CSU-CHIVO RF Exposure Calculation

RF exposure for the CSU-CHIVO radar is computed using the methods outlined in [1] and [2]. 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

Input parameters are defined as shown in Table 1.

Parameter	Value	Unit	Value2	Unit2	Description
Antenna Gain	45	dBi	31622.776		*G*
Antenna Diameter	4.3	m			*D*
Antenna beam width	1	degree	0.01745	rad	*Beam width specified by vendor*
Antenna sidelobe level	-28	dB	0.00158		*Sidelobe specified by vendor*
Transmit frequency	5.6	GHz	5600000000	Hz	*Frequency of operation*
Speed of light	3.00E+08	m/s			
Transmit Wavelength	0.054	m	5.36	cm	*λ*
Peak power	250	kW	250000	W	*Nominal peak power*
Duty Cycle (max)	0.0012				*Maximum radar duty cycle*
Avg. transmit power	300	W			*Average power from peak, duty cycle*

Calculated beam width	0.0174	rad	0.999	degree	*Computed from n, λ and D*
N	1.5				*Taper factor*

Table 1 Input Parameters

The power density at the near-to-far field transition distance is computed using the formulas on p 4-38 of [1] as shown in Table 2.

Parameter	Value	Unit	Value2	Unit2	Description
Far-field distance	690.293	m	2264.742	feet	*Near-to-far field transition distance*
Far-field power density	1.584	W/m^2	0.158	mW/cm^2	*Power density at the transition distance*

Table 2 RF Power Density (Far-field)

Next, the on-axis power density in the near-field is computed. Fig 4.3(c) in [1] gives the power density variation along the antenna boresight (on-axis). The results are plotted below.

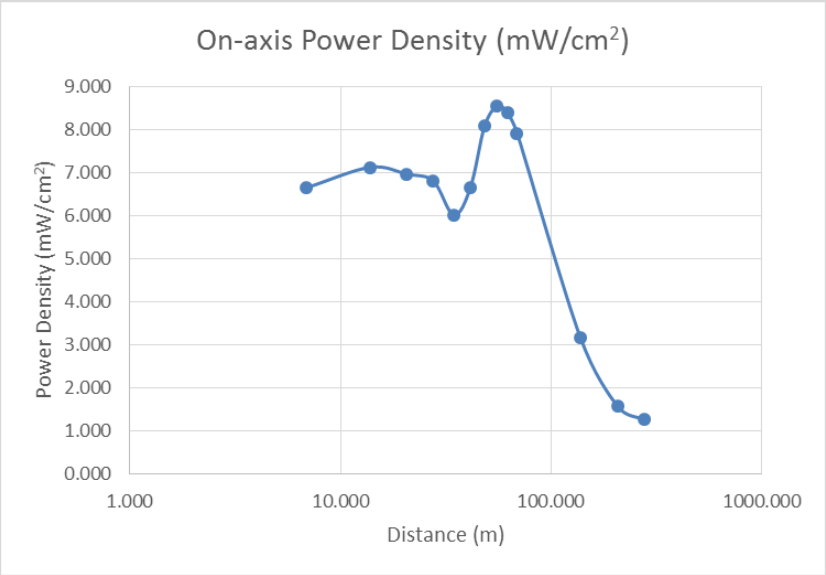

Figure 1 On-axis power density variation with distance

This can be combined with the variation in RF power density with angular offset in degrees off-axis, as indicated in [2]. The results, corresponding to a static antenna, are tabulated in Table 3. The cells are color-coded to indicate the following. White cells fall below the FCC general population/uncontrolled exposure limits. Yellow cells fall in the occupational/controlled exposure limits. Red cells are above the occupational/controlled exposure limit.

Angular offset off-axis	Distance (m)													
	6.903	13.806	20.709	27.612	34.515	41.418	48.321	55.223	62.126	69.029	138.059	207.088	276.117	345.147
-10	0.007	0.007	0.007	0.007	0.006	0.007	0.008	0.009	0.008	0.001	0.000	0.000	0.000	0.000
-9	0.013	0.014	0.014	0.014	0.012	0.013	0.016	0.017	0.017	0.001	0.000	0.000	0.000	0.000
-8	0.033	0.036	0.035	0.034	0.030	0.033	0.040	0.043	0.042	0.001	0.000	0.000	0.000	0.000
-7	0.067	0.071	0.070	0.068	0.060	0.067	0.081	0.086	0.084	0.003	0.001	0.000	0.000	0.000
-6	0.210	0.225	0.220	0.215	0.190	0.210	0.256	0.271	0.266	0.016	0.006	0.000	0.000	0.000
-5	0.665	0.713	0.697	0.681	0.602	0.665	0.808	0.856	0.840	0.050	0.020	0.002	0.002	0.000
-4	2.104	2.255	2.204	2.154	1.904	2.104	2.555	2.705	2.655	0.100	0.040	0.008	0.006	0.001
-3	3.335	3.573	3.494	3.414	3.017	3.335	4.050	4.288	4.208	0.199	0.080	0.050	0.040	0.005
-2	4.711	5.047	4.935	4.823	4.262	4.711	5.720	6.057	5.945	0.500	0.200	0.316	0.253	0.032
-1	6.654	7.129	6.971	6.813	6.020	6.654	8.080	8.555	8.397	7.922	3.169	1.584	1.267	0.158
0	6.654	7.129	6.971	6.813	6.020	6.654	8.080	8.555	8.397	7.922	3.169	1.584	1.267	0.158
1	6.654	7.129	6.971	6.813	6.020	6.654	8.080	8.555	8.397	7.922	3.169	1.584	1.267	0.158
2	4.711	5.047	4.935	4.823	4.262	4.711	5.720	6.057	5.945	0.500	0.200	0.316	0.253	0.032
3	3.335	3.573	3.494	3.414	3.017	3.335	4.050	4.288	4.208	0.199	0.080	0.050	0.040	0.005
4	2.104	2.255	2.204	2.154	1.904	2.104	2.555	2.705	2.655	0.100	0.040	0.008	0.006	0.001
5	0.665	0.713	0.697	0.681	0.602	0.665	0.808	0.856	0.840	0.050	0.020	0.002	0.002	0.000
6	0.210	0.225	0.220	0.215	0.190	0.210	0.256	0.271	0.266	0.016	0.006	0.000	0.000	0.000
7	0.067	0.071	0.070	0.068	0.060	0.067	0.081	0.086	0.084	0.003	0.001	0.000	0.000	0.000
8	0.033	0.036	0.035	0.034	0.030	0.033	0.040	0.043	0.042	0.001	0.000	0.000	0.000	0.000
9	0.013	0.014	0.014	0.014	0.012	0.013	0.016	0.017	0.017	0.001	0.000	0.000	0.000	0.000
10	0.007	0.007	0.007	0.007	0.006	0.007	0.008	0.009	0.008	0.001	0.000	0.000	0.000	0.000

Table 3 RF power density (mW/cm^2) for various angular offsets and distances

Due to the scanning nature of the radar, exposure to RF will be well below the values in the above table (Table 3) as the antenna continuously moves in azimuth and/or elevation. An interlock mechanism between the transmitter and scanning systems ensures that the radar will not transmit while the antenna is idle.

For the case of this radar's 1 deg scanning antenna rotating 360 deg in azimuth, the time-averaged power is obtained from the static antenna case corrected by the percentage of time each space region is illuminated. In this situation **all regions fall below the maximum level for uncontrolled exposure**, with the maximum level (corresponding to the on-axis maximum power density at 55 m from the radar) being as follows:

$$0.024 \text{ mW/cm}^2 \ (< 1.0 \text{ mW/cm}^2)$$

Additional considerations

The radar is located inside the fenced perimeter of the Laporte, TX airport in a tract of land adjacent to the runway that is closed to the general public with a buffer area of 75 m to the property fence. The distance to the on-axis maximum power density at 55 m from the radar is therefore located inside the airport fenced perimeter.

The radar antenna is mounted on top of a 10ft tower structure that ensures that the bottom of the beam is always above anyone near the radar.

The radar antenna is scanned at least 0.75 deg in elevation to ensure that the beam is propagating upwards from the ground.

The radar scanning typical minimum speed of 6 deg/s ensures that the average exposure period is in the order of 1 minute or less.

References

1. NTIA TM-87-129 Procedures for Calculating Field Intensities of Antennas
2. NTIA TM-90-145 Procedure for Calculating the Power Density of a Parabolic Circular Reflector Antenna