Black Mountain Tower Canberra

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Abstract: Two historic papers from a special issue of the *Journal* in 1981 featuring the new Black Mountain telecommunications tower in Canberra.

Keywords: Telecommunications, History, Canberra, Black Mountain Tower.

Introduction

In 1981 the Society produced a special issue of the *Telecommunications Journal of Australia* (Volume 31 Number 2) featuring eight papers on the new Black Mountain telecommunications tower in Canberra. Two of these papers have been selected for this historic review.

The first paper (Taylor & Brigden, 1981) is an introduction to the construction of the tower and the vigorous protests against the project. The construction was debated by Planning Authorities and in Parliament by successive Governments and the associated environmental protests even reached the Supreme Court.

The second paper (Derrick, 1981) discusses the reasons for selecting the Black Mountain tower location and the long-term provisions therein for radio relay, FM and TV broadcasting, mobile radio, paging and other services.

The tower was opened to the public by Prime Minister Malcolm Fraser in May 1980 and has been a feature of the Canberra skyline ever since.

The other papers in that special issue of the *Journal* on the Black Mountain tower are highly recommended for further reading and cover the following topics:

- A Historical Review of the Planning of the Sydney–Canberra–Melbourne Trunk Route
- Project Development and Building Facilities
- Design and Construction
- National TV and FM Broadcasting Facilities
- Commercial Television Installation
- Buildings Engineering Services

Laurie Derrick (the author of the second paper) is still working in the Australian telecommunications industry and is accredited to provide Frequency Assignment Certificates

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in relation to Apparatus Licences and Interference Impact (and related certificates) for Spectrum Licences for the Australian Communications and Media Authority (ACMA).

Laurie confirmed an interesting anecdote regarding Black Mountain tower when I was researching this paper. Once electronic ignitions were first introduced to motor vehicles in Australia, it was possible to get stranded in the carpark at Black Mountain tower due the levels of RF radiation in the vicinity. The solution was to place a foil-backed space blanket over the dashboard and the car would start normally.

References

Taylor, F. L. C. & Brigden, W. F. (1981). "The Black Mountain Tower – an Introduction", *Telecommunications Journal of Australia*, Vol. 31, No. 2, 1981, pp. 91-93.

Derrick L. J. (1981). "The Tower Radio Functions and Specification", *Telecommunications Journal of Australia*, Vol. 31, No. 2, 1981, pp. 101-113.

The Historic Papers

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The Telecommunications Tower, Canberra

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.

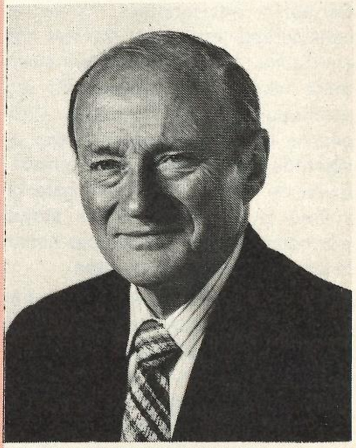
In March 1972, NCDC issued a public statement which gave recognition to the importance of visitor aspects of the proposal, but indicated that NCDC was now of the view that the tower should be reduced in scope to that representing minimal technical facilities for television, radio and telecommunications.

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.

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The Telecommunications Tower, Canberra

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

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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° 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.

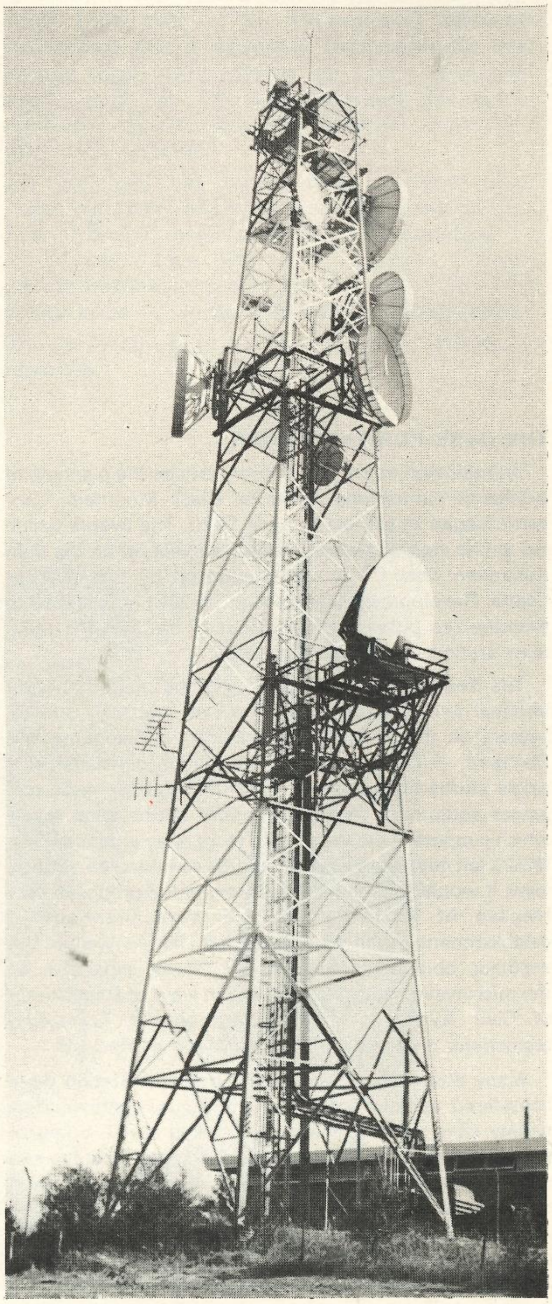


Fig. 1 — The Red Hill RT Station

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.

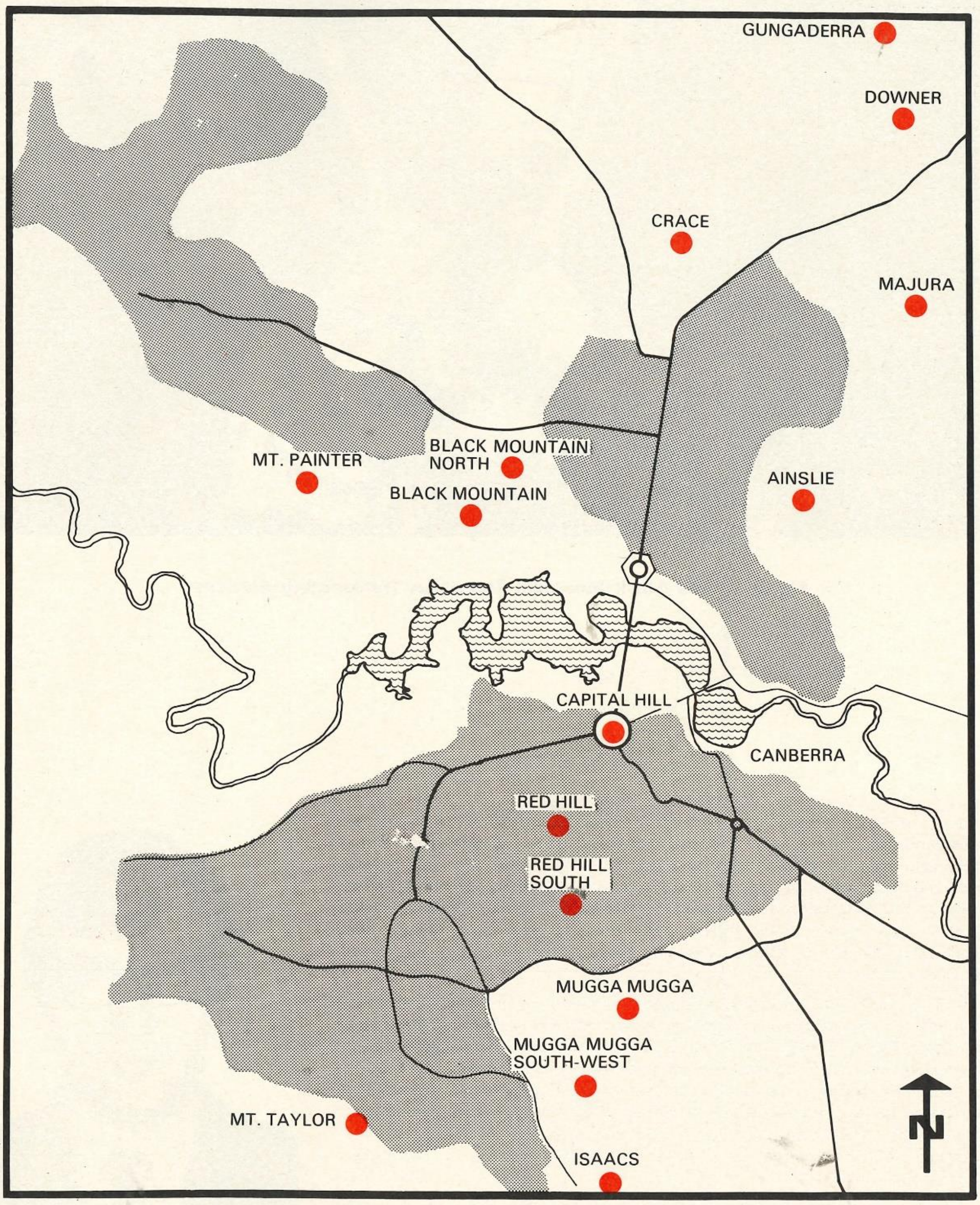


Fig. 2 — Alternative Sites Studied

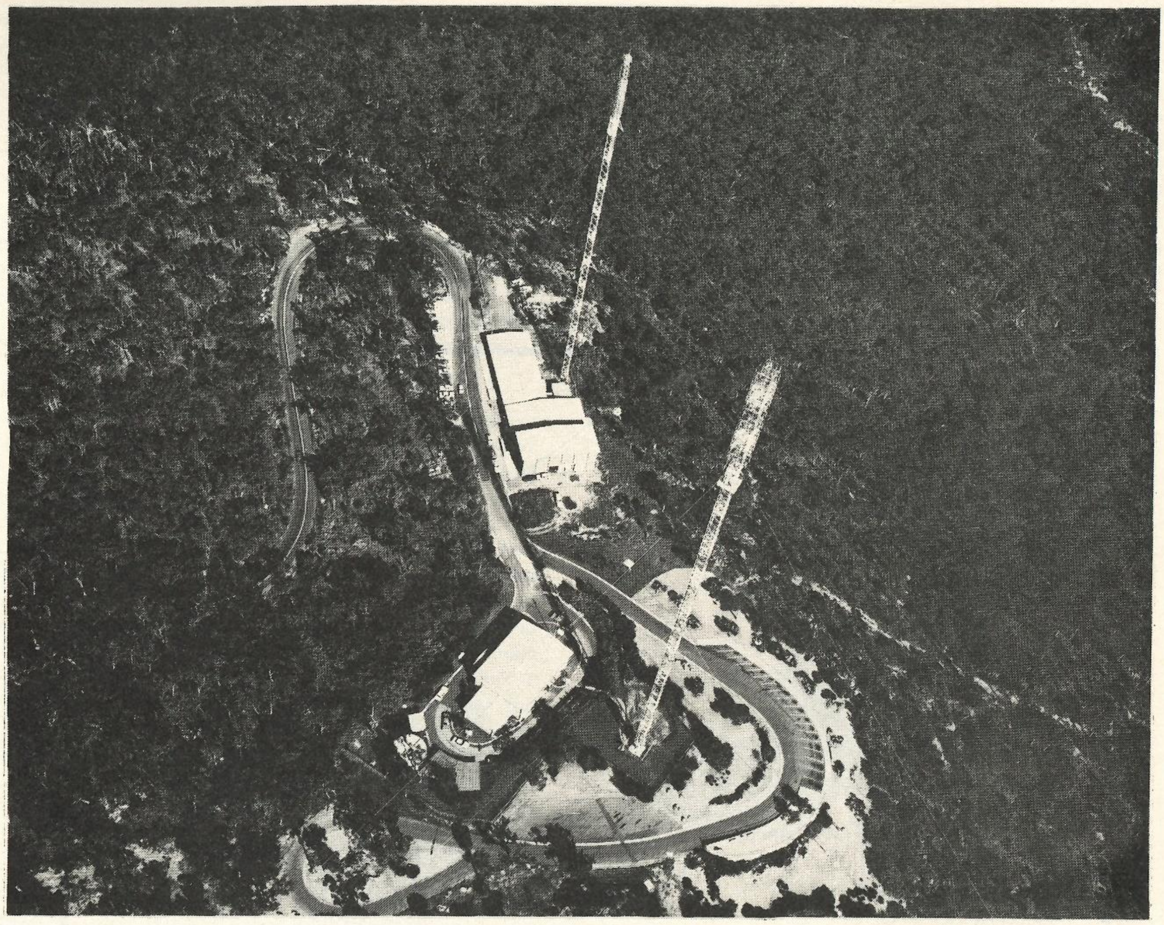
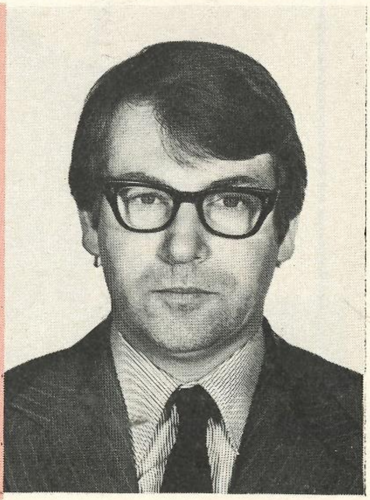


Fig. 3 — The Black Mountain Television Transmitting Stations

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.



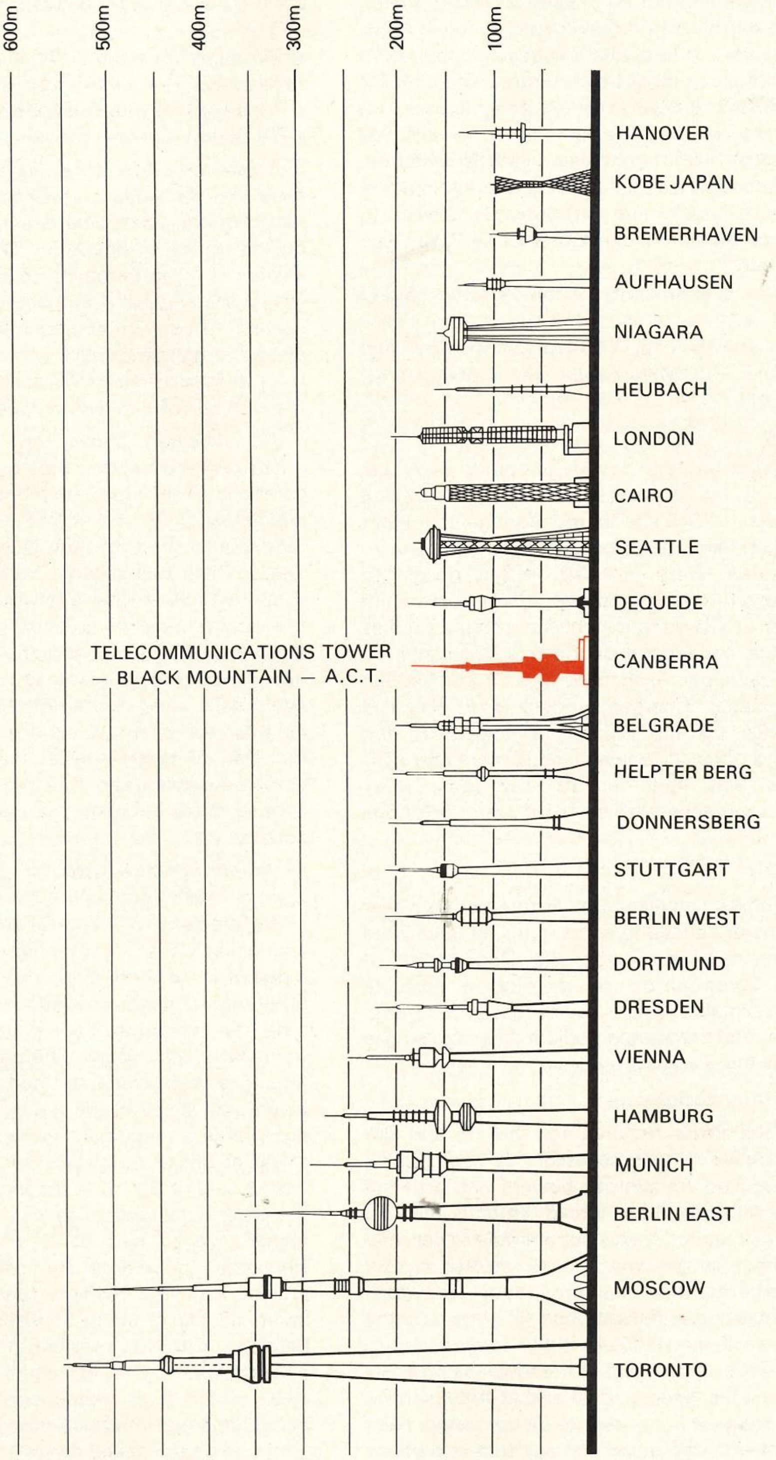


Fig. 4 — Some Overseas Towers

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

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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 ductility 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.

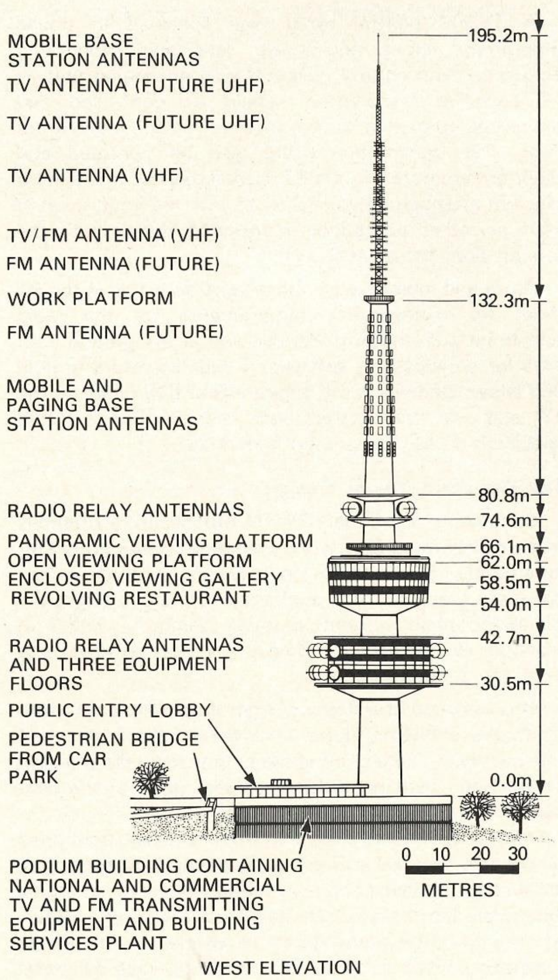

Fig. 5 — The New Tower Outline

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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

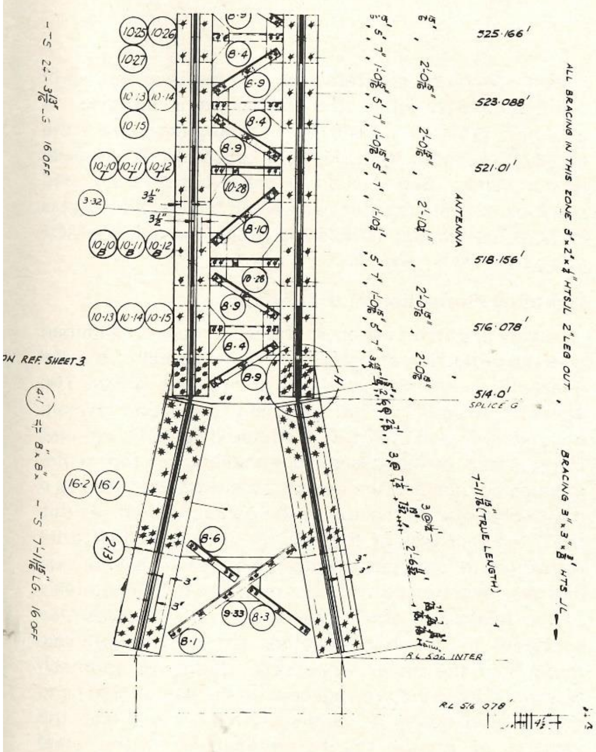

Fig. 6 — Portion of Antenna Column — Detail

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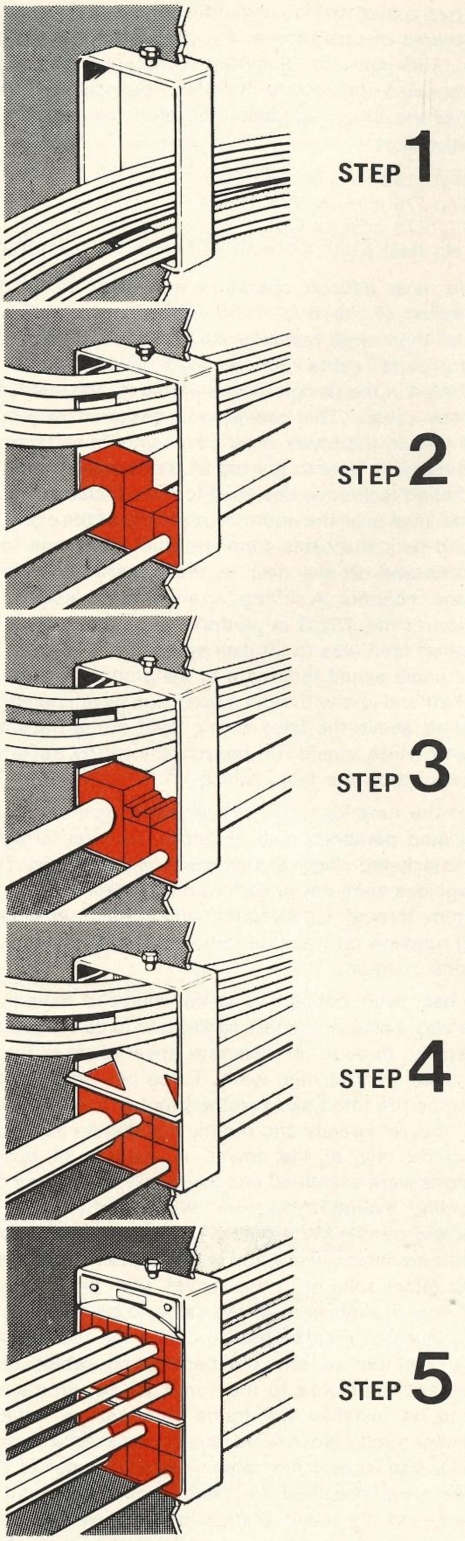

Fig. 7 — Multicable Transit (MCT) Unit — Cable Installation

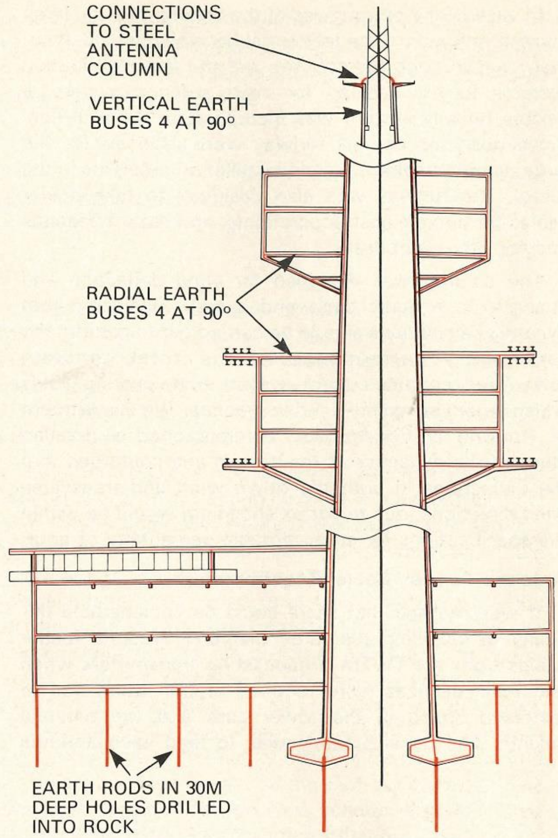

Fig. 8 — Lightning Protection System

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.

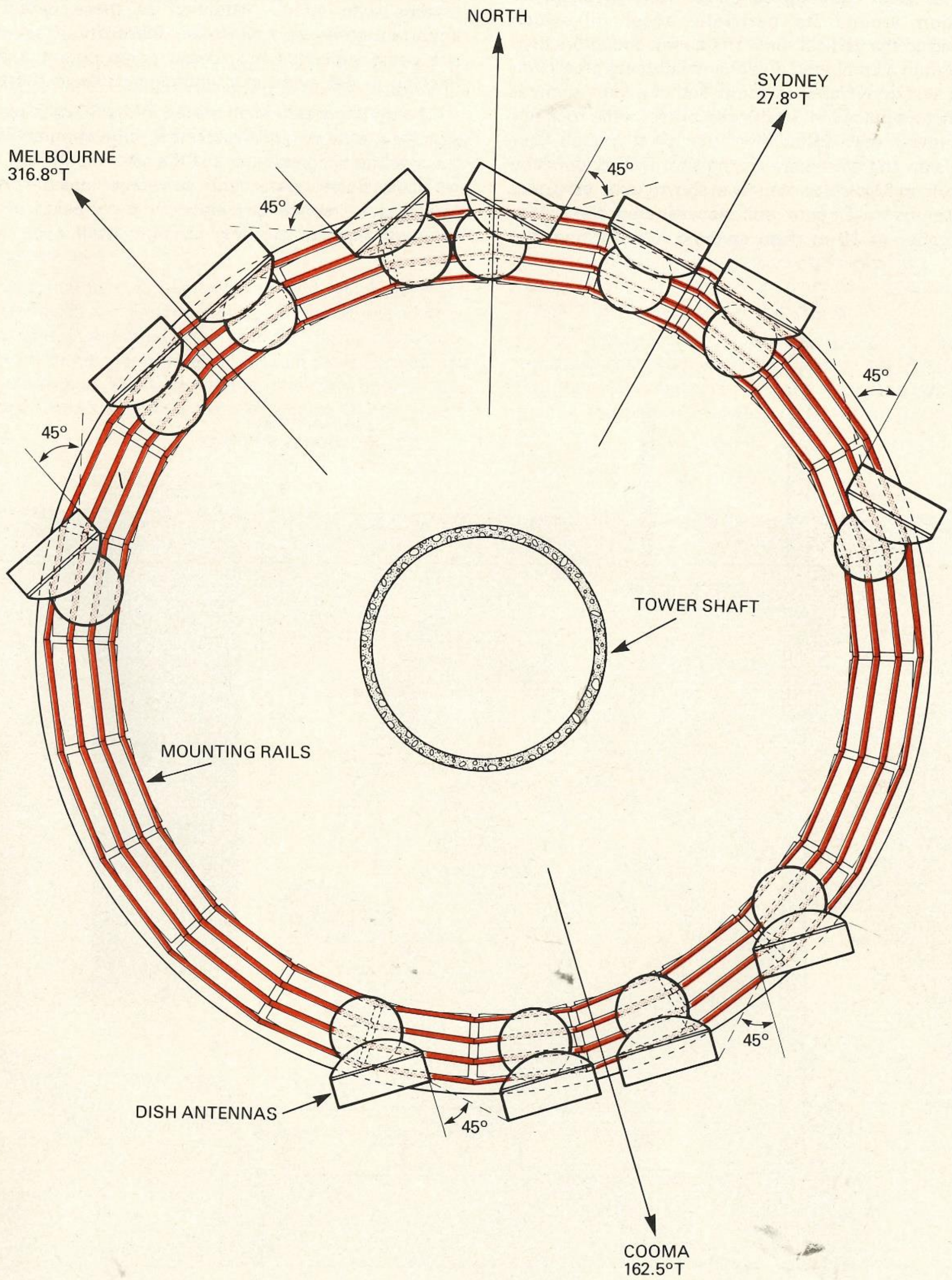

Fig. 9 — Parabolic Antenna Mounting System — Plan

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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

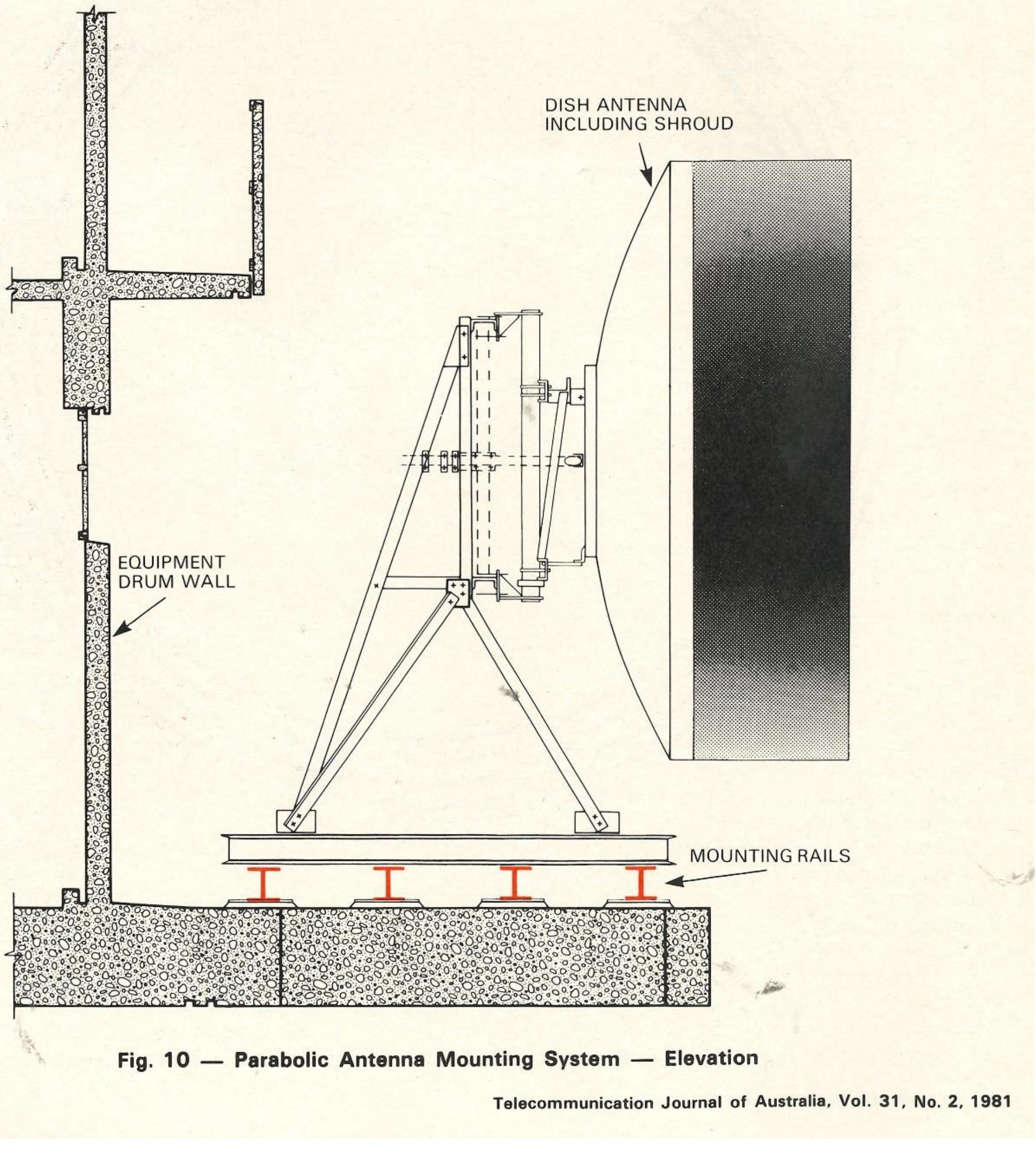

Fig. 10 — Parabolic Antenna Mounting System — Elevation

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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.

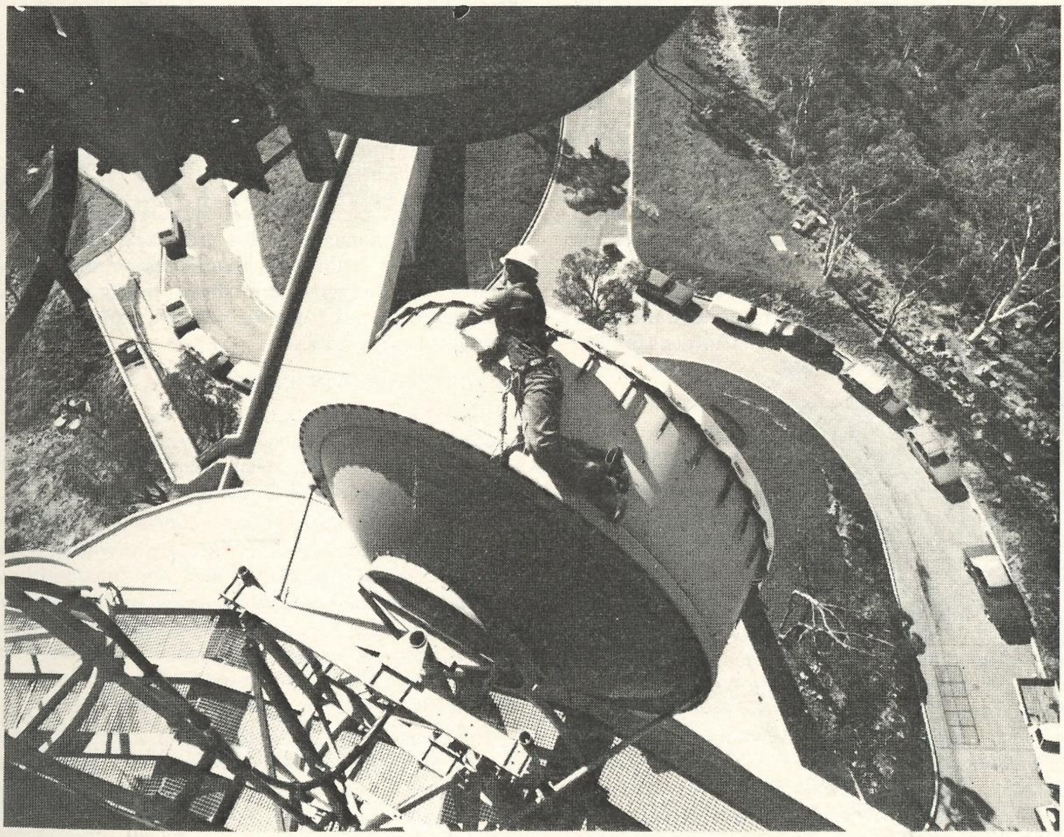
A rail mounting system was devised which gave the required flexibility. Four concentric rails were specified to be installed at the three levels of the RT drum. The antennas were to be mounted on individual mounting frames with ring beam bases and these mounting frames with dishes attached would then 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

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