Microwave Engineering Project
OET Bulletin 65 Worksheet v2.0

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Executive Summary: With the baseline antenna, a 0.5m dish, and 10W of transmit power, the maximum permitted exposure (RF Safety) limits mandated by the FCC are exceeded. A warning and explanation must be included in the Antenna Requirements Document. Precautions must be taken by the operator in order to ensure the safety of the operators and the general public.

What follows is an investigation of Maximum Permissable Exposure for the baseline Microwave Engineering Project (MEP) Antenna, as guided by OET Bulletin 65. This is an RF Safety compliance issue mandated by the FCC.

$$\text{UplinkFrequency} := 5660000000\text{Hz}$$

$$\text{UplinkWavelength} := \frac{299792458\,\frac{\text{m}}{\text{s}}}{\text{UplinkFrequency}}$$

$$\text{UplinkWavelength} = 0.053\,\text{m}$$

Table 1 in FCC Bulletin 65 (power thresholds for routine evaluation of amateur radio stations) states that for SHF and EHF, all bands, the Transmitter Power Threshold for routine evaluation of amateur radio stations is 250 Watts. Therefore, a routine evaluation is not required.

Satellite-earth uplink stations have been analyzed and their emissions measured to determine methods to estimate potential environmental exposure levels. An empirical model has been developed, based on antenna theory and measurements, to evaluate potential environmental exposure from these systems [Reference 15 from OET Bulletin 65]. In general, for parabolic aperture antennas with circular cross sections, the following information and equations from this model can be used in evaluating a specific system for potential environmental exposure. More detailed methods of analysis are also acceptable. For example, see References [18] and [21in OET Bulletin 65].

Antenna Surface. The maximum power density directly in front of an antenna (e.g., at the antenna surface) can be approximated by Equation 1. P is power fed to the antenna, r is the radius, and Area is the physical area of the aperture antenna.

$P := 10W$

$r := .25m$

$Area := \pi \cdot (r)^2$

$S := \frac{4 \cdot P}{Area}$ Equation 1

$S = 20.372 \cdot \frac{mW}{cm^2}$

In the near-field, or Fresnel region, of the main beam, the power density can reach a maximum before it begins to decrease with distance. The extent of the near-field can be described by Equation 2. D is maximum dimension of the antenna. It's the diameter if circular.

$D := .5m$

$Rnf := \frac{D^2}{4 \cdot UplinkWavelength}$ Equation 2

$Rnf = 1.18\,m$

The magnitude of the on-axis (main beam) power density varies according to location in the near-field. However, the maximum value of the near-field, on-axis, power density can be expressed by Equation 3. The efficiency of 60% is based on using an offset-feed dish.

$\eta := .60$

$Snf := \frac{16 \cdot \eta \cdot P}{\pi \cdot D^2}$ Equation 3

$Snf = 12.223 \cdot \frac{mW}{cm^2}$

Calculated antenna gain.

$$Gain := \frac{(4 \cdot \pi \cdot \eta \cdot Area)}{UplinkWavelength^2}$$ Equation 4

$Gain = 527.694$

$Gain\_dB := 10\log(Gain)$

$Gain\_dB = 27.224$

Power density in the transition region decreases inversely with distance
from the antenna, while power density in the far-field (Fraunhofer region) of the antenna decreases inversely with the square of the distance. For purposes of evaluating RF exposure, the distance to the beginning of the far-field region (farthest extent of the transition region) can be approximated by Equation 5.

$$Rff := \frac{\left(0.6 \cdot D^2\right)}{UplinkWavelength}$$ Equation 5

$Rff = 2.832\,m$

The transition region will then be the region extending from Rnf, calculated above, to Rff. If the location of interest falls within this transition region, the on-axis power density can be calculated from the following equation, where R is the distance of interest. For example,

$Range := 2m$

$$St := \frac{Snf \cdot Rnf}{Range}$$ Equation 6

$St = 7.212 \cdot \frac{mW}{cm^2}$

The power density in the far-field or Fraunhofer region of the antenna pattern decreases inversely as the square of the distance. The power density in the far-field region of the radiation pattern can be estimated by Equation 7.

$$Range := Rff$$

$$Sff := \frac{P \cdot Gain}{4 \cdot \pi \cdot Range^2} \qquad \text{Equation 7}$$

$$Sff = 5.236 \cdot \frac{mW}{cm^2}$$

In the far-field region, power is distributed in a series of maxima and minima as a function of the off-axis angle (defined by the antenna axis, the center of the antenna and the specific point of interest). For constant phase, or uniform illumination over the aperture, the main beam will be the location of the greatest of these maxima. The on-axis power densities calculated from the above formulas represent the maximum exposure levels that the system can produce.

Off-axis power densities will be considerably less.

$x := 1.18, 1.19 .. 2.83$

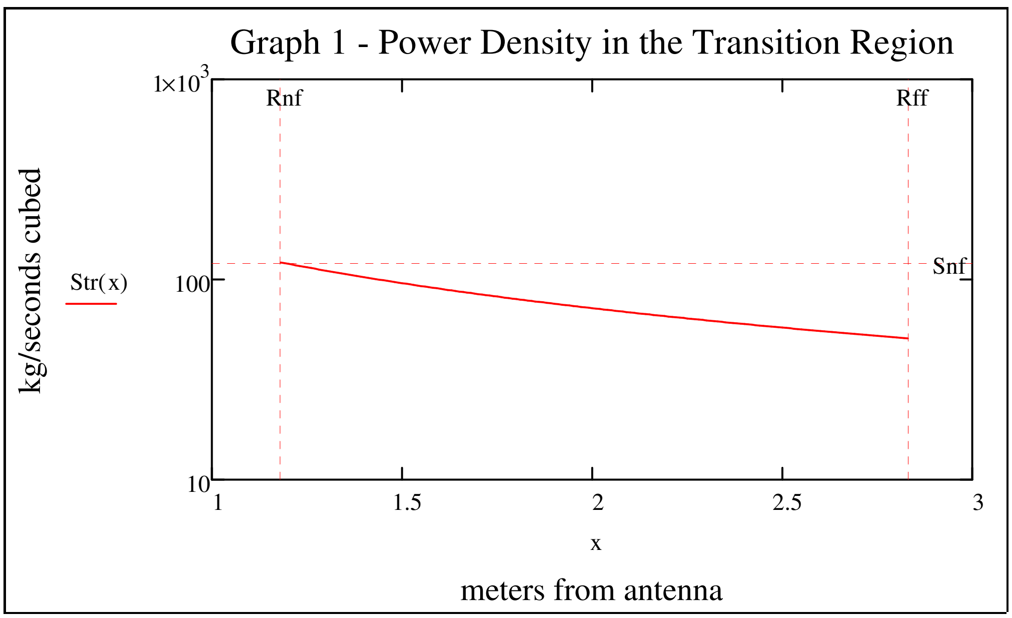
$$Str(x) := \frac{Snf \cdot Rnf}{x}$$ Equation 9

$Rnf = 1.18\,m$

$Rff = 2.832\,m$

$Snf = 12.223 \cdot \frac{mW}{cm^2}$

Graph 1 shows a model of how the power density in kg/seconds cubed varies with distance from the baseline antenna in the transition region between near and far field. The power density starts out at maximun near-field energy, then decays inversely proportional to range.



The legal limit is 1 mW/cm squared for general population/uncontrolled exposure, and5 mW/cm squared for occupational/controlled (amateur radio operators) exposure. The averaging time in minutes for controlled is 6, and uncontrolled is 30.

Assuming constant transmission, which may be the case with data usage of Namaste, the duty cycles required to comply with MPE are calculated below.

$$uncontrolled := 1\frac{mW}{cm^2}\cdot 6min$$ Equation 10

$$LHSu := \frac{uncontrolled}{Snf}$$ Equation 11

$$LHSu = 29.452\,s$$

$$DutyCycle\_u := \frac{LHSu}{6min}$$ Equation 12

$$DutyCycle\_u = 8.181\cdot\%$$

$$controlled := 5\frac{mW}{cm^2}\cdot 30min$$ Equation 13

$$LHSc := \frac{controlled}{Snf}$$ Equation 14

$$LHSc = 736.311\,s$$

$$DutyCycle\_c := \frac{LHSc}{30min}$$ Equation 15

$$DutyCycle\_c = 40.906\cdot\%$$

At what distance does the power density fall below the maximum permitted exposure? Solve Equation 16 for a far field power density of 1 mW/cm squared for the uncontrolled safe range.

$$SafeRange := \sqrt{\frac{P\cdot Gain}{4\cdot\pi\cdot\left(1\frac{mW}{cm^2}\right)}}$$ Equation 16

$$SafeRange = 6.48\,m$$

At what power does the power density fall below maximum permitted exposure in the near field? Solve Equation 17 for a maximum near field power density of 1 mW/cm squared for the uncontrolled safe power.

$$\mathrm{SafePower} := \left(1\,\frac{\mathrm{mW}}{\mathrm{cm}^2}\right)\cdot\frac{\pi\cdot D^2}{16\cdot\eta} \qquad \text{Equation 17}$$

$$\mathrm{SafePower} = 0.818\,\mathrm{W}$$

After an evaluation is performed, and if a determination is made that a potential problem exists, which is the case for the baseline antenna assumption of a 0.5m DirecTV style dish, then section 4 of Bulletin 65 should be consulted for a discusssion of recommended methods of reducing or controlling exposure.

The applicable part of section 4 concerns restricting access to the areas where maximum permitted exposure would be exceeded. This would be along the main axis of the beam coming from the dish.

What is the likelihood of the portion of the antenna pattern where maximum permitted exposure limits are exceeded being occuped by a human? At low elevation angles and with a low tripod mount, the opportunity exists for limits to be exceeded, and a warning and explanation must be included in the Antenna Requirements Document.

It is the responsibility of the station operator to set up the station in compliance with RF Safety regulations. It is the designer's responsibility to clearly explain the RF Safety requirements to potential operators, so that the antenna may be set up and operated in a safe manner. The power levels and duty cycles required for link establishment and usability with the baseline 0.5 meter dish result in power density levels that exceed FCC-mandated maximum permitted exposure levels. Precautions must therefore be taken by the operator in order to ensure the safety of the operators and the general public.

Comments, questions, and corrections to w5nyv@yahoo.com

Further Questions

Does the offset feed (DSS type) antenna differ significantly enough from acirculat cross section parabolic to make any difference in the analysis?

Consider the powe rilluminating the operator's eyes as he or she looks around the edge of the dish towards the feed. A study of the unreflected feed for tose inclined to look into it or poke fingers into it.

Find actual patterns of the DSS antenna for the uplink band. Paul Wade W1GHZ has some patterns on his website that suggest such patterns could exist.

Revision History

Version 1.0 released 10 April 2008
Review input received from Roger AD5T and Paul KB5MU.

Version 2.0 released 27 April 2008