Radiation Hazard Analysis

This exhibit constitutes the radiation hazard analysis for Row 44 's transmitter using the FCC procedure outlined in FCC Bulletin #65. The limit for exposure to RF energy, for frequencies greater than 1.5 GHz, is 5 mW/cm^2 for up to a six minute duration (occupational/controlled exposure) and a 1 mW/cm^2 for up to 30 minute duration (categorized as general population/ uncontrolled exposure).[1]

Analysis for exposure to radiation is presented for the near field, far field, and the transition region. Appropriate separation-distances are provided for the controlled and uncontrolled exposure scenarios considering individuals located in the direction of either the antenna's main beam or its side lobes.

Analysis

The extent of the near field region for the main beam is defined in terms of the radius R_{nf} according to the relation

Equation 1: Near Field Region Radius

$$R_{nf} = \frac{D^2}{4\lambda}$$

where D is the maximum dimension of the antenna panel, and λ is the transmit signal's wavelength.

The near field maximum power density, S_{nf}, is determined from

Equation 2: Near Field Maximum Power Density

$$S_{nf} = 0.1\,\eta\,\frac{P_{PA}}{A}\left(\frac{in\,mW}{cm^2}\right)$$

where P_{PA} is the transmit power (after cable losses are accounted for) and A is the surface area of the antenna aperture, and η is the efficiency of the antenna aperture.

The far field region for the main beam is defined as beginning and continuing out-from a radius R_{ff}, given by

Equation 3: Far Field Region Radius

$$R_{ff} = 0.60\left(\frac{D^2}{\lambda}\right)$$

The far field power density S_{ff} at the minimum far field radius and farther is given in terms of the EIRP denoted by P_{EIRP} according to

[1] "Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields," Federal Communications Commission, Office of Engineering and Technology, Bulletin 65, Fourth Edition, August, 1999, p. 15 http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf

Equation 4: Far Field Power Density

$$S_{ff} = \frac{P_{EIRP}}{(4\pi)(R_{ff}^2)}$$

(The value of P_{EIRP} should already consider coax losses and aperture efficiency.)
Note that when the radius is expressed in meters, the Power Density is in units of W/m^2. The results are converted to units consistent with the FCC limits (mW/ cm^2) by multiplying values in W/m^2 by 0.1.

Near Field Exposure from Main Antenna Beam

The GSAA antenna has the "quasi-oval" dimensions of D=0.627 m (24.7 inches) and h=0.198 m (7.8 inches). However, all considered, the adjusted surface area "A" equals 0.1019 m^2.

At the highest frequency of 14.5 GHz, the wavelength is 0.0207 m. The near field radius is then R_{nf} = 4.75 m

The antenna aperture efficiency factor, η, is 0.77 and losses attributable to various hardware is 4.21 dB.

Based on the wavelength and the panel-width given farther above, the Far Field radius is then R_{ff} = 11.41 m

In the operation of GEE's system, the antenna may be fed with ten different signal levels, as provided in **Table 1** and **Table 2**. The associated Near Field radius Power Density Values are:

Table 1: HPA Transmit Power, EIRP, and Near Field Power Density as a Distance R_{nf}

HPA Transmit Power (Watts)	HPA Transmit Power (dBm)	Transmit Power (dBm)*	S_{nf} (mW/cm^2)*
25.00	43.98	39.77	7.17
22.28	43.48	39.27	6.39
19.86	42.98	38.77	5.69
17.70	42.48	38.27	5.07
15.77	41.98	37.77	4.52
14.06	41.48	37.27	4.03
12.53	40.98	36.77	3.59
11.17	40.48	36.27	3.20
9.95	39.98	35.77	2.85
8.87	39.48	35.27	2.54
7.91	38.98	34.77	2.27
7.05	38.48	34.27	2.02
6.28	37.98	33.77	1.80
5.60	37.48	33.27	1.60
4.99	36.98	32.77	1.43
4.45	36.48	32.27	1.27
3.96	35.98	31.77	1.14
3.53	35.48	31.27	1.01
3.15	34.98	30.77	0.902
2.81	34.48	30.27	0.804

HPA Transmit Power (Watts)	HPA Transmit Power (dBm)	Transmit Power (dBm)*	S_{nf} (mW/cm^2)*
2.50	33.98	29.77	0.717

*Incorporates hardware losses

Note that the equation for the maximum Power Density in the Near Field considers a given radiated signal/power confined-to and passing-through a physical area corresponding to that of the antenna aperture. Along these lines, the S_{nf} values cannot be assumed to vary with distance from the antenna, for locations within the Near Field.

The associated Far Field radius Power density values are as well:

Table 2: HPA Transmit Power, EIRP, and Far Field Power Density at Distance R_{ff}

HPA Transmit Power (Watts)	HPA Transmit Power (dBm)	EIRP (dBm)*	Sff (mW/cm2)*
25.00	43.98	73.37	1.33
22.28	43.48	72.87	1.19
19.86	42.98	72.37	1.06
17.70	42.48	71.87	0.942
15.77	41.98	71.37	0.839
14.06	41.48	70.87	0.748
12.53	40.98	70.37	0.667
11.17	40.48	69.87	0.594
9.95	39.98	69.37	0.530
8.87	39.48	68.87	0.472
7.91	38.98	68.37	0.421
7.05	38.48	67.87	0.375
6.28	37.98	67.37	0.334
5.60	37.48	66.87	0.298
4.99	36.98	66.37	0.265
4.45	36.48	65.87	0.237
3.96	35.98	65.37	0.211
3.53	35.48	64.87	0.188
3.15	34.98	64.37	0.167
2.81	34.48	63.87	0.149
2.50	33.98	63.37	0.133

* Incorporates hardware losses

Row 44 is considering exposure to two values of Power Density: 5 mW/cm^2 and 1 mW/cm^2.

5 mW/cm^2 Analysis

Some of the S_{nf} values in **Table 1** are greater than 5 mW/cm^2, and some are less than 5 mW/cm^2. As the Near Field analysis assumes that the Power Density in the Near Field does not vary with distance, for cases where S_{nf} values are less than 5 mW/cm^2, there is no location in the Near Field where the Power Density is higher. No individual located in the Near Field anywhere whatsoever will be subjected to a 5 mW/cm^2 exposure level.

For the S_{nf} values in **Table 1** which are greater than 5 mW/cm^2, we'll assume that the Power Density decreases linearly between the Near Field radius and the Far Field radius. Interpolating the respective Power Density values, **Table 3** lists the distances where the Power Density will equal 5 mW/cm^2 (for the selected TX powers).

Table 3: Separation for Controlled Exposure Limit (Main Beam)

HPA Transmit Power (dBm)	Separation for Controlled Limit (5 mW/cm^2)	
	Meters	Feet
43.98	7.22	23.7
43.48	6.52	21.4
42.98	5.74	18.8
42.48	4.87	16.0

As mentioned previously, if for S_{nf} values less than 5 mW/cm^2, in attempting to determine the location at which the Power Density may equal 5 mW/cm^2, we cannot project a location closer than R_{nf}.

For such cases, and for these power levels, a conservative approach will be adopted. **Table 4** therefore designates the Near Field radius of 4.75 meters (15.6 feet) as the minimum physical separation guaranteeing an exposure no greater than 5 mW/cm^2.

Table 4: Separation for Controlled Exposure Limit (Main Beam)

HPA Transmit Power (dBm)	Separation for Controlled Limit (5 mW/cm^2)	
	Meters	Feet
41.98	4.75	15.6
41.48	4.75	15.6
40.98	4.75	15.6
40.48	4.75	15.6
39.98	4.75	15.6
39.48	4.75	15.6
38.98	4.75	15.6
38.48	4.75	15.6
37.98	4.75	15.6
37.48	4.75	15.6
36.98	4.75	15.6
36.48	4.75	15.6
35.98	4.75	15.6
35.48	4.75	15.6
34.98	4.75	15.6
34.48	4.75	15.6
33.98	4.75	15.6

1 mW/cm^2 Analysis

For the cases in **Table 2** where the S_{ff} values are greater than 1 mW/cm^2, the distance of separation will be calculated by inverse-squared analysis. For the cases in **Table 2** where the S_{ff} values are less than 1 mW/cm^2, linear interpolation will be used to identify the location between

R_{nf} and R_{ff} where the 1 mW/cm^2 value will be encountered. For the cases in **Table 1** where the S_{nf} values are less than 1 mW/cm^2, a distance of R_{nf} will apply.

For the TX levels where S_{ff} values exceed 1 mW/cm^2, standard inverse-squared analysis has been used to identify the necessary separations listed in **Table 5**.

Table 5: Separation for Uncontrolled Exposure Limit (Main Beam)

HPA Transmit Power (dBm)	Separation for Uncontrolled Limit (1 mW/cm^2)	
	Meters	Feet
43.98	13.1	43.1
43.48	12.4	40.7
42.98	11.7	38.4

For the TX levels where S_{ff} values are less than 1 mW/cm^2, linear interpolation will be employed (considering the Power Density values at R_{nf} and R_{ff}) in order to project the location at which a 1 mW/cm^2 exposure exists.

Assuming that the Power Density decreases linearly between the Near Field radius and the Far Field radius, the distances at which the Power Density equals 1 mW/cm^2 are listed in **Table 6**.

Table 6: Separation for Uncontrolled Exposure Limit (Main Beam)

HPA Transmit Power (dBm)	Separation for Uncontrolled Limit (1 mW/cm^2)	
	Meters	Feet
42.48	11.3	37.1
41.98	11.1	36.5
41.48	10.9	35.7
40.98	10.6	34.9
40.48	10.4	34.0
39.98	10.1	33.0
39.48	9.71	31.8
38.98	9.31	30.6
38.48	8.87	29.1
37.98	8.38	27.5
37.48	7.83	25.7
36.98	7.21	23.6
36.48	6.51	21.4
35.98	5.73	18.8
35.48	4.85	15.9

For TX levels where S_{nf} values are less than 1 mW/cm^2, a conservative approach will be adopted. **Table 7** therefore references the Near Field radius of 4.75 meters (15.6 feet) as the minimum physical separation to facilitate an exposure no greater than 1 mW/cm^2 for the respective power levels.

Table 7: Separation for Uncontrolled Exposure Limit (Main Beam)

HPA Transmit Power (dBm)	Separation for Uncontrolled Limit (1 mW/cm^2)	
	Meters	Feet
34.98	4.75	15.6
34.48	4.75	15.6

HPA Transmit Power (dBm)	Separation for Uncontrolled Limit (1 mW/cm^2)	
	Meters	Feet
33.98	4.75	15.6

Exposure from Antenna Beam Side-Lobes

The previous calculations assumed the individual was located in the sight of the main antenna beam (The main antenna beam is less than 10 degrees beam-width in azimuth). The following analysis provides insight into the exposure when an individual is located to the side of or behind the antenna.

Table 8 provides Power Density values at distances R_{nf} and R_{ff} when an individual is located in the direction of the highest antenna side-lobe (which corresponds to a 17 dB gain reduction from the main beam).

Table 8: Transmit Power, EIRP, and Far Field Power Density at Distance R_{ff}

HPA Transmit Power (dBm)	Sidelobe (dB)	Sidelobe Transmit Power (dBm)*	Sidelobe EIRP (dBm)*	S_{nf} (mW/cm^2)	S_{ff} (mW/cm^2)
43.98	-17	22.77	52.16	0.0542	0.0265
43.48	-17	22.27	51.66	0.0483	0.0237
42.98	-17	21.77	51.16	0.0431	0.0211
42.48	-17	21.27	50.66	0.0384	0.0188
41.98	-17	20.77	50.16	0.0342	0.0167
41.48	-17	20.27	49.66	0.0305	0.0149
40.98	-17	19.77	49.16	0.0272	0.0133
40.48	-17	19.27	48.66	0.0242	0.0119
39.98	-17	18.77	48.16	0.0216	0.0106
39.48	-17	18.27	47.66	0.0192	0.00942
38.98	-17	17.77	47.16	0.0171	0.00839
38.48	-17	17.27	46.66	0.0152	0.00748
37.98	-17	16.77	46.16	0.0136	0.00667
37.48	-17	16.27	45.66	0.0121	0.00594
36.98	-17	15.77	45.16	0.0108	0.00530
36.48	-17	15.27	44.66	0.00965	0.00472
35.98	-17	14.77	44.16	0.00860	0.00421
35.48	-17	14.27	43.66	0.00766	0.00375
34.98	-17	13.77	43.16	0.00683	0.00334
34.48	-17	13.27	42.66	0.00609	0.00298
33.98	-17	12.77	42.16	0.00542	0.00265

*Incorporates Coax Feeder Loss

As is obvious, neither the S_{nf} or S_{ff} values (at distances R_{nf} or R_{ff}) exceed even the uncontrolled limit of 1 mW/cm^2. Therefore, no minimum distance criteria of separation will apply for individuals located in directions outside the antenna's main beam.

Summary

This exhibit presents the radiation hazard analysis for Row 44 's GSAA transmitter transmitting at HPT output/transmit power levels of 33.98 to 43.98 dBW in increments of 0.5 dB. Considering the worst-cases, individuals positioned in the direction of the main beam of the antenna, and in the controlled exposure environment should be at least 7.22 meters (23.7 feet) away from the antenna aperture (for a six minute duration). Under the same circumstance, individuals in an uncontrolled exposure environment should be at least 13.1 meters (43.1 feet) away from the antenna aperture (for a 30 minute duration).

For individuals located in directions which are outside the antenna's main beam, no minimum distance of separation is applicable.