OET 65 Definition of Terms and Formulas:

OET 65 Radiation Hazard Analysis

Definition of terms

The terms are used in the formulas here are defined as follows:

$S_{surface}$ = maximum power density at the antenna surface
S_{nf} = maximum near-field power density
S_t = power density in the transition region
S_{ff} = power density (on axis)
R_{nf} = extent of near-field
R_{ff} = distance to the beginning of the far-field
R = distance to point of interest
P = power fed to the antenna
A = physical area of the aperture antenna
G = power gain in the direction of interest relative to an isotropic radiator
D = maximum dimension of antenna (diameter if circular)
λ = wavelength
η = aperture efficiency, typically 0.65 to 0.75

Formulas

Antenna Surface. The maximum power density directly in front of an antenna (e.g., at the antenna surface) can be approximated by the following equation:

$$f_{S.surface}(P, A) := \frac{4 \cdot P}{A}$$

Near-Field Region. 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 the following equation **(D** and l in same units):

$$f_{R.nf}(D, \lambda) := \frac{D^2}{4 \cdot \lambda}$$

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 the following equation:

$$f_{S.nf}(P, D, \eta) := \frac{16 \cdot \eta \cdot P}{\pi \cdot D^2}$$

Aperture efficiency can be estimated, or a reasonable approximation for circular apertures can be obtained from the ratio of the effective aperture area to the physical area as follows:

$$f_\eta(G, D, \lambda) := \frac{\left(\frac{G \cdot \lambda^2}{4 \cdot \pi}\right)}{\left(\frac{\pi \cdot D^2}{4}\right)}$$

If the antenna gain is not known, it can be calculated from the following equation using the actual or estimated value for aperture efficiency:

$$f_G(A, \lambda, \eta) := \frac{4 \cdot \pi \cdot \eta \cdot A}{\lambda^2}$$

Transition Region. 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 the following equation:

$$f_{R.ff}(D, \lambda) := \frac{0.6 \cdot D^2}{\lambda}$$

The transition region will then be the region extending from **R nf** to **R ff** . If the location of interest falls within this transition region, the on-axis power density can be determined from the following equation:

$$f_{S.t}(S_{nf}, R_{nf}, R) := \frac{S_{nf} \cdot R_{nf}}{R}$$

Far-Field Region. 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 the general equation discussed earlier:

$$f_{S.ff}(P, G, R) := \frac{P \cdot G}{4 \cdot \pi \cdot R^2}$$

Table 1 - Mantarray M40:

Table 1: Radiation from Mantarray M40 Antenna

Input Parameters

Antenna Aperture Major Axis:		$D_{maj} := 31 \cdot in$	$D_{maj} = 78.74 \cdot cm$
Antenna Aperture Minor Axis:		$D_{min} := 6.2 \cdot in$	$D_{min} = 15.748 \cdot cm$
Frequency of Operation:		$F := 30 \cdot GHz$	
Max Power into Antenna:		$P := 5.38 \cdot W$	
Aperture Efficiency:		$\eta := 1$	
Aperture Corner Horn Area:		$ca := 3.6 \cdot in^2$	

Calculated Values

Wavelength:	$\lambda := \frac{c}{F}$	$\lambda = 0.01 \cdot m$	
Area of Aperture:	$A_{apr} := (D_{maj} \cdot D_{min}) - ca$	$A_{apr} = 0.122\, m^2$	$A_{apr} = 188.6 \cdot in^2$
Effective Aperture Diameter:	$D_{eff} := \sqrt{\frac{(4 \cdot A_{apr})}{\pi}}$	$D_{eff} = 39.36 \cdot cm$	
Antenna Gain:	$G := \frac{\eta \cdot 4 \cdot \pi \cdot A_{apr}}{\lambda^2}$	$G = 1.531 \times 10^4$	$10 \cdot log(G) = 41.85$ dBi
Length of Near Field:	$R_{nf} := \frac{D_{maj}^2}{4 \cdot \lambda}$	$R_{nf} = 15.511\, m$	
Beginning of Far Field:	$R_{ff} := 0.6 \cdot \frac{D_{maj}^2}{\lambda}$	$R_{ff} = 37.226\, m$	

Power Density Calculations

Far Field:	100% Duty Cycle	Idle Mode	Normal Mode	High Capacity Mode
$S_{ff} := \frac{P \cdot G}{4 \cdot \pi \cdot R_{ff}^2}$	$S_{ff} = 0.473 \cdot \frac{mW}{cm^2}$	$S_{ff} \cdot 06\% = 0.028 \cdot \frac{mW}{cm^2}$	$S_{ff} \cdot 10\% = 0.047 \cdot \frac{mW}{cm^2}$	$S_{ff} \cdot 30\% = 0.142 \cdot \frac{mW}{cm^2}$

Near Field:	100% Duty Cycle	Idle Mode	Normal Mode	High Capacity Mode
$S_{nf} := \frac{16 \cdot \eta \cdot P}{\pi \cdot D_{maj}^2}$	$S_{nf} = 4.419 \cdot \frac{mW}{cm^2}$	$S_{nf} \cdot 06\% = 0.265 \cdot \frac{mW}{cm^2}$	$S_{nf} \cdot 10\% = 0.442 \cdot \frac{mW}{cm^2}$	$S_{nf} \cdot 30\% = 1.326 \cdot \frac{mW}{cm^2}$

Transition Region: Power density is less than the maximum near field region power density and greater than the minimum far field region power density.

Aperture:	100% Duty Cycle	Idle Mode	Normal Mode	High Capacity Mode
$S_{apr} := \frac{4 \cdot P}{A_{apr}}$	$S_{apr} = 17.686 \cdot \frac{mW}{cm^2}$	$S_{apr} \cdot 0.6\% = 0.106 \cdot \frac{mW}{cm^2}$	$S_{apr} \cdot 10\% = 1.769 \cdot \frac{mW}{cm^2}$	$S_{apr} \cdot 30\% = 5.306 \cdot \frac{mW}{cm^2}$

Table 2 - Mantarray M32:

Table 2: Radiation from Mantarray M32 Antenna

Input Parameters

Antenna Aperture Major Axis:	$D_{maj} := 24.8 \cdot in$	$D_{maj} = 62.992 \cdot cm$
Antenna Aperture Minor Axis:	$D_{min} := 6.2 \cdot in$	$D_{min} = 15.748 \cdot cm$
Frequency of Operation:	$F := 30 \cdot GHz$	
Max Power into Antenna:	$P := 5.38 \cdot W$	
Aperture Efficiency:	$\eta := 1$	

Calculated Values

Wavelength:	$\lambda := \frac{c}{F}$	$\lambda = 0.01 \cdot m$	
Area of Reflector:	$A_{apr} := D_{maj} \cdot D_{min}$	$A_{apr} = 0.099\, m^2$	$A_{apr} = 153.76 \cdot in^2$
Effective Aperture Diameter:	$D_{apr} := \sqrt{\frac{(4 \cdot A_{apr})}{4}}$	$D_{apr} = 31.496 \cdot cm$	
Antenna Gain:	$G := \frac{\eta \cdot 4 \cdot \pi \cdot A_{apr}}{\lambda^2}$	$G = 1.248 \times 10^4$	$10 \cdot log(G) = 40.963$ dBi
Length of Near Field:	$R_{nf} := \frac{D_{maj}^2}{4 \cdot \lambda}$	$R_{nf} = 9.927\, m$	
Beginning of Far Field:	$R_{ff} := 0.6 \cdot \frac{D_{maj}^2}{\lambda}$	$R_{ff} = 23.824\, m$	

Power Density Calculations

Far Field:	100% Duty Cycle	Idle Mode	Normal Mode	High Capacity Mode
$S_{ff} := \frac{P \cdot G}{4 \cdot \pi \cdot R_{ff}^2}$	$S_{ff} = 0.942 \cdot \frac{mW}{cm^2}$	$S_{ff} \cdot 06\% = 0.056 \cdot \frac{mW}{cm^2}$	$S_{ff} \cdot 10\% = 0.094 \cdot \frac{mW}{cm^2}$	$S_{ff} \cdot 30\% = 0.282 \cdot \frac{mW}{cm^2}$

Near Field:	100% Duty Cycle	Idle Mode	Normal Mode	High Capacity Mode
$S_{nf} := \frac{16 \cdot \eta \cdot P}{\pi \cdot D_{maj}^2}$	$S_{nf} = 6.905 \cdot \frac{mW}{cm^2}$	$S_{nf} \cdot 06\% = 0.414 \cdot \frac{mW}{cm^2}$	$S_{nf} \cdot 10\% = 0.691 \cdot \frac{mW}{cm^2}$	$S_{nf} \cdot 30\% = 2.072 \cdot \frac{mW}{cm^2}$

Transition Region: Power density is less than the maximum near field region power density and greater than the minimum far field region power density.

Main Reflector:	100% Duty Cycle	Idle Mode	Normal Mode	High Capacity Mode
$S_{ref} := \frac{4 \cdot P}{A_{apr}}$	$S_{apr} = 17.686 \cdot \frac{mW}{cm^2}$	$S_{apr} \cdot 0.6\% = 0.106 \cdot \frac{mW}{cm^2}$	$S_{apr} \cdot 10\% = 1.769 \cdot \frac{mW}{cm^2}$	$S_{apr} \cdot 30\% = 5.306 \cdot \frac{mW}{cm^2}$

The antennas will be operated in a controlled environment with access to the region near the radiator limited - typically vehicle roof mounted or aircraft tail or fuselage mounted. Antenna will be turned off for maintenance as necessary to protect workers or general population.