SIDEMOUNT FM ANTENNA PATTERNS

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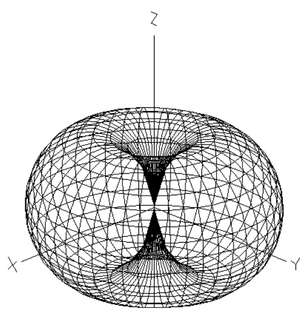
Omnidirectional FM broadcast antennas often are assumed to have a free-space radiation pattern that is perfectly circular in the azimuth[1] (horizontal) plane. For many modern antenna designs, the shape of the free-space radiation pattern in the elevation (vertical) plane from *each element* (bay) of the antenna is assumed to be nearly a cosine function.

But are these assumptions justified? The following computer study provides some insight.

Figure 1 is a far-field[2] surface plot of the total radiation from an element with the pattern assumptions described above. The X and Y axes are two, right angle directions in the azimuth plane. The Z axis is at 90 degrees to X and Y in the elevation plane. The antenna element is located at the intersection of the three axes, but is omitted here for clarity.

Figure 1



While the driven radiators of a well-designed antenna element alone could produce these nearly perfect patterns, additional components are needed to supply RF power to the radiators, and to support them physically on a tower. These components necessarily must be electrically connected to, and physically close to the driven radiators of each element. Significant RF currents will flow on these additional components and on the tower as well, whose added radiation changes the shape of the original patterns from the driven radiators.

The overall result is that the real-world radiation patterns from a sidemounted FM antenna can differ substantially from the theoretical patterns assumed for them.

As an illustration of real-world antenna patterns, Figure 2 is a calculated surface plot of the total H+V radiation of a 2-bay, full-wave spaced antenna complete with its feed system and mounts, installed on a 20' length of 24" face, triangular cross-section tower. Figure 3 is a rendering of the computer model used in the calculations. A form of the "rototiller" element was used because it is easy to model, and is widely used. Similar patterns likely are produced by other element designs, as well.

Figure 2

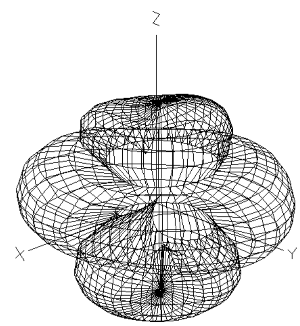
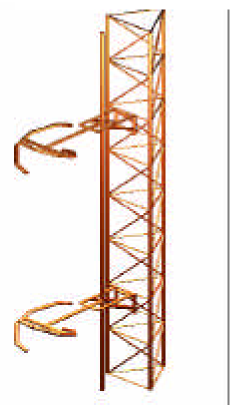


Figure 3



The surface pattern in Figure 2 clearly shows the nulls in the elevation plane near +/-30 degrees in this model, where the fields from the two bays are about equal in magnitude and opposite in phase, nearly canceling each other.

The position and depth of the nulls near +/-90 degrees elevation have been altered, compared to the theoretical patterns expected for this array. Although not as visible in Figure 2, azimuth plane patterns have been affected as well. These effects are the result of the additional radiation from the antenna feed system, antenna mounts, and the tower.

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[1] The terms azimuth and elevation are used to describe directional bearings to avoid confusion with the horizontal and vertical planes of polarization.

[2] Far-field conditions exist at distances from the antenna > [2 * (Antenna Length)^2] / Wavelength.

Figures 4 and 5 are plots of the azimuth and elevation patterns, respectively, for the surface plot shown in Figure 2. Here, the horizontally-polarized (h-pol) and vertically-polarized (v-pol) fields are shown separately, along with the corresponding reference fields that would be produced by the elements with no feed system, antenna mounts, or tower present.

Figure 5 show more serious effects from the tower, with v-pol more affected than h-pol.

Recall that, for most installations, virtually all FM listeners are served by the portion of the elevation pattern from the horizontal plane to a depression angle of less than 10 degrees.

Figure 4

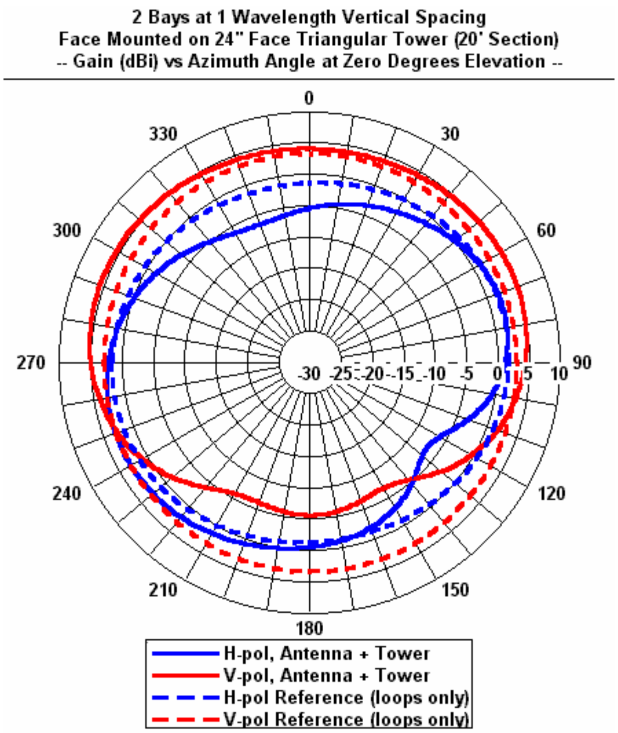
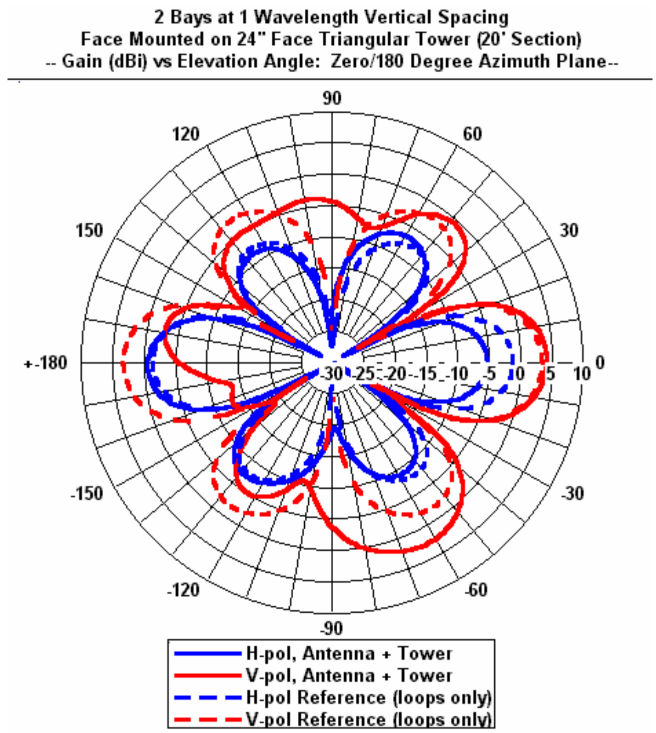


Figure 5



Gains in Figures 4 and 5 are shown along the scale +10 to -30 in decibels with respect to an isotropic radiator. Subtract 2.15dB from the values plotted to convert them to gain with respect to a 1/2-wave dipole (dBd).

Figure 4 is a view from the top of the antenna looking at the radiation directed in the horizontal plane, i.e., toward zero degrees elevation. Figure 5 is a side view of a slice of the elevation pattern along the zero/180 degree azimuth axis. The data values plotted for 0 and +/-180 degrees on the elevation plot will be the same as those for 0 and 180 degrees on the azimuth plot. For all other angles, the values can be (and usually are) different.

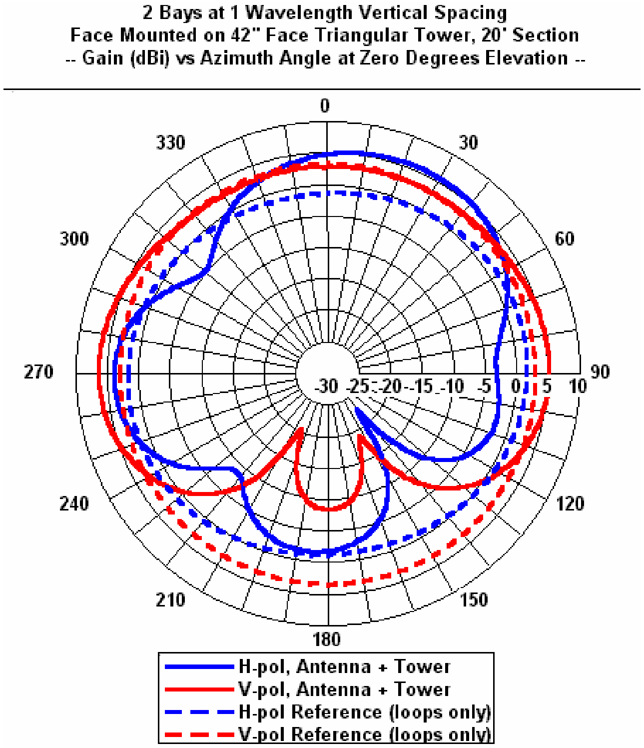
The azimuth patterns in Fig. 4 still have fairly good circularity. The elevation patterns in

In Figure 5, those sectors are shown from 0 to -10 degrees, and +/-180 to -170 degrees. All radiation at higher and lower elevation angles is essentially wasted.

The elevation patterns shown in this paper are for the zero/180 degree azimuth angle. A large number of them covering many other azimuth angles would be needed to adequately describe the full envelope of the radiation patterns.

Now that we have seen patterns for an FM antenna on a relatively small-faced tower, and have reviewed the process needed to interpret them, let's look at the same 2-bay array mounted on a 42" face tower. Figure 6 shows the azimuth patterns, and Figure 7 shows the elevation patterns.

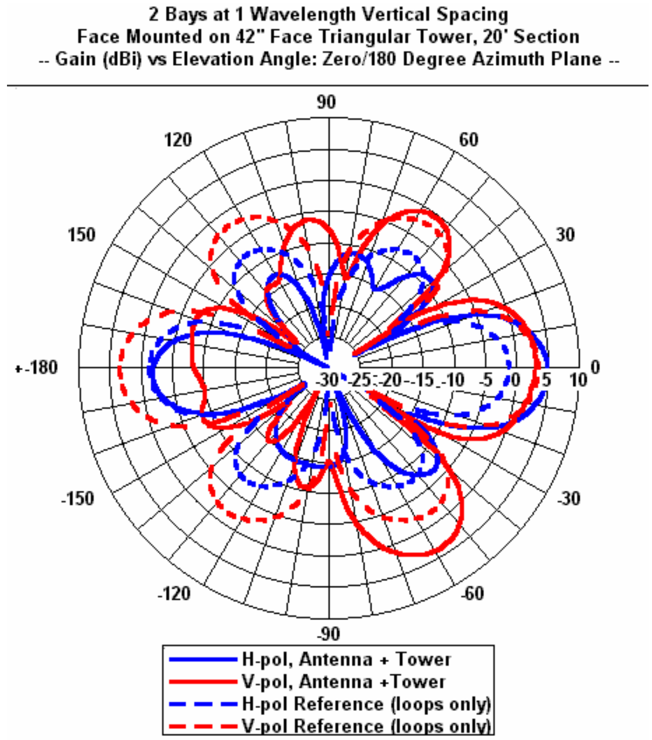
Figure 6



The azimuth patterns shown for a 42" face tower in Figure 6 have very significant variations. In fact for this model, h-pol ERP in the null at ~142 degrees azimuth would be less than 1% of its value at azimuths of ~25 degrees. The v-pol ERP shown in Figure 6 also has significant nulls. Obviously these patterns could produce listener and advertiser complaints, and would not provide the coverage that the FCC assumed and allocated for an omnidirectional FM station.

The elevation patterns in Figure 7 also show more significant variations than seen for the same array on a 24" face tower. But as stated earlier in this paper, the only really important sector of the elevation pattern as far as most FM receivers are concerned lies from the horizontal plane to ~10 degrees below it. The elevation patterns of Figure 7 are quite substantial in this sector, and assuming they stay that way at all other azimuth angles, the large variations present at higher and lower elevation angles are relatively unimportant -- *except* as to how they may affect real power density levels near the tower base, versus using perfect elevation patterns as a basis for "radhaz" evaluations.

Figure 7



Conclusion and Caveats This paper has shown through a computer study the affect on radiation patterns of side-mounting a small FM broadcast antenna on two, simple tower structures. The study confirms previous, typical pattern testing and coverage experience for the configurations analyzed.

The patterns in this study are representative of the conditions stated, and will vary *widely* with tower face width, frequency, mounting configuration (distance and angle off the face or leg), the exact mechanical construction of the tower and its appurtenances (presence and location of ladder, conduits, other antennas, etc), and other factors. Locations and gains of pattern nulls and lobes change rapidly with different conditions. Each case is unique.

This study has illustrated the point that for best overall performance, the real-world patterns of side-mounted FM antennas should be analyzed and chosen carefully, especially when larger cross-section towers are used. Many antenna manufacturers and consultants can assist in this process, and the benefits can be well worth their effort and cost.

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