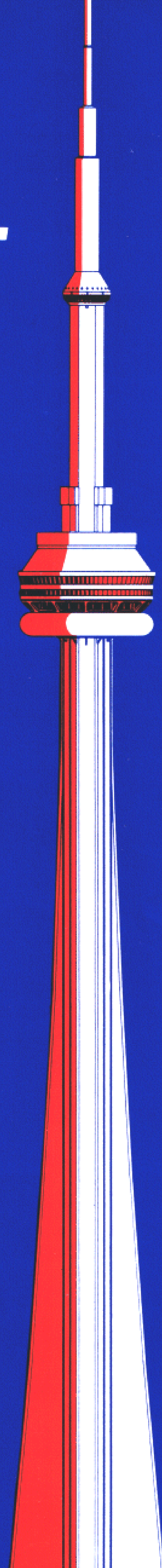
BROADCAST EQUIPMENT TODAY

NOV/DEC
1975



CN Tower

NAFMB Now it's . . . NRBA

The National Radio Broadcasters Association is the new name for the National Association of FM Broadcasters.

The U.S. group voted to widen into an all-radio organization at its annual conference and exposition, held in Atlanta, Georgia, September 17-20. The move reflects the concern of many U.S. radio station operators that the National Association of Broadcasters had become overly television-oriented. As one enthusiastic AM broadcaster put it: "NAB is a television company, NAFMB was an FM company; now you're a radio company, and I'm joining!"

Heading the 400-station association is James Gabbert, president of K-101 FM & AM in San Francisco, which is to be the site of next year's NRBA Conference and Exposition, September 19-22, 1976, at the Hyatt Regency Embarcadero Hotel.

A leader in the move to make NAFMB an all-radio association, Gabbert says the object is not "confrontation" with NAB, "Television has caused problems for radio," he says, citing restrictions on cigarette advertising. NAFMB has been instrumental in improving radio regulation and NRBA, as a "total" radio organization, will do an even greater job for radio.

* * *

The conference included several engineering sessions, and over 60 equipment manufacturers and suppliers filled the Exhibit Hall of the Marriott Hotel. Other sessions dealt with sales, programming and promotion, with a number of the companies servicing these areas providing hospitality suites.

Among Canadians attending the Atlanta get-together: John Stark and Maurice Foisy of CHQM Vancouver, Jerry Good and Ron Turnpenny of CHFI, George Jones of CHUM, Israel Switzer, David Lafrenais of M.S.C., Bill Jones of Caldwell A/V. Canadian equipment suppliers who exhibited included McCurdy Radio Industries and the Orange County Corporation from Winnipeg.

* * *

FCC Wins Favor

There was strong representation from the Federal Communications Commission, including an address by Chairman Richard E. Wiley. In the view of many delegates, the regulatory agency appeared to be striving for good rapport with the broadcasters.

Wiley, appointed chairman in 1974, won favor with his remarks on a range of topics:

- Re-regulation. Some 300 rules have been modified or eliminated. "Regulation which is overly-complex, burdensome and unnecessary should be removed from the books."
- Longer licence terms. The FCC has rules to deal with the poor performer stations, and could do a better job if it had fewer applications to process each year.
- Short-form Renewal Applications. The FCC's goal is less paperwork. Engineering aspects, which represent about one-third of the shortened form, need reflect only major changes.
- Ascertainment. (This refers to requirements that stations survey their communities to determine which local issues and social problems should be given public airing.) Stations in communities of less than 10,000 population are to be exempted, on an experimental basis, and Wiley favors a higher cutoff figure. Broadcasters in smaller communities, he observed, are close enough to their audiences to know the needs.
- Non-duplication. Wiley sees both AM and FM as part of one aural service, hence the discouragement of duplication (simulcasting). "Independent stations will probably like this."
- Format. Choice of format should be up to the licensee. "If they're locked in, how will anyone experiment—for example, with a classical format in a large city?"
- Fairness Doctrine. With 65 signals in Chicago, 59 in Los Angeles, and 43 in New York City, the FCC favors an experiment to discontinue equal-time requirements in the larger markets, where there are plenty of outlets for varied opinions.

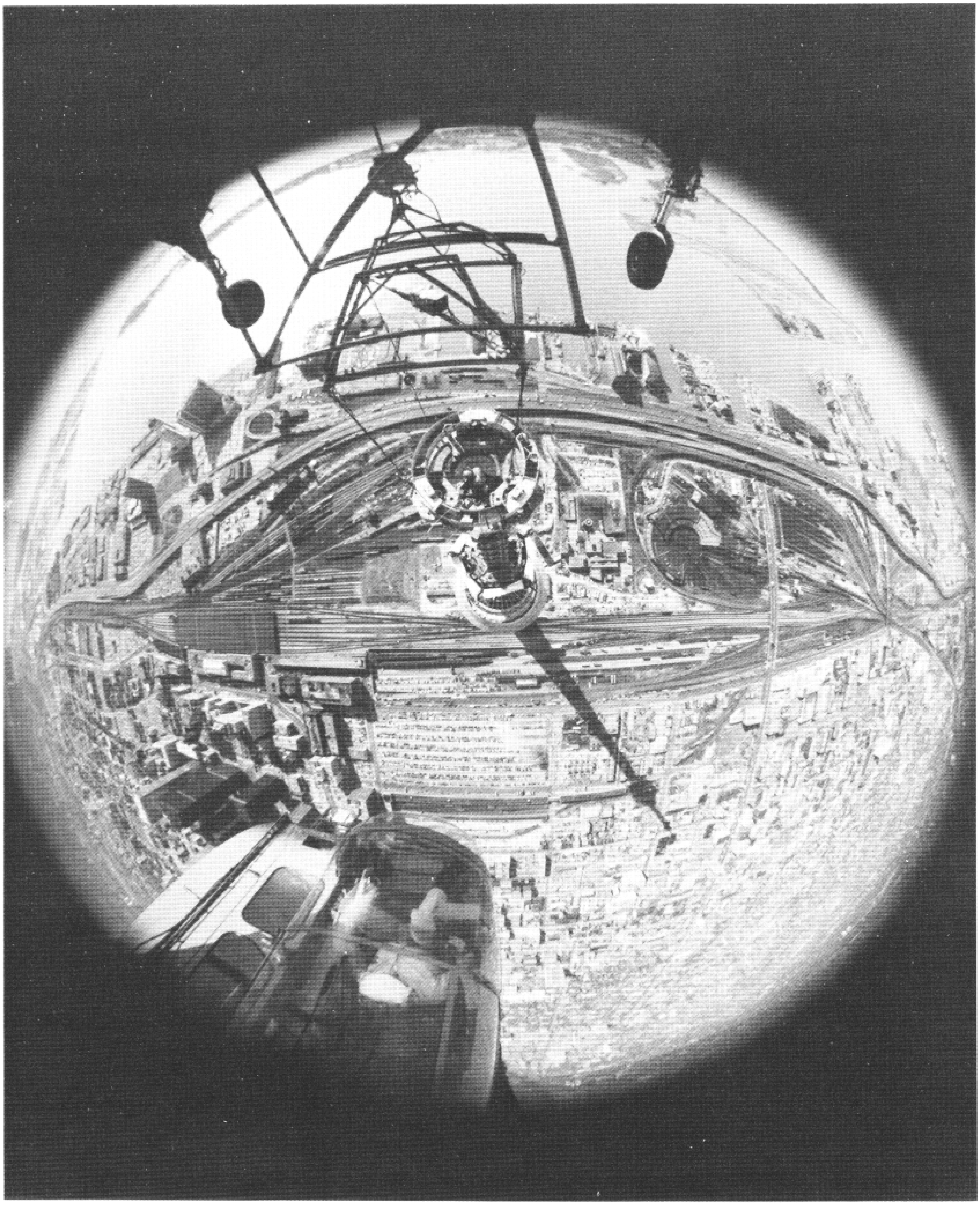
* * *

Engineering topics discussed during the three-day conference included:

- Discrete Quadraphonic FM Broadcasting—Five Ways To Go
- Controlling FM Modulation—A New Way
- SQ—A System for AM and FM
- The New Emergency Broadcasting System for U.S. stations
- New AM Processing Rules of the Federal Communications Commission.
- A session on Engineering Fundamentals for non-technical people.

Future issues of BROADCAST EQUIPMENT TODAY will be dealing with some of these topics in detail.

THE ULTIMATE ANTENNA



Fisheye lens captures a dramatic moment in the construction of the CN Tower, as a damper ring is placed on the communications mast. The camera was bolted beneath the fuselage of the Erickson S-64-E air crane. Ironworker Paul Mitchell stands at the top of the mast while aft pilot Larry Pravecek is at helicopter controls. (Photo courtesy of Sikorsky Aircraft)

Within a few months, the world's highest self-supporting structure will commence operations as the transmitter and antenna site for Toronto's five television stations and five of its six FM radio stations.

Eventually, the 1806-foot high CN Tower will accommodate eight TV stations and 11 FM stations.

An incredible engineering achievement, this Canadian landmark is also destined to become one of the world's great tourist attractions.

But the CN Tower's raison d'etre is as a broadcast facility. It will both improve and extend the signals of the Toronto stations.

For many years, the CBC held land in the northeast suburb of Don Mills, awaiting government funding of its consolidation plans. It expected that a new tower in Don Mills would overcome many of the obstacles which surrounded its 500-foot downtown tower on Jarvis Street.

But CFTO-TV, with an 885-foot tower at its Agincourt studios, a few miles east of Don Mills, was less than satisfied with its location. Many home antennas remained pointed towards Buffalo, N.Y., 65 miles south. When the Toronto stations came on the air (CBLT in 1952, CFTO-TV in 1961), viewers experienced reception difficulties and many turned to more complex roof-top antennas and eventually to cable TV.

At one point, the federal Department of Transport designated an area between Don Mills and CFTO-TV as an "antenna farm" where all future stations should be located. But CBC studies soon concurred with CFTO-TV's experience. The ideal location was neither north nor east; it was south.

Then, Metro Centre was proposed by Canadian National and Canadian Pacific Railways—a massive development scheme for the railway property along the city's waterfront. It soon included several proposals for a tower—none as ambitious as the one now built. CFTO-TV said more height was needed. The CBC gave impetus to the concept by agreeing to swap its Don Mills property for a building site in Metro Centre.

Many observers were sceptical that the plan would ever materialize. Private broadcasters have a reputation for individualism—could they be persuaded to co-operate among themselves, *and* with the CBC, as well?

The logic of a common tower triumphed.

But the logic of a common tower triumphed. The broadcast engineers studied what had been done in other countries and it was evident that common towers are the trend—particularly in Britain and Europe. In the U.S., New York's Empire State Building, Chicago's John Hancock Building and San Francisco's Mount Sutro are examples. Even Johannesburg, South Africa, built one—10 years before it had TV.

Among the advantages will be improved reception and penetration, and the elimination of "ghosting". Viewers who still rely on roof-top antennas will have to make adjustments, but it will be the last time. The tower will accommodate all future TV and FM stations on channels assigned to Toronto. (One centralized tower is also preferred by aviation to the numerous hazards presented by many individual towers.)

"CN is going to go it alone."

It is Norman MacMillen, now retired as president and chairman of Canadian National, who deserves much of the credit for proceeding with the project. The tower was originally planned as a joint venture with CBC and CP. When they withdrew, MacMillen studied its viability and made his decision: "CN is going to go it alone".

Costs have multiplied from the first estimate of $13 millions for 1570-foot tower to $52 millions—but the result is a higher and more attractive tower. Attraction is important: it is the visitors who will pay the lion's share of the cost. Not that broadcasters get off lightly: each FM station, for example, will be looking at close to $100,000 a year. Extras such as the television workshop and storeroom areas below ground level represent additional rental charges for some stations.

Harmony among the broadcasters has proven to be outstanding. There was some hesitation to give CN a commitment before obtaining CRTC approval. But once the go-ahead was received, they wasted no time in forming a consortium, selecting EMI Limited of England out of three bidders to supply the antenna at a cost of over $3 million.

EMI are several months ahead of schedule in completing the contract. Subcontractor for installation of the antenna, radome and feeder lines is Sky-Hook Construction Ltd. of Brampton, Ont. Sky-Hook's Don Isaac says that the CN Tower has been the "most complex job we've ever worked on" requiring tremendous preliminary planning. The installation crew, directed by chief engineer Jack Leyland, has comprised 15 to 18 men, often working long hours. Their method of hoisting materials—an outside cage suspended on cables anchored out from the tower's base—was controversial, but proved to be effective in getting needed materials to the top when elevators and other hoists were congested. Isaac, with many others, is enthused with the problem-solving cooperation which has been characteristic of the project. And Sky-Hook has met its objective of closing in the antenna before adverse weather conditions set in.

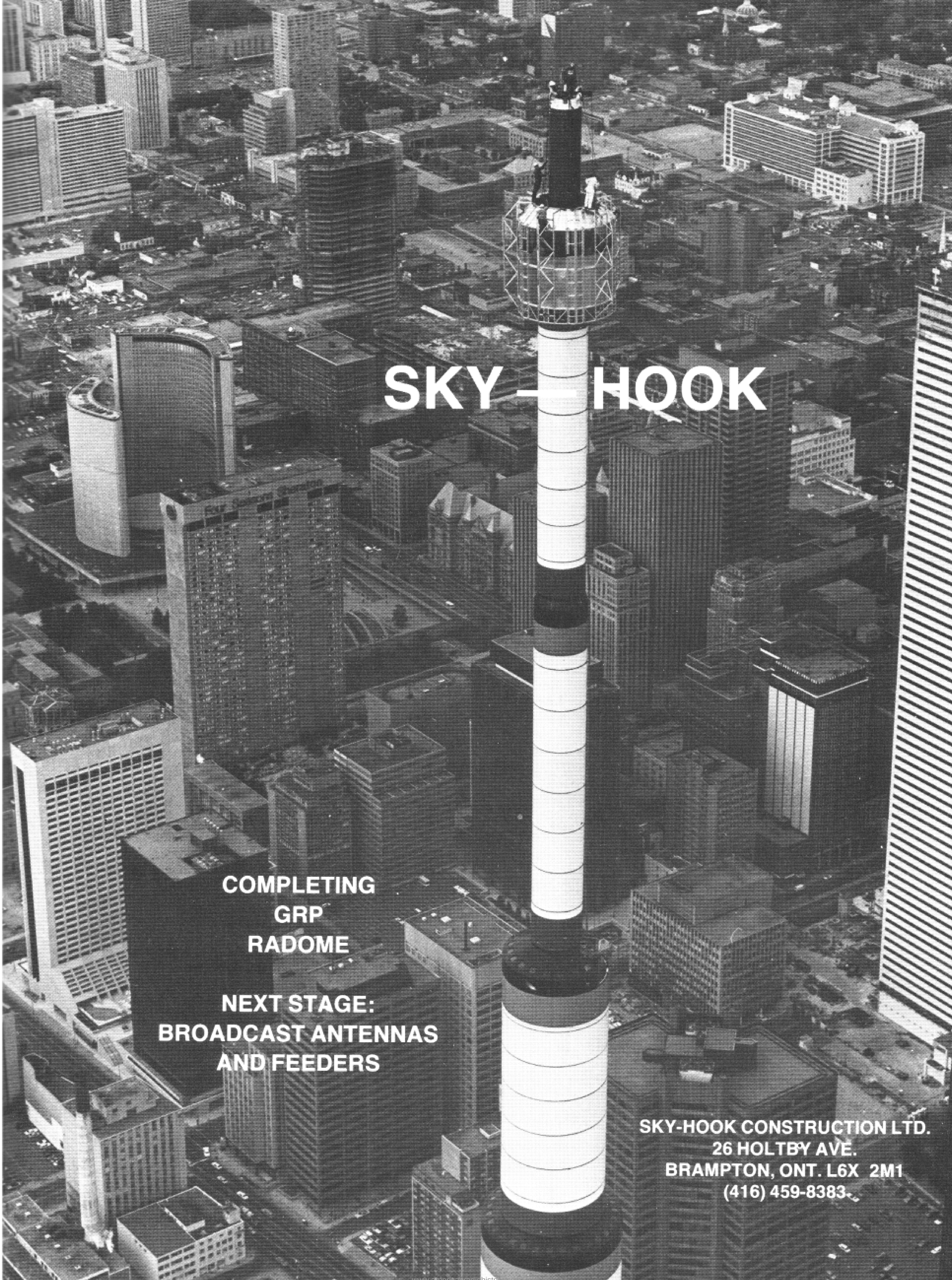
The five FM stations formed Master FM Limited, choosing Clive Eastwood, director of engineering for CFRB/CKFM, as chairman. Representing the other private FM stations were Paul Hunter of CHIN, George Jones of CHUM and Ron Turnpenny of CHFI.

Bob Smee was project engineer for the CBC, responsible for television transmission for CBLT, CBLFT and CICA-TV. CFTO-TV and CITY-TV are the other participating TV stations. Channels 45, 51 and 57 are also assigned to Toronto and a 50-foot section of the antenna is reserved for them.

Positions were determined logically—the combined FM antenna, the largest, is at the bottom of the mast, while CITY-TV's, the smallest, is at the top. And the broadcasters have agreed they are staying together: all stations will go on-air from the CN Tower at the same time. While some may be ready sooner, that date may not be until April or May, 1976.

"A fantastic team effort."

CHFI's Ron Turnpenny says: "We've worked as a group and we have to stay as a group". Mal Grant, director of design and construction for CN Tower, who also participated in the broadcasters' Technical Committee, agrees. In every way, he says, the tower is "a fantastic team effort".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Basic Broadcast Considerations

by J. Gordon Elder

One important objective of any broadcaster is to provide a signal of high quality and satisfactory field intensity to as many homes and people as possible. Quality may be impaired by visible ghosting, audible multi-path distortion or by a field intensity at the receiving location that is insufficient to suppress locally generated RF noise.

Urban Interference

These problems have been aggravated in urban areas, by the increasing use of high rise steel frame construction and by increased electrification.

Television service in all large cities is subject to some ghost or echo interference. This occurs when the signal arrives over two or more paths—that is, both in a straight line from the transmitter and also after reflection from a high rise building or some other object. The reflected signal arrives later than the direct one. If it is strong enough and late enough, a visible ghost image will be displayed on the picture tube. Its displacement from the direct picture is proportional to the path delay.

In Toronto the problem is aggravated by the fact that many receiving antennas still face the Buffalo stations and some are broadside to the Toronto stations. Both VHF Channels 5 and 9 suffer in varying degree in different parts of Toronto. The reflection problem is more severe at UHF. It was recognized that ghost type and also RF noise interference would be minimized if all our stations could transmit from one high point near the waterfront. In 1967, broadcasters agreed that the proposed Metro Centre Development would be ideally located. DOT confirmed that a 1500' or 1600' tower height would be acceptable there as an aeronautical obstruction.

Basic Objectives

The following basic objectives were recommended and assumed by us:

1. Provision of sufficient capacity to accommodate all Toronto FM and Television Allocations, whether already assigned or still vacant, at maximum permissible powers.
2. Compliance with good engineering practice to be paramount.
3. Economic and aesthetic considerations to be secondary.
4. Assumed structural loads imposed by antennas to approximate the maximum expected in practice, based upon a detailed design.

Other factors we considered included the probable growth and penetration of CATV within the market. Until now cable television has often been a substitute for well engineered transmission facilities and some broadcasters might have relied upon it instead of relocating onto the CN Tower. However, the concensus was that only 60% of the urban population will probably have CATV connections by 1985.

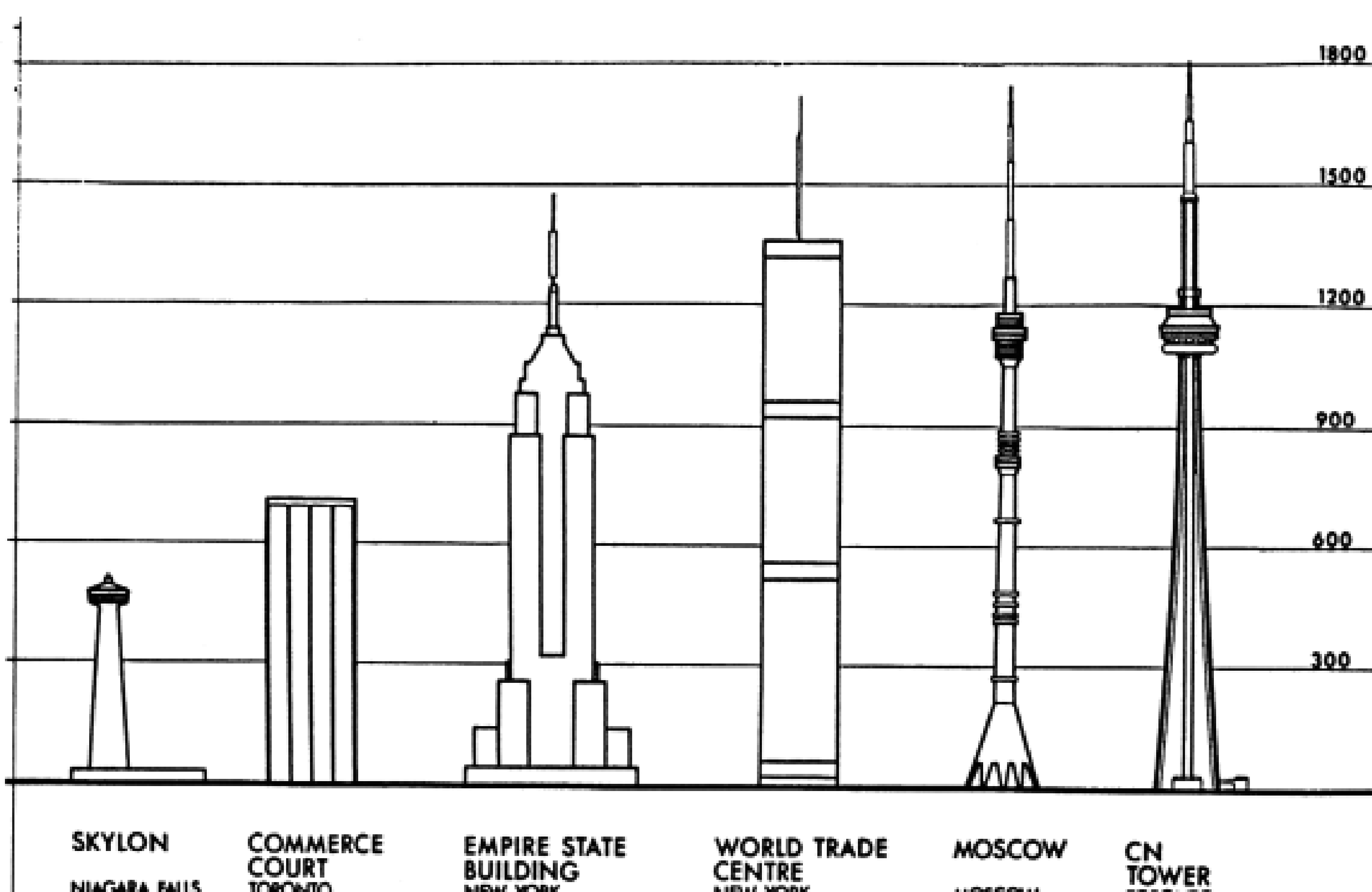
Single 350' Mast

Initial physical antenna design concepts that were considered included two, three or four vertical masts with between 50' and 100' horizontal spacing between them, each supporting one or more antenna. Relatively inexpensive standard antennas can usually be employed because the cross-section is small. However, close coupling usually causes some pattern distortion and ghost images and the design is therefore a compromise.

A single 300' mast with a series of collinear antennas and a tripod of three short UHF antennas on top was then considered. However their over-turning moment would have required a very expensive structure or else resulted in excessive wind deflection. Interleaving of some of the antennas would also have been possible, but with additional design complications and other penalties.

For all these reasons it was decided to recommend two or three broadband UHF antennas occupying the top 125' of the mast and lengthen it to a total of 350' to accommodate them. Since the wavelength and consequently the element size decreases with increasing frequency, all the television antennas were arranged for increasing operating frequency and channel number with increasing height above ground. One longer mast also proved to be attractive to the developers, because it was more pleasing to the eye and also helped to ensure that the tower, now to be 1805' high, would be the tallest free standing structure on earth for the time being.

Maximum normal wind deflections were specified of ±0.3 degrees at the microwave level and ±1.5 degrees at the top of the mast, based upon the proposed radiation pattern shapes and moderate power gains. Very high power gains were ruled out, due to excessive structural and antenna costs, with narrow vertical beam widths. These would have aggravated ghosting interference and have increased the variation in received signal level caused by deflection of the tower. (For example, a receiving antenna that is served off the side of the lobe could be subjected to signal variations exceeding 12 db, assuming that wind gusts caused deflections of 1 or 2 degrees. The effect would be similar to the flutter caused



COMPARATIVE HEIGHTS

by a passing aircraft. Usually, the receiver's automatic gain control would compensate for variations of less than 10 or 12 db, with little or no picture degradation.)

Ghost interference will not become a serious problem provided that the CN Tower continues to dominate the scene—in other words, provided that the upper storeys of future skyscrapers are not intensely illuminated by the broadcast signals.

Enclosed Antenna

The antenna supporting structure consists of a 300' lattice steel tower of hexagonal cross-section. It is friction bolted to avoid the difficulties of welding thick plates. The decision to use complete radome enclosure eliminated many problems associated with electrical or hot air de-icing of the VHF antennas and supporting structure as well as facilitating antenna inspection and aeronautical lighting maintenance.

The broadcast transmitters and combiners will be located on Levels 5 and 6 of the Upper Accommodation. Microwave, land mobile and radio paging equipment will be on Level 1, where antennas will be protected by an inflated radome.

The diesel electric sets for standby power supply will be located in the basement to comply with the Fire Marshal's requirements.

Isolation Measures

An important consideration throughout has been the provision of adequate isolation between services, minimization of harmonic generation and intermodulation. Co-sited high power transmitters operating on adjacent frequencies will generate objectionable third and fifth order intermodulation products unless adequate precautions are taken. Combiners, diplexers and transmitters must all be designed and adjusted to minimize out of band spurious. Metallic finishes and bonding must be adequate.

The Tower's internal communications system will include voice intercom throughout and an extensive CCTV system for security and surveillance, crowd control, and public display purposes.

J. Gordon Elder, of Elder Engineering Limited, King City, Ont. is broadcast engineering consultant for the CN Tower.

CN Tower

Antenna Complex

by Michael B. Anders

One of the purposes of the CN Tower antenna complex, mounted as it is, between 1480 ft. and 1805 ft. above ground level, is to ensure better reception in the city of Toronto with its high-rise buildings.

At present the mean height of the antenna is about 800 ft. above the next highest building. But with the introduction of even higher buildings with the passing of time it is well to make sure that the antennas will be well above them for many years to come.

The antenna complex can be roughly divided into three parts: Radome, Antennas and Main Feeder lines.

RADOME

The functions of the radome, which completely encloses all antenna systems, include: minimizing the ice hazard by reducing the amount of ice build up, and thus the dangers of falling ice; weather protection; reduction of antenna wind loading and ease of antenna maintenance.

Construction

The radome consists of a number of different diameter cylinders mounted around each antenna, ranging from 26 ft. diameter down to 5 ft. diameter (See Fig. 1.). Transitions are provided at levels where the diameters change. For handling purposes the cylinder was divided into a number of segments.

Each ring is independently mounted back to the steel structure to provide for independent articulation when the structure is under stress. It also makes for easier replacement if ever necessary. The gap between each ring is sealed, thus completing the weather protection.

Each radome segment is made up of a double skin of glass reinforced plastic (GRP). These sandwich a 2-inch layer of fire retardent polyurethane foam. The outside surface of the radome is covered by a gel coat to give a hard wearing smooth surface to resist the adhesion of ice. The inside surface of the radome is painted with a fire retardent material which further minimizes the fire risk. The double GRP skins are held together by flanges along the edges of each segment which also facilitate the bolting together of segments.

This form of radome has excellent thermal properties which encourage the melting of any accumulated ice on the radome from the outside, in towards the radome skin, thus reducing the likelihood of large dangerous lumps of ice breaking loose.

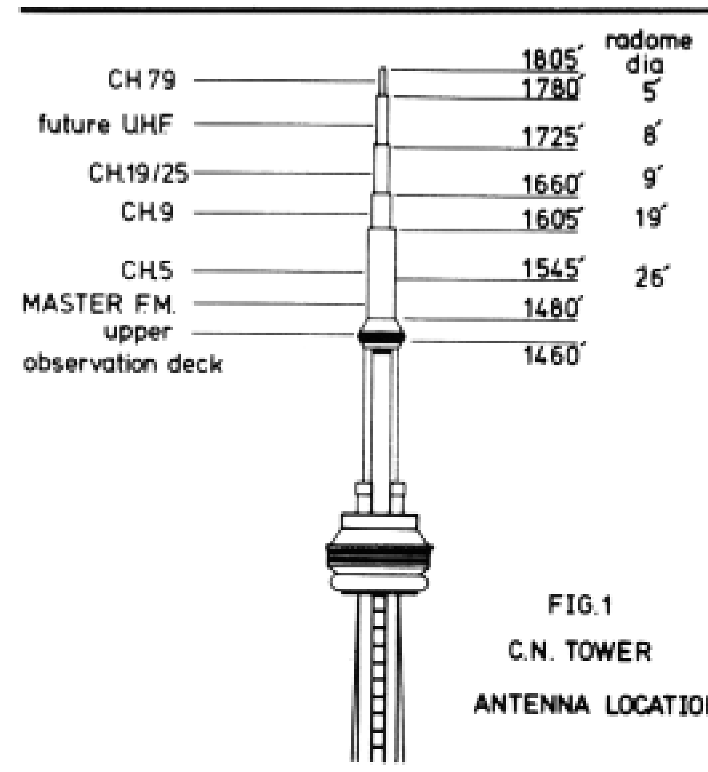


FIG.1
C.N. TOWER
ANTENNA LOCATIONS

ANTENNAS

The 325 ft. of antenna aperture is divided into individual and separated apertures for each antenna system. There are many advantages in mounting the antenna arrays co-linearly, not least being the avoidance of interaction between radiation patterns.

Each array except Channel 79 is divided into two similar "halves" fed by separate main feeder transmission lines, thus providing a standby arrangement in the event of a fault.

The Vertical Radiation Pattern (VRP) for each antenna had to be carefully tailored to give the necessary amount of null fill for angles of depression down to −55 degrees. The VRP for each antenna is obtained by a feed system developed with the aid of a computer that varies the relative amplitude and phase of the currents feeding each radiating element. All radiating panels are fitted with a probe in addition to reflectometers at the input to the antennas to provide a comprehensive monitoring facility. High transmitter powers necessitate special power handling precautions, which include the treating of inner and outer conductors of coaxial lines to improve their heat radiation efficiency.

The antennas were designed so that there was complete continuity of screening around the structure. This helped to keep the field within the structure to a minimum for maintenance purposes, etc.

Master FM

The Master FM antenna consists of five tiers of circularly polarized crossed dipoles. The dipoles, originally developed by Alford Manufacturing Co., are broadband devices covering 87 MHz to 108 MHz. Each "half" of the antenna is capable of handling the total eleven channels having a total input power of 155 kw. The HRP is onmidirectional for all channels.

Channel 5

The horizontal radiation pattern which is basically omnidirectional is achieved with four half-wave dipoles per tier. There are six colinear tiers. The antenna is expected to have a nominal ERP of 100 kw (video).

Channel 9

The antenna, which has the same basic horizontal radiation pattern as Channel 5, consists of 7 tiers of halfwave dipole panels with 5 panels per tier symmetrically mounted around the structure. The ERP of the system is nominally 325 kw (video).

Channel 19/25

This is a diplexed antenna system that is capable of simultaneous radiation of the two channels from the same radiating elements. The antenna consists of 8 tiers of 4 wavelength 'Emislot' panels, with 5 panels per tier. The HRP's are omnidirectional. The antenna system is capable of handling four 55 kw video transmitters plus aural with an average ERP per channel of 2750 kw.

Channel 79

This antenna, situated at the top of the complex with a cardioid shape of HRP, consists of 4 tiers of 'Emislot' panels with 3 panels per tier mounted around a square structure. The max. ERP is 330 kw.

Future Antenna

The antenna complex has been designed so as to leave sufficient space for a future 50 ft. aperture multiplexed UHF antenna.

MAIN FEED LINES

The main feed lines are of the semi flexible type supplied by Kabelmetal and vary in size from 3⅛" diameter for Channel 5 to 6⅛" diameter for Channel 19/25 and the FM antenna.

With the transmitters at a nominal 1150 ft. level the maximum feeder run is approximately 700 ft. to Channel 79, thus the feeder losses are considerably less than if the transmitters were located at the base of the tower. Because of the very high power handling required by the 6⅛" feeders, it is necessary to overpressure them with dehydrated air up to 5 atmospheres.

Michael B. Anders is general manager, aerials, for EMI Sound and Vision Equipment Ltd., Hayes, Middlesex, England.

CBC Facilities

by Robert E. Smee

The CBC started preliminary planning for the relocation of its transmission facilities in Toronto in 1968, when the construction of high-rise buildings in the downtown area started to degrade the quality of television transmission.

The degradation was in the form of multiple ghost images, as well as severely reduced signal levels. These conditions varied from area to area, but were particularly bad in the region from Hamilton to St. Catharines.

Following several in-depth studies of possible relocation sites, a site downtown, in close proximity to the high buildings producing the reflections, was considered the optimum location. This downtown location afforded the advantage of radiating a minimum of energy toward the cluster of high buildings in the core of the city due to the vertical radiation patterns of the antennas. Ghosting would therefore be reduced to a minimum.

The increased antenna height required to overcome heights of existing buildings also produced a greatly increased coverage area for each of the television and FM stations.

In early 1973, CN made the decision to proceed with the construction of the tower. At that time, the CBC made the decision to relocate all of its television stations and FM radio station to the tower, and applications were filed with the Canadian Radio-television Commission. CRTC approval was received in December, 1973.

These facilities are as follows:

- Television stations CBLT (5), CBLFT (25), CICA (19)
- FM radio station CBL-FM
- Microwave interconnection between studios and the Telesat earth terminal at Allan Park
- STL for AM stations CBL and CJBC
- Outside broadcast pickup facilities for radio

Parameters of the stations when operating on the tower are generally close to or at the maximum allowable:

CBLT—100 kw ERP at approx. 1700' EHAAT. Transmitter power is 22 kw directional, with a null toward Syracuse, N.Y. (precision offset with WHEN-TV, Channel 5, Syracuse). Population covered: 4,000,000, excluding U.S. coverage.

CBLFT—2,000 kw ERP, with a transmitter power of 110 kw.

CICA-TV—1,000 kw ERP, with a transmitter power of 55 kw. Both stations are omnidirectional and share a common antenna. Their coverage in Ontario is 3,400,000.

CBL-FM—38 kw ERP on 94.1 MHz, with a transmitter power of 14.4 (20) kw. Population within the 500 mv contour is 3.8 million, while that within the 50 mv contour is 4.3 million.

The CBC transmitters are located on level 5 of the Sky Pod—the floor immediately above the restaurant. The outputs of the transmitters are connected to the antennas by semiflexible coaxial transmission lines ranging in size from 3⅛ to 6⅛ inches, depending upon the channel.

As the high power transmitters of the type used require a lot of cooling, excess heat must be transferred to the outside. The total air requirement to cool the transmitters is 125,000 cu. ft. per minute. This dictates large duct sizes and large openings on the exterior skin of the upper accomodation of the pod. At the height of 1100 feet, wind speeds are much higher than at ground level, and the size and shape of the tower also produce extremely high surface flow or boundary velocities on the outer skin. Wind tunnel tests have shown that the air pressure which can be anticipated on the outer skin at level 5 varies from ± 10 inches of water. Intake of 125,000 cfm of air would be quite easy when the wind direction produces +pressure, but fairly difficult at −10''. In order to reduce this differential, wind tunnel tests were carried out to determine the effects of a continuously perforated skin.

It was determined that if the effective open area of the outer skin was 10 to 15% of the total area, a pressure variation of $\pm$½ inch of water could be anticipated within. These results led to the incorporation of a circular air intake plenum occupying the total perimeter of level 5. A similar plenum is also being installed on level 6 for the private FM transmitters.

The program feed to the transmitters is brought in via microwave and the microwave antennas are located within an air-inflated radome at level 1. Waveguide connects the microwave antenna to the receiving equipment located on level 5.

Only one of the four elevators which can be seen from the outside of the tower provides access to level 5, and all personnel must use this elevator. At least one technician will be on duty at all times. The transmitters for all three television stations were hoisted to level 5 during the week of September 22.

The equipment being installed for channel 19, which the CBC operates on behalf of the Ontario Educational Communications Authority, consists of the Marconi 55 kw transmitter now in use at Jarvis Street and a Pye 10 kw standby. Initial operations from the CN Tower will utilize the 10 kw until the existing 55 kw can be disassembled, relocated and re-installed. Program feed for CICA will be received via microwave directly from the OECA studio at Yonge and Eglinton.

The equipment for CBL-FM consists of two Collins 20 kw FM transmitters, each operating at the licensed power level of 14.4 kw, corresponding to an effective radiated power of 38 kw. The transmitters operate in a main/alternate configuration. Upon failure of the main transmitter, as sensed by loss of carrier level, operation is automatically transferred to the alternate transmitter.

Channel 25—CBLFT—like channel 5, is a parallel system. Programs originate in the CBC studios at Jarvis St. and are used to modulate two 6.6 GHz microwave transmitters which operate in phase-lock. The audio signals are carried by way of FM subcarrier at a frequency above the video information. This link is capable of, and equipped with, four subcarriers.

At the CN Tower, the signal is divided. A diversity switch, using approx. 4 dB of hysterisis, selects the better signal-to-noise ratio at the output of the receivers and connects this signal to the transmitter. After the video and audio signals are fed to input and monitoring equipment, they are used to modulate two separate Marconi 55 kw UHF transmitters. The exciters of these transmitters are phaselocked, and an electronic variable phase network is used to compensate for the considerable variating in electrical length of the klystron amplifiers. The phase of the 55 kw outputs must be kept in quadrature in order that 110 kw of signal appears at the output of the 110 kw combining unit.

In the event that a change of phase angle between the transmitters occurs because of a fault condition, up to 110 kw of power can be present in the balancing load located on the combiner. This load has a constant water flow of 10 gal. per min. through it, but even with this high flow, this amount of power cannot be absorbed. The water flow only permits the thermal trip circuits to turn off one transmitter before load burnout occurs. With one tx off, 22.5 kw of RF power is dissipated in this load, which is well within its ratings. Therefore, failure of phase-lock or of either transmitter results in a power reduction of 6 dB or from 110 kw to 22.5 kw without interruption of service.

continued

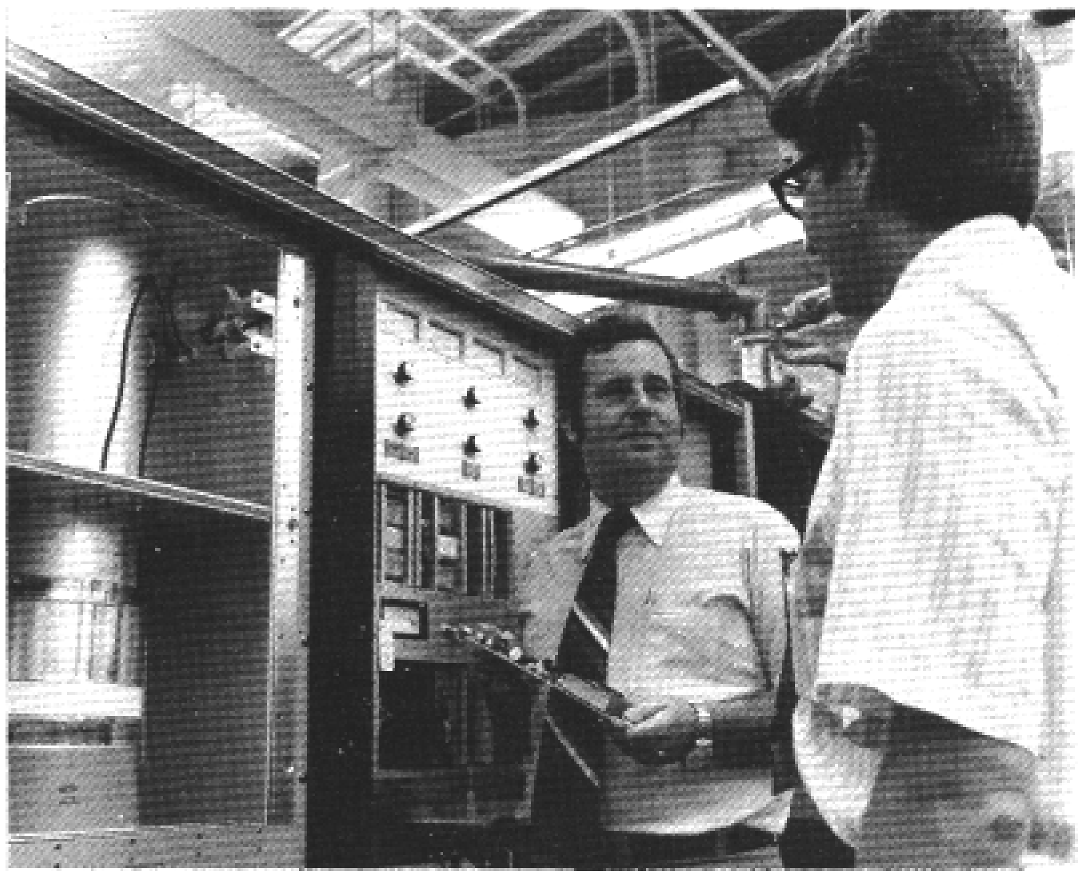
Also present in the combining unit is a power divider (50:50) which divides the 110 kw equally. The two feeds are then connected to the channel combining filters located in the centre area, which weld channel 25's signal to that of channel 19 for radiation by a common antenna.

For channel 5—CBLT—the microwave feed is the same as that for channel 25. In fact, these two microwave links are transmitted using the same dishes. After processing and monitoring, the video and audio feeds are fed to parallel 15 kw RCA transmitters. This type of transmitter, operating between 76-82 MHz, utilizes conventional power tubes and modulates on channel at a moderately high power level.

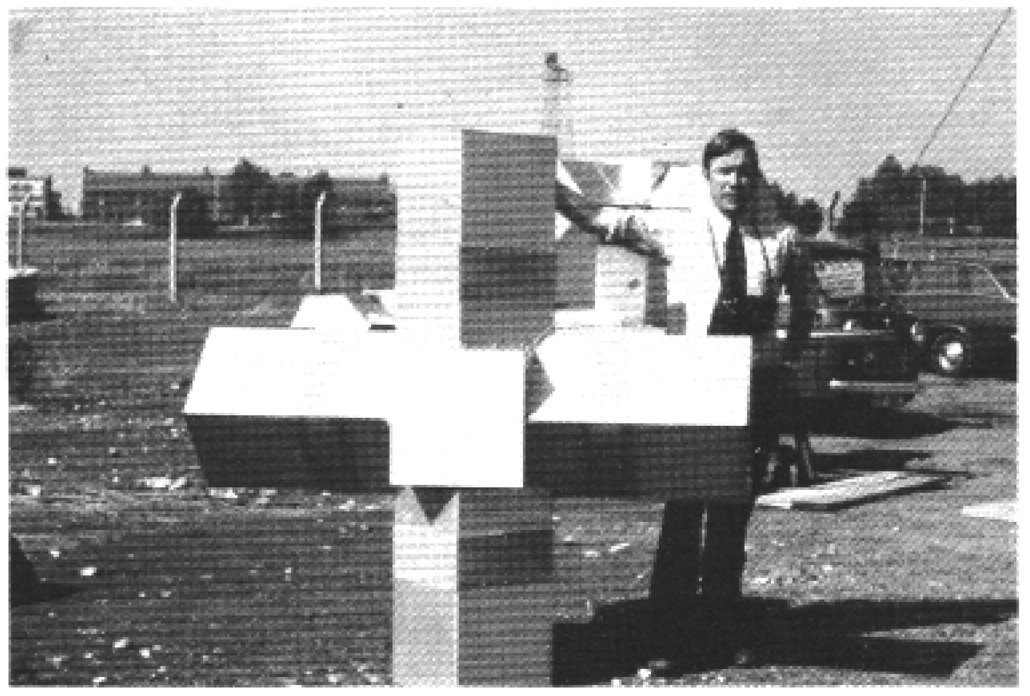
The transmitter does not employ phase-locked exciters, but utilizes two separate exciters with automatic switching. The switching time used is sufficiently fast that it is not noticeable in the transmitted picture or sound signals. Following modulation, the visual and aural signals are amplified to the 15 kw and 3 kw levels respectively. The signals are then fed to a combining and switching matrix suspended from the ceiling outside the transmitter cubicles.

All of the combining and switching utilizes constant impedence coaxial transmission line, most of which is 3⅛ inches. The switching allows either 15 kw tx to be fed to a test load while the other is on-air, or to set up the parallel configuration. The output signals from the switching matrix are fed to a combined vestigial sideband filter and sound/vision diplexer or "filterplexer". This unit produces the lower sideband attenuation required for television transmission, as well as isolating the visual and aural transmitters.

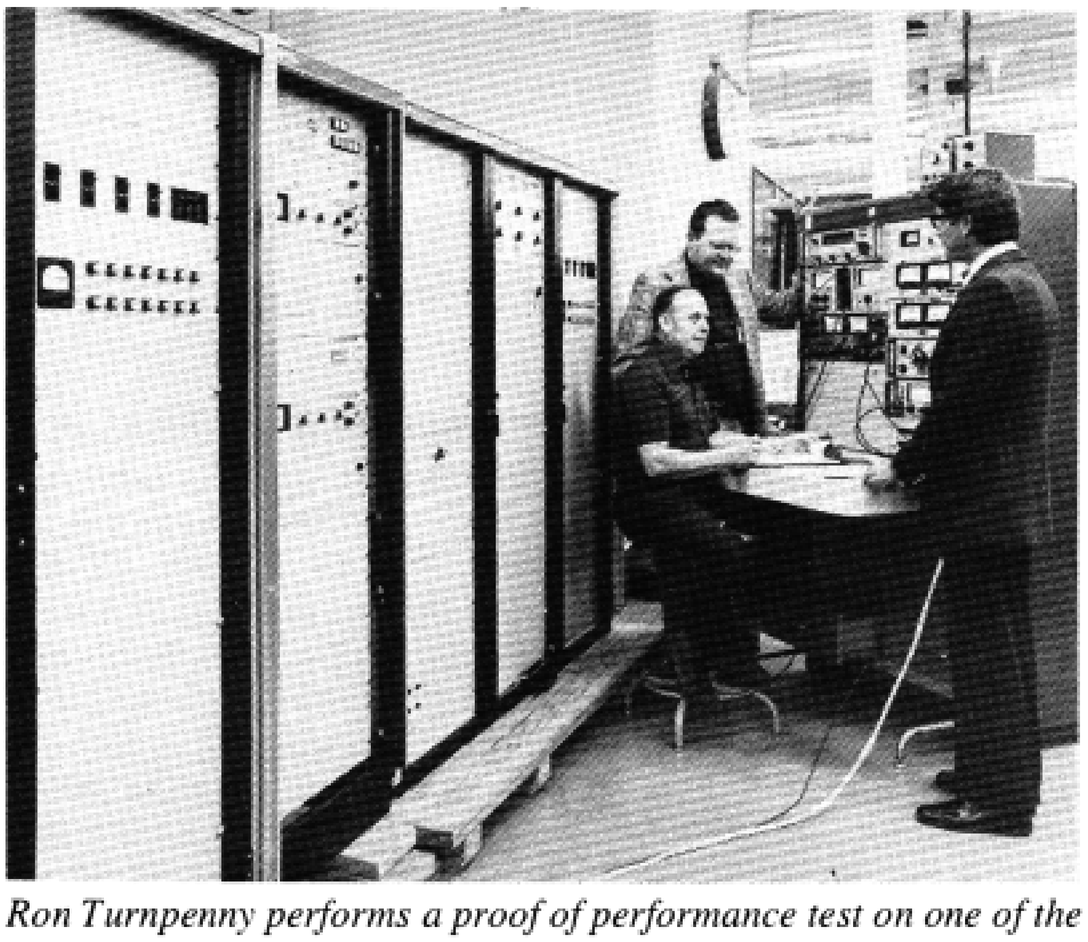
Bob Smee of Engineering Headquarters, Montreal, is project engineer on the CN Tower for the Canadian Broadcasting Corporation.



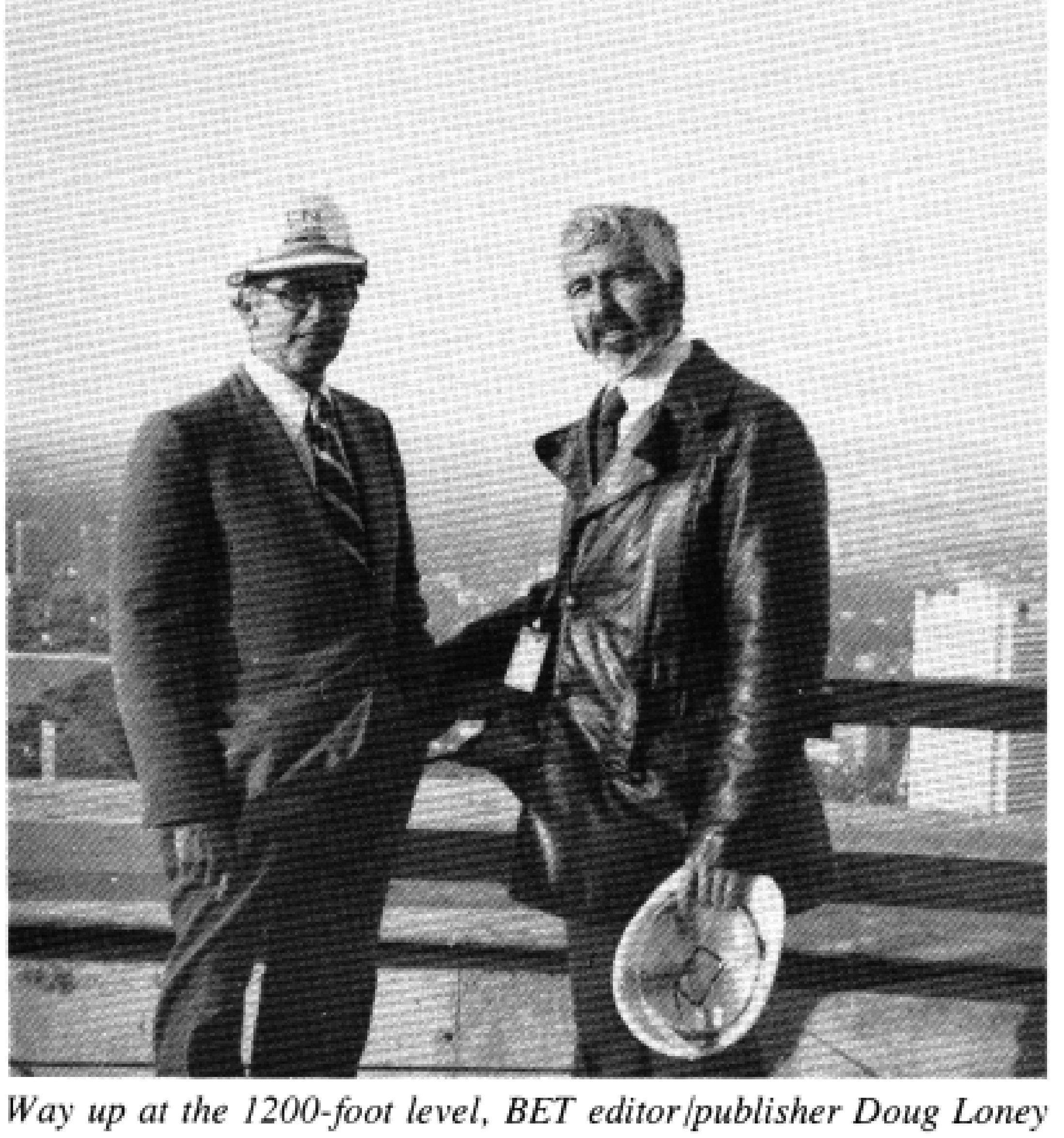
At Collins Radio, CBC's Bob Smee inspects the power amplifier board of one of the two 310Z-2 "Phase 4" exciters included in the dual transmitter system. Carl Fosmark looks on. At left is the 20 kw PA Plenum. Note that the transmitters are in the process of being initially joined together for the start of the final factory test.



Larry Dobby of CBC stands beside dipole of FM antenna, prior to shipment to Canada.



Ron Turnpenny performs a proof of performance test on one of the two CHFI-FM transmitters at Collins' plant in Dallas, Texas. Jack Sellmeyer, design engineer of the "Generation 4" transmitters, looks over his shoulder, with Carl Fosmark, co-ordinator of International sales in foreground.



Way up at the 1200-foot level, BET editor/publisher Doug Loney takes his hat off to the CN Tower. The confident, relaxed fellow at left is Malachy Grant, director of design and construction for CN Tower. Cameraman for the occasion was CHFI-FM's Ron Turnpenny.

CFTO's Berger:

"A Great Canadian Achievement"

CFTO-TV, channel 9, will use two parallel Gates 18 kw transmitters to broadcast from the CN Tower. The outputs are combined and feed two transmission lines to each half of the antenna to give maximum authorized power and ensure continued operations automatically in the event of a failure of any link or component within the system.

Hellmut Berger, director of engineering for Baton Broadcasting Inc. explains that the greater height, along with other benefits, will enable CFTO to maintain the maximum ERP of 325 kw with less input—resulting in cost savings with the new transmitters.

The location of the transmitters in the Sky Pod results in shorter transmission lines, hence less power loss. The CN Tower is the first in North America in which all broadcasters have used Kabelmetal's Flexwell transmission lines, a type which is highly flexible, in one piece, and permits solid clamping (rather than expanding hangers to allow for heat expansion).

CFTO-TV will use a Raytheon KTR 2 studio transmitter link, providing a dual system with fully automatic changeover in case of failure.

As mentioned elsewhere the antenna is sensitive to vortex forces. This problem is corrected by two "hoola hoop" dampers—each of which contain about 30 tons of lead—located above and below the channel 9 antenna. These rings remain stationery when the structure is excited by wind movement. The dampers are, in effect, shock absorbers which restrict any motion of the antenna structure and bring it back into line. The energy of the motion is transformed into heat—when winds reach 100 m.p.h., about 26 kw—which is then released through cooling devices.

A monitoring system will locate any failures in the antenna and facilitate maintenance and routine checks. Each dipole has a feed to a central monitoring panel for initial phasing and power control.

Berger is confident that intermodulation, which can be caused by adjacent antennas, particularly in candelabra arrays, has been avoided. The CN Tower provides protective spacing or staggering of the antennas, which are, of course, in a colinear vertical arrangement.

With characteristic understatement, but obvious pride, Berger describes the tower as "a great Canadian achievement", and Mal Grant, he adds, is "the optimist who said it *could* be done".

Power and Lighting

by Paul C. Ellard

The CN Tower was designed as a structure to house the UHF, VHF and microwave transmission equipment of the main TV, FM radio and communication facilities in the Toronto area.

The reliability of the incoming power supply, and the method of making it available at the upper level of the tower, were the main criteria for the design of the electrical system.

The main component elements of this system are:

- Normal power supply
- Emergency power supply
- Security Systems
- Lighting
- Mechanical Systems.

Normal Power Supply

The incoming power is brought to the site by the Toronto Hydro Electric System through four 13.8 KV feeders. These serve a multiple vault located at ground level which contains three 1500 KVA 13.8 KV/240-416V oil-filled transformers, and a vault in the upper accommodation containing four 2000 KVA 13.8 KV/416V askarel-filled transformers, all with network protectors.

Seven 15 KV cable risers are provided between the lower accommodation and the upper accommodation. Four of these are for the normal power supply, two for the house emergency system, and one for the broadcaster's emergency system.

The cables are three conductor #3/0 aluminum with semi-conducting thermosetting shield, cross-link polyethelene insulation, semi-conducting insulation shield, metallic insulation shield, PVC outer jacket and galvanized steel wire armour.

Cables of similar construction are also provided for the T.H.E.S. metering and control system.

The secondaries of the transformers in each vault are connected through a collector bus to the low voltage switchboards.

In the ground level Electrical Room two switchboards supply the normal power for the lower level and the emergency power for both the lower and upper levels.

In the upper Electrical Room three separate switchboards provide the normal power for all upper level requirements, including the broadcasters. Two other switchboards provide the emergency power requirements for the building and for the broadcasters.

All main switchgear is equipped with modified fused air circuit breakers, manually operated, drawout type with 200,000 amp. interrupting capacity.

A ground fault protection system is provided for the complete distribution system from the secondaries of the T.H.E.S. transformers to the power panels. Ground fault protection is also provided on the emergency power feeders.

These systems consist of solid state ground fault relays, associated zero sequence current transformers and interconnecting wiring, co-ordinated with the breaker settings, fuse sizes, T.H.E.S. primary protective relays, transformer damage curves, and the emergency generators full load, damage and fault decrement curves.

Power is distributed at 416V 3ϕ 3W from the main switchboards to the distribution and power panels throughout the complex in the majority of cases by means of corrugated seamless aluminum sheathed cables with copper conductors, cross-link insulation and P.V.C. jacket.

Dry type transformers are used to step down the 416 volt power to 120/208V 3ϕ 4W where required.

Emergency Power Supply

The building facilities emergency system supplies power for lighting, elevators, fire pumps, sewage and bilge pumps, pipe tracing cables, de-icing cables, the fire alarm system, the smoke control system, the audio communication system and CCTV system.

It consists of three 450 KW, 416V three-phase diesel-driven generator sets, operated in parallel and located at the power level.

The sequence of operation of the system is that on normal power failure the starting contact on the transfer switch closes, initiating engine cranking of all generator sets. When any generator set produces rated voltage and frequency the associated breaker is closed, and this becomes the master unit. The other two generators are then automatically synchronised and the transfer switch is then operated. The period from power failure to closing of the transfer switch is approximately 25 seconds. Power is distributed from the lower level to the upper level by means of duplicate step-up and step-down transformers and duplicate 15 KV riser cables.

The emergency system for the broadcasters consists of two 450 KW, 416 volt three-phase diesel-driven generator sets, operated in parallel. These generators are also located at the lower level.

The sequence of operation is different from the building services emergency system in that after engine cranking is initiated and each generator approaches synchronous speed the breakers close. Synchronism is then achieved by the voltage regulators. The period from power failure to closing of the transfer switch is a maximum of 10 seconds.

On power failure, the broadcasters normal operating load is automatically reduced so that only essential services are maintained.

Security Systems

The Fire Alarm and Smoke Detection System is a zoned, non-coded, electrically supervised two-stage system with Class 'A' circuitry on the alarm initiating and alarm sounding devices.

The alarm initiating devices consist of manual pull stations, thermal detectors, sprinkler flow valves, area and duct smoke detectors.

The alarm sounding devices are duplicate tone generators connected to the speakers of the sound system. A central control console is provided for the use of the fire chief indicating the location and type of alarm; it also provides controls for the alarm sounding devices, an emergency audio communication and fire fighter's intercom.

A digital output printer, which records all alarms, and a stereo tape recorder, which records all communications and messages on the emergency audio communication system and the fire fighter's intercom, are connected to the central console.

The smoke detection and control system automatically starts the operation of the smoke purge fans and smoke relief dampers.

A zoned, electrically supervised Sound System provides speaker coverage throughout the complex and is suitable for public address announcements, radio, phonograph, tape and wired music.

The sound system is compatible with the integrated asset protection system, the emergency audio communication system, fire fighter intercom and the fire chief's central control console. The system consists of three amplifiers, two of which drive duplicate access to each speaker while the third is a stand-by which is automatically switched on if any of the other amplifiers fail.

The Lightning Protection system consists of air terminals at the top of the Tower, as well as at intermediate levels, and copper strap down leads are connected to a grounding grid buried below grade and anchored with 20-foot long copper rods, 12 feet apart. The stairs, window mullions, sewer and water risers, elevator rails and the reinforcing steel are also connected to this grounding system. Associated with the lightning protection system is a lightning warning installation which receives the radio frequency SFEICS signal of developing or approaching storms from a distance of 100 miles, and therefore provides an early warning of approximately four hours.

Lighting

Interior lighting is designed to avoid glare and reflection on glass. All interior lighting is dimmer controlled.

The portion of the tower above the upper accommodation will be floodlit by means of specially designed beam controlled fixtures using tungsten halogen lamps to give a floating effect.

All elevators are equipped with a battery of beam controlled floodlights, operated by the elevator cab and giving a comet-tail effect.

The high intensity aircraft warning lighting system consists of three strobe flash heads on five tiers, giving 360 degree coverage. The effective intensity around the perimeter of the tower is 200,000 candelas during day time, 20,000 candelas during the time when the north sky luminance falls to 60 foot candles, and 2000 candelas when it falls below 5 foot candles.

The flash duration is 10 milliseconds maximum during daytime and twilight, and 250 milliseconds during the night. The flash rate is normally 40 flashes per minute, but during bird migratory periods this is reduced to 5 flashes per minute, with a light-off period of 10 seconds, to avoid blinding the birds. In addition red flashing lights are provided for the full height of the tower.

Mechanical Systems

The heating installation consists of electric duct heaters, fan assisted baseboard or convection heaters, and unit heaters. A system of pipe tracers is provided for the water and sewer pipes located in unheated areas, while de-icing cables prevent the formation of icicles at drip points and on the instrumentation booms located on the Tower legs.

Paul C. Ellard, of Ellard-Willson Limited, Willowdale, Ont., supervised the power and lighting installations for the CN Tower.

FM Combiner

by R. G. Wills

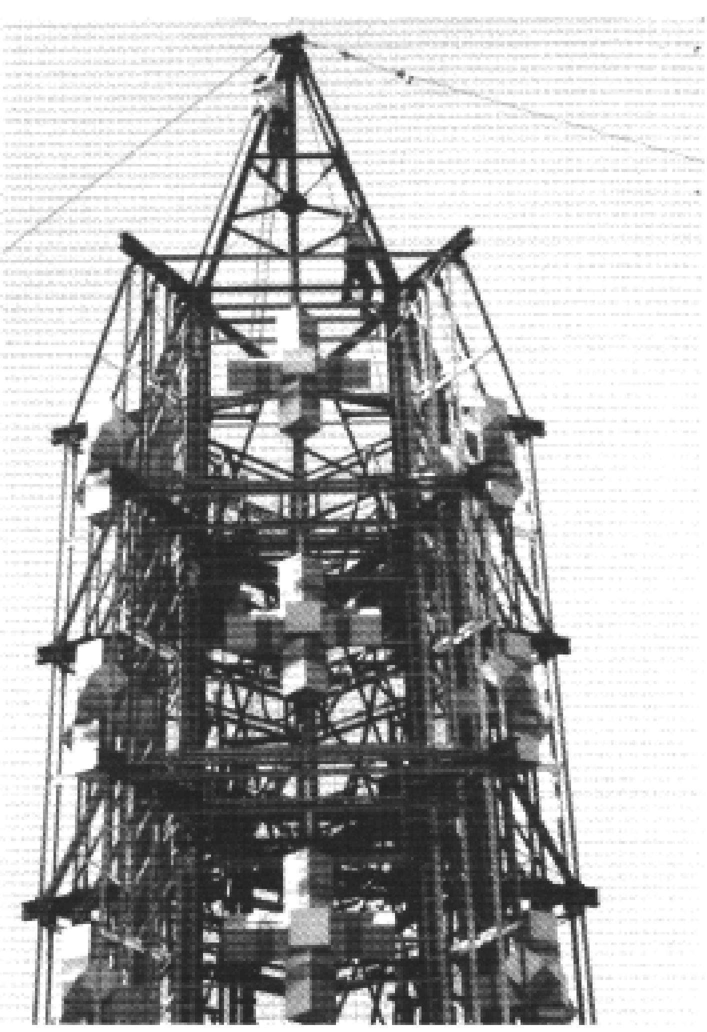
The CN Tower has a single transmitting antenna from which it is planned that 11 FM signals will be radiated.

Initially only 5 stations will be in operation. The combiner unit combines the RF outputs of these 5 stations into a single feeder and then splits the combined power into the two main feeders for the antenna. This unit has to be extendable from 5 to 11 stations by add-on modules with minimum disturbance to the initial system and the initial system must be capable of handling the full power of the 11 stations from the outset.

Combiner System

The combiner system is built in modular form with one module per transmitter, each module having wideband and narrow-band inputs and a combined output port.

The modules are cascaded one after the other by feeding the combined output of one into the wideband input of the next, the transmitters being added in one-by-one at the narrow band input ports. The output of the last module, which will be 130.5 kw when all 11 transmitters are working, is fed to the Output Network which divides the power in the ratio 59:41 into the two ½ antenna feeders.



Top three tiers of FM antenna, each having five dipoles, undergo tests at EMI, England.

The Output Network incorporates automatic change-over switching, actuated in the event of failure of a ½ antenna, and various by-pass facilities selectable by patch panels. A 6⅛'' E.I.A. rigid feeder is used for all main R.F. paths except for the individual transmitter inputs which are 3⅛'' E.I.A.

Combiner Module

The combiner module consists of two 3dB couplers, each having one pair of diagonally opposed ports connected to those of the other by equal length feeders. Shunted across each of these joining feeders are a pair of resonators spaced by one quarter-wavelength arranged to perform as a band-stop filter which stops one FM channel while allowing all the others to pass with negligible attenuation.

The single transmitter is brought into the narrow-band input to be reflected by the bandstop filter which is tuned to its channel and thereby is caused to combine with the wideband signal.

Resonators

In order to meet the low loss specification (0.1dB max.) copper coaxial resonators of 36 inches diameter with silver-plated inner conductors have been used in the bandstop filters.

3dB coupler

The 3dB coupler is of 16'' square cross-section with 6'' × 1½'' slab inner conductors broadside-on at one inch spacing. This is designed to match into the 6⅛'' feeders with the output ratio unity within 1% over the band 86-108 MHz.

Monitoring

The forward and backward true power in all input and output lines is sampled by directional couplers and measured by TFT heads. From this information alarms and executive switching actions are initiated if VSWR's higher than pre-set values occur, the results varying from changing from full antenna to ½ antenna, to shutdown of one or more transmitters.

R. G. Wills is the chief of the Aerial Group at Marconi Communication Systems, Chelmsford, Essex, England.

FM Antenna Design

by Andrew Alford

In the early stage of the project it was agreed that we use our modeling and computer facilities at Alford Manufacturing Co. in Winchester, Massachusetts, to evaluate various proposed antenna arrangements for the CN Tower. The objective was to arrive at one concept—or several concepts—for further study and discussion by engineers and representatives of the business interests concerned.

While this work was being done, the firm of Roger Nicolet and Associates, Consulting Engineers, developed additional concepts of what the tower may be like. These changes in concept did not deter us very much because the overall cross sections of the tower, at various levels, as measured from the top, remained roughly the same in size, even though they sometimes differed in conceptual shape.

At the beginning, only antennas were to be de-iced. Later, in April 1969, the "coronet" for the UHF Channels was dropped and a partial radome adopted. A month later an overall radome appeared on the drawings because of the location of the tower. The worry about falling ice was there from the beginning. The radome seemed like the best solution.

The second stage of our participation in the CN Tower project was in connection with FM. We were asked by EMI of England to act as their subcontractor for the FM antenna.

We proposed an adaptation of the array design we used on the John Hancock Building in Chicago. This antenna is located about 1175 feet above ground and is presently serving 10 FM stations. It was designed to radiate circularly polarized signals. Each cross dipole is provided with what we call a "niche" which is a squarish reflector designed to:

(1) eliminate deep nulls in horizontal patterns of the vertical components of the cross dipoles;

(2) equalize the vertical patterns of the vertical and horizontal components of the cross dipoles; and

(3) reduce the coupling between adjacent layers of antennas.

This arrangement also results in improved circularity, not only near the horizon but also at angles below the horizon. Each cross dipole has only one feeder. The arrangement for obtaining two currents in time quadrature is inside each dipole. The large cross section of the radiating elements, together with the unconventional method of feeding, resulted in a low SWR over the FM frequency range.

In Chicago, each group of five dipoles are mounted within five "niches" arranged around a cylinder 12 feet (3.65 m) in diameter. There are two groups of five dipoles. The same basic arrangement was adopted for use on the CN Tower. The construction of the "niches" was changed by Mr. Peter Hawker of EMI to fit the conditions within the radome, without, however, jeopardizing the electrical properties. This was verified from the patterns obtained with a model built at our plant, incorporating the essential features of the CN Tower "niches."

Dr. Andrew Alford of Alford Manufacturing Co., Winchester, Mass., is a well-known pioneer in broadcast engineering and holder of many patents for his inventions in this field.

A People Place For People City

Architect for the CN Tower is Edward R. Baldwin of Toronto.

Baldwin notes that post-war Europe has seen the construction of a variety of the so-called "broad-banded" antenna installations lined vertically on top of spectacular free-standing towers. Most North American cities in contrast, have scattered independent antenna systems on top of office buildings. As broadcast technology continues to develop and the population of our urban centres grows, undoubtedly we will see more of the European-type transmission towers constructed as the years go by.

But he describes the "transmission towers cum tourist attractions" found in many European cities as "without exception, quite unpleasant both to look at and to visit".

The CN Tower had to be much more than the world's tallest tower.

While many of its components are found elsewhere, Baldwin says the experiences which the visitor will encounter at the CN Tower are so unique that its success as a tourist attraction is ensured.

Observation Tower

The tower will rise out of a parkland setting with landscaped terraces sloping to a large reflecting pool surrounding the base of the tower. There will be plenty of space to enable visitors to fully appreciate the mammoth structure.

The entrance structure will contain reception and briefing areas for organized tours, a family restaurant, boutiques, and display areas. Visitors will be able to enter these areas without paying admission to the tower.

A glass-enclosed bridge over the reflecting pool will lead to four glass-faced elevators with a capacity of over 2,000 persons per hour.

The elevator climb will take slightly more than a minute. On arrival at the Sky Pod,—a seven storey structure located between the 1,100 and 1,200 foot levels—visitors will have a potential 75 mile view from two public observation levels.

A feature of the observation area will be six high-powered zoom telescopes. The 200-power telescopes, with 8" objective lens are the result of a $350,000 research and development project. They were designed and built in Ontario by a consortium of optical and mechanical designers, including Leitz. The effect, says Baldwin, of going from 10X to 200X magnification, is the same sensation as "an apparent flight through the air at a speed in excess of one mile per second". A laser-beam device in the telescope pinpoints the target in a beam of light.

Two mini-theatres are to be built, where a 7-minute spectacular audio-visual presentation will show the tower under unusual weather conditions. Features to be included are a zoom from the base of the tower, rising up the interior shaft and right out the top, to an exterior view from a climbing helicopter; and gale wind and lightning conditions as seen from the very top of the tower.

A further observation area—the highest public observation gallery in the world—at the 1,500 foot level, will offer views of up to 100 miles.

The revolving restaurant, at the 1,150 foot level, is the largest and highest in the world, accommodating approximately 450 people, and will revolve every 1½ hours. Built by Macton, a New York firm which has supplied 170 turntables for revolving restaurants throughout the world, the turntable is driven by two motors of only ¾ h.p. each. It will be quite independent of the observation areas, and the large elevator capacity makes it possible to use one or more elevators exclusively for the restaurant. Diners, whose reservations may be entered into a computer years in advance, will enter a reception and cocktail lounge area overlooking the reflecting pool at the base of the tower before going to the restaurant.

Down on the ground, workers attach choker cables to a section of the 335-foot antenna mast . . .

. . . the mast section is then whisked to the top of the tower and positioned by "Olga", the Sikorsky S-64E Skycrane.

Microwave Radome

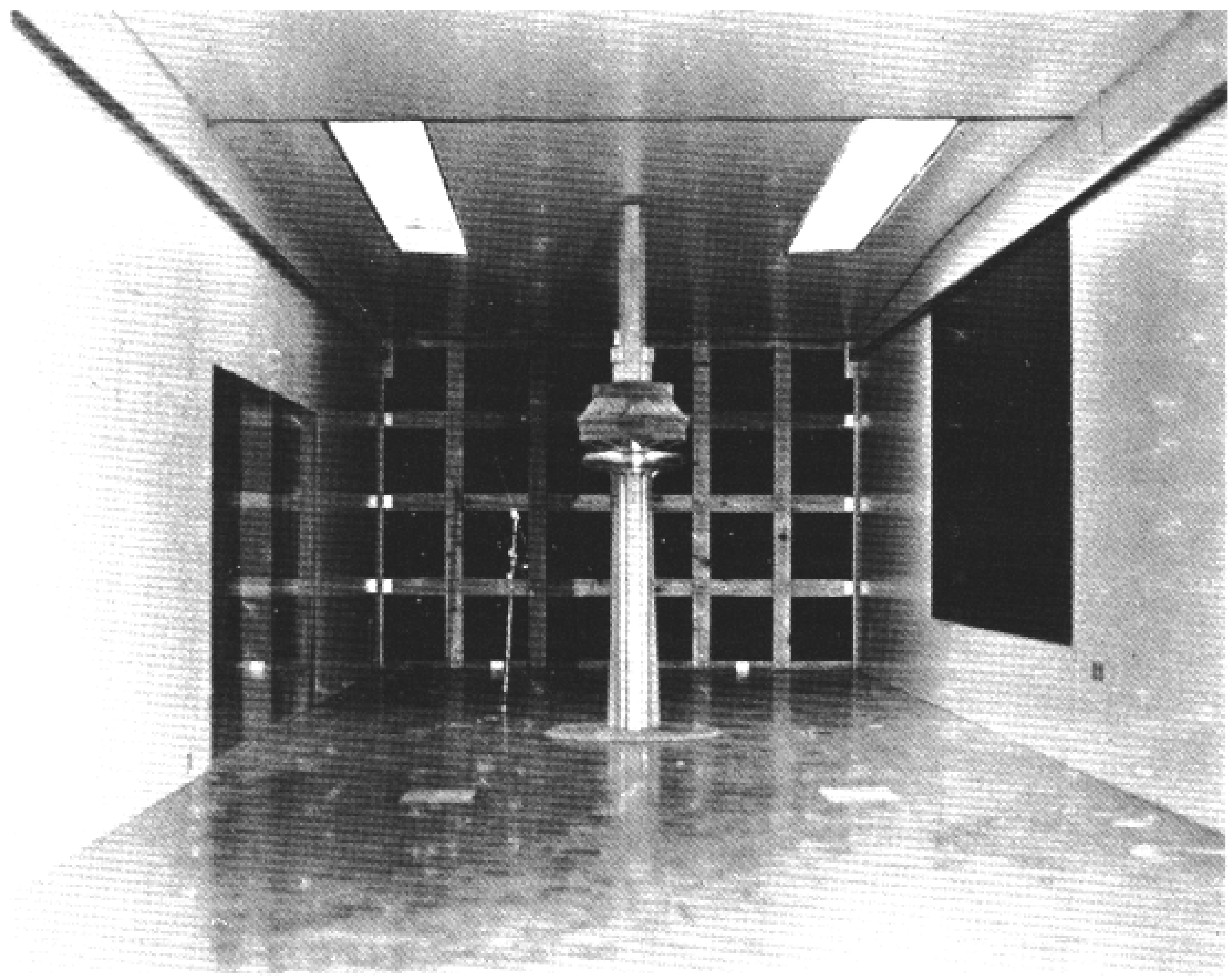
by Milton B. Punnett

In June of 1973 Birdair Structures was contracted by the designers of the CN Tower in Toronto, Canada, regarding the feasibility of enclosing the microwave level of the world's tallest freestanding tower with an air-inflated radome.

At that date, although it was well established that a prime function of the tower was for microwave communications, the exact method of mounting and protecting the various antennas had not been determined. Artist concepts showed the antenna dishes mounted outboard around the base of the so-called "sky-pod," but it was recognized that such an arrangement was not practical and some form of protection would have to be provided.

Birdair's proposal was basically simple and clean: a 25'6" high, horizontal section of a torus is formed of a single flexible coated fabric skin which is held in shape by internal air pressure. Naturally, many conventional approaches were considered as well, but the unique concept of a 360 degree continuous, RF transparent, torus surrounding the pod base not only appealed to the aesthetic and progressive concepts of the architects, it also promised performance features otherwise unobtainable. These included:

- Complete protection not only for the various antenna surfaces, but also for maintenance, repair, and replacement. At over 1200 ft. above street level, such a feature was almost demanded. The design allows technicians to easily service an antenna and its associated feed, even in severe weather. Complete protection from the elements also allows a much simpler antenna/feed structure.
- Flexibility for future expansion and changes. The essentially uninterrupted enclosure with no supporting framework allows antennas of various sizes and configurations to be located as desired for optimum performance. The area inside the radome is divided into angular sectors leased to tenant clients. In order to adapt to the various present and future tenant requirements, it is obviously desirable to have the maximum flexibility possible. The choice of a thin, highly RF transparent skin reduces any significant variation in transmission at different frequencies. A geometrically similar 1/2 wave-length dielectric radome or an electrically tuned metal framework would have to be designed for a specific operating frequency.
- Smooth exterior surface. It has frequently been observed that an uncluttered smooth radome surface does not tend to collect snow and ice as would a conventional antenna structure. This is extremely critical on the tower, as falling ice which might accumulate on irregular antenna and feed structures would present an extreme hazard for people in the area below.



Model of CN Tower (1/120 scale) underwent exhaustive testing at University of Western Ontario's Boundary Layer Wind Tunnel. Note turbulence grid behind model.

Geometry

The antenna mounting plane was dictated by the dimensions of the tower "sky pod." The 25'6" height of the enclosure was selected to allow variable mounting of antennas of at least 12 ft. diameter. The vertical curvature and outer diameter (138'-3") was then a function of space required and skin stresses.

As originally conceived, the area behind the antennas was to be open bays for the electronic gear. Concern by the building officials finally resulted in an inner firewall to separate the individual equipment rooms from the common radome area. The entire microwave level is pressurized with the radome, thus eliminating the need for airlocks and seals between the equipment and antennas. The radome pressurization system is located under the equipment deck in essentially unused space.

Wind Tunnel Testing

Although wind tunnel data for ground-based radomes has been available for many years, the concern as to the effects of the more recently recognized turbulence factors and wind probability functions, as well as unique tower geometry, resulted in CN sponsoring a special test program at the Boundary Layer Wind Tunnel Laboratory at the University of Western Ontario. Of special interest was not only what internal pressure levels would be required, but also what aerodynamic pressure would be experienced at the air intakes, particularly those located facing inward between the supporting webs.

The Laboratory fabricated a very unique 1/120th scale model. The model includes a .001" thick polyurethane skin radome which can be maintained at various pressures. The deflection of the skin and the pressure distribution were measured with special electronic instrumentation. Different turbulence effects to simulate possible actual wind conditions were induced. The tests also indicated that under high wind conditions it would be necessary to supply air from the air conditioning intake located at the top of the sky pod.

Pressurization

Even though the lower radome is retained by clamping rings at top and bottom, the envelope depends upon inflation pressure for the pretensioning which provides shape and stability. Pressurization systems can vary to a wide range of complexity as a function of the radome system requirements. Over a period of many years, Birdair has established certain basic principles which, if adhered to, will provide a reliable pressurization system. These include:

- Continuous blower operation. In contrast with the cyclic operation utilized in early systems, it has been demonstrated that continuous blower operation provides greater reliability than a start-stop system.
- Size blower motors to be non-overloaded under any and all conditions of operation.
- Select blowers which provide a maximum pressure equal to the desired inflation pressure with a flat performance curve. The blower itself then provides a simple and reliable means of pressure control.
- Provide multiple blowers, parallel installed, equipped with reverse flow check valves. This provides a redundant system that insures against mechanical failure of a single blower.
- Provide a reliable source of power to the inflation system. (In the case of the CN tower, emergency power is already a critical safety factor; thus the requirement does not dictate anything unique.)
- Provide a system which will furnish several pressure levels if there are severe wind requirements. This permits the radome to operate at low pressures (lightly stressed) during the majority of the time, yet have full stabilizing pressure during periods of high wind velocities.

Based upon the wind requirements, an automatic, three-stage pressurization system is utilized. The radome will be maintained at a pressure of 3.3'' H_2O (0.12 psi) for winds up to 40 mph. Anemometers on the tower will actuate the control system to automatically switch over to a second stage mean level of 7'' H_2O for winds between 40 and 75 mph. For winds from 75 to a nominal 120 mph the radome will be at 10-13'' H_2O.

The inflation system has seven blowers (plus two special purpose units). Two identical main blowers (each 5 HP) are available for normal inflation. A single, 10 HP blower is used for the middle stage. Four high pressure, 10 HP blowers are available for the peak condition. (Because of the possible high combined power load, the system includes automatic sequential start.)

Pressure sensors detect an unsafe condition at any wind speed to actuate supplemental blowers.

Calculated Loads

Stresses in the tensioned skin of the radome envelope are variable, but reach a peak under aerodynamic loading in the area of maximum negative pressure. From the model tests we know that this occurs at a yaw angle of 150 degrees with 110 mph winds. The principal stress is in the vertical direction. The radome is patterned in the vertical direction, the typically higher strength warp threads run continuous from top to bottom.

Under a normal inflation pressure with no winds, the skin is stressed to only 20 lb./in.

Material Selection

One of the most critical aspects of the radome design was the selection of the envelope material. The final choice is a recently developed coated fabric combining superior electrical characteristics with physical performance never before available for radomes.

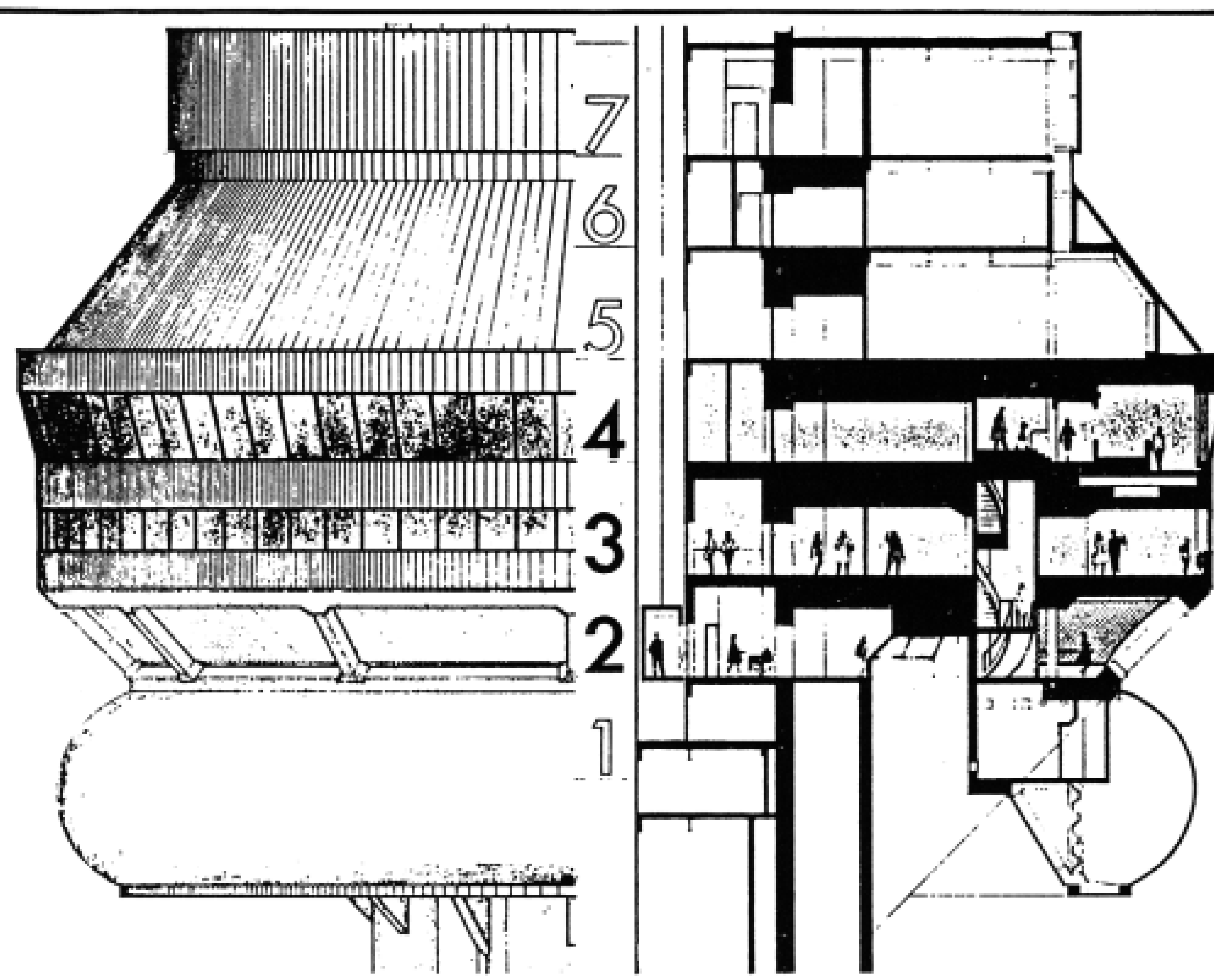
A special "Beta" glass yarn, developed by Owens-Corning Fiberglas Corp., is woven into an 18 oz./sq. yd. structural base fabric. This is then coated with duPont "Teflon" fluorocarbon resin to a total weight of 50 oz./sq. yd. A combination of TFE and FEP Teflons are fused to the fabric. The latter permits a high temperature thermal weld to be used in the radome fabrication. Weaving and coating was by Chemical Fabrics Corp. to Birdair specifications.

The resulting material, although less than 1/16" thick, is anticipated to have a life expectancy of more than 20 years. Accelerated exposure tests show the Teflon coating to have excellent resistance to weathering, aging, and resists adherence of ice and dirt. In addition, the envelope is actually less costly than the more common two ply, Hypalon-coated Dacron polyester.

The CN Tower is not the first structure to take advantage of this new material, but it certainly is the highest. Because of the more difficult access, combined with life desired, a heavier Teflon coating was specified for the radome. Every role was subject to complete physical testing in Birdair's laboratory before acceptance and use in the radome. The material actually exceeds our specified tensile strength of 600 lb./in. warp and fill (935 lb./in. average warp and 863 lb./in. average fill). After folding tests, the strength was still 700 lb./in. x 817 lb./in.

Water absorption characteristics can have a very significant effect upon RF performance. After 24 hours total immersion, the material shows only 0.1% absorption. Even after immersion for 48 hours, the absorption is less the 0.5%.

Materials are initially tan in color, but within a few days bleach out to a white.



Cutaway illustration of Sky Pod indicates its massive size. Functions of the seven levels, in descending order:
1. *Mechanical, air-conditioning*
2. *FM transmitters*
3. *TV transmitters*
4. *Revolving dining room*
5. *Indoor observation area*
6. *Outdoor observation area*
7. *Microwave equipment, enclosed by radome*

RF Properties

Measurements of electrical properties have been made by several different groups on this and similar materials.

A brief series of tests were conducted by the National Research Council-Canada. In these tests a large sample of the actual production material was inserted between two waveguide horns. The results showed a total loss at 7 1/2 GHz of 0.2 db (normal incidence) and 0.3 db (45 degrees incidence). Slightly higher losses (0.5 db—normal, 0.4 db—@ 45 degrees) were measured at 15 GHz. Although these results are less favorable than some other measurements on Teflon/Fiberglas, the conclusion was that the effect upon microwave system performance would be negligible up to the 7 1/2 GHz band and slight at 15 GHz. If, in the future, even higher frequencies up to 20 GHz are employed for short haul systems, CN consultants reported that the radome would still be satisfactory.

Installation

Although Birdair does not have prime responsibility for the tower installation, the method developed may be of interest.

The envelope has been fabricated in three 120 degree segments weighing 1500 lbs. Each segment was prefolded at the factory and placed on a separate pallet, ready for placement. The three pallets are placed equally spaced on the lower deck.

There is a special hoist I beam located just below the upper clamp ring. Originally intended for lifting antennas, it also is used for the radome. Special temporary lifting clamps were provided to lift the accordion-folded ribbon to the I beam ring. These clamps hook to roller trolleys on the ring. Once hooked up, the envelope is pulled open much like a shower curtain. It is then permanently attached to the top and bottom clamps, working in succession around the tower. A non-metallic segmented clamp joins the sections together at the three vertical joints. These joints were carefully located to minimize interference with the antenna patterns. Once clamping is completed, the envelope is pressurized.

The installation procedure is sensitive to weather conditions and is therefore intended to take less than a day.

Design Features

The radome envelope is fabricated with 90 identical gore panels. A 3" wide thermal weld lap joint is used between panels. Although the joint contains no metal and is RF transparent, it does present a double thickness. A sample joint was tested by the National Research Council; they concluded that it would have no significant effect upon total performance.

The three sectionalizing field joints are made by clamping overlapping roped edges. The clamp members are extruded 3" fiberglass channels. Stainless steel bolts of 3/8" diameter are used for the assembly. As this does present a potential blockage, the joints were oriented to have a minimum effect upon desired antenna directions.

The top and bottom radome edges have a load-carrying bead. The edge is then clamped using 3 ft. long clamping strips.

One of the unique features of the Tower radome is the method to be employed in adding or removing full size antenna reflectors. An electric hoisting winch rides under a steel beam ring just below the upper radome clamp. The winch has sufficient line to hoist an antenna dish from the ground 1200 ft. below. The base of the radome attaches to the tower structure ring to form a "chin" with a lower deck about 8 ft. wide. This deck is actually a series of removable hatch plates each 3 ft. x 5 ft. By removing the plates directly under the antenna position, the dish can easily be hoisted directly thru the hatchway. In order to make up for the volume of air which will be lost through the opening, two 10 HP high volume propeller blowers are used to supplement the normal system. The envelope will thus retain its shape, but at a considerably lower pressure.

Naturally, this operation must be performed with very calm wind conditions.

Other Applications

The CN Tower radome is not the first structural use of the Teflon/Fiberglas. Its original strong features have been both the predicted long life and unusually high fire resistance.

A 68,000 sq. ft. building complex for LaVerne College, near Los Angeles, is of tensioned fabric design, encompassing a gym, theatre, and creative arts facility. The roof is actually an outer skin, almost identical to the CN radome, with a fiberglas insulation suspended underneath. Interestingly, this unique structure cost less than 1/4 that of a traditional brick and mortar alternative design. It has been in service since early 1973.

In Pontiac, Michigan, an 80,000 seat sports stadium is being erected for the Detroit Lions. The air-supported roof system, which is cable reinforced, is made of Teflon/Fiberglas. The roof covers approximately 10 acres, making it one of the largest fabric air structures to date. Surprisingly, because of the cable reinforcing, this structure utilizes a lighter, 13 oz./sq. yd. base fiberglas.

Future Potential

Even though the Teflon/Fiberglas material is almost "state of the art" and the CN Tower radome represents the viable concepts possible with air structures, we can foresee even further developments.

A weak point in the design of inflated radomes has been the need to use a two-ply bias-reinforced fabric construction to obtain maximum tear and shear strength. Two-ply, Teflon-coated fabrics are not available. But now a new loom developed by Dow Weave has great promise. Rather than the conventional 90 degree square pattern, it weaves on a triaxial 60 degree grid. The result is a high tear resistance in a single ply of fabric. There are difficulties in weaving Fiberglas on the Dow Weave looms, but we already are testing a 3.5 oz./sq. yd. Dacron with a urethane surface, which may be applicable to small, thin skin, inflatable radomes.

Fiberglas itself may not be the ultimate fabric. High-tenacity Aramids, such as Kevlar, have strength/density ratios two to three times that of glass or steel. Kevlar's high cost is rather prohibitive, but we have been experimenting with its use on very special applications.

The old concept that a radome must be a sphere is gradually being displaced. Naturally, the inflated shape must be inherently stable, but the CN Tower radome is a good example of the variations possible.

Milton B. Punnett is chief engineer for Birdair Structures, Inc., of Buffalo, N.Y., contractors for the microwave radome on the CN Tower.


CN Tower

A Unique Structure

The CN Tower is a unique structure in many ways and as a result, has attracted as much interest from architects and engineers around the world as from the public.

CN Tower Limited, a subsidiary of Canadian National, is responsible for all aspects of construction and the operation of the Tower. The manager contractor on the site is the Foundation Building Construction Company.

EXCAVATION

Excavation work for the Tower commenced in February, 1973, but before the CN Tower could go up, a soils expert had to go down to analyze the bedrock.

As part of the most thorough exploration program of its kind in recent construction history, a drill rig bored four holes, each 30 inches in diameter, penetrating as far as 90 feet into the rock.

Air and drainage systems were installed in readiness for the soil engineer and a photographer to descend in small cable-cages.

The exploration program was planned and conducted by Dr. Eli Robinsky of the University of Toronto, a consultant in foundation design. Equipped with oxygen tanks and lighting facilities, the men shot hundreds of color photographs of the rock strata. Samples of rock were taken to a lab for testing, and strength tests were also conducted on the spot.

Workmen first removed the overburden to get at the rock. Ninteen feet down into the earth they reached the water table (the site is about one third of a mile from Toronto's lakefront). A 300-hole wellpoint system was hooked up in order to 'head off' the water and keep the excavation dry.

A further problem existed. This type of shale has a tendency to heave or move if normal pressure is interfered with in some way. A series of 63 holes, each 2.5 inches in diameter, were drilled into the rock around the excavation to relieve the hydrostatic pressure in the area of the excavation and thereby reduce the tendency to heave.

Some 62,000 tons of shale were disgorged by giant back-hoes during the deeper excavation. In the final stages, roughly 50 feet below ground, the shale was smoothed and cleaned. Then wet burlap was applied to the exposed surface to maintain its consistency, and a foot-thick blanket of concrete poured to ensure that no deterioration occurred in the base rock.

On top of this blanket the 22-foot thick concrete and steel foundation was placed. The Y-shaped foundation contains 9,250 cubic yards of concrete, 500 tons of reinforcing steel and 40 tons of tensioning cables.

CONCRETE SLIPFORM

The concrete used in the Tower project was reinforced by a unique system of post-tensioning using more than 80 miles of steel cable and has a strength of more than 6,000 pounds per square inch.

An extremely high level of material quality control was achieved by continuous monitoring and testing procedures and the use of the "accelerated strength-testing method".

This 48-hour test has supplanted the 28-day test previously used in most construction. Its importance lies in the fact that it allows engineers to predict accurately what the final optimum strength of the concrete will be at the end of a two-day period.

This was an obvious necessity for the CN Tower, which at times, grew by more than 20 feet a day.

Concrete was placed from the top of a slipform, which began its ascent four months after excavation work for the Tower commenced. As the slipform moved up under hydraulic pressure, supported by a ring of climbing jacks, it left continuous extrusion of hardened concrete.

The concrete-shaping slipform was reduced in size as it climbed skyward, producing a gracefully tapered three-legged contour.

Concrete was placed 24 hours a day, five days per week. The Tower became the tallest structure in Toronto in September, 1973, and the tallest in Canada in January, 1974. Top of slipform concrete, 1,464 feet, was reached on February 22, 1974.

This was followed by an additional 16 feet of special concrete work to serve as the base for the steel transmission mast, about 335 feet tall, which occupies the top of the Tower.

As might be expected, the sheer height of the Tower created problems. One was the need for the structure to be capable of sustaining maximum stresses at every point, something which is not required in conventional building. At one time or another the whole Tower will be subject to the tolerable stress limits. Instead of 5,000 psi concrete, the Tower has been built with 6,000 psi concrete, beyond what is accepted as safe or necessary.

The Tower can withstand anything that nature might throw against it—from high winds, snow, ice and lightning to earth tremors.

A TRUE TOWER

To ensure that the world's tallest free-standing structure stands straight, an assortment of precision-made optical instruments, backed up by the traditional plumb bob, were used. Every reading was checked and double-checked as the structure inched skyward.

This technique was so effective that Mal Grant, director of design and construction, is able to affirm that the alignment is "not out more than ¾ of an inch all the way up".

The control system not only made sure the Tower does not incline; it also held a tight rein on what engineers describe as "torsional oscillation". This is the inexplicable tendency of tall, slender structures to begin to twist slightly (in a counter-clockwise direction when built in the Northern Hemisphere). This is related to the rotation of the earth.

Three German-made optical plumbs or "bombsights", worth $2,400 each, were the mainstay of the control system for CN Tower. At two-hour intervals, one of these instruments was affixed to a permanent mount on the slip form and sighted against a permanent target on the foundation.

At the same time, a reading was taken from a plumb bob consisting of a 250-pound steel cylinder, attached to a steel aviation cable suspended through the hexagonal core of the Tower.

Both the optical instrument and the plumb bob were used to measure the plumbness of the Tower as well as any tendency to rotate.

Further control was provided by daily surveyor's readings from the ground. Adjustments in the jacking technique were made when it was evident the deck had to be "pitched" one way or another in accordance with the latest set of readings.

BRACKETS

During August, 1974, 45-foot angle brackets were bolted to the Tower at the 1,100-foot level. These support the Sky Pod—a seven-storey circular structure containing public observation areas, revolving dining room and broadcast transmission equipment. A computer was used to determine exact positioning of the anchor plates which secure the brackets. The 12 brackets and associated wood and steel forms weigh a total of 350 tons.

TOWER CRANE

During the early stages of construction in April, 1973, a 47.5 ton crane was erected at the centre of the Tower's foundation and from that time performed most of the required lifting operations.

Capable of lifting loads up to 8,000 lbs., the crane performed 4½ years work, often on a round-the-clock basis. It rose along with the concrete slipform to a height of 1,480 feet.

The last main function of the tower crane was the erection of the base section of the antenna mast—which was too difficult to lift by helicopter—and the erection of steel framings for the roof of the upper observation platform.

- *The antenna mast, 335' high, weighs 290 tons and cost $1.4 million.*
- *The CN Tower is hexagon shaped. Considerable adaptation was required when it was discovered the antenna had to be pentagon-shaped to meet DOC requirements for omni-directional antennas.*
- *The first shipment of transmission cable from Germany was damaged in transit when the cargo ship encountered a severe storm in the Gulf of St. Lawrence. Fortunately, a second shipment to replace it was quickly provided by Kabelmetal.*
- *Above the pod there will be a 30,000 gallon water tank to maintain water pressure. Should a fire break out, it would operate the sprinkler system for three hours. This would be a disaster for all stations except CFTO-TV, which opted for an expensive halon (a harmless gas) system, instead of sprinklers, for fire protection.*
- *Contractors thought they had anticipated every problem. That was before a woodpecker started work on the site in September. The bird was attracted to GRP radome and had EMI's installation chief Ray Tattershall worried—until it was caught by ironworker Louis Strufel.*
- *Broadcast engineers throughout Europe, where there's great interest in common towers, are reportedly ready to give the title to Canada. The word has it that "CN is the king".*
- *There were no precedents to many aspects of the tower, and even now, minor changes are still being made. "We really had to play it by ear," says Mal Grant.*
- *The Sikorski sky-crane was popularly nick-named "Olga". There was an Olga Sikorski: she was the inventor's sister and in 1909-10—when the inventor was only 19—financed his early studies of aviation and initial attempts to build a helicopter. Sikorski arrived in the U.S. almost penniless in 1919 after fleeing the Russian Revolution.*

ANTENNA MAST

A giant Sikorsky helicopter erected the Tower's 335-foot high transmission mast and took down the Tower's crane in eight sections.

It took 3½ weeks to complete this task. This compared with six months if conventional methods were used. Fifty-five lifts were involved in the operation—an operation which took the Tower to a world record height.

Early in the spring of 1975, the CN Tower became the world's tallest free-standing structure, reaching a height in excess of 1,815 feet. It surpassed Moscow's Ostankino Tower—previously the world's tallest—which is 1,748 feet high.

Ross McWhirter, editor of the Guinness Book of World Records, of London, England, was on hand to officially certify the height of the Tower. He determined the Tower to be 1,815 feet, 5 inches.

Only 17 other self-supporting structures in world history have held the title of tallest, according to the Guinness Book of Records. The CN Tower is the 18th holder of the title, bringing the title to Canada for the first time.

It became the world's tallest free-standing structure when the 36th piece of the antenna mast was placed on top of the Tower.

The Sikorsky acted as a skyhook, lifting the 39 mast sections into place. Designed especially for aerial construction, the giant $4 million Sikorsky S64E Skycrane has a lifting capacity of 11 tons. The heaviest of the mast sections weighed eight tons.

HOOLA-HOOP DAMPERS

During the antenna mast erection, the Sikorsky lifted two devices which will reduce vibration and sway. One damper was installed at the 1,600-foot level and the other 50 feet higher.

These two devices represent a remarkable breakthrough by a team of young Canadian engineers. The devices are the first of their kind designed to solve one of the most unique engineering problems in the world, and they are a totally Canadian invention.

They solve one of the major problems faced by CN Tower designers; that of how to control the sway and vibration of the 335-foot steel transmission mast, caused by winds of varying intensities.

The solution turned out to be based primarily on the hoola-hoop principle. Two absorbers, which are finely tuned to two different frequencies, were designed to operate in the opposite direction to the motion of the Tower and transmission mast but, like hoola-hoops, they will move in any possible direction to counter the motion of the mast.

directions

A review of recent announcements, decisions and policies of the Canadian Radio-Television Commission.

OTTAWA HEARING NOV. 4

Among the applications to be heard by a CRTC public hearing commencing November 4 at the Chateau Laurier, Ottawa:

- The Ontario Educational Communications Authority (OECA) is requesting licences in four cities to extend its television network. They are Peterborough (10.2 kw video on channel 33), North Bay (19 kw on channel 6), Timmins (14.9 kw on channel 7) and Sault Ste. Marie (76 kw on channel 20).
- The CBC has applied to change the frequency of 1prt CBLH at Hornepayne, Ont. from 1340 to 1090 khz.
- Ex-Cen Cablevision Ltd., Clinton, Ont., seeks a change of head-end location for its system serving Exeter, Centralia and Huron Park, Ont.
- Among applications by various cable systems for changes in channel distribution, CUC (Scarboro) Limited would add to its converter service two local origination channels (for information and children's programming) and Canadian feature films on its Canadian re-run channel.
- Native Communications Inc., Box 5, Thompson, Man. requests a 50 watt AM station on 1340 khz at Norway House, Man.
- At Lethbridge, Alta., the CBC seeks a rebroadcaster for CBRT Calgary on channel 10, with 123 kw ERP video, directional. It, in turn, would have a 5-watt rebroadcaster on channel 4 at Waterton Park, Alta. CJOC-TV (Lethbridge Television Ltd.) would disaffiliate from the CBC television network.
- Fraser Valley Broadcasters, Chilliwack, B.C., propose a change of frequency and power for CFVR Abbotsford from 1240 to 840 kHz, with 10 kw day and night (DA-2).

DEC. 15 DEADLINE

Applications for cable licences to serve areas within the overlapping Grade B. contours of

1) CKNC-TV and CKSO-TV Sudbury,
2) CKNC-TV and CKSO-TV-1 Elliot Lake, and
3) CFCL-TV-3 and CKSO-TV-4 Kapuskasing, must be filed by December 15, 1975. Applications must detail routes and costs of any use of microwave, including distant head-end site, agreement with common carrier and monthly cost to subscriber. The Commission expects applications to outline how they will strengthen off-air services, and requests local stations to make representations to protect their continued viability.

DELETION ORDERED

Cable systems in the Toronto-Hamilton-London areas of southern Ontario and in the Vancouver area of British Columbia have been instructed to report to the Commission by December 31, 1975, on plans for the deletion of commercials from the signals of U.S. stations. The commercials are to be replaced with suitable material.

Agreements are to be made among cable and television station licensees in each area to share the costs of the construction and operation of deletion facilities. This is a condition of the licence renewals of all the cable systems concerned.

The Commission does not specify that *all* commercials must be deleted from U.S. stations. It also recognizes that sufficient time will be required to coordinate and develop plans "so that the process may be performed efficiently at a reasonable cost and without disruption to the service now being provided to subscribers".

Other aspects of the renewals:

- Certain cable systems which carry the Toronto stations have been permitted to delay changes in channel distribution until March 1, 1976, or the date when television transmissions begin from the CN Tower, whichever is earlier, to avoid unnecessary confusion to subscribers.
- British Columbia Television, while commended for its program production and extension of service to many areas of the province, is now expected to apply for rebroadcasters in the East and West Kootenays, according to a previously proposed

BROADCAST EQUIPMENT TODAY

CUSTOMER SERVICE

Please attach your address label here when making an inquiry.

___CHANGE OF ADDRESS: Print your new address below.

___INQUIRY: Clip your address label to your letter.

___SUBSCRIPTION: Mail this form with your payment.

___1 Year $ 9.00
___2 Years $15.00
___3 Years $18.00

Name ....

Title ....

Company ....

Address ....

....

City ....

Province ....

Postal Code ....

Telephone ....

Mail to:
Customer Service,
BROADCAST EQUIPMENT TODAY,
Box 423, Station J, Toronto, Ont.
M4J 4Y8 (416) 463-5304

directions

continued

plan. The company will provide CTV service to Vancouver Island through its existing station, CHEK-TV Victoria (now a CBC affiliate), when the CBC establishes its own stations on Vancouver Island. Applications for two CHEK-TV rebroadcasters were approved for Vancouver Island.

• Four Maclean-Hunter Cable TV operations in southern Ontario were told to improve their community channel service "in terms of access, mobility and the provision of a unique local programming service".

MONTREAL HEARING

Applications heard at the October 7 hearing in Montreal included:

• Television rebroadcasters for the Canadian Broadcasting Corporation at St. Pamphile, Quebec, and three locations in the Northwest Territories—Hay River, Lake Demarais and Fort Providence.

• A rebroadcaster at Lac Etchemin, Que., on 920 kHz with 1 kw, for Radio Beauce Inc. (CKRB) St. Georges.

• A nighttime power increase for CHGB La Pocatiere, Que., from 5 kw to 10 kw.

• A change of antenna location for CHRM Matane, Que.

PUBLIC NOTICES

Several applications are under consideration by the Commission for matters which are not expected to require a public hearing. These include:

• A reduction in power for CFCN-TV-8 Medicine Hat, Alta., a satellite of CFCN-TV Calgary, from 13.4 to 6.7 kw video.

• A request by Global Communications Ltd. to replace certain programming on its Windsor, Ont., transmitter with promotional announcements. It is a condition of the sale of most U.S. shows to Canadian networks that they not compete with telecasts of the same shows over Detroit stations.

• Establishment of studios for CKVO Clarenville, Nfld., by Colonial Broadcasting System.

DECISIONS

• CBC Television rebroadcasters have been approved for St. Lazare, Ste. Rose du Lac and Thompson, Manitoba, and Cumberland House and Island Falls, Sask.

• CBC FM rebroadcasters have been approved for five Manitoba communities, to carry the English AM network.

• In approving the renewal of cable television licences in the West Kootenay area of British Columbia, the Commission states that it will "expect each licensee to serve the community needs more adequately and to give encouragement to community organizations to participate in local programming".

• The Commission has denied renewal of the cable licence held by Jacqueline Boucher for St. Come, Que., and has granted a licence to Claude Brisebois. Addition of a local programming channel was also approved on the condition that no advertising be carried.

• The licence of Kelowna Cable T.V. Ltd. is renewed, subject to conditions regarding commercial deletion and the immediate start of community programming.

• A change of frequency from 1490 to 1470 kHz for the CBC rebroadcaster CBGI Magpie, Que., is approved.

• In approving applications by various cable TV systems in Quebec, the Commission has re-stated its requirement that Radio-Quebec, the provincial educational television network, be carried uniformly on cable channel 8 to facilitate easy identification by viewers. Radio-Quebec operates UHF stations in Montreal and Quebec City.

• As the result of an intervention by CHLT-TV, the Commission has made it a condition of the licence of Transvision Magog Inc. that program substitution be implemented when requested by CHLT-TV or CKSH-TV, both of Sherbrooke, Que.