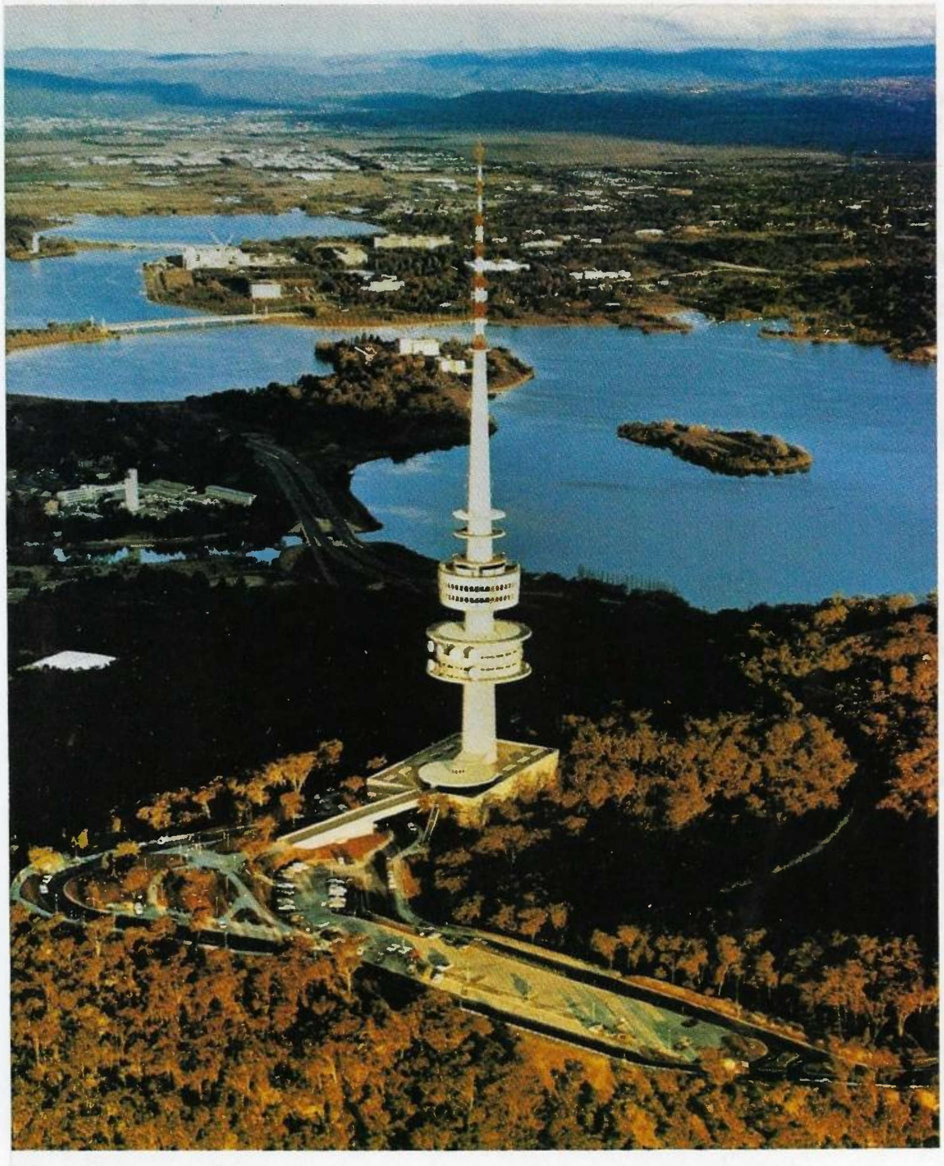
Volume 31, No. 2, 1981

# the telecommunication journal of Australia



SPECIAL ISSUE
TELECOMMUNICATIONS TOWER, CANBERRA

31/2

# THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

Volume 31, No. 2, 1981

ISN 0040-2486


## CONTENTS

### The Telecommunications Tower, Canberra



COVER: Telecommunications Tower, Canberra

Other Items:

# The Telecommunication Journal of Australia

The Journal is issued three times a year (February, June and October) by the Telecommunication Society of Australia. The object of the Society is to promote the diffusion of knowledge of the telecommunications, broadcasting and television services of Australia by means of lectures, discussions, publication of the Telecommunication Journal of Australia and Australian Telecommunication Research, and by any other means.



Residents of Australia may order the journal from the State Secretary of their State of residence; others should apply to the General Secretary. The current subscription rates for both Telecommunication Journal of Australia and Australian Telecommunications Research are shown on the inside back cover of this issue. All rates are post free (by surface mail). Remittances should be in Australian currency and made payable to the Telecommunication Society of Australia.



Information on how to prepare and submit manuscripts and contributions for the Journal is available from members of the Board of Editors and their outposted representatives.

Membership fees and subscription orders should be addresed to:

**WITHIN AUSTRALIA**

**The State Secretary,** Telecommunication Society of Australia,

Box 6026, G.P.O., Sydney, N.S.W. 2001.
Box 1802Q, G.P.O, Melbourne, Vic. 3001.
Box 1489, G.P.O., Brisbane, Qld. 4001.
Box 1183, G.P.O., Adelaide, S.A. 5001.
Box T1804, G.P.O., Perth, W.A. 6001.
Box 10,000T, G.P.O., Hobart, Tas., 7001.

**OVERSEAS APPLICATIONS**

**The General Secretary,** Telecommunication Society of Australia,
Box 4050, G.P.O., Melbourne, Victoria, Australia, 3001.

# The Black Mountain Tower — an Introduction

F. L. C. TAYLOR and W. F. BRIGDEN

The articles that follow will describe the construction of the tower, the facilities it provides, and explain why it was established on Black Mountain rather than on one of the many other sites that were suggested during the planning phase. It is sufficient in this introduction to say that Black Mountain was the only site that was truly suitable for both TV and radio telephone transmission, and was by far the most economic of all the alternatives considered.

Black Mountain is also a most sensitive part of the Canberra environment. It is a national park of considerable ecological interest containing unique flora and fauna, and the tower was clearly going to be a land mark which some people felt would dominate other aesthetic Canberra structures. With quite a number of people this feeling reached the point of outrage and vigorous protest against the project. Protests against the tower on aesthetic and ecological grounds were strongly voiced during the earlier stages of the approval procedures and at the various hearings which included a lengthy Supreme Court case.

Over a period, the emphasis of the objections against the tower gradually moved away from the ecology onto the visual and technological aspects. The Australian Post Office (henceforth referred to as Telecom) had little difficulty in disarming the accusations of faulty technology; e.g. you should not be planning interstate microwave systems because fibre optics will soon do the job better; you will get results just as good on other less elevated sites, on which the tower will be less prominent, etc. The question of visual impact was more subjective with a wide spectrum of public opinion, and finally this was the factor that most seriously threatened the project.

The tower saga started in April 1970 when Telecom asked the Department of Housing and Construction (H&C) to carry out a feasibility study in relation to a tower on Black Mountain, accommodating both communications services and facilities for visitors. Telecom and the Department of H & C presented the first tower proposal to the National Capital Development Commission (NCDC) in August 1970. The NCDC held a unique responsibility for the development of Canberra. Every new structure required their specific approval. The planning skill of the NCDC was reflected in the beauty of the City and their longstanding authority over the City development had never been seriously challenged. Thus the public clash which ultimately developed between Telecom and the NCDC over the tower design was an unfortunate affair for both parties. It was certainly the first time two major government authorities appeared before the Parliamentary Standing Committee on Public Works (PWC) in head-on contention. The events leading to this situation at the PWC hearing in June 1972 can be traced fairly briefly.

Following the submission of the first design (which was closely in accordance with the tower as it now stands) to the NCDC further alternative designs were prepared as a basis for discussion with the NCDC Advisory Committee. After the first round of discussions the Committee gave its support in principle to the design which included both the look-out and restaurant facilities. This was in December 1970.

However, NCDC was still uneasy about the aesthetics of the project and in April 1971 they proposed that the public facilities "drum" be deleted and replaced by an observation platform with spiral stairway access beneath the radio telephone (RT) "drum" at about 18 metres above ground level. Telecom indicated that this would seriously jeopardise the earning capacity of the tower and was not acceptable.

After further negotiation NCDC expressed the view that a tower with technical facilities only, presented the most satisfactory proposal. However; if the Government were to approve the Telecom proposal for added public facilities, they considered that the equivalent of one enclosed floor should be eliminated to reduce the impression of bulk at the visitor level. This effectively meant the elimination of the restaurant floor, and by this time, Telecom was becoming seriously concerned at the delay in reaching agreement.

Telecom finally stood by the view that the restaurant should be retained, having in mind that:

- After months of close consultation between Telecom and Department of Housing and Construction on the one hand, the NCDC and the National Capital Planning Committee on the other hand, there was substantial agreement. In practical terms, the only point finally in dispute was the question of inclusion or not of restaurant facilities on the tower. The NCDC stated its objection to this on aesthetic grounds.
- The Department of H & C and Telecom believed that the difference in aesthetic qualities between a tower with the restaurant and one without a restaurant was

so marginal as to be insignificant when viewed from a distance.

- The inclusion of the restaurant would add prestige and, further strong interest in the other visitor facilities, all of which would improve Telecom's commercial position.

The proposal, including the disputed restaurant floor was submitted to Cabinet in October 1971 and Cabinet endorsed the technical aspects of the project for development to the stage where it would be ready for examination by the PWC.

In March 1972, NCDC issued a public statement which gave recognition to the importance of visitor aspects of the proposal, but indicated that NCDC was now of the view that the tower should be reduced in scope to that representing minimal technical facilities for television, radio and telecommunications.

The public hearing of evidence by the PWC took place in Canberra in June 1972. This was an unusually lengthy hearing with evidence being given by Telecom, Department of H & C, Australian Broadcasting Control Board, and Department of Interior. Other evidence was given by organisations which opposed the project on environmental or aesthetic grounds. Foremost amongst these was the NCDC which presented a quite new counter-proposal that television services be co-masted at Black Mountain and radio telephone services be provided on a tower at Mt. Crace. Telecom opposed the Mt. Crace proposal strongly on economic and other grounds.

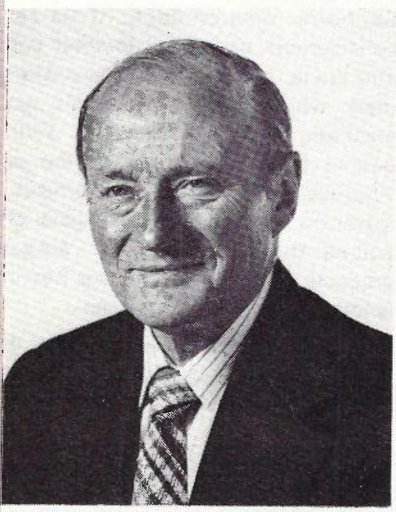
In August 1972 the PWC recommended to Parliament that construction proceed in accordance with the proposal as submitted by Telecom.

The Prime Minister of the day considered the proposal should be examined by his Ministers before it was debated in Parliament. A second Cabinet Submission had to be prepared. In September 1972 Cabinet endorsed the recommendation that the project proceed. The project was approved by the House of Representatives in October 1972, but Parliament was dissolved before the Senate debate was finalised.

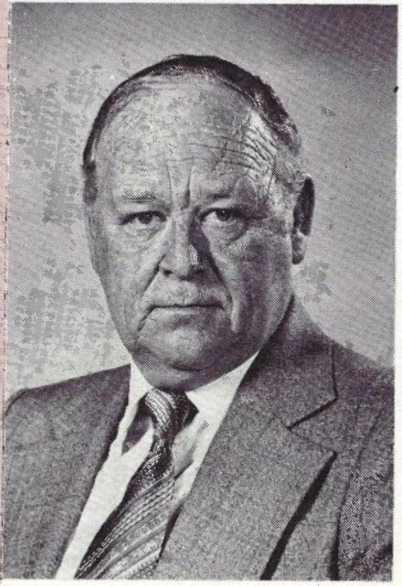
On 5 February 1973 the Postmaster-General in the newly elected government requested the preparation of an Environmental Impact Statement. This statement went to Cabinet and was released by the Minister for Environment and Conservation on 28 February 1973. It attracted strong criticism from opponents of the project, much of which, in retrospect, was probably justified. However, this was the first Impact Statement to be

F. L. C. TAYLOR began as a Cadet Engineer in PMG in 1939 and rose to the top of the profession in Telecom to become General Manager Engineering, the position he held at retirement in 1980. During these 40 years he occupied a wide variety of engineering positions in Victoria, Queensland and at Headquarters. Additionally he did a tour of duty in London as Engineering Representative and also headed the APO in New South Wales as Director, Posts and Telegraphs. From Vesting Day he relieved as Chief General Manager for lengthy periods.

As SADG Programming Services he was the lead witness for PMG in the lengthy hearing into the Telcom Tower project by the Parliamentary Standing Committee on Public Works during 1972. He also appeared for the Department in the subsequent court cases as well as before the Parliamentary Labour Caucus in a debate with opponents to the Tower. The outcome of this virtually clinched the Government support to the project and paved the way for its construction.



W. F. BRIGDEN joined the PMG Department in Sydney as a Draftsman after returning from War Service in 1946. His subsequent studies in the Building Sciences and Real Estate Evaluation fitted him for service in the Buildings Branch where he worked through the various levels in NSW and Headquarters for 30 years, attaining the rank of Deputy Assistant Director-General. At Vesting Day he was appointed to his present position of Manager Programme and Projects Branch in the Buildings Sub-Division at Headquarters. For the past 20 years he has been directly associated with the designing and construction of every special major building erected for PMG/Telecom in the Commonwealth. He is the sole remaining Buildings Branch member who was involved from the earliest conceptual stages of the Telecom Tower in the 1960's through its developmental phases to completion in 1980.



presented to an Australian Government, and to meet the time commitment it was prepared by a small group of people over one week-end.

Tenders had been called in January 1973 and on 6 June 1973, a Letter of Acceptance was issued by Department of H & C to Concrete Constructions (Canberra) Pty. Ltd.

A few weeks later the Attorney-General advised the Postmaster-General of representations made by a group of fourteen prominent Canberra citizens seeking his fiat to an action to challenge the power of the Government to execute and carry out the construction of the tower.

The Attorney-General granted his fiat on 4 July 1973 to the institution of proceedings on behalf of these citizens seeking an injunction to restrain the construction of the tower on three grounds, namely, building on a public park, lack of NCDC approval, and that the tower would constitute a nuisance.

However, on 20 July 1973, Cabinet endorsed both the Black Mountain tower proposal and the Environmental Impact Statement. The approval of the Governor-General in Council was obtained on 19 September 1973.

After inter-locutory proceedings the case brought by the fourteen prominent citizens went to substantive hearing before the Supreme Court in Canberra. The hearing lasted some 4 weeks and traversed at length the environmental and ecological issues, and the authority of the Commonwealth to proceed with the work. In a judgment handed down on 31 October 1973 the Court rejected the arguments brought by the plaintiffs on environmental and ecological grounds, but found that as the Postmaster-General and the Minister for Housing and Construction did not have the approval of the NCDC a case for an injunction to stop the project proceeding had been established. The Court found that in every other way the Commonwealth was properly authorised, but on the issue of lack of NCDC approval, preliminary site works which had been going on for about a month ceased forthwith.

The Attorney-General lodged an appeal to the High Court against the Supreme Court finding in respect of the requirement for NCDC approval and this appeal was listed for hearing in May 1974.

In the meantime in December 1973 following the Supreme Court decision the Postmaster-General arranged for officers of this Commission to address a joint meeting of Caucus Committees and other interested Caucus members. The meeting was also addressed by a representative of the group who instituted The Supreme Court Action. Following this discussion which amounted to a debate between the Telecom representatives and the opponents of the project on the environmental, conservation, technological and economic aspects of the proposal, Cabinet agreed that the project should be implemented.

In the face of this further Cabinet decision the NCDC on 13 December 1973 gave unconditional approval to the project as approved by the PWC. This approval cleared the way for the project to go ahead and the Commonwealth did not proceed with the High Court Appeal. The Plaintiffs had lodged a cross-appeal against the Supreme Court finding that construction of the tower would be lawful (apart from the role of the NCDC). This was heard in May 1974 by the High Court and dismissed.

Thus after having been approved by the Parliamentary Works Committee after the longest hearing on record in August 1972, by Cabinet in September 1972, by the House of Representatives in October 1972, again by Cabinet in July 1973, by the Governor-General in Council in September 1973, and again by Cabinet in December 1973, and having been the subject of hearings in the Supreme Court and the High Court the project finally got under way in December 1973. With the Tower construction substantially completed by mid-1977, TV and FM broadcasting, and radiotelephone services were progressively installed and commissioned from that date. The Tower was finally completed and formally opened to the public in May 1980 by the Prime Minister of Australia.

# A Historical Review of the Planning of the Sydney-Canberra-Melbourne Trunk Route

N. SMITH

Canberra is a significant source and sink for trunk line traffic as well as a major repeater on the main Sydney-Melbourne trunk route. Consequently the growth of traffic and the route itself has been most dramatic over the past 50 years requiring the use of the largest capacity facilities available. This article describes this growth, the planning involved and speculates on the future.

The story of the Black Mountain Tower and the reason for its existence would not be complete without some understanding of the Sydney-Canberra-Melbourne trunk route and its historical development, particularly those aspects affecting Canberra. This route forms the backbone of the trunk network, linking as it does the two major state capitals and the federal capital as well as providing a through connection to the other capitals and service to important towns along the route. It is the trunk route carrying by far the greatest volume of traffic and at the present time comprises a six-tube coaxial cable and two microwave radio systems on the direct route via Canberra and also a back-route of combined radio and coaxial sections via Bendigo, Griffith, Wagga and Orange. See **Fig. 1**.

## HISTORICAL REVIEW

### Pre 1940

Telephone service between Sydney and Melbourne began in the year 1907 when the first trunk circuit was provided; the second did not follow until 1921. Both these circuits were provided on physical pairs of wires on poles.

Soon afterwards, in 1925 three further circuits were provided by a carrier system with repeaters at Goulburn, Wagga and Wangaratta. A further four 3-circuit carrier systems were added by 1937 and the first 12-circuit carrier system in 1939, at which stage the total of the Sydney-Melbourne circuits had grown to 30. The higher frequency working (150kHz) necessitated the installation of 6 further intermediate repeater stations.

In addition, the establishment of the national capital at Canberra in 1927 had necessitated the provision of trunk line facilities for that centre. The first carrier systems were a 3-circuit Melbourne-Canberra system in 1938 and a Sydney-Canberra system in 1939.

While these numbers of circuits are very small compared with present day levels of over 2000, 1100 and 300 circuits for Sydney-Melbourne, Sydney-Canberra and Melbourne-Canberra respectively, at that time the provision of the circuits represented a very substantial investment in the open-wire pole route. The Sydney-Melbourne open-wire pole route which has now almost disappeared followed a route along the railway line while Canberra was served by a spur open-wire from Goulburn.

### 1940-1950

No further significant development occurred until after World War II when the route was expanded rapidly in the post-war boom years.

By 1947 the route was carrying 90 circuits: 48 Sydney-Melbourne, 4 Melbourne-Brisbane, 12 Sydney-Canberra, 22 Melbourne-Canberra and 4 Sydney-Adelaide, apart from circuits serving intermediate centres.

At this stage, the route along the railway line was nearing saturation and for this reason, as well as for security reasons, construction of a second Sydney-Melbourne route commenced in 1948. A new pole route was erected between Blayney and Seymour by way of Cowra, Narrandera, Deniliquin, Echuca and Bendigo to connect with the existing Sydney-Blayney-Orange and Melbourne-Seymour carrier cables.

### 1950-55

The erection of this "back-route" resulted in additional 12-circuit systems being brought into service in 1950, 1951 and 1952 with a further two systems in 1953. Following the recession in 1951 when a levelling off in traffic on the route occurred, there was a period of rapid growth during the Korean War.

Largely as a result of a number of disastrous floods in

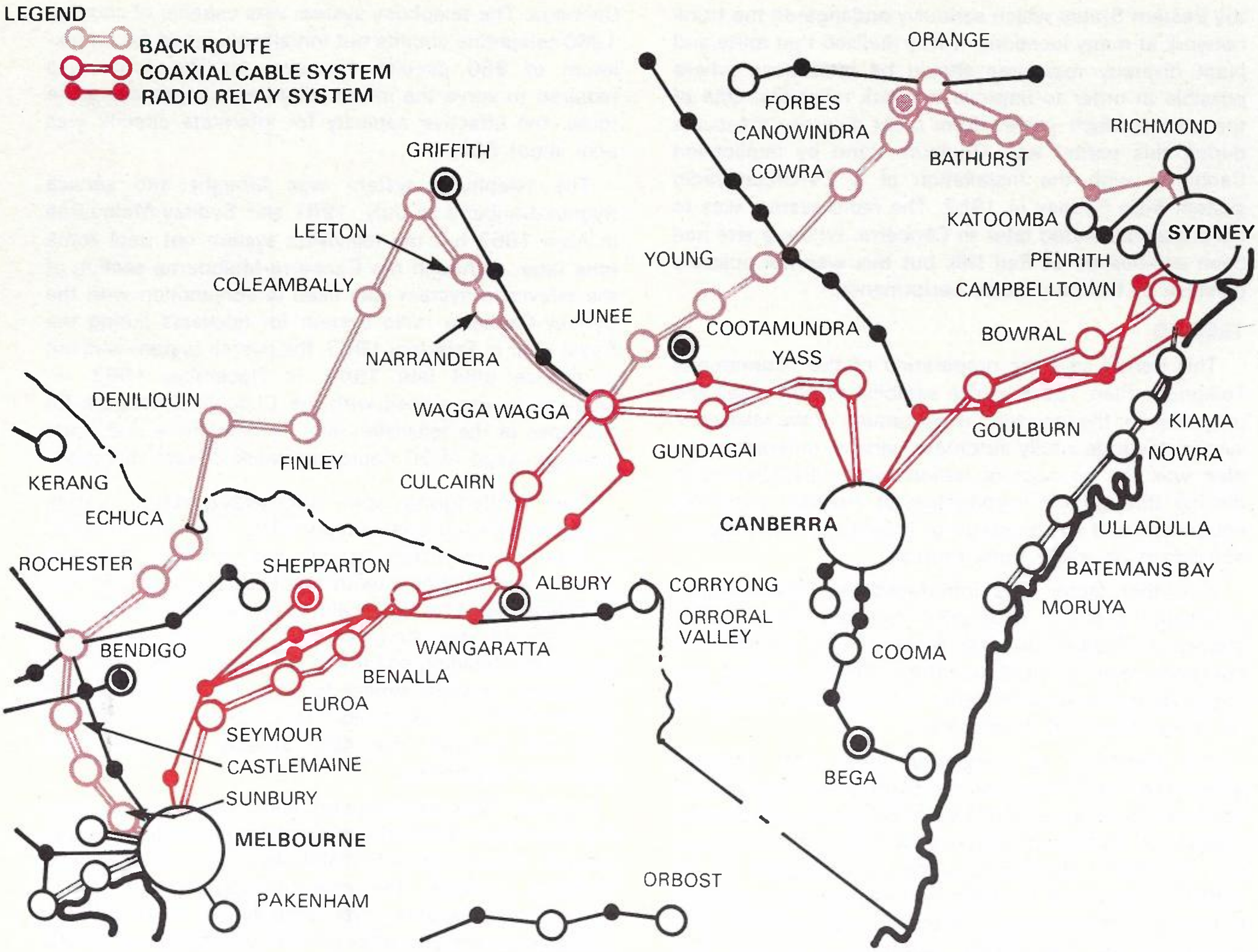



**Fig. 1 — Sydney-Canberra-Melbourne Trunk Route**

N. SMITH graduated from the Queens University Belfast NI with the degree of B.Sc (Electrical Engineering) in 1955. He immediately joined the PMG's Dept. and came to Sydney where after five years experience in various sections he was seconded to the Planning Branch. Initially engaged in planning subscriber cable reliefs and rural exchange area planning, he has been the Engineer Class 3 responsible for the NSW broadband bearer planning and programming since 1972.

the Eastern States which seriously endangered the trunk network at many locations, it was realised that route and plant diversity measures should be introduced where possible in order to improve network reliability. One of the places which gained from plant diversity measures during this period was Goulburn, (and by implication Canberra) with the installation of a 24-circuit radio system from Sydney in 1952. The radio system was to have been extended later to Canberra, where a site had been established at Red Hill, but this was not possible because of the poor noise performance.

### 1955-60

This period saw the preparation of the "Community Telephone Plan 1960" which established objectives and principles for the long term development of the telephone system towards a fully automatic service. Inherent in the plan was the concept of nation-wide subscriber trunk dialling through the introduction of crossbar switching equipment and the provision of broadband transmission equipment on major trunk routes.

A further factor was introduced into the telecommunication scene in 1956 when television broadcasting started in Melbourne and Sydney. The provision of television relay facilities to future country stations and interstate had to be considered in conjunction with plans for trunk telephony development.

The need for a completely new high capacity broadband trunk system on the Sydney-Melbourne route had been foreseen for many years and various alternative broadband systems capable of carrying both telephony and television relays were under consideration in the period during which the open-wire routes were exploited to their maximum capacity, reaching a total of some 200 circuits by the late 1950s. Eventually a decision was taken to provide a six-tube coaxial cable system on a route which passed through Canberra, rather than serve it by a spur as the open-wire route did.

However, urgent relief was required for Canberra. As there was to be a delay of some three years in providing the coaxial cable system, a later decision was taken to provide a Sydney-Canberra microwave radio system operating in the 4GHz frequency band (with a spur to Wollongong from Maddens Plains) for installation one-year in advance of the coaxial cable project. The radio terminals were installed at Redfern Exchange and Red Hill, with coaxial cable tails linking to the trunk exchanges at City South and Central (East Block) in Sydney and Canberra respectively; use was made of 4 existing intermediate repeater stations. The microwave radio system was brought into service in July 1960.

### 1960-1965

The coaxial cable was equipped with two 6MHz valve-operated line systems on two pairs of tubes, one for telephony and one for both-way television relays, and terminated at City South (Sydney) and City West (Melbourne). The third pair of tubes was kept spare for future development.

The route length of the coaxial cable was some 965 km and repeaters were required at intervals of approximately 9 km. In all some 103 unattended repeater stations were established together with main repeaters at 12 intermediate towns and a back-to-back terminal at Canberra. The telephony system was capable of carrying 1260 telephone circuits but initially equipped for a maximum of 960 circuits. However, as the cable was required to serve the intermediate exchanges along the route, the effective capacity for interstate circuits was only about 500.

The telephony system was brought into service Sydney-Canberra in July, 1961 and Sydney-Melbourne in April 1962 but the television system not until some time later. Although the Canberra-Melbourne section of the television system was used in conjunction with the Sydney-Canberra radio system for telecasts during the Royal Visit in February 1963, the overall system was not in service until late 1963. In December 1963, an agreement was signed with the Channel 9 network for the lease of the television relay facilities for a maximum average usage of 70 hours per week in each direction.

The Wollongong spur microwave radio system commenced service in January 1962. Then in late 1962, a one-way television bearer was provided between Sydney and Canberra (with a spur to Knights Hill from Maddens Plains for the Wollongong area transmitter), for the national television service. The Canberra national transmitter building and tower were established on Black Mountain, as were similar facilities for the commercial station CTC-7. Coaxial cable tails were provided linking Red Hill, Central, the ABC Studios and the Black Mountain transmitter.

In 1961, Civic exchange at Canberra was destroyed by fire. The aftermath of the restoration generated a special attitude towards diversity and security in the sensitive Canberra network. The new building, which was to replace the portable huts brought in to house the switching equipment after the fire, was designed to also accommodate the ARM trunk exchange for Canberra, and the trunk carrier equipment associated with the radio bearer.

The large numbers of trunk circuits which were installed during this period enabled STD to be provided for telephone users in Canberra in 1962, for Sydney subscribers into Canberra by 1965, from Sydney to Melbourne by November 1964 and from Melbourne to Sydney by October 1965.

A new tower and building extension at Red Hill were completed in time to permit the extension of the regional television relay to the Wagga area national television station which was cut over in April 1965 and extended further to Griffith (via radio to Wagga and then coaxial cable) by July 1966.

Also during this period, a radio relay system was established in the Victorian section of the route to provide television relays from Melbourne for the national television stations serving the Shepparton and Albury areas. The Melbourne radio terminal was at Surrey Hills and the Albury terminal at Eastern Hill. There were 5 intermediate repeaters. The Shepparton station, which was on a spur link from Hughes Creek Hill, opened in November 1963 and the Albury station, served by a short-haul system from Eastern Hill, opened in December 1964.

In 1963, a plan had been prepared for extensive development of the route, primarily in association with the proposed establishment of the Eastern States STD grid by late 1967. The plan included:

- Provision of mastergroup equipment Melbourne-Wangaratta so that the full 1260 circuit capacity of the coaxial cable telephony system could be utilised over this part of the route.
- Installation of a separate microwave radio system Sydney-Maddens Plains for Sydney-Wollongong traffic;
- Installation of 960-circuit radio telephony bearers Canberra-Wagga and Melbourne-Albury and a new radio telephony system Albury-Wagga thereby completing the through system from Sydney to Melbourne and providing back-up and diversity for the coaxial cable;
- Provision of a mastergroup Sydney-Canberra-Wagga.

Provision of the radio telephony bearer was preferred to equipping the third pair of tubes on the coaxial cable as it was decided to await the development of 12MHz coaxial line systems which were expected to be commercially available shortly.

In 1964, the plan had been amended to include a both-way intercapital television bearer to be installed at the same time as the radio telephony bearers.

In January 1965, the Sydney-Canberra-Melbourne coaxial cable TV relay was leased for a further 2 years for 60 hours per week in each direction to the 9 network who were authorised to make arrangements with the ABC for joint use of the facilities.

## 1965-1970

Once the coaxial cable had been brought into service, the traffic rose markedly and by June 1966 a total of 430 intercapital circuits, including 354 Sydney-Melbourne circuits, had been provided to meet demand.

A Canberra-Cooma-Brown Mt. radio relay system was established in 1966 to provide telephony circuits to Cooma and a television relay to the national transmitter for the Cooma/Bega area. A second Sydney-Canberra one-way TV bearer was also provided in 1966 so that the Wollongong and Cooma/Bega national stations could share a common programme from Sydney which was separate from that provided for Canberra.

The through radio system, which required establishment of two new repeater stations, was brought into service in November 1967 and enabled STD to be provided from Sydney to Adelaide and between Melbourne and Brisbane. Total intercapital circuit provision at this stage was about 700 (excluding Canberra). The three main groups were Sydney-Melbourne about 500 circuits; Melbourne-Brisbane 90; and Sydney-Adelaide 80.

Provision of the new interstate television bearer on the radio system enabled the television relay facility on the coaxial cable to be transferred to the radio system in 1968 and permitted the use of the second cable system for telephony relief, expected to be needed by 1969. A gain of 300 circuits resulted from the use of the 1260-circuit coaxial cable system for telephony rather than the 960-circuit radio bearer.

A further bothway radio bearer was provided late in 1969 and leased part-time to the 7 network who had made use of the protection bearer of the microwave radio system for occasional and regular part-time relays up to that date.

In 1969, OTC(A) established a westward looking earth station near Ceduna, South Australia for communication via the Indian Ocean INTELSAT satellite principally to Europe. Supergroups were provided from the earth station to the OTC(A) gateway exchange in Sydney. From this time, the needs of OTC(A) for additional supergroups to Ceduna and the provision of international television relays via Ceduna became a factor in the planning of the Sydney-Melbourne route.

Other decisions taken in the period included the provision of separate radio relay systems for the TV facilities serving the Shepparton and Wollongong national regional stations which had previously spurred from Melbourne-Albury relay at Hughes Creek Hill and the Sydney-Canberra relay at Maddens Plains, respectively. Also, the ABC decided that the Cooma/Bega national regional TV station should be served from Canberra rather than from Sydney with a common programme relay with Wollongong. This latter decision left a surplus one-way bearer Sydney-Canberra which was expanded to both-way operation and converted for telephony use by late 1971.

## 1970-1975

By 1971, all the bearers of the Sydney-Canberra section of the 4GHz radio system were in use and further relief was planned by means of a new through route developed in conjunction with plans for intrastate coaxial cable systems Bendigo-Echuca, Griffith-Deniliquin and Wagga-Orange intended originally merely to serve places along the routes. In the final plan, two-tube coaxial cables equipped with 12MHz solid state line systems with a capacity of 2700 circuits were installed, linking with existing systems and with a potential capacity of up to 1800 circuits for interstate traffic. As a result a new Sydney-Adelaide route via Orange, Wagga, Griffith, Bendigo and Mildura bypassing Melbourne was established by December 1971.

A plan was also prepared for further development of the coaxial cable system to meet expected traffic demands up to about 1975. This comprised installation of a 12MHz line system on the third pair of tubes held spare since their initial provision, with the subsequent removal of the 6MHz line equipment on the second pair of tubes, followed by installation of a second 12MHz line equipment on this pair of tubes. The higher frequency line system necessitated twice the existing number of repeaters being provided, but the additional ones could be placed underground. During construction it was necessary to take the cable out-of-service during light traffic periods at night or at week-ends in order to make cuts in the cable and install the new repeaters. The first 12MHz system commenced service in 1973 and the second in 1975.

As indicated in other articles, the Parliamentary Works Committee approved the Black Mountain Tower in late 1972. This was to include accommodation for all radio relay requirements for the future and those presently accommodated at Red Hill.

In mid 1974, the Prime Minister's Department instructed the A.P.O. to vacate East Block/Central by 1979, though this was later modified to the 1980/85 period. Plans were made to phase out Central and transfer the various facilities to other locations, including the manual trunk exchange and the Television Operating Centre (T.O.C.)

Meanwhile, based on the growth patterns of the late 1960s, an additional Sydney-Canberra-Melbourne radio system operating in the 6.1GHz frequency band with a capacity of 1800 circuits per bearer was planned. Because of the expected high growth on the route, two working bearers plus the protection bearer were to be installed at the outset. The route chosen for the new system generally followed the route of the existing 4GHz system but the Sydney terminal was to be at Waverley rather than Redfern and 4 new repeater sites were involved.

It had been intended to install the Canberra terminal at Red Hill and transfer it to Black Mountain later, but as a result of reduced traffic growth in this period it was possible to defer making use of the system until the Black Mountain tower was available. However, in order to make capacity available for relief Melbourne-Albury and for the Moomba-Sydney gas pipeline communications, installation of the radio system at all sites except Black Mountain was completed prior to the tower availability. Although the through system did not come into operation Sydney-Canberra-Melbourne until early 1979 it had been used to provide some Sydney-Melbourne circuits, using a temporary arrangement for a few months, following the Granville railway bridge disaster in January 1978 when a 12MHz coaxial cable system was lost. In this arrangement a through connection was made from Gun Gun to Mt Carroll bypassing Canberra.

A third television relay was brought into service in late 1975 using recovered telephony bearers Melbourne-Albury and Sydney-Canberra, and a new 4GHz bearer Albury-Canberra. The telephony traffic was diverted to one of the new 6.1GHz radio bearers between Melbourne and Albury and to a 12MHz coaxial cable system between Canberra and Sydney. The new bearer was leased to the ABC enabling the 9 network to takeover full utilisation of the previously shared bearer.

During this period, consideration was given to the possibility of installing a 60MHz (10,800 circuit capacity) line system on the pair of tubes in the coaxial cable still equipped with a 6MHz line system. Eventually the proposal was rejected largely because of the difficulty of installing two additional repeaters between existing repeaters while still keeping traffic operating on the other pairs of tubes. Another factor in the decision was the network disruption likely to occur in the event of line system outage or cable damage.

Also, a decision was taken to construct a new broadband route from Ceduna via Port Augusta, Broken Hill, Cobar, Dubbo and Orange to Sydney enabling some traffic from the Ceduna earth station and Western Australia to follow a more direct route bypassing Adelaide and Melbourne. This route which came into service in 1979 had a significant influence on the capacity planned for the Sydney-Melbourne route.

**1975-1980**

In 1978, the Melbourne-Canberra section of the last remaining 6MHz valve-operated line system was recovered to achieve savings in power costs and maintenance effort. Circuits were transferred to other available capacity. However, the Sydney-Canberra section was retained as the circuits were needed to meet demand.

The Black Mountain tower was finally available for installation of radio relay equipment in 1978 enabling the last link in the 6.1GHz radio system to be completed as well as the transfer of all radio equipment from Red Hill. The Red Hill radio terminal building and tower were demolished in 1979.

In late 1979, an order was received from the 10 network for the provision of a fourth dedicated both-way television bearer. To facilitate this, a new 6.1GHz bearer is to be provided throughout, but in the Sydney-Albury section, the new 1800-circuit bearer will be interchanged with the existing 1200 circuit 4GHz bearer. Until the dedicated bearer is available, the 10 network makes use of the protection bearers of the 6.1GHz radio system. In early 1980, the Special Broadcasting Service began leasing the south-going 4GHz protection bearer for ethnic television relays from Sydney to Melbourne.

**1980-2000**

On the 6.1GHz radio relay system, a third Sydney-Canberra telephony bearer is planned for completion by mid-1982 to facilitate release of the remaining Sydney-Canberra 6MHz valve-operated coaxial cable system. This will make tubes available for an 18MHz line system with a capacity of 3600 circuits which is to be installed Sydney-Canberra-Melbourne by late 1983. This radio bearer is in addition to the bearer for the 10 network which is to be provided by late 1982.

Based on current forecasts of demand which include a significant requirement to meet the needs of the proposed Digital Data Service to be introduced in December 1982, further through radio bearers will be required in 1984, 1985 and 1986 which will virtually exhaust the bearer capacity of the 6.1GHz radio system. This could occur one year earlier if the Special Broadcasting Service require a dedicated bearer for the ethnic television service.

Because of the very rapid growth of digital data services and the expected moves towards an integrated digital network and an integrated services digital network in the future, it is expected that a digital radio system with a capacity of 140 Mbit/s per bearer will provide the next stage of relief on the route. To this end, action is in hand to provide tower extensions as necessary to permit installation of the second 6.1GHz antenna for the remaining analogue bearers and also for main and diversity antennas for the digital system at each repeater along the route. Further, it is proposed to conduct a field "experiment" of digital equipment on the Waverley-Cecil Park section of the route, to study propagation aspects of digital radio operation, and a field "trial" on the Surrey Hills-Eastern Hill section of the route, to become familiar with the operation of digital radio equipment. Installation of the systems is planned for 1981/82 which should permit an adequate testing programme prior to installing an operational system by 1985.

Following the establishment of the national communications satellite now expected late in 1985, it would appear likely that most television relays on the route, apart from national regional relays in Victoria, will transfer to the satellite. However it may be decided to retain at least one interstate dedicated bearer on the route. Loss of these relays will permit at least partial recovery of the 4GHz radio system particularly the obsolescent valve-operated Melbourne-Albury section. It is expected that the new digital radio system will terminate at the new Melbourne radio terminal to be established at Maidstone by 1983. The Sydney terminal may be at Dural but a decision is yet to be taken.

In the longer term, it may well be that a trunk optical fibre system will be installed on the route. As there is room for another cable to be laid along the track of the existing coaxial cable, this route may be chosen for logistic reasons. On the other hand, another route may be preferred to enable wayside towns to be readily bypassed for security reasons.

## SUMMARY

Apart from being important as the transmitting station for Canberra television services and FM broadcasting services and as a base station for other radio communications facilities, the Black Mountain tower is a key station in trunk communications for Canberra and an important node in the intercapital broadband network. It is also important in respect of television relaying, catering for up to 5 simultaneous interstate relays as well as national regional relays from Sydney and Melbourne and relays originating in Canberra.

**REFERENCES:**

"The Sydney-Melbourne Coaxial Cable Project", Telecommunication Journal of Australia, Vol. 13 No. 3, February, 1962.


**Television Operating Centre (TOC)**

# NEW EDITOR-IN-CHIEF

Mr Ron Keighley has been elected by the Board of Editors as the next Editor-in-Chief of the Telecommunication Journal of Australia. He will take over these responsibilities from Mr Lindsay Mitton, who has held this position for the past four years, later this year.

Mr Keighley brings to the position over thirty years of varied experience in Telecom: telephone exchange maintenance as a technician and senior technician; construction, customer equipment design and industrial engineering; marketing and directory services management.

As Principal Industrial Engineer, Mr Keighley designed management improvement systems and led studies into value analysis and computer applications in this field. He also conducted management training courses for engineers.

In 1974 Mr Keighley took up a position with the Australian High Commission in London, representing Telecom in engineering matters within Europe. During his three years there, Mr Keighley visited most European countries to study and report on engineering approaches adopted by overseas administrations and manufacturers, and represented Telecom at international meetings of the ITU, OECD and ESA. Whilst in London he acted as overseas agent for the Telecommunication Society of Australia.

On return to Australia, Mr Keighley joined the Customer Services Department to head the new Marketing Planning Branch and get this function started.

In 1979, he transferred to the Directory Services Branch (now part of the Commercial Services Department) and is presently responsible for the planning and development of major national projects such as the Computerised Directory Assistance System and the national computer compilation systems.

Mr Keighley has represented Customer and Commercial Services Departments' interests on the Editorial Board; recent articles from these areas — including the DAS/C Trial and Telecommunications for the Disabled in the previous issue — testify to his efforts in this regard.

We welcome him to the Journal's editorial leadership.

# The Tower Radio Functions and Specification

L. J. DERRICK, B.E. (Elec.)

This article follows on from the introductory article and discusses in more detail the reasons for the tower being constructed and for the selection of the Black Mountain location. Also outlined are the technical specifications made for long-term requirements for radio relay, FM and TV broadcasting, mobile radio, radio paging and other services.

Some details are given of the accommodation requirements for internal plant and the associated antennas for the above services. The electrical and mechanical design criteria for the lattice steel antenna column, the tower lightning protection, and other details specified in the tower brief to allow for the continued orderly expansion of services when required in the future, are also discussed.

## THE CASE FOR THE TOWER

As indicated in the introductory article, the planning of a telecommunications tower for Black Mountain, Canberra, began in earnest in April 1970. The events which led to this stage, however, began in 1964 when the then Australian Post Office was requested by the National Capital Development Commission (NCDC) in Canberra to examine the possible phasing out of the Red Hill radio relay station on aesthetic grounds.

The Red Hill station **(Fig. 1)** was the major Canberra terminal and repeater for microwave telephony and TV bearers on the Sydney — Canberra — Melbourne and Canberra — Cooma routes. The station consisted of a single storey brick building which housed the radio and power equipment, and a 39 metre lattice steel tower which supported the associated radio relay antennas. The NCDC felt that the tower should be removed as, in their view, it would detract from the view of the proposed new Houses of Parliament which were planned for establishment in the vicinity of Red Hill. As well as the aesthetic objections to the tower, future expansion on the microwave routes was limited in view of Department of Civil Aviation (now Department of Transport) restrictions on the height of the tower at Red Hill.

Many alternative sites for the Red Hill Station were considered subsequently, and eventually approximately twenty sites were selected for detailed study. Some of these are shown on the map **Fig. 2.** In each case the site was examined for suitability as a radio relay site and costs were estimated for establishment of the site including cost of power lines, roads, towers and coaxial cable connections to existing and proposed exchanges. Aesthetic and environmental factors were also taken into account. Hill top sites already established for other purposes were obviously of particular interest and one of these was Black Mountain. Black Mountain already had two separate establishments existing — the National television transmitting station and the Canberra Television Ltd. (CTC-7) television transmitting station and studio **(Fig. 3)**. Accommodating the radio relay facilities on Black Mountain was shown to be significantly more economic than the establishment of another site. A road, power lines, coaxial cable route and other facilites already existed although additions and upgrading of some facilities would obviously be required.

The NCDC were advised that Black Mountain was the most suitable site for a combined TV and radio relay station and it was agreed that a study would be made of suitable structures to accommodate all requirements in a combined complex. The concept of a single aesthetically acceptable tower to provide for present and future TV, FM, radio relay and other radio requirements was, therefore, developed. The single tower solution was also favoured by the then Australian Broadcasting Control Board (ABCB) as it was expected to remove a TV reception problem. The existence of the two TV transmitting masts on Black Mountain had resulted in "ghosting" to TV reception in some parts of the service area because of mutual re-radiation of signals from the adjacent mast. Studies were carried out on many possible designs of towers in conjunction with the Commonwealth Department of Works (now Department of Housing and Construction). It was considered that the tower should provide facilities for all requirements for up to 50 years without any significant extension to the tower structure or associated buildings. The design of a number of existing and proposed overseas communications towers were examined as part of the study. The physical characteristics of some of these towers are summarised in **Fig. 4.** Finally in 1970, a tower design evolved which appeared to meet all requirements known and predicted and was flexible enough in design to cater for possible shifts in emphasis between the services. The tower has been constructed with very little modification to this original design.

## THE SERVICES DESIGNED FOR

In view of the criterion mentioned above, which was to construct a tower suitable for requirements for up to 50 years, considerable thought was given to possible long term developments and requirements for radio relay, mobile radio and paging and TV/FM broadcasting. For the TV/FM broadcasting requirements, the appropriate planning body at the time, the ABCB was consulted.

### Television Broadcasting

The ABCB specified that a minimum of 8 high power television services should be designed for with 4 in the VHF bands and 4 in the UHF bands. The VHF services were to be nominally of 100 kW effective radiated power (ERP) and the UHF — 1000 kW ERP. The VHF channel allocations originally specified were 3 (existing), 5, 7 (existing) and 9. In the UHF range, operation in any channels in BAND IV and BAND V was required. Later developments in FM broadcasting, however, resulted in Channel 5 not being available and the VHF channels allocated became channels 3, 7, 9 and 10 (see Table 1 for channel and band frequencies). In view of the closeness of some of the Canberra service areas to the Black Mountain site, the ABCB specified that the vertical antenna pattern should not fall below 7dB of the maximum down to a 10$^{o}$ depression angle.

As Canberra was developing in most azimuthal directions from the site, omnidirectional antenna horizontal patterns were appropriately called for. A minimum height of 122 m above the top of Black Mountain for the antennas was also a requirement.

The above specifications were believed to be appropriate for the design period for TV broadcasting for Commercial, National and possible Special and/or Educational Services.

| TV Channel or BAND | Frequency MHz |
|---|---|
| CH 3 (VHF) | 85 -92 |
| CH 5 (VHF) | 101 - 108 |
| CH 7 (VHF) | 181 - 188 |
| CH 9 (VHF) | 195 - 202 |
| CH 10 (VHF) | 208 - 215 |
| TV BAND IV (UHF) | 520 - 585 |
| TV BAND V (UHF) | 610 - 820 |
| FM BAND (VHF) | 88 - 108 |

**Table 1 — TV and FM Frequencies**

### FM Broadcasting

The ABCB agreed that a minimum of 10 services of 10-20 kW ERP should be designed for. Although originally the frequency band of operation was specified as UHF, this was later modified to VHF after a decision was taken to revert to the international VHF band for FM broadcasting in Australia. A height for the antennas of 122 m nominal was specified.

As with the TV services, National, Commercial and possible Special/Educational services were to make up the 10 specified.

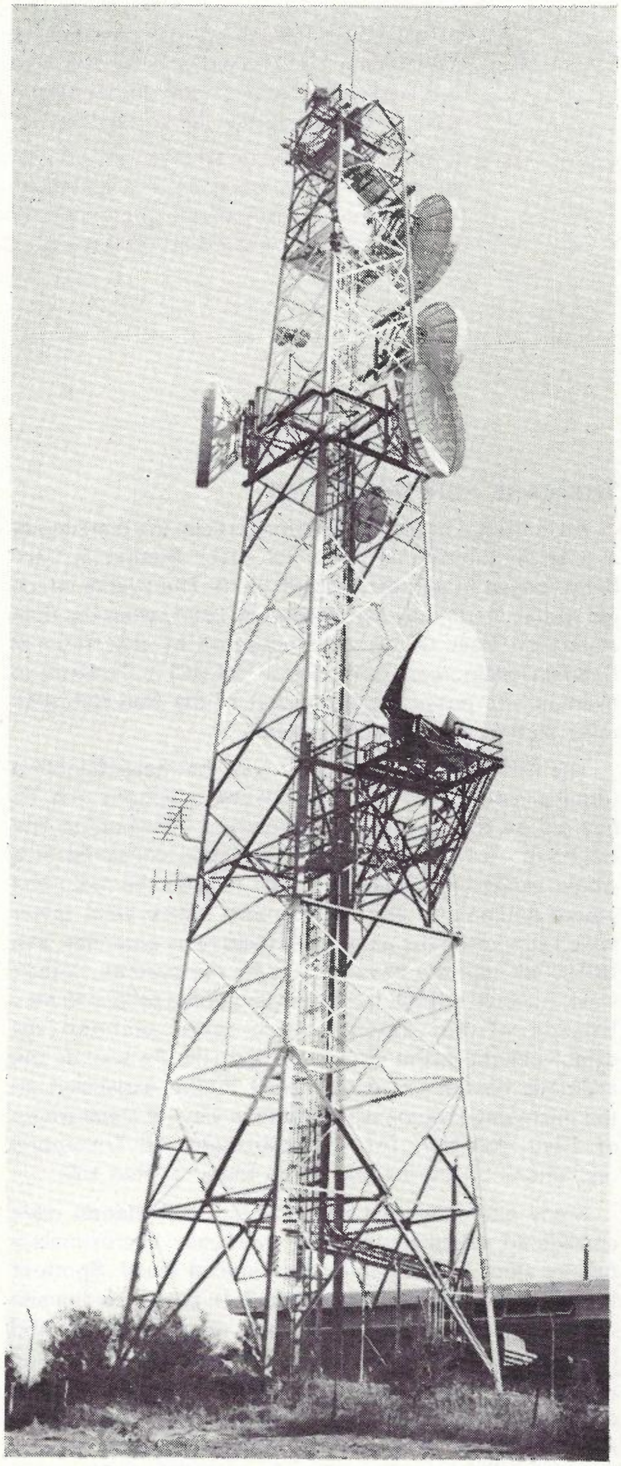


**Fig. 1 — The Red Hill RT Station**

**Radio Relay**

To cater for long term radio relay requirements it was decided to allow for full deployment of all the microwave bands between 2 and 15 GHz on the three main routes to Sydney, Melbourne and Cooma. Both telephony and TV bearers were to be accommodated. Path profiles were examined to the existing repeater sites and also to a number of other possible future repeater sites. Clearance of antennas above the site was specified to enable satisfactory transmission to all of these sites. A flexible antenna mounting arrangement was also required to enable transmission to be possible in any direction from the tower as requirements developed, in perhaps unpredictable directions. To achieve the above specification it was necessary to allow for 14 — 4 metre diameter dish antennas in each of the three directions, i.e. a total of 42. It was also thought necessary to cater for horn type antennas as alternatives. With operation in the higher frequency bands, close proximity of the equipment to the antennas was important to avoid excessive losses and intermodulation problems.

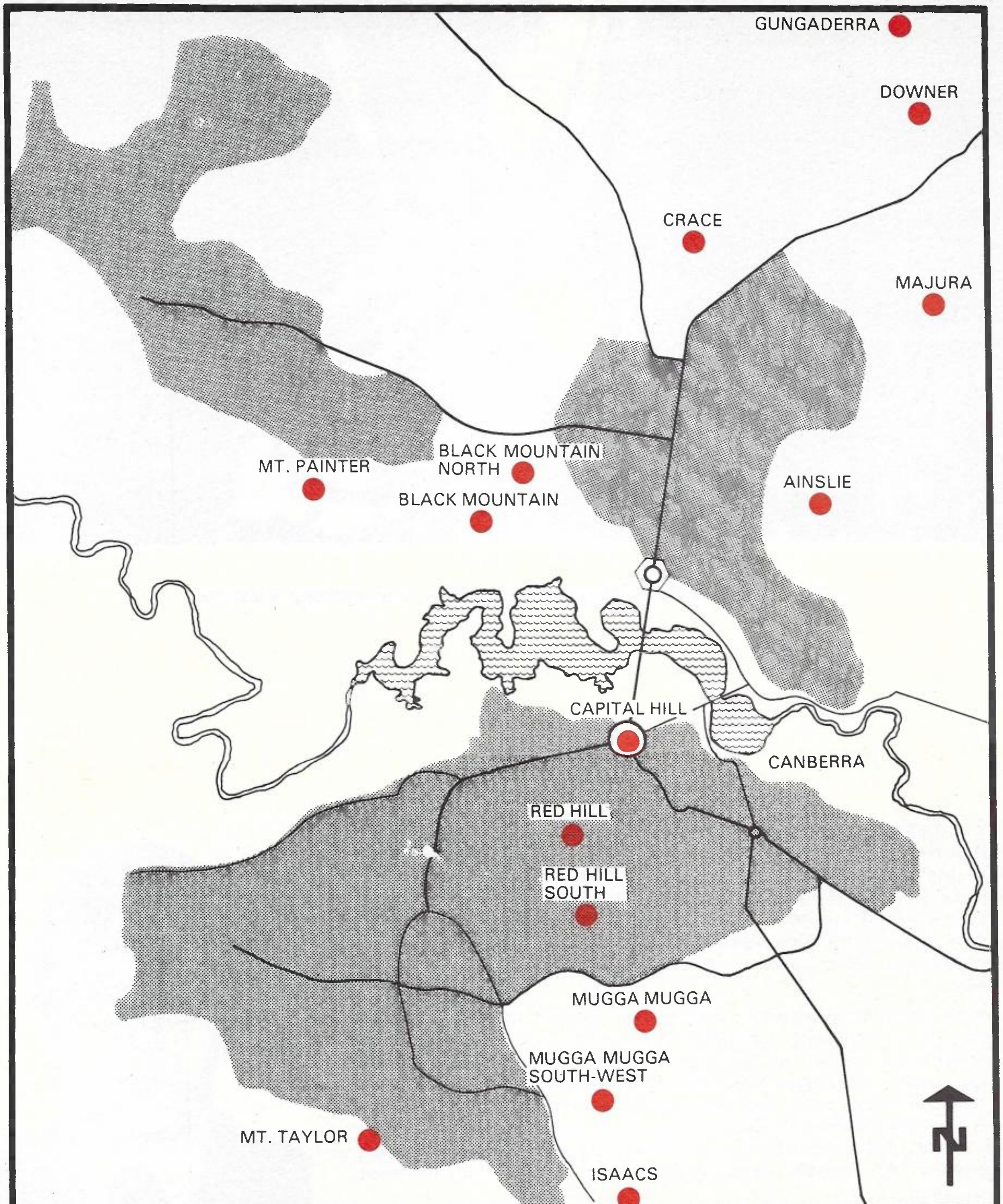



**Fig. 2 — Alternative Sites Studied**

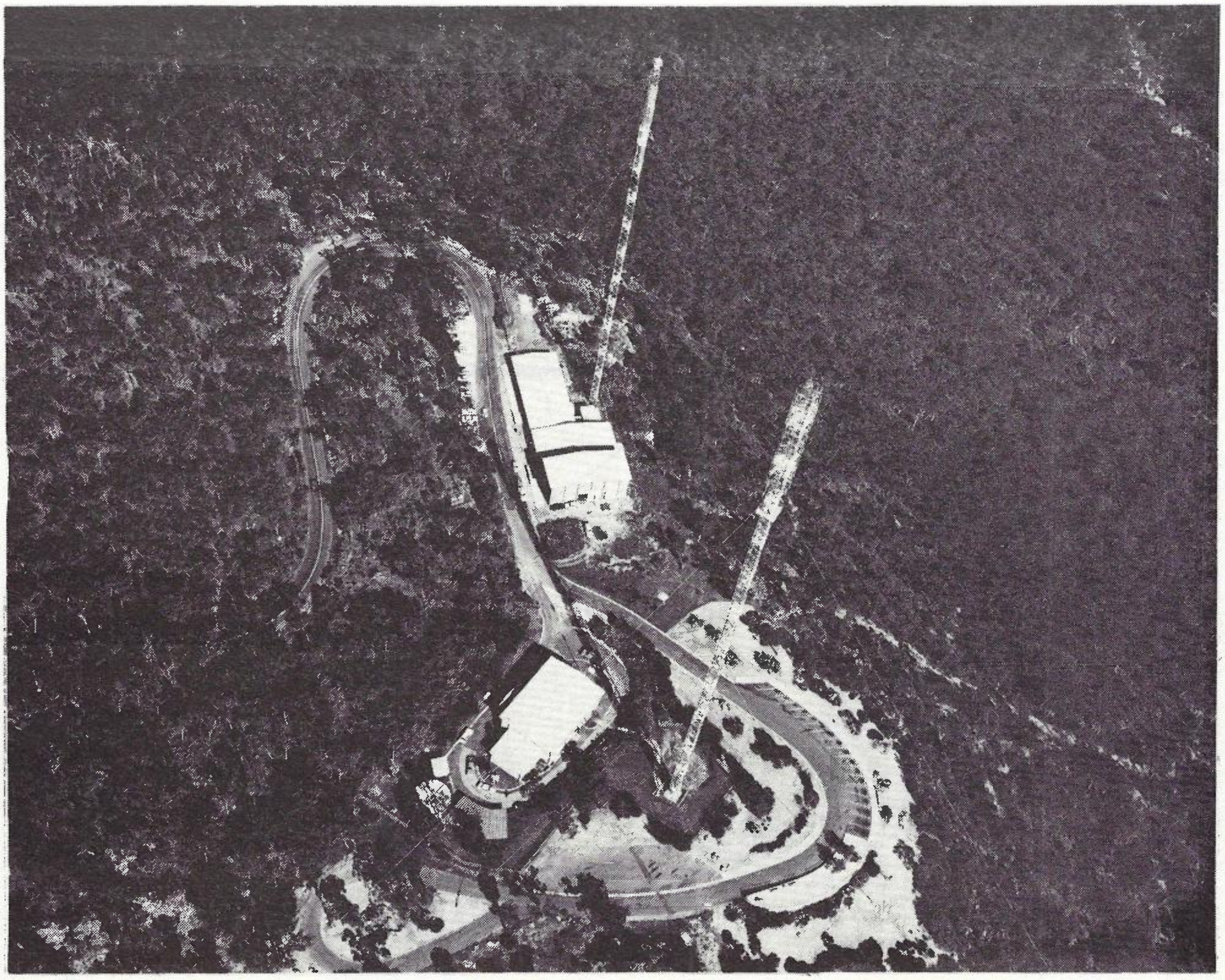
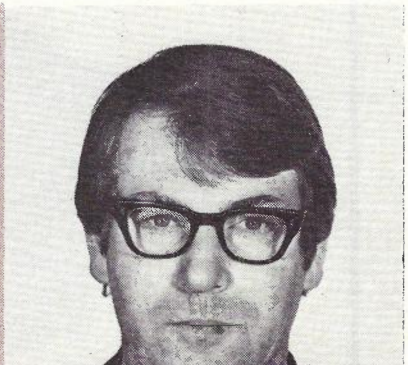


**Fig. 3 — The Black Mountain Television Transmitting Stations**

L. J. DERRICK completed a Bachelor of Engineering (Electrical) Degree at Melbourne University in 1961 and joined the Headquarters Radio Section of the Australian Post Office as an Engineer Class 1 in 1962. Since that time he has occupied a number of positions in the Broadcasting and Radiocommunications areas in the APO/Telecom Australia, and has worked on a number of large projects including the Radio Australia HF Broadcasting Station, Darwin, the Black Mountain Tower, Canberra, and the Public Automatic Mobile Telephone Service.

In 1971 he commenced work in a project team formed in the Radio Section to examine all broadcasting and radiocommunications aspects of the Black Mountain Tower Project, and in 1973 took up the Class 4 Engineer Project Leader position. His responsibilities included the identification and specification of long-term broadcasting and radiocommunication requirements and their impact on tower designs, the detailed design of the tower antenna column and the TV/FM transmitting antennas design and provision. In 1973 he gave evidence in the Supreme Court Case on objections raised to the tower construction.

He is currently the Staff Engineer Design Co-ordination Secretariat in the Design Sub-Division, Engineering Department, at Headquarters.



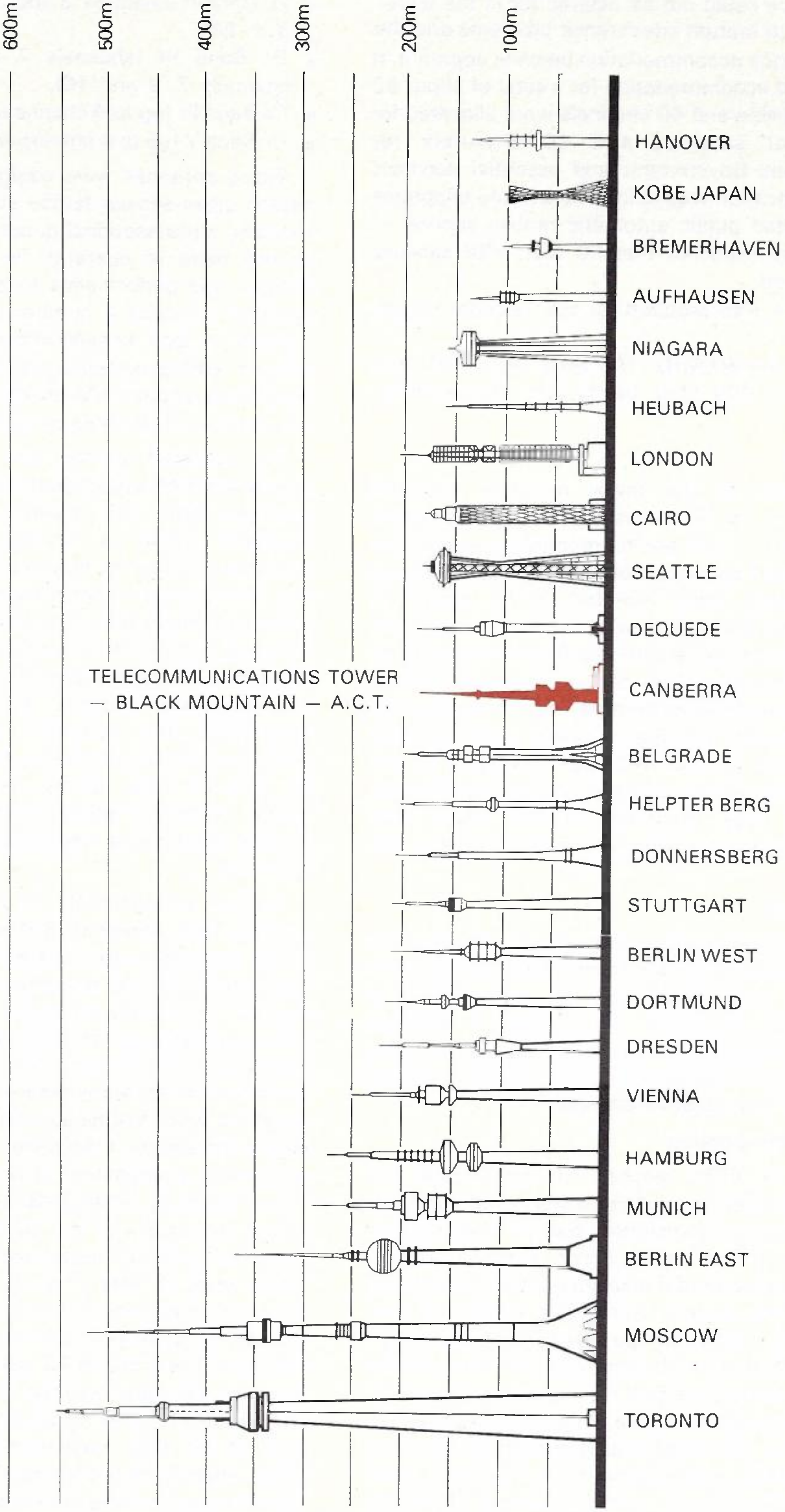



**Fig. 4 — Some Overseas Towers**

### Mobile Radio and Paging

It became obvious after studying the requirements for all likely Government, semi-Government and Commercial mobile radio base station facilities, that all of Canberra's needs of this type could not be catered for in the tower. Limitations due to mutual interference problems and the difficulty of antenna accommodation became apparent. It was decided that accommodation for a total of about 80 services was feasible and 40 channels were allocated for APO (Telecom) services and 40 channels for Government, semi-Government and essential services. The Telecom allocation was to include a future telephone network connected public automatic mobile service. In the main, it was expected that 50 watt ERP services would be required.

Facilities were also required for the Telecom paging service.

Operation in the 80 MHz, 160 MHz, 450 MHz and eventually in the 900 MHz bands was envisaged for these services.

### Other Services

Accommodation in the tower of other technical facilities such as for TV bearer switching (Television Operation Centre — TOC) and for monitoring and remote control of medium frequency broadcasting transmitters in the Canberra area, were included in the design to maximise the use of operational and maintenance staff. Of course, other ancillary equipment for systems such as the coaxial cable connection of the telephony and TV bearers to the telephone exchanges and TV studios had to be accommodated. Emergency power plant was also required to back up the AC mains supply to the broadcasting and other AC powered equipment and a DC battery supply was specified for the radio relay equipment, in accordance with standard practice for this equipment.

## THE SOLUTION

With the technical facilities to be accommodated over the life of the tower defined in some detail, studies were carried out in conjunction with the Department of Housing and Construction to develop a suitable aesthetically acceptable single tower design. A large number of tower and associated podium building designs were studied in this iterative process.

### Antenna Accommodation

To achieve the ERPs required for the TV and FM broadcasting services, it was necessary to compromise between the required transmitter powers and antenna gains. In view of the rather broad antenna vertical radiation patterns required it was not possible to use very high gain antennas as this would have resulted in very narrow vertical radiation patterns with resultant difficulties in achieving sufficient "null fill" down to the 10° depression angle specified. As it was also desired to minimise the cross-sectional size of the tower as much as possible to reduce the visual impact and as the antennas for the broadcasting services were to be comasted, each antenna had to be limited in vertical aperture and hence gain to enable a structurally feasible antenna mounting structure to be designed. In view of the large number of TV and FM channels to be catered for, it became obvious that multichannel antenna systems should be employed as much as possible.

Starting from the minimum specified height for the TV/FM antennas of 122 m above the Black Mountain summit, the solution adopted was to design for four stacked antenna systems as follows:

- TV Band II (channels 3 and 5 later changed to channel 3 + FM)
- TV Band III (channels 7 and 9 later changed to channels 7, 9 and 10).
- TV Band IV (up to 4 channels)
- TV Band V (up to 4 channels)

These antennas were designed to be mounted on a square cross-section lattice steel antenna column with reducing cross-sectional dimensions with increasing frequency band of operation to allow optimum antenna designs and performance to be achieved. The antenna systems comprise a number of levels of four radiating "panels" — one on each of the four faces of the antenna column. Additional space was allowed for on the antenna column for another FM broadcasting antenna in view of the number of services proposed for the long term.

As indicated above, for full deployment of the microwave frequency bands between 2 and 15 GHz, 14 parabolic dish type antennas in each of the three directions would be required. It was also considered desirable to allow for horn type antennas as alternatives. The possible use of other multiband antennas was also examined where their use would result in a reduction in the total number of antennas required. Although a few designs of this type of antenna existed at the time, it was not considered prudent to rely on their long term availability and suitability and, therefore, a total complement of single band dish antennas was allowed for. Use of these special multiband antennnas is, of course, feasible if required in the future and would result in more space being made available for other minor route antennas.

Various arrangements for the accommodation of 42 parabolic dish antennas (3 directions — 14 in each) of 4 metre diameter were considered. It was realised that it was unlikely that all antennas of this diameter would be required in all three directions, however there would be other requirements for small capacity system antennas in other directions for minor systems such as TV studio to transmitter links. Many different configurations of the 42 antennas were examined and the impacts on the total height and shape of the tower were estimated. The most acceptable arrangement arrived at, reducing the overall tower height as far as possible, was to group 36 antennas (3 sets of 3 x 4) in a compact volume. Mounting of the other 6 dish antennas was designed for at a separate higher level (3 sets of 2) to allow for adequate path clearance requirements for possible 2 GHz systems or to provide sufficient diversity spacing from the bulk of the antennas. The group of 36 dishes with suitable clearance between dish rims resulted in a volume about 30 m in diameter and 12 m in height existing behind them. In view of the high frequencies of operation eventually being required, to reduce possible waveguide losses and intermodulation noise, it was considered highly desirable to locate the microwave equipment in close proximity to the antennas. The use of the volume behind the group of dishes for an equipment housing therefore evolved and a 3-floor "drum" design eventuated. The height of the bottom of the drum was set by the minimum antenna height to give satisfactory radio path clearance to existing and possible repeater sites allowing for some growth of the trees on the Black Mountain summit.

Having set the level of the bottom of the RT drum at 30.5 m and allowing for the drum height, the height of a "public" drum and the mounting of the additional 6 dish antennas on another simple platform, the space between 80.8 m and the TV/FM antenna column base level of 132.3 m was examined for its suitability to accommodate additional antenna systems for mobile radio, paging and additional future FM broadcasting services. Studies of a number of possible antenna configurations and transmitter combining systems for mobile and paging services requiring omnidirectional cover from the tower were carried out. It was determined that there was sufficient space available in this region for the required number of antenna systems composed of 2 dipole units, one on each side of the tower to cater for the requirements. Mounting arrangements on the shaft and suitable weatherproof penetrations for cables were specified to accommodate these antennas and their associated cables.

Television Outside Broadcast (OB) antennas were allowed for on a dish platform above the 6 radio relay antennas, and on the RT drum while antenna space was not required for the fixed microwave systems. Finally, an allowance was made for possible mobile/paging antennas on the top of the lattice steel antenna column.

Thus the full complement of antennas for all radio services likely to be required in the lifetime of the tower was taken into consideration in the tower design. The arrangement for antennas was chosen to be flexible to allow for operation in different frequency bands, different direction of transmission and took into account possible shift in emphasis, e.g. less antennas required on the main Sydney, Melbourne and Cooma routes and more on minor routes in unpredictable directions from the tower. The design was also sufficiently flexible to enable broadcast antenna space to be used for mobile radio and paging services if required or vice versa.

### Internal Plant Accommodation

As mentioned above, the volume enclosed by the main group of radio-relay antennas was utilised for an equipment housing for the radio-relay equipment allowing short wave-guide connections from the equipment to their associated antennas. The volume available for the equipment drum was sufficient to allow a three floor design.

Based on the size of modern microwave equipment and ancillaries such as battery supplies and line equipment, one floor could accommodate the fully expanded microwave needs. The use of the additional two floors for mobile, paging, broadcast monitoring, maintenance, T.O.C. and other functions then became a logical step.

A podium building was incorporated in the design to house the rather high power (and hence high volume and weight) TV and FM transmitters. The building was designed to accommodate the following transmitters estimated to be the maximum requirement during the proposed life of the tower:

VHF TV 2 x 10 kW (parallel, air cooled)— 4 installations
UHF TV 2 x 30 kW (parallel, vapour cooled)— 4 installations
VHF FM 10 kW (air cooled) — 10 installations

Floor layouts and installation techniques proposed were chosen to allow for maximum flexibility in the choice of the type and size of transmitters. A "one floor" transmitter installation was adopted and attention was given to the progressive installation of transmitters and the need for electrical connections, cooling requirements and antenna feeder runs to the tower cable riser. It was decided to draw cooling air for the air cooled transmitters and for the heat exchangers for the vapour cooled transmitters through perforated walls on the outside of the building. The cooling fans, heat exchangers, other pumps and noisy rotating machines associated with the transmitters were specified to be located in partitioned rooms adjacent to the outer perforated walls to reduce internal building noise levels. The cooling air from the transmitting plant was specified to be discharged through the building roof to reduce the mixing of hot discharged air with the input cooling air. The cooling air outlets in the roof consisted of aesthetic cowl units which blended with the roof surrounds and were flanged on the inside to connect to the ducting runs from the transmitters.

A TV/FM control room was specified to house programme input equipment, test and monitoring equipment and control desks. It was envisaged that all TV and FM transmitters would be controlled and monitored from this central location on the transmitter floor. The transmitters could also be operated and monitored remotely in the RT drum if this became a more efficient arrangement in the future with the integration of staff on other operational/monitoring duties with the ground floor broadcasting staff.

Store and maintenance areas were specified in the RT drum for maintenance requirements for the radio telephone and ancillary services and in the ground floor area for broadcasting services. A separate store to hold and allow handling of the large transmitting tubes for the TV and FM transmitters was also included in the specification for the ground floor area.

### The Resultant Tower Design

Comasting of the main TV/FM broadcasting antennas and a mobile/paging antenna produced a requirement for an antenna column of 63.1 m in height. As these antennas were specified to be a minimum of 122 m above the Black Mountain summit, a tower height of 195.2 m resulted, allowing for the drop in level of the tower site from the summit.

The selection of a tower design of reinforced concrete up to the antenna column level solved the problem of minimising the deflection of the antennas on the antenna column due to wind loading, as discussed in the next section.

With the basic user specification set, as mentioned previously, the Department of Housing & Construction architects produced many alternative tower designs. Eventually the design of the now constructed tower **(Fig. 5)** emerged after many iterations where the functional, aesthetic and environmental merits of each proposal were exhaustively studied. Before the design was finalised, other related aspects which impacted on the design were taken into account. Antenna installation methods, antenna feeder cable runs and installation methods, coaxial cable requirements, DC and AC power leads, lifting methods (catheads, cranes and winches), interfloor cabling and aircraft warning lighting installations were some of these aspects, which were examined in detail and had significant influences on the detailing of the tower.

## DETAILS OF THE DESIGN OF INTEREST

### Antenna Column

Because of the interaction of the electrical design of the TV/FM transmitting antennas with the dimensional/structural design of the antenna column, the design and detailing of the column was carried out by the APO/Telecom for inclusion in the tower tender documentation. The required comasting of a number of antenna systems with the electrical requirement to have a decreasing maximum cross-sectional size of column with increasing frequency band of operation resulted in a need for a long and fairly slender structure. As deflection of the antenna column as a result of wind or uneven solar heating would cause the antennas horizontal beams to tilt causing unsatisfactory reception in the distant parts of the service area, the following maximum tolerable deflections were specified:

| | | 100 kph Wind | Solar Heating |
|---|---|---|---|
| UHF TV Antenna Systems | | ± 1.0° | ± 0.65° |
| VHF TV/FM Antenna Systems | Band 3 | ± 2.2° | ± 1.3° |
| | Band 2 | ± 3.2° | ± 1.0° |

The maximum tolerable deflections are set by the maximum gain and hence the narrowness of the vertical radiation pattern of each antenna system likely to be installed on the antenna column. The 100 kph wind level was based on the small percentage of the time the wind would exceed this speed on Black Mountain.

A higher tolerance was placed on the deflection of the column due to solar heating because it is a relatively long term steady deflection whereas the wind deflection is a short duration effect and would occur only when the wind speed gusts to the 100 kph level. These specifications refer to the total tower performance and for the wind loaded case mainly relate to the antenna column deflection as the concrete section of the tower would have an insigificant deflection in winds of this speed. For the solar heating, however, the main contribution to the movement would be in the concrete shaft due to the elongation of the side facing the sun and the relatively poor concrete thermal conductivity. The structural design of the antenna column, therefore, was governed by the wind deflection criteria.

The column design adopted used the standard bolted galvanised angle iron construction of radio relay radio towers. In view of the length and relative slenderness of the column the windloaded column deflection (rather than strength of the individual members) became the limiting design factor and a very heavy design resulted. The leg members at the top of the concrete shaft utilised four 8" x 8" x 1" (203 x 203 x 25mm) angle iron sections back to back per leg. For one of the transition sections where the column tapered to a small cross-sectional area plate members 25.4 mm thick were designed in view of strength requirements and the limited space available inside the column for access and cable and antenna feed system installation. As wind induced vibration of this slender column was expected, special lock nuts were specified to prevent the standard tower nuts from becoming loose. Both high tensile and mild steel members were used in the design and in view of the low temperature conditions experienced in Canberra, steel with suitable notch ducticility at 0°C was specified.

For each antenna system the back to back spacing of the radiating panels had to be kept within a maximum specification for suitable horizontal radiating patterns to be achieved. In view of the relatively heavy construction required to achieve the wind deflection criteria, considerable attention had to be given to the detailing of the design to avoid a larger than optimum cross-sectional dimensions while allowing sufficient effective space inside the column for cables, feed systems and access. A portion of one of the detailed antenna column drawings is reproduced in **Fig. 6**.

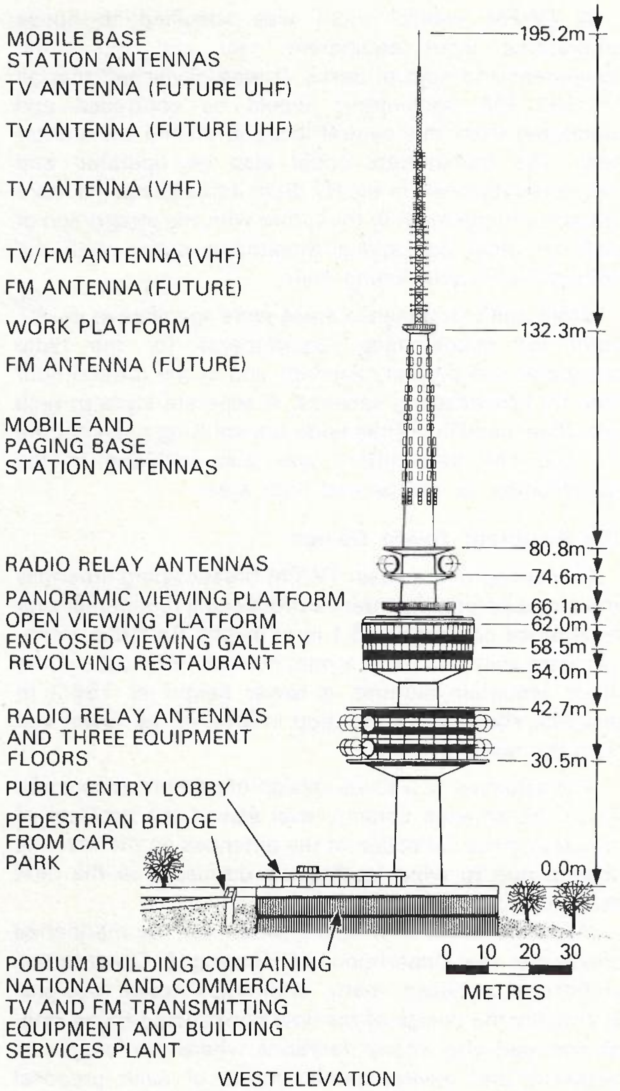



**Fig. 5 — The New Tower Outline**

In view of the narrowness of the column and the large number and size of the feeder cables which would eventually run through the column, and the feed distribution systems to be installed for each antenna system, a flexible runway system was incorporated in the design. Cable positions on this runway were reserved for the large diameter cable to avoid installation problems in the future. The runway was also designed to take power cables for aircraft obstruction lights, and hazard beacons and for other purposes.

The column was designed for wind deflection and strength on a static basis and it was considered that dynamic calculations should be carried out to confirm the satisfactory performance of the total concrete tower/steel antenna column system in the gusting winds which would be experienced in practice. The Department of Housing & Construction commissioned a detailed study of the dynamics of the system and confirmed that the deflections in both the down wind and transverse wind directions (due to vortex shedding) would be within the specifications for an acceptable percentage of time.

**Antenna Feeder Cable Requirements**

It was realised that there could be considerable difficulty in installing the large diameter antenna feeder cables from the TV/FM broadcasting transmitters when additional services were required in the future due to restricted space in the tower core and the antenna column. The usual practice was to feed each antenna with two cables and in view of the length of the runs and frequencies of operation in the UHF band cables up to 6$^1/_8$" (156 mm) in diameter were envisaged. Cable layouts and installation techniques were specified on the basis of the following plastic jacketed corrugated outer coaxial cables:

4 x 6$^1/_8$" (156 mm) for UHF TV
4 x 3$^1/_8$" (79 mm) for VHF TV/FM
4 x 3$^1/_8$" (79 mm) for FM
1$^5/_8$" (41 mm) & $^7/_8$" (22 mm) for Mobile Radio and Paging

The most difficult operation was seen as the later installation of the 6$^1/_8$" (156 mm) diameter cables in view of their large bending radius, size and weight. The underground cable tunnel was dimensioned and positioned in the design to be suitable for the installation of these cables. This tunnel was designed to join the cable riser in the tower shaft which was to run from the sub-basement level to the top of the concrete shaft. The installation technique designed for was to use a winch at ground level near the entrance manhole to the cable tunnel and haul the cable from its drum down the tunnel manhole and up the riser to the required level in the antenna column. A lifting arrangement designed for location at the 132.3 m platform level was used in this operation (and also to lift dish antennas). The lower end of the cable would terminate at the ground floor level of the shaft and join with rigid coaxial line which penetrated the shaft above the false ceiling level in the transmitter hall and which would run horizontally to the transmitter cubicles inside the false ceiling.

For the runs from the microwave equipment to their associated parabolic dish antennas, flexible corrugated plastic jacketed elliptical waveguide was adopted. These waveguides were designed to run in a false ceiling in the RT drum, through a penetration unit in the drum wall and along runways on the outer drum wall to the appropriate antenna position.

It had been noticed in some overseas towers that there was a problem where cables had to be subsequently installed through the concrete tower shaft or through floor slabs and building walls. These penetrations often had to be fire rated and weatherproof and ideally should have allowed speedy and orderly installation as required during the life of the tower. A number of possible solutions were examined and eventually an existing commercially available system was adopted — the multicable transit (MCT) frame. This consisted of a cast-in steel frame which was fitted with modular silicon rubber blocks either solid or in two halves, with an appropriate sized hole in them to seal the cable to be installed. The frame included components to clamp the rubber blocks tightly together to seal the penetrating cables to the blocks and the blocks to the frame. At any time a cable was to be installed the frame clamp/screw could be loosened, a solid-block removed and replaced with one of suitable size to seal the cable. A large number of these frames were specified for installation throughout the tower, — in the tower shaft to the outside for antenna cables, in the floor slabs and walls of the RT drum and podium building and at the top platform of the tower where the antenna column commenced. It was discovered in some of the earlier towers overseas that there was insufficient provision for cable penetrations with resulting later problems of cutting through the

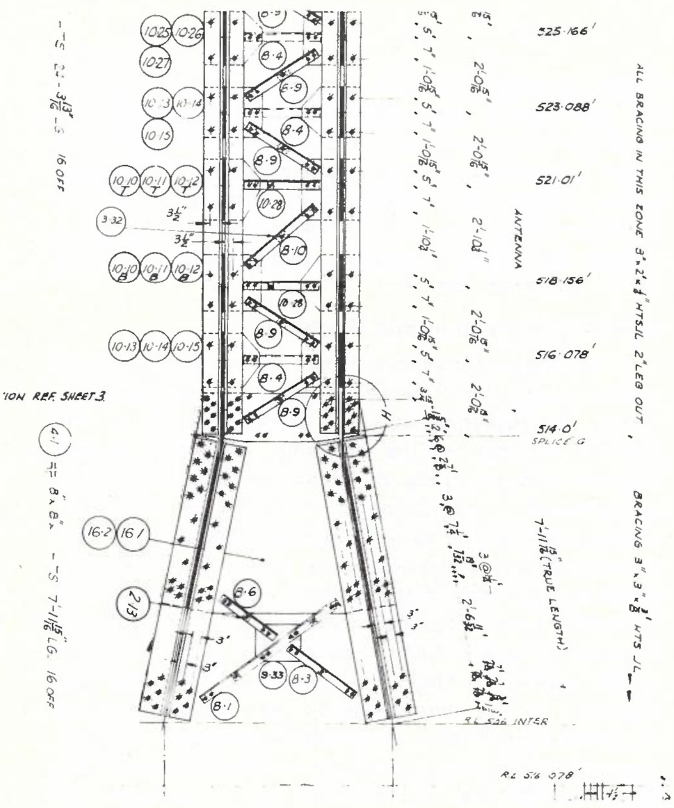


Fig. 6 — Portion of Antenna Column — Detail

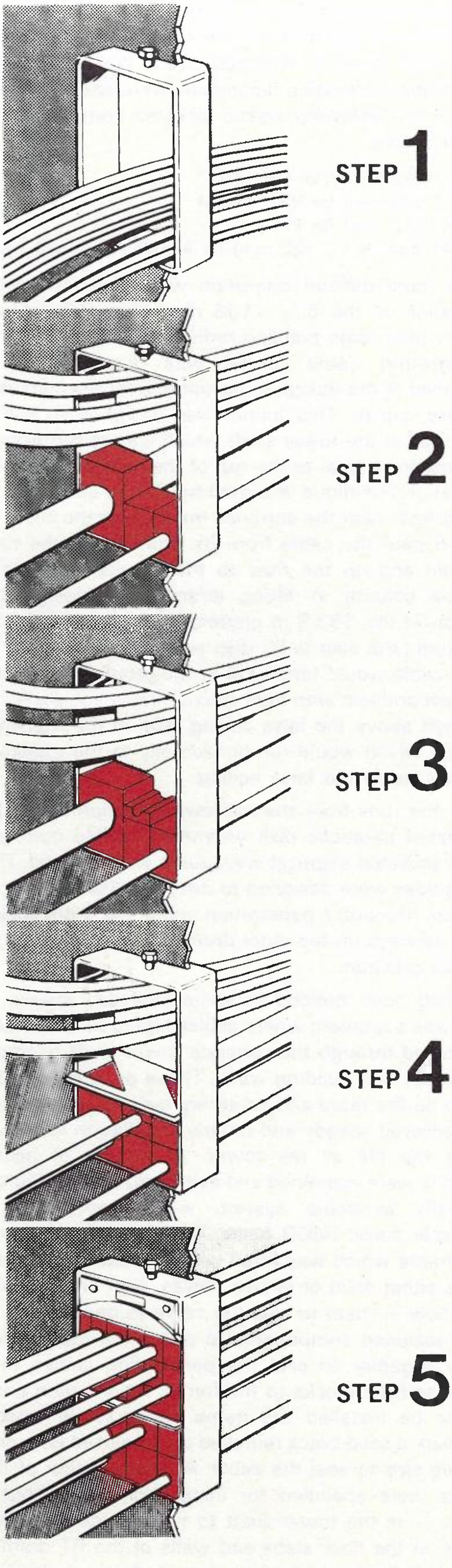



**Fig. 7 — Multicable Transit (MCT) Unit — Cable Installation**

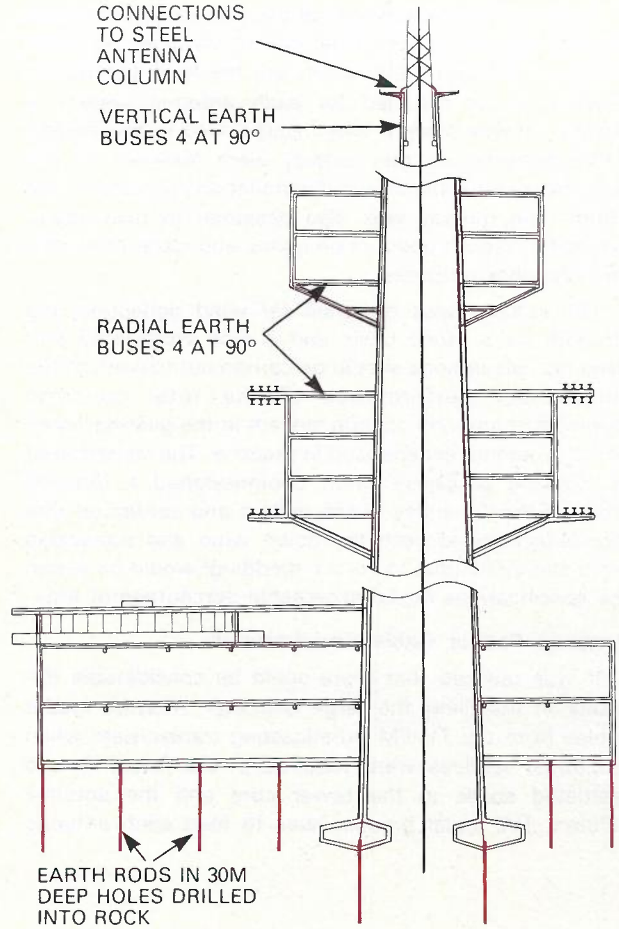



**Fig. 8 — Lightning Protection System**

heavily reinforced concrete and with the later sealing of the penetration when the cables were installed. A generous provision of the MCT frames throughout the tower is expected to avoid these problems. The special rubber blocks used expand in the event of a fire and continue to seal the cable even when the plastic jacket is melted. The method of installing cables through the MCT unit is shown in **Fig. 7**.

**Lightning Protection and Earthing**

A very important aspect of the tower design examined was the protection of personnel and equipment from the effects of a lightning strike to or near the tower. The general principle of the lightning protection system adopted is shown in **Fig. 8.** A standard lightning rod was incorporated in the design for mounting on top of the antenna column and the column steelwork was used as a downconductor to the top of the concrete shaft. At this point the four legs of the column were specified to be connected to four steel downconductors which were cast into the concrete and which were tied at regular intervals to the reinforcing steel. The reinforcing steel was also specified to be tied together at regular intervals throughout the tower. A possible alternative approach was considered but was rejected on the basis of cost and degree of difficulty in carrying it out — this was the welding of groups of the vertical reinforcing steel together to form downconductors. All metal components in the tower of significant size were specified to be connected to the four vertical downconductors. Four radial conductors were designed to run from the shaft vertical runs to the extremities of the public and RT drums in each floor and roof slab. These connect to the reinforcing in wall columns, the antenna mounting rails, window frames and other metal components. Internal to the shaft the steel ladderway, cable trays and other large metal fittings were also connected to the downconductors. The arrangement at the RT and public drums in effect produces a faraday cage which would protect people and equipment inside.

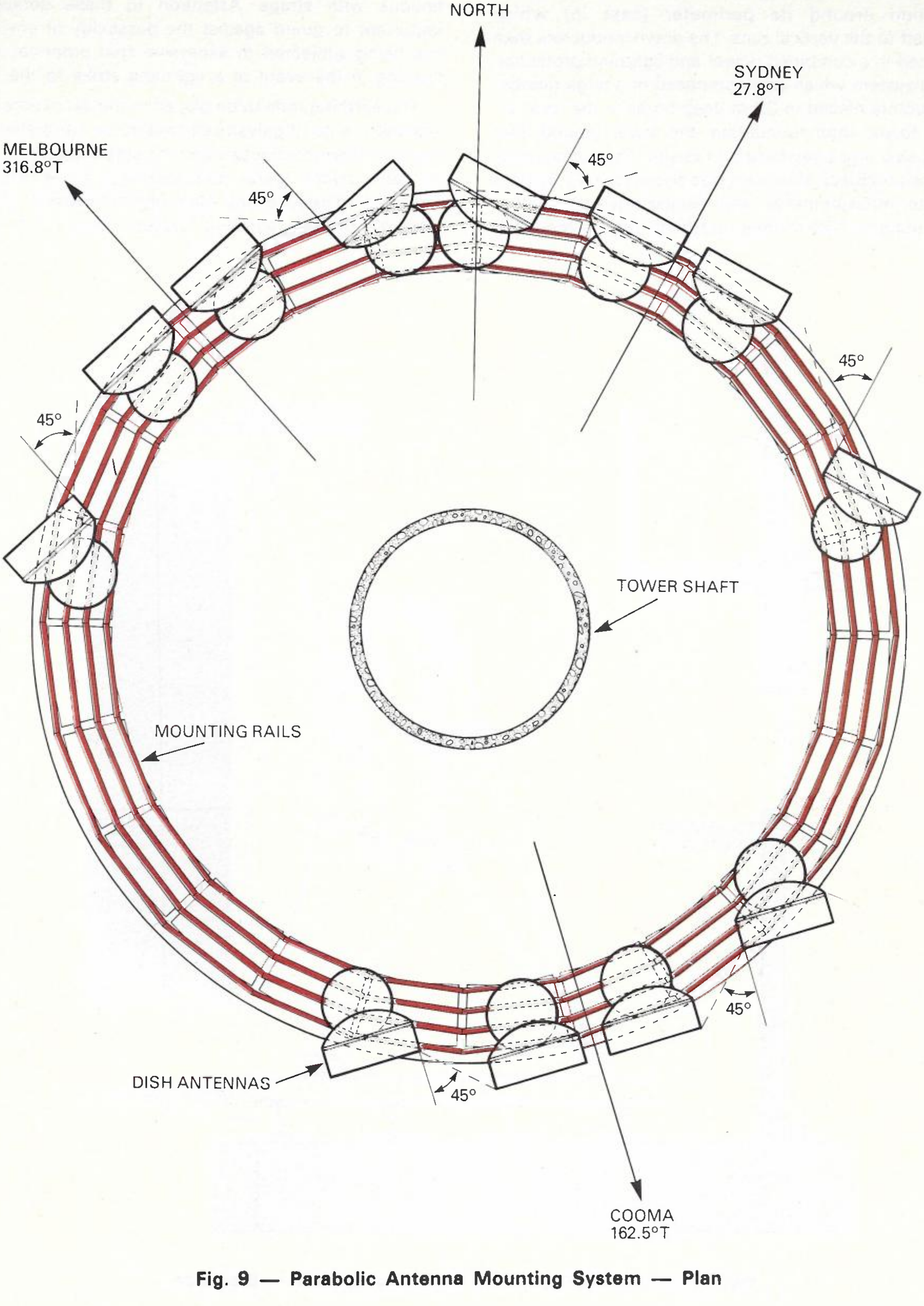



**Fig. 9 — Parabolic Antenna Mounting System — Plan**

The above philosophy was also applied in the podium building where horizontal runs of steel conductors in the concrete slabs were specified which connected the wire tied reinforcing rod and other components to the main vertical conductors. Tags from these vertical and horizontal conductors were specified to penetrate the concrete surface at intervals to allow earthing of installed equipment as required.

The tower reinforced concrete foundation also had a number of steel lightning conductor runs specified for installation around its perimeter (cast in) which connected to the vertical runs. The downconductors then terminated in a combined power and lightning protection earthing system which was composed of a large number of conductors placed in 30 m deep bores in the rock under the tower shaft foundation, the lower ground floor building slab and elsewhere on the site. The conductivity of the rock on Black Mountain was shown to be very pocr from site measurements and necessitated the rather large number of 30 m deep earthing rods to meet the earthing resistance specification. For lightning purposes, an earthing resistance of less than 10 ohms was required with a desirable target of 2 ohms. The power earthing for the sub-station in the tower was specified at 1 ohm, however, and this then became the target. All reinforcing in walkways, roadways, cable tunnel, water tanks, etc. and coaxial cable ducts, water and sewer pipes, were specified to be connected together and to the tower earthing. Some service pipes which used rubber sealing joints were also specified to be made electrically continuous with straps. Attention to these details was important to guard against the possibility of anyone on site being subjected to excessive step potential or side flashing in the event of a lightning strike to the tower.

The earthing rods to be placed in the 30 m bores were specified to be of galvanised steel to be compatible with the steel downconductors and the steel reinforcing, coaxial cable ducts, water and sewerage pipes. This was expected to reduce any electrolytic corrosion of these facilities or the earthing system itself. The power

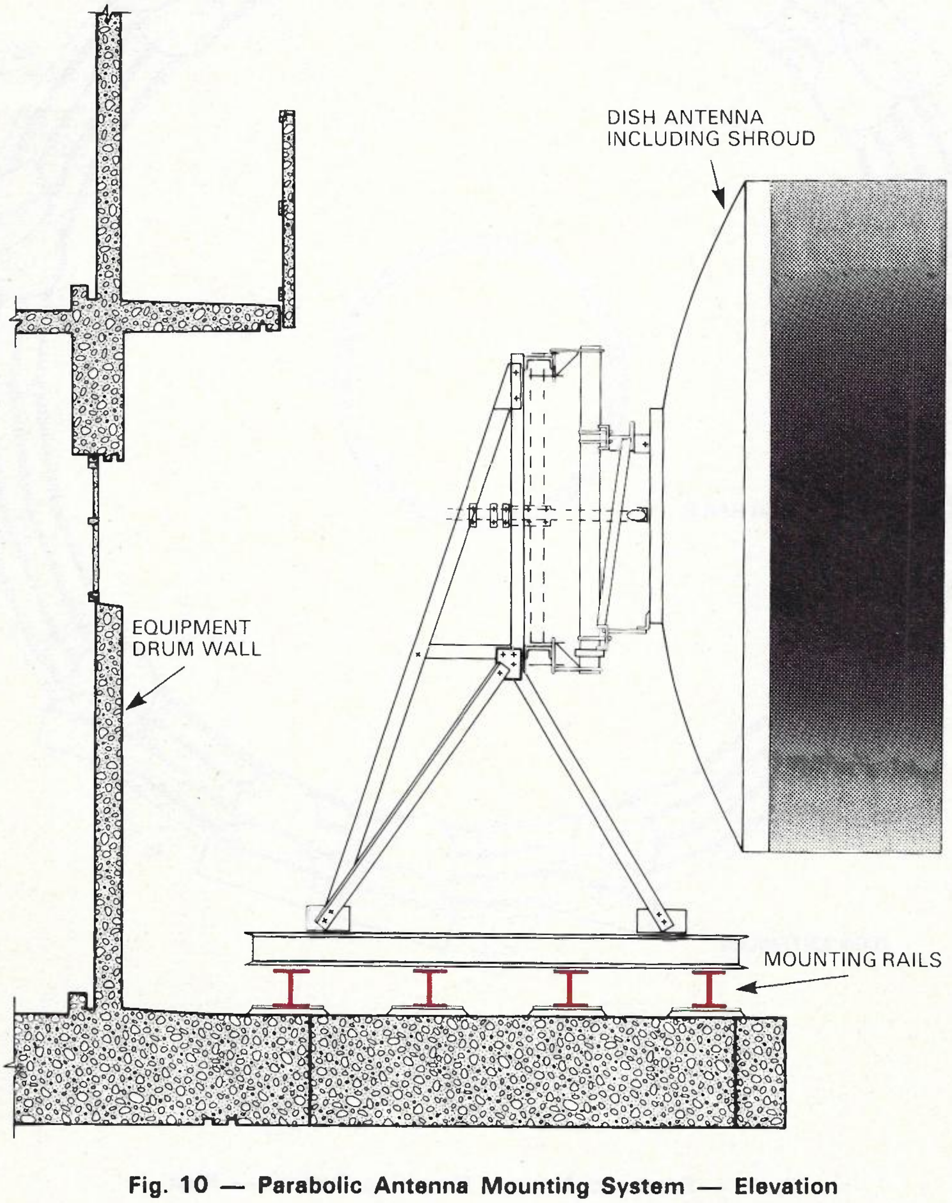



**Fig. 10 — Parabolic Antenna Mounting System — Elevation**

authority, however, insisted on copper being used for the rods in view of their experience of galvanised earthing systems measuring high in resistance after some time.

As there is always a possibility that lightning could strike lower down on the tower and not at the top, an outside conducting band on the highest parts of the podium building roof was specified to be connected to the downconductor system. The steel safety fence on the public drum and the antenna mounting rails on the RT drum would similarly protect those areas.

### Microwave Antenna Mounting Arrangements

A flexible mounting arrangement was required for the installation of parabolic, horn or other multiband antenna systems on the RT drum and dish platform. The requirement was to accommodate antennas of varying sizes without restricting any direction of transmission. The spacing between the RT drum floor and roof was chosen to allow the installation of two levels of the largest parabolic dish size (4 m) or a single level of horn type antennas.

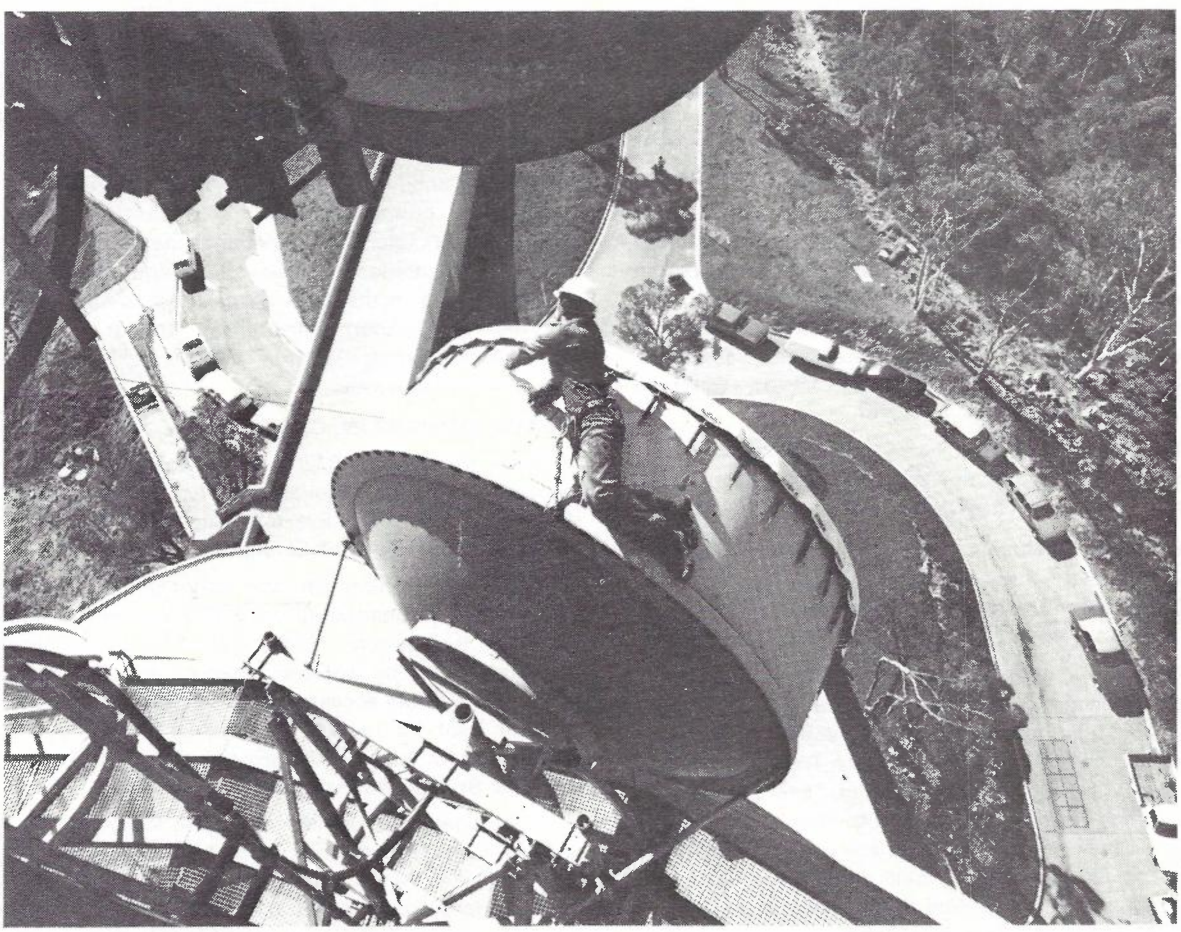
A rail mounting system was devised which gave the required flexibility. Four concentric rails were specified to be installed at the three levels of the RT drum. The antennas were to be mounted on individual mounting frames with ring beam bases and these mounting frames with dishes attached would then be clamped to the rails in any required position or orientation. This system is shown in plan and elevation in **Figs. 9 and 10.** At the lower and upper RT drum levels the mounting frames are placed on top of the rails whereas at the second level the mounting frames hang from underneath. The frames have been designed to mount antennas of varying size and the design was based on the use of the usual dish mounting arrangement for standard radio relay towers.

## CONCLUSION

This article has outlined the main broadcasting and radiocommunication requirements which influenced the design of the tower and its location. Antenna, transmitting equipment and ancillaries accommodation specifications, which formed part of the brief to the then Department of Works are also discussed.

Other articles in this issue discuss the construction of the tower and the installation of the broadcasting and radiocommunication equipment in it, and indicate that little departure was necessary from the originally specified tower design or from the accommodation arrangements adopted in the design.

As additional services are required in the future, it is expected that they will be efficiently accommodated in the tower without the need to extend or significantly modify the podium building or tower proper.



**Installation of Radio Relay Dish Antenna on RT Drum**

# Project Development and Building Facilities.

J. F. McCARTHY, MIE Aust.

The Black Mountain Tower story is unique and unlikely to be repeated. This article summarises the developments leading to the conception, construction and commissioning of the tower and describes its more unusual features, particularly those associated with the accommodation of facilities for the public.

Since the decision by the States to federate led to the creation of the Australian Capital Territory (ACT) the Burley Griffin design of Canberra, the eventual completion of construction of Parliament House in 1927 and the first sitting of the Commonwealth Parliament in Canberra on May 9th of that year, Canberra has had special needs for telecommunications within the ACT, between the ACT and each of the States, and with the world at large.

The population of Canberra in 1927 was only about 5,000 and growth was fairly slow up to 1939, when the population was approximately 11,000. After the 2nd World War the rate of development of Canberra's city and its suburbs started to accelerate and Canberra's population grew from about 13,000 in 1945 to 150,000 in 1970. It is now nearly 210,000.

Although Canberra is still very much a public service city, it nevertheless contains a healthy and active private sector in the retail, service, building and tourist industries.

The rapid growth in population, which reflected increasing activity of government and business, created a rapidly increasing demand for telecommunications, both customer services and trunk facilities.

At the same time as Parliament House was being constructed in the early 20s, two other major buildings were being built for the Commonwealth Government, nearby. One of these was to house the Treasury and was known as "West Block," and the other, "East Block", was to be office accommodation for other government functions. These three buildings made up the "Parliamentary Triangle". Provision in East Block was made for Canberra's first GPO, as well as a telephone exchange. Both West Block and East Block were completed prior to May 1927.

A 2 000 lines Strowger step-by-step automatic exchange, the first auto exchange to be installed in the Australian Capital Territory, was cut over successfully the week before the official opening of Parliament House on 9th May 1927. This exchange was appropriately named "Central Exchange" it being located at that time, more or less, in the geographical centre of Canberra.

Today Canberra has more than 117,000 telephone customers connected to 12 separate automatic exchanges. Its telecommunication systems serve not only the normal domestic needs but they also play an important role in the USA space programme, "NASA". Nearby to Canberra are three tracking stations: Honeysuckle Creek (Apollo), Tidbinbilla (Mars, Mercury) and Ororral (Sky Lab).

## BLACK MOUNTAIN, CANBERRA

Black Mountain is 813 m above sea level and 250 m above Lake Burley Griffin and is only 3 km from Canberra City. It is one of the five topographic keypoints of the Burley Griffin design of Canberra.

Before the commercial and national TV transmitting stations were constructed in 1962 there was no access road to the summit. Until then the mountain was penetrated only by walkers, botanists and the like. With the building of the access road, Black Mountain became a popular spot for tourists in coaches and private cars, because from the summit excellent views of Canberra and the Brindabella Ranges are available.

The slopes of Black Mountain and surrounding areas are, by Statute, a public nature reserve covering some 521 hectares. At the base of the mountain, fronting Clunies-Ross Drive is the 51 hectares of the National Capital's Botanical Garden, noted for its wide variety of Australian native flora and its manmade rain forest. Apart from being one of Canberra's topographic keypoints, conservationists and environmentalists consider Black Mountain and its nature reserve to be unique both for the species of flora and fauna for which it is habitat and for its large area of natural bushland on the doorstep of the nation's capital city. In view of this, as soon as the possibility of the tower project came to public notice through the media as early as 1970, it was not surprising that it came into question from conservationists and others.

## CONCEPT OF THE TOWER

Recognising the need to co-mast the TV antennae to avoid ghosting with colour transmission, to provide for the explosive growth and future requirements of trunk line demands and to move the radio station from Red Hill, the PMG's Department, conceived the idea of a single multi-purpose tower on the summit of Black Mountain which would not only satisfy the TV and radio-telephone needs but also provide a high-level lookout and dining facilities for visitors. It was that idea which is now a fact of life.

What has been built on Black Mountain is certainly the first of its kind in Australia, but in many overseas countries can be seen communication towers which co-mast TV, FM and radio-telephone antennae, and many of these provide lookout and restaurant facilities for the public. The Canberra tower's height is modest at 195 metres compared with the most recently completed tower, the CN Tower, Toronto, which is the tallest manmade structure in the world. It is 550 metres high and cost $52M to construct.

Not only is the Black Mountain tower a "first of its kind" for Australia, and Telecom Australia, but it is a unique project for Telecom, who have never previously constructed an asset which, on the one hand, is an important communications facility in the broadest sense of the word, while at the same time catering for the tourist public. In fact, the ACT Tourist Advisory Board considers that it will become one of Canberra's major tourist attractions.

The complex nature of the several facilities and the diverse and sometimes conflicting demands have required many original and novel approaches by those involved in bringing the tower into operation. In this regard the resources of Telecom Australia and the Commonwealth Department of Housing and Construction have been used to maximum advantage with the assistance as necessary from others involved in the particular special areas concerned. The various areas housing national and commercial TV transmitters, FM radio, mobile radio telephone, broadband radio bearer and channelling equipment together with the associated support facilities and staff accommodation presented their own particular problems because of the unusual shapes of the areas concerned, the restricted access (particularly vertically) and the special security requirements; these were dealt with, as described in other articles in this Journal, with a minimum of delay and disruption. The end result is an efficient and effective equipment installation.

## SECURITY

The design of the building included the basic security facility which keeps the public and the equipment areas clearly segregated except under conditions of emergency evacuation when the one escape stairway serves all areas.

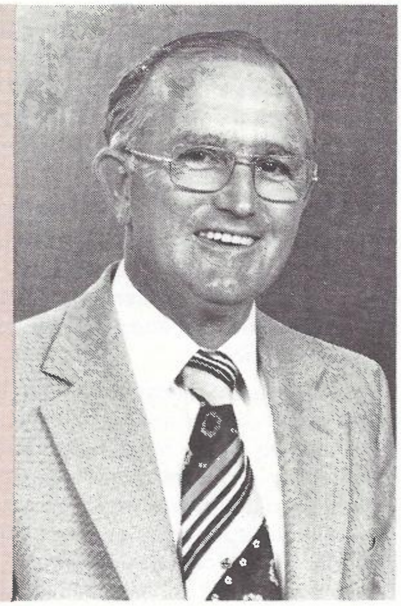
Entry for the public is through the ground floor, whilst Telecom and restaurant concessionaire staff enter and depart via the basement.

A highly sophisticated security system providing door alarms, presence detectors and TV cameras is manned continuously by staff of a security contractor. Access to certain areas and lift control is by magnetic card key only.

## ADMINISTRATION

The technical staff operating the equipment in the tower are under the direct control of the functional services managers and the local District

JIM McCARTHY joined the PMG's Department in 1944 as a Technician-in-Training. He qualified as an Engineer through the "Open" Engineers examination during his early career in the Planning Branch. On promotion as a Divisional Engineer to the Trunk Service Section in 1969 he assumed the duties of NASCOM Liaison Officer involved with all of successful lunar missions and in 1970 was NSW Communications Officer on the Royal Tour. After promotion to Supervising Engineer, Trunk Service he returned to the Planning Branch from where he was selected to manage the newly recreated Buildings Branch in NSW. He is currently Manager, Buildings Branch in NSW and in this position has been responsible for the oversight of the erection of the Black Mountain Tower including the special contractual and lease arrangements involved. A member of the NSW Committee of the Telecommunication Society of Australia for the past 10 years, he is currently the NSW Editor of this Journal.



Telecommunications Manager.

The tower Controller, assisted by rostered duty officers to cover the weekend and holiday periods, controls security and public access, liaises with the contractors for cleaning, security, and operation of the turnstiles, snack bar and restaurant facilities, and represents Telecom Australia on the site.

## PUBLIC FACILITIES

The facilities for the public presented special problems. The public facilities in the tower comprise an entry foyer and turnstiles, passenger lifts, a restaurant with a revolving floor capable of seating 150 patrons, an enclosed viewing platform and souvenir/snack bar, an open viewing platform and an observation platform, whilst in the lower ground floor area special public relations facilities and a theatrette have been included.

Two special visitors' rooms are provided, one on the ground floor for important (generally non-technical) visitors, with another room on the radio-telecommunications floor which will be used only for those visiting the technical areas.

To facilitate the access of the public, a car park has been established on the summit of Black Mountain adjacent to the base of the tower, with facilities for 150 cars and 6 tourist buses. These siteworks were specially designed to complement the tower, to restore the mountaintop ecology to its original state and to provide pleasant attractive facilities for the tourists. Maximum use has been made of natural materials with paving, roadworks, signposting and lighting harmonising with the several thousand native shrubs which were propagated from seeds gathered on the mountain and planted in the parking area. This facility was provided by Telecom and has been handed over to the Department of the Capital Territory for ongoing maintenance.

The ground floor entry foyer contains a model of the tower and public toilet facilities, together with a small display area and stairs leading down to the main public relations and display area. A plaque mounted beside the model commemorates the official opening on 15 May 1980, by the Prime Minister of Australia, The Right Honourable Malcolm Fraser, PC, MP.

The entry turnstiles are token operated, with the sale of tokens and the supervision of the crowd controlled by staff located at a special booth on the ground floor. The turnstiles are controlled by a microprocessor which, amongst other things, produces an hourly revenue check for accounting purposes.

The two passenger lifts serving the public areas are normally unattended but in peak periods can be manually controlled from within the car under magnetic card key operation. The third lift serves the technical staff and the restaurant staff and again is operated under magnetic card key control.

The restaurant (located on the lowest level of the upper drum on the tower) and the snack bar/souvenir shop (located on the middle level of the upper drum) are operated by a private contractor to Telecom Australia. The fitting out of these areas was in accordance with a design commissioned by the contractor and approved by Telecom. The concessionnaire's contract involves Telecom Australia in the management of the facility, which provides high-class restaurant service on one level and light refreshments above. The view from these two levels is magnificent. The restaurant's revolving floor which takes one complete revolution in 83 minutes is an added attraction.

To service the restaurant a large goods storage and bulk preparation area is located in the basement and food from this (some partly prepared) is transported to the restaurant area by means of the service lift. On the restaurant level facilities are provided for the final food preparation and service and a bar is provided for pre-dinner drinks.

## PUBLIC RELATIONS

During the final stages of construction of the tower it was decided to add public relations facilities in the lower ground floor section to provide for organised tours, particularly those of an educational nature.

In this area graphic displays of Telecom Australia's activities throughout Australia, both past and present, have been arranged and a theatrette, capable of division into small viewing rooms, has been provided. Facilities in this area provide for viewing of movie and slide films, videotapes and observation of programmes being relayed through the tower.

With the assistance of television station CTC-7, a number of movies have been produced of the construction and operation of the tower, and in late 1980 production of a film of the technical areas commenced. These films permit a detailed appreciation of the tower to be gained without the need to actually visit the areas concerned. Such visits present security and logistic problems, so they are only arranged for those with a real need.

Off the ground floor area a suite has been provided for the Controller of the tower, including a room for the entertainment of official visitors. This room was dedicated on 16 May 1980, by Mrs Betty Sawkins to the memory of her late husband, Mr Evan Sawkins, MBE, who as Deputy Director-General, PMG's Department,

| | Adults | Children | Group Adults | Group Children |
|---|---|---|---|---|
| MAY 1980 | 21,329 | 7,430 | — | — |
| JUNE 1980 | 35,234 | 8,409 | 15 | 179 |
| JULY 1980 | 27,981 | 6,738 | 383 | 244 |
| AUG. 1980 | 38,153 | 16,981 | 1,596 | 713 |
| SEPT. 1980 | 28,846 | 10,804 | 1,630 | 699 |
| OCT. 1980 | 29,331 | 6,726 | 2,300 | 785 |
| NOV. 1980 | 24,529 | 6,081 | 1,926 | 951 |
| DEC. 1980 | 30,676 | 9,309 | 1,596 | 327 |
| JAN. 1981 | 55,445 | 19,628 | 3,000 | 508 |
| FEB. 1981 | 23,753 | 3,260 | 2,165 | 87 |

**Table 1 — Attendances.**

was most instrumental in gaining acceptance for the tower project as it has now been built.

The "Evan Sawkins Room" contains facilities for TV and film viewing as well as normal VIP entertainment. A smaller, similarly equipped room has been provided on the radio telephone equipment floor to perform the same functions when entertaining visitors whose main interest is in the technical areas.

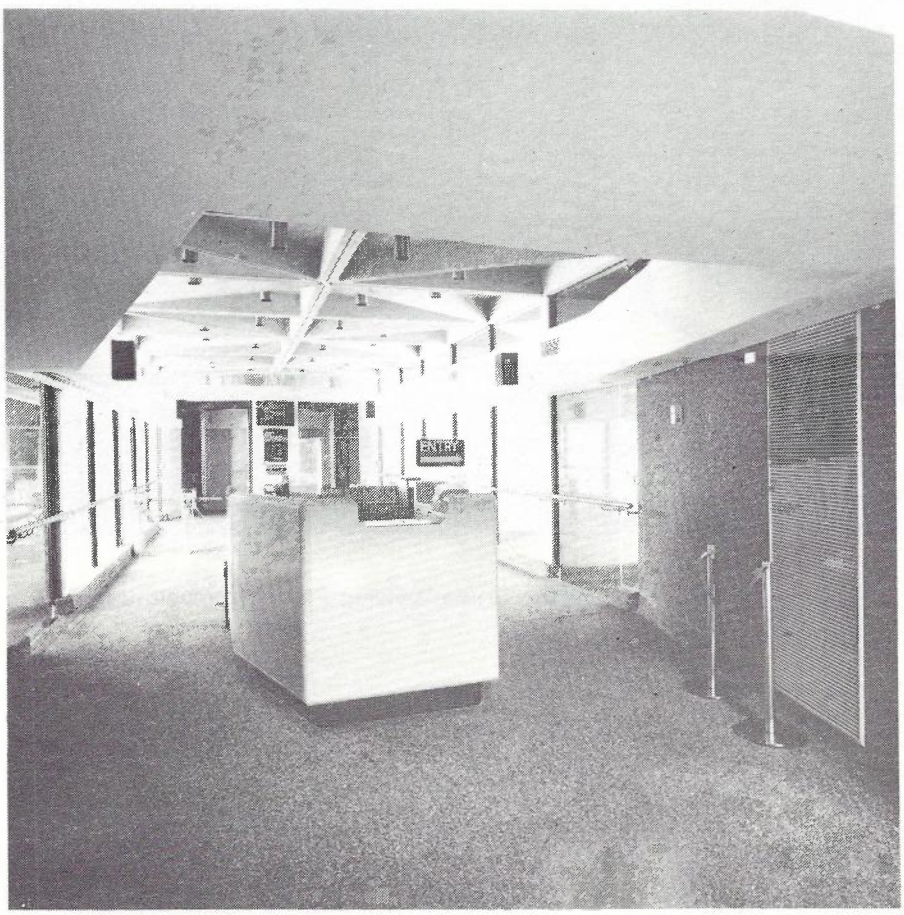
During the first 9 months of operation the popularity of the tower as a tourist attraction and as a place to eat and entertain has been proven by the attendances shown in Table 1.

These figures do not include those who attended during "Operation School Kid" but include those catered for by "Operation Shuttle Bus". The former provided a free visit to the tower during its first three weeks of operation for all schoolchildren in the ACT. This was availed of by 26,000 schoolchildren and 870 school teachers. The latter provided a free shuttle bus service from the Civic Centre to Black Mountain for the first four weekends following the opening, to allow the local population to inspect their tower. This attracted a total of 16,200 adults and 6,000 children, all of whom paid $1 and 20c respectively.

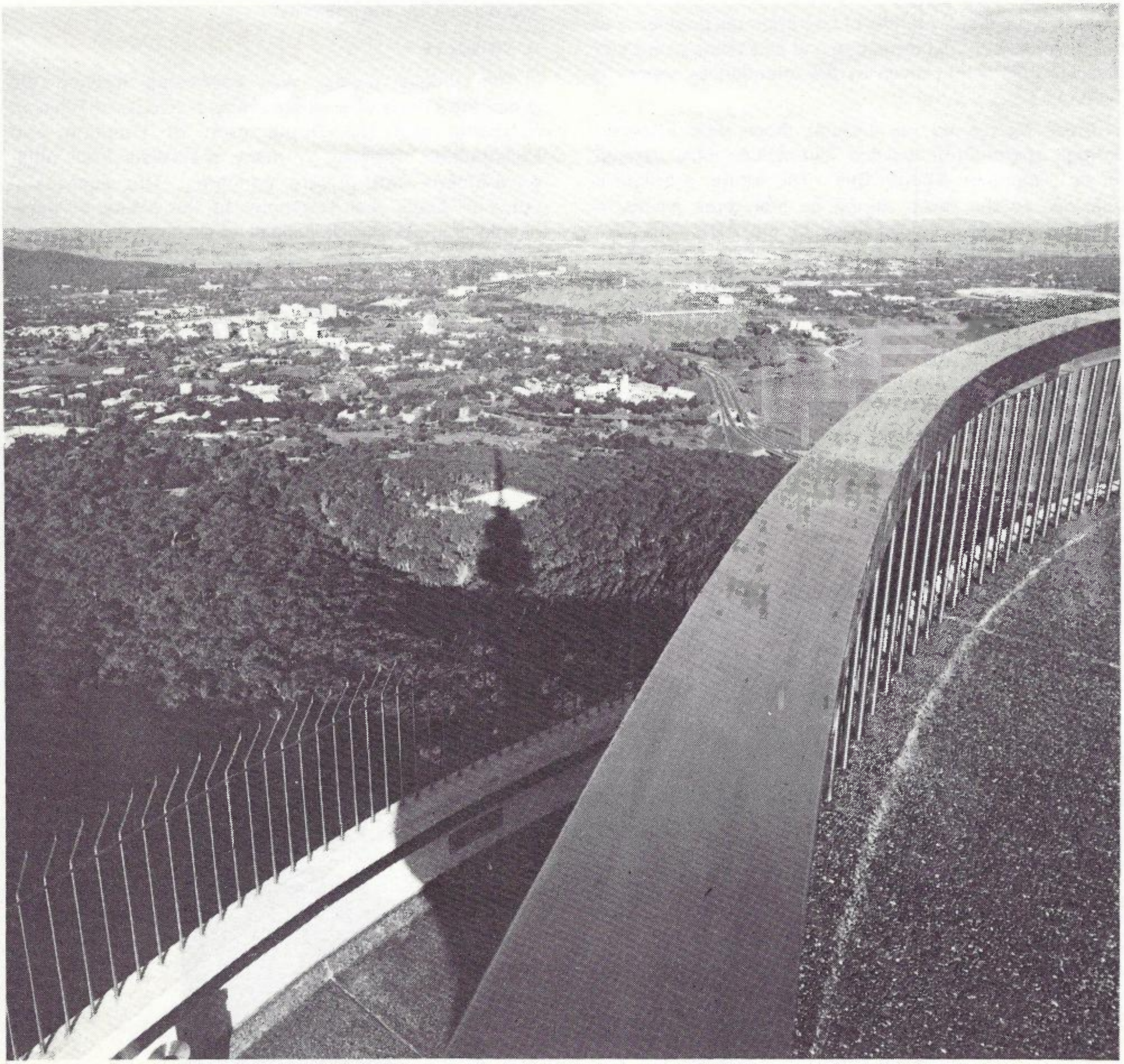
Since its completion and opening to the public the feedback received suggests that although the tower has had some effect on the mountain, the gains exceed the losses and the facilities provided to the public are greatly appreciated by the majority.

**A TRIBUTE**

This unique project was completed through the concerted efforts of a whole range of people in Telecom Australia and the Department of Housing and Construction, assisted by many specialists from other government and private concerns. The successful outcome bears real testimony to the ability of these people to meet the challenges of a unique project with innovative and creative skills often beyond their normal calling. It was only possible through real dedication on the part of all concerned.




**Public Entry to Lifts**



View from Panoramic Platform (Open Viewing Platform Visible Below).

View of Lake Burley Griffin from Panoramic Platform.

# Design and Construction

M. F. COLE

A unique structure designed to house critical electronic equipment and provide public restaurant and viewing facilities on what is basically a tall chimney-like structure required many innovative and novel engineering solutions to the many critical issues involved. This article describes the design and construction issues which were encountered in achieving completion.

The Telecommunications Tower recently completed on Black Mountain in the Australian Capital Territory is an unusual structure with a unique history.

The functional and aesthetic requirements for the 195m tower demanded sophisticated design solutions for both the structure and the servicing of the complex, and its location in the attractive Black Mountain bushland setting required sympathetic treatment in both design and construction.

This paper provides a coverage of the architecture and engineering of the project in design and construction with emphasis on building and structural aspects.

## BACKGROUND AND HISTORY

Early in 1970 the Australian Post Office asked the Department of Works to undertake a feasibility study for a Tower on Black Mountain and following initial briefing, a joint overseas study of similar telecommunications and tourist facilities was undertaken.

The early design studies carried out in 1970 led to preferred design schemes similar in form to the present Tower. During 1971 there was considerable official debate and disagreement on matters of design and siting. Some disagreements with the National Capital Development Commission (NCDC) were unresolved and they maintained their opposition to the project because of concern they had about the dominance of the tower and its visual impact on Black Mountain and the central area of the City. By mid 1972 the proposal had been reviewed by the Parliamentary Standing Committee on Public Works who recommended that the project should proceed with full tourist facilities.

The main contract was arranged in five stages to provide for progressive occupancy and installation of equipment by Telecom; the first stage was completed in November 1976 and the final stage in March 1979. This process enabled Telecom to achieve the transfer of TV broadcasting to the new Tower for the Australian Broadcasting Commission (ABC) in December 1977 and for the local commercial station CTC-7 in December 1978; radio telephone transmissions went on line in October 1978.

Towards the end of the main contract additional contracts were arranged for security, demolition of existing facilities, siteworks and landscaping, together with the provision of some additional facilities for the public and the fit-out of the restaurant and other areas to be utilised by the consessionaire.

The project was formally opened by the Prime Minister Malcolm Fraser on 15 May 1980.

## THE SITE AND ENVIRONMENT

The site, located on the summit of Black Mountain some 250m above Lake Burley Griffin, and 813m above sea level has a commanding view of Canberra City and the surrounding areas. One needs to have spent only a very short time in Canberra to appreciate the quality of the Black Mountain site in terms of both its location within a magnificent parkland and its visual prominence within the central area of Canberra.

In terms of the Griffin Plan, the formal framework within which the inner areas of Canberra have been developed, Black Mountain lies at the north-west end of the water-axis through Lake Burley Griffin and is therefore a particularly significant element in the basic design of the central area of the city and the Parliamentary Triangle. The location of any significant structure on such a prominent point was therefore bound to attract the closest scrutiny and controversy.

Black Mountain is a gazetted public park of about 520 hectares managed and used as a nature reserve of considerable scientific interest; it is highly regarded by local residents and is of immense value to the Canberra community.

The design and construction of the Tower had, therefore, two very important factors to take into account:

- a site with highly critical design and siting demands
- a delicate physical environment requiring special care and attention in design detail and construction

Planning aimed to contain all new development to areas already disturbed by previous development on the summit, a total area of about 2 hectares. The need to retain existing TV transmission facilities in service during construction of the new Tower also placed real constraints on the design and construction of the building.

## FUNCTION

The purpose of the Tower is to centralise on one structure in Canberra relay and broadcast facilities for a number of essential communication services, including radio-telephony, television, FM radio, radio paging and mobile radio telephone.

The Tower also provides facilities for visitors by way of viewing and lookout galleries and a public restaurant.

## DESIGN OF A TOWER

### General

The design concept was for a slim unobtrusive and economic structure having the necessary structural rigidity and providing for all accommodation required on the shaft. Many alternative design forms were considered and the architects produced almost 200 outline sketch proposals in the early stages of developing the preferred design solution.

Once the fundamental decisions had been taken on siting and construction materials, the functional requirements largely determined the structural form. The height of the Tower was determined by minimum space and elevation requirements for TV and FM broadcasting antennae. The level and diameter of accommodation for radio-telephony was determined by minimum ground clearances and the number of large dish antennae to be accommodated.

Concrete rather than steel construction was chosen for the main structures after consideration of alternatives, having regard to functional, aesthetic and economic factors; costing of alternatives had shown only marginal differences between comparable schemes and concrete was considered to offer far superior functional and aesthetic qualities. The concrete provides a maintenance free and aesthetically satisfactory finish, and its extensive use throughout the complex provides essential fire resistant construction.

### Building Arrangement

The building complex comprises:

- the Tower structure itself with its two supported drum structures (the public drum and the radio telephone drum), several service platforms, and the steel antenna column mounted on top of the concrete shaft
- the podium building at the base of the Tower
- the public entry building
- the pedestrian access bridge

The steel antenna column and the upper section of the concrete shaft are to carry antennae for TV and FM broadcasting and mobile telephone services.

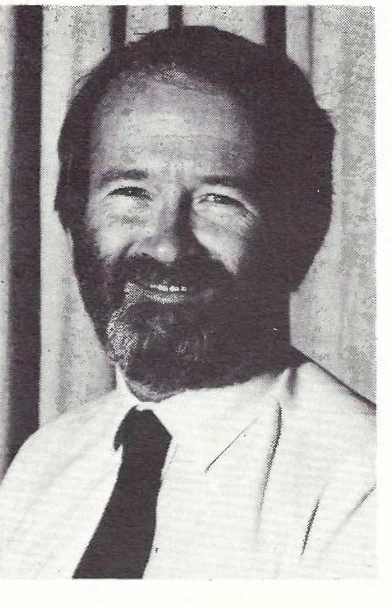
The lower drum, the RT drum, supports externally around its perimeter the large parabolic dish antennae for radio telephone transmissions and houses Telecom technical equipment and services. The upper drum, the public drum, incorporates viewing and dining facilities for the public.

The two concrete platforms above the public drum will support future RT antennae.

The public entry at ground floor level on the roof of the podium provides amenities for the public and access for visitors to the Tower. The two storey podium accommodates TV transmitters, sound broadcasting facilities, engineering services and essential car parking, together with some additional public facilities and an all weather access for visitors.

The Tower shaft itself provides vertical circulation for personnel and for the public, for communications feeder cables, and for engineering services. There are three lifts, two passenger and one service lift, serving levels up to the enclosed viewing gallery in the public drum.

MERVYN COLE commenced his career with the Dept. of Works in Perth as a cadet engineer in 1961. He graduated as a Bachelor of Civil Engineering at the University of Western Australia in 1964 and as a Master of Engineering Science from the University of Melbourne in 1969. After five years in the Melbourne headquarters of that Department engaged on structural design and investigation he transferred to the ACT Region at Canberra. From 1972 to 1975 he was project manager of the Black Mountain Tower project and from then until completion he has been involved in various capacities with this project. Mr Cole is currently Acting Assistant Director in the ACT Region of the Commonwealth Department of Housing and Construction.



## CONSTRUCTION DETAILS

| | |
|---|---|
| **MAIN FOOTING** | |
| Outer Diameter | — 20.9 m |
| Inner Diameter | — 7.2 m |
| Total Depth | — 3.28 m |
| Steel Reinforcement | — 112 t |
| Concrete Volume | — 630 $m^3$ |
| **TOWER SHAFT** | |
| Base Diameter | — 13.1 m |
| Top Diameter | — 3.9 m |
| Wall Thickness | — .65 m |
| Steel Reinforcement | — 335 t |
| Concrete Volume | — 1930 $m^3$ |
| Shaft Height | — 142.3 m |
| **STEEL ANTENNA COLUMN** | |
| Steel Members | — 90.0 t |
| Column Height | — 63.1 m |
| **PODIUM** | |
| Two levels each | 59.7 m x 40.0 m |
| Public entry lobby | — 10.3 m dia. |
| **EQUIPMENT FLOORS** | |
| 3 levels average diameter | — 27.56 m |
| Total Volume | — 12690.49 $m^3$ |
| **PUBLIC FLOORS** | |
| 3 levels average diameter | — 27.89 m |
| Total Volume | — 8446.43 $m^3$ |

Architects and Engineers:
Department of Construction:
Prime Building Contractor:
Concrete Constructions (Canberra) Pty. Ltd.

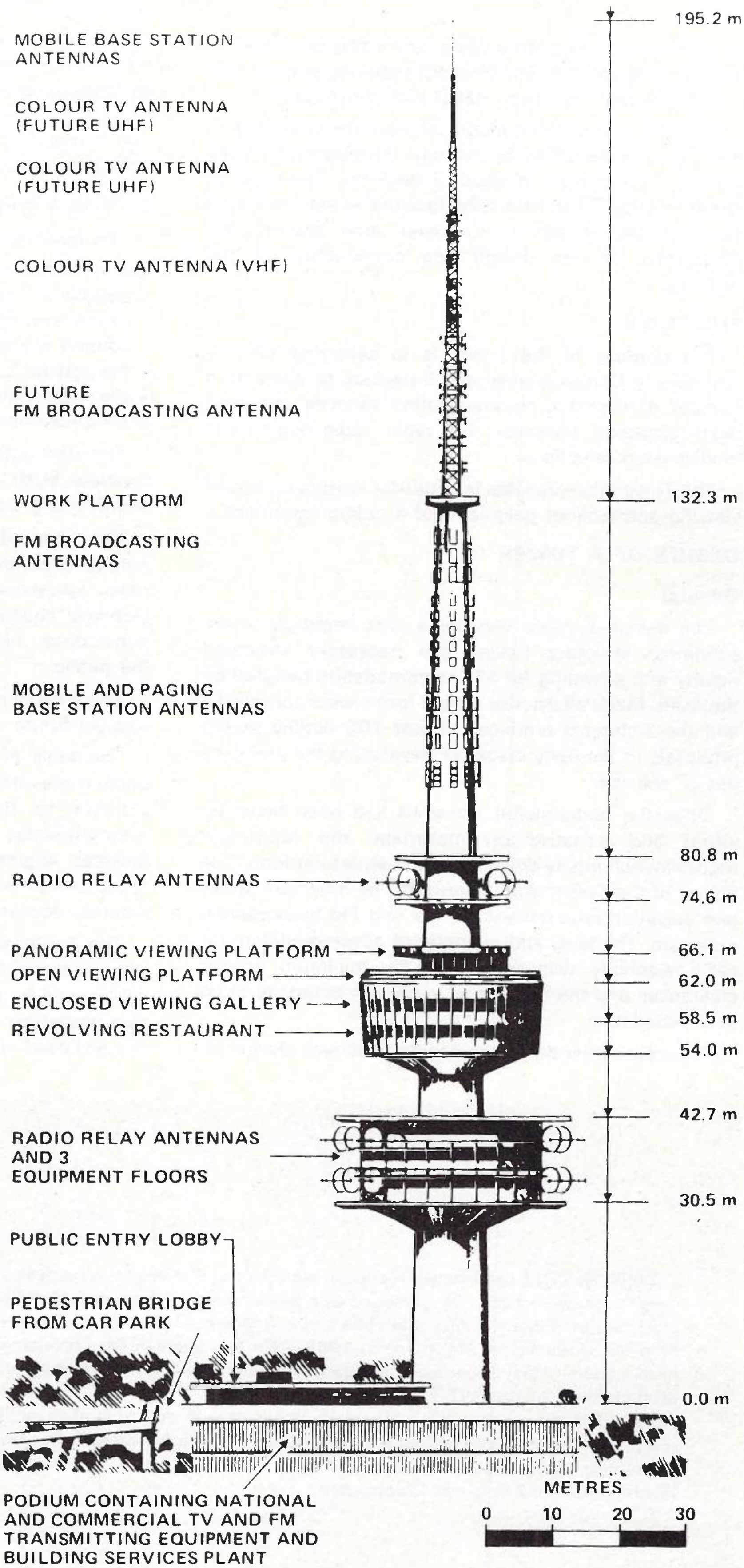



**Fig. 1 — Elevation of the Tower**

**Principal Structure Elements (See Fig. 1).**

#### The Tower Shaft

Over its 147 m height above the base the reinforced concrete shaft tapers in both diameter and thickness; at the base the outside diameter is 12.06 m and the thickness 0.62 m, at the top 3.96 m in diameter with a thickness of 0.3 m. The shaft profile is in the form of linear tapers in both dimensions, with an increase in the rates of taper occurring at about mid-height.

Inside the shaft the 150 mm vertical concrete walls separate and isolate the lift shafts, the emergency stairway, and a number of service risers; See **Fig. 2.**

#### The Tower Base

The base is a reinforced concrete gravity annular footing some 19.5 m in overall diameter, 6.7 m wide and of varying thickness tapering from a maximum of 3.05 m beneath the shaft.

#### The Radio-Telephone and Public Drums

The superstructure of these building masses (or drums) supported on the tower is generally of traditional reinforced concrete construction; beam and slab for suspended floors and, for the RT drum levels, in-situ columns and external walls. The overall diameter of both drums is about 26.2 m. A special precast concrete load bearing facade was used for the public drum because of the functional and aesthetic requirements for viewing from these levels; this slim and elegant facade was given a slight outward slope of 4 degrees from the vertical for the improved viewing characteristics and external appearance.

For each drum a reinforced concrete conical shell, keyed to the main shaft, is the primary structural element for transfer of vertical loads. These shells taper in thickness from 300 mm at the outer perimeter to 375mm at the junction with the shaft. Each shell is closed at the top by a 300 mm flat slab which completes a very stiff and strong shell/slab unit.

At both top and bottom levels on the RT drum, 24 radial concrete beams cantilever out beyond the column lines and are tied together at their outer ends by circumferential beams. These levels of radial and circumferential beams have overall diameters of 33.5 m and are to support the large RT dish antennae fixed to a secondary system of circumferential steel beams.

#### The Antenna Column

From the top of the concrete shaft at a height of 132m above ground floor level the steel antenna column rises a further 63 m to an overall height of 195.2 m. This square lattice mast is built up in four segments designed to accommodate antennae for eight TV channels (two per segment); the leg-to-leg dimensions of each segment were determined by the optimum spacing requirements of the TV antennae to be accommodated. For a mast of this height the leg-to-leg dimensions were minimal resulting in high structural loads and heavy leg members. The structural requirements were such that special arrangements had to be made to achieve a satisfactory connection between the mast and the shaft.

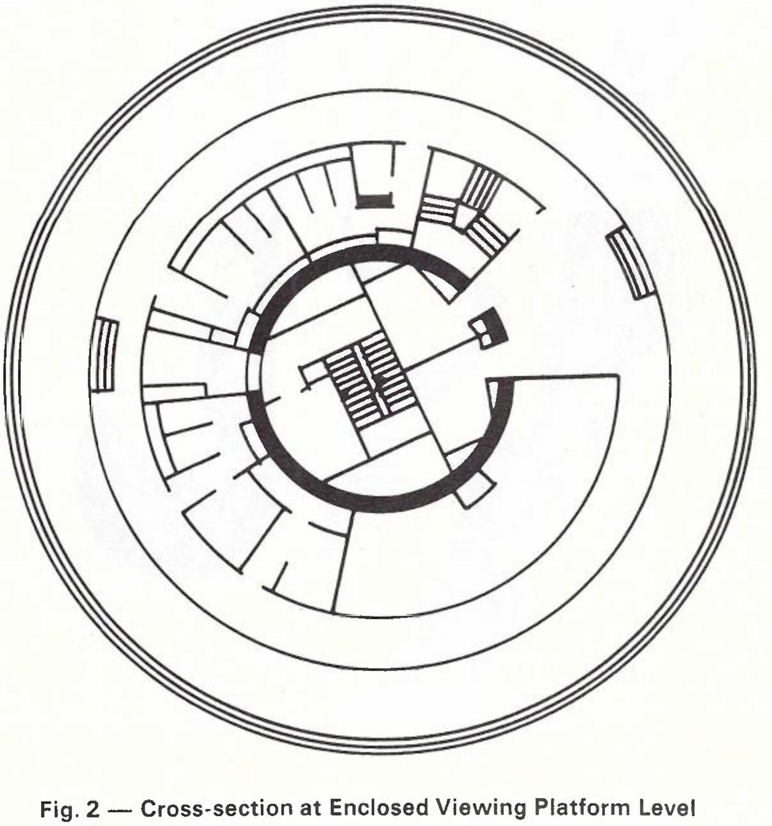


Fig. 2 — **Cross-section at Enclosed Viewing Platform Level**

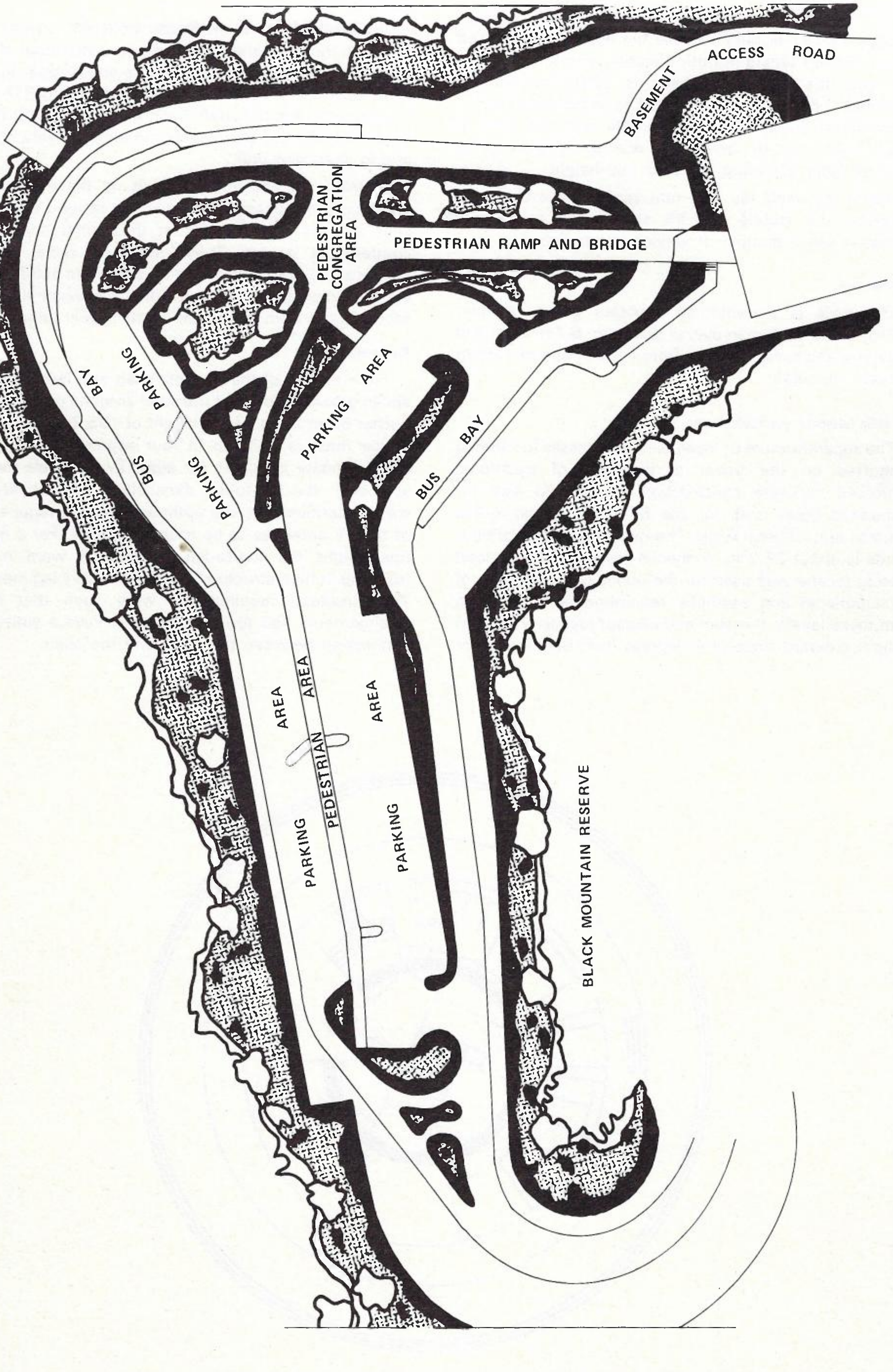



Fig. 3 — Summit Loop Road and Carparking

## Engineering Services

The Tower is a highly serviced building because of its technical and public functions and, with the particular form of the building and its location, the design of engineering services has incorporated a number of unusual and interesting features. Included are mechanical and electrical services, lifts, fire protection services, a revolving floor and window cleaning gantry, security services, building earth and lightning protection, hydraulic services.

## Siteworks and Landscaping

Once the National and Commercial TV broadcasting had been transferred to the new Tower, the previous TV masts, buildings and services on the summit were demolished to make way for a new loop roadway and parking for 150 cars and 6 buses. **(Fig. 3).**

Designs for the loop road, carparking and associated landscaping were given careful consideration from the outset and the concepts were developed in close consultation with the local planning and management authorities, the National Capital Development Commission and the Department of the Capital Territory.

The bushland nature of the immediate environment has been kept foremost in mind and landscaping has involved general rehabilitation of the area with exclusive use of endemic planting.

# STRUCTURAL DESIGN

## General Consideration

Due to the proportions and siting of the structure, wind loading was a primary design factor and required careful consideration by designers.

As the Tower is not particularly tall (when compared with a number of similar overseas towers and tall chimneys) together with the fact that the bulk of the supported building mass is on the lower part of the shaft, it was assessed that the structure, as a whole, would not be highly sensitive to wind gust fluctuations. There was, however, some concern about the likely response of the slender steel mast to wind effects and the magnitude of forces to be transmitted to the top of the concrete shaft. Telecom had set tight deflection limits and, among other requirements, had specified a maximum allowable rotation of only one degree at the top antenna level on the mast when subjected to a wind of 96 km/h (60 mph) at ground level.

## Meteorological Investigation and Dynamic Analysis

In anticipation of the need for some form of dynamic analysis, three wind anemometers had been installed on the then existing ABC-3 television mast and by the time it was required some 7 months of continuous wind record had been collected; although extremely limited in duration this data was of value in the meteorological study undertaken.

Preliminary calculations had shown that a whiplash effect of the steel mast could be significant, and Professor Vickery of the University of Sydney was therefore commissioned to undertake a theoretical study of wind effects on the proposed structure. The commission included a meteorological study to determine wind speed profiles and turbulance levels at the site using the limited site data and long term records from nearby meteorological stations, (Canberra Airport and Wagga) the estimation of a design speed corresponding to a return period of 100 years, and a dynamic analysis of the Tower.

The dynamic analysis confirmed acceptable performance of the proposed structure and acceptable design loads at the connection between the steel mast and the concrete shaft. Mean and peak deflections predicted by this analysis for return periods of one year and one hundred years, to an order of accuracy of ± 25%, are given in **Table 1.**

## Design Approach for Wind Load

For the actual design and detailing of the Tower structure a working load method using a quasi-static approach was adopted in designing for wind load. A 100 year return period was used in the assessment of design wind velocities which yielded a velocity profile varying from 170 km/h (106 mph) to 238 km/h (148 mph) over the height of the Tower. To ensure sufficient reserve in ultimate strength, the Tower shaft was also checked and designed to withstand, with a load factor of 1, an extreme event taken as a wind load equal to twice that for the 100 year return period wind (on the basis of the available data such a wind loading would have a theoretical return period of once in 5000 years).

## Seismic Analysis

Since the Black Mountain site is located in a region subject to minor seismicity, an important phase in the design process was to ensure that the Tower structure would perform satisfactorily if a significant seismic event were to occur. The analysis was in two parts:

| Height | 1 Year Return Period | | 100 Year Return Period | |
|---|---|---|---|---|
| | Mean | Peak | Mean | Peak |
| 132.3 m — Top of concrete shaft | 61 mm (0.20 ft.) | 98 mm (0.32 ft.) | 195 mm (0.64 ft.) | 335 mm (1.10 ft.) |
| 192 m — Top section of lattice mast | 271 mm (0.89 ft.) | 393 mm (1.29 ft.) | 853 mm (2.8 ft.) | 1320 mm (4.33 ft.) |

**Table 1 — Mean and Peak Deflections**

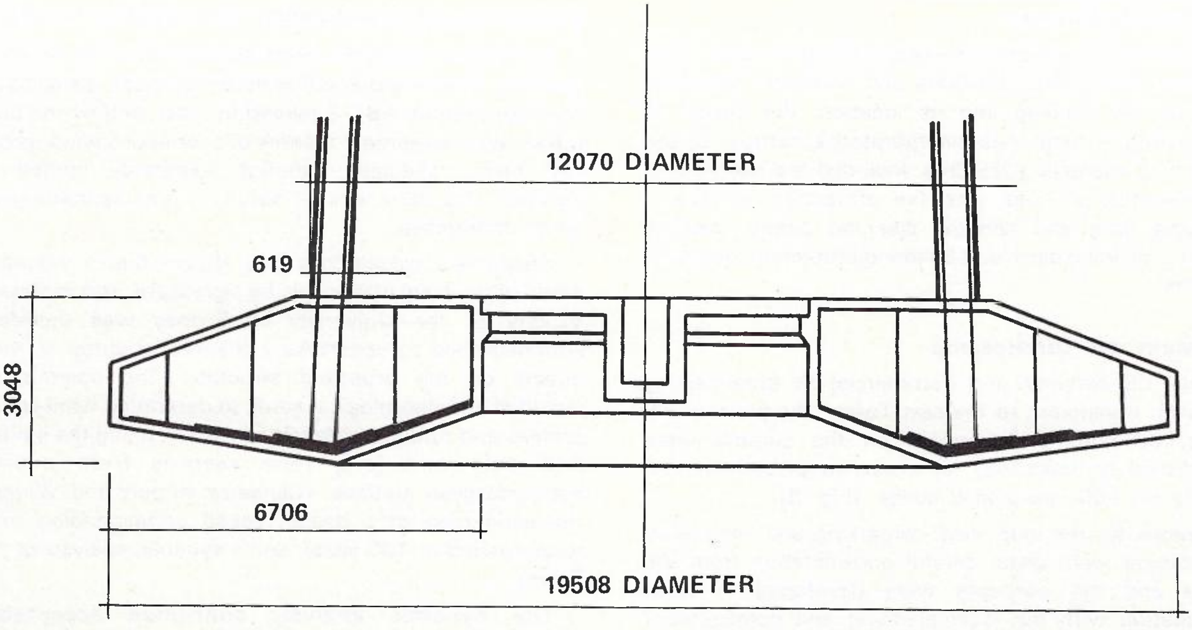



**Fig. 4 — Section through Tower Base**

- an assessment of the seismicity of the region leading to an estimation of maximum ground motions and a selection of appropriately scaled earthquake events for use in the dynamic analysis, and
- evaluation of the response of the proposed Tower structure to simulated earthquake motions.

The structure was modelled using a lump-mass representation (up to 36 elements) and analysed using an available Departmental computer program. The analysis indicated generally acceptable stress levels in the structure with significant yielding confined to the uppermost portion on the steel antenna column. Such yielding was considered to be acceptable on the basis that the steel used would have appreciable ductility and in any event only a few yielding cycles would be expected.

### Foundation Design

Late in 1972 a detailed investigation of foundation conditions was undertaken by a firm of specialist consulting engineers; field work included diamond boreholes and trenching.

The mountain is part of the Black Mountain Horst and is made up of the Black Mountain Sandstone group of rocks. The rock encountered within the building area was classified into three main types — sandstone, quartzite and siltstone — with the differences being to some extent gradational, occurring in a layered sequence; the rock mass was variably weathered, jointed and contained clay seams.

The foundation conditions were assessed as quite satisfactory for the founding loads anticipated from the Tower.

The form of the gravity annular reinforced concrete footing, illustrated in **Fig. 4** was selected for reasons of structural efficiency and economy. This type of base has been used on other major overseas towers and is considered to provide better distribution of bearing pressures and greater stability in the long term when compared with a more traditional disc foundation. The footing was sized to contain bearing pressures on the rock within acceptable limits and the cross-section dimensioned and reinforced to accommodate bending, shear, torsion and hoop stresses.

The design foundation bearing pressures were approximately:

- 480 kPa — for vertical loading only
- 815 kPa — for vertical loading plus wind design loading (for 100 year wind)
- 1240 kPa — for vertical loading plus wind ultimate loading (= 2 x design loading)

### Tower Shaft

Unlike that for a concrete chimney the design of the concrete shaft was complicated by the architect's desire for a slender tapering section, by the very heavy superimposed loads from the drums, the service platforms and the antenna column, and by the numerous openings and penetrations required in the shaft for access and services.

While structural considerations largely determined the dimensions of the shaft it was necessary at one stage late in the design process to increase the shaft diameter by 150 mm at the level of the public drum in order to accommodate the operating gear for the uppermost lift doors.

Design stress levels in the shaft are generally high and particularly so in areas of localised stress concentration, e.g. at the top and bottom of the shaft, at all junctions with structures supported on the shaft, and at all significant openings and penetrations. At the junction between the shaft and the conical shell supporting the RT drum the shaft had to be locally thickened by some 610 mm, or more than twice its thickness, around its full circumference and over a height of about 3.3 m, in order to resist the very heavy thrusts imposed by the shell.

As it turned out the design provided for a uniform area or constant number of bars (216 No. 20 mm diameter) of primary vertical reinforcement over the full height of the shaft. Additional vertical and horizontal reinforcement was added where required to cope with local stress conditions generated at the top and bottom of the shaft, at junctions with supported structures, and at openings and penetrations. Horizontal hoop reinforcement was required in the shaft wall to resist stresses due to shear loads, wind pressure moments, temperature effects, and to support and restrain the vertical reinforcement.

The dimensions and forces involved in the design of the junction between the steel antenna column and the top of the concrete shaft precluded a direct connection between the two. In the chosen design approach the bottom of the steel mast was socketed into the top of the concrete shaft and this permitted transfer of bending moment and shear loads from the antenna column to the shaft as horizontal loads through two levels of bearings 4.6 m apart. **(See Fig. 5).**

The design forces in this coupled connection are substantial and involved a maximum mast leg force of 7560 kN, a horizontal shear force of 4450 kN in the bottom section of the mast within the shaft, and individual bearing loads of up to 2670kN. Elaborate sliding bearings at the top and bottom of the connection transfer the horizontal forces from mast to shaft and accommodate significant vertical movements designed to occur between the steel and concrete sections.

The internal structure to the Tower shaft comprises 150 mm reinforced concrete vertical walls rising to a height of 88 m above the Tower footing, enclosing the three lift shafts, the emergency stairway, and ducts for Telecom cables and engineering services. The emergency stairway consists of precast concrete treads on steel stringers with concrete landings cast-in-site on steel decking. Above the lift motor rooms the internal structures are a steel access ladder and a cable runway grid supported on steel beams.

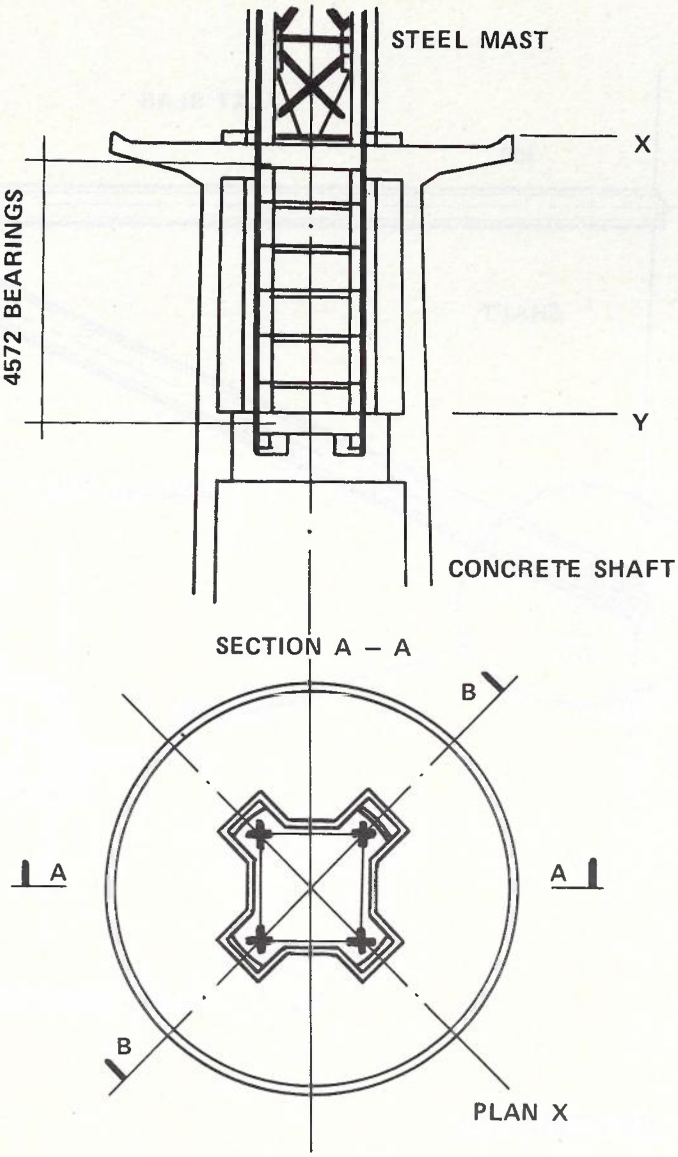



**Fig. 5 — Top of Shaft to Mast Connection**

### RT and Public Drums

The structural systems used in the two drums have already been briefly outlined, and the most interesting and critical structural feature in their design was the use of a flat conical shell to provide the primary means of vertical support for the building mass of each drum. **Fig. 6** represents a section through one half of the shell and illustrates the simple and elegant system as used in the RT drum. The shell at an angle of 66 degrees to the shaft axis combined with the flat slab above forms a very strong and stiff structural unit to carry the heavy loads from the floors above.

The structural action of the shell/slab unit involves membrane stresses of hoop (circumferential) and radial tension in the slab and hoop tension and radial compression in the conical shell. Radial and circumferential bending moments act in both elements due to self weight and other loads applied to them.

In order to control the tensile membrane stresses in the concrete the shell/slab unit was post-tensioned using circumferential prestressing cables cast into the ring beam at the junction between the shell and the slab. The eight BBR cables used in the RT drum gave an effective prestress of about 700 tonnes designed to limit the membrane stress to a low 1.38 MPa with the aim of eliminating cracking due to direct stress. By applying the prestress with an eccentricity below the mid plane of the slab it was also possible to further reduce tensile hoop and bending stresses in the cone.

The critical load transferring connection between the conical shell and the Tower shaft has been designed as a simple 'pin-joint', with soft packing to reduce the effective width of bearing area between shell and shaft. The shell penetrates into a shallow keyway formed in the shaft with the interface stepped for more direct transfer of the thrust and slightly eccentric to give a more uniform distribution of bearing stress.

The inner edge of the flat slab is recessed into the shaft and is simply supported on a narrow ledge.

The same form of structural system has been used for both drums and also for the two service platforms above the public drum; a common shell slope was chosen to permit reuse of formwork in construction.

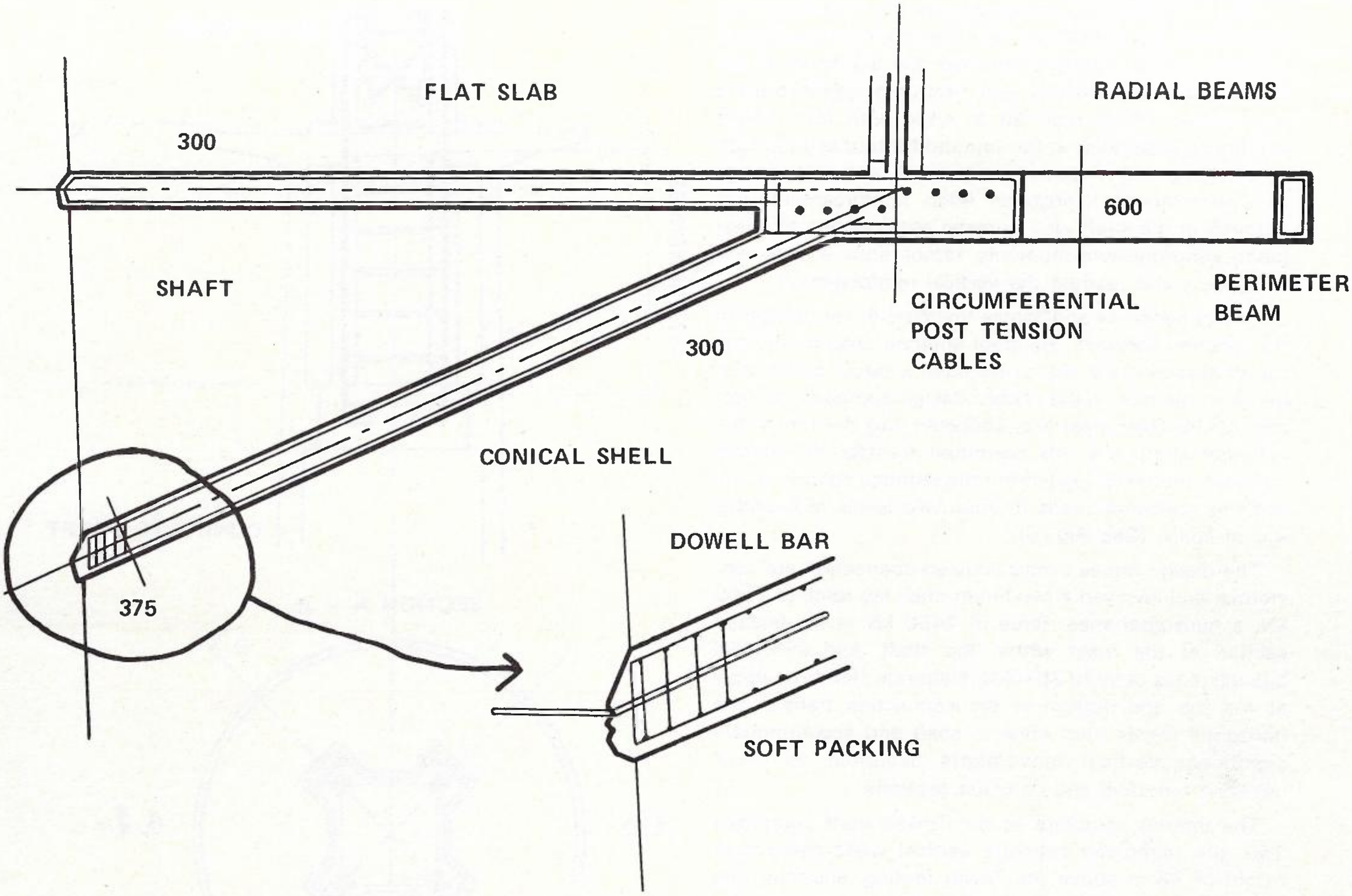



**Fig. 6 — Conical Shell/Slab Structure to RT Drum**

## CONSTRUCTION

### General

In January 1973 tenders were invited from four selected firms on the basis of provisional documents. The tenders were for a lump sum contract subject to variation based on the future adjustment of provisional quantities and provisional sums with the progressive development and issue of detailed working drawings. The work was to be completed in five stages to allow for the progressive installation of technical equipment by Telecom.

### Foundation Construction

The excavation for the podium and the Tower base, which was cut into a ridge just below the summit of Black Mountain, involved heavy ripping and blasting in rock and removal of some 9000 m³ of soil and rock from the mountain. The large pit for the Tower footing was carefully trimmed and cleaned back to sound rock material before placing 126 m³ of blinding concrete to make up levels and form the required profile for the footing.

The steel reinforcing cage for the Tower footing (**Fig. 7**), incorporating 90 tonnes of primary reinforcement, was an impressive sight when completed prior to the placement of concrete; the central opening in the annular footing was formed by means of a large cylindrical timber form supported on a residual rock knoll. A 27.5 MPa concrete with a low heat cement was used and the 630 m³ of concrete was placed in one continuous operation. The concrete was transported to the site in a fleet of ready mixed concrete trucks and placed over 13 hours using chutes and cranes.

Well before concreting the main footing, there had been concern about the possible effects of temperature build up in the concrete because of the size and thickness of the footing and the considerable amount of heat that would be released by hydration of the cement. High temperature differentials within the footing would result in significant thermal stresses within the concrete which could have lead to cracking. Significant structural cracking could have been a problem in regard to the long term durability of the foundation.

The literature was inconclusive about what might be critical levels of temperature build up, or more importantly temperature differentials, within such a mass of concrete. In collaboration with the CSIRO a network of thermocouples was therefore installed to monitor the build up of concrete temperature within the footing during the early days after casting. Measured temperatures in the centre of the thickest section climbed to a surprising 47°C during the fifth day after casting with the temperature differential between the centre and top

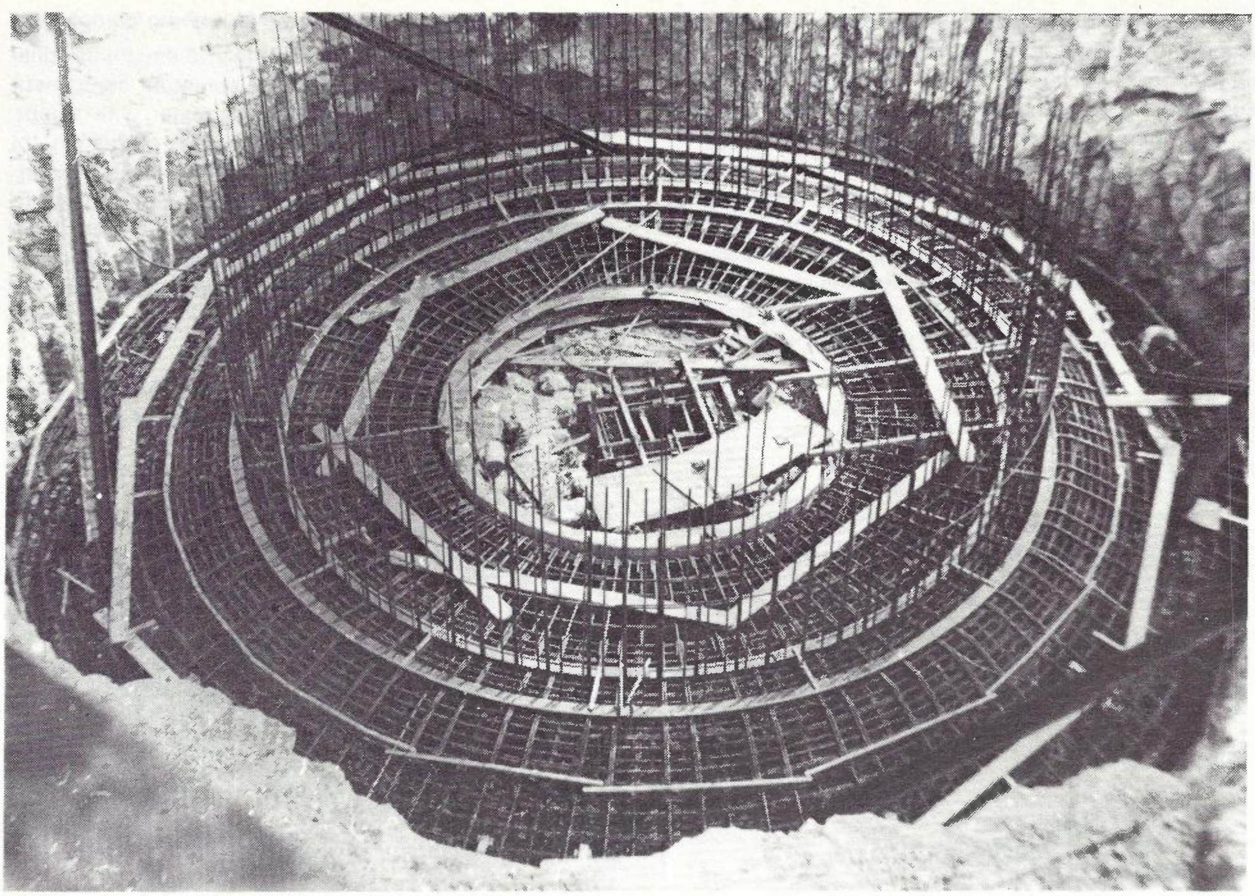


Fig. 7 — Steel Reinforcing Cage for Tower Base

surface reaching a maximum of 25°C. Cracking would have been more likely in the upper part of the footing where temperature differentials were greater, however careful inspection of the top surface many weeks after placement revealed no detectable cracking.

Before any concrete was placed in the Tower excavation four vertical copper electrodes were installed in cored holes to a depth of 24 m and grouted in bentonite slurry. They were the first of the vertical elements in the station earth network which is described in greater detail in an accompanying paper.

**Concrete Surface Finishes**

Considerable emphasis was placed on the achievement of high quality off-form finishes to all exposed concrete surfaces for the Tower shaft, the RT and public drums, the service platforms and the public entry building; an off-white cement and Class 2 formwork/Type B colour control, to the requirements of the Australian Standard AS CA72, were specified.

For the off-white concrete used extensively throughout the building the contractor selected Brightonlite cement and, with a minimum cement content of 356 kg/m³, readily obtained the required characteristic strength of 34.5 MPa. High standards of surface finish were achieved by use of appropriate construction techniques.

**Reinforced Concrete Shaft**

Despite the complexities associated with the many internally and externally supported structural elements, nowhere did cast-in reinforcement project from either the inner or outer surfaces of the shaft; this greatly facilitated the forming operation.

Because of the complex shaft design, tight tolerances, and the high quality surface finishes required, the contractor developed a sophisticated custom designed climbing formwork system. Steel gang forms were used to cast the shaft in 2.44 m (8 ft.) lifts and casting surfaces were protected with an epoxy treatment; the outside forms were insulated to permit the shortest possible stripping time even in cold weather (about 16 hours was typical at lower levels).

The basic elements of the climbing formwork system are illustrated in **Fig. 8,** and comprised:

- a telescoping support tower incorporating a large hydraulic ram to raise the tower,
- two heavy beams at right angles to support the base of the tower and hung from the inside of the shaft on brackets bolted to anchors cast into each concrete lift,
- the main support truss spanning across the shaft to support the system during the lifting operation via jacks onto the top of the new concrete shaft
- a spider truss at the top of the system from which hung the gang forms and work platforms via hangers and chain blocks
- internal and external gang forms with associated work platforms

After the concreting of each lift the climbing operation proceeded by taking up the weight of the system on the main support truss via jacks onto the top of the shaft wall once the young concrete had achieved sufficient strength. The telescoping tower was then retracted to lift the base of the tower and main support beams for fixing into the next concrete lift and, after releasing the external forms, extended to lift this form into place for the new lift. Reinforcement was then fixed in place, with all inserts, blockout etc. and the inner form finally lifted into position, with chain blocks, in readiness for concreting of the lift. **Fig. 9** shows the construction of the Tower shaft at an early stage while **Fig. 10** shows it nearing completion.

The steel forms were an assembly of small individual panels each with the capability of curvature adjustment to provide for the reducing shaft diameter with height. The shaft taper was obtained using a system of alternating rectangular and trapezoidal panels for both inner and outer forms each assembled in three gangs to facilitate the climbing process. Successive reductions in shaft diameter could be accommodated in timber make-up panels between gangs and by progressively reducing the number of individual panels.

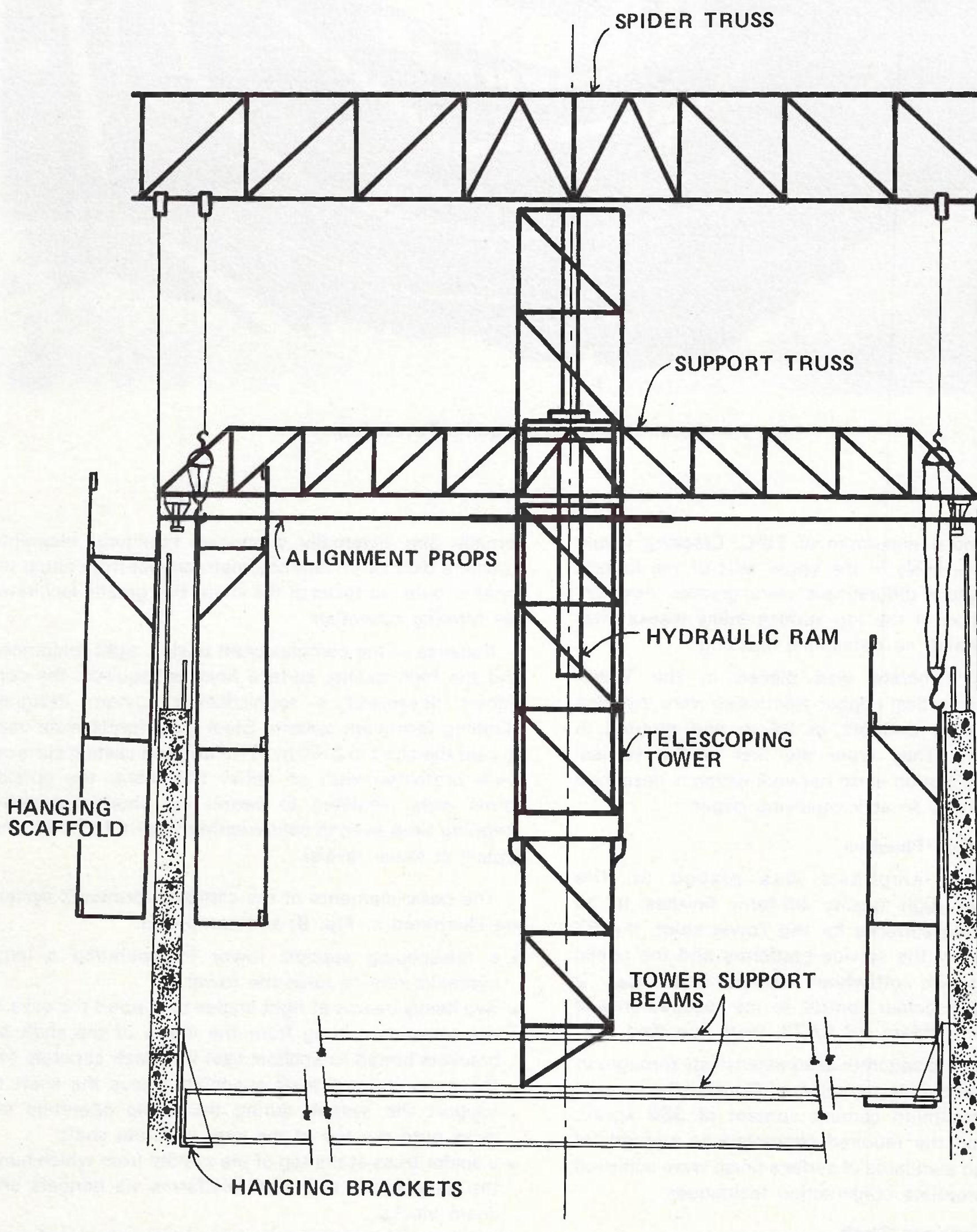



**Fig. 8 — Climbing Formwork System for Construction of Tower Shaft**

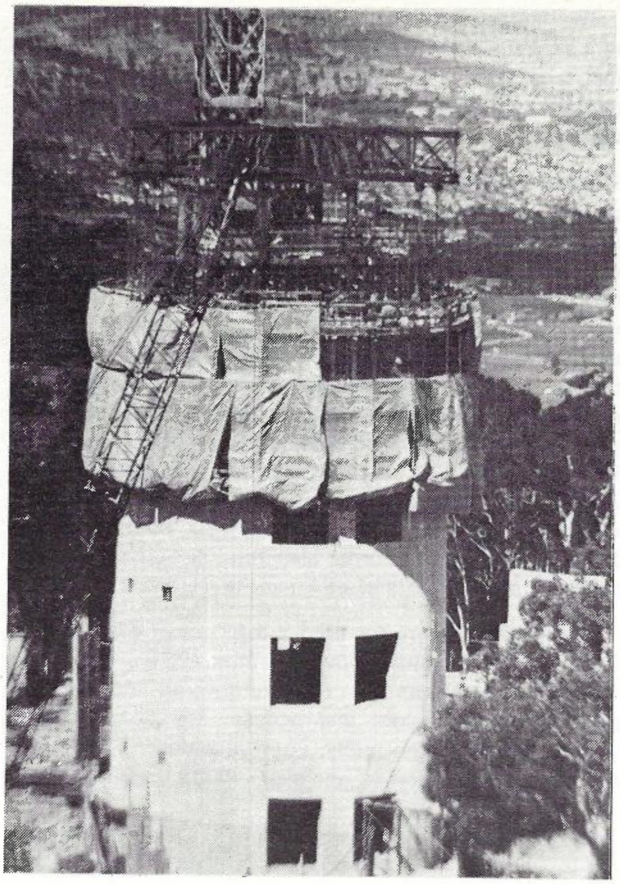


Fig. 9 — Construction of the Tower Shaft

Fig. 10 — Construction with Shaft Nearing Completion and Drums Well Advanced

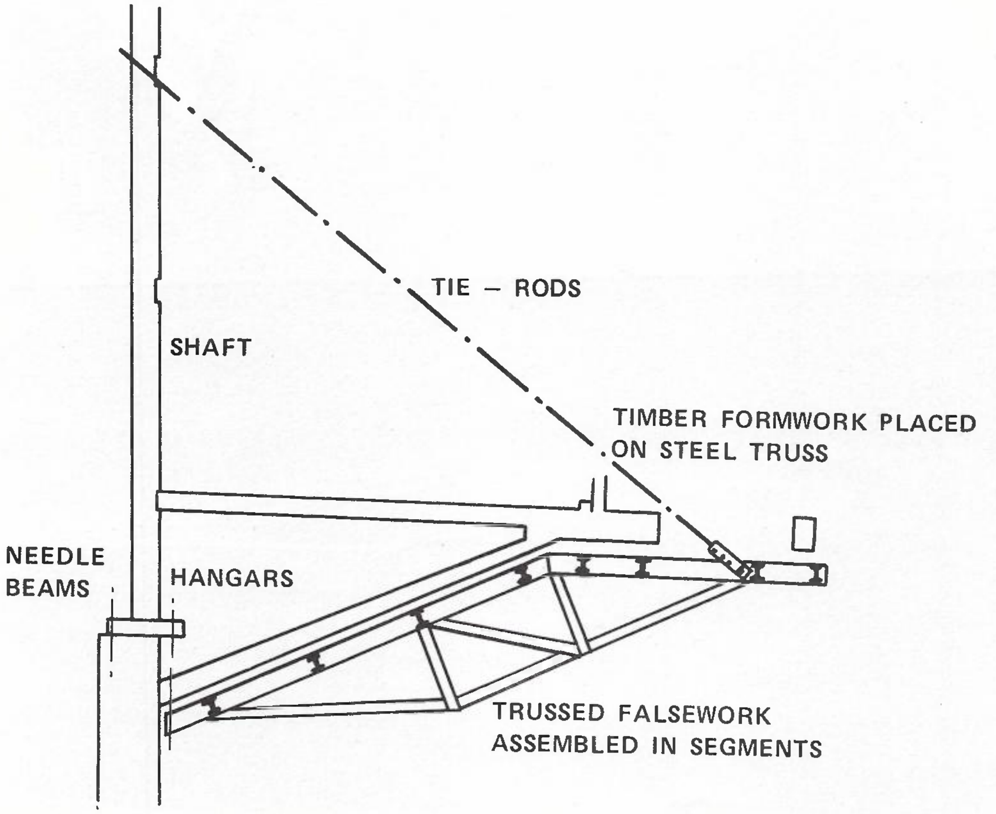



Fig. 11 — System for Construction of RT Drum Shell/Slab Structure

Construction provided for simple flush joints both horizontally and vertically, with vertical joints staggered in a random fashion. With the system the contractor was able to achieve close dimensional control in constructing the shaft; each lift was optically plumbed and all inserts and openings in the shaft were spotted-in by a licensed surveyor working on the climbing formwork system.

Concrete and other materials were lifted by the tower crane up to the 80 metre level (top service platform) and thereafter by double lift using the tower crane and a rescue derrick carried on the climbing formwork system.

**Supported Structures**

The most unusual feature in the erection of these structures — the two drums and the two service platforms — was the construction of the post-tensioned conical shell/slab units which were the principal structural elements involved.

Starting with the RT drum the formwork for the conical shell and cantilever beam system was supported on an assembly of trussed falsework hung from the shaft by means of tie-rods and hangers. The falsework was made up in segments, prefabricated pre-assembled and sheeted off site before transport to site and lifting into place. The system is illustrated in **Figs. 11, 12, 13 and 14** and was used with modification in forming the other three shell/slab units.

The falsework carried the full weight of construction until after the closing slab was cast and the shell/slab unit post-tensioned. The falsework assemblies were then lowered and taken away to be refurbished for use on the next shell structure.

While the techniques of circumferential prestressing have been well established on elements such as circular water retaining structures where tendons are anchored and stressed at external buttresses, the Tower incorporated the less commonly used BBR Type Z anchorages which provide for "in-line" stressing of the cables. Because of the features of the anchorages and the details of their installation some initial stressing difficulties were encountered on the RT drum requiring many increments of loading and restressing to provide the required level of prestress and an acceptable level of friction loss. Close attention to anchorage recesses and associated details for subsequent work on the public drum and service platforms alleviated similar difficulties and permitted quick and effective stressing.

The superstructure for both the RT and public drums was erected by fairly conventional methods, but with considerable challenge in overcoming difficulties associated with height and access. The precast load bearing facade to the public drum provided a functional and practical solution to enclosure of that drum.

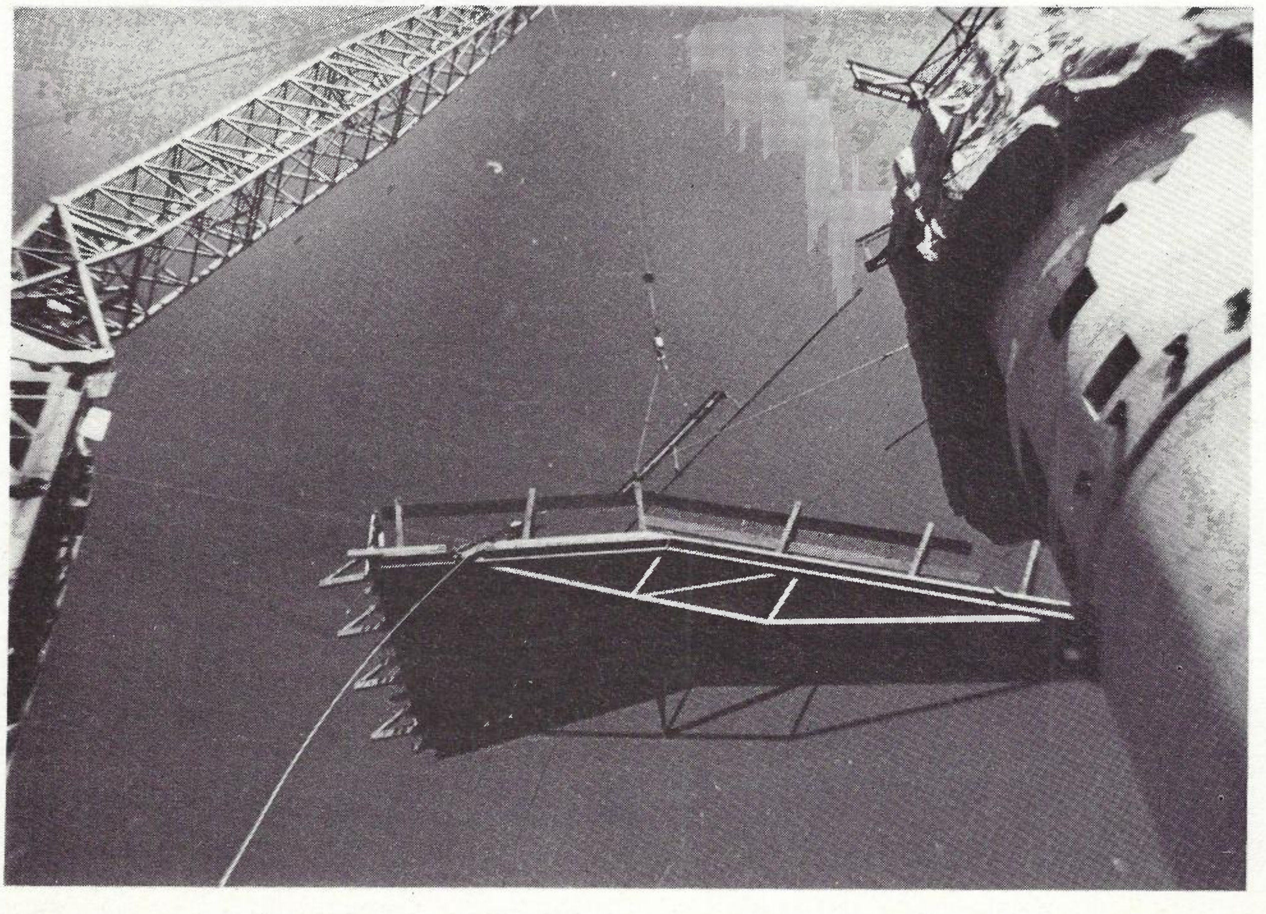


**Fig. 12 — Erection of Falsework System for RT Drum Shell/Slab Structure**

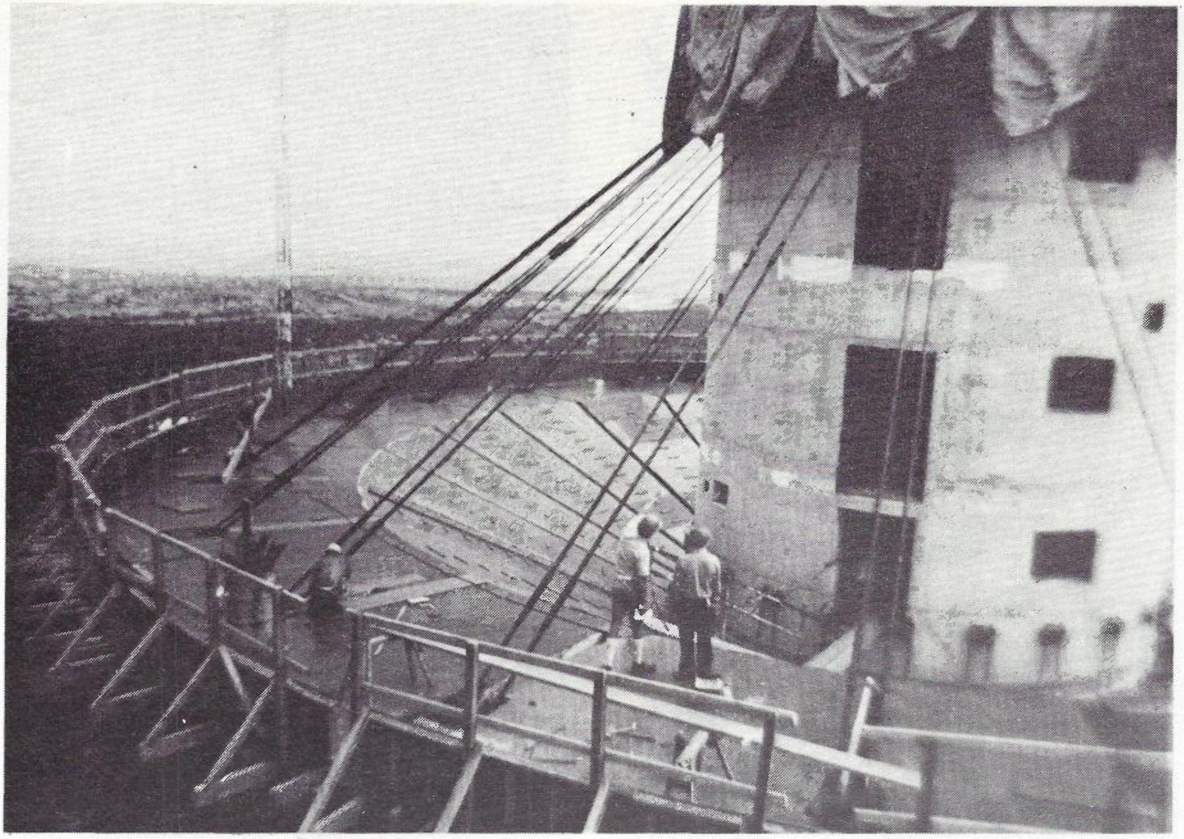


Fig. 13 — Formwork for RT Drum Shell/Slab Structure

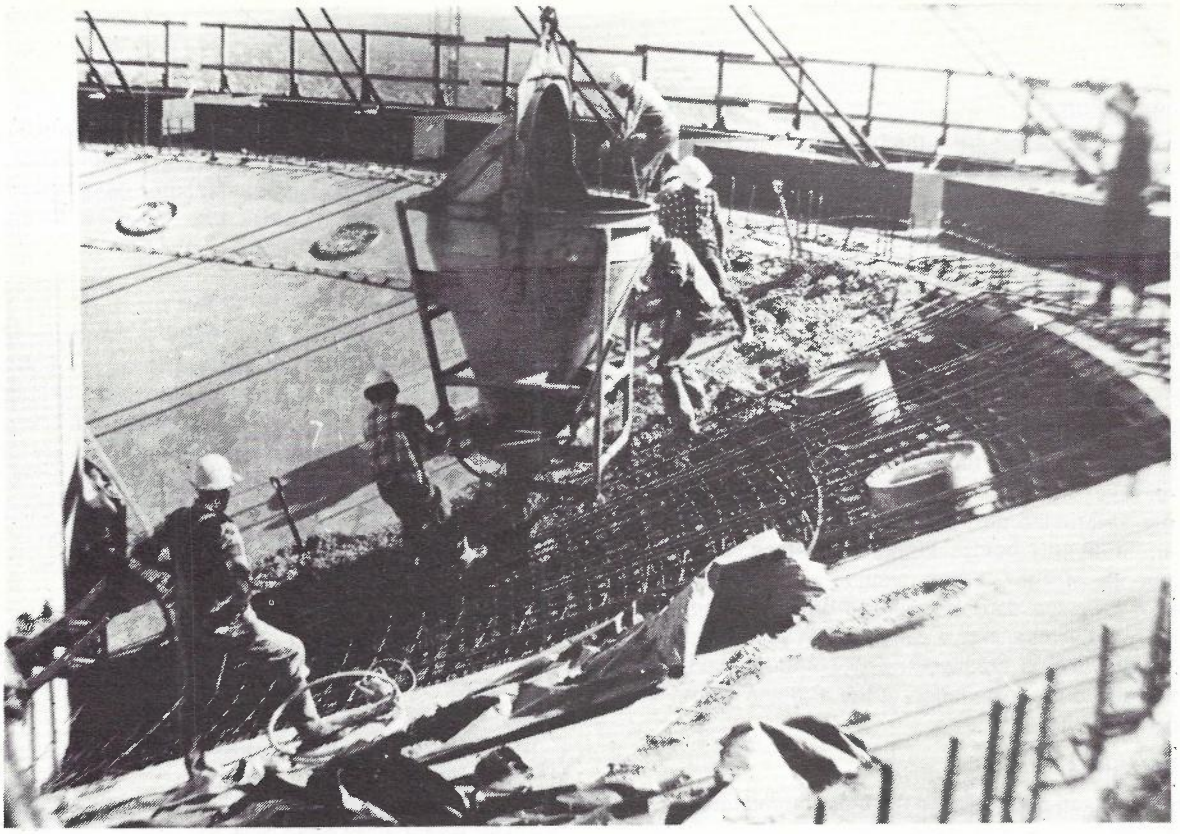


Fig. 14 — Concreting of Conical Shell to RT Drum

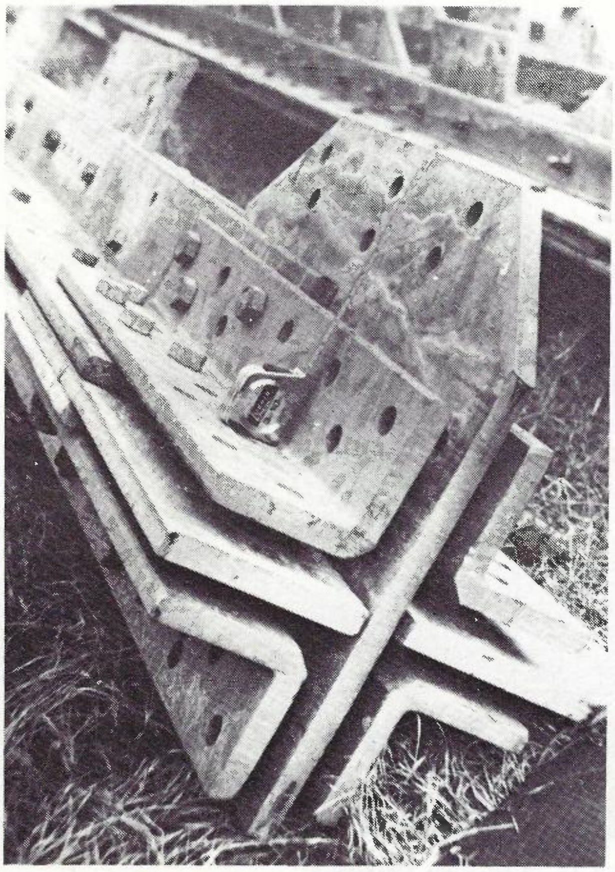


Fig. 15 — Pre-assembled Sections of the Antenna Column

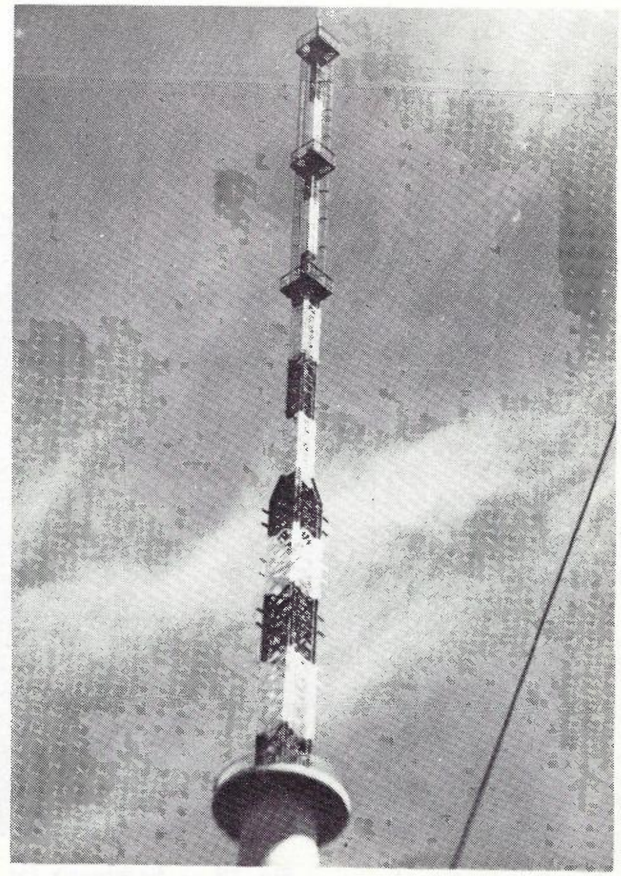


Fig. 16 — Completed Antenna Column before Fixing of Antennae

**Antenna Column**

The antenna column from the first splice above the top of the concrete shaft was designed and specified by Telecom engineers because of their specialist expertise in steel towers; the bottom section is a complex and integral part of the connection between the mast and the shaft was designed by the Department. The column is quite slender for its height and the design therefore required the use of heavy steel members, many in high strength steel, in order to satisfy stress and deflection limitations. Generally of bolted construction the steelwork was fully galvanised for corrosion protection.

Fully trial assembled before galvanising the mast went together like clockwork during erection. Leg sections were pre-assembled on the ground in components of up to 6 m in length before lifting into place (**Fig. 15**). Components of the bottom section were erected by means of a rescue derrick mounted on top of the shaft and the rest by means of a climbing gin pole supported from the advancing steelwork. The completed antenna column prior to the installation of the antenna systems is shown in **Fig. 16**.

**CONCLUSION**

While this paper has limited itself to a broad discussion of the Tower's general design features together with some further consideration of matters of special interest in the area of structural design and construction, the project has certainly involved interest and challenge in many other areas. The project has been a demanding one from start to finish and its satisfactory completion is a credit to Telecom and all those who have had the opportunity to make a contribution.

**Award for Excellence in Concrete**

In 1979 the Tower as an entrant in the Awards for Excellence in Concrete conducted by the Concrete Institute of Australia was successful in gaining a Certificate of Merit, one of seven equal merit awards made to projects selected from among the sixty or so national buildings and structures submitted (**Fig. 17**). The award was a fitting recognition for the outstanding quality achieved in both design and construction of the concrete work on the Tower.

**Civic Design Award**

The tower was also awarded the Civic Design Award of the Royal Australian Institute of Architects for 1980 with the following citation:

"This is a new award which caused the jury some moments of concern until criteria were agreed.

The jury judged this award in terms of the project's total success with regard to impact on people, the environment and Canberra as a whole. Using these criteria Telecom's Black

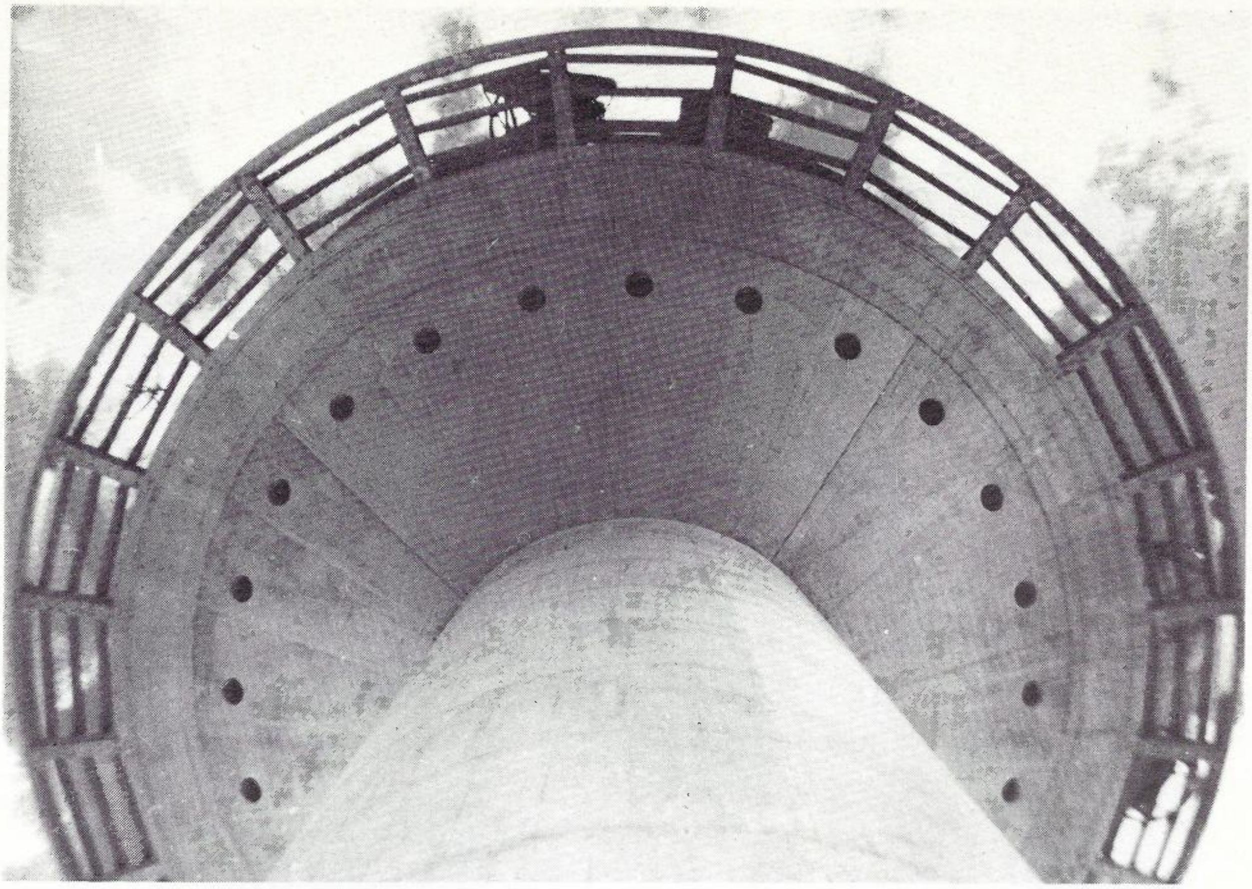


**Fig. 17 — The Tower Received a Certificate of Merit for Excellence in Concrete Awarded in 1979 by the Concrete Institute of Australia.**

Mountain Tower designed by the Department of Housing and Construction was the unanimous choice for the Civic Design Award.

Whilst acknowledging that the site is probably the best in Canberra it was agreed that the tower design was aesthetically pleasing (both up close and at a distance) functional, well integrated with its surroundings, fulfilled a major civic function (tourism) and was generally well thought through with regard to its use as a major tourist attraction.

There is no doubt that the tower dominates Canberra from every angle and as such the architects had a very special design problem. As the most exposed and visible structure in the territory it was essential that, within the constraints of its technical function, its form should be visually satisfying. This, the jury believes, has been successfully achieved."

**Carparking Area and Pedestrian Walkway to Tower**

---

# OBITUARY MR. F. P. O'GRADY, CBE

It will be with sadness for the readers of the Telecommunication Journal to learn of the sudden death on May 6th 1981 of Mr Francis Phillip O'Grady. He was 80 years of age.

Mr O'Grady joined the Postmaster-General's Department in 1917, and, after a break in private industry, returned to the Department and, in 1925, qualified as an Engineer.

His career as an Engineer was studded with many personal achievements in the radio, long-line and signalling fields. The knowledge gained by him was readily shared with all by a series of lectures, talks and many articles to this and other Journals. His advice and opinion was also sought by overseas communication authorities.

In February 1949, he took up an appointment with the Weapons Research Establishment as a Principal Scientific Officer and was rapidly promoted to the position of Chief Engineer. His duties included the association with the atomic trials at Emu Field and Maralinga. His intense interest in Telecommunication was exemplified when he returned in 1957 to the PMG Department as the Assistant Director, Engineering, Adelaide. Later in that year he was appointed as Deputy Engineer-in-Chief, Headquarters. He became Director-General Post and Telegraphs in 1961, the position from which he retired in 1965.

Mr O'Grady was honoured by the Queen in 1965 when he was awarded the CBE for his outstanding contributions to the development of telecommunications in Australia. Those who were privileged to work with Mr O'Grady held him in very high esteem. He possessed a brilliant mind and yet was so humble.

Among his many outstanding attributes was his ability to communicate with others and this engendered extreme loyalty from subordinates and respect of all who associated with him. Upon his retirement he returned to live in Adelaide where he maintained his interest in the activities of Telecom and, in particular, the personnel both retired and still employed. Each year he held a function at his home to which the members of the former Transmission Section, Adelaide, and their wives were invited. He remained an active member of the Institution of Engineers, Australia. Frank will be remembered by all who associated with him as a man with a great sense of humour with a ready smile; a man of integrity who would never condone what he thought was wrong.

# National TV and FM Broadcasting Facilities

V. J. AUDET

The installation of high powered television and sound broadcasting transmitters is always a challenging and rewarding engineering exercise. When you add to this the complexities that this particular construction and layout imposed on the installers the exercise is unique. This article describes the background and highlights of this project.

Following exhaustive investigation for suitable sites by the Post Office and the Australian Broadcasting Control Board (ABCB), the National Television Service (NTS) for Canberra was originally established at Black Mountain in 1962.

One of the most important considerations in selecting the site was the requirement of the National Capital Development Commission (N.C.D.C.) that satisfactory reception be available with minimum use of outdoor receiving aerials and without the need for TV translator stations on hills surrounding the City. As household aerials need to be substantially in line of sight of the transmitting aerial for satisfactory reception of television signals the site for the transmitters needed to be as centrally placed and as high as possible. Some areas around Canberra are shaded from the Black Mountain antennas by natural obstructions. For example, a translator has been established on Mt. Taylor to serve the expanding Tuggeranong area which is shaded from Black Mountain by Mt Taylor. Among other factors was the need to minimise the possibility of 'ghosting' due to reflection from nearby hills. With the more recent requirement for the establishment of a centralised Communications Tower, from the point of view of TV and FM Broadcasting it was therefore logical to locate it on Black Mountain.

## BLACK MOUNTAIN BROADCASTING PLANT

### Internal Plant

The question of whether to shift the existing TV transmitters to the tower for further use or to install new transmitters in the tower was resolved after investigations indicated that from an economical view point considered over a 20 year period it would be cheaper to provide new transmitters in the tower and keep the old transmitters working in their original location in the interim period.

High powered television and broadcasting plant is large in both physical size and weight. For this reason it is necessary to locate such plant on floor levels where the structure is sufficiently strong to support it and there is ample space to accommodate it. Hence the Black Mountain broadcasting complex occupies the lower ground floor of the tower surrounding the tower shaft and as shown in **Fig. 1** includes the Control Room, Television Transmitter Halls (National and Commercial) and FM Transmitter Room.

### External Plant

Two separate aerial systems are used for National and Commercial Services which operate in Television Bands 2 and 3 respectively. The higher band commercial antenna operates on Channel 7 and is mounted on the upper section of the aerial column. A common aerial system is utilised for National TV and FM transmissions. The associated antenna which accommodates Channel 3 and the FM band (88-108MHz) is larger and is mounted towards the base of the aerial column. Each antenna system has been designed to radiate additional TV or FM channels as required in the future. An outline of the facilities installed in each of these locations follows.

## INTERNAL PLANT

### The Control Room

In order to control the equipment which is used to transmit sound or television programme at high power stations, control rooms are usually provided. In keeping with the design of standard high power stations the installation of the TV and FM transmitters at Black Mountain includes a control room which is located on the eastern side of the building.

The purpose of the control room is to enable programme monitoring control and supervision of the

Sound and Television broadcasting services in the Canberra area, including the ABC-3 Television Transmitter, the ABC FM transmitter and 2CN/2CY medium frequency broadcasting stations. The functions include:

- Local TV and FM Alarms
- Remote Alarms from MF stations 2CN/2CY
- FM Programme Monitoring
- FM Programme Selection
  - — On Line
  - — Second Programme Source
  - — Local Tape Replay
- Remote TV Transmitter Control
- TV Waveform Monitoring
- TV Picture Monitoring
- TV Programme Selection
  - — On Line
  - — Off Air (Rebroadcast Receiver)
  - — Local Test Pattern

The equipment is contained in a control console and programme input equipment racks (PIE). All cabling between the console and equipment racks and from other areas is routed under the computer flooring provided to facilitate the installation of the large number of interconnecting cables. The floor is covered with carpet squares and with the acoustically treated ceiling effectively deadens sound in the area.

The main feature is the control console which is constructed from seven standard 483 mm wide desk console units butted together.

The console is placed such that it allows the operator(s) to see over it into the central column area of the tower through a glazed partition by which limited supervision of activities at the front of the TV transmitters is possible.

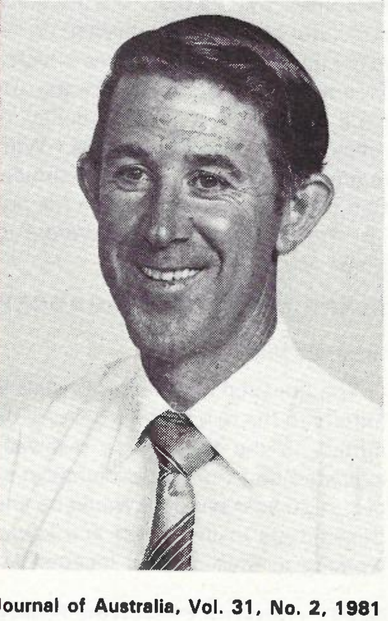
The console is laid out in two sections, one for sound broadcasting and the other for television broadcasting. The Sound Broadcasting section comprises three desk bays with audio programme selection and monitoring facilities and programme level controls for 2CN/2CY MF stations and ABC-FM. Controls also are extended to 2CN/2CY for remote switching, on and off of those transmitters from Black Mountain. The Television section of the console is spread over four desk bays which house video and audio switching panels. Separate programme preview monitor switches and programme selection switches allow the connection of the desired programme to the transmitter whilst another programme can be monitored in readiness for connection as desired. The transmitter output is demodulated as are a number of other points through the transmitter and extended to the console via a transmission monitoring switch controlled from the console. High quality monochrome and colour television picture monitors in association with a video waveform monitor enable the operator to assess the technical and the subjective quality of all available monitored points.

Television transmitter alarms are extended to the console where they are displayed individually as are those alarms associated with sound broadcasting equipment. One common audible alarm however is provided for both services. On/off switching of the transmitters can be controlled from the console.

The term 'Programme Input Equipment' is used loosely here to cover programme input equipment, testing and monitoring racks.

Three suites of equipment racks are installed across the control room as opposed to the console which is installed along the length of it. This layout was adopted to facilitate access to any suite by the operator at the console. Space remains for future expansion to a fourth suite if required. Two suites have been established for broadcasting equipment — the FM/MF PIE suite and the TV PIE suite. The third suite contains audio and video terminating racks for the broadband radio bearer systems. The FM PIE is contained in a single rack and comprises audio monitoring amplifiers. There are no programme amplifiers in the line to the transmitter. The right and left hand audio channels, however, are processed and fed to the transmitter as a "stereo multiplexed' signal. This processing takes place in the stereo limiter and the stereo encoder after which the output is connected directly to the FM transmitter. FM and stereo modulation monitors are included in this rack and measurements of FM

V. J. AUDET joined Amalgamated Wireless (A'sia) Ltd. as a trainee engineer in 1954 and graduated with the Diploma of Radio Engineering, Sydney Technical College, in 1960. In the following years he worked on the development of high power communications transmitters until he joined the Postmaster-General's Department in 1966. Here he was employed in the Radio Section, initially in Radiocommunications Maintenance, where during the NASA Apollo space programme (Apollo 10 — Apollo 17) he was technical liaison officer with NASCOM and was responsible for oversighting the installation, testing and subsequent operation of special microwave links from the Honeysuckle Creek tracking station and the Parkes radiotelescope. In 1974 he took up the position of senior engineer, Colour Television, responsible for the colour conversion of all main national television stations in NSW. In 1977 he transferred to Broadcasting Construction where, as well as the Black Mountain broadcasting facility, he was engaged in several other noteworthy projects including the Newcastle National FM Service, Ethnic Television Services in Sydney for the Special Broadcasting Service, and Remote Area Television via Intelsat satellite.



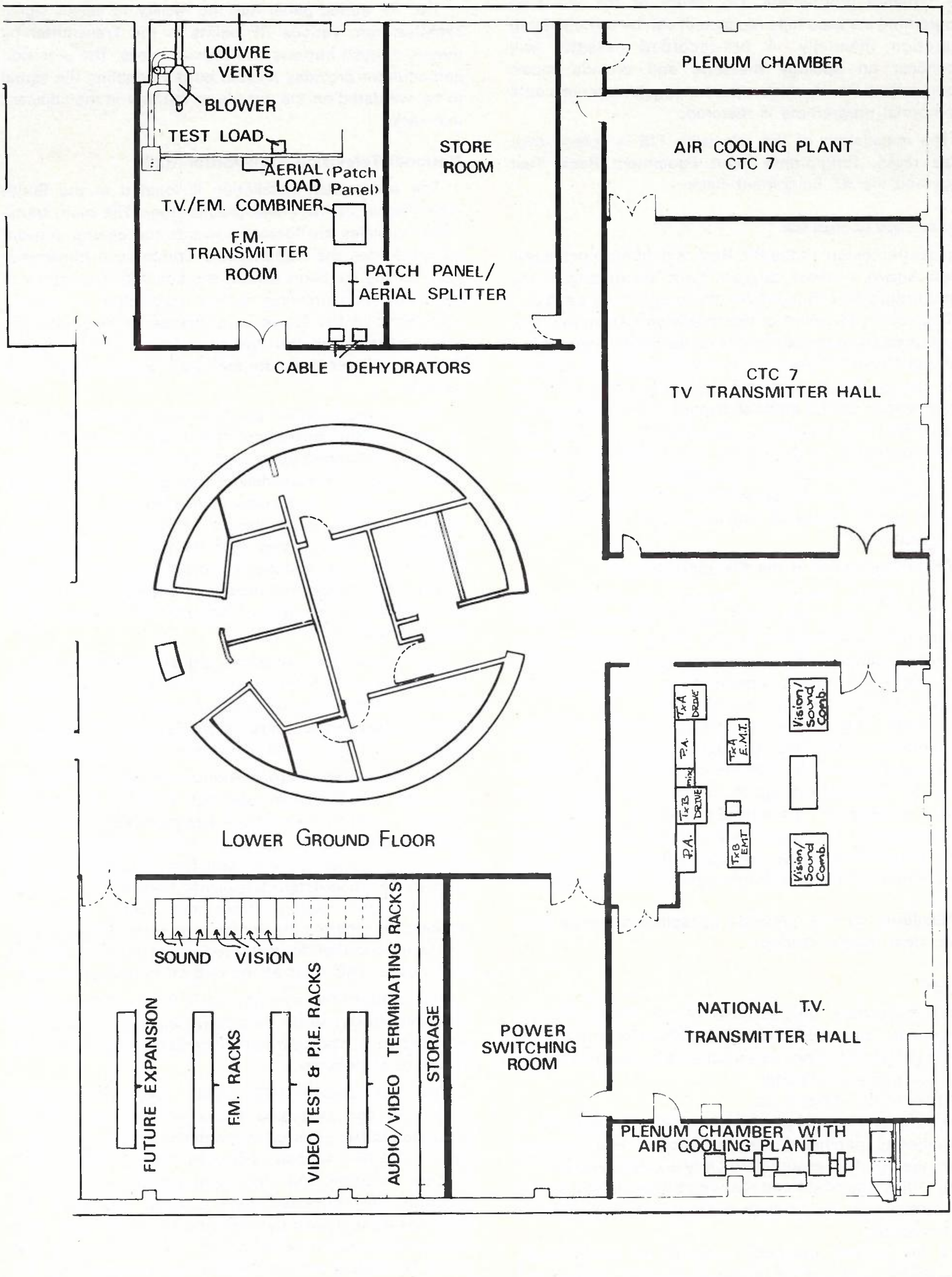



**Fig. 1 — Broadcasting Facilities**

performance are made at this point. An off-air FM monitor receiver is included for subjective evaluation of the radiated programme. On failure of the incoming programme a stereo tape replay unit can be switched into operation manually. A pre-recorded cassette will broadcast an apology message and provide music programme both of which repeat at regular intervals until the normal programme is restored.

The installation of the television PIE is spread over three racks: Programme Input Equipment Rack, Test Rack and the RF Equipment Rack.

#### Programme Input Equipment Rack

The central feature of the PIE Rack is a mimic patch panel which shows in block diagram form the routing of the video programme signal from the programme source in the station to the input of the television transmitter. The signal appears at various points on the mimic panel at the nominal 1 volt P-P level and by the use of U-link connectors can be fed through the normal programme input equipment or can be made to bypass some sections. The normal circuit connection is identified by red lines and when connected all U-links are in a horizontal position. Alternative circuit paths are represented by other colours and when these are connected some of the U-links will be vertical which indicates immediately a non standard configuration.

Other equipment in the PIE rack includes:

- Video clamp amplifiers provided to stabilise the incoming signal by back porch clamping. Video Distribution Amplifiers as the name suggests have multiple outputs (6+1) for the distribution of video programme signals to various items of equipment for programme, monitoring and splitting.
- Insertion test signal generator, which not only generates all full field test signals needed for station maintenance but also has the capability to insert local vertical interval test signals which allow checking of the transmitter parameters during programme transmission. To enable this function it is connected in the programme signal path but is designed to be self protecting in that it will automatically bypass itself on failure.
- Waveform monitor provided to replace a mobile CRO for most routine testing.

#### Test Rack

The Test Rack houses most of the colour TV test equipment, the station U-link patch field, monitoring switches, station sync. pulse generator, colour encoder and test pattern generator.

Of particular interest are

- the station U-link patchfield which is basically a monitoring patchfield and the cabling, has been so arranged that no programme carrying cable appears on the U-link patchfield and the withdrawal of any U-Link or termination can be made without fear of programme interruption,
- the test pattern generator provides an electronically generated test pattern similar to the ABC pattern but with the station's call sign in the text area.

#### The RF Rack

The RF Rack houses an RF Mimic Panel, a precision vestigial sideband (VSB) RF/IF demodulator and a sideband analyser.

The RF mimic panel has the facility to select signal samples from various RF points in the Transmitter by means of push buttons and coaxial relays. The precision demodulator provides a video output enabling the signal to be evaulated on the waveform monitor in the adjacent test racks.

### National Television Transmitter Hall

The transmitter installation is located in the South West corner of the lower ground floor. The main transmitter cubicles are located towards the central corridor which divides the National and Commercial transmitter halls on the southern side of the building. The layout of the installation provides for the installation of another transmitter in the future as a change of frequency has been mooted for the National Television Service in Canberra to accommodate the eventual expansion of FM services.

The new transmitters are AWA type TVB-10C capable of covering the Australian VHF Channels 1-4 with an output power rating up to 12kW peak vision power. They include state of the art design concepts and are suitable for monochrome and colour transmissions. Two transmitters operate in a parallel arrangement and are combined in such a way that the failure of one transmitter will incur a reduction of output power which would mainly affect fringe area reception. The associated sound transmitters are frequency modulated and produce 1kW output power.

Each transmitter comprises signal processing stages, modulators and amplifiers housed inside a single suite of cabinets divided into two main sections each having two bays. One section contains the drive stages, and the other contains the high power vision and sound amplifiers.

The drive stages are manufactured by the Marconi Company Ltd. The driver operates on the IF modulation principle in which the vestigial sideband (VSB) shaping is done at low level at an intermediate frequency (38.9 MHz) which is compatible with drive equipment for all modern IF modulated television transmitters in this country. This method does not suffer from the deficiencies inherent in the high level modulation process employed in earlier designs which demanded the use of a high power VSB filter at the output of the transmitter.

This output filter was physically large and expensive, especially when used in Band I and required an extremely laborious tuning process to the operating frequency of the individual transmitter.

The high tension (HT) power supply and output combining and switching equipment are mounted as separate entities external to the main cabinets.The vision and sound HT supplies comprise three phase transformers, rectifiers and filter components mounted in a separate, fully enclosed steel cabinet. Access to the components is gained by removing the front panel. Personnel protection is provided by control interlocks and supply grounding switches which are actuated when the panel is removed.

The FM sound and VSB vision outputs are combined onto one feeder in an external combining unit mounted in a free standing unistrut frame. Connection to the transmitters is via 54 mm rigid coaxial feeders. Mounted on the frame are diplexers, resonators and balancing load which make up the combining unit with directional coupler probe assemblies which enable continuous monitoring of forward and reflected power of vision, sound and combined RF output signals both in the transmitter hall and the control room.

Each complete transmitter uses only three valves. The vision and sound high power amplifiers use one each and the drive stage vision output uses the third. The vision and sound amplifiers are cooled by forced air from high velocity centrifugal blowers located in a plenum chamber adjacent to the transmitter hall on the western side of the building. One blower is used per transmitter, and air is drawn through vertical weatherproof louvres to the plenum chamber and fed through overhead circular section air ducts to the transmitters.

### FM Transmitter Room

The FM transmitter room which is located on the eastern side of the building adjacent to the loading dock will house up to four 10 kW FM transmitters and at present houses the FM patch panel and aerial splitter, the TV/FM combiner, feeder dehydrators and an aerial dummy load patch panel.

A new Siemens 10kW VHF/FM transmitter type SU 10/6209 was installed to replace the working FM transmitter which has subsequently been recovered and installed in Sydney. This transmitter which is suitable for the transmission of monophonic or stereophonic programmes is capable of operation over the frequency range from 87.5 MHz to 108 MHz and has been tuned for broadcasting on 101.9 MHz in Canberra.

The transmitter is mounted in a single cabinet 580 mm wide with the front set into the wall which divides the equipment room and the plenum chamber at the rear.

It is laid out in two sections, the lower half containing low power plug-in modules and an upper section in which the 10 kW amplifier is located.

The stereo multiplexed signal from the PIE rack as described above is fed to the input of a 50 watt VHF FM transmitter (modulator) which provides an output between 87.5 MHz and 108 MHz. This modulator is fully solid state being constructed almost entirely on printed circuit boards. It has the drive capability to the final VHF power amplifier stage to enable it to produce an output level of 10 kW. The entire input circuit of the final VHF amplifier is accommodated on a single printed circuit board, together with the input matching and neutralisation circuits. The 10 kW RF output is fed via a directional coupler to the TV/FM combiner and in turn to the aerial system via the patch panel/aerial splitter.

The transmitter is equipped with safety devices to prevent personnel from accidentally touching parts which are carrying high voltage. The relevant sections of the transmitter to which access is needed for maintenance can only be opened with a key which cannot be withdrawn from the front panel of the power distribution panel until the AC supply voltage has been switched off and all parts carrying high voltage have been earthed.

As with most modern high power transmitters the final output is cooled by forced air. To this end an external air cooling blower and filtering system is located in the plenum chamber at the rear of the transmitter. The blowers are designed to run slowly and thus maintain a low noise level in the vicinity of the transmitter.

## EXTERNAL PLANT

### Aerial Systems

Two independent systems — a high band system (Channel 7) for the Commercial Operator (CTC-7) and a low band system (Channel 3) for the National Television and FM Service, are accommodated on the open lattice steel section of the tower above the concrete shaft which terminates at a height of 132 metres above the ground level. The lattice steel section extends to 195 metres. The high band antenna being considerably smaller, physically, is located nearer the top and is centred at the 163-metre level while the centre of the low band antenna is at 147 metres.

The antenna panels for both systems were manufactured by Coel, Italy under contract to RCA. Each antenna array comprises 16 identical broadband dipole panels, 4 on each face in 4 levels. Each panel contains two or four full wave dipoles on a reflecting screen and are fed in parallel to obtain the desired radiation pattern. The individual panels are connected to the main feeder via a system of power distribution transformers (power dividers) and coaxial cables.

The two top levels are combined as are the two bottom levels and each combined section is fed separately. By this arrangement transmisssion can continue at half power should problems develop in an aerial panel or associated feeders.

The antenna installation was carried out by private contractor under Telecom supervision. There were only a few minor difficulties associated with this installation. It was important to ensure that some panels be inverted in critical locations to achieve the correct radiation pattern. Also it was only possible to haul the panels from one side of the tower. This meant that panels to be mounted on the opposite face had to be transferred to the other side of the column during the hauling process.

In their final location the size of the panels from ground level appear deceptively small. In fact the high band panels measure 1290 mm x 2890 mm and the low band ones 3120 mm x 2600 mm across the reflecting screens.

### Feeders

Both internal sections and external sections of the main feeder cables are three inch air dielectric flexible coaxial lines. The internal feeders follow a route from the television transmitter hall to the vertical cable duct in the main tower shaft via a false ceiling above the lower ground floor (**Fig. 2**). The only intermediate connection in each cable is made just prior to their exit from the false ceiling to the vertical cable duct.

Flexible internal feeder cable was used at Black Mountain in preference to the usual 54 mm rigid line, as used at most other main television stations, because of the many bends between the transmitter switching frame and the exit to the cable duct. This would have involved the use of so many 90-degree elbows each of which contributes a degree of degradation, that the overall performance of the system would have been impaired.

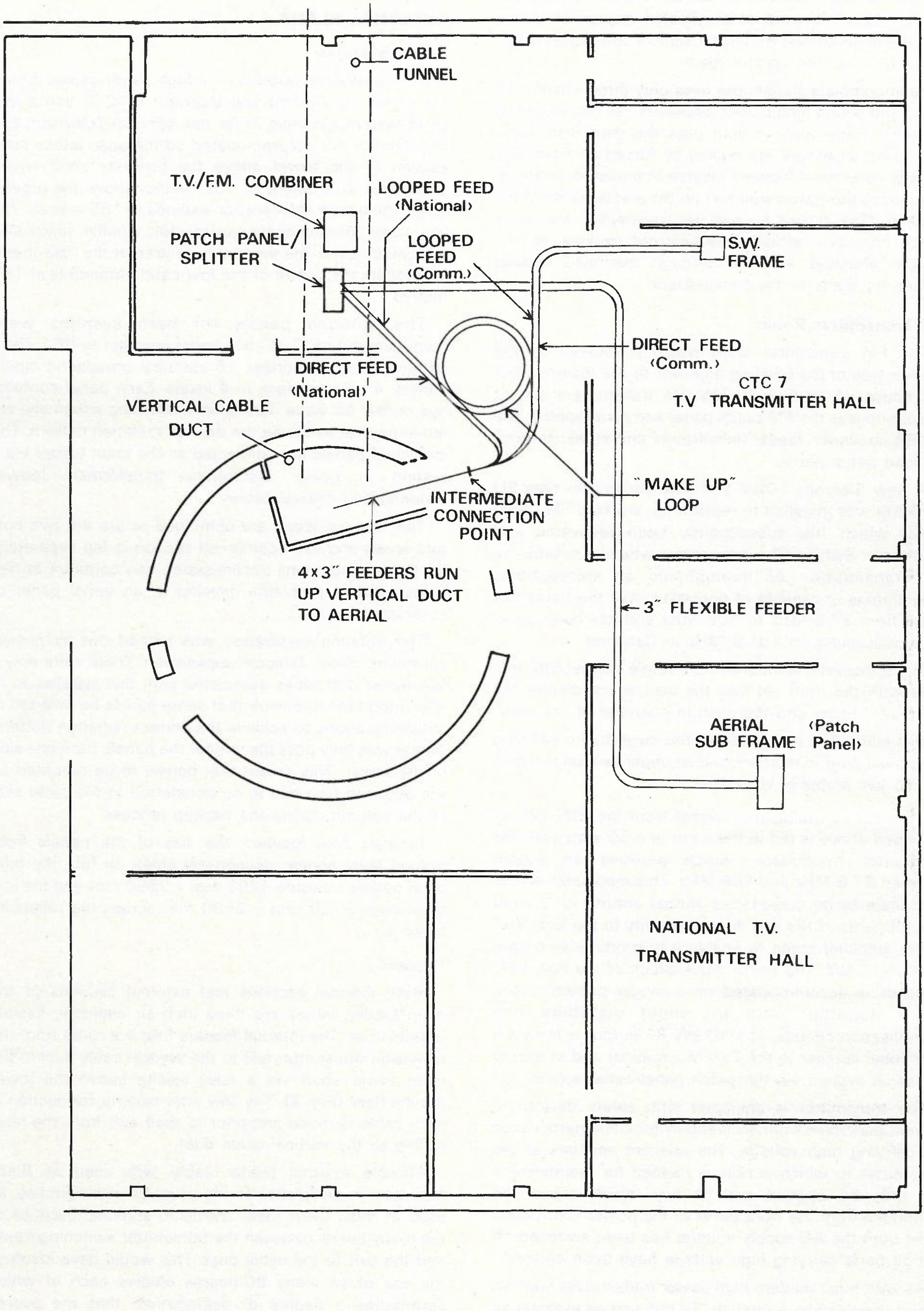



Fig. 2 — RF Feeder Arrangement

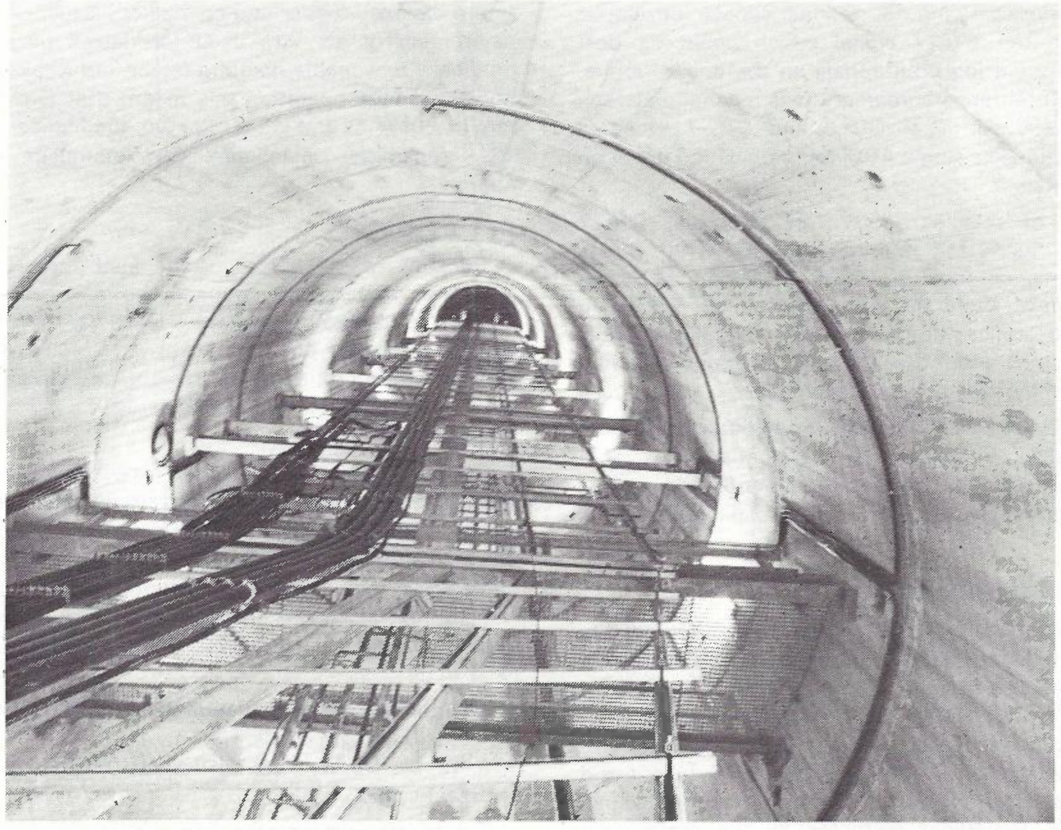
Two cables are fed from the transmitter to its antenna, one cable being connected directly to the upper half. As the system operates at VHF frequencies differences in cable length between upper and lower halves of the antenna would result in substantial phase difference in the signals arriving at the respective halves of the antenna. The cable to the lower half of the antenna was therefore cut to the same electrical length as the upper cable and the 'overflow' cable formed into a 'make-up loop' and mounted in a circular tray located in the false ceiling.

As the National FM Broadcasting Service was also to be accommodated on the low band aerial system with the National Television Service this installation was a little more complex in that internal TV feeder cable does not run direct to the vertical cable duct. A single TV feeder cable runs from the TV transmitter hall to the FM room where it is connected through the TV/FM combiner with the FM feeder cable. The output of the TV/FM combiner is split to enable separate feeds to be run — one to the upper stack, the other to the lower stack via the 'make-up loop'.

The installation of the external feeder cables ie, the section above the intermediate connecting point in the false ceiling was somewhat novel, in that with the usual lattice tower installations, the drum on which the cable is delivered can be located beneath the tower and the cable hauled directly up off the drum. At Black Mountain this method, of course, was not possible, the access to the vertical cable duct being via a 20-metre long horizontal cable tunnel which is entered from a pit in the loading area outside the basement level. The cable had to be fed, firstly, down into the cable pit off the drum, then along the cable tunnel to the cable room. Because of the restricted space between the end of the cable tunnel and the opposite wall of the vertical cable duct it was essential that the cable be bent upwards immediately leaving the tunnel. Once in the cable room the cable was again straightened so that it could be pulled up the duct. This operation had to be carried out over the full length of the four cables (each approx 140 metres long) ensuring at all times that the minimum bending radius was not exceeded.

The cables were lifted until their ends were to the level of the multi-cable transit units which provide access from the cable duct into the false ceiling area. As the cables were lowered the ends were bent and fed through to inter connect with the internal feeder at the intermediate connection point.

The National TV and FM Broadcasting facilities were placed in service on 19 November 1977 and have since been operating satisfactorily from the new site. It is of interest to note that the initial field strength survey showed a depression in the expected signal level in the Murrumbateman area to the North of Black Mountain. This was suspected as, and later proved to be due, to the old National Television mast about 150 metres from the tower. When this mast was dismantled the signal around Murrumbateman was restored to its expected level.



**Antenna Feeders on Cable Runway in Concrete Shaft of Tower**

# Commercial Television Installation

R. K. BURBIDGE, M.I.E. Aust.

Separate commercial and national TV transmitting installations existed on Black Mountain. With the advent of the Telecom Tower, it was decided that the two facilities should be co-located in the new complex. Operation and maintenance of the commercial installation is carried out by Canberra Television Limited, under an agreement with Telecom which is unique in Australia. This article describes aspects of the commercial TV installation.

In June 1962 Canberra Television Limited (CTC-7) commenced its service from Black Mountain, Australian Capital Territory. Some months later the completion of the higher mast carrying the national service introduced ghosting on the CTC-7 signal which could be best eliminated by placing both aerials on the one structure. During 1970 tentative agreement was reached between the then Australian Post Office and CTC-7 to share accommodation in a single APO communication tower on Black Mountain.

As part of this agreement in principle, CTC-7 surrendered its Black Mountain lease with all its improvements, and took up a lease at Watson, A.C.T., on which a new building was erected in 1973 to accommodate offices and fully colour equipped studios, leaving the transmitters operating in the original building until the completion of the Telecom Tower.

By October 1978 full agreement had been reached on sharing details in the tower and CTC-7 undertook a transmitter installation with all new equipment and several design features unusual for commercial television in Australia.

## TRANSMITTED POWER

Black Mountain is centrally located in Canberra City and there are several suburbs quite close in to the foot of the mountain. Because of this Telecom provided television transmit aerials on the tower with an omnidirectional horizontal pattern and a broad vertical pattern, providing good null fill-in to angles well below the horizon. In addition the vertical size of the aerial for use by CTC-7 is somewhat restricted by the mechanical requirements of sharing the self supporting steel structure on top of the concrete tower with present and future VHF and UHF broadcast aerials. As a result of these two factors, and after allowing for present and future diplexer, feeder and connector losses, an effective aerial gain of six was used for design purposes. To provide a reasonable derating factor and to allow for full power standby operation this meant that two transmitters of 20kW output were required, the highest powered T.V. transmitter installation for Australian Band III operation.

## RELIABILITY

Because of the nature of the final agreement with Telecom whereby the transmitters are installed and operated by CTC-7 in an isolated leased area of the tower with no separate outside access, an installation which allowed very reliable operation and minimum of maintenance visits was considered to be of prime importance.

Control and supervision of the installation is via a GTE Lenkurt 51L2 remote control system which uses high security data transmission. Each data word consisting of 51 data bits is transmitted in a frequency shift keyed pulse width, non return to zero format that is insensitive to level inversion, bias errors and jitter. In addition each data word must pass the following tests to be released as valid data:

- An underflow / overflow data bit count check.
- A data bit length check.
- A 12 bit BOSE - CHAUDHURI - HOEQUENGHEIM (BCH) cyclic check.

Transmitter programme and control data is carried over two studio to transmitter microwave links (STL). The control data channels have pilot sensing at the transmitter site with automatic switching and alarm indication.

Two full power transmitters are used in an alternative main operation, each transmitter being run on alternate days. This was considered more reliable and less subject to operational adjustments than the more complex arrangement of operating two half power transmitters in parallel. In the case of transmitter failure with the CTC-7 installation, full power normal operation is restored within 10-15 seconds from a cold start. Automatic changeover initiated by sensing of parameters in a vertical interval test signal was considered but not proceeded with on the grounds of complexity and hence reduced reliability.

Transmitters are operated well within their capabilities. The transmitters are at present run at 18kW output although conservately rated at 20kW.

The transmitters provided were of recent design, largely solid state and from a manufacturer with an established record of reliability and backup service, in this case NEC of Japan.

Attention was given to such details as minimizing insect entry to the area and providing more extensive air filtration than normal. In this case 3 levels of mechanical filters are followed by electronic filters in the supply to the air cooled transmitters.

## ANCILLARY EQUIPMENT

As the transmitter room is unattended and under remote control, reasonably elaborate ancillary equipment was installed to cater for various forms of automatic performance control, remote switching and remote supervision of equipments status.

Automatic control of picture level, sync pulse amplitude, burst amplitude, chroma level and chroma phase was initially installed in both transmitters. A vertical interval test signal (VITS) is inserted at the studios and detected at the output of the transmitters by the standard demodulator. This signal was then compared with reference signals in a corrector installed in the transmitter input and appropriate predistorted signals supplied to the transmitter. In practice it was found that the stability of the transmitters and links was of the same order as the corrector and this has since been removed in the interests of increased reliability. At present vision parameters are continuously monitored at the studios by means of a television transmitter to studio microwave link (TSL) and Marconi VITS analyser. This latter unit provides an alarm condition when any one of 13 parameters goes outside preset limits, and gives an automatic printout of the same parameters when requested and at preset intervals. Off-air vision and sound is also monitored by studio staff.

Sound level is automatically controlled by a tri-band limiter-compressor in each transmitter input in association with an average level sensing variable gain amplifier at the studios. This arrangement has proved very successful, maintaining correct levels with a wide range of input signals, without objectionable side effects.

Remote switching is provided by the GTE 51L2 system to allow either transmitter to be connected to either STL. The input to the TSL can also be remotely switched to various monitoring points, feeds from outside broadcast (OB) receivers, or from the Telecom Television Operating Centre (TOC) located in the tower. Similarly the TOC can be fed outputs of either link, off-air programme or the O.B. receivers.

Remote supervision of up to 96 equipment status and alarm conditions along with 15 analogue readouts are returned to the studios in one voice frequency channel on the TSL. via the GTE 51L2 and 51T2 telemetry equipment. Much of the setting up of this control and supervision equipment, along with the supply of various interface items and distribution amplifiers was carried out by IRT, a Sydney based firm specializing in this field.

A motor driven coaxial switch is remotely controlled and supervised to allow either transmitter output to be connected to the aerial whilst simultaneously connecting the alternate transmitter to a 20kW water cooled dummy load. Changeover time is approximately four seconds. Associated with this switch is a comprehensive coaxial "U" link patch panel to allow various emergency patch arrangements between the transmitters, the two sections of the aerial and the dummy load.

ROSS BURBIDGE joined the Australian Post Office as a Grade 1 Engineer in 1956. He worked in the Victorian Radio Section in most areas including expansion work at Radio Australia, setting up Phase III television transmitters and commissioning microwave bearers. From 1965 until 1972 he was Project Manager for RCA responsible for the installation of external plant and Receive Station equipment at Radio Australia, Darwin. He is currently Project Engineer for Canberra Television Limited, involved with the major rebuilding and expansion of the Company's facilities.

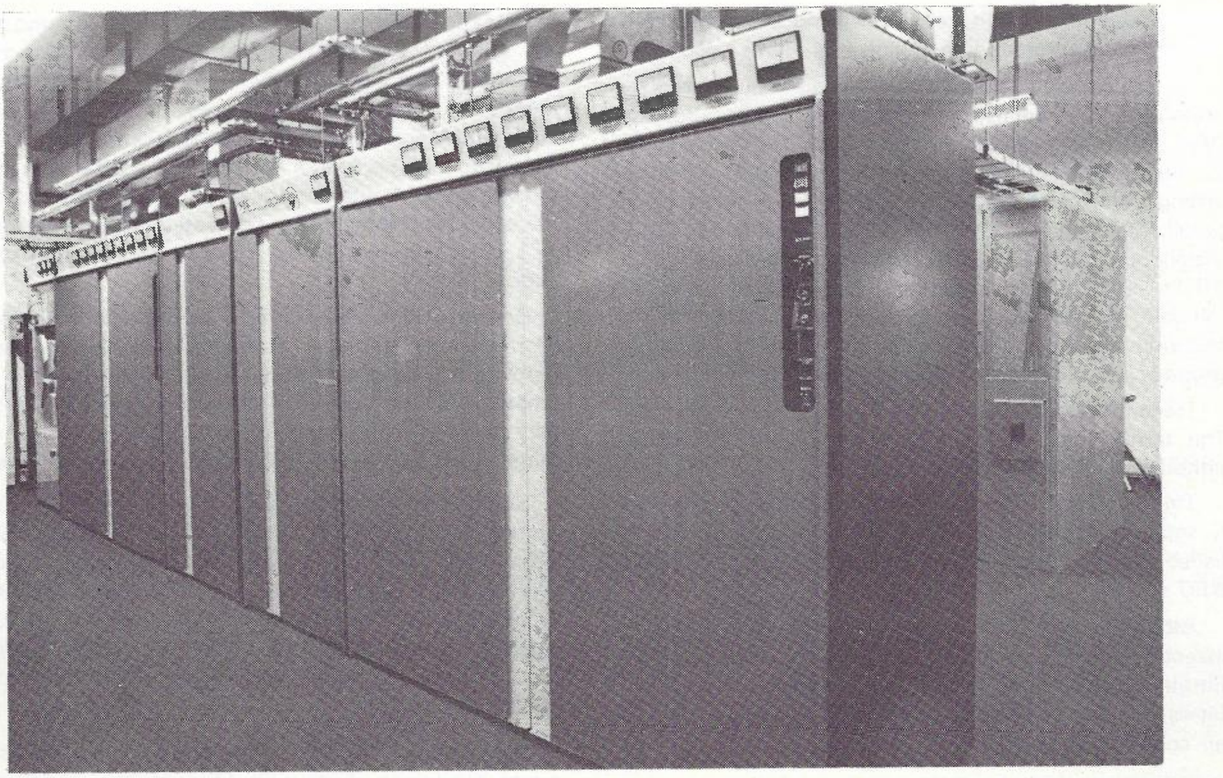


Fig. 1 — Transmitter Cabinets.

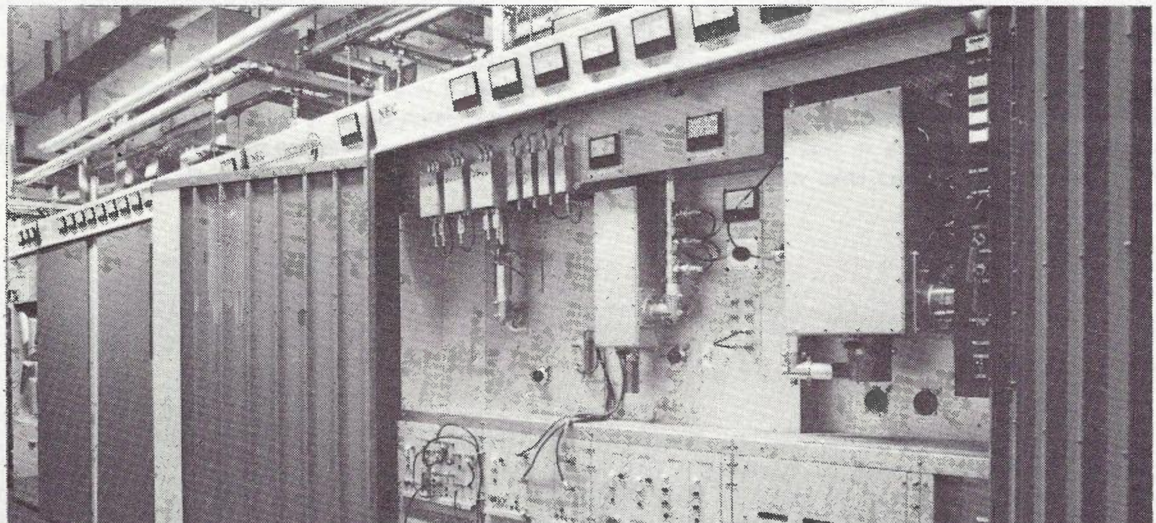


Fig. 2 — Transmitter 2 Modules.

**Fig. 3 — Input Equipment and Transmitter Coaxial Patch.**

## INSTALLATION

The location of the leased area provided some minor constraints on the equipment layout. In particular all exhaust air had to be routed to a single roof penetration to one side of the best equipment location. As the transmitters and heat exchanger for the dummy load had a total flow of approximately 200 cubic metres per minute, ducting and noise problems were somewhat more severe than usual. In the case of the transmitters, auxiliary fans were installed in the exhaust ducts to overcome the extra frictional losses and the whole complex of six fans and one water pump was located in a sound isolated air intake room next to the transmitters. Carpeting of the floor around the transmitters provided some sound absorbency in an otherwise very "live" location. At present the noise level in front of a transmitter is of the order of 80dB flat. Any further reduction would have involved sound proofing the ducts and increasing room absorbency and was not considered to be warranted for an unattended site.

Installation of the transmitter station was done by four to six members of CTC-7 staff from October 1978 to the on-air date of December, 15th 1978. IRT supplied and commissioned much of the input, control and supervisory equipment. A separate sub-contractor supplied and installed the ducting to CTC/NEC design. An NEC engineer was on site for some equipment updating and proof of performance tests over a period of two to three weeks. **Fig. 1** shows a general view of the transmitter cabinets with a partial view of one high voltage cage on the right. **Fig. 2** was taken from the same general location with the front doors of transmitter T2 opened. **Fig. 3** taken from the other end of the main cabinets shows on the left the aerial patch panel next to transmitter T1, with the microwave links and input equipment on the right.

## CONCLUSION

The installation, operation and maintenance of a high power television transmitting station by a commercial operator within a high security Telecom Building is unique for Australia. The drawing up of the legal agreement allowing this to occur took several years. This deed which is believed to be the first of its type was agreed to by CTC-7 in October, 1978.

The transmitter installation has now been on the air for over 2 years with negligible problems, proving in the Company's view that the remote control of unattended high power television transmitters is a practical arrangement with modern concepts and equipment. The agreement with Telecom has also worked very smoothly due in no small part to the excellent co-operation obtained at the tower from Telecom and security staff.

# Buildings Engineering Services

M. S. PEMBROKE, M.I.E.E. (London).

This paper outlines the nature and extent of buildings engineering services provided at the Black Mountain Communications Tower. Reference is made to procedures leading to the development of documentation for calling tenders, and the roles of Telecom as client and the Department of Housing and Construction as the design and construction authority are explained. Brief comments on costs and maintenance are included, but the main purpose of the paper is to describe the services installed relative to requirements contained in Telecom's design brief.

Consideration of the engineering services required in buildings constructed for Telecom begins when justification for the facilities to be housed is formulated. At this early stage of planning, meetings between representatives of sponsoring branches and the Buildings Branch are held in order to establish parameters for the design of the buildings and their support services. Usually, this information is then examined by the Department of Housing and Construction (DHC) and, subject to advice in respect of feasibility, Telecom proceeds to develop a brief of requirements for use by that Department in proceeding with detailed designs.

For Telecom buildings in NSW and the ACT, the engineering services component of projects is handled by the Buildings Engineering Services Section of the NSW Buildings Branch, which is located in Sydney. Staff of this section undertakes a multi-functional role involving liaison, information gathering, the preparation of design briefs, collaboration with the DHC during detailed design, the recommendation of tenders, takeover of completed works on behalf of the Commission, and arranging ongoing operational maintenance after expiration of contract warranties.

In terms of cost, novelty and significance, both as a communications facility and as an unusual type of building located in a nature reserve close to the national capital, the Telecom Tower was regarded as a special case, and all matters leading to acceptance of a tender for its construction were handled by Telecom headquarters in collaboration with the DHC. Subsequently, the Buildings Engineering Services Section in Sydney participated as required with the DHC in Canberra during the construction phase.

## ENGINEERING REQUIREMENTS IN TELECOM'S DESIGN BRIEF.

Design briefing information to the DHC included details of the following engineering services. At the time the brief was drawn up, imperial units were in use. These have been converted to metric near-equivalents in this article:

**Security**

- Security guard post
- Controlled access for vehicles
- Restricted access for people
- Closed circuit television and audio surveillance
- Segregation of Telecom and public
- Selective control of lifts
- Peripheral protection and detection

**Air Conditioning for**

- Areas occupied by Telecom staff and communications equipment
- Public and Telecom areas at ground floor level
- Restaurant at 4th floor level
- Enclosed viewing gallery on 5th floor

**Mechanical Ventilation of**

- Toilets
- Engineering plant and equipment areas
- Power and battery rooms
- Vehicle parking area and security lock
- Cable tunnel

**Fire Protection**

- Automatic wet pipe sprinkler system to basement, 4th floor and 5th floor
- Early Warning detection systems to Telecom equipment areas and associated operational areas

- Thermal detection to ground floor and temporary storage space on lower ground floor
- Manual break glass alarms at all levels
- Fire hydrants and hosereels throughout the building and an external hydrant ring main
- Fire isolated stair and stairwell pressurisation system
- Smoke exhaust and fire mode operation of air handling system

**Electrical Services**

- Substation and main switchboard
- 415/240 Volt distribution for light and power
- Earthing
- Lightning protection
- Metering
- Tower obstruction lighting

**Emergency Power Generation**

- Diesel alternator and fuel supply

**Lifts**

- Two passenger lifts of maximum capacity consistent with building design
- One goods/passenger lift of 1400 kg capacity
- Modes of operation to suit particular circumstances

**Hoisting Facilities**

- Monorail and retractable cathead with a 3 tonne electric hoist for loading and unloading vehicles at basement level.
- Crane at 80 m level with a lifting capacity of 1500 kg for hoisting antennae into position.

**Domestic Services**

- Hot and cold water to basins, sinks, and showers
- Hot water urns, refrigerated drinking water units, etc.
- Sump pump in cable tunnel

## COST OF ENGINEERING SERVICES

At 1973 prices, the estimated total cost of the project including road and siteworks was $6.8M, and the engineering services component was estimated at about $1.5M, or 22% of the total.

Allowing for deletions, this estimate was closely matched in practice and, after tenders had been let for nominated sub-contracts, the cost of services represented about 20% of total cost.

## AREAS OCCUPIED BY ENGINEERING PLANT

| | |
|---|---|
| • Basement | 390 $m^2$ |
| • Lower Ground Floor | 28 $m^2$ |
| • Ground Floor | 7.4 $m^2$ |
| • R. T. Drum | 223 $m^2$ |
| • Public Drum | 223 $m^2$ |

## ENGINEERING SERVICES FOR RESTAURANT, SNACK BAR AND ASSOCIATED AREAS

Although capacity for engineering requirements to operate the restaurant and snack bar was specified, including requirements for food preparation and storage in the basement, extension of these services was determined after selection of a concessionaire to operate these facilities and design and construction work required by the concessionaire was oversighted by the DHC.

## MAINTENANCE OF ENGINEERING SERVICES

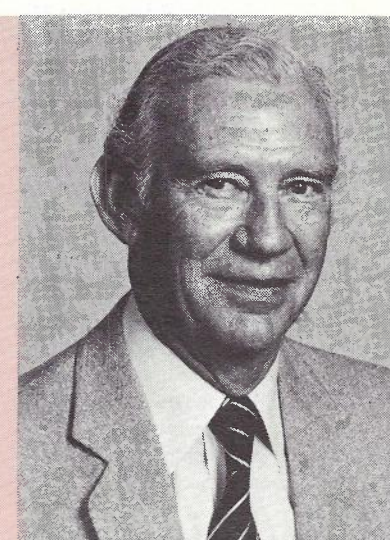
As stages of the building and their associated services were taken over progressively by Telecom, contract warranties for the services expired at various times, in some cases before these services could be brought into use in areas still to be completed.

In anticipation of the need to ensure the levels of security and reliability consistent with use of the Tower for local and national communications and as a public facility, an early decision was taken to employ experienced Telecom staff for operational maintenance of the engineering services. A detachment of the Buildings Engineering Services Section in Sydney was established for this purpose late in 1977, and is now located permanently at Dickson, ACT.

Initially, the maintenance cell was located at the Tower to enable staff to become familiar with the services as installed, to establish plant registers, and to assist with the resolution of problems occurring during commissioning and at takeover by Telecom.

Now, with the exceptions of lifts and some security systems, the cell is responsible for routine maintenance and first-in repair work at the Tower and other Telecom buildings in the ACT.

MAURIE PEMBROKE joined the PMG's Department as an engineer after working for nine years in the private sector on the design and development of electro-mechanical communications equipment. Until 1960 he was responsible for the maintenance of telegraph services in NSW and subsequently, as senior engineer, he directed activities associated with the installation and maintenance of mail handling plant. In 1966 he was seconded to work on the planning of special projects for the State Director and from 1971 to 1975 he worked as materials inspection engineer in the NSW Support Services Branch. After vesting day Mr Pembroke was promoted as Engineer Class 5 to manage the Engineering Services Section of the Buildings Branch which had been established as a separate branch of the state administration in 1973.



## ENGINEERING SERVICES AS INSTALLED

### Security

Basic security has been designed into the building by providing for the physical segregation of Telecom and other users and this is complemented by restricting access to Telecom equipment areas, including access from lifts, by a controlled pass system.

A guard post equipped with facilities for monitoring the status of secured points throughout the building and remote control of vehicle entry is provided, and key points are continuously monitored by a closed circuit television and audio surveillance system.

Other systems and devices are installed to detect breaches of security both inside and within the building during times when the Tower is not open to the public, and details of breaches are recorded.

### Air Conditioning

#### Design Parameters

- Site elevation: 798 m. above sea level
- Outside ambient temperature: 35°C dry bulb, 21°C wet bulb
  Maximum solar load to -1°C dry bulb, -1°C wet bulb
- Inside conditions
  Equipment area: 18°C to 29°C dry bulb; 30% to 75% relative humidity
- Other Occupied areas: 20°C to 25°C dry bulb; 60% relative humidity (max.).

#### Cooling System

The cooling capacity for conditioned areas is supplied from two similar chiller sets comprising a centrifugal compressor, water circulating pump, and cooling tower. These items are housed in a plant room at basement level and chilled water is distributed through a closed loop to fan coil units located in proximity to the areas served. Designed in and out water temperatures of the chillers are 15°C and 7°C respectively.

Each of the chiller sets is sized to provide for 50% of the maximum cooling load of about 2500 MJ / hour and manually operable valves are provided to permit of cooling capacity to selected essential loads in the event of a sustained breakdown in one of the chiller sets. For shorter outages of one chiller set, conditions in each of the treated areas would vary according to demand and capacity.

Although the design brief called for cooling towers to be located remotely from the building, it was later decided to place them within the building for aesthetic and practical reasons associated with security.

The towers are conventional induced draught evaporative coolers using water in heat exchanges as the cooling medium for hot refrigerant gases. Outside air is induced through louvred panels in the south wall of the building and air heated by contact with water through the cooling towers is discharged through louvres in the same wall.

#### Heating

Heating is provided by electric air heaters installed as primary heater banks in main discharge ducts from supply air fans, or as reheaters in branch ducts to areas requiring individual temperature control.

#### Conditioners and Distribution

Conditioned air is ducted from fan coil units containing fans, cooling coils and dry fabric filters. In addition, where necessary the output from separate steam humidifiers is fed into the air distribution systems.

For the larger conditioners, both during heating and cooling modes of operation, maximum advantage is taken

| | Litres/sec. | MJ/Hour |
|---|---|---|
| **Basement:** | | |
| Radio maintenance | 380 | 22.2 |
| Security, PABX, First Aid | 610 | 47.5 |
| **Lower Ground Floor:** | | |
| Transmitter hall, FM radio | 3000 | 253 |
| Control room | 1200 | 95 |
| **Ground Floor:** | | |
| Public entry building | 3600 | 295 |
| **R. T. Drum:** | | |
| South east sector | 5100 | 385 |
| South west sector | 3200 | 237 |
| North west sector | 2700 | 216 |
| North east sector | 3800 | 306 |
| **Public Drum:** | | |
| West sector | 3000 | 285 |
| East sector | 3000 | 285 |

**Table 1: Location and Ratings of Fan Coil Units**

of outside conditions to support requirements in treated areas. This is achieved by automatically optimising the balance of fresh air intake and recirculated air to provide the most economical use of installed plant.

In order to provide clear usable space for functional purposes, conditioners have been located variously above ceilings, in mezzanine plant rooms, and in the truncated conical sections below the Tower drums.

The locations and ratings of fan coil units are shown in Table 1.

## Ventilation

### Exhaust Systems

Ventilation for the following uses is provided by ducted axial flow exhaust air systems located in proximity to the areas served:

- Cable Tunnel:
- Basement:
  Plant rooms, electrical switchroom, toilets, locker rooms, storeroom, kitchen, cool room and car parking.
- Lower Ground Floor:
  Television transmitter rooms and switchroom.
- Ground Floor:
  Toilets and Cleaner's room.
- RT Drum:
  Battery room, toilets and locker rooms.
- Public Drum:
  Kiosk and Kitchen.
- Tank Room (74 m. Level):
  Lift motor room (exhaust and filtered supply).

In all, there are 21 exhaust air systems installed varying in size from 470 l/s in the RT drum toilets to 13 000 l/s for the emergency generating plant room.

### Supply Systems

Supply air to the stairwell is normally provided by filtered air ducted from two axial flow fans, one located in the RT drum plant room and the other in the Public drum plant room. Each fan has a capacity of 470 l/s and exhaust is by filtration.

In order to inhibit smoke logging during fire emergencies, an additional fan of 2600 l/s in each of the plant rooms serving the R.T. and Public drums is activated by the fire alarm system to provide stairwell pressurisation. As with the normal stairwell ventilation system, supply air is filtered and exhaust is by filtration but the normal ventilation fans are automatically switched off when stairwell pressurisation fans are activated.

## Fire Protection

### Fire Control Equipment

An automatic wet pipe sprinkler system complying with SAA Code CA16-1971 has been provided to cover the basement and public drum. The system is standard and the fusing of any sprinkler head would automatically sound a local alarm and extend an alarm to the Fire Brigade.

Water supply to the sprinkler and hydrant system is stored in two 228 000 litre capacity tanks located underground below the pedestrian walkway leading to the main entrance, and static head is maintained by an electrically operated jacking pump.

In the event of fire and the fusing of a sprinkler head, an electrically operated pump would be activated to pressurise the system for fire control. If the electrically driven pump failed to operate, a secondary pump driven by a diesel engine would automatically be brought into operation.

Hydrants and hose reels provided at all levels inside the building are charged from a single rising main fed from the same tanks which supply the sprinkler system, and a hydrant ring main around the building and car park also draws its supply from these tanks.

As for the sprinkler system, an automatic electrically operated pump backed up by a pump driven by a diesel engine is installed to provide pressure for fire fighting, and static pressure is maintained by a separate electrically operated jacking pump.

Hydrant points are provided also at intervals along a 100 mm main which follows the access road to a reservoir and pumping station lower down the mountain. This main supplies water to the storage tanks for the tower and, as backflow from the tanks is inhibited by design, pressure for fire fighting purposes from this main requires boosting by the Fire Brigade.

All pumps for fire control equipment are located in the basement and are designed for the duties indicated in Table 2.

| | |
|---|---|
| **Sprinkler Boost Pumps:** | |
| 1 Electrical | 30 l/s at 46 m Head |
| 1 Mechanical | 30 l/s at 46 m Head |
| **Hydrant Boost Pumps:** | |
| 1 Electrical | 15 l/s at 116 m Head |
| 1 Mechanical | 15 l/s at 116 m Head |
| **Jacking Pumps, Electrical:** | |
| 1 Sprinkler | 0.38 l/s at 92 m Head |
| 1 Hydrant | 0.38 l/s at 92 m Head |

**Table 2. Fire Control Pump Ratings.**

### Fire Detection Equipment

All Telecom equipment areas are protected by early warning combustion type smoke detectors wired in a checkerboard pattern with adjacent detectors on separate circuits. Operation of one detector only will raise a local alarm and extend an alarm to the Fire Brigade, but operation of detectors on separate circuits will, in addition, initiate close down of supply air fans and operation of exhaust fans to reduce smoke logging.

Other spaces protected by early warning smoke detectors are:

- Cable tunnel
- Fire stairway
- Risers for Telecom cables, electrical distribution and mechanical services
- Lift shafts and lift machine room
- Tower shaft at levels 68 m and 81 m.

Thermal detectors are provided to protect the lower ground floor, the ground floor, lift lobbies and air conditioning plant rooms at levels above the basement, and operation of any one of these will raise a local alarm and extend an alarm to the Fire Brigade. These alarms can also be manually initiated by operation of break glass alarms which are provided at all levels in the building.

A fire indicator board installed inside the staff entry at basement level provides the following basic facilities:

- Identifies the location of a fire source,
- Initiates local and extended alarms,
- Initiates 'Alert' and 'Evacuate' signals
- Causes selective close down of supply air to the affected area,
- Establishes smoke exhaust paths to atmosphere,
- Causes close down of air conditioning in the event of fire in an air conditioning plant room,
- Causes operation of stairwell pressurisation fans,
- Puts lifts into 'fire' operating mode.
- Releases all doors normally secured by electro-mechanical devices.
- Supplies mimic information to security post.

#### General

Due regard was given in design to minimising the use of readily combustible materials, maintaining the integrity of fire isolation, and complying with relevant codes for safe occupancy and use of the building. During construction, liaison with the Fire Brigade was maintained and, so far as is practicable, alterations and additions recommended by the Fire Brigade have been implemented.

### Electrical Services

#### Electricity Supplies

Electricity supply is taken from the ACT Electricity Authority via two separate 11 kV feeders derived from different distribution systems. One feeder is run underground most of the way up the mountain, and the other is run overhead to the local area and then underground to a substation at basement level in the building. As the separate feeders are each capable of carrying the Tower load, a high level of reliability is assured.

The substation comprises 3 x 1000 kVA oil filled naturally cooled stepdown transformers, each of which feeds dedicated loads via the main switchboard with 415 V/ 240 V three phase 50 Hz supplies. Provision has been made for bus links between the transformers, which are over capacity, thus ensuring adequate backup in the event of any one of the transformers becoming unserviceable.

#### Distribution

The total load of the building is expected to vary from approximately 1400 kVA in the early stages of operation to an ultimate load of about 3000 kVA when fully developed services have been installed. Supplies from the main switchboard are distributed as follows:

- Television transmitters
- FM transmitters
- Television operations centre
- Control room, lower ground floor
- Mobile radio telephone
- Radio relay
- Concession areas in public drum
- Emergency lighting
- Tower obstruction lighting
- Lifts
- Fire services
- Security systems
- General light and power
- Mechanical services

With the exception of general light and power and chiller sets for air conditioning, automatic transfer switches connect a locally generated emergency power supply in the event of failure of the commercial mains.

All sub-mains are run in PVC sheathed MIMS cable on trays and ladders, rising cables are installed in a riser provided in the tower shaft for the purpose, and distribution boards are located on all levels of the building.

#### Lighting

Lighting, which is chiefly by fluorescent tube fittings, has been arranged to suit the functional requirements of the various areas. Facilities such as dimming for the television operating centre, programme transmission rooms, and control room, have been provided and two-way switching is installed for the safe entry and exit of staff.

Emergency lighting for the stairwell and lift lobbies is operated through a static inverter to ensure uninterrupted supply during changeover from mains to locally generated power during emergencies, and exit signs have been provided throughout these areas to assist the safe movement of staff and the public.

In accordance with aviation requirements, continuously operated aircraft warning lights are installed on the Tower at a level 130 m. above the ground floor and at various other levels and, in the event of mains failure, supply to the warning lights is provided from the local emergency generating plant.

#### Earthing and Lightning Protection

The basic system consists of lightning rods on top of the steel antenna column, and four vertical conductors disposed equidistantly around the Tower and embedded in the concrete wall. At each platform or floor level these conductors are connected to horizontal steel reinforcement to provide potential equalisation of all areas. No special earthing conductors are provided on the steel antenna column above the concrete tower as this section provides an adequate conducting path for lightning strikes.

Four electrodes below the tower footings, and a similar electrode at each corner of the podium structure, penetrate to a depth of about 30 m. below basement level to form the main connection to ground, and these are supplemented by six additional electrodes disposed around the pedestrian ramp and local access roads.

All electrodes are interconnected by bonding cables laid under and around the building to form an extensive earth mat, and reinforcing steel in the building and pedestrian ramp is connected to the mat at frequent intervals.

Tags connected to earthing conductors in the concrete were provided to extend earthing to plant, equipment and metal objects, and provision was made for a common earthing bus 2 m. below basement level inside the tower shaft.

In practice, the measured resistance of less than 1 ohm for the earthing system was well within the target of 2 ohms specified in Telecom's design brief and the 1 ohm specified by the ACT EA.

## Emergency Power Generation

### Diesel Alternator Plant

Emergency power is supplied from a 940 kVA, 415 V/ 240 V 3-phase 50 Hz alternator driven by an automatic-start diesel engine located adjacent to the main switchboard at basement level. An associated control cubicle provides for sensing the status of the mains supply, automatic start/stop functions and frequency control.

The diesel engine is started by compressed air which normally is maintained at the correct pressure by an electrically operated compressor. However, if this compressor is unserviceable for any reason, pressure in the reservoir is obtained from a separate compressor driven by a diesel engine.

Run-up time of the emergency generating plant is about 10 seconds and, in order to overcome the problems resulting from interruptions of a repetitive nature over a short period, the diesel/alternator set will continue in operation for an adjustable minimum period of several minutes before switching back to the mains supply after a failure.

The prime mover for the alternator is an eight cylinder, supercharged, water cooled diesel engine designed to operate at 1500 rpm. Water for cooling is cycled through a conventional induced draught evaporative cooling tower located in the basement, filtered air for aspiration is induced via louvres in an external wall and acoustic chamber by a ducted axial flow exhaust fan, and exhaust gases are discharged via a flue through the roof of the podium building.

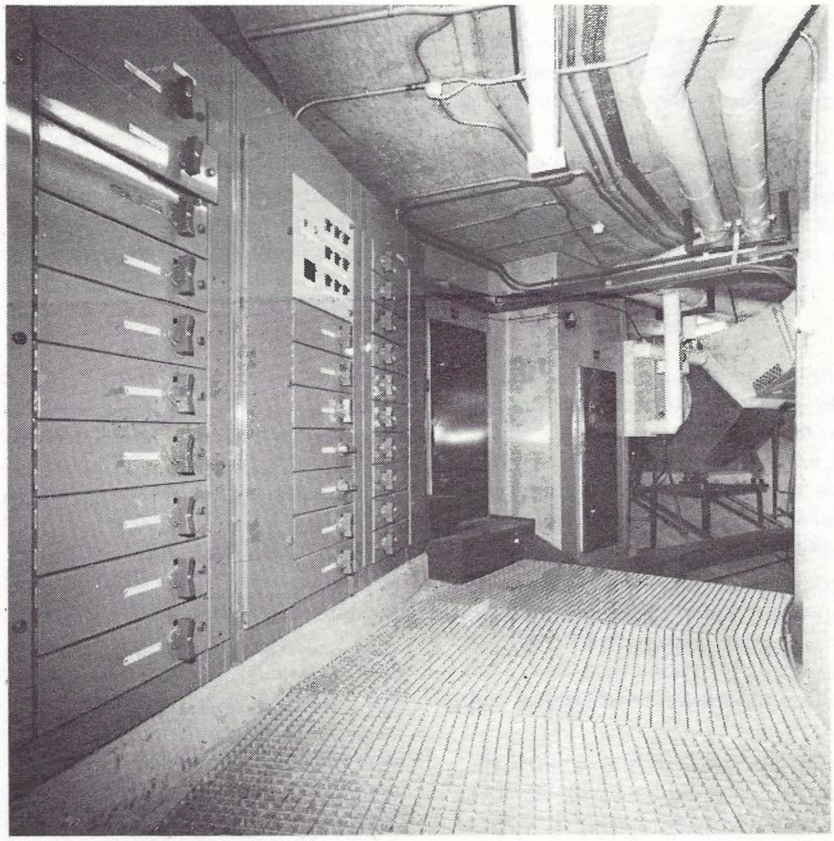
### Alternative Supply

In order to cover the contingency of the local emergency supply being unserviceable during a period of mains failure, provision has been made for the connection of a 250 kVA mobile diesel alternator set. Mobile sets and the resources to place them in service are held by Telecom for such purposes.

The facilities available at Black Mountain Tower for this purpose comprise a connecting cubicle adjacent to the basement entry, cabling to the main switchboard and manual changeover switches to connect selected priority loads up to a total of 250 kVA.

### Fuel Supply

Two 50 000 litre capacity diesel fuel tanks replenished by road tanker are installed underground in proximity to the vehicle entrance at basement level. Supply to local tanks for the diesel generating set and diesel operated fire pumps is effected by automatically operated electric pumps and, to cover the event of failure of the latter, hand operated pumps are installed to maintain local supplies.



**Power Distribution Boards and Air Conditioning Plant in Conical Area at Bottom of Drum.**

## Lifts

Two passenger lifts, each with a capacity of 23 persons, and one goods/passenger lift with a capacity of 1400 kg or 20 persons, are capable of serving eight common levels from the basement to the public viewing gallery. In addition the goods/passenger lift serves plant rooms below the public and RT drums and the roof above the RT drum.

Both passenger lifts which are designed to operate at 3.6 m/s and the goods lift which operates at 2.5 m/s, have a full travel distance in one direction of 69.4 m, and sheaves, hauling gear and control equipment are mounted on floors 75.9 m, 78.1 m, and 81.4 m. above basement level.

### Operation

Whilst the control system provides for conventional automatic programming, the lifts are capable of being operated in several modes to provide for normal use and to meet contingency requirements brought about by unserviceability or special circumstances.

Any of the cars can be selected for use as a fire service lift and normally the pair of lifts available from the public entrance would be programmed for use by the public between the ground floor, the restaurant, and the viewing gallery only. Indication at ground floor level is provided to inform the public as to the areas served by each lift at a particular time.

In normal circumstances, the goods lift is available for use at set times by the concessionnaire between the basement, restaurant and viewing gallery only. Its primary purpose, however, is to serve Telecom requirements at all levels except the restaurant and viewing gallery.

The different modes of operation known or likely to be required are achieveable through timed programmes, card key access to controls by authorised people, and attended operation.

Telephone facilities between each car and the security control post in the basement are provided to deal with emergencies, and closed circuit television surveillance is available between the same points.

## Hoisting Facilities

### Hoists

A monorail fitted with a manually operated retractable cathead and three ton lifting capacity electric hoist is mounted overhead in the loading dock on the lower ground floor. The dock, which has an area of about 4 m. x 11 m., is located above the vehicle and staff entrance at basement level, and the hoist is intended for loading and unloading vehicles at this point.

The loading dock access is normally secured by a roller shutter door and, when this is open, safety gates across the access provide for the safety of operating staff. The monorail runs the full length of the loading dock, and when the cathead is fully extended the hoist hook is 2 m. clear of the building.

Because the lift machine and control rooms are, respectively 9 m. and 12 m. above the highest floor served by lifts, a 1.5 tonne capacity monorail with a retractable cathead and hoist trolley is installed overhead in the control room. A monorail only is installed overhead in the machine room for moving machines to or from a hatchway in the ceiling where hoisting facilities in the control room can be used to move items of plant. Doors in the control room open out from the tower wall to enable the hoist to be extended outside the tower, and so allow loads to be manoeuvred through hatchways in platforms and ceilings at intervening levels between the lift control room and the public viewing gallery.

### Crane

Although a crane for the installation of antennae was called for in the design brief, its provision was subsequently deleted due to a lack of acceptable tenders for the work. Alternative methods for lifting and installing antennae in position were arranged by Telecom.

## Domestic Services

### Water Supply

Water for domestic purposes is derived from the same reservoir and main which supply the fire water tanks referred to in 'Fire Control Equipment'.

The main feeds a 23 000 litre capacity break tank located in the basement, and duplicate electric pumps, each having a pumping rate of 4.5 l/s at 107 m. supply a header tank in the tank room 74 m. above ground floor level.

### Services

Cold water is reticulated to all wash basins, sinks, showers, and toilets, and hot water is provided at these points by mains pressure electric storage units located adjacent to the areas of use.

Boiling water and refrigerated water units are located in lunch rooms and amenity areas, and provision has been made for refrigerators and stovettes in accordance with Telecom's Amenities Code.

### Seepage

Seepage water entering the cable tunnel and at the base of the tower is removed by electrically operated submersible pumps. Two pumps serving the cable tunnel each have a capacity of 0.8 l/s at 7.6 m and the single pump at the tower base has a capacity of 7.6 l/s at 9 m.

## Additional Services

### Emergency Warning and Intercommunication System

During construction of the Tower, Telecom determined its policy for dealing with emergencies capable of affecting the safety of people and the integrity of communications services. In particular buildings this policy requires the installation of emergency warning and evacuation systems (EWIS) as a basis for establishing effective planning and control during emergencies created by fire, gas leakage, spillage of hazardous substances, civil disturbances, and bomb threats etc.

In accordance with this requirement, an EWIS has been installed at Black Mountain Tower. The system comprises a master control station in the security control room in the basement, floor control stations on each floor, and a public address system covering the entire building. Facilities provide for selective communication between the master control and floor control stations, public address on an individual or collective basis, and the generation of "alert" and "evacuate" signals.

Used by a team of trained wardens drawn from people working in the building, it is expected that the EWIS will enable the orderly direction of people in the event of emergencies, and effective co-ordination of local staff and personnel of civil authorities attending to deal with these emergencies.

**CONCLUSION**

With minor exceptions, the principles of design established about eight years ago have been confirmed by practice. Additional facilities required for public usage of the building have created a need for the extension of some engineering services but, in general, the services provided will satisfy Telecom and public requirements for many years into the future. Experience points to a need for greater consideration of physical access for maintenance purposes. In a number of cases this has proved to be inadequate, and rectification is being undertaken by Telecom separately from construction contracts.

---

# Book Review

## Handbook for Radio Engineering Managers

**J. F. ROSS BSc(Eng), FIREE (Aust), MIE (Aust), AFAJM.**
**(Butterworths, London, Boston)**

In the continuously expanding field of radiocommunications and broadcasting, a handbook on engineering project management is a valuable tool. The subject book serves this purpose very adequately. It brings together the many managerial and technical factors that need to be taken into account by the radio engineer concerned with the planning and establishment of a radio system.

Section 1 gives a comprehensive cover of the factors to be taken into account during the programme formulation stage. The cover is comprehensive and includes project control methods, objectives, design programmes, monitoring techniques, and resource and budget planning. The subject is well covered with illustrative diagrams, list of activities, etc.

Section 2 covers the complex area of engineering economics. Inevitably the engineering manager is faced with the decision on the worth of his investment and the most efficient and economic method of implementing a proposal. The various factors that need to be taken into account and the studies that need to be undertaken are well covered in this Section. These aspects are complemented with a significant number of examples to illustrate the effects of various parameters, such as the expected life of various plant units and interest rates. An important factor which has not been taken into account is the effect of inflation on the investment decision process.

Sections 3 and 4 outline the safety practices that need to be considered to protect both staff and plant. The chapters in these sections cover various items of station equipment and their susceptibility to damage, as well as the risk of accidents that they impose on staff. The areas of responsibilities and preventive measures are adequately covered. The area of radiation hazards is of particular interest where, as indicated in Table 25. I, national recommended safe levels of exposure vary by a factor of about 10. Perhaps on a matter of detail, reference could have been made to the requirements for air navigation clearance when erecting masts and towers.

In Section 5, environmental aspects are covered in detail ranging from chemical reactions through to the use of the radio frequency spectrum. Finally, Section 6 is dedicated to the preparation of specifications and the administration of contracts. Again these sections are supported by a significant number of illustrative detail such as typical check lists (Table 46. 1) and examples of acceptance test specifications (Example 48. 1).

In preparing this Handbook, the author acknowledges that no attempt has been made to deal with the technical aspects of design and measurement or the theoretical aspects of management and organisation. These are left to the multitude of other excellent expert publications which are adequately referenced under the individual Chapters.

In a Handbook of this size it is inevitable that some omissions will occur. However these can only be considered as a matter of minor detail which should not detract the user from the benefits offered overall. The text is entirely practical in its approach and is well supported through extensive use of illustrations, worked examples and case studies. Cost of the book is A$80.50.

Reviewed by V. A. A. Caruana, Engineering Department, Telecom Australia.

# In Brief

## "ELECTRONIC YELLOW PAGES" TO REACH $2.5 BILLION BY 1990

Information on products and services, of the type which is currently available in telephone yellow pages, will soon be provided in electronic form, according to a newly-published 170-page report from International Resource Development Inc. The report predicts that the U.S. operators of "electronic yellow pages" services will derive revenues of more than $200 million by 1985; the market will pass the $2.5 billion level in 1990, according to IRD. Because these new "yellow pages" can be constantly updated, they can provide information on prices, special sales, etc. of the type which is currently the province of newspaper classified advertising; thus electronic yellow pages represent both a threat and an opportunity to the newspaper industry.

### Washington Post Talks With GTE — Franchised Operation Planned

Revealed in the report is the outline of a planned INFOVISION service which General Telephone & Electronics is offering to The Washington Post and other newspapers on a franchised basis. The service would allow a local newspaper to become an EYP operator; local information banks would be augmented by access to centrally-provided databases and services. "GTE seems to be close to obtaining the five signed letters of intent which the company decided it needed before proceeding further with INFOVISION", stated Celeste Hynes, one of IRD's researchers. Meanwhile, the report points out, The Arizona Republic and The Phoenix Gazette have formed a joint venture company, RG Cable, and will sell classified advertising and editorial content on three leased channels to cable companies. The report pointed out also that AT&T has designated electronic yellow page service as one of the first activities to be pursued by its new non-regulated subsidiary, assuming that legislation is not passed eliminating Bell's role in EYP.

### Link With Electronic Mail

The availability of electronic yellow pages will help stimulate the move towards the installation of home terminals, including view-data-type equipment, integrated video terminals and hand-held portable terminal devices. The report points out that hobbyists with Radio Shack, Apple and other home computers can already access electronic classified-ad services operated by Source Telecomputing (a subsidiary of Readers Digest) and CompuServe (a subsidiary of H&R Block). The same terminals used for EYP access will also be increasingly used for sending and receiving "electronic mail", predicts the report.

### EYP on ACS

The report speculates on the possible features of AT&T's "new" Advanced Communications Service (ACS) which is expected to be announced soon, and the possibility is raised that ACS will be structured as an information utility and will include both EYP and electronic mail capabilities. The Communications Act of 1980 (which failed to pass) included wording (the so-called Wirth Amendment) which would have greatly restricted AT&T's role in electronic yellow pages. AT&T is expected to lobby strongly in 1981 to remove such wording from any 1981 Communications Act, although the powerful American Newspaper Publishers Association is very much alert to the consequences of EYP on newspaper classified advertising and is expected to support retention of the Wirth Amendment.

### Paper Directory Phaseout Set for 1995 In France

In France the government-controlled Post, Telephone & Telegraph organization is moving ahead with an ambitious plan to phase out paper telephone directories over the next fifteen years, with complete elimination of phone books by 1995. Consumers will be provided with a simple, inexpensive ($100) TV-like terminal device with a keyboard which will enable them to request directory information "on-line". The French expect that savings on paper, printing and distribution of paper directories, coupled with a reduced load on directory-information operators, will more than pay for the required terminals and computer hardware. The same types of terminals, manufactured by the French company Telic, will be used

**Ten Year Projections for Electronic Yellow Pages/Classified Advertising Revenues in USA**

**(billions of dollars)**

| Time Frame | Projected Revenues ($ millions) | Percentage Leakage From Paper YP/CA (%) To EYP |
|---|---|---|
| 1980 | < 1 | — |
| 1981 | 5 | — |
| 1982 | 10 | 0.1 |
| 1983 | 30 | 0.3 |
| 1984 | 110 | 1.0 |
| 1985 | 250 | 2.0 |
| 1986 | 580 | 4.0 |
| 1987 | 940 | 6.0 |
| 1988 | 1400 | 8.0 |
| 1989 | 1900 | 10.0 |
| 1990 | 2500 | 12.0 |

(Source: International Resource Development Inc.)

for GTE's INFOVISION service in the U.S.

The impact on paper directories in the U.S. is expected to be slower than in France. "Paper phone books will be around for a long time in the U.S.", predicts Hynes, who believes that "the net impact of electronic yellow pages on phone books will be to make them a little thinner — advertisers will continue to advertise in the paper directories, but some ads will be smaller because of diversion of advertiser dollars to the new electronic media". Hynes believes that the impact on newspaper classified advertising will be more noticeable, while some specialized industry directories will "have their usefulness and circulation devastatingly cut by EYP". "In terms of paper consumption, EYP may result in a reduction of some 50,000 tons of uncoated groundwood paper consumption by 1990", predicts Hynes.

The IRD report, entitled "ELECTRONIC YELLOW PAGES", includes a detailed scenario for the development of EYP services, together with discussion of the probable roles to be played by CATV companies, telephone common carriers, timesharing companies, publishers and others.

## FINANCIAL RESOURCES LACKING FOR ITT TELECOMMUNICATIONS EXPANSION

ITT is now faced with several business opportunities which have potential for dramatic expansion, but the company has insufficient available resources to be able to take advantage of these opportunities to the fullest extent possible, says a new report by International Resource Development Inc., a market research and consulting firm. ITT has already made some moves to increase its U.S. market share, as a supplier of telecommunications equipment and as an operator of tele-communications services — both areas of traditional strength for ITT. Major divestments might have to be made to provide the finances ITT needs for a major thrust into this market.

The 57-page report on ITT is part of IRD's Directions Intelligence series of reports which are published periodically. Each report examines the present activities of a major company on an industry by industry basis. The ITT report discusses the developments of the company's corporate expansion and diversification strategy; its financial resources; possible new areas for expension and diversification, the methods to be used, whether acquisition, joint venture or internal expansion.

ITT has always had a strong telecommunications business outside the United States — but has not been able to expand its business in the United States successfully in the past, in great measure because of the dominant position of the AT&T organization as a supplier and user of telecommunications equipment. According to IRD the new era of deregulation in communications and the fast pace of technical innovation will help companies such as ITT expand in this market area. ITT is also helped by the settlement of ITT's antitrust charges against AT&T and GTE which assures ITT of a substantial volume of business with the United States telephone companies during the next ten years.

## HOME TIME-SHARING — 100,000 SUBSCRIBERS BY THE END OF 1981?

Consumers are flocking to sign up for home time-sharing services, and there may be as many as 100,000 subscribers to these services by the end of 1981, according to a new 148-page report from International Resource Development Inc. There are currently two consumer time-sharing services in operation, with a combined total of about 8,000 users according to the report, which predicts entry into the market by several other "major" companies during the next three years. Total revenues generated from these services could exceed $1 billion per year before the end of the current decade, and most of these revenues will be derived from the use of computer and communications facilities which otherwise would have been idle during evenings and weekends.

### Current Contenders — The Source and CompuServe

Demand for the services recently has become so strong that the computer facilities have been overloaded, point out the report. However, both The Source and CompuServe are adding more computers, and will be able to deal with the expected ten-fold expansion in the number of users over the next year or so. The Source has reached an agreement with Tymshare, one of the largest commercial time-sharing companies, to use Tymshare's computers in off-hours; CompuServe has several more of its own computers which could be made available as its consumer business expands. According to Charles W. Newton, project manager for the IRD study, "Tymshare has very cleverly positioned itself so as to obtain an inside view of the development of consumer time-sharing over the next three years, without needing to make a major commitment in terms of new computers and facilities." Newton views several other large time-sharing organizations, including General Electric Information Services and Boeing Computer Services, as possible entrants into the consumer time-sharing services market.

### First The Affluent and The Hobbyists — Broader Market Later

The IRD report predicts that several years will elapse before the market for consumer time-sharing services broadens beyond its current user base of computer hobbyists and affluent gadget-lovers. However, because

| Segments | Applications Processing | Education | Electronic Mail | Entertainment | Information Services | Personal Computing | Transaction Services | Word Processing |
|---|---|---|---|---|---|---|---|---|
| Timeliness | X | | X | | X | | X | |
| Cost Effectiveness | | | X | | | X | | |
| Availability | X | X | | X | X | | X | X |
| Format | X | X | | | X | | X | |
| Social Interaction | | | X | X | | | | |
| Group Influences | X | X | | X | X | X | X | |
| Self Improvement | | X | | | X | X | | X |
| Entertainment | | | X | X | X | X | | |

**Reasons For Using Home Time-Sharing Services**

(Source: International Resource Development Inc.)

| Average Monthly Expenditures | Millions of Households | | | |
|---|---|---|---|---|
| | 1981 | 1984 | 1987 | 1990 |
| $10.00 | .04 | .25 | 1.00 | 3.5 |
| $25.00 | .03 | .15 | .60 | 1.3 |
| $50.00 | .02 | .10 | .30 | .7 |
| $75.00 | .01 | .05 | .15 | .2 |
| $100.00 | | .03 | .10 | .2 |
| Number of Households | 100,000 | 580,000 | 2,150,000 | 5,900,000 |
| Annual Expenditures | $30-35M | $175-200M | $700-750M | $1,500-1,750M |

**Projected Home Time-Sharing Market Through 1990**

the services are nationwide, these categories alone will provide good revenue growth to suppliers through 1985, according to the report. As Newton points out, "Of the expected 1 million home computer users, 10%, or only 100,000 users will be accessing the time-sharing services from the home in 1981."

In an interview program conducted during the study, the IRD researchers asked all of the leading commercial time-sharing vendors how they expected the consumer time-sharing market to develop over the next five years; the response was about evenly divided between cautious optimism and downright skepticism, reports Newton.

Included in the report is an analysis of the demographics of current and potential future users of home time-sharing services, with detailed projections of the expected levels of utilization of informational, transactional and educational services offered by the time-sharing vendors. Noting that CompuServe was recently acquired by H&R Block, the tax-preparing services company, Newton speculates that Block may have in mind an interactive automated tax-preparation service offering, which could be programmed to minimize the user's taxes, while at the same time alerting the user to the percentage probability of an IRS audit. "Maybe we'll get to the point where Block's computers can outwit the IRS computers," comments Newton.

International Resource Development, Inc., is a specialised management consulting and market research firm. Further details of the three reports, including free tables of contents and descriptions, are available from International Resource Development at 30 High Street, Norwalk, CT 06851; USA.

# The Telecommunication Journal of Australia

## ABSTRACTS: Vol. 31 No. 2.

\

**AUDET, V. J.: 'The Telecommunications Tower, Canberra — National TV and FM Broadcasting Facilities'; Telecom. Journal of Aust., Vol. 31, No. 2, 1981, page 137.**

The installation of high powered television and sound broadcasting transmitters is always a challenging and rewarding engineering exercise. When you add to this the complexities that this particular construction and layout imposed on the installers the exercise is unique. The article describes the background and highlights of this project.

**BURBRIDGE, R. K.: 'The Telecommunications Tower, Canberra — Commercial Television Installation'; Telecom. Journal of Australia, Vol. 31, No. 2, 1981, page 144.**

Separate commercial and national TV transmitting installations existed on Black Mountain. With the advent of the Telecom Tower, it was decided that the two facilities should be co-located in the new complex. Operation and maintenance of the commercial installation is carried out by Canberra Television Limited, under an agreement with Telecom which is unique in Australia. This article describes aspects of the commercial TV installation.

**COLE, M. F.: 'The Telecommunications Tower, Canberra — Design and Construction'; Telecom. Journal of Aust., Vol. 31, No. 2, 1981, page 120.**

A unique structure designed to house critical electronic equipment and provide public restaurant and viewing facilities on what is basically a tall chimney-like structure required many innovative and novel engineering solutions to the many critical issues involved. This article describes the design and construction issues which were encountered in achieving completion.

**DERRICK, L. J.: 'The Telecommunications Tower, Canberra — Radio Functions and Specifications'; Telecom. Journal of Aust., Vol. 31, No. 2, 1981, page 101.**

This article follows on from the introductory article and discusses in more detail the reasons for the tower being constructed and for the selection of the Black Mountain location. Also outlined are the technical specifications made for long-term requirements for radio relay, FM and TV broadcasting, mobile radio, radio paging and other services.

Some details are given of the accommodation requirements for internal plant and the associated antennas for the above services. The electrical and mechanical design criteria for the lattice steel antenna column, the tower lightning protection, and other details specified in the tower brief to allow for the continued orderly expansion of services when required in the future, are also discussed.

**McCARTHY, J. F.: 'The Telecommunications Tower, Canberra — Project Development and Building Facilities'; Telecom. Journal of Aust., Vol. 31, No. 2, 1981, page 114.**

The Black Mountain Tower story is unique and unlikely to be repeated. This article summarises the developments leading to the conception, construction and commissioning of the tower and describes its more unusual features, particularly those associated with the accommodation of facilities for the public.

**PEMBROKE, M. S.: 'The Telecommunications Tower, Canberra — Buildings Engineering Services';Telecom. Journal of Aust., Vol. 31, No. 2, 1981, page 148.**

This paper outlines the nature and extent of buildings engineering services provided at the Black Mountain Communications Tower. Reference is made to procedures leading to the development of documentation for calling tenders, and the roles of Telecom as client and the Department of Housing and Construction as the design and construction authority are explained. Brief comments on costs and maintenance are included, but the main purpose of the paper is to describe the services installed relative to requirements contained in Telecom's design brief.

**SMITH, N.: 'The Telecommunications Tower, Canberra — A Historical Review of the Planning of the Sydney-Canberra-Melbourne Trunk Route'; Telecom. Journal of Aust., Vol. 31, No. 2, 1981, page 94.**

Canberra is a significant source and sink for trunk line traffic as well as a major repeater on the main Sydney-Melbourne trunk route. Consequently the growth of traffic and the route itself has been most dramatic over the past 50 years requiring the use of the largest capacity facilities available. This article describes this growth, the planning involved and speculates on the future.

---

# THE TELECOMMUNICATION JOURNAL OF AUSTRALIA

Volume 31, No. 2, 1981

ISN 0040-2486

## CONTENTS

### The Telecommunications Tower, Canberra



**COVER: Telecommunications Tower, Canberra**

Other Items:



Printed by Standard Commercial Printers, 2 Railway Rd., Cheltenham, 3192.

# The Telecommunication Society of Australia

## Subscription and Membership Rates, 1981

**TELECOMMUNICATION JOURNAL OF AUSTRALIA**

| | |
|---|---|
| (Australia) Membership rate — See Note 3 | $4.50 |
| (Australia) Non-member rate | $8.00 |
| Overseas subscription rate (post free by surface mail) — See Note 2 | $12.00 |

**Single copies** (including back issues)

| | |
|---|---|
| (Australia) members | $3.00 |
| (Australia) non-members | $4.00 |
| Overseas subscription rate | $ 5.50 |

**AUSTRALIAN TELECOMMUNICATION RESEARCH**

| | |
|---|---|
| (Australia) members — See Note 3 | $6.00 |
| Non-members | $12.00 |
| Overseas subscription rate (post free by surface mail) — See Note 2 | $16.00 |

**Single copies** (including back issues)

| | |
|---|---|
| (Australia) members | $4.50 |
| (Australia) Non-members | $9.00 |
| Overseas subscription rate — See note 2 | $10.50 |

**AUSTRALIAN TELECOMMUNICATIONS MONOGRAPH No. 4**

**Automatic Telephony in the Australian Post Office**

| | |
|---|---|
| Members (Australia) | $3.00 |
| Non-members (Australia and Overseas) — See Note 2 | $6.00 |

Notes: (1) Subscriptions addressed to an office (e.g. Librarian, General Manager, etc.) cannot be accepted at membership rate.

(2) Overseas readers: Please note that the rates must be paid in Australian currency. Special rates for air mail postage are available on application.

(3) Telecom Australia employees should arrange to have their membership costs deducted from salary. Your local agent or State Secretary will advise procedures.