DFW NETWORK X-band Radar RF Exposure Calculation

RF exposure for the X-band radars in the DFW network is computed using the methods outlined in IEEE Std C95.3-2021, "IEEE Recommended Practice for Measurements and Computations of Electric, Magnetic, and Electromagnetic Fields with Respect to Human Exposure to Such Fields, 0 Hz to 300 GHz". Table D.5 – *Determining power density for antenna with circular aperture* in Annex Section D.4.4 *Aperture antennas* is used to compute the worst-case power density values emitted by the radar's parabolic reflector antenna.

From the FCC rule 47 CFR 1.1310, the allowed uncontrolled RF exposure (in the 1.5-100 GHz band) for general population is 1 mW/cm^2 of average exposure over a 30 min period and 5 mW/cm^2 of average exposure over a 6 min period for occupational/controlled exposure.

Definition of terms

Occupational/controlled exposure limits apply in situations in which persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. The phrase *fully aware* in the context of applying these exposure limits means that an exposed person has received written and/or verbal information fully explaining the potential for RF exposure resulting from his or her employment. With the exception of *transient* persons, this phrase also means that an exposed person has received appropriate training regarding work practices relating to controlling or mitigating his or her exposure. In situations when an untrained person is transient through a location where occupational/controlled limits apply, he or she must be made aware of the potential for exposure and be supervised by trained personnel pursuant to § 1.1307(b)(2) of this part where use of time averaging is required to ensure compliance with the general population exposure limit. The phrase *exercise control* means that an exposed person is allowed and also knows how to reduce or avoid exposure by administrative or engineering work practices, such as use of personal protective equipment or time averaging of exposure.

General population/uncontrolled exposure limits apply in situations in which the general public may be exposed, or in which persons who are exposed as a consequence of their employment may not be fully aware of the potential for exposure or cannot exercise control over their exposure. For example, RF sources intended for consumer use shall be subject to the limits for general population/uncontrolled exposure in this section.

Procedure

IEEE Std C95.3-2021 states that "A conservative approach for circular apertures would be to determine the maximum value of power density (S_{ETSI}) determined according to ETSI TR 102 457 v2.1.0 [B95] (S_{ETSI}) and the power density (S_A) from considering the effective area" and provides the table below as guidance for the computations. This table is applied with the following inputs to compute a worst-case on-axis power density for our radar system.

X-band Radar Parameters

Antenna Beamwidth	$bw =$	1.4	deg
Antenna Far-field Gain	$G_{FF}=$	42	dB
Peak Power into Antenna	$P_{peak}=$	18	kW
Max Duty Cycle	$DC=$	0.0012	
Power into Antenna	$P_{in}=$	21.6	W
Frequency	$f=$	9.4	GHz
Wavelength	$\lambda=$	0.032	m
Antenna Inner Diameter	$a=$	1.8	m
Multiplicative Factor	$F=$	13	

Table D.5—Determining power density for antenna with circular aperture

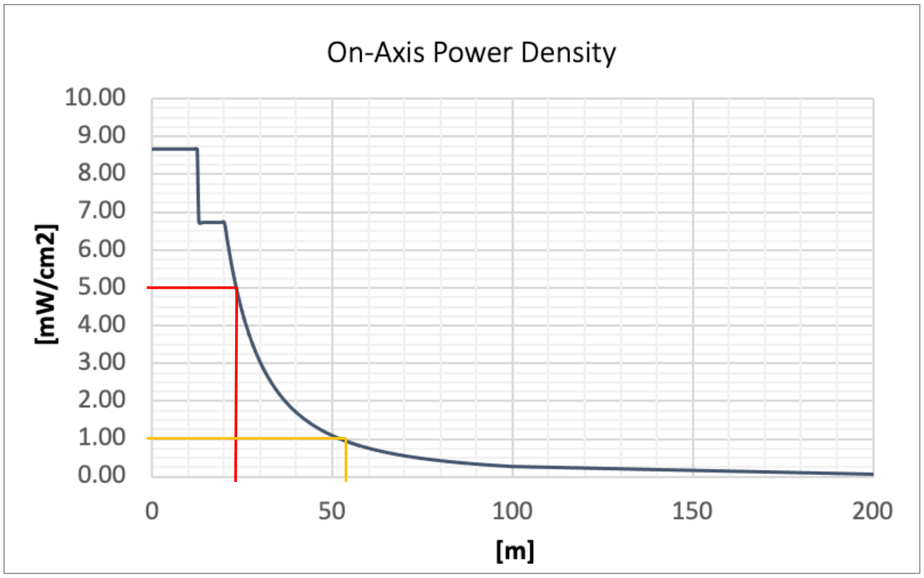
Equation	Freq. range	SEP [a]	Complexity	# of inputs
$S_A(d) = \min\left[\frac{16\pi P_{in}}{G_{FF}\lambda^2}, \frac{P_{in} \times G_{FF}}{4\pi d^2}\right]$ $S_{ETSI}(d) = \frac{F \times P_{in}}{a^2}$ for $d \le \frac{a^2}{8\lambda}$ $S_{ETSI}(d) = \frac{F \times P_{in}}{2a^2}$ for $\frac{a^2}{8\lambda} < d \le \frac{a}{2}\sqrt{\frac{2G_{FF}}{F\pi}}$ $S_{ETSI}(d) = \frac{P_{in} \times G_{FF}}{4\pi d^2}$ for $d > \frac{a}{2}\sqrt{\frac{2G_{FF}}{F\pi}}$ $S(d) \le \max[S_A(d), S_{ETSI}(d)]$	>1 GHz	II-0, III-0	Simple	6
	Applicability: Circular aperture antennas with $a > 10\,\lambda$ Points of interest within the cylinder formed by projecting the aperture area in the direction along the main beam axis			
See Table D.4	Points of interest outside the cylinder formed by projecting the aperture area in the direction along the main beam axis			
where $S_A(d)$ is the (maximum) power density at distance d from the aperture in the near-field region (W/m^2) considering the effective area [b] $S_{ETSI}(d)$ is the (maximum) power density at distance d using the ETSI TR 102 457 v2.1.0 [B95] mask (W/m^2) [b] $S(d)$ is the maximum power density at distance d (W/m^2) [b] P_{in} is the power into the antenna (W) [c] G_{FF} is the far-field gain over isotropic (linear) a is antenna diameter (m) F is a multiplicative factor (13 when a is dish inner diameter, 15 when a is dish external diameter) (see ETSI TR 102 457 v2.1.0 [B95]) d is distance from the antenna (m)				
NOTE—From its definition A_e, the effective area, is determined by: $A_e = \frac{G_{FF}\lambda^2}{4\pi}$ and is smaller than A the physical area of the aperture determined by: $A = \frac{\pi a^2}{4}$. Considering the conventional $S = \frac{4P_{in}}{A}$ as used for the uniform illumination case, by substituting A with A_e to compensate for illumination taper, the near-field term for S_A becomes: $S_A = \frac{16\pi P_{in}}{G_{FF}\lambda^2}$. At some distance from the aperture, the near-field term equals the power density determined from the standard far-field term. By using the minimum value of S from the near-field and far-field terms, a conservative estimate of S can be determined for all distances in SEP II-0 and SEP III-0 along the main beam axis.				

[a] The source-environment plane regions described in A.5 within which the method is applicable.

[b] At distances significantly less than the classic far-field distance, these are conservative values likely to be approached only in limited locations close to the main beam axis.

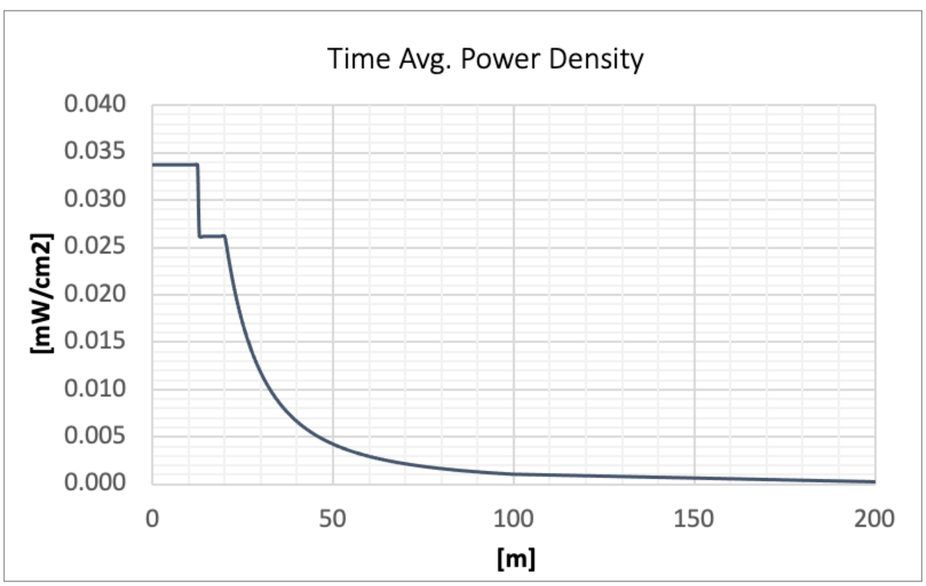
[c] To determine the best-estimate of S, the power radiated is the power input to the antenna port minus the power reflected from the port and minus the power dissipated as heat in the antenna circuitry. To err on the side of overstating the real value of S, P_{in} may be assumed to equal the forward power presented to the antenna port.

Applying the recommended procedure with the X-band radar parameters inputs yields the following worst-case on-axis (i.e., stationary antenna) power density plot as a function of distance



From the plot we can determine that for the stationary antenna case the conservative limit for occupational/controlled exposure is at 24 m along the antenna pointing direction and for the general population/uncontrolled exposure the conservative limit is at 52 m along the antenna pointing direction.

However, the narrow pencil beam radar antenna is constantly scanning at a typical angular velocity of 15 deg/s, greatly reducing the percentage of time a person would be illuminated while being near the radar. Applying this correction factor, the worst-case time-averaged (i.e., scanning antenna) power density plot is presented below.



From the plot we can determine that for the scanning antenna case there's no distance at which the power density is above the limit for general population/uncontrolled exposure, with the highest value of 0.034 mW/cm^2 being well below the limit of 1.0 mW/cm^2.

Additional Considerations

To further mitigate any effects from the radars' presence the radars are deployed following the considerations below.

The radars are operating atop towers and/or building rooftops on a mounting structure located inside a locally elevated fenced area with existing electromagnetic field warning signage. There's no public access to any of the radar deployment locations.

The radars are operating with a minimum beam elevation angle of 1 deg to ensure upward propagation of the signal.