ET Docket No. 03-137 - Comments on the Proposed Changes in the Commission's Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields

Comments on Near-Field / Far-Field Boundary Calculations

Summary: *A change in the guidelines for determining the near-field/far-field boundary is proposed based on a concept of "equivalent aperture". A derivation from generally accepted antenna equations is provided as proof that this change is technically reasonable.*

We respectfully submit the following comments for the Commission's review:

Often, especially in multi-emitter, multi-frequency RF exposure environments, modeling is the only means of effectively assessing worst-case RF exposure. (reference our separate comment submission on measurement issues using shaped probes).

The FCC provides many equations for modeling RF exposure, and some guidelines for applying them. We believe that with some additional guidance, the FCC could greatly assist the industry in creating models that could be used in assessing appropriate "near-field" scenarios, as well as "far-field" scenarios for all types of antennas. This would also assist localities, and the general public in the understanding and maintenance of RF safety through the implementation of ordinances, permitting rules, and other means that generally meet the intent of the Commission's rules and guidelines.

<u>Near-field boundary definitions.</u>

In OET-65, the FCC makes a specific near-field/far-field boundary recommendation only in the case of aperture antennas. OET-65 defines the closest extent of the far-field as:

$$R_{nf} := \frac{D^2}{4 \cdot \lambda}$$

There are also other widely-accepted variants of this equation, most commonly found is:

$$R_{nf} := \frac{2\,D^2}{\lambda}$$

There is much confusion regarding the applicability of these equations, especially with regard to applying them to widely deployed panel antennas. For instance, D is often assumed to be the largest dimension of an antenna (regardless of type), so a 5-foot panel antenna operating at a nominal frequency of 2,000 MHz would yield a boundary distance

of over *100 feet*, clearly an absurdly large distance from a technical and theoretical perspective.

We believe that the above equations were intended to be applied for aperture antennas and that their application for all types of antennas is an erroneous extrapolation of the theoretical concept.

To clarify the situation, and build upon the body of experience and theory created of the past decades, we feel, that the guideline for near-field/far-field boundary should be one based on "equivalent gain" of a circular aperture. We request that the Commission consider this as the overall definition for defining the near/far field boundary. A derivation of such an equation is included for reference.

The bottom line is that for most panel antennas, the boundary will be properly proportional to wavelength at somewhere between 10 λ and 20 λ (depending on the working assumption used for aperture efficiency).

Respectfully,

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Derivation of far-field boundary equation based on equivalency to a circular aperture.

η = efficiency

$$G = \frac{4\pi A}{\lambda^2}\eta$$

rewrite, solve for A

$$\frac{G\lambda^2}{4\pi\eta} = A$$

redefine area, A as πr

$$\frac{G\lambda^2}{4\pi\eta} = \pi r^2$$

solve for r

$$\frac{G}{\eta}\frac{\lambda^2}{\pi^2}\cdot\frac{1}{4} = r^2$$

$$r = \frac{D}{2}$$

$$\frac{G}{\eta}\frac{\lambda^2}{\pi^2}\cdot\frac{1}{4} = \frac{D^2}{4}$$

$$\frac{G}{\eta}\cdot\frac{\lambda^2}{\pi^2} = D^2$$

$$\boxed{\frac{\sqrt{G}}{\sqrt{\eta}}\cdot\frac{\lambda}{\pi} = D}$$

Use this calculated value of D in Most prevalent standard equation for the nf boundary:

$$R_{nf} := \frac{2D^2}{\lambda}$$ **,which yields** $$R_{nf} := 2\cdot\left(\frac{G}{\eta}\cdot\frac{\lambda}{\pi^2}\right)$$

For most panel-type antennas, results vary from between 10 λ and 20 λ, depending on value of aperture efficiency chosen

An example application of the above derivation, for a typical 2000MHz, 5 ft, 17.1 dBi panel antenna is shown below:

Effective Aperture Calcs

$freq := 2000 \cdot MHz$ $\qquad$ $c := 3 \cdot 10^{8} \cdot \frac{m}{sec}$

$$\lambda := \frac{c}{freq}$$

$$Eff_{ap}(G, ef, \lambda) := \frac{\sqrt{\left(10^{\frac{G}{10}}\right)}}{\sqrt{ef}} \cdot \frac{\lambda}{\pi}$$

ef = efficiency (typically 55%-90%)

G = Gain (in dBi)

$Eff_{ap}(17.1, .6, \lambda) = 1.448 \cdot ft$

The size of an Equivalent Circular Aperture

Farfield for equivalent Gain Circular Aperture

$$\frac{2 \cdot \left(Eff_{ap}(17.1, .6, \lambda)\right)^2}{\lambda} = 8.524 \cdot ft$$

Typical Calc:

$$\frac{2 \cdot (5 \cdot ft)^2}{\lambda} = 101.6 \cdot ft$$