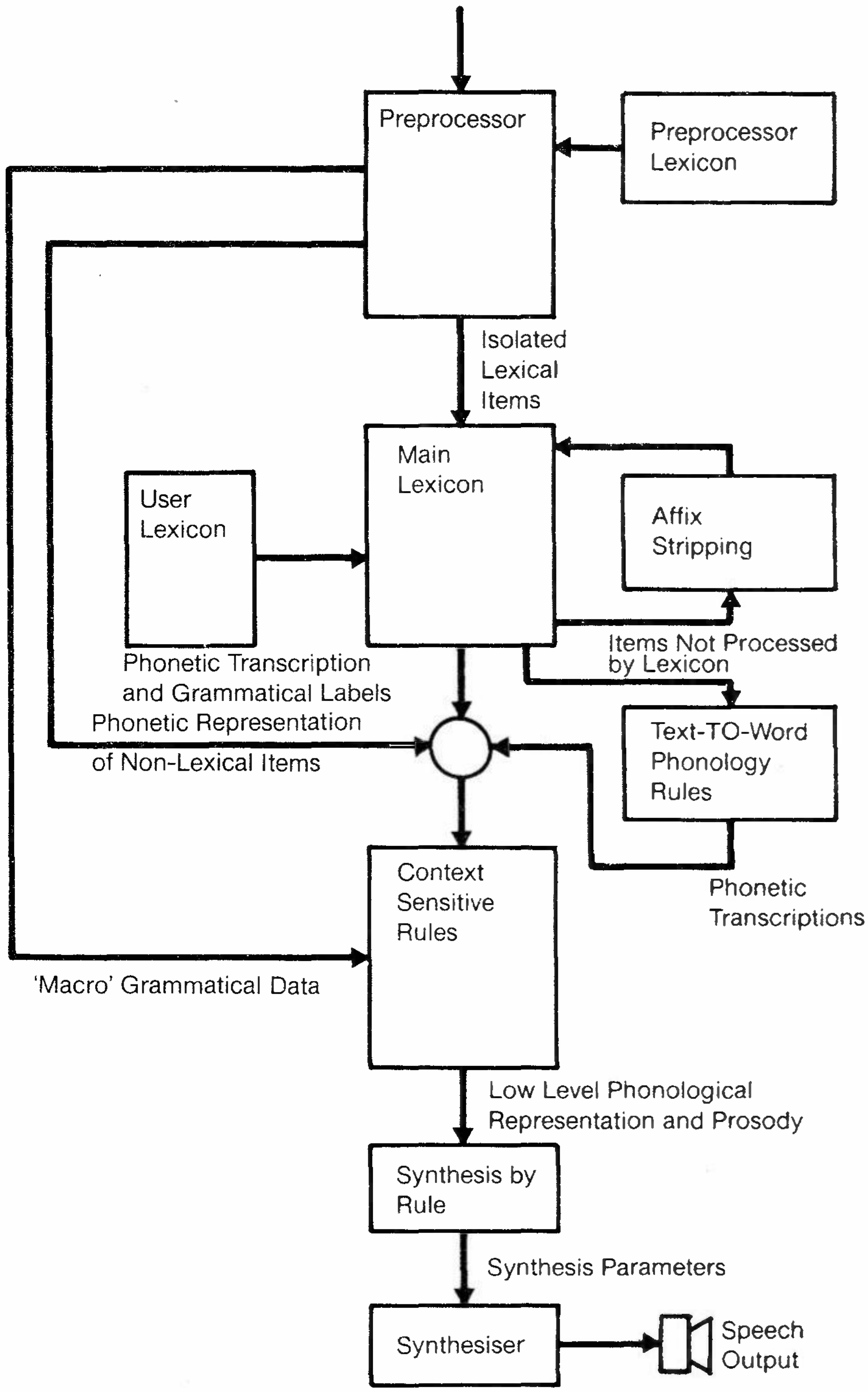


Fig. 3. A Complete Text-To-Speech System

FROM TELECONFERENCING TO COMPUTER-BASED TELECOMMUNICATIONS

Human Communication Research

'Human Communication Research' is presently a small but important part of the Research Department's activities. It has changed from an historical concern with the psychophysics of telecommunications — hearing and vision — to a broader research view encompassing all aspects of people using telecommunications. During the 1970s, the Research Department recruited its first professional psychologist thus complementing the interests of some technical researchers seeking to understand the customer's view of telecommunications. New questions were asked and the research went out from the laboratory into the field, amongst the customers in their own environment. Instead of asking only whether people can hear effectively over the telephone or what characteristics a videophone should have to match human visual processes, questions began to be asked about how people organize themselves using telecommunications. 'What aspects of individual and organizational communication needs were not being adequately satisfied by current telecommunications services? How could new uses of existing or prospective technology be designed to meet these needs?' These questions have been asked in the context of group communication and more recently in the context of computer based telecommunication services.

Teleconferencing

Modern society is complex with individuals belonging to many different but often overlapping groups. Individual decisions are frequently taken only after discussion with group members — work groups, social groups, formal committees. For 100 years, the telephone was essentially a two-person communication medium and did not match people's group communication requirements very well. An awareness of this fact provided motivation for the Research Department's human communication research in the 1970s, namely research into the processes of group communication using telecommunications. Associated technical research into teleconferencing complemented the psychological studies of group communication.

In 1979, the number of psychologists in the Department was increased to three. The psychologists joined with the engineers and technical staff to form an effective interdisciplinary team. The research into group communications continued. The results of social psychological research in the field and laboratory studies of people's behaviour in teleconferences influenced the exploratory development of three experimental teleconference systems. 'The Electronic Chairman' was a system for group-to-group audio teleconferences. Its design enabled a number of ideas to be evaluated and it served as a tool in a number of laboratory experiments. 'The Convenor Controlled Conference Bridge' is a digital system for multi-point conferences on the switched telephone network. A convenor, using a Touchfone 12 tone-signalling telephone, can control the bridge automatically to set up a telephone conference. 'The Small Group Teleconference Terminal' is a novel device for group-to-group teleconferences. The techniques used overcome the problems of audio feedback endemic to loudspeakers working with open microphones.

Telecom offers the Small Group Teleconference Terminal for audio conferencing and Australian companies have been licensed to manufacture the system for export markets. Telecom has also made licence agreements with Australian companies to manufacture and market the Convenor Controlled Conference Bridge.

Computer-Based Telecommunications

Computers have affected telecommunications as much as any other activity. New services have become economically feasible for both business and domestic use but the question has been posed with greater force than previously, 'What new telecommunications services do Telecom's customers want, when the possibilities appear limitless?'

This question is multi-faceted. One view reflects the customer's needs to communicate extensively both within his organization and with the world beyond, using many different modes — voice, image, text and data. This view requires research to be oriented toward the structure of organizations and the way that they operate. What effects will the 'office automation' have on the organization and its needs for communication? Our human communication research activity in this dimension has, as a general aim, the understanding of the fundamental forces within organizations that lead to communication needs. Within this general aim, the results of a series of related research projects will be provided to service designers and marketers to use in planning Telecom's new service offerings.

Another view of the question is that of the individual user of telecommunications services. The new computer-based services potentially offer customers opportunities to satisfy many of their communication needs. However, the new services could be considerably more complex to operate than the existing telephone service. Experience has shown that people are reluctant to take up new, potentially-beneficial tools if they need to spend considerable effort on learning new skills. Thus telecommunications service providers must design services and facilities so that users can quickly learn to operate them efficiently. The complexity must not be a barrier to acceptance. The services must be simple, pleasant and efficient to use.

The problem is to know how to meet this requirement. Our research into the human factors that are important in using computer controlled telecommunications is to this end. We want to understand how to design technical systems to be best suited to the users and our customers' purposes. Research results provide guidelines for Telecom people evaluating and designing new services for Australia and influence international equipment suppliers through contributions to studies of the international telecommunications standardization body, the CCITT.

The Why and How of Human Communication Research

Our human communication reseach is an important source of information about our customers' needs for new telecommunications services and facilities. It rests on the precept that the user comes first and the technology second, whether the user is seen as an individual, an organization or a community. It is not that technology is unimportant. Efficient, cost-effective technology is an essential element of service but the technology is to serve the needs of our customers and these come first.

The pursuit of human communications research requires special skills that cannot be found in a single disciplinary profession. Telecommunication is people using complex technical systems. Knowledge and perspectives from the social and technical sciences are necessary attributes for the research. The Research Department has a team of people whose skills and capabilities collectively meet the criterion for good human communication research. Such reseach is increasingly important in helping Telecom to meet its customers' needs.

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HUMAN FACTORS RESEARCH: MAKING NEW SERVICES EASY TO USE

The Need for Human Factors Research

Human factors research, which studies the characteristics of people interacting with complex machines, is a means of helping Telecom to provide services that its customers will find easy and convenient to use. In the past, the services offered were fairly simple and consequently there was not too much trouble also keeping them simple to use. These days, many telecommunications services can be offered economically but many of these services will be a good deal more complex than the existing telephone service. The latter is well established for people to use. Unfortunately, designing a computer system that is easy to use, whether the system is for telecommunications or for some other application, is more difficult than it sounds. One need only look around to see that many systems fall far short of this ideal and that therefore there is still a lot to learn.

Aims of Human Factors Research

What it is hoped to gain from Human factors research is a set of general guidelines for designing or selecting new services so that they match the capabilities and preferences of the people that have to use them. Traditional human factors research has included classic ergonomic studies investigating, for example, legibility of print on screens. The area in which the Research Department is working however concentrates on more complex studies of how machines can be tailored to match people's learning and memory abilities. The central question here is, 'How do people develop an understanding of what the computer system does and what they must do to use it?' There main sources of information will be the computer system itself and the documentation that accompanies it.

The Research Department has to learn how to design both of these to make the user's task as easy as possible. The sorts of specific questions that are studied therefore should include:

- How much information should be presented at once?
- What words or symbols should be used?
- Under what circumstances should the interaction be user-initiated, e.g. command driven, or computer-initiated, e.g. menu driven?
- What information should be included in 'on-line' help and in accompanying written documentation?
- How should information be laid out?

Telecom's Human Factors Research Program

It should be apparent that, although general principles are being sought, the sorts of questions that are being asked cannot be answered in the abstract. They rely on observing people actually interacting with computer systems. The Department's approach is to program computers to simulate some of the possible new telecommunications services, then to invite people into the Department to try out these 'new services' under various conditions. With simulation methods, people's interactions with potential services can be studied before the services actually exist. The nature of the service can be varied simply by changing the computer program and observing any resulting changes in performance. By experimenting with several different kinds of potential new services, the Department can also test how far its results can be generalised.

The first 'service' that the Department has studied in this way is a form of electronic mail where people enter a typed message at one computer terminal and send it through a messaging network to another terminal. In order to send a message, a person must specify a number of details, such as whom the message is from and to whom it is to go, and may also choose between a large range of other available options, for example to send the message at an express rate, to send multiple copies, to inform each recipient of whom else has received the message and so on. This simulated service incorporates some of the large number of options defined by the international telecommunications body of the International Telegraph and Telephone Consultative Committee (CCITT) for their Interpersonal Messaging Service (IPMS). In the future, the CCITT IPMS should form the basis of an internationally standardized and highly complex service, which will handle messages including a mixture of text, graphic and voice information. At this stage only text messages are being investigated by the Research Department.

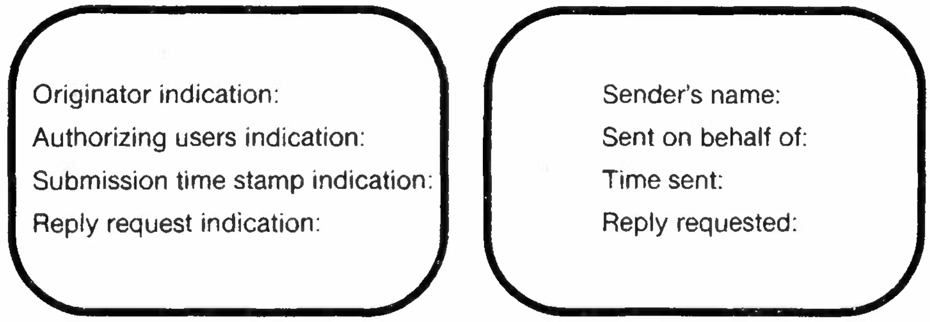
The Department's initial experiments with the messaging system deal with the names chosen for the various options. It is generally known that particular words may mean different things to different people, depending on the context in which they are used, the past experience of the person and many other factors. The major clue to a new user in deciding what a particular option of a computer systen does is, of course, that option's name. It is expected that some names will give users a clearer idea of what the system does than others and that having clearer names will lead to better performance on the system for new users. To test these assumptions, a set of three names was generated for each of the options in our simulated Message Handling Service, always including the name originally defined by the CCITT. Then these names were given, along with a description of the associated service elements, to a number of people in a pencil-and-paper test that asked them to rate how well each name matched the service. Another group of people were asked to send and receive messages on the Department's computer system, where the prompts given by the system were either the most preferred, intermediate of least preferred names according to the pencil-and-paper ratings. Both the ratings given in the pencil-and-paper tests and the performance on-line with the system confirmed that some option names were much easier than others for subjects to understand and to use. See Fig. 1. The CCITT names, which were chosen originally for technical purposes, proved decidedly inferior on both these measures. A second encouraging finding was that the pencil-and-paper tests gave a good indication of later performance on the system. This suggests that such tests, which are quick and easy to administer, will, under certain circumstances, be useful in assisting the Department to make decisions about human factors aspects of new systems.

So far, the Department's simulated messaging system has also been used to study the effects of:

- the amount and type of instructions given to people before they use the new service,
- the order in which information is presented,
- whether or not the order of information on the screen is consistent with the order of information in any written instructions and
- having previous experience with the system.

Future experiments will examine still more aspects of messaging and, as explained above, also extend investigations to other new services to increase the range of applicability and the generality of the findings.

Contact: Loris Perry 03-541 6727



Which System is Easier to Use?

Fig J : A Comparison of Two Screens with Different Option Names

RESEARCH & DEVELOPMENT IN TELECONFERENCING

What is Teleconferencing?

Teleconferencing is the use of telecommunication services, systems and products for communication between and among groups of people.

One example is telephone conferencing, in which a number of individuals may converse, each using their own telephone. A teleconference service is exemplified by Confravision, for which Telecom currently provides public studios in Melbourne and Sydney. The studios are linked by closed circuit TV and, for a fee, a group in one capital may book the facility and 'meet' with people in the other.

Telephone conferencing and Confravision are only two of the many possible forms of teleconferencing which have been studied or developed by the Research Department.

Why is Teleconferencing Important?

It is noteworthy that, for almost a century, the main development thrust in telecommunications has been towards the establishment of an all-pervasive network for one-to-one interpersonal communication, i.e. the telephone network. On the other hand, modern society is very much based on co-ordination, co-operation and communication between and among groups of people. Thus there exists a partial but significant mismatch between our society and its communications infrastructure. Teleconference services and systems alleviate this mismatch and, consequently, the potential use of teleconferencing is considerable.

Most people and organizations are so thoroughly used to the idea that telecommunications provides pairwise communication that group telecommunication must be seen as a major innovation as far as most potential users are concerned. In short:

> Teleconferencing or group communication is an important generic class of telecommunication services that offers to organizations and individuals a new and different set of communication options compared to those traditionally available.

Types and Varieties of Teleconferencing

There is a very wide range of group communication requirements and a very wide range of services, systems and products that can be offered to meet them. Table 1 gives one classification of group communication services and should sufficiently illustrate their range and diversity.

Live video systems have the greatest immediate appeal for many potential users of teleconferencing but costs are relatively high and there are often difficulties in getting live video to and from the required locations. However, recent developments, including the growing penetration of digital transmission and the advent of 2 Mbit/s video codecs and of communication satellites, are reducing the cost and accessibility problems of television conferencing.

Audio teleconferencing has the major advantage that it can be readily and inexpensively implemented and made widely available within existing telephony or voice networks. The number of group communication requirements that can be met by good audio teleconferencing systems and services is substantial but yet to be generally appreciated.

We expect the most common need in the community to be for various forms of small group conferencing and this, therefore, has been the main focus of our research. The location of potential users is an important consideration in all forms of teleconferencing and Fig. 1 shows some of the small group configurations that are commonly required.

(See diagrams over)

Research Interest in Teleconferencing

Even from the earliest days, attention has been paid to human and social as well as technical factors and since the mid 1970s the Research and Department has included one or more psychologists.

Design studies in the Research Department led to the establishment in 1972 of the Australian Confravision service between Sydney and Melbourne and technical studies continued for some years after that date.

From the mid 1970s there was growing concentration on the human, social and organizational aspects of teleconferencing with consequent changes in the technological study program. The main emphasis shifted from television to audio conferencing services and systems, particularly those that could be implemented in the telephone network. With these changes of emphasis, the work undertaken included:

- laboratory studies of the manner in which particular teleconference systems influence the patterns of group interaction during a meeting,
- development of a critique of the travel substitution and media type allocation models of teleconferencing,
- field studies of telephone conferencing in social welfare and for social contact amongst the housebond,
- a rural field study of educational audio teleconferencing,
- application of social network analysis in a diffusion of innovation study of audio teleconferencing in a rural community,
- technical, human and social factors assessments of a variety of teleconference equipment,
- preparation, for Telecom's Commercial Services Department, of a television conferencing handbook, incorporating technical guidelines and sample specifications for various grades of television conference facility,
- exploratory development, laboratory and field performance studies of an automatic, user controlled telephone conference bridge and
- exploratory development, laboratory and field performance studies of a low cost, portable audio conference terminal.

Two Key Developments

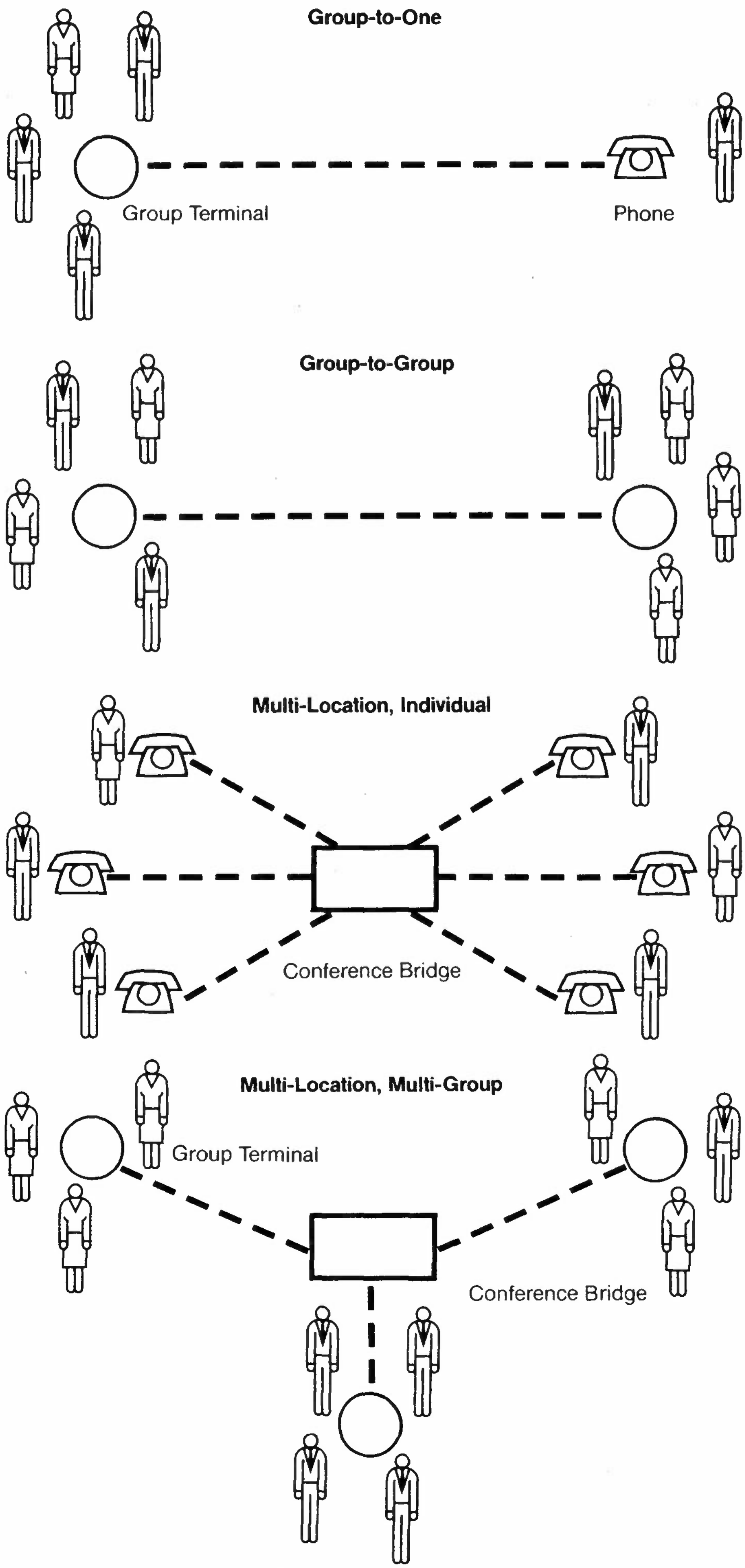
Two important conclusions of our research have been that multi-location small group audio conferencing in the existing telephone network is one of the most important forms of teleconferencing and that the available means of accomplishing it have not been particularly satisfactory to date.

Number of Locations	Variability of Locations	Participants per Location	Mode(s) of Communication		Access/ Availability	Terminal Type	Primary Service Basis
two only	fixed	single	(4) speech only	"Audio Conferencing"	private	full studio	network
multiple	arbitrarily variable	small group (6-10 max)	(5) speech plus		public	meeting room/ minimal studio	terminal
	mobile	(2) large group	(6) live video	"TV Conferencing"	(10) mixed	normal office or home	hybrid
	(1) mixed	(3) mixed	(7) live video plus				
			(8) mixed asymmetric				
			(9) computer				

Notes

(1) mixed location services are those which cater for both fixed and variable or mobile sites, e.g. individual telephones linked into a conference between fixed sites.
(2) e.g. as in convention halls, lecture theatres etc.
(3) e.g. a combination of small groups and individuals linked through a telephone conference bridge.
(4) e.g. normal telephone conferences.
(5) two sub-divisions:
   (a) speech plus auxiliary modes e.g. fax, Slow Scan TV, and
   (b) speech plus auxiliary cues e.g. speaker identification, request to talk, who's present, etc.
(6) live video conferencing will always incorporate speech links and may include some form of video-based graphics.
(7) video plus conferencing, e.g. video with auxiliary fax, video with data base access, etc.
(8) (a) mixed mode systems e.g. a video conference linked speech only to other participants.
   (b) asymmetric systems e.g. one-way video, both-way speech.
(9) computer conferencing is usually implemented as a non-real-time service or facility.
(10) e.g. private TV conference studio linked to public Confravision terminal.

Table 1: Classification of Group Communication Services



For this form of conferencing, two distinct entities must be available; firstly a small group audio terminal and, secondly, a facility or system for establishing multi-point connections, i.e. a conference bridge. We have designed and built both a small group teminal (SGT) and a convenor-controlled conference bridge (CCCB) whose main features are described below. Using the SGT and CCCB separately or in combination, communication can be established for all of the locational configurations shown in Fig. 1.

The Convenor-Controlled Conference Bridge

This device is not being demonstrated at the 1985 Open Days but the basic principle involved is that any telephone customer may ring the bridge and set up a multi-location connection. This person acts as the convenor and has complete control over the connection, being able, for example, to add, disconnect or re-connect parties to the conference at any time while it is in progress. The convenor and the other conference participants may be located anywhere in the telephone network while the bridge itself may be on private premises or in a public telephone exchange. The convenor sends command codes to the bridge by using a tone signalling telephone, such as Telecom's standard Touchfone 12.

Controlling a telephone conference connection is a moderately complex task so particular attention must be paid to the design of the user interface, which includes the instruction manuals. In our bridge, we use artificial speech to provide voice instructions and feedback to the convenor, and all control procedures have been carefully chosen and tested.

Fig. 1: Diagrams for Group-To-One, Group-To-One, Multi-Location Individual and Multi-Location Multi-Group

The Research Small Group Conference Terminal

The Research SGT, which is being demonstrated at these Open Days, is portable and can be used in most existing meeting rooms, classrooms and offices. The only installation requirement is that a mains power outlet and a standard telephone socket must be available.

Our prototypes and the first production models of the SGT have been configured as a plinth style telephone attachment. Speech in the conference room is picked up by a microphone, which is column mounted on the plinth, while speech from the other locations is carried by infrared radiation from the column on the plinth to individual receivers worn by the local participants. Users actually hear the speech through lightweight headphones that are acoustically transparent and permit normal conversation within the conference room. Users may individually adjust their receiver volume to suit their own preference and hearing sensitivity.

The use of headphones eliminates acoustic feedback, allowing a sensitive microphone to be used without voice switching or push-to-talk controls. Both of the latter are common in loudspeaking telephones and other audio conference terminals and both frequently cause difficulties for users.

Our SGT is intended also to be used as a building block for audio conference systems and therefore has some important auxilliary capabilities. Conventional audio equipment can be connected to inputs and outputs provided at the rear of the terminal.

A standard 12 key dialling pad is incorporated and can be used during a conference to control devices in the network (e.g. the CCCB) or at other conference locations. If the SGT is also fitted with circuitry to detect dialling tones, ancilliary equipment connected to the SGT, such as slide projectors, video cassette players or computer systems, may be controlled from any other location in the conference.

Status of The Bridge and Terminal

Both devices have been through several stages of refinement and both have been used extensively in our field studies noted in above. Users' comments collected during those studies have been a particularly important input to the development process. Other areas of Telecom have used the devices on a trial basis and both have been made available for assessment by the Commercial areas in the States and in Headquarters. The concept of both devices is now well proven and the majority of user comments have been favourable.

The SGT has progressed furthest through the development cycle and has been commercially released by Telecom as part of its product line in teleconferencing. The design of the SGT has also been licensed for manufacture to a commercial company and international sales are likely.

Our CCCB is a moderately complex device and requires further development before it could be released as a commercial product or form the basis of a public telephone conferencing service. No further development by Telecom is envisaged but the latest prototype design has also been licensed to a commercial company for further development and possible manufacture.

Conclusion

Since the late 1960s, Telecom has conducted a wide ranging program of teleconferencing research, always with a strong emphasis on understanding user requirements and generally attempting to apply innovative design and the most appropriate of available technologies to meeting those requirements.

Over the last few years there has been considerable knowledge transfer from the Research Department to the commercial areas of Telecom and further major research projects in teleconferencing are not envisaged. Commercial activity in teleconferencing can be expected to increase significantly in the next few years while research into human factors and communication needs will continue in other new service areas.

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SUBJECTIVE TESTING OF SPEECH QUALITY

Facilities

This area of the Research Department provides the facilities required to assess subjectively the speech transmission performance of telephones, the equipment associated with providing speech connections and overall speech quality, including digitized and synthesized speech. Three separate studios enable various test configurations for conversing or listening to speech. The studios provide acoustic isolation between the occupants and from outside noise. Their interiors are acoustically damped to minimize acoustic reflections and reverberation.

The two smallest studios are used for conversational testing of equipment as required in performance testing of echo suppressors, digital speech interpolators and digital speech storage devices. They are most frequently used for rating the transmission performance of new telephones, which involves comparing the loudness of a test telephone system. The large listening studio provides facilities for group (up to six persons) listening to samples of speech that may have been processed in a variety of ways.

Digitized Speech

One of the future requirements is for the quality assessment of speech generated by digital processes that is used in many new services or for the enhancement of existing services. Examples of the use of digitized speech include:

- speech transmitted over data networks,
- synthesized speech output from a computerized information service and
- services using speech storage.

The use of digitized speech in such services introduces new quality impairments to speech such as variable transmission delay times, spectrum and pitch errors and compounding quantization distortion.

Method Categories

The assessment of overall quality must take into account all the impairments present in reproduced speech and combine the effects of all the impairments into a single figure of merit for quality. Methods for doing this broadly fall into three categories : objective, subjective and hybrid (those between objective and subjective).

Objective methods of measurement are applicable if certain impairments are known to dominate and they then provide a measurement of quality on a relative scale. If many significant distortions are present, objective measurements become difficult to use as the interrelationships between the impairments cannot be assessed.

Subjective methods usually involve listeners rating the perceived quality of a speech sample on a five point rating scale: excellent, good, fair, poor or unsatisfactory. Sometimes listeners may be asked to concentrate on certain aspects of the speech, which are defined using descriptors such as 'hissy', 'nasal', or 'thin'. The testing procedure is usually large or lengthy to reduce the inherent variability in the raw results.

Test Displayed

The type of test on display here is an example of a 'hybrid' test (partly objective and partly subjective in nature). The block diagram (Fig.1) shows the interconnection of the equipment. The computer generates in text form a word to be spoken into a telephone by a person in the speaking studio. This speech signal is then passed through a digital encoder and decoder (codec). The output of the codec is thus a degraded form of the original speech signal. Electrical noise is then added to the codec output. This increases the sensitivity of the test and is also a condition that may occur in practice. The listener hears the incoming speech and noise on the telephone, together with some added room noise. At the same time the listener is presented with a list of several rhyming words on a visual display unit. The listener then chooses the word that was thought to be heard. For the purpose of this demonstration the computer displays on a visual display unit the spoken word and perceived word and also a running average of the percentage of correctly perceived words for the last ten results.

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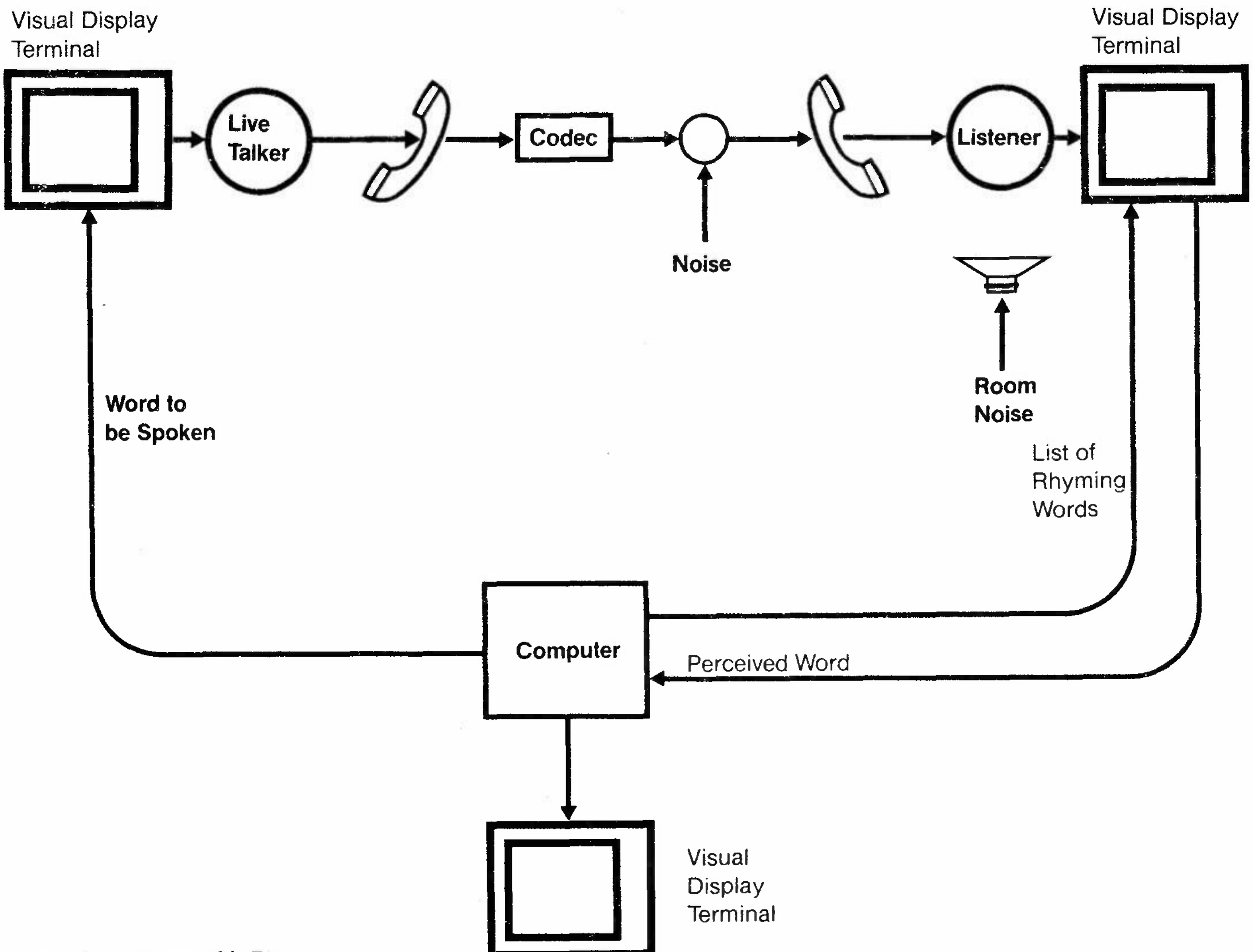

Fig. 1: Block Diagram of the Test

VOICE ACTIVATED TELEPHONE SYSTEMS

Spoken Directives

The advent of new technology has made it possible to enhance the basic telephony (voice) service by providing many new facilities to increase its usefulness. A consequence is that there will be a greater need for the telephone user to communicate directives to the central processor in the exchange, which controls these facilities. The standard rotary dials or key pads (usually about 12 buttons) normally available are limited in their ability to signal the central processor without complicated sequences of digits that have no inherent relationship to the directive being given and hence would be difficult for people to give directives by means of spoken words, necessitating the use of automatic speech recognition. Such a facility could easily be extended to provide handsfree dialling, which would not only be a convenience to normal telephone users but also a boon to certain handicapped people.

Effect of the Speaker

Automatic speech recognition is related to two other fields, viz. speaker verification and speaker identification, because a speech signal is the composite of what was said and the speaking characteristics of the person who said it. The variability between speakers (or even the same speaker under different conditions) for the same utterances, detracts from the ability of a machine to recognize speech reliably. Many relatively simple speech recognition systems are available for use where handsfree control of the processes are required but usually these involve prior 'training' of the system to recognize key words spoken by a particular speaker. In order to apply speech recognition in the telephony service, the central processor should respond to a general talker without prior 'training' of the system being necessary and should also cope with typical telephony impairments such as ambient or circuit noise, limited bandwidth, carbon transmitters, etc.

Although regional accents are markedly different within countries such as the United Kingdom and the United States, such marked differences are not found in Australia. Therefore the aim of speaker independent speech recognition may be more readily achieved for people that have been brought up in Australia. However, recent immigrants would be at a strong disadvantage, unless the system was extended firstly to identify the ethnic group and then to take this into account by normalization of the basic speech elements (phonemes) or other techniques. Normalization may also be applied to reduce the effect of specific physiological causes such as differences between men, women and children in the length of the vocal tract.

Analysis of Speech

Automatic speech recognition of words or short phrases usually involves analysing the utterance for distinctive features as a function of time and comparing these features against a reference template, for each utterance to be recognised. Differences in speaking rate are accomodated in the simpler systems by having perhaps ten different templates for the same utterance that differ mainly in the talking rate. More advanced systems use time warping (i.e., nomalization of time) to optimize the match between an utterance and the corresponding template. Dynamic programming is a powerful mathematical technique that has been used to limit the number of alternatives in seeking the optimum.

Since the ear is not very sensitive to phase, a significant amount of phase shift is permitted in telephone circuits and waveform features are therefore not very robust. The main waveform feature that is commonly used is the number of zero crossings per unit time, which is an indication of whether the speech segment is voiced (as in vowels) or unvoiced (as in fricative consonants such as /s/, /sh/, /f/, etc).

Frequency analysis is particularly useful because it closely models the behaviour of the ear. Depending on the phoneme being uttered, the speech spectrum will show several resonant peaks known as formants. The locations of the first two or three formants are strongly correlated with the phoneme and therefore are very good features to include in the feature vector from which the template is constructed.

Finally the short term average signal energy (varying at a syllabic rate) provides a means for determining the beginning and ending of an utterance. This is not a trivial exercise if considerable background noise is present.

Constraints

The problem of automatic speech recognition for a general talker is so formidable that certain constraints must be applied. Firstly, the vocabularly must be limited to a few key words only and therefore many synonyms will be rejected. Secondly, the person-machine dialogue should be highly interactive, so that verification of correct interpretation by both the user and the system may be carried out as much as practicable. Finally, some useful facility must be provided that is not readily available by other means, in order that customers will accept these constraints.

The simpler speech recognition systems require the key words to be separated by a short pause. In handsfree dialling, for example, the talker is likely to run the words together and so the system should be able to cope with what is termed connected words. Work is also going on in laboratories around the world on so-called continuous speech recognition systems that permit much more freedom in the spoken phrase. In some cases the aim is speech understanding, in which 100% recognition of all words is not required but merely a correct response to the spoken phrase.

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TELEMATIQUE SERVICES

Range of Services

The field of telematique services has blossomed in the past decade from the established world of telex and low-quality facsimile to a seemingly boundless set of opportunities embracing electronic messaging, electronic documentation, information data banks and funds transfer and management systems.

Apart from voice telephony, the main thrusts in the development of end-user telecommunication services in recent decades have been associated with document and data transfer. Such services have generally been motivated by the needs of business for inter-office communication. As technology is now providing extraordinarily powerful terminals or workstations for processing of data and documents and is also opening up the concept of information bank access, the range of business customer telecommunication needs has broadened considerably. The field of telematique services can now be considered to embrace those end-user services that employ both computing and telecommunication technologies to provide a versatile range of facilities to the customer involving access to, and the transfer and storage of, information in text, image, voice (encoded) or data form.

Text Services

Telex has been the mainstay of Telecom Australia's telematique services in recent times, providing a widespread customer service with local and international capability and proving to be a substantial revenue earner for Telecom. Despite improvements in the technology of telex terminals, the emerging generation of text services will eventually place telex in the background. The character-by-character transmission of telex is being superseded by the more efficient document-based methods of Teletex, a new internationally standardized service for the transfer of properly formatted business documents. When this service is introduced by Telecom Australia in 1985, it will allow direct communication from suitable terminals or word processor systems to distant end users, whether they be other word processors or standard Teletex terminals, thus enabling reliable document transfer across national and international networks. The introduction of this service has taken into consideration the capability for interworking between Teletex and the Telex network. This facility will also soon be available in Australia.

Message Handling

The scope of text services has been expanded by the introduction of a Computer Based Messaging Service, offered by Telecom Australia as Telememo. This provides users having limited capability ASCII terminals access to a host 'electronic mailbox' sited within Telecom's network. Public subscribers may deposit mail in text form in a personal mailbox, which is always accessible to its subscriber. More advanced forms of electronic messaging systems in which 'mail' in the form of compound documents may be transferred on a store-and-forward delayed delivery basis, potentially across international boundaries, are currently under study in the Research Department. The so-called compound document may comprise any combination of text, images, computer data and encoded voice. Such systems are known as Message Handling systems and much investigation is current throughout the world in this field. Message Handling systems will not only facilitate access to store-and-forward services by other telematique terminals, e.g. videotex, teletex and facsimile, but will ultimately provide conversion facilities to enable interworking between these service types, e.g. videotex characters and standard text in a Teletex document.

Research Department Contributions

The Research Department has made a major contribution to the new telematique service developments within Australia in various ways. The skills generated in the Department are being applied in the planning and implementation aspects of Telecom's new service offerings, in the fields of Teletex, interworking between Teletex and Telex, Telememo and electronic funds transfer. Initiatives taken in the electronic messaging field have stimulated service developments in Australia that the customer is only beginning to see. With accelerated effort in world standardization bodies in the fields of electronic messaging and electronic directories, internationally compatible products can be expected on the world market by 1986-87. Telecom's Research Department staff have contributed to the standardization efforts concerned, both through the Standards Association of Australia (affiliated to the International Standards Organization) and the CCITT (International Telegraph and Telephone Consultative Committee). The importance of international standards in the fields of electronic document transfer, financial transaction services and business data communication is paramount. Telecom is dedicated to the implementation of systems that achieve maximum, internationally-standardized connectivity.

Future Developments

The future holds an enormous range of possibilities for the customer in the telematique services area. Developments in office automation products and personal computing that make the facilities for information access, processing and transfer more accessible and friendly to the user are being witnessed. New technology is giving people the capability to mix various information modes (voice, text and images) into one electronic document. Such documents are generally communicated on a delayed-delivery basis or they may be accessed from within databases in an interactive (query-response) manner. Within these operations, a number of generic categories of communication process and of information content can be identified as follows:

(a) basic information representations for voice, text, images, business graphics and computer data,
(b) document architecture (agreed structured representation of information when several information types are involved),
(c) Store-and-Forward messaging of information, which may have a mixed-mode information content, with a wide range of facilities associated with multiple delivery (to distribution lists), time stamping of messages, non-delivery notification, priority delivery, conversion of content types, etc., and
(d) interactive access to databases (containing the full range of information types) and to business and financial transaction services.

Value Added Services

The four categories above embrace the future of telematique services, in which the users' requirements take highest priority. These categories provide the framework for the development of a range of future Value Added Services. These Value Added Services are end user services that meet special customer needs and involve information processing, information access and a range of additional information technology features. These services will facilitate the convergence of increasingly diversified user services and the increasing proliferation of user terminal types. Such Value Added Services will be based within telecommunications networks and will provide facilities that maximize the customers' communication options. Value Added Services are provided when network infrastructures are not only developed for information carriage but also for increased functionality within those networks. Particularly useful Value Added Services include:
(a) versatile international messaging systems,
(b) service interworking facilities providing conversion capabilities for dissimilar users,
(c) Electronic Directories, providing, in a distributed manner, access to other international directories, support functions for the management of multiple service communications and an extensive database of user facilities and names and
(d) interactive transaction services including financial and business transactions, access to information banks, telesoftware access and security and authentication services.

All of these developments are particularly useful in the business environment and all are telematique services.

Summary

The Research Department is investigating many of the fundamental aspects of these new telematique services, with a view to contributing to interim strategies for their implementation and to longer term planning for their deployment within Australia's telecommunication networks. The results of this work will be seen through Telecom's Commercial Services product developments over the next decade, resulting in substantial benefits for the customer in all fields. Particularly in the business field, Telecom will be able to facilitate wider public access to information sources, compatible communications between complex office systems and more efficient access to rapidly changing directory information. For the general telecommunications' user, these developments will lead to ease of information access and to more efficient use of our highly developed network infrastructure, giving the prospect of more favourable tariff structures in the future.

LIST OF EXHIBITS

MESSAGE HANDLING — ELECTRONIC MAIL SERVICE

Electronic Mail

'Electronic mail' is an exciting development for the business environment of the 1980s. In its most general form, electronic mail denotes the exchange of messages over telecommunications networks or computer systems. It is distinguished from interactive communications in that messages typically do not require an immediate response.

Electronic mail takes some diverse forms in today's world. Three examples are:

- Teletex — a development of Telex (one of the earliest forms of electronic mail) providing for the reliable exchange of office documents at high speed and with word-processor quality.
- Facsimile (telecopying) — a service for transferring already existing material through a process of scanning, transmission and remote printing. It is very important in specialized applications, its chief advantages being that text material need not be retyped prior to transmission and that diagrams (graphics) are easily sent.
- CBMSs (Computer-based message systems) — systems that allow subscribers to send typically short and informal messages to one another through the agency of electronic 'mailboxes'. Messages are usually entered and retrieved by the end-user and are rarely printed out as hardcopy.

These individual forms of electronic mail generally do not permit interworking, i.e. sending a message from one service form to another (e.g. CBMS to Teletex). Moreover, not all CBMS systems can interwork with each other.

Message Handling

Telecommunications providers and CBMS operators have combined in recent years to attempt to develop a forward-looking electronic mail environment known as Message Handling. This environment is intended to support the interworking of existing systems and to provide the framework for the introduction of powerful new capabilities in future systems to the year 2000. Among the capabilities that Message Handling systems will offer are:

- access via a large range of terminals, including Telex and Teletex equipment, 'dumb' terminals, personal computers and even ordinary telephones,
- ability to handle a wide range of message content types: text, image, voice etc., even within the one document,
- conversion (where practical) between message forms, to a form that can be delivered to the recipient's terminal, e.g. conversion of text input for delivery to a facsimile printer or an ordinary telephone, and
- ability to specify recipients by name, rather than a Telex or network address and associated with this, an on-line directory service to help identify the intended recipients or their capabilities.

This development of a global Message Handling system is far from complete, despite considerable effort on the part of those bodies involved in the development. Efforts to date have taken place on two fronts. Standardization bodies such as the CCITT (International Telegraph and Telephone Consultative Committee) have been developing standards for the model of a Message Handling system, the service features of such a system and the data communications protocols required to support such a system across international or administrative boundaries. Also, CBMS operators have attempted to upgrade their systems and implement the CCITT protocol standards.

It is in the standardization area that the Research Department has been directing its activities. The success of any new electronic mail service depends strongly on the number of users it can connect. Telecommunications organizations have regarded the international interconnectivity of Message Handling systems as a high priority and the key to future success for the service.

Model of a Message Handling System

The first step in developing standards for the service features and protocols for Message Handling was to devise a model for the system. A well constructed model can improve the generality and regularity of a concept and is particularly important when planning for future extensions, which can only be partially foreseen. The CCITT model (Fig.1) separates the functions of a Message Handling service into those concerned with pure message routeing and those concerned with interactions between users. At its kernel is a network of Message Transfer Agents (MTAs) for reliably passing a message between the MTAs of originator and recipient. Interacting with the MTA kernel on behalf of the service users are User Agents (UAs). UAs support the user in the preparation, examination and archival of his message. They interact with the MTA for such things as message submission and delivery and with other UAs (through the MTAs) for such interpersonal messaging services as auto forwarding, receipt notification and so forth.

The model is a conceptual one and does not constrain actual implementations so long as their external behaviour matches that of the model in regard to their protocols and message formats. Fig.2 shows a possible mapping onto a combination of public and private administrative domains.

Protocols for Message Handling

The problem of interconnecting Message Handling systems is complicated by their service requirements. Messages are transferred on a fully automatic store-and-forward basis, with the recipient taking full responsibilty for the message, whether it is an MTA or a UA. Totally reliable message transfer is therefore a necessity.

Three new protocols have been developed for Message Handling. They are the P1 or Message Transfer Protocol, the P2 or Interpersonal Messaging Protocol and the P3 or Submission and Delivery Protocol. Message Handling has been placed within the Application layer of the CCITT/International Standards Organisation (ISO) Open Systems Interconnection (OSI) Reference Model, so standard OSI protocols operate at layers 1 to 6. In particular, Message Handling can be implemented over any network, as OSI layer 4 hides network differences.

The Research Department has been closely following these international developments, through participation in CCITT and the ISO. Projects are implementing aspects of a prototype Message Handling system as a means of studying the protocols and service features. The MAIL system on display uses a subset of the new Message Handling protocols, though this is not visible to the user, and demonstrates a possible text-only User Agent terminal.

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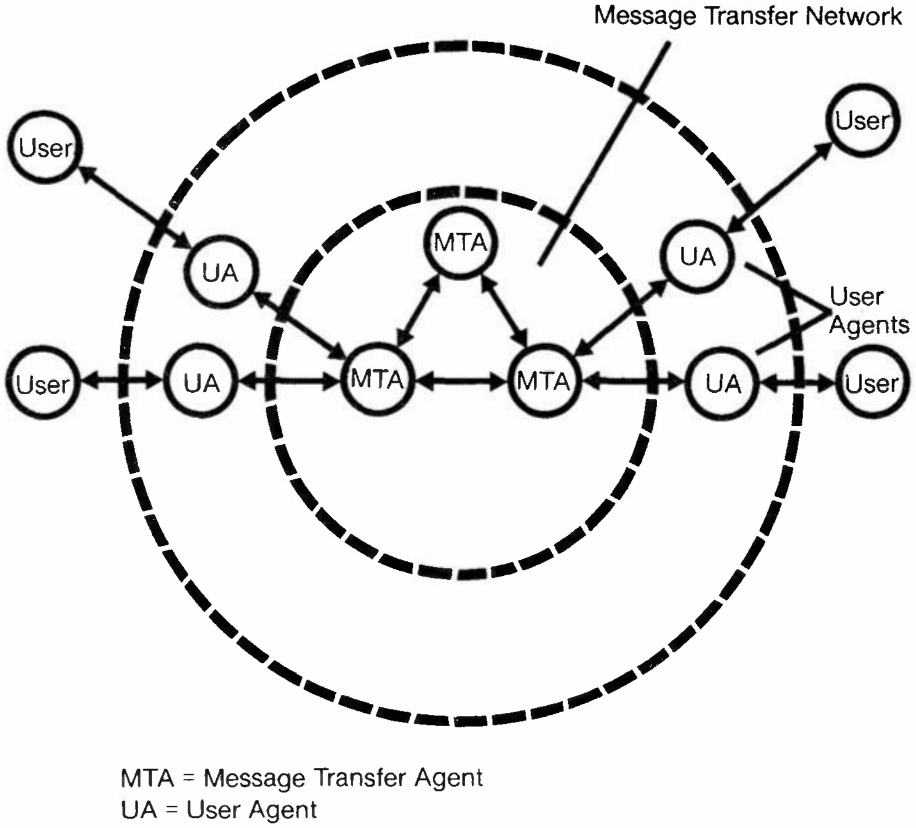

Fig.1: Model of a Message Handling System

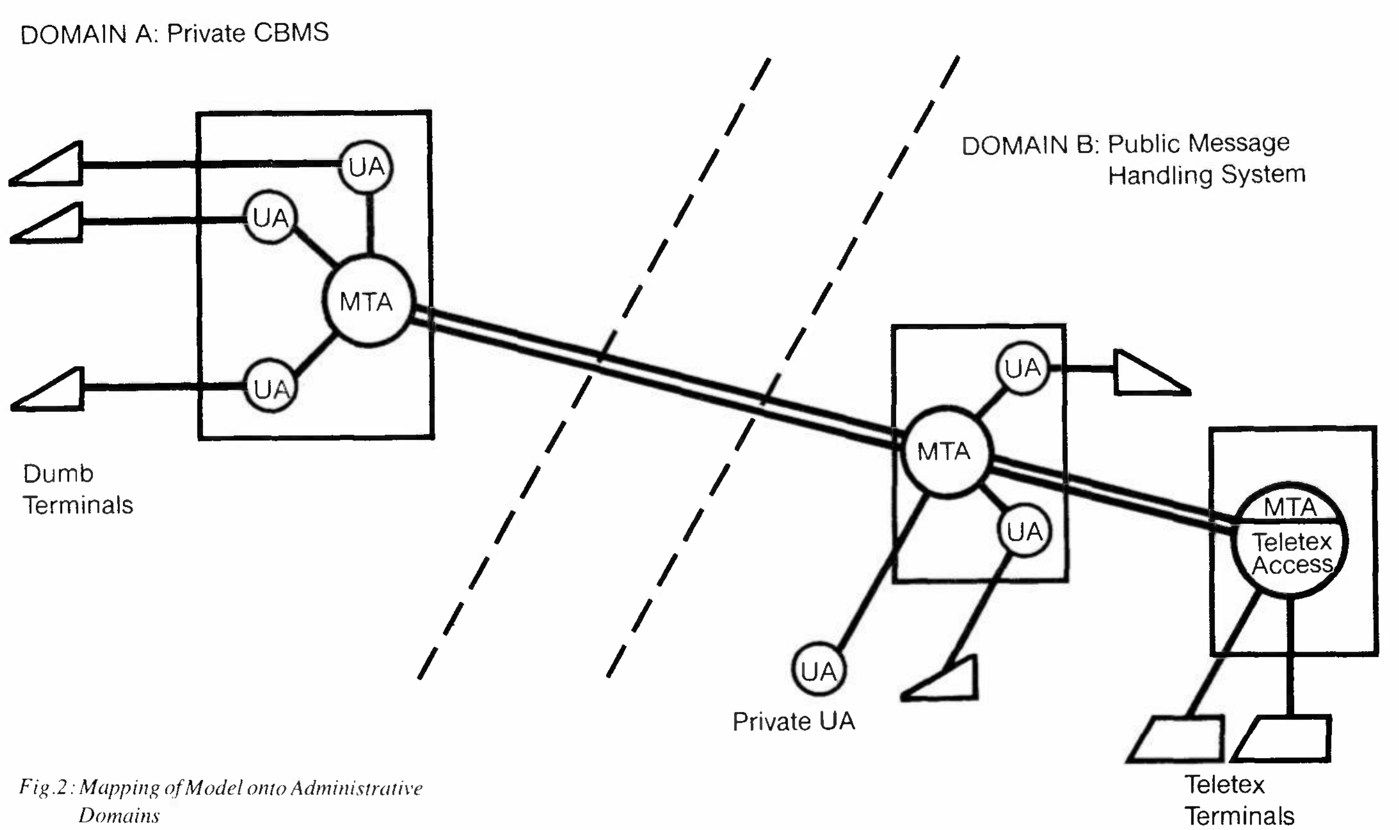

Fig.2: Mapping of Model onto Administrative Domains

ELECTRONIC DIRECTORY SERVICE

Naming and Addressing

The successful offering of any telecommunications service requires and depends on the support of an efficient directory system. Traditionally, as exemplified in the well known telephony service, the directory assists customers and users in finding the network location or address (i.e. telephone number) of the person with whom they wish to communicate. This address is then used to initiate the setting up of a communication path between the two parties. Other services such as telex and data will use addressing schemes different from that of telephony. Separate directories are provided for these services.

Network addresses are generally specified in a machine-oriented fashion (comprising a string of numerical or alpha-numerical digits) because they are devised to be used directly by network processing nodes for setting up communication paths. As a result, addresses are not meaningful to human users and are difficult to remember. With the emergence of a range of new service offerings, e.g. videotex, teletex and computer-based messaging, it becomes inconvenient if a business user has to remember different addressing schemes for accessing or communicating in different service environments.

Instead of using addresses, it would be far more convenient if customers were able to use human names to denote the persons with whom they want to communicate. This is particularly desirable from the standpoint of electronic messaging — a means by which a great deal of future text communications between business offices may be conveyed. For this to be possible, however, a standardized naming convention needs to be developed internationally and a network-based on-line electronic directory service provided that will perform the automatic translation of user-specified names to appropriate network addresses. The translation process would be entirely invisible to the users.

Service Interworking

Telecommunication networks worldwide are evolving towards a multiservice environment, in which a multiplicity of different services will be supported over different network types and accessed by a variety of terminal types. In order to allow customers with terminals of different types and different service access capabilities to intercommunicate, network-based service interworking facilities will be needed. Since an electronic directory may also contain information pertaining to the basic properties and service access capabilities of users' terminals, it can also be used to assist in terminal compatibility checking and service interworking activities. Other more general information retrieval services will also be provided to the users, as discussed later.

International Standards

The need for a global directory service to support the above and other applications, especially in the context of message handling and telematique services, has been recognized worldwide by major telecommunication network providers and terminal and network equipment manufacturers alike. To this end standardization bodies such as CCITT (International Telegraph and Telephone Consultative Committee) have recently commenced work to attempt to define a set of standards covering the following aspects of the directory service:

- architecture model,
- standard name forms to be used,
- relationship of directory services to naming authorities and their operating rules,
- facilities offered and
- communication protocols for user-directory and directory-directory interactions.

Telecom Australia Research Department, like most other advanced telecommunications administrations, is pursuing research in these areas. The scope of work is summarized below.

Functional Model

Functionally the directory service consists of a collection of distributed Directory Service Agents (DSAs) that, when necessary, co-operate with each other in order to provide the services to the Directory User Agents (DUAs) (Fig. 1). The DUA acts on behalf of the user to access the distributed directory databases provided by DSAs using a set of standard access protocols. One DSA may serve more than one DUA and one DUA may interact with more than one DSA.

Basic Service Elements

A DSA maintains a database consisting of a set of names and, for each name, a set of properties or directory entries such as network address, password, terminal type etc. to be associated with that name. The directory service (DS) assists users, strictly upon request, with retrieval of database information in a flexible manner; e.g. either an item (such as the network address), a specific subset or the full set of properties associated with a name may be retrieved. This is known as a name-to-properties mapping service. The DS also offers a property-to-set-of-names mapping service.

The DS will allow privileged users to modify, maintain or update various parts of the DS database. Strict authentication and access control procedures and database update mechanisms must therefore be defined in order to ensure the reliability, integrity and accuracy of the DS.

Naming Convention

The naming convention being defined is intended to be general. It can be used to provide names for a wide variety of communication entities, including human users and service types etc. These names must be easily derivable by human users. A name validation service will be provided to the DS to assist the users.

A hierarchically structured name form has been adopted initially for business applications, comprising three components:

- the user's personal name,
- the organizational name and
- the name of the country.

Name forms for other applications have yet to be developed.

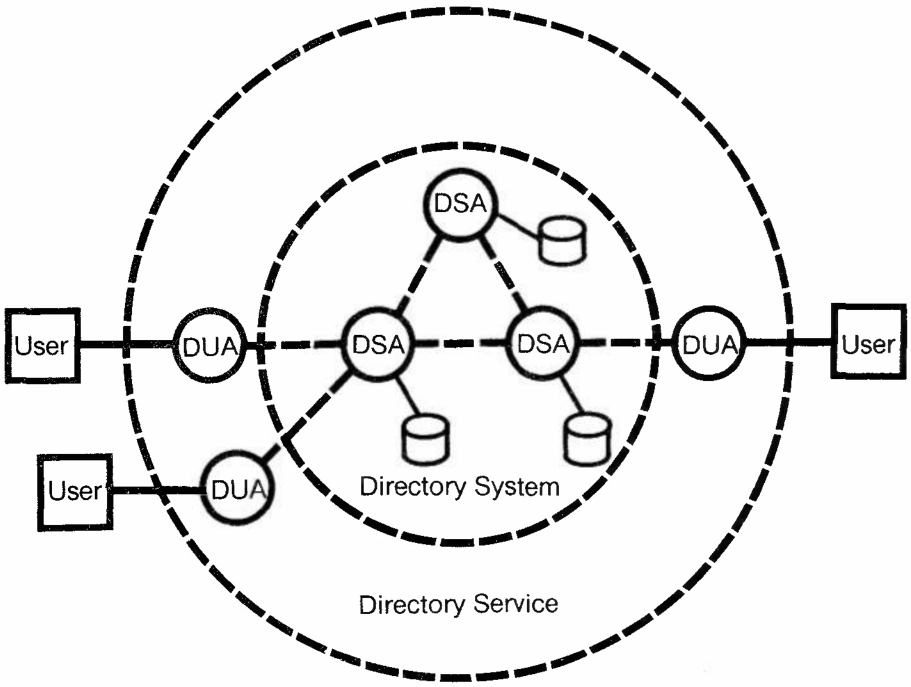

Fig. 1: Functional Model of Directory Services

Communication Protocols

The necessary communication protocols required for accessing directory database cannot be defined until the service elements and associated primitives to be supported by the DS are specified — a task currently being undertaken by the international standards bodies.

Summary

Extensive research work is needed before an on-line electronic directory service can be fully specified and standardized. In this regard the international standardization bodies provide a good forum for the sharing and exchange of research ideas.

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TELECOMMUNICATION SERVICE INTERWORKING

Classification

In recent years, demand has grown for the provision of a wide range of telecommunication services for customer use. Such services may be classified in a variety of ways, such as:

(a) in terms of the information media involved, e.g. voice telephony, computer generated data, videotex information frames or facsimile images,
(b) according to the communication bandwidth required, e.g. 4 kHz analogue voice channel or 65 kbit/s data stream,
(c) according to the switching method employed, e.g. circuit switching, packet switching or message switching and
(d) in terms of the network function provided, e.g. the data transport function of the Digital Data Service or the communication processing facilities of the Teletex and Telememo services.

Interworking Strategy

Typically, existing services can be described by a single or limited number of choices from each of the above classifications. In cases where two services offer similar functionality or media types to the customer, e.g. telex and teletex, a gateway or conversion facility will often be provided to allow users of one service to communicate (or interwork) with users of the other. Such a situation is shown in Fig. 1.

(See diagrams over)

Clearly, the increasing use of advanced information processing facilities and the growing importance of timely and accurate dissemination of information in the modern office environment will fuel the demand for new communication services. Such services will be required to operate across both the wide geographical areas covered by traditional public telecommunication networks and within restricted customer premises. Adherence to the interworking strategy outlined above could easily lead to:

- a proliferation of terminal types required by a given customer,
- a multiplicity of conversion facilities required within the service provider's network and
- inaccessability of particular terminals for a given customer.

Such developments are certainly unattractive for both service user and provider.

Future Network Development Strategies

In response to this expected proliferation of service types and interworking requirements, the Research Department is currently involved in the study of future network development strategies, which will support communication across a wide variety of service and terminal equipment types. Such a situation is shown in Fig. 2. It depicts the interworking of existing services and terminals with future equipment, which may be capable of supporting information transfer in a variety of formats, e.g. alphanumeric text, videotex graphics, imagery and digitized voice. Such interworking will not be achieved through a multiplicity of gateways but by the development of Integrated Service Provision Facilities, which will transparently encompass the full range of expected service types. Key strategies in the development of such integrated facilities would include:

- increasing use of store-and-forward communication techniques for the transfer of multi-mode messages, i.e. messages which contain a variety of information types such as text, graphics and voice,
- provision of network-based processing centres capable of translating between the range of information formats found in messages,
- adoption of internationally standardized protocols for Open Systems Interconnection as the basis for communication between network centres and terminals in order to achieve syntax independence during information transfer,
- use of directory service functions to aid the identification and reconciliation of service and terminal incompatibilities and
- incorporation in the network of user-level facilities designed to simplify the customer's interaction tasks, e.g. to support the transparent connection to a range of databases or information sources on request, assist in the preparation and submission of messages or provide a command interface based on natural language comprehension.

The adoption of techniques such as those outlined above will ensure the development of a particularly flexible telecommunications network, well able to satisfy the requirements of future service types and as yet undeveloped applications.

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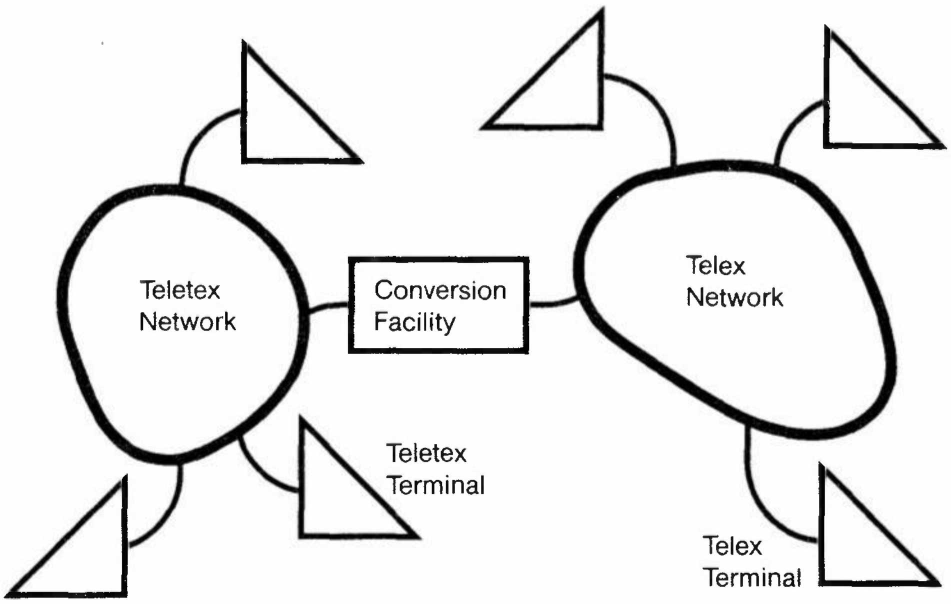

Fig. 1: Current Interworking Example

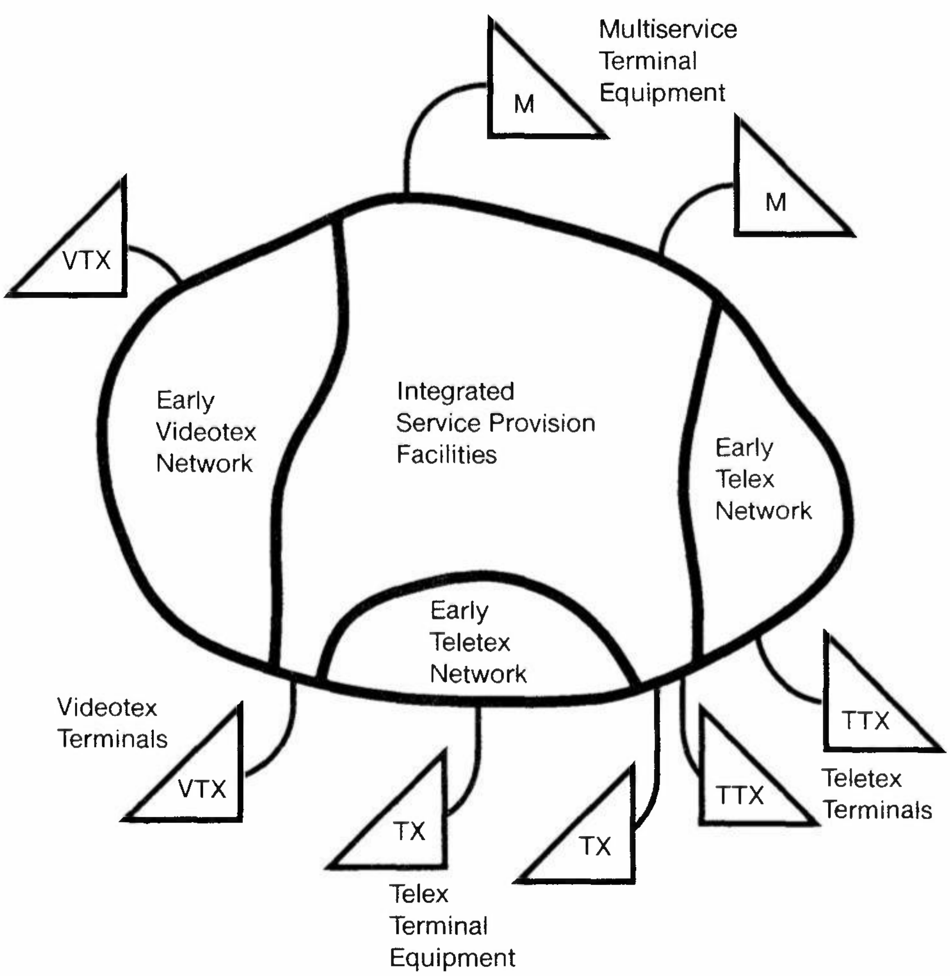

Fig. 2: Possible Future Interworking Strategy

VOICE STORE & FORWARD SERVICES

Purpose

Voice Store and Forward (VSF) Services provide a means of communicating messages between telephone customers when both parties are not simultaneously available. Such indirect communication is accomplished by segregating the message deposition and message retrieval functions of the communication by the use of intermediate storage facilities.

Types of System

Network systems for the storage and delivery of voice messages may be divided into two types. The first may be considered to be a centralized telephone answering service that may be invoked, by the called party, to receive calls at any desired time, especially during the customer's absence or when busy on another call. The second type may be considered to be a centralized message delivery service. In this case the VSF customer deliberately accesses a VSF centre for the purposes of recording a spoken message to a specific telephone customer. This action may be the result of the wanted party being busy or not answering. When such a message has been recorded, the VSF system will then either attempt to deliver this message at regular intervals by dialling the intended recipient or indicate to the intended recipient that he has a message waiting by imposing a tone (or interrupted dial-tone) on the telephone line when next the customer lifts his telephone handset. In this latter instance the message recipient must access the VSF centre to retrieve his message.

Extra User Facilities

A VSF service communicates with the user by means of spoken prompts and the user provides control information to the VSF centre by means of dual-tone multi-frequency (DTMF) tones. To be useful, a VSF service must incorporate a number of extra user facilities. For the calling part these might include:

- the capability to edit and review messages,
- the delivery of a message to a group of recipients,
- the capability to enquire about the number and details of messages still retained by the VSF system and the ability to cancel any or all of these messages and
- the capabil ty to specify message priority level, specific delivery time, maximum retention time and a specific time for automatic cancellation of an undelivered message.

For a message recipient, VSF user facilities might include:

- the capability or retaining or deleting the message currently being delivered and
- the capability of replaying or deleting previously retained messages.

A schematic diagram of a typical VSF system is shown in Fig. 1 below.

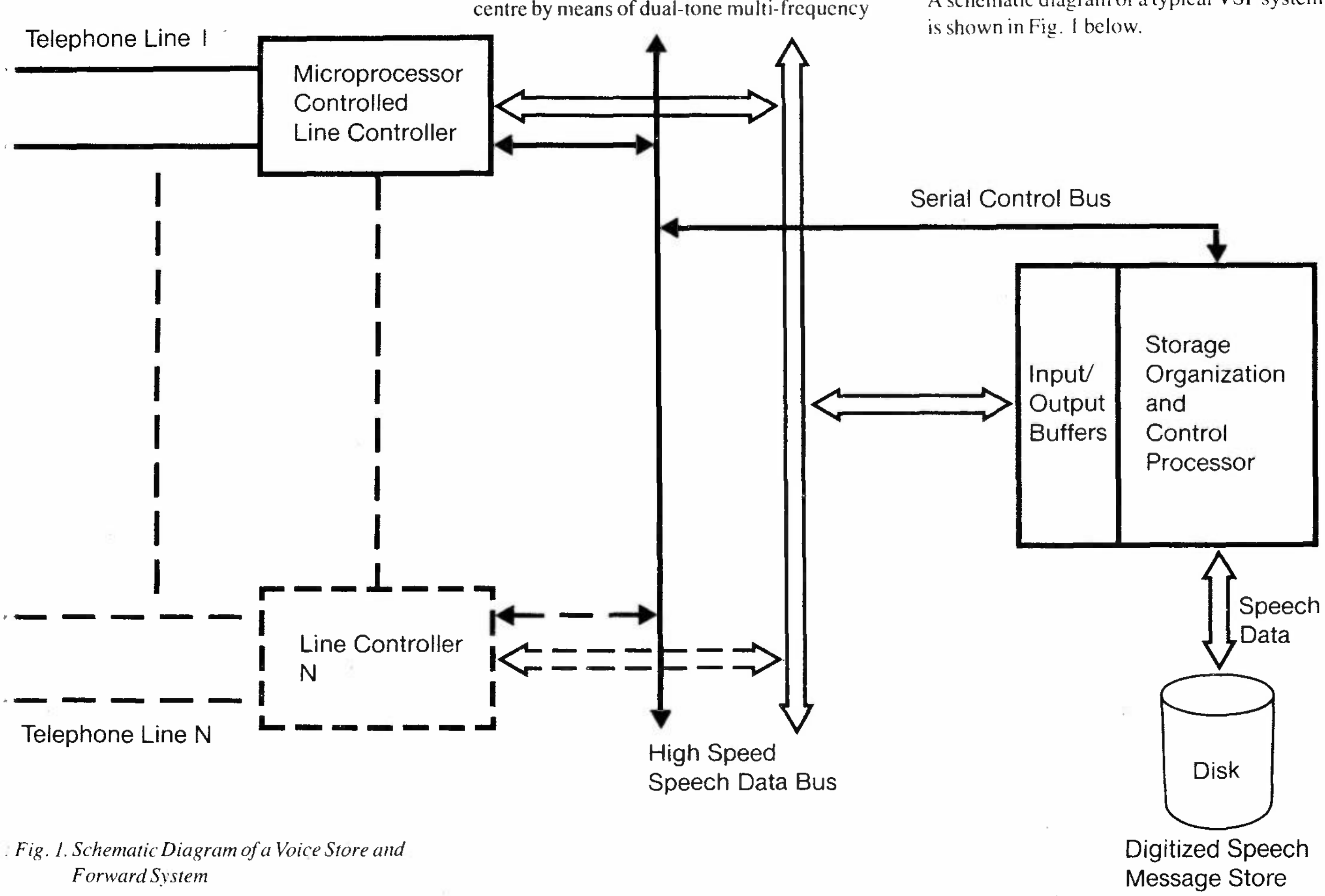

Fig. 1. Schematic Diagram of a Voice Store and Forward System

Functions of the VSF System

The functions of the VSF system can be segregated into two components, a microprocessor controlled line controller for each incoming telephone line and a speech data-base organization and control processor. The latter processor controls the bulk storage media on which the spoken messages and systems prompts reside, as well as keeping the directory of stored messages and other directory information relating to the VSF service users. This processor also schedules the delivery of spoken messages. Requests for specific messages (both user and prompt), either to be stored or retrieved, are sent from the line controllers to the data base controller via the serial control bus. The functions of the line controller are depicted in Fig. 2

Line Controller

The line controller handles the usual line interface requirements for a telephone, as well as the DTMF tone decoding (by which the user indicates his requirements to the system) and the encoding and decoding of the speech signals. The microprocessor interprets the user commands, as decoded by the tone decoder, and sends high level commands via the serial control bus to the database processor. Information in the form of directory information is returned via the serial control bus and speech message segments are transferred (in both directions) via the high speed speech bus.

Message Handling Services

A VSF service is a specific example of a generic class of services referred to as Message Handling Services (MHS). The functional model of a MHS is depicted in Fig. 3 Users interact with a User Agent (UA), which provides the facilities for the deposition and retrieval of stored messages. Messages are passed on by the UA to a network of Message Transfer Agents (MTA), which route the messages to the appropriate User Agent.

For voice messages, a UA would be functionally equivalent to the line controller plus associated storage within the database processor. For reasons of storage economy these UAs are grouped together to form a VSF access unit (VSFAU). The VSFAU can then be incorporated into an integrated MHS by appropriate connection to an ATA as shown in Fig. 4

The VSF access protocol refers to the manner by which the MHS user would communicate with the VSFAU and is no different from that already discussed. The P1 protocol is the procedure for moving messages through the message transfer network. The P2 protocol ensures that messages are delivered to a co-operating User Agent, that is, voice messages are delivered to voice User Agents, text messages to text User Agents etc. The P3 protocol refers to the LC transfer procedure for messages from a User Agent or access unit to a Message Transfer Agent and vice versa.

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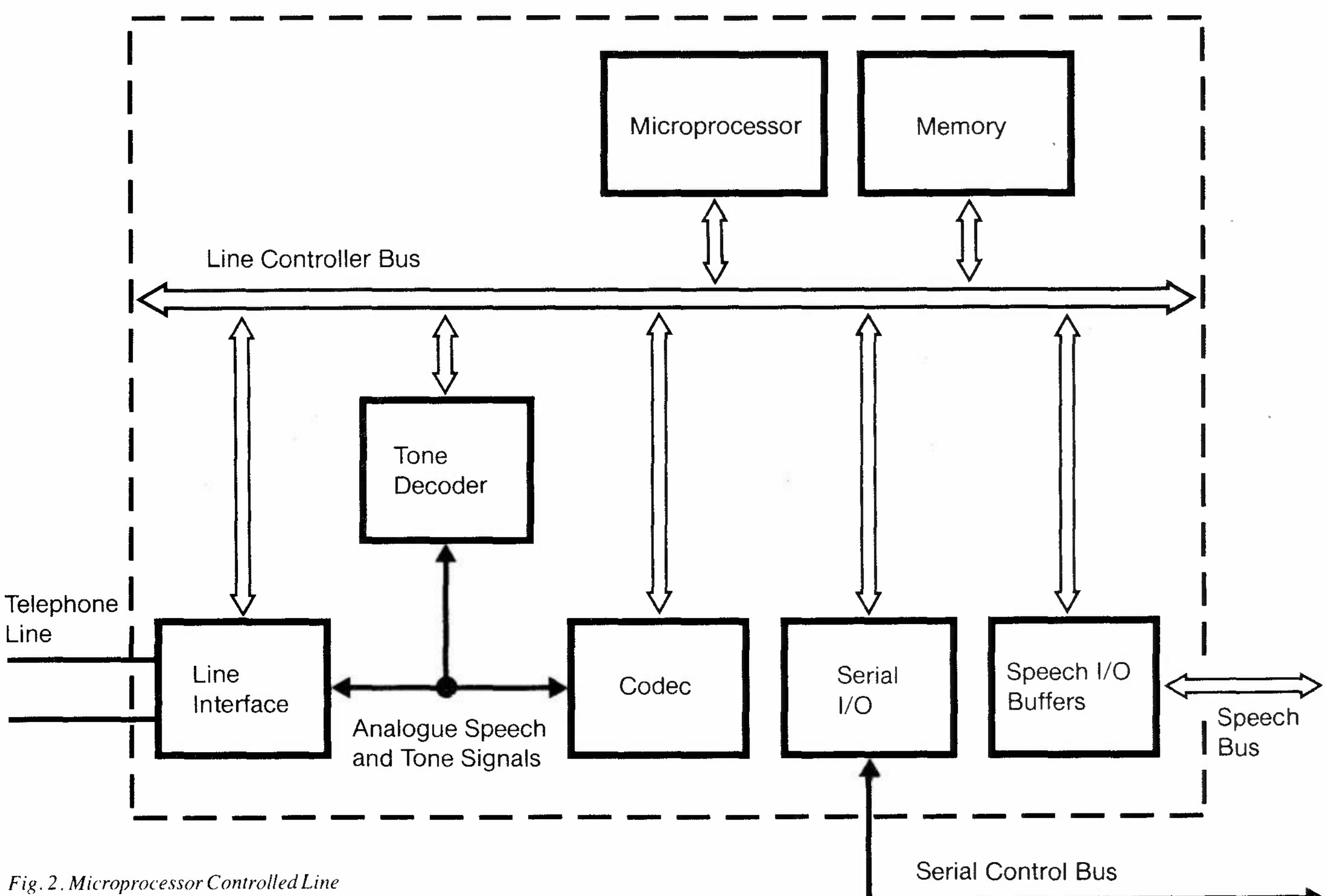
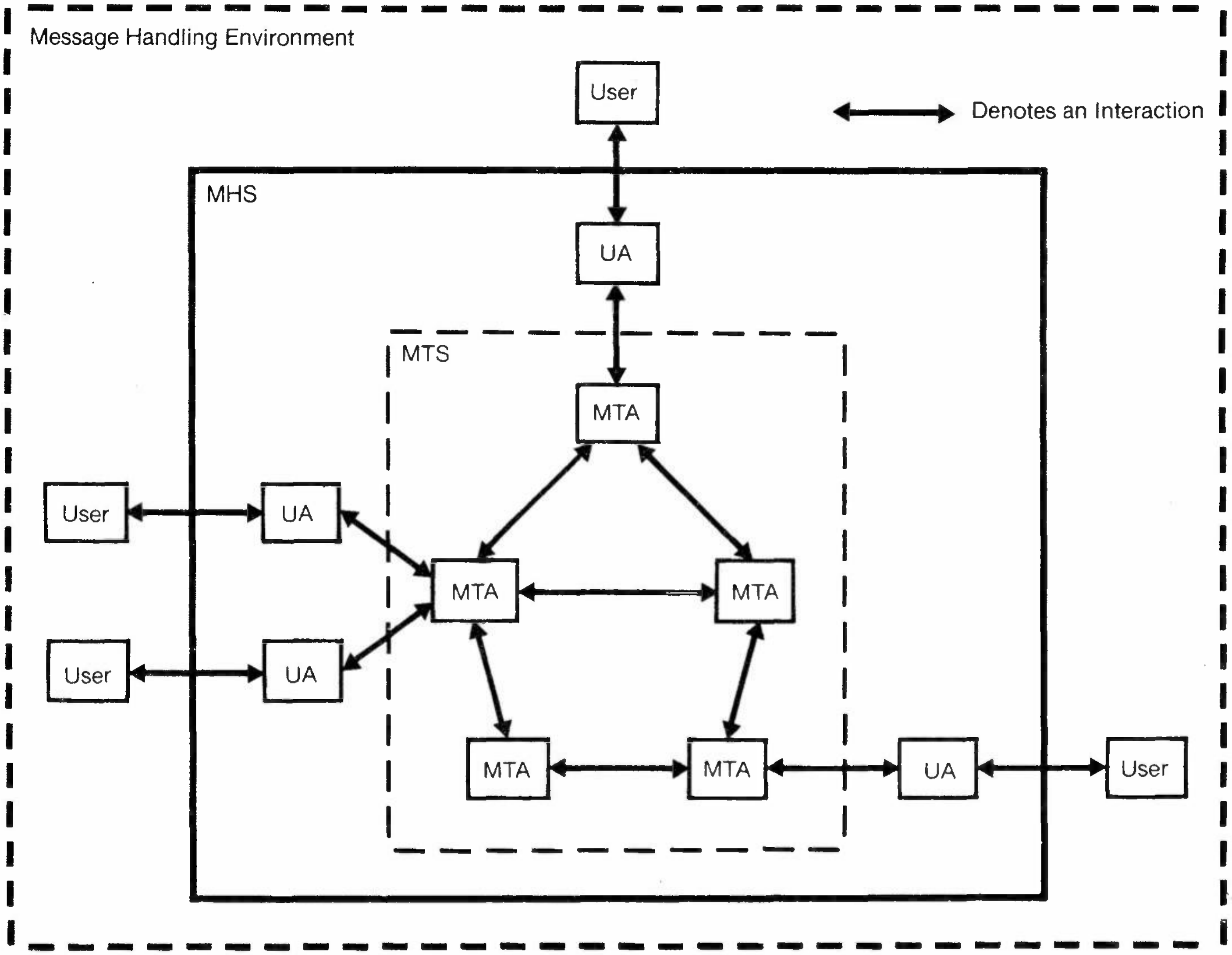


Fig. 2. Microprocessor Controlled Line Controller



LEGEND:
MTS: Message Transfer Service
MTA: Message Transfer Agent
UA: User Agent

Fig. 3. Functional Model of an Integrated Message Handling Service (MHS)

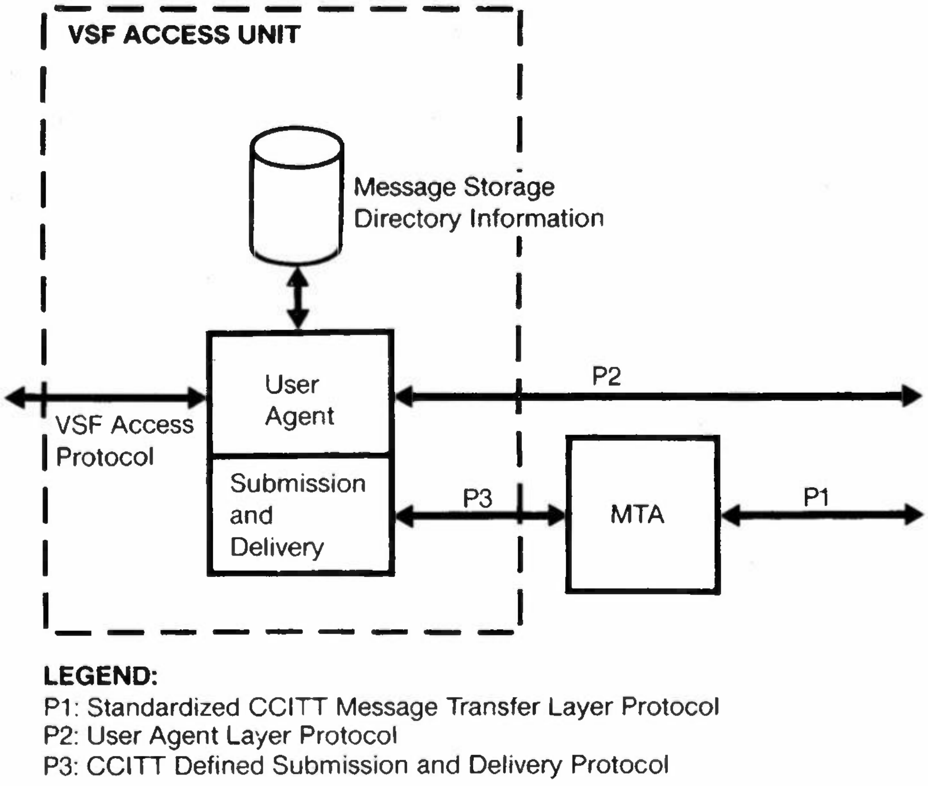


Fig. 4. The Integration of Voice Storage and Forward into a Generalized Message Handling Service

VIDEOTEX SERVICES

Videotex

Videotex provides a means for a customer to access data bases interactively through a standard television set and a keypad or a keyboard terminal. The connection is by a pair of telephone lines over the normal telephone network or through a data transmission network.

Encoded information to generate text, graphics, image or sound can be sent from the host to the terminal using graphic elements of the categories: Alphanumeric, Mosaic, Dynamically Redefinable Character Set (DRCS), Geometric, Photographic and Musical notes.

Types of Videotex System

Videotex services are available or are under development in different countries and regions. The main existing Videotex Systems employ different techniques to encode the information, e.g. the pioneering Prestel (England) uses alphanumeric and mosaic graphic elements; the Canadian Telidon uses alphanumeric, geometric and a smaller set of mosaic graphic elements. The different encoded categories of Videotex systems hamper their interworking. A terminal designed for one service cannot access the other services unless a facility (gateway) for transcoding or conversion is available. Likewise, one service cannot use the facilities of the other service if a gateway is not provided.

Ability to Interwork

The ability of Videotex services to interwork not only allows a terminal to access a larger number of databases but also allows for the services to communicate with each other to enhance their services so that, for instance, one service can access a database of another service. It may also be valuable for the Videotex services to interwork with other telematique services, such as Teletex, Telex, Facsimile etc.

Currently, the Research Department is studying conceptual models that may be applied to the problems of Videotex service interworking. These techniques, which may be extended to the general implementation of electronic documents, including text, script and images, will be applied to the development of videotex-style database services of the future. The Research Department has a significant role in assisting Telecom's new Commercial Services' planning in these various respects.

Benefits to Customers

Customers will benefit from these developments as a result of:

- greater freedom of access to multiple data bases,
- greater level of compatibility between originally disparate terminals and information databases and
- longer term, higher quality graphics associated with videotex images.

Telecom introduced its own videotex system, Viatel, in February, 1985. Viatel, based on the English Prestel system, will allow both business and private users access to large amounts of information using relatively inexpensive terminal equipment. Viatel users will also be able to access services provided by commercial services organizations.

Typically, the Commonwealth Bank introduced Australia's first home banking service on Viatel in March, 1985. Fig. 1 outlines the structure of the new service.

(See diagram over)

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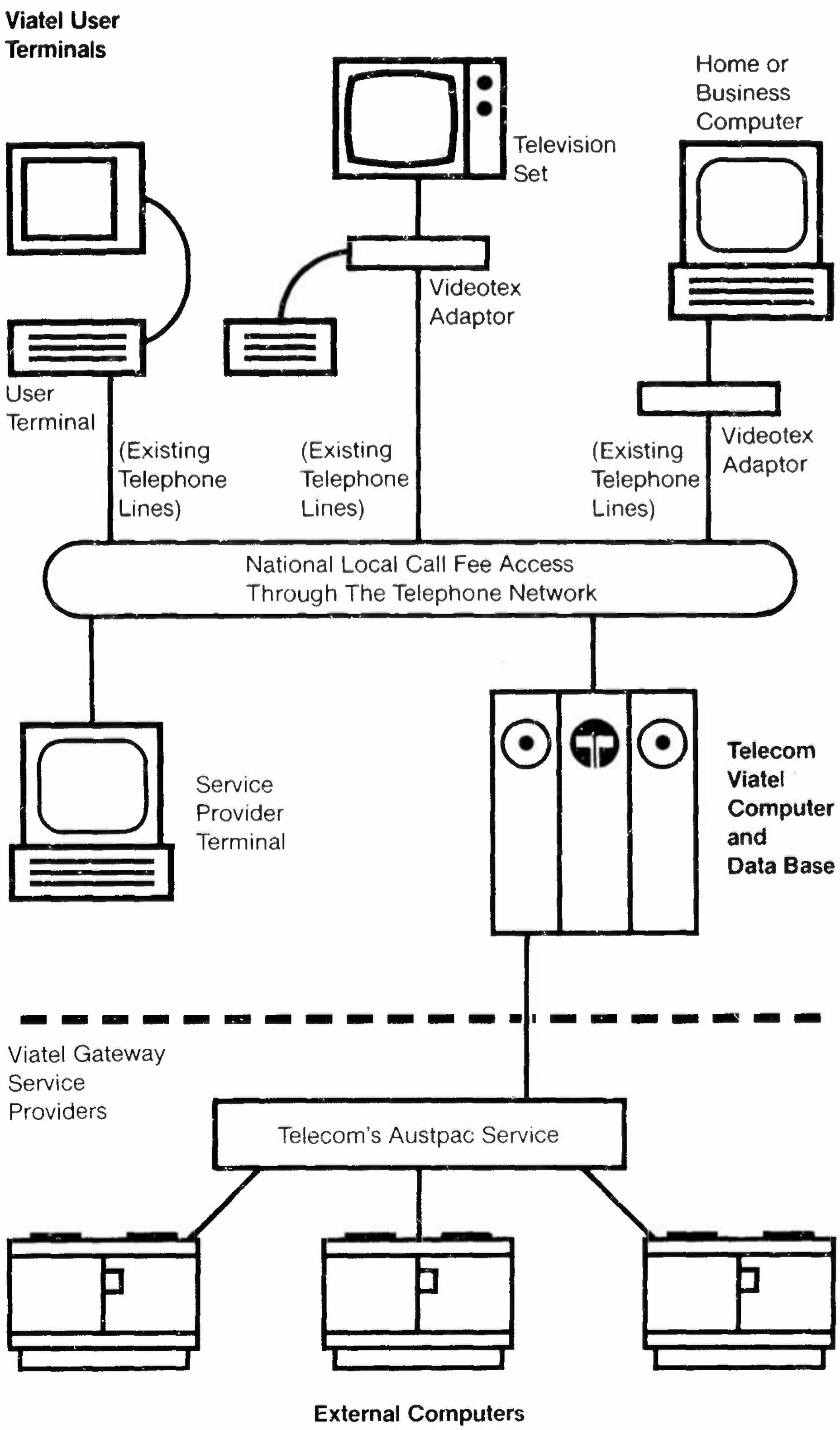

Fig. 1: Viatel Videotex System

INTEGRATED SERVICES DIGITAL NETWORKS

Introduction

An Integrated Services Digital Network (ISDN) is a network able to support a wide range of services, including voice and data services, to which users have access by a small set of standard multi-purpose customer interfaces. Establishment of these interfaces then allows independent developments in the customer's premises, such as terminal equipment, and in the network itself, such as transmission, switching and signalling equipment, within a common framework. The ISDN approach is increasingly being viewed by telecommunications network administrations worldwide as the long term solution to the problem of providing for the diverse range of communication services expected to be required in coming years.

Work in many areas of the Telecom Australia Research Department is either directly or indirectly concerned with the definition of this future ISDN.

Background

Telecom Australia, like most other network administrations, has adopted a strategy of using digital technology for most future network development. Recent cost trends favour this approach but the real impetus comes from the accelerating customer demand for new services based on digital techniques. Accordingly, large investments are being made to introduce digital transmission and digital switching systems to meet increased demand or to replace obsolete equipment. At currently forecast rates of development and equipment provisioning it is expected that approximately 50% of the network will consist of digital equipment by the year 2001.

Most of the initial investment in digital technology is being used to construct a fully digital 'overlay' network of digital exchanges interconnected by digital radio and line transmission systems (twisted pair, coaxial cable and optical fibre). This network is known as the Integrated Digital Network (IDN) and will provide for circuit switched 64 kbit/s connections between local exchanges. A powerful inter-exchange signalling system based on packet switching techniques known as CCITT Signalling System No. 7 will also be introduced with the IDN, providing faster call set-up and considerable flexibility for future enhancement.

The IDN will not initially be directly accessible by the customer but rather will enable significant cost and performance advantages to be realized in the inter-exchange part of the network. The IDN will also provide the transmission capacity for a number of specialized data networks meeting particular needs of the business customer. These include the Digital Data Network (DDN), which provides high performance leased-line data services at rates up to 48 kbit/s and AUSTPAC, Telecom Australia's packet switched public data network.

The final stage of network digitalization is the introduction of digital technology into the link between the customer's premises and the local exchange. The resultant network providing digital connections end-to-end between customer terminals forms the basis for the Integrated Services Digital Network (ISDN). The ISDN differs from existing voice and data networks in its potential to support a range of voice and data services on a single 'multi-service' digital network. This unified approach offers significant advantages in cost and convenience to both the customer and network administration.

The international Telegraph and Telephone Consultative Committee (CCITT) is playing a central role in the setting of standards for the ISDN, particularly in the area of customer-network interfaces. Representatives from Telecom Australia, including representatives from the Research Department, have regularly attended the CCITT working party meetings dealing with ISDN and have contributed to the development of these standards.

Various Research Department activities are discussed below.

Customer Access

A key element of the ISDN will be the ISDN customer-network interfaces being developed within CCITT. The major thrust of the ISDN customer access standardization activities has been to develop an interface structure that can be produced at sufficiently low cost to allow widespread deployment in both business and domestic markets but with the flexibility to handle a wide range of present and future communication needs. This has led CCITT to adopt a basic interface structure that provides each customer with two 64 kbit/s channels suitable for either voice or non-voice information and a 16 kbit/s channel reserved primarily for carriage of signalling to control the use of these 64 kbit/s channels. This high capacity signalling channel uses a packet mode protocol and allows for fast call set-up but also provides spare capacity, which can be used to carry other packet mode information (e.g. data or telemetry). Hence, the future ISDN user will, through the one interface, be able simultaneously to operate several independent communications that would otherwise require the separate provision of a number of individual access lines.

Current research activities include investigation of the way an ISDN user can best use this 'multi-media' capability and studies of the complex interactions between the customer access signalling and the inter-exchange signalling within the network. Formal description of the customer access protocols and experimental verification of their correctness are also current research topics. In addition, an experimental ISDN terminal is being developed to investigate the integrated delivery of multiple services.

Digital Transmission

The development of a two wire, full duplex, digital line transmission system that can provide basic ISDN access to almost all customers, over the existing local copper pair cable network, is a necessity for achieving a viable ISDN capability. This task has received considerable worldwide attention and many telecommunication administrations and companies are currently at various stages of finalizing national system specifications and equipment designs to achieve this end. The various design approaches being pursued involve different trade-offs between system complexity and transmission performance.

Since most customers have only a single cable pair to their local exchange, the line transmission systems used to provide basic ISDN access must separate the go and return transmission signals. The system most likely to be used by Telecom will achieve the directional separation by using a hybrid with echo cancellation circuitry to remove any residual transmit signal that appears in the receiving direction owing to both finite trans-hybrid loss and reflected signal power from impedance discontinuities along the cable pair (i.e. owing to gauge changes and bridged taps). Since on long cable pairs the receive signal can be attenuated by perhaps 40 dB, the successful operation of echo cancellation systems relies on their ability to achieve 50–60 dB echo cancellation. This can only be achieved with complex circuitry, which must be implemented in LSI technology to be cost effective. However, this complexity also makes the process of converting prototype designs into production LSI chips a difficult task. Other factors, such as the choice of line code and the various adaption algorithms adopted to automatically control the echo cancellation operation and signal detection process used in the receiver, also have a significant impact on the performance and operation of a system design.

Before any particular transmission system can be adopted by Telecom its suitability for operation in the Australian customer network must be assessed. To facilitate this task the Research Department has developed a wide range of analytical skills and computer simulation tools to model the system's operation and the transmission impairments and noise processes that limit the achievable cable loop length. Appropriate studies are also under way into the implementation aspects that impact on the design and operation of the line transmission systems. The results of Research work are used to predict system limitations and the restrictions that these would impose on the number of customers that can gain direct basic access to Telecom's future ISDN.

Network Structure and Interworking

Whereas the customer-network interface will be subject to detailed international standardization, the internal structure of the ISDN will be much more a national matter, strongly influenced by the existing network structure. Possible approaches range from a number of distinct internal sub-networks each handling a single service (voice, circuit-switched data, packet-switched data, leased-lines etc.) available to the user by a common access arrangement, to a single integrated network that supports all the ISDN services. In Australia the ISDN will develop from the IDN, using the IDN to provide 64 kbit/s circuit switched connections between customers for both voice and data. Leased line services will also be able to be supported as semi-permanent connections through the IDN. Related research activities include detailed studies of the signalling requirements, technical characteristics of interfaces between equipment within the network and facilities for fault detection and location.

The role of packet switching in the ISDN is receiving special attention in studies by the Research Department. The CCITT identified packet switching as a service to be provided by the ISDN. Initially the ISDN will probably not handle packet traffic directly but will act as a circuit switched access network to the specialized packet switched data network (AUSTPAC). If packet switching develops as a major ISDN service, this approach may prove inefficient and some more integrated approach may be required. The impact on future exchange design could be profound. Present research activities include identification and evaluation of some of these alternative approaches.

Initially the emerging ISDN will need to coexist with the existing single service networks. Interworking between the new ISDN and these existing networks is a necessity for orderly growth of the ISDN. Network interworking is a many faceted problem that includes signalling and protocol conversion, addressing considerations, tariff considerations and network operations and maintenance. In collaboration with other Telecom Departments, the Research Department is investigating aspects of this problem relating to particular network interworking situations and to a general approach to network interconnection based on the Open Systems Interconnection (OSI) work of ISO and CCITT.

Experimental ISDN Exchange

To facilitate further experimental investigations to ISDN the Research Department is purchasing an experimental model of an ISDN exchange and associated terminal equipment, which is scheduled for installation during the second quarter of 1985 and will then provide a valuable test bed for trialling signalling protocols and ISDN services. Experience gained from the experimental ISDN exchange will assist in the later introduction of ISDN as a public service.

A range of representative ISDN terminal equipment will also be connected to the experimental ISDN exchange, to provide a realistic small-scale demonstration of the eventual capabilities of a public ISDN.

LIST OF EXHIBITS

ISDN TERMINALS & INTEGRATED SERVICES DELIVERY

Present Terminals

Currently there exist several proprietary 'integrated terminals' that can support more than one service, e.g. voice and data. These terminals use a combination of several separate sets of standardized interfaces and procedures to access various service-dedicated networks, e.g. the public switched telephone network and data networks. Examples of these interfaces and procedures include telephony signalling such as the dual tone multi-frequency (DTMF) arrangement and the CCITT (International Telegraph and Telephone Consultative Committee) V-series and X-series interfaces.

ISDN Terminals

With the emergence of the new 1984 CCITT ISDN (Integrated Services Digital Network) access interface recommendations or standards, a new breed of terminals is expected to become available. These 'ISDN terminals' will be able to support a range of services, e.g. voice, data, text and image, using an integrated user-network access interface, e.g. the ISDN basic access interface consisting of two B-channels at 64 kbit/s and a D-channel at 16 kbit/s. The new ISDN interfaces will have a multi-channel access arrangement together with an out-of-band common channel signalling scheme for controlling circuit-switched user traffic channels.

New Communication Capabilities

With the expected capabilities of the emerging ISDNs and associated access protocols, ISDN terminals will provide users with new ways of using present and new telecommunications services. Examples of these communication capabilities include:

- circuit-switched connections under the control of common channel signalling; once established, these connections can support any user traffic, e.g. voice and non-voice, including traffic in packetized form, at compatible bit rates,
- packet-switched communication over the user traffic channels, e.g. B-channels, and the (mainly) control traffic channel, e.g. D-channel,
- compatibility checking of terminal capabilities, prior to and during call establishment, e.g. with respect to communication and application-oriented characteristics, using the out-of-band common channel signalling facilities,
- signalling between end-users and network-based facilities, e.g. data bases such as electronic directories,
- end-to-end signalling between users in the out-of-band control facility, e.g. to change mode of communication over an already-established connection and
- a combination of the above as in multi-media communication, whereby several simultaneous modes of communication can take place under common signalling control.

More importantly, ISDN terminals will facilitate the integrated delivery of multiple services to the end-users, for both information carriage, or 'bearer services' and user-oriented applications, or 'teleservices'. The latter will include the new out-of-band end-to-end signalling facility or 'order wire' facility, allowing a range of new communication capabilities to be exploited.

Experimental ISDN Terminal

Indeed, an experimental ISDN terminal and associated protocol testing arrangement are being implemented within the Research Department. This experiment will serve as a vehicle for investigating various aspects of the new ISDN communication capabilities mentioned earlier, in particular those of the integrated services delivery concept.

The experimental terminal involves the design and construction of an ISDN Access Unit. An ISDN Access Unit is that part of an ISDN terminal that allows the user to access and control the communication capability offered at the ISDN user-network interface.

The experimental ISDN Access Unit is designed around a processing module that features a 16-bit microprocessor and dual-port memories. Individual modules can be 'stacked' together to provide a multi-processing system. The dual-port memories provide adjacent processors (in this 'stacked' arrangement) with an 'open window' into each other's address space. That 'window' enables the processors to observe each other and exchange messages. This approach allows for the addition of extra processing power to the ISDN Access Unit in a systematic manner with minimal impact on the existing system.

Early versions of the experimental ISDN Access Unit will support Layers 2 and 3 of the D-channel protocol hierarchy defined in CCITT Recommendations I.441/Q.921 and I.451/Q.931 respectively. Initially the protocol of each Layer will be assigned to a single module, making the ISDN Access Unit a two-processor system. However, if the need for more processing power becomes apparent, e.g. to boost throughput or to support new services, extra modules will be added to share the load.

Modular Design

In keeping with the flexible modular approach adopted for the hardware, the software is also modular. Each processing module has its software partitioned into two parts namely

- a Control Program, which is protocol independent and
- one or more Protocol (dependent) Data Structures.

The Control Program co-ordinates message passing between modules and accesses the Protocol Data Structure in order to determine the module's response to those messages. The Protocol Data Structure or table completely defines the protocol supported by the module. It is derived from CCITT Specification and Description Language (SDL) descriptions of the protocol to be implemented. To alter the protocol supported by a particular module, no specialist's knowledge of the module's hardware architecture or the intricacies of its communications software, i.e. Control program, is necessary. Only the Protocol Data Structures need to be changed.

The ISDN Access Unit could provide an independent means to test ISDN Customer Access Signalling Protocols both in the Research Experimental ISDN Exchange and the Headquarters Ericsson AXE ISDN field trial. Further it is expected that it will support studies in the area of Local Area Network (LAN) to ISDN interworking and in the continuing area of integrated services delivery in an ISDN environment.

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COMPUTER MODELLING OF CUSTOMER ACCESS NETWORKS

The ISDN Concept

The economic advantages of digital transmission and switching ensure that a growing proportion of links between local exchanges in telephone networks will become fully digital during the 1980s. Questions of the benefits of extending digital transmission from the local exchange to the customer have led to the concept of an integrated services digital network (ISDN). This concept is attracting considerable interest within telecommunications administrations around the world, including Telecom Australia.

Digital Transmission Path

An important element in the evolution towards an ISDN is the two-way digital transmission path linking customer and local exchange. It is imperative that such paths should initially be provided over the existing network because it represents a significant investment. In Telecom Australia's case, it is 30% of the total network asset.

Considerable overseas resources have already been devoted to this area of investigation and a number of alternative digital transmission techniques, capable of operating on existing local cable networks, have been proposed.

Computer Package

To facilitate the assessment and comparison of the various digital transmission techniques proposed, the local loop must be accurately known in terms of its physical and electrical characteristics. Within Telecom Australia, information of this type has been obtained from a local loop survey recently conducted by the Engineering Department. In addition, the Research Department has developed a versatile computer package that combines

(a) network composition data obtained from the survey,

(b) transmission parameters of various cables obtained from open and short circuit measurements on short lengths of each cable type and

(c) parameters of various components of digital transmission equipment such as transmission rate, line code, equalizer frequency response, mode of transmission, etc. to produce a number of important outputs.

These include:

- customer to exchange impulse and frequency response,
- customer end and exchange end echo impulse and frequency responses,
- eye patterns and
- near end and far end crosstalk noise figures.

The outputs from the model have been verified by measurements performed in the laboratory and they make it possible to predict the percentage of existing customers that could obtain direct digital access to their local exchanges for the transmission method employed.

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INTERFERENCE FROM DECADIC DIALLING

Required Interference Tolerance of Systems

Digital transmission systems that are installed in the customer network will have to tolerate for the rest of this century the interference caused by decadic dialling on rotary dial telephones. This interference is electromagnetically coupled from the pair of wires carrying the analogue telephone circuit into all nearby pairs in the cable. The interference may result in errors on digital transmission systems on these nearby pairs.

Quantifying the Effects of Interference

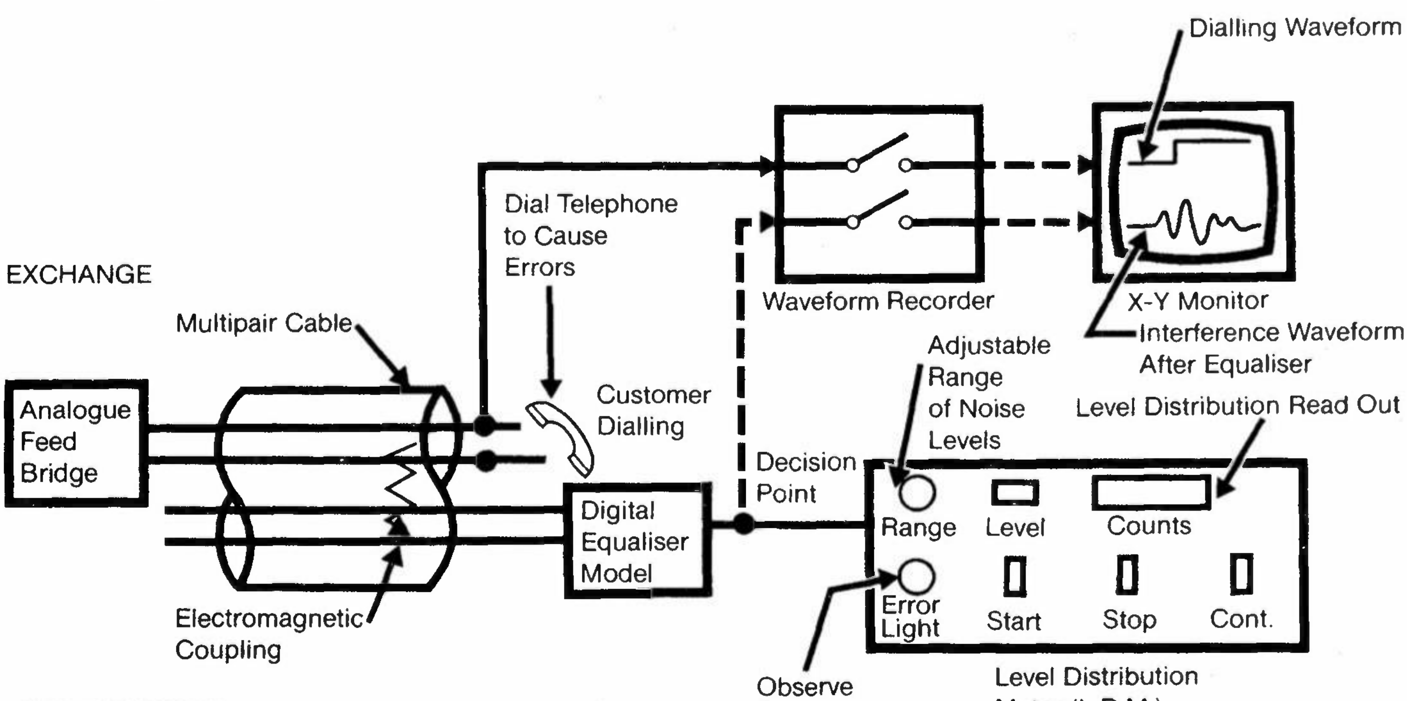
The extent to which the interference would affect various proposed digital transmission systems may be assessed using a statistical model for the electromagnetic coupling paths within the cable. The model enables the expected numbers of errors per dial pulse disturbance to be predicted. That number is multiplied by the rate of occurrence of the dial pulses on the nearby telephone circuits to obtain an estimate of the rate of occurrence of errors on the digital system.

When the receiver or a hardware model of the receiver filter is available, a direct measurement of the number of errors per event is possible. This measurement (see Fig. 1) uses the noise waveform at the decision point in the digital receiver. A level distribution meter samples the noise and compares the samples with a number of thresholds to obtain a histogram of the numbers of samples between each pair of levels. (See Fig. 2).

Following a measurement, the counts in each level may be scanned to provide the data for this histogram.

The noise level that would cause an error depends on the signal level and the location of the thresholds in the digital receiver. For longer lines the signal level is lower and the threshold noise level that results in an error is lower. The number of errors for a given noise threshold can be obtained by adding the counts in all of the classes to the right of that threshold in the histogram.

Fig. 1: Measurements of Noise Waveforms and Error Rates



WITH EQUIPMENT

Functions:

1. Dial and Watch Error Light Flash
2. Change Range on L.D.M. to Eliminate Errors (Equivalent to Reducing Cable Length)
3. Recall 1 Setting on Waveform Recorder to Observe Dial Pulse Train and Noise Spikes
4. Recall 2 Settings on Waveform Recorder to Observe a Single Level Transition and Noise Waveform
5. Set Continuous on L.D.M., Dial Several Times, Stop L.D.M., Check Counts in Levels

Fig. 2: Example of a Noise Level Histogram

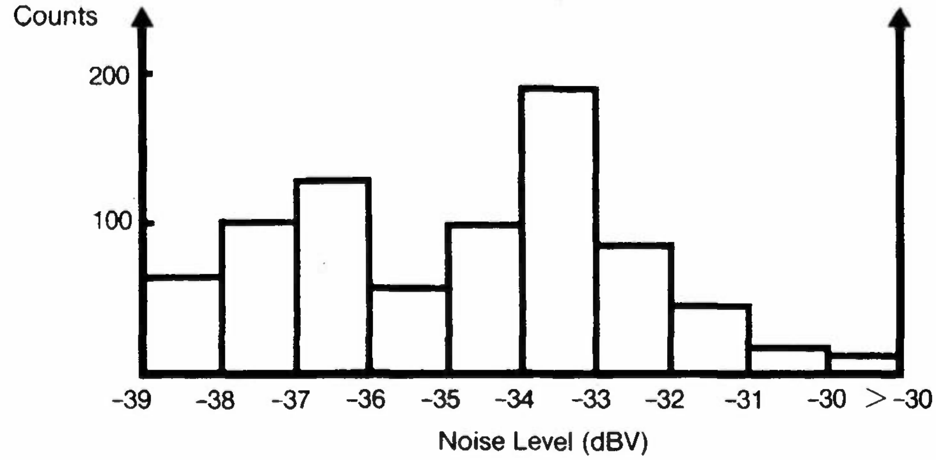
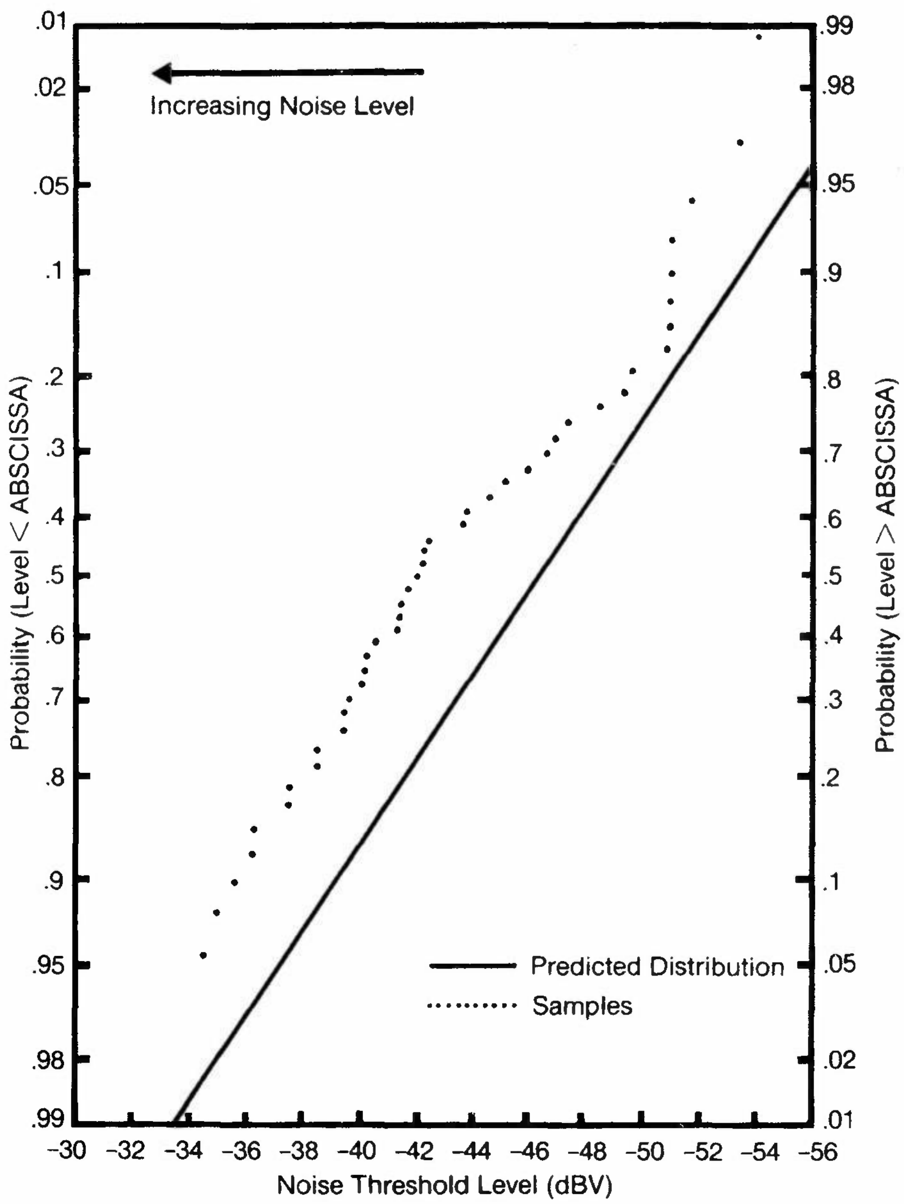


Fig. 3: Comparison of Predicted and Sample Noise Level Distributions for 0.1 Errors per Event.
(for dialling on 0.64 mm copper pair cable where the disturbing waveform is modelled as the multiple event shown).



Performance Objective

The rate of occurrence of errors in a system installed in the network should be less than the limit specified in the performance objective. This means that the number of errors per dial pulse is restricted (to a value of about 0.1 errors per dial pulse on average) and we may determine the noise threshold for which a specified number of errors per event occurs.

The noise threshold varies from one disturbing pair to the next (all electromagnetic coupling paths are different) and the statistical distribution of these noise thresholds may be obtained by measuring a large number of pair combinations. In Fig. 3 this is compared with the distribution predicted by theory.

This shows reasonable agreement between the theoretical model and the measured performance.

Contact: Philip Potter 03-541 6424

THEORETICAL STUDIES OF DIGITAL TRANSMISSION SYSTEMS

Line Transmission Systems

In addition to the work of simulation and evaluation of transmission systems, the Research Department devotes considerable effort to theoretical studies of line transmission systems. These studies are directed towards a better understanding of some of the fundamental limitations of line transmission, such as, the study of mutual interference between digital line systems sharing the same cable. Studies are also directed towards developing new techniques for digital line transmission.

The carrying out of these studies is a necessary step in establishing a strong theoretical understanding of digital line systems. Our objective has been to develop this expertise to the highest possible standard so that, firstly, when Telecom evaluates digital transmission equipment and systems from manufacturers it has available a sound theoretical basis on which to make its assessment and, secondly, it may introduce this equipment in the network in the optimum manner. In some cases our studies have led to new techniques, which have been accepted internationally.

The papers on display illustrate some of our studies and all have been published in overseas journals.

Crosstalk in a Synchronous Network

One paper proposes a new technique to characterize the performance of digital line systems with respect to crosstalk by the crosstalk noise figure. This technique has received international recognition by being adopted by the International Telegraph and Telephone Consultative Committee (CCITT) in its recommendations. Another paper addresses the problem of the effect of synchronization on the mutual interference between digital line systems. In the early stages of development of a digital transmission network, individual digital line sections are not mutually synchronized. However, an integrated digital network requires that all links be synchronized. This work examines the effect of synchronization. In particular, it has required the use of cyclostationary statistics of the digital data signals and a very careful modelling of the various modem processes involved.

Impulse Noise

Introducing digital transmission into the existing analogue telephone network means that there is interference between analogue and digital services. Dialling pulses from the analogue telephone are coupled via cable crosstalk and interfere with the digital services. Whilst some measurements have been conducted, this is the first theoretical study of this problem.

Timing Recovery

In some digital line receivers there is a desire to perform all of the receiver operations using digital operations. This is particularly so for Integrated Subscribers Digital Network (ISDN) customer access over existing subscriber lines. In this paper a new method of timing recovery using only baud rate samples is described.

Contact: Andrew Jennings 03-541 6394

DIGITAL TRANSMISSION FOR THE LOCAL CABLE NETWORK

Digital Transmission

Over the past decade Telecom Australia has been steadily extending digital transmission throughout its telecommunications network. Many advantages accrue to the customer and Telecom from this progressive development. It provides for cheaper transmission and enables integration of services. By introducing digital transmission over existing cables, Telecom can expand its services at a lower cost than by the expensive replacement of cables.

In the existing telephone network, digital information can be transmitted via modem devices that couple the digital information to the analogue channel. These devices modulate and demodulate the digital information, hence the name modem. Also, Telecom provides leased line digital transmission via the Digital Data Service. So there are now means of transmitting digital information across the national and international telecommunications network but only at low rates and not in an integrated manner.

Increased requirements for digital transmission of information leads to advantages in integrating digital transmission into the entire network. Telecom has begun this process by introducing 2 Mbit/s transmission in the inter-exchange network and by introducing 140 Mbit/s digital transmission to the inter-city network, initially by radio and later by optical fibres.

Use of digital exchanges to switch the digital transmission completes an integrated digital network where digital transmission direct from customer to customer without the use of a modem becomes a possibility if some form of digital transmission over the existing cable network can be provided.

ISDN

In the future it is likely that the telecommunications network will evolve into a digital network supporting a wide range of services in a unified manner — the integrated services digital network. At present customers have access to the telecommunications network via a 2-wire copper line to the local exchange. The Research Department is actively involved in work aimed at exploiting that existing line to connect to an ISDN, which is preferable, as this results in substantial economies. The use of existing lines means that any new equipment must be compatible with the existing network and must be capable of operation in a transmission environment originally designed for services with less demanding transmission requirements.

Use of the existing pair of wires to support digital transmission in both directions simultaneously (full duplex operation) requires the application of sophisticated technology. The presence of two signals simultaneously on the pair of wires leads to echoes at the transmitted signal in one direction interfering with signals transmitted in the reverse direction. An echo canceller forms a replica of the echo path and cancels the echo signals. The echo canceller must adapt to each different line echo path. In a sense it 'learns' each line characteristic. Digital transmission in the customer network involves a coupling of old technology (the cable pair network) to new technology (LSI echo cancellation).

Simulation

The existing customer network is complicated. It has lines of widely differing length and composition. To assess the performance of various items of transmission equipment by measurement is a prohibitively costly exercise so the Research Department has developed a large simulation program that enables rapid assessment of a wide range of customer line configurations and different transmission system techniques and parameters simply by assembling a computer model of the line. In this way measurements that would take weeks to perform can be simulated in a few minutes on a computer.

Analysis — Crosstalk

When digital transmission systems share the same cable, a small proportion of the signal transmitted by each system is coupled via the cable and interferes with the other systems sharing the cable. This mutual interference between systems is called crosstalk. The presence of crosstalk means that the more systems that are placed in a cable, the more crosstalk is present. The Research Department has conducted extensive theoretical studies of this problem and the results of these studies are used for the engineering of the digital transmission network.

In the early stages of digital network development, the digital transmission systems are operated by independent clocks, i.e. they operate in a plesiochronous fashion. However, in an integrated digital network all of these clocks must be tied together, i.e. the network operates in a synchronous fashion. The Research Department has been at the forefront of the world in the analysis of the effect the synchronization has on the crosstalk between systems sharing the same cable.

Analysis — Impulsive Noise

When digital transmission systems share the same cable with analogue transmission systems at local exchanges, compatibility between the two services is of concern. The normal telephone service uses signalling that can interfere with the digital transmission system. Dialling from the ordinary telephone is usually the worst problem. The dial pulses from an ordinary telephone are coupled within the cable and can interfere with the digital transmission system. Theoretical studies of this problem have led to design guidelines.

Hardware

Evaluation of prototype hardware enables the Research Department to assess developments leading to new technology introduction to the telecommunication network. This enables the Research Department to keep abreast of developments of importance to Telecom's operations.

Through this process of evaluation, simulation and analysis, the Research Department, in conjunction with other Telecom departments, is actively involved in the introduction of digital transmission connecting the customer to an integrated services digital network.

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DIGITAL MICROWAVE RADIO

Errors

For all types of transmission systems, information can be passed from end to end without corruption for a very large part of the time. Sometimes, however, disturbances to the transmission medium can occur, which may result in the receiver being unable to correctly receive what was sent by the transmitter. In digital systems this results in errors in the output digital information.

Optimizing System Design by Predicting the Loss of Performance due to Intermittent Signal Fading

A principal cause of errors in digital microwave radio systems is intermittent multipath signal fading. This intermittent fading results in distortion of the received signal and the receiver does not correctly detect the transmitted signal. The data from the output of the receiver thus sometimes contain errors.

During the design phase of digital radio systems, it is necessary to predict the amount of time that the data will suffer from errors due to intermittent multipath fading. This information is required to fix parameters such as the radio path length (typically 40 to 60 km) and the type of equipment to be used on any particular path. Through this process a complete radio system can be designed to meet international performance objectives.

During still summer nights, stable layers form in the atmosphere. These stable layers have the ability to refract microwave radio signals and cause two signals to arrive at the radio receiver instead of one signal, which is normally the case.

The original signal arrives at the receiver at two slightly different times with a different amplitude at each. Depending on the relative phase of the two signals at a particular frequency, the amplitude of the signal at the receiver will vary and cause intermittent multipath fading.

Small variations in the relative delay and amplitude of the two rays will cause the amount of distortion of the radio signal to vary and consequently the number of errors in the detected signal will also vary.

Multipath Fading Formulae

From a radio point of view, the multipath fading can be characterized by :

- a multipath activity factor η (time) and
- a mean relative echo delay τ_o

The time for which a Bit Error Ratio (BER) threshold is exceeded can be predicted from the formula:

time BER equals or exceeds threshold

$$= \eta \left(\frac{\tau_o}{2}\right)^2 K^2$$

where K is an equipment dependent parameter and T is the baud period of the system.

The effects of multipath fading can be reduced by using space diversity at the receiver. The time for which the BER threshold is exceeded is then given by the formula

time BER equals or exceeds threshold

$$(\text{diversity}) = \tau \left(\frac{\tau_o}{T}\right)^4 13K^2$$

The use of the above two formulae enables digital microwave radio systems to be economically designed to meet international systems performance objectives.

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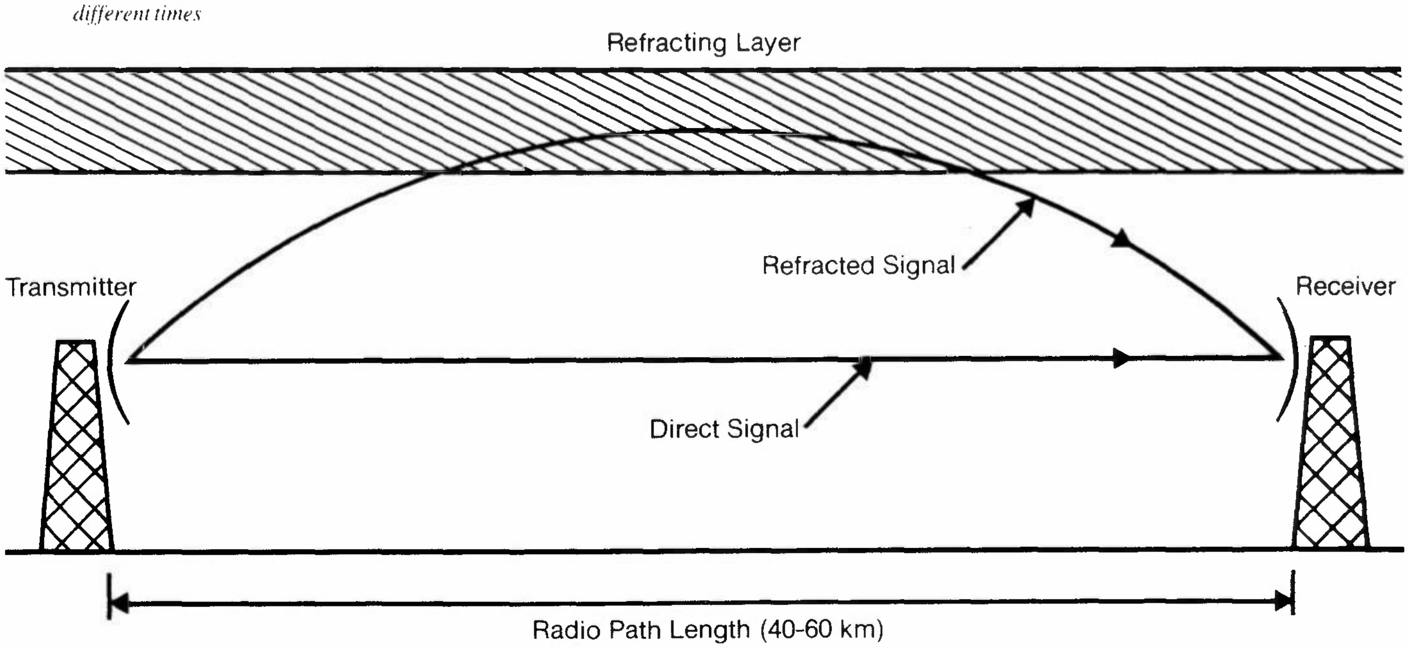
Fig. 1: Microwave Radio Path Configuration showing how the Same Signal Can Arrive at the Receiver at two slightly different times



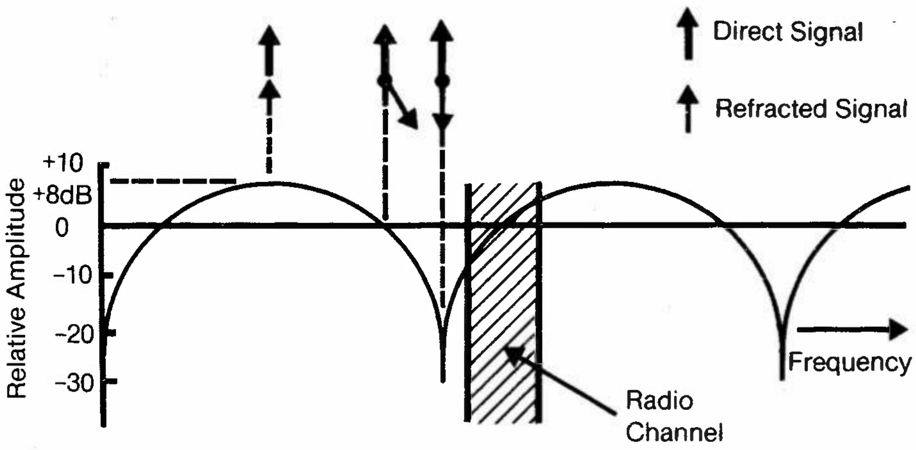


Fig. 2: Amplitude Effects of Multipath Propagation

POINT-TO-POINT ATMOSPHERIC OPTICAL COMMUNICATIONS

Introduction

An infrared beam, propagating through the atmosphere, can be used to transmit information over short distances. Point-to-point systems based on this principle have been developed in recent years with the aid of optoelectronic semiconductor devices used in optical fibre technology. Fig. 1 illustrates the concept for a data link application.

Advantages

Atmospheric optical systems are of interest for a variety of reasons:

- The systems are simple and relatively inexpensive.
- High bit rates for computer links or wide bandwidth for video links are readily provided.
- Demand for short-haul data links is becoming great, particularly for computer equipment.
- Installation and alignment are relatively simple, which assists the rapid provision of services.
- The narrow beam (0.25°) provides secure communications.

Applications

Potential applications exist within the Telecom network and for private on-site installations.

Within the network, Telecom currently uses low cost microwave radio links, e.g., as digital PABX tie lines, where the provision of service is required at short notice or in locations difficult for cable installation. For short path lengths, atmospheric optical links provide an alternative to these microwave radio systems. Optical systems are less expensive than equivalent microwave systems and are less bulky. Furthermore, they do not have the same licensing requirement and their use conserves the radio spectrum.

Examples of on-site applications for atmospheric systems include communication links for computer equipment, video surveillance or monitoring and video conferencing. They can be used for inter and intra-office communications (Local Area Networks).

Other applications that have been proposed for atmospheric optical links are as a backup for microwave radio systems and as a quickly set up emergency communication link.

Field Experiment

The performance of atmospheric optical systems is dependent upon meteorological conditions which affect atmospheric visability. For system planning and design purposes, it is necessary to quantify these effects. For this reason, the Research Department recently conducted a field experiment using commercially available equipment, similar to the optical data link of Fig. 1.

Fig. 1: An Infrared Point-To-Point Data Link

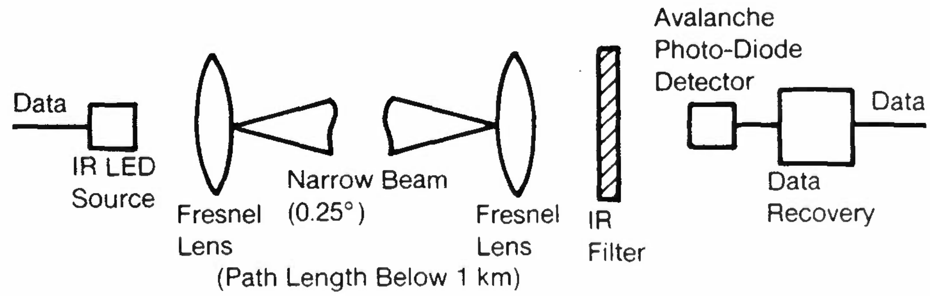


Fig. 2: The Onset and Clearing of Heavy Fog

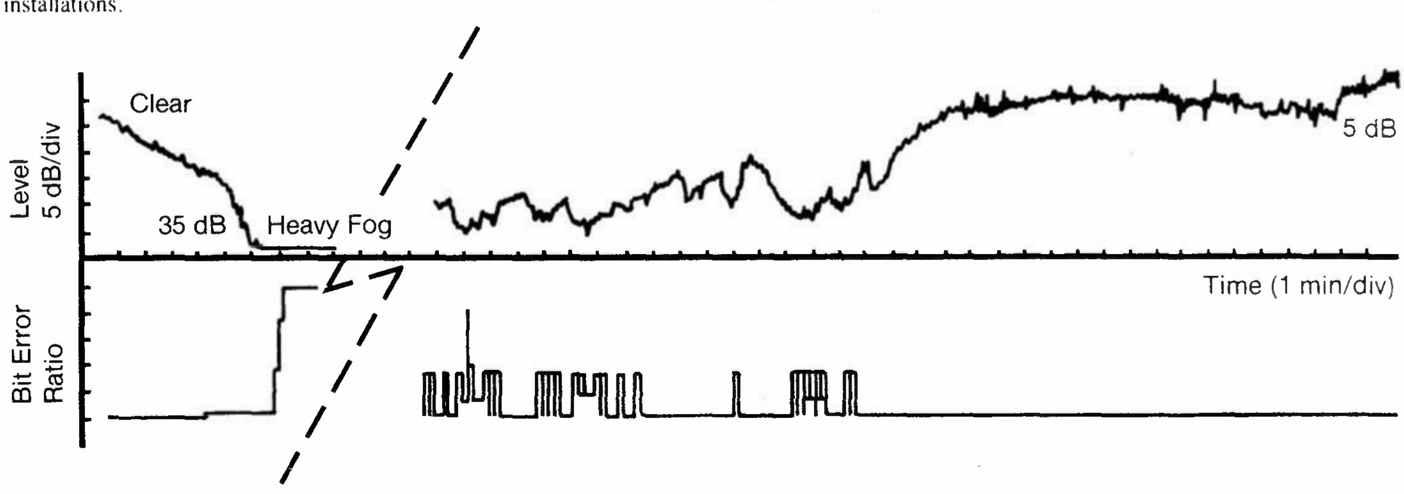


Fig. 3: The Effect of Scintillation During Warm Still Air Conditions

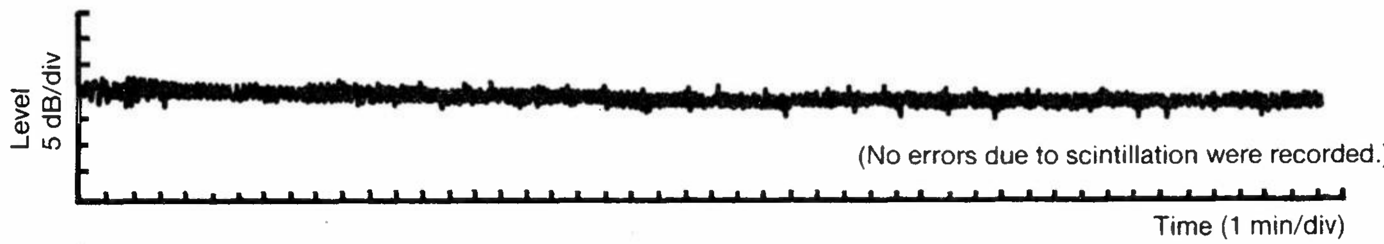
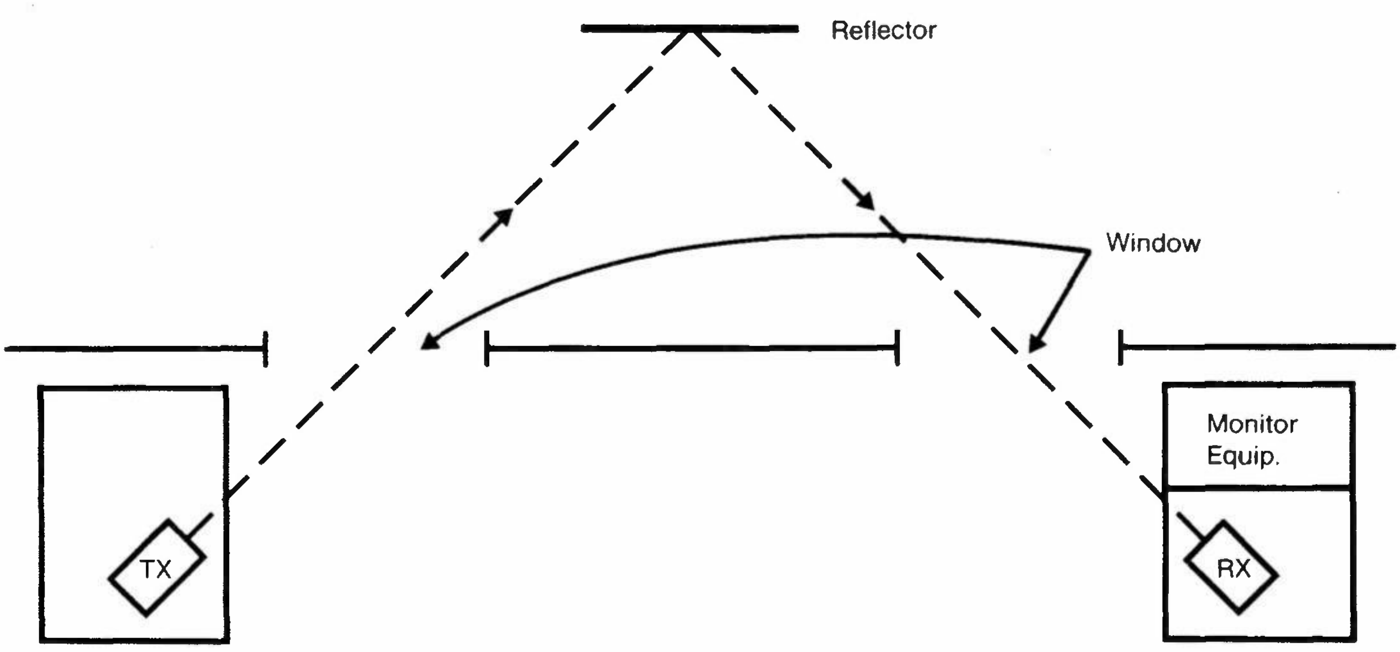


Fig. 4: Experimental System Layout



The system shown in Fig. 4 was operated over a 350 metre long path in the Clayton North area and carried pseudo-random binary data, at a rate of two megabits per second. Weather conditions, system parameters and transmission performance (bit error rate) were monitored over a ten month period. Figs. 2 and 3 show chart records of some of the propagation phenomena encountered.

Analysis of results of this kind has established that, for distances of less than 1 km, atmospheric optical systems can provide reliable communications in most weather conditions, with the exception of dense fog. Operational hands-on experience has been gained and quantitative data on system parameters have been analysed, providing the means to make performance predictions and assess the viability of planned services.

In conclusion, infrared links can offer customized solutions for special requirements. The emergence of these systems has provided Telecom with another tool from which to choose in the planning and design of the telecommunications network.

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CELLULAR MOBILE RADIO SYSTEMS

Concept

Cellular mobile radio telephone systems can provide service to large numbers of customers without placing inordinate demands upon available space in the crowded radio frequency bands. This important advantage is achieved through the re-use of the radio channels in a co-ordinated manner throughout the service area. The concept is illustrated in the diagram, *(See over)* depicting a number of contiguous cells, each with its own base station, covering a service area. Present systems of this type employ analogue transmission of information between the mobile units and the base stations. However systems using digital transmission are being intensively investigated, by both telecommunications authorities and equipment manufacturers, because of the advantages they offer.

Examples of Systems

Examples of analogue systems include the Public Automatic Mobile Telephone System (PAMTS) presently operating in most Australian cities and a proposed new high capacity system, scheduled for introduction in 1986-87. The current PAMTS system, operating at 500 MHz, has limited capacity (about 8000 customers in a large metropolitan area), whereas the proposed new system, operating at 800-900 MHz, will be capable of expansion to serve 100000 or more customers. Later in the 1990s, the introduction of an Australian digital system is foreseen.

In Fig. 1 below, the indicated non-uniform cell size reflects a corresponding non-uniformity of customer density throughout the service area. Large cells serve regions of low customer densities while small cells are employed where the density is high. Furthermore, in order to accommodate customer populations of 100000 or more, the new systems will be designed so that cells may be split as the customer base grows.

Advantages to Customers

From the customer's viewpoint, one of the main advantages of a digital system is that it will be able to operate with the same variety of customer service options that is being developed for the fixed network. That is, it will provide compatibility with the future Integrated Services Digital Network (ISDN).

One important feature of the proposed ISDN is that advisory, monitoring and control data will be able to be conveyed between the customer equipment and the network, simultaneously with the main information signal (voice or user related data). By this means it will be possible, for example, to inform customers of the progressively accumulated call charge or the existence of a calling third party, without interruption to the progress of an existing call.

Another important advantage of the extra advisory, monitoring and control data stream is that it will improve the operation of various automatic functions performed within cellular systems. A good example is provided by the so-called 'hand off' function, which is performed as a mobile travels out of the coverage area of one cell and into an adjacent cell. This function requires that the mobile should cease operating with the base station in the cell that it is leaving and commence operation with the base station of the cell that it is entering, without appreciable disruption to a conversation.

With present analogue systems, which do not have a separate control data stream, hand off action can at times cause noticeable breaks in conversation continuity. However, future digital systems will facilitate the design of procedures to minimize such effects, including the potentially more serious impact of breaks upon future mobile high speed data dependent services.

Security and Versatility

In addition to these advantages, digital systems can enhance security, since they readily accommodate encrypted voice signals. Furthermore, they allow the use of a range of transmission techniques, unique to digital signals, that offer the potential to combat the so-called 'multipath effects' that are so pronounced on land based mobile radio channels.

Multipath effects arise because the antennas on the mobile and hand-held units are almost always below heights which would permit direct line-of-sight propagation to and from the base stations. Thus the communication takes place via a generally large number of indirect signal components, resulting from the random diffraction and reflection of the radio waves by buildings and other objects. These random components add to form an interference pattern in the space through which the mobile travels, generating severe multipath fading on the currently used narrowband channels and frequency selectivity on potential future wideband systems.

It is expected that certain digital transmission techniques used with wideband systems will be able, for example, to resolve individual multipath components and so mitigate against their effects. Improved system performance and a reduction in the power requirements (and hence the mass) of hand-held units are two of the potential benefits that may result from the use of these techniques.

Investigations in Progress

In view of the above-mentioned expected advantages of digital mobile systems, the Research Department is pursuing investigations in the area. The work in progress includes:-

(a) modelling and comparison of the various possible systems, i.e., narrowband digital, time division multiple access (TDMA) systems and spread spectrum or code division multiple access (CDMA) systems.

(b) wideband channel modelling and

(c) support and liaison for an industrial research and development contract to supplement the Research Department's own work.

Scheduled future work will cover—

- wideband channel measurement,
- laboratory and field evaluation of experimental transmission systems and
- participation in the activities of the International Telecommunications Union, which is seeking to standardize future digital mobile systems.

Through this program, the Research Department will gain experience and develop expertise in the field and so place itself in a position to supply well-founded technical advice on future digital mobile systems to Telecom's planning, marketing and design groups.

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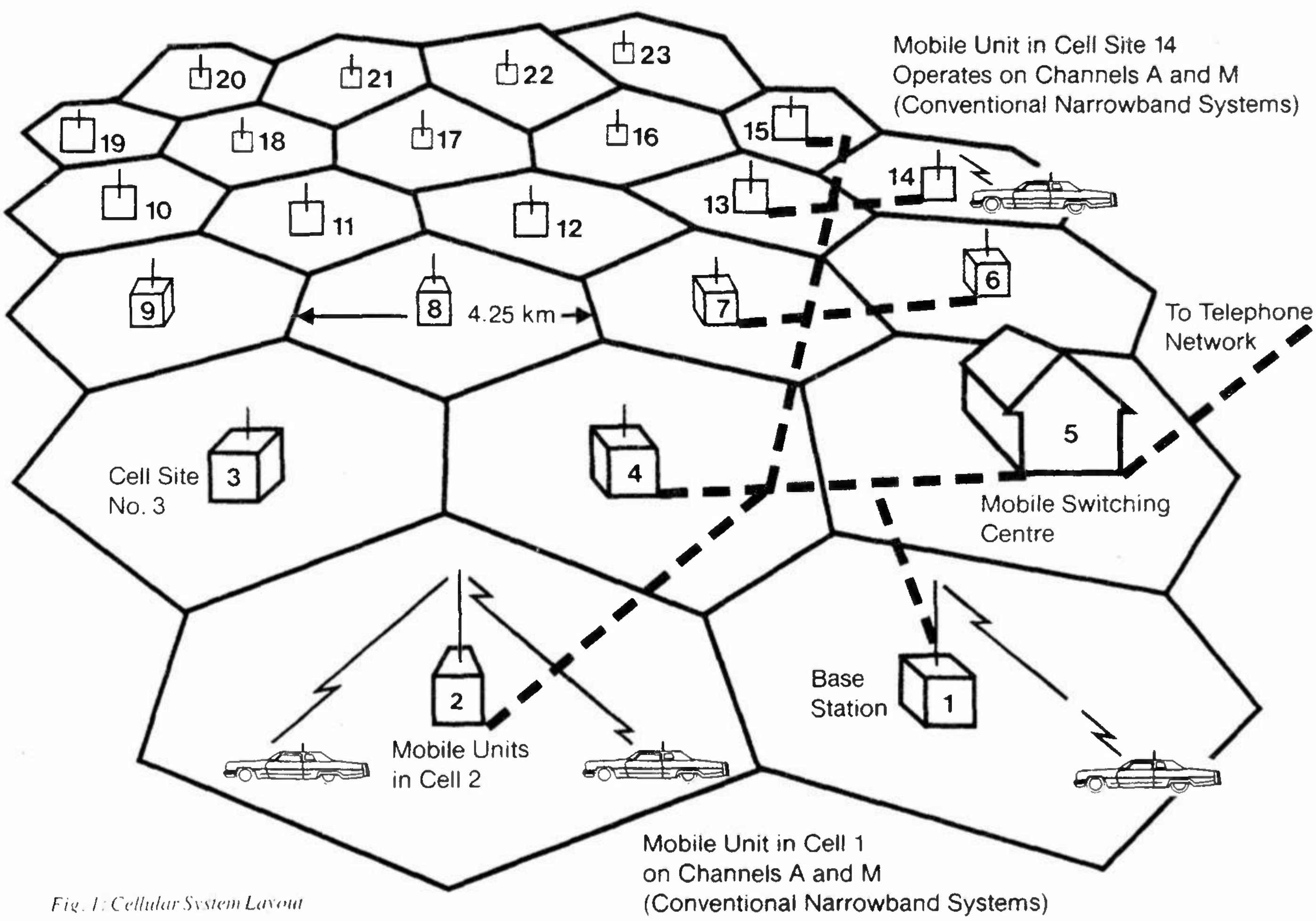

Fig. 1: Cellular System Layout

WIDEBAND INTEGRATED SERVICES EXPERIMENT

Local Area Networks

Local Area Networks (LANs) are currently in a state of very active development and standardization. They are primarily designed for data transmission between computers and associated devices (e.g. terminals, workstations), are generally confined to an area of, say, 10 km radius and are privately owned. Although these networks are frequently employed to serve a single building, their use in covering several buildings is becoming widespread. Two classes of LAN are emerging, viz. baseband and broadband LANs, classified according to the technology used to implement the network. These networks are increasingly being used in businesses, administrations and universities to provide communication facilities for the sharing of resources such as central processors, data bases and high speed printers.

'Wisenet'

The equipment on display is part of a Wideband Integrated Services Experimental Network ('Wisenet') used for exploratory investigations. It is a broadband LAN based on a synergistic combination of analogue and digital communications technologies. The network employs a Cable Television (CTV) system and a mid-frequency-band-split single coaxial cable to support full-duplex communications of various analogue (e.g. video) and digital communications services on the network. In this system, transmission in each direction is achieved in a separate frequency band, but both share the single cable.

A simplified schematic diagram of Wisenet is presented in Fig. 1. The network currently serves three buildings in the Research Department at Clayton — two at 22 Winterton Road and one at 770 Blackburn Road. A total of five underground repeaters and about 2 km of 12.7 mm coaxial CTV cable has been used in existing Telecom manholes and ducts along Winterton, Dandenong and Blackburn Roads. The headend of Wisenet is situated at 22 Winterton Road. Here, a frequency translator converts incoming signals in a low band of frequencies to another higher frequency band for retransmission downstream. In this way, full-duplex transmission with a potential total bandwidth of 105 MHz may be supported on a single coaxial cable. A further 100 MHz or so of bandwidth is available on Wisenet for a significant number of wideband channels (such as those from video cassette recorders) to originate at the headend and be broadcast downstream to all users.

Services Available

With appropriate interface equipment on Wisenet, some of the services which can be supported include:

- packet communication between host computers and workstations,
- full-duplex analogue video (5 MHz each way),
- full-duplex data transmission at 2 Mbit/s or higher on dedicated frequency bands. (These could also be used as tie-lines for digital PABXs) and
- in-house video originating at the headend and broadcast to all users.

Packet Communication

The multiple access technique employed for packet communication on Wisenet is Carrier Sense Multiple Access with Collision Detection (CSMA-CD). Using this technique, a Packet Communication Unit (PCU) that has a data packet to send must first listen to the channel to ensure that it is idle before transmitting its packet. It is possible, however, for two or more PCUs to sense an idle channel and transmit almost simultaneously. This results in packet collision, rendering errors in received data, but it can be detected by CD circuitry in each PCU. The PCUs resolve the contention problem by waiting a random time (within some limits) before attempting retransmission. Should another collision occur, the limits on this random delay are extended, and so on, until transmission is successful.

Display

On display are two computer terminals attached to separate PCUs. These terminals may communicate (via PCUs) either with each other, with any other terminal attached to the network or with a multiuser microcomputer resident at the headend. Each PCU has RS-232C (V.24) interface ports supporting port speeds of up to 19.2 kbit/s. Data packets are transmitted by the PCUs at 128 kbit/s over a pre-selected channel of 300 kHz bandwidth on the CTV cable. Also on display are analogue video channels co-existing on the same CTV cable with the channels used for packet data communication.

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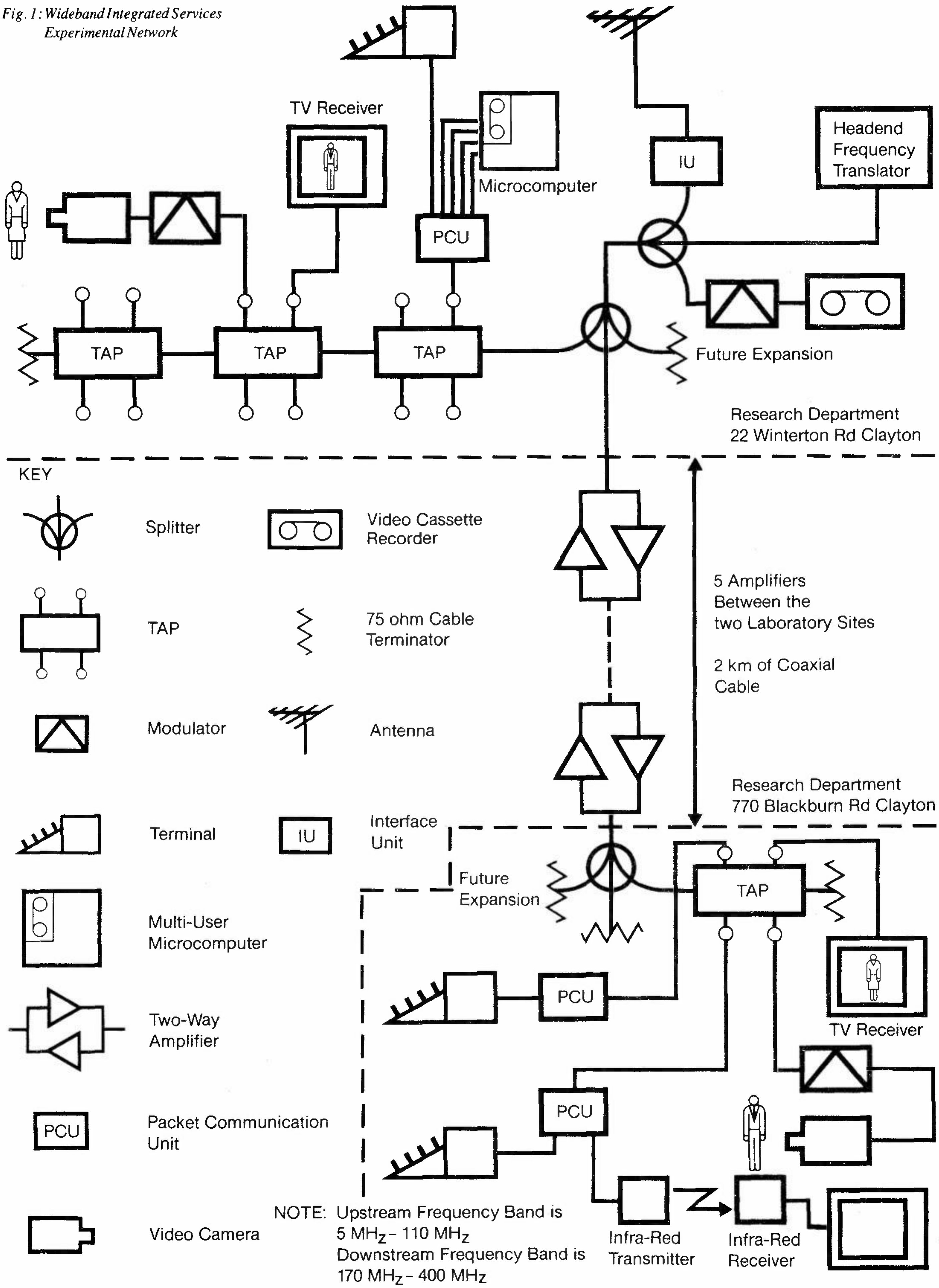
Fig. 1: Wideband Integrated Services Experimental Network



SPREAD SPECTRUM COMMUNICATION

Original Application

Spread Spectrum communication, originally developed for military use, involves techniques that deliberately use very high bandwidths for each individual channel, these being much higher bandwidths than are normally employed or required.

Different Spread Spectrum Techniques

There are a number of quite different techniques of Spread Spectrum communication, some of them providing a single communication channel and others providing multi-channel capacity. Some of these techniques are:

(a) Frequency Hopping. A pseudo-random binary sequence (code) is used to vary the transmitted frequency in a pseudo-random manner.

(b) Direct Sequence. Binary digital information is directly modulated (using modulo 2 addition — the Exclusive OR function) by a higher speed pseudo-random binary sequence (code).

(c) Time Hopping. A pseudo-random binary sequence is used to vary the instant of transmission time (time-slot) of information digits in a pseudo-random manner.

(d) Chirp (Pulse Frequency Modulation). Use of short bursts of signals, each burst being a sweep in frequency — typically used in radar systems.

(e) Hybrid Systems. Combinations of the above methods, e.g. combined Frequency Hopping and Direct Sequence or combined Time and Frequency Hopping.

It is possible to have Spread Spectrum codes that are nearly orthogonal, implying that many data channels can occupy the same frequency spectrum, simultaneously in time. In such cases, the code becomes the 'key' to decoding the required message, i.e. separating it from other channels. This leads to the name 'Code Division Multiple Access' (CDMA). This CDMA technique represents another alternative to the well-known Time Division Multiplex and Frequency Division Multiplex techniques.

Direct Sequence Code Division Multiple Access

Investigations of one particular CDMA Spread Spectrum technique, viz. Direct Sequence Code Division Multiple Access, are being undertaken. Direct Sequence techniques utilize special near-orthogonal pseudo-random binary sequences (from shift registers) to 'modulate' the source data stream, thereby widening (i.e. spreading) their spectra. A family of binary sequences is used, each channel having a unique sequence.

Advantages of Spread Spectrum

Although Spread Spectrum initially appears wasteful of bandwidth, a number of benefits are gained:

- Immunity to jamming: An interfering signal has its corrupting effect significantly reduced.
- The transmitted signal usually requires lower power spectral densities. This can give a degree of privacy of transmission. Further, the reduced power level may be beneficial in reduced interference to other users sharing the same band.
- In order to decode the transmission, the receiver needs knowledge of the transmitter's code sequence. Thus, Spread Spectrum systems have a rudimentary element of secrecy or encryption inherent in the transmission technique.
- Because Spread Spectrum techniques use large bandwidths, they are less prone to multipath radio effects, where sharp frequency nulls cause difficulties.
- In a number of areas, Spread Spectrum techniques appear highly cost competitive. This is because the shift register, the basic hardware associated with spreading the spectrum, is very low in cost.

Fig. 1: CDMA System

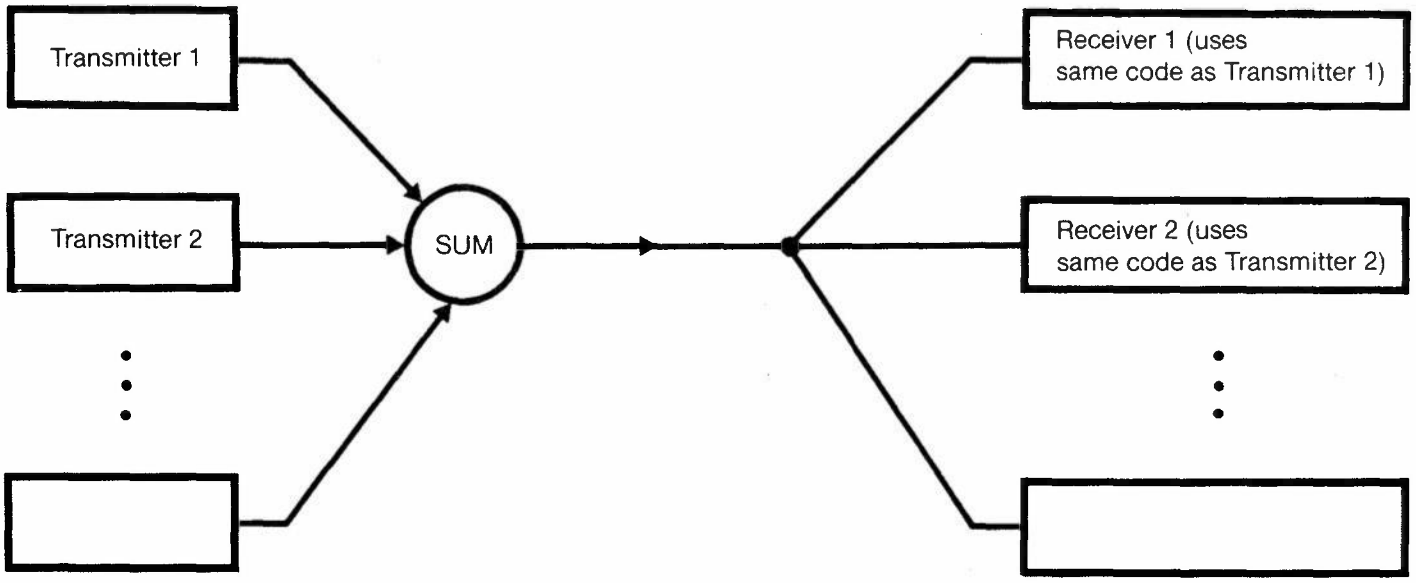
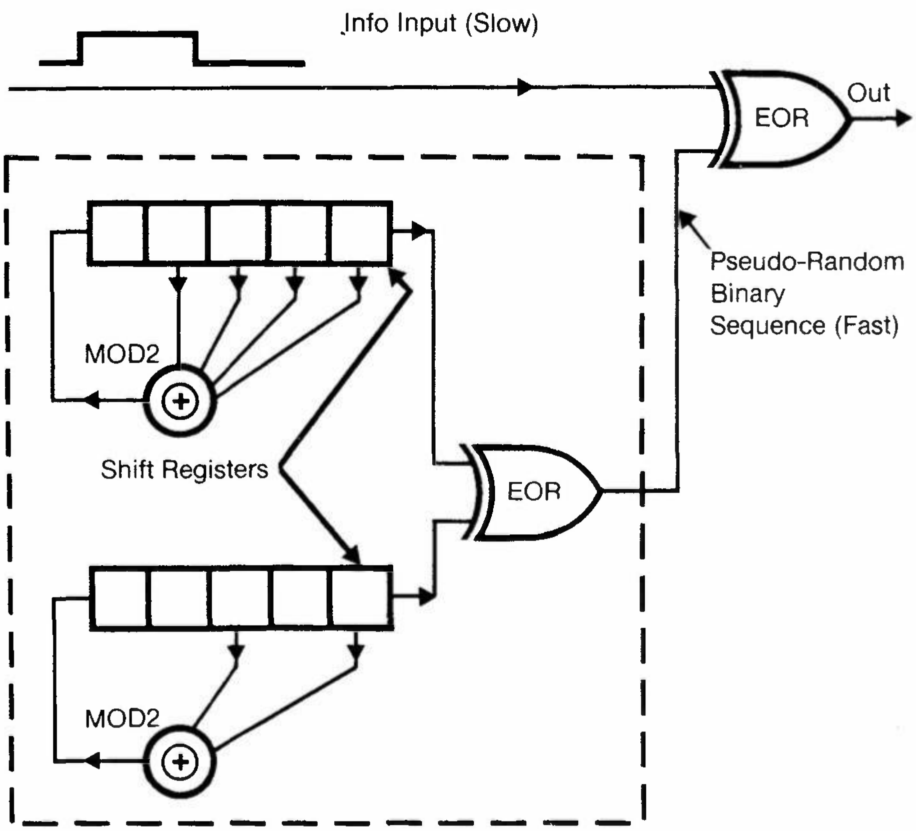


Fig. 2: Direct Sequence Transmitter



Applications

Possible future applications could include Local Area Networks (cable, radio or optical fibre media), local subscriber digital reticulation, satellite access, cordless telephones and multiple allocation of existing radio bands.

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POINT-TO-MULTIPOINT ATMOSPHERIC OPTICAL COMMUNICATIONS

Basic Forms

Infrared communication systems operate in the near infrared band of the electromagnetic spectrum, i.e., from 750 nm to 1500 nm. The optical sources employed are either Laser Diodes (LD) or Light Emitting Diodes (LED), while the detectors are PIN Diodes or Avalanche Photo Diodes (APD).

There are two basic forms of freespace infrared communications. The first is a point-to-point system which is suitable as a secure outdoor link for data and digital voice transmissions. The second system is for point-to-multipoint communications which form the transmission medium for a Local Area Network (LAN). Point-to-point systems are the subject of a related display.

Point-To-Multipoint Communications

In an open office or a factory environment, conventional communication links are over copper wires. This is acceptable if the communication units (e.g. telephones, data terminals, robots) are fixed but, if there is a need to move these units about within the office space or factory, cabling becomes a major problem. Point-to-multipoint infrared communication links provide a potential solution to this problem.

A unit wishing to transmit some information broadcasts its data to all other units using a wide infrared beam and diffuse reflections from the ceiling and walls. This provides an infrared bus which is accessible to all units. Selection of the data from the bus is controlled by the access method employed. This access method requires all data to be preceded by the address of the unit to which it is being sent. Only that particular unit receives the information from the bus.

This system allows communication units to be moved about within the area served by the infrared bus, without the cabling problems that currently exist. Access to other infrared systems, separate data networks or digital voice networks can be provided by an access unit that performs the infrared to cable network interfacing.

Research Areas of Interest

Work is being commenced in the following areas:

- infrared device characteristics,
- infrared modulation techniques,
- infrared properties of offices and open indoor areas,
- point-to-point infrared link availability and
- access methods for infrared point-to-multipoint systems.

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FIXED MULTIPOINT RADIO

System Characteristics

Fixed multipoint radio is a versatile, quick and efficient method of providing medium rate digital services to urban customers when they cannot easily be reached by equivalent cabled services.

Line-of-sight radio links are used, with low cost microwave radio equipment that is compact and easily installed or relocated. Nodal stations with conventional digital network access have fan beam antennas and each customer outstation has a pencil beam antenna directed on a line of sight to a nodal antenna. Maximum range, in the 10 to 20 GHz bands, is typically 10 km with a 600 mm outstation antenna and it is limited by signal fading in heavy rain. Costs of the central station are shared by all users in a sector and each outstation can also serve several nearby customers via low cost cabled or infrared extensions.

A schematic diagram of a typical system is shown in Fig.1

(See illustration over)

Research Department Projects

Current Research Department projects are:

- Quantification of the service density limitations caused by mutual interference, in a way related to topographical urban data and to the modulation characteristics of the radio equipment.
- Study of advanced modulation techniques with improved spectral efficiency derived from optimum combinations of bandwidth occupancy and robustness against mutual interference.
- Improved system spectral efficiency obtainable by novel or dynamically controlled antenna beam shapes and by active avoidance of interfering packet timing in sectors reusing the same radio frequency.
- Exploitation of the 60 GHz 'absorption' band. Interference in this band is significantly reduced by atmospheric absorption of the microwave beam, at ranges over 500 metre. Present applications are restricted by microwave equipment limitations. Potential aplications include wideband services to private customers, indoor radio links and local area radio networks.

Time division multiplexing of medium rate services, e.g. n x 64 kbit/s, at sector rates of 2 to 8 Mbit/s uses the radio spectrum efficiently. Efficiency is further improved by demand assigned multiple access to the radio bearer, providing service to hundreds of part time users in each sector with an average total rate matched to the sector capacity.

Mature systems in high rise areas have overlapping cells to guarantee visibility of one or another nodal antenna throughout the service area. A small set of radio bearer frequencies is reused in non-adjacent sectors. Consequently the number of nodes and users is limited by mutual interference caused by overshoot and by scattering of the microwave beams by heavy rain or by reflection from large buildings.

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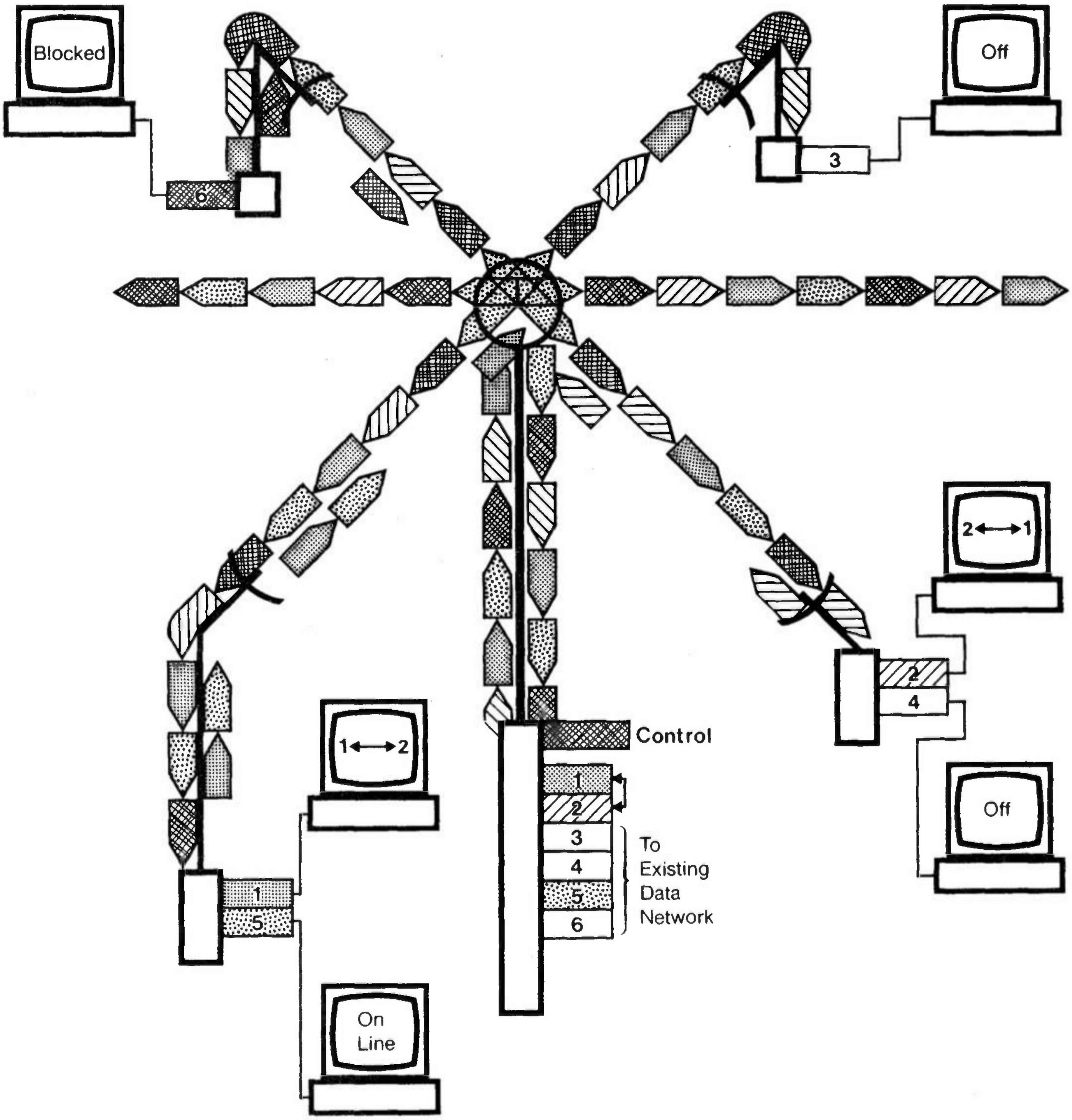

Fig. 1: A Typical Fixed Multipoint Radio System

ECHO CANCELLATION

To provide digital transmission to customers over the existing cable network requires transmission in two directions over a single pair of wires. This is accomplished by a large-scale integrated circuit echo canceller. In this way the old technology of the copper wire is married to the new high technology integrated circuit to bring new services to the customer.

The echo canceller enables two-way communication over a single pair of wires by forming a replica of the echo signal due to the transmitted signal. At the receiver the echo signal is subtracted from the received signal giving basically echo-free two-way transmission.

Since every customer's line is different, the echo canceller must adapt to different line conditions. This display shows an echo canceller adapting to form a replica of the echo signal.

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ELECTROMAGNETIC INTERFERENCE FROM INFORMATION TECHNOLOGY EQUIPMENT

Scope of Interference

The rapid proliferation of Information Technology Equipment (ITE) into commercial and residential environments has led to concern for the fact that electromagnetic interference (EMI) radiated and conducted from ITE has caused annoyance to, or even catastrophically interfered with, the reception of many forms of radio broadcast services. Victims of such interference can include those concerned with mobile communications, safety and emergency services as well as more widespread systems like AM and FM radio and television broadcasting. Examples of ITE involved are home computers, video games, Small Business Systems (SBS telephones), desk-top calculators, computer terminals and PABX.

Development of Standards

The development of standards, national and international, for the control of EMI emissions from ITE is in its infancy. In some cases (for example, FCC and CISPR standards) it can be argued that the standards will not provide sufficient protection of radiocommunication services in Australia.

The problem arises primarily because the desired signal strengths that determine the primary broadcast service areas in Australia are generally lower, by from 2 to 20 dB, then the desired signal strengths that are to be protected in many other countries. Therefore, to provide in Australia the necessary protection margins (the ratio of desired signal strength to be protected relative to interfering signal) the permissible EMI at the required protection distance must be 2 to 20 dB or more lower than that allowed by the standards of other countries, where they exist.

A common characteristic of the physical realization of ITE is the distributed nature of the equipment. As distinct from the stand-alone nature of some devices that produce emanations from a single cabinet and power supply cable only, many ITE are composed of numerous peripheral devices that are cable connected to each other and a host or host units, thus greatly increasing the number of potential EMI emitting devices and cables. This leads to a consequent extreme increase in the complexity of the systems' electromagnetic compatibility (EMC) considerations and increased difficulty in devising realistic EMI test and measurement techniques to ensure conformance to specified emission standards in a real-world environment.

Electromagnetic Spectrum

A principal feature of the EMI emissions from ITE is the large range of the electromagnetic spectrum that can be affected, up to 1 GHz and higher. The predominantly digital technology employed in ITE and the fact that most logic system timing is derived from and controlled by quartz crystal oscillators, means that emissions consist largely of harmonically related spectral lines having relatively stable frequencies. The wide EMI spectrum arises from the impulsive logic fast switching transitions occurring in the ITE. Depending upon the impulse repetition rate, and thus the spectral line spacing, relative to the receiver bandwidth or passband of the affected radiocommunication service, interference can be manifested as either just one interfering carrier (Fig. 1) or as impulsive noise when a number of EMI spectral lines in the receiver passband coherently add at a timing rate equal to the repetition rate of the originating impulsive EMI source (Fig. 2).

One of the most common communication services affected by EMI from ITE is Television reception. Subjective impairment of perceived picture quality caused by the relatively stable interference patterns produced by ITE emissions can be particularly annoying, especially if the interference is present for lengthy periods of time. Since many items of ITE are operated virtually continuously, the protection margins imposed to limit ITE emissions should be greater than the margins that may be applied to offending items of equipment that are operated very intermittently or are normally mobile, for example, motor car ignition systems.

(See diagrams)

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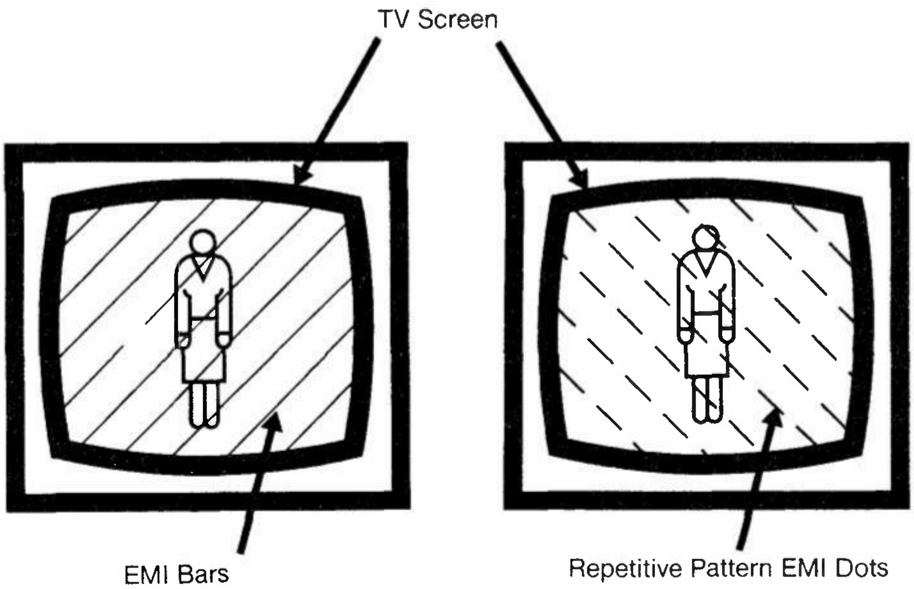

Fig. 1: Single Carrier EMI

Fig. 2: Impulsive EMI

HISTORY & EVOLUTION OF SWITCHING SYSTEMS

History

When the telephone was invented, it was used for communicating between, say, an office and a workshop, with copper wire as the connection. An early need was to interconnect such isolated installations, as people required communal communications. They used copper wire connections from each telephone to each other telephone, resulting in a network. Six telephones with full access required 15 connections and it was soon realized that this would be impractical on a large scale. With 1000 telephones, 500,000 connections would be required. Clearly more economic ways had to be found to limit distribution costs.

Switching Concept

Early engineers devised exchanges where connections between the telephones were made at a central point. This required only one line per telephone service and was a more economical solution. The central point permitted any telephone to be 'switched' to any other, using connections available at the exchange.

Exchange Plant Utilization and Grade of Service

It was then seen that internal switching interconnections at the exchange could be shared by customers, resulting in lower capital and maintenance costs per customer, as they usually only require a connection for a small period of the day. Probability theory determines the amount of switching facilities that can be economically provided while offering an acceptable 'grade of service'. Typically, exchange switching plant is utilized twenty times more than individual lines and the probability at peak period of a customer not obtaining a connection is one in a hundred.

Location and Number of Exchanges

One large telephone exchange to serve, say, Melbourne is impractical economically and technically. In practice a community like Melbourne is divided into geographical areas each served by its own telephone exchange. The size of an exchange area and its particular boundaries are determined by a balance of the cost of telephone lines to customers' premises and the cost of the exchange establishment. Multi-exchange networks are thus formed with groups of circuits ('routes') between exchanges to cater for calls between customers in different exchange areas.

Exchange Interconnections

The number and destination of calls ('traffic') determines the route between exchanges and the number of circuits in each route. Network design ensures that only sufficient routes and circuits are provided to carry the traffic in most situations. Uneconomic routes (i.e. where the number of calls is low) are catered for by collecting such traffic and switching it through an intermediate ('transit' or 'tandem') exchange. In effect the transit switching exchange is a central exchange for other exchanges.

Sometimes all circuits in one route between exchanges are busy (congested) and the call cannot be completed. Modern switching systems however are capable of choosing among routes. If the first (direct) route between exchanges is busy, the call is offered to a second choice route, employing a transit exchange to complete the connection. Further alternatives are possible. The facility is called alternative routeing.

Network Development

Connections between major cities and towns throughout Australia were initially by manual means. As the demand increased, more cost-effective measures were necessary. Automatic operation (subscriber trunk dialling) was introduced using alternative routeing principles and a hierarchy of exchanges.

The network is expanding and developing each year to cope with demand. Enhancements are being introduced exploiting technological developments. It will be possible, for example, for new signalling facilities called Common Channel Signalling, to test through the network (without using the switching equipment) to tell whether the wanted customer is free before switching occurs. Utilizing such a system will mean a saving, as the circuits between exchanges will be provided only for calls to free lines. These developments are in the research and planning stages.

Functions

The key functions of switching systems illustrate their evolution. The discussion below concentrates on their implementation using the available technology from 1880 onwards. For brevity, emphasis is on the functions necessary to set-up connections only. Lifting the handset and dialling the number after receiving dial tone are simple operations that set in train a series of complex functions called signalling, control and switching.

Signalling

There are two broad areas, customer signalling and network signalling. Customer signalling includes:

(a) the lifting of the receiver either to make or receive a call,

(b) listening for special tones e.g. dial tone signifying the exchange being ready to accept the wanted party's number and

(c) sending the wanted directory number signalling by pulses (momentary interruptions in the current of the customer's line) imparted by the dial or voice frequency tones in the case of some push button telephones.

Network signalling is a complex series of signals that transmit and receive information between exchanges to enable calls to be established.

Arrangements to protect the privacy of a connection and information concerning charging and the type of service required are also transferred using network signalling.

Control

This function deals with the processes that govern the logical sequences of action and tasks necessary to effect the switching processes. Functions are needed to set up and supervise connections and ensure charging records are kept and to clear connections.

Switching

Connections are formed by using switching stages that provide a path from the incoming circuit to the required outgoing circuit.

Manual Switching Circa 1890

A considerable level of technological maturity was achieved in 1890 with manual switching, only 12 years after the opening of the first exchange in the USA. The Australian switching network commenced in 1880 with the establishment of manual exchanges in Melbourne, Sydney and Brisbane. The key functions were implemented in the technology of that time as follows.

Signalling

Customer signalling was provided by hand generators (magnetos) in the telephone and at the exchange. The electrical current energized an 'annunciator' shutter on the switchboard announcing a call request. At a later stage lamps replaced shutters. Connections between exchanges were established by the operators.

Control and Switching

These were all combined in manual switching by operator functions. The operator controlled the call set up and switched using plugs and jacks. Power for the conversation after connection was supplied by batteries at the telephone and the exchange. Later a common battery at the exchange eliminated the need for the battery at the telephone.

Automatic Switching Electro-Mechanical Technology 1910-1974

In 1912 the first Australian public automatic exchange was opened at Geelong in Victoria. To explain Australian developments, the period 1910-74 is divided into the early step-by-step systems and later crossbar systems. The term 'step-by-step' applied to those systems that selected a network path directly from the digits dialled.

The term 'crossbar' refers to the type of switching system using common control introduced in 1960. Common control means that network switching is not performed on a digit by digit basis. Instead, the switching control equipment can collect and analyse groups of digits before the switching function is performed. Additionally, common control equipment can be shared between many users. This permitted the Australian switching network to develop in a more economical manner than was possible using step-by-step systems. The key functions of both systems are shown in Table 1.

Automatic Switching — Stored Program Control (SPC) 1974

To provide new facilities and services the logic and common control functions of an exchange are periodically changed. This is extremely costly in the relay logic technology of crossbar systems. Computer technology offers a cheaper solution.

Stored program control (i.e. computer control) systems are now operating in both the trunk switching (Subscriber Trunk Dialling) and local switching parts of the network. New facilities and services are possible with processor controlled switching. Other advantages include lower installation and maintenance costs with a significant reduction in space used. It can provide for future services more economically than can electromechanical technology.

The logic functions are performed by a combination of software and hardware. SPC exchanges use the same principles of common control and flexible switching paths (alternative routeing) as employed in crossbar. However higher switching speeds occur owing to the faster operation of processors. The software programming feature is programmable logic, which permits additional facilities and arrangements to be added into the system cheaply. Advances made in microelectronics and semiconductor technology can be incorporated into an SPC system bringing savings in future capital investment.

Function	*Step-By-Step*	*Crossbar*
Signalling	Lifting the receiver initiates a call request with the customer's individual equipment at the exchange selecting a switch from a common pool. The address of the wanted party (the directory number) is signalled by dial pulses, which also represents network signalling.	Same procedure as for step-by-step. However, network signalling is applied independently of the digits received from the customer. The network signalling uses multi-frequency tones as well as digits generated by the equipment.
Control	The customer exercises control by dialling the directory number, with each digit dialled operating a switch. The call path is progressively established by each digit.	The address of the wanted party is stored in the common equipment at the exchange, which then analyses that part of the number that represents the route to the required exchange serving the wanted customer.
Switching	The 1st switch responds to the 1st digit. In the waiting period for the 2nd digit, a path is selected to a 2nd switch. Switching proceeds in accordance with the digits contained in the wanted party's number. Each switch used in the process is a bi-motional electro-mechanical device.	When sufficient digits have been received, the register equipment tries to trunk the call over the most economical route available. A choice is exercised through a number of alternative paths. In the case of heavy telephone traffic e.g. in peak calling times, a 'backbone' route is the final choice. The switching element is the crossbar switch.
	The last 2 digits select the wanted party, via a final selector that tests the condition of the line. If it is free, ring is applied and ringtone returned to the calling party. Power is supplied on answer for conversation and metering occurs.	The last 3 digits select the wanted party. When wanted party is determined, the condition of the information signals control the connection of the call and the setting of metering conditions.

Table 1: Key Functions of Switching Systems

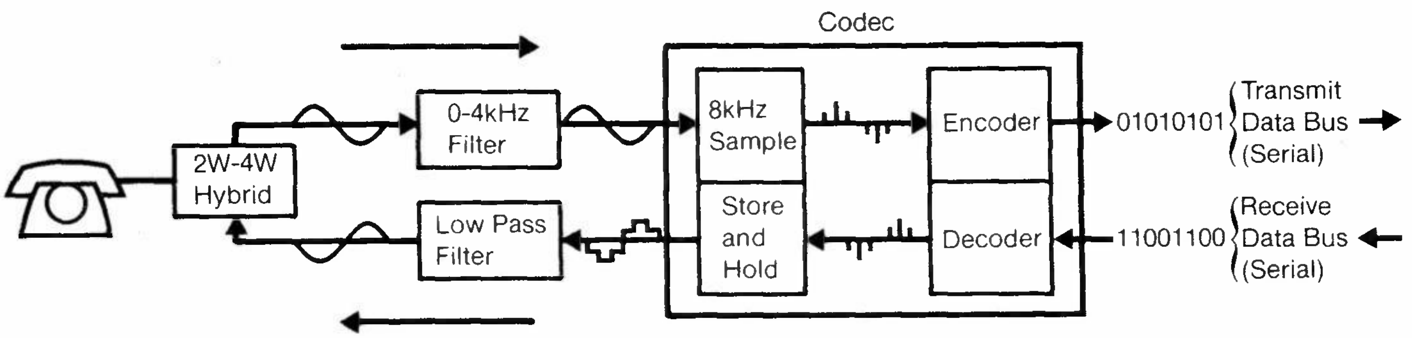

Fig. 1: Schematic Diagram of a CODEC Device

Digital Switching

Advances in semiconductor technology have permitted the economic introduction of digital switching. This technique uses time division switching under computer control. Instead of physically switching the analogue voice channels, digital switching involves the switching of serial binary data channels using electronic logic circuitry.

To do this, the analogue voice signal from a conventional telephone must be converted to digital form. A common technique for this is Pulse Code Modulation (PCM). The analogue signal from the telephone is sampled at a rate of 8 kHz and the magnitude of each sample is encoded into an 8 bit binary number. This results in a serial bit stream of 64 kbits/s (8 bits/sample x 8000 samples/s = 64 kbits/s). At the receiving end the binary stream is converted back to an analogue signal by decoder, store and hold and low pass filter. Devices that perform the encoding and decoding of the analogue voice signals are called CODECS. The technique is illustrated in Fig.1.

The high speed switching capability of digital logic circuits introduces the possibility of time sharing (time division multiplexing) many voice lines within an exchange over a smaller number of physical lines. The 64 kbits/s binary streams from a number of CODECS are sequentially multiplexed (combined) onto a single serial 2048 kbits/s data line. Thirty-two channels can be multiplexed onto the line (32 x 64 kbits/s = 2048 kbits/s) and this multiplexed bit stream consists of 'frames' of 32 'timeslots'. Normally 30 channels are used. Each timeslot is 8 bits long (4 microseconds) and represents the data for one channel. Fig. 2 illustrates the concept.

To connect any incoming to any outgoing voice channel means that the switch must be capable of connecting any time slot on any incoming line to any time slot on any outgoing line. This means that a digital switch must be able to perform both 'space' and 'time' switching. Practical switch elements are being realized as large scale integrated (LSI) circuit devices combining both space and time switching into a single circuit device. A typical device has eight incoming and eight outgoing 2048 kbits/s lines and is capable of switching 256 voice (64 kbit/s) channels. A typical digital switch element is illustrated in Fig.3.

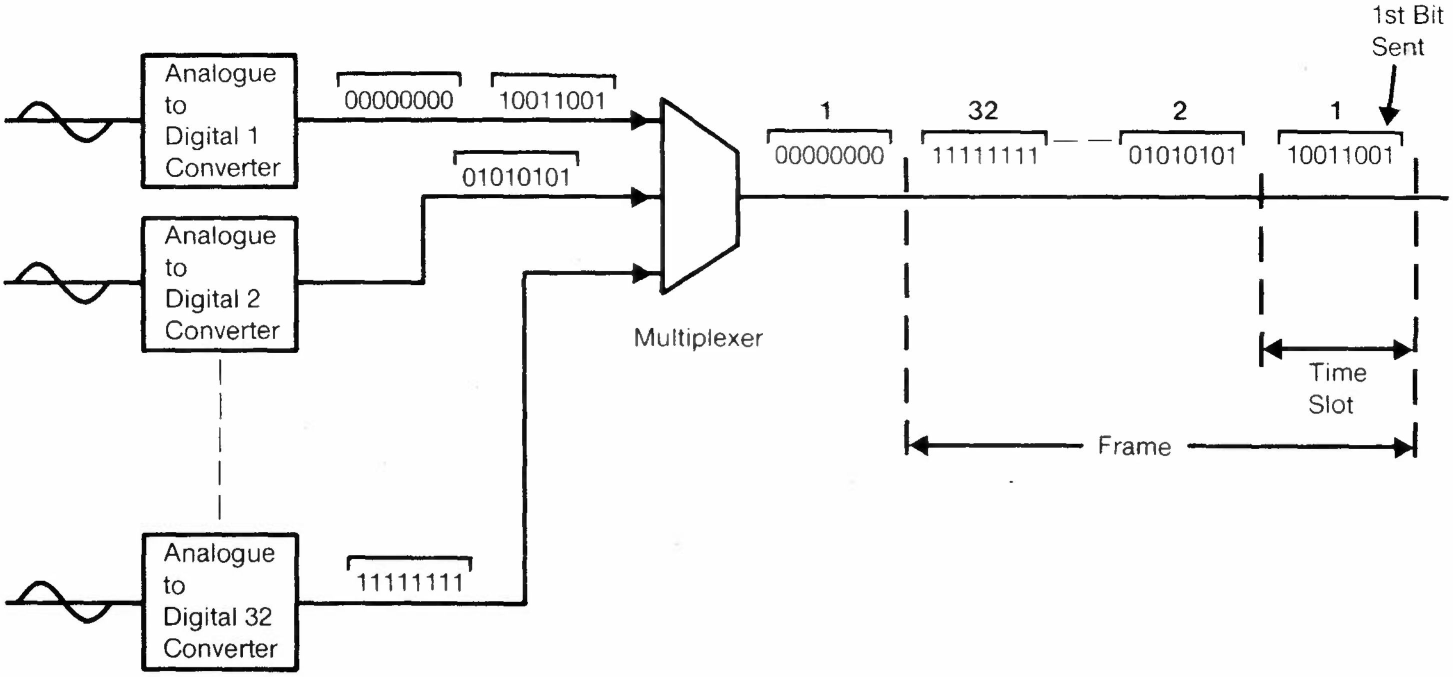

Fig.2: Time Division Multiplexing Concept

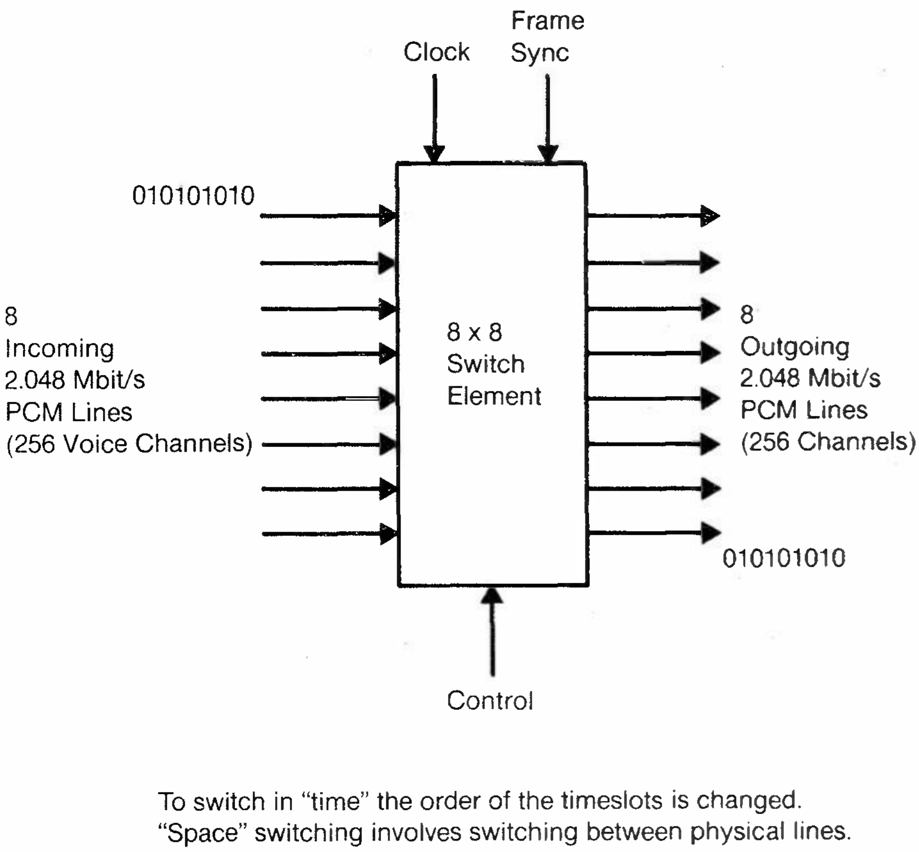

Fig. 3: Diagram of a typical Digital Switch Element

Advantages of Digital Switching

Some of the major advantages of digital switching are:

- Lower cost and greater reliability compared to electromechanical techniques due to integrated circuit (IC) technology.
- Size reduction. Owing to IC technology the space required for a digital switch is much less than its mechanical counterpart.
- Shorter call set-up times since digital switch operation is very fast.
- Increased capacity. Very large switches can be built using digital techniques.
- Economic design of switching networks with very low blocking probability.
- Digital data as well as digitized voice can be switched.

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HOW COMPUTERS CONTROL TELEPHONE EXCHANGES

Introduction of SPC Exchanges

Over the last twenty years computer controlled telephone exchanges have been gradually introduced into world networks. They are usually called Stored Program Control (SPC) exchanges. Telecom Australia operates several different types of SPC exchange. The number of SPC exchanges installed in the network will rapidly increase in the future.

Principles

A computer controls the actions of the SPC exchange in SWITCHING and SIGNALLING. Switching involves the connection of items of equipment to the customer or to each other with the instructions for the connection being issued by the computer. Signalling is the receiving and sending of information concerning the progress of the call. For example, the calling customer must be connected at various stages of a call to different equipment which

- sends dial tone,
- receives dialled digits and
- sends ring tone.

Finally the calling customer must be connected to the called customer. Signalling may occur not only between the exchange and the customer but also between exchanges, when the called customer is not connected to the same exchange as the calling customer.

In controlling the switching and signalling functions, the computer directly replaces electromechanical equipment, such as relays, used in older exchanges. In addition, the computer can provide facilities not previously feasible or economically possible. These may benefit the customer directly (e.g. the provision of itemized call accounting) or improve the efficiency of the telecommunications network. One of the particular advantages of SPC exchanges is that many changes to the operation of the exchange or the network can be made by altering only the data in the computer while the computer is still running. There is no interruption to the service to the customer. In electromechanical exchanges, extensive re-wiring may be necessary, causing possible service interruptions.

Distributed Processing

The computer has to perform a large number of tasks for many different calls at different stages of progress. The computer therefore has to be very fast in operation. In the past, special computers were used for SPC exchanges but the trend now is to share the workload among many co-operating computers. This allows conventional microcomputers to be used since, although they may not be very fast, there are many of them to share the work. This technique of 'distributed processing' may also increase the reliability of the exchange.

Software

The specification, design, coding, testing, documentation and later alteration of SPC computer programs are complex tasks, requiring highly skilled software engineers. A complete system is far too large to be understood by one person. There is much research being done worldwide to develop formalized engineering techniques for specifying and implementing software. The International Telegraph and Telephone Consultative Committee (CCITT) of the International Telecommunication Union has produced recommendations for

- a "Functional Specification and Description Language" called SDL
- a high-level programming language called CHILL
- a man-machine language (MML), which specifies how a user communicates with the computer.

Thus a system can be specified using SDL and implemented using CHILL, while the operations staff communicate with the system using MML. The Research Department has contributed extensively to the development of SDL and is currently investigating the use of CHILL.

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THE USE OF COMPUTER-BASED LEARNING IN THE FIELD OF TELETRAFFIC ENGINEERING

Educational Role of Research Department

The Research Department provides instruction in two types of internal course in Teletraffic Engineering. About once every two years, a two-week residential course is held for staff from Telecom and from other telecommunications administrations by invitation. The theory of Teletraffic Engineering is covered, from basics up to the level needed by practising engineers. Also, a three-day course is run, when required, for Telecom staff that need an overview of principles and applications.

Computer-Based Learning

Computer-based Learning has been described as occurring 'whenever a person and a computer get together and one of them learns something'. In more specific terms Computer-based Learning can be divided into three distinct areas as follows:

- Computer-managed Instruction : The computer is used in the management and administration of the courses to be presented. The students need not have any actual contact with the computer
- Computer-supported Learning Resources : A database of knowledge that, by itself, does not teach. Effectively it is an electronic library with the computer acting as the librarian.

Why Use it?

A number of universities and colleges, in Australia and overseas, have applied and evaluated Computer-based Learning techniques. Many have found evidence that these techniques can improve the effectiveness of training. Improvements have been observed in the planning, delivery and management of personalized instruction.

Computer-based Learning techniques are particularly suitable where the subject matter is relatively stable, the material is suitable for interactive presentation, the students are widely dispersed and there is a wide audience of potential students.

The Research Department is therefore studying the potential application of Computer-based Learning in the field of Teletraffic Engineering.

Present and Proposed Use of Computer-Based Learning

The Research Department has been investigating the available Computer-based Learning aids and specifying its own requirements for such aids. The Department is starting to introduce Computer-assisted Instruction into the internal courses in Teletraffic Engineering. Currently we are evaluating programs which help in the teaching of various aspects of Teletraffic Engineering as follows:

- Mathematical Models. Teletraffic engineers need to be familiar with mathematical modelling techniques. To introduce such techniques and motivate students, one program simulates the arrivals and departures of telephone calls over a period of time. Different displays can be selected such as the number of calls in progress as a function of time or a histogram showing the time spent in each state.
- Traffic Measurement. By using the displays generated by the simulator described above, the variability of traffic measurements can be illustrated. Each time the simulation is run, a different average traffic is observed.
- Forecasting Techniques. To plan telecommunications networks, it is necessary to forecast traffic values. Techniques which are used for forecasting are illustrated with the assistance of two demonstration programs. One shows the values of a variable, such as the number of call-hours per year, over a number of years and allows trend lines to be fitted to the data on a trial and error basis. The other program allows students to experiment with techniques known as 'matrix balancing'.
- Problem Solving. Various computer programs are made available to students to assist them in solving tutorial problems and projects.

As experience is gained we expect to find additional opportunities to use Computer-based Learning techniques effectively. We will either adapt available software or develop programs to suit our own specific needs. Possibilities that are being studied include tutorials in Mathematics and Statistics, further simulations and demonstrations and additional programs to assist in problem solving. We expect that these techniques will be used in the presentation of Teletraffic Engineering and its theoretical foundations to a wide audience of professionals.

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NETWORK DESIGN & OPTIMIZATION

Background

Telecom Australia annually spends many millions of dollars in installing new switching equipment and circuits in its telephone network. The process of determining the size of circuit groups in a network is known as dimensioning. Research being carried out in the Research Department involves determining suitable mathematical models for optimally designing networks for minimum cost, whilst satisfying particular performance objectives. These objectives have been established for the network in order to provide a satisfactory level of service for customers. Over the past decade, a number of sophisticated mathematical models for network design have been developed in Australia and these models have now been adopted in many overseas countries.

New technologies have affected the ways in which telephone networks are designed and therefore new systems of dimensioning must be developed.

About this Display

The display demonstrates one of the latest computer-aided design systems, which has been developed in the Research Department to assist network planners in this very complex task. It has a number of special features that have been designed to enable a planner to investigate closely any desired section of a network. They will be described shortly.

In order to illustrate the features of this network design facility, the Melbourne Telephone Network has been modelled as envisaged for the year 1990. The network at that time is expected to be evolving from an analogue to a digital form, with some sections possibly still retaining older equipment types. During the demonstration, it can be seen what circuit allocations have been made by the network design and optimization process so far, as well as the effects on traffic distributions when circuits are altered on prescribed routes in the network.

Melbourne Telephone Network — 1990

Fig. 1 gives a simplified picture of a typical routing pattern for traffic flows in the Melbourne Network of 1990. It should be noticed that the analogue section of the routeing pattern has been separated from the digital part for greater clarity. Roughly speaking, this figure illustrates how the new digital network is going to 'overlay' the older analogue network. As mentioned previously, the task of designing a telephone network is a very complex task and requires some particularly sophisticated techniques in order to obtain the minimum cost network design. In order to give some appreciation of the magnitude of the task facing our planners, some statistics on the Melbourne Network Study should be considered.

The network is expected to include 160 exchange locations, which will support nearly 900 different traffic switching points. These switching points will be connected together by nearly 25000 different circuit paths called 'links'.

The data required for the design task are often very substantial and, for a project of this size, amount to over 96 MBytes of storage on a powerful mainframe computer. The data needed by planners includes:

- forecasts of traffic demands, which must be specified for each pair of exchanges in the network,
- a set of potential routeing plans showing how traffic may be sent from one exchange to another,
- a set of performance standards that specify the congestion levels that can be tolerated in the design process,
- cost information for all types of transmission media that can be used, eg. analogue (VF) or digital systems (PCM), and
- module sizes for circuit groups that employ digital transmission media.

The Network Design Package

The total network design package that has been developed involves two processing phases:

(a) An interactive phase in which a skilled network planner, seated at a suitable computer terminal, studies the current network design and prepares a list of changes based on the information displayed, local knowledge, or administrative policy. Once the list of changes has been completed, it is passed to the next processing phase.

(b) A batch processing phase in which the changes are implemented, the traffic flows arising from these alterations are computed and the network is costed for the new configuration.

The second phase requires very substantial computer resources and may frequently take several hours to complete; hence the demonstration today will only be able to illustrate the first (interactive) stage of the process.

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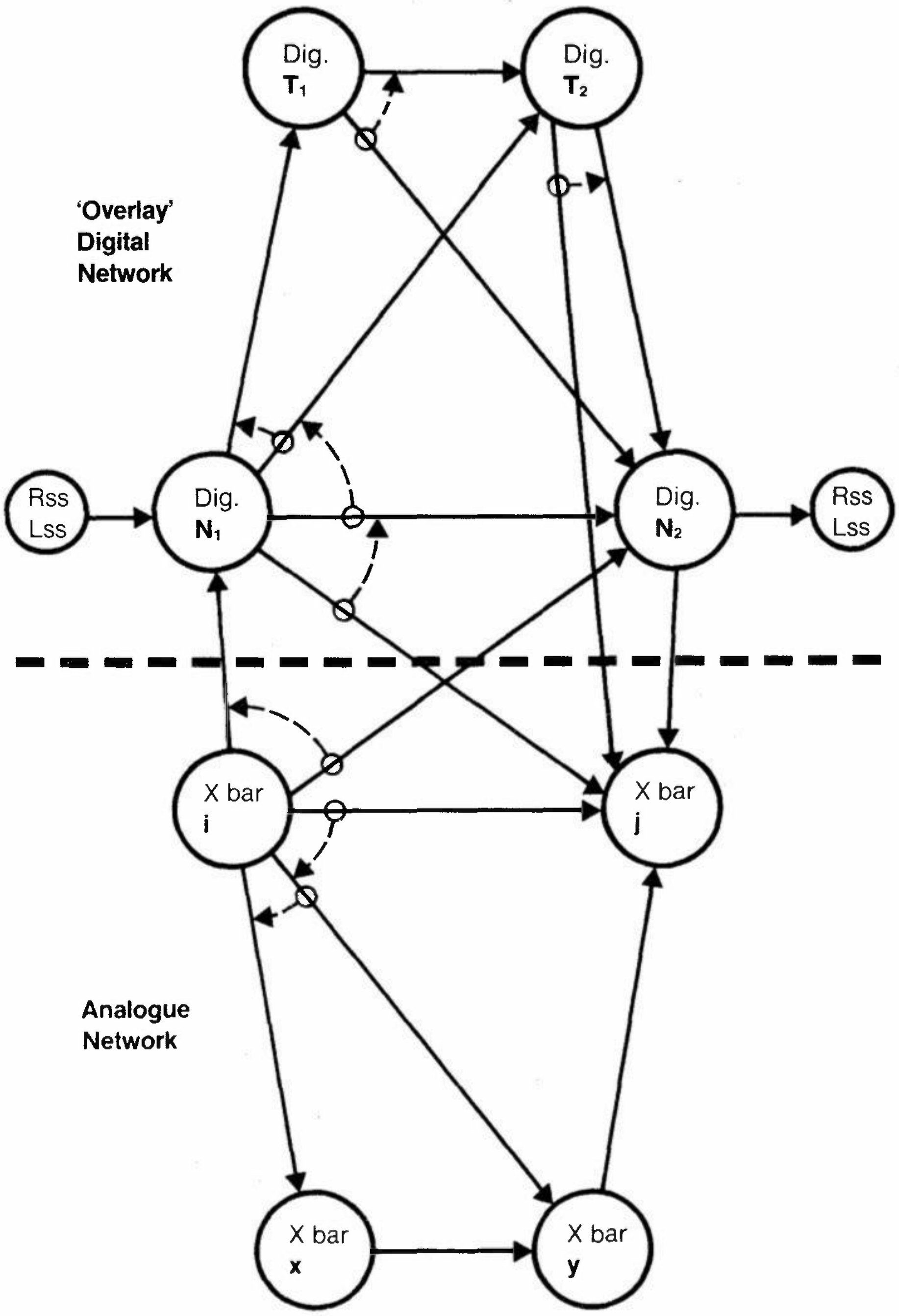


Fig. 1: Melbourne Network Study — Simplified Overall Trunking Scheme (Dashed lines (- -▸) indicate how traffic overflows in this network)

PERFORMANCE TESTING OF PACKET SWITCHED DATA NETWORKS

Introduction

If a customer desires to send varying amounts of data to a number of different locations at different times, packet switching is a very cost effective method of providing the required data service.

A packet switched data network is composed of:
(a) exchanges where data packets are switched,
(b) high capacity digital transmission links between the exchanges and
(c) digital links to customers' packet mode equipment.
Such networks provide a means of switching and transmitting data between any two customers with the capability of making multiple simultaneous calls on a customer's link. The structure of a typical packet switched network is shown in Fig. 1.

The X.25 Interface

The International Telegraph and Telephone Consultative Committee (CCITT) Recommendation X.25 specifies the interface between a public packet switched data network and the customer's equipment. X.25 is a three level layered protocol. The packet level provides the means of call set-up or cleardown and the multiplexing of several calls onto a single network access link. The link (frame) level provides packet transfer in the correct sequence and with no duplication. Each frame contains a single packet and frames associated with different calls are transmitted serially on the link. Error protection is provided at the link level through cyclic redundancy checking of each frame. Frames with errors are not accepted and must be retransmitted. The physical level provides a bit serial full duplex point-to-point circuit for digital transmission. The structure of the X.25 interface is shown in Fig. 2.

(See diagrams)

Performance

It is most important to ensure that the performance characteristics of public packet switched data networks are within the requirements specified by the network administrators and expected by the network users.

The Research Department is currently investigating data network performance testing techniques. The objectives of this work are:
(a) to develop testing techniques that will enable packet switched network performance, including capacity and delay, to be quantified,
(b) to develop traffic generators to load data networks under various connection conditions and
(c) to contribute to the definition and extension of international standards on the performance aspects of packed switched networks.

The quality of service of a packet switched data network can be quantified by the following performance parameters:
- call setup, packet processing and packet transfer delay distributions,
- probability of call failure due to network congestion,
- transmission performance including throughput and residual error rate,
- probability of call failure due to network malfunction and
- probability of loss of service.

Standards

International standards that specify the performance parameters for data switched networks are only now being developed by the CCITT. Standards for the delay (CCITT Recommendation X.135) and the congestion (CCITT Recommendation X.136) aspects of grade of service for public data networks have been drafted. Many of the parameters specified are only interim suggestions with further study required. Although the standards refer to networks providing international packet switched data services, the performance of that portion of the connection in the national networks is also specified.

Methods of Measurement

In addition to specifying the quality of service parameters, methods for their measurement must be developed. A general measurement methodology involves setting up a call and generating a known and sufficient quantity of traffic. The protocol and user information signals transferred across the user-network interfaces are observed in real time and a chronological event history is compiled. This event history can then be analysed at a later time to provide various performance parameters. This method is particularly suited to throughput measurements and delay measurements. However end-to-end transfer delay measurements are further complicated by the requirement for synchronized real time clocks at each end of the call.

Initial Tests

In relation to the measurement of throughput, work has involved the development of a suite of computer programs to run on a super minicomputer that has a connection to AUSTPAC (Telecom's packet switching network service). These programs utilize a proprietary packet switching interface software package and are capable of generating traffic for various connection configurations between the super minicomputer and the AUSTPAC Network. Using these programs in conjunction with a software facility that records all protocol exchanges with the network, tests have been conducted from which capacity parameters have been calculated.

Typical Results

For particular connection configurations, it has been possible to achieve throughput figures of 32 packets per second using a 9600 bit/s line. For a data packet size of 128 octets the effective data transfer rate can approach 90% of the line speed while achieving a line utilization of 99%.

These initial tests have demonstrated the versatility of the event history methodology for testing packet switched networks. As a result of the experience gained in the testing of the AUSTPAC Network, the Research Department will be in a strong position to contribute to international standards on the subject of quality of service parameters for packet switched data networks.

Demonstration

The demonstration shows a typical throughput performance test. Having estalished a call to a data sink, 50 packets of known (set) size are transmitted to the sink. A throughput figure can be calculated from the time taken to send the 50 packets. An average figure can be calculated from the results of a number of runs. The average throughput result of a large number of tests is compared to the theoretical maximum throughput on the display. The results clearly show that for large packet sizes (i.e. above 64 octets of user data) the throughput is limited by the line speed of the link.

Contact: Peter Hicks 03-541 6308

Fig. 1: Packet Switched Data Network.

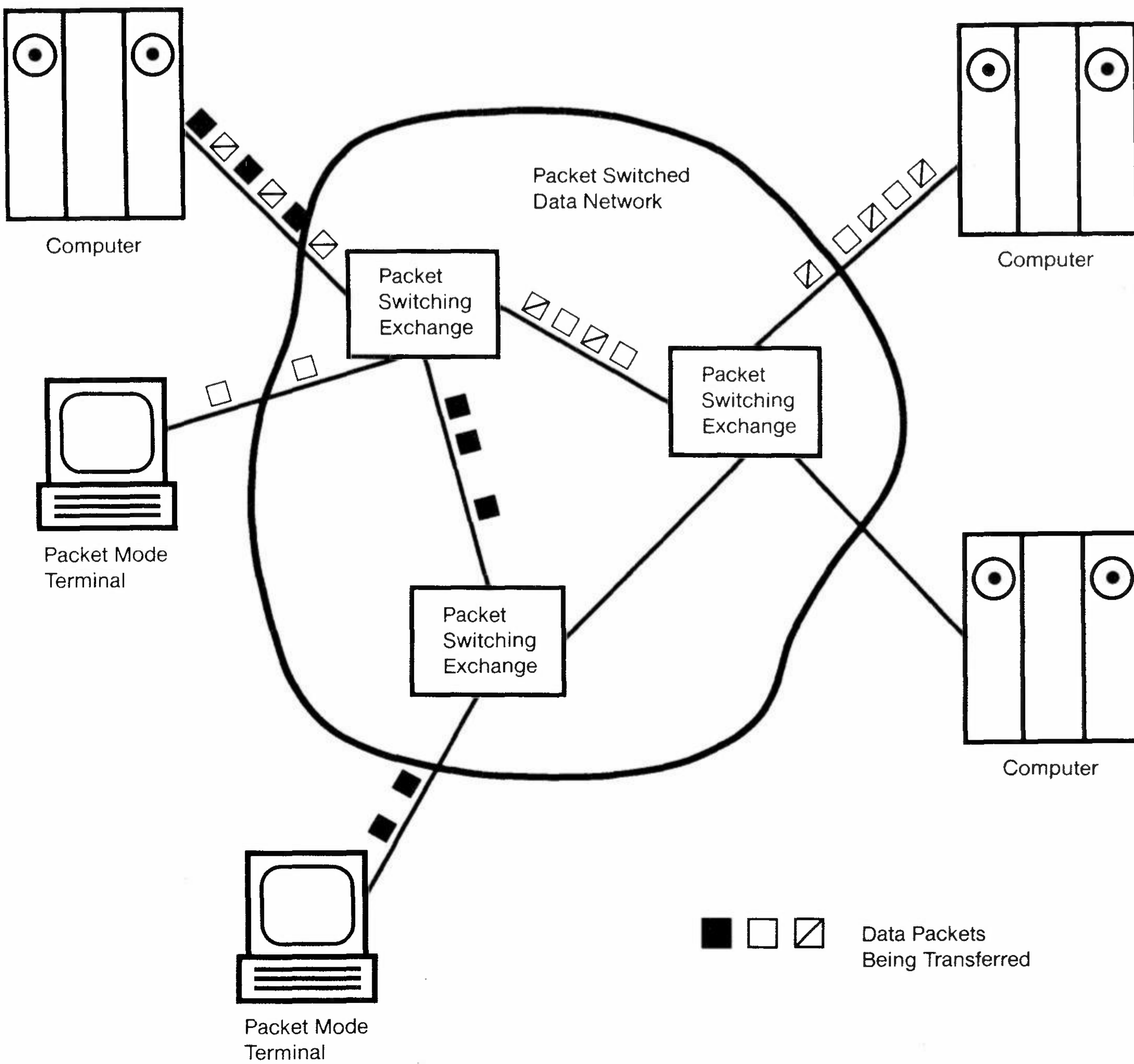
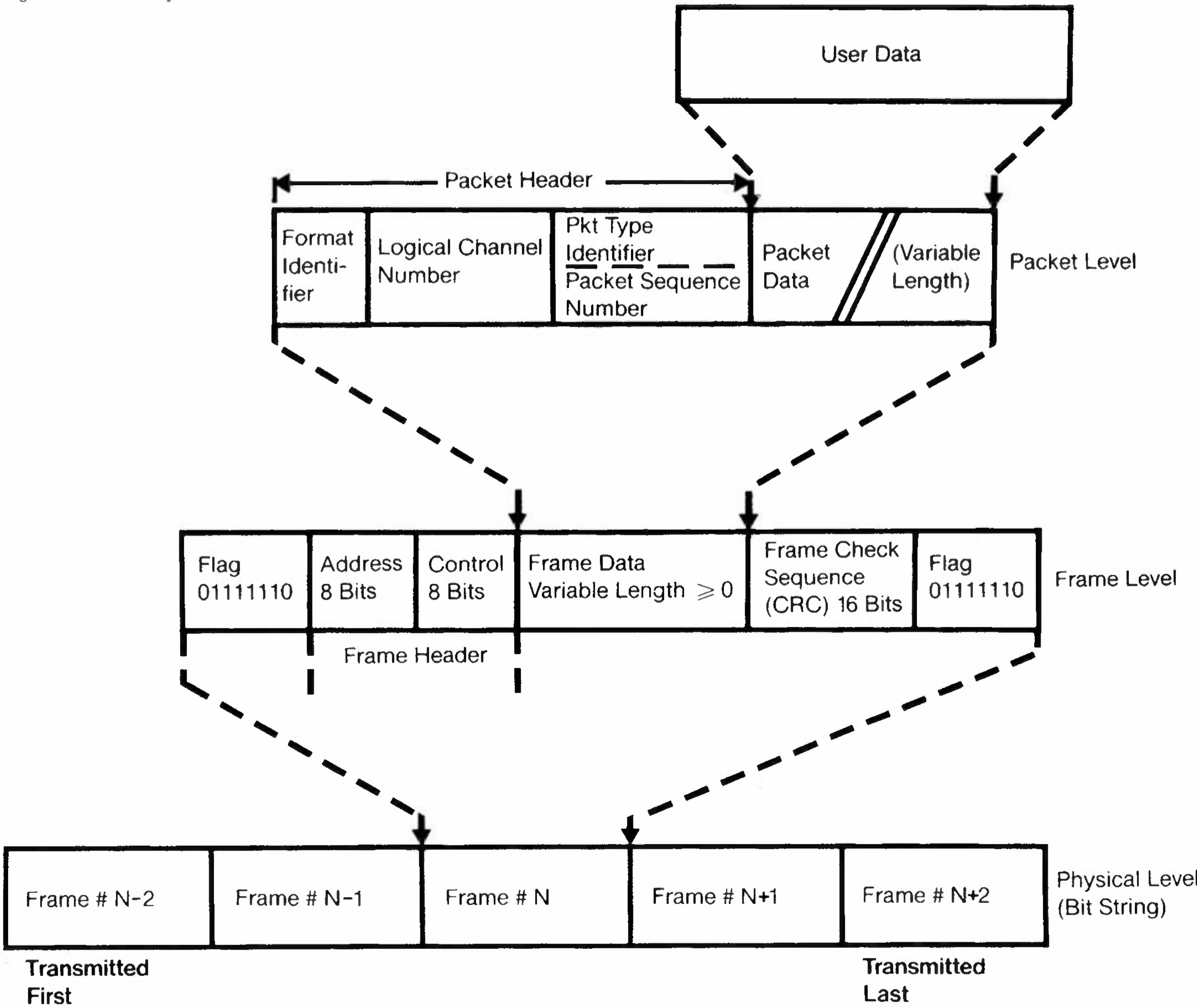


Fig. 2: The X.25 Interface.



PROTOCOL VERIFICATION USING 'PROTEAN'

Protocols

Protocols are the rules and conventions used in the conversation between communicating systems. Protocols are needed for accessing networks and for communication within and between networks.

The complexity and sophistication of signalling schemes and data protocols is increasing as communications equipment is becoming more complex and as new facilities are being introduced. The interconnection of different facilities requires new protocols to allow information to be exchanged.

At present these protocols and signalling schemes are designed using engineering intuition. Many have been relatively successful. However, almost all have failed in unforeseen circumstances owing to logical errors in their procedures. Thus there is a need for formal design rules that can guarantee the proper functioning of protocols. Before these design rules can be derived, there is also a requirement for general methods of specifying, modelling, analysing and verifying protocols. If a protocol can be verified before it is put into service, there will not be a need for expensive remedies for faults that are only discovered when the protocol is actually used.

Methodology

Within the Research Department a methodology that can be used to specify, analyse and verify the operations of communications protocols has been developed. A summary of the methodology is shown in Fig. 1. This methodology considers the logical operation of protocols. It does not address performance issues.

Usually a protocol is only specified by its designers in a narrative form. The methodology requires protocols to be formally specified. This is done using Numerical Petri Nets (NPNs), a generalization of Petri Nets. Once formally specified the protocol is analysed using an automated tool. If there are any faults the specification is changed and the protocol re-analysed. This process is repeated until the protocol is fault free.

Protocol Analysis

The analysis of practical protocols is too complex and error prone to be done manually. PROTEAN, a PROTocol Emulation and ANalysis computer aid, has been designed to automate the analysis. PROTEAN is a user-friendly system. On-line help is always available and there are meaningful error messages.

NPNs are entered into PROTEAN textually. They can be stored for later use. Once entered the NPN can be displayed graphically. PROTEAN's graphics have been designed for use on a simple graphics terminal and an inexpensive printer.

Given an initial condition, the NPN can be executed. The results of PROTEAN's analysis are the NPN's reachability set and its Computation Flow Graph (CFG). The reachability set is the set of all possible global states, also known as 'markings', of the system that can be reached from a specified initial state. The CFG shows the relationship between these states. PROTEAN can then detect faults such as deadlocks and livelocks in the protocol's operation. A deadlock is a state from which no other state can be reached. A livelock is a group of states from which no states not in the livelock can be reached.

Once the CFG has been produced it can be displayed graphically. PROTEAN makes a first attempt at laying out the CFG. The user can then alter this using an editor. Deadlocks and loops in the CFG can be highlighted. It is also possible to highlight any livelocks.

The CFG is often very large. If the user wishes to check sequences of events with some property it is extremely difficult to find all of these sequences manually. The REDUCE feature tackles this problem by reducing the CFG to show only the sequences of events of interest. This allows the user to verify specific features of any protocol, such as verifying in a data protocol that data are never lost or duplicated.

PROTEAN allows moderately complex protocols to be analysed and verified. The graphics facilities greatly enhance its power. Further work on both the methodology and on PROTEAN should allow more complex protocols to be verified.

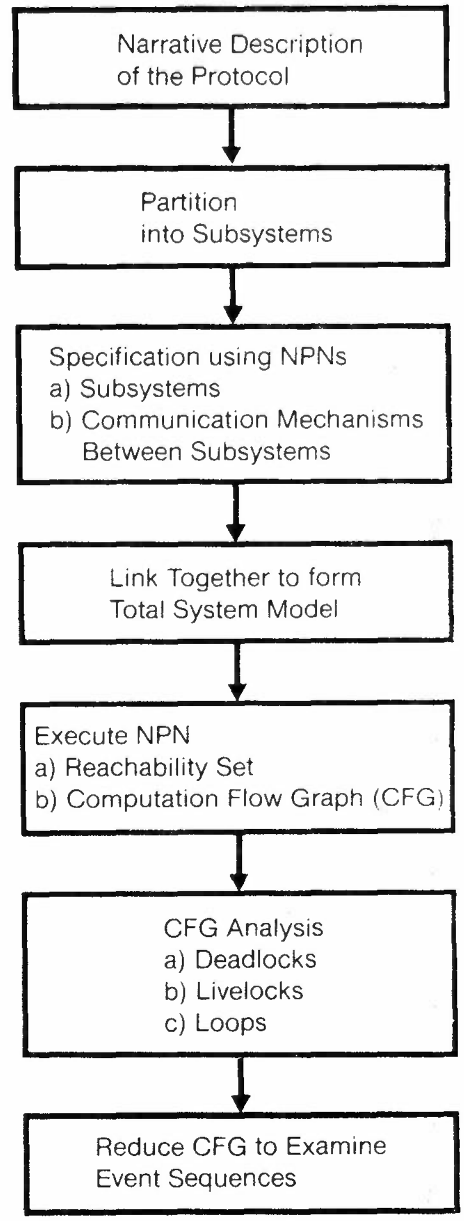


Fig. 1: The Protocol Verification Methodology

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'MELBA'

Definition

The MELBA system provides automated generation of compilable programming language code from graphical, flowchart-like system specifications for a wide variety of telecommunications applications. It results from work begun in 1979 by the Department of Communication and Electronic Engineering and the Department of Computing of the Royal Melbourne Institute of Technology (RMIT) under research and development contracts with Telecom Australia.

Features

Features of the MELBA system are:

- Automatic production of implementation from specification — reduces manual programming effort.
- Input is via the International Telegraph and Telephone Consultative Committee (CCITT) Specification and Description Language (SDL), a graphical language based on state transition diagrams. See Fig.1.
- Output is the CCITT High Level programming Language (CHILL). See Fig.2.
- Three-tiered team of specialized users works together on a single software project.
- High-level, self-documenting interface presented to the users.
- Modifiable library of data types allows MELBA to be used for a wide variety of applications, e.g. packet switching nodes and computer-controlled telephone exchanges, without changing the MELBA software.
- Well suited to rapid prototyping.
- MELBA system coded in Pascal language.

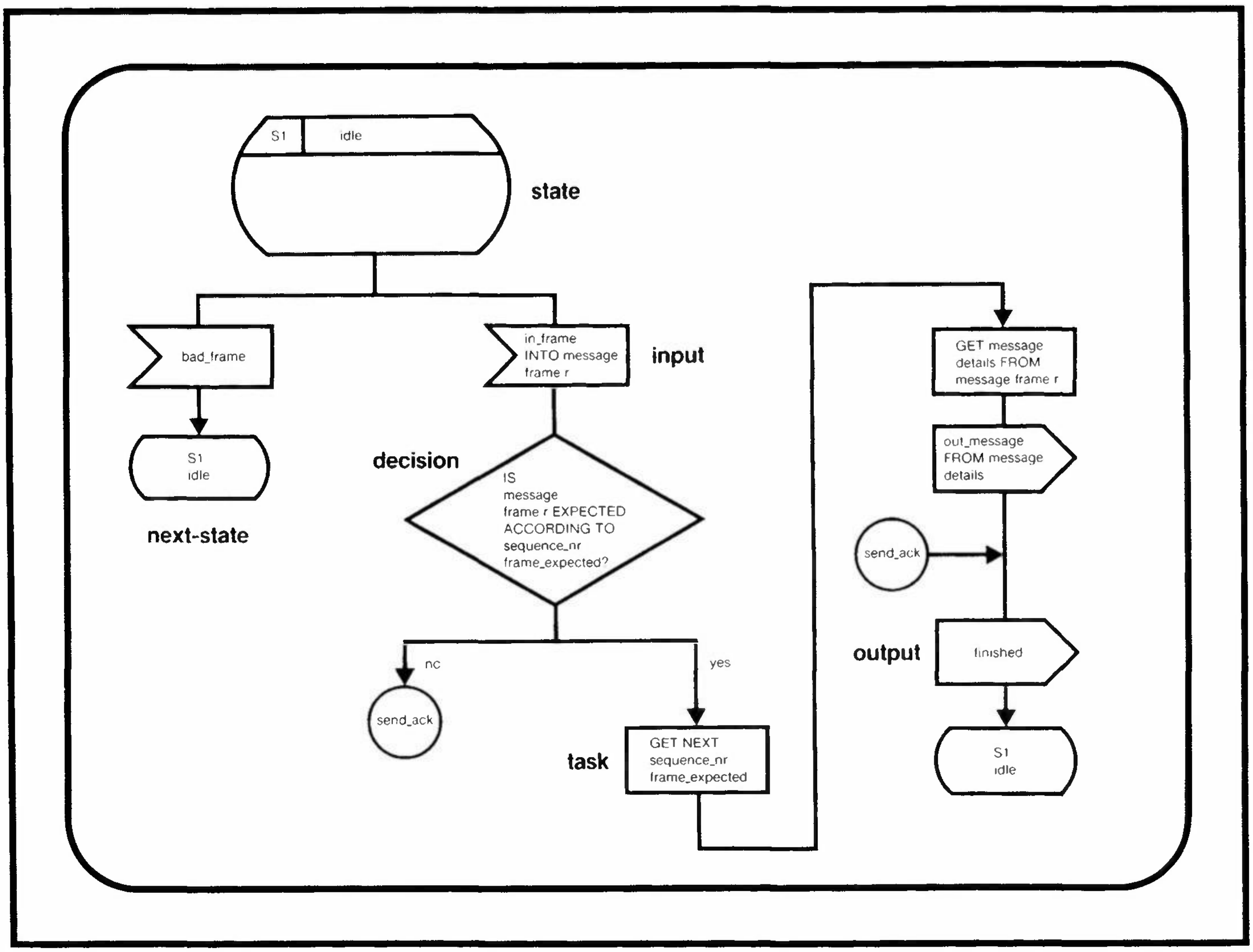

Fig.1 Example of SDL Input (Specification)

```
S1 : /* idle */

RECEIVE CASE
    (in_frame IN message_frame_r):
        /* good frame received from physical layer */
        CASE IS_message_frame_EXPECTED_ACCORDING_TO_sequence_nr
        (message_frame_r , sequence_nr_frame_expected ) OF
            (no):
                GOTO send_ack;
            (yes):
                CALL GET_NEXT_sequence_nr (sequence_nr_frame_expected );
                CALL GET_message_FROM_message_frame (message_details , message_frame_r );
                /* extract message from frame */
                SEND out_message (message_details );
                /* send to higher protocol layer (network) */
                send_ack :
                SEND finished;
                /* return positive acknowledgement to physical layer */
                GOTO S1 /* idle */;
        ESAC;
    (bad_frame).
        /* physical layer encountered corrupted frame */
        /* ignore bad frames */
        GOTO S1 /* idle */;
ESAC;
```

Fig.2 Chill Code Output (Implementation)

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FIELD TRIAL OF AUSTRALIA-JAPAN COMMON CHANNEL SIGNALLING SYSTEM

Signalling

'Signalling' is the term used to describe the operations that must take place to control the establishment of a communications circuit, e.g. a telephone connection, between two customers. Signalling is necessary initially between the calling customer and his exchange, subsequently between exchanges in the network and finally between the terminating exchange and the called customer. Signalling is used to control the set-up of the communications circuit and to transfer information, e.g. the dialled digits, to the following exchanges.

Signalling has been customarily performed over the communication circuit being set-up, before it is used by the customers. A considerable amount of equipment is necessary to perform the signalling functions. For efficiency, facilities are therefore provided to connect this equipment to circuits only when required, thus allowing the equipment to be shared among many circuits. This type of signalling has evolved with the mechanical exchanges and works well with 'step-by-step' and 'cross-bar' exchanges. It is called 'associated' signalling.

Common Channel Signalling

With the introduction of electronic Stored Program Controlled (SPC) exchanges, many shortcomings of the 'associated' signalling became evident, in particular its slow speed and limited range of signals. A new signalling scheme that would overcome these problems and be suitable for international and national use was therefore devised by the relevant international body, the International Telegraph and Telephone Consultative Committee (CCITT).

The new scheme was a 'Common Channel Signalling' (CSS) system, which separates the signalling information from the voice information and uses dedicated 'signalling links' between exchanges to transfer that information. Fig.1 shows the principles of the two kinds of signalling system.

CCS allows the setting up of a separate dedicated signalling network, with Signalling Transfer Points (STP) to interconnect all exchanges.

Signalling System No.7

Signalling System No.7 (SS No.7) is the second CCS system specified by CCITT and is designed particularly for digital networks. SS No.6 was also a CCS system but designed for analogue networks and is now in widespread use internationally, e.g. between Australia and Canada, USA, Japan, Singapore and many other countries.

Using faster digital links, SS No.7 can handle a lot more traffic than previous systems. It can also cater for many other services as well as telephony. It will be introduced within Australia in 1986 and will form the basis for the introduction of the Integrated Services Digital Network (ISDN), which will offer many new services and facilities to customers.

An Australia-Japan field trial completed recently was the first international connection of SS No.7, using equipment developed independently by different organizations. The objectives of the field trial were:

- to verify the accuracy and completeness of the CCITT specifications for No.7 CCSS by performing extensive functional tests and
- to compare the traffic handling performance of the various alternative error correction procedures available in No.7 CCSS, using satellite and terrestrial cable circuits.

The results of the field trial showed that the CCITT specifications were complete and unambiguous, with only a few minor amendments being necessary. The measured traffic handling capacity was found to be very close to that predicted by theoretical formulae, so that these formulae can be used reliably in future for signalling network planning and dimensioning.

*Contact: Mike Suboc*z *03-541 6294*

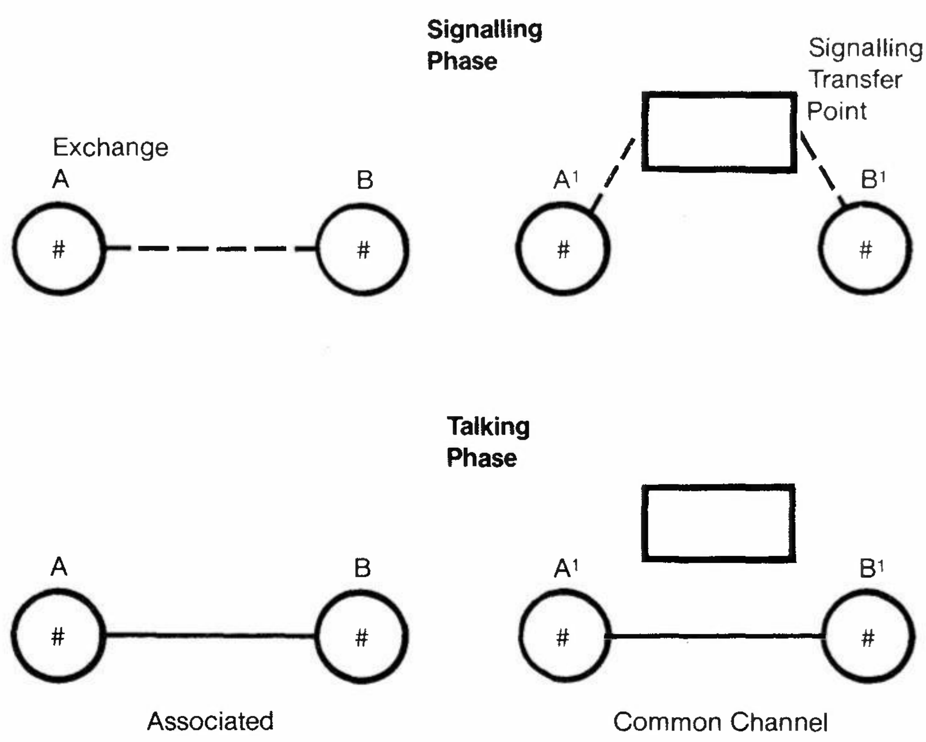


Fig.1: Principles of 'Associated' and 'Common Channel' Systems

EXPERIMENTAL ISDN EXCHANGE NETWORK

ISDN

The abbreviation ISDN refers to the Integrated Services Digital Network, the result of a set of developments that are promising to transform the nature of present public telephony and data networks. By basing its entire design on the use of digital microelectronics technology, the ISDN will be able to offer new as well as familiar services, based on digital switching techniques and transmission right to the customer equipment. Telecom is now proceeding to plan its forward network development with the aim of making ISDN services and facilities available within the 1980s.

Preparation for ISDN

A great many technical problems need to be resolved in preparing for introduction of ISDN even though the basic hardware technology is already available. A basic problem is the search for efficient techniques for transmission of digital information at high bit rates on customer lines that were designed in another era. Other problems relate to selection of suitable standards for design and operation of the ISDN network. These standards issues are of considerable complexity, because a very wide range of new capabilities is possible and must not be precluded by lack of careful preparation.

As well as allowing new services to be provided, adequate means must also be found for interworking with older forms of customer equipment and with the variety of existing special-purpose networks that are now used for telephony, data or text services such as telex. By providing such a universal capability, the ISDN is expected to simplify eventually the complexities of providing new forms of communications service, most importantly as seen by the customer.

In order to gain experience in this new field, the Research Department is proceeding to purchase equipment for an Experimental ISDN Exchange Network, a major new experimental installation that is expected to be operational in the Department by mid-1985. Two commercially designed prototype ISDN public exchange units will comprise the core of this network, together with ISDN customer line and terminal equipment. The capabilities of this network will allow exploration of the technical characteristics of a wide variety of new types of network connection. Interworking with existing telephony and data networks will be introduced as well in order to prove the adequacy of new standards likely to be adopted for these purposes.

The benefits in skills and experience made possible by this comprehensive network are being maximized by a carefully planned experimental program. This program will mainly involve people from the Research Department but will also provide opportunities for other engineering staff in Telecom Headquarters to be involved for experience-gaining purposes. It is expected that the experimental program will run for up to 3 years. Figs. 1 and 2 below show how equipment is to be arranged in the experimental network and give an indication of some possibilities for connection of varied call types in this ISDN environment.

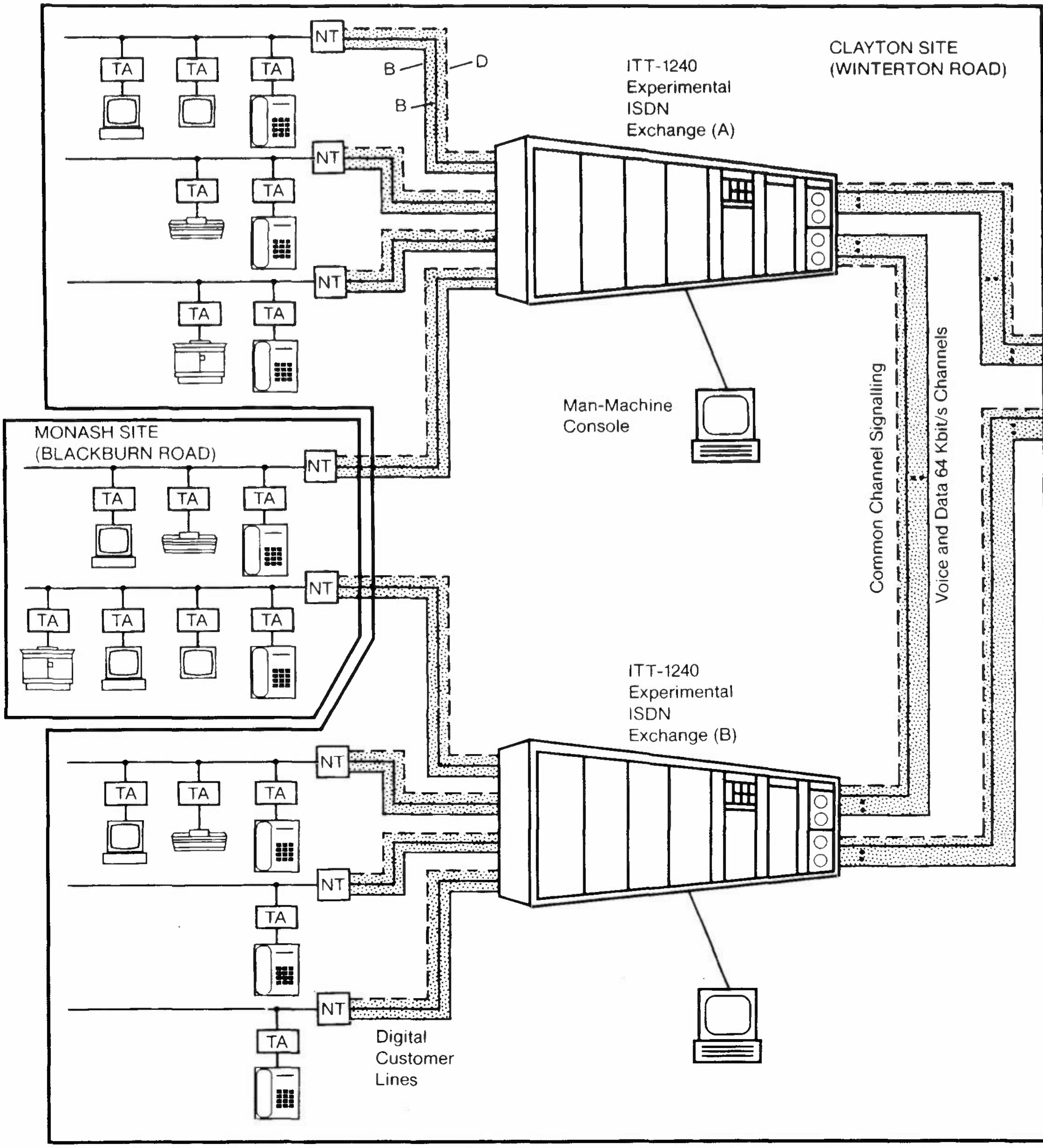
(See diagram over)

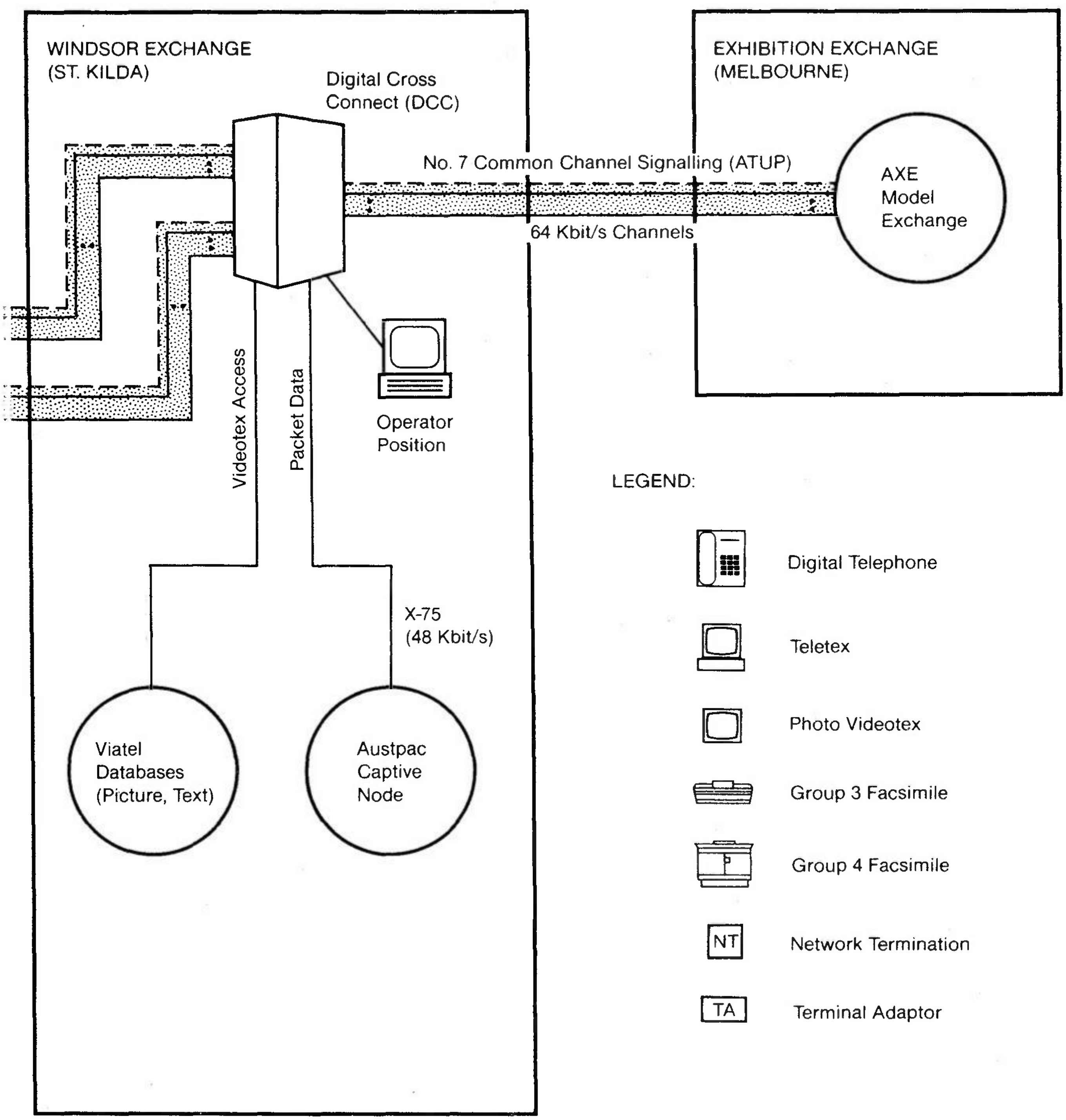
Fig. 1: Experimental ISDN Exchange Network

Contact: Jim Vizard 03-541 6348

TELECOM RESEARCH LABORATORIES

EXPERIMENTAL INTEGRATED SERVICES DIGITAL NETWORK (JUNE 1985)




WINDSOR EXCHANGE
(ST. KILDA)
Digital Cross
Connect (DCC)
EXHIBITION EXCHANGE
(MELBOURNE)
No. 7 Common Channel Signalling (ATUP)
AXE
Model
Exchange
64 Kbit/s Channels
Videotex Access
Packet Data
Operator
Position
X-75
(48 Kbit/s)
Viatel
Databases
(Picture, Text)
Austpac
Captive
Node
LEGEND:
Digital Telephone
Teletex
Photo Videotex
Group 3 Facsimile
Group 4 Facsimile
NT
Network Termination
TA
Terminal Adaptor

OPTICAL FIBRE COMMUNICATIONS

Introduction

The history of optical fibre communications is brief but includes an impressive series of developments. The optical fibre was conceived as a transmission medium in 1966 and the first practical all-glass fibre was made only in 1973 yet, by the end of the 1970s, telecommunications cable manufacturers around the world were closing their coaxial cable manufacturing facilities and setting up optical fibre manufacturing and cabling plants.

The high transmission capacities and long repeater spacings offered by modern single-mode optical fibre systems make them very attractive in planning the expansion of the telecommunications network. The cost of optical fibre cables and transmission equipment is competitive with other media and the use of optical transmission systems offers a number of other advantages. For example, an optical fibre cable need not contain metal elements and can thus be immune from lightning-induced damage.

In Australia, optical fibre cables are being installed between telephone exchanges in the major cities and are soon to be installed on major trunk routes linking those cities. With the growing sophistication of customers' equipment and the growth of customer wideband services, optical fibres may in the future be used to link a customer's premises to the telecommunications network.

Despite the impressive progress made to date in optical fibre communications, there are a number of further developments that will, over the next decade, greatly influence planning of long-distance communications networks. These include increasing sophistication of transmission techniques and the use for optical fibres of new materials that offer extremely low losses.

Both developments allow greatly increased transmission distances for high capacity systems, to the extent that the ideal of trans-continental or trans-oceanic communications systems without intermediate repeaters is no longer considered an impossibility.

History

The development of the laser in the early 1960s led communications engineers to consider the possibility of using light beams for signal transmission. The very high frequency of an optical signal allows, in theory, an enormous information transfer rate. Early experimental systems using free-space transmission proved to be as unreliable as the weather but it was not until 1966 that the use of an optically transparent guiding structure was proposed and the concept of the optical fibre was established.

Techniques for fabricating the extremely pure silica glasses required to achieve low transmission losses and for drawing those materials into strong fibres that could be used in communications cables were developed in 1971. In that year, fibres with an attenuation of only 20 dB/km were reported. The achievement of this attenuation level was significant because it marked the point at which optical fibre systems could begin to seriously challenge the established coaxial cable technology.

Early optical fibres were based on single-mode designs. However in 1971, attention shifted from single-mode fibres to multimode fibres, for which fabrication problems were not so critical, and for which useful, although lower, transmission capacities could be achieved. In 1973, attenuation levels of only 2 dB/km were reported. Continuing improvements in materials and fabrication techniques since that time have enabled large scale production of good quality multimode and single-mode fibres. For multimode fibres, an attenuation of 0.6 dB/km and a bandwidth of approximately 800 MHz at 1 km are now achieved routinely. Single-mode fibres with an attenuation of 0.4 dB/km and over 100 GHz bandwidth at 1 km are readily available from most competent manufacturers. Laboratory-made fibres have been reported with the ultimate low loss, for silica-based fibres, of 0.16 dB/km.

In parallel with the optical fibre developments outlined, a similar effort was being made in optical source development. Semiconductor laser diode sources capable of continuous operation at room temperature were first reported in 1971. Because of their high output power, ease of modulation and small size, which is compatible with optical fibre dimensions, laser diodes are a most attractive source for optical communications systems and are used almost exclusively.

Continuing developments have led to greatly improved lifetimes and have allowed operation at the longer wavelengths at which silica optical fibres offer minimum attenuation and dispersion.

Laboratory trials of multimode optical transmission systems commenced as soon as the first optical fibres became available but it was not until 1976-77 that large-scale field trials of non-commercial transmission systems took place. Since late 1979, many countries have begun to install multimode optical fibre cables between urban telephone exchanges in preference to using other media. As the use of optical fibres has increased, advances in manufacturing techniques have improved production volume and yield. Consequently optical fibre prices have decreased dramatically.

The manufacturing technology improvements needed to fabricate good quality single-mode fibres on a large scale were also made quickly and trials of prototype single-mode systems suitable for long-distance transmission commenced in 1982.

Current Optical Technology

The use of multimode optical fibre systems in urban areas is now well established. A useful span of 15 km or more, depending on the transmission capacity required, can be achieved between repeaters. This means that most repeaters can be located in exchange buildings. Multimode fibre systems are used where medium capacities are required, principally at 34 and 140 Mbit/s (equivalent to 480 and 1920 voice channels respectively), although lower capacity systems are also used in many countries.

The use of single-mode optical fibre systems is becoming established for routes where high traffic capacities or very long repeater spans are required. In general, those systems operate at rates of 140 Mbit/s and higher and at these rates offer repeater spans of over 30 km. Perhaps the most ambitious of the early single-mode trunk networks is that commenced in 1982 by NTT in Japan, which consists of a link operating at 400 Mbit/s running the entire length of the chain of islands and connecting every major city. When completed in 1985, this will include over 2000 km of cable and 70 000 km of single-mode fibre.

Australian Developments

The Research Department first became involved with optical fibres in 1971, when the Commonwealth Scientific and Industrial Research Organization (CSIRO) produced a liquid-filled fibre with what was then a world record minimum attenuation performance of 10 dB/km. The Department carried out transmission performance measurements on these fibres and demonstrated the transmission of analogue video signals over kilometre lengths of fibre early in 1972. Over the next few years a variety of laboratory experiments were performed on liquid-filled and later all-glass fibres, calculations were performed on transmission characteristics and source-coupling efficiency, techniques were established for optical measurements and experimental light-emitting diodes were fabricated.

Telecom Australia's first field experiment began in 1978 with the laying of a 1.6 km step-index fibre cable in cable ducts near its Research Department at Clayton. Transmission systems for analogue video and PCM telephony signals at 2 and 8 Mbit/s (30 and 120 voice channels) were designed and built by Research personnel for use on that cable. A second field experiment involving the linking of the Clayton and Springvale telephone exchanges with the two Telecom Research Department sites in Clayton began in 1980.

Investigations at the Research Department were complemented by research and development work sponsored by Telecom in Industry and the Universities. AWA Ltd. established a pilot plant for the manufacture of optical fibres under a series of contracts that commenced in 1976. The first wholly-Australian optical fibre cable was delivered to Telecom in 1979. Extensive theoretical studies of optical fibres have been undertaken at the Australian National University and other optical fibre device work and development of optical fibre equipment has been carried out at the Universities of Western Australia and New South Wales. Two companies received contracts to investigate optical fibre cable design strategies and the University of Queensland has also been involved in the development of optical fibre test equipment.

In 1983 Telecom commenced its optical fibre Engineering Field Trials involving installation of commercial cables and transmission equipment in Melbourne, Brisbane and later Sydney. Cable for one of the two Melbourne systems was made in Australia from Japanese fibre and both fibre and cable for the Sydney trial were Australian-made. Since 1984 Telecom has been installing multimode optical fibre systems on a routine basis in urban areas.

Telecom's single-mode fibre field trial linking Melton and Ballarat in Victoria is under way and will be completed by mid-1985. This will be soon followed by work on a system to link Darwin and Katherine in the Northern Territory and by the Australian Bicentennial Project being undertaken by Telecom, which is a large cable linking Melbourne and Sydney via Canberra to go into service late in 1987.

Telecom's plans for the use of single-mode optical fibre on inter-capital trunk routes and rural routes are ambitious. These plans, coupled with Telecom's acknowledged preference for local manufacture, have prompted two companies to set up large-scale optical fibre manufacturing facilities in Australia to meet the expected demand.

It is interesting to note that Telecom appears to be a world leader in the implementation of high-speed, long distance optical transmission systems. This arises in part because of Australia's unique geographic characteristics and it means that Telecom will need to play an increasing role in the setting of standards for these systems by the appropriate world bodies.

Current Research and Future Developments

There are two clear trends in current research worldwide and these are mirrored by work being undertaken in the Research Department. The first recognizes that present optical techniques, whilst they offer transmission capacities and repeater spans unimaginable a decade ago, are unsophisticated and that considerable improvements in the sensitivity of optical receivers can be made through the use of heterodyne or homodyne receivers and frequency or phase modulation techniques. These require a number of advances in semiconductor lasers and stabilization techniques but work in these areas is progressing and a number of laboratories have reported experimental systems offering improved performance over conventional systems. Experiments in laser stabilization are being undertaken at the Research Department, in preparation for the construction of an experimental system.

The longer term trend in optical fibre studies recognizes that the ultimate attenuation limit in silica-glass optical fibres has been reached and that further attenuation reductions are not possible. However, other materials, especially the heavy-metal fluoride glasses, may be used at longer wavelengths where they offer the potential for very much lower attenuation levels. In theory, it should be possible to achieve losses of 0.01 dB/km and below and this raises the possibility of trans-continental or trans-oceanic systems without intermediate repeaters.

Considerable advances in a number of areas, including material purification, fibre manufacturing and optoelectronic device technology are required before such systems reach the field trial stage. Progress in the material technology area in particular has been impressive and it is expected that the performance of present silica-based fibres will be exceeded by laboratory-fabricated fluoride glass fibres before the end of this decade. Fully engineered systems for such very long wavelengths may become available in the mid-1990s.

LIST OF EXHIBITS

COMMUNICATION WITH LIGHT

The Laser

The use of light to transmit telecommunications signals on a large scale was only seriously considered with the invention of the laser in the early 1960s. This coherent, monochromatic optical source allows a large amount of information to be transmitted because of the very high frequency of the optical carrier (above 100 THz).

Glass Fibres

Initial optical communication systems were free space systems where the light propagated freely through the atmosphere. Many methods for providing a means of suitably guiding the light beam were suggested but glass fibres were soon recognized as the most favourable transmission media.

Since 1966 when glass fibres were first proposed as transmission media, much effort has been expended to reduce the loss and dispersion ('pulse spread') of optical fibres sufficiently to provide a viable communication system. Research into optical sources and detectors and other components for optical fibre systems has been undertaken concurrently with fibre development during the last 20 years.

Unique Features of Fibres

Optical fibre communication systems have several unique features that make them versatile communication media. Two characteristics giving rise to the great potential of optical fibres in communication systems are their low transmission loss and large transmission bandwidth. These allow long repeater spacings and high data rates, i.e. large information capacity. The optical cables are also small and light in weight leading to ease of installation and efficient use of duct space. Optical fibres are immune to electromagnetic interference. When used in a metal-free cable, they are unaffected by lightning strikes. This immunity enables optical fibres to be used in harsh environments. Optical fibres also offer a secure communication medium since the information being carried cannot be tapped without breaking the fibre itself.

Telecom Australia is actively involved in the installation of optical fibre transmission systems, exploiting the advantages of this exciting new technology.

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INTRODUCTION TO OPTICAL FIBRE SYSTEMS

Transmission and Reception

In an optical fibre transmission system, an optical source converts the input electrical signal into an optical signal which is then launched into the optical fibre and transmitted to the receiver. At the receiver end, an optical detector reconverts the optical signal into an electrical signal which is then used to reconstruct the transmitted data.

Optical Fibres

The optical fibre in current systems is a cylindrical waveguide made of silica that is doped to form a suitable refractive index profile. The fibre has a core region, surrounded by a cladding region of lower refractive index. The fibre may support many propagating waveguide modes (rays) in the case of multimode fibre, or may be designed to support only one propagating mode (single mode fibre). Typically, in multimode fibres, the core region is approximately 50 µm in diameter, while for single mode fibres it is approximately 8-10 µm in diameter (Fig.1).

The Optical Signal

A narrow optical pulse launched into the fibre broadens as it travels through the fibre. The amount of broadening (dispersion) depends on various factors including the number of propagating modes, the spectral width (wavelength spread) of the optical source and the composition of the waveguide. The smaller the source spectral width and the smaller the number of propagating modes, the lower the dispersion. Obviously, the less the pulse is dispersed, the easier it is to reconstruct the transmitted data at the receiver accurately. Dispersion limits the maximum transmission rate of optical fibre transmission systems.

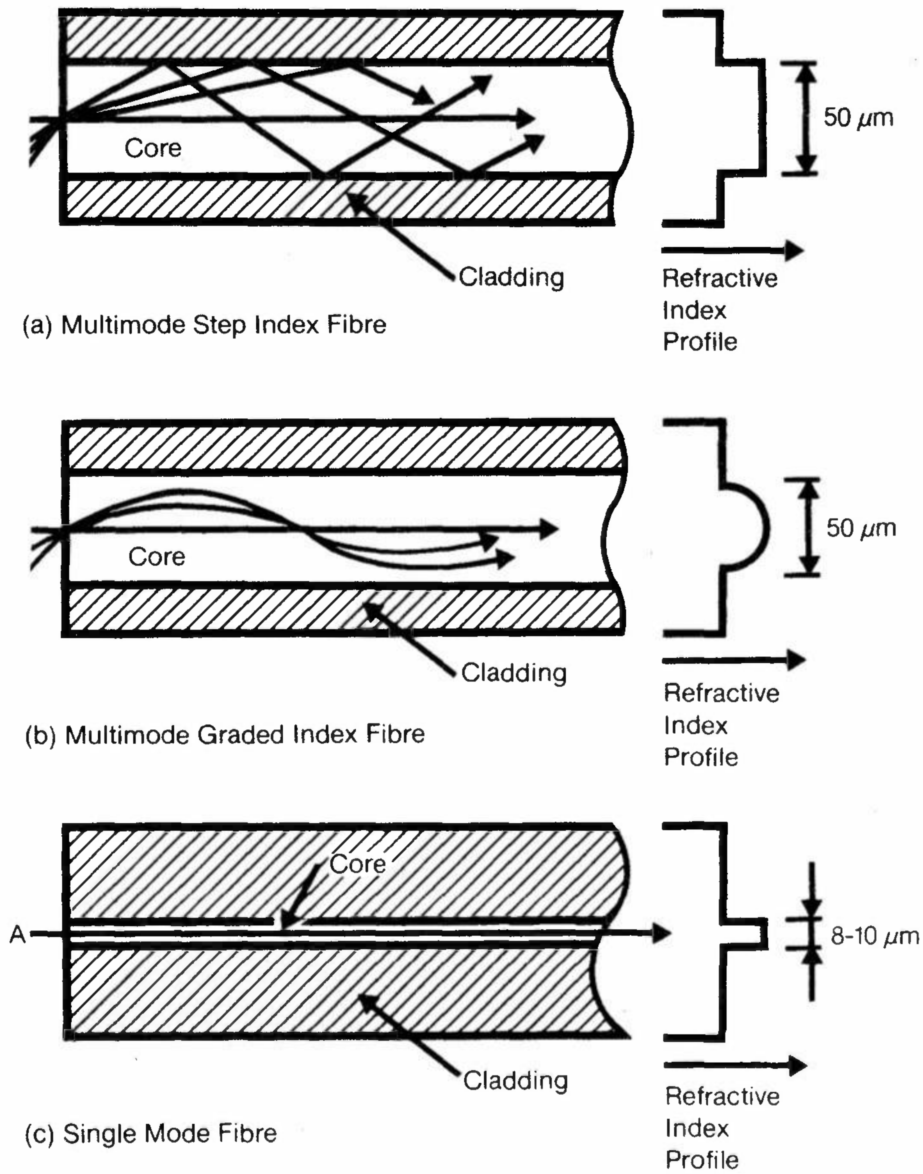

Fig. 1: Types of Optical Fibre

Operating Ranges and Losses

Currently, three 'windows' of operation of optical fibre systems are considered corresponding to wavelength regions of low attenuation and for which optical sources and detectors are available. These are the 800-900, 1300 and 1550 nm regions. The attenuation of optical fibres has decreased greatly over recent years, particularly in the 1300 and 1550 nm wavelength regions, see Fig. 2. Minimum losses of approximately 0.5 and 0.2 dB/km for multimode and single mode optical fibres are realizable for very good quality commercial fibres operating in the 1550 nm window.

Multimode Fibres

The use of optical fibre technology for a number of applications in the telecommunications network has become economically viable. Telecom Australia's use of this technology was initially in the 800-900 nm wavelength region, using multimode optical fibres. Multimode fibre systems now operate in the 1300 nm region and many of these systems are to be installed in the inter-exchange network.

Single Mode Fibres

Single-mode optical fibres are becoming increasingly dominant particularly in the long distance network and from 1986 onwards, nearly all new systems will use single mode optical fibres. These fibres are especially suited to applications requiring long transmission distances and high capacities. These systems will operate in the 1300 nm and later in the 1500 nm wavelength regions. Currently planned single-mode systems will operate at bit rates up to 565 Mbit/s.

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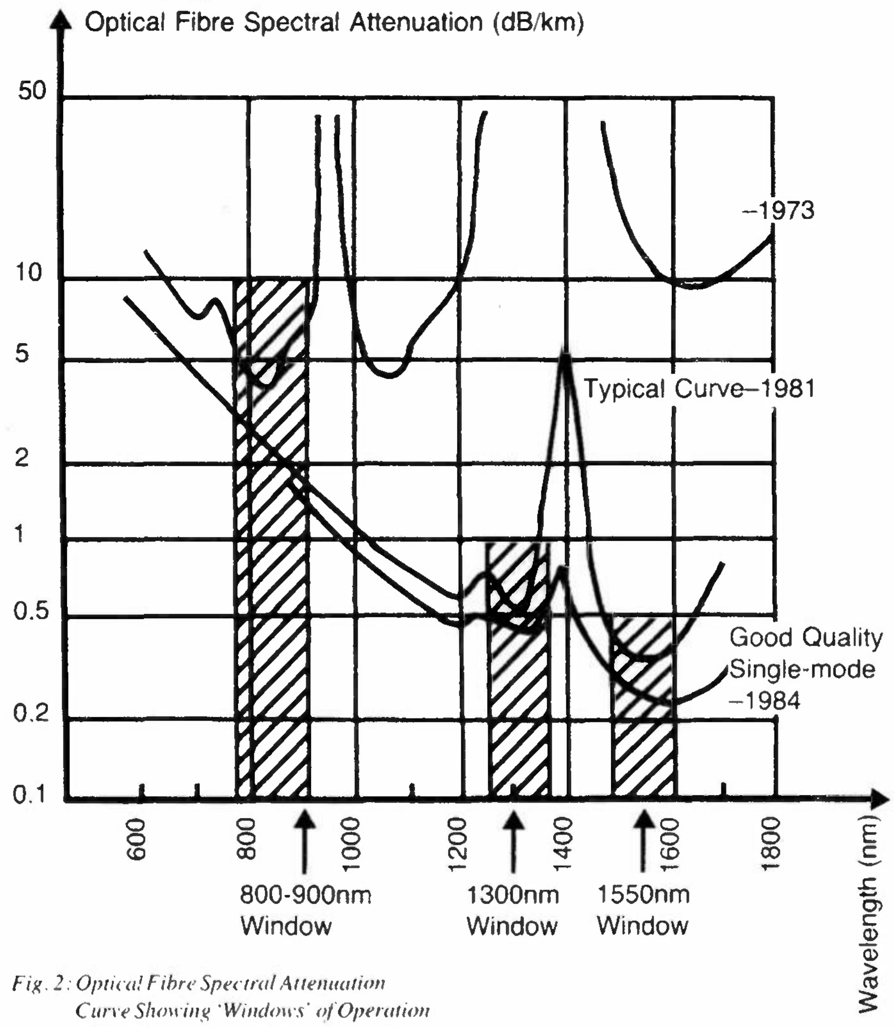

Fig. 2: Optical Fibre Spectral Attenuation Curve Showing 'Windows' of Operation

OPTICAL FIBRE ELONGATION AT CABLE PLOUGH-IN

Single Mode Optical Fibre Systems

Single mode optical fibre systems are soon to be introduced into Australia's inter-city trunk network. A field trial involving the installation of 75 km of single mode fibre cable is under way and plans for the first major system (1000 route-km) are well advanced. Single mode optical fibre systems are also favoured as a means of providing digital transmission facilities into and between small rural centres.

Single mode fibre systems are attractive for major trunk routes because they offer high transmission capacities and long repeater section lengths. Even on routes between small rural centres, single mode optical fibre systems are still attractive because of the long repeater section lengths available. The use of optical transmission is also attractive because it offers the possibility of a metal-free cable that is immune from lightning-induced damage.

Installation of Cables

In comparison with other transmission media, optical fibre cables and transmission systems are competitively priced. However, cable installation costs are substantial and, in order for optical systems to remain competitive on an overall cost basis, it must be possible to install optical fibre cables using similar methods to those used for other cables. In rural areas of Australia, as in many other countries, cable ploughing techniques have been established as the most attractive method of installing cables.

Comparison with Metal Conductor Cables

In general, cable ploughing equipment and techniques have been developed with robust metal cables in mind. However, optical fibre cables are very much smaller and lighter than metal cables of similar capacity and have a lower tensile strength. Thus, there is a possibility that conventional cable ploughing equipment and techniques may create excessive cable tension and lead to excessive strain levels in the fibres. Optical fibres are proof-tested during manufacture to strain levels of typically 0.5% to 0.8% and may fail instantaneously if exposed to strain levels in excess of the proof-test value. A more insidious problem also arises, in that optical fibres within a cable are susceptible to failure through static fatigue if they are subjected to even small strain levels over a long period of time. This raises some concern as to the lifetime of an optical fibre cable installed by ploughing, using the techniques developed for the more robust metal cables.

Cable Ploughing Trials

In order to evaluate the effects of installation by ploughing on optical fibre cables, a series of cables has been installed in preliminary ploughing trials. During these trials, fibres within the cables were monitored to detect changes in length arising from applied tension. The results of these trials have assisted in identifying features in cable construction and installation techniques that can be employed to minimize both transient and residual strain levels in the fibres of a cable thus installed.

Details of Measurement Equipment

A block diagram of the equipment used to measure fibre elongation is given in Fig. 1. The cable to be tested contains a loop of two fibres spliced at the far end. An optical signal from a modulated laser source is coupled to one fibre and the signal returning on the second fibre is coupled to an avalanche photodiode detector.

The vector voltmeter measures changes in the phase difference between the transmitted and received signals and the calculator calculates the equivalent elongation. The calculator records this information, together with the received signal magnitude, time of day, length of cable installed and any comments entered by the operator on magnetic tape for later analysis.

The equipment thus described is capable of measuring the fibre elongation. In order to determine the strain it is necessary also to know the length of cable installed. This is measured by a follower wheel mounted on the plough, over which the cable passes. As each extra metre of cable is ploughed, a data word is relayed to the measurement station and entered into the calculator's data record. After the initial setting-up, the measurement system is capable of unattended monitoring and can be used to generate a number of records, such as fibre elongation and strain of either steady-state or transient nature, changes in attenuation, length of cable installed at various times and cable ploughing speed. Operator-entered comments can be used to identify particular events or features. In addition, a real-time plot of average strain against length of cable installed is displayed so that the installation progress can be monitored and installation techniques modified if necessary.

Results of Trials

These trials have confirmed that optical fibre cables can be satisfactorily installed using cable ploughing techniques similar to those developed for metal cables. Details of the trial results are available in published Research Department Reports:

RLR7681 "Measurement of Longitudinal Strain in Optical Fibre Cable"

RLR7733 "Measurement of Elongation of Optical Fibre Cables During Installation : Report on Ploughing Trials May 1984"

Contact: Robert Ayre 03-541 6733

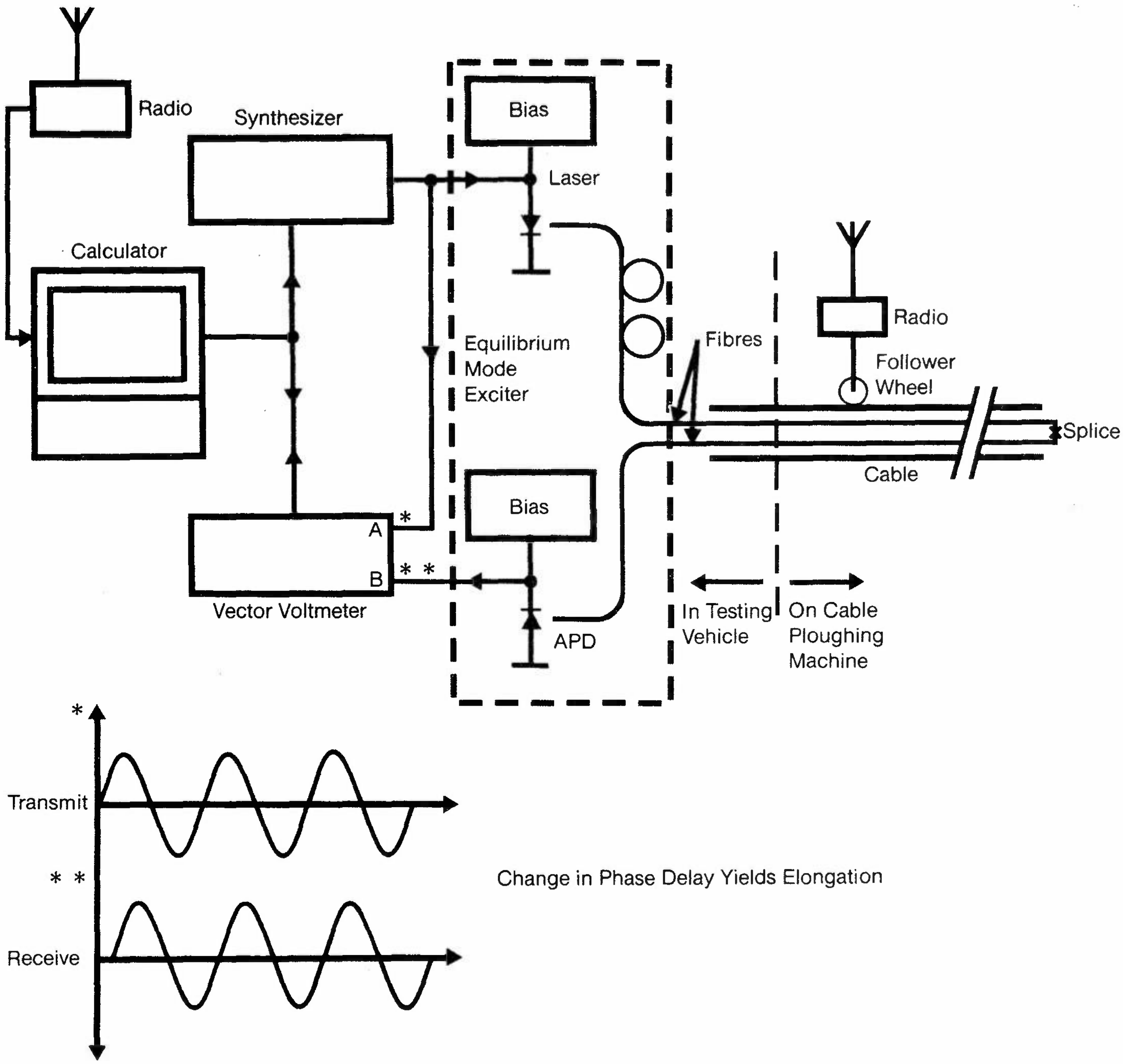

Fig. 1: Equipment used for Strain Measurements

JOINTING OF OPTICAL FIBRE

Increasing Importance of Low Loss Joints

As the loss of signal per kilometre of optical fibre has decreased (from 3 dB/km to 0.5 dB/km) owing to new developments and increased purity of the fibre materials, the loss in a joint between two lengths of fibre has become a significant factor in determining the length over which a system can operate with a safe margin, without needing regenerating.

Arc-Fusion Joints

One of the most effective ways of jointing fibres with little loss (less than 0.1 dB), compared with a demountable connector (0.5 dB to 1.0 dB), is to fuse or weld the fibres together. The ends of the fibres are heated until the glass just melts and the two sections flow together.

Alignment of Ends

To achieve a low loss joint, the fibre central cores must be precisely aligned so that the light in the core of the first fibre passes directly to the core of the other fibre (Fig.1). Any misalignment of these cores will cause an increase in the loss of the joint.

To align the ends, the fibres are clamped in two Vee shaped grooves to hold them straight and steady (Fig. 2). The Vee blocks can be moved around by micrometer manipulators to position the cores for minimum loss. In more sophisticated machines small motors manipulate the Vee blocks under the control of a computer which has been programmed to position the fibres so that maximum signal is passed to a receiver at the far end of the fibre cable.

Temperature of Fusion

When the ends are aligned and butted together a high voltage is applied to the electrodes, which are positioned in the centre of the joint area (Fig. 3). The amount of power in the arc determines the temperature of the arc. This temperature can be varied to cater for different types of fibre, as typical types of glass used to manufacture fibres melt in the range of 900°C to 2200°C. The temperature of the arc is thus an important factor in making a good joint.

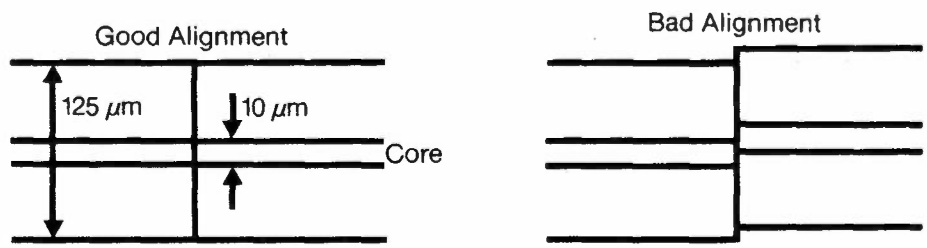

Fig. 1: Good and Bad Joint Alignments

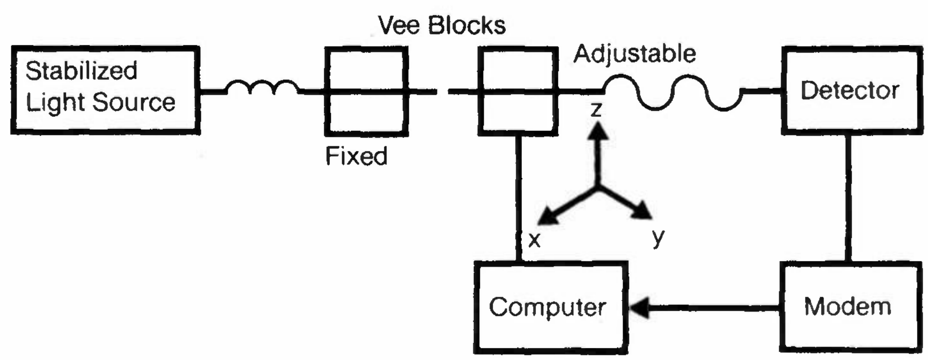

Fig. 2: Method of Alignment

The joint is visually inspected to see that there have been no malfunctions then removed from the splicer and protected in a heatshrink sleeve that covers the exposed fibres.

Testing of Joints

Optical testing of the joints can be done with an Optical Time Domain Reflectometer. This device makes use of the effect of Rayleigh Scattering (scattering of light by variations in composition of the glass). A high intensity optical pulse is launched periodically into an optical fibre and the level of back-scattered light provides information from which a number of fibre parameters can be derived.

These include fibre attenuation as a function of length, joint insertion loss, reflection coefficients at discontinuities and the location of faults (Fig.4).

The back-scattered light is collected on a photodetector which converts the light levels to electrical signals. These signals are amplified and processed by the computer to reduce the noise levels, then analysed by different programs to determine the characteristics desired. These are displayed on the visual display unit or plotted on paper as a permanent record (Fig.5).

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SINGLE MODE OPTICAL FIBRE MEASUREMENTS

Transmission Performance

The Research Department has developed methods of characterizing the transmission performance of single mode optical fibres. The characterization methods are an important aspect of a fibre specification that is required for the introduction of single mode fibre systems into the Australian telecommunications network. The transmission parameters of a single mode fibre which are identified as being important to specify include:

- the attenuation of the cabled fibre,
- the effective cutoff wavelength,
- a mode field diameter,
- a geometrical description of the cladding and its relation to the mode field location and
- the dispersion or bandwidth.

Using Parameters in Design

To illustrate the use of these parameters in designing a single mode optical fibre system, consider the example of jointing optical fibres (sometimes called splicing). The parameters which are most important in determining the fibre joint loss are:

- the mode field diameter, which is a convenient measure of the width of the field propagating in the optical fibre at its operating wavelength (Fig. 1) and
- the concentricity error, which is the radial distance between the centre of the cladding surface and the centre of the core or equivalently the centroid of the mode field (Fig. 2).

An optimum value for the mode field diameter at 1300 nm wavelength in a single mode optical fibre is in the range 9-10 µm, depending on the shape of the fibre's refractive index profile. The concentricity error should be as small as possible. However, manufacturing techniques for optical fibres give a range in the concentricity error up to a maximum of typically 1 µm.

Joint Loss

The minimum joint loss is achieved when the mode field diameters in each fibre are identical and they are spatially aligned. For jointing, a common practice is to align the outside cladding surfaces of each fibre, so that alignment of the two mode fields is best achieved with minimum concentricity error in each fibre.

The joint loss, i.e. the fraction of the optical power lost at the joint, can be numerically predicted by considering the overlap between the mode fields at the joint. A typical joint loss, with proper attention to the mode field diameter and concentricity error, is about 2% (0.1 dB).

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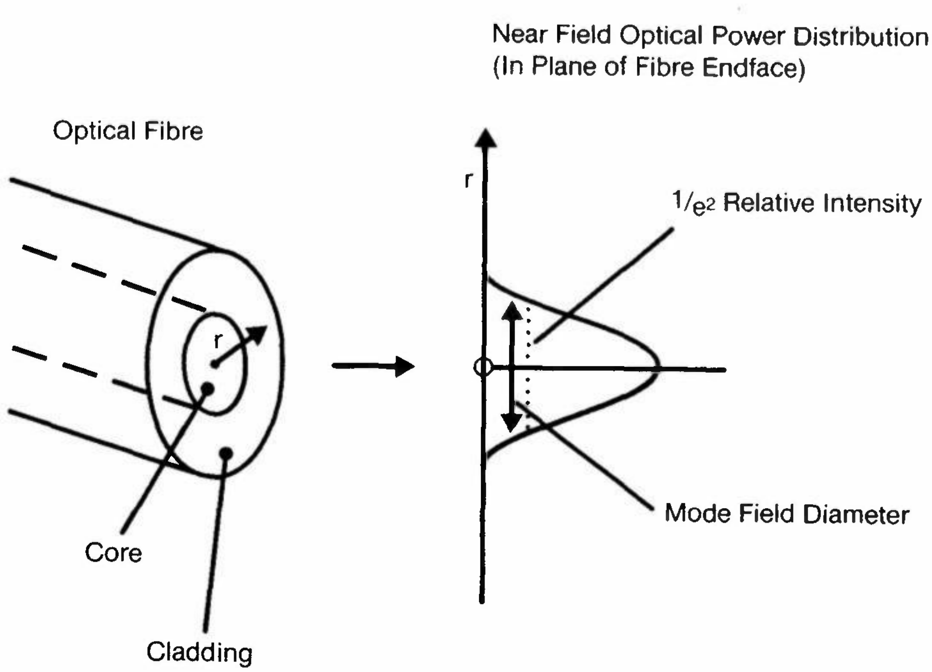

Fig. 1: Concept of Mode Field Diameter

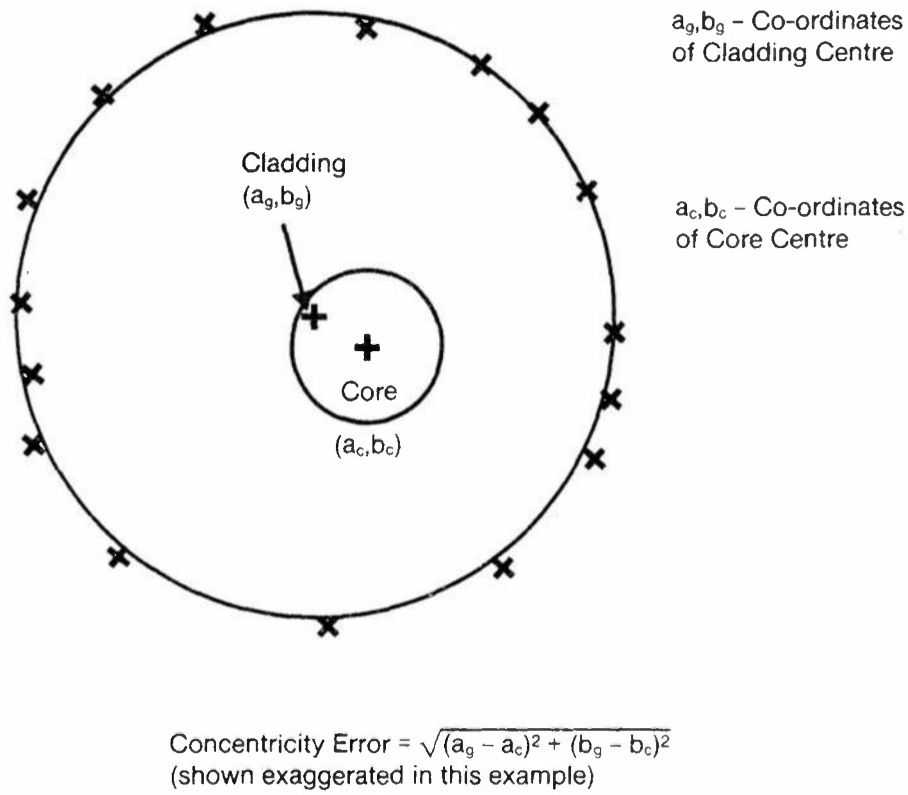

Fig. 2: Concentricity Error

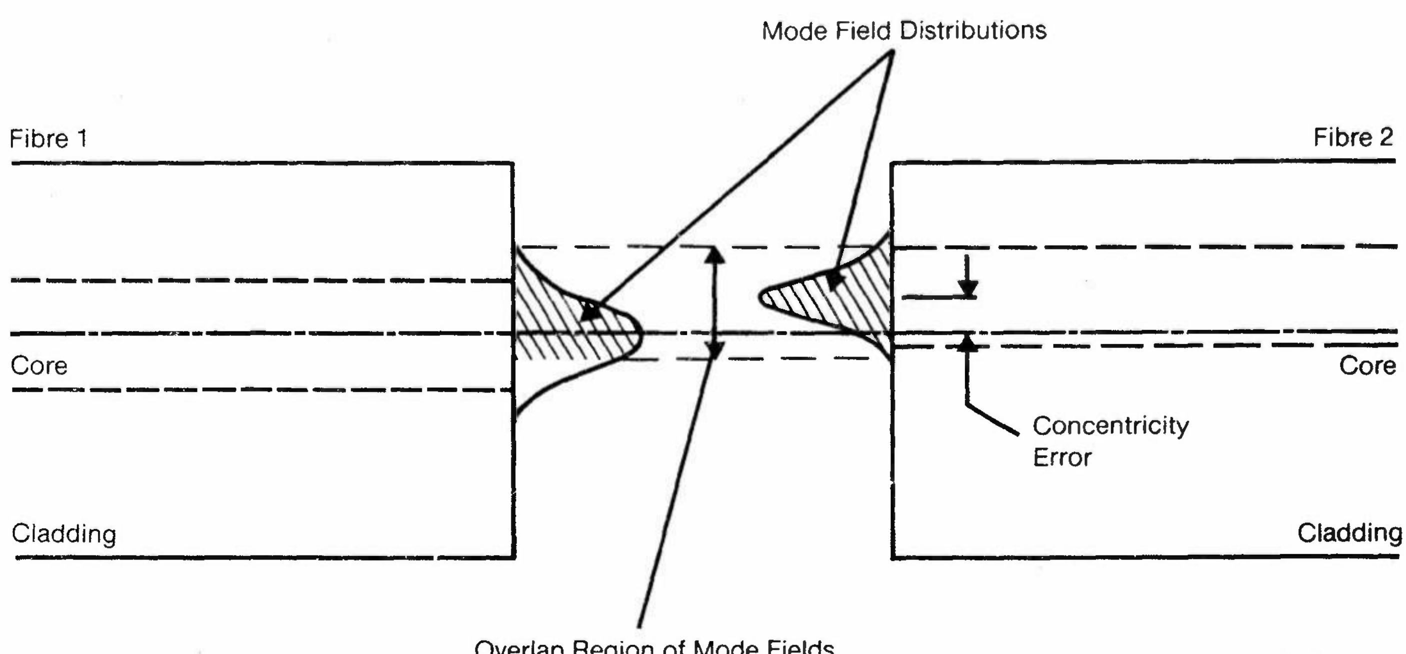

Fig. 3: Factors Affecting Joint or Splice Loss

HETERODYNE OPTICAL SYSTEMS

The Need for Heterodyne Systems

The 1990s are expected to bring a continually increasing demand for larger transmission capacity within the Australian telecommunications network. The provision of data and voice services, television transmission and wideband teleconferencing services all contribute to this growth. As a result, considerable pressure will be placed on all telecommunications media and this provides a strong stimulus for research into new techniques that may enhance transmission capacity. For optical fibre transmission systems, the next significant development is expected to be the application of heterodyne techniques. Compared to present single mode systems, systems based on this technique are expected to offer:

- a significant increase in repeater spacing
- the desired larger information capacity
- the possibility of using optical amplifiers and regenerators.

A Typical Heterodyne System

A typical configuration for a heterodyne system is illustrated in Fig.1. At the receiver the incoming optical signal is heterodyned (or mixed) with an optical local oscillator signal, then detected to produce an electrical intermediate frequency signal that is demodulated using conventional techniques. The key to the improved performance of heterodyne systems is to provide sufficient local oscillator power to swamp other noise sources and enable the theoretical limit of signal detection (called quantum noise limited detection) to be approached. The result is a significant improvement in the sensitivity of the receiver compared to that of current single mode optical systems. For a system operating at 565 Mbit/s (the equivalent of 7680 voice circuits), the improvement in receiver sensitivity can be 15 to 20 dB. This allows a significant increase in repeater spacing, with spans in excess of 80 km being possible.

Advantages of Heterodyne Systems

The information capacity of heterodyne systems can be considerably greater than conventional single mode systems. This advantage is a consequence of the stringent requirements on the spectral purity of the optical source and optical local oscillator. The narrow spectral linewidth of the laser sources allows wavelength division multiplexing techniques to be employed more effectively, and the transmission characteristics of the fibre in its optimum performance region can be fully utilized. An additional advantage of heterodyne systems is the possibility of applying laser amplifiers for both transmitter power amplifiers and in-line repeaters, the latter making large terminal-to-terminal spans possible.

Achievement of Practical Systems

Several experimental heterodyne systems have been reported overseas and have demonstrated the feasibility of these systems. Investigations in the Research Department include in-depth theoretical system modelling and performance evaluation, development of appropriate measurement techniques and a system implementation program. However, the realization of practical systems is dependent on the further development of several crucial components. Provided these technological problems can be solved, heterodyne optical systems seem certain to play a vital role in telecommunications in the 1990s and beyond.

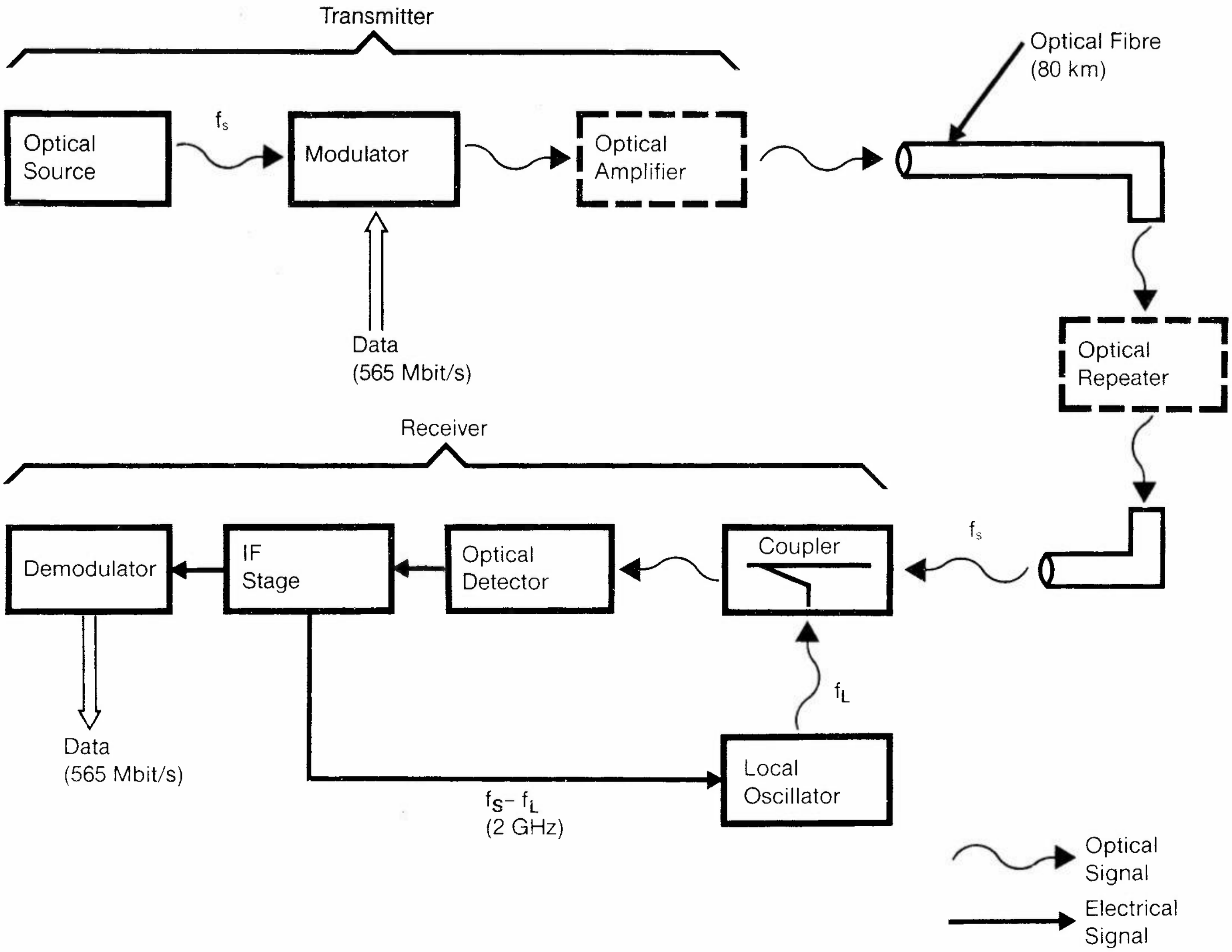

Fig. 1: Block Diagram of a Heterodyne System

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HIGH CAPACITY SINGLE MODE OPTICAL FIBRE

Increasing Requirement for Capacity

The Telecom Australia transmission network will progressively require more digital transmission capacity at a continually increasing rate over the next ten or so years. This trend stems from the introduction of an Integrated Digital Network (IDN) for telephony, the Digital Data Service (DDS) and other networks and services such as the Special Services Network (SSN) and leased 2 Mbit/s services.

Provision for Higher Capacities

To meet this increasing demand for digital transmission capacity, high capacity single mode optical fibre systems will be used, augmenting the high capacity digital radio systems, to connect together the nodes of Australia's long distance digital trunk network. Fig.1 illustrates the proposed use of single mode optical fibre in the long distance trunk network into the mid-1990s.

The transmission bit rate on the initial long distance routes will be 140 Mbit/s and 565 Mbit/s depending on traffic requirements.

For both of those rates, conventional intensity modulation line transmission equipment will be used. On these long links with many repeaters it is more economic to increase the digital transmission capacity by using time division multiplexing rather than the alternative technique of wavelength division multiplexing. Looking further into the future it may be possible to use, in place of conventional intensity modulation line transmission equipment, the more sensitive heterodyne or homodyne line transmission equipment. This equipment will allow longer repeater section lengths to be achieved or, over shorter distances, the digital transmission capacity to be increased.

Increasing Bit Rates

With these developments in the future, it is clear that single mode optical fibre systems will carry digital information at increasingly higher bit rates. At present, systems operating at 1.2 Gbit/s, 1.6 Gbit/s and 2 Gbit/s are being investigated both here in Australia and overseas.

As the bit rate is increased the technology of the electronic circuitry associated with the line transmission and measurement equipment must change significantly. At bit rates in excess of 500 Mbit/s, microwave semiconductor devices including silicon bipolar and Gallium Arsenide (GaAs) field effect transistors, high speed Emitter Coupled Logic (ECL) and GaAs digital integrated circuits will be used in conjunction with thick and thin film microelectronic circuit construction techniques.

Specific Investigations

To prepare for the future the Research Department is currently investigating various aspects of high bit rate digital transmission over single mode optical fibre as shown in Fig.2. Specific areas of work include:

- the characterization and effect of laser diode mode partition noise in intensity modulation (IM) systems,
- the modulation of semiconductor laser diode sources at very high bit rates,
- specialized test equipment to characterize the performance of single mode optical fibre systems operating at very high bit rates,
- wide-band and band pass low noise optical preamplifiers and
- theoretical analysis of the bit error rate performance of different types of transmission equipment.

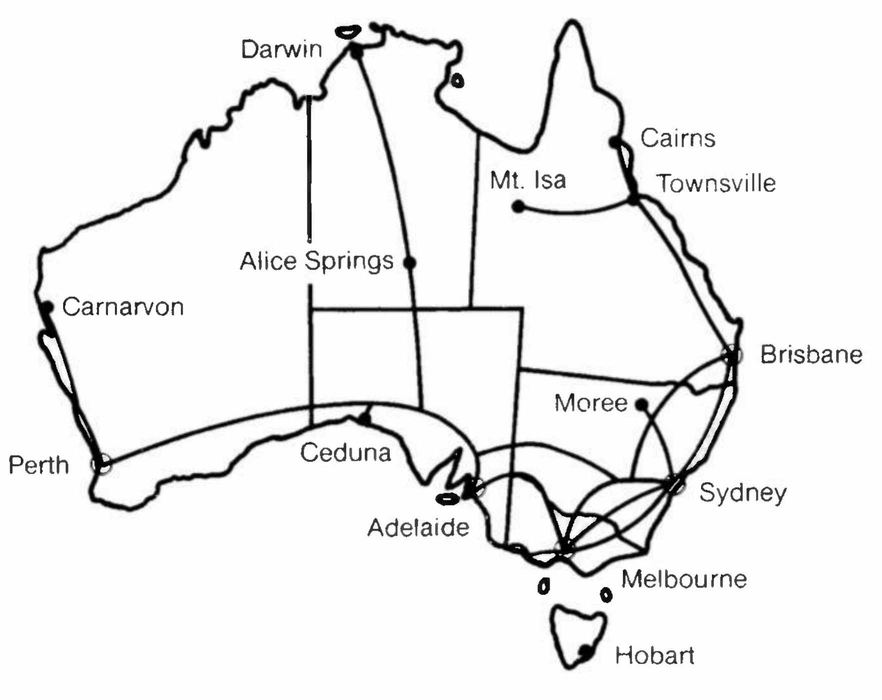

Fig. 1: Proposed Optical Fibre Systems Network for Mid-1990s.

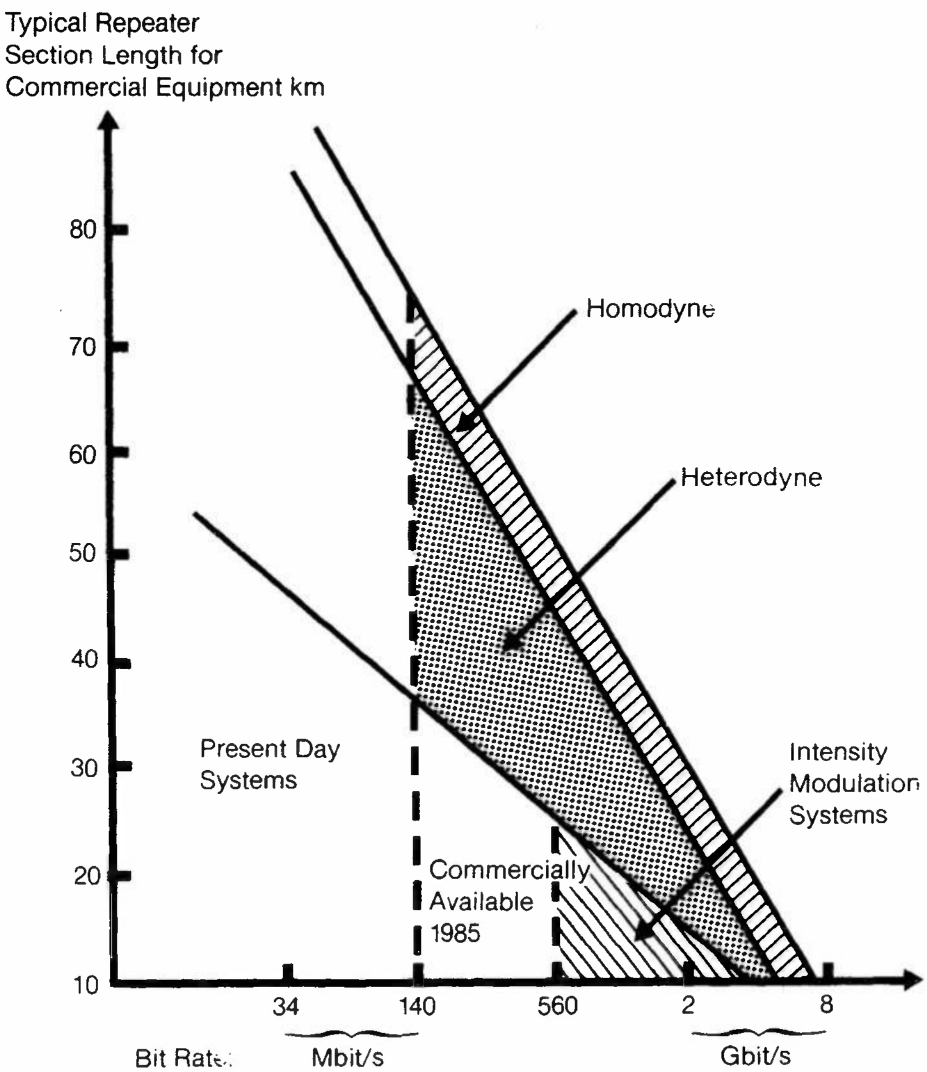

Fig. 2: Current Areas of Research in High Bit Rate Systems.

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OPTICAL FIBRE ENVIRONMENTAL TESTS

Background

Optical fibre cables offer several advantages for telecommunications, including small size and weight, wide bandwidth and immunity to electrical interference. Already optical fibre systems are a cost effective method of providing communications on routes carrying large volumes of traffic. Telecom has commenced using optical fibre cables between exchanges in the local network and will soon be installing substantial quantities on the major trunk routes.

There have been several reports of increased signal losses with fibre aging in optical fibre installations overseas. The degradation in performance is thought to be due to chemical changes in the fibre caused by the presence of hydrogen, possibly evolved from the fibre coating material. Fibre phosphorus content also appears to be a factor.

Aim of Investigation

The aim of this investigation is to determine the rate and extent of loss increase in optical fibre that can be expected under Australian conditions. The effects of the following factors are being investigated:

- temperature during aging.
- operating wavelength.
- fibre coating material (silicone versus acrylate).
- fibre phosphorus content.

Method

A number of combinations of fibre composition and fibre coating material are being tested. Drums containing a number of kilometres of each combination are being aged in environmental chambers under controlled conditions of temperature and relative humidity. The fibre ends are ducted into a nearby optical measurement laboratory, where the fibres' transmission loss spectra are recorded at regular intervals, using the measurement apparatus shown in Fig. 1.

(See illustration)

For each spectrum measured the fibre ends are firstly aligned carefully in the measurement systems by the operator. The desktop computer then automates the actual measurement process, scanning the monochromator across the 800 to 1500 nm portion of the infrared spectrum and taking readings from the digital voltmeter.

A short 'reference length' of a few metres of fibre is also measured and the ratio of reference length signal amplitude to long fibre signal amplitude is used to compute the transmission loss of the long fibre for each wavelength. This method eliminates errors due to aging of the white light source and other components in the measurement system. The white light source may even be replaced during the life of the experiment if necessary.

The light intensity reaching the photodiode detector is extremely low, because the monochromator at each wavelength setting passes only a small proportion of the incident white light. To enable accurate measurements of such low signal levels to be made the light beam is chopped by a chopper wheel at a frequency of 1 kHz. The photo-diode output can then be a.c. amplified and the signal component recovered using a synchronous detector.

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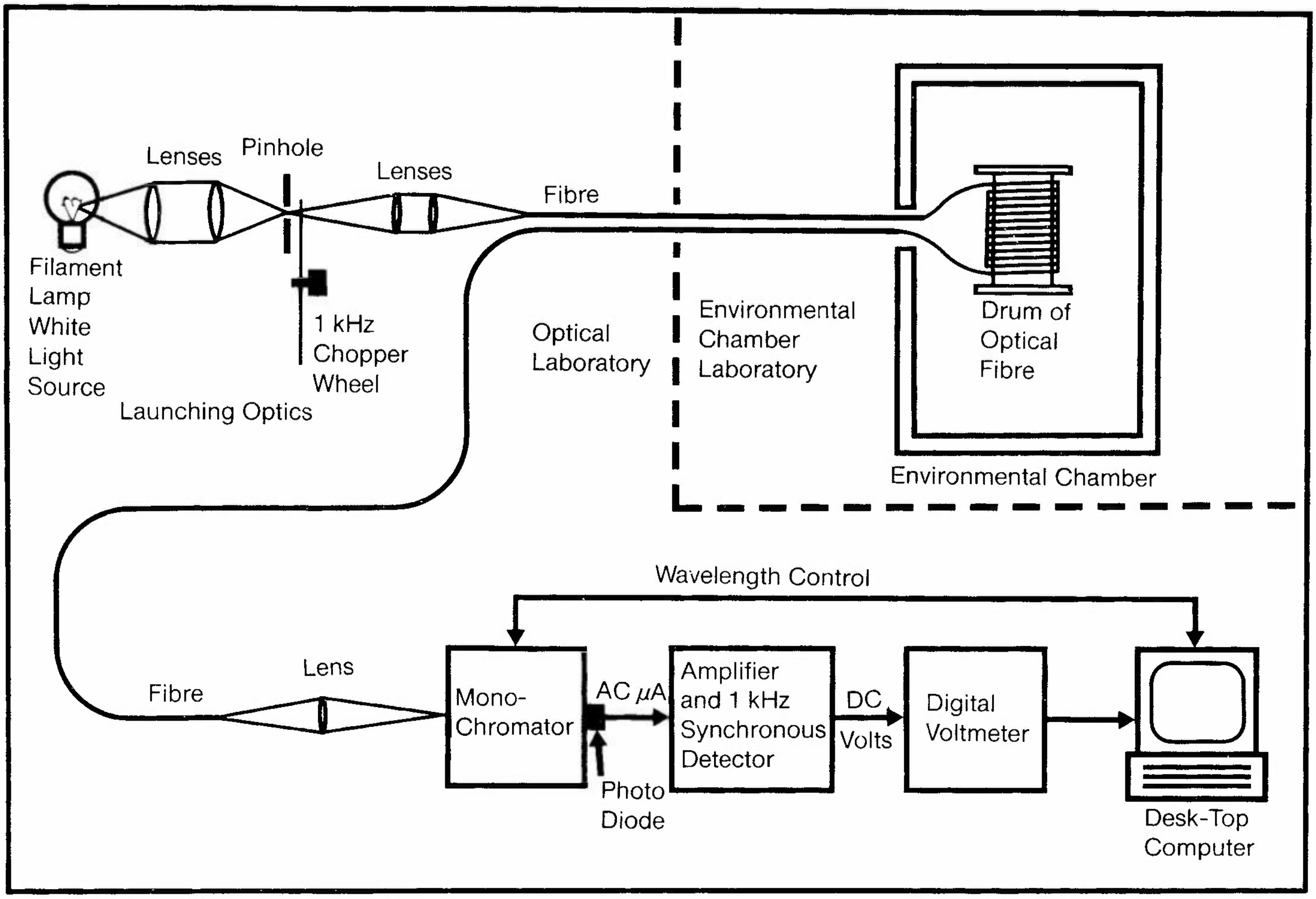

Fig.1 Apparatus for Measurement of Optical Fibre Degradation

FIXED POLARIZATION OPTICAL FIBRES

Polarization of Light

The ability of some materials to eliminate 'glare' from the reflections from flat surfaces such as bitumen roads or water will be familiar to those that, in the summer months, use sunglasses having lenses designed for that purpose.

A light beam can be considered as a wave travelling in the direction of the beam. The wave has a propagation direction (the direction of the beam). It also has a polarization direction analogous to the angle to the horizontal in flight of the wings of an aeroplane or the fletches of an arrow. The sun or a hot filament generates light that has a random temporal and spatial distribution of polarization direction. However, some materials and light sources (e.g. certain lasers) can produce light having a preferred direction of polarization.

The anti-glare effect works because, although the sun generates randomly polarized light, some surfaces are far more efficient reflectors of horizontally polarized light than vertically polarized light, enabling a suitable polarization-sensitive material to be used to reduce the level of reflected light substantially. Materials that respond differently to different polarization states of light are said to be birefringent.

The most striking effects of birefringence can be observed in some crystalline solids such as calcite, which can efficiently separate a light beam into its 'ordinary' and 'extra-ordinary' polarization components by refracting or bending them by different amounts. This is illustrated in Fig.1.

Implications for Optical Communications — Birefringent Fibres

Recent advances in stable laser sources have made possible the concept of a heterodyned optical communications system, similar to conventional microwave systems, thus fully realizing the enormous potential information capacity available at optical frequencies.

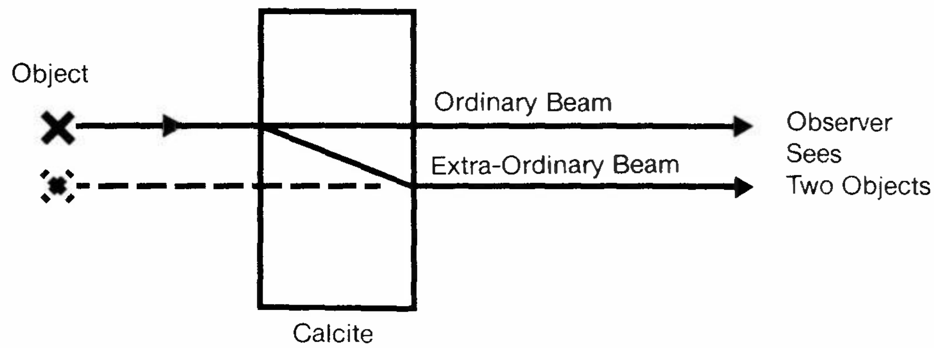

Fig 1: Birefringence in Calcite

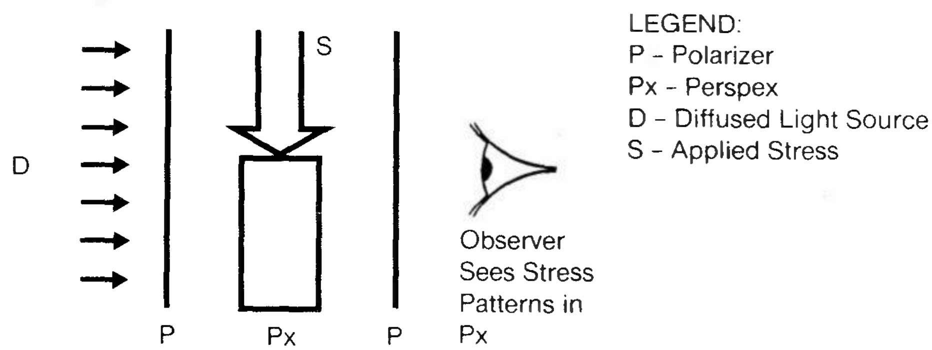

Fig 2: Stress Patterns Made Visible Under Polarized Light

Receiver design of such a system is considerably simplified if the state of polarization of the received optical signal is well known in advance. Achieving this requires light to maintain a fixed polarization relative to the fibre as it propagates — i.e. a birefringent fibre.

Glass fibres can be made birefringent by geometrical means, say by fabricating an elliptically shaped core but the result is a relatively weak birefringent effect. A far stronger effect can be achieved using the stress-optic effect, which can be conveniently demonstrated in a block of acrylic. When stress is applied to the acrylic and viewed with polarized light, the stress distribution becomes visible and then disappears as the stress is removed. See Fig.2.

Several overseas laboratories have successfully fabricated birefringent optical fibres utilizing the stress-optic effect. The Research Department has acquired specimens of such fibres for analysis and experimentation.

Birefringent Optical Fibre Observations — (Beats and Profiles)

Modern fabrication techniques enable optical fibres to be manufactured to operate over a very wide bandwidth for a range of wavelengths of operation. In the limit, the fibre operates in so-called 'single mode', although for fibres having circular symmetry this is really a misnomer. Light may propagate down circular fibre with any polarization since there is a twofold degeneracy of the lowest modes of such a fibre. This may not be a problem if fibres are perfect but in practice small imperfections or perturbations will favour one state of polarization (SOP) over another. Such polarization states are unstable and may depend upon temperature, small vibrations and the like.

An example of a fibre that circumvents the above limitations and paves the way for fixed polarization optical heterodyne communications systems is the bow tie fibre, supplied by the University of Southampton in the United Kingdom. It utilizes the stress-optic effect in the core to induce birefringence and hence separates the SOPs into two modes.

Some interesting laboratory observations can be made on a specimen of bow tie fibre. Firstly, under a Scanning Electron Microscope (SEM) the complex profile of the 30μm wide 'bow tie' can be seen as shown in Fig. 3. The outer dark areas are the stress-inducing zones while the faint irregular area between them is the core.

By forming a near field image of the output end and illuminating with either polarization of the input, the SOP at the output may be seen with a polarizer. Addition of a detector allows direct measurement of the 'extinction ratio' of the fibre, which is a measure of the fibre's quality in discriminating between SOPs.

Beats

Finally, the most striking experiment is the direct observation of 'beats'. As two waves propagate down the fibre, each with its own speed and polarization state, they move in and out of time phase. Put in another way, the total field in the fibre changes from linearly polarized, through elliptical, to circular and so on down the fibre as shown in Fig. 4. At certain angles of observation, the core will be seen to have periodic dark bands corresponding to locations where the polarization direction is pointing towards the observer. The dark bands are separated by the 'beat length', which is a measure of the degree of the separation of the two polarization modes (the shorter the beat length the greater the separation).

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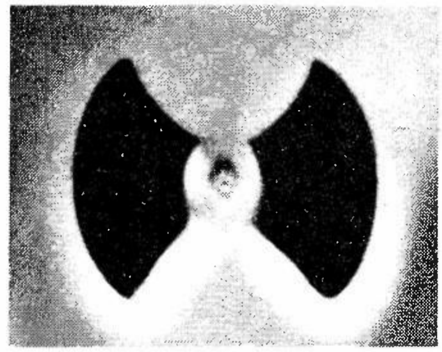


Fig.3: Micrograph of Bow Tie Cross-Section

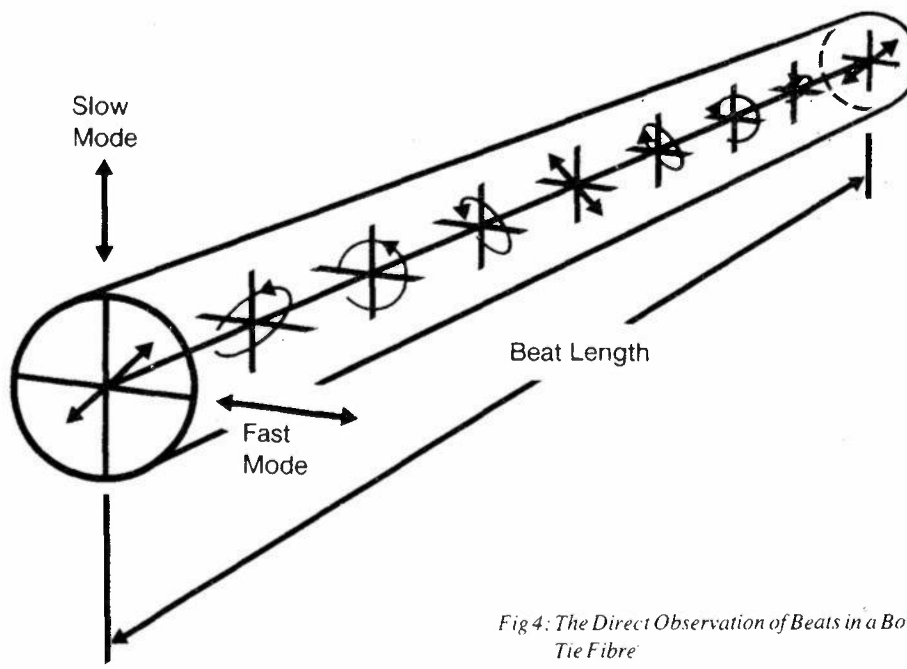


Fig 4: The Direct Observation of Beats in a Bow Tie Fibre

INFRARED IMAGING SYSTEMS

The Trend Towards Mid-Infrared Optical Fibre Communications

Light propagating in optical fibres is affected predominantly by two loss mechanisms, Rayleigh scattering and infrared (IR) absorption.

Rayleigh scattering is caused by light scattering from small particles and it increases its effect as the wavelength of light decreases. This phenomenon can be seen every day. Blue light, being at the shorter wavelength end of the visible spectrum, is scattered by the small particles present in the atmosphere, hence the sky appears blue. The small particles in optical fibres are not impurities but rather local fluctuations in refractive index of the glass material.

Infrared absorption occurs in a material if optical energy causes significant vibration of the atoms. The frequency or wavelength of light at which this resonance effect happens depends on the mass of the atoms and the strength of the bond between the atoms.

In silica glass fibres, which are used at present, the silicon and oxygen atoms are both rather light and the bonding between them is strong. Therefore the resonance frequencies in silica are at relatively short wavelengths around 2 μm.

Other glasses, where infrared absorption starts at longer wavelengths, are therefore being investigated. This will allow the operating region for optical fibres to move further down the Rayleigh scattering curve and achieve a much lower total fibre transmission loss as shown in Fig. 1.

However this means working at longer wavelengths than the present 1.3 — 1.5 μm band used in silica glass fibre communications systems. Initial results indicate that 3-5μm will be the new band of wavelengths where the losses of new fibre materials will be at a minimum.

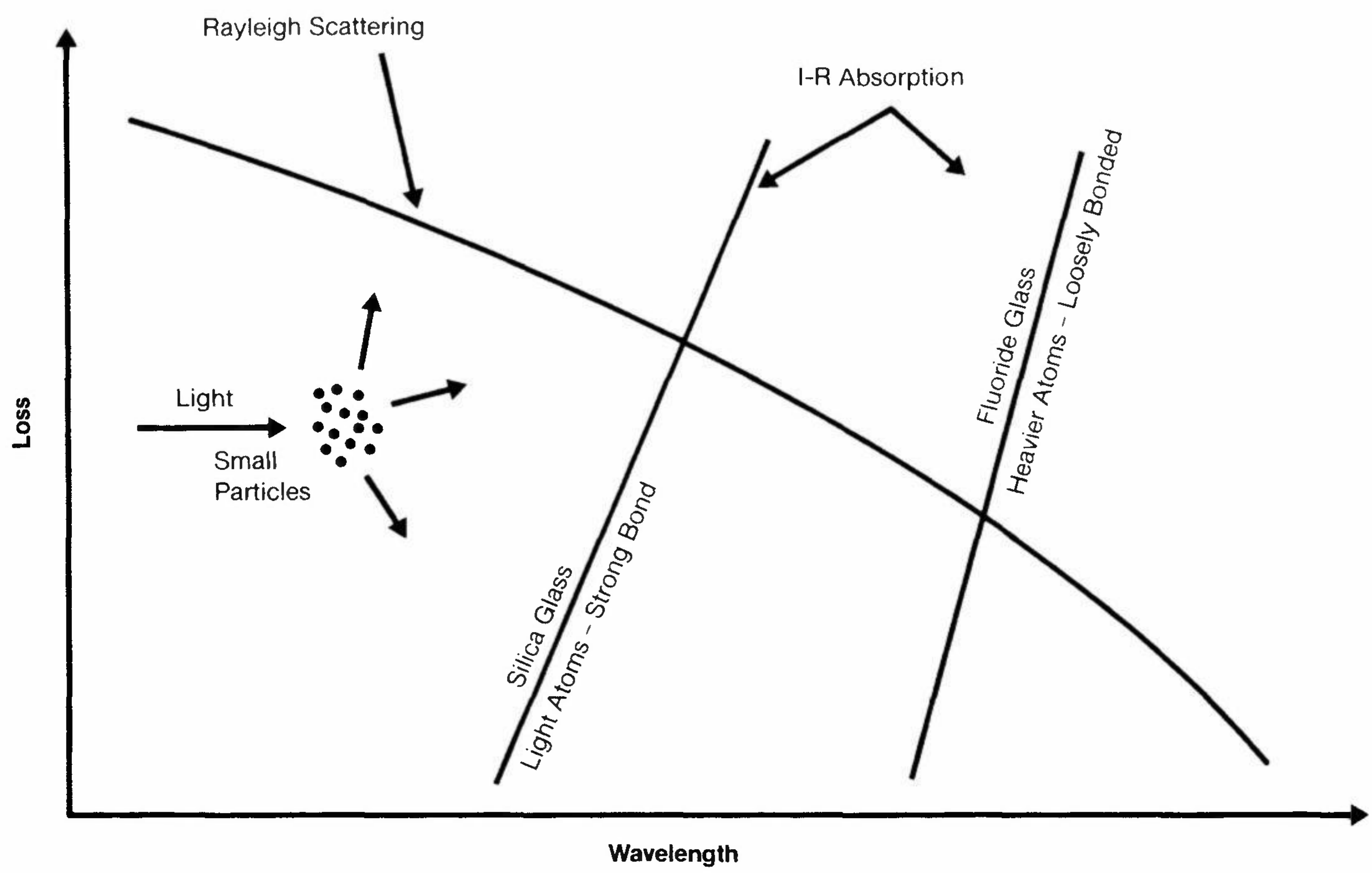
Fortunately, there are laser sources that can be made to operate at various wavelengths in the mid-IR band, but there are only a few different types of detectors and imaging systems available.

Fibre Testing

When new types of optical fibres are manufactured, a detailed process of testing the fibres to determine their suitability for communications will be required. With optical fibre research moving to the mid-IR Band, problems arise because suitable sources and detectors that operate at these wavelengths are not readily available. Therefore new equipment is needed to test these fibres.

One method of testing a fibre that gives an indication of its properties, is to look at the near and far field images of an illuminated fibre as shown in Fig. 2.

Fig. 1: Optical Loss Mechanisms in Glasses



Imaging Systems

There are three basic methods of viewing or measuring near and far field images. They are:

(a) single detector scanned across a fixed image,

(b) image scanned across a fixed single detector and

(c) television camera tube systems.

Unfortunately detectors that operate at mid-IR wavelengths are affected by the ambient temperature of the surroundings. To overcome this, liquid nitrogen cooling is employed. This makes it very difficult to move the housed detector across an image. Therefore only techniques (b) and (c) above are viable. Both techniques, i.e. mechanically scanning an image across a fixed detector cooled by liquid nitrogen or alternatively a specialized IR television camera, are used in practice, e.g. for thermal imaging (temperature mapping of objects).

In order to assess the suitability of these techniques for the Research Department's particular application, a system, using mechanical scanning and a fixed detector as shown in Fig. 3, has been built.

This imaging arrangement works in the following way. The far field image from a fibre is reflected via two mirrors, one vibrating in the X-plane, the other in the Y-plane, onto a fixed detector. The X and Y mirrors are moved so that all parts of the image scan the detector. Mirror position information and intensity levels from the detector are fed into the video frame store. The data is then available in standard video format for display on a television monitor. The frame store can be accessed by a computer so that the data can be analysed and the characteristics of the fibre determined.

Viewing systems using IR television camera tubes are simpler to manufacture because there are no intricate moving mechanical parts. Television signals can usually be obtained directly from the camera head without the need for further processing. However, IR television camera tubes generally have relatively low sensitivity and often have 'shading' problems. Shading is caused by different parts of the detector target having different sensitivities.

Fig. 2: Observing Near Field and Far Field Images of Fibre Outputs

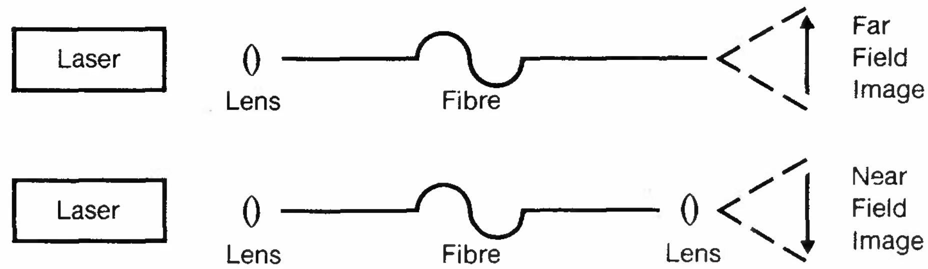


Fig. 3: Block Diagram Scanning Mirror Imaging System

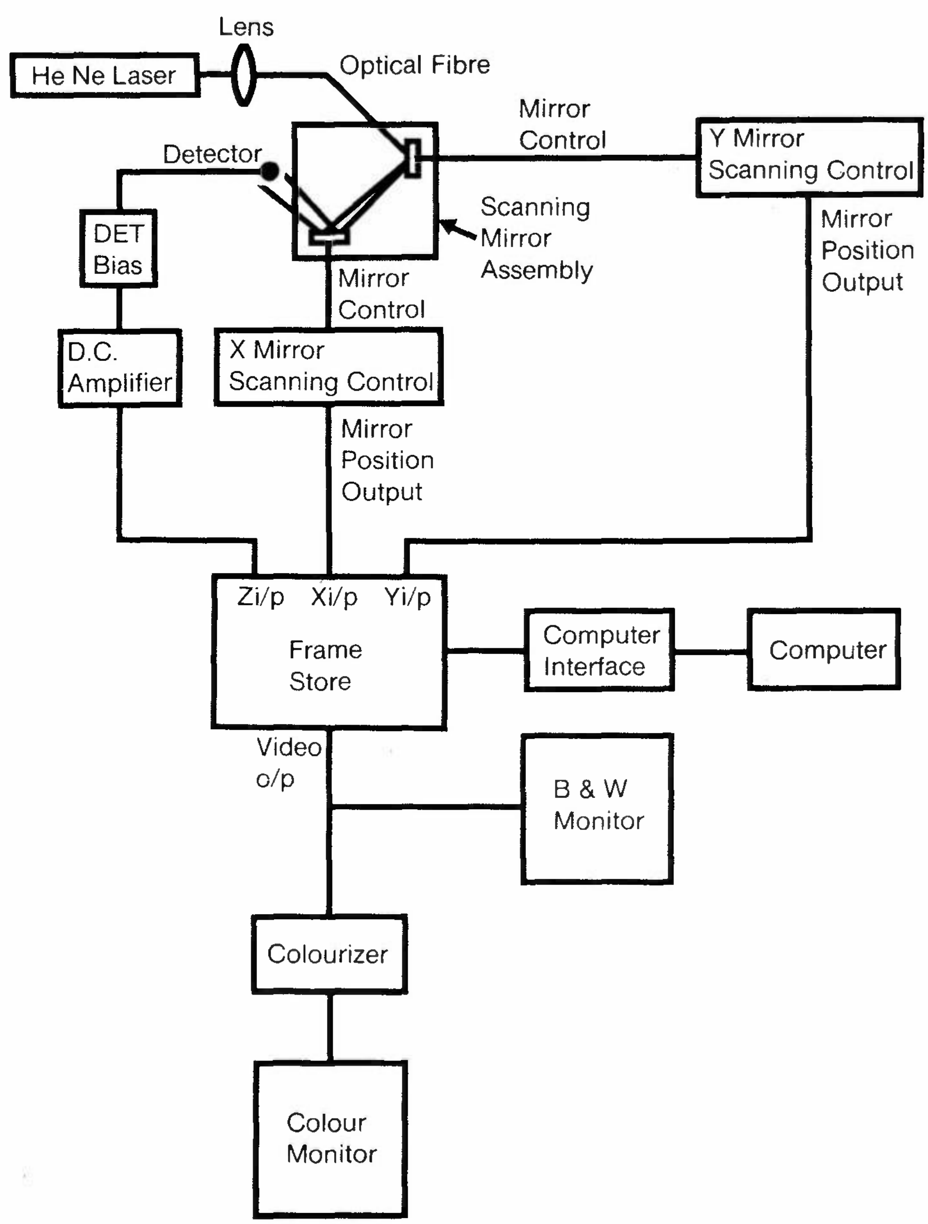
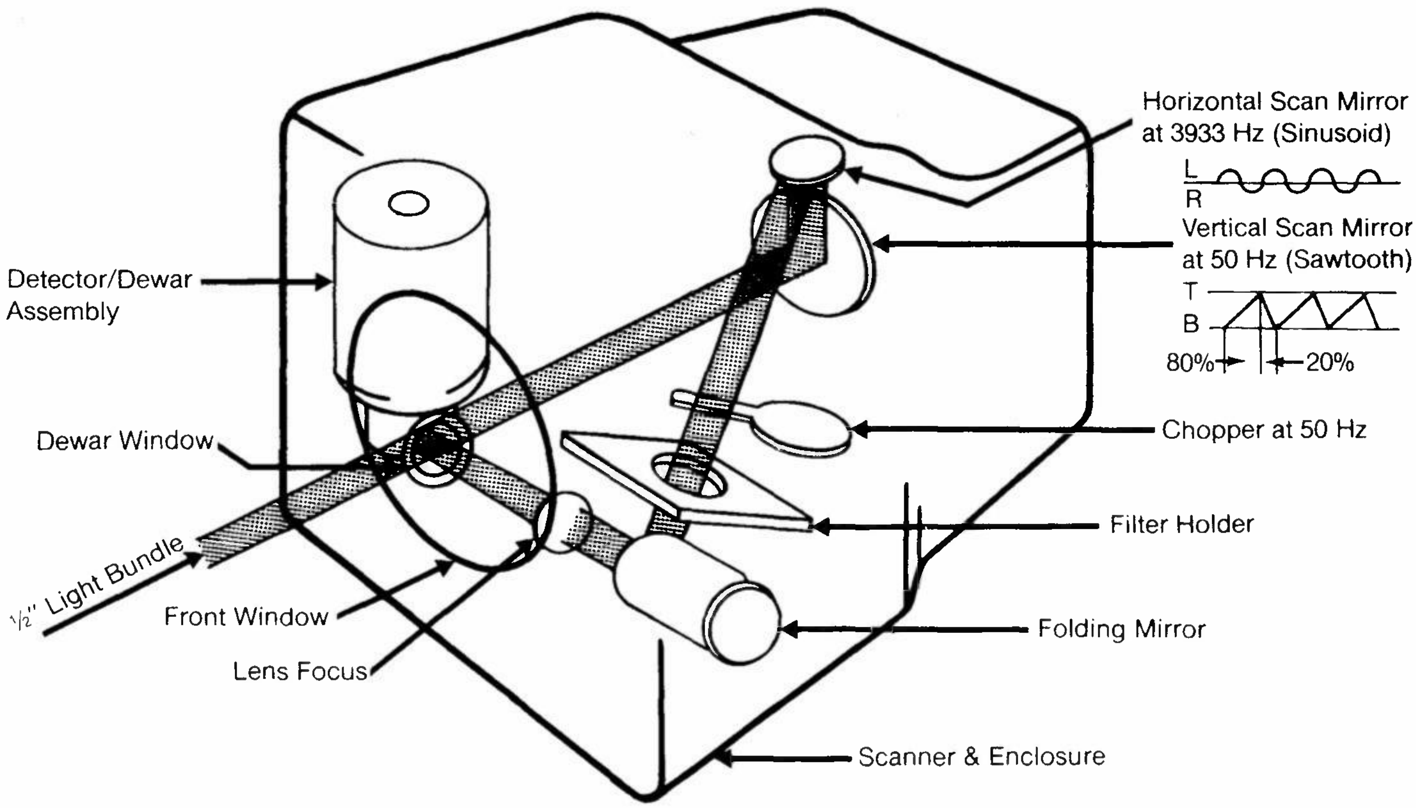


Fig 4: Commercially Available Mechanically Scanned IR Imaging Unit

INFRAMETRICS MODEL 525



The mechanically scanned fixed detector system appears to offer the best solution to the Department's IR imaging requirements. It allows liquid nitrogen cooling, which improves the sensitivity of the detector. Various single-element detectors optimized for particular wavelengths can be readily installed into the scanner head. Another benefit is an improvement in the accuracy of quantitative results, because the data obtained from scanned near and far field images is measured by the same single detector and not an array of detectors as with IR television camera tubes.

Fig. 4 depicts a commercially available scanner from the U.S.A. that uses the principles described and costs in the vicinity of $50 000.

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THE OPTICAL FIBRE FUTURE

Silica Glass

The experimentally measured attenuation in optical fibres made from silica glass has been reduced to essentially the theoretical limit (0.16 dB/km at a wavelength of 1.55 µm in the near-infrared region of the spectrum). Fig. 1 shows the spectral loss curve of such a fibre.

Present research efforts with silica glass fibres are now being directed mainly towards the maximum utilization of the fibre bandwidth, e.g. by using narrow-linewidth laser diode sources and heterodyne detection. Over the last 15 years, practical transmission losses in silica fibres have been reduced by nearly 4 orders of magnitude. In the process, a great deal has been added to the knowledge of intrinsic optical loss mechanisms in materials.

As illustrated in Fig. 2, only 2 fundamental loss mechanisms are important over the wavelength range of practical interest for long-distance communications. The better known of these is Rayleigh scattering, which dominates at the shorter (visible and near-infrared) wavelengths. Rayleigh scattering is caused by microscopic changes in the density, and hence refractive index, of the glass and is inversely proportional to the fourth power of the wavelength.

This wavelength dependence of Rayleigh scattering is one reason for the progression of fibre system operating wavelength from the initial 0.85 µm, where convenient sources and detectors were available, to the present 1.3 µm and soon to 1.55 µm. Beyond this wavelength the loss in silica glass increases owing to the second mechanism, infrared absorption, which occurs when optical energy is absorbed by the glass causing the atoms of the material to vibrate. The frequency or wavelength of light at which this resonance effect takes place is determined by the mass of the atoms and the strength of the bond between the atoms. Infrared absorption loss increases exponentially with wavelength e.g. for silica glass the total loss rises from 0.16 dB/km at 1.55 µm, to 23 dB/km at 2.0 µm and 2.9×10^3 dB/km at 2.5 µm.

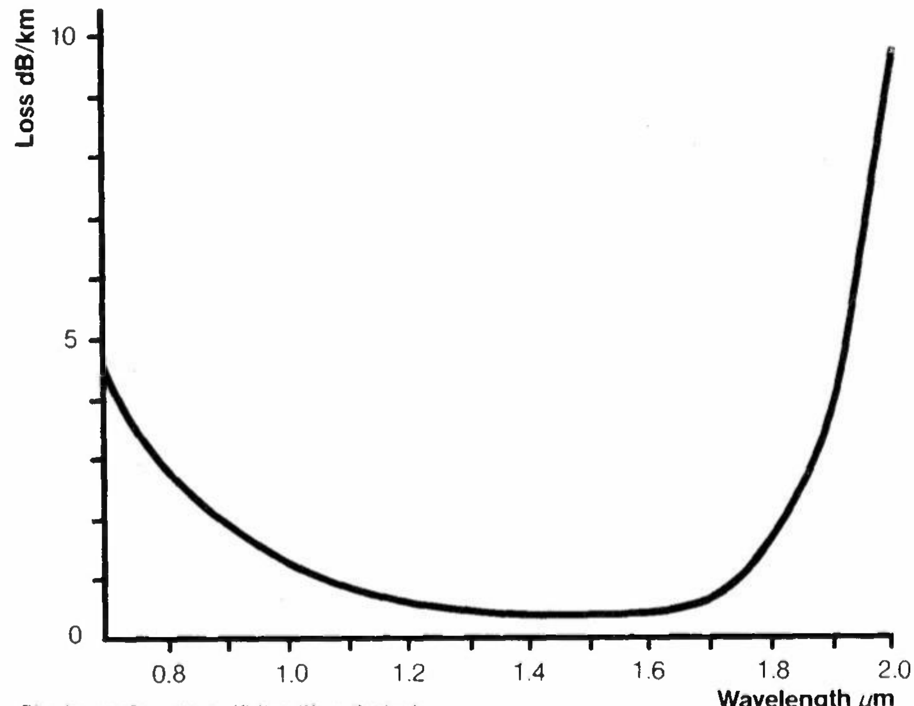

Fig. 1: Loss Spectrum of Silica Glass Optical Fibre Manufactured by Vapour-Axial-Deposition (VAD) Process.

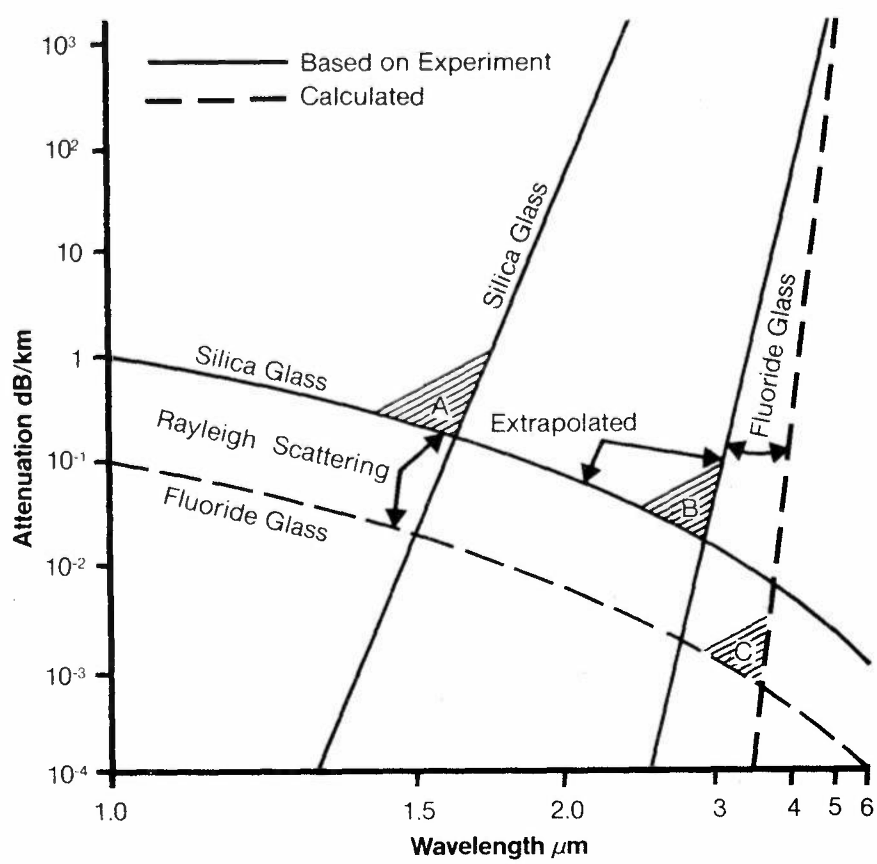

Fig. 2: The Potential for Optical Fibre Systems at Near and Mid-Infrared Wavelengths

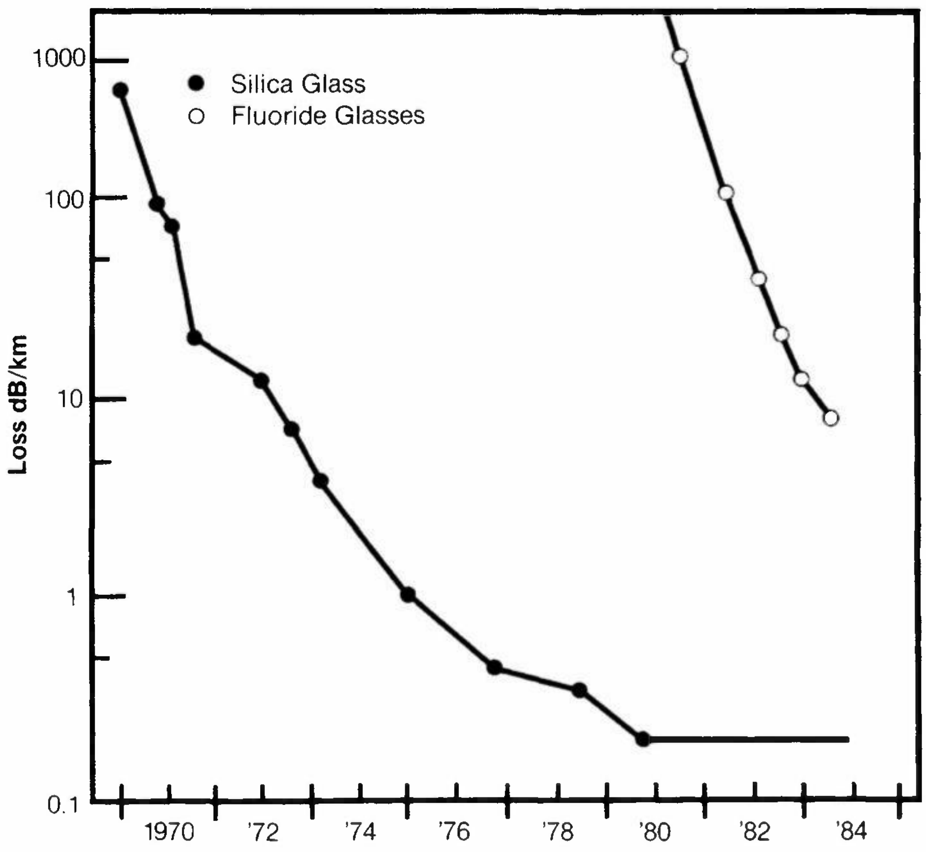

Fig. 3: Progress Towards Low-Loss Glass Fibres

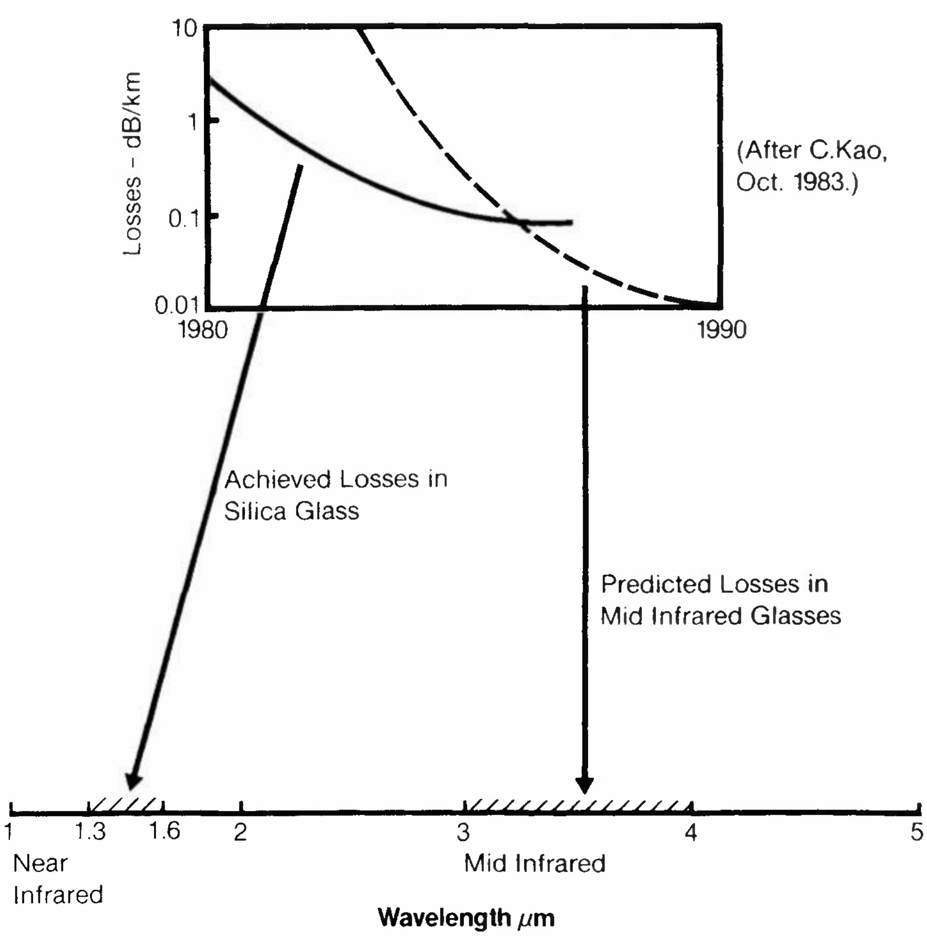

Fig. 4: Regions of Interest in the Optical Spectrum for Fibre Development

Fluoride Glasses

To further improve the performance of optical fibre systems, it is necessary to research new types of fibre materials that exhibit a Rayleigh scattering loss comparable to or lower than silica glass and in which the onset of the infrared absorption is transferred to wavelengths greater than 2 µm in the mid-infrared region of the spectrum. This latter consideration suggests that materials formed by heavier atoms that are loosely bonded should be investigated — the new families of heavy metal fluoride glasses, such as zirconium tetrafluoride (ZrF_4), are promising candidates.

As shown in Fig. 2, extrapolated experimental results for glasses based on ZrF_4 indicate a minimum attenuation of about 0.01 dB/km at a wavelength of 2.8 µm (region B). Calculated results, based on chemical and physical properties, suggest that a loss of 0.001 dB/km at 3.4 µm (region C) is possible in the longer term. For the purpose of comparison and to highlight the trend towards longer wavelength systems to achieve reduced transmission loss, the optimum performance of silica fibre is also indicated in region A.

To date practical results for mid-infrared fibres fall a long way short of theoretical limits. However, as illustrated in Fig. 3, steady progress comparable to that achieved in the development of low-loss silica glass fibres during the 1970s is being made. The lowest loss yet recorded in a fibre made from ZrF_4 is 6.8 dB/km at a wavelength of 2.55 µm.

As was also the case with silica glass technology, a great deal of research effort must be put into the establishment of techniques for materials purification, preform fabrication and fibre drawing techniques that are compatible with these new materials. This effort is now under way. Recent predictions by Dr Charles Kao, who in 1966 accurately forecast the emergence of lower-loss silica glass fibres, suggest that this mid-infrared fibre technology will mature in the early 1990s. See Fig. 4.

It should be noted from Fig. 3 that losses in practical mid-infrared fibres are already low enough for special applications where transmission of laser light at these wavelengths is essential viz. industrial machining, surgical and military. Losses are also already below the 20 dB/km limit set more than a decade ago in relation to silica glass as the performance level required for telecommunications needs.

Despite technological obstacles that must be overcome in the next few years, there is every reason for cautious optimism that losses in fluoride glasses can be reduced to near the theoretical minimum of 0.01 to 0.001 dB/km — nearly 2 orders of magnitude lower than the intrinsic limit of silica glass fibres. The intriguing possibility that optical fibre transmission (without repeaters) can be extended to thousands of kilometres, thus allowing oceans and continents to be spanned, is the goal that will encourage the telecommunications industry's continued involvement in mid-infrared fibre systems.

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FIBRE DRAWING TOWER

Around 100 years ago fibres of fused silica were sometimes created by drawing near-molten glass behind a flying arrow.

Nowadays, in the interests of staff safety and far better product quality control, communication fibres are produced on specially designed fibre drawing towers. In the most common form of drawing tower, a silica rod called the preform, is slowly driven down through a furnace which uses an electrically heated carbon element. The strand that emerges from the furnace is drawn at a particular speed to produce a fibre of the required diameter.

No die is used. Instead, a laser gauge located close to the furnace outlet continuously monitors the diameter of the fibre and provides the necessary information to control the drawing speed.

On Friday, 8 March, a ceremony was held at Telecom's Research Department in Clayton to mark the installation of a fibre drawing tower, Telecom's first such unit.

This unit was designed by the AWA Research Laboratories (under a Research and Development contract placed by the Telecommunications Technology Branch) and is constructed in a special modular form to allow for adaption to a variety of research projects.

In the long term the tower will be used to draw fibres from materials other than the silica used in present day optical fibres.

Although the silica-based fibres have succeeded far beyond even the most optimistic expectations of a few years ago, the material limit of these fibres has now been reached. In other words, we have gone as far as we can with silica materials from the transparency point of view.

Now that the transmission of light through glass is generally better understood, glass scientists in many laboratories throughout the world are striving to devise new glass materials which they hope will be more transparent and have a wider optical window (i.e. cover a wider range of optical wavelengths).

This would provide significant benefits for Telecom as it would mean fewer repeaters required to boost the optical signals and more channels per fibre.

Compared to many other more closely settled countries this possibility is very significant for Australia where wide band signals are transmitted across remote expanses.

Remote power is difficult to provide and the fewer repeaters the better. Recent tests overseas (in the UK and USA) have shown that silica fibres can transmit wide band signals over 200 kms without the need for signal boosting along the way. An order of magnitude improvement which seems possible with the new glass materials would mean increasing this figure to 2000 kms.

Alternatively, some of the distance could be traded for increased channel capacity, i.e. putting more channels, each at a different optical wavelength, on the fibre.

There is however, much research to be done before this can become a reality. Firstly, the new glass materials must be refined to an extraordinary degree of purity and the right sort of refractive index structure built into the preform so that the light is guided properly. Then the fibre must be drawn without any recrystallation taking place. This is a very real problem with many of the new materials which do not form such a stable glass as silica.

However, the potential rewards are so great that Telecom has given a contract to a team at the Chemistry Department of Monash University, which will be fabricating glasses based on heavy metal-halides such as zirconium tetrafluoride. These will be drawn into fibres on the new drawing tower.

In the meantime, the drawing tower is available for experiments with silica fibres, and was used in a project for the Applied Science Branch, while still at the AWA Laboratories, to investigate aspects of fibre coating, including controlled surface damage. This was done by introducing measured amounts of grit into the coating material.

The Materials Engineering Department at Monash University is also interested in applying their expertise in polymers to the coating of fibres. As well as providing a research tool for studying the feasibility of new glass materials, the fibre tower will thus enable researchers in a variety of fields to turn their theories and ideas into reality.

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OPTICAL TECHNOLOGY

The Properties of Light

All the known properties of light can be described in terms of the experiments by which they were discovered and the many and varied demonstrations by which they are frequently illustrated. Numerous though these properties are, these demonstrations can be grouped together and categorized under one of three headings:

(a) geometrical optics where the paths taken by light signals can be represented by rays,
(b) wave optics where phenomena are described by considering the wave-like nature of light,
(c) quantum optics where phenomena are described by considering the particle-like nature of light (photons).

Some of the most important properties within these categories are listed below.

Many advanced research projects, e.g., investigating optical fibres, laser technology, holography, aimed at achieving the timely introduction of optical transmission and signal processing techniques into the national telecommunications network, rely upon the successful exploitation of these fundamental properties of light and the matter with which it interacts.

Geometrical Optics

- Rectilinear (straight-line) propagation
- Finite speed
- Reflection
- Refraction
- Dispersion

Wave Optics

- Interference
- Diffraction
- Electromagnetic character
- Polarization
- Bi-refringence

Quantum Optics

- Atomic structure of matter
- Energy levels
- Quanta (photons)
- Photoconductivity (optical detectors)
- Stimulated emission (lasers, coherence)

Photons — The Most Efficient Messengers of All

What is meant by 'telecommunications'? It is the means whereby two or more people or groups of people separated by a considerable distance are able to communicate, i.e., to exchange messages in various forms.

The earliest methods required humans to be the messengers. Perhaps the most famous is Pheidippides who ran 40 kilometres to seek assistance at the battle of Marathon (490 BC) and whose feat is remembered in the endurance race on today's athletic programs. To avoid such strenuous exertion, humans trained other creatures to deliver written messages and hence to become substitute messengers. Ghengis Khan used pigeons during the later 12th Century and dogs carried military information in World War I. Advances were made also in the original message transfer medium of sound — drums, hollow tubes and megaphones.

The idea of using light to send messages is a very old one. The news of the Greek victory in the Trojan War, about three thousand years ago, is said to have been communicated to Greece by a chain of bonfires on the tops of neighbouring hills.

There were a number of other methods of using light to communicate, for example, the heliograph, where a mirror was used to flash the light of the sun in a particular direction to send a message in code. Semaphore signalling using flags, wooden arms or light was also quite common in the early 1800s and has continued in use in some special situations.

But all of these methods of communication had the same deficiencies: they took a very long time to send information, they could be interrupted by bad weather and they required a large number of observers within sight of each other who could take down the message and repeat it to the next observer in the chain.

With the invention of the electric telegraph in the 1840s, communication by means of light signals seemed to become obsolete. Electricity surging through metal wires was not interrupted by weather and repeating stations could be hundreds of kilometres apart, instead of needing to be within sight of each other.

In a very real sense, particles of electricity which came to be called electrons (when their properties were thoroughly investigated in the latter half of the 19th Century) had become the most efficient messengers. After the invention of radio around the turn of the century, such communication could be carried on even without wires. Indeed, today much of Australia's telephone traffic is carried across long distances by microwave radio beamed from one repeater tower to another.

Yet in one way it could be said that the wheel had turned full circle, for microwaves are closely related to light waves, both being a form of electromagnetic radiation. Light waves, however, have much shorter wavelengths (and therefore higher frequency) than microwaves.

Communication scientists have long known that, in theory at least, the amount of information that can be carried by radio waves increases as the wavelength becomes shorter and the frequency increases. Microwaves, with wavelengths around half a metre, can carry much more information than broadcast radio with wavelengths typically of hundreds of metres. But light waves have wavelengths in the order of one millionth of a metre (1 m). It was therefore obvious that light should be able to carry a vast amount of information, far more than could be carried by the equivalent radio channel or on a copper wire. The problem was how to utilize this potential.

The 'Photophone'

The first device to allow conversations to be transmitted over moderate distances using the medium of light rather than telephone wires was the 'photophone', demonstrated by Alexander Graham Bell in 1880 and in later years described by him as his 'greatest invention'. In the photophone, a thin mirror flexed in response to sound waves. A bright light focussed on this mirror was deflected to a varying extent by the sound waves. The reflected beam was transmitted through the atmosphere and at the receiving end was brought to a focus on a photo-sensitive selenium cell by a parabolic mirror.

As the strength of the beam changed because of the vibrations of the mirror, more or less light reached the selenium and so allowed more or less electrical current to pass through the selenium cell, which was in circuit with a battery and a pair of Bell telephones. The varying current in the circuit created sound in the telephone, a sound exactly like that vibrating the mirror.

But, remarkable as it was, the photophone was before its time. The light beam could only be used reliably over relatively short distances and the receiver and transmitter had to be within sight of each other. Fog or smoke would interfere with its operation. So its uses were really quite limited.

It was to take nearly another hundred years before communication by light beam became really practical and useful.

Photons

Up until the beginning of this century a great argument raged as to whether light was made up of waves or particles. This mystery was largely resolved by Einstein in 1905 when he showed that light waves could, in appropriate circumstances, be considered as a stream of individual particles which he called photons. Einstein was careful to point out that this new idea of light as photons did not conflict with the use of a wave theory for investigations of optical behaviour on a large scale. However, when the interaction of light with matter required small scale considerations, perhaps involving only one or a few atoms of the material, the photon approach was essential. Out of this concept came a deep understanding of the atomic structure of matter which could explain how vision works, why the sky is blue, the ruby red and the grass green and which paved the way for such inventions as atomic energy and the laser.

Lasers

The invention of the laser in 1960 was the first real breakthrough.

A laser is a source of very intense, non-spreading light rays, all of exactly the same wavelength. Scientists were quick to see that the laser could be used for communications and some preliminary experiments were done in firing a laser beam through the air between two towers many kilometres apart. But just as with the photophone, fog and rain often blocked communication. The only solution seemed to be to try to send light along some kind of pipe or cable.

Optical Fibre

Eventually it was found that light entering a solid fibre of glass surrounded by a suitable cladding can be confined within the glass, even though it is bent, because rays which strike the sides at a shallow enough angle are reflected back within the glass.

Although it was found possible to pipe light in this way, there were still great difficulties in trying to send light through kilometres of such fibre. Imagine how much light would be absorbed by a kilometre-thick pane of ordinary window glass. The basic problem, then, was to find a way of making optical fibres with very low absorption of light.

The answers lay in the appropriate properties of silica glass and the development of suitable fibre fabrication methods to achieve very high purity material that would provide very low absorption and scattering of light. This development process saw the loss of optical fibres fall from 10,000 dB/km (i.e., the light intensity was reduced by 50% for every 300 mm of glass through which it travelled) in 1966, to 20 dB/km in 1970, 1 dB/km in 1976 and 0.2 dB/km in 1979.

Today the theoretical minimum loss of 0.16 dB/km at a near-infrared wavelength of 1.55 μm has been achieved in practical silica glass fibres. Light can travel 19 kilometres through such a fibre before its intensity is reduced by 50%. Present research efforts with these fibres are aimed at maximizing their information-carrying capacity (or bandwidth). Commercially available systems can provide information transmission rates of 140 million bits (pulses) per second over distances of about 50 kilometres without the need for repeaters to amplify the signal. In the research laboratory, transmission rates in excess of 1000 million bits per second have been demonstrated over fibre lengths of 100 km.

Future Developments

The story of optical communications technology does not end here. In the process of developing low loss silica glass fibres, a great deal was discovered about the physical mechanisms and material properties that contribute to losses as light propagates along an optical fibre. This knowledge indicates that new types of glass, such as those made from the so-called heavy metal fluorides, e.g., zirconium tetrafluoride, offer the potential for extremely low loss optical fibre transmission at longer wavelengths in the mid-infrared region of the spectrum. Losses of 0.01 dB/km or even 0.001 dB/km at wavelengths of 3-4 μm have been predicted. Just imagine! A loss of 0.01 dB/km would allow light to travel 300 kilometres before its intensity was reduced by half. An optical fibre system that could span continents and oceans without the need for repeaters would be feasible. At present, practical optical fibres made from fluoride glasses cannot approach these ideal limits, the best reported result being a loss of 7 dB/km. However, there are many indications that this new fluoride glass fibre technology, given the similar intensive research effort to that required to bring silica glass fibres to their current level of sophistication, will develop rapidly to approach ideal performance early in the 1990s.

The laser and silica glass optical fibre research of the 1960s and 1970s saw the photon clearly re-established as the most efficient telecommunications messenger of all. Current research efforts on new fibre materials will ensure that this remains the case during the 1990s and into the 21st Century.

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APPLIED HOLOGRAPHY

Conventional Holography

Holography was invented in 1948 by Dennis Gabor in an effort to improve the electron microscope. The technique did not receive much attention until the early 1960s when Leith and Upatniks demonstrated the recording of a three dimensional image using a laser. Since then holography has progressed in a number of directions. Today holography has been applied to non-destructive testing, holographic optical elements (HOE), optical computing and three dimensional displays. Large holographic portraits have become possible with the development of long coherence length ruby lasers. 'Q' switched ruby lasers are now used for pulsed holography which finds application to non-destructive testing.

Telecom's involvement with holography began in the late 1970s with an investigation into the holographically encoded telephone credit card. A number of techniques were explored using continuous wave helium-neon lasers. Potential applications of holography in Telecom include HOEs for fibre couplers, optical data storage, solar concentrators and filters for image processing and pattern recognition.

Unlike conventional photography, holography can record a true three dimensional image of an object. Conventional photography records a scene from one angle only. It is not possible to look around an object and view changes in perspective. In a hologram it is possible to see around objects by shifting one's viewing position.

The extra dimension is a result of phase information recorded in the hologram.

When a hologram is made, light from a laser is split into two components, one of which forms the object beam and the other a reference beam.

The object beam illuminates the subject and some of the resulting scattered light is directed onto the recording medium (a photographic emulsion). Light from the reference beam also falls onto the recording plate as shown in Fig. 1. A complex interference pattern between the mutually coherent object and reference beams is recorded in the photographic emulsion.

After the photographic emulsion has been developed, the resulting transmission hologram can be viewed by illuminating it with a laser beam as shown in Fig. 2.

Following the development of short pulse ruby lasers with high energy and coherence, it has become relatively easy to make holograms of large objects. The problem of providing a stable laboratory environment is minimized owing to the short exposure time required to make the hologram (typically 30 billionths of a second). Moving objects can be recorded in a similar way to that whereby an electronic flash is used in conventional photography. Pulsed holography can be used for non-destructive testing such as vibration analysis and displaying deformations in test objects due to mechanical stress and thermal gradients. For example, the double pulse ruby laser of the Research Department has been used to produce holograms of vibrating diaphragms and thereby display the vibrational mode pattern.

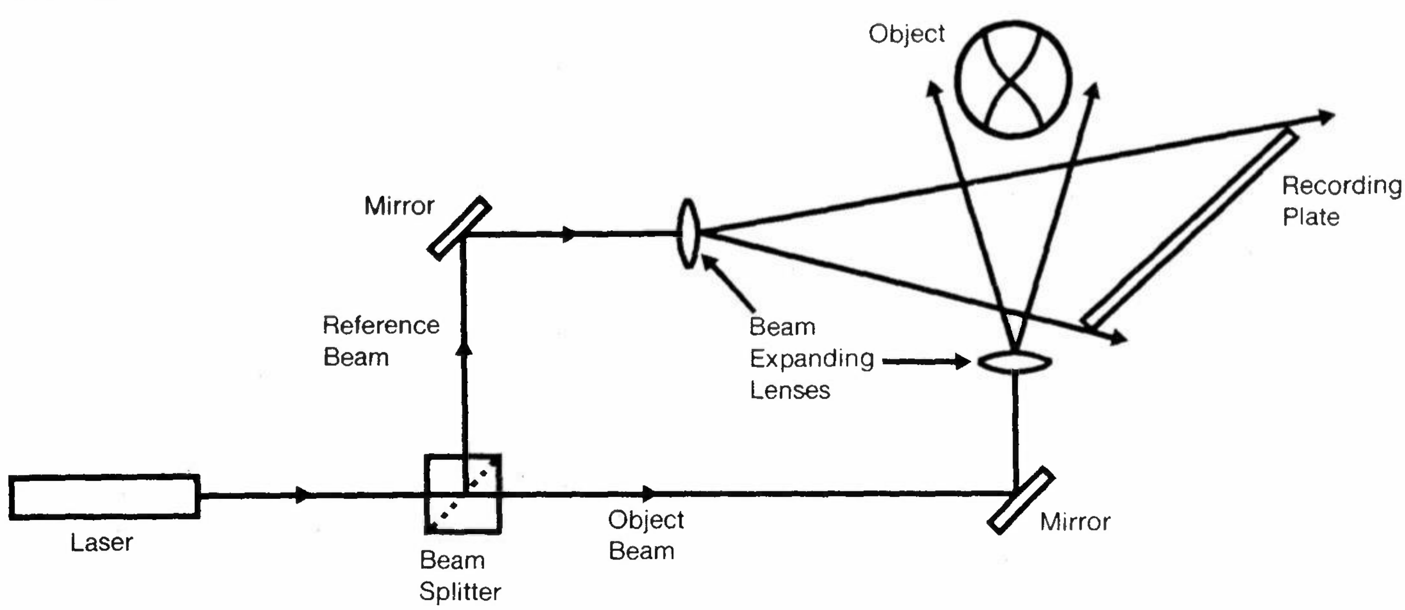

Fig. 1: Arrangement for Recording Transmission Holograms

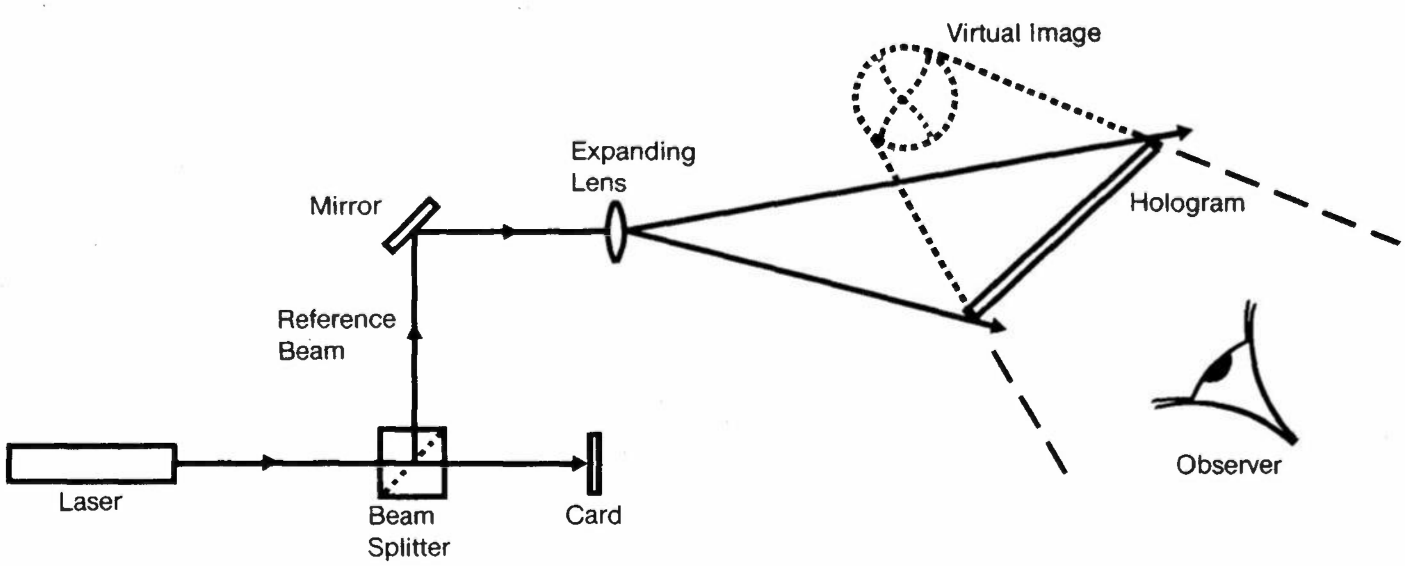

Fig. 2: Arrangement for Viewing a Transmission Hologram

Real-Time Holographic Interferometry

When a photorefractive crystal is used as the recording medium in place of the commonly-used photographic film, holograms can be formed in real-time (or nearly real-time). The time-consuming task of processing the exposed film is no longer required. Within a photorefractive crystal the image-storing mechanism arises from photo-induced charge carriers generated by the incident light. Because these charge carriers move quite slowly the response times for the recording and erasure of holographic images in photorefractive crystals are relatively slow, typically measured in tenths of seconds.

These response times can be exploited to develop a technique for real-time double-exposure holographic interferometry of transparent objects.

This new technique has some basic similarities to conventional holographic interferometry as frequently used in industry for non-destructive testing of vibrating or stressed components. As one example of this established form of holographic interferometry, consider the testing of a pressure vessel to determine the stress distribution. A hologram of the vessel is recorded on a photographic plate. Without otherwise disturbing the object or the measurement system, the pressure within the vessel is changed and another holographic exposure made on the same photographic plate — a double exposure. When the plate is processed and the holographic image reconstructed, the viewer sees a three dimensional image of the pressure vessel. A series of light and dark interference fringes crossing the image of the vessel indicates the small changes in shape produced by the pressure change.

The experimental arrangement for the new real-time holographic interferometric measurement technique discovered and developed at Telecom Research Department is shown in Fig. 3. The source is a high power argon ion laser and, as for conventional holography, the input light beam is split into two separate paths — the reference and the object beams.

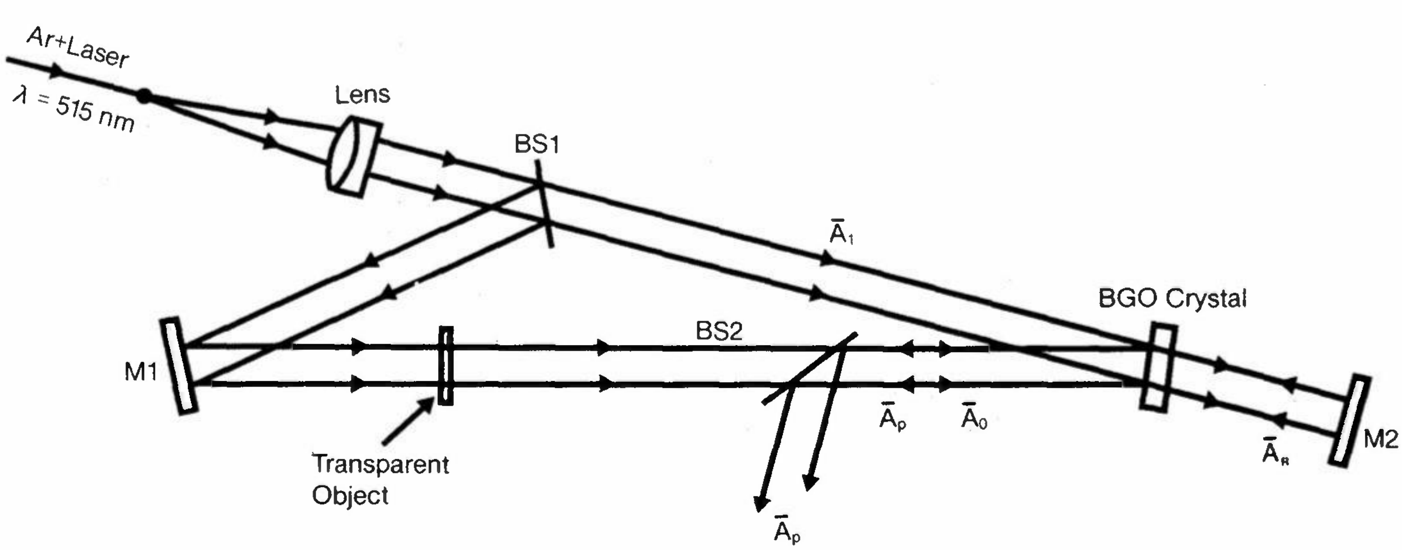

Fig. 3: Experimental Setup for Real-Time Holographic Interferometry

The plane waves of object A_O and reference A_R impinge on a photorefractive crystal of Bismuth Germanium Oxide (BGO) from opposite sides and reading beam A_1 is obtained directly from the beam splitter BS1. Owing to photoexcitation, diffusion and retrapping of photocarriers, a periodic space-charge field is generated inside the crystal. This field in turn modulates the refractive index of the crystal through the linear electro-optic effect and a phase volume hologram is created. Reading beam A_1 is diffracted by the hologram and a fourth beam A_p is generated and travels along the opposite direction of A_O, finally being separated from A_O by beam splitter BS2 to form a real image of the object.

Utilizing the slow recording and erasure times, a method to observe in real-time the fringe patterns of the double-exposure interferogram of a transparent object can be easily realized as follows:

(a) Insert the object under test into the object beam as shown in Fig. 3 and hold it stationary for a few seconds to allow the recording to reach its saturation value. Thus the hologram of the object is recorded in the crystal (the first exposure).

(b) Remove the object quickly from the object beam. Then the hologram of the air (no object) is slowly recorded (the second exposure) while the first hologram as recorded in step (a), i.e., the holographic recording of the object, is erased slowly by the incident beams (see Fig. 4).

During a short time interval (say 0.8 s) the images obtained from these two holograms both exist and interfere and consequently fringe patterns can be observed by eye or recorded permanently using an ordinary camera with an exposure time of 0.5 s. Experimental results are shown in Fig. 5. The objects used in our experiment are thin optical flats and lenses.

This new technique has many applications in the non-destructive testing of transparent objects to determine in real-time such parameters as thickness or shape uniformity, material homogeneity, optical phase properties etc.

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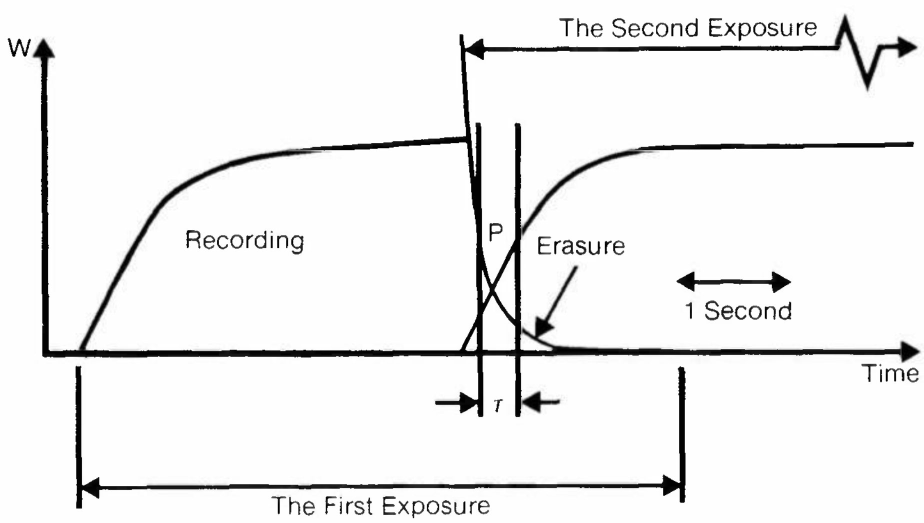
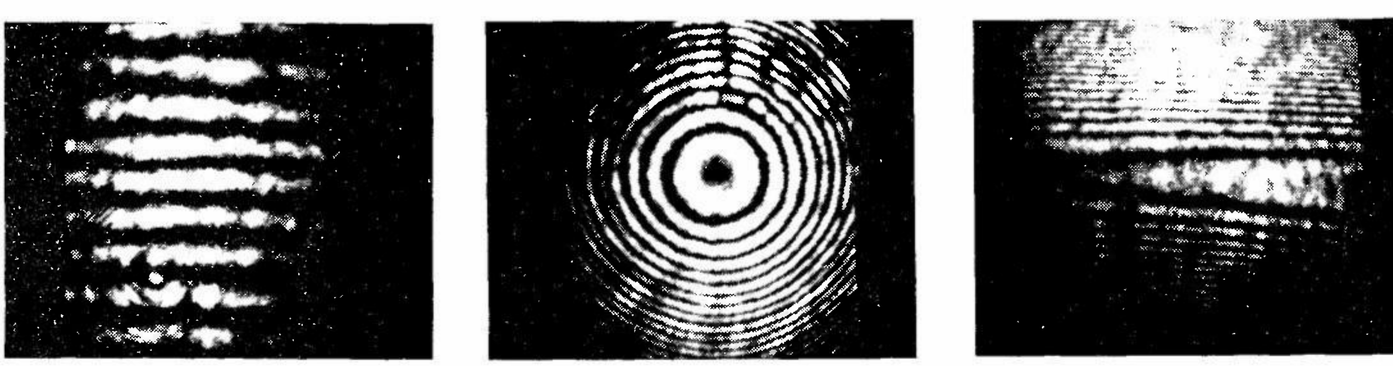


Fig. 4: Recording-Erasure Cycle of Holographic Recording in BGO Crystals



(a) Pyrex plate (thickness 3 mm)

(b) Spherical lens

(c) Cylindrical lens

Fig. 5: Photographs of Interferograms of Transparent Objects

SEMICONDUCTORS FOR MID-INFRARED OPTOELECTRONICS

Mercury Cadmium Telluride (MCT)

Ever since theorists showed several years ago that it should be possible for optical fibres made of fluoride compounds to transmit mid-infrared wavelength signals, 2-11 μm, with a loss of only 0.01 dB/km, there has been a great interest in developing fibres for use in the infrared part of the spectrum. This interest has been stimulated by the knowledge that silica fibres, at 0.2 dB/km in the 1.3-1.55 μm wavelength range, have been developed to about their practical limit and that there is still a need for fibres that can transmit for a distance greater than the present 100 km without repeaters. Practitioners would be pleased to have a whole transcontinental or transoceanic link without repeaters. Such a situation could be achieved if some of the newly-found materials could be developed to their theoretical limit, determined as 0.001 dB/km.

Rapid progress in the area of new mid-infrared fibre materials has created an urgent need to develop active optoelectronic devices, such as lasers and detectors, that can be used at the transmit and receive terminals of telecommunication systems operating in the mid-infrared region.

Fig. 1 shows the operating wavelength for infrared semiconductor devices and clearly indicates that, in the spectral region 2-12 μm, only one optimum material is available namely $Hg_{1-x}Cd_xTe$ (Mercury-Cadmium-Telluride : MCT alloy).

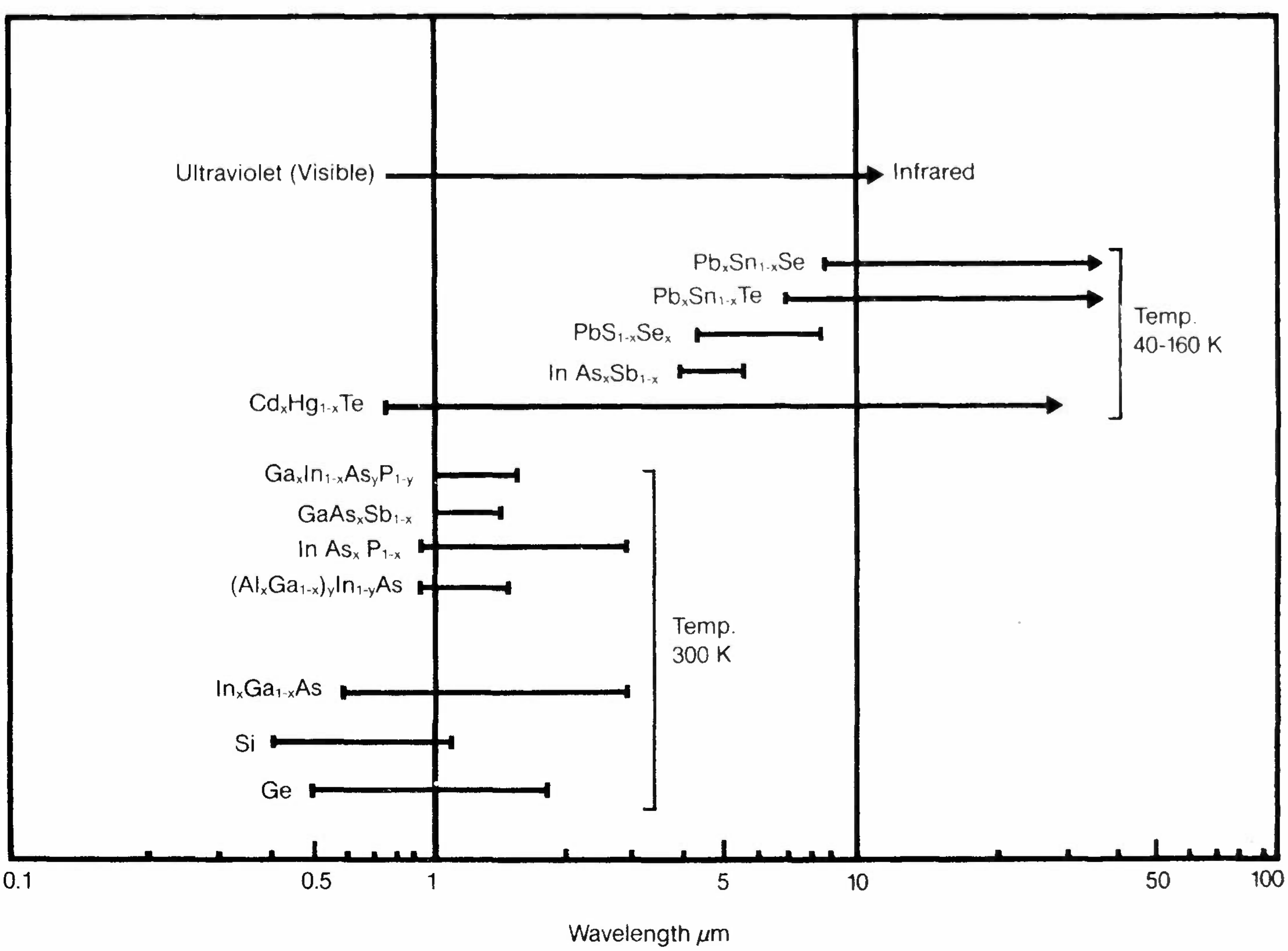


Fig. 1: The Range of Wavelengths for Various Semiconductors

Historical Background

The discovery and development of MCT in recent years are mainly due to its infrared detection capabilities and the resulting military applications. In this respect, the most widely used infrared wavelengths correspond to the two atmospheric transmission windows, i.e. 3 — 5 µm and 8 — 12 µm.

In the late 1950s known materials such as the lead salts (PbS, PbSe, PbTe) and indium antimonide (InSb) made it possible to cover only the 3-5 µm window at an operating temperature of 77 K. Mercury-doped germanium was the only known material for the 8 — 12 µm window and operated at a temperature of 30 K only. The need was thus felt for a new material that would respond in the 8 — 12 µm range and that would operate at a more easily accessible temperature (e.g. 77 K or higher).

In 1959, a research team at the Royal Radar Establishment (Malvern, U.K.) first emphasized the promising future of MCT. The 1960s were essentially devoted to metallurgical research of MCT alloys. Photoconductor detectors for thermal imaging systems appeared as early as 1965. At the same time, two other materials capable of operating in the 8 — 12 µm window were developed: PbSnTe and extrinsic silicon. From 1970 onwards however, both were progressively abandoned owing to inherent limitations.

Presently MCT single crystal thin films formed by epitaxial growth and compatible with planar device technologies hold great promise for future infrared imaging systems. These will feature a matrix including a high number of photovoltaic detector units hybridized to a silicon charge coupled device (CCD) for signal reading, this being a preliminary step before detection and reading can be performed inside the MCT itself.

This enthusiasm for MCT in infrared applications, along with new applications for injection lasers, non-linear optics and CCD, makes MCT one of the most important semiconductor materials.

Main Properties of MCT

MCT alloys ($Hg_{1-x}Cd_xTe$) form a solid continuous solution between two definite compounds: the semiconductor CdTe and the semimetal HgTe. The main physical properties of this alloy can be made to vary constantly with the 'x' cadmium atom fraction. The semiconductor thus obtained features an energy band gap Eg varying from the value for HgTe (x = 0, Eg = 0.3 eV) to the value for CdTe (x = 1, Eg = 1.6 eV). (An energy band gap — Eg — is the difference in the energy of an electron in a stable state and an electron in an excited state after absorbing energy). The transition between semimetal and semiconductor takes place at an intermediate composition (x = 0.15, Eg = 0), as presented in Fig. 2.

The electrical properties of MCT are summarized in Table 1.

(MCT crystallizes according to the Blende-Type Cubic Structure shown in Fig. 3)

Composition $Cd_dHg_{1-x}Te$	x = 0.20		x = 0.30	
Temperature T (K)	300	77	300	77
Wavelength (µm)	7.7	12	4.2	4.8
Intrinsic carrier concentration (cm^{-3})	5×10^{16}	9×10^{13}	6×10^{15}	10^9
Electron mobility n-type ($cm^2V^{-1}s^{-1}$)	10^4	2×10^5	5×10^3	5×10^4
Hole mobility p-type ($cm^2V^{-1}s^{-1}$)		800		500

Table 1: Electrical Properties of MCT

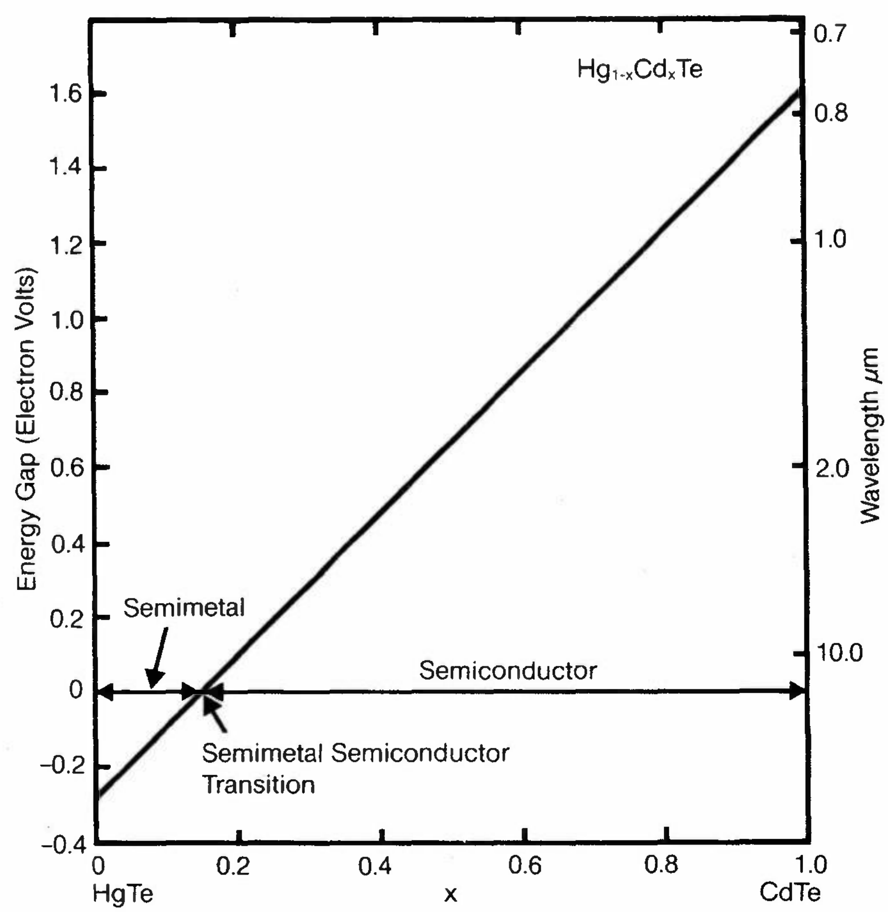


Fig. 2: Energy Gap as a Function of Composition in $Hg_{1-x}Cd_xTe$

Applications

Today MCT is the most important semiconductor in the field of infrared detection and also one of the most thoroughly studied semiconducting materials generally. From an investment point of view, MCT is the third most important semiconductor, presently outranked only by Si and GaAs.

The usual applications of MCT are in the 3 to 5 μm and the 8 to 14 μm atmospheric windows but HgCdTe devices have been made across the range from 1 to 35 μm. These devices allow us to see through clouds and to see in the dark. They even allow one to look backwards in time as in the case where a cool shadow remains on the runway after a plane has left. Infrared (IR) detectors are used in medicine to detect cancers and other defects which affect skin temperature. They are used to find heat leaks in homes and to find hot spots on circuit boards. They are used as detectors in IR spectrometers. IR detectors are used extensively for earth resources evaluation from satellites. Military applications include mapping and surveillance of facilities and rocket launches, tracking cold bodies in space and as heat seeking sensors for the terminal guidance of rockets.

Several telecommunication organizations, including Telecom Australia, have initiated research programs aimed at investigating non-silica fibres and the optoelectronic materials and devices needed to produce communications systems at mid-infrared wavelengths. We believe that MCT alloys will play a very important role in realizing the potential of low loss, mid-infrared fibre communications links.

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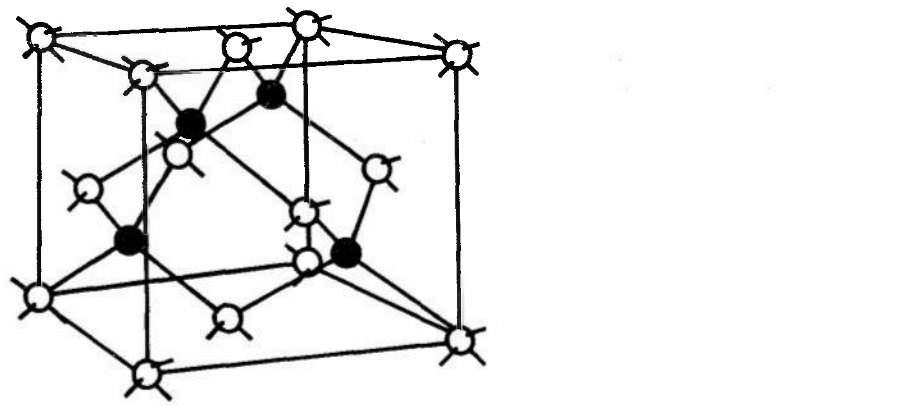


Fig. 3: MCT — Crystalline Structure Blende Type

REDDER THAN RED — THE NEAR INFRARED

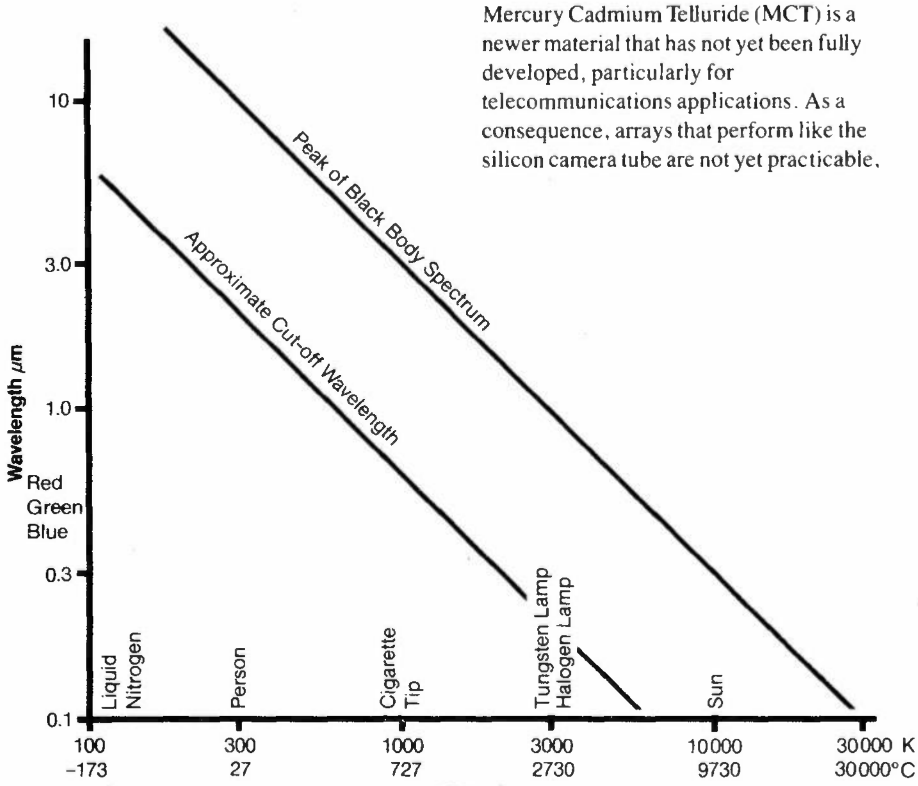
Why the General Interest?

Any object that is warmer than absolute zero temperature (-273°C or 0 K) emits radiation, with a spread of wavelengths from very long wavelengths down to a cut-off point that is uniquely determined by the object's temperature, as shown in Fig. 1.

An object can be 'seen' by the radiation that it emits. That is why military authorities have a great interest in detectors that respond to:

- near infrared radiation — for jet engines and rockets,
- far infrared radiation — for people and vehicles or
- near to mid infrared radiation — for receipt of line-of-sight transmission of signals.

Fig 1: Peak & Cut-off Radiation Versus Temperature



Likewise, medicine uses far infrared radiation for observing hot and cold spots on the body to detect tumours or circulation deficiencies. Satellites such as Landsat look at relative emissions to judge the health of crops or detect the presence of underground ore deposits.

Silicon Detector

This is a target that is a thin disc of silicon in the form of a two-dimensional diode array with one side exposed to the light and the other to a scanning beam of electrons. The varying charge on each diode, corresponding to the varying light falling upon it, repels varying proportions of electrons in the beam. These repelled electrons are collected and converted into a time varying voltage and displayed on a television monitor.

The same principle is used in most television cameras. The main difference is in the material used for the target since this determines the range of wavelengths that are seen.

MCT Detector

Mercury Cadmium Telluride (MCT) is a newer material that has not yet been fully developed, particularly for telecommunications applications. As a consequence, arrays that perform like the silicon camera tube are not yet practicable, although some research groups are close to achieving this goal.

Single element detectors have been available for some time and so a mechanical scanning of the optical image across this detector can be used to form a picture. Although this means that the detector response is uniform across the entire optical view, the detector is only exposed to a small part of the image at any one time. This contrasts with the use of the large two dimensional (Silicon) detector array that is exposed all over. Many military systems use arrays of limited size, mechanically and electronically scanned — a half-way house.

Telecom's Interest

Telecom's interest in infrared radiation is because of its potential in signal transmission. Glassy materials offer very much lower attenuation to infrared radiation than to visible light, which has much shorter wavelengths. The attenuation of infrared radiation is so low that signals can be carried for 100 km in an optical fibre without the need to reamplify them.

In order to work on developing these highly transparent materials, some means is needed to detect and display the light fields that surround the light sources and fibres. Potential detector materials are:

- Near infrared wavelengths: Silicon — up to 1 μm
- Near and mid-infrared wavelengths: Gallium Arsenide compounds (GaAs) 1-2 μm
- Mid and far-infrared wavelengths: Mercury Cadmium Telluride compounds (MCT) 1-30 μm.

As longer and longer wavelengths are used, the background radiation from the camera itself and the air becomes progressively more significant and some form of cooling of the detector must be employed, such as thermo-electric (Peltier), refrigeration or liquid nitrogen and helium.

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SPECIFIC OPTICAL FIBRE APPLICATIONS

Adjustable Fibre Optic Directional Couplers

Optical fibre systems using multimode and single mode fibre are finding increasing use in high bandwidth transmission systems and sensor applications. The advantages of large information rates and small physical size make them ideally suited for digital data communication in general and the specific application of local area networks (LANs).

Optical fibres bring to the LANs the now familiar advantages they have brought to other transmission systems:

- immunity from interference,
- electrical isolation,
- small size,
- low weight,
- flexibility and
- low attenuation.

Fibre optic LANs also offer increasing range-bit rate products of around 500 Mbit/s.km, compared to flexible coaxial cable systems in the region of 10 Mbit/s.km.

Unfortunately the couplers and connectors needed to interface the fibres to the various stations on the LAN are less well developed. Although passive taps on coaxial cables are easily fitted and have low insertion loss, their fibre counterparts have been difficult to fit, expensive and quite lossy.

The Research Department has been investigating new techniques for the fabrication of cheap, easy to install, low loss fibre optic directional couplers. Previous attempts elsewhere to manufacture optical fibre tap couplers using fibre fusion processes and butt joints have had some success, however the excess insertion loss (the ratio of output to input power) for a desired tap ratio (tap to input power) can lead to problems. As couplers are usually cascaded in LANs, their accumulated insertion losses essentially determine the number of customer terminals that can be accommodated on the LAN.

The fibre optic directional couplers developed by the Research Department and illustrated in Fig. 1 offer a number of advantages over tap couplers and include the following features:

- a four port junction, which preserves propagation direction,
- absence of need to break the main fibre,
- low excess insertion loss (approx. 0.1 dB for a 20 dB coupler),
- high directivity (of the order of 60 dB),
- field installation becoming practical owing to low cost components and
- full adjustability over a large coupling range.

Prototype couplers have been fabricated using a moulding process followed by careful lapping and polishing to expose an elliptical area of the fibre. The two prepared fibres are brought into close contact using an adjustable jig with index matching oil between the polished faces. Coupling of optical power between the two parallel fibres is made possible owing to the evanescent fields that extend outside the fibre cores, however much of the cladding must be removed to allow sufficient overlap of the field.

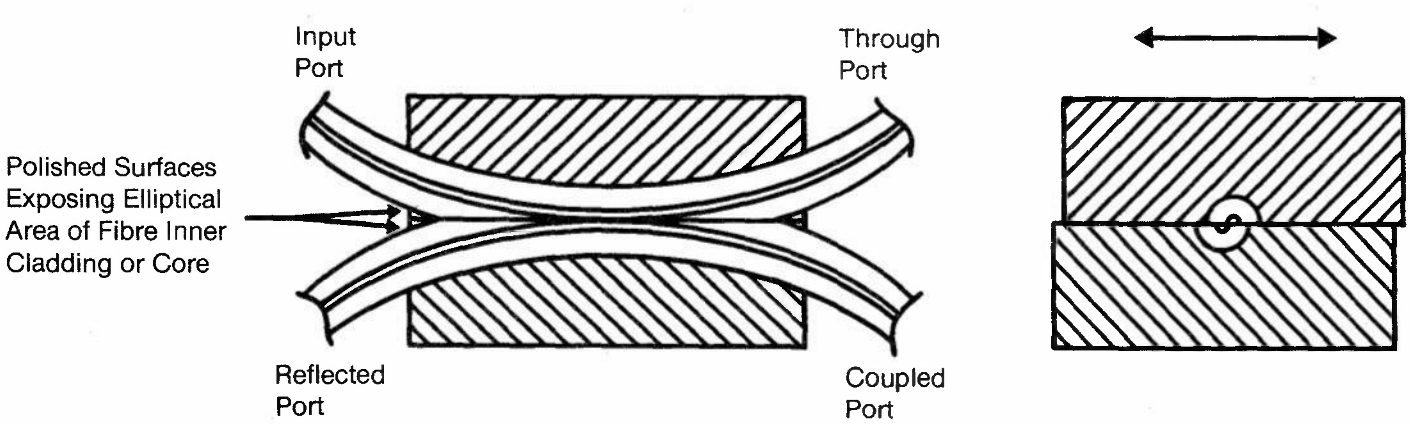
These couplers offer the designer of a LAN the increased flexibility of using conventional wire pair and coaxial cable topologies in a fibre optic LAN. Previous fibre optic LANs have employed duplex fibre cables and a 'star' topology, resulting in complicated cable runs and increased cost. The fibre optic directional couplers will allow full duplex operation and implementation of the fibre optic LAN using 'bus', 'ring' and 'tree' topologies, resulting in cheaper, efficient solutions to the growing acceptance of LANs for telephone extensions, data processing and digital data transmission systems.

A Specialized Optical Fibre Bundle to Aid Semiconductor Characterization

The Research Department, having conceived of an original application for optical fibres, has constructed a special-purpose optical fibre bundle to aid the optical characterization of semiconductor materials. Photoluminescence spectroscopy is a proven method for measuring some of the important properties of semiconductor materials. In particular, the Department routinely uses photoluminescence to characterize layers of gallium arsenide grown in its Molecular Beam Epitaxy growth facility.

Photoluminescence spectroscopy requires that a specimen of the semiconductor material be irradiated with laser light, e.g. from an argon ion laser of wavelength 514 nm. The luminescence resulting from this excitation is

Fig. 1: Side View and Front View of a Directional Coupler



collected and transferred to the input slit of a monochromator for spectral analysis. In a typical experimental arrangement, a series of lenses, mirrors and optical filters is used to achieve input coupling of laser light to the semiconductor specimen and output coupling of the broad-spectrum photoluminescence from the specimen to the monochromator slit. Problems such as vibration, large spot size on the specimen and the need for constant readjustment to maintain light levels lead to difficulties in achieving repeatable measurements. The lens, mirror and filter system also requires a large number of expensive optical components.

The specialized fibre bundle illustrated in Fig. 2 overcomes many of these disadvantages and introduces a number of unique features. These are:

- a central fibre in the bundle providing the laser light excitation as a small spot on the semiconductor sample,
- a surrounding close-packed circular array of fibres collecting the luminescent emission,
- one fibre near the centre of the array providing monitoring of the laser power incident upon the semiconductor sample and the resulting luminescence and
- the fibre array configuration transforming from circular at the specimen end to linear at the monochromator slit, providing efficient coupling of the luminescence into the monochromator.

In contrast to the conventional arrangements, the fibre bundle allows an experimental arrangement that does not require frequent realignment and is insensitive to vibration and in which components such as the monochromator, laser and cryostat specimen holder can be located with a high degree of flexibility.

A prototype bundle was fabricated using 114 fibres of 2 m length. The fibre was a communications-type multimode graded-index design, chosen because of its availability rather than its particular suitability in this application. Practical measurements have shown that, even in this sub-optimum form, the bundle provides greater light coupling efficiency than the common lens, mirror and filter system, as well as the benefits detailed above. The overall result is photoluminescence spectroscopy measurements that are more accurate, more repeatable and less tedious.

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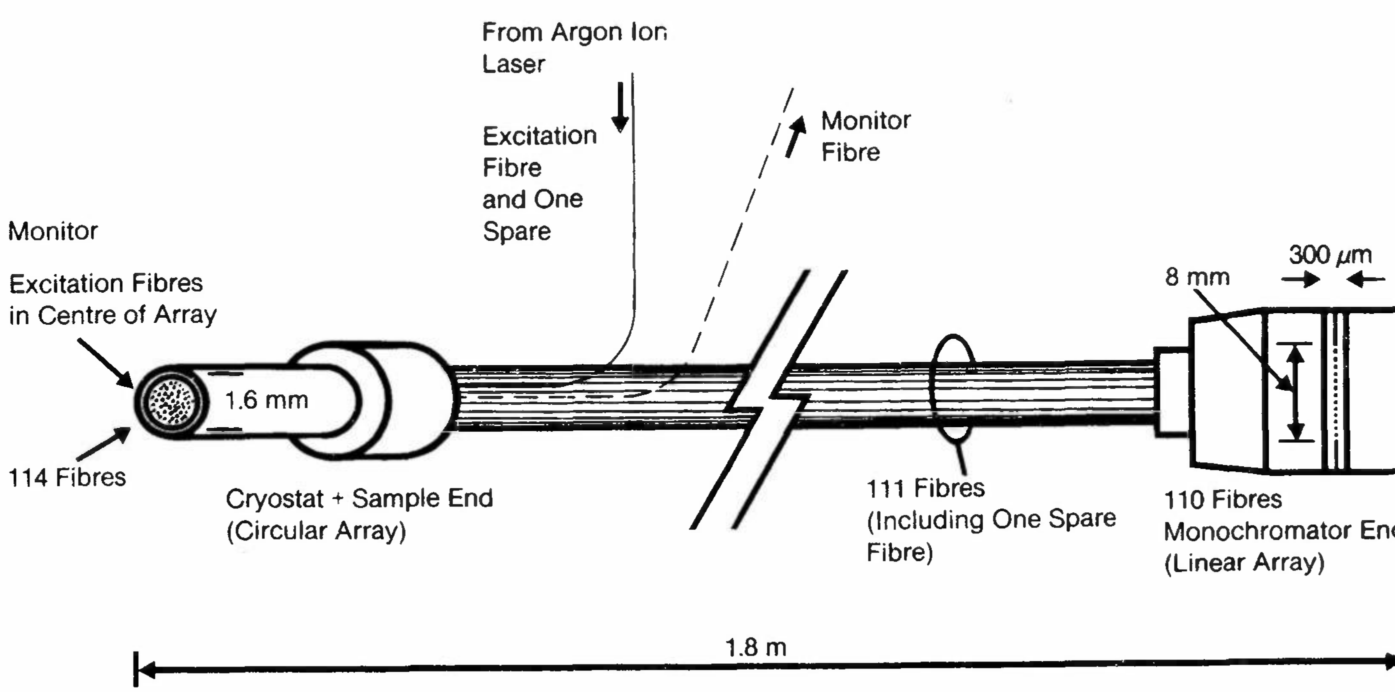
Fig. 2: Schematic Illustration-Optical Fibre Bundle for Photoluminescence Characterization



SATELLITE COMMUNICATIONS

Introduction

Satellites are now finding widespread application in national communication networks. Satellites are placed in geostationary earth orbit so that they remain fixed in the sky and can be used to relay radio signals between any points within the satellite coverage area. By suitably designing the satellites and associated earth stations, satellite networks can meet users' needs for public and private communication services.

Telecom is including satellites in the range of technological options it uses to provide services to its customers. As with all such options, there is a range of situations where satellites are a practical and cost effective solution to customers' communications requirements. Satellite based systems are well suited to the provision of services at short notice, the provision of facilities that may require frequent rearrangement, the provision of services to remote areas and the provision of services to customers that need to own and control their own communications facilities. Telecom's range of satellite based services is structured around these applications.

Telecom Satellite Services

ITERRA Satellite Services (ISS) has been chosen as the collective name of the range of satellite services to be provided by Telecom. These services will use satellite transmission capacity leased from Aussat Pty. Ltd., which is the government-owned company that operates Australia's national satellite system. Telecom is a 25% owner of Aussat and the two organizations co-operate closely.

The first service via the domestic communications satellite to be offered by Telecom is the ITERRA Network Service (INS), which will provide telephone, data (up to 4.8 kbit/s) and text facilities connected to the national switched telephone network. This service will give Telecom the ability to satisfy immediate customer demand very quickly and will be of particular interest to customers operating in the more remote areas of Australia. It will be available in 1986.

Other ISS products currently under consideration include medium and high speed data services to business customers. These services are expected to be attractive to customers needing links or networks under their own control for reliability or security. The range of ISS products will be specifically tailored to suit customer needs and will exploit more fully the flexibility that a satellite system has to offer.

Telecom expects to make use of satellite facilities to meet some of its internal needs. Leased satellite transmission capacity is being considered as a convenient and cost effective method of overcoming short term congestion in some parts of the Telecom long distance network. When less expensive terrestrial alternatives become available, they could replace the satellite facility.

Research Department Satellite Studies

While Telecom has been planning commercially available satellite services for only a short time, it has been active in the study of satellite communication systems for over twenty years. These studies have been conducted by its Research Department, which is responsible for advising Telecom on technologies that may be economically incorporated in the Australian communications network.

In preparing Telecom for its use of satellite communication systems, the Research Department has been involved with a number of innovative activities that assisted in the specification of Australia's national satellite system. Between 1967 and 1971 the Research Department carried out several experiments using the NASA/ATS-1 satellite, a NASA transportable earth station located in Queensland and a smaller earth station developed by the Research Department in Melbourne. These studies greatly enhanced Telecom's understanding of satellite communications to remote areas. From 1972 to 1977, Research Department officers participated in a Telecom Satellite Task Group. Its final report, 'National Satellite Systems Studies', was a significant input to planning of the national satellite system. Another input to these plans was the co-ordination of trials of small satellite earth stations conducted in 1979 using the Canadian 'Hermes' satellite. The trials successfully demonstrated Telecom's ability to provide automatic telephone services to its remote customers. Another significant input to the development of the Australian national satellite system was the Research Department's modelling of impairments that satellites introduce onto signals they relay.

The ability to predict these impairments accurately using both hardware and computer modelling techniques was a critica input to the planning of the Homestead and Community Broadcasting Satellite Service (HACBSS) to be provided by the Australian Broadcasting Corporation. Studies had shown that design limitations for this service were severe and the proposed systems would require experimental verification. This was subsequently done under contract to the Overseas Telecommunications Commission (OTC) in 1981 through tests conducted in Italy using the European Space Agency (ESA) Orbital Test Satellite (OTS).

A continuing Research Department activity that has further contributed to the implementation of the Australian national satellite system and has attracted international recognition is the measurement of the effect of rain on satellite radio signals. Satellite systems make use of microwave radio signals and these signals are attenuated by any rain that intercepts the transmission path. Measurements of these effects have been conducted since 1971 using radiometers and results have been incorporated in internationally accepted procedures for designing satellite systems. When a satellite transmission is not available, earth-space rain attenuation effects are measured with radiometers, which measure sky radiation. Past results in this area are soon to be enhanced with results from two new experimental programs. A new radiometer operating in the 30 GHz microwave radio band is being designed and constructed in the Research Department and, when complete, will be located at Perth to assess the effect of rain on satellite systems operating in this new frequency band — a band that could be used in future Australian satellite systems. At the same time another series of measurements in the 12 GHz radio band will be conducted in conjunction with Aussat Pty. Ltd. using signals emanating from either the INTELSAT V satellite or the

Aussat satellite. A special beacon receiver terminal will continuously monitor signals from the satellite on both orthogonal polarizations and will provide Australian propagation data from an operating satellite for the first time. These results will be compared with existing results from radiometer measurements and are expected to confirm existing design procedures

The Research Department has in the past successfully modelled the imperfections suffered by radio signals as they are relayed by communications satellites and this work remains an important continuing activity. A new travelling wave tube amplifier has been purchased to provide hardware that accurately models the operation of Aussat satellites and that will be used to assess the feasibility of services Telecom proposes to implement via the national satellite system.

Hardware satellite models are complemented by computer models and existing models are being expanded to encompass digital techniques, which are expected to be a major aspect of future satellite systems. The combination of these models provides accurate predictions of the performance of proposed satellite systems and allows Telecom to develop services that minimize customer costs while meeting agreed performance standards.

Besides the systems studies mentioned above, Telecom considers that it is essential to participate in technological studies if it is to be able to offer services based on the use of satellites. An important aspect of this work is the study of antennas for satellite earth stations. Antenna performance is critical in the design of satellite communication systems as antennas control the strength of signals received from satellites and the amount of interference received from satellites in nearby portions of the sky. The Research Department has a continuing program of antenna studies and is presently concerned with the control of antenna side-lobe and polarization discrimination performance and methods of designing and fabricating microstrip planar array antennas for low cost satellite earth stations. Another technological study now under way is the investigation of methods of implementing and applying small low cost portable and mobile earth stations. It is expected that these studies will lead to an experimental system to demonstrate Telecom's capability in this aspect of satellite utilization.

International Affiliations

Telecom's involvement with satellite-based services obliges it to participate in international activities aimed at standardizing communications systems and minimizing the possibility of interference between them. Towards this end, the Research Department participates in the activities of the International Telecommunications Union (ITU) and its subsidiaries such as the International Radio Consultative Committee (CCIR). Many of Telecom's recommendations on satellite systems have been accepted internationally. Among these are recommendations to co-ordinate access to the geostationary orbit, control side-lobe performance of satellite antennas, limit possible interference between satellite systems by appropriate design and change the way in which the acceptable transmission performance of digital satellite systems is specified. The outcomes of this continuing work are an international recognition of Australia's requirement for satellite systems, a recognition of its ability to engineer satellite systems effectively, a recognition of its status as an informed purchaser of equipment and a reduction in the actual cost of satellite systems developed for Australia.

LIST OF EXHIBITS

TELECOM AND SATELLITE COMMUNICATIONS RESEARCH

The Creation of AUSSAT

Since the establishment of a Government Task Force in November 1977 to inquire into all aspects related to a national satellite communication system for Australia, there have been many considerations by various government departments and commercial enterprises about the form that a domestic satellite system should take. This has culminated in the AUSSAT satellite system due for launch in mid-1985, which will be owned and operated by AUSSAT Pty. Ltd., a separate government company. AUSSAT has responsibility for the management and sale of the Australian domestic satellite's capacity and for the provision of the space segment of the various services to its customers. Telecom has taken up 25% ownership of AUSSAT and will be leasing satellite capacity to offer a wide range of telecommunications services. Many of these services will be especially designed and constructed to meet customers individual requirements.

Initial Telecom Involvement

Telecom engineers have followed the development of satellite communications technology since its inception. An early opportunity for significant hands-on involvement in that technology in Australia arose in 1967 when the then Australian Post Office (APO) Research Laboratories carried out three experiments using the US National Aeronautics and Space Administration's (NASA) transportable earth station located at Cooby Creek, near Toowoomba, in Queensland. While participating in the US Applications Technology Satellite (ATS-1) Program, Telecom engineers gained valuable experience in satellite techniques and practices.

Early Use for Traffic in Australia

In 1969, to provide extra capacity between the eastern states of Australia and Western Australia before the terrestrial microwave radio system was completed, the APO leased 24 telephone circuits between Sydney and Perth from the Australian Overseas Telecommunication Commission (OTC(A)). These circuits were routed via OTC earth stations at Moree and Carnarvon using the satellite system of the International Telecommunications Satellite Consortium (INTELSAT) of which OTC was, in 1964, a founding member. For its time, this use of satellite circuits for domestic traffic by the APO was considered to be a novel and imaginative technological advance.

Task Group

In order to keep abreast of satellite communication technology and to assess the technical feasibility, likely use and economic viability of a satellite communication system for Australia, the APO formed an internal task group in 1972, comprising members from both the Engineering Planning Sub-Division and the Research Laboratories. For a period of approximately five years a wide range of tasks was undertaken. The major results of those years of effort are summarized in a final report, 'National Satellite Communications System Studies', which was released in November 1977.

Remote Area Experiment

Another opportunity arose in August 1979 for Telecom to participate actively in a satellite communications experiment involving the use of small earth terminals to provide telephony to remote areas of Australia. This occasion involved the use of the joint Canadian-US experimental satellite known as 'Hermes'. For the purposes of the demonstration the satellite was positioned over the Pacific at longitude 140° E so that it could be simultaneously viewed by the eastern states of Australian and Ottawa, Canada, for tracking and command purposes. Two small transmit-and-receive earth stations were provided by the Canadians for demonstrations of telephony to remote areas. Telecom undertook responsibility for the organization and conduct of the telephony demonstrations and the implementation of any new equipment needed to interface with the terrestrial system. The demonstration was totally successful in allowing Telecom to provide, for the first time, an automatic telephone customers' connection to remote areas by integrating a satellite link into the terrestrial system. The results of this demonstration were reported in April 1980 (Research Laboratories Report 7318).

Consultancy Work

In 1981 the Telecom Research Department carried out comparative measurements between its satellite transponder simulator and an operational satellite transponder. The Department was engaged under a consultancy arrangement with OTC(A) to verify conclusions drawn from the Research Department's experimental simulation of sound carriers combined with a television carrier in a non-linear satellite transponder. The European Space Agency (ESA) made the Orbital Test Satellite (OTS) available and the measurements were carried out at the OTS control station at Fucino, Italy. The OTS trials provided useful validation of the Research Department simulator.

Rain Attenuation

Starting in 1971 and still continuing, propagation studies have been carried out by the Research Department to study the effects of rain on earth-space paths at frequencies above 10 GHz. Initially, because of the lack of appropriate satellites to transmit signals to Australia, radiometers were used to measure sky radiation (thermal noise), which can be related to the magnitude of rain attenuation (fade) of a signal on the earth-space path being monitored. Measurements were carried out at 11 and 14 GHz in tropical areas of Australia and the Melbourne area using radiometers designed and built in the Department. Future measurements will be made at 30 GHz using a Research Department built radiometer, which will be initially located in the Perth area. Based on past experimental results a rain attenuation prediction model, which is published in ATR, Vol.16, No.2, 1982, has been proposed for Australia.

Propagation Studies

Future satellite propagation studies will employ a beacon receiver terminal to monitor satellite beacon transmission from either the INTELSAT V satellite or the AUSSAT satellite due for launch in mid-1985. A collaborative program between Telecom and AUSSAT has been initiated, which will allow the Research Department, for the first time, to measure such propagation effects as cross-polarization discrimination and scintillation. AUSSAT is purchasing a beacon receiver terminal and a 12 GHz radiometer, both of which will be lent to the Research Department for the continuing propagation measurements in the Perth area. This collaborative project is aimed at enhancing the body of knowledge and data available in Australia to upgrade the present rain attenuation prediction model.

Some Present and Future Research Activities

Satellite communication research activities within the Research Department have been analytical,theoretical and experimental. This is reflected in the planning of present and future investigations. Some of the activities are listed below with a brief description of each.

Satellite Simulations

The amplifer system (transponder) in a satellite is non-linear, i.e. the output is not proportional to the input for all input levels. As a result there is distortion of the signal and increased noise due to intermodulation products. The Department has developed both a software and hardware simulation of this non-linear amplifier to better predict satellite link performance.

Satellite Link Analyses

Satellite communications systems will increasingly use digital techniques in the future. To evaluate satellite link performance for the full range of data rate transmission requires a comprehensive total link analysis (earth station-satellite-earth station). The Research Department is continuing to add software and hardware to its satellite simulator program to better predict total link performance for various digital modes.

Portable and Mobile Earth Stations

There is a trend worldwide toward smaller earth stations for satellite services. The ultimate goal is a small, inexpensive land-mobile terminal that can operate through a satellite. The Department is presently studying the means of achieving this goal and the comparable problem of very small portable terminals that might be used for two-way low-data-rate services from any point in Australia via the AUSSAT satellite.

Antenna Technology

Antenna performance is extremely important in most earth station designs. To achieve that last little bit of margin requires efficient antennas and to prevent interference both to and from other services requires good polarization discrimination and low side-lobe radiation. All of these aspects are under study in the Department both from an analytical and experimental point of view. In addition, microstrip planar arrays are under experimental investigation for use in low cost portable and mobile terminals.

Future Satellite System Studies

In order that Telecom can plan efficient and reliable low cost satellite services, engineers at the Research Department keep abreast of newly emerging technology and perform analytical studies of future systems. Some important aspects that are considered include the performance objectives associated with particular services, the potential interference within and between services, the use of the precious electromagnetic spectrum and the co-ordination requirements to maximize that spectrum utilization.

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EXPERIMENTAL SATELLITE EARTH STATIONS

Classes of Terminal

The various experimental earth terminals in use within the Telecom Research Department over the past years and those expected to be in use in the near future can be classified into two broad categories, those associated with propagation research and those serving as a 'test bed' for satellite link studies.

Radiometers and satellite beacon receivers can be classed in the first category and a television receive-only and two (two-way) terminals to be implemented in the near future satisfy the latter category. The two-way terminals, envisaged as 'test beds', will comprise a large 6.4 m terminal for most studies involving access to the AUSSAT satellite and a general purpose smaller terminal that is portable and easily installed anywhere in Australia.

Radiometer

A radiometer measures incoherent thermal radiation and when pointed at the sky measures sky noise or sky 'temperature'. A measure of the antenna 'temperature' can be directly related to the excess earth-space path attenuation relative to clear sky that one would experience during rain at frequencies above approximately 10 GHz. These radiometers have been used extensively in earth-space propagation studies where a satellite signal was not available for direct measurements.

Beacon Receiver Terminal

When a satellite signal is available, usually as a fixed stable beacon transmission, a beacon receiver terminal employing two orthogonal channels is used to measure propagation characteristics. Whereas the radiometer can measure only attenuation, a beacon receiver can measure attenuation, cross-polar discrimination and scintillation effects. These terminals usually employ small antennas for transportability and state-of-the-art narrow band receivers with sensitivities better than -140 dBm.

Propagation Research Installations

A dual channel beacon receiver and a 12 GHz radiometer have been purchased by AUSSAT and lent to the Research Department as part of a collaborative effort to continue propagation studies in Australia. The beacon receiver will initially be installed in the Perth area and monitor transmissions at 12.75 GHz from the AUSSAT satellite. The 12 GHz radiometer will be co-sited with the beacon receiver to allow measurements of frequency and elevation angle dependencies.

A 30 GHz radiometer that is similar to previous radiometers used in initial 11 and 14 GHz rain attenuation studies will also be co-sited in the Perth area to measure rain attenuation statistics for the 20-30 GHz (millimetre-wave) satellite bands, which have applications for future generation satellite systems. Again, the radiometer has been chosen as the measurement system since there are no satellites in the view of continental Australia with transmissions in the 20-30 GHz bands.

Test Bed Installations

An experimental 'test bed' earth terminal installed several years ago at the Research Department is a 6.5 m television-receive only terminal similar to those used in the Australian Remote Area Television Service (RATS). The terminal allows reception of television transmissions at 4 GHz from the INTELSAT IVA satellite located over the Pacific Ocean. The received signal is capable of being rebroadcast locally with good quality. This terminal allowed engineers in the Research Department to get first hand experience in characterizing earth station performance and in evaluating television baseband receiver characteristics. It has also been used many times to measure characteristics of the INTELSAT satellite transmissions into Australia.

Two experimental 'test bed' earth terminals, which will both transmit and receive signals, are planned for installation at the Research Department in the near future. The larger 6.4 m station will be a general purpose system capable of high capacity services through the AUSSAT satellite. This terminal will also serve as the 'hub' or gateway station for experimental studies involving very small terminals. The second 'test bed' earth terminal planned for use in the Research Department is a small portable system with a dish size less than 500 mm diameter. This terminal will be designed to operate to any AUSSAT transponder with radiated power levels low enough to satisfy the interference limits imposed by AUSSAT. Small terminal satellite services such as paging, two-way telex and low bit-rate telephony will be theoretically and experimentally evaluated using these 'test bed' facilities.

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STEERABLE MICROSTRIP ARRAY ANTENNAS

Microstrip Antennas

Microstrip array antennas usually have a low profile, are compact and light in weight, have easy to manufacture radiative elements and can have a steerable beam. These features make them well suited to applications that require signal acquisition or signal following capabilities or interference rejection or that require the antenna to be mounted flush with a surface.

In the telecommunications area such antennas may be used as transportable or mobile earth terminal antennas for satellite services or as beam steerable antennas for terrestrial point-to-point services. As well, these microstrip arrays may be used as feed elements for reflector antennas.

What are Microstrip Antennas?

In their most common form microstrip antennas look very much like double-sided printed circuit boards where one side of copper has been left entirely intact and the other has been etched into a pattern that acts as an efficient radiator or receiver of radio-frequency (RF) or microwave energy to and from free space. The pattern itself is of a special shape, usually a rectangular or circular element. That shape is repeated to form the grid-like pattern. Technically, each element and the copper on the other side of the board act as a leaky resonant cavity when fed with a signal. The radiation into free-space is due to the electric fields that occur at the edges of each rectangular or circular element.

Method of Operation

If each of the individual elements is properly fed with an RF or microwave signal, the radiated patterns of each of the elements combine in effect to produce a well defined composite pattern. The antenna is then called an array antenna.

A further level of sophistication occurs when the signal to each of these elements is manipulated in a set fashion. It is then possible to make the main beam of the array antenna point in different directions without physically moving the antenna itself. When the RF or microwave signal is changed under computer control the array antenna can be made to seek out or follow desired signals or to reject unwanted interference.

Beam Steering Display

The display illustrates beam-steering, which is controlled via a computer. Each array element is fed with a signal whose relative phase is adjusted according to a set formula. The antenna main beam can be swung up to 30 degrees off the axis perpendicular to the plane of the antenna surface.

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RESEARCH ACTIVITIES IN SATELLITE COMMUNICATIONS

Satellite System — General

All communications satellites are in orbit around the earth. Most of them are placed in what is called the geostationary orbit, which is a circular orbit in the same plane as the equator at a height of about 36000 km.

In this orbit, the satellite circles the earth once every 24 hours and thus, if travelling in the same direction as the earth's rotation, appears stationary from the earth — hence 'geostationary' orbit.

The satellite can be envisaged as a 'radio repeating station in the sky' that receives radio signals from individual sources on earth, transmitting earth stations, and then retransmits those signals back to earth to be received by the appropriate earth stations within the areas covered by the satellite's transmit antennas, sometimes called the satellite 'footprints'. The process of repeating the signals requires both amplifying the signal to overcome the loss of signal strength due to the distance it has to travel and altering its frequency to avoid mutual interference between the signals being sent up to the satellite and those being sent back.

The radio signals repeated by the satellite are normally in the microwave frequency range and use much of the technology employed in terrestrial microwave telecommunications systems.

The Australian domestic satellite system (AUSSAT) uses the frequency band 14.0-14.5 GHz for transmissions from earth stations to the satellite (uplink) and the frequency band 12.25-12.75 GHz for transmissions from the satellite to earth stations (downlink).

A particular benefit of the 12-14 GHz bands is that they are distinct from the frequencies currently used in terrestrial microwave systems in Australia. Earth stations will therefore be able to be located almost anywhere, including heavily populated centres, without danger of radio interference to other services.

Accompanying this benefit is the drawback that signals in this band are attenuated by heavy rainfall much more than signals at the lower frequencies. This fact must be allowed for in the design of earth stations.

Some Satellite Services

A geostationary satellite system has several unique features that make it particularly suited for certain communications requirements.

The cost of providing a communications link via satellite is distance independent. It thus costs the same to provide a satellite link between, for example, Perth and Brisbane as between Melbourne and Geelong. This contrasts with the distance dependent cost of providing equivalent links by terrestrial means. Satellite technology can therefore offer an economically attractive alternative to terrestrial provision for certain long distance point-to-point links. Because of this distance independence and wide coverage, a satellite system can also be used to provide services in sparsely populated remote areas where the distances between customers are large and the costs of providing a service by terrestrial means would be very high.

A satellite system is especially suitable for broadcasting purposes, whether radio or television. Any location within the transmit beam can receive the signal by using a relatively cheap receive-only earth station. Earth stations can be added and removed from the broadcast network at any time without disruption to the service.

Another feature of a satellite system is that it permits almost immediate provision of service. All that is needed is to install and align the required capacity earth station and associated equipment. No other terrestrial support is needed. When a particular service is no longer required the earth station can be recovered and is ready for immediate re-use elsewhere.

In addition to the normal services of telephony, telegraphy, TV broadcast, telematique (teletex, videotex, etc.) and data distribution, the unique features of satellites allow such diverse services as mobile (land, sea, air), disaster relief, law enforcement, defence, remote areas, private networks, man-portable and transportable terminals and school-of-the-air.

Some Research Department Activities

For over twenty years the Telecom Research Department has been involved in many diverse satellite communication research activities. These activities have been analytical, theoretical, and experimental in nature. A few of the activities that are currently under investigation are outlined below with a brief description of each.

Satellite Simulation

All satellites use either a travelling-wave tube (TWT) or a solid-state power amplifier system (for their transponders) that is non-linear when operated close to saturation, i.e. the output phase and amplitude are not proportional to the input for all input levels. When one reduces the input signal level or 'backs off' from saturation, the non-linear characteristic is reduced. Because it is desirable to extract the maximum radiated power from a satellite, some degree of non-linear operation is expected. However, this non-linear operation has serious consequences that must be known and controlled.

The effects of non-linear amplification are mainly signal distortion, increased noise due to intermodulation products, spectral spreading, and reduction of usable output power. Signal distortion and spectral spreading can lead to adjacent channel and co-channel interference (ACI and CCI) and intersymbol interference (ISI) of digital signals.

When more than one signal is passed through a non-linear amplifier there is power lost in intermodulation products resulting in unequal power sharing and unwanted interference components. It is important to be able to simulate this non-linear behaviour in order to predict the best 'backoff' level for a particular performance requirement.

The Research Department is engaged in both software (computer) and hardware (TWTA) satellite simulation studies. The non-linear behaviour of a satellite transponder is approximated theoretically and then simulated on a computer. An actual satellite transponder is simulated experimentally by the use of a travelling-wave-tube amplifier tube (TWTA) and filters, which closely approximates the operating characteristics of the AUSSAT TWTAs. The experimental (hardware) simulation allows a check on the software simulation assumptions thus creating a self-consistent approach to the understanding of this problem. The final results of this satellite simulation are then used for total satellite link analyses (earth station-satellite-earth station) of various assumed transmission modes.

Earth-Space Propagation

For transmission to and from a satellite at frequencies above approximately 10 GHz there are many propagation effects which need consideration. The most important of these are rain attenuation (fading), depolarization, and scintillation effects. Water droplets (hydrometeors) will not only reduce the level of signal received, either through absorption or scattering, but will also couple energy from one polarization to another resulting in interference in satellite systems that use orthogonal polarizations to increase usable bandwidth. A smaller effect, but one that needs consideration, is the modulation of a signal (scintillation) due to turbulence effects in the troposphere. This effect is more pronounced at low elevation angles where the path length through the atmosphere is increased.

In order to measure these propagation effects, one usually monitors a signal transmission from a satellite, if a satellite is available. In the absence of an appropriate satellite the more important rain attenuation effect can be measured using passive radiometry techniques. A radiometer measures the thermal radiation from the sky and that radiation can be related to an equivalent signal loss on the earth-space path being monitored. Since 1971, the Research Department has used 11 and 14 GHz radiometers, built in-house, to measure rain attenuation statistics in tropical areas of northern Australia, and more temperate areas in Victoria. Based on these many years of measurements, a rain attenuation prediction model has been proposed for Australia (ATR, Vol.16, No.2, 1982).

With the availability of the INTELSAT V satellites and the AUSSAT satellites, it will now be possible to monitor beacon transmissions at frequencies above 10 GHz with an appropriate receiving earth terminal. Telecom is entering into a collaborative program with AUSSAT to continue earth-space propagation measurements in the Perth area. AUSSAT is purchasing a beacon receiver terminal, and a 12 GHz radiometer, both of which will be lent to the Research Department to measure, for the first time, cross-polarization discrimination and scintillation effects. This collaborative project is aimed at enhancing the body of knowledge and data available in Australia to upgrade the present rain attenuation prediction model.

The Research Department has also designed and built a 30 GHz radiometer, which for the first time in Australia will provide rain attenuation measurements in the millimetre-wave band. This band has potential application for future generation satellites. As with previous radiometer results the new Australian data will be submitted to the International Radio Consultative Committee (CCIR) for use in establishing an international model for predicting earth-space propagation effects.

These propagation results can be correlated with rain intensity statistics. In that way propagation effects due to rain can be predicted for an area by referring to long term rain rate data available from the Bureau of Meteorology. The two types of rain rate measuring equipment that have been used by the Research Department are tipping-bucket rain gauges and distrometers. The first measures precise amounts of rain accumulation versus time and the second measures the impulses of individual raindrops. The latter can also give a measure of the raindrop size distribution, which is important in theoretical studies of rain effects.

Small Earth Terminal Technology

There is a trend worldwide toward smaller earth stations for satellite services. In the past, where major (large) earth stations were used with antenna diameters in excess of 30 m, the emphasis was on reducing the cost of the satellite since the ground segment was relatively inexpensive. However, for services requiring a very large number of earth stations, more attention is now being paid to minimizing the cost of the ground segment. The limit of very small terminals is seen by many as the Dick Tracy wristwatch communicator! More realistically, one can perceive a land-mobile terminal that is hand-held and employs some form of car-mounted antenna. Whatever the small terminal configuration, there will be a concentrated effort worldwide to reduce the cost, as well as size, because of the potential large quantities involved. In summary, the basic characteristics of very small terminals used for certain satellite services, such as land-mobile telephony, are —

- ground segment costs comparable to or greater than the space segment,
- very large number of ground stations,
- low-cost,
- small size and weight,
- mobile, portable or easily transportable and
- easily installed anywhere.

The Research Department is presently looking at small earth terminal technology and the potential services that can be economically provided by them. While the limit for small terminal services may be some form of mobile communication, slightly larger portable terminals and still larger easily transportable terminals are under investigation. To put antenna size for these various terminals in perspective, consider arbitrarily that antenna sizes less than approximately 2 m diameter are easily transportable, those less than 0.5 m diameter are easily portable and those less than the size of a car roof can be mobile.

Initially, the Research Department will be directing its attentions to services that can be provided via the AUSSAT satellite systems. These include paging, two-way telex and low bit-rate telephony and data distribution. The results of these studies are applicable to the final goal of a land-mobile satellite service.

The use of very small terminals with relatively large antenna beamwidths creates the problem of interference to and from other satellite services. This problem of an appropriate multiple access scheme is one of many problems being addressed in these studies. Cost will also be a predominant consideration as well as size and weight.

In parallel with theoretical studies of small terminal satellite services, an effort is underway in the Research Department to establish an experimental 'test bed' facility with which one can demonstrate total link performance using the AUSSAT satellite. This facility would include a large earth terminal, which would serve as the 'hub' or gateway station for a small terminal network, and an appropriate small terminal designed for easy portability to any location in Australia.

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MATERIALS SCIENCE

Importance of Materials Science Activities

Materials science plays an important part in Telecom's R&D (Research and Development) activities. The bulk of this work is applied research aimed at ensuring that the materials Telecom uses are the most effective available in terms of both cost and performance. This investigative work is mainly performed at the design and prototype stages of equipment production. The Research Department is also engaged in basic research into the production and characterization of new materials that may be used in telecommunication equipment in 5 to 10 years' time.

As Telecom buys the overwhelming majority of its material requirements from private industry, it is sometimes argued that the choice of material should be left to the manufacturer. In fact, most such decisions are made by contractors, certainly those that maintain substantial R&D and quality control organizations. Some products do fail prematurely, however, especially when a material has been chosen without a full understanding of Telecom's operational practices, the range of Australian climates or the interaction of one material with another. There can also be subtle changes in properties due to variations in process technology. Such changes are not always detected by conventional quality control procedures. In equipment that is often at the forefront of the telecommunications state-of-the-art, it is also not uncommon to find that a material or component choice has had to be made without a full knowledge of all facets of its behaviour or before production processes are truly stabilized. Hence Telecom has for many years found it advantageous to be able to assess products, to solve materials-based problems and to make informed proposals for the improvement or modification of manufacturing processes. In a capital expenditure program of more than 1400 million dollars annually, such work results in considerable savings by minimizing replacement or maintenance, reducing equipment outages, improving the grade of service to customers, protecting the safety of staff and ensuring that the best product for a given price is bought.

Range of Materials Science Activities

Examples of a few recent investigations, which illustrate the range of materials science activities in Telecom, are:

- kinetics and interaction in polymer stabilizer systems,
- study, by voltage contrast, marginal voltage or electron beam induced current techniques, of materials defects in integrated circuits,
- effects of organic acid contamination in battery electrolytes,
- hydrogen evolution from optical fibre cable materials,
- surface characterization of contact materials,
- telephone keypad elastomers,
- fire-resistant plastics cable,
- characterization of solder fluxes,
- field trials of paint systems,
- plastics for packaging of integrated circuits,
- electrical insulating mats and protective clothing,
- amorphous silicon for solar cells,
- photovoltaic solar modules,
- cellular polyethylene,
- fibreglass laminate materials for radomes and
- III-V semiconductor compounds for optoelectronic devices.

III-V Semiconductors

The last item listed is one of the current basic research projects. III-V semiconductors are compounds of elements from columns III and V of the periodic table of elements. The best-known compound is gallium arsenide (GaAs) but more complex alloys such as indium gallium arsenide phosphide (InGaAsP) are widely used in telecommunications.

The III-V semiconductors have the fastest operating speeds known. They can exchange carriers, i.e. they can switch between electrons and photons as carriers of a given train of information and they can operate at light wavelengths that perfectly match silica optical fibres. Thus III-V semiconductors can provide an interface between the optical fibre and the outside world via devices such as solid state lasers and detectors.

The development of these materials and of the devices made from them is recent and relatively immature when compared with that of silicon. It is thought that many potential properties and applications of these materials remain to be discovered and the rate of advance of this technology is a major factor in the speed of the development of telecommunications as a whole. These reasons motivated the Research Department to establish a III-V materials growth and device fabrication capability using the Molecular Beam Ipitaxy (MBE) technique.

In this technique the elements are evaporated under stringently clean conditions, e.g. the vacuum used is 10–13% atmosphere, and are condensed onto a crystalline substrate. The resulting compound takes up the crystalline structure of this underlying substrate. The growth is slow — one atomic layer a second — so it can be controlled with atomic precision. A resulting single crystal can consist of different materials that, on an atomic scale, have near perfect interfaces. The focus of this work in the Research Department is on the exploitation of these heterostructures for optical and electronic communications. The devices that have been fabricated here include double heterostructure lasers, waveguides, optical modulators and GaAs field effect transistors. Of particular interest was the successful fabrication of the two-dimensional electron gas field effect transistor. Present and future work is concentrated on developing the technology required to integrate optical and electronic devices onto GaAs substrates.

Amorphous Silicon for Solar Cells

Amorphous silicon is a disordered assembly of silicon atoms, which can be made semiconducting by the addition of hydrogen. The hydrogen absorbs unpaired silicon valence electrons giving a low carrier state density that can be modified by conventional p- or n-type dopants. Hydrogenated amorphous silicon (a-Si:H) has a major advantage over its crystalline counterpart in that it absorbs light over much shorter distances. The light absorbed creates electron-hole pairs that can be separated across a potential barrier in a p-n junction structure to convert incident solar radiation into electrical energy. The a-Si:H layer need be no thicker than 500 nm allowing the use of cost-effective, thin film, mass production technology for manufacturing solar cells. The small quantities of material required can be directly deposited from silane (SiH^4) gas at low temperatures, further reducing costs. These advantages make a-Si:H a prime candidate to eventually become a serious competitor with conventional sources of electricity. The Research Department is investigating amorphous silicon as a possible power source for telecommunications equipment in remote locations. The Department has established amorphous silicon solar cell processing facilities incorporating the technologies that are those most likely to be used in industry. In this way it will be in a position to assess the characteristics of amorphous silicon solar cells in a quite fundamental manner and also have the flexibility to optimize process parameters with a view to improving efficiency and lifetime.

Failure of Polyethylene Insulant

An example of a major investigation into the cause and rectification of an important materials-related plant failure problem is the work being done on premature embrittlement of solid, medium density, polyethylene insulation of cables installed in above-ground joint enclosures. This problem has been shown to be confined to cables manufactured in the period 1965-74 and to be caused by oxidative degradation due to the early depletion of an initial low concentration of antioxidant. The rapid rate of depletion has been proved to be caused by a number of competing and interacting factors such as losses during processing; interaction between antioxidant, metal ions, pigments and opacifiers; high temperatures in the jointing enclosures and the migration of antioxidants to the polymer surface. To demonstrate the causes and effects associated with these and other factors has required a major investigative effort, in particular in devising novel analytical and test methods for determining the various reactions taking place in the polymer system. The work has already resulted in the specification of new stabilizing systems and hence far greater cable life expectancy. Most importantly it has led to a better fundamental understanding of the role of metal deactivators and of the behaviour of antioxidants, how they interact with other polymer additives and the quantitative relationship between their concentration levels and the life expectancy of polymers.

Conclusion

To cover this wide diversity of applied and basic research, the Department has installed a comprehensive range of analytical, mechanical, electronic and environmental test and measurement equipment. A staff of chemists, metallurgists, physicists and other technically qualified staff work individually in particular areas of expertise and also in multidisciplinary teams. Using a highly interactive and co-operative approach to solve materials-related problems they are making a significant contribution to the continuing efficiency of the Australian telecommunications network.

LIST OF EXHIBITS

ELECTRICAL SAFETY OF CUSTOMERS, STAFF AND EQUIPMENT

Hazards

There are a number of sources which can induce or inject harmful voltages and currents into communication networks. These could be equipment malfunctions, power distribution lines, radio transmitters, natural and user generated static electricity and of course electrical storms.

Of these the most common and harmful source is lightning discharges generated by electrical storms. At any one time there are about two thousand electrical storms in progress around the world. These generate several hundred lightning discharges per second out of which about ten million terminate on the earth in a period of 24 hours.

A storm that lasts for an hour can generate about ten million megajoules of electrical energy. This energy is then dissipated in amounts averaging about ten thousand megajoules with dissipation rates in the vicinity of several thousand million megawatts.

In some instances the damage to lightning struck objects has been estimated to be equivalent to that produced by several hundred kilograms of TNT.

Lightning strikes therefore can and do cause considerable damage to property and to communication networks.

Development of Protection

Protection of telephone line equipment and its users from the effects of lightning and other sources of high voltage was an integral part of the early telephone network. As the network evolved its switching and terminal equipment became electrically more robust and also capable of providing an adequate barrier between the operator or the user of the equipment and the parts which could acquire harmful potentials. The original overhead lines were also gradually replaced with underground cables. The underground cables were predominantly lead-sheathed with paper-insulated conductors.

This led to the breakdown potentials of the equipment being generally higher than the potentials which could pass along the cables and hence protection of at least the equipment had become redundant in the majority of installations.

This situation started to change when the lead-sheathed cables began to be replaced with plastic-sheathed and plastic-insulated cables and the electromechanical switching and terminal equipment was replaced by solid state electronic switching devices. The need for protection also increased with changes to the environment in which the network operated. These included the use of non-metallic pipes for water and sewerage services, the use of concrete slabs for floors and walls and the use of metallized thermal insulation in house construction.

These changes increased the levels of potentials that could pass along the cables, removed the shielding and current sinks provided by metallic water and sewerage pipes and reduced the tolerance levels of equipment to over-potentials.

The impending introduction of optical fibre cable and cordless telephones into the network will, however, again change the character of the telecommunication network.

In view of this evolving change, protection policies and practices are periodically reviewed to meet any new requirements of the network.

Factors in Protection

Some of the parameters that determine the need, the level of the protection required and the effectiveness of that protection in today's network are:

- the location of the building housing the telecommunication equipment i.e. city, suburban or rural, in hilly or flat terrain, on what type of soil, etc,
- the type and constructional features of the building,
- the type and location of the equipment within the building,
- the type and lengths of the external cables,
- the topography and the soil resistivity of the areas through which these cables run,
- other services that come into the building and
- the frequency and duration for which the equipment is in use and, in the case of lightning strike problems, the frequency and duration of electrical storms and the number of strikes they generate.

Means are now available which allow reasonably accurate measurements to be made of the number and location of ground strikes generated by electrical storms. A lightning location system used by Telecom appears as a related display.

The ability of underground cables to resist damage by a given level of electrical stress can be controlled by the way the cables are installed or by their design and construction. For example, armoured cables or cables with metallic screens sandwiched between plastic insulation will be less susceptible to damage than ordinary plastic insulated cables. Another example is ordinary plastic cable which may have a comparable performance with a sandwiched cable when it is installed in a plastic duct or buried with a guard wire or have a superior performance to an armoured cable if it is installed in a galvanized iron pipe.

The resistance of equipment to damage can also depend on equipment design or added external protection.

The protection of terminal equipment which does not come into contact with local earth or requires a local earth for some of its functions is relatively simple and inexpensive — a combination of gaseous arrestors with resistors and varistors or zener diodes would protect the equipment in most situations. Similar protection can be applied to the switching equipment but in this case the protection is also referenced to earth.

Typical protective devices used by Telecom are displayed.

The protection of terminal equipment requiring local earth for its operation and the protection of equipment users from electric shocks is more difficult and costly. In some situations this protection is not very effective and is also capable of transferring the problem to other parts of the system or causing other problems such as noise, distortion, loss of signal and other faults on the system.

The protective device in the case of user protection need not have well defined and stable parameters. What, however, is very important in this situation is equalization of the electric potential between the equipment protection earth and all other earths on the premises.

The required degree of potential equalization can be achieved only by metallically bonding the equipment protection earth to the power distribution earth, all metallic pipes and any other metallic structures and fixtures on the premises.

Safety Considerations

Today, with most of the past restrictions on bonding the various earths removed, the telecommunication service is, where necessary, fitted with an effective protection system. Nevertheless, in common with other telecommunication authorities, Telecom Australia recommends that all users of the service observe some simple rules as set out in the Telephone Directories when using the service during local electrical storms.

In the course of their duties, Telecom staff also can be subjected to harmful potentials. This may occur, for example, during cable jointing, work in or near power installations or excavation areas containing buried power cables or installation work in domestic or commercial premises that involves drilling into ceilings or walls and also when power tools develop faults.

In these situations prescribed work practices and the use of protective apparel such as rubber gloves, boots and mats together with devices that test power outlets and devices that disconnect power to tools when they develop faults have been very successful in preventing injuries to staff. Some of the protective apparel and devices are displayed.

The involvement of the Research Department in the protection field, frequently with assistance and collaboration from the Standards Association of Australia and various Telecom Departments, State Electricity Commissions, and Industry and Tertiary Institutions, has been in the areas of component and systems testing, in field tests, measurements and data collection and in the development of new or the modification of existing protection methods to best meet the demands of the constantly evolving telecommunication network and the changing environment in which it operates.

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LIGHTNING LOCATION

Background

The introduction of new technology materials has seen a significant change in the potential for lightning damage to the telephone network. Solid state devices, designed to operate at very low power levels, can be subjected to extremely large voltage surges, causing disruption to services. In order to provide protection for such equipment, lightning prone areas must first be identified, preferably prior to damage being caused.

Until recently, the only information on lightning activity has been from isokeraunic maps. These maps are based on data acquired from meteorological observers and indicate the number of days thunder was heard within a region per year. The limitations of that approach are:

(a) the small number of observers used,
(b) their inability to classify lightning strikes (i.e. cloud to ground, inter-cloud or intra-cloud) and
(c) their practice of recording on a day merely whether one or more strikes occurred rather than recording the total number of strikes for that day.

Because of those limitations, isokeraunic maps do not accurately depict the level of lightning activity likely to be experienced by Telecom equipment.

Lightning Location System

The lightning location system is capable of providing the location and intensity of lightning strikes from cloud to ground at the time they occur, thereby producing accurate information on the location and number of strikes occurring over areas several hundred kilometres wide.

Each system consists of a number of Direction Finding stations (DFs), located throughout the area of interest. These DFs are connected to a central Position Analyser (PA), which collates all of the available data and produces the location and time of occurrence of each individual lightning strike.

Direction Finder

The Direction Finder station has two antennas, which monitor disturbances in the electric and magnetic fields. These signals are fed to electronic circuitry, which is able to discriminate between cloud to ground strikes and all other forms of disturbance, including inter-cloud and intra-cloud strikes. When a strike is detected, its bearing is computed by means of two orthogonal loops in the magnetic field antenna. The bearing and a measure of the strength of the strike is then transmitted to the Position Analyser.

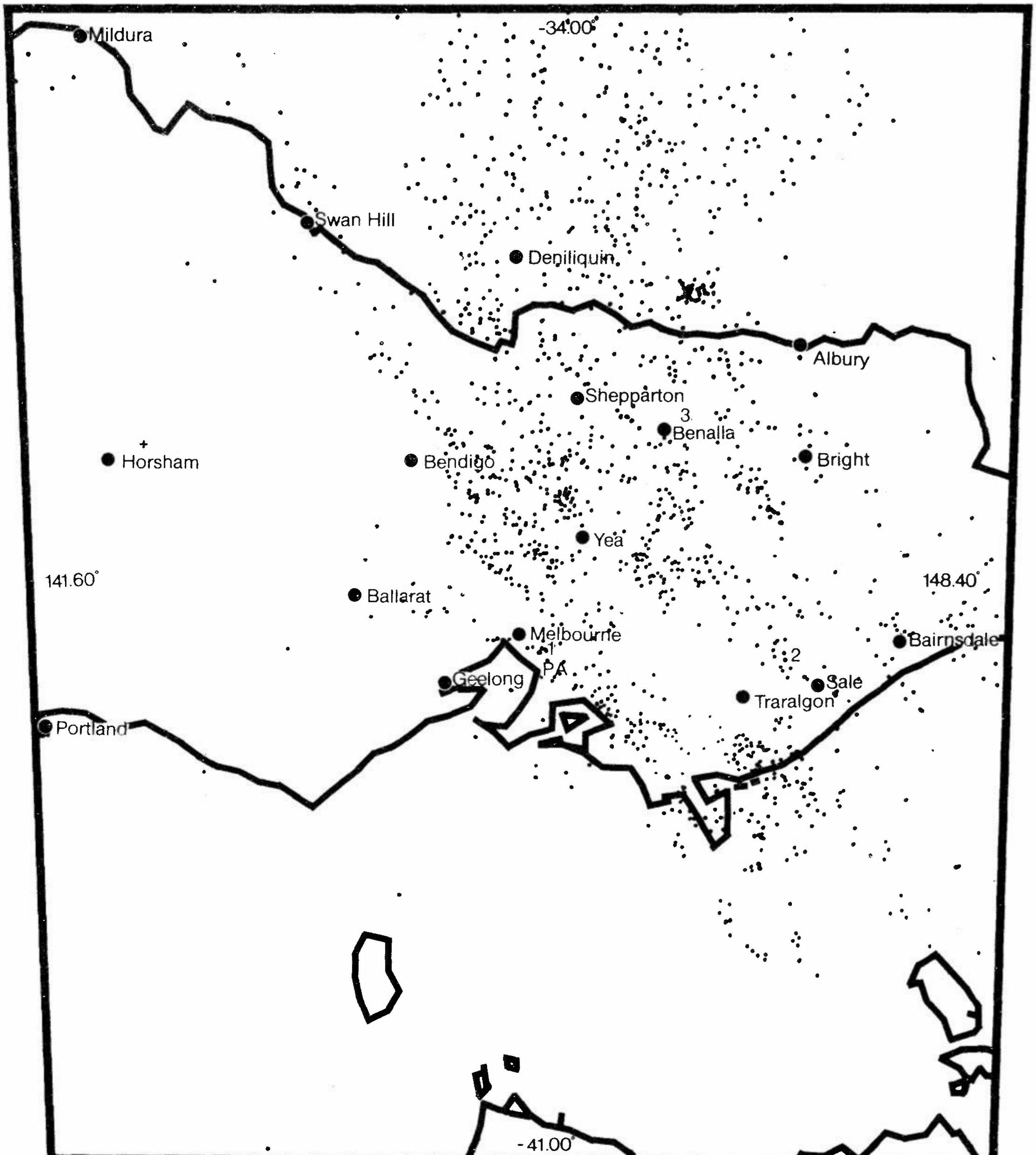
Position Analyser

The Position Analyser receives all available data concerning the strike and selects data from two DFs. Using the process of triangulation, the PA computes the intersection of the two bearings and hence the location of the strike. This location is displayed on a terminal and plotted on a map of the region, to give real time access to lightning activity. In addition the location is stored in a computer, to enable the investigation of long term trends in lightning activity.

By utilizing a computer to generate density patterns of strikes, based on data collected over long periods, an accurate description of the true level of ground strike activity can be presented, thereby replacing the isokeraunic maps.

Contact: Ian Stevenson 03-541 6603

From 11: 0 29-1-1984 To 2: 0 30-1-1984



Total No. of Strikes Within Time Period = 2169.
Total No. of Strikes Within Region = 1585.

Fig. 1 Lightning Reprocessing — Strike Locations

ELECTRICAL OVERLOAD TESTING OF TRANSISTORS

Electrical Overload of Transistors

Under conditions of severe electrical overload, it has been found that some plastic-packaged transistors have a susceptibility to bursting into flame. In the evaluation of two types of TO237 transistor, the failure mechanism that causes the transistors to ignite and burn was investigated. It was found that the restrictive nature of the encapsulation material would often not allow the emitter bonding wire to fuse open circuit. Electrical continuity can thereby be maintained until temperatures sufficient to ignite the encapsulant material and melt the lead frame are reached.

Testing Procedure and Results

Preliminary overload testing of the transistors, at an overstress current of 5 ampere (voltage limited to 35 volts), resulted in two distinct modes of failure. Either the transistors failed open circuit with no external damage (designated Type 1 failure) or they would smoke and usually burst into flame whilst continuing to draw current (designated a Type 2 failure). To study the progress of the failure mechanism, overload conditions were applied to a specimen of each transistor type for approximately 1 second.

Type 1 Failure

Decapsulation and subsequent Scanning Electron Microscope (SEM) examination of the transistor chip showed that in each case the emitter bonding wire had fused. This was accompanied by a flow of molten gold,,which alloyed with silicon on the chip surface. The gold-silicon eutectic temperature is 370°C.

Type 2 Failure

Decapsulation of specimens that suffered the Type 2 failure after the first short (1 second) overload revealed that a conductive bead of black material had formed around the gold emitter bonding wire. The bead was dissected to reveal the nature of the conduction path. This showed that remnants of the fused gold wire had been trapped by the surrounding carbonized encapsulant to form a conductive element.

No bead structure could however be found in the remains of some specimens that suffered the Type 2 failure only after they had been subjected to multiple electrical overloads. Although a conductive path between the collector and emitter still existed, SEM-EDX (Energy Dispersive X-Ray) examination revealed that a significant concentration of copper and silver was present between the collector flag and the emitter lead. The melting of the lead frame and the ensuing copper-silver migration had created another conductive path. This represents the final stage of the failure process.

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KEYPAD TECHNOLOGY

Background

Present day keypads are extremely simple in design compared with the complex assemblies typical of early keypad designs. An indication of the extensive changes in keypad technology can be seen from the two Touchphone keypads displayed. The new keypads are not only simpler but many have greater mechanical life (more than 1 million operations compared with 50,000 — 200,000 operations for the earlier complex mechanical designs). Failures in the early keypad designs were usually due to breakages of the leaf spring or rod contacts, with these breakages often preceded by intermittent contact operation.

Rubber Membrane Keypads

In the elastomer membrane type of keypad shown in Fig.1, pads of conductive, carbon-filled rubber are vulcanized to a sheet of non-conductive elastomer at the contact points. The non-conductive mat lies flat against a printed circuit board except at the contact points where raised domes are formed to accommodate the conductive pads. These domes will collapse when a button is pressed forcing the conductive pad onto a gold plated printed circuit grid. The shape of the domes determines the tactile feedback to the user.

Although the contact resistance of the conductive rubber is much higher than metal contact designs, being typically 10 to 100Ω depending on the applied force, the use of Metal Oxide Semiconductor (MOS) devices for keypad encoding allows contact resistances of up to nearly 100 kΩ before a contact closure fails to be detected.

Mechanical life testing has shown these keypads to be extremely reliable with a useful life in excess of one million operations. In addition, very little degradation of the initial tactile feedback to the user has been observed.

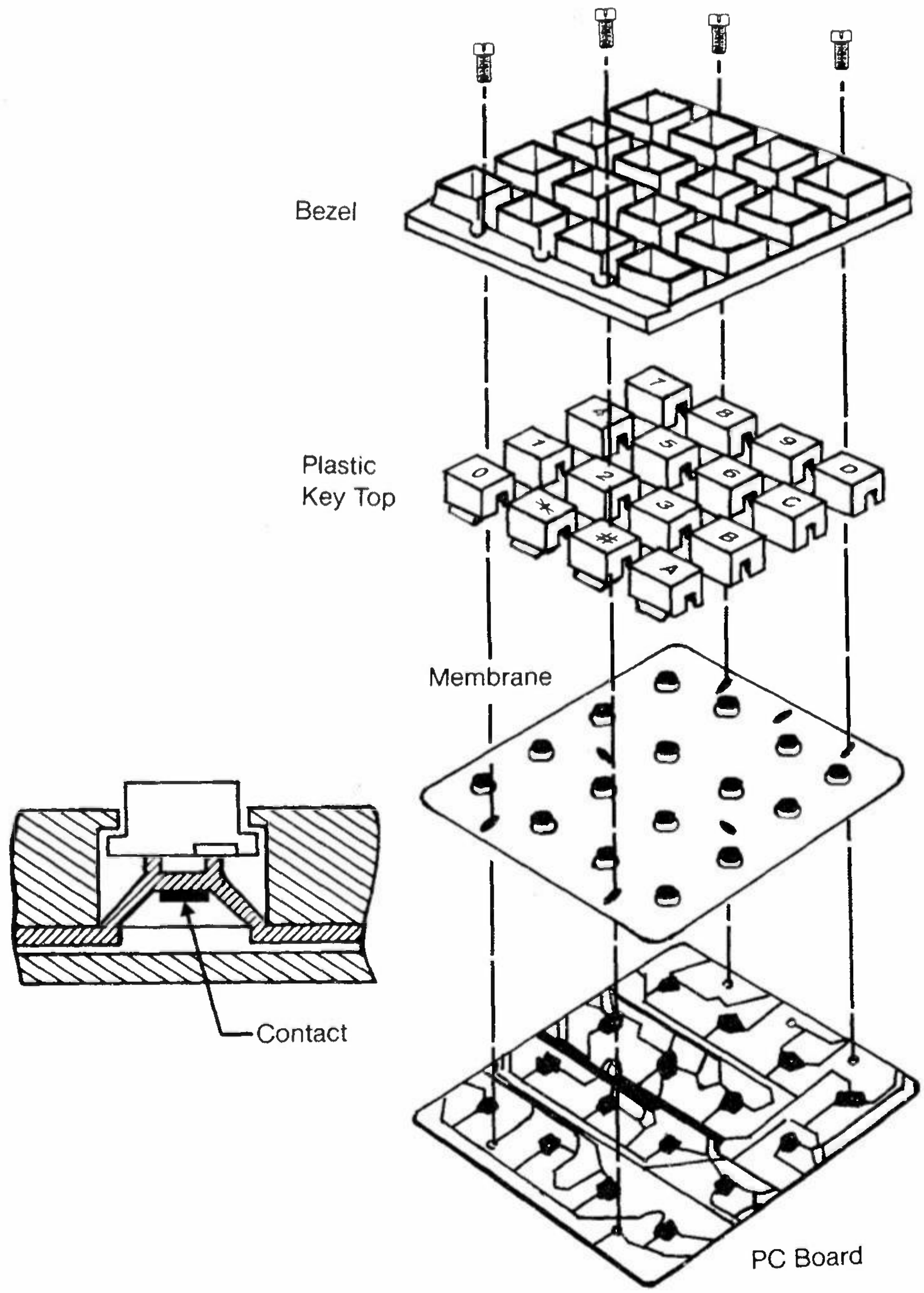

Fig. 1: Schematic Diagram of a Typical Rubber Membrane Keypad

Printed Laminate Keypads

The other basic type of membrane keypad incorporates polyester or polycarbonate laminates with conductive tracks screen printed onto them. As shown in Fig. 2, the keypad is constructed as a sandwich of two layers of polymeric film with a spacer between them. Conductive pads and tracks are deposited on the inner side of each film. To activate a contact, pressure is applied to the top sheet, which flexes through a hole in the spacer and establishes electrical contact between the conductive pads of the upper and lower sheets. If tactile feedback is required, the top sheet will have bubbles moulded at the contact points, otherwise the top sheet will be flat.

Laminated membrane contact sets are often combined with push button actuators into a moulded assembly that can be used as a keypad insert, as in the keypad displayed.

The main failure mode of laminated keypad assemblies has been breakage of the button actuators at their hinge points. Degradation of the keypad, such as cracking of the domes or flaking of the conductive tracks also occurs when the actuators have sharp edges. Similar designs without sharp-edged actuators can achieve more than 1 million operations compared with 50,000 — 200,000 operations for those with sharp edges.

Laminated membrane keypads are a viable alternative to the rubber membrane types because of their cheapness and greater suitability for low profile applications. Like the rubber membrane keypads, they can have labels or markings printed on the top surface or they may be covered with a protective printed sheet, which also renders them splash proof.

Metal Dome Keypads

Metal dome keypads are similar in design to conductive rubber keypads except that the dome is metal. The domes are made from either stainless steel, beryllium copper or phosphor bronze and are usually gold plated, either totally or with a 'stripe' across the contact area. The metal domes are much lower in profile than the rubber domes and their contact resistance is much lower being some tens of milliohms.

Failures of these keypads during testing by the Research Department have resulted from misalignment of the metal domes and from collapse of the domes due to relaxation or metal fatigue of the spring material.

Keypads with metal dome contacts are capable of reliable operation and long mechanical life. Through the refinement of these simple designs, keypad reliability has been substantially improved and the current generation of Telecom telephones has keypads which may be expected under normal circumstances to last beyond the useful life of the telephone as a whole.

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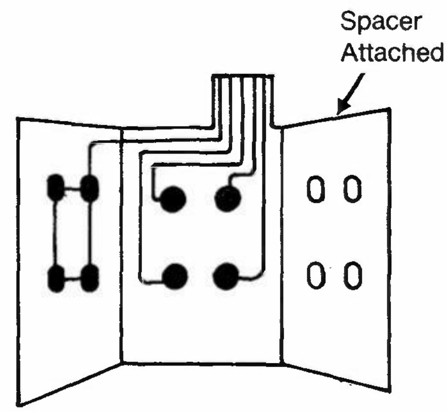


Fig.2: Schematic Diagram of Printed Laminate Keypad

PULSED SOLAR SIMULATOR

Performance Rating

The primary performance rating of a solar photovoltaic module is the electrical output generated when the module is irradiated with sunlight. This is usually presented as a current-voltage operating curve (I-V curve) from which the basic solar module parameters of peak power, short circuit current and open circuit voltage can be derived. I-V curves can be measured outdoors with sunlight when conditions are suitable or indoors with either continuous or pulsed light sources. A pulsed solar simulator is being used for this project.

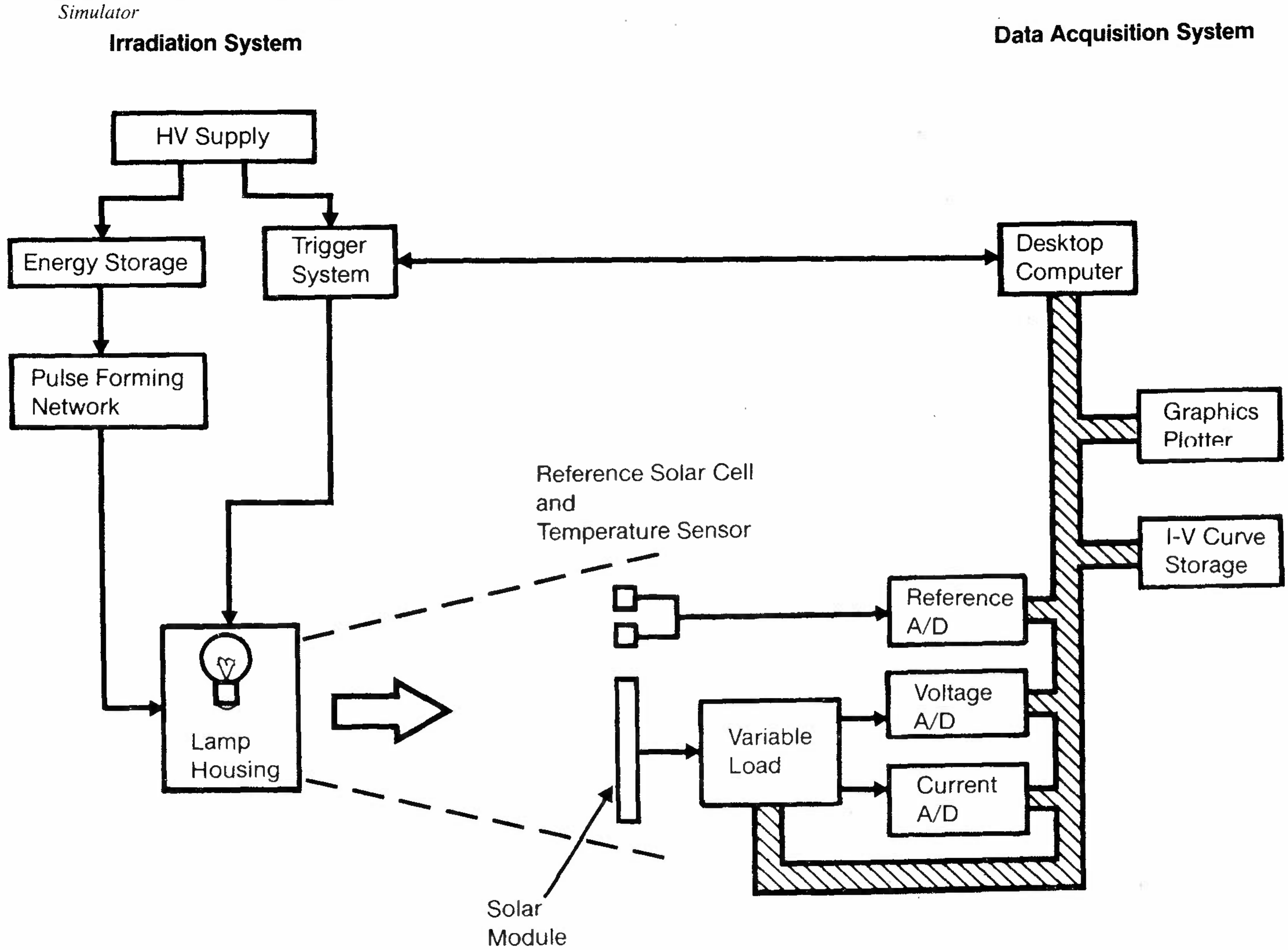
Irradiation System

The pulsed solar simulator shown in the schematic diagram (Fig.1) can be considered as two interacting parts: the irradiation and data acquisition systems. The irradiation system is a pulsed xenon arc light source capable of irradiating a 1.2 m by 1.2 m test plane with simulated solar radiation of intensity equivalent to that outdoors on a clear sunny day, i.e. 1 kW/m^2. The uniformity of the irradiance across the test plane is ±2%. Because the pulse duration is only 20 milliseconds, negligible heating of the solar module occurs and measurement can be made at a constant and known temperature.

Data Acquisition System

During the pulse, the solar module is connected to a varying electrical load that takes the module from open circuit to short circuit. There are 128 sets of current and voltage data recorded in memory by analogue to digital converters, enabling an I-V curve to be plotted by the computer. Accurate absolute measurements are produced by referring each module current reading to a short circuit current reading obtained simultaneously by the data acquisition system from a calibrated reference solar cell also mounted in the test plane. This reference cell, whose spectral response matches that of the module being

Fig. 1. Schematic Diagram of Pulsed Solar Simulator



measured, has been previously calibrated in standard sunlight conditions. The reference cell readings are used by the computer to compensate for differences between the spectral irradiance distributions of the pulsed solar simulator and sunlight and for temporal variations from the 1 kW/m^2 light output from the pulsed solar simulator. The excellent repeatability obtained using this method allows small changes in module performance to be readily detected.

The I-V curve of a typical solar module is shown in Fig.2 below. The 'raw' data measured has been corrected to standard conditions of 1 kW/m^2 irradiance by the simulator's data acquisition system as explained above. The measurement was made at room temperature (23°C). If the temperature coefficients of open circuit voltage and short circuit current and the internal series resistance of the module are known, the system can also modify the data to produce I-V curves for the module at other temperatures of interest and for different irradiance levels.

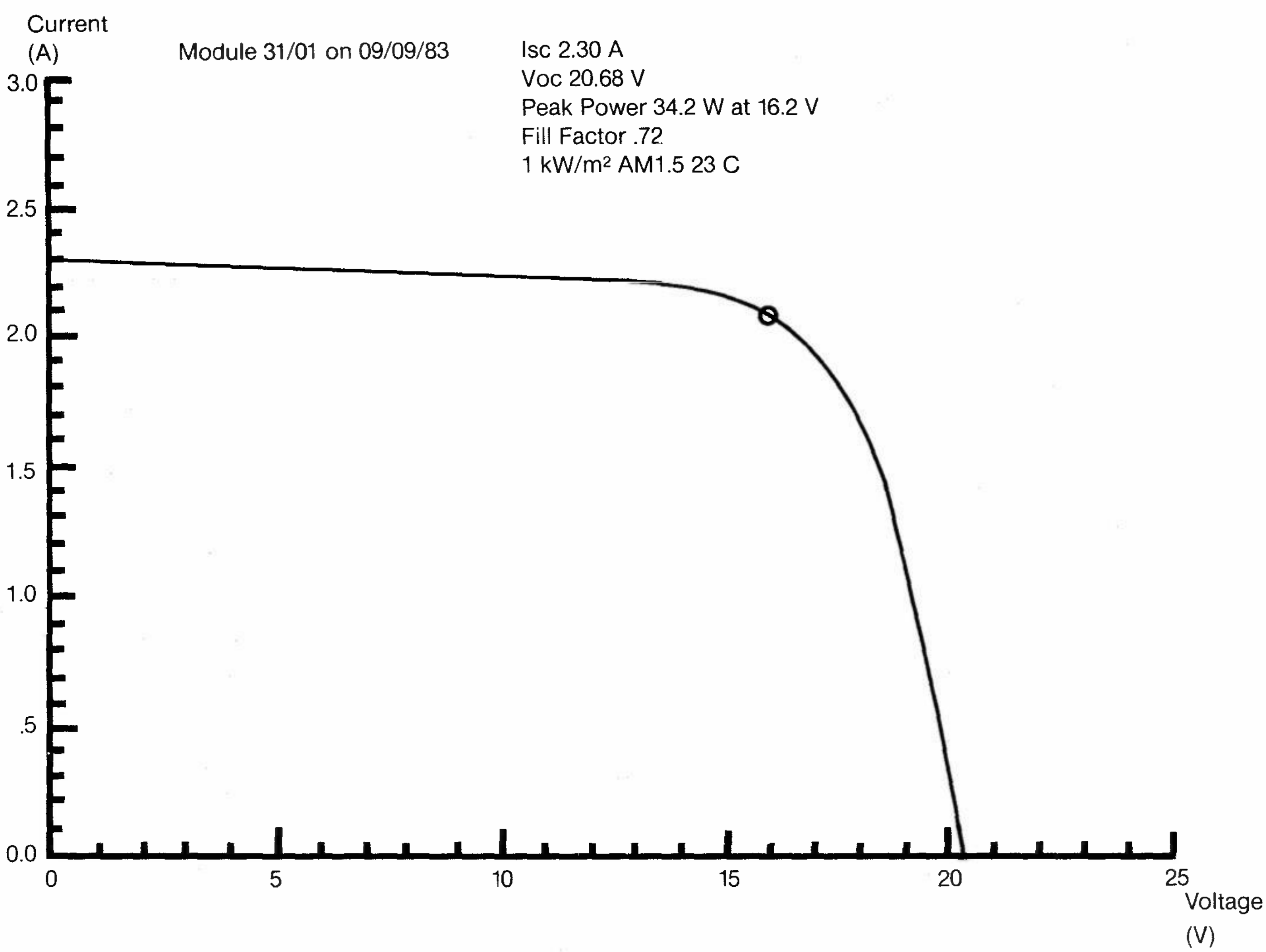
The temperature coefficients for a module are calculated from solar simulator measurements made on a number of cells of the same type as those used in the module. Cells rather than modules are used because it is less difficult to hold them at known temperatures above and below room temperature during the measurements.

Acknowledgement

The project and equipment described have been substantially funded by grants from the National Energy Research Development and Demonstration Council (NERDDC) of the Commonwealth Department of Resources and Energy.

Contact: Alan Murfett 03-541 6621

Fig. 2. Typical I-V Curve



LABORATORY TESTING OF SOLAR MODULES

Test Plan

The accelerated stress testing program for solar modules used in this laboratory generally follows the United States Jet Propulsion Laboratory's program for evaluating terrestrial solar modules intended for medium-size system applications. The detailed flow plan for the test is shown as Fig.1.

(See diagram over)

Aim

The aim of the tests is to subject modules to stresses of the kind that they would experience in ordinary use, in a controlled and reproducible manner and to a much greater degree, in order to induce degradation or failure much faster. Accurate performance measurements and visual inspections are made before and after tests, to assess the effect of each test on a module.

Test Details

The main tests performed are:

(a) Temperature Cycling Test: 200 cycles between +90°C and −40°C with a temperature rate of change of approximately 100°C/h.

(b) Relative Humidity Test: 10 cycles of 20 h at 85°C, 85% relative humidity followed by rapid cooling to −40°C.

(c) Wind Loading Test: 10 000 cycles of 2.5 kPa pressure applied alternately to the front and back of the module, to simulate the effect of 160 km/h wind gusts.

(d) Twisted Mounting Surface Test: A test to simulate mounting onto a non-flat plane.

(e) Hail Impact Test: Artificial hailstones (ice-balls) of 25 mm diameter are fired to strike the module at 23 m/s (approx. 80 km/h) at 10 selected points.

(f) Hot Spot Test: A test to determine the ability of a module to withstand hot spot heating due to, for example, cracked or mismatched cells, interconnection failures or partial shadowing or soiling.

Two further longer term tests that will be performed are a Dry Heat Test to accelerate thermal degradation of module materials and a Weathering Test, in which the combined influences of high temperature, water spray and high intensity ultraviolet radiation are used to accelerate the breakdown of polymer materials in particular.

Acknowledgement

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Contact: Alan Murfett 03-541 6621

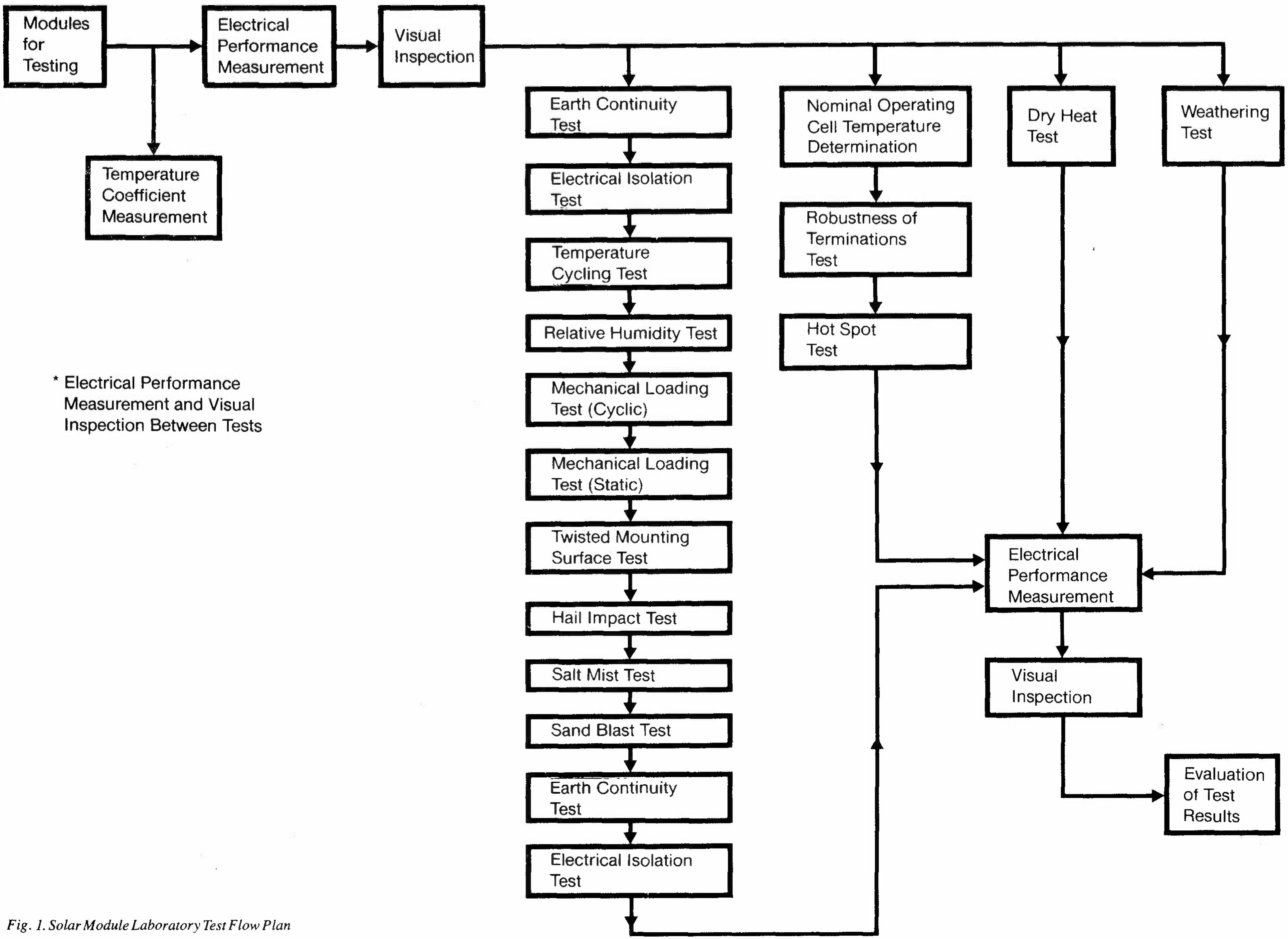


Fig. 1. Solar Module Laboratory Test Flow Plan

SURFACE CHARACTERIZATION STUDIES

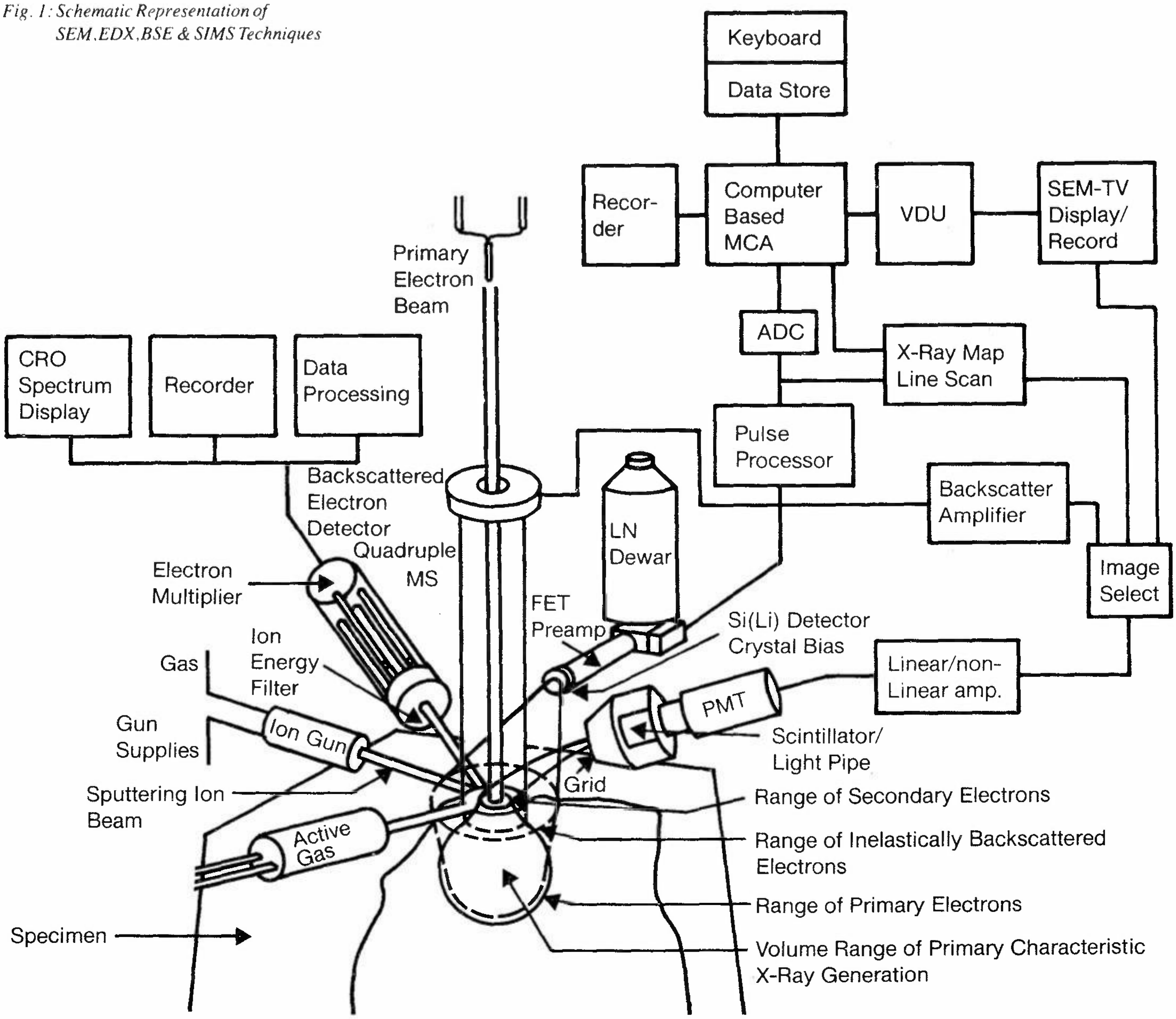
The Need for Surface Studies

The characterization and analysis of surfaces is vitally important in studies of electrical contacts, corrosion, adhesion, wear and lubrication, oxidation, passivation, catalysis, etc.. Unfortunately, no single analytical technique provides the complete answer for the scientific study of the surface and chemical composition of materials. The real capability for effective problem solving relies on the concerted application of a wide spectrum of advanced techniques.

Major Techniques

Scanning Electron Microscopy (SEM), Energy Dispersive X-Ray Analysis (EDX), Back-scattered Electron Imaging (BSE) and Secondary Ion Mass Spectroscopy (SIMS) are currently the major techniques available within the Research Department for the solution of surface related problems. These techniques are utilized in the one vacuum chamber such that any or all of them may be applied during an investigation, depending on the information sought, e.g. SEM for visual examination of sample artifacts, BSE for surface composition inhomogeneity, EDX for X-Ray analysis of the near-surface region and SIMS for surface layer identification.

Fig. 1: Schematic Representation of SEM, EDX, BSE & SIMS Techniques



Scanning Electron Microscopy (SEM)

In SEM, a beam of energetic electrons is rastered across a sample surface in synchronization with a television raster. The number of secondary electrons generated by the incident primary beam depends largely on the topography of the surface, thus the intensity and contrast of the television image is directly related to the topography of the surface.

Energy Dispersive X-Ray Analysis (EDX)

In EDX, the primary beam of energetic electrons excites surface atoms, which subsequently de-excite by the emission of characteristic X-rays. The X-rays are then collected and displayed according to their energy, thus forming a 'finger-print' spectrum of the elements present in the near-surface region of the specimen.

EDX can also be used to display the spatial position of a particular element.

Back-Scattered Electron Imaging (BSE)

In BSE, the contrast of the television image is directly related to the atomic numbers of the individual elements in the near-surface region of the specimen and can thus be used to depict spatial inhomogenities of the various elements present in the specimen.

Secondary Ion Mass Spectroscopy (SIMS)

In SIMS, the specimen is irradiated by a beam of energetic argon ions, which causes atoms on its surface to be ionized and liberated from it. These 'sputtered' ions can be mass analysed, resulting in a characteristic mass spectrum that can be used to identify the elements and compounds on the specimen surface.

Fig. 2: Secondary Electrons. (Contrast is directly related to surface topography).

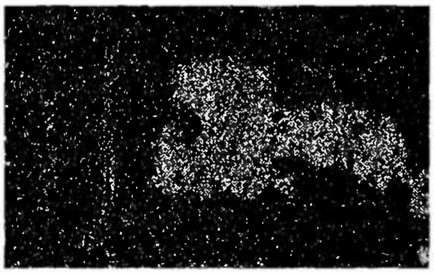


Fig 4: X-Ray Map of Tin (Contrast due to the EDX signal i.e. a 'map' of the spatial distribution of tin).

Fig. 5: Back-Scattered Electrons (Contrast is directly related to atomic number, Sn = 50 (bright area) Cu = 29 (dark area)).

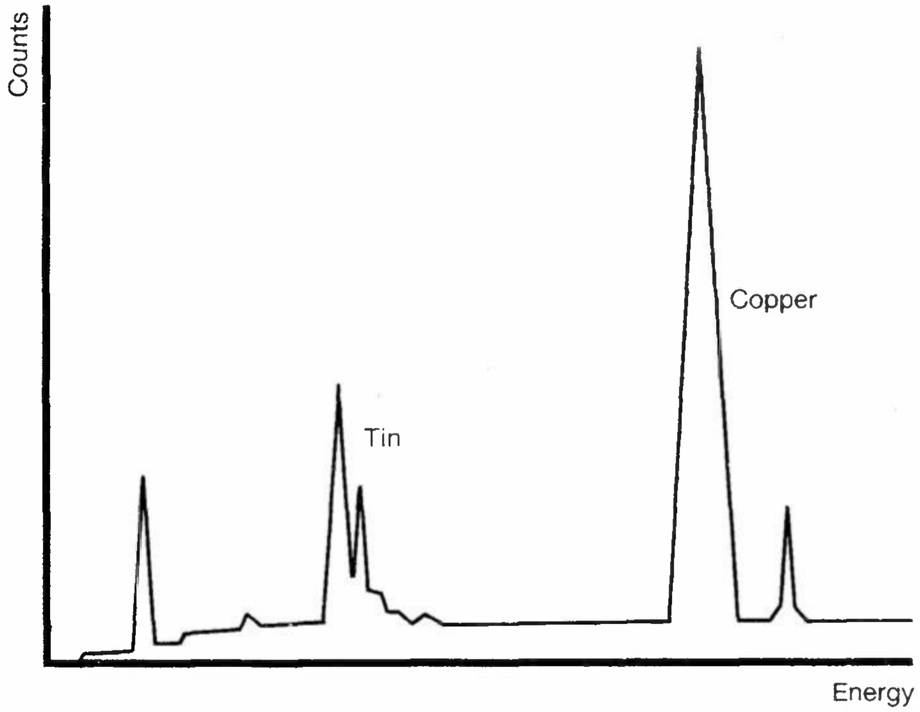


Fig. 3: Energy Dispersive X-Ray Spectrum of Copper with Tin

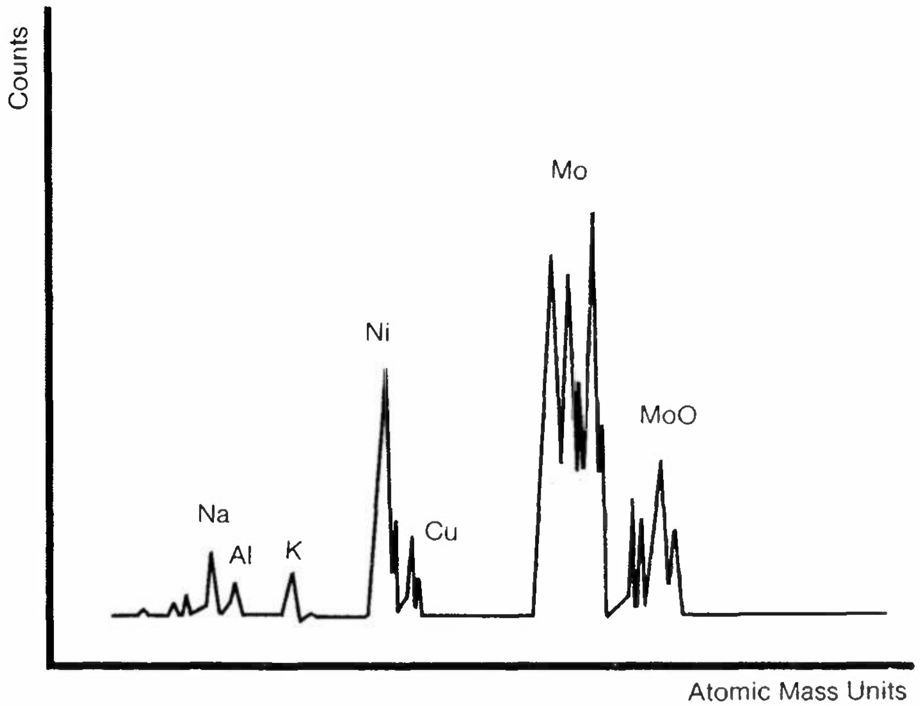


Fig. 6: Secondary Ion Mass Spectroscopy Spectrum of Molybdenum.

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MECHANICAL LIFE TESTING OF DIP SWITCHES

Dip Switches

Dual In-line Packaged Switches (DIP switches) are used for logic firmware, i.e. setting wired logic that may be periodically changed, such as the data transfer rate for a printer or the tariff rate in a coin telephone. As such, the main requirements are reliable switching for tens to hundreds of operations spread over a few years.

Most DIP switches are relatively cheap, costing about a dollar for a bank of 8 switches. In some cases the very basic switching mechanism combined with cheap contact materials results in a poor quality switch.

Indicators of Reliable Design

Testing conducted by the Research Department has shown that the indicators of a reliable switch design are:

(a) a good quality gold plating on all contact surfaces,

(b) a pronounced wiping action of the switch contacts and

(c) mechanical integrity of the switch.

The cross-sectional views shown in the accompanying display indicate the variety of internal design features of DIP switches. Externally the switches are either a 'slide' or 'rocker' type.

Testing Jigs

Two custom-designed computer-controllable jigs have been produced to mechanically test the switches and are shown in the display.

Contact: Geoffrey Mitchell 03-541 6602

STABILIZATION OF POLYETHYLENE CABLE INSULANT

Early use of Polyethylene

Polyethylene insulated and sheathed cable was introduced into the Australian telecommunications network in 1956. It featured solid low density polyethylene (LDPE) insulated copper conductors and a black low density polyethylene sheath. In 1976, 'filled' cable with (petroleum jelly) was introduced to overcome the cable's vulnerability to water penetration and infiltration over long distances. To overcome the increase in dielectric constant caused by the change from an air-filled core to a jelly-filled core the insulation was foamed (35%), using medium or high density polyethylene to improve the toughness of the cellular structure.

Discovery of Deterioration

The oxidative stability of polyethylene insulation was considered to be satisfactory, until the mid-1970s, when a small number of faulty cable joints were returned from the field for examination. Inspection of the cable revealed cracking and embrittlement of the insulation (see Fig. 1) in that section from which the sheath had been removed for jointing. These observations raised doubts about the long term stability of polyethylene insulation. The subsequent rapidly increasing number of reported failures of solid insulation from many areas throughout Australia indicated that a major problem existed.

Thermo-Oxidative Degeneration

Preliminary investigations revealed that the failures, observed in cables manufactured in the period 1965-74 and located in above ground joint enclosures, were a direct result of thermo-oxidative degradation brought about by the early depletion of the sole stabilizer, Santonox R, used during that time.

Stabilizer Losses

A comprehensive laboratory investigation was undertaken to determine the causes and extent of stabilizer losses in both failed insulation and in current cable production.

Migration of Stabilizer

The premature loss of antioxidant has been attributed to a number of competing and interacting factors, such as process losses, reaction with colourants, high temperatures in joint enclosures and more importantly the migration of antioxidant to the surface.

Migration is dependent on specific properties associated with the stabilizer, in particular its solubility and diffusion in the polymer, hence the investigation was directed towards finding highly soluble non-migratory stabilizers for use in both solid and cellular polyethylene insulation.

Numerous stabilizers were examined to determine the relationship between both migration and temperature and migration and time for each base polyethylene. The results indicated that a number of stabilizers behaved in a non-migratory manner in both types of insulation.

Investigations were then commenced to provide information relating to the life expectancy of the insulation, that is, the effectiveness of any of the non-migratory stabilizers to protect against oxidation under normal service conditions.

Protection for Solid Insulation

Of the materials evaluated to date, it has been shown that Permanax WSP together with Eastman Inhibitor OABH offer the best protection as a primary antioxidant and metal deactivator respectively for *solid* insulation.

Protection for Cellular Insulation

Further studies are underway to determine the optimum stabilizing system for *cellular* insulation in both filled and air-core cables.

Fig 1: Cracked Insulation from Above Ground Jointing Enclosure

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MACHINE FOR IMPACT TESTING OF TELEPHONE CASES

Impact Testing

Telecom over a number of years has been studying the effects of sunlight on plastic telephone cases. Impact testing is used to measure the degree of strength reduction which occurs on the telephone cases.

Methods of impact testing vary. Some involve dropping a telephone from a fixed height onto a hard surface. Another method involves clamping the telephone, without the handset, to a rigid support. The telephone is then struck by a free falling, guided mass.

This latter method was used in an earlier testing machine but was found to give inconsistent results owing to energy losses caused by friction.

Design of Machine

In the latest type of testing machine, developed by the Research Department, the falling mass is guided by a pendulum similar to that used in standard Izod and Charpy testing machines. This pendulum type testing machine is designed so that the velocity of the striking face and the kinetic energy on impact is each equivalent to that of a 1.18 kg mass falling freely from a height of 750 mm.

In the addition the design is such that:

- the energy lost in the downswing is less than 0.25% of that available at release of the pendulum,
- the machine is self-calibrating and
- about 99% of the energy available at impact is transferred to the telephone cas under test.

Previous test results and field surveys indicate that the most vulnerable weak spots in the telephone casings are the corners. Consequently all measurements are made having the pendulum strike the case at those points.

Contact: Frank Wolstencroft 03-541 6213

PARROT DAMAGE TO MICROWAVE FEEDS

Microwave Feed Windows

Telecom Australia operates microwave telecommunications systems throughout Australia. These systems carry telephone calls, telex messages and other kinds of communications across long distances. The microwave beams travel between large dish-shaped metal antennas on high towers at intervals along the telecommunications route. The microwave beam is fed onto the dish surface via metal tubes placed at the centre of the antenna.

The beam in these systems leaves or enters the feed tube through a plastic window because such beams cannot pass through metal. A sealed window is necessary because the tube is kept pressurized with dry air to avoid corrosion and other undesirable effects of moist, external air.

Need for a Stronger Window

The antenna-feed windows in normal use around the world are very thin (0.15 mm) and are made of 'teflon' plastic. However, a problem has arisen in Australia because parrots have taken a liking to pecking and damaging these windows. There is thus a need to find a stronger bird-proof window.

Telecom has experimented with thicker (1.5 mm) windows in six different plastics materials that have been selected because they transmit microwave beams with negligible disturbance and have promising weather-resisting properties.

Exposure to Parrots

The various windows were exposed for 12 months to attack by five species of cockatoos in an aviary to obtain information on the performance of each window material and the behaviour of the cockatoos towards them.

Cockatoos were chosen as they are among the most destructive of Australia's parrots. The window type that has been used to date was included for comparison. All the materials are non-toxic to parrots.

Any window damaged was replaced several times after it had been damaged so that the frequency and pattern of attacks could be assessed.

The tests did not require the use of microwaves and none were used.

The rack on display was one of three placed in the aviary to hold simulated feed tubes during the trial. Fig. 1 shows a Pink or Major Mitchell Cockatoo (Cacatua leadbeateri) damaging the existing type of thin window.

(See photograph)

Results

The tests resulted in two of the materials being recommended for use and the others being recommended against.

The outcome of this investigation should increase the reliability of microwave telecommunications systems in many parts of Australia. It should also produce worthwhile savings by avoiding the high costs of refitting the present windows every time they are damaged by parrots.

Acknowledgement

The assistance of the Sir Colin MacKenzie Zoological Park at Healesville, Victoria, is gratefully acknowledged.

Contact: Geoffrey Goode 03-541 6604

Fig.1: Major Mitchell (Pink) Cockatoo Damaging the Existing Type of Thin Window

ANALYSIS OF VAPOURS FROM INDUSTRIAL PROCESSES

Hazard Surveillance

The application of new analytical techniques to the surveillance of telecommunications plant and practices has resulted in several areas of Research Department input to guard against hazardous exposure of workers and plant.

Examples of these applications are discussed below.

Polyurethane (PUR)

PUR materials may be used in telecommunications for a wide variety of purposes. For example:

(a) as rigid foams to seal occupied and unoccupied cable ducts, thus preventing unwanted vapour and liquid migration between sections of underground plant
(b) as air-cured elastomeric encapsulants for cable 'joints' which can be stripped and remade
(c) as resilient foams for cushioning delicate electrical parts in transit and
(d) for foam-in-place packaging, wire varnishes, coating applications and in fact anywhere where the item increases engineering efficiency and economical advantage.

This increased potential usage has required the preparation of safety assessment data owing to the possible presence of diisocyanate monomer in urethane curing processes.

Vapours of low molecular mass diisocyanate have a documented history of producing toxic respiratory effects in sensitized workers at very low exposure levels.

Analysts have found quantitative methods based on colour development to lack sensitivity for monitoring pilot scale trials of PUR applications. By use of reverse phase high pressure liquid chromatography (HPLC), values one-tenth of the recommended safety standard levels for any diisocyanate monomer may easily be detected in a 40 litre air sample.

The experimental procedure involves drawing workplace air through an all-glass absorption system. This air stream is brought into intimate contact with the absorbing and complexing solution, which may be a simple alcohol or a more complex structure, e.g. 'nitro reagent'. Any diisocyanate present rapidly forms a chemically stable derivative that can then be analysed in solution by HPLC with detection by molecular absorption of ultraviolet radiation at 254 nanometres.

This analytical procedure also enables a mixed diisocyanate system to be separated and allows simultaneous quantification.

Polychlorinated Biphenyls (PCBs)

These constitute an eco-toxicological hazard that could, in some circumstances, be encountered in certain types of telecommunications equipment. These chemical materials are encountered as heat transfer media in transformers or capacitors that are normally sealed systems at the time of manufacture.

Since leaks may occur, a rapid analytical procedure for the identification of any spillage was found necessary to guide staff taking remedial action. A laboratory method that depends on the analytical technique of capillary column separation, followed by gas chromatography coupled with mass spectrometry (GC-MS), was developed. The coiled capillary columns used for this work were of flexible silica and were 25 metres in length with an internal diameter of 0.3mm. The inner wall of the column was coated with a methyl silicone compound to enable the separation of the chlorinated biphenyl mixture.

A range of commercial PCB compounds have been analysed using this technique and the resulting mass spectra have been stored on computer disc. These stored data have enabled the collection of a comprehensive reference library of the mass spectra of PCB compounds. Mass spectra obtained from the GC-MS analysis of an unknown sample can be quickly compared with the reference spectra using a computer program to give unambiguous identification of the many specific types of PCB in the sample.

Encapsulants

When making external terminations of conductors or jointing cables, the connection or joint is frequently protected from the environment and electrically insulated by encasing it in a special resin encapsulant.

Ingredients used in combination to form encapsulants of the epoxy type need to be carefully checked for low residual levels of intermediate processing chemicals that are unacceptable in the working environment of the ultimate Telecom user.

Epichlorohydrin is one such material that the chemical analyst must determine in very small amounts.

A new technique that enables these trace level measurements to be made routinely using fine bore, flexible tubes of silica as chromatographic separating columns is now in use.

Contact: Frank Baker 03-541 6570

DURABILITY OF PAINTS ON GALVANIZED STEEL STRUCTURES

The Need for Painting

For many years Telecom Australia has erected considerable numbers of radio transmitting masts and towers. Current technology indicates a continuing need for the erection of these structures.

The masts and towers are fabricated from galvanized steel. In inland rural areas of Australia this combination of zinc and steel is an extremely durable system. The protection that the zinc coating gives to steel is dependent on zinc being more chemically reactive than iron so that the zinc sacrificially corrodes in preference to the steel. In corrosive environments, such as coastal or heavily industrialized areas, the zinc corrodes rapidly and eventually all galvanic protection is lost, giving rise to the rusting of the steel substrate.

Two situations where it becomes necessary to paint towers and masts are:

(a) in corrosive environments where the zinc is susceptible to rapid corrosion and

(b) where the structures are within prescribed distances of flight paths and are painted in contrasting aircraft warning colours, to increase their visibility.

Adhesion

Difficulty is often experienced in obtaining good adhesion to galvanized steel, especially to new galvanized surfaces. All too often the paint flakes off after a short period of exposure. A chief cause of such early adhesion failure, apart from improper cleaning of the surface, is chemical reaction between the new zinc and many paint vehicles.

Durability

Good durability of paints applied to galvanized steel can be assured by:

(a) thorough cleaning of the surface immediately prior to painting, which may involve abrasive blasting,

(b) chemically treating the zinc surface to form a corrosion resistant, paint receptive barrier between paint and zinc and

(c) careful choice of primers and paint systems that are compatible with galvanized surfaces.

Generally speaking, it is in pursuit of this last objective that exposure trials of painted galvanized steel are conducted by the Research Department, at the following sites in Australia.

Mild:

Clayton, Victoria. Urban, light industrial with moderate ultraviolet radiation intensity.

Moderate:

Mount Isa, Queensland. Arid with high ultraviolet intensity.

Brisbane, Queensland. Urban, sub-tropical with moderate ultraviolet intensity.

Severe:

Ceduna, South Australia. Coastal with high ultraviolet intensity.

Very Severe:

Portsea, Victoria. Marine environment with medium to high ultraviolet intensity.

Tully, Queensland. Tropical with high humidity and moderate ultraviolet intensity.

Results of Trials

Results of exposure trials at these sites have indicated:

(a) Water based acrylic latex paints have excellent adhesion to new galvanized surfaces and excellent resistance to ultraviolet radiation. They are highly suitable for use in non-corrosive environments of high heat and ultraviolet intensity, such as inland Australia and in any mild to moderate environment. They are non-toxic.

(b) Chlorinated rubber paints effectively protect galvanized surfaces in very severe environments. They are cheap, easy to apply, give excellent intercoat adhesion and are non-toxic. They do tend to chalk markedly but, if high build coatings are used, this is not a serious shortcoming. Currently trials are being conducted with high build chlorinated rubber paints, top coated with acrylic latex paints, to protect the chlorinated rubber paint from ultraviolet radiation degradation.

(c) Acrylic modified polyurethane enamels are showing no perceptible change in colour or gloss and no chalking after two years exposure. While this time is short, they have demonstrated a durability superior to other paint systems over that period. Although they are two-pack, isocyanate prepolymer cured and more suited to shop application than field application, their high abrasion resistance permits pre-coated members to be successfully transported to an erection site, with minimal damage. They combine excellent ultraviolet and chemical resistance with high abrasion resistance but, unlike unmodified polyurethanes, exhibit good intercoat adhesion, which enables them to be successfully recoated several years after the initial application.

Contact: Roger Pierson 03-541 6578

BATTERY TEST FACILITY

Mechanical and Electrical Systems

Telecom Australia has a large investment in secondary storage batteries in the no-break power supplies of exchanges and other equipment stations throughout the network. The stationary lead-acid batteries, which are the basis of the emergency power supplies, must combine long service life with reliability. The Research Department has therefore for some years undertaken test programs to monitor the quality of these batteries.

In order to improve the efficiency of this testing, an automated, fully instrumented battery test facility has been designed and constructed within the Reseach Department.

The test programs, conducted in accordance with Australian Standard AS 1981, provide for cyclic charge and discharge routines to determine battery capacity of six types ranging in capacity from 25 to 3200 ampere hours. The facility provides six distinct test bays, one for each type of exchange battery, arranged so that each type can be tested readily at its ten, three and one-hour discharge rates.

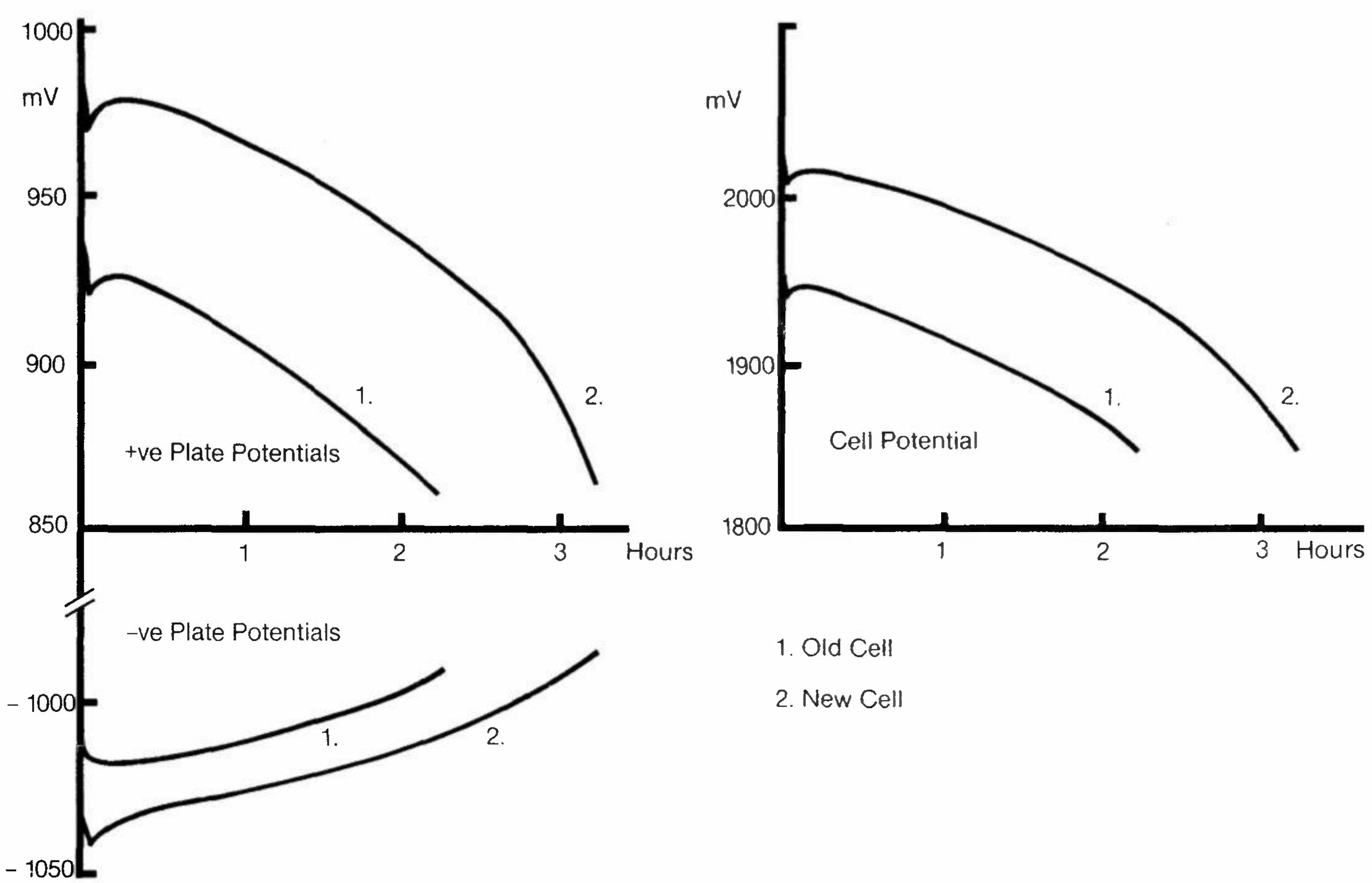
Each battery under test is provided with its own set of resistive loads, which are terminated on an insulating panel above the battery. Charging and discharging are achieved by the controlled operation of a contactor, the change-over contacts of which interconnect the battery with the load or charger by means of heavy cables or busbars, depending on the required current level.

Electrical mains power supply to the battery chargers totals over 50 kVA. If simultaneous discharge tests are conducted on all bays at the one-hour rate, the power dissipated in the load resistors exceeds 26 kW. Thus, most loads are water cooled with an externally-located, chilled, cooling water system. The plant is sized to handle 22 kW. The smaller load resistors are air cooled.

A comparison between a new cell and an old cell, during a 3h discharge test, shows changes in cell potentials and positive and negative plate potentials with respect to time; as well as positive and negative plate polarization differences during discharge.

By comparing the relevant charge curves, it can be seen that the older cell accepts much less capacity during charge. Its positive plate polarization is also considerable.

Fig 1: Discharge Curves



Positive and Negative Plate Potentials Versus Mercury-Mercury Sulphate

Automated Control and Data Analysis System

Control software and hardware is essentially identical for all bays. The facility comprises seven sub-controllers, each of which controls the test program for batteries of a particular capacity. The seven sub-controllers are themselves controlled by a desk-top computer type via an IEEE Standard 488 bus. This computer can commence a series of tests via any sub-controller individually, as well as process the collected test data.

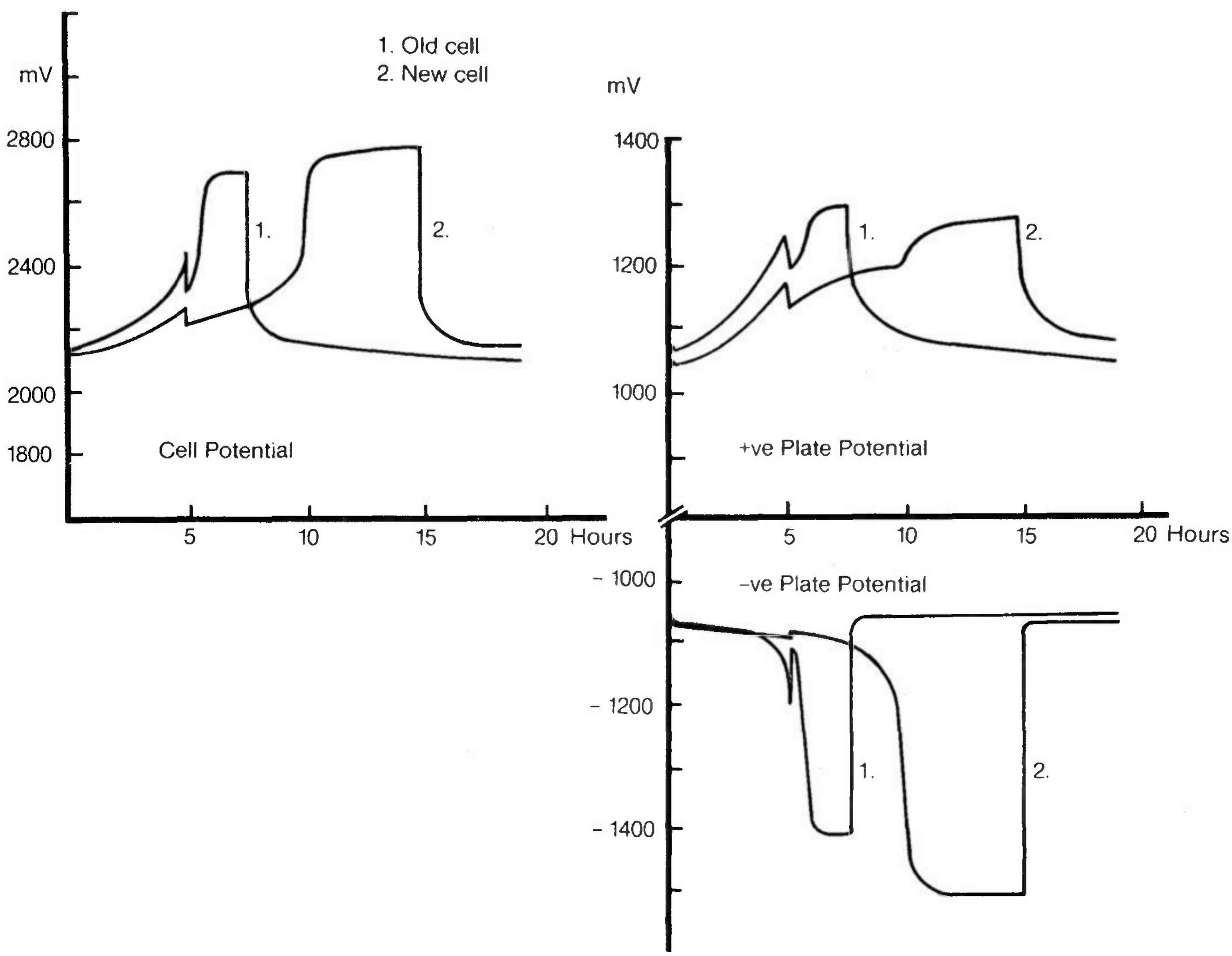
Because battery testing is a continuous process over many days, a special multi-tasking software program was written for the computer, which would collect the data from the sub-controllers when necessary, while allowing the operator to obtain results of current or previous tests in either tabular or graphical form. The data received from the sub-controller contains header information about the test, measurements of cell voltages, positive and negative half cell voltages and cell temperature for each cell being tested, as well as battery ampere hours and circuit test current. The data block, containing some 500 to 3000 bytes, is stored into a selected file on the Winchester disc memory (16 Mbytes capacity). A separate file (containing up to 2000 data blocks on 0.5 Mbytes of disc storage) is used for each particular test run.

Program operation is by means of ten different sets of special function key overlays. The eight key definitions for each overlay in use can be displayed on the computer screen. Other elements of the program are operated either by menu selection, form filling or the special input routine. Provision has been made for utility programs, in the form of sub-programs, to be loaded into memory as required to perform non-standard tasks.

While data are being collected, other data that has been collated and analysed from current or past tests can be presented as a graphical display either on a computer screen or by using a multi-pen plotter. The screen image can be modified using the digitizing facilities of the computer to home in on any particular part of the test of special interest.

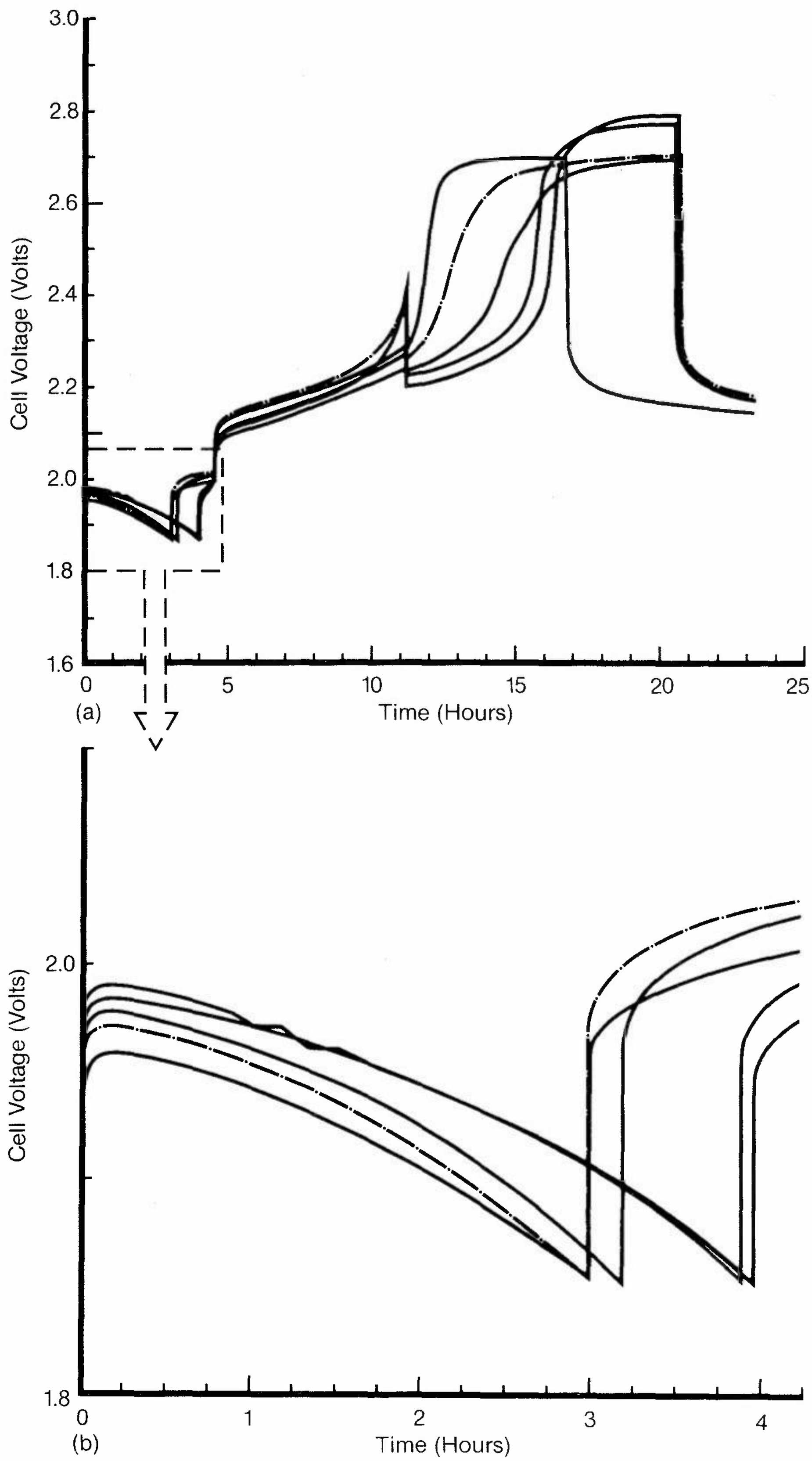
The Research Department's battery test facility has now been automated to a degree that allows an extensive program of battery testing to be performed. This automation is expected to permit data on the service behaviour of re-chargeable batteries to be collected and analysed more systematically, to assist in the development of more efficient operating practices and, hopefully, of better battery design techniques.

Fig.2: Charge Curves



Positive and Negative Plate Potentials Versus Mercury – Mercurous Sulphate

Fig.3: Typical Cell Voltage Characteristics of Five Batteries During Discharge-Charge Tests:



(a) Over one complete discharge-charge cycle

(b) Expanded portion of (a) showing discharge cycle in greater detail.

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EFFECT OF CHEMICAL CONTAMINANTS ON LEAD-ACID BATTERIES

Chloride Ion

The chloride ion is a common contaminant in battery acid. The introduction of contaminated acid or topping-up water or the breakdown of chlorine containing components within the battery are the most frequently encountered sources. Some of the chloride ion may be converted, by chemical oxidation at the positive plate, to gaseous chlorine and subsequently expelled from the battery. However, the remaining chloride will be converted to perchlorate ion, which is quite stable and eventually builds up to a damaging concentration.

Organic Contaminants

Another contaminant occasionally found in b^ttery electrolyte is organic acid. Organic acids are produced in a lead-acid battery by hydrolysis and by the oxidation of organic substances at the surface of the positive plate. A common end product from the degradation of organic materials is acetic acid, because it is relatively stable to oxidizing conditions. Contamination can occur by the use of acid or topping-up water containing organic material. Wood products, sugar contained in beverages or alcohol (accidentally used instead of distilled water) are examples or materials responsible for battery failure.

Effects of Contamination

The observed effects of the perchlorate ion and organic acid on the lead-acid battery are similar. Severe corrosion of the positive grid occurs and may continue to the point where cracking of the case, due to expansion of the positive plate, will terminate the life of the battery.

Analysis of Chloride and Perchlorate Ions in Battery Acid

The battery acid sample is refluxed in a 40% sulphuric acid medium containing titanous ions, with metallic zinc pellets also being present to maintain the concentration of titanous ions. The perchlorate ion is reduced to chloride ion and the titanous ion is oxidized to titanic ion. The total chloride concentration is determined potentiometrically (See Fig. 1, with a silver/silver chloride electrode using a mercury/mercurous sulphate reference electrode) by titration with standardized silver nitrate solution.

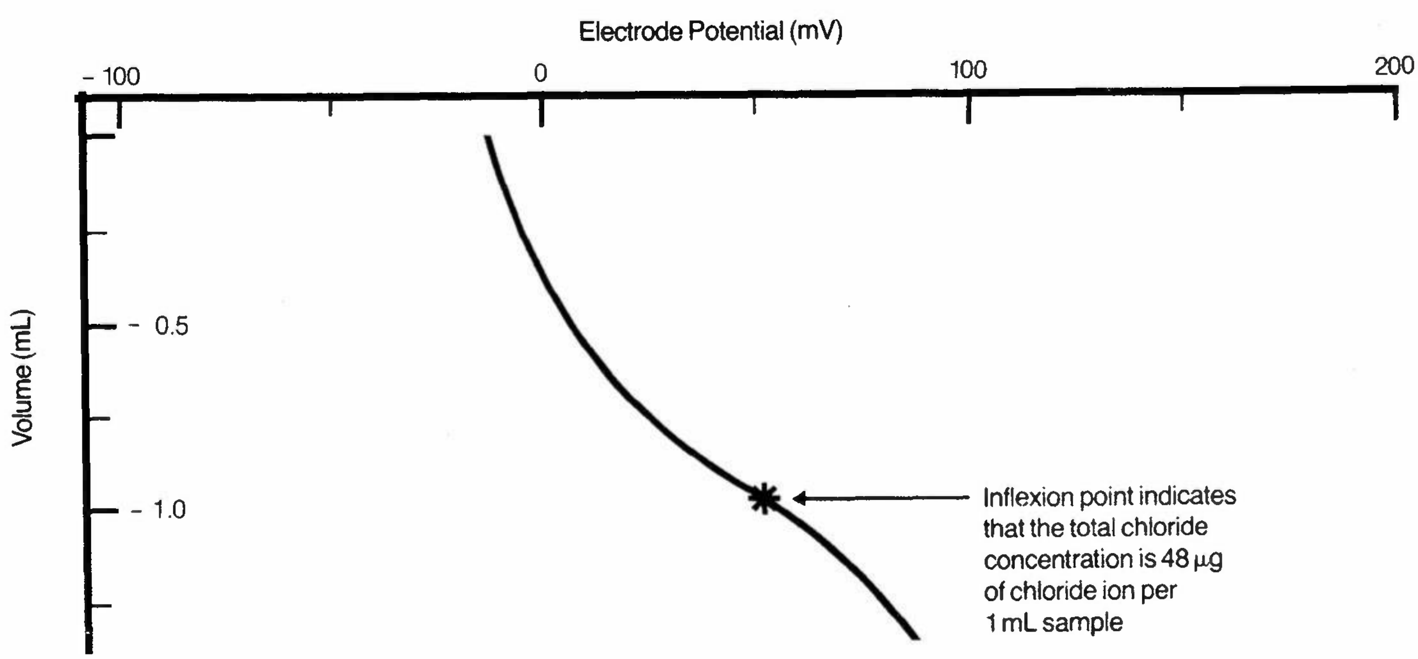

Fig. 1: Potentiometric Determination of Total Chloride Ion

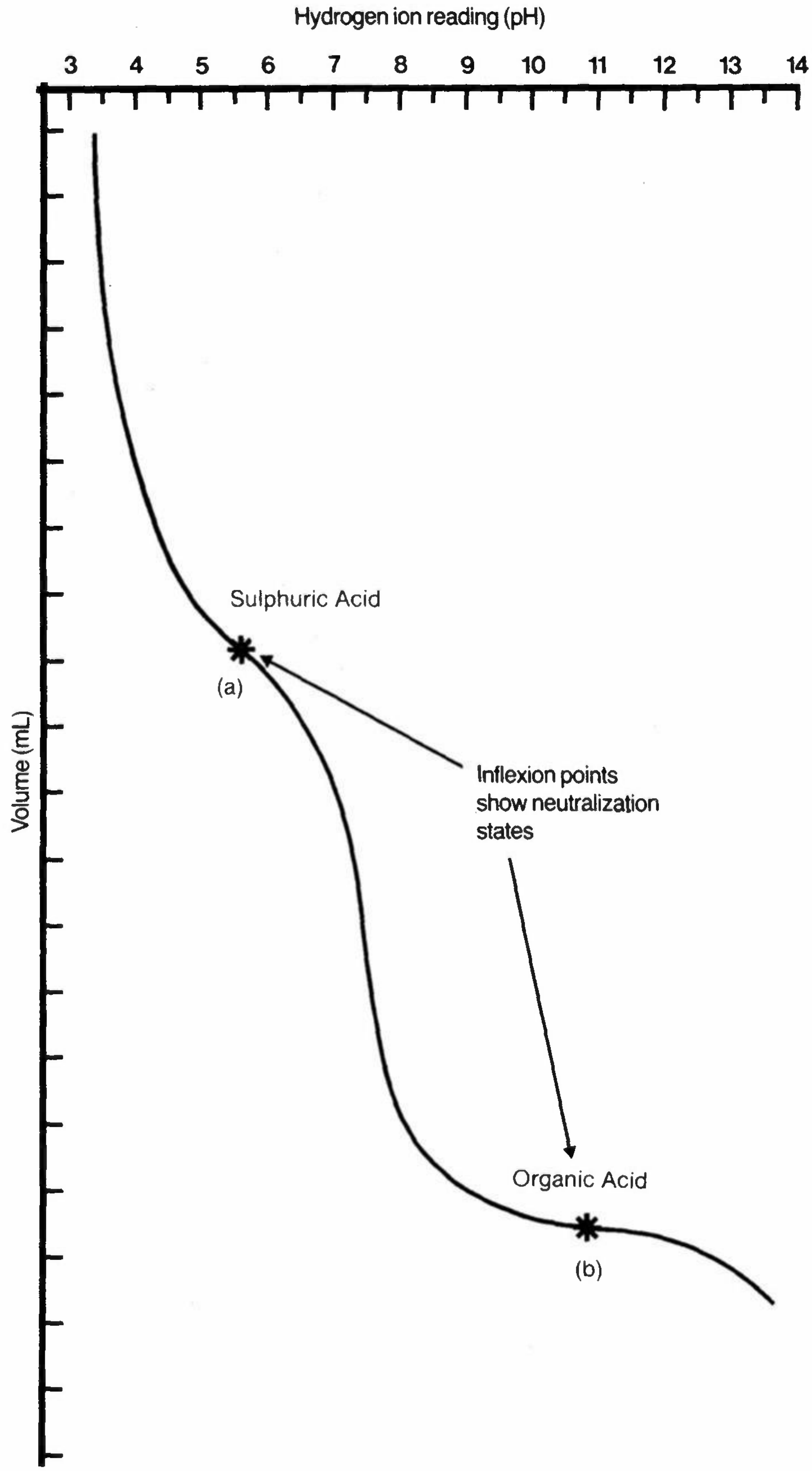

Fig.2: Titration of Organic Acid

A separate sample of the battery acid is titrated to determine the concentration of chloride originally present. The difference between the first titration (total chloride) and the second titration gives the amount of chloride derived from the reduction of perchlorate.

Analysis of Organic Acid in Battery Acid

The battery acid is distilled to separate the volatile organic acids from the extreme excess of the sulphuric acid. A sample of the distillate is then titrated potentiometrically with alcoholic alkali in an alcoholic medium using a glass pH sensing electrode so as to utilize the difference in ionization constants exhibited by the strong and weak proton activities of the acids in non-aqueous media.

A titration curve (See Fig. 2) with organic acid present will show two well defined inflexion points:

(a) the first indicates the neutralization of sulphuric acid (and any other strong mineral acids such as hydrochloric or nitric),

(b) the second indicates the neutralization of the weaker volatile acids such as acetic acid.

Contact: Joe Der 03-541 6561

METAL SERVICE FAILURES & DEVELOPMENT PROJECTS

Range of Exhibits

Metallurgical work performed by the Research Department in part incorporates both developmental and failure analysis on a wide range of components and metals. Examples of these include microwave and radio frequency masts, automotive plant, tools, small electronic components and telephone exchange equipment.

The display comprises a demonstration of typical metallurgical microstructures, a selection of components that have been examined for failure analysis and several components that involved developmental work.

Metallurgical Microscope

The display demonstrates the use of a metallurgical microscope for the examination of microstructures. The information gained plays a vital part in determining aspects such as heat treatment, method of manufacture and service effects such as corrosion, fatigue work hardening and the initiation and growth of cracks.

Metal Whiskers

Metal whisker growth has been widely reported in a variety of metals. These fine filamentary growths have occurred in low current capacity electrical equipment, such as telephone exchange relay sets, telephone handset dials and transistors, causing short circuits. Measurements made on typical zinc whiskers indicate the fusing current is of the order of 2 to 8 milliampere.

Typical whiskers can be 3 mm long with a diameter of up to 1 µm.

Cavitation Erosion of a Cylinder Liner

The cavitation of these cylinder liners has been caused by the 'implosive' force of bubbles formed within the cooling water by engine vibration.

Strain Age Embrittlement

Certain types of steel when cold worked and then reheated within a critical temperature range can become brittle.

Fractures Due to Fatigue Cracking in Steel Components

Fatigue failures are associated with high alternating stresses. The excessive stress is usually caused by incorrect design, poor surface finish, incorrect balancing or misalignment of components.

Towing Eyes for Plant Trailers and Caravans

Failures have been experienced with fabricated towing eyes owing to inadequacies in design and material strength and deficiencies in fabrication. The redesigned towing eyes are forged from steel conforming to Australian Standard A.S. 1444-1981 Grade 4140 and then heat treated. Sharp notches in high stress areas and the welding operation are avoided.

Pneumatic Excavation Tool Bits

These tools have been redesigned to give higher impact and wear resistance using a 2% silicon shock-resisting steel in place of the traditional plain carbon steel. Field trials are currently being performed.

Ditch Digging Teeth

These items have long had a poor service history of wear and failure. This has resulted in costly down time. A specification of material, heat treatment and hard facing has been developed to improve their performance.

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TESTING OF MT. WELLINGTON RADOME

The Need for a Radome

Telecom Australia is responsible for technical servicing of Australian Broadcasting Corporation broadcasting installations. For a number of years problems have been experienced with the ABC television antenna on Mt. Wellington (1300 m above sea level) near Hobart, Tasmania. During winter, ice builds up on the antenna and, unlike more severe climates where the ice remains frozen until spring, it may thaw out a number of times through winter. Blocks of ice, some weighing as much as two tonnes, break off and fall to the ground, sometimes damaging the antenna, the tower and coaxial feeder cables. Various methods have been tried, unsuccessfully, to overcome the problem and when the decision was made to upgrade the old TV antenna and to install an FM radio transmitter on top of the TV tower, it was also decided that a protective radome should be constructed around the two antennas to prevent ice forming.

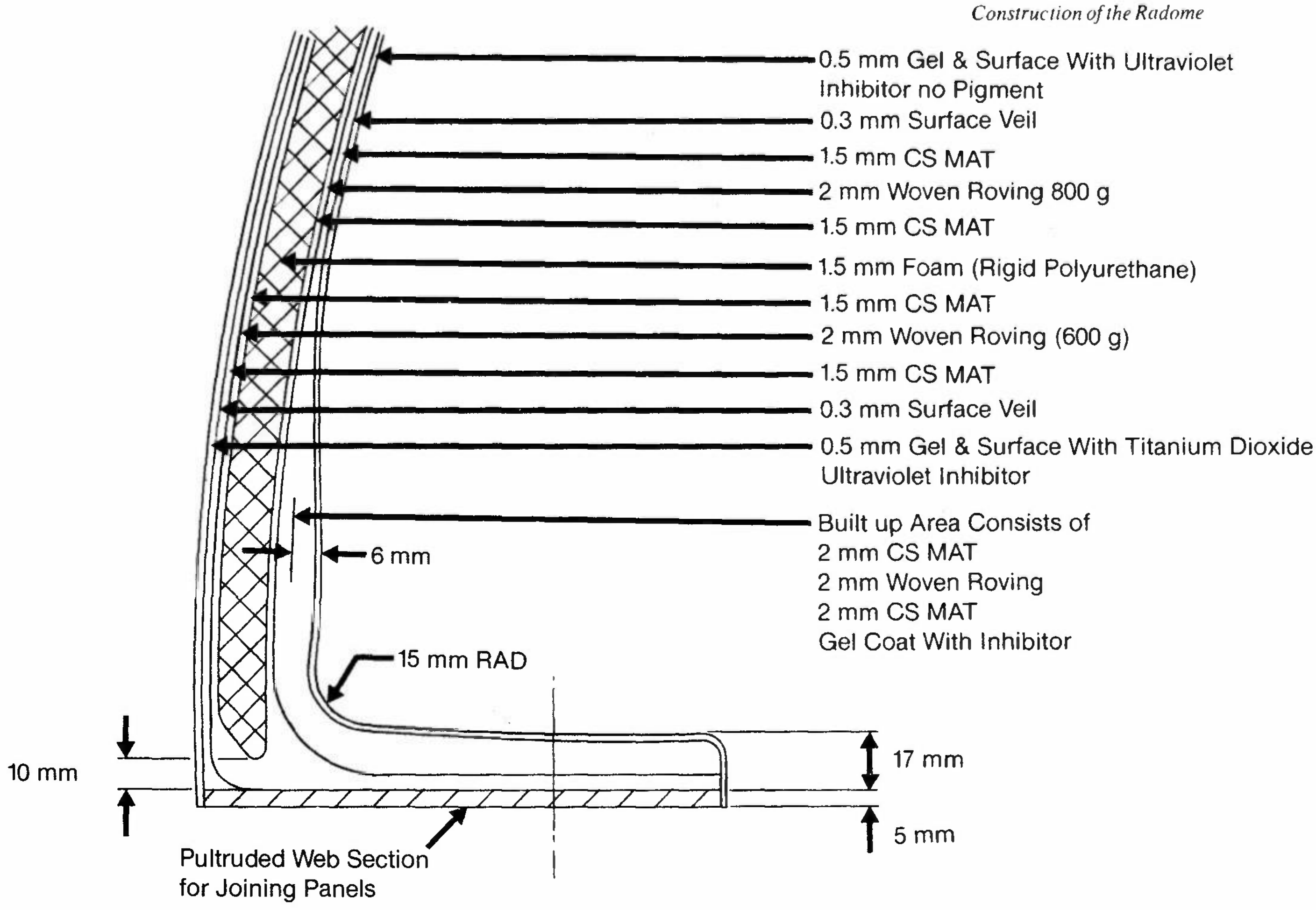
Scientists in the Research Department provided technical support for the project. Initially, advice was given on material selection, properties and methods of fabrication, which was followed by prototype testing and quality assurance surveillance on the raw materials used for manufacture.

The Radome Shell

The radome is positioned on the tower 74 m above ground and the shell consists of two hollow cylinders built up from sandwich panels of Fibreglass Reinforced Polyester (FRP) laminate and polyurethane foam, manufactured using the hand lay-up technique. Fig.1 shows cross-sectional details of a panel and joining web. The lower cylinder is 19 m high and 7.6 m in diameter and comprises 40 interlocking panels each weighing 250 kg, which had to be hoisted from the ground and fitted into place. This was completed early in 1982. Fig. 2 shows that stage of the work in progress. The upper cylinder, which comprises 12 panels, is 7.6 m high and 2 m in diameter. The 12 panels were lowered into position from a helicopter early in 1983, to complete the project. The completed radome is shown in Fig. 3. The space between the two cylinders is enclosed by a 3 m high sheet steel truncated cone, with acrylic windows to provide natural lighting for staff inside the radome carrying out maintenance on the antenna.

(See photographs)

Fig. 1 Cross Section of Sandwich Panel of FRP and Polyurethane Foam used in Construction of the Radome



Support Structure for the Shell

The support structure for this shell comprises a number of 'pultruded' beams with U-channel, right angle and I-beam cross sections. 'Pultrusion' is a continuous process where reinforcement (typically glass rovings) is impregnated with resin (usually polyester) and pulled through a heated die to produce the required profile. The I-beam used was of special interest, having approximate cross sectional dimensions of 300 x 150 x 13 mm, and was produced by pultrusion as a special mill-run in the USA. It is the first time that such a large plastics beam has been used by Telecom.

Testing of Support Structure

The design for the support structure of the radome was based on the manufacturer's data but, in the absence of previous field experience with this material, it was considered worthwhile to determine certain engineering properties by full scale testing. Special jigs were constructed for use in a 60 tonne tension and compression testing machine. Bearing forces around bolt holes in the pultruded sections were determined and found to be well in excess of the figures allowed for in the design. Deflections of the I-beam under three-point bending were measured and were found to be greater than the theoretical values calculated using the manufacturer's data. Nevertheless they met design requirements.

Test of Shell Panels

During its expected working life of at least 30 years, the radome will need to withstand the extremes of temperature and wind gust speed to be found at the site. Gusts can reach 230 km/h, which would produce a positive pressure of 2.4 kPa and a negative (suction) pressure of 5.75 kPa on the radome. A prototype panel mounted on a special test jig was subjected to these pressures over the temperature range −6 to 29°C. The panel deflections that were measured confirmed that the design was satisfactory.

During fabrication of the panels, quality assurance testing was necessary to ensure that design parameters were achieved. This involved measuring the exothermic reactivity of the resin used for lay-up and mechanical tests, such as hardness, flexural modulus and inter-laminar shear, on sample laminates prepared concurrently with the main panels.

To date, the radome has withstood the rigours of three winters. It can confidently be expected to do so for many years to come.

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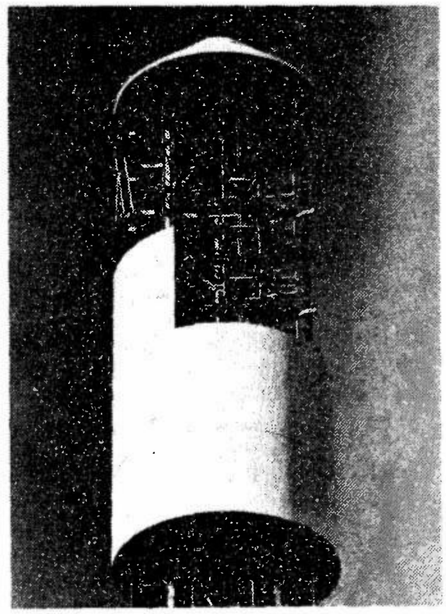

Fig. 2 Construction of Lower Section of Radome, Early 1982

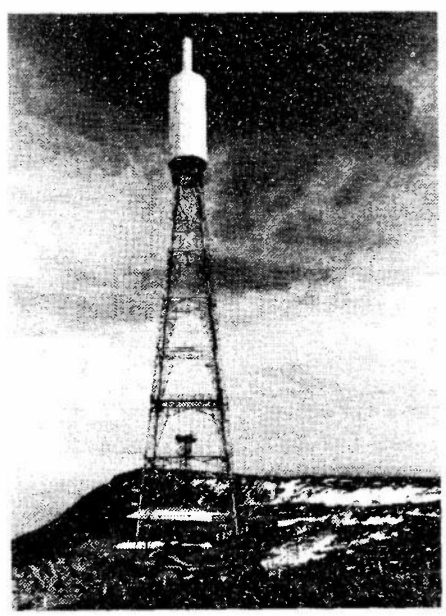

Fig. 3 View of Completed Radome on Tower at Mt. Wellington, Tasmania

FIRE-RESISTANT WIRE & CABLE

The Need to Replace PVC

Wires and cables currently used in telephone exchanges throughout Australia are insulated and sheathed with flexible polyvinyl chloride (PVC) compounds. As well as being relatively cheap, with an ability to be formulated and compounded at the cable manufacturing site, they were historically used because of their resistance to fire due to the presence of chlorine atoms in the structure of the polymer. Unfortunately, once a fire is established they will burn and give off hydrogen chloride gas which, with water, forms hydrochloric acid. This corrosive acid affects personnel, switching apparatus and even the structural steel in the buildings. Hence replacement materials for insulation and sheath have been pursued in recent times. An additional reason for finding an alternative to PVC for insulation is that modern telephone exchanges demand a thinner wall thickness which PVC cannot provide.

Fire-Resistant Wire Insulation

A material that is currently favoured for insulation on wires is a modified polyphenylene oxide (PPO), which does not contain any halogens (chlorine, fluorine, bromine or iodine). For insulated wires, a combustion test that measures the concentration of oxygen required just to keep the insulation burning shows that a typical value for the PPO wire is approximately 33% oxygen, compared to the not less that 28% oxygen currently specified for PVC insulated wire. The concentration of oxygen in the normal atmosphere is 21%.

Fire-Resistant Sheath

For the sheath, a polyolefin, filled with up to a 60% loading of aluminium hydroxide ($Al(OH)_3$), is being considered. In a fire, the filler is reported to act as a fire retardant by the following method. Firstly the high filler loading significantly reduces the amount of plastics in a given length of sheath and hence reduces the amount of combustible material. Secondly, $Al(OH)_3$ endothermally decomposes to give $Al_2O_3.3H_20$ and thus absorbs heat that would, in the case of many other plastic materials, be decomposing the plastics. Thirdly, the $Al(OH)_3$ is eventually consumed. The water of crystallization in the $Al_2O_3.3H_2O$ is given off as steam and that is also a process that absorbs heat. Fourthly, the steam dilutes the gaseous combustion fuels and restricts the availability of oxygen from the atmosphere.

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OUTDOOR WEATHERING OF SAFETY HELMETS

The Need for Weathering Tests

Plastics safety helmets are issued to Telecom Australia's staff in a variety of work situations in accordance with the overall policy on occupational safety and health. The majority of helmets are worn by staff working outdoors and therefore exposed to the weather. Generally speaking, exposure of plastics to sunlight (ultraviolet and infrared radiation) initiates degradation mechanisms that ultimately lead to the embrittlement and failure of the plastics. Such embrittlement reduces the impact strength of the plastics, one of the key properties required in a safety helmet.

However information gathered from industrial sources and literature, up to 1979, revealed that no comprehensive long-term evaluation of the weathering properties of plastics industrial safety helmets had been reported either in Australia or overseas, although the relevant Australian Standard at that time, A.S. 1800-1975, advised that helmets be checked for compliance with the standard after 5 years use outdoors. This period was later reduced to 3 years in A.S. 1800-1981. It was obvious that reliable data on the outdoor weathering of plastics industrial safety helmets was needed and in 1979 a project was commenced to:

- study the effects of outdoor exposure upon plastics industrial safety helmets and select the material most suited for this purpose and
- determine the 'safe working life' of a helmet manufactured from this material.

The Outdoor Testing Program

A total of 2500 helmets was manufactured from the plastics listed below and some 1700 were mounted on foamed polystyrene head forms, in the grounds of the Research Department at Clayton, Victoria. The remainder were stored indoors as 'control' helmets. The plastics were:

- ABS — Acrylonitrile butadiene styrene
- ASA — Acrylonitrile styrene acrylic elastomer
- HDPE — High density polyethylene
- PP — Polypropylene
- PC — Polycarbonate

At half-yearly intervals, helmets were withdrawn from the racks and subjected to the following tests in accordance with AS 1801-1981:

- Stiffness — assessed by stressing the helmet with forces applied to the sides and noting the maximum deflection.
- Shock absorption — assessed by measuring the maximum deceleration of a striker impacting a helmet fitted to a rigidly mounted headform.
- Penetration — assessed by impacting a helmet fitted to a rigidly mounted headform, with a specified striker and noting whether or not contact is made between the headform and the striker.
- Electrical insulation resistance — assessed by applying a specified test voltage to a helmet that has been conditioned in brine and noting the maximum leakage current.
- Colour change — additional to tests listed in AS 1801. Colour expressed in terms of Hunter's L, a, b co-ordinates.

Unexposed helmets being used as the control specimens were tested on an annual basis over the test period.

Results of the Tests

After the five years continuous outdoor exposure, only helmets manufactured from ABS and polycarbonate met the requirements of AS 1801-1981. Since the helmets used by Telecom Australia, all of which are of ABS, are withdrawn from service 3 years after their date of manufacture, which is stamped on them, a useful safety margin is apparent.

The final stage of this project is now in progress with ABS helmets exposed in a hot, dry climate at Cloncurry in Queensland. Helmets will be removed annually and subjected to the series of tests previously described. Data will be compared against that obtained from the Clayton site to determine the extent by which service life is reduced by more severe climatic conditions.

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IC CHARACTERIZATION & FAILURE ANALYSIS

Reverse Engineering of Integrated Circuits (ICs)

A wide range of integrated circuit technologies is currently in use in telecommunications equipment and ICs may fail in a number of different ways.. When failures occur it is essential to discover the reason in order that corrective measures may be taken. The process of taking the circuit apart one layer at a time, to discover how it was designed and fabricated, is an essential prerequisite for failure analysis. Technology is advancing continually and individual failure analysis and reverse engineering techniques may have to be varied in particular cases but there are many common features in the process.

Removal of Encapsulant

The first step is to expose the IC chip in an undamaged condition so that it may be examined. ICs in ceramic packages may be opened by applying mechanical pressure if they are of the frit-seal type or desoldered if of the lidded type but, for plastic packaged ICs, the encapsulant, which usually consists of a thermosetting mixture of resin and glass, is selectively removed from over the chip by applying hot fuming nitric acid. With care, this severe chemical treatment does not damage the IC and enables it to be inspected optically. The chip at this stage appears a uniform colour, usually green or light brown when viewed under a vertically illuminated microscope, with components delineated by dark lines on the surface. A colour contrast between layers in the circuit, which allows positive identification of all individual features, may be obtained by removing the one micrometre thick glass passivation layer protecting the surface of the chip.

Metallization Layers

This layer is removed using buffered hydrofluoric acid and etching is continued until the top metallization layer is exposed. The features formed during each processing stage will now have different colours because of interference effects occurring in the different thicknesses of transparent silicon dioxide covering them and they thus may each be distinguished and identified. Thus, in a simple bipolar integrated circuit, the isolation, transistor collectors, transistor bases and resistors formed by base diffusion and transistor emitters, may be identified and components electrically characterized by microprobing to the exposed metal interconnection layer on the surface of the chip. In addition, sensitive electrical measurements used in conjunction with mathematical models may be used to obtain details of the diffusion processes used to form components in the silicon substrate and information on the vertical structure of the device may be obtained using a sectioning technique known as lapping and staining.

Lapping and Staining

Vertical distances in the chip can be amplified by mounting the chip, which has been removed from its package and carefully prepared, on a glass block and lapping it away at a shallow angle using an abrasive paste. A suitable preferential etch or stain is then applied to the chip which causes the p type layers to be differentiated from the n type layers. Vertical junction depths and important features such as transistor base width may then be measured directly with an optical microscope.

File of Information

By applying these step by step analysis processes, a remarkably complete file of information concerning the design, processing quality control, etc. of the device can be prepared and may be used as an aid in maintaining a high standard of reliability in ICs supplied to Telecom.

Fig 1: TTL Device after Removal of the Glass Passivation and Metallization Showing Contrasting Oxide Colours.

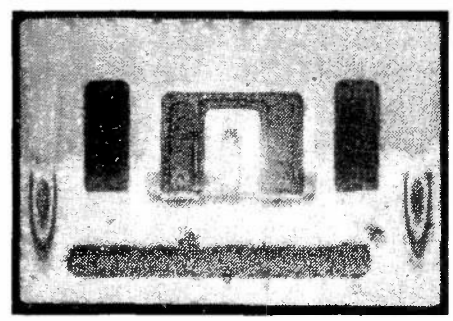

Fig 2: Lapped and Stained Section of a Transistor on a TTL Integrated Circuit Showing Base, Emitter and Isolation Diffused Regions.

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THICK FILM HYBRID MICROELECTRONICS

Hybrid Microelectronics

Hybrid microelectronics represents one of the several possible approaches to electronic interconnection and packaging. As the term 'hybrid' implies, this approach encompasses multiple technical disciplines that sometimes require compromises among layout design, process flow, component selection and final package configuration.

Developing a successful hybrid circuit design usually follows an optimized sequence of steps. This allows optimum ordering of the compromises to be made and the adoption of available options for the design concept.

Hybrid circuits represent a packaging approach for electronic components that is an intermediate between the conventional printed board assembly of discrete components and monolithic integrated circuits. The hybrid circuit approach substantially reduces the total volume of the packaged circuit as compared to printed board assemblies and retains the flexibility of being able to utilize and interconnect a variety of circuit components without the extensive design and tooling effort required for integrated circuits.

Hybrid circuits have many components such as resistors, capacitors and conductors deposited on the substrate, while other components such as transistors, integrated circuits and diodes are mounted there. The latter discrete components can be either cased devices, such as those used in a printed board assembly or, for increased packaging density, they can be uncased devices such as transistor, diode and integrated circuit chips.

Thick Film Circuit Elements

Thick film circuit elements are formed by sequentially screen printing, drying and then firing (850°C) conductive, resistive and dielectric pastes on a substrate. Multilayer interconnections are formed by the layering of conductor and dielectric pastes. Conductors, resistors and capacitors can be formed with this technology, while discrete components can be electrically joined to this interconnect system by solder or adhesive attachment. Both miniature, individually-packaged, components and uncased components can be used in this technology depending on the degree of environmental protection required.

The advantages of the thick film hybrid process include relatively low capital equipment requirements, a wide selection of resistor resistivities and cost-effective multilayer techniques.

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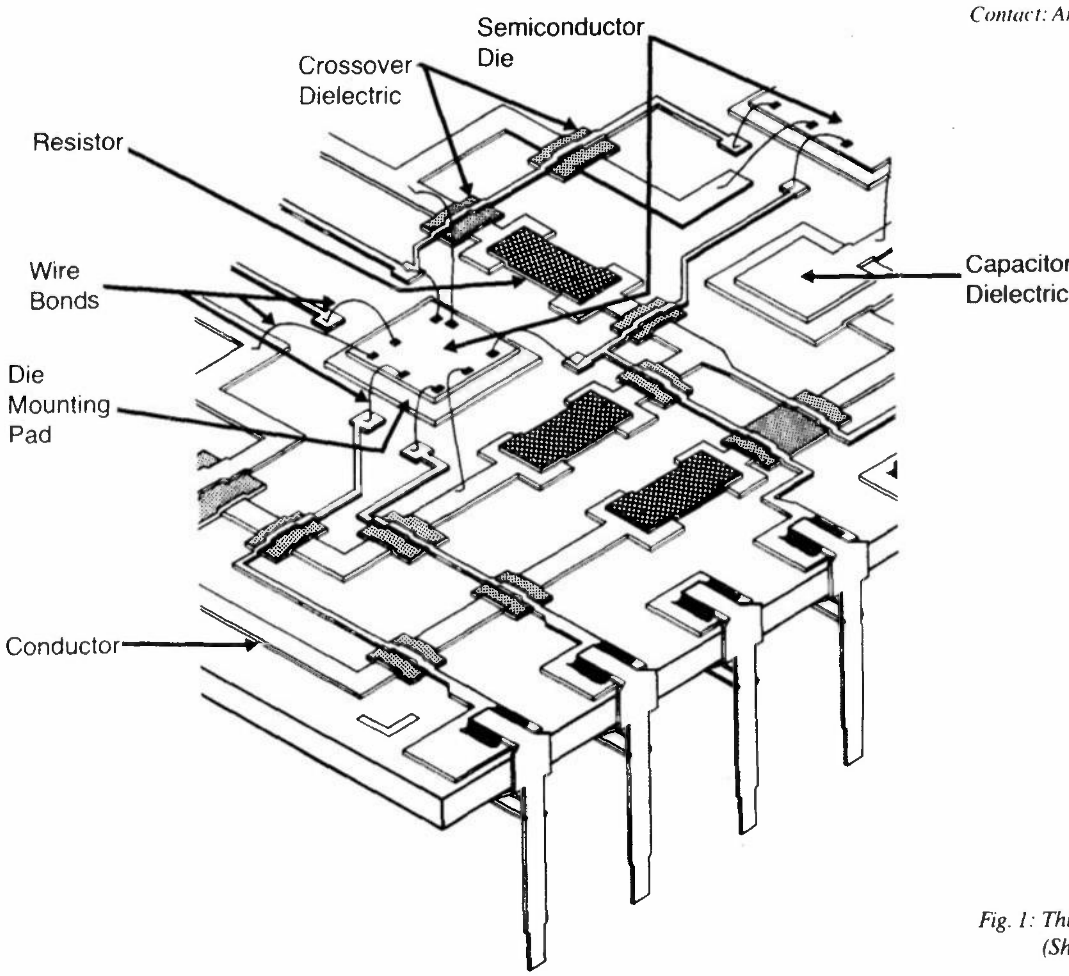

Fig. 1: Thick Film Hybrid Technology (Shown approximately 6 times real size)

PRINTED BOARDS

Background

The Research Department has a continuing requirement for prompt delivery of a considerable variety of printed boards for experimental and prototype electronic circuits. The artwork necessary for fabricating a printed board is either produced manually or with the aid of an Interactive Design System (IDS).

Artwork Production

Manual artwork is prepared at four times full size using a clear sheet of mylar onto which opaque tapes are added in the required conductor pattern. These artworks are made as either single sided or double sided and are subsequently photoreduced to obtain the production masters. However, the majority of artwork is achieved using an interactive design system. This system allows interaction between the layout designer and a library of information (data base) held in the computer system. This database has been developed over a period of many years and contains all the likely elements required to lay out even the most complicated circuits.

In operation the database is accessed by the designer from either a plotter and digitizer terminal or a Visual Display Unit (VDU). This allows the designer to create and view the layout as it progresses. On completion, a verification plot is drawn and checked against the original circuit requirements. Following any modification, the layout is produced on photographic film by means of an X-Y controlled light pen (photoplotter) to create the original production masters. Also, a paper tape is produced for a Numerically Controlled (NC) drilling machine, which is used to drill the hole pattern in copper-clad base material.

After the N.C. drilling operation, the non-plated-through-hole boards are processed to obtain the required conductor pattern. These processes involve photosensitizing, exposing, developing and finally etching to remove the unwanted copper to form the required conductor pattern.

Plated-Through-Hole Boards

On the other hand, plated-through-hole (PTH) boards are more complex to produce, requiring about 80 distinct operations. Some of these operations are necessary to deposit copper on the non-conductive interior wall of the drilled holes. The remaining operations are necessary to produce the plated-through hole and the conductor pattern. The plated-through hole is provided where necessary to interconnect the conductive patterns.

Many of these chemical and electroplating processes are automated. Briefly, the plated-through-hole processing sequence is:

(a) drill the metal clad base material,
(b) deposit electroless and electroplated copper (panel plate) over the entire board,
(c) laminate photopolymer resist, expose and develop,
(d) electroplate copper and tin-lead alloy to form conductive pattern (pattern plate),
(e) strip photopolymer resist,
(f) etch away unwanted copper,
(g) melt tin-lead plate to form solder layer and
(h) conduct inspection.

The final inspection is to ensure that the boards comply with the national (Standards Association of Australia) and international (International Electrotechnical Commission) standards necessary for their end use.

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THIN FILM HIGH SPEED HYBRID TECHNOLOGY

Uses

Thin film hybrid technology is being introduced into the Research Department for producing high speed digital and wideband analogue circuitry. Thin film hybrids have achieved wide acceptance in high frequency applications because of their excellent electrical performance and cost effectiveness. The high accuracy required in the microstrip transmission lines is easily realized in this technology.

Thin film hybrid technology is associated with vacuum, photolithographic and etching techniques. Either by sputtering or evaporation, the substrates are blanket coated with the relevant resistive, barrier and conductive layers, which are subsequently etched to produce the circuit pattern. Resistors are integrated into the circuit. Nickel-chromium resistors are extremely stable with temperature and may exhibit almost zero temperature drift. Trimming to 0.1% of value can be achieved.

Evaporation Techniques

In Telecom's facilities at the Research Department, both flash and electron beam evaporation techniques are used to coat the undrilled substrate. See Fig. 1. The substrate, which is normally 99.5% alumina, is placed in a high vacuum chamber where the material of the film to be deposited is heated until it evaporates as an atomic or molecular stream. This stream then condenses on the exposed substrate where it forms a film of that material. Control of the deposition rate and thickness of the film is accomplished by a microprocessor acting on information from a quartz sensor inside the chamber. Thickness of layers that may be deposited range from a few tenths of a nanometre up to thousands of nanometres depending on the material and purpose of the layer.

Patterning

A coated substrate having been produced, patterning the surface to form a circuit can then proceed. Photoresist is applied, selectively exposed to ultraviolet radiation and developed to form a pattern where thicker gold conductors are required to achieve optimum transmission properties. These conductors are built up by electroplating gold to a thickness of 8 to 10 μm. The photoresist is then removed. Repeated processes of photoresist spinning, ultraviolet exposure through masks, developing to remove unwanted photoresist and etching follow for each layer. Etching may be performed chemically or by sputter etching where the substrate is placed in a vacuum chamber and bombarded with high velocity ions. Sputter etching is used where extremely fine tolerances are necessary, as no undercut occurs.

The etched circuit is baked in a furnace to stabilize the resistors, which are subsequently laser trimmed to the tolerance required. Holes to connect the conductor pattern to the earth plane are then diamond drilled. Components that may then be mounted include chip and active devices in microminiature packages or with beam leads.

Vacuum Coating

At present, research is being carried out into techniques of vacuum coating laser drilled alumina-substrates to produce a connection between the two sides. The resistive layer, nickel-chromium, is the first layer, which is then overlayed with titanium and palladium barrier layers before the gold conductor layer is deposited. Further work envisages the use of tantalum nitride resistive films.

A current project is the manufacture of two prototype circuits. A 4-channel multiplexer and a 4-phase-divide-by-2 clock generator have been designed and implemented as printed board assemblies working at bit rates up to 1.1 Gbit/s. Fabrication of the circuits as thin film hybrids is presently being undertaken and the finished products are hoped to achieve bit rates up to 2 Gbit/s. The work involved has been instrumental in gaining experience and refining techniques for high speed thin film hybrid processing.

(See photograph over)

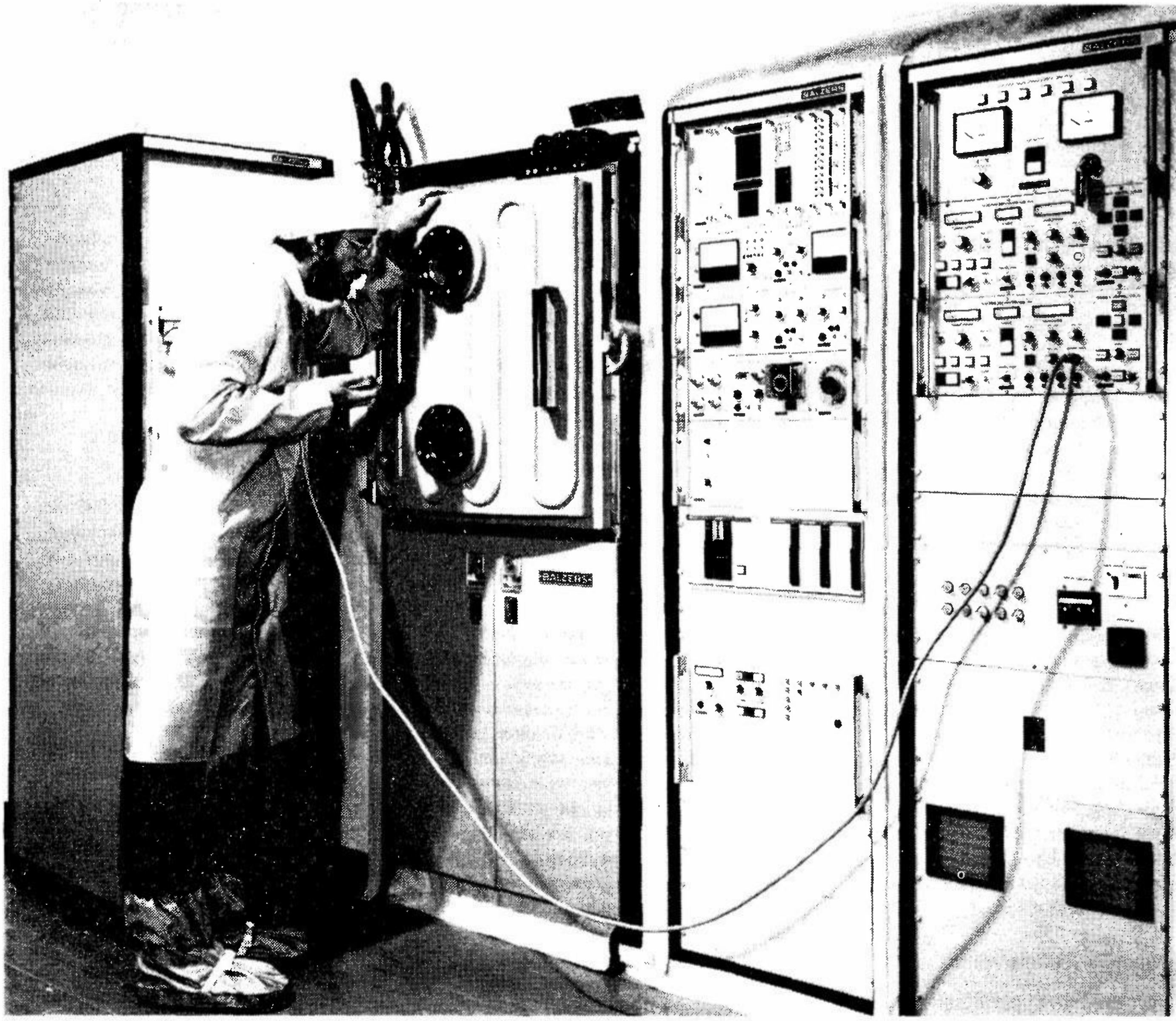

Fig. 1: High Vacuum Evaporation System

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CUSTOM-DESIGNED INTEGRATED CIRCUIT

From Multiproject Chip to Production

The Multiproject Chip (MPC) is an excellent method for bread-boarding a circuit in silicon. By sharing the cost of fabrication among a few designers, the chips can be produced at a reasonable price. However, the finished products cannot be used in real-life environments for the following reasons:

- the unsealed packages do not meet reliability requirements,
- the quantity received from MPC is too small and the chip is cluttered with other unrelated circuits,
- many of the circuit cells used in the design have not been characterized and tested,
- the adoption of simplified and conservative design rules in MPC reduces efficient area utilization and achievable performance,
- inoperative chips have not been weeded out before packaging and each returned chip has to be tested individually thus incurring high costs and
- no means is provided to exploit a particular fabrication-house processing speciality.

Fabrication Considerations

Whilst information on integrated circuit (IC) design for participation in MPC is readily available from various educational institutions, the design for production requires close co-operation with a fabrication-house. To find out the pitfalls and the considerations required for production of ICs, the Research Department has undertaken a project to fabricate chips by emulating production requirements. The following broad considerations summarize the findings:

- the design should be preceded by a complete system specification,
- circuit cells should be simulated and characterized to meet performance specification,
- design must be insensitive to processing parameter variations with simulation and verification at every stage of the design being necessary,
- IC production can rarely be multi-sourced remembering that the advantages of a particular fabrication-house in terms of its design rules, test equipment, processing features, mask requirement and yield statistics should be fully considered and desirable features exploited with consultation with the fabrication-house early in the design stage to prevent back-tracking,
- test circuits for automatic wafer testing should be incorporated during the design stage and input and output pads allocated for the purpose with consideration being given to any limitation of the test equipment, particularly when dynamic circuitry is used in the design,
- test specifications including test vectors, leakage current, temperature performance, supply voltage tolerance, input and output circuits logic levels, drive capability, current drain, operation speed and power consumption should be prepared,
- alignment marks on all mask levels and scribe-channels on levels specified by the fabrication-house must be included in the layout,
- packaging considerations should include cost, operating environment, reliability, chip size, number of pins, mounting techniques, substrate connection, identification of the design and orientation of the chip relative to the package pins,
- bread-boarding the design by participating in MPC is highly desirable for small designs or a small portion of a large design if simulation tools are not available but, ideally, simulation of the design covering process parameter variations is more effective,
- some factors may seem trivial but have significant effect on yield, thus bonding pads should be sufficiently large and well placed relative to the package bonding pads and active circuitry should be well spaced from the pads as well as from the scribe-channel to avoid damages during sawing or bonding operations and
- the designer should be prepared to allow two or even three design cycles before full production can begin and should also expect to change some portion of the circuit during the production stage to improve yield.

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PROGRAMMABLE ARRAY LOGIC DEVICES

Introduction

A characteristic feature of microelectronics technology has been the explosive growth in the capacity for performing an increasing number of functions in a single Integrated Circuit (IC) chip accompanied by a decreasing cost per function. There is now a number of alternative paths that designers can take to realize a 'customized' circuit. Fig.1 shows these alternatives and their basic features and Fig.2 shows their relative costs as a function of production volume. Reference 1, below, discusses these alternatives in more detail. The subject of this article is the Programmable Array Logic (PAL) family of devices, which is one of the field programmable device families. Reference 2 discusses the PAL family in more detail.

What is 'PAL'?

Programmable Array Logic (PAL) devices are mass-produced 'general purpose' devices that can be programmed by the user to suit his particular application. They are highly suitable for realizing low to medium complexity logic circuits and are most economical for small number of production runs, up to around 1000 units depending on circuit complexity.

Pal Structure

Internally, a PAL device consists of an array of AND gates that perform Boolean product operations on the inputs and an array of OR gates that perform Boolean sum operations of the Boolean terms formed by the AND array. The user can program the interconnection of the inputs to the AND array, thus forming the desired Boolean terms. The fixed internal OR gates enable the formation of Boolean Sum of the Product Terms. Since any logical function can be expressed in Boolean Sum of Product terms, the PAL can be used to realize any logical function provided the expressions do not exceed the capacity of the PAL.

PAL Features

Features of PAL are:

- The easy to use and to customize PAL programming facility is available on most popular PROM Programmers.
- Promotes methodical approach to logic design, hence the potential for design automation.
- Flexible, the same device type can be customized to perform different functions thus reducing inventory of devices.
- High speed propagation delay of 25 ns (typical)
- Small board space. PAL devices are packaged in 20 or 24 pin 'Skinny' DIP.
- Compared to standard TTL devices, a PAL solution requires a smaller number of chips, up to 12:1 reduction.
- Compared to custom and semicustom devices, PAL circuits require much less development time and they are more cost effective for small production quantities.

Fig. 1: Alternative Design Methods

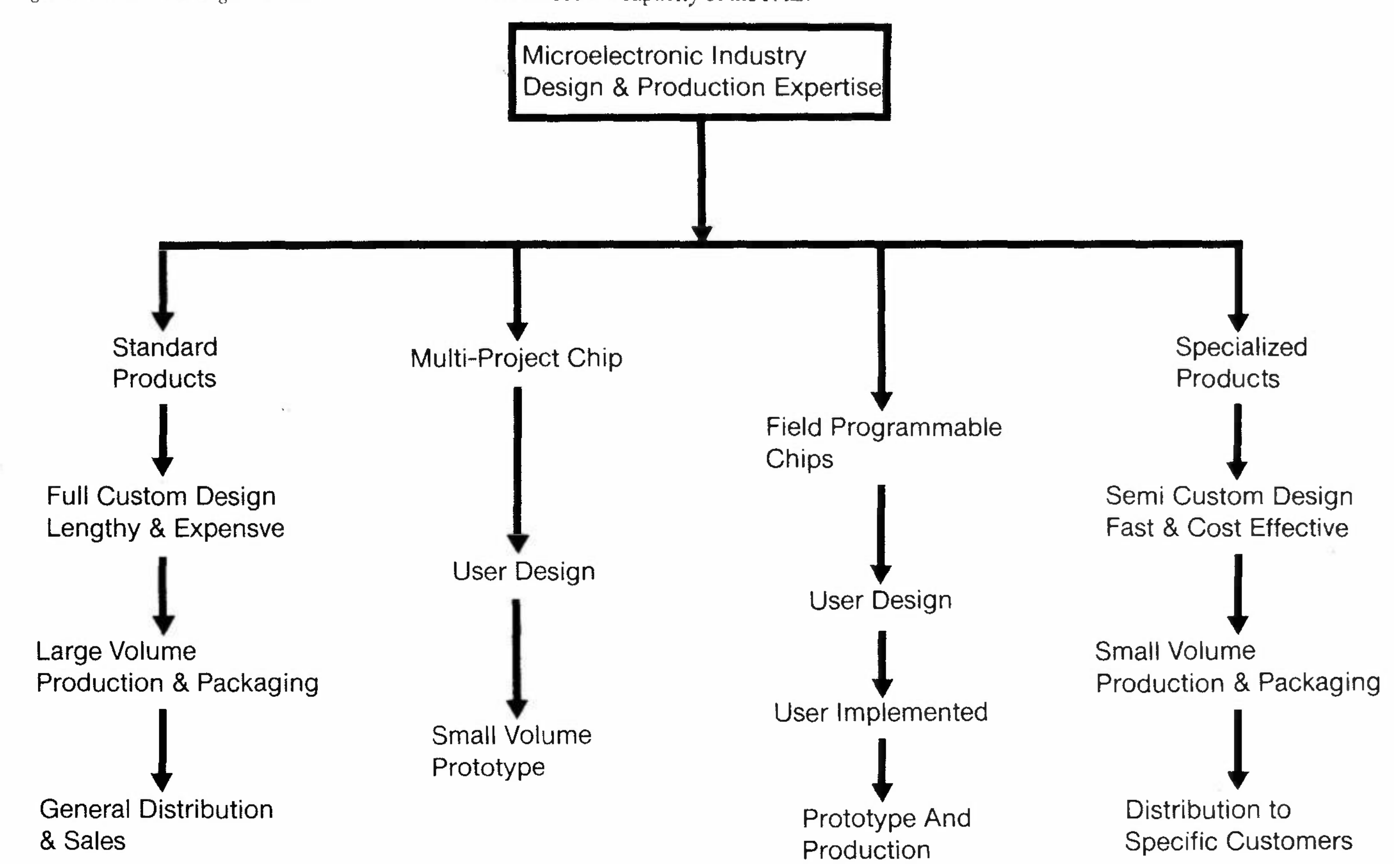
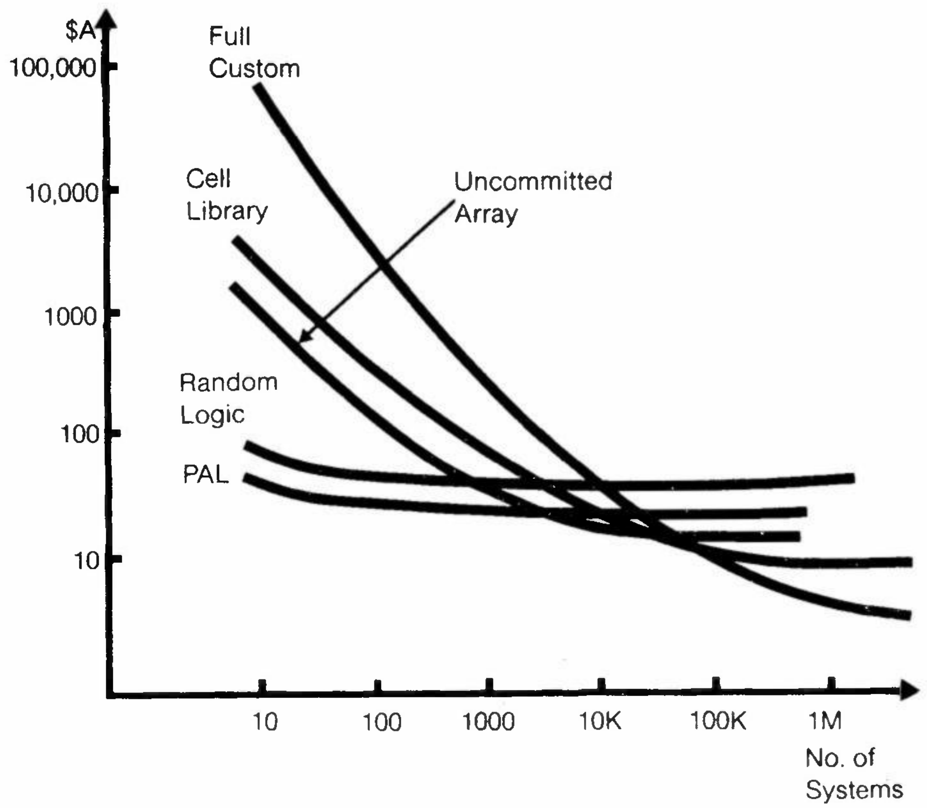


Fig. 2: Unit Cost Versus Production Quantity



PAL Design

The PAL design process involves translating the required logical functions into Boolean expressions. As PAL devices directly implement logic functions expressed in Boolean Sum of Product form, a computer program can be used to generate appropriate fuse patterns for a specific PAL. The fuse pattern can then be automatically entered into the PAL program to realize those functions.

Computer programs can also be used to aid designers in forming and optimizing Boolean expressions that represent the required functions. An 'Expert' system being developed in the Research Department can help designers to design PAL circuits methodically.

REFERENCES
1. Court, R.A. et.al. 'The New Microelectronics Revolution', Telecommunication Journal of Australia Vol.34, No.1, 1984, pp73-83.
2. Tirtaatmadja, E. "Programmable Array Logic Design Techniques", Telecom Australia Research Laboratories Report No.7591, Feb. 1983.

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THE MICROCHIP

Circuit Design

Complex integrated circuits, or 'microchips', are becoming commonplace in the telecommunications network and are helping to revolutionize telecommunications. Systems that use integrated circuits (ICs) have been part of the network for some time, but it is only recently that very complex circuits or Very Large Scale Integration (VLSI), with tens of thousands of transistor switches, have become the basis of these systems. Rather than being general purpose or standard components, such complex circuits can be specially designed to meet specific needs of the network.

Initial Simulation

Like any electronic system, an integrated circuit begins as an electrical circuit designed to perform a certain function. For complex digital ICs, the circuit or logic-gate diagram is designed interactively on a computer terminal using Computer Aided Design (CAD) software. Using computer aids, the designer is able to design the circuit more quickly since he can use libraries of previously designed circuits. The circuit can be simulated during its design to ensure that it operates according to the specification. This is quicker and cheaper than building a prototype of the system.

Physical Layout

Once the designer is satisfied that the circuit operates correctly, it must then be translated into a physical layout so that the IC can be fabricated. The layout consists of several layers of geometrical patterns that define the structure of transistors and their interconnections, and it forms the basis of the IC. Since the generation of the layout is very time consuming, CAD software is used in the form of geometrical editors and the finished layout is checked by the computer to ensure that it is correct.

Volume Production

The layout data is then converted into photographic masks that are 20 times the final size of the IC using a pattern generator at the IC fabrication plant. These masks are then photographically reduced to the final size of the IC and the patterns are repeated many times to form the production masks so that large numbers of ICs can be made at the same time, all on the one wafer of silicon.

The various layers of the transistors are formed sequentially according to the particular processing technology at the fabrication plant, with all of the ICs on a wafer and many similar wafers being processed at the same time. Once the wafers are finished, the ICs on the wafer are tested by a computer controlled wafer prober, sawn into separate 'chips' and packaged. After further testing the ICs are then ready for assembly as parts of equipment in the telecommunications network such as telephones and exchanges.

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COMPUTER AIDED DESIGN OF INTEGRATED CIRCUITS

Purpose

As integrated circuit (IC) complexities increase to Very Large Scale Integration (VLSI) size, the time taken to design the IC has increased greatly, both for the geometrical mask layout and the actual circuit design itself. At the same time, the chances of errors in the design or layout have increased dramatically. To try to alleviate the risk of errors and to reduce the design time and design cost, Computer Aided Design (CAD) software tools are used.

Logic Circuit Diagram

To generate the logic circuit diagram, a circuit diagram editor is used. This allows circuit diagrams to be created or modified interactively with the computer. Once completed, the circuit diagram of the system or subsystem is translated into a 'net list', which contains all of the logic-gates and their interconnections in a textual format. This net list is then used as the input to circuit or logic simulators.

Computer Simulation

To ensure that the logic circuit will function correctly and to the desired level of performance, its operation is simulated with the computer before the IC layout is completed and the IC is fabricated. The simulation may be either a very accurate transistor-level simulation to verify the detailed operation of a particular circuit or the logic-gate level simulation of the system or a subsystem to verify the interconnection of the gates in the overall system. Any errors or performance limitations can easily be corrected.

Layout Editor

Once the complete system has been designed and its performance verified, the geometrical layout of the circuit for the production of the IC fabrication masks is performed using a geometrical layout editor. For the layout, each mask layer in the fabrication process must be individually generated, using rectangles or polygons for the metal interconnections, the polysilicon transistor gates and interconnections, ion implantation stages and so on. Different colours are used for each layer to differentiate them.

Rule Checking

The dimensions, spacings and relationships between the polygons in the layout are prescribed by a set of design rules for the processing technology to be used. Errors in the layout could be fatal to the circuit operation and so the layout must be thoroughly checked to avoid them. This time consuming and error prone task is performed by a Design Rule Checking program (DRC), which indicates on a layout plot any design rule errors discovered. A DRC only detects layout geometry errors, however, and not transcription errors from the circuit diagram to the layout. To detect errors in the circuit layout and electrical errors, such as incorrect pull-up or pull-down, Field Effect Transistor (FET) dimensions or shorted interconnections, an Electrical Rules Checker (ERC) is used to check the circuit net list as extracted from the layout. The circuit extractor also determines the parasitic node capacitances of the layout and this information can be used as an input to the simulators to provide a more accurate indication of the performance of the fabricated IC.

Once the layout is completed and verified, it is converted into a standard layout textual format, such as Caltech Intermediate Format (CIF), and then transferred to the IC fabrication house for mask making and chip fabrication.

Further Automation

VLSI offers the potential for the integration of complete systems on a single chip, rather than just individual components of the system as has been possible up until now. While current CAD software tools can handle the simulation and the layout of the IC, the design of the system is still a huge and difficult task. Current work in many research establishments is aimed at attempting to automate the tasks of detailed circuit design from the system architecture and the generation of the mask layouts. As well as reducing the design time dramatically, this will also ensure correct circuits and layouts without the need for verification.

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MULTIPROJECT CHIP IMPLEMENTATION

Need for Simpler Methods

During the latter half of the 1970s it was recognized by researchers and academics in the USA working in the area of integrated circuit design that new and simpler methods of teaching and implementing designs were necessary to take full advantage of the rapidly advancing technology. One of the most significant developments in this area was the introduction of a new design methodology for VLSI systems by Carver Mead at Caltech and Lynn Conway of the Xerox Palo Alto Research Centre. This Mead-Conway design methodology was taught at a number of leading research institutions in the USA from 1978 onwards. As part of this course, students were required to implement small circuit designs on silicon, so that their ideas could be tested in real circuits. The resultant chips, each of which contained a number of student projects, became known as Multiproject Chips, or MPCs.

Multiproject Chips

The MPC is a way of producing designs, usually digital logic circuits, in integrated circuit form, at a relatively low cost per circuit. Under this scheme (Fig. 1), a number of small circuit designs are merged onto a single silicon die, forming one chip type containing several independent circuits. This die is repeated over a single silicon wafer together with several different die types. After fabrication and packaging, each circuit designer receives several integrated circuits in which only his circuit is bonded to the package pins. This approach enables the total mask making and wafer fabrication costs to be spread over a number of different projects, giving a much lower cost per circuit than is possible with conventional custom integrated circuits.

MPC Fabrication

The technology used to fabricate MPCs is usually a silicon gate NMOS depletion load process, using six mask levels. It is a relatively straightforward process, used by many manufacturers. The minimum line widths used in MPCs range from about 5 to 3 µm, which are from four to two years behind the current state of the art processes, but quite adequate for typical MPC applications. This technology, which forms the basis of the Mead-Conway design methodology, was chosen because of its maturity and design simplicity. The design techniques are based upon a simplified set of conservative design rules and very basic transistor models that are used to produce geometric layouts for each of the six process masks. Computer aided design tools are widely used to design MPC circuits. In fact, MPCs have proved to be of great value in developing and evaluating many of the sophisticated design tools now available around the world.

Introduction to Australia

The Multiproject chip concept was introduced to Australia by the CSIRO VLSI Program in 1982, with the first Australian MPC, dubbed AUSMPC 6/82. This event has proved to be a catalyst for the teaching of VLSI design techniques within Australian academic institutions and for their use within many research laboratories. MPCs are run on a fairly regular basis by a number of Australian institutions, using both local and overseas integrated circuit fabrication facilities. While they are not suitable for use as commercial products, owing to the highly simplified approach taken to design and testing, they serve three important functions. Their main application is as a teaching tool for introducing circuit designers to VLSI design principles and techniques. However, they are also highly useful for testing integrated circuit design ideas and for developing prototype circuits where the performance and size advantages of custom integrated circuit technology is required.

(See diagram)

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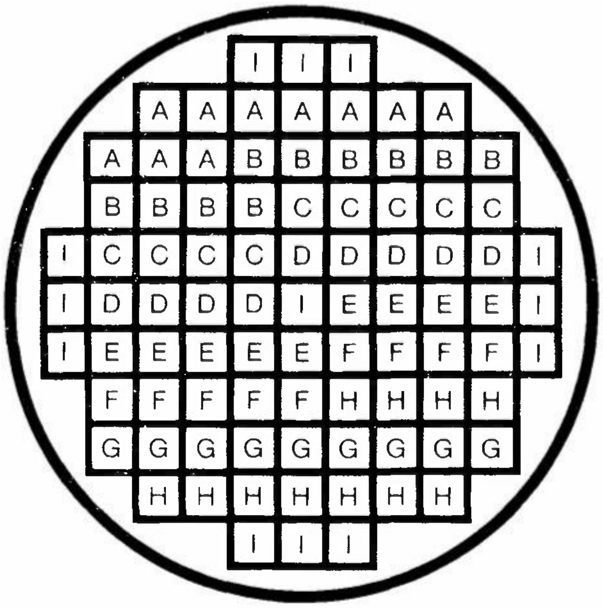
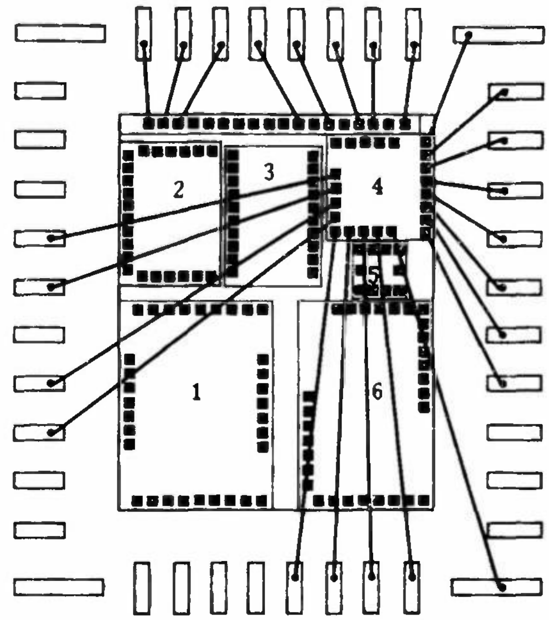


(a) 3" Wafer Map from AUSMPC5/82
Showing 9 Die Types (A-I)



(b) Pin Bonding Diagram for Die
Type G Circuit 4

Fig. 1: Multiproject Chip Details

A GATE ARRAY AND CUSTOM INTEGRATED CIRCUITS

Implementation

An early consideration in the design of an Integrated Circuit (IC) is whether the system implementation is to be either gate array, standard cell, or fully-customized . Here factors such as design time, design cost, system complexity, system performance, chip size (and, hence, yield and manufacturing cost), fabrication house, the experience of the chip designer and Computer Aided Design support will influence the choice made.

Gate Array

Gate array technology has been established for over 15 years but has become popular in the last 5 years or so. At present there are a large number of arrays and array manufacturers, with the arrays varying widely in the processing technology and in the array size offered. Gate arrays consist of regular arrangements of transistors and interconnect channels surrounded by power supply buses and interface circuits that have been previously defined so that the designer only has to define the interconnections between the transistors. This imposes a limitation on (a) the circuit topology that can be implemented, e.g. Read-Only Memories(ROMs) and Random Access Memories(RAMs) are difficult to implement efficiently, (b) the number of transistors that can be placed on the one chip and (c) the performance that can be obtained. However, design time and manufacturing cost are reduced since only the interconnect levels are specified. Most gate array manufacturers have libraries of standard functions such as flip-flops, logic gates and I/O circuits that have been previously designed and verified and the designer builds his system from this library in the same way that he would if he were designing with standard TTL or Complementary Metal Oxide Semiconductor(CMOS) parts.

Standard Cell

With the standard cell approach, libraries of standard functions are also used but the layouts are not array based. Once the system is specified in terms of the library cells, the physical layout of the mask levels for the chip can be assembled by positioning the cell layouts and then interconnecting them as required. Although this technique is more costly than the gate array since all mask levels for the chip need to be specified, the design time can be very short. Standard cell chips offer higher performance than gate arrays since it is possible to optimize cells for speed, chip area or power dissipation. This allows significantly smaller chips to be produced or alternatively more transistors to be placed on the one chip.

Fully-Customized Approach

The alternative is the fully-customized approach in which all process mask levels are defined but the designer is not constrained by previously defined cells and can optimize each. As a result, the design time for such chips can be very long and it is more usual for library cells to be used where possible and for new circuits or layouts to be as regular as possible to allow their design to be assembled from smaller optimized cell designs. To offset long design time and the high fabrication cost, the chip is highly optimized in terms of system performance and chip size and has the smallest per unit cost of all 3 design styles for large quantities.

Choice of Technology

Another decision that must be made early in the design of an IC is that of the processing technology to be used for chip fabrication. The choice is determined by the application since each technology has its own performance advantages and complexity limitations. Once determined, the technology then strongly influences the circuit design and the circuit layout.

Bipolar Technology

Bipolar technology is the oldest technology and in different forms produces Transistor-Transistor Logic (TTL), Integrated Injection Logic (IIL) and Emitter-Coupled Logic (ECL) families. The relatively low realizable complexity of bipolar technologies means that they are only used when the high speed potential of the technology is required. For designers away from the fabrication site, bipolar designs are usually done on gate arrays since this simplifies the otherwise considerable difficulty of producing optimum high performance bipolar designs.

NMOS Technology

N-channel Metal Oxide Semiconductor (NMOS) technology appeared in the early 1970s and has been used for the most complex chips since the logic circuits are simple and the basic transistor is small. As a result, the number of transistors that can be placed on the one chip of manufacturable size is significantly increased. Compared to bipolar logic the design process is easier, since the main factors that need to be considered in the design of the logic gate are the speed-power tradeoff for a given load capacitance and the transconductance ratio of the depletion and the enhancement FETs (Field Effect Transistors) (called 'ratioed logic'). Logic design is also easier in NMOS owing to the ability to use a single FET as a switch (a 'pass' transistor) and the use of 'dynamic' logic, which allows circuit simplification by storing logic levels on gate capacitances.

NMOS has become the most widely used logic technology for large integrated digital systems, although most designs are either fully-customized or standard cell. Few simple standard products are available, although most LSI and VLSI designs are NMOS at this stage.

CMOS Technology

CMOS technology has also been available since the early 1970s, initially as a standard product range, and later as gate array products. CMOS gate arrays have become well established and a large number of manufacturers offer a wide range of products varying in size and in the sophistication of the processing technology. There is a growing trend for the use of CMOS in VLSI applications as the new generation of CMOS technology becomes established. Early CMOS used a metal gate FET process resulting in slow operation and poor area utilization when compared with NMOS. The use of self-aligned silicon gates and the 'oxide-isolation' of devices improved both NMOS and CMOS, with CMOS performance and size improving to a point where it could be considered for VLSI. With only P-or N-channel devices being on at the same time, the inherent advantage of very low static power dissipation of CMOS means that it will be used more often in the future for VLSI where the higher power dissipation of NMOS is starting to be a limit to the complexity that can be achieved with conventional packaging.

CMOS has the advantage of not being a ratioed logic family but, like NMOS, it allows flexible designs through the use of transmission gates, which act as switches. Dynamic logic circuits can also be used, as can many of the techniques used in NMOS.

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FIELD TESTING OF SOLAR PHOTOVOLTAIC MODULES

Investigations

For solar photovoltaic modules to be a cost-effective means of power generation they must have a low purchase price and a reasonably long service life. Over the past few years the lifetime goal has risen from 10 years to 20 years and recently 30 year lifetimes have been considered feasible.

Telecom Research Department is investigating the reliability and expected service life of solar modules by both:
(a) accelerated environmental and mechanical testing in the laboratory and
(b) field site exposure.
The closely-monitored field site exposure trials will enable an early assessment to be made of module degradation and failure mechanisms in conditions that closely reproduce actual working conditions. By correlating the field and laboratory test results, better estimates will be made of laboratory test acceleration factors.

Field Site Locations

The four field test sites below and shown in Fig.1, were established to represent some Australian climatic extremes:

- Innisfail – a tropical climate with high rainfall and periods of high relative humidity.
- Cloncurry – a hot and dry climate.
- Sydney – on the coast, at North Head, which has a salt mist laden atmosphere and is subjected to periodic high winds.
- Clayton – on the roof of building M2 of the Research Department. This location provides exposure to a moderately polluted environment and is a convenient site to prototype test modifications, etc.

Solar Module Loads

At each of the Innisfail, Cloncurry and Clayton field sites, five pairs of modules are operating into their own solar power systems which comprise lead-acid batteries, a regulator and a constant current load. This also enables the assessment of batteries operating with solar module charging and provides data that will assist in future solar power system sizing calculations.

The other modules at these sites and all the modules at the Sydney site are connected to constant-voltage loads that simulate battery charging conditions. It is expected that peak-power-tracking loads will also be used in a future extension of the sites.

Data Logging

At each field site a computer controlled data logger records information relating to module output, battery performance (where applicable) and meteorological conditions. The parameters measured are shown in Table 1.

Parameters which can vary rapidly, e.g. global irradiance and module current, are measured each second whereas more slowly varying parameters such as air temperature are measured each 5 minutes. Some averaging of data is done on-site and these reduced data and the other raw data are stored on a tape data cartridge which has the capacity for 3 days' data. The system is interrogated daily by a computer at the Research Department and the stored data are transmitted to this computer by telephone line.

Data Analysis

The received data are checked to ensure that the readings are within reasonable limits. The data are then stored in a compact format on magnetic tape. There are several data analysis programs, the most important being the plotting program and those that produce the monthly reports for each site. Solar module parameters such as peak power, short circuit current and fill factor can be plotted against time to detect small real changes in module performance.

Meteorological	*Battery Data*
Air Temperature	Current into Batteries
Relative Humidity	Current from Batteries to Load
Rainfall	Battery Cell Potentials
Wind Speed	Battery Electrolyte Temperatures
Wind Direction	
Global Irradiance (Horizontal)	
Global Irradiance (Inclined)	

Module Data
Current into Battery or Constant Voltage Load
Module Temperature
Daily I-V Curve

Table 1: Parameters Measured at Field Sites

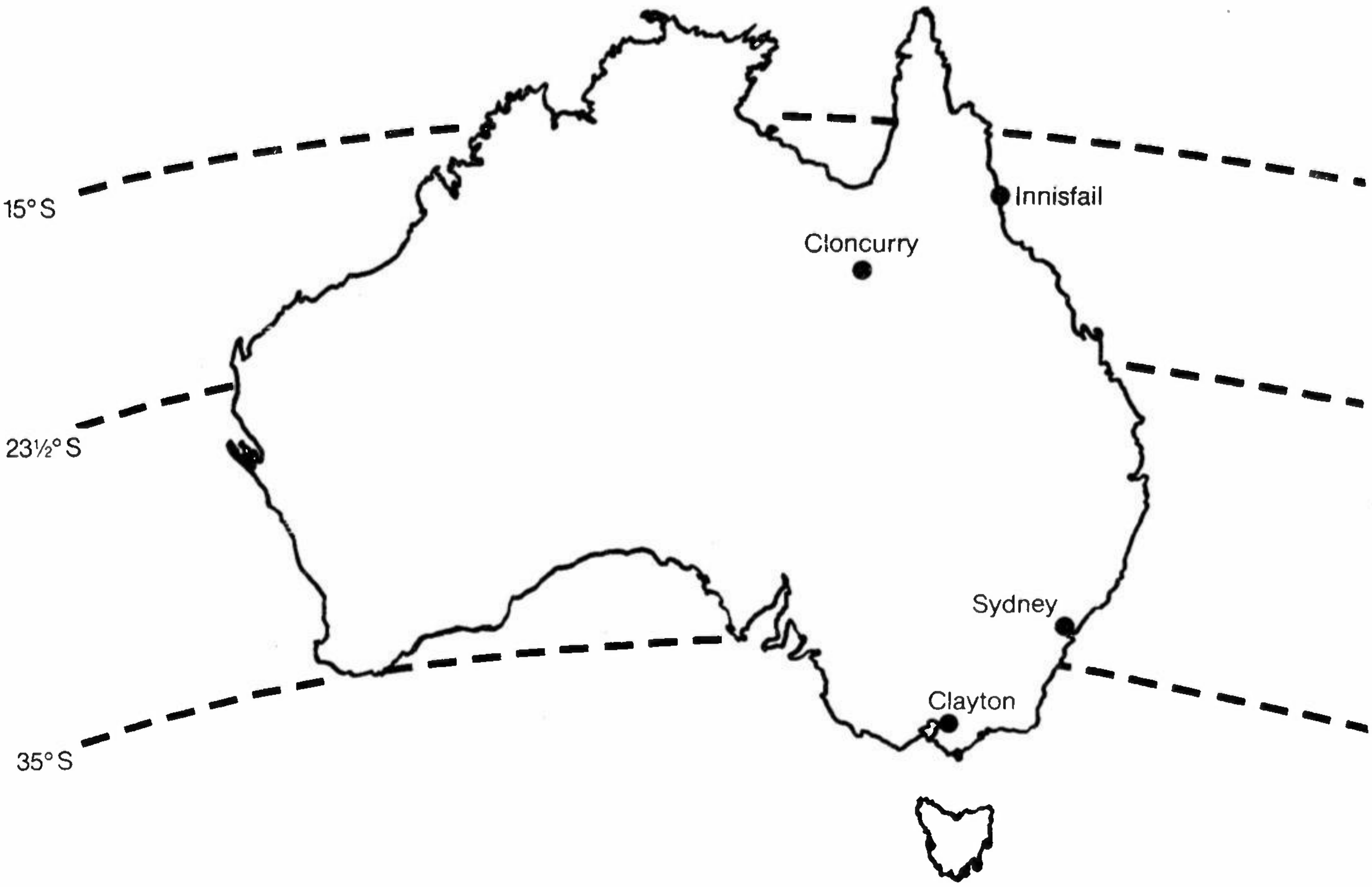

Fig. 1 Location of Field Test Sites in Australia

Maintenance Visits

The remote field sites are visited at 3 monthly intervals to enable:

(a) visual inspection of the solar modules,
(b) cleaning and calibration of sensors,
(c) maintenance of the data logger and
(d) repairs to the site as necessary.

Test Duration

The field site test program will definitely continue until December 1986 and will probably run beyond that date.

Acknowledgement

The project and equipment described have been substantially funded by grants from the National Energy Research Development and Demonstration Council (NERDDC) of the Commonwealth Department of Resources and Energy.

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PHOTOELECTROCHEMICAL ENERGY CONVERSION & STORAGE

PEC Cells

In recent years, thin film photoelectrochemical (PEC) cells have been developed with solar energy conversion and storage properties that suggest them as promising large scale devices for useful energy production. A PEC cell is formed by immersing a semiconductor electrode and a metal counter-electrode in an electrolyte solution as shown in Fig. 1. If the electrolyte contains a suitable "redox" couple, the current generated by light incident on the semiconductor surface can flow to the counter electrode and thence via an external load back to the semiconductor.

Advantages of PEC Cells

The advantages of PEC cells over conventional solid state cells are that no expensive front metal contact is needed to collect the current and, since the liquid contact conforms to the entire surface of the semiconductor, it is possible to use cheaper lower grade thin film materials in place of higher quality single crystal material.

However, the major advantage of PEC cells is that it is possible to generate chemical products via the redox reactions, as well as electricity. Hence, it should be possible to integrate energy storage into the cell design, reducing the cost of photovoltaic power systems that use separate batteries for energy storage.

Three-Electrode Storage Cell

The simplest method of obtaining in-situ PEC storage is by using a three-electrode storage cell, shown in Fig. 2. This cell consists of a semiconductor photoelectrode (S) connected via loads to a counterelectrode (C) and a storage electrode (A) that are immersed in different electrolyte solutions. The two electrolytes are separated by a membrane that allows a current to flow but prevents the solutions from contaminating each other. When the photoelectrode is illuminated, light energy is simultaneously converted into electrical energy and stored chemical energy.

The load resistors R_1 and R_2 are chosen so that, during illumination, part of the current generated flows across R_1 from S to C and can be used, while part flows over R_2 to the storage electrode (A), where it is stored as chemical energy. In darkness, current flows from A to C across R_1 and R_2. The storage electrode must be able to undergo a reversible chemical change, as shown in Fig. 3.

The electrode reactions at S and C are the same as those for an ordinary two-electrode PEC cell.

Present research is directed toward developing improved semiconductor photoelectrodes. Tandem heterojunction thin films, which have higher conversion efficiencies and develop larger photovoltages than single electrodes, are being used to increase the overall efficiency of the three-electrode storage cell.

(See diagrams over)

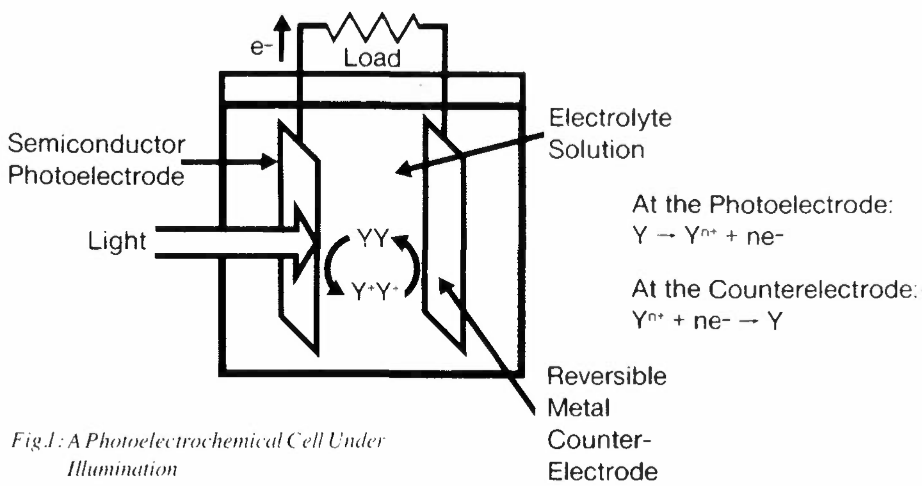

Fig.1: A Photoelectrochemical Cell Under Illumination

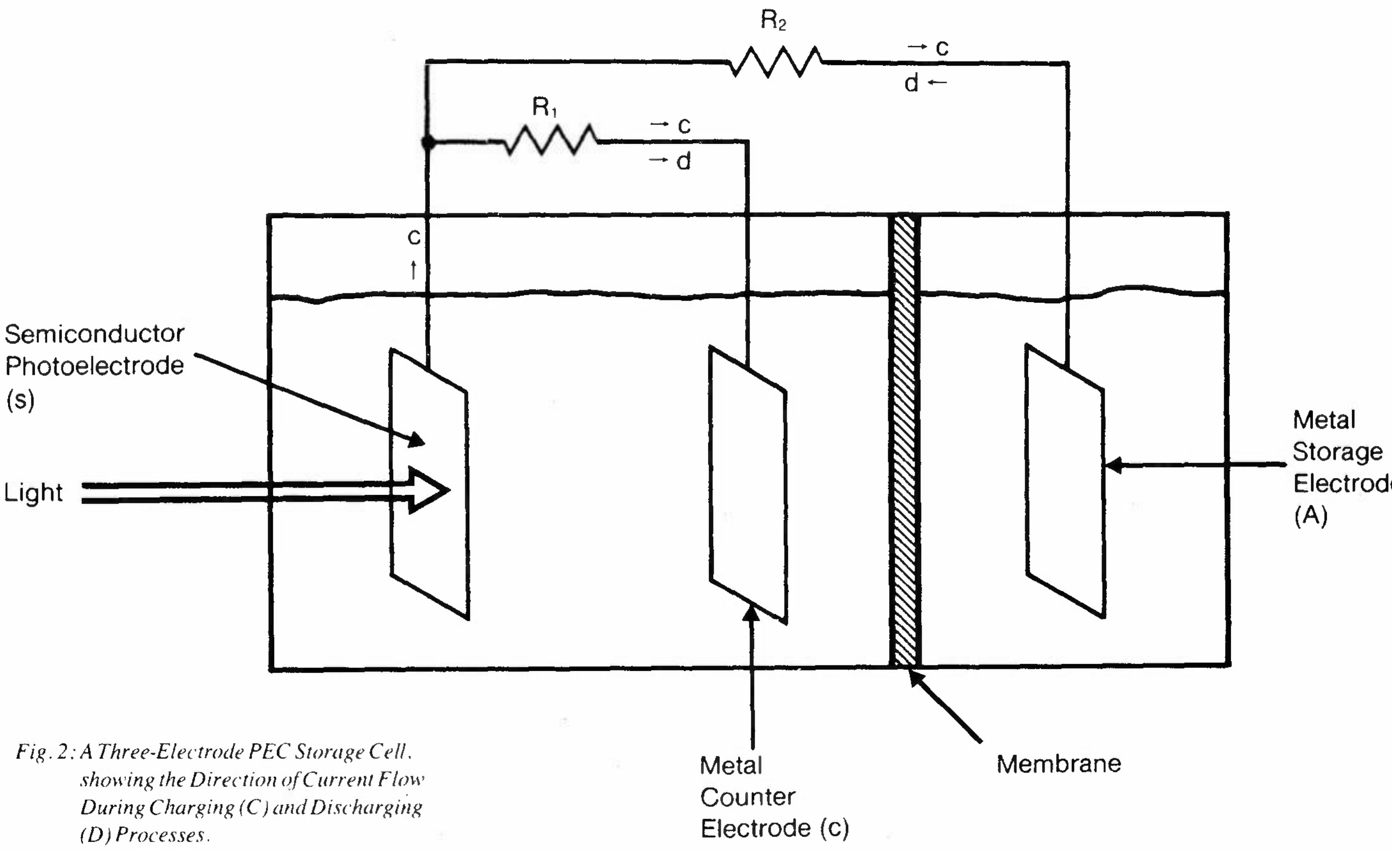

Fig. 2: A Three-Electrode PEC Storage Cell, showing the Direction of Current Flow During Charging (C) and Discharging (D) Processes.

$AX + ne^- \rightleftharpoons A + X^{n-}$
Where X is the Solute Present in the Electrolyte.

Fig. 3: Storage Electrode Reversible Chemical Change

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REMOTE POWER SYSTEM CONCEPTS

The Need

With the proliferation of remotely located Telecom equipment for optical fibre systems, digital microwave radio links, the Digital Radio Concentrator System(DRCS) and satellite terminals, there is a rapidly increasing need for stand-alone power supply systems over the range from 8 W to more than 1 kW.

Energy Sources

Power systems exploiting renewable energy sources such as the sun and wind offer many engineering advantages such as reduced maintenance and the avoidance of regular refuelling. However, they must also be economically competitive if they are to replace conventional equipment such as diesel generators. Energy from renewable sources may not always be available when needed. At other times considerably more energy than required may be available and it may be desirable that it be stored for later use.

System Design

The design of an effective and reliable power supply system using wind and solar energy sources involves considerable analysis and understanding of local weather patterns. For example, in order to size the battery storage, the likelihood of a number of successive days of low energy input must be known as well as the load profile over those days. Also of importance is the number of high energy days before the onset of another low energy input period because the storage must be replenished during that time.

The complementarity of the wind and solar energy sources needs to be examined to proportion the inputs from each optimumly. An ideal location for a hybrid power system is one where the wind blows at night and on dull winter days. Sizing of a wind generator cannot rely on long-term average wind speeds as such generators only work over a restricted range of wind speeds — when the wind velocity is too low they do not turn and when it is too high, they feather or are held braked.

Orientation

The orientation of the solar cell array is also important. In most locations the array size is determined by the required output in the winter months. In summer however, considerable energy is wasted because the array is providing more than the load can consume and the storage is full. The array is best oriented so that its output is reasonably uniform over the year with the least severe winter minimum. This orientation is dependent on total insolation levels, the proportion of direct and diffuse radiation and the distribution of the diffuse component.

The optimum system design must include economic aspects also. It may be possible to achieve the required system performance but at lower cost with a different combination of energy sources and storage size.

All these facets of remote power supply system design are being studied with the aim of developing a design approach that produces the cheapest design that meets the performance criteria.

Reliability

Telecom equipment can only be as reliable as the power source connected to it, thus it is imperative that, as a part of the design process, the 'availability of energy' is determined. Some applications will require higher availability than others, for example, a main trunk repeater is more critical than a single customer's equipment. By specifying availability as an input into the design process, it is expected that power systems will be better suited to their load, i.e. cheaper, smaller systems for less critical equipment.

Fault Tolerance

There is also considerable scope for reduction of the consequences of degradation or failure of components within the complete power supply system. The solar array consists of numerous panels, each panel typically containing 30-40 solar cells. There are many possible combinations of series and parallel interconnections of a large number of cells with some combinations providing better immunity to the effects of individual cell failure. Electronic sensing and control can also be used to match the solar array to the load dynamically under conditions of changing insolation, temperature, load and array performance.

Battery Charging

The process of charging the storage batteries is another area that will affect the reliability and lifetime of the power supply system. To be able to determine the current 'battery state of charge' accurately is difficult but it is necessary if suitable charging strategies are to be implemented. Other factors to consider if battery life is to be maximized are battery temperature, previous cycling history and terminal voltage.

Long-Term Performance

The Research Department is investigating various aspects of systems reliability with the goal of being able to predict long term performance in the field. Fig. 1 shows a typical hybrid system. One unknown is future weather conditions but previous years' meteorological data are being examined to identify atypical years.

(See diagram)

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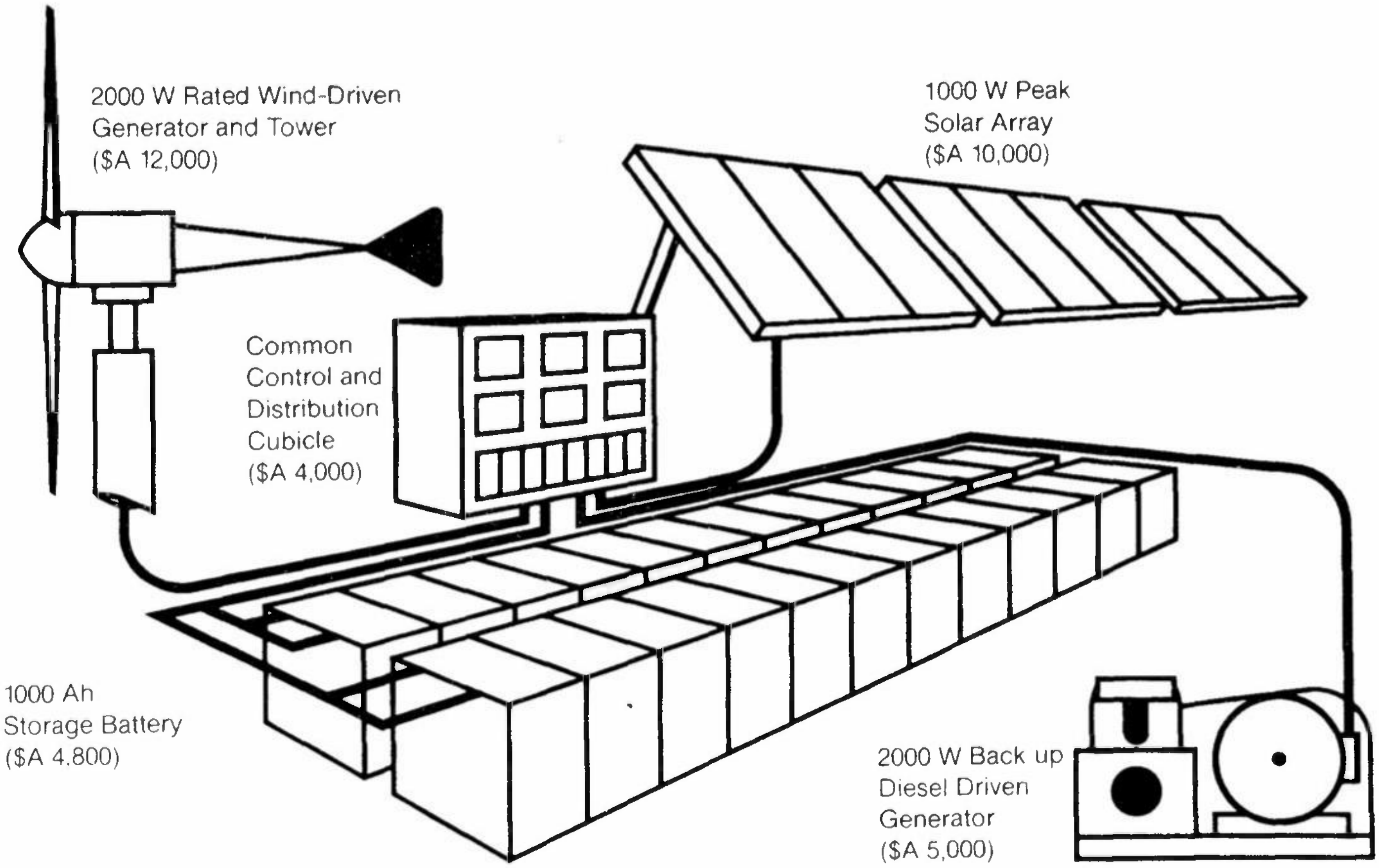

Fig 1: Trial Hybrid Power System Equipment

OPTOELECTRONIC SEMICONDUCTORS

Ultrafast Optoelectronic Semiconductors

The Research Department has the only Australian laboratory for research into, and development of, ultrafast optoelectronic semiconducting materials and devices.

It is intended to introduce this most advanced form of semiconductor technology into Australia to provide a knowledge base suitable for rapid and profitable exploitation in the 1990s.

The Research Department can grow semiconducting single crystals of extraordinary purity and the most complex structure, with atomic precision. For example, a few atomic layers of one semiconductor material can be inserted into a bulk crystal of another and it can be ensured that the atoms of all three parts of the resulting crystal line up exactly.

Applications of these kinds of material range from solid state lasers, repeaters and detectors that match the silica optical fibre to high powered microwave amplifiers for satellite communication. These materials are also destined to be the key elements in the fifth generation supercomputers of the 1990s.

III-V Materials

III-V compound semiconductors are so called because the elements used are those of columns III and V of the Periodic Table. The Group III elements are gallium (Ga), indium (In) and aluminium (Al) and the Group V are arsenic (As), phosphorus (P) and antimony (Sb). The best known compound semiconductor is gallium arsenide (GaAs) but more complex alloys such as aluminium gallium arsenide (AlGaAs) and indium gallium arsenide phosphide (InGaAsP) are widely used in telecommunications. The growth technique used is molecular beam epitaxy (MBE), illustrated in Fig. 1.

Silicon

Silicon is not used for high speed optoelectronics. It is the general purpose semiconductor used, for example, in household electronics and computers but it is too slow for the fastest applications. It is also optically inactive. This means it is only useful for slow information flow using electrons and not for the fast information transfer using both electrons and light (photons) demanded by modern telecommunications. A comparison of silicon and the III-V compounds is shown in Fig. 2.

Characteristics of III-V Compounds

The III-V compounds provide an ideal 'meeting place' for electrons and light (photons). A good example is the solid state laser shown in Fig. 3.

(See diagrams over)

Electrons and holes are injected into the active GaAs region. They recombine producing light. Light amplification takes place and the region lases.

For such a device to work, all the atoms in the structure must lie on the same lattice (no disorder at the interfaces), the refractive indices of the outer layers (AlGaAs) must be less than that of the active central region (GaAs) so that the generated light is confined to the active layer, i.e., n2 must exceed both n1 and n3, and the electronic properties of the materials (the band gaps) must be arranged so that the charge carriers (electrons and holes) are also confined to the active layer. All these requirements are met simultaneously by the III-V compounds over a very wide range of wavelengths of radiation as shown in Fig. 4.

The elements required in the resultant compound are evaporated in an ultra high vacuum (10^{-13} atmospheres) onto a suitable substrate. The crystal grows slowly - one atomic layer per second - with all the atoms taking up positions in a regular lattice - hence a single crystal is grown. Shutters can easily control the growth with a precision of one atomic layer.

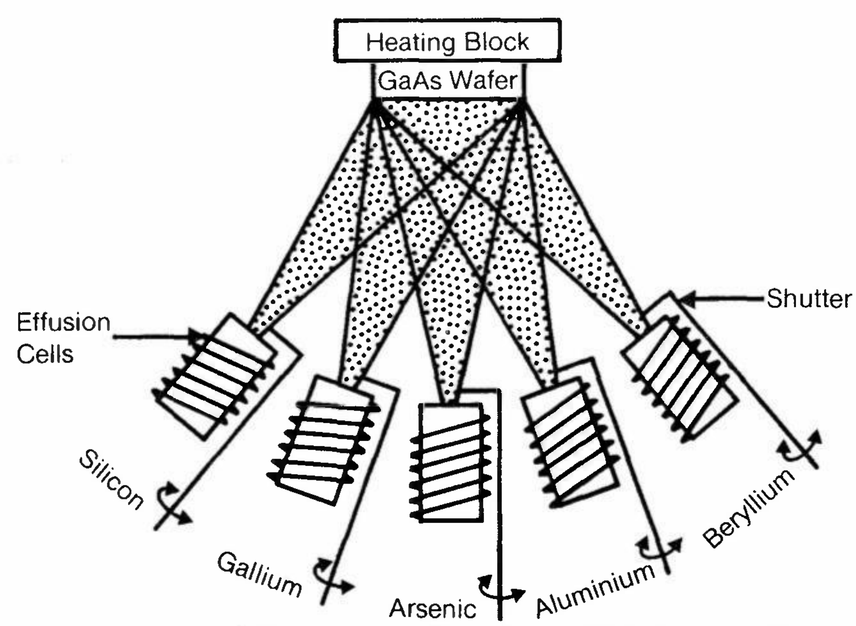

Fig. 1: Molecular Beam Epitaxy

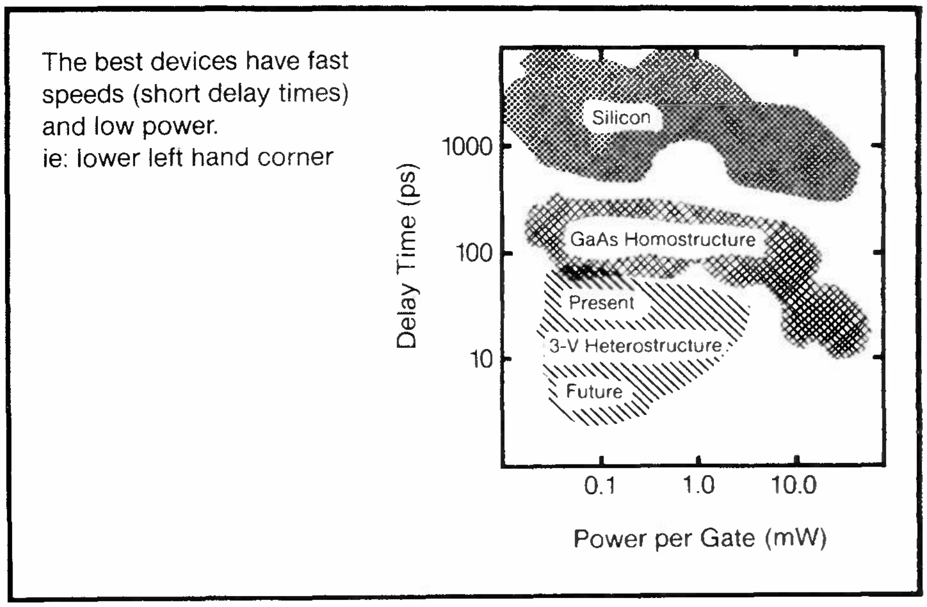

Fig. 2: A Comparison of Silicon and III-V Compounds

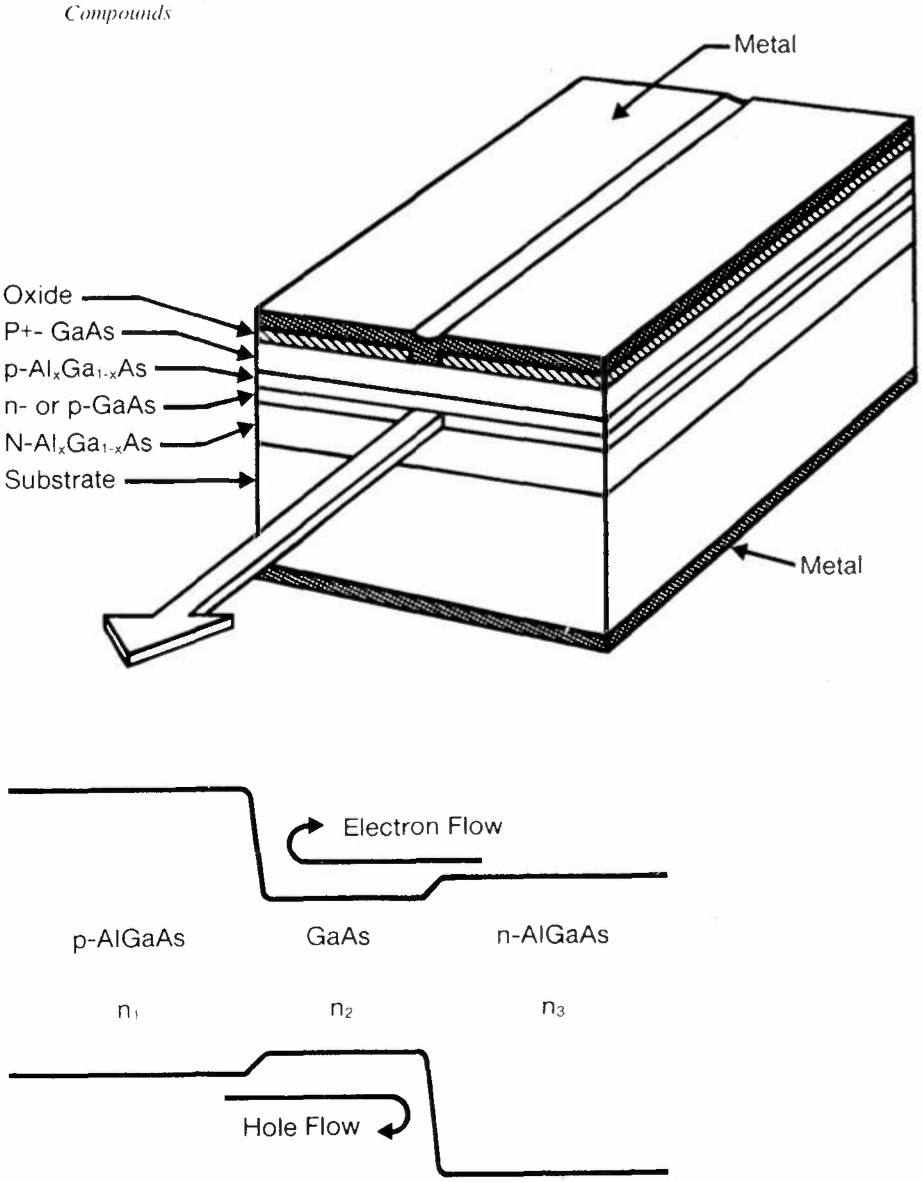

Fig. 3: A III-V Laser

Examples of Research Department Work

An example of current Research Department work is the continuing development of the $Al_{1-x}Ga_xAs$/GaAs materials system. The GaAs and AlGaAs used is of 'state of the art' purity. A two dimensional electron gas (2DEG) is formed at the interface of these two materials. This 2DEG is the fastest useful device material known and is now made routinely in the Research Department.

Another example of present research is the $In_{1-x}Ga_xAs$/GaAs system. Work in that area has only recently begun. InGaAs matches the silica optical fibre and, if grown on GaAs, holds the promise of very large scale optoelectronic integration.

Devices

Current work is on low noise ultrafast transistors, small scale integration of logic elements, lasers and waveguides in AlGaAs.

Work is just beginning on detectors and repeaters in InGaAs.

Characterization

A large proportion of the work involves characterizing the materials grown by the Research Department. The smallest concentration of impurities and crystalline defects can prevent a device from working. Thus very sensitive techniques have been developed and are used routinely. These include:

- photoluminescence.
- deep level transient spectroscopy.
- Hall mobility.
- capacitance — voltage profiling.
- scanning electron microscopy.
- electron microprobe with energy and wavelength dispersion.
- low energy electron diffraction.
- reflection high energy electron diffraction.
- double crystal X-ray diffraction.
- auger electron spectroscopy and
- high resolution electron energy loss spectroscopy.

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This plot shows the wavelength regions spanned by the 3-5 compounds and how well they match the silica optical fibre. Note that the quaternary (4 element) compounds e.g. GaInAsP span a range of wavelengths unlike the binary compounds which operate at a single wavelength only.

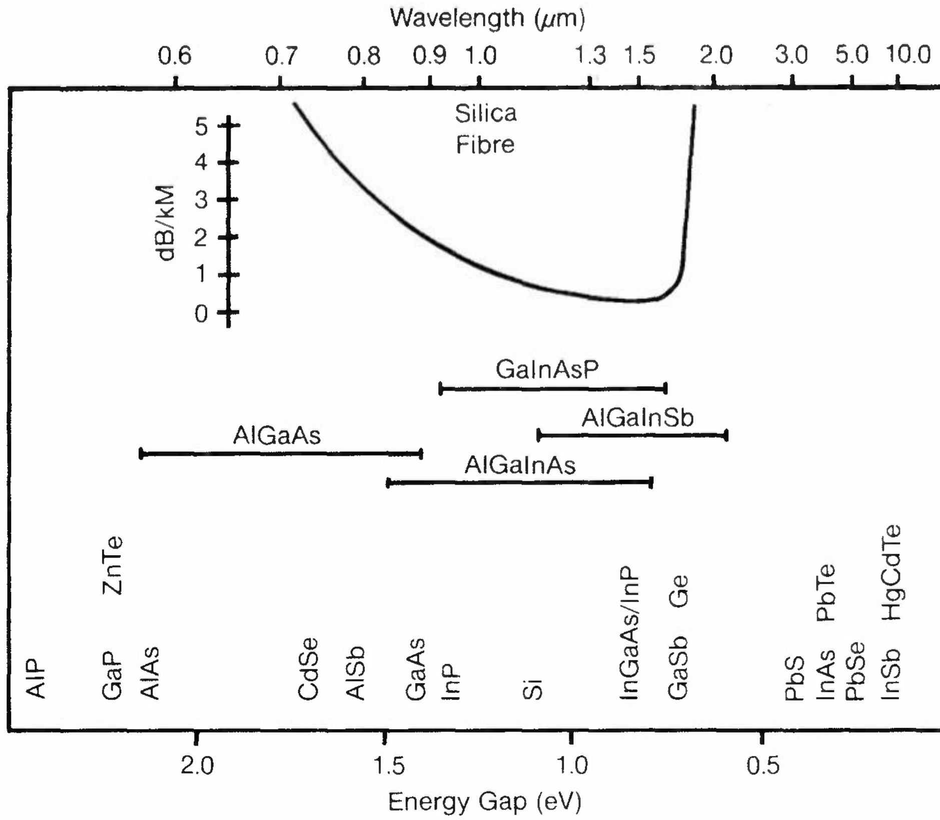
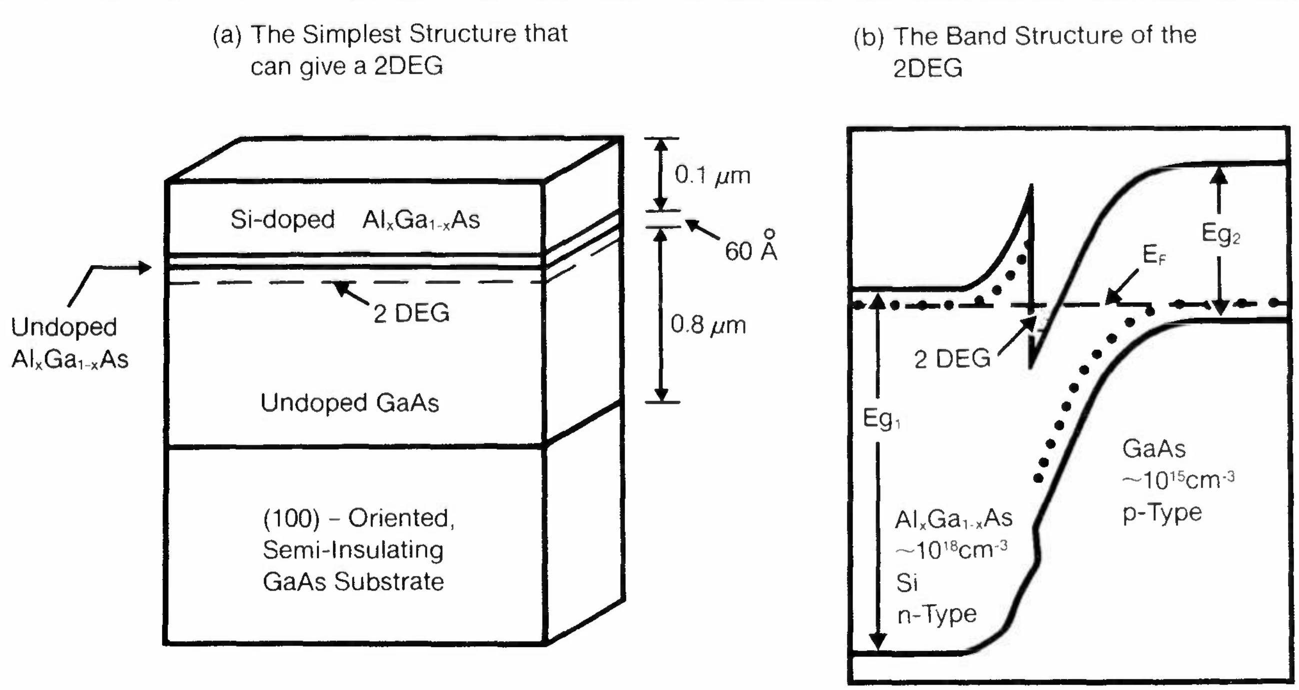


Fig. 4: Match Between Silica Fibre & III-V Characteristics



The electrons donated by the AlGaAs to the GaAs can move freely now that they are away from their 'parent' ionized impurity.

Fig. 5: Details of a Two Dimensional Electron Gas (2DEG)

TRANSPARENT CONDUCTIVE OXIDE FILMS

Dip-Coating Advantages

Transparent conductive oxide films can be used for a variety of window, solar-collector, photovoltaic and industrial heat shielding applications. Of the many methods, e.g. sputtering, ion plating, chemical vapour deposition and dip-coating, investigated for the production of these films, the last-mentioned process, dip-coating, has not been used extensively. The advantages however, are numerous and include:

(a) simple production of chemical solutions,
(b) layer composition built into solution,
(c) complete utilization of solution bath and
(d) no environmental pollution.

For these reasons, the dip-coating process is being further evaluated.

Reaction Process

The dip-coating process involves many chemical reactions that eventually lead to oxide layers. Usually, metal alkoxides in suitable solvents are allowed to react with a glass surface upon which a reaction occurs between the metal alkoxide and presumably silanol groups to form a layer of metal oxide precursors as shown in Fig.1.

After exposure to moisture and heat treatment at about 500°C, metal oxides are formed, which are bound into the glass matrix. Besides having desirable optical properties, the layers are hard and resistant to mechanical scratching.

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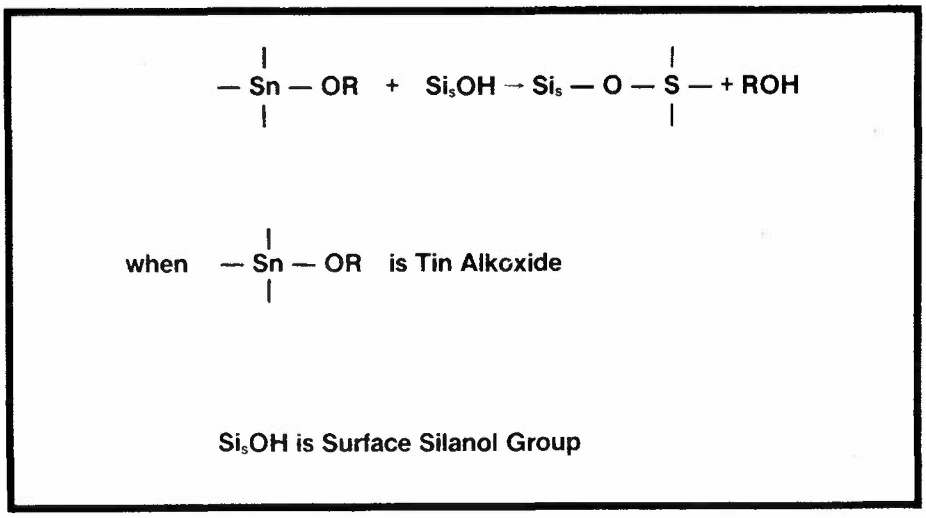

Fig.1: Formation of Metal Oxide Precursors

AMORPHOUS SILICON SOLAR CELLS

Crystalline Silicon Solar Cells

Since the world oil crisis in the early 1970s, scientists and engineers have quickened the pace of their search for alternative energy resources and means for harnessing sunlight for heating and electricity generation. The crystalline silicon solar cell, which is a product of earlier space research, appears to be an obvious choice for converting sunlight into electricity. However, the crystalline solar cell remains a novelty, even to this day, because of the high cost and high wastage in the manufacturing process.

Amorphous Semiconductors

Amorphous semiconducting materials, particularly amorphous silicon semiconductors, have emerged as promising candidates for utilizing sunlight. Japanese and U.S. researchers are intensely interested in amorphous semiconductor technology because it offers a much cheaper and simpler method of producing silicon alloys for use in solar cells. Amorphous silicon semiconductors are also found to be extremely useful in many other products of the 'electronic revolution', such as computer chips, integrated circuits and light sensing devices for video cameras and photocopiers.

Overseas Research

The Japanese Government has distributed funds amounting to many millions of dollars over the past five years to universities, government institutions and industrial groups for research into amorphous semiconductors. Significant support has also been provided by the U.S. Government to its researchers.

Giant Japanese corporations, such as Sanyo and Sharp, have already begun to reap the benefits of their research efforts by marketing amorphous solar cell powered calculators and wristwatches. However, solar panels for electricity generation are still in the experimental stage because amorphous solar cells are not yet as efficient or as long-lasting as the crystal-based solar cells. More research into this technology is urgently needed.

Remote Area Power Systems

In view of the current significant contribution by crystalline solar cells to the powering of the telecommunications network in remote areas and the imminent availability of the much cheaper amorphous solar cells, a comprehensive understanding of these new materials is of paramount importance, especially with regard to the planning and design of future power supply systems.

The Research Department has initiated a research program to study the properties of amorphous semiconductors and solar cells made with these materials. Of particular interest are the aging characteristics of this type of solar cell and its suitability for incorporation into remote area power supply systems.

The experimental glow-discharge deposition system used for preparing amorphous semiconductors is shown in Fig. 1. A typical amorphous silicon solar cell structure is shown in Fig. 2.

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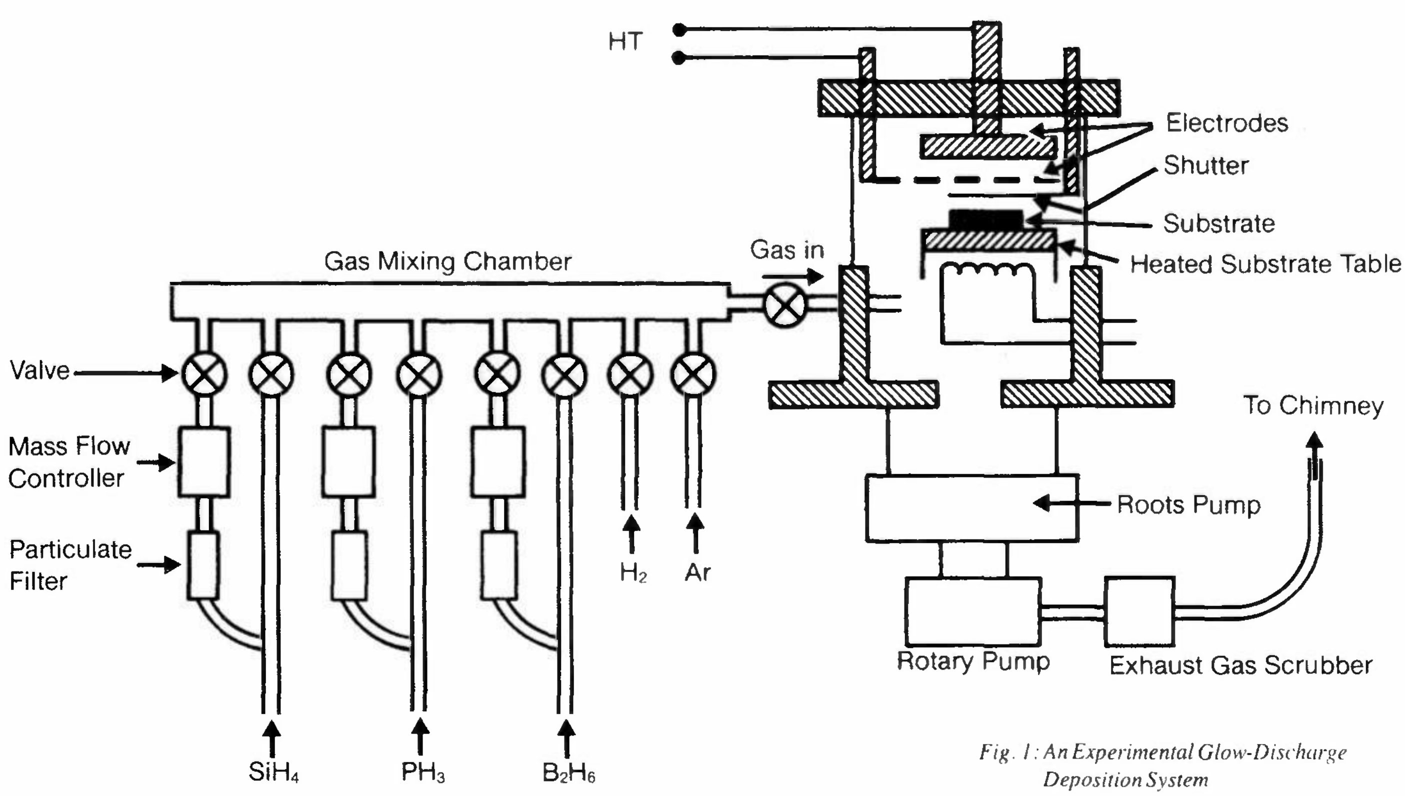

Fig. 1: An Experimental Glow-Discharge Deposition System

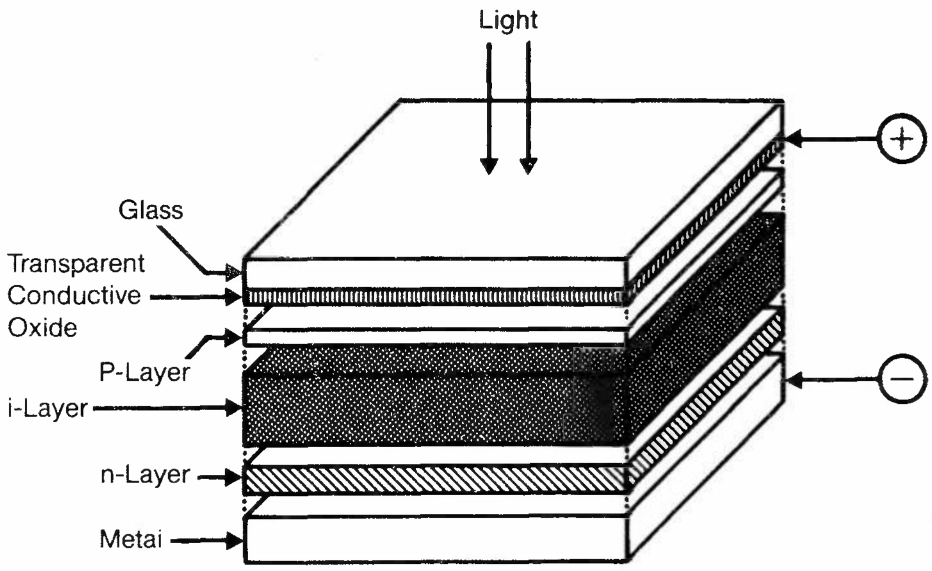

Fig. 2: Typical Amorphous Silicon P-I-N Solar Cell Structure

SCIENTIFIC REFERENCE STANDARDS, INSTRUMENTATION AND SPECIALIZED FACILITIES

In addition to its investigatory role, the Research Department provides some specialized services to Telecom Australia. These services are related to:

- the development and application of the Commission's reference standards for the measurement of time interval, frequency, electrical quantities, telephone transmission, and the physical, chemical and metallurgical properties of materials;
- the development and provision of technical information and associated library services;
- the provision of consultant advice and assistance related to the execution of Telecom's policy regarding industrial property (patents, etc.) and to general industrial property matters arising out of Telecom's activities.

Associated with the reference standards activities, specialist groups of the Research Department undertake the development, procurement, calibration and servicing of a wide variety of laboratory instrumentation, used both within the Department, within Telecom, or, in some instances, within local industry.

LIST OF EXHIBITS

Page No.	*Title*	*Description*
218	ATTENUATOR CALIBRATION	Precision attenuation measurement system in a screened room for the calibration of 75 ohm reference attenuators.
219	CALIBRATION OF AC THERMAL CONVERTER	Computer controlled precision measurement system for the determination of the AC-DC transfer of thermal converters. The AC-DC transfer procedure is the standard method of providing calibration of absolute AC measurements.
220	CALIBRATION OF THERMISTOR MOUNTS	Involves a set-up for the precision calibration of microwave thermistor power mounts. The set-up employs a desk top computer 'controller' to reduce measurement uncertainties and calibration times.
223	TRANSDUCER MONITOR FOR GAS PRESSURE IN CABLES	The evolution of in-cable monitoring devices is depicted. Several examples of actual units are on exhibit; including the hybrid digital prototype currently under development.
226	COMPUTER TERMINAL RESPONSE TIME MEASUREMENT	The ALERT unit monitors the response time of LEOPARD terminals in the Fault Dispatch Centers (FDCs).
227	A COMPUTERIZED INSTRUMENTATION RECORDS SYSTEM	Search and sort techniques are depicted. Visitors may interrogate the Department's Asset Records.
228	TECHNIQUES FOR SERVICING ELECTRONIC EQUIPMENT	A video film provides detailed step-by-step instructions on the correct approach to replacing components on printed circuit boards. A second video film outlines the basic operations of a microprocessor and introduces a number of appropriate servicing techniques.
229	AUSTRALIAN DEVELOPMENT OF DIGITAL TRANSMISSION TEST EQUIPMENT	Outlines the involvement of the Research Department in Telecom's Innovation, Research, and Development Program with respect to Digital Transmission Test Equipment. Laboratory prototypes together with contractor developed equipment are displayed.
230	ACOUSTIC CHAMBERS	1. Anechoic Chamber — measurement of polar sensitivity of a directional microphone. 2. Reverberant Chamber — measurement of acoustic spectra for telephone calling devices.
232	ADVANCED ANTENNA TEST RANGE	The procedures and considerations inherent in the measurement of antenna characteristics are detailed. Computer controlled antenna positioning equipment is demonstrated.
233	EXTERNAL FACILITIES FOR EQUIPMENT ENGINEERING	A video film describes the role, capabilities and equipment of the Equipment Engineering Section.
237	EQUIPMENT ENGINEERING SERVICES	Explains the role of Equipment Engineering Services and some of their areas of expertise. Photographs of examples of specialised equipment produced are on display.
238	MICRO ELECTRODISCHARGE MACHINING	Holes of approximately 0.008 mm diameter, using the Micro E.D.M. fine hole erosion process, are being produced.
239	INSPECTION OF SPACES USING ENDOSCOPES	Visitors may inspect inaccessible areas in recesses and bores.
244	LIBRARY USE OF MICROFORMS	The lack of physical storage space is a problem common to all libraries. The use of microforms such as microfilm and microfiche help minimize storage problems. Typical microform material is displayed.
245	ON LINE INTERACTIVE RETRIEVAL SERVICES	The use of computer terminals with link to central mass storage databases has revolutionized the role of libraries. The time required for information searches has been reduced from weeks to minutes.
246	MICROCOMPUTERS IN THE LIBRARY	The advent of microcomputers has made computer power widely available without the need for costly facilities or specialist staff. Within the library environment the microcomputer has been applied to a range of hitherto labour intensive activities.

STANDARDS & MEASUREMENTS TRACEABILITY

Measurement Traceability in Telecom

In a large organization such as Telecom there is a need for reference standards to ensure compatability of measurements within the organization and with its suppliers. Such standards must be provided on a sound scientific basis and be nationally and internationally compatible. The Research Department maintains for Telecom, on a national basis, the reference standards for electrical quantities, frequency and time interval and is responsible for disseminating these throughout Telecom.

Dissemination is achieved by calibration of reference standards for State Calibration Centres, which calibrate working standards for Instrument Calibration Centres, which in turn calibrate field instruments. Calibrations are also performed for the Research Department, Headquarters, Tasmanian Administrations, Telecom Contractors and areas requiring highly specialized measurement capabilities.

Measurement Traceability in the Reference Measurements Section

To provide traceability to Australian Standards, the Research Department has its transfer standards directly calibrated in terms of the national standards by the Division of Applied Physics, CSIRO. These transfer standards are used to maintain reference standards from which a wide range of measurement capabilities are derived.

The Reference Measurements Section of the Research Department is a National Association of Testing Authorities (NATA) registered laboratory for a wide variety of tests and issues test reports in accordance with NATA's requirements of accuracy and traceability.

Table 1 shows examples of the type of standard calibrated, the measured quantity, frequency and measurement uncertainty.

(See table)

Table 1: Examples of the Type of Standard Calibrated

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Standard	Measured Quantity	Frequency	Uncertainty
	Voltage Ratio		
Kelvin Varley Divider	0 to 1	Up to 10 kHz	0.2 p.p.m.
Volt Ratio Divider			
Potential Transformer			
Inductive Voltage Divider			
Potentiometer			
	Attenuation		
Attenuator	Up to 120 dB	Up to 18 GHz	0.001 to 1.5 dB
Directional Coupler			
	Impedance		
Impedance Bridge	2 to 2 kΩ	Up to 18 GHz	0.3%
Slotted Line	-90° to +90°	"	1.2°
Impedance Standard			
Reflection Bridge			
	Capacitance		
Capacitance Standard	Up to 1 nF	50 to 2 kHz	10 p.p.m. + 0.03 pF
Capacitance Bridge	1 nF to 1.1 µF	"	0.01 %
Capacitance Meter	1.1 to 11 µF	"	0.05%
	Up to 1 nF	Up to 1 MHz	0.1%
	Inductance		
Inductance Standard	Up to 1 H	50 Hz to 10 kHz	0.03% + 0.1 µH
Inductance Bridge	1 to 10 H	"	0.2%
Q Meter			
	Resistance		
Resistance Standard	Up to 100 kΩ	Zero	2 p.p.m. + 1 nΩ
Resistance Bridge	100 kΩ to 10 MΩ	"	10 p.p.m.
Ohmmeter	10 MΩ to 100 TΩ	"	0.01% to 1%
	Temperature		
Thermometer	0 to 100° C	—	0.003° C
	Current		
Ammeter	Up to 100 A	Zero	0.002%
Current Shunt	"	50 Hz	0.01%
Thermal Converter	Up to 10 A	Up to 1 kHz	0.01%
Current Transformer			
	Voltage		
Voltmeter	Up to 1 kV	Zero	5 p.p.m. + 1 nV
Voltage Multiplier	Up to 300 V	Up to 100 kHz	30 to 300 p.p.m.
Thermal Converter	300 to 1 kV	"	30 p.p.m. to 0.1%
Reference Voltage Source	Up to 20 V	100 kHz to 1 GHz	0.05% to 0.5%
Selective Voltmeter			
Signal Generator			
Receiver			
	Power		
Wattmeter	Up to 10 kW	Zero & 50 Hz	0.05%
Power Meter	Up to 10 W	Up to 18 GHz	0.5%
Level Meter			
Power Transfer Standard			
Level Transfer Standard			
	Frequency		
Frequency Standard	—	Up to 18 GHz	4×10^{-12}
Counter			
Oscillator			
	Time Interval		
Time Interval Meter	From 1 ns	—	1 ns
Counter			

Note 1. The uncertainty shown above is that which is the best measurement capability and is not necessarily realizable over the full measurement or frequency range.

Note 2. Where a requirement exists for a measurement outside that shown above, special techniques and standards may be devised and employed, but the uncertainty may be greater.

PRECISION QUARTZ RESONATORS & OSCILLATORS

The overall efficiency of present day telecommunications and broadcasting would not be possible but for the development of modern quartz resonators. The Research Department is engaged in such development. Quartz resonators are known to the 'trade' simply as crystals. They are manufactured from crystalline quartz, SiO_2, which occurs in nature as a rhombohedral crystal. It is glass-like in appearance, with a melting point of 1750°C, density 2.56 Mg/m^3 and hardness 7 on the Moh scale.

Quartz is a piezoelectric material. Piezoelectricity is electric polarization produced by mechanical strain. Conversely a mechanical strain is produced in a crystal by a polarizing electric field. As suitably prepared slices of the crystal make efficient vibrators, these slices can therefore be employed as the frequency determining elements in electronic circuits such as highly stable oscillators and narrow band filters etc.

The quartz slices are designed to vibrate with a mode of motion that permits, among other considerations, rather small pieces of quartz to be used. The largest elements are bars up to 80 mm in length and these are for the low frequencies. Those for the higher frequencies are thin discs about 7.5 mm in diameter.

Crystalline quartz that has been grown artificially in autoclaves is now widely used in place of natural quartz for the manufacture of resonators and optical instruments.

Fig. 1 shows the orientation of the most commonly used crystal 'cuts'. The slices as shown are cut from the parent crystal by circular diamond saws, then machine lapped and polished to the required dimensions with special emphasis on flatness and surface finish. To minimize frequency change with temperature, the angle that the major surface makes with the crystalline axis is critical. In some cases the tolerance is ± 20'' of arc.

This angle is measured in an X-ray (Cu target) goniometer. The metal electrodes, usually gold or silver, that couple the quartz element to the electrical circuit are deposited on the surface by vacuum evaporation at low pressures. Resonators designed for precision oscillators are mounted in evacuated glass enclosures. In an oscillator the resonator functions as a resonant tuned-circuit of extremely high 'Q' that, in some cases, is greater than 2x10^6. Oscillators are designed to employ the crystal in such a manner that full advantage is taken of this property. At certain frequencies oscillators employing well made crystals of modern design may have a daily frequency drift as low as one part in 10^{11} and a short term stability over an averaging time of 1 second in the order of 1 x 10^{-11}. Oscillators of this quality at 5 MHz made in the Research Department have been in continuous service for more than 12 years.

The display shows stages in the production of high quality crystal units and the evaluation of both crystal units and the associated electronic circuitry.

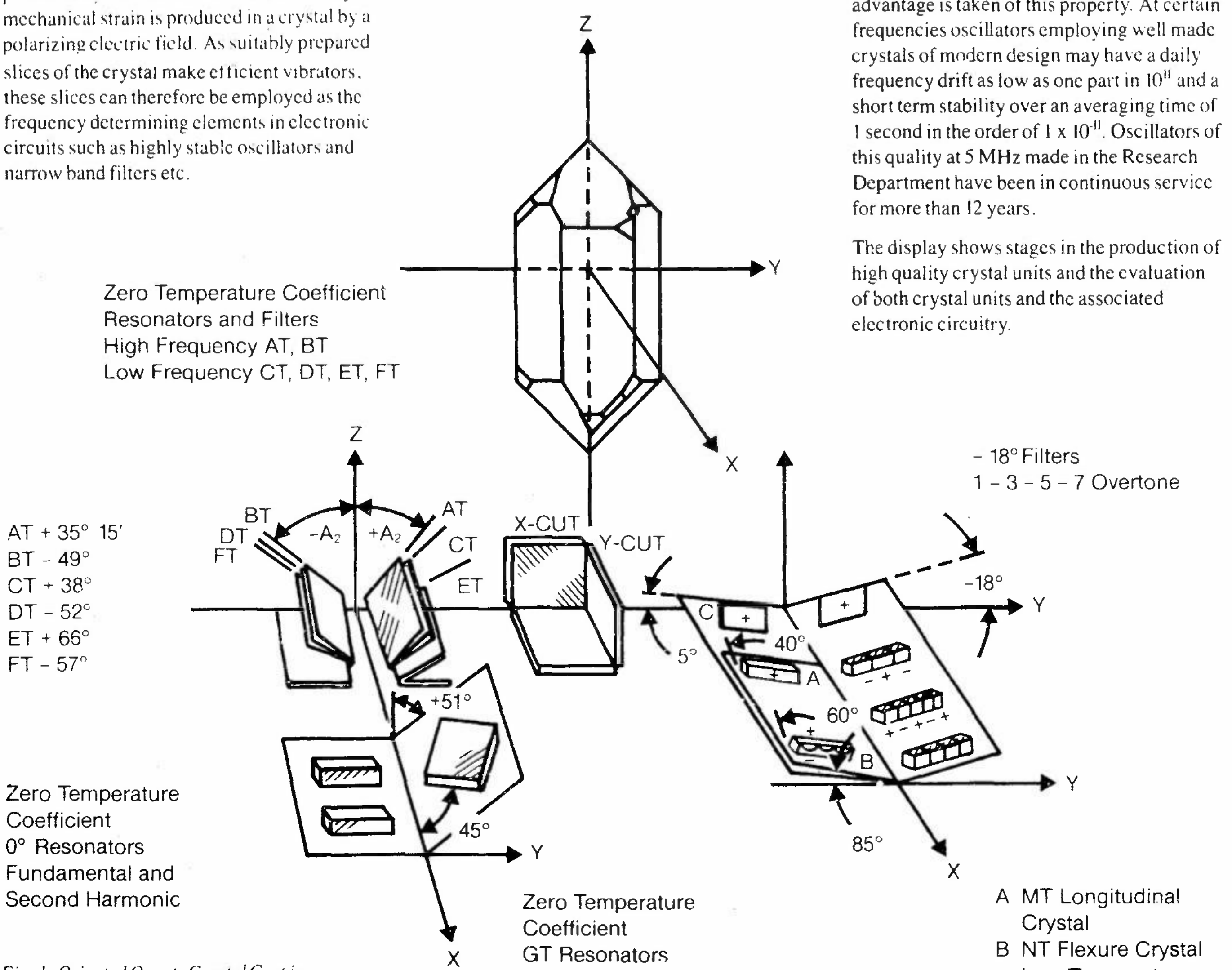

Fig. 1: Oriented Quartz Crystal Cust in Relation to the Crystalline Axis

Resonant Frequency

The resonant frequency of a quartz crystal is generally determined by the dimensions of the plate combined with the mode in which it vibrates.

Resonant frequencies in standard quartz plates range from about 1 kHz to 150 MHz.

The equivalent circuit of a vibrating crystal (Fig. 2) is useful in explaining the basic concepts governing the crystal's performance.

C_0 represents the static capacitance and is the sum of the capacitance between the electrodes and capacitance added by the wire leads and holder.

The R_1, L_1, C_1 branch is known as the motional arm. C_1 represents the motional capacity of the quartz. L_1 is a function of the mass and R_1 is the sum of the bulk crystal losses.

C_0 : Static Capacitance (electrode plus holder)
C_1 : Motional capacitance (mechanical elasticity)
L_1 : Motional inductance (mass)
R_1 : Equivalent series resistance (energy loss)
All crystals may be used either in series or parallel resonance (anti-resonance). The latter is generally more sensitive to external parameter changes especially with respect to stray capacitance.

Therefore, it is recommended to oscillate crystals near the series resonance frequency.

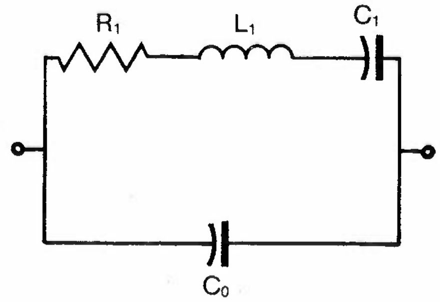

Fig. 2: Equivalent Circuit of a Vibrating Crystal

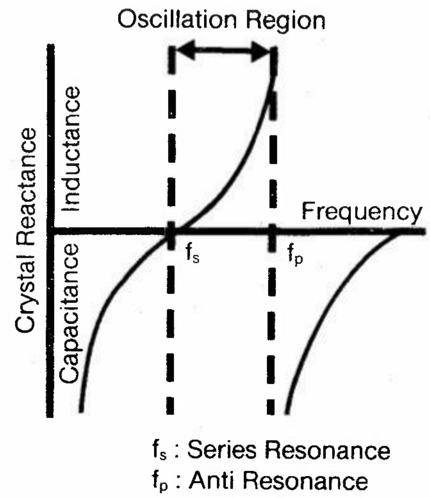

Fig. 3: Relationship of Series Resonance to Parallel Resonance (Anti-Resonance)

Temperature Coefficient

Temperature coefficient is frequency stability or deviation with temperature change. Temperature coefficient is expressed in parts per million change over the operating temperature ranges.

The mode of vibration, the orientation of the plate in relation to the axis of the quartz , the dimensions of the plate and the harmonics determine the temperature coefficient.

Resistance and 'Q' Factor

Resistance is the equivalent impedance of the quartz resonator and it determines the 'Q' factor of a quartz crystal. High crystal 'Q's are obtained by reducing mechanical and acoustic energy loss, which is equivalent to R_1.

The crystal 'Q' is related to the series reasonance frequency f_s, the motional inductance L_1 and the equivalent series resistance R_1 by the formula:
$Q = 2_\pi f_s L_1/R_1$

A high 'Q' factor, i.e. low resistance R_1, reduces the influence of external parameters, such as variations in supply voltage, load, temperature and oscillator components.

Spurious Modes

Spurious modes (unwanted modes) are actually inharmonic modes of vibration of the quartz plate. Since spurious modes are inherent in every crystal resonator, they are suppressed by special design techniques.

Typical spurious specifications are 6 dB below the desired mode of oscillations.

Drive Level

The drive level normally expressed in milliwatts is the dissipated power between two crystal leads.

Drive level should be the minimum necessary to start and maintain crystal oscillation, to assure optimum performance and stability. Excessive drive can result in breakage of the crystal element, excessive frequency drift and poor aging characteristics.

Frequency Tolerance

Frequency tolerance is the amount of frequency deviation (plus or minus) from the desired operating frequency at a specific temperature. It should be noted that commercially, the accuracy requirement for crystal tolerance is expressed as a percentage.

Aging

Aging of a quartz crystal is a general term applied to any change in parameters of a crystal unit taking place over a period of time.

To prevent severe aging, circuits should be designed to keep the drive level at the absolute minimum.

Load Capacity

The load capacity is the sum of the capacity of the crystal socket and any other parasitic capacitance across the crystal in an oscillator.

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GENERATION OF STANDARD FREQUENCY & TIME INTERVAL

Basic Definition

The basis of all frequency and time measurements is the second, which was defined by the 13th General Conference of Weights and Measures (CGPM) as the duration of 9,192,631,770 periods of the radiation corresponding to the transition between two hyperfine levels $F=4$, $m_F=0$ and $F=3$, $m_F=0$ of the fundamental state 2S.½ of the atom of caesium 133 undisturbed by external fields. The modern approach to the generation of time interval is to produce an electrical signal of known frequency and measure elapsed time by maintaining an accumulated total of the number of cycles of this signal. The commonly used methods of generating standard frequencies and time are described below.

Caesium Beam Frequency Standard

This device is the practical embodiment of the current definition of the second and is capable of realizing the definition to a fractional accuracy of less than $\pm 1 \times 10^{-11}$.

It may be seen from Fig. 1 that the caesium beam frequency standard consists of a 5 MHz quartz crystal oscillator whose electronic (varactor) tuning is determined by a control loop containing a caesium beam tube. A microwave signal (9192.6 . . . MHz) is synthesized from the 5 MHz signal and is applied to an atomic beam spectrometer where the magnetic component of the microwave field reacts with a beam of caesium atoms to produce atomic resonance. The electronic tuning loop is arranged so that the 5 MHz oscillator is automatically tuned to the frequency that produces maximum resonance indication. The beam tube detector output signal varies with applied microwave signal frequency as shown in Fig. 1. The largest peak is the one that corresponds to the required atomic resonance. The control loop seeks maximum beam tube detector output by varying the tuning current to the 5 MHz quartz crystal oscillator's varactor. The sense of the required tuning correction is determined by frequency modulating the microwave signal at a small deviation. When the microwave signal differs from resonance, the beam tube detector output signal contains a component of the low frequency modulation signal. This component will have a certain phase relationship to the modulating signal when the microwave frequency is less than resonance and the reverse phase relationship when the microwave frequency is higher than resonance. The magnitude and phase of this component is determined by a phase detector, shown in Fig. 1, and the resultant loop error signal, after integration is applied to the crystal oscillator's tuning varactor.

Fig. 1: Simplified Diagram of Caesium Beam Frequency Standard

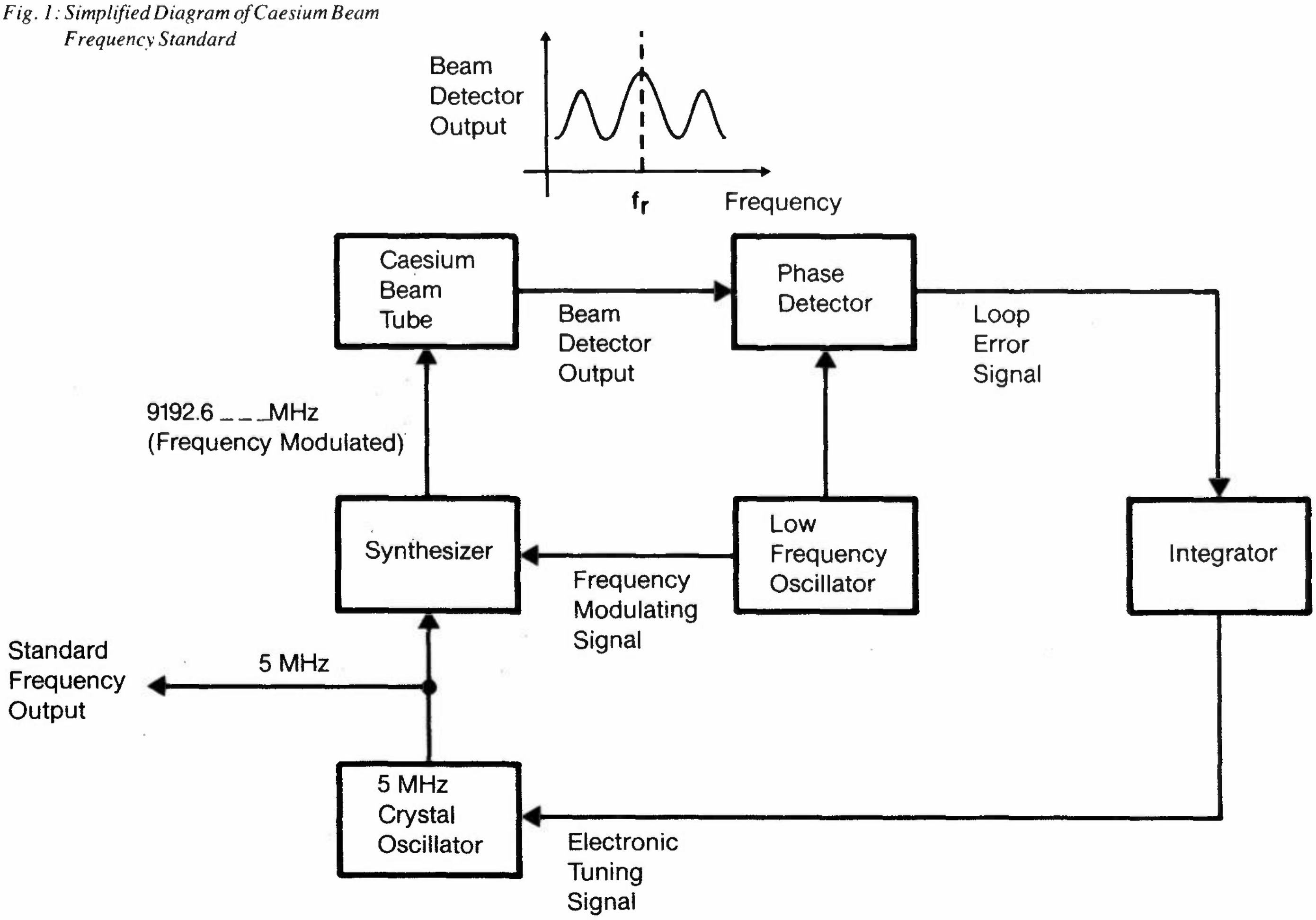


Fig. 2 represents, in simplified form, the internal arrangement of the caesium beam tube. An oven provides a source of neutral caesium atoms that effuse through the tube. The mechanism of state selection of atoms and interaction may be demonstrated by reference to Fig. 3. This figure, which shows the energy levels of caesium 133 in the 2S.½ ground state as a function of the applied magnetic field, indicates that the (3, 0), i.e. F=3, m_F=0, and the (4, 0) states are least affected by magnetic fields (in the small field region). It is these two states that determine the atomic resonance of this device and at zero field the frequency corresponding to the difference in these energy levels is defined as 9,192,631,770 Hz. If the beam tube were operated at zero field, all energy states would enter into the interaction. Since this is undesirable, the tube is magnetically shielded to remove the earth's field and operated with a small, constant field, known as the C-field, which ensures that atoms preserve their state identity. Although the (3, 0) and (4, 0) energy states are the least field dependent, there is still a small shift in the energy levels due to the presence of the C-field, which causes a frequency increase of approximately 1.7 x 10^{-10} in the atomic resonance frequency for the C-field intensities used in modern commercial beam tubes. This output frequency offset is removed in the synthesizer section of the frequency standard by arranging it to generate a microwave frequency that is 1.7 x 10^{-10} higher than the defined frequency.

Caesium atoms effusing from the oven are formed into a beam by the collimator and enter the intense magnetic field of the 'A' state selector magnet. Here the atoms undergo a deflection whose direction is dependent on both the strength of the field and the sign of the atom's effective magnetic moment. That sign may be determined by the negative derivative of the energy curves, shown in Fig. 3, at the point corresponding to the particular field strength. The approximate strength at the state selector magnet is indicated on Fig. 3. Those states whose curves have positive gradients at this field strength are deflected downwards, in Fig. 2, while those states whose curves have negative gradients are deflected upwards.

Thus the F=4 states, with the exception of the (4—4) state, are deflected into the interaction area, which contains the C-field and two regions of microwave field as shown in Fig. 2. It can be shown that two microwave field regions separated by a region of uniform C-field gives a narrower resonance line width than a single microwave cavity of the same overall length and is easier to construct. Atoms in other states are deflected upwards and miss the microwave cavities. Atoms whose states are not changed by passage through the microwave fields will be deflected downwards at the 'B' state selector magnet and thus miss the detector. If the microwave field is of frequency corresponding to the (4, 0) → (3, 0) transition, atoms in the former state will emit a quantum of energy and 'flip' to the (3, 0) state with a maximum probability. Since the effective magnetic moment of atoms in the (3, 0) state is opposite, as shown in Fig. 3, to the moment of all the other states now in the beam, the (3, 0) states are the only ones to reach the detector and the number of such atoms reaching the detector is proportional to the accuracy with which the microwave frequency equals the atomic resonance frequency.

The detector consists of a hot wire ionizer, a mass spectrometer and an electron multiplier. The ionizer imparts surface charge to those atoms that impinge on it, the spectrometer separates caesium ions from impurity ions and the electron multiplier detects the ionized caesium atoms and generates a current proportional to the intensity of the ionized beam of atoms. This current is therefore a measure of the atomic resonance and is used to control the electronic tuning of the quartz oscillator so that the synthesized microwave field produces a maximum of (4, 0) → (3, 0) transitions.

It has been mentioned above that the C-field has a small effect on the atomic resonance frequency. It is necessary therefore to set the C-field intensity precisely to a specific value in order to generate the correct output frequency. The C-field is generated by current through a coil wound around the interaction space, the current being provided by a precisely regulated source. The field-dependent transitions, such as (4, 1) → (3, 1), (4,-1) → (3,-1) etc., are used as a means of setting the C-field. The frequency at which these transitions are excited is a function of the magnetic field intensity in the tube. Therefore, if the microwave frequency is modulated with a known frequency and the C-field intensity is adjusted by varying the current regulator, a field intensity will be reached where the sidebands generated around the main signal frequency will excite the field-dependent transitions. This excitation will increase the number of atoms that are in F=3 states with a resultant increase in detected beam current.

Fig. 2: Diagrammatic Representation of Caesium Beam Tube

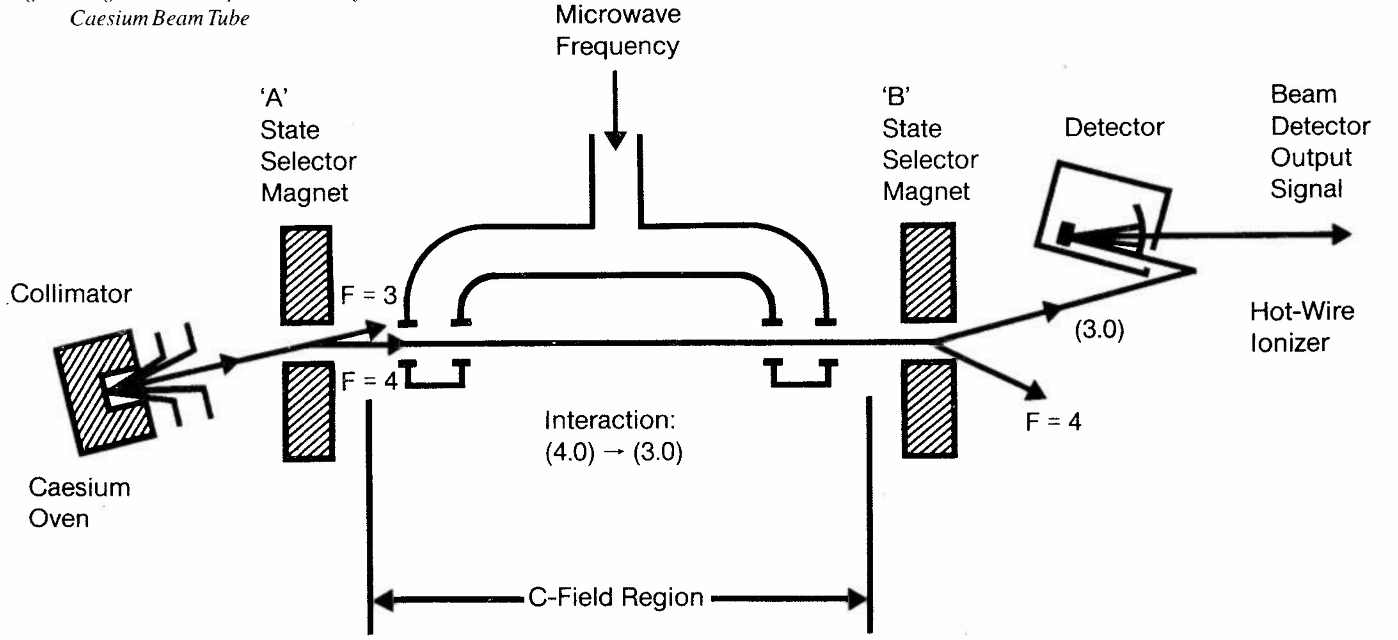
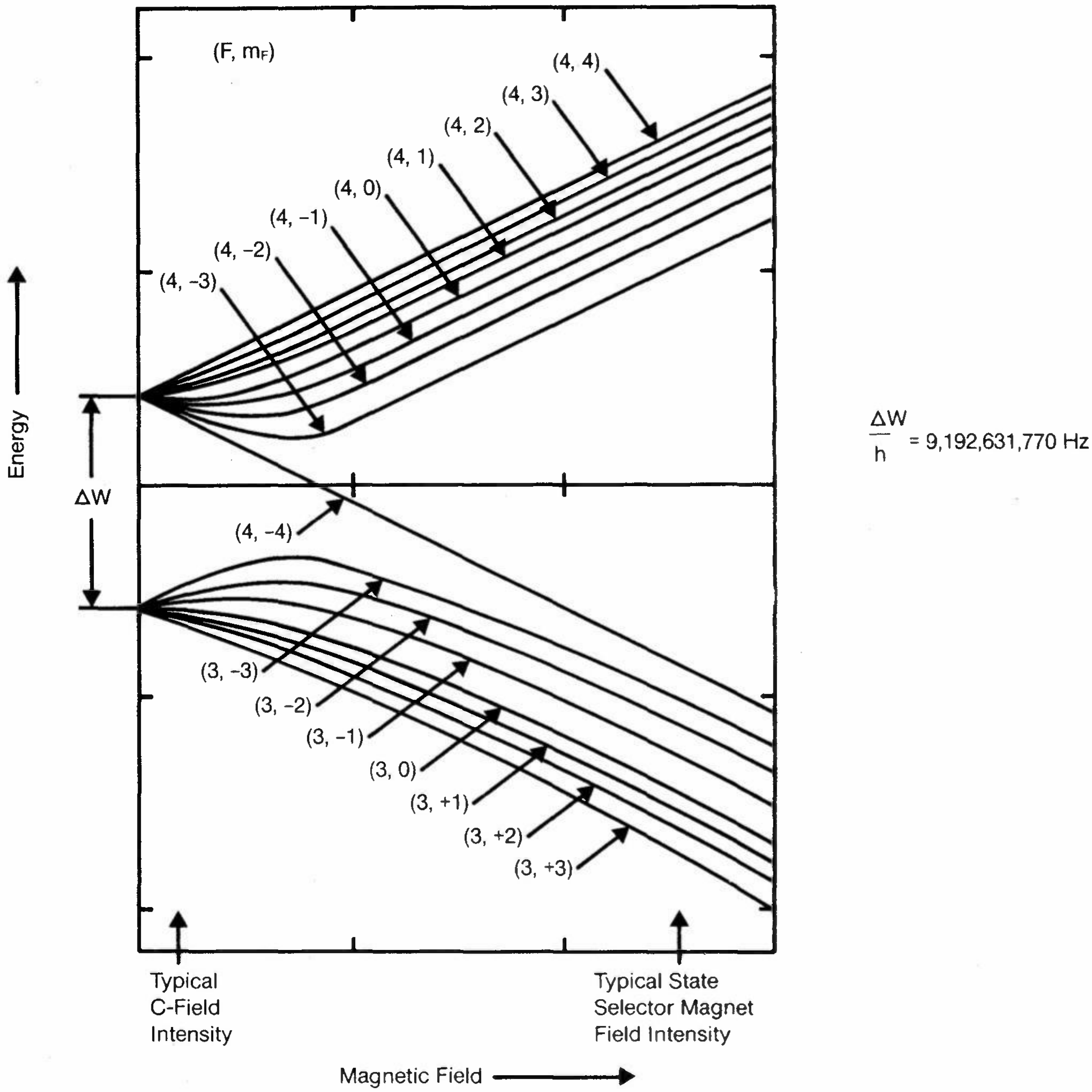


Fig. 3: Energy Level Diagram of Caesium 133 in the 2S.½ Ground State as a Function of the Applied Magnetic Field



Rubidium Vapour Frequency Standard

This type of frequency standard utilizes the (2, 0) → (1, 0) transition of rubidium 87 gas to control a quartz crystal oscillator. The peripheral equipment is basically similar to that used in a caesium beam standard, viz. a synthesizer to produce 6,834.6 . . . MHz, which is frequency modulated to a low frequency rate, and a phase detecting system to provide a control signal for the quartz crystal oscillator varactor.

The interaction cell is a pyrex gas-tight container, within a resonant cavity, containing rubidium 87 atoms and a buffer gas (a mixture of inert gases) at low pressure. The buffer gas produces an increased interaction time (for rubidium atoms with the field), which results in an atomic resonance that is proportionately narrower than that for the case of no buffer gas. Interaction time is increased because the rubidium atoms collide elastically with the buffer gas atoms and take longer to reach the cell walls. Initial state selection is accomplished by optical pumping using light from a rubidium 87 lamp filtered by a cell of rubidium 85 gas. Filtering removes the portion of the radiation that could be absorbed by those rubidium atoms that are in the F=2 states. Atoms in the F=1 states absorb a photon from the pump radiation and thereby raise their energy levels to optical states.

Relaxation, accompanied by the release of a photon, occurs from these optical states to both the F=1 and F=2 ground states. Since atoms in the F=1 states are immediately pumped back to optical states, the overall effect of optical pumping is to convert F=1 to F=2 states. With the F=1 states depopulated, photons of the pump radiation are able to pass through the cell to a photodetector. If then a microwave field of frequency equal to the (2, 0) → (1, 0) transition is applied to the interaction cell, atoms in the (2, 0) state will release energy and flop to the (1, 0) state in which state they will absorb photons of pump radiation and be raised to optical states. On relaxing to ground states, these atoms will emit photons in a random direction so that the overall effect will be to reduce the amount of light reaching the photocell. Minimum light transfer through the cell therefore occurs when the microwave field frequency equals the required atomic resonance. The control circuitry is arranged to change the frequency of the quartz crystal oscillator to maintain this condition.

The rubidium vapour frequency standard cannot be regarded as a primary frequency standard because of the effect of rubidium atom collisions with the buffer gas and changes in the pump light intensity. Collisions with buffer gas atoms cause the atomic resonance frequency of the rubidium atoms to be raised in proportion to the rate of collision, i.e. in proportion to pressure and temperature. The pressure and temperature dependence of the output frequency is minimized by a suitable mixture of two inert gases. Slight variations in buffer gas pressures between cells make it necessary to calibrate each unit against a primary standard. After calibration, however, small dimensional changes in the cell, resulting in pressure changes, and temperature variations in the cell oven contribute to frequency errors. Variations in frequency due to changes in the intensity of the pump light are minimized by a suitable choice of buffer gas pressure. The final pressure and mixture of inert gases as normally used in commercially available units, causes an increase in frequency of approximately 2×10^{-7} in the atomic resonance with respect to the zero field value of 6,834,682,605 Hz (this frequency offset is removed in the design of the synthesizer). Such units serve well, however, as secondary standards, which generate frequencies having short term (one second average) stabilities of approximately 1×10^{-11} (standard deviation) and long term stabilities of 5×10^{-11} per month (standard deviation).

Quartz Crystal Frequency Standards

Modern quartz crystal standard frequency oscillators generate frequencies with short term (one second average) stabilities of approximately 1.5×10^{-11} (standard deviation) and long term stabilities of approximately 1×10^{-11} per day (standard deviation). Because of their high reliability they are useful as tertiary standards in conjunction with the more complex atomic standards. The long term stability mentioned above is one that is fairly constant and is therefore additive with time. Thus, after three months, for example, a quartz oscillator's frequency would have changed by approximately 1×10^{-9}. This phenomenon, known as 'aging', requires that the quartz oscillator be retuned frequently by reference to a primary or secondary frequency standard.

Generation of Time Interval

To produce standards of time interval it is necessary to accumulate cycles of standard frequency so that the total number of accumulated cycles is a measure of elapsed time. Accumulation is normally done in a digital clock that consists of a series of digital dividers whose total count capacity is equal to the number of input cycles necessary to produce the required time interval. For example, if the available standard frequency is 5 MHz and the clock has a count capacity of 5×10^6, it would deliver one output cycle for every 5×10^6 input cycles, i.e. the time interval between output pulses would be one second. Such a clock can, of course, be extended to provide time-of-day information in hours, minutes and seconds. Digital dividers, when used for this purpose, have provision for accurately changing the phase of their output signals to allow their epoch (i.e. time-of-day) to be set to known phase relationships with respect to other clocks in a time standard installation.

Such clocks not only provide standards of time interval but also a long term method of rating frequency standards. The changing time difference between output pulses of clock systems driven by different frequency standards provides a convenient means of determining the average frequency difference between standards.

Accumulation of pulses to form a time scale requires that no interruptions occur to either the frequency standard or its clock systems. This places stringent requirements on reliability and requires the use of standby systems to continue the accumulation should the main system fail. In practice, a number of independent systems, each with adequate emergency power systems, are operated and compared to provide the required reliability and hence accuracy and continuity of time scale.

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TELECOM'S TIME & FREQUENCY STANDARD

Definitions of Time and Frequency

Before describing the Standard, it is helpful to consider the definitions of time and frequency and the way in which these definitions are realized.

The fundamental unit of time interval is the second, which is, as defined by the 13th General Conference of Weights and Measures, October 1967, the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels $F=4$, $m_F=0$ and $F=3$, $m_F=0$ of the fundamental state 2S.½ of the atom of caesium 133 undisturbed by external fields. This second is chosen to equal the ephemeris second, which is based on the orbital motion of the Earth in the year 1900.

Frequency is simply the number of events occurring in an interval of one second.

Instant, or time of day, is determined by reference to International Atomic Time, IAT, which is defined (14th General Conference of Weights and Measures, October 1971) as a time scale based on the operation of a group of independent atomic clocks, co-ordinated by the Bureau International de l'Heure in Paris. The initial instant of IAT coincided with zero hours UT2, an astronomically derived time scale based on the rotation of the earth on its axis, on the 1st January 1958. Time of day on the IAT scale is simply given by the number of seconds intervals, expressed in years, months, days, hours etc. that have accumulated since the initial instant.

The time scale used for normal activities, radio time signals etc. is called Co-ordinated Universal Time (UTC). This time scale is co-ordinated by the Bureau International de l'Heure so that it is an integral number of seconds displaced from IAT but in such a way that it is within about 0.9 of a second of the astronomically derived scale of Universal Time, UT1. UT1 is a measure of the Earth's angular position on its axis and is also known as Greenwich Mean Time.

Because of the non-uniformity of UT1, occasional step adjustments of precisely one second, 'leap seconds', are made to UTC to maintain the two scales within about 0.9 of a second. These adjustments are performed as determined by the Bureau International de l'Heure. Standard time in Australia is defined in terms of UTC, e.g. Australian Eastern Standard Time (AEST) is UTC + 10 hours.

The Standards Installation

The Australian Telecommunications Commission (ATC) Standard of Time and Frequency is operated by the Research Department to provide time and frequency references for the various telecommunications activities of Telecom Australia. The standard also provides time and frequency services that are widely distributed and used by government departments, academic institutions, armed services, industry and the public.

The ATC Standard is recognized by the National Standards Commission as a Working Standard of time interval and frequency under the Weights and Measures (National Standards) Act 1960. This means that the ATC Standard is appointed by the CSIRO to provide means by which measurements of time interval and frequency may be made in terms of the Commonwealth legal unit.

The primary standard of frequency in the Time and Frequency Standards installation is generated by proprietary caesium beam frequency standards with back-up provided by rubidium vapour secondary standards.

A clock system consisting of micro-phase steppers and digital divider units, both commercially and laboratory made devices, generates time scales from the primary standard, which are designated AT(ATC) and UTC(ATC). Adjacent pulses on both scales are separated by the second but, for UTC(ATC), time of day is modified by the step adjustments, leap second insertions, mentioned above.

Other scales are generated from the secondary frequency standards and are used to back-up the above time scales. All equipment is powered from a system of large capacity batteries to provide immunity to mains supply failure.

The accuracy of the standards, i.e. the deviation of frequency from the nominal value, is maintained within the following limits: Caesium beam standard is 4×10^{-12}, within $\pm 2.5°C$. The stability of standards, defined as the deviation from the predicted frequency on a long term basis is:

- Caesium beam standard: $\pm 3 \times 10^{-12}$.
- Rubidium vapour standard: $\pm 1 \times 10^{-11}$/month.

The aging rates of the standards are:

- Caesium beam standard: negligible to these accuracies,
- Rubidium vapour standard: -3×10^{-13} per day.

The time scale UTC (ATC) is maintained within 50 microseconds of the Bureau International de l'Heure's scale of Co-ordinated Universal Time, UTC(BIH).

Comparison Techniques

It is essential that the component parts of a frequency and time standard (e.g. its different clock systems) be compared for internal consistency and that the standard as a whole be compared with other standards organizations around the world. The following paragraphs review the comparisons made in the ATC Time and Frequency Standards Installation.

The most satisfactory method of determining time errors and hence frequency errors is a series of portable clock measurements. Readily portable and highly accurate frequency standards and clocks are now being transported between standards installations to provide the most effective measurement of the behaviour of standards at different locations. Such experiments, often referred to as flying clock experiments, provide time measurements accurate to 1 microsecond and thus frequency differences between standards may be determined to parts in 10^{13} with visits spaced by 100 days. Portable clocks from the US Naval Observatory provide the link between the ATC and IAT.

In 1970, a system was instituted to compare clocks in different standards laboratories accurately by reception of television field synchronizing pulses. Each laboratory tunes to a common television program (a daily news bulletin originating in Sydney and distributed over the interstate television network is currently used) and each measures the time difference between its local clock and the same field synchronizing pulse. A knowledge of the television system propagation times allows the individual clock differences to be calculated. Propagation times are determined by occasional portable clock experiments and have been found to remain constant to within a few microseconds.

Continuous phase tracking of a number of stabilized very low frequency (VLF) radio signals provides a comparison of the ATC standard with standards at the National Bureau of Standards (USA) and the United States Naval Observatory. The VLF signals are derived from atomic frequency standards and are transmitted by a number of stations operating in the 10 kHz to 30 kHz band. The propagation time of signals in this band, when measured at a specific time each day, is stable to a few microseconds so that the record of received phase closely represents the relative phase of the ATC standard with respect to each station's standard. Changes in transmitted phase, signal fades resulting in the receiver slipping cycles and receiver interruptions may cause ambiguities in the relative phase results. Accordingly, a reference phase calibrating system has been installed to enable phase results to be referred to UTC(ATC).

Time difference measurements between the master clock, UTC(ATC), and each of the other clocks and time code generators in the installation are made daily to a precision of 1 nanosecond. These measurements are performed automatically at specific times and the results are stored for later analysis.

Continuous phase records of the output signals from all standards in the installation allow the accurate calculation of the frequency difference of any particular standard with respect to the other standards. The comparators used have a resolution of 1 nanosecond of phase, which allows a fractional frequency difference of one part in 10^{12} to be measured in about 15 minutes.

VNG TIME OF EMISSION, AEST	FREQUENCY (kHz)
1945 — 0730	4500
Continuous, except 0830 — 0845	7500
0745 — 1930	12000

Distribution of Time and Frequency VNG

The ATC operates a standard frequency and time signal broadcast from the Lyndhurst Radio Station near Dandenong, Victoria, as a service to surveyors, navigators, scientists and industry. The service is broadcast continuously in accordance with the following schedule to provide an Australia-wide coverage.

The carrier frequency as transmitted is maintained within one part in 10^{11} of the ATC standard (24 hour average) and the time signals as transmitted are maintained within 10 microseconds of UTC(ATC). The time signals are coded to indicate quarter hour, five minute and minute intervals.

Two-Tone Distribution

Telecom distributes a 1 kHz standard frequency from its frequency standard to all capital cities in voice frequency channels of its broadband system. The 1 kHz is transmitted as the difference of two tone frequencies, 1.7 kHz and 2.7 kHz. Since the broadband system uses single sideband suppressed carrier transmission, the two tones are recovered at the far end with the same frequency translation error. Thus the frequency difference between them is accurately preserved at 1 kHz and is recovered by demodulation of the tones. The tone frequencies are chosen to minimize the unwanted products added during transmission by the normally accepted imperfections of the trunk system, e.g. intermodulation and incidental frequency modulation, and by the final demodulation.

The demodulator must have long-term phase stability and small phase movement with signal level and temperature change. A number of 1 kHz outputs are provided for distribution.

The recovered 1 kHz has added fast phase jitter from the telecommunication network whose amplitude depends on the transmission path but is typically of order 0.5 microseconds. The long-term phase wander is not accurately known and is the subject of present measurement. Short-term (10 seconds) frequency measurements against the 1 kHz are limited by the noise to an accuracy of 10^{-7} but long-term measurements, using a chart recorder, for instance, readily achieve parts in 10^{-11} in a day. The demodulator includes a means for averaging *n* phase comparisons against the local signal to be calibrated, reducing the standard deviation of the phase measurement by the factor $n^{0.5}$. The Two-Tone Distribution System (see Fig. 1) is used by Telecom for calibration of its trunk network frequencies.

Controlled Oscillators

In a new development the two- tone system is used to control high quality quartz crystal oscillators, which drive other equipment as required. In this way, a range of services having precise time and frequency will become available in various locations, which can be any location reached by the Telecom network. In particular, precise phase will be distributed, in the first instance for the engineering requirements of Telecom. The order of accuracy envisaged is 1 microsecond plus seasonal movements.

Frequency Distribution

Standard frequencies of 1 kHz, 10 kHz and 100 kHz are available for distribution over leased lines in Melbourne (10 kHz and 100 kHz on a limited basis only). 1 kHz is also available on leased lines in other capital cities as outputs of the previously described two-tone system. Development of various phase-locked oscillator systems is proceeding and will result in the availability of higher standard frequencies, e.g., 1 MHz, of good short and long term stability under the control of two-tone or 1 kHz signals.

National Reference Clock

To ensure satisfactory performance of the expanding digital network, it is necessary to control accurately the rate at which digital signals are transmitted throughout the network by synchronizing the clocks controlling digital switches, multiplexers and transmission systems.

Network synchronization will be implemented by synchronizing all exchange clocks to a single national reference clock by means of a master-slave system. Each exchange clock will be slaved to one or more clocks over synchronization links that will be ranked in a predetermined order of preference and automatically selected to achieve the highest network reliability.

The national reference clock will contain equipment to generate synchronous mean clocks at 2.048 MHz from the ensemble of three dedicated caesium clocks and provide a basis for the decision-making of the rate and phase alarms which operate respectively at 1×10^{-11} and 60 ns.

Serial Time Code

A serial time code is generated each second containing complete Australian Eastern Standard time of day, day number and time signal information and is distributed over VF channels as a pulse width modulated binary coded signal using a 300 baud FSK data modem. The timing accuracy of the signals as transmitted is similar to that of the Time Standard.

Civil time receiver design permits individual compensation for propagation delay for each receiver location up to 40 µs. By this means the system maintains a uniform accuracy of 0.5 µs at all locations in Australia.

The receiver automatically translates to local time as required at each location.

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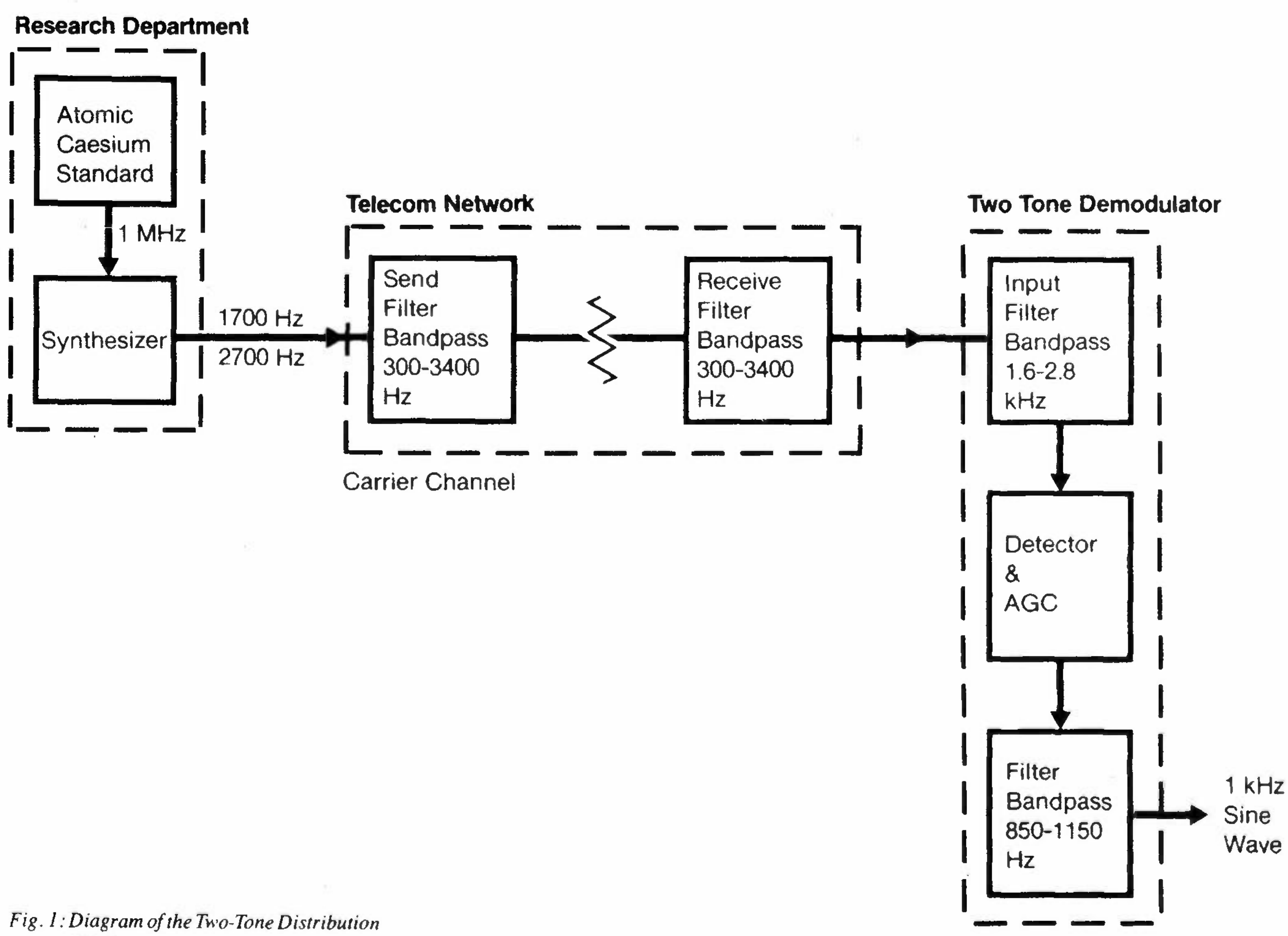

Fig. 1: Diagram of the Two-Tone Distribution System

SOLID STATE SPEAKING CLOCK

The Need for a New Clock

A prototype announcing system for a new speaking clock has been produced within the Research Department to replace the speaking clocks presently operated by Telecom Australia. The existing clocks in Melbourne and Sydney were designed by the British Post Office and purchased in 1955. This old system consists of a number of glass discs with voice tracks recorded on them as a photographic print. The recording is read by a light source transmitted through the disc to a photo-detector. Different tracks are accessed by a series of rods and cams that shift the light source and photodetector to the required tracks on the glass disc. This clock has given an extremely long life with the mechanical pieces still operating and giving good service, however the optical discs have deteriorated to a point where the signal to noise ratio of the voice output is approaching a point where replacement is necessary. Rather than an optical disc replacement it has been decided to consider a completely new installation.

The new clock will feature the same phrasing and voice quality as the original but in a completely solid state form. The system will consist of two controlled oscillators, one civil time receiver, two local clocks, one supervisory system and two announcing systems. Operation is as follows.

The Civil Time Receiver (CTR) will provide a reference for commencement of the whole system giving local time in parallel Binary Coded Decimal (BCD) code. The two controlled oscillators will be of the type, shown in the display 'A Phase Locked Oscillator', that phase locks precision quartz oscillators to the two tone reference and provides an output of 1 MHz. The CTR, which is also shown in another display, decodes a frequency shift keyed time code generated at the Research Department and produces parallel BCD time information, hours, minutes and seconds and a seconds pulse (as well as control signals).

On startup, the local clocks are resynchronized to the civil time receiver seconds pulse and time information latched. After synchronization, the local clocks, driven by the controlled oscillators, are used as the timing source. Periodically this reading is compared against the CTR. The local clock produces a parallel BCD code of time information in the same format at the CTR for use as a source of data for the announcing system. This procedure occurs on both local clocks and announcing systems.

Announcing Systems

The announcing system decodes the 'time code' into hours, minutes and seconds and then uses this information to set up a sequence table of phrases for final output as the complete phrase.

The supervisory system compares the time code information from the CTR and the local clocks and the analogue outputs of the two announcing systems. It decides which announcing system, if any, can be utilized. In an emergency the announcing systems can be run directly from the CTR alone. Manual switching between announcing systems is possible.

The announcing system is based on a microprocessor for the control of the announcement sequence and involves the direct storage of speech. The requirement is for an announcing system with a voice quality that does not sound artificial and has an acceptable signal to noise ratio. The system uses a dedicated delta-modulator chip for voice encoding and decoding with a sampling rate of 32 kilobits per second to achieve the required voice quality. The voice occupies 60 kilobytes of memory and the control program 800 bytes

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PHASE LOCKED OSCILLATOR

Design

A phase locked oscillator has been designed and built by the Research Department as a second level standard for the provision of precise phase and frequency throughout the Telecom Australian network.

Three versions of this oscillator have been produced for various applications including that of a Master Clock for Precise Time-keeping, a Trunk Carrier Control Frequency source and a Main Clock in future digital networks.

The oscillator is phase locked to the Caesium Frequency Standards operated by the Research Department at Clayton, Victoria, via the low frequency 2-Tone Distribution system.

This 2-Tone Reference signal has phase noise added to it in the transmission path and modem processes and is thus not usable directly as a standard source. It consists of two frequencies (tones) transmitted within one voice channel and separated by precisely one kilohertz. In the Phase Locked Oscillator, the 1 kHz control signal is recovered from this reference with a filter and demodulator circuit and fed to one input of the phase comparator.

This method of distributing the reference signal avoids any frequency translation errors resulting from its transmission over the existing frequency division multiplexed trunk network.

Precision Quartz Crystal

The oscillator itself uses a Precision Quartz Crystal in the range 4 to 6 MHz. It is vacuum mounted in a temperature stabilized oven inside a dewar flask and its frequency is voltage controlled by means of a varactor. This oscillator has an aging rate of less than 1 x 10^{-10} per day. Figs. 1 and 2 show a block diagram and front panel photograph of the oscillator.

(See photograph over)

Loop Control Circuit

The oscillator forms part of a Second Order Phase Locked Loop Control Circuit. The Main Store consists of a 20-bit binary up-down counter chain, which serves as a 'memory' during periods of failure of the 2-Tone Reference signal, to maintain output phase. The control circuit has been designed to produce a minimum oscillator frequency step upon both the loss and restoration of this reference signal.

Performance tests have shown that the output signal phase will follow that of the reference source to within 500ns, with a short term oscillator frequency stability of better than 1 x 10^{-11}.

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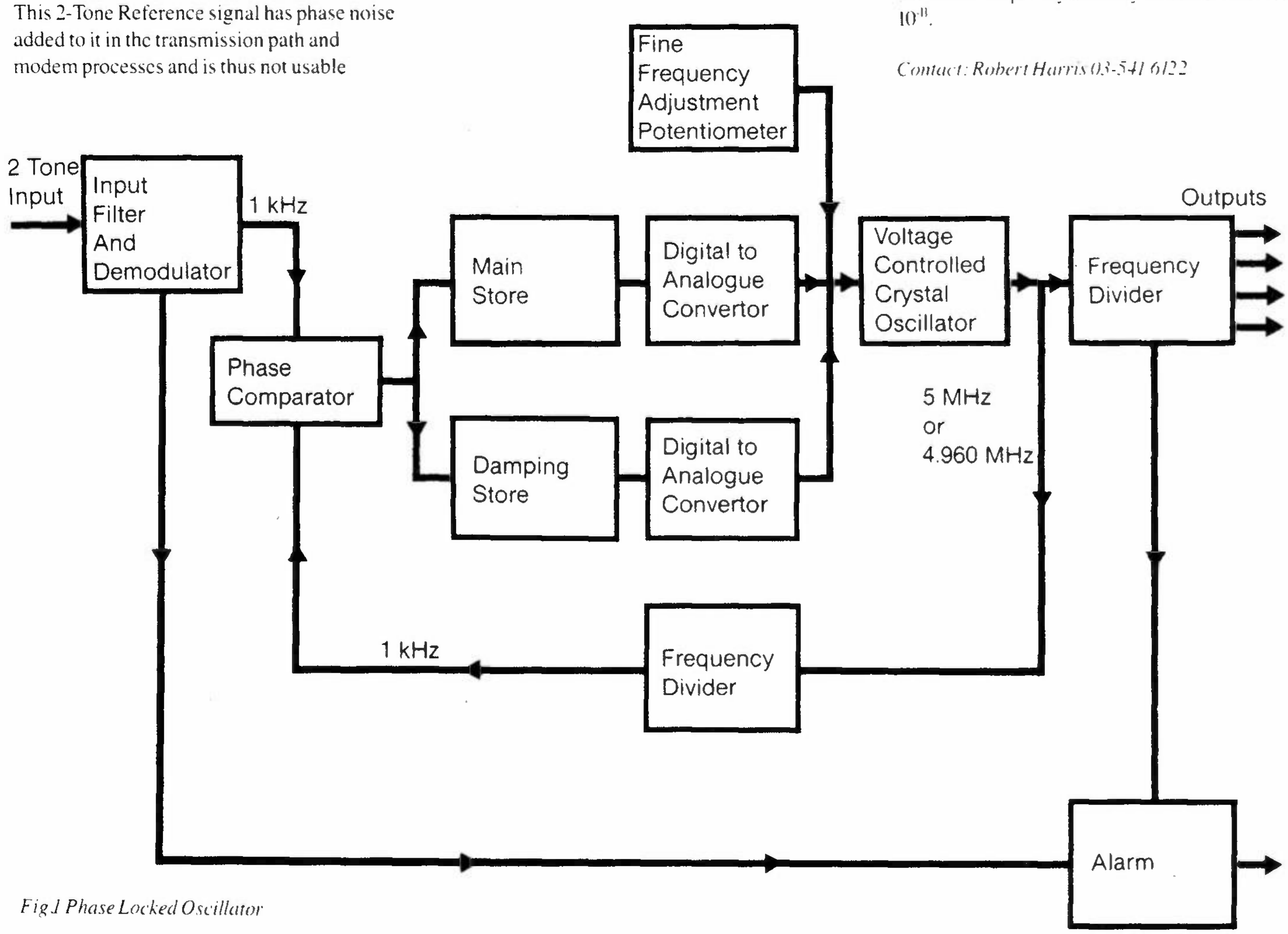


Fig.1 Phase Locked Oscillator

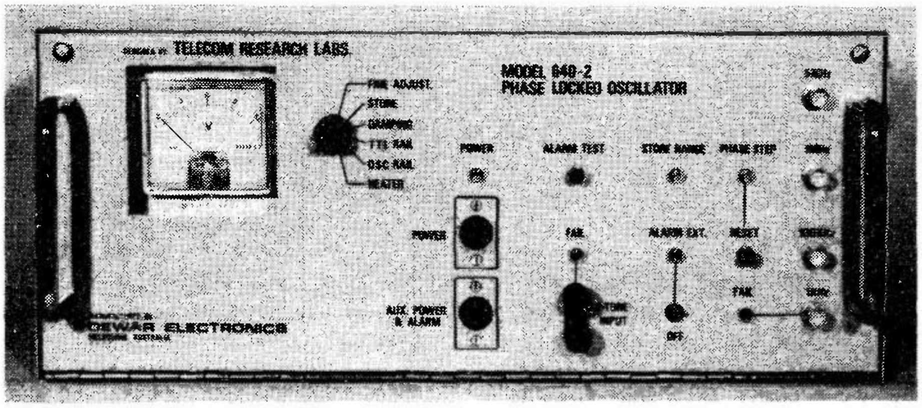


Fig.2 Phase Locked Oscillator Front Panel

CIVIL TIME CODE RECEIVER

Standard Time

Telecom Australia is the principal distributor of Civil Time in Australia — i.e. it makes Standard Time available for the various requirements of the community. A system has been developed for the more efficient distribution of standard time information over the national telephone network and has advantages in reliability, flexibility and precision.

A time code generator at the Research Department encodes the time signal information under the control of inputs from Telecom's Time and Frequency Standard. The timing accuracy of the signals as transmitted is similar to that of the Time Standard. The data format is generated each second and contains complete Australian Eastern Standard time of day, day number and time signal information in a VF channel as a pulse width modulated binary coded decimal signal using a 300 baud frequency shift keyed (FSK) data modem. Provision is made for automatic Daylight Saving Time adjustments in each of Australia's time zones.

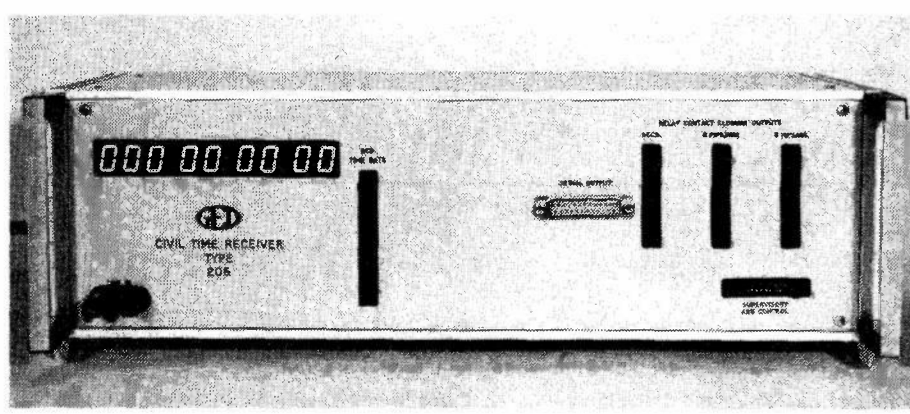
The Receiver

At a distant location a receiver decodes the information and produces the time signal required for each particular second as determined by its decoding instruction without dependence on previous timing history. The integrating concept inherent in many timing systems is thus removed and the reliability of the time signals is improved. The system also offers good flexibility as the decoder can be designed to produce any desired time code or sequence of outputs. The digital display and Binary Coded Decimal (BCD) output can indicate local time if required.

The receiver design permits individual compensation for propagation delay for each receiver location by use of the timing pulse following each data stream. Delays up to 40 milliseconds can be compensated to maintain a uniform accuracy of ± 500 microseconds at all locations in Australia. The system is thus capable of higher accuracy than can be obtained from existing services such as VNG or speaking clocks. It also gives a better signal-to-noise ratio.

The system will have application wherever precise and reliable time of day information or particular coded time signals are required, e.g. hourly radio time signals, TV operating centres, airline operations, master clock systems and scientific and industrial applications.

Fig. 1: Photograph of a Civil Time Code Receiver



Options 1 and 2

Civil Time Receivers are manufactured commercially and are available as two models, Option 1 and Option 2. Option 1 provides all outputs and these are on the front panel. This unit is made for rear mounting. Option 2 provides only a digital display and a serial output, the serial output being on the rear panel. This unit is made for front mounting. Fig. 1 is a photograph of a Civil Time Receiver. Table 1 shows outputs from an Option 1 receiver.

(See table)

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Table 1 : Outputs from an Option 1 Civil Time Receiver

1. Digital Display
   Days Hours Minutes Seconds
   One of the following time zones may be selected:
   a. Eastern Australian Standard Time
   b. Central Australian Standard Time
   c. Western Australian Standard Time
   d. Co-ordinated Universal Time (UTC)
   Either a 12 hour or 24 hour format may be selected for any of these time zones except UTC as well as Daylight Saving when in operation.
2. BCD Output
   30 line parallel BCD output with standard TTL level of Days, Hours, Minutes and Seconds plus signal fail and 1 ms duration seconds pulse outputs.
3. Standard Time Signals
   Relay contact closure outputs are provided for:
   a. Seconds pulse, 100 ms duration (10 outputs)
   b. 8 pips per minute, 100 ms duration (10 outputs)
   c. 8 pips per hour, 100 ms duration (10 outputs)
4. Serial Output
   RS232 Output is provided by the receiver on the receipt of an ASCII "S" character in the form of:
   CR, D100, D10, D, H10, H, M10, M, S10, S, CR.
   The leading CR is coincident with the seconds epoch corresponding to the time data represented in the data stream. The trailing CR is coincident with the next seconds epoch.
5. Supervisory and Control
   This output provides the following functions:
   - Serial data output (Inverted)
   - Receiver disable input
   - Seconds pulse output
   - 8 pips/hour output (Inverted)
   - 8 pips/min output (Inverted)
   - Inverted seconds pulse output
   - Signal fail output
6. Delay
   The seconds epoch produced by the receiver may be delayed over a range of 40 ms in 256 binary steps of 199 ms.
7. Power
   240 V AC, 50 Hz

CALIBRATION OF POWER LEVEL TRANSFER STANDARDS

One of the most important requirements in the efficient operation of the national telecommunications network is the accurate measurement of power level. Power level meters used for testing must be calibrated against reference standards if system performance is to be maintained.

Power level meters are calibrated at 0 dBm (1 mW) by the use of power level transfer standards designed and developed in the Research Department.

A power level transfer standard consists of a thermal converter (see CALIBRATION OF AC THERMAL CONVERTER display) and a radial resistive network, both of which operate equally well on high frequency (H.F.) and low frequency (L.F.) power apart from small errors. This permits the generation of H.F. power in terms of L.F. power at a specific impedance.

The computer controlled measurement system shown in Fig.1 utilizes a network analyser and a reference level meter to calibrate power level transfer standards.

Measurements are made on power level transfer standards up to a frequency of 300 MHz with an uncertainty ranging from 0.02 to 0.05 dB.

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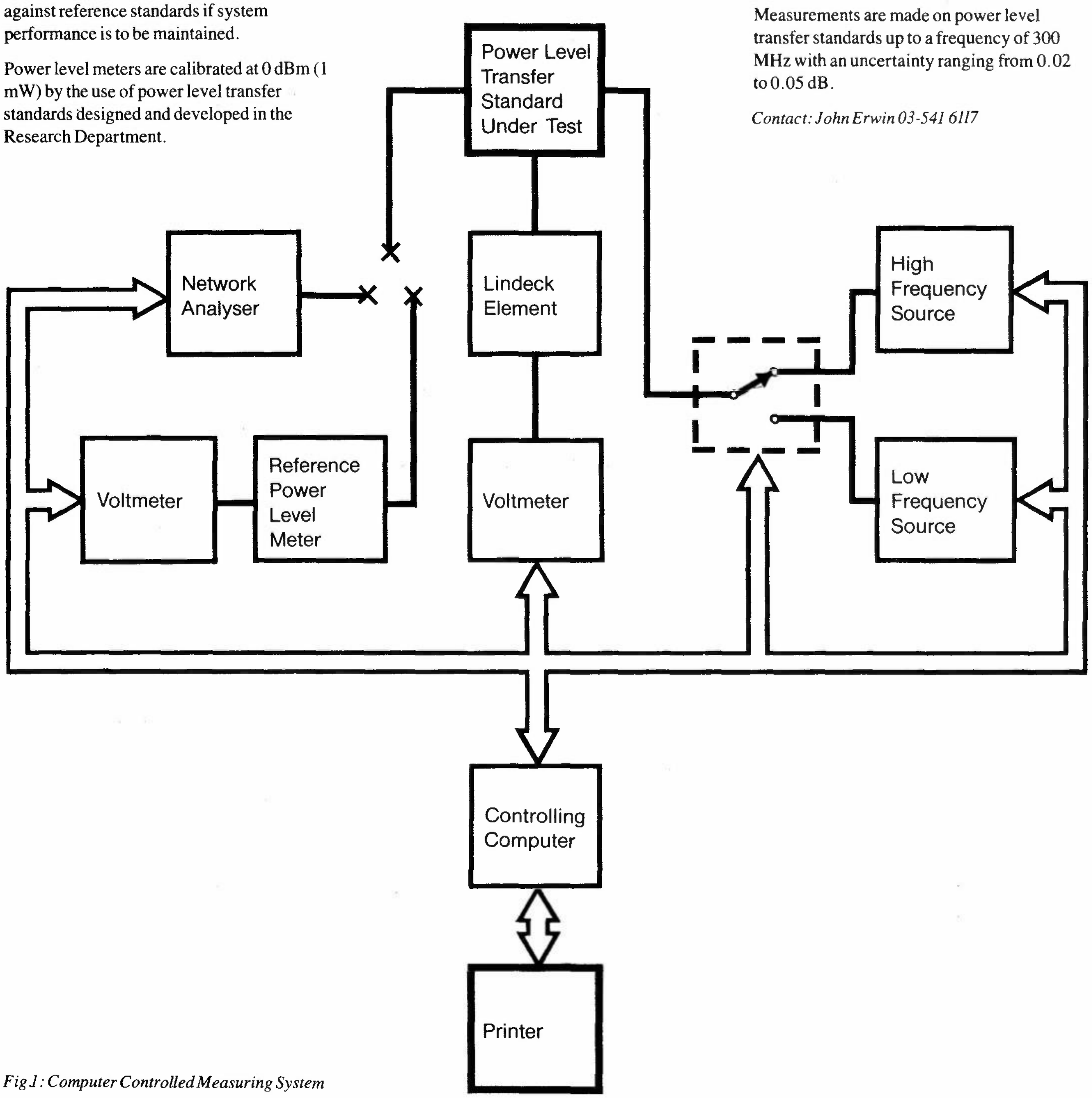

Fig 1: Computer Controlled Measuring System

TEMPERATURE CALIBRATION (NATA)

'NATA' Registration

In order to support the large temperature measuring workload of the Research Department a progressive upgrading of the standard and accuracy of measurements has occurred over recent years. The major task in this operation was the acquisition of suitable standards and measuring equipment to meet both the short and long term needs of the Department. A significant outcome was the achieving of NATA (National Association of Testing Authorities, Australia) accreditation in several classifications relating to temperature measurement. An additional outcome was that the Department now possesses a range of certified standard thermometers, one of which has an uncertainty of only ±0.005 K (±0.005°C) over the range of temperatures normally used for environmental testing. The standard thermometers are supported with a range of measuring equipment whose resolution directly complements their accuracy.

Standardization

All of this measuring equipment and the standard thermometers are directly traceable to the National Standards held by the CSIRO Division of Applied Physics. Their primary use is to enable the calibration of the thermometers used in the routine work of the Department. The usual method of accomplishing this is to use a very stable source as a transfer medium. For the majority of our applications a precision oil bath is utilized. The sensors to be used for the routine measurement task are immersed in the oil bath simultaneously with an appropriate standard thermometer and the variations in measured output or temperature are recorded for use as a correction factor which may need to be applied to the routine measurements at a later date, depending on the accuracy required.

Type of Thermometers

It should be realized that these thermometers and sensors are not the glass thermometers that one normally envisages but are devices that give changing electrical parameters in response to changing temperature. The type of device used for a standard is called a resistance thermometer and consists of a coil of fine platinum wire whose resistance changes as a function of the wire temperature. A cheaper form of resistance thermometer as well as a thermocouple is used for routine measurements. A thermocouple is a device constructed from two lengths of dissimilar metals which are joined together as a single point at one end. A voltage is developed across the open end which essentially represents the temperature difference between the joined end and the connection point to the measuring instrument. For the majority of our applications thermocouples give the best combination of accuracy and economy.

Ice Point Reference

In practice a measuring thermocouple thermometer system consists of a group of three thermocouples, only one of which is in the environment being measured. The other two, one in each leg of the thermocouple in the environment being measured, are held at a fixed reference temperature, usually 0°C, and are utilized to enable the measuring instrument to be connected via copper conductors. Since an ice point reference is 0°C by definition the measured voltage is a direct function of the measuring thermocouple temperature in °C. Two general methods of obtaining 0°C are in common use. These are a mixture of finely crushed ice and water and an electronically controlled ice point reference. A typical thermocouple and ice point measuring system is explained in Fig.1, whilst Fig.2 explains the operation of an electronic ice point.

(See diagrams over)

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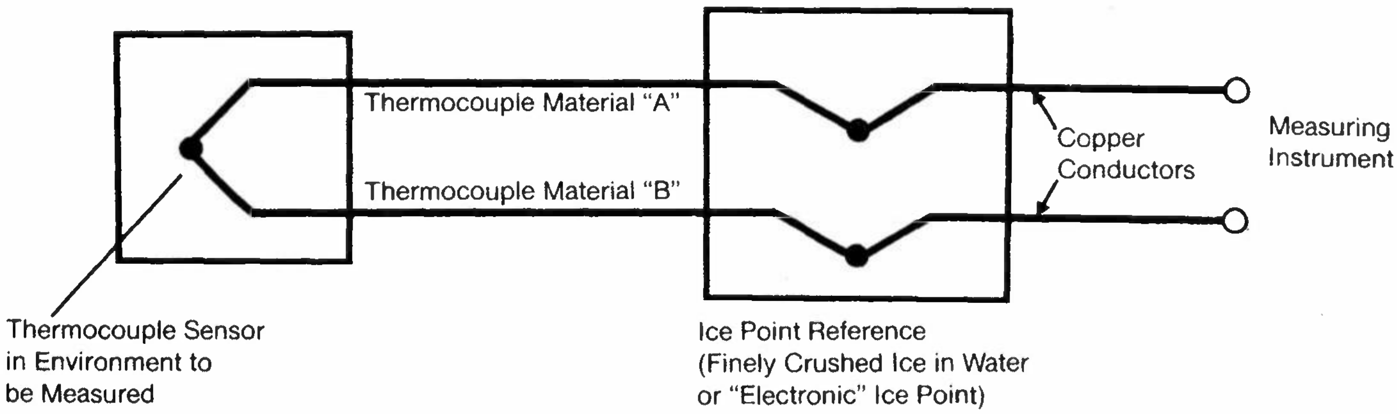

Fig. 1. Measurement System for Thermocouple Sensors

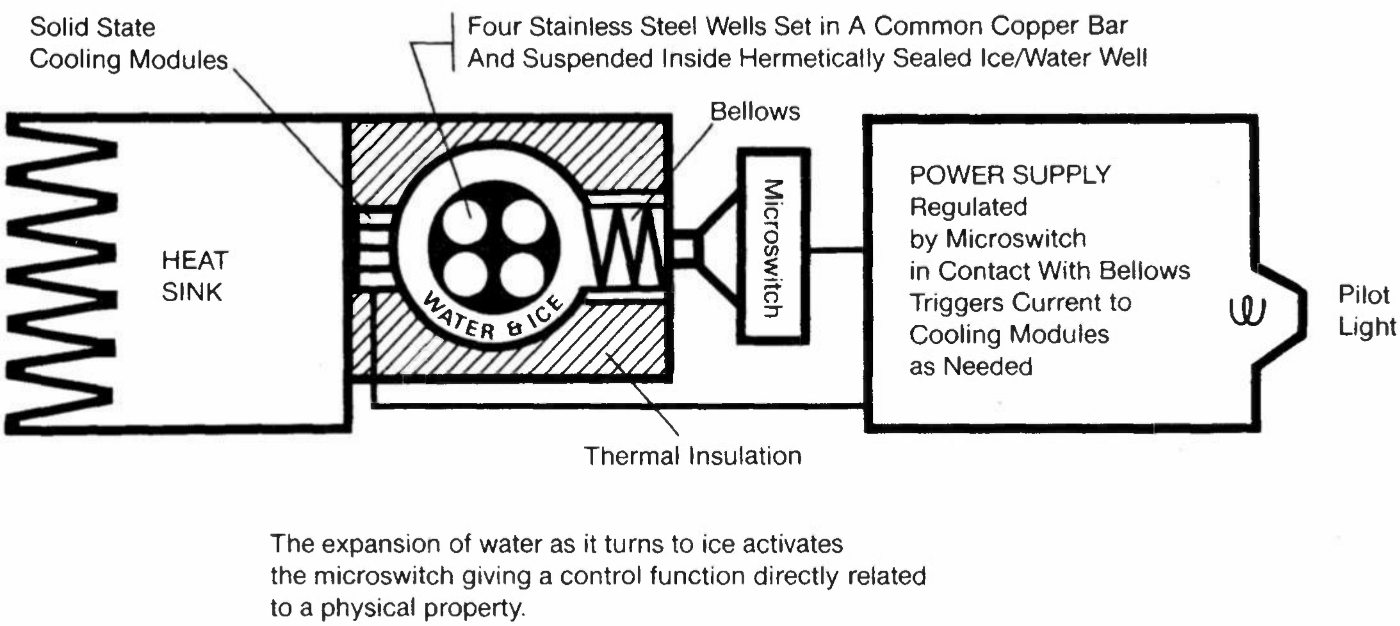

Fig. 2. Operation of an 'Electronically' Controlled Ice Point

ENVIRONMENTAL TEST CABINETS

Environmental Conditioning

The cabinets on display in this area are all utilized to create some form of environmental conditioning and between them they can create one or more of the following environmental characteristics:

- Temperature
- Humidity
- Sunlight
- Rainfall

The large cabinets are designed to accommodate such items as a rack of telephone exchange equipment, a medium sized P.A.B.X., a medium power radio transmitter or possibly a series of solar panels. Typical examples of the use of smaller cabinets are in the testing of telephones, relays, keypads and switches together with all forms of electronic components.

Why is it necessary to test?

Telecom Australia requires that all items of equipment should operate in all parts of Australia. Imagine the chaos if an item of equipment that was designed to operate at low temperatures only (e.g. southern Tasmania) was inadvertently sent to the Northern Territory or the northern part of Western Australia. In addition to the requirement to operate in all parts of Australia, Telecom also expects its equipment to have a minimum operating life of 20 years. The judicious use of extremes of both temperature and relative humidity allows scientists and engineers to assess the likely reliability of a component or item of equipment over its expected lifespan.

How is testing performed?

An item of equipment or a series of components whose operating characteristics have already been measured and documented is placed in a cabinet capable of carrying out the required test. This test may be temperature only, temperature and relative humidity or a sunlight oriented test. At the conclusion of the test (whose duration may vary from hours to months), the operating characteristics are again measured and compared with the original characteristics.

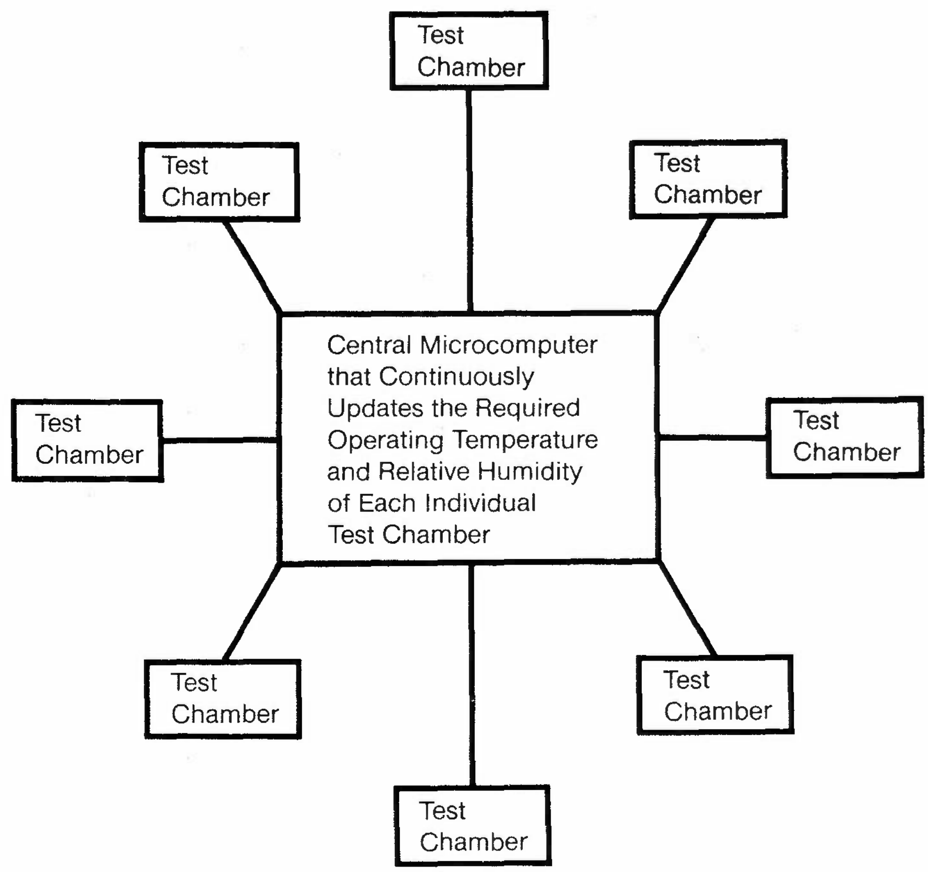

Fig.1: Overall Chamber Control System

An assessment of the likely long and short term performance of the specimen is then made for the particular test. It is usual to carry out a series of tests each of which is designed to attempt to find situations under which the tested items may not perform to their designed standard. After all the environmental, electrical, mechanical, etc. tests have been completed, a final assessment is made as to the suitability of the items for use in the Telecom network.

About the equipment

Many of the tests performed are very demanding on both the equipment being tested and the test cabinets performing the tests. In relation to the cabinets, extensive use is made of computer technology in order to independently control and monitor their performance. The computer oriented (microprocessor) control equipment also allows the temperature (and relative humidity) of each cabinet to be varied with time. This is achieved through a small central microcomputer that stores the required temperature and relative humidity changes and sends them to the appropriate cabinet at the correct time, as schematically indicated in Figs. 1 and 2.

(See diagram over)

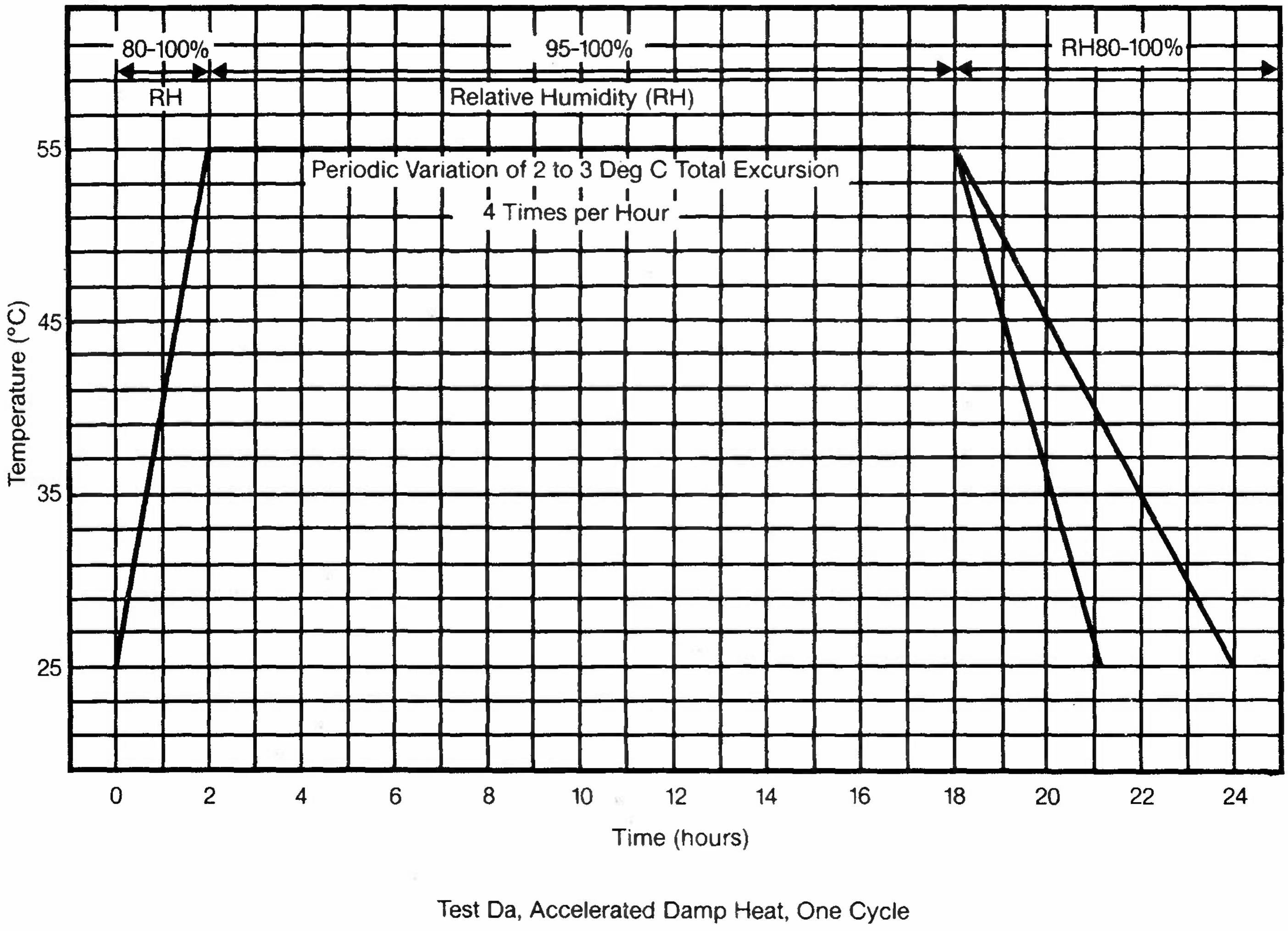

Fig.2: Typical Test Parameters to be Executed by the Central Microcomputer

Both of the computer devices in the environmental cabinets and the small central microcomputer were designed and prototyped within the Research Department because of its specialized needs. The prototype of the devices in the environmental cabinets, known as a microprocessor based temperature control system, was released to Australian industry to produce a quantity for Telecom use and also for possible sale to industry on a royalty basis. Specifications of this unit are outlined in Table 1.

In order to ensure that all the environmental parameters are met throughout the duration of the test, a continuously operating data logging system records the most critical parameters and provides twice daily summaries that permit the operator or users to readily observe minor variations in the test conditions. Table 2 shows a typical summary.

(See tables opposite)

In addition to this statistical information, the data logging system also provides an almost immediate visual and audible indication of a significant variation from the test conditions. This permits fast remedial action to be undertaken in the event of an equipment failure.

Remote Monitoring

A feature of the activities undertaken by this section that is not evident from the display is the ability to measure environmental conditions at remote sites and to send the information back to the Research Department at Clayton at regular intervals for further analysis. This enables professional and technical staff to make appropriate adjustments to laboratory tests in the light of what is happening in the real world. Sites that have been or are being utilized for this purpose are Mt. Isa in Queensland, Doordwoordoo in W.A. and a site in the Northern Territory approximately 100 km north of Alice Springs.

Contact: Michael Hooper 03-541 6618

Temperature range	−50 to +150°C dry bulb. +10 to +99°C wet bulb.
Control accuracy of installed system	±0.25°C wet and dry bulb.
Control stability	±0.5°C throughout the ambient temperature range 0 to 50°C during a 12 month period.
Indicator accuracy	±0.2°C
Setability	0.1°C increments over the design temperature range either manually or by remote electronic means.
Response time	Measuring system should track to within ±0.1°C for rates of change of air temperature up to 2°C per minute.
Compatibility	Any system must be capable of operating in association with cabinets using resistive heating (up to 4 kW) and solenoid controlled mechanically refrigerated cooling systems.

Table 1: Target Specifications for a Dual Channel Temperature and Humidity Controller using a Wet and Dry Bulb Sensing System.

Average Reading	Minimum Reading	Time of Occurrence	Maximum Reading	Time of Occurrence
39.9°C	39.7°C	1920.3	40.2°C	1923.3

Table 2: Typical Statistical Information Produced for each Measurement Point

ATTENUATOR CALIBRATION

One of the most important measuring tools used in measurements on communications systems in Telecom to evaluate plant and system performance is the attenuator.

An attenuator is a device for introducing a power loss in a circuit and, for the most critical applications, it is necessary to know the actual loss.

The calibration of a precision 75 ohm resistive attenuator in an electromagnetically shielded room is shown in this exhibit.

The attenuator in Fig.1 is being compared against a reference attenuator operating at 30 MHz by a parallel substitution method using a 30 MHz tuned receiver.

With this system measurements are made over a range of 100 dB with a resolution of 0.002 dB up to 500 MHz. The uncertainty ranges from 0.02 to 0.5 dB, depending on value.

Contact: John Erwin 03-541 6117

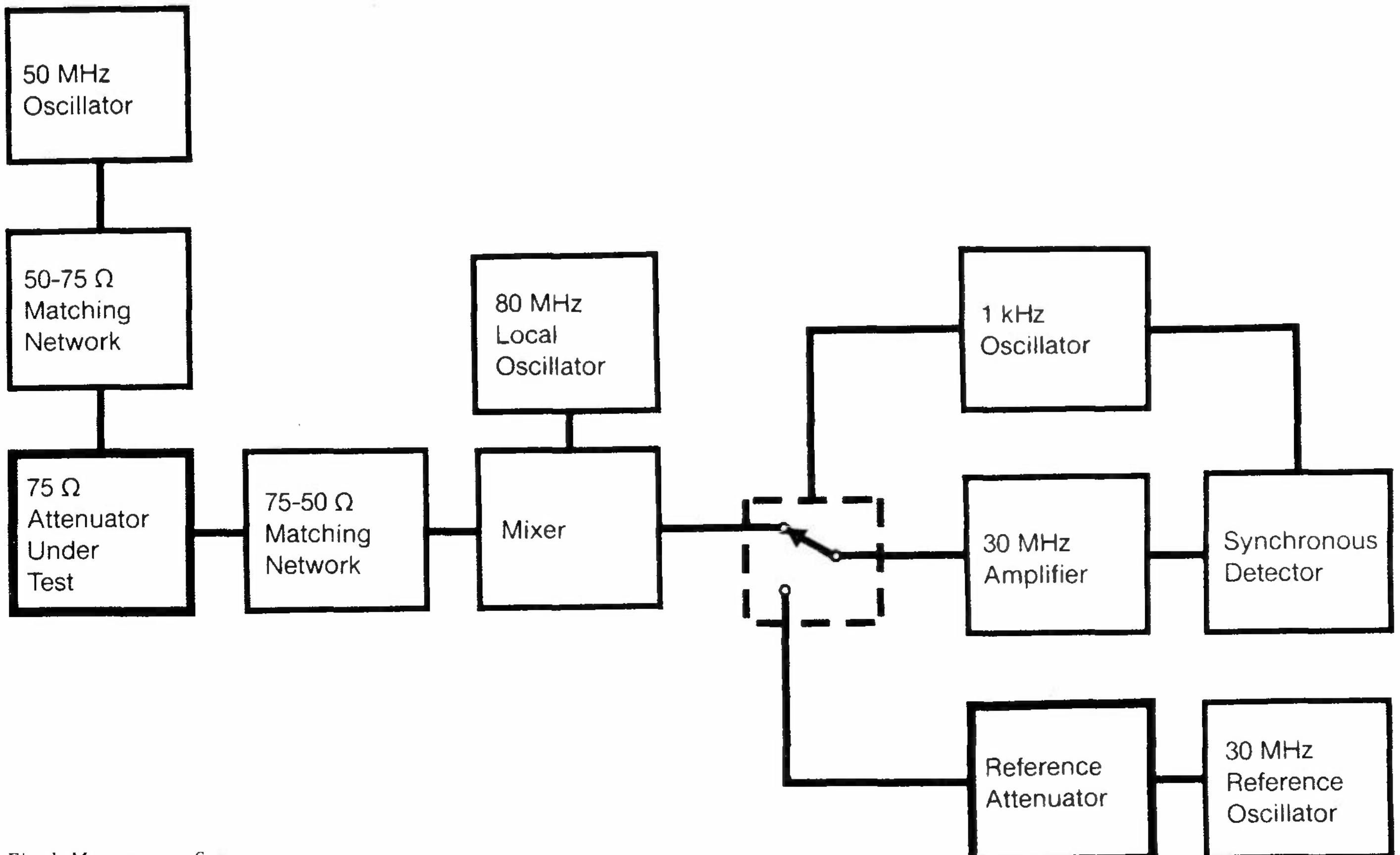

Fig. 1: Measurement System

CALIBRATION OF A.C. THERMAL CONVERTER

Precision alternating current (a.c.) voltage measurements are generally made using a transfer device called a thermal converter (thermoelement type), which allows an a.c. voltage to be determined in terms of a direct current (d.c.) voltage.

A thermoelement thermal converter consists of a straight wire heater through which a current is passed, with a thermocouple to measure the mid-point temperature. The converter has the virtue of responding, apart from small errors, equally to a.c. and d.c.

The computer controlled system shown in Fig.1 determines the error of the thermal converter by comparison with a calibrated reference thermal converter, with the results being displayed on the printer.

Measurements are made over a frequency range of 50 Hz to 100 kHz and voltages from 1 V to 1000 V.

Accuracy of measurements is limited to the uncertainty in the reference converter, which is about 30 parts per million (p.p.m.) at 1000 Hz but measurement resolution is better than 0.1 p.p.m.

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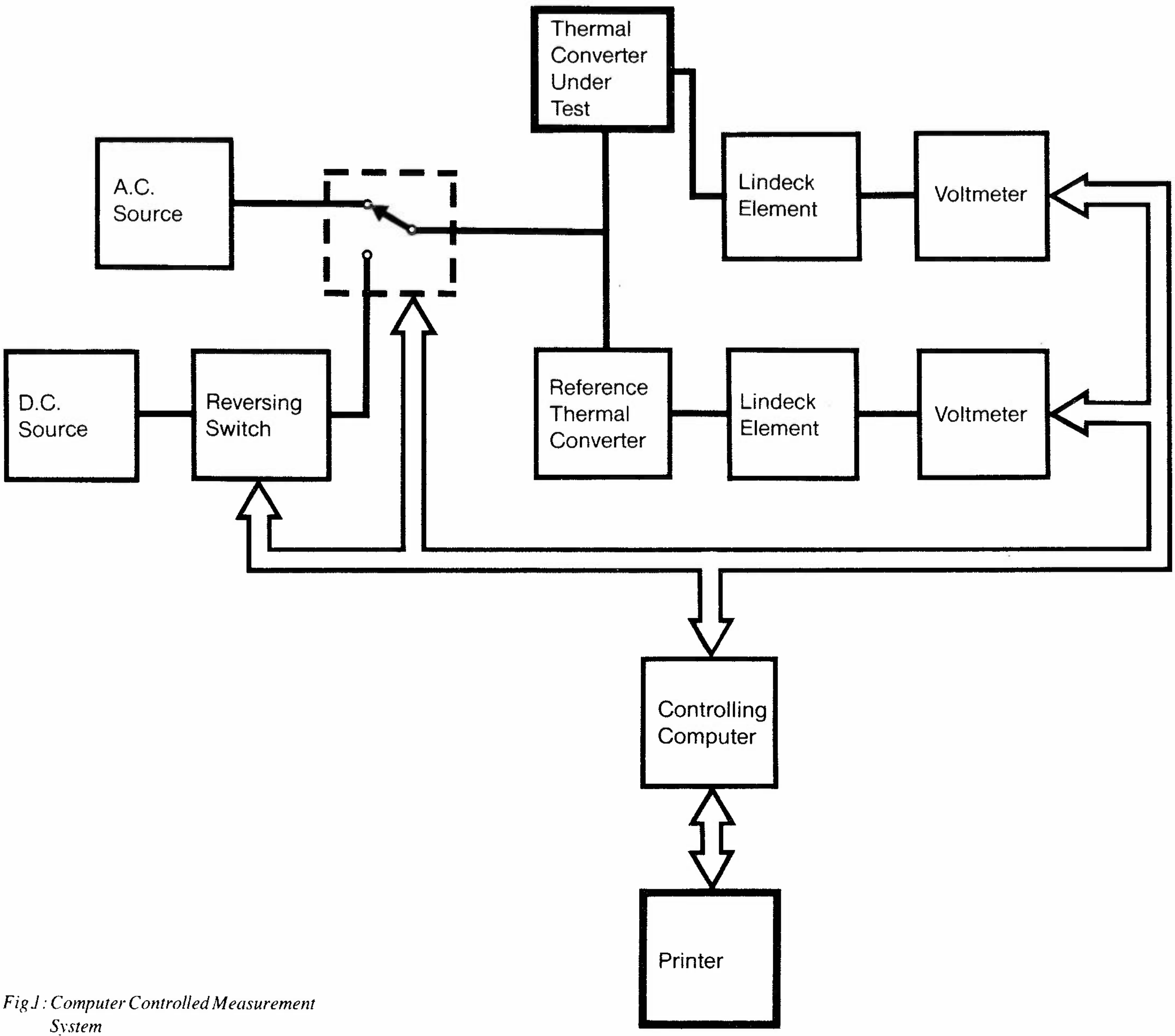

Fig J : Computer Controlled Measurement System

CALIBRATION OF THERMISTOR MOUNTS

The measurement of power at radio frequencies (r.f.) is as important as the measurement of voltage and current at low frequencies. Power meters are used extensively throughout Telecom for system performance testing.

The thermistor mount is the most common device for measuring r.f. power. It consists of a power sensitive resistor (thermistor) mounted at the end of a length of transmission line. In the operation of the power meter, direct current (d.c.) power is substituted to obtain the same heating effect. In practice the substitution is not perfect and to account for the error a term called "Calibration Factor" (C.F.) is employed.

The computer controlled measurement system shown in Fig.1 determines the C.F. of the thermistor mount under test by comparison with the known C.F. of the reference power transfer standard. The results are shown on the printer.

Measurements are made over a power range of 1 to 10 mW at frequencies up to 18 GHz. The uncertainty ranges from 0.5 to 2.5%.

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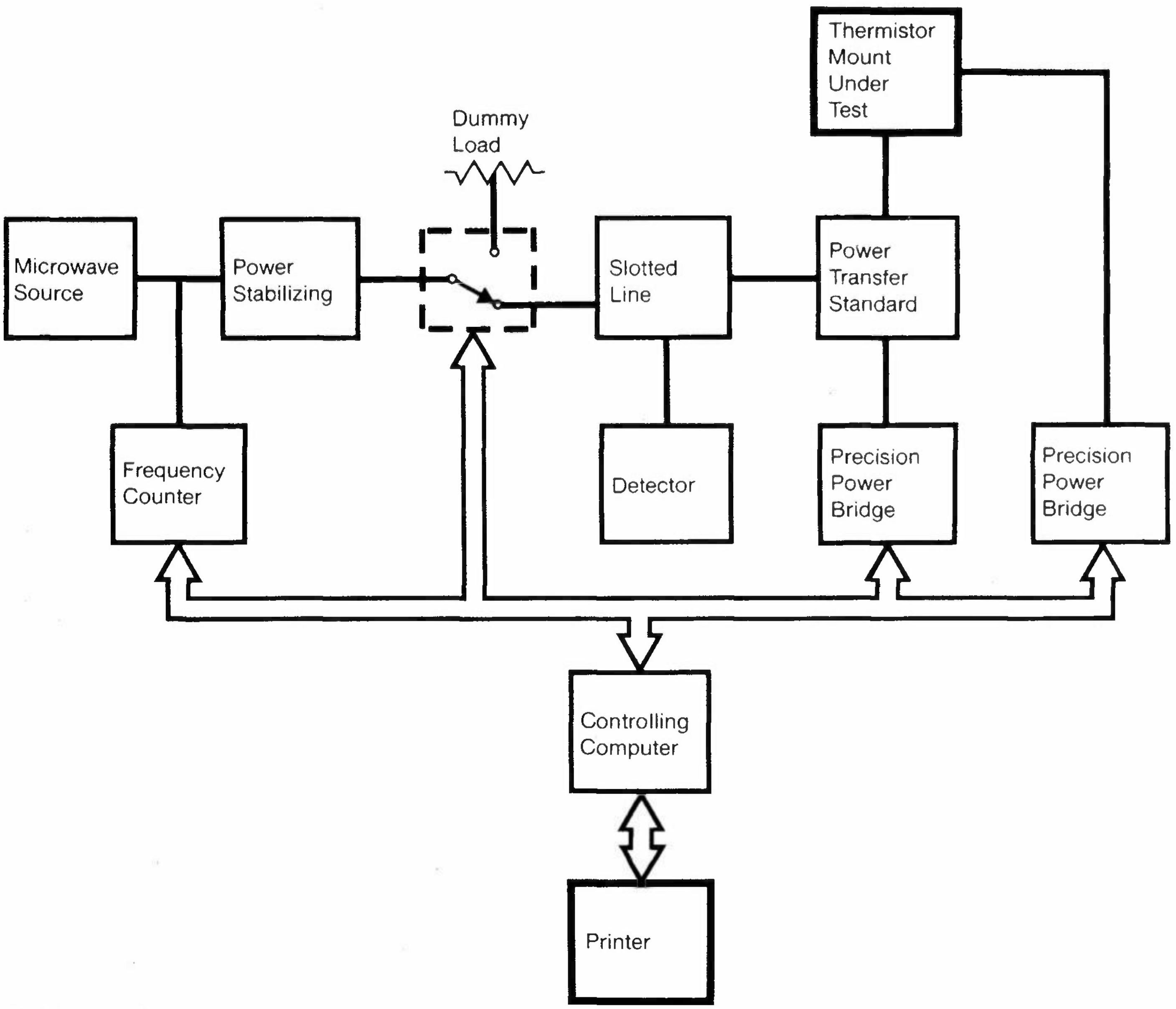


Fig 1: Computer Controlled Measurement System

DEVELOPMENTS IN INSTRUMENTATION SERVICING

Broad Change: 1960s to the 1980s

Instrumentation over the last quarter century has undergone considerable change due to the great advancement in new technology in the electronics industry. Today's instruments are more compact, inherently more efficient and considerably more versatile. Much of this change has been due to the accelerated development of miniaturization techniques in the semi-conductor field. To accommodate these changes, appropriate servicing techniques have been developed, which differ vastly from the techniques used 25 years ago.

This display attempts to illustrate those changes in digital voltmeter technology, the associated instrumentation and the techniques required, over a period of two and a half decades. The active displays contrast the techniques and equipment and the static displays illustrate the changing technology from the early digital voltmeters to the high precision, multi-function units in common laboratory use today.

Servicing Instrumentation in the 1960s

Observation of the 1960s exhibit shows that servicing techniques were, compared with today's procedures, quite simple. The test equipment was adequate to maintain the comparatively low level of complexity of instrumentation in those days. These servicing systems, commonly using vacuum tube technology, consisted of a series of discrete items. Each item had a specific application and was, by today's standards, functionally limited. Most instrumentation was analogue-based and, as such, required analogue test equipment and techniques. In today's terminology, these systems were "hardware" oriented.

The Transition to the 1980s

The period up to the 1980s saw the introduction of digital technology using, initially, discrete components and progressing logically, through small scale integration to Large Scale Integration (LSI) techniques. The exhibits illustrate this progression and it can be noted that over the last several years the rate of application of new technology has increased. Even today's most simple instruments use LSI techniques.

Complexity of Modern Instrumentation

Modern instrumentation, whilst being far more user-friendly, has achieved a degree of complexity that is significantly above that of the 1960s. The introduction of LSI techniques has resulted in 'intelligent' instrumentation in which the facilities of the instrument are controlled by a processor. Coupled with this has been the development of 'custom' Integrated Circuits (ICs) or Programmable Read Only Memories (PROMs), commonly called 'firmware'. This firmware retains programmed information for use when called upon by the various functions of the instrument. As can be seen by observing various exhibits, this application of new technology has led to miniaturization, compactness, functional versatility and an increase in ease of operation. However, to cope with this technological advancement, special servicing techniques and complex test equipment are required to perform remedial maintenance on this new generation equipment.

Servicing Instrumentation in the 1980s

Today's servicing personnel have been required to encompass this new technology. Wider disciplines, a greater number of variables, environmentally sensitive devices and the mere fact of miniaturization have led to a drastic change in the servicing procedures. The 1980s test system illustrates the use of instruments such as logic analysers and emulators to assist in the diagnosing of faults in new generation instrumentation. These diagnostic instruments, usually used in conjunction with a set of programmable instructions or 'software', act as data gatherers to amass the large bulk of digital information transmitted within the instrument.

Once this great array of data from data-lines and BUS-lines has been collected, complex analysis of the output data is required to establish where inconsistencies are apparent. The exhibit demonstrates remedial maintenance on a modern digital voltmeter. All test instruments are under the control of a central controller and the data is readily displayed for analysis. You are invited to observe, for yourself, the routines associated with this particular system.

In general, most measurement instrumentation has been greatly affected by the revolution of new technology. Instruments such as voltmeters, audio and radio frequency (r.f.) generators, analysers, general purpose and precision bridges, reference sources, even cathode ray oscilloscopes, are all now relatively complex in nature. In addition, non-measurement instrumentation such as computers, computer peripherals and controllers, most of which are maintained within the Research Department, all require this revised approach to maintenance.

The implication of the above is that remedial servicing has become more complex in nature. Typical aspects that warrant consideration are:

- theory and application of digital techniques including micro-processors, PROMs and EPROMs
- operation of complex analytical test equipment
- associated analysis of test data
- clean environment servicing of printed circuit boards
- servicing of miniature components and associated printed circuit boards, including multi-layer types
- servicing involving environmentally sensitive components including electrostatically sensitive devices.

Today's servicing personnel are required to adopt an approach that is in keeping with these advances in instrumentation and consequently must possess a working knowledge and the practical skills necessary to enable servicing of this equipment.

Contact: Danny Wilson 03-541 6190

HANDICAPPED PERSON ACCESS DIALLER

The 'Access Dialler' is an instrument originally developed to meet the needs of people with manual dexterity problems. Its simple operation and built-in features enable it to be of benefit to users with other disabilities when they are making a telephone call.

The Basic Concept

The concepts and system were developed over several years by 'Comskill', a dedicated volunteer group, who arranged with Telecom Australia for the instrument to be developed and made available to customers as requested. It would provide an alternative solution to the problem of using a conventional telephone, with a standard rotary or keypad dial.

For persons with limited or spasmodic muscle control, the task of dialling can be an obstacle sufficient to prevent them initiating a telephone call. Likewise the demands on others to carry out the dialling process may place psychological limitations on the use of the telephone for social contact.

The Research Department was asked to investigate the concepts and prepare a feasibility model based on the 'Comskill' specifications and then produce a pre-production model. Several alternative shapes and styles were considered with appropriate circuits, operator pads and display configurations before the pre-production model was supplied to Telecom's Headquarters Engineering Department for adaptation and production manufacture.

Operational Techniques

The Access Dialler is part of a communication system, used in conjunction with standard telephones, loudspeaking telephones, light-weight headsets or remote operating controls.

The Access Dialler is operated by hand, chin, elbow or with a mouth or head-stick via two rubber pads, sensitive to a light touch but also capable of withstanding a heavy blow without damage.

For normal operation, the number to be dialled is recalled from one of the memory locations and displayed using the 'S' (Select) pad. Dialling or re-dialling is commenced by the 'C' (Call) pad.

The user is able to enter new numbers or change existing numbers by using the 'S' and 'C' pads.

The speed with which individual digits are displayed when setting a number can be controlled to suit the individual customer.

Special Facilities

Provision has been made for the addition of special extra facilities such as external activating devices and remote triggering of emergency dialling.

The dialler has a memory for fifteen numbers including a special simply-activated emergency number. The number being called or set up by the user to be called is displayed on a large liquid crystal display. The memory and the display are both powered from the telephone circuit. The dialler has internal batteries to sustain the memory and the programmed numbers while the dialler is briefly disconnected from the telephone circuit, as may be necessary, for example, when it is being relocated.

The unit can be mounted vertically on a wall or cabinet for bed patients or horizontally on a table or shelf.

Local, STD and ISD calls can be initiated either from the internal memory, for regular numbers, or by setting up an individual number as a once off call, or for storage in the memory for later use.

Contact: Peter Meggs 03-541 6214

TRANSDUCER MONITOR FOR GAS PRESSURE IN CABLES

The Need for Gas Pressurization

To maintain the integrity of its underground trunk, junction and main subscriber cables, Telecom Australia uses cables that are positively pressurized with air. The advantages of this approach are that, if there is a sheath fault, ingress of moisture is restricted by the escaping air and that a pressure profile of the cable can be used to locate the fault.

Existing System

Until recently the pressure alarm network has been confined to indicating simply that a fault existed. This network consisted of contactor alarms, in which contacts, connected in parallel on a dedicated pair of wires, close when the pressure drops below a pre-determined level. These alarms are spaced at approximately 2 km intervals. When a contact is closed, an alarm sounds at the telephone exchange and the loop resistance is measured to obtain an approximate location of the fault. Then the lines staff will measure the cable pressure at test points around the approximate location. There are several test points between each contactor alarm. A pressure profile of the cable around the fault is drawn up and from this a more accurate location can be established (to within a couple of hundred metres). To locate the fault more accurately, another technique, such as using Freon gas and a halide detector, is used. This method of fault detection is labour intensive, slow and costly.

Addressable Monitors

Recently a program has commenced to replace the contactor alarms with addressable pressure monitors. These monitors respond, to an enquiry from a central station (exchange), with the cable pressure at the location of the monitor. The advantage of this method is that the pressure profile of the cable can be determined more quickly. The system that is being implemented uses a variable resistance pressure transducer and thus it only has a resolution of 3.5 kPa. Although this might seem to be adequate, it could, because of the 'inertia' of the system, take several hours before a drop in pressure is noticed. A further disadvantage is that the transducer is mounted on the cable pit wall with a plastic tube connected to the cable, similar to the contactor alarm.

Improved Digital Monitor

A digital pressure monitor has been constructed by Telecom in South Australia using Large Scale Integration (LSI) devices and an integrated pressure transducer. This monitor uses the same container and mounting techniques as the previous monitor. This monitor is being redesigned by the Research Department with state-of-the-art components, especially the pressure transducer and the analogue to digital converter and will initially be constructed as a hybrid with the aim of installing it in the actual cable joint. The monitor is being partitioned so that a transducer of any type e.g. temperature or humidity, could be used to provide a small monitor capable of being powered by the telephone line. Eventually, as experience of in-joint installation is gained, most of the monitor could be produced as an integrated circuit using Very Large Scale Integration (VLSI) techniques.

Contact: Neil Leister 03-541 6746

TILT ALARM FOR TRACTORS

The Need for the Alarm

The need to develop the Tilt Alarm for Tractors arose from a request for a tilt angle warning device for plant operators using field vehicles such as bulldozers, tractors, four wheel drive vehicles, etc., in undulating terrain. This request was made by the Automotive Plant and Transport Section of Telecom Australia following discussions with the Forests Commission of Victoria.

The alarm, which is set to activate at a preset safe working angle in the vehicle's sideways tilting planes, is triggered by an inclinometer which measures angles from the horizontal. The need for such a device is highlighted when operators are working on the side of steep hills. In conditions such as these an inclinometer would warn the operator that the vehicle had approached its maximum safe working angle.

Design of the Alarm

The inclinometer uses a two tone, high power, audible alarm that can be heard over the noise of the engine by an operator wearing earmuffs. In addition, an amber light in front of the operator provides a visual alarm.

Because of the harsh environments in which the inclinometer will be used, the detection system must be robust with few moving parts. A square PVC block houses a light emitting diode and a phototransistor, which are placed on either side of a glass tube containing a steel ball. When the preset angle of tilt is reached, the ball moves along the glass tube and breaks the light beam, activating an electronic circuit to trigger the audible and visual alarms. See Fig.1.

(See diagram over)

The inclinometer has an automatic system check, when the vehicle is switched on.

Owing to severe vehicle vibration, damping of the motion of the ball is necessary. That can be achieved either by placing a shock absorbing material e.g. felt, at each end of the ball's travel or by use of a silicone damping fluid.

PVC was chosen for the block in the prototype units because of its machinability, low cost and adequate corrosion resistance. Glass tubing was chosen because of its low co-efficient of friction for the rolling surface of the ball.

Presetting the 'Safe Working Angle'

The inclinometer alarm is activated within one degree of the preset angle and remains on until the safe working limits are regained. The Safe Working Angle is preset at the assembly stage to suit the characteristics of the particular vehicle.

The mounting bar for the two PVC blocks has two reference holes which are used when presetting the angle and as a datum when attaching the unit to the vehicle.

Housing and Warning Light

The die cast box used not only houses the circuit, triggering mechanism and alarm but also protects them from the natural elements of direct sunlight, rain, heat and dust, which could affect the performance of the inclinometer.

The two main considerations for the selection and positioning of the amber alarm light were:

(a) the direction of maximum light output from commercially available light units of various shapes and the availability and cost factors in their initial purchase, repair and replacement and

(b) the best position to obtain maximum attention of the operator as determined by photometer experiments and field trials.

The result of these experiments led to the choice of a square light positioned on the front of the inclinometer unit with the unit placed approximately in front of the operator.

Overall the unit developed is compact, easy to manufacture and reasonably cheap.

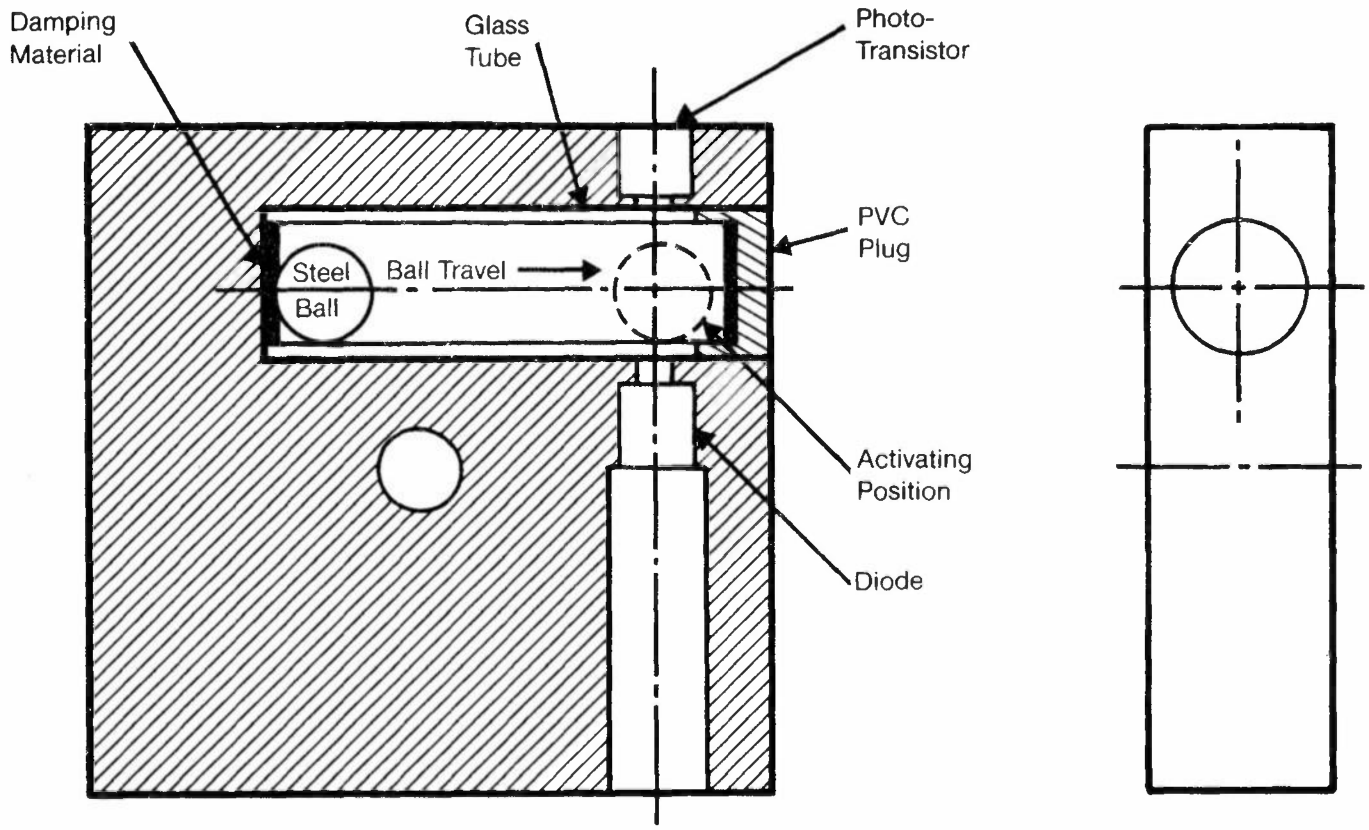


Fig 1 PVC Block Assembly

Contact: Peter Meggs 03-541 6214

COMPUTER TERMINAL RESPONSE TIME MEASUREMENT

The Need for Response Time Measurement

The response time of the LEOPARD (Local Engineering Operations Processing Analysing and Recording of Data) fault reporting system is important to Telecom.

The LEOPARD computerized fault reporting system provides Telecom with on line access to subscriber service records, real time reporting and allocation to repairers of service faults. In order for Telecom to assess the performance of this system, expecially while it is in its formative years of growth, it is necessary to measure the 'response times' accurately. To facilitate these measurements the Research Department has designed and constructed a microprocessor controlled unit that will automatically measure and record these times.

Measurement Unit

This unit is self-contained, transportable and easily connected to a terminal. For installation it requires the following connections:

- 240 volt power.
- RS232 connection to the rear of the terminal and
- data connection to the keyboard.

Once the unit is connected, it is only necessary for the terminal address to be dialled up on the front panel and the RESET button to be pressed. As soon as a message is sent from the terminal, the keyboard interface circuitry recognizes that the SEND key has been depressed and initiates a routine to measure the response times. This information is then entered into the display and also stored onto a microcassette ready for subsequent processing and evaluation.

With the ALERT unit monitoring a terminal, the response times will be continually measured and recorded along with the message code and time of day. This will not only provide Telecom with more accurate details of LEOPARD's performance but also cut down on the manhours used in collecting the data.

Contact: Ian Dresser 03-541 6744

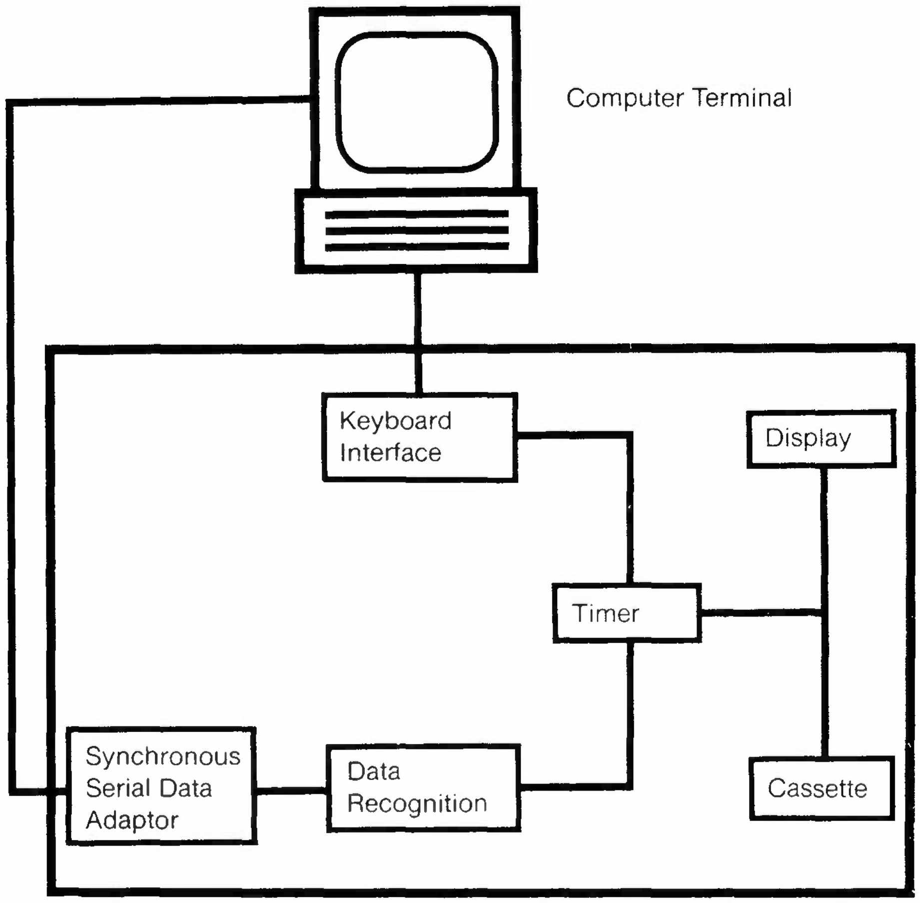


Fig 1: Diagram of Response Time Measurement Unit

A COMPUTERIZED INSTRUMENTATION RECORDS SYSTEM

The Need for a Computerized System

The existence of an efficient records system is vital in maintaining information related to equipment assets with respect to procurement, costing, depreciation, auditing, maintenance and history. The data must be capable of being modified to account for changing circumstances of asset equipment from procurement, through the period of its useful life, to disposal by various means. The database consists of some 15000 items, with an annual increase in size of about 300-400 items worth about $2 million (at current values).

Inadequacy of Manual Systems

Manual recording systems have numerous inherent problems. By their nature, they are not user-friendly, data and effort are often duplicated and control and security are much reduced owing to loss of management control. Consequently, the integrity of these manual systems is severely diminished. In addition, relevant information for timely and regular decision making is not readily available.

The computerized records system on display has been specifically designed to facilitate efficient handling of all records associated with the Research Department's asset equipment. It replaces a cumbersome file-card based system and related hard-copy filing systems. The system inherently has software-based checks to evaluate input data to an internal standard and to comply with auditing regulations. Summary reports can be produced for review and evaluation. Lines of responsibility are clearly indicated and this delineation leads to enhanced responsibility, accountability and control.

Databases Employed

The system utilizes a Nova III computer, with terminals for use of the staff, strategically placed throughout the Instrumentation Engineering Section. It is capable of accessing a number of databases. The following are examples of the databases and their functions:

(a) Test Sheet Database: contains data from time of delivery of equipment. Utilized, before incorporation into asset database, for acceptance test purposes.

(b) Asset Database: contains data relevant to equipment description, nominal section owner, pertinent history and documentation. Used as general reference throughout the working life of equipment.

(c) Service Contract Database: contains data of all asset equipment for which a maintenance contract has been negotiated.

(d) Disposal Pending Database: data of asset equipment for which disposal action has been initiated but not finalized.

(e) Deleted Asset Database: contains all data of deleted asset equipment disposed of via the normal disposal procedures.

(f) Museum Database: contains data of deleted asset equipment that has been allocated to the Research Department's Museum Collection.

(g) Personal Allocation Database: data of asset equipment where it is more expedient to allocate on a personal rather than section-owner basis.

Use of the Databases

The databases may be accessed by any staff member but, to safeguard against database corruption, built-in software protection ensures that only authorized personnel with the appropriate 'password' can modify the database or databases for which they are responsible. Back-up facilities are built-in to enable recovery of original records on a last transaction basis.

The design of the system is based on several levels of menu, which clearly indicate the options available to the operator. Displayed messages inform the operator as to the legality of the input data, subsequent options or the barring of access to certain functions or areas of the operating system.

The system has extensive search and sort facilities. Data may be searched for by designated Research Laboratories Number, Owner Section, Title, Make, Type, Purchase Date, Contract Number, Cost or any inherent characteristic field desirable. Data may also be sorted with priority to any one of these fields.

In general day to day operation, the Asset Database is the most frequently referenced database. Together with the search and sort facility, this database contains data related to a documentation 'register' which is vital in determining what documentation, for operational and maintenance purposes, exists for all asset equipment. This Asset Database also forms the basis for all annual stocktaking operations, an instance where search and sort is vital.

As with all computer-based recording systems, protection against database corruption and catastrophe must be taken into account and databases must be regularly and systematically backed-up.

Overall Value

The computerized records system in operation substantially reduces arduous and time-consuming manual procedures and, at the same time, enhances overall responsibility and control. This leads to a recording system that has significant advantages and integrity over the equivalent manual system.

Contact: Peter Dawson 03-541 6745

TECHNIQUES FOR SERVICING ELECTRONIC EQUIPMENT

Video Displays

This subject is illustrated by two video presentations that are typical examples of training media used throughout the Research Department for the purposes of instructing trainee staff in the recommended techniques to be adopted for electronic servicing. Whilst service staff will adapt and modify techniques to suit the application at hand, certain standards must be observed and precautions taken where necessary. No hard and fast rules exist for any servicing problem. Good service staff will adopt an attitude consistent with basic rules.

Desoldering

The first video presentation broaches the subject of de-soldering. Its title 'High Reliability Hand De-Soldering' implies the damage-free removal of components from printed circuit boards. Damage-free removal is important to preserve either the device being removed, which may be in working order and expensive, or the printed board itself, which also may be valuable and indeed re-usable. Several de-soldering methods are described from the simplest, a solder absorption technique using a flux-impregnated braid, to the expensive desoldering stations using a vacuum system combined with a specially-tipped soldering iron.

For electronic service staff, good soldering is vital but, owing to the introduction of printed circuit board construction, de-soldering has assumed an equal importance.

A useful reference is "Interconnection Repair Techniques for Electronic Equipment", Volume 1, produced by the RAAF and RAN.

Microprocessor-Based Systems

The second video presentation, 'Troubleshooting Microprocessor-based Systems', is a valuable insight into the way modern intelligent systems operate and the associated servicing techniques recommended for maintenance. Much of today's instrumentation is processor controlled and service staff are required to utilize techniques that enable a service problem to be rectified. This video uses an analogous situation to explain how a microprocessor operates and how the requirements for its input, output and control lines are configured. After the structure and organizational aspects have been demonstrated, a practical service problem is examined.

A useful reference is 'Practical Microprocessor Theory' by William Cardwell for Hewlett-Packard, 1978.

Contact: Doug Daws 03-541 6177

AUSTRALIAN DEVELOPMENT OF DIGITAL TRANSMISSION TEST EQUIPMENT

Background

One of the functions within the transmission area of the Research Department is to investigate new concepts for the measurement and testing of digital transmission systems. In many cases these concepts have been developed into laboratory prototype equipment to explore the concepts and to carry out investigations and measurements both in the laboratory and in the field. These concepts have in some cases resulted in international recognition and acceptance, e.g. the crosstalk noise figure as a measure of the performance of a digital line system regenerator.

Development Contracts

In some cases there is a requirement to develop a more advanced instrument than the laboratory prototype. It has been found appropriate to let contracts to Australian firms under the Telecom Industrial Research and Development (IR&D) Program for the further design, development and refinement of such equipment. This often entails a significant amount of microprocessor development and it has been advantageous to use firms with skills in this area as well as in general electronic equipment development. This has permitted Research Department staff to remain working mostly in measurements and investigations of digital transmission systems, rather than in areas that are secondary to the major activities of the transmission area.

In several cases, the instruments developed under contract have been further developed into commercial products with sales to Telecom and, in one case, to an overseas Telecommunications Administration.

The development of the instrumentation, initially for the requirements of the Telecom Research Department, has led to an increase in the telecommunication skills in local industry within Australia, especially with respect to specialized instrumentation for the measurement of digital transmission systems.

Instruments

On display we have instruments associated with two areas, viz.,

(a) the investigation and measurements of crosstalk interference between digital line systems in multipair cable and

(b) digital transmission system error performance measurement.

The display shows prototypes developed by the Research Department and then progresses to some instruments developed by firms under the IR&D program. Finally, some commercial products that are based on the instruments developed under the IR&D program are shown.

The IR&D program is a continuing program and further instruments are being developed, which may lead to further commercial products.

Contact: Rick Coxhill 03-541 6428

ACOUSTIC CHAMBERS

Standardized Environments

Two quite different acoustic chambers are used for acoustic measurements by the Research Department. Each provides a simple standardized environment as described below.

Anechoic Chamber

This chamber provides a quiet reflection-free environment having a working volume of about 21 m^3 (2.4m x 3.6m x 2.4m high) for free field acoustic measurements. It has been designed to meet stringent performance standards in the frequency range from 200 Hz to 10 kHz but is useful for less critical measurements from 150 Hz to 20 kHz.

It comprises a heavy inner room, with masonry walls and a concrete floor and ceiling all 340mm thick, resiliently supported on a special fibreglass mat to isolate it from ground and building vibration, and fully lined with acoustically-absorbing tapered rock wool wedges, each 600mm in length and with a 300mm square base. The wedge surfaces are lightly sprayed with acrylic paint to minimize fall-out of surface fibres. An outer room constructed from 120mm thick masonry walls and concrete roof assists in providing good isolation from external noise for the internal working volume.

The inner room has a tensioned-cable trampoline-type floor that allows occasional access with a minimum of acoustic reflections from the floor. In addition, mesh-grating modules can be fitted to support heavy test objects or for use as a more stable floor when the highest room performance is not required. The chamber is equipped with force ventilation to control air temperatures for tests involving heat-dissipating equipment and to allow lengthy tests with human subjects.

The main applications for the anechoic chamber include free-field frequency response calibrations of microphones (an example being the sensitivity and frequency response checking of the microphone of the NOSFER telephone transmission reference system), sensitivity and frequency response measurements on loudspeakers, directivity measurements on electro-acoustic transducers generally and particularly on unidirectional microphones, loudspeaking telephones and noise sources. Other applications are attenuation tests on models of noise-attenuating screens and psycho-acoustic tests on human subjects relating to speech generation and sound perception processes, including comparisons of sound pressure level distributions around artificial voices and human speakers.

The measurement of the directivity characteristics of a microphone suited to a specific teleconferencing application will be demonstrated. The test microphone is mounted on a rotating turntable so that the direction of the axis of the microphone can be varied through 360 degrees relative to a sound source. The directivity at any frequency, (or the relative sensitivity with angle of inclination to the source) is plotted as a polar response. By selecting the frequency of the source, the directivity can be measured for any frequency of interest.

Reverberant Chamber

The reverberant chamber is a room specially constructed with hard reflecting surfaces and non-parallel walls, floor and ceiling to provide multiple reflections of sounds generated within the room. This creates a sound field in which, at any point within the chamber distant from the source, the sound power coming directly from the source is small compared to the sound power which has been reflected one or more times. The resultant sound field for this chamber, which has an enclosed volume of about 35 cubic metres, is nearly uniform in intensity and random in direction throughout most of the room for frequencies greater than about 200 Hz.

The diagram (Fig. 1) shows the general shape and construction of the chamber, which is built on a separate heavy concrete foundation to isolate building structural vibrations from it. A 150mm thick heavy door and a double-glazed window are provided, each having a 60 dB sound transmission loss rating. The walls and ceiling are constructed from 100mm thick high density concrete cast in situ and are painted internally with gloss enamel.

The reverberation time of the chamber, which is the time for the sound energy to decay by 60 dB (one millionth of its original energy), is typically about 5 seconds, being higher at the lower frequencies and slightly lower at the higher frequencies.

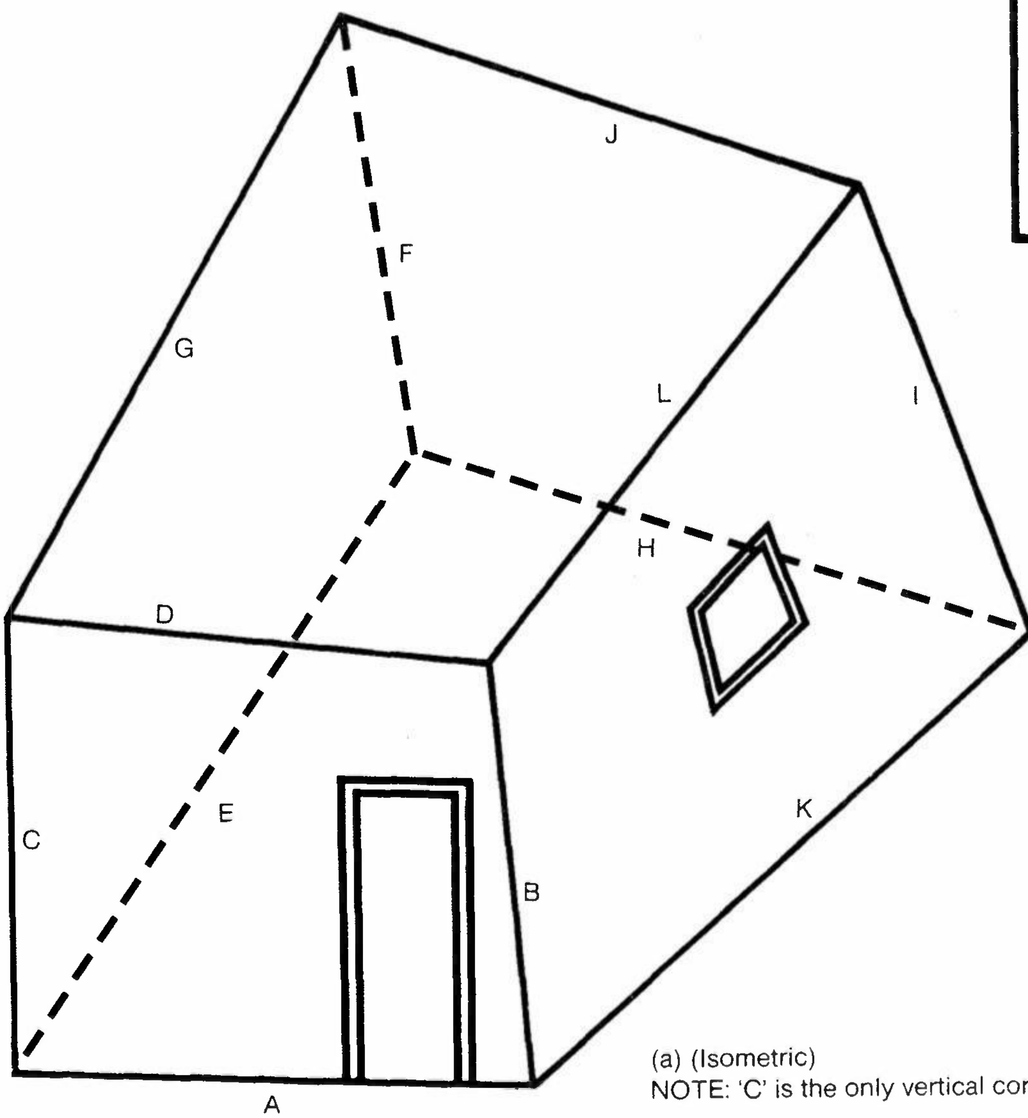
The diffuse nature of the sound field produced by the chamber is useful for calibrating sound level meters for random incidence sound. It is also used for generating high level random fields for investigating unwanted microphonics in sound level measuring equipment and for measuring and comparing total acoustic power outputs and acoustic spectra of sound sources such as loudspeakers, teleprinters, rotating machinery and telephone calling devices.

The use of the room to compare the sound pressure level spectra (in one-third octave bands) of two telephone calling devices (a standard bell and an electronic caller) will be demonstrated.

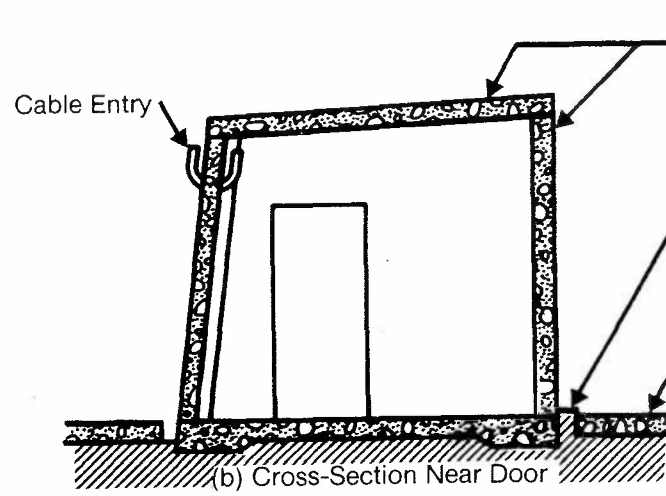
Contact: Eric Koop 03-541 6756

Fig. 1: Dimensions of the Reverberant Chamber

Internal Dimensions		
A	2.96 m	Approx. Internal Volume **34.7 m³**
B	2.53 m	
C	2.70 m	
D	2.72 m	
E	4.35 m	
F	3.20 m	
G	3.99 m	
H	3.38 m	
I	2.96 m	
J	3.06 m	
K	4.02 m	
L	3.68 m	



(a) (Isometric)
NOTE: 'C' is the only vertical corner



(b) Cross-Section Near Door

AUTOMATED RF SOURCE CONTROL UNIT FOR AN ADVANCED ANTENNA TEST RANGE

The Test Range

A modern antenna test range, such as Telecom operates at Caldermeade in Victoria, relies on a variety of sophisticated equipment to position and measure antenna patterns accurately. Generally, an antenna test range is made up of a transmitting site, which contains a radiating source and antenna, and a receiving site, at which the antenna-under-test is mounted on a rotator. At Caldermeade, the range-length, the distance between these two sites, is 2.4 km. Measurements are carried out by firstly setting the source power and frequency, as well as the source antenna height and polarization, and then rotating the antenna-under-test at the receiving site. Receiver equipment attached to the antenna-under-test measures the response of this antenna with angular rotation.

Operation of Measurement and Control System

The operation of this system of instrument setting, antenna positioning and measurement is computer controlled and fully automated. It allows highly efficient and accurate measurements to be made of co-polar and cross-polar radiation patterns for example. The control system is based around the IEEE-488 interface bus and a computer.

Basically, this central system facilitates the two-way exchange of information between the computer and the equipment being controlled. At the receiving site one section of the controller, which is located in the measurement cabin, converts commands in IEEE-488 format into serial format and sends these off to intelligent equipment on the receiving tower and vice versa receives data from monitoring devices on the tower and relays these back to the computer in the proper format.

Remote Source Control Unit

For information to be relayed back and forth between the receiver and transmitter sites, as shown in this demonstration, the commands and data, in IEEE-488 format, are sent from the receiver site by telephone line. At the transmitter site these signals are received by an automated intelligent terminal (ARTSACE) and either passed directly on to instruments connected to the IEEE-488 interface bus format or converted into a microprocessor bus format and sent out on a parallel input-output bus to the source antenna polarization positioner, the source antenna height adjustor and other devices. Information about the height and orientation of the source antenna is monitored by ARTSACE and this information is used to control the appropriate drive motors and is also fed back to the receiving site computer by the telephone line.

The heart of ARTSACE is a single 6800 microprocessor controlled by software stored in read-only memory. The incorporation of software into hardware decreases the complexity of the circuit design and increases the intelligence and flexibility of well designed equipment. Taking a broader view, the ultimate benefit is a much more cost effective way of carrying out antenna measurements.

Contact: Sasti Sastradipradja 03-541 6254

EXTERNAL FACILITIES FOR EQUIPMENT ENGINEERING

Range of Facilities

The equipment engineering facilities of the Research Department are located externally to the site at which the 1985 Open Days are being held.

As much of the extensive range of equipment used is not suitable for short term relocation for display purposes, a videotape has been produced showing the selected items of equipment that are described below.

Equipment Produced

Examples of the equipment produced by the equipment engineering staff using these facilities are presented in a related display. Some of them are included in the above videotape.

Thermal Cutting of Plate Metal

Flame or Thermal Cutting is a process that has been used over the past hundred years. It is a method of cutting steel plate by the use of a very hot flame. The cutting torch is supplied with oxygen and acetylene as a fuel gas and a separate supply of oxygen as a cutting medium. The steel plate is heated to its melting point of approximately 800°C and the cutting gas is then forced through the centre of the cutting tip at high pressure thus cutting the steel by blowing the molten steel away.

This process, depending upon the size of the cutting tip, can cut through thicknesses of between 3 and 300 mm.

The principles of the process have been incorporated in the very modern design of the Department's cutting machine. Fig.1 shows a photograph of the machine.

The cutting heads are driven by a chain drive along the X and Y axis and are able to cut sizes up to 1 m by 2 m. With the aid of the X-Y tracing unit the machine can cut out shapes from a profile drawn on paper to a tolerance of 0.9 mm. The photoelectric detector reacts to the contrast between light and dark and follows the outline of the drawn shape. The profiles can be black on white or white on black. Silhouettes with the light and dark contrast may also be used. The templates

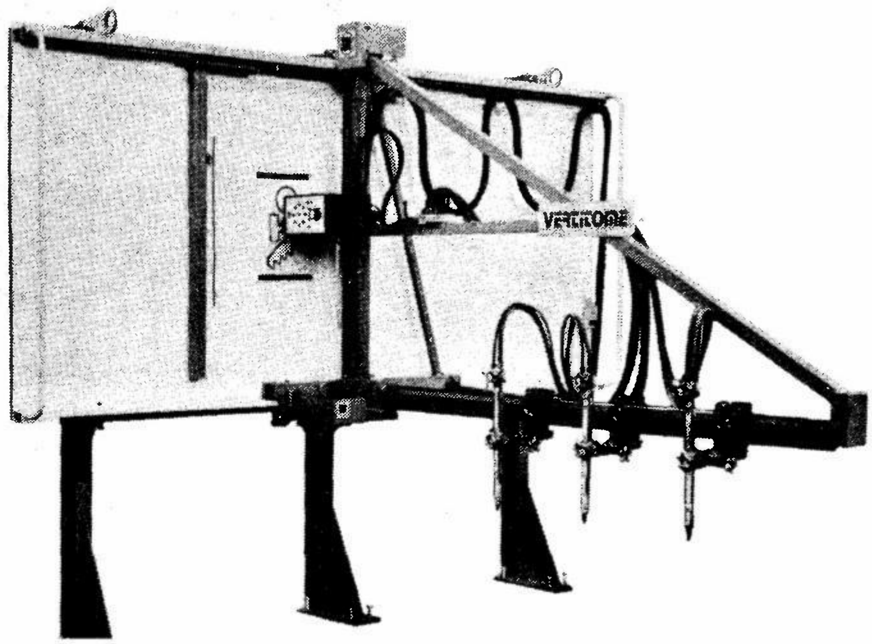


Fig.1: Thermal Cutting Machine

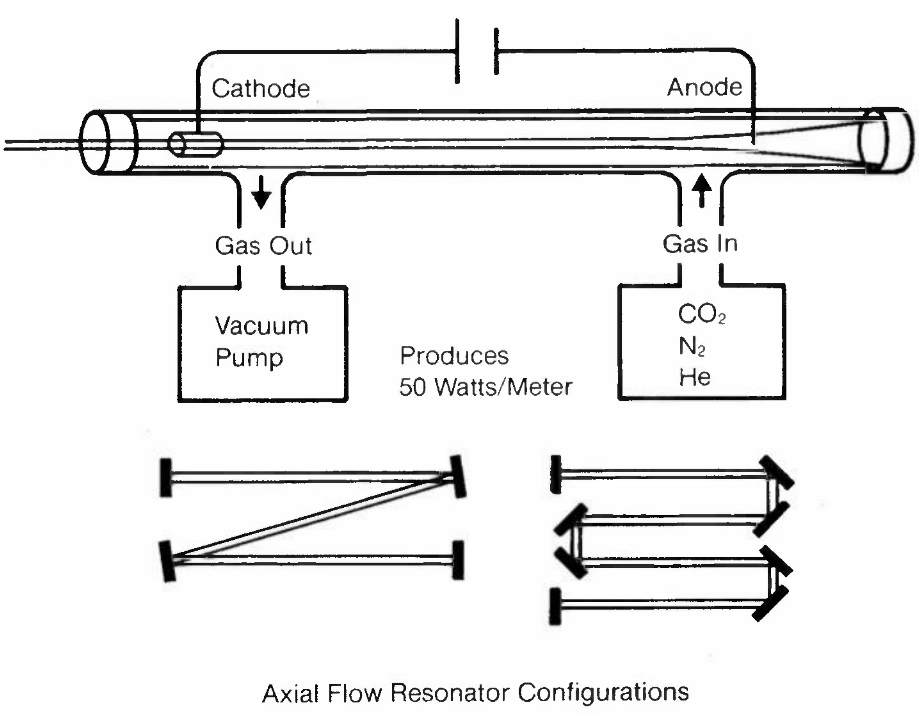


Fig.2: Diagram Showing a Typical Axial Flow CO_2 Laser Configuration

are held on a metal back board of magnetic strips. The back board is in a vertical position, which saves considerable floor space compared with the conventional horizontal position.

As the photoelectric detector follows the pattern, the shape is duplicated at the cutting head or heads. This machine can be fitted with up to four cutting heads, which will operate simultaneously, thus saving time in mass production.

With the aid of the plasma cutting unit this machine can also cut metals such as stainless steel and aluminium. This process is very similar to the conventional process but a plasma gas replaces the oxygen. Also the cutting torch is different. An arc is created at the torch head, which is surrounded by a plasma. A high velocity plasma from the centre of the torch blows away the molten metal as in normal thermal cutting.

Carbon Dioxide Laser Processing

Most people are aware of lasers through the media or science fiction films. They are portrayed as destructive or used for entertainment. Lasers fall into four categories: gas, solid state, chemical and semiconductor. Each is suited for different applications, e.g. helium-neon for holography and surveying and carbon dioxide (CO_2) for cutting materials. The Research Department has a Coherent Radiation Carbon Dioxide Laser, which extends capabilities in welding, cutting, drilling and heat treatment processes for specialized application in the manufacture of experimental hardware prototypes.

In the continuous wave mode, the laser operates at between 100 and 600 watts but peak output powers of up to 3500 watts can be achieved when it is operated in a pulsed mode at a very low pulse rate and a short pulse duration.

The CO_2 laser operates at an infrared wavelength of 10.6 μm, which is in a non-visible part of the electromagnetic radiation spectrum. The application of the laser therefore requires special attention to operator safety aspects.

The useful feature of the laser is that its beam can be focussed onto a small area of pinpoint dimensions (typically 0.12 mm diameter) above, on or below the surface to be worked upon. This results in a very high, controlled power density that either heats or vapourizes the material being worked upon.

The power density of the sun's radiation at the surface of the earth on a clear summer day at noon is about 1.4 kW/m^2, which produces the commonly experienced sunburn and suntan effects. By comparison, the CO_2 laser can produce a power density in excess of 1 million kW/m^2. Its applications are as follows:

(a) Cutting. Because a contact free transfer of energy is used, precluding any wear of the tool, high quality cutting of both hard and brittle materials as well as soft materials such as rubber or foamed plastics is possible. In addition to being contact free, the operation is clean and pollution free and produces no contamination of the work piece.

Fig.3 shows a typical gas jet system used for cutting. The nozzle outlet is in the region of focus and is larger than but is comparable with the diameter of the focussed beam. The gas jet also assists in removing vapour and particles that might condense in the cutting region or on the focussing lens.

(b) Welding. The main advantage of laser welding is that the beam can be focussed to a small pinpoint on the work piece to provide a minimal but adequate heat to fuse two surfaces together. Distortion of the material is thereby reduced and the ensuing heat-affected zone is minimized. The result is often a stronger weld than that obtained with conventional methods.

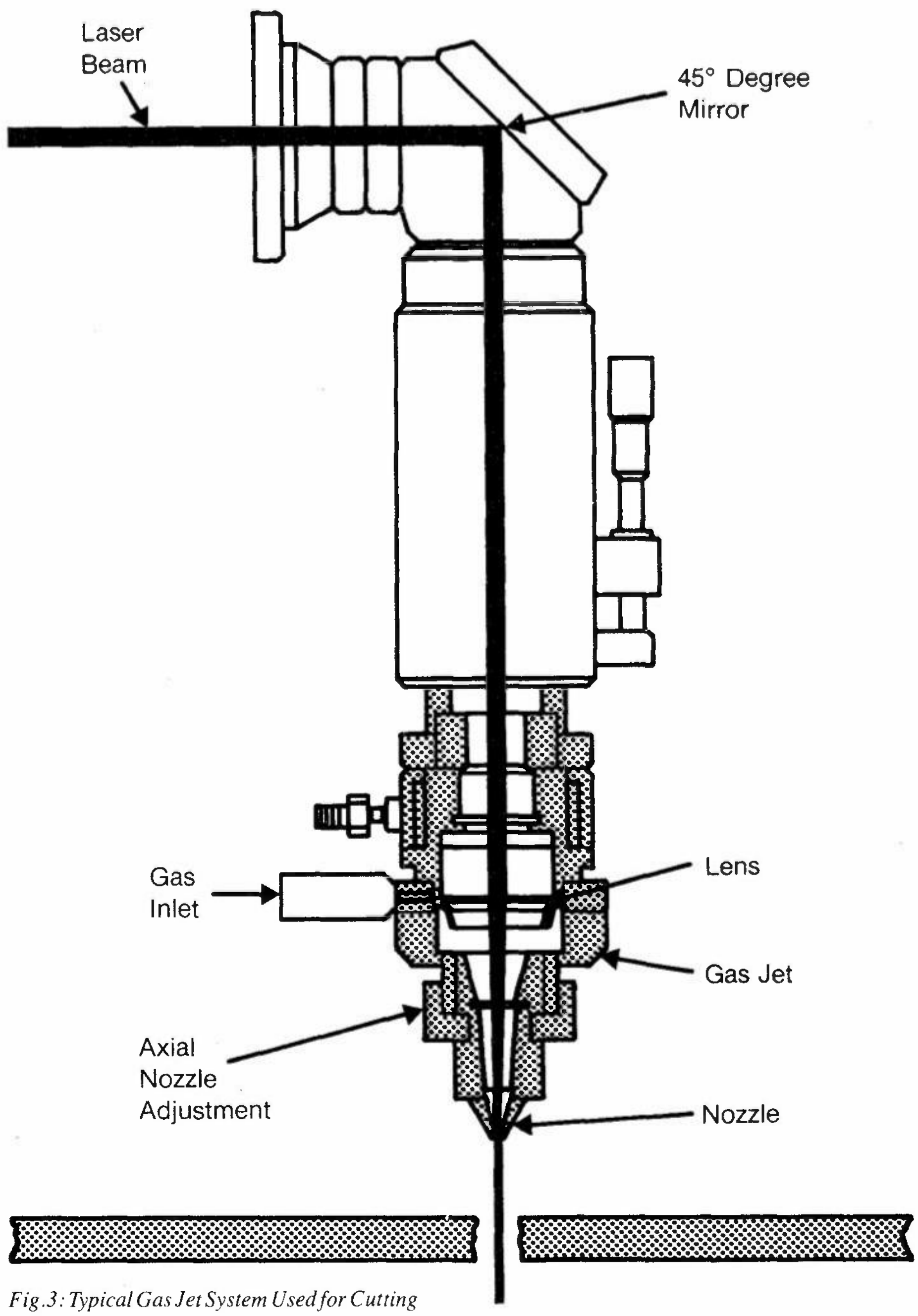


Fig.3: Typical Gas Jet System Used for Cutting

(c) Drilling. Because laser drilling is a contact-free process, there is no risk of breakage or slippage of the work-piece. The drilling of holes in irregular or curved surfaces and at any angle to the surface, which would be virtually impossible by conventional drilling methods, is readily achieved.

(d) Heat treatment. The ability to focus the beam directly onto the actual areas to be specially hardened, while leaving adjacent areas untreated, is an important feature. With localized and controllable heating there is no surface distortion, alleviating the usual need for grinding the heat treated component to final tolerance.

An X-Y numerically controlled table allows movement of the workpiece. The controller is programmed in numerical control (NC) machine language, which consists of codes to set the traversing speed of the table, the mode of movement (arcs, lines, etc.), incremental or absolute co-ordinates and miscellaneous codes to operate the laser. For example, the program to cut a 20 mm square with a 3 mm hole in the centre is as shown in Table 1.

The programming for a simple job can be very long and is subject to error. To aid in the production of NC programs, a desktop computer is used to allow a graphical input of a job with visual confirmation of the correctness of the data entered. Co-ordinates may be entered freehand on a graphics tablet or, if precision is required, on the keyboard. The computer displays each move as it is entered on its graphics screen making any incorrect entries immediately obvious.

The computer also has the facility for creating menus of commonly used shapes, e.g. various brands of connector. Each shape can be selected and placed on its location with the stroke of a pen. It can also be rotated or scaled as required and the job plotted on paper for confirmation when complete. Text can also be entered as part of the job. The final NC program can then be punched on paper tape if it is short or, if it is long, it can be dumped directly into the controller memory.

The complete system (computer controller, table and laser) makes the production of complex shapes from materials as diverse as steel, wood, perspex or foam rubber easy to program and modify, while making errors easy to correct.

Micro Plasma Arc Welding

Development of Micro Plasma Arc Welding originated from the need to provide a stable arc at low currents for high quality welding of foil thicknesses of dissimilar and exotic materials.

A schematic diagram of a Micro Plasma Torch is shown in Fig.4. The basic elements of the torch are the tungsten electrode, the orifice insert through which the plasma emerges and a gas cap, which provides the passageway for the shielding gas.

A plasma is created by passing a small amount of argon gas through an internal low current pilot arc struck between the tungsten electrode and the orifice insert. This internal arc heats the argon gas to a very high temperature, 10 000 to 20 000°C, whereupon electrons are removed from their orbits within the gas atoms, thus ionizing them to produce positive ions and free electrons, which form a plasma. The plasma issuing from the orifice insert is electrically conductive.

The Research Department has a Micro Plasma Arc Welder with the specifications shown in Table 2 below.

The Micro Plasma Welder can be used to weld materials ranging in thickness from 0.025 to 1.6 mm. Welded joints can be made in thicker materials when special edge preparation techniques are employed. Materials that can be welded by the Micro Plasma Welder include mild steel, brass, titanium, copper and various grades of stainless steel.

The two modes of operation of the Micro Plasma Welder are the transferred mode and the non-transferred mode. The transferred mode can only be used on conductive materials because the main arc is struck between the tungsten electrode and the workpiece. The Torch can be held up to 20 mm away from the workpiece and still have good stability. Heat input also is not dependent on torch to workpiece distance.

M42	Turn on the cutting gas.
G4X5.	Wait 5 seconds for gas to flow.
G91G71F1000.	Set incremental metric mode and cutting speed of 1000 mm/min.
M13	Turn the laser on.
G12R1.5	Cut a hole with a radius of 1.5 mm.
M14	Turn the laser off.
G1X-10.Y-10.	Set straight line mode and move to one corner of the square.
M13	Turn the laser on.
X20.	Cut out the square.
Y20.	
X-20.	
Y-20.	
M14M43M2	Turn the laser and cutting gas off and end program.

Table 1: Program to Cut a 20 mm Square with a 3 mm Central Hole

MAIN ARC:	
OPEN CIRCUIT	
D.C. VOLTAGE	100 V nominal 150 V peak DC
LOW CURRENT RANGE	0.1 to 2.0 A
HIGH CURRENT RANGE	0.1 to 15.0 A
PILOT ARC:	
OPEN CIRCUIT	
D.C. VOLTAGE	100 V nominal 150 V peak DC
HOT START CURRENT	6 A at 28 V
RUNNING CURRENT	2.5 A at 24 V
TORCH:	
CURRENT RANGE	0.1 to 15 A
PLASMA GAS	ARGON
SHIELDING GAS	ARGON or ARGON WITH 5-10% HYDROGEN
INPUT VOLTAGE:	
200 — 250 V single phase	50 Hz 12 A
TORCH COOLING WATER SUPPLY:	
3.7 litres per minute at 690 kPa	

Table 2: Specifications of the Research Department Micro Plasma Arc Welder

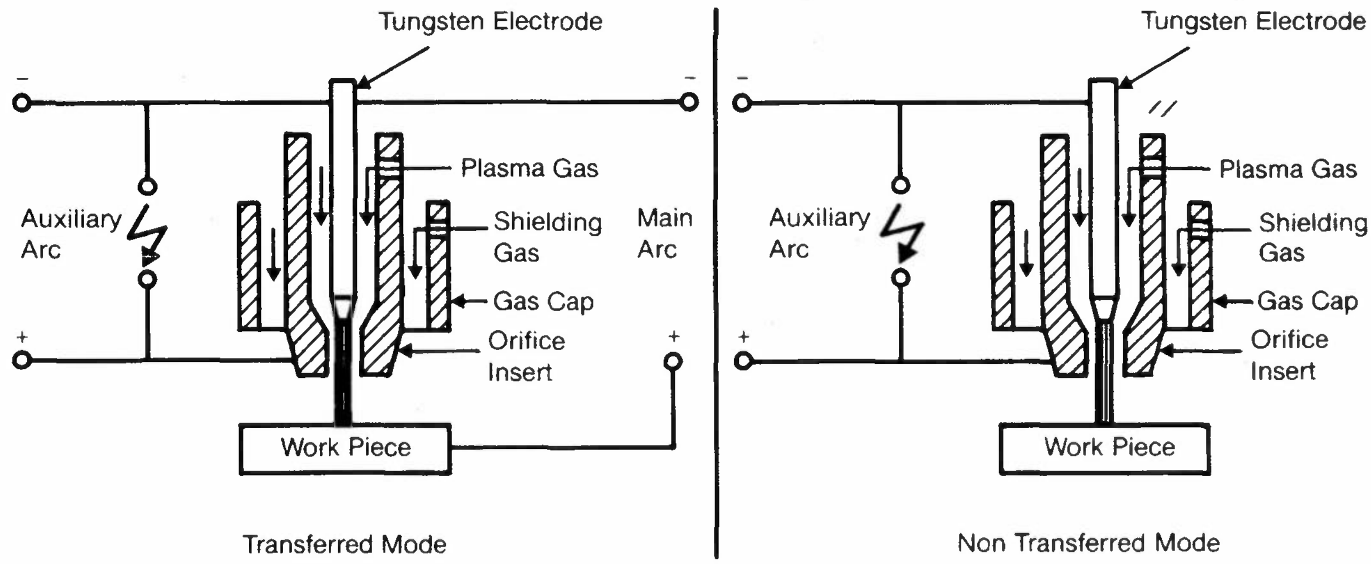


Fig 4: Schematic Diagram of a Micro Plasma Torch

In the non-transferred mode, the main arc is struck between the tungsten electrode and the orifice insert and is used for welding non-conductive materials. Heat input is dependent on Torch to workpiece distance. Fig.4 shows both modes.

The Micro Plasma Torch is small and light in weight and can be operated by hand or used with manipulators for high quality welds. For such welds on vacuum equipment, gas backing, which involves shielding the back side of the weld with an inert gas, is used. This procedure prevents porosity and scale forming, which may cause outgassing and eventual loss of vacuum.

A major advantage of using this welding method is that, because of the concentrated heating, the heat affected zone is kept to a minimum. This helps to prevent distortion, especially when welding materials of foil thickness.

The Micro Plasma Welder also lends itself to hard and soft soldering. When used in the non-transferred mode, it can take the place of an oxy-acetylene torch.

Computer Numerical Controlled Machining

A Computer Numerical Controlled Machining Centre has recently been established. The machine is 'state-of-the-art' in numerical control technology. The controller incorporates Interactive Conversational Programming, which leads the operator, step by step, through the programming procedure. A display can be called up on the computer screen in coloured graphics to show the sequence of operations and cutter paths, thus enabling the operator to check that the program is producing the desired effect before commencing the actual work-piece machining. A data file in memory storage automatically determines the spindle speed and feed rates for the material specified by the operator during programming.

The role of this type of machine within the Research Department is to provide a wider range of complex machining capabilities of high accuracy for the more complex projects that are generated within the Department. It provides high reliability and significantly improves the performance-to-cost ratio relative to conventional machining methods.

Programs can quickly and easily be altered and new components produced when minor design changes are required. All features of the new components, except for the design changes, are identical to the original components thus ensuring, as far as possible, that interchangeabilily requirements are maintained.

Contact: Frank Wolstencroft 03-541 6213

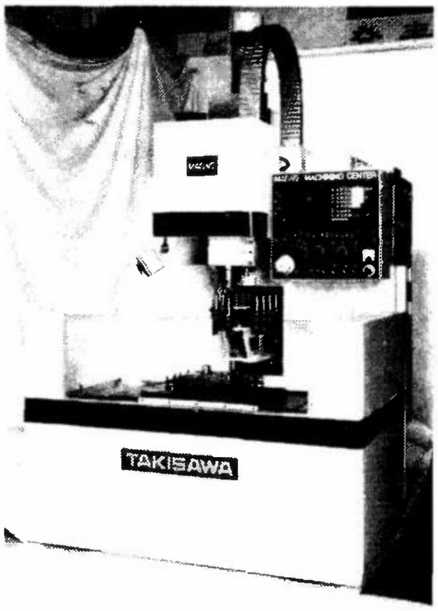


Fig.5. Computer Numerical Controlled Machining Centre

EQUIPMENT ENGINEERING SERVICES

Staff

Equipment engineering services for the Research Department are provided by staff located at another site in Clayton.

Being primarily mechanically oriented but with strong electronic, electrical and manufacturing engineering skills, the equipment engineering staff support other areas of Telecom and its Research Department by design conception and realization, feasibility studies and modelling and the prototyping of specialized telecommunication or non-telecommunication oriented equipment and investigatory aids.

The staff are often the interface between the Research Department and industry for the subsequent development or manufacture of the Department's requirements that fall within the field of equipment engineering.

The staff have a specific role to examine advanced techniques of material processing and fabrication and manufacturing technologies that could find application within Telecom.

Facilities

The range of engineering facilities available is presented in a related display.

Examples of Equipment Produced

Examples of equipment produced for the Research Department by its equipment engineering staff are:

(a) hailstone impact equipment for testing solar panels,
(b) wind loading simulator for testing solar panels,
(c) digital display dialler,
(d) specimen exchange carousel for the molecular beam epitaxy system,
(e) molecular beam oven flange for surface characterization system and
(f) high resolution electron energy loss spectrometer.

Contact: Frank Wolstencroft 03-541 6213

MICROELECTRONIC DISCHARGE MACHINING

Principles of Operation

In Electro Discharge Machining (EDM) or spark erosion, a series of electric discharges is used to remove material from a metal workpiece. These discharges are produced by applying a voltage between the electrode and the workpiece separated by an insulating fluid (known as a dielectric). When the voltage breaks through the insulation it creates a conductive channel along which a current is established. This current creates high temperatures and pressures, which heat the surface of the material. On the interruption of this current the metal is vapourized to a certain depth. As one discharge follows another, a number of craters are formed resulting in the workpiece being eroded away.

The dielectric fluid also plays an important part in removing the microscopic metal particles and gas bubbles produced during the erosion process.

The cutting tool or electrode is made of an electrically conductive material. From experience the most suitable materials used are usually copper, tungsten, tungsten-copper or graphite.

Capabilities of the Micro EDM Machine

With the Micro EDM machine it is possible to erode very small holes (down to 0.04 mm diameter) as well as slots or complex shapes. Obviously for such small holes an electrode of the same diameter is required. These electrodes can be produced by various methods such as turning on a small precision lathe or using wire as an electrode. It is possible to produce electrodes of about 0.08 mm diameter on the lathe. These electrodes are usually made of brass, as copper and tungsten copper are difficult to turn to such small diameters.

If wire is used as an electrode, it is necessary to use some method of straightening the wire. This is usually achieved by heating and stretching the wire, which also reduces its diameter. The failings in this technique are the uncertainty of the eventual diameter and tapering and misalignment of the wire in its holding collet.

Another more sophisticated method, which allows the production of very small electrodes (0.04 mm diameter), is to use the Micro EDM machine to erode its own electrodes. With this method it is possible to turn down a copper or tungsten-copper electrode to approximately 0.5 mm diameter and then erode it down to the desired size.

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INSPECTION OF SPACES USING ENDOSCOPES

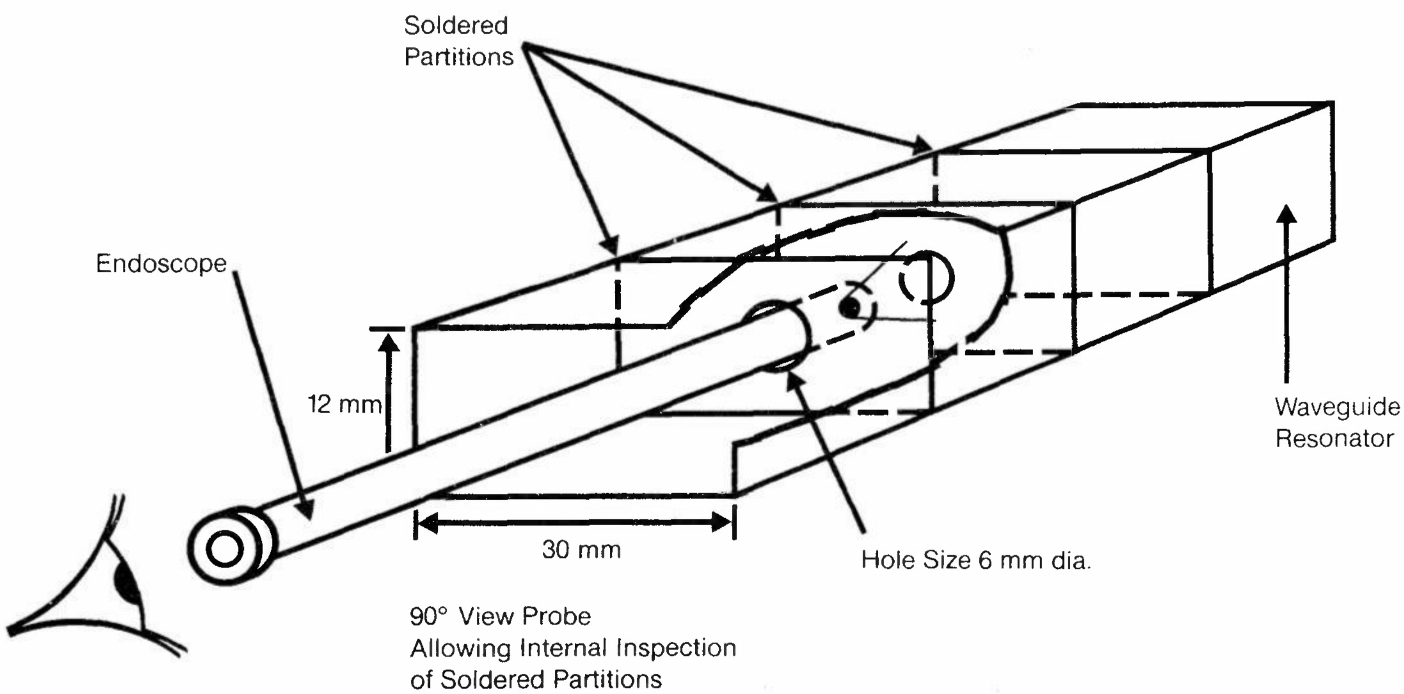
Purpose of Endoscopes

Sometimes it is necessary to inspect, in equipment or machines, areas that have restricted access. The opening might be far too small for an inspection mirror, or the desired side to be viewed might be at right angles to the entrance.

One of the items produced in-house is a waveguide resonator cavity. This consists of a waveguide with a number of spaced partitions, which are normally soldered into place. It is important that there is a good solder flow around each of the partitions. See Fig.1.

Fig.1 shows a typical situation where an endoscope is ideal, because it provides a quick and simple visual check of the interior.

Fig.1: Use of Endoscopes in Inspecting Cavities



Endoscopes may also be used partially submerged in liquids.

Types of Endoscope

Endoscopes fall into the following two categories of construction:

(a) Rigid body construction

The endoscope is a sturdy optical instrument that is simple to use. Its layout is shown in Fig.2. The area to be viewed is illuminated from a remote light source that is transmitted via a flexible fibre cable to the instrument's own built-in fibre bundle. The view is then obtained through a matched set of lenses. At the objective end, the image is focussed and reduced to a transmittable size. It is then relayed along the matched series of lenses to the eyepiece where the ocular lens rebuilds a sharp and precise image.

In addition to different viewing directions, as shown in Fig.3, the angle of coverage can be chosen to suit the situation. The viewing angles can vary from 10 to 80 degrees, on most probes.

(b) Flexible body (fibrescope) construction

Basically the fibrescope consists of thousands of precisely aligned glass fibres with an objective lens at one end and a magnifying eyepiece at the other. The objective focusses the image which is then transmitted, via internal reflection, up the fibrescope to the eyepiece where it is magnified for viewing. A second bundle transmits light down the fibrescope to illuminate the area. As this is purely light, neither significant heat nor electricity is introduced to the area under inspection.

This type of probe is also used in medical applications, where the probe is inserted into a patient's body for internal examination. Further applications can be found in the aeronautical, motor and machining industries.

Contact: David Kisby 03-541 6208

Fig.2 Layout of an Endoscope

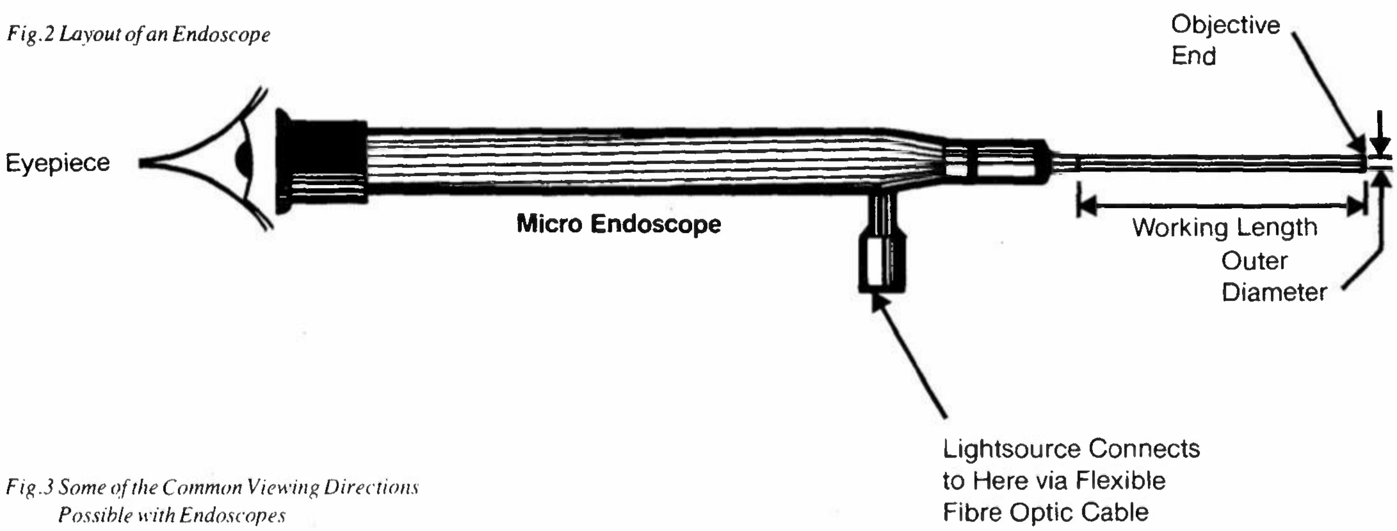


Fig.3 Some of the Common Viewing Directions Possible with Endoscopes

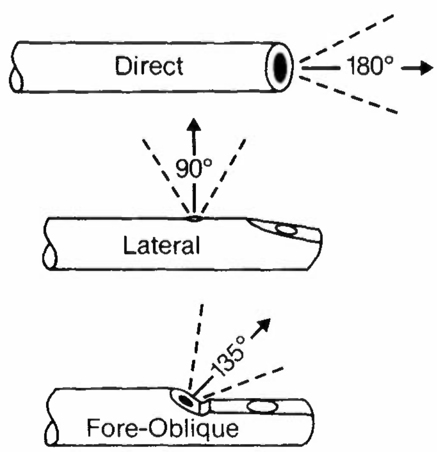
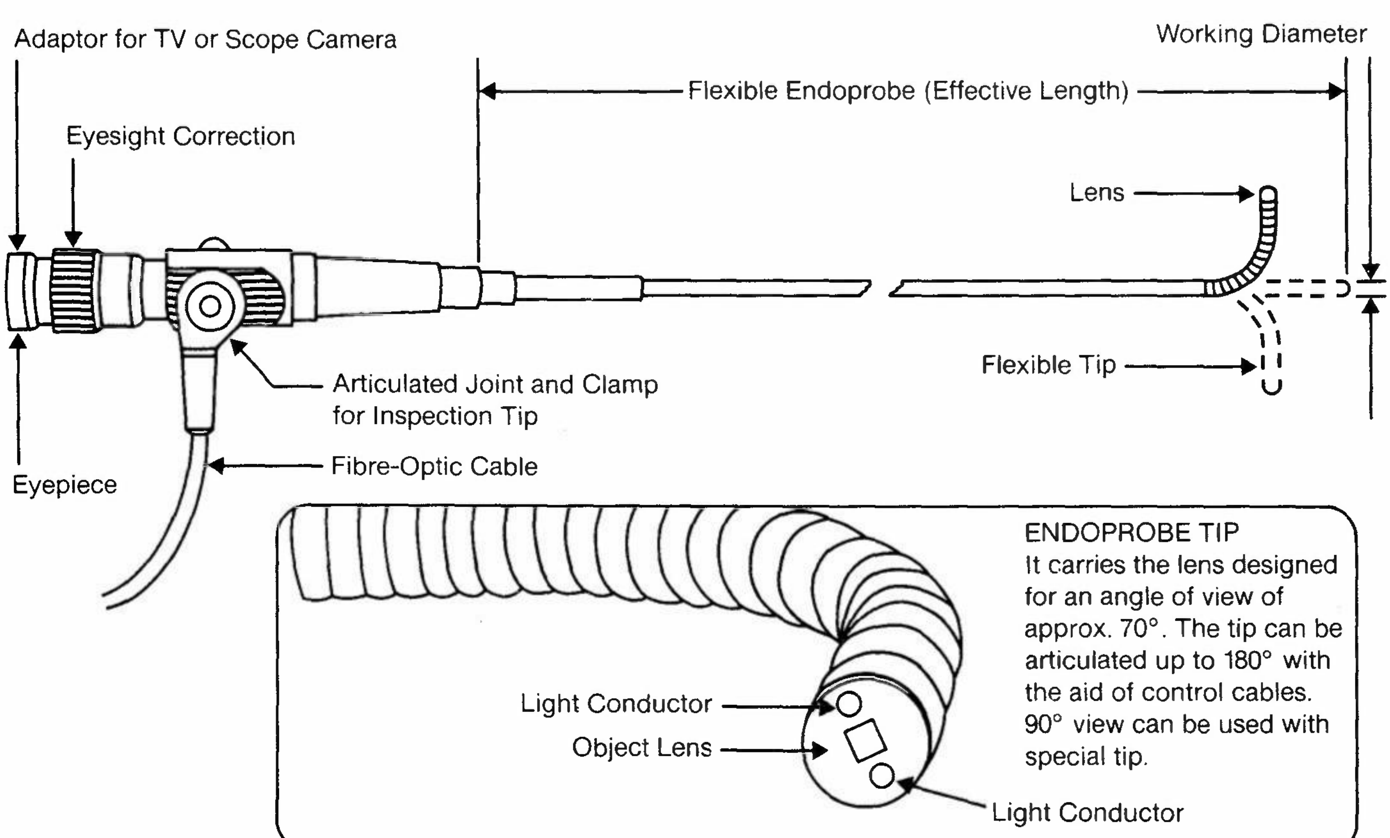


Fig.4 Details of a Fibrescope



RESEARCH DEPARTMENT MUSEUM COLLECTION

Communications Equipment

To maintain a history of the Research Department's involvement in Australian communications, a local museum is being established to provide both storage and display facilities for a wide range of communications-related equipment.

Such items include:

- Specimens of early telephone cables
- Examples of recording instruments: Edison cylinder players, record players, wire recorders, tape recorders and video recorders
- Radio transmitters and communication and domestic receivers.

Research Equipment

As the Department is concerned mainly with research and prototyping, a great deal of time is spent in testing and measurement. A representative range of measuring instrumentation has been collected. This includes:

- Voltmeters. From early galvanometers to modern digital voltmeters
- Calculation. From abacuses and slide-rules to calculators and computers
- Oscilloscopes. From early oscillographs to modern multi-trace CROs.

An important aspect of the museum collection is that it is being continually updated. The historical value of equipment no longer required within the Department is also being continually assessed.

It is hoped that in the near future an area within the Department will be reserved to allow a permanent display of museum items.

The number of items in the current display represents only a small portion of the collection, most of which is held in storage. Unfortunately, a great many items require restoration before they can be exhibited. The cost of restoring all items would be prohibitive, hence only a few items can be restored at any one time. A great deal of restoration work is done by volunteer staff from within the Department. Those who have an interest in the 'by-gone era' donate their time to help restore some of the items.

As previously indicated, the Museum caters for all types of instrumentation, old and new. If you have an item you may wish to donate, please contact the person below.

Contact: Sean Curlis 03-541 6747

THE TELECOM AUSTRALIA HEADQUARTERS LIBRARY

Functions

The functions of the Headquarters Library are:

- to provide a comprehensive library service to all Departments and Directorates at Telecom Headquarters
- to co-operate with State Administrations and provide consultative services in regard to common standards and systems.

The Library aims at providing information in anticipation of demand and on request to support the activities of Telecom Headquarters and at providing services to all officers in connection with Telecom Headquarters work and related studies.

Organization of Headquarters Library

The Headquarters Library is located within the Research Department.

A Library Committee determines policies and objectives and provides high level support to ensure that the Library is meeting its objectives.

The Telecom Library operates as a single unit, although there are a number of collections and access points. The two main collections are located at:

(a) 770 Blackburn Road., Clayton. This collection primarily serves the Research Department. The Principal Librarian is also located here, together with the centralized Technical Services Unit.

(b) 199 William Street, Melbourne. Some of the areas served by this collection are the Engineering, Commercial Services, Human Resources, Information Systems, Accounting and Supply Departments, Finance and Business Development Directorates, the Secretary's Office and the International Branch.

Library Services

- Purchase of materials on request from officers and selection by professional library staff.
- Loans and Inter-Library Loans.
- Reference and Information.
- Literature Searches.
- Selective Dissemination of Information (SDI).
- Current Awareness Bulletins.
- Translations.

Subjects

The primary subject of the Library is telecommunications. Support subjects include management, computers, industrial relations, occupational health and safety and public administration.

Library Publications

These are:

(a) Telecom Library News. A monthly selective list of new library acquisitions, together with notes and articles keeping users up to date with the library developments and services. It also includes lists of bibliographies compiled by library staff.

(b) Daily News Bulletin. Topical and general information from daily newspapers, Hansard and other sources.

(c) Telecom Library Topics. Current awareness tool provided to officers on request listing articles in sixteen broad subject areas from new periodicals.

(d) Conference List. A quarterly listing noting International and Australian conferences designed to assist officers planning overseas trips or submission of papers and to facilitate the purchase of conference proceedings for the Library's collection.

(e) Periodicals List. A list of all periodical titles held with information on title, country of origin, frequency, holdings and location.

Forms of Material

The collection includes a variety of materials from which information can be obtained as shown in Table 1.

(See diagram)

Telecom needs to be aware of current research and developments both in Australia and overseas to continue to provide modern, efficient telecommunications services and facilities to the people of Australia.

The Headquarters Library provides Telecom Personnel with access to world information sources as well as the human and technical resources to identify and disseminate relevant material.

Thus Telecom Headquarters Library exists as an essential component of Telecom Australia's current activities and services to the public and its goals and objectives for the future.

Contact: Moyra McAllister 03-541 6607

Books	Standards	Cassettes (Audio & Video)
Periodicals	Theses	Films
Pamphlets	Translations	Slides
Reports	Trade Catalogues	Press Cuttings
Patents	Handbooks	Reprints
Microforms	Manuals	Maps
	Telecom Australia Publications	
	Overseas Telecommunication Authorities	
	International Documents	
	Publications (including British Telecom and BBC Reports)	
	Census and Statistics Materials	
	Government Publications	

Table 1: Some of the Forms of Material Available

LIBRARY USE OF MICROFORMS

Microforms

All libraries are short of storage space. Space is saved by using microform records such as microfilm and microfiche.

Standards

Standards are an important source of information for engineers but they present a particular problem to librarians because of the difficulty of keeping up to date with the frequent amendments.

In order to solve this problem partially and to supplement the collection of standards in traditional printed form, the library subscribes to a number of standards on microfilm. These standards are updated every two months with the latest issues and amendments.

In addition, there is a subject index which groups together all standards on a particular topic, regardless of the issuing body, thus allowing comparisons to be made.

The service includes the following standards:

- SAA (Standards Association of Australia) – Complete set
- ASTM(American Society for Testing and Materials) – Complete Set
- IEEE(Institute of Electrical and Electronics Engineers) – Complete Set
- IPC (Institute for Interconnecting and Packaging Electronic Circuits) – Complete Set
- FIPS (Federal Information Processing Standards) – Complete Set
- ANSI (American National Standards Institute) – Information Processing Only
- ISO (International Organisation for Standardisation) – Selected Sections
- IEC (International Electrotechnical Commission) – Selected Sections
- ECMA (European Computer Manufacturers Association) – Complete Set
- Videotex standards from the U.K., France, CEPT and Canada.

The ECMA and Videotex documents are updated every six months.

Electrical and Electronic Components Information

Telecom HQ Library has recently acquired a new source of information on electrical and electronic components handbooks. All information is stored on microfilm cartridges, from which good quality paper copy can be produced.

The VSMF (Visual Search Micro File) System has a number of features which make it useful for electronic engineers and technicians, particularly when the manufacturer of the item concerned is not known.

(a) Semiconductor Devices
The following indexes are available:

- Devices listed by device type number and cross reference type number (military devices listed by MIL-SPEC slash sheet number).
- Diodes and rectifiers listed by parameters such as forward current, frequency, switching time, etc.
- Transistors listed by parameters such as power dissipation, collector current, switching time, etc.

(b) Integrated Circuits
The following indexes are available:

- Circuit type number.
- Original circuit number.
- Function listing e.g. photo sensors, digital gate elements, memory or storage circuits.

(c) Instruments and Equipment
A detailed subject index is provided.

(d) Suppliers' Directory
If the manufacturer is known, items can be identified using the suppliers' directory which is also a useful source of information for addresses and phone numbers.

Files

When the required item has been identified it can be located in one of the two files below:

- The Design File. This contains manufacturers' data, circuit diagrams, etc, arranged so that similar products are on the same cartridge and detailed comparisons can be made.
- The Vendor Catalogue File. This contains catalogues arranged by a manufacturer. In many cases it contains items which cannot be located in the Design File.

The entire system is updated every two months with the latest product information.

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ON LINE INTERACTIVE RETRIEVAL SYSTEMS

Services

Computer terminals located in the Headquarters Library have direct on-line access to a number of local and overseas information retrieval services.

These are:

- AUSINET
- DIALOG
- ORBIT
- ESA/IRS
- NEWSNET
- EMIS
- I.P. SHARP
- BRS
- INKA
- PERGAMON INFOLINE

Range Covered

These services, with over 300 databases, contain in excess of 100 million records. The units of information range from a directory type listing of specific manufacturing plants to a citation with bibliographic information and an abstract referencing a journal, conference paper or other original source. The databases cover a very broad range of subjects and include such sources as COMPENDEX (the machine-readable version of the Engineering Index), Economics Abstracts International, Inspec and Management Contents.

Sources can be searched to create bibilographies in most subject fields of interest to library users, especially in cases where manual searches of published information services are inadequate or where recent information is required.

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MICROCOMPUTERS IN THE LIBRARY

The Impact of Microcomputers

Many authors have compared the development of the microcomputer to the invention of movable print. Certainly, the impact on the information handling industry has been no less dramatic than that associated with Gutenberg's invention nearly 600 years ago.

The computer greatly simplified complex information handling tasks. Unfortunately, large mainframe machines or even minicomputers are expensive devices available only to larger organizations in which the size of the operation can justify the cost of the machine itself and the expense of the specialist support staff required for its operation.

The development of the microcomputer has dramatically changed the situation, making computer power widely available, at relatively low cost, and without the need for costly support facilities or staff.

Many of the tasks performed in libraries are ideally suited to computerization and the library community has long been involved in the development of computer-based systems to handle some of these routine operations. Computer-controlled book and magazine circulation and machine-produced catalogues are commonplace in Australian libraries today. Huge numbers of references to books and periodical articles are stored in massive centralized databanks which librarians can access from terminals in their libraries to locate material sought by their users.

Because of the costs involved, these operations were confined to large libraries or to applications that were of interest to the widest possible range of users. With the advent of the microcomputer, however, smaller libraries such as the Telecom HQ Library, which is based within the Research Department could develop specialized systems tailored to their own requirements.

Applications of microcomputers in three major areas of library operation are summarized below.

Reader Services Applications

The two major applications in this area are the support of in-house databases and the reprocessing of data retrieved from the large centralized databases supplied by outside vendors.

In-house data bases can store information on a wide variety of subjects, offering at the same time improved methods of record keeping and increased ease of access and therefore greater use of the material stored. They can be easily updated and designed to meet the requirements of the library's users. Some possible applications include:

- Local bulletin boards,
- Information and referral files,
- Calendars of events,
- Corporate services,
- Library policies, hours of service, etc.,
- Ready reference files,
- Specialized indexes to newspapers, magazines and reports,
- Catalogue of special collections and
- Bibliographies on various topics.

The use of microcomputers in conjunction with large commercial information retrieval systems is increasingly common. The microcomputer can be used as an 'intelligent' terminal to download information from the larger system, editing, sorting and generally reformatting the information prior to distribution to the end user. Local information can be added, search strategies stored for future use and statistics for analysis of patterns of system use collected.

One such application in the Telecom HQ Library Service uses a microcomputer to maintain a locally developed list of forthcoming conferences of potential interest to Telecom. Records for each conference include details of name, location, date held, contact address and subject. Information may be retrieved under any of these headings, either individually or in combination.

Technical Services Applications

Microcomputers are being used in most of the library operating areas in which mainframe systems have already been developed, from acquisitions, through cataloguing and circulation to periodicals control. Development has in some areas been relatively slow, as highly sophisticated systems are required to handle the complex tasks involved, but the increasing power available to users of the microcomputer is rapidly providing solutions to the problems involved.

Perhaps the most interesting development in this area is the increasing use of microcomputers in conjunction with systems based on mini-and mainframe machines to provide a degree of local autonomy in system operation.

Management Applications

In addition to the two areas outlined above, microcomputers may be applied to exactly the same range of management tasks in a library as they are in a standard office environment. This would include, for instance, word processing tasks, such as preparing letters and reports, as well as storage of text for frequently updated library publications such as guides and bibliographies. The use of 'spreadsheet' packages for analysis of times and costs associated with various library operations and the use of other packages to develop databases for maintaining statistical and financial reporting systems are all examples of the application of microcomputers to library management.

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