BROADCAST EQUIPMENT

Part XII—Broadcast Antenna Towers

By DON C. HOEFLER

PROBABLY all of the antennas used in early broadcast practice consisted of some form of multi-wire arrangement, such as the T, inverted L; though sometimes a single vertical wire, all of these were operated above their natural fundamental frequency. These were suspended between two tall structures (usually self-supporting steel towers), spaced some distance apart. Later, as the advantages of vertical polarization were discovered, experiments were made with various types and sizes of vertical steel towers, which themselves acted as the radiators.

Most of the developments in tower design have occurred since 1927. For several years, the guyed cantilever ("cigar-shaped") structure was considered to be the very last word in broadcast antenna design, and a number of them are in use today. Then, development work reverted to the broad-based self-supporting type, and most recent practice favors the uniform-cross-section structure, which may be either guyed or self-supporting.

EFFICIENCY OF PROPAGATION

The directivity in the vertical plane of a vertical antenna is determined in part by its natural wave length. Current distribution in straight single-wire vertical radiators of various heights is shown in Fig. 1. In broadcast work it is desirable to have as much of the radiated power as possible be emitted as ground wave, with an absolute minimum of high-angle radiation. This will increase the primary service area, and reduce fading and interference at remote points. Practical experience has proved that best results are obtained when the radiator is either approximately one-quarter wave length or slightly over one-half wave length.

Ballantine demonstrated that the optimum condition of power efficiency, considering maximum ground-wave radiation and maximum sky-wave suppression, occurs when the effective antenna height is around 0.50 to 0.56 wave length. This corresponds to an actual physical height of 0.62 wave length. This indicates that the advantage of initial cost in a quarter-wave antenna is not as great as might first appear, for while the effective height of the half-wave structure is roughly 85½% of the physical height, the effective height of the quarter-wave vertical radiator is only 64% of the actual height.

Up to the condition of optimum efficiency, the effective signal strength available at a receiving antenna is determined by the meter-amperes at the transmitting antenna. This figure is the product of the effective antenna height in meters and the effective antenna current in amperes. This does not indicate any factor of the antenna power, but is an arbitrary figure which demonstrates that the effective signal increases with the antenna height. This fact holds true up to the optimum condition, but beyond that the second lobe of the standing wave would be in phase opposition with that of the first half-wave section, as shown in Fig. 1 (D).

Attempts to approach the optimum radiation condition while avoiding the expense of a fully optimum-height tower have led to some rather interesting developments in tower construction. Fig. 2 shows the current distribution for several common types of antenna towers operating under optimum conditions. When the tower is insulated from ground, the exciting voltage is simply applied between the base and ground. The grounded antenna employs a somewhat different method of excitation, to be discussed presently.

THE TOP-LOADED TOWER

The capacity-top arrangement permits the height required for optimum operation to be reduced somewhat, but when used alone this is hardly enough to be practicable. However, the sectionalized tower with series inductance permits a reduction in total height of 20% to 30%. There is an additional advantage in that it is possible to vary the effective height of the tower by adjusting the series inductance without involving expensive structural changes. The disadvantages are the additional expense of sectionalizing the tower and the losses of energy occurring in the inductance. Station WABC, New York, uses a combination of these two types of construction, known as "top-loading." A site in Long Island Sound known as Columbia Isle (formerly Pea Island) was selected because of the excellent coverage that a transmitter located there would provide. However, due to the proximity of New York Municipal airport, Flushing Airport, and Westchester County Airport, a tower of optimum height would create a hazard to the large volume of aircraft traffic. Top-loading proved to be the solution. Since the theoretical optimum of a broadcast tower is predicated upon a current distribution which places the current maximum at a point 0.375 wave length from the base of the tower, designers attacked the problem of a smaller tower for optimum operating conditions by attempting to establish electrical control over this anti-node by some means other than altering the tower size. It was found that since the L/C ratio along the length of the tower determined the location of the loop, this value could be varied by connecting a variable amount of lumped capacity or inductance near the top of the tower. Hence the term "top-loading." The WABC system represents the latest advance in broadcast antenna design in the use of a uniform cross-section tower. This enables the electrical characteristics of such a radiator to be calculated accurately, whereas any structure involving a taper introduces variables which can often be determined only by actual experimentation, a method which may prove very costly.

THE SHUNT-EXCITED TOWER

The shunt-excited antenna is a vertical tower with its base grounded, and which is excited at some point above ground. This system makes use of a loop formed by the ground and the exciting transmission line attached to the tower at a point above it. The coupling arrangement at the antenna end is simply a variable condenser in series with the exciting conductor. This wire runs from the coupling unit to the antenna, is usually inclined at an angle of about 45 degrees and is tapped on to the tower at a point corresponding to approximately 20% of the height. A connection at this point has a resistance of 100 ohms or less, which permits a concentric type transmission line to be matched to the tower. The loop thus formed is tuned to the carrier frequency by the series condenser, and carries a large circulating current. This develops sufficient voltage across the section of the tower included in the loop to excite the remainder of the tower. Since the tower itself is grounded, much less trouble with program interruptions due to lightning and other static discharges is encountered. As a result, the cost of lightning-protection devices is saved. Another saving is in the elimination of the large and expensive base insulators. All tower radiators have the advantages of simplicity, low cost, and high efficiency.

PROBLEMS OF GROUNDING

The ground system surrounding the tower base is a problem of exceedingly great importance, for upon it largely depends the overall efficiency of the radiation system. If the earth exhibited a characteristic even approaching perfect conductivity, any firm connection to it would provide a satisfactory termination. However, all soils, including even salt-water marshland, are poor conductors at radio frequencies. Therefore, the ground system associated with the tower must make the best possible contact with the existing terrain. Although it was at first believed that a ground system

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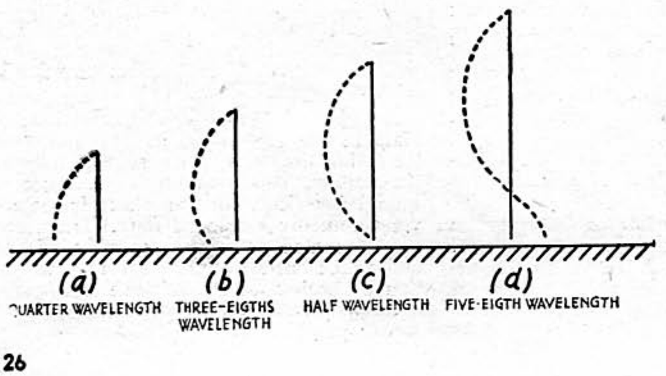

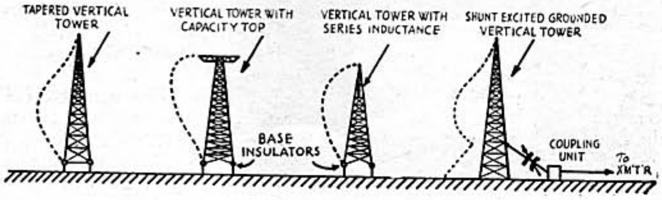

Fig. 1, left—Current distribution on various heights of straight-wire vertical broadcast antennas. Fig. 2, right—Current distribution on several types of broadcast towers under optimum conditions.

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extending to the practical limits of the induction field was sufficient, it has been found that, in order to serve effectively as a reflecting surface for the downward radiation, the ground system must extend outward considerably beyond this distance.

The ideal ground system would be a solid sheet of some material having a high conductivity and covering an extensive area in all directions surrounding the base of the tower. Although such a system would be prohibitively expensive, much theoretical and experimental work, due to Brown[1], has resulted in certain definite standards for the design of broadcast tower ground systems which approach the ideal. 120 buried radial conductors, spaced 3 degrees apart, and extending outward from the base of the tower in straight lines not less than one-half wave length at the operating frequency comprise such a "near-ideal" broadcast ground. This length is quite necessary, for when it is less the ground losses increase considerably even when the physical height of the antenna is small.

OTHER CONSIDERATIONS

In most instances it is necessary to provide the tower with a system of aircraft-warning lights. In order that the radiated energy will not be shunted to ground through the 60-cycle power line, it is necessary to supply the lights through a low-pass filter inserted in the line. This consists simply of an R.F. choke in series with each side of the line, and a condenser across the line at each end of the chokes.

Steel buildings, trolley wires, guy wires, and other conductors in the vicinity of the tower will alter its radiation pattern, so an antenna site must be chosen with care. Guy wires must be as few as possible, and they must be broken up by insulators into lengths that are a small part of a half wave length. Transmission lines must approach the radiator at right angles for minimum couplings.

In northern climates, where trouble is encountered due to sleet and ice, a de-icing system must be installed. This consists of a means of passing a heavy 60-cycle heating current through the tower itself to melt the formations. Since it is desirable that this function may be carried out while the station is "on the air," a low-pass filtering system, similar to that used with the warning lights but more elaborate, must be employed.

[1]Brown, G. H., "The Phase and Magnitude of Earth Currents Near Radio Transmitting Antennas," *Proc. I.R.E.*, February, 1935; "Ground Systems As a Factor in Antenna Efficiency," *Proc. I.R.E.*, June, 1937.

HOW RADAR OPERATES

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only slowly (e.g., from 1 to 20 r.p.m.) and since the light from an ordinary cathode-ray tube fades away almost instantly, one might expect not to see a "map" at all, but only bright flashes at various spots as the antenna revolves. Some way had to be found to make the brightness of these flashes persist for many seconds after they were produced. Special screens were developed which continue to glow for some time after being lighted by a signal. Thus the whole map is displayed at once.

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CORRECTION

The screen-grid in the drawing on page 597, *Radio-Craft*, June, 1945, is connected directly to ground. This would of course make the circuit inoperative. This drawing appeared in the article "Tuning on the U.H.F." The line which connects the filament with the screen-grid side of the screen resistor in the drawing should be taken out, leaving the screen-grid connected to high voltage through the resistor.

Our thanks are due to Mr. Davilo R. Reyes, of Gamboa, Canal Zone, who pointed out this error.