§ 73.150 Directional antenna systems.

(a) For each station employing a directional antenna, all determinations of service provided and interference caused shall be based on the inverse distance fields of the standard radiation pattern for that station. (As applied to nighttime operation the term “standard radiation pattern” shall include the radiation pattern in the horizontal plane, and radiation patterns at angles above this plane.)

(1) Parties submitting directional antenna patterns pursuant to this section and § 73.152 (Modified standard pattern) must submit patterns which are tabulated and plotted in units of millivolts per meter at 1 kilometer.

(b) The following data shall be submitted with an application for authority to install a directional antenna:

(1) The standard radiation pattern for the proposed antenna in the horizontal plane, and where pertinent, tabulated values for the azimuthal radiation patterns for angles of elevation up to and including 60 degrees, with a separate section for each increment of 5 degrees.

The standard radiation pattern shall be based on the theoretical radiation pattern. The theoretical radiation pattern shall be calculated in accordance with the following mathematical expression:

\[ E(\phi, \theta)_{th} = \sum_{i=1}^{n} F_i f_i(\theta)S_i \cos \theta \cos (\phi_i - \phi) + \psi_i \]

(Eq. 1)

where:

- \( E(\phi, \theta)_{th} \) Represents the theoretical inverse distance fields at one kilometer for the given azimuth and elevation.
- \( k \) Represents the multiplying constant which determines the basic pattern size. It shall be chosen so that the effective field (RMS) of the theoretical pattern in the horizontal plane shall be no greater than the value computed on the assumption that nominal station power (see § 73.14) is delivered to the directional array, and that a lumped loss resistance of one ohm exists at the current loop of each element of the array, or at the base of each element of electrical height lower than 0.25 wavelength, and no less than the value required by § 73.189(b)(2) of this part for a station of the class and nominal power for which the pattern is designed.
- \( n \) Represents the number of elements (towers) in the directional array.
- \( i \) Represents the \( i \)th element in the array.
- \( F_i \) Represents the field ratio of the \( i \)th element in the array.
- \( \theta \) Represents the vertical elevation angle measured from the horizontal plane.
- \( f_i(\theta) \) represents the vertical plane radiation characteristic of the \( i \)th antenna. This value depends on the tower height, as well as whether the tower is top-loaded or sectionalized. The various formulas for computing \( f_i(\theta) \) are given in § 73.160.
- \( S_i \) Represents the electrical spacing of the \( i \)th tower from the reference point.
- \( \phi_i \) Represents the orientation (with respect to true north) of the \( i \)th tower.
- \( \psi_i \) Represents the azimuth (with respect to true north).
- \( Q \) Represents the electrical phase angle of the current in the \( i \)th tower.

The standard radiation pattern shall be constructed in accordance with the following mathematical expression:

\[ E(\phi, \theta)_{std} = 1.05 \sqrt{\left[ E(\phi, \theta)_{th} \right]^2 + Q^2} \]

(Eq. 2)

where:

- \( E(\phi, \theta)_{std} \) represents the inverse distance fields at one kilometer which are produced by the directional antenna in the horizontal and vertical planes. \( E(\phi, \theta)_{th} \) represents the theoretical inverse distance fields at one kilometer as computed in accordance with Eq. 1, above.
- \( Q \) is the greater of the following two quantities: 0.025g(\( \theta \)) \( E_{\infty} \) or 10.0g(\( \theta \)) \( P_{sw} \)

where:
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The effective (RMS) field strength in the horizontal plane of \( E(\phi, \theta)_{\text{std}} \), \( E(\phi, \theta)_{\text{hs}} \) and the root-sum-square (RSS) value of the inverse distance fields of the array elements at 1 kilometer, derived from the equation for \( E(\phi, \theta)_{\text{hs}} \). These values shall be tabulated on the page on which the horizontal plane pattern is plotted, which shall be specifically labelled as the Standard Horizontal Plane Pattern.

(4) Physical description of the array, showing:

(i) Number of elements.
(ii) Type of each element (i.e., guyed or self-supporting, uniform cross section or tapered (specifying base dimensions), grounded or insulated, etc.)
(iii) Details of top loading, or sectionalizing, if any.
(iv) Height of radiating portion of each element in feet (height above base insulator, or base, if grounded).
(v) Overall height of each element above ground.
(vi) Sketch of antenna site, indicating its dimensions, the location of the antenna elements, thereon, their spacing from each other, and their orientation with respect to each other and to true north, the number and length of the radials in the ground system about each element, the dimensions of ground screens, if any, and bonding between towers and between radial systems.

(5) Electrical description of the array, showing:

(i) Relative amplitudes of the fields of the array elements.
(ii) Relative time phasing of the fields of the array elements in degrees leading [+] or lagging [-].
(iii) Space phasing between elements in degrees.
(iv) Where waiver of the content of this section is requested or upon request of the Commission staff, all assumptions made and the basis therefor, particularly with respect to the electrical height of the elements, current distribution along elements, efficiency

\[
g(\theta) = \sqrt{\frac{(f(\theta))^2 + 0.0625}{1.030776}}
\]

\( E_{\text{rms}} \) is the root sum square of the amplitudes of the inverse fields of the elements of the array in the horizontal plane, as used in the expression for \( E(\phi, \theta)_{\text{hs}} \) (see Eq. 1, above), and is computed as follows:

\[
E_{\text{rms}} = k \sum_{i=1}^{n} E_i^2
\]

\( P_{\text{sw}} \) is the nominal station power expressed in kilowatts, see §73.14. If the nominal power is less than one kilowatt, \( P_{\text{sw}}=1 \).

(ii) Where the orthogonal addition of the factor \( Q \) to \( E(\phi, \theta)_{\text{hs}} \) results in a standard pattern whose minimum fields are lower than those found necessary or desirable, these fields may be increased by appropriate adjustment of the parameters of \( E(\phi, \theta)_{\text{hs}} \).

(2) All patterns shall be computed for integral multiples of five degrees, beginning with zero degrees representing true north, and, shall be plotted to the largest scale possible on unglazed letter-size paper (main engraving approximately 7½×10½) using only scale divisions and subdivisions of 1, 2, 2.5, or 5 times 10⁻². The horizontal plane pattern shall be plotted on polar-coordinate paper, with the zero degree point corresponding to true north. Patterns for elevation angles above the horizontal plane may be plotted in polar or rectangular coordinates, with the pattern for each angle of elevation on a separate page. Rectangular plots shall begin and end at true north, with all azimuths labelled in increments of not less than 20 degrees. If a rectangular plot is used, the ordinate showing the scale for radiation may be logarithmic.

Such patterns for elevation angles above the horizontal plane need be submitted only upon specific request by Commission staff. Minor lobe and null detail occurring between successive patterns for specific angles of elevation need not be submitted. Values of field strength on any pattern less than ten percent of the maximum field strength plotted on that pattern shall be shown on an enlarged scale. Rectangular plots with a logarithmic ordinate need not utilize an expanded scale unless necessary to show clearly the minor lobe and null detail.

(3) The effective (RMS) field strength in the horizontal plane of \( E(\phi, \theta)_{\text{std}} \), \( E(\phi, \theta)_{\text{hs}} \) and the root-sum-square (RSS) value of the inverse distance fields of the array elements at 1 kilometer, derived from the equation for \( E(\phi, \theta)_{\text{hs}} \). These values shall be tabulated on the page on which the horizontal plane pattern is plotted, which shall be specifically labelled as the Standard Horizontal Plane Pattern.
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Field strength measurements to establish performance of directional antennas.

The performance of a directional antenna may be verified either by field strength measurement or by computer modeling and sampling system verification.

(a) In addition to the information required by the license application form, the following showing must be submitted to establish, for each mode of directional operation, that the effective measured field strength (RMS) at 1