TELEVISION AND FM BROADCASTING ANTENNAS

BASICS FOR TV AND FM ANTENNAS

Antennas for television and FM broadcasting are usually installed on tall towers to maximize the service area. The maximum allowable tower height everywhere in the United States is 2000 ft above ground. The distance to the horizon from a height of 2000 ft over flat terrain is 63 mi. The average tower height in the United States is 1200 ft and the corresponding distance to the horizon is 49 mi.

A high-power transmitter feeds the broadcast antenna to provide "passable" picture and sound at distances approaching 70 m. In the UHF range (TV channels 14 to 69), the transmitter's peak power could be as high as 280 kW. In the VHF range (TV channels 2 to 13 and FM), a transmitter's peak power of 70 kW is not unusual. In this article, references made to channels and bands (VHF, FM, and UHF) are based on the US designation.

In addition to high power-handling capability, broadcast antennas must continue to perform under severe weather conditions, such as ice storms and hurricane winds. As a protection against adverse weather conditions, broadcast antennas are supplied with a protective radome or with electrical deicing heaters. Because downtime due to antenna failure would result in severe financial loss, TV and FM broadcast antennas must be designed with extremely high reliability.

The radiation pattern of broadcast antennas is shaped in the elevation and azimuthal planes to provide service for as many households as possible. When the tower is geographically located near the population center, an omnidirectional azimuthal pattern is common. When the tower is geographically separated from the area served, a directional azimuthal pattern is more desirable.

Antennas, especially for television broadcasting, must be designed to accept and radiate all of the power delivered by the transmitter. Even a small percentage of the delivered power reflected back toward the transmitter is a cause for concern. In analog television, if 0.1% of the delivered power is reflected back by the antenna and then radiated by a second reflection at the transmitter, an annoying picture "ghost" appears on an average size TV screen.

After years of experimentation, transition from analog to digital television broadcasting in the United States was scheduled to begin in late 1998. Antennas for digital television must be designed to meet more stringent specifications than those for antennas for analog television. In analog TV, poor specifications translate into degradation of picture quality. In digital television, picture quality remains unaffected by poorly designed antennas. Instead, poor antenna design for digital television broadcasting results in loss of coverage area.

Elevation and Azimuthal Radiation Patterns

Broadcast antennas are designed to focus power toward the radio horizon. The radiation is described by two patterns, one in the elevation plane and one in the azimuthal plane. The elevation pattern depicts the relative field strength radiated at various depression angles above and below the horizon. Figure 1 shows a typical elevation pattern before and after shaping. The purpose of radiation pattern shaping is to direct maximum power toward the radio horizon and to provide essentially equal field strength to all users from the base of the tower to the radio horizon.

Null Fill and Beam Tilt

Pointing maximum power toward the horizon is accomplished by tilting the elevation pattern, usually less than 2° below the horizontal plane. In Fig. 1 the tilt angle of the shaped pattern is 1°. Typically, the tilt angle corresponds to the depression angle Θ toward the horizon which can be calculated from the formula

$$\Theta = 0.0153\sqrt{H}\ \text{degrees}$$

where H is the height of the antenna above the average terrain in feet as defined by the FCC.

The shaping of the elevation pattern to provide essentially equal field strength to all viewers requires that all nulls in the elevation pattern are filled at depression angles below the horizon. The ideal shape of the elevation pattern before and after shaping, when applied to angles below the horizon, can be expressed as

$$\frac{\sin x}{x}$$

before shaping and

$$\frac{1}{\sin x}$$

after shaping

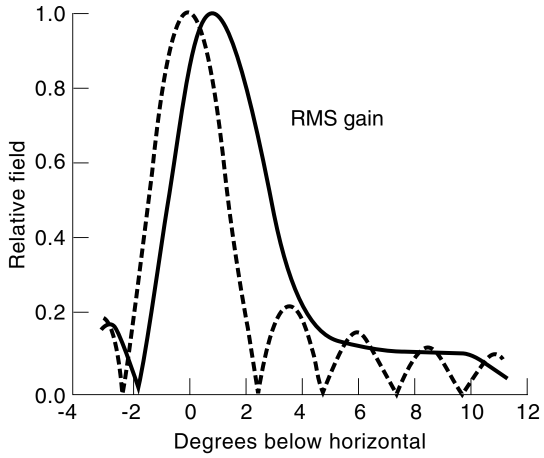

Figure 1. Elevation pattern.

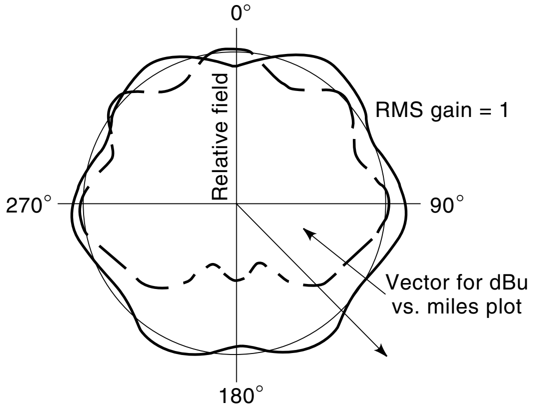

Figure 2. Azimuthal pattern.

The azimuthal pattern depicts the relative field strength radiated at various angles around the horizontal plane. Figure 2 shows a typical omnidirectional pattern and an example of a directional pattern.

A broadcast antenna is an array of individual radiators, such as dipoles, slots, or helices. The number of individual radiators varies between 2 and 24 in a VHF array and, between 8 and 180 in a UHF array. Pattern shaping, such as shown in Figs. 1 and 2, is accomplished by nonuniform distribution of the phase and current feeding individual radiators in the array.

Gain and ERP

The gain of an antenna is a figure of merit that describes the antenna's ability to focus the input power within a certain angular sector. For example, referring to Fig. 1, most of the power in the elevation plane is contained within ±2° around the peak of the elevation pattern.

The gain of broadcast antennas is specified relative to a half-wave dipole rather than relative to an isotropic radiator. Because the gain of a half-wave dipole relative to an isotropic radiator is 1.64, the peak gain of a broadcast antenna is given by

$$G_{\mathrm{P}} = g_{\mathrm{A}} g_{\mathrm{E}} = 4\pi\eta \frac{|E(\theta,\phi)|^2}{1.64 \int\int |E(\theta,\phi)|^2 \sin\theta \, d\theta \, d\phi}$$

where $E(\theta, \phi)$ is the electric field strength in the direction (θ, ϕ) at which the gain is desired and η is the power transfer efficiency of the array's distribution system. The peak gain is calculated in the direction of the peak of the elevation and azimuthal patterns.

It is customary to assume that the elevation pattern is not a function of azimuth. With that assumption, the double integral is separable into a product of two integrals, and the peak gain becomes the product of the azimuthal pattern gain g_A and the elevation pattern g_E.

The effective radiated power (ERP) is the product of the antenna's gain and the power delivered to the antenna. The maximum allowable ERP is set by each country's regulatory agency so as to maximize the service to consumers and to minimize the interference to and from all broadcast stations and other services. In the United States, the maximum allowable ERP for analog TV service is 100 kW for VHF channels 2 to 6, 316 kW for VHF channels 7 to 13, and 5,000 kW for UHF channels 14 to 69.

Table 1. Field Strengths for Analog TV Broadcasting

TV Channel	2–6	7–13	14–69
dBu[a]	47	56	64
mV/meter	0.22	0.63	1.6

[a] Assuming an outdoor antenna 30 feet above ground. dBμ = dB above 1 microvolt/meter. dBu = dBμV/m is an FCC term.

Coverage and Service

Passable picture and good sound quality require that a minimum level of field strength be available at the receiver. In the United States, the defining field strengths for analog TV broadcasting are shown in Table 1.

The coverage contour is described by the maximum radii beyond which, for a given transmitter power and antenna height above ground, the field strength falls at or below the minimum level. Coverage contours are thermal-noise-limited. Where unacceptable interference from another station penetrates the thermal-noise-limited coverage contour, the coverage contour is modified into a service contour.

As an example, consider the UHF antenna described by the elevation patterns of Fig. 1 and the azimuthal patterns of Fig. 2. The antenna gain and input power were set to radiate ERP equal to 1,000 kW. The field strength versus distance from the transmitter are shown in Fig. 3 in the direction of N135°E, as marked on Fig. 2. One of the two curves in Fig. 3 is for the omnidirectional antenna without elevation pattern shaping and the other is for the directional antenna with a shaped elevation pattern. As shown in Fig. 3, both antennas

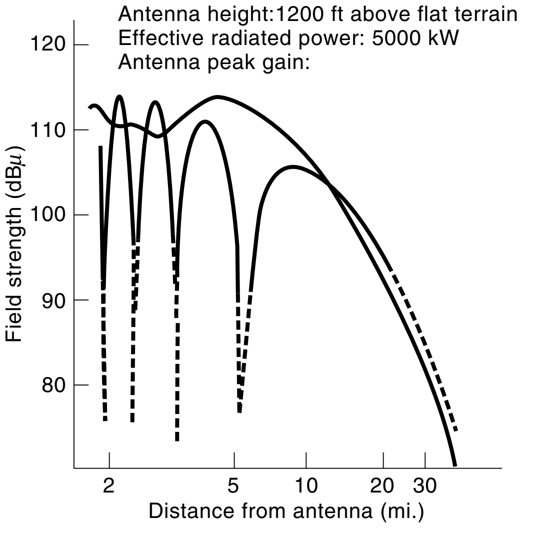

Figure 3. F(50,50) Field strength.

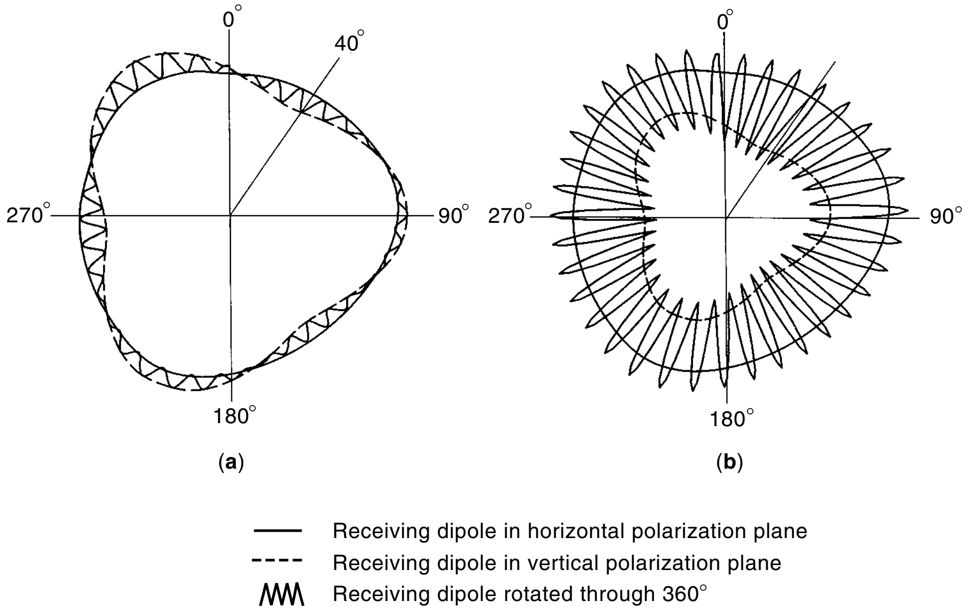

Figure 4. Voltage induced at the output terminals of a linear dipole receiving antenna: (a) Circularly polarized transmission; (b) Elliptically polarized transmission.

can provide a passable picture (64 dBu) for at least 53 m, but the antenna without beam shaping will not deliver a usable signal at 5.5, 2.7, and 1.8 m from the transmitting tower.

The curves of Fig. 3 were obtained with US-FCC's F(50,50) propagation curves which translate the known ERP and antenna height into dBu versus distance. The 50,50 designation refers to the field strength that will be exceeded "at least 50% of the time at the best 50% of the locations."

Polarization

For the vast majority of TV stations the electric field of the radiated power is polarized so that its vector lies in the horizontal plane, essentially parallel to the ground. Horizontal polarization was originally selected for broadcasting because its propagation is least affected by vertical obstructions, such as trees and utility poles and also because measurements, conducted during the early stages of television development, showed that the polarization of man-made noise is more pronounced in the vertical than in the horizontal plane.

Circular polarization for broadcasting was introduced in the United States during the 1960s, first to FM and later to TV. Circular polarization allows for substantially improved reception of FM and TV with small receiving antennas of arbitrary physical orientation, such as those in automobiles or on top of portable TV sets.

By definition, circular polarization requires that equal power be radiated in the horizontal and vertical planes and that the two electric fields be phase-shifted 90° relative to each other. In practical antennas, the conditions for circular polarization cannot be met in all directions. The improved reception of circular and elliptical polarization broadcasting is best explained with the aid of Fig. 4.

Figure 4(a) shows the relative voltage delivered by a small, rotating dipole in any direction from the transmitting antenna when facing an essentially circularly polarized incoming signal. In the azimuthal direction of 40°, rotation of the receiving antenna varies the voltage available to the set by 1.4 dB at most. In contrast, if the incoming signal were horizontally polarized and the receiving dipole were positioned perpendicularly to the ground, the available voltage would drop to zero.

Figure 4(b) shows the relative voltage delivered by the same dipole when facing an essentially elliptically polarized incoming signal. In the azimuthal direction of 40°, rotating the receiving antenna causes the voltage delivered to the set to vary by as much as 7.6 dB, not as stable as the voltage available from a circularly polarized signal.

The gain of broadcast antennas for circular or elliptical polarization is normally specified in either the horizontal polarization plane or the vertical polarization plane. Because the two planes are orthogonal, it can be shown that

$$\text{Gain of horizontal polarization} = \frac{G_h}{1 + (G_h/G_v)|P|^2}$$

and

$$\text{Gain of vertical polarization} = \frac{G_v}{1 + (G_v/G_h)|P|^2}$$

where G_h is the gain in the absence of vertical polarization, G_v is the gain in the absence of horizontal polarization, and $P = E_v/E_h$ is the ratio of the vertical component of the electric field to the horizontal component of the electric field in the direction in which the gain is calculated.

Coaxial and Waveguide Transmission Lines

The output power of the transmitter is delivered to the antenna via a coaxial or waveguide transmission line. A coaxial line is made of a circular pipe with a circular inner conductor. A waveguide is made of a hollow pipe of circular, elliptical, or rectangular cross section. For VHF channels 2 to 13, coaxial lines with outside diameters from 3 in. to 8 in. are used. For UHF channels 14 to 69, either coaxial lines or waveguides of various sizes are used, depending primarily on channel and power requirements. The widest cross section of waveguides for UHF broadcasting varies from 11.5 in., to 18 in. depending on the TV channel.

The main attribute of a waveguide transmission line is the high power-carrying capacity. Because of its large size with a typical vertical run of a 1000 ft up the tower, a waveguide is a major contributor to wind-load stresses on the tower. For a given cross section, a waveguide is limited to carrying only those UHF channels that propagate in its dominant mode. In contrast, for diameters not exceeding 7 in. a coaxial line accommodates any broadcast channel from 2 to 69.

In transferring the power from the transmitter to the antenna, some loss of power due to surface heating of the transmission line is inevitable. The power-transfer efficiency of a transmission line is defined by

$$\eta(\%) = 100\,\frac{\text{Input Power}}{\text{Output Power}} = \frac{100}{\text{Antilog}(\alpha l/100)}$$

where α is the attenuation in dB/100 ft and l is the transmission line's length in ft.

ANTENNAS FOR TELEVISION BROADCASTING

Single-Station VHF Antennas

Most VHF antennas designed to accommodate a single TV station fall into the three distinct categories shown in Fig. 5.

The most popular category worldwide is an antenna made of a central support pole with a multiplicity of dipoles wrapped around the pole. One version of such an antenna, designed for circular polarization transmission, is shown in Fig. 5(a). This antenna accommodates any TV or FM channel. A typical gain of such an antenna is 3.0 in either the horizontal polarization plane or the vertical polarization plane. The height and weight of the antenna vary from 68 ft and 5.7 tons for channel 6 (United States) to 97 ft and 9.9 tons for channel 2 (United States).

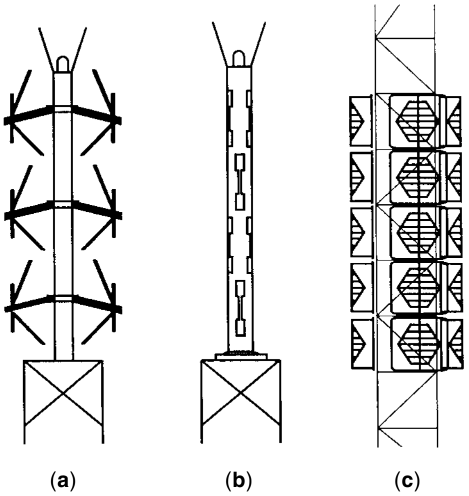

Figure 5. Single-station VHF antennas: (a) Channels 2–6; (b) Channels 7–13; (c) Panel antenna.

A second category, popular mostly in the United States, is the slotted-pipe traveling-wave antenna, the horizontal-polarization version of which is shown in Fig. 5(b). The RF power enters this antenna at its bottom and continues to travel toward the beacon at the top. While traveling upward, power leaks outward through the slots, decaying exponentially. The remainder of the power is forced out of the top slot.

The panel antenna shown in Fig. 5(c) is composed of an array of dipoles, each placed approximately one-quarter wavelength in front of a reflecting screen. Then the array is wrapped around a support spine which is often the tower itself. The panel antenna is popular mostly outside the United States because it is easily installed. In the United States VHF panel antennas are used primarily where a directional pattern is required, if the top of the tower is unavailable, or as a support structure for one or more antennas stacked over the panel antenna.

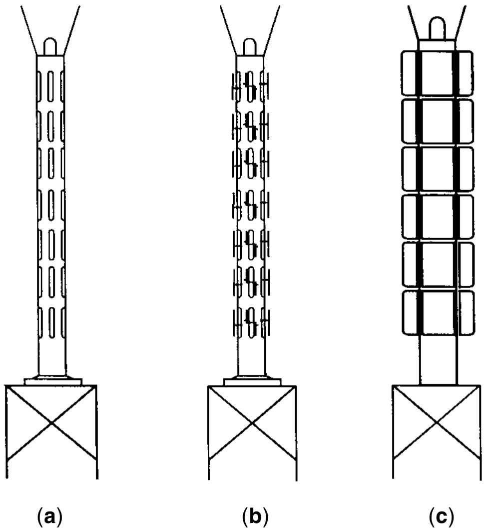

Figure 6. Single-station UHF antennas: (a) Horizontal polarization; (b) Circular polarization; (c) Panel antenna.

Single-Station UHF Antennas

The vast majority of UHF antennas for TV broadcasting in the United States are the slotted pipe variety shown in Fig. 6(a) (horizontal polarization) and Fig. 6(b) (circular polarization). In the circular polarization version of the slotted-pipe antenna, a parasitic Z-shaped dipole is placed approximately one-eighth of a wavelength in front of each slot. The Z-shaped dipole intercepts some of the horizontal polarization power emitted by the slot and radiates the intercepted power as vertical polarization, phase-shifted −90° relative to the horizontal polarization. The Z-shaped dipole can be adjusted for any power ratio of horizontal to vertical polarization. When the power ratio is one, the polarization is circular. For an unequal ratio, the result is elliptical polarization. Both elliptical and circular polarization provide superior analog TV reception on sets equipped with small indoor antennas, such as loops or monopoles.

In contrast, the vast majority of UHF antennas for TV broadcasting outside the United States are made of an array of panels as shown in Fig. 6(c) (horizontal polarization). The panel antenna is relatively inexpensive and its azimuthal pattern is easily shaped for directional antenna application. The panel antenna exhibits some drawbacks. The most noticeable drawbacks are large aerodynamic area and multiplicity of pressurized components which adversely affect the long-term reliability and maintainability of the panel antenna.

Broadband VHF and UHF Panel Antennas

One of the most vexing problems for TV and FM broadcasters is the scarcity of tower space, especially at locations that permit maximum service. This problem is especially acute due to safety, legal, and environmental regulations in major metropolitan areas. Because of the scarcity of tower space and to save construction costs, broadcasters have been using antennas designed to accommodate multiple channels on single antennas. These so-called "broadband" panel antennas are used for VHF and UHF channels. A stack of two such antennas is shown in Fig. 7. The top antenna accommodates a multiplicity of UHF channels in the range from 450 MHz to 800 MHz, subject to average and peak power limitations. The bottom antenna accommodates a multiplicity of VHF channels in any one of three bands. These bands (United States) are 54 MHz to 66 MHz (Low-V), 66 MHz to 88 MHz (Mid-V) and 174 MHz to 216 MHz (Hi-V).

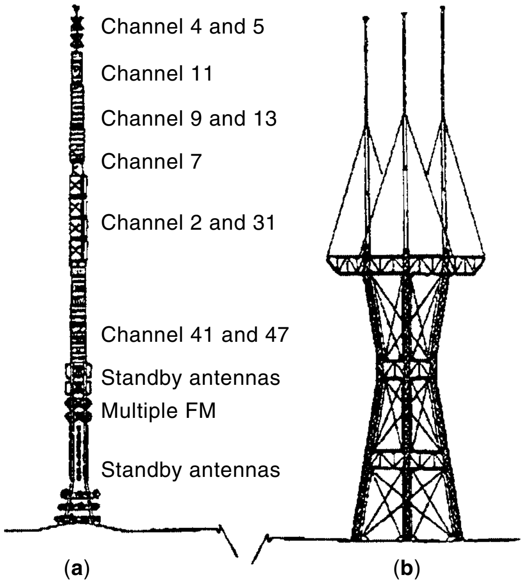

Figure 8. Multistation master antennas in New York: (a) Present stack on World Trade Center 1; (b) Future candelabra on World Trade Center 2.

Multistation Master Tower

Another solution to the problem of tower scarcity is deploying a master TV/FM tower that supports all the antennas necessary to serve the market, and placing it near the center of population. Master towers are either in the form of candelabras, where several antennas are installed side-by-side on a platform at the top of the tower, or a stack of several antennas installed one on top of another beginning at the top of the tower.

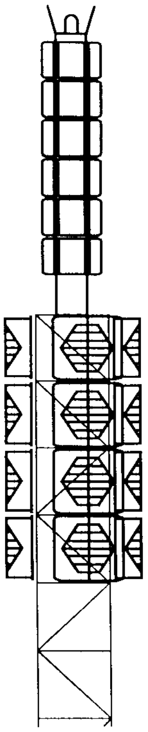

Figure 7. Broadband panel antennas.

Two examples of a master tower, a candelabra and a stack, are shown in Fig. 8. The stack shows all of the analog TV antennas on top of the north tower of the World Trade Center in New York City. This stack has been in operation since the 1970s. The height of the stack is 350 ft above the roof. The second master tower is a proposed design of a candelabra to be constructed early in the twenty-first century to support future digital TV service on channels 2 to 51 in New York City. The triangular top platform of the candelabra has a corner-to-corner width of 45 ft. A stack of three, slotted-pipe UHF antennas occupies each corner of the platform. One of the nine antennas designed to serve two multiplexed channels has a total tower capacity of 10 digital TV stations.

Radiation Pattern Distortion

When an antenna is positioned close to other antennas or side-mounted on the support tower, undesired scattering of the intercepted primary radiation by nearby obstructions results. This undesired scattering combines vectorially with the primary radiation to produce a new pattern that could significantly differ from the desired primary radiation pattern.

For example, when a perfectly omnidirectional antenna is mounted on top of the support tower without any nearby obstructions, its primary azimuthal pattern remains undistorted, as shown in Fig. 9. When side-mounted eight ft from the center of a triangular tower with a 10-foot side, the same antenna shows a marked distortion in its pattern. Further, the distorted pattern shows significant variation in some directions when swept over the 6 MHz of the TV channel. Such a distorted pattern causes a significant reduction in the picture quality of analog TV in many directions. In the case of

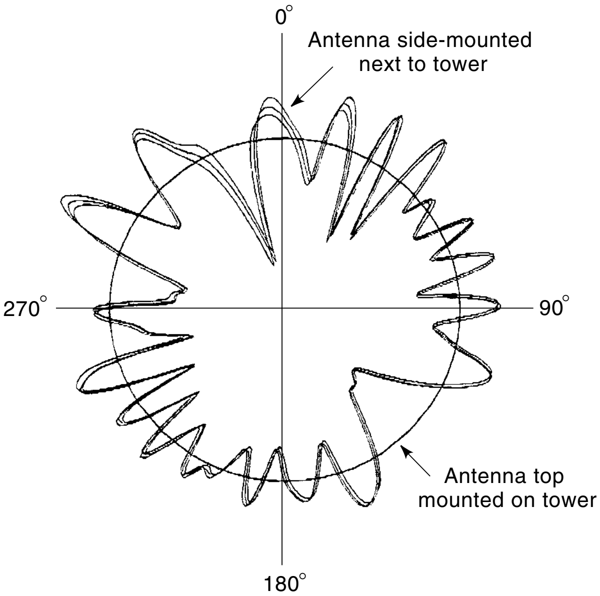

Figure 9. Tower distortion over 6 MHz for omnidirectional antenna.

digital TV, total loss of picture and sound can be expected in the directions where the signal power is low or where power variation over the channel width of 6 MHz is significant. Depending on the country, the channel width could be 6, 7, or 8 MHz. In North America it is 6 MHz.

In contrast, a directional antenna properly mounted close to a support tower, exhibits relatively small distortion of its primary pattern, as shown in Fig. 10. By judiciously mounting the antenna so that the minimum of its primary pattern points in the direction of the largest obstruction, the level of significant pattern distortion due to scattering is limited to an angular sector of 90° to 120° behind the support tower.

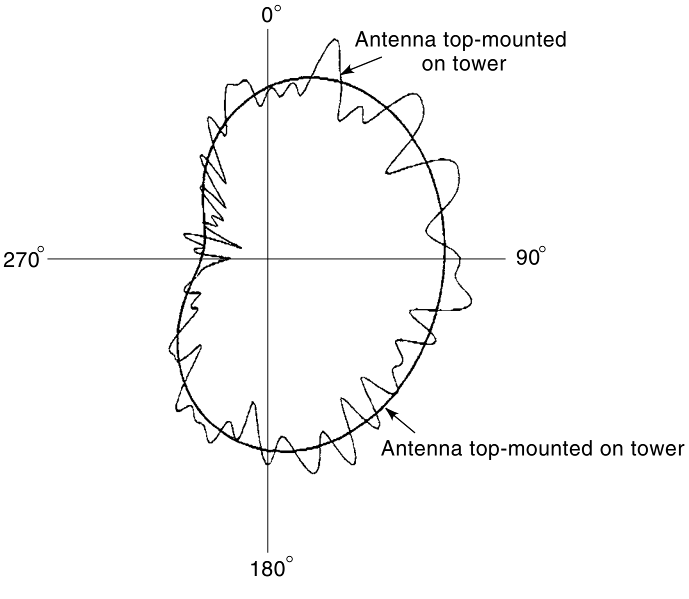

Figure 10. Tower distortion of directional antenna pattern.

ANTENNAS FOR FM BROADCASTING

Single-Station Antennas

FM antennas for single-channel broadcasting are designed to be inexpensive relative to TV antennas. They are also designed to add a minimum of aerodynamic stress on the support tower. These two objectives are relatively easy to meet because of the narrow bandwidth of the FM channel. The FM channel width in North America is 200 kHz, in Europe 100 kHz, and in Africa 86 kHz.

FM broadcasting was originally planned for reception by an outdoor antenna, and the polarization of the electric vector was linear, polarized either in the horizontal or vertical plane. Since the introduction of low-cost, portable, solid-state radios for automobiles and homes, polarization of the FM signal has gradually shifted worldwide to circular polarization.

The most popular implementation of the single-channel, low-cost, circular polarization FM antenna is shown in Fig. 11. The antenna is an array of one to twelve radiators or "bays." Each radiator consists of two to four interwoven, bent, half-wave dipoles. The dipoles are typically bent around a circular form approximately 20 in. in diameter. In another implementation of this design, the interwoven dipoles are bent in a V-shape. The radiators are mounted along a pipe, the diameter of which depends on the number of radiators and on whether the antenna is to be top-mounted or side-mounted on the tower.

There are several disadvantages associated with the single-channel antenna shown in Fig. 11. The antenna is de-

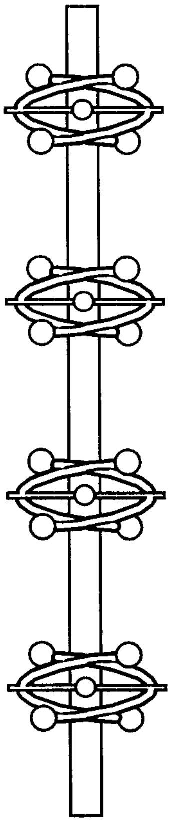

Figure 11. Single-station FM antenna.

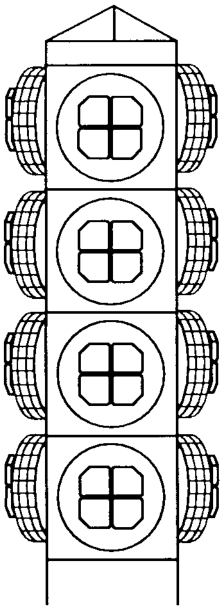

Figure 12. Multistation master FM antenna.

signed to be omnidirectional and to radiate circular polarization in the absence of the pipe supporting the "bays." When mounted on the pipe as shown, the antenna radiates elliptical polarization, and the vertical component of the electric field is substantially attenuated in the shadow of the support pipe. If the antenna with the support pipe is then side-mounted on the transmission tower, as is often the case, the radiation patterns in the elevation and azimuthal planes are further severely distorted. Another difficulty due to the physically small radiator of this antenna is a somewhat excessive downward radiation which may raise the level of the RF power density near the ground above the allowable protective limit. The downward radiation level can be reduced by spacing the array elements at half-wavelength intervals.

Multistation Master Antennas

The master FM antenna, capable of supporting multiple FM stations on a single antenna, is gradually replacing single-station antennas in major cities worldwide. Such a master antenna, made of multiple broad-band panels, is shown in Fig. 12. The master FM antenna does not exhibit any of the disadvantages of the single-station antenna and is ideal where tower space is scarce. Master FM antenna construction is similar to that of VHF-TV panel antennas with a high price to match. The installation cost is sometimes shared by the individual FM channels which are multiplexed on the master antenna, making the antenna affordable.

ADVANCED TOPICS: ANALOG VERSUS DIGITAL TV

Spectral Distribution

Fundamental differences exist in the performance specifications of antennas for analog and digital TV broadcasting. Reception of analog TV is subject to fading, man-made noise and to picture degradation in poor reception areas. In contrast, the reception of digital TV yields a perfect picture and sound all of the time or not at all. The same sources that cause poor reception of analog TV combine to reduce the coverage area of digital TV. Some of the coverage area of analog TV is traded off for the higher picture and sound quality of digital TV much as the long range and poor sound quality of AM radio are traded off for the shorter range and higher quality sound of FM radio.

An understanding of the specifications required for digital TV can be gained by comparing the spectra of analog TV and digital TV at the transmitter and at the receiver. Figure 13(a) shows the flat (except for the pilot) power distribution of the digital signal over 6 MHz, superimposed over the analog signal at the transmitter output. As shown in Figure 13(b), poor antenna response and undesired reflections at the receiver, have significantly distorted the digital spectrum. Having most of the power centered near the picture and sound carrier hardly affects the analog spectrum.

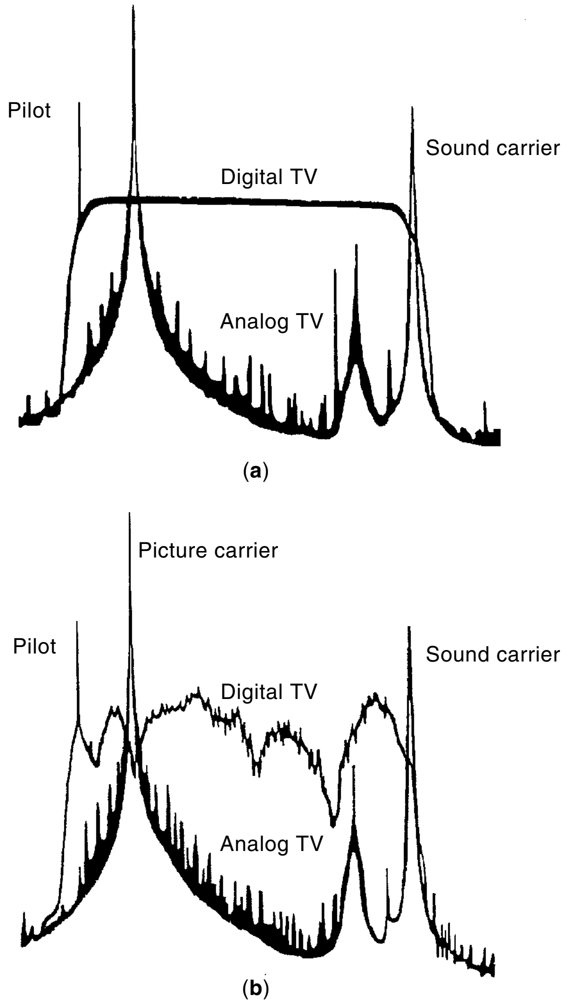

Figure 13. Analog and digital spectra: (a) At the transmitter; (b) At the receiver.

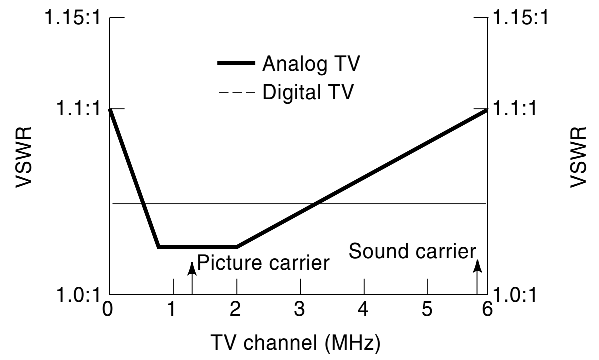

Figure 14. Antenna VSWR for a 6 MHz channel.

From these spectra it is clear that the antenna specifications in analog TV are critical only around the three carriers. In contrast, antenna specifications for digital TV are equally critical throughout the TV channel.

Voltage Standing-Wave Ratio

The magnitude of the voltage standing-wave ratio (VSWR) inside the transmission line, which connects the antenna to the transmitter, is an example of an antenna specification that depends on the spectral distribution. In analog TV the VSWR must be minimized around the picture carrier to a value of 1.025, as shown in Fig. 14, to avoid an echo which appears as a "ghost" image. In other portions of the channel the VSWR can be higher, up to 1.10 at band edges. In contrast, the VSWR must be minimized and equalized across the digital channel to a value not exceeding 1.05.

Effective Radiated Power

The effective radiated power (ERP) is a product of the antenna gain and the total input power to the antenna at the picture carrier frequency. For analog transmission, the total input power may include undesirable power components, such as intermodulation products and internal reflections. The undesirable components affect the picture quality of analog TV but not its range. The same undesirable power components affect the range of digital TV but not its picture quality. Therefore, the calculation of the ERP of digital TV must be based on the net useful power, rather than on the total available power.

Gain

In analog TV, antenna gain is specified at the picture carrier frequency around which most of the power is concentrated. In digital TV, where the power out of the antenna may be unevenly spread across the channel due to distortion, the electric field in the gain equation must be replaced by its value averaged over the operating channel bandwidth.

Pattern and Polarization Bandwidth

The same reasoning that was applied to the VSWR, ERP, and gain specifications, requires that the antenna's transfer characteristics be specified across the digital TV channel rather than at a single frequency, as with analog TV. In particular, knowledge of the radiation pattern's behavior, including the polarization behavior across the TV channel, is fundamental to proper specification of broadcast antennas for digital TV.

Peak and Average Power

In analog TV, the peak-of-sync power is the significant parameter. It is used for ERP, coverage, and interference calculations. The peak-of-sync is defined by the RMS amplitude of the carrier during the horizontal and vertical sync periods.

The average power of analog TV is not constant, unlike the peak-of-sync power during synchronization pulses. It depends on the picture being transmitted. Measurements over long periods indicate that the average picture power is 4.32 dB below peak-of-sync. With total blanking, the average picture (black) power is constant and is 2.2 dB below peak-of-sync. For analog TV, the peak-of-sync, the peak instantaneous, and the average power are given by the following:

$$P_{\mathrm{SYNC}} = \frac{V_{\mathrm{RMS}}^2}{Z_0} = \frac{V_{\mathrm{PEAK}}^2}{2Z_0}$$

$$P_{\mathrm{PEAK}} = \frac{V_{\mathrm{PEAK}}^2}{Z_0} = 2\left(\sqrt{P_{\mathrm{AURAL}}} + \sqrt{P_{\mathrm{SYNC}}}\right)^2$$

and

$$P_{\mathrm{AVG}} = P_{\mathrm{SYNC}}\mathrm{APL} + P_{\mathrm{AURAL}}$$

where Z_0 is the characteristic impedance of the transmission line and APL is the average picture level which is 0.6 during blanking and 0.37 during program transmission.

During program transmission (APL = 0.37) and with $P_{\mathrm{AURAL}}/P_{\mathrm{SYNC}} = 0.1$ (typical for UHF channels),

$$\frac{P_{\mathrm{PEAK}}}{P_{\mathrm{AVG}}} = 8.68\,dB$$

In digital TV, the average power is the significant parameter. It is independent of the content of the image being transmitted, and unlike analog TV, it has a constant value. The average power of digital TV is used for ERP, coverage, and interference calculations.

The average and peak instantaneous powers of digital TV are related by

$$P_{\mathrm{PEAK}} = \frac{V_{\mathrm{PEAK}}^2}{Z_0} = R_{\mathrm{PA}}P_{\mathrm{AVG}}$$

where R_{PA} is the ratio of peak instantaneous power to average power at the transmitter output.

Depending on the modulation scheme and channel filters, the peak instantaneous power of the digital TV signal can reach 7 dB to 13 dB above the average power, and 7 dB peaks occur as often as 0.01% of the time.

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