THE AUSTRALIAN POST OFFICE

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COURSE OF TECHNICAL INSTRUCTION

Engineering Training Section, Headquarters, Postmaster-General's Department, Melbourne C.2.

INTRODUCTION TO BROADBAND CARRIER TELEPHONY

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1. INTRODUCTION.

1.1 The rapid development of capital cities and large provincial cities and towns within the Australian States, has led to a demand for large numbers of interstate and intrastate trunk circuits, and also for large numbers of junction circuits within metropolitan areas.

1.2 In modern trunk and junction telephone networks, extensive use is made of derived carrier telephone circuits which are provided by systems ranging from single channel to 1260 channel capacity.

1.3 Over the years many developments in carrier telephone systems have taken place. These developments can be broadly divided into the following categories:-

(i) An increase in the number of channels provided per system.

(ii) An upgrading in the V.F. range for each channel - from about 300-2600c/s to about 300-3400c/s.

(iii) A decrease in physical size, brought about largely by the use of smaller components.

(iv) A standardisation of frequency ranges, levels and impedances - this allows direct interconnection of various systems.

1.4 This paper outlines the functions of broadband carrier telephone equipment and associated twelve channel carrier telephone systems in a carrier telephone network. The modern trend is to associate the term "Broadband" with carrier systems which are capable of providing either a block of several hundred telephone channels, or a television programme, each of which requires a frequency bandwidth of several megacycles per second.

2. STANDARDISATION.

2.1 To gain maximum flexibility from the carrier telephone network most of the larger systems (12 channels and upwards) have certain common features. These are specified as international standards, and are listed as follows:-

(i) Each channel has an effective bandwidth of 300-3400c/s with a frequency separation of 4kc/s between adjacent carrier frequencies. In general, facilities are also available for "in-built" out-of-band signalling using a frequency of 3,825c/s. One or more channels can be used as a bearer circuit for a 24 channel voice frequency telegraph system.

(ii) Standardisation of a group of 12 channels in the range 60-108kc/s (basic group) facilitates interconnection with similar groups from other systems. (Additional information is given in Section 4).

(iii) By dispensing with three adjacent channels in any twelve channel group, a programme channel, having a bandwidth of 10kc/s, may be obtained in each direction of transmission. (Details are given in the paper "Programme Equipment").

(iv) Equipment used up to the basic group stage of 60-108kc/s is interchangeable with coaxial cable, microwave radio, open wire and balanced pair cable systems.

(v) Systems having multiples of 60 channels (5 × 12 channels) employ basic supergroups of 312-552kc/s which can be interconnected with other large capacity systems. (Additional information is given in Section 4).

3. BROADBAND SYSTEMS.

3.1 The need for broadband systems is due to three main factors, which are:-

(i) Limitations of Existing Trunk Lines. Until recently, trunk telephone and trunk telegraph routes consisted predominantly of pole and open wire construction. Although a few open wire routes were originally designed for high frequency working, the majority were designed for voice frequency working, and have been successively upgraded for 3 channel carrier operation. A maximum of 120 long distance channels has been obtained on some sections of interstate routes, but considerable expense would be involved to upgrade most pole routes to achieve a channel capacity of this order which could still be inadequate to meet the demand for circuits.

On the more heavily developed routes, radiating from larger cities to nearby provincial centres, paper insulated cables, for V.F. or carrier operation, have replaced the open wire pole routes. A considerable number of these cable routes are approaching or have reached their ultimate trunk channel capacity, and can no longer meet the trunk requirements.

(ii) Increased Demand for Trunk Telephone Circuits. A rapidly increasing demand for trunk telephone circuits, particularly on main trunk routes, is evident at present. The demand is being stimulated by rapid industrial development and the extension of automatic telephone working and subscriber trunk dialling.

(iii) Demand for Television Relays and Data Transmission. The demand for interstate and intrastate television relays is increasing as National and Commercial television services are extended. Broadband bearers in use on television routes are designed to cater for both telecommunication and television transmission.

In addition, a demand is expected for new services, using a large bandwidth such as data transmission for accounting purposes, defence information, facsimile transmission, etc.

3.2 Broadband Principles. The basic broadband system in use in Australia is referred to as a 4 megacycle system and using a frequency range from 60-4028kc/s provides a total of 960 voice channels, or using a frequency range of 300-4028kc/s provides up to 900 voice channels. By providing additional equipment for another 300 channels using frequencies up to about 5564kc/s, the 4 megacycle system can be extended to a 6 megacycle system with a total of 1260 voice channels. A 12 megacycle system provides 2700 channels and effectively represents three 4 megacycle systems assembled one above the other in frequency.

3.3 Broadband Bearers. Broadband systems are divided into two categories according to the bearer used. The two types of bearers are coaxial cable and microwave radio.

Coaxial cables are at present available in Australia with 2, 4, 6, 8, 10 or 12 coaxial tubes in the one sheath, with paper insulated interspace control pairs, and are obtainable with a layer or layers of conventional paper insulated cable pairs which can be used for short distance trunk circuits and ancillary services such as alarms.

With existing valve type line equipment, using repeaters spaced at approximately 6 mile intervals, a pair of tubes provides 960 long distance channels occupying a frequency bandwidth of 4Mc/s. By using a frequency band up to 6Mc/s these repeaters can provide 1260 channels for shorter circuits. Alternatively a 625 line television channel may be provided on each single tube. A frequency range of about 30c/s - 5Mc/s is required for direct video transmission and a frequency range of about .5-5Mc/s when a television programme system is used. With repeaters located every 3 miles a bandwidth of 12Mc/s can be transmitted and 2700 telephone channels are obtainable. The latter higher frequency system is not yet in use in Australia. Future coaxial cable systems will use transistorised line equipment with repeaters spaced at intervals of 6 miles or 3 miles to provide bandwidths of 4Mc/s and 12Mc/s respectively.

Broadband radio systems provide from about 300 to 1200 voice channels, but most systems at present in use in Australia provide 960 channels or accommodate a 625 line television channel, in each direction, per bearer. Microwave bearer systems of this type use frequencies in the 2, 4, 6 and 7Gc/s bands. (1Gc/s equals 1000Mc/s). In most frequency bands it is normally possible to add up to six radio bearers in each direction on a single set of aerials (antennas), while in the 6Gc/s band up to eight radio bearers can be added on one set of aerials. By using frequencies in the 6Gc/s band systems can provide 1800 channels per bearer.

3.4 Fields of Application. The choice of deciding between a radio and coaxial cable system for a route is dependent on conditions and circumstances associated with the project. The trunk requirements between intermediate towns must be considered, as relief of these circuits may be just as important in the overall telephone service as the provision of an adequate number of trunks between the main centres. The effect of existing plant on the proposal must be assessed because the provision of a radio system may necessitate the retention of an existing open wire route to intermediate centres, or its replacement with cable.

Broadband radio systems require direct line of sight transmission between adjacent stations. Terminal stations are usually situated near or in towns but repeater stations are often located on the tops of hills, remote from intermediate towns. It is possible to select blocks of channels at intermediate stations for local traffic commitments, but the numbers and intervals are limited by acceptable standards for signal to noise ratio. A long haul radio system, therefore, does not readily provide trunk circuits between intermediate towns. These may be provided however, by separate short haul radio systems when economically justified.

Coaxial cable is admirably suited for routing through towns, and is capable of providing trunk circuits to all centres on the route. This is achieved by carrier channel "drop-out" at the larger towns, and by the use of the paper insulated interstice or layer pairs in the cable, for trunks to minor centres. Most repeaters on coaxial routes can be power-fed over the cable, and transistorised repeaters are housed in cases and buried in the ground, or located in manholes, thus avoiding the need for repeater buildings.

4. BROADBAND SYSTEMS IN THE TRUNK CARRIER NETWORK.

4.1 To appreciate the part played by broadband carrier systems in a trunk carrier network it is necessary to have an understanding of the basic build-up of a broadband terminal.

Fig. 1 shows a typical 960 channel broadband terminal where the 0.3-3.4kc/s bandwidth channels are translated to the 60-4028kc/s frequency range in the following stages.

(i) The channels are modulated in groups of 12 to produce the basic group frequency range of 60-108kc/s. For a fully equipped terminal 80 twelve channel modems are used; five are shown in the diagram.

(ii) Five basic groups are, by stages of group modulation, translated to the basic supergroup frequency range of 312-552kc/s. For a fully equipped 4Mc/s terminal 16 such basic supergroups are produced; one is shown in the diagram.

(iii) The required frequency range of 60-4028kc/s is produced by stages of supergroup modulation. For example, a basic supergroup is translated to 60-300kc/s to form supergroup 1, supergroup 2 coincides with the basic supergroup and is transmitted as 312-552kc/s. Basic supergroups are translated to 564-804kc/s for supergroup 3, 812-1052kc/s for supergroup 4, and so on up to 3788-4028kc/s for supergroup 16.

The necessary demodulating processes are the reverse of the modulating steps.

Summarising, each channel has a bandwidth of 0.3-3.4kc/s, each basic group (60-108kc/s) consists of 12 channels, each basic supergroup (312-552kc/s) is comprised of 60 channels, and in turn 16 supergroups make up the overall frequency range of 60-4028kc/s for the 960 channels.

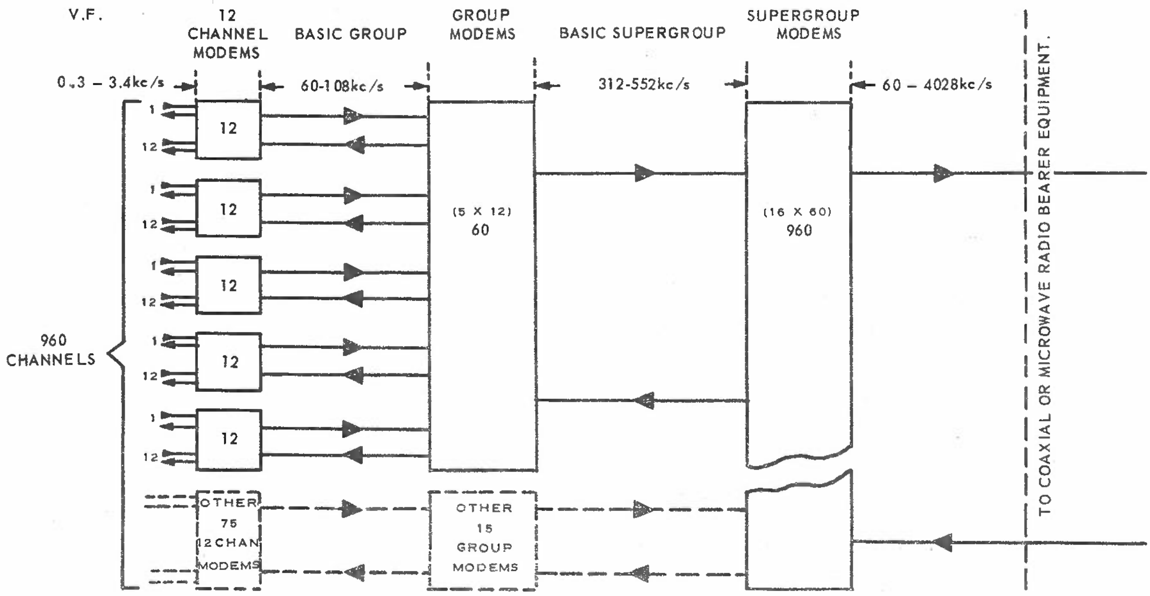

FIG. 1. SIMPLIFIED BLOCK DIAGRAM OF BROADBAND TERMINAL.

4.2 A system, of the type shown in Fig. 1, using either a coaxial cable or radio bearer, could provide 960 speech circuits between two terminals and on some trunk routes this quantity is required. On other trunk routes the broadband system is a "backbone" system providing overall trunk circuits, intermediate trunk circuits and also a part of trunk circuits through to neighbouring cities and towns.

4.3 Supergroups can be used for interconnection between terminals and intermediate stations and between one intermediate station and another. At certain repeater stations, on a coaxial bearer, it is possible to "drop" supergroups 1 and/or 2 and "replenish" supergroups 1 and/or 2. In addition it is possible to "drop" any supergroup without "replenishment".

Fig. 2 shows a portion of a typical broadband trunk network in which supergroup 1 is dropped at repeater "B" providing 60 circuits between terminal "A" and that repeater station. By replenishing supergroup 1 at repeater "B" and dropping at repeater "C", 60 circuits are provided between stations "B" and "C". Supergroup 2 is dropped at repeater "D" and provides 60 circuits between stations "A" and "D". Supergroup 1 and 2 are also used to provide 120 circuits between stations "D" and "E" and 120 circuits are obtained between stations "A" and "C" by dropping supergroup 5 and supergroup 6. As only 8 supergroups are in use a total of 240 circuits between "A" and "E" are obtained by supergroups 3, 4, 7, and 8.

Suitable filters at the repeater stations allow the desired supergroup to be selected from the overall frequency range and associated terminal equipment performs the necessary modulating and demodulating functions.

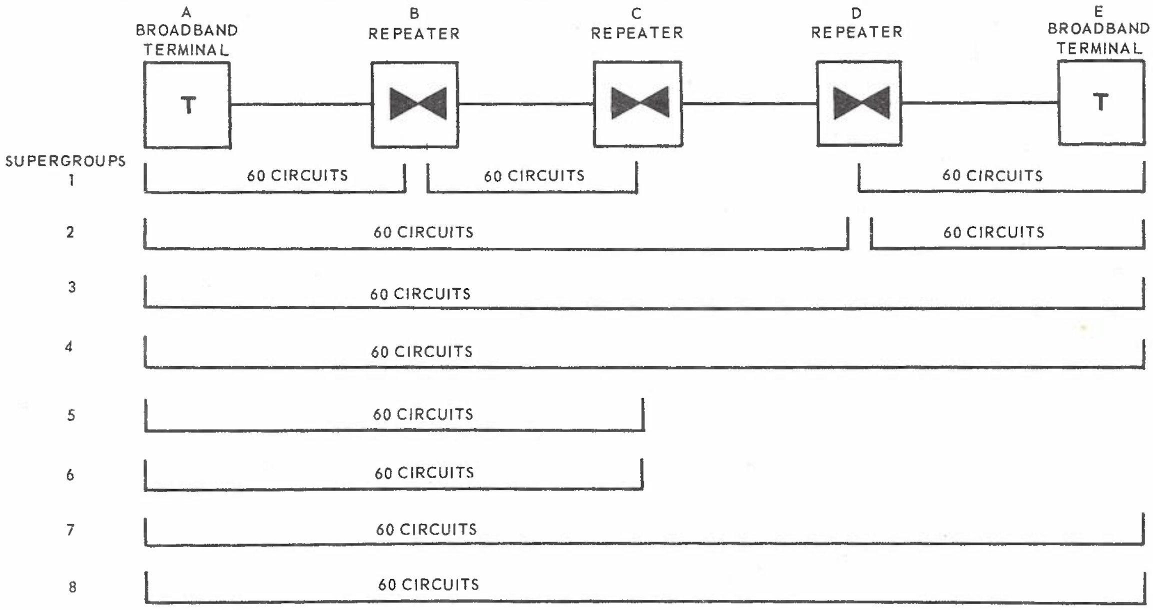

FIG. 2. PORTION OF TYPICAL TRUNK NETWORK.

4.4 Dropping and replenishing, as described for a broadband system operating on a coaxial cable bearer, is also possible, with certain limitations, for a broadband system using a radio bearer. When using a coaxial cable bearer the supergroup frequencies are transmitted to line and can be directly selected for dropping and/or replenishing at repeater stations. When using a microwave radio bearer the supergroup frequencies are converted by frequency modulation into the U.H.F. or S.H.F. range for transmission. To drop or replenish a supergroup at an intermediate station it is necessary to convert from the high radio frequencies back to the supergroup frequency range which is termed the "baseband". The dropping and replenishing arrangements are then similar to those used at coaxial cable system repeater stations. The modulating and demodulating process associated with each drop-out or replenishment at a radio relay terminal has a detrimental effect on the signal to noise ratio and the number of intermediate drop-out and replenishing stations is limited by the overall acceptable standards as regards signal to noise ratio. A repeater station which converts back to baseband is called a "demodulating repeater" or "back-to-back terminal" and one which does not convert back to baseband is called a "non-demodulating" repeater, although amplification for each direction takes place at an intermediate frequency band of 70Mc/s.

4.5 Standardisation of the basic supergroup frequency range allows direct interconnection of blocks of 60 channels. A typical example is shown in Fig. 3. A basic supergroup produced by terminal equipment at station "1" is applied via a coaxial bearer to station "2" where it is combined as supergroup 4 with 15 other supergroups to form an overall frequency range of 60-4028kc/s. A Through Supergroup Filter is used in the transmit and receive direction to confine the frequencies passed to 312-552kc/s.

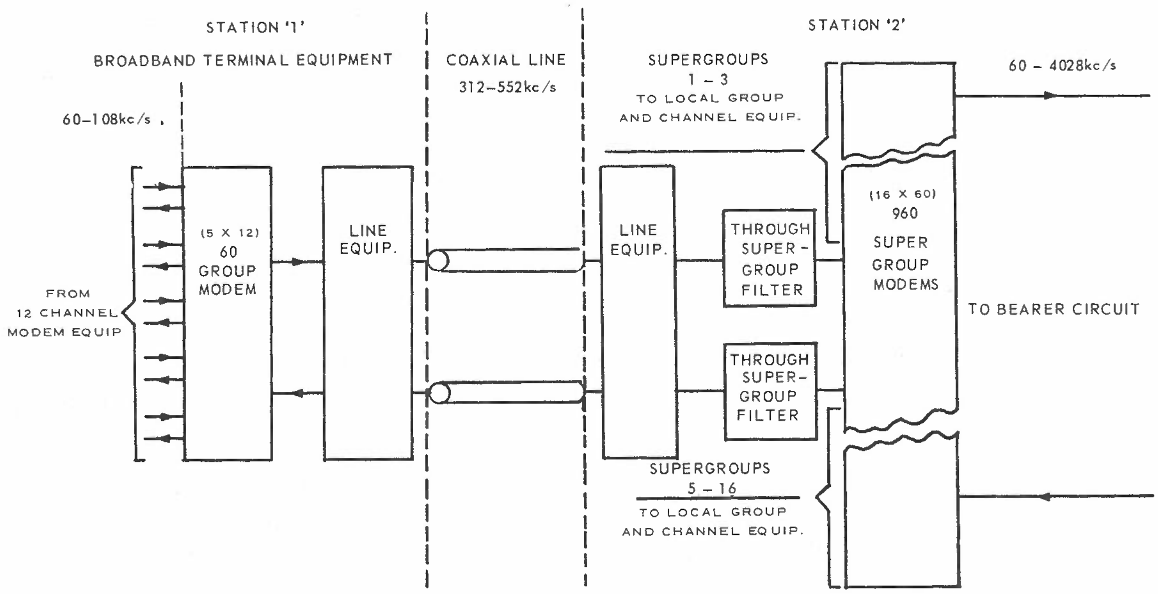

FIG. 3. TYPICAL THROUGH SUPERGROUP CONNECTION TO AN OUTLYING STATION.

4.6 Another example of through supergroup connections is shown in Fig. 4, where supergroup 3 of each system is through connected and supergroup 4 of the system to station "X" is through connected to supergroup 6 of the system to station "Z". The through connected supergroups provide 120 traffic circuits between station "X" and station "Z" and the other supergroups provide traffic circuits between stations "X" and "Y" and between stations "Y" and "Z".

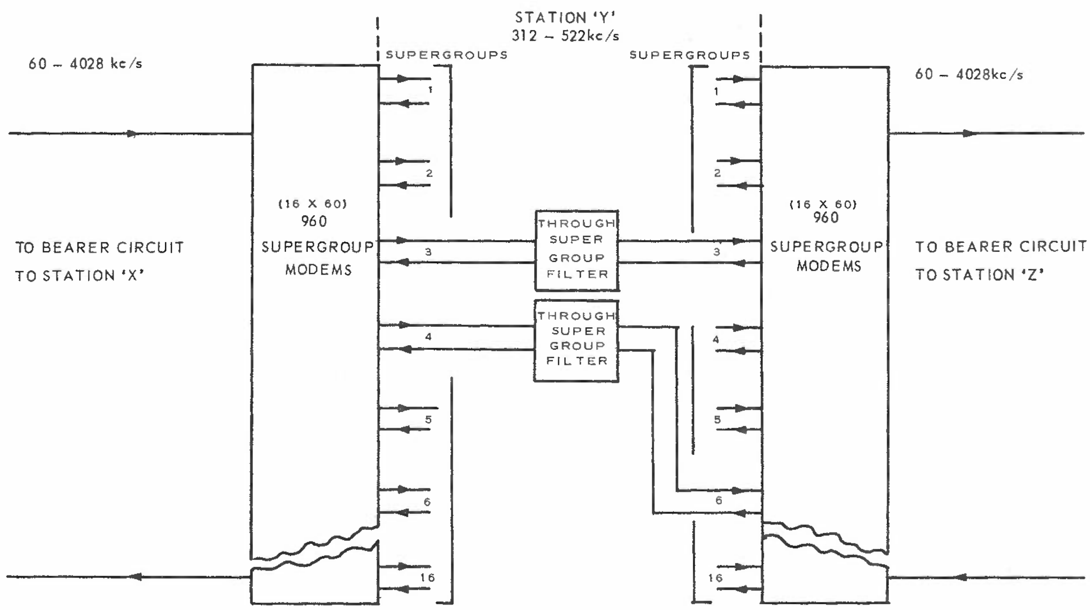

FIG. 4. TYPICAL THROUGH SUPERGROUP CONNECTION - TO PROVIDE 120 THROUGH CIRCUITS.

4.7 Blocks of twelve channels (basic groups) can be interconnected in a similar manner to that described for a basic supergroup. Fig. 5 shows a portion of a broadband terminal in which three of the basic groups are produced by local channel modem equipment and two basic groups are applied from twelve channel systems incoming from outlying centres. Through Basic Group Filters are used in the transmit and receive circuits to restrict the frequencies to 60-108kc/s.

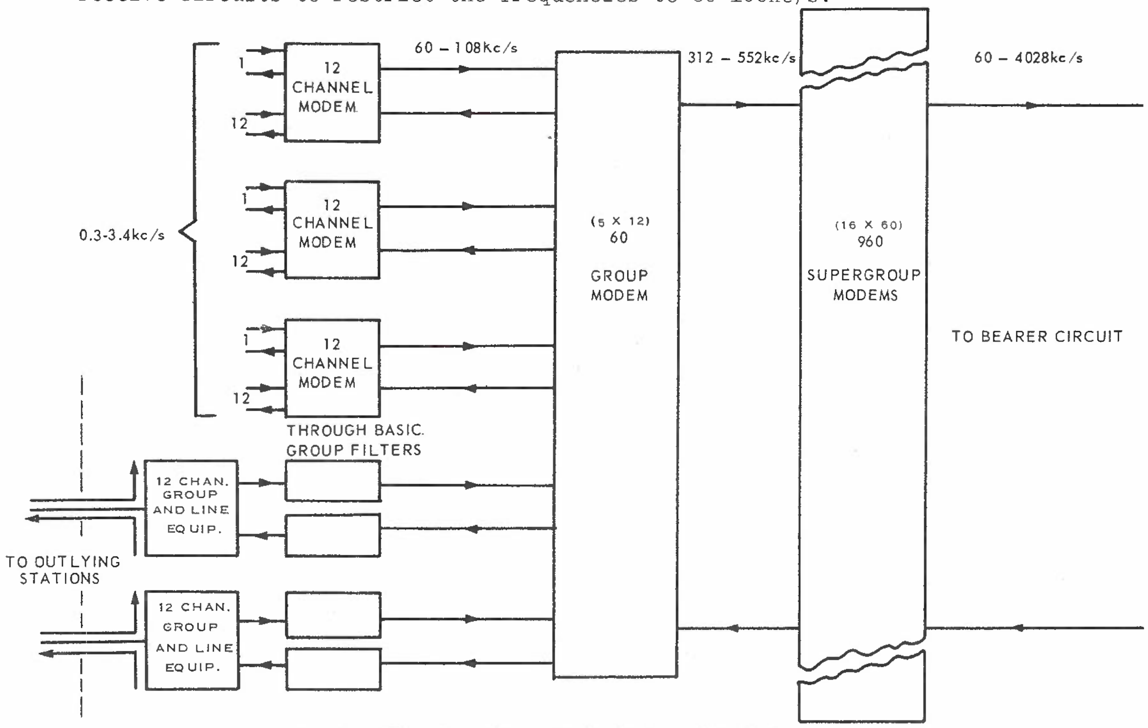

FIG. 5. TYPICAL THROUGH BASIC GROUP CONNECTION.

4.8 The standardisation of the basic group frequency range also permits a simple means of interconnecting various twelve channel systems, without the necessity of demodulating all channels to the voice frequency range, and then modulating to the line frequencies of the other system. Fig. 6 shows a typical twelve channel open wire carrier telephone system group connected to a typical twelve channel pair cable carrier telephone system. A group connecting unit includes the necessary through Basic Group Filter and level adjusting pads. Additional information is given in the paper "Twelve Channel Cable Carrier Systems".

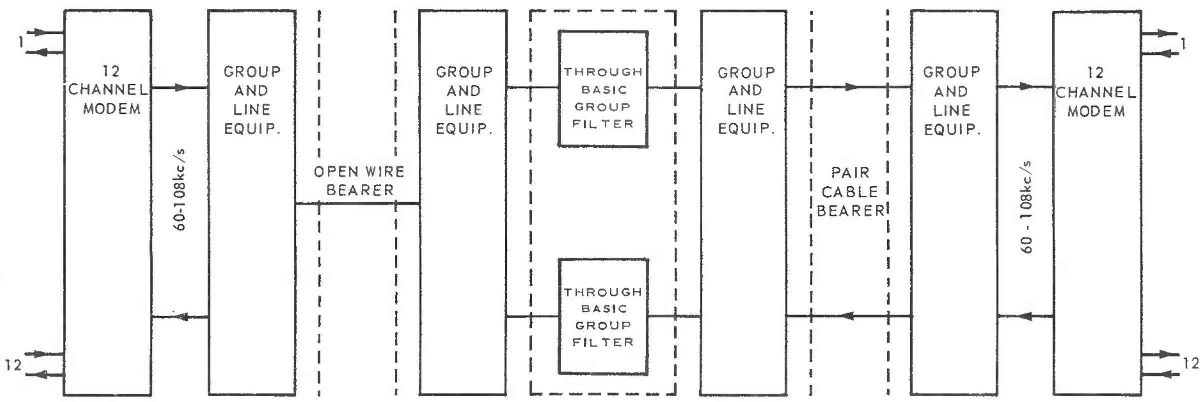

FIG. 6. TYPICAL THROUGH CONNECTION OF TWELVE CHANNEL OPEN WIRE AND PAIR CABLE SYSTEM.

4.9 Fig. 7 shows typical coaxial cable systems with 12 channel systems feeding into one terminal. In addition to the trunk circuits available, hundreds of junctions are provided between Melbourne and Dandenong and Melbourne and Frankston.

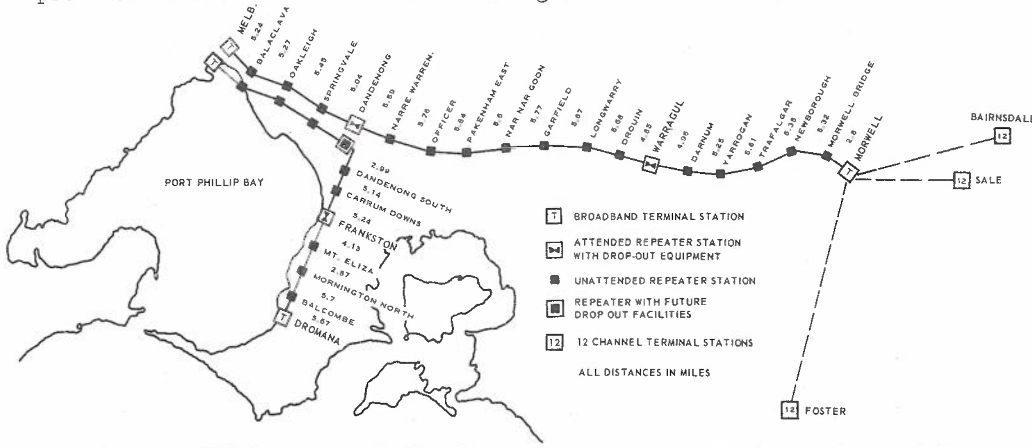

FIG. 7. MELBOURNE - MORWELL, MELBOURNE - DROMANA COAXIAL CABLE ROUTES.

4.10 The broadband communication link provided between Sydney and Cairns, to operate in conjunction with the SEACOM submarine cable system, is an example of the use of various broadband systems in an overall circuit. Fig. 8. shows the geographic and system arrangements for the Sydney-Cairns section. The broadband system provides one basic supergroup (312-552kc/s) over which speech, facsimile, data and telegraphy circuits operate to Madang, Guam, Hong Kong, Jesselton, Singapore and Kuala Lumpur.

Terminal equipment in the Sydney O.T.C. International exchange produces the SEACOM supergroup which is transmitted on a coaxial bearer to Sydney City South Long Line Equipment station where it is connected, via through supergroup filters, to supergroup 4 of a 960 channel coaxial tail system. At Redfern, the output of the coaxial tail system is applied to a microwave radio bearer system with a number of non-demodulating repeaters (not designated) and a back-to-back radio relay terminal station at Port Macquarie where drop-out and replenishing can be made. The terms coaxial tail and coaxial tail equipment describe the coaxial bearer and associated line equipment used to feed the baseband frequencies to and from a radio relay terminal and its adjacent Long Line Equipment station. Line regulation is not used as usually very short distances are involved.

At Lismore the baseband frequencies from the radio terminal equipment are demodulated into 16 supergroups and a number of these, including the SEACOM supergroup, are connected to the supergroup equipment associated with the Lismore-Brisbane coaxial cable system. The SEACOM supergroup is transmitted to Brisbane as Supergroup 4 but drop-out and replenishing of supergroups 1 and 2 and drop-out of supergroup 16 occurs at various repeaters shown on the route. A coaxial tail system makes the connection to Mt. Gravatt.

From Mt. Gravatt a radio relay system, providing 10 supergroups, completes the overall broadband connection. The SEACOM supergroup is through connected as supergroup 4 from the coaxial system to the radio system and the remainder of the supergroups 1-10 are injected to carry traffic to intermediate stations north of Brisbane. At each of the back-to-back radio relay terminal stations named, facilities are provided to permit one or more supergroups to be dropped and replenished to meet local traffic requirements. From the radio relay terminal at Cairns, the signal is taken via a coaxial tail system, to modem equipment at the Cairns Long Line Equipment station where the basic supergroups originate and are recovered. The 312-552kc/s from supergroup 4 is passed on to the O.T.C. at Cairns via a coaxial tail system.

4.11 The broadband communication network proposed by 1969 is shown in Fig. 10. By means of through connection of supergroups and basic groups at various centres and in conjunction with 12 channel systems, not shown in the diagram, an extensive network of trunk circuits exists and will be extended.

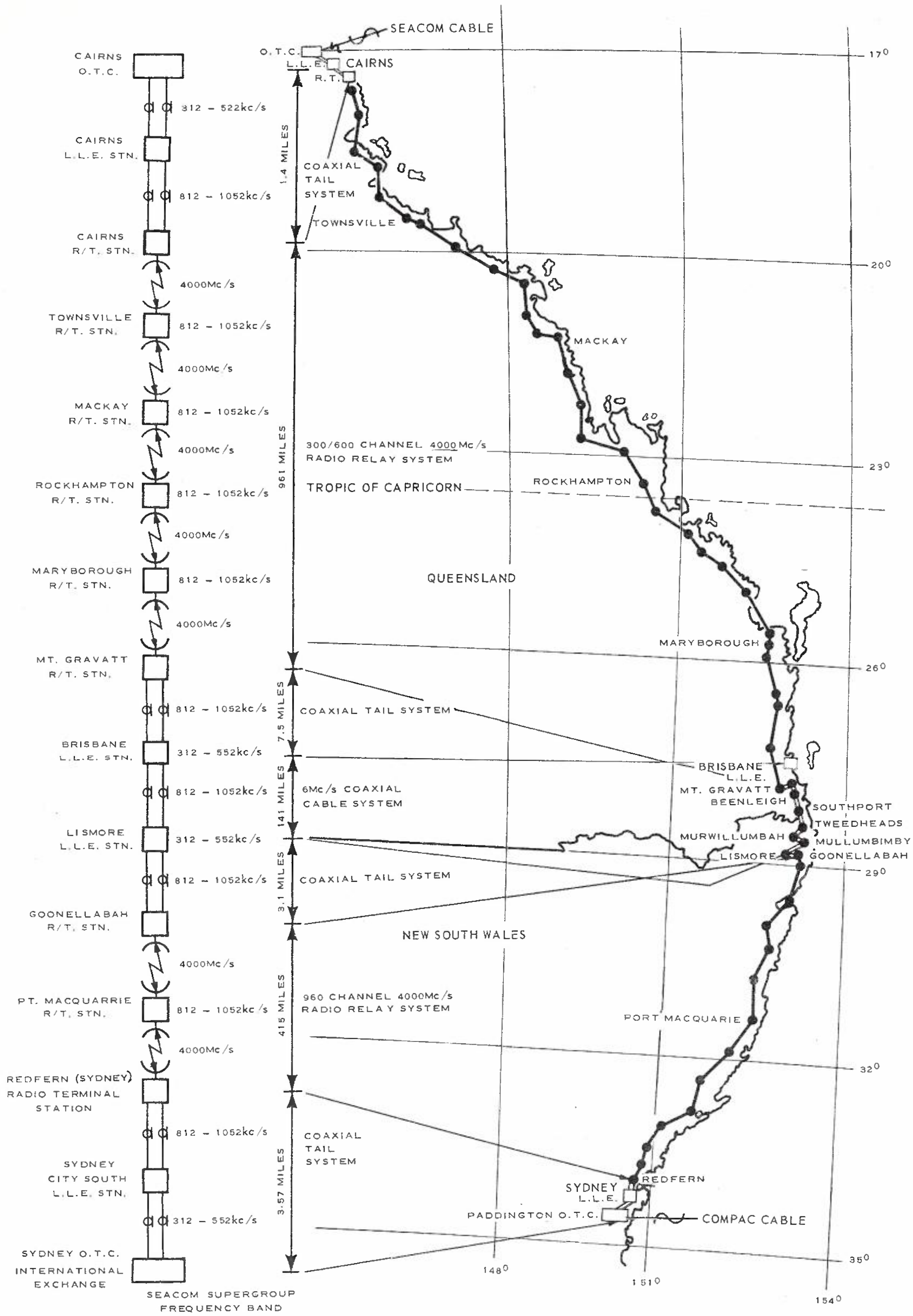

FIG. 8. GEOGRAPHIC AND SYSTEM ARRANGEMENT. SYDNEY-CAIRNS BROADBAND.

5. SUMMARY OF 12 CHANNEL AND BROADBAND PAPERS.

5.1 The equipment associated with twelve channel and broadband carrier systems can be divided into two main categories which are:-

(i) Terminal Equipment.

(a) Twelve Channel Modem Equipment.

(b) Group Equipment (Group and Supergroup equipment for broadband systems).

(ii) Line Equipment.

5.2 Terminal Equipment. The twelve channel modem equipment translates 12 voice frequency channels to the basic group frequency range and vice versa. This equipment is common to all twelve channel and broadband systems.

Group equipment is necessary to translate the basic frequency range to the required frequency band for transmission on the bearer circuit. The complexity of the group equipment depends on the number of modulation stages required, the section of the frequency spectrum used and also the degree of standby equipment considered necessary.

5.3 Line Equipment. This equipment is associated with the bearer circuit and can be divided into equipment used with open wire, pair cable, coaxial cable and radio bearers. In each case the equipment can further be sub-divided into terminal line equipment and repeater line equipment.

5.4 Because of the number of common factors associated with twelve channel and broadband systems, the papers on these subjects are presented as shown in Table 1.

Television programme are usually transmitted on a coaxial tube or over a radio bearer system and for this reason a paper on the subject of Television Programme Transmission is included in the series.

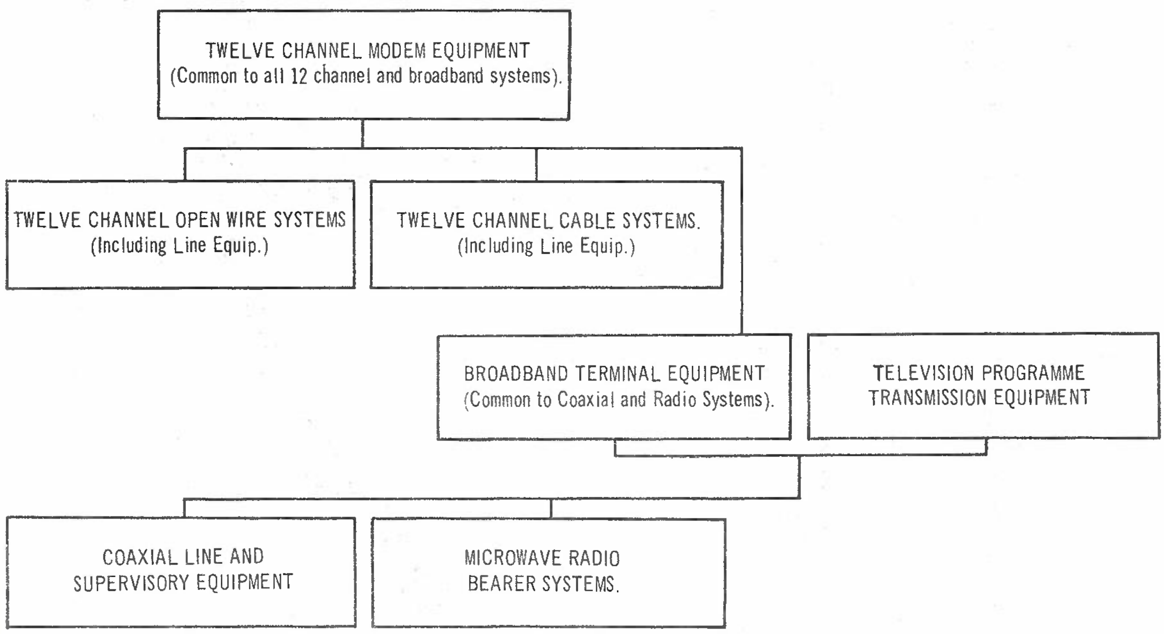

TABLE 1. PRESENTATION OF 12 CHANNEL AND BROADBAND CARRIER SYSTEM MATERIAL.

6. DRAFTING SYMBOLS.

6.1 The subject of drafting symbols for Telecommunication drawings is kept under continual review by the Department. The symbols adopted by the Department are generally those symbols accepted on an international basis by a committee representative of various National Administrations.

6.2 The carrier equipment symbols shown in Fig. 9 are used in the papers on 12 channel and broadband carrier systems.

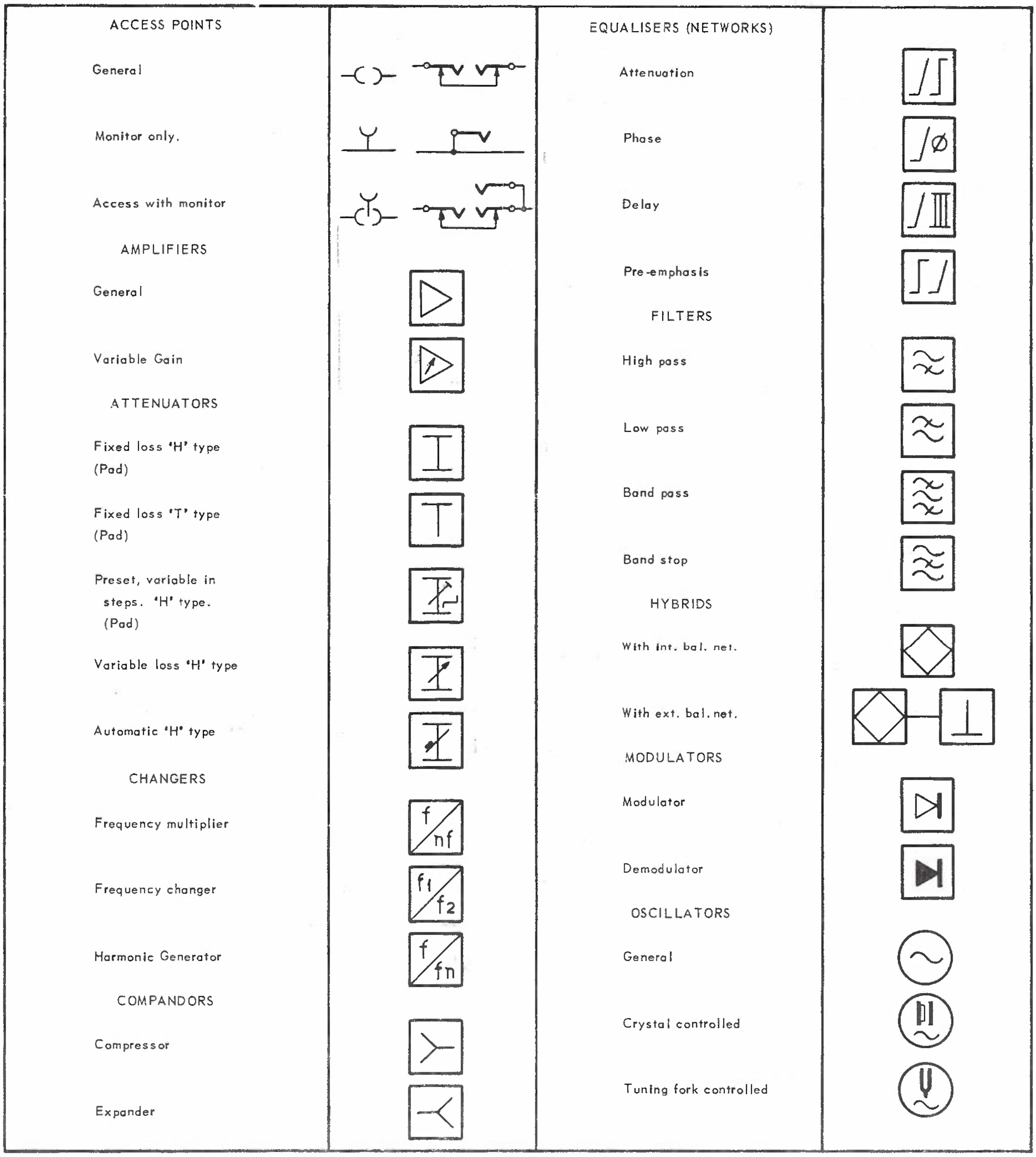

FIG. 9. DRAFTING SYMBOLS FOR CARRIER EQUIPMENT.

7. TEST QUESTIONS.

1. State the voice frequency range provided by a channel of a 12 channel or broadband carrier telephone system.

2. What is the standard out-of-band signalling frequency used by broadband systems?

3. How many voice channels comprise a basic group and what is the basic group frequency range?

4. What is the basic supergroup frequency range and how many voice channels are contained in a basic supergroup?

5. Draw a simplified block diagram of a 960 channel broadband terminal.

6. With the aid of a simple diagram show how supergroups can be through connected.

7. What is the approximate repeater spacing on a coaxial cable bearer using frequencies up to:-

   (i) 4Mc/s?
   (ii) 6Mc/s?
   (iii) 12Mc/s?

8. What frequency bandwidth is required for television transmission using:-

   (i) Direct video transmission?
   (ii) A television programme system?

9. With the aid of a simple diagram show how basic groups can be through connected.

10. How many voice channels can be obtained:-

    (i) A 4Mc/s broadband system?
    (ii) A 6Mc/s broadband system?
    (iii) A 12Mc/s broadband system?

11. State briefly what is meant by the terms "dropping" and "replenishing".

12. Briefly explain the difference between a "back-to-back radio relay terminal" and a "non-demodulating repeater".

13. How is power supplied to most repeaters on a coaxial cable route?

14. Why are through connections of basic groups or basic supergroups made via band pass filters?

15. How many radio bearers can be used, in the 6Gc/s band, on one set of aerials?

16. State the advantages gained by standardisation of the basic group and basic supergroup frequency ranges.

17. Draw the drafting symbols for the following:-

    (i) A variable gain amplifier.
    (ii) A harmonic generator.
    (iii) A band pass filter.
    (iv) A hybrid with external network.
    (v) A modulator.

END OF PAPER.

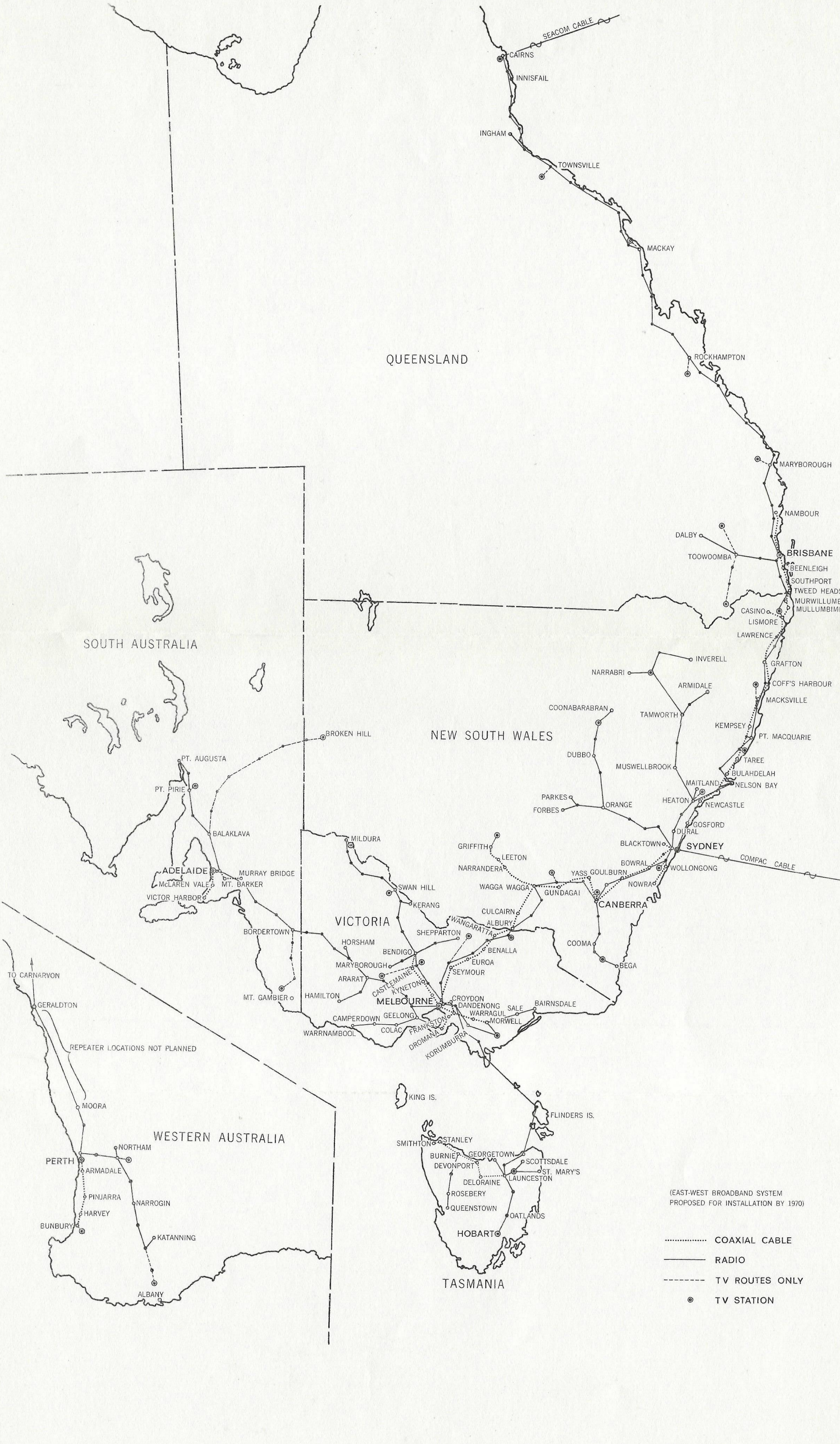

FIG. 10. PROPOSED BROADBAND COMMUNICATION NETWORK.