RADIATION HAZARD ANALYSIS

In this document RF radiation power density levels in different regions around the antenna are calculated for the 1.05m 20W user terminal and it is demonstrated how compliance will be achieved with respect to the RF radiation exposure requirements of §1.1310 by using a combination of installing fences around the antenna and installing the antenna at a certain height.

The power density limit specified in §1.1310 is 1 mW/cm^2 for General Population (Uncontrolled Exposure) at transmitting frequency bands of the earth station in this application. **Error! Reference source not found.**1 shows the RF radiation power density calculations.[1]

Table 1: Maximum RF radiation power density calculations (main beam)

Antenna Parameters	
BUC power [W]	20
Feed horn and waveguide losses [dB]	0.6
Power fed to the antenna [W]	17.5
Antenna diameter [m]	1.05
Frequency [GHz]	29.7
Wavelength [m]	0.0101
Antenna efficiency	0.65
Antenna peak gain [dBi]	48.4
Radome loss [dB]	0.7
Antenna peak gain after radome [dBi]	47.7
Max EIRP [dBW]	60.1
FCC Limit for Maximum Permissible Exposure (MPE)	
Power Density Limit for General Population/Uncontrolled Exposure [mW/cm^2]	1
Power Density Calculations	
Maximum power density at the antenna reflector surface [mW/cm^2]	8.1
Maximum near-field power density [mW/cm^2]	5.3
Extent of near-field [m]	27.3
Maximum far-field power density [mW/cm^2]	1.9
Distance to the beginning of far-field [m]	65.5

From **Error! Reference source not found.**1 it can be seen that the calculated maximum power density exceeds the FCC limit of 1 mW/cm^2 for general population in the near-field, far-field, and antenna surface. In order to protect the general population, the antenna will be installed at a certain height and there will be fences around the antenna. There will also be warning signs on the fence to warn of high RF radiation levels inside the fenced area and close to the antenna. Below it is

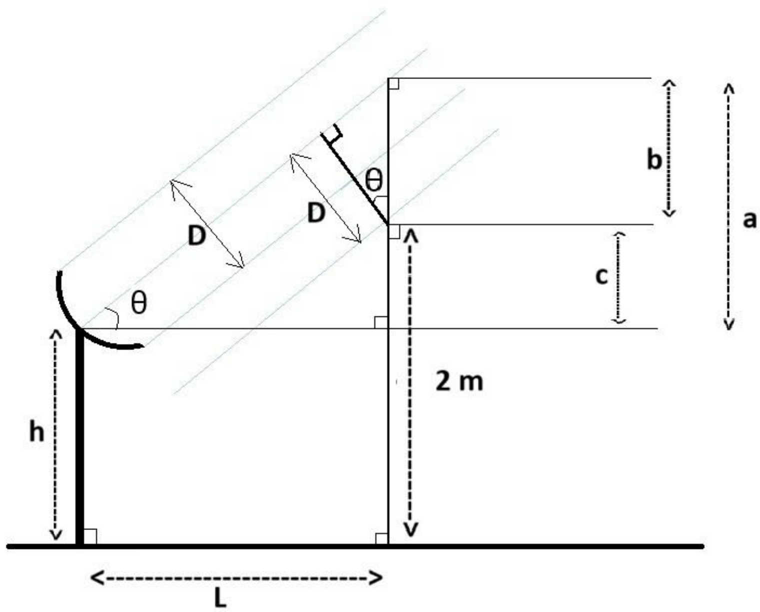
[1] For these calculations, the methodology described in the FCC's *OET Bulletin 65*, "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields" has been used.

explained how the distance of the fenced area from the antenna (around the antenna) is determined as a function of the height at which the antenna will be installed.

As stated in FCC's 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". This has been used in the calculations presented below. In this case, the power density level at one antenna diameter from the beam center will be 5.3/100 = 0.053 mW/cm^2 which is well below the General Population limit.

The minimum operating elevation angle of the antenna is 20 degrees. The maximum height of a typical person is considered as 2 m. The height of the antenna and the distance of the fenced area from the antenna are calculated so that the near-field power density at the edge of the fenced area at a height of 2 meters (and less) does not exceed the FCC limit of 1 mW/cm^2. Figure 1 shows the schematic for the geometry considered in the off-axis near-field power density calculation.

Figure 1: Diagram used in the calculation of off-axis near-field power density



In Figure 1:

- *h* is the height of the antenna reflector centre above the ground [m]
- *L* is the required distance of the fence from the antenna
- *D* is the antenna diameter
- *θ* is the antenna elevation angle

For a selected *h*, the parameters *a*, *b*, *c,* and *L* can be calculated as shown below:

$$L = \frac{a}{\tan(\theta)}$$ Equation (1)

$$b = \frac{D}{\cos(\theta)}$$ Equation (2)

$$c = 2 - h$$ Equation (3)

$$a = b + c$$ Equation (4)

Substituting b and c from Equations (2) and (3) into Equation (4) and the result into Equation (1) we get:

$$L = \frac{\frac{D}{\cos(\theta)} + 2 - h}{\tan(\theta)}$$ Equation (5)

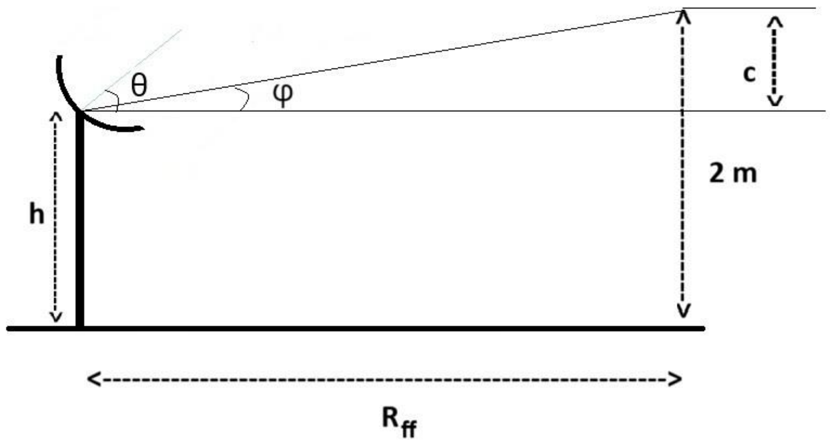
Equation (5) was used to calculate the required distance of the fence from the antenna (around the antenna) for a few choices of the antenna height (h). The results are shown in Table 2.

Table 2: Calculation of the distance of fence from the antenna (around the antenna)

Antenna diameter [m]	1.05	1.05	1.05	1.05
Minimum antenna elevation angle [deg]	20	20	20	20
Height of the antenna reflector centre above the ground [m]	**1.5**	**2**	**2.5**	**2.75**
Required distance of the fence from the antenna (around the antenna) [m]	**4.4**	**3.1**	**1.7**	**1.0**
Maximum near-field power density outside the fenced area at a height of 2m above ground (see Figure 1) [mW/cm^2]	0.053	0.053	0.053	0.053

For the calculation of the power density in the far-field region the off-axis gain of the antenna is considered (as recommended in FCC's OET Bulletin 65).
Figure 2 shows the diagram used for the calculation of the off-axis far-field power density at 2 meters height at the beginning of the far-field region.

Figure 2: Diagram for the off-axis power density calculations in the far-field



In
Figure 2 the antenna centre is at a height of h, the elevation angle of antenna is θ, and R_{ff} denotes the distance from the antenna to the beginning of the far-field region. The equations below show how the far-field power density is calculated at the beginning of the far-field at 2 meters above the ground.

$$\tan(\varphi) = \frac{c}{R_{ff}} \qquad \text{Equation (6)}$$

$$c = 2 - h \qquad \text{Equation (7)}$$

$$\text{Antenna off-axis angle} = \theta - \varphi \qquad \text{Equation (8)}$$

Previously in Table 1 the distance from the antenna to the beginning of the far-field region was calculated to be 65.5 m. For a few choices for the height of the antenna (*h*), Equations (6), (7), and (8) were used to calculate the off-axis angle and the far-field power density at 2 meters above the ground at the beginning of the far-field region. The results are shown in Table 3.

Table 3: Power density calculations in the far-field at a height of 2m above ground

Distance to the beginning of far-field [m]	65.5	65.5	65.5	65.5
Minimum antenna elevation angle [deg]	20	20	20	20
Height of the antenna reflector centre above the ground [m]	**1.5**	**2**	**2.5**	**2.75**
phi [deg]	0.44	0.00	-0.44	-0.66
Off-axis angle at the start of far-field region [deg]	19.56	20.00	20.44	20.66
Off-axis gain of the antenna at 2m height at the beginning of far-field region [deg]	0	0	0	0
BUC power [W]	20	20	20	20
Feed horn and waveguide losses [dB]	0.6	0.6	0.6	0.6
Power fed to the antenna [W]	17.5	17.5	17.5	17.5
Maximum far-field power density at a height of 2m above ground [mW/cm2]	0.00003	0.00003	0.00003	0.00003

From Table 2 and Table 3 it can be seen that a combination of installing the antenna at a certain height plus fencing around the antenna can ensure the public is protected. For instance, as shown in Table 2, if the antenna is installed at a height of 1.5 m above ground and the fence around the antenna is 4.4 m away from the antenna the public will be protected outside the fenced area. Similarly, if the antenna is installed at a height of 2.75 m above ground and the fence around the antenna is 1.0 m away from the antenna the public will be protected outside the fenced area. There will be warning signs installed on the fence to warn with respect to high radiation levels inside the fenced area. It is noted that the antenna will be installed where it is not blocked by buildings or other structures. If there are buildings or structures or higher altitudes in the vicinity of the antenna, the antenna will be installed high enough so that people in those buildings or structures or higher altitudes are not exposed to power densities higher than 1 mW/cm^2.

It will be ensured that any technician or personnel that enters the fenced area is not exposed to power density levels exceeding the exposure limit of §1.1310. One of the ways this will be accomplished is to turn off the transmitter once personnel enter the fenced area. It is noted that, as stated in §1.1310, the power density limit of 1 mW/cm^2 is for continuous exposure, that is, for indefinite time periods. Table 4 shows the power density limits of §1.1310 for the frequency bands of this earth station. According to §1.1310, power density levels higher than the limits are permitted for shorter exposure times, as long as the average exposure over a period not more than the specified averaging time in Table 4 is less than the exposure limits. Earlier in Table 1 it was shown that the maximum near-field power density is 5.3 mW/cm^2. Therefore, if the transmitter is turned off within 5 minutes after personnel enter the fenced area the maximum near-field power density averaged over 30 minutes will be $5.3 \times \frac{5}{30} = 0.88$ mW/cm^2 which is less than the required limit of 1 mW/cm^2 (The personnel will also be trained to ensure they avoid exposing themselves to the area between the antenna surface and the antenna feed until the transmitter is turned off). There will be warning signs at the site for the employees as well to ensure they follow the procedure if they need to enter the fenced area.

Table 4: FCC Limit for Maximum Permissible Exposure (MPE)

	Power Density [mW/cm^2]	Averaging Time [Minutes]
Limits for Occupational/Controlled Exposure	5	< 6
Limits for General Population/Uncontrolled Exposure	1	< 30