ELECTROMAGNETIC RADIATION SAFETY
(SAFE DISTANCE TO REFLECTOR ANTENNAS)

JAMES HUDSON
WA5JAT

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FCC OET Bulletin 65

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- REQUIRED CALCULATIONS:
  - FRONT
    - FAR FIELD
      - » Bystander Safety
    - NEAR FIELD
      - » Bystander Safety
      - » Operator Safety
  - REAR
    - FEED SPILLOVER
      - » Operator Safety

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ALLOWABLE EXPOSURE LIMITS:

(B) Limits for General Population/Uncontrolled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $\|E\|^2$, $\|H\|^2$ or S (minutes)
0.3-1.34	614	1.63	(100)*	30
1.34-30	824/f	2.19/f	$(180/f^2)$*	30
30-300	27.5	0.073	0.2	30
300-1500	--	--	f/1500	30
1500-100,000	--	--	1.0	30

f = frequency in MHz *Plane-wave equivalent power density

At 10 GHz THE ALLOWABLES ARE:

$$E_m = 61.4\ (V/m)$$

$$H_m = 0.163\ (A/m)$$

$$S_m = 10\ (W/m^2)$$

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FRONT - FAR FIELD

Power Density:

$$S = \frac{P_t G_t}{4\pi R^2} \qquad (1)$$

For >Fraunhofer Distance:

$$R_f = \frac{2D^2}{\lambda} \qquad (2)$$

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DETERMINE THE FRAUNHOFER DISTANCE:

- FOR 1 Watt into1 M DISH AT 10.368 GHz:

$$R_f = \frac{2D^2}{\lambda} = \frac{2\,(1)^2}{0.03456} = 58\text{ m}$$

-AT THIS DISTANCE, FROM EQUATION 1, THE COMPUTED POWER DENSITY IS:

$$S = \frac{P_t G_t}{4\pi R^2} = \frac{1 \text{ x antilog36}}{4\,\pi\,(58)^2} = \frac{4000}{42252} = 0.095\text{ W/sqM}$$

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Note:

AT 50 W, YOU WOULD ONLY BE 3 dB UNDER THE ALLOWABLE EXPOSURE LIMIT AT 58 M.

FRONT - FAR FIELD-cont.

CALCULATING DISTANCE TO SAFE LEVEL AT BORESIGHT:

$$R_m = \sqrt{\frac{P_t G_t}{4\pi S_m}} \qquad (3)$$

AT OFF BORESIGHT THE DISTANCE WILL BE LESS:

$$R_m = \sqrt{\frac{P_t G_t(\theta_o, \phi_o)}{4\pi S_m}} \qquad (4)$$

AND DIFFICULT TO DETERMINE

FRONT - NEAR FIELD

First, we must determine the far-field power density at the boundary of the far-field and Fresnel regions (S_0). Then the procedure to estimate the power density in closer distances is mainly divided into three sections:

1. Determine the tapering factor of dish illumination, which shows how uniformly the dish is illuminated. A tapering factor of n = 0 means that the feed antenna illuminates the dish uniformly. As n increases, illumination rapidly decreases by moving away from the center of the reflector.
2. Determine the correction factor for power density along the boresight in the Fresnel or near-field regions.[4]
3. Determine the correction factor for the off-boresight angle.[5]

FRONT - NEAR FIELD-contd

Correction factors depend on the tapering factor of the dish. We apply the correction factors to S_0 and estimate the power density at the desired point.

The above items are described in more detailed steps as follows:

1. Determine the tapering factor, n.

- Determine λ/D, where D is the diameter of the dish and λ is the wavelength at the largest frequency.
- Determine the half-power beamwidth from gain patterns, θ.
- Determine the $\theta/(\lambda/D)$, and compare it to the factor in the second column of Table 1 on Page 3-2 of ref. 5. Based on this comparison, choose a tapering n from the first column.

2. Determine the Fraunhofer distance:

$$R_f = \frac{2D^2}{\lambda}$$

FRONT - NEAR FIELD-contd

3. Determine field power density at R_f:

$$S_f = \frac{P_t G}{4\pi R_0^{\,2}}$$

where G is the numerical value of the gain of the antenna.

4. Determine the normalized distance:

$$p = \frac{R}{R_f}$$

5. Use Figure 4-3(b) in ref. 4 to determine the on-axis power density for p and n = 1. If tapering is different, use the applicable plots in Figures 4-3.

6. Determine the off-axis angle according to the desired observation point.

7. Use Figure 3-10e in ref. 5, assuming n = 1, to determine the correction factor. Apply the correction factor.

FRONT - NEAR FIELD (Ref FCC OET Bulletin 65)

- For off-axis calculations in the near-field and in the transition region it can be assumed that, if the point of interest is at least one antenna diameter removed from the center of the main beam, the power density at that point would be at least a factor of 100 (20 dB) less than the value calculated for the equivalent distance in the main beam (*See* para. 160 of *Report and Order*, ET Dkt 93-62. *See also*, 47 CFR § 97.13, as amended.).

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BEHIND THE REFLECTOR:

- FEED SPILLOVER:

determine the power density at locations behind the reflector, where there is line-of-sight to the feed antenna. It is not possible to use the method described in the previous section because the correction factor for an off-boresight angle of larger than about 30 degrees is expected to be very small; therefore, it is not provided in ref. 5. The power density computed with this method would be negligible.

BEHIND THE REFLECTOR:

- FEED SPILL OVER:

Here, to estimate the power density behind the antenna, the spillover effect will be considered. The diffraction that occurs at the edge of the reflector is not accounted for.

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BEHIND THE REFLECTOR:

- FEED SPILL OVER:

FOR A FEED OF 10 cm DIAMETER, WITH 15 dB GAIN and 12 dB TAPER

$$R_f = \frac{2D^2}{\lambda}$$ = 0.56 M

$$S = \frac{P_t G_t}{4\pi R^2}$$ = 0.0705 W/sqM

FOR A LOCATION THAT IS AT 1.5 M FROM THE FEED

AT 100 W, YOU ARE APPROACHING THE ALLOWABLE EXPOSURE LIMIT.

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North
Texas
NTMS
Microwave
Society

REFERENCES:

1. U.S. Department of Defense, MIL-STD-188 165A, 2012.
2. Federal Communications Commission: Office of Engineering & Technology, Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields, 1997.
3. Health Canada, Limits of Human Exposure to Radiofrequency Electromagnetic Energy in the Frequency Range from 3 kHz to 300 GHz (Safety Code 6), 2015.
4. A. Farrar and E. Chang, Procedures for Calculating Field Intensities of Antennas, 1987.
5. H. K. Kobayashi, Procedure for Calculating the Power Density of a Parabolic Circular Reflector Antenna, 1990.