RADIATION HAZARD STUDY
For
AvL Technologies 2.0-meter Ku-Band Antenna

This analysis predicts the radiation levels around a proposed earth station complex, comprised of one or more aperture (reflector) type antennas. This report is developed in accordance with the prediction methods contained in OET Bulletin No. 65, "Evaluating Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields," Edition 97-01, pp 26-30. The maximum level of non-ionizing radiation to which employees may be exposed is limited to a power density level of 5 milliwatts per square centimeter (5 mW/cm^2) averaged over any 6 minute period in a **controlled environment** and the maximum level of non-ionizing radiation to which the general public is exposed is limited to a power density level of 1 milliwatt per square centimeter (1 mW/cm^2) averaged over any 30 minute period in a **uncontrolled environment**. Note that the worse-case radiation hazards exist along the beam axis. Under normal circumstances, it is highly unlikely that the antenna axis will be aligned with any occupied area since that would represent a blockage to the desired signals, thus rendering the link unusable.

Earth Station Technical Parameter Table

Antenna Actual Diameter		2.0 meters
Antenna Surface Area		3.1416 sq. meters
Antenna Isotropic Gain		47.5 dBi
Number of Identical Adjacent Antennas*		1
Nominal Antenna Efficiency (ε)		64.2
Nominal Frequency		14125 MHz
Nominal Wavelength (λ)		0.0212 meters
Maximum Transmit Power / Carrier		25 Watts
Number of Carriers		1
Total Transmit Power		25 Watts
W/G Loss from Transmitter to Feed		0.5 dB
Total Feed Input Power		22.3 Watts
Near Field Limit	$R_{nf} = D^2/4\lambda =$	47.1 Meters
Far Field Limit	$R_{ff} = 0.6\ D^2/\lambda =$	113.1 Meters
Transition Region	R_{nf} to R_{ff}	

*The Radiation Levels will be increased directly by the number of antennas indicated, on the assumption that all antennas may illuminate the same area.

In the following sections, the power density in the above regions, as well as other critically important areas will be calculated and evaluated. The calculations are done in the order discussed in OET Bulletin 65. In addition to the input parameters above, input cells are provided below for the user to evaluate the power density at specific distances or angles.

1.0 At the Antenna Surface

The power density at the reflector surface can be calculated from the expression:

PD_{refl} = 4P/A = 2.84 mW/cm² (1)

Where: P = total power at feed, milliwatts

A = Total area of reflector, sq. cm

In the normal range of transmit powers for satellite antennas, the power densities at or around the reflector surface is expected to exceed safe levels. This area will not be accessible to the general public. Operators and technicians should receive training specifying this area as a high exposure area. Procedures must be established that will assure that all transmitters are rerouted or turned off before access by maintenance personnel to this area is possible.

2.0 On-Axis Near Field Region

The geometrical limits of the radiated power in the near field approximate a cylindrical volume with a diameter equal to that of the antenna. In the near field, the power density is neither uniform nor does its value vary uniformly with distance from the antenna. For the purpose of considering radiation hazard it is assumed that the on-axis flux density is at its maximum value throughout the length of this region. The length of this region, i.e., the distance from the antenna to the end of the near field, is computed as Rnf above.

The maximum power density in the near field is given by:

$PD_{nf} = (16\,\varepsilon\,P)/(\pi D^2)$ = 1.82 mW/cm² (2)

From 0 to 47.1 meters

Evaluation

Uncontrolled Environment:	Exceeds FCC Limits
Controlled Environment:	Within FCC Limits

3.0 On-Axis Transition Region

The transition region is located between the near and far field regions. As stated in Bulletin 65, the power density begins to vary inversely with distance in the transition region. The maximum power density in the transition region will not exceed that calculated for the near field region, and the transition region begins at that value. The maximum value for a given distance within the transition region may be computed for the point of interest according to:

PD_t = $(PD_{nf})(R_{nf})/R$ = dependent on R (3)

where: PD_{nf} = near field power density

R_{nf} = near field distance

R = distance to point of interest

For: $47.1 < R < 113.1$ meters

We use Eq (3) to determine the safe on-axis distances required for the two occupancy conditions:

Evaluation:

Uncontrolled Environment Safe Operating Distance,(meters), R_{safeu}:	85.8 meters
Controlled Environment Safe Operating Distance,(meters), R_{safec}:	0.0 meters

4.0 On-Axis Far-Field Region

The on-axis power density in the far field region (PD_{ff}) varies inversely with the square of the distance as follows:

PD_{ff} = $PG/(4\,\pi\,R^2)$ = dependent on R (4)

where: P = total power at feed

G = Numeric Antenna gain in the direction of interest relative to isotropic radiator

R = distance to the point of interest

For: $R > R_{ff}$ = 113.1 meters

PD_{ff} = 0.78 mW/cm² at R_{ff}

We use Eq (4) to determine the safe on-axis distances required for the two occupancy conditions:

Evaluation:

Uncontrolled Environment Safe Operating Distance,(meters), R_{safeu} :	See Section 3
Controlled Environment Safe Operating Distance,(meters), R_{safec} :	See Section 3

5.0 Off-Axis Levels at the Far Field Limit and Beyond

In the far field region, the power is distributed in a pattern of maxima and minima (sidelobes) as a function of the off-axis angle between the antenna center line and the point of interest. Off-axis power density in the far field can be estimated using the antenna radiation patterns prescribed for the antenna in use. Usually this will correspond to the antenna gain pattern envelope defined by the FCC or the ITU, which takes the form of:

$G_{off} = 32 - 25\log(\Theta)$

for Θ from 1 to 48 degrees; -10 dBi from 48 to 180 degrees

(Applicable for commonly used satellite transmit antennas)

Considering that satellite antenna beams are aimed skyward, power density in the far field will usually not be a problem except at low look angles. In these cases, the off axis gain reduction may be used to further reduce the power density levels.

For example: At one (1) degree off axis At the far-field limit, we can calculate the power density as:

G_{off} = 32 - 25log(1) = 32 - 0 dBi = 1585 numeric

$$PD_{1\ deg\ off\text{-}axis} = PD_{ff} \times 1585/G = 0.02\ mW/cm^2 \qquad (5)$$

6.0 Off-Axis power density in the Near Field and Transitional Regions

According to Bulletin 65, off-axis calculations in the near field may be performed as follows: assuming that the point of interest is at least one antenna diameter removed from the center of the main beam, the power density at that point is at least a factor of 100 (20 dB) less than the value calculated for the equivalent on-axis power density in the main beam. Therefore, for regions at least D meters away from the center line of the dish, whether behind, below, or in front under of the antenna's main beam, the power density exposure is at least 20 dB below the main beam level as follows:

$PD_{nf(off\text{-}axis)} = PD_{nf}/100 =$ 0.02 mW/cm² at D off axis (6)

See page 5 for the calculation of the distance vs elevation angle required to achieve this rule for a given object height.

7.0 Region Between the Feed Horn and Sub-reflector

Transmissions from the feed horn are directed toward the subreflector surface, and are confined within a conical shape defined by the feed horn. The energy between the feed horn and subreflector is conceded to be in excess of any limits for maximum permissible exposure. This area will not be accessible to the general public. Operators and technicians should receive training specifying this area as a high exposure area. Procedures must be established that will assure that all transmitters are rerouted or turned off before access by maintenance personnel to this area is possible.

Note 1:
Mitigation of the radiation level may take several forms. First, check the distance from the antenna to the nearest potentially occupied area that the antenna could be pointed toward, and compare to the distances appearing in Sections 2, 3 & 4. If those distances lie within the potentially hazardous regions, then the most common solution would be to take steps to insure that the antenna(s) are not capable of being pointed at those areas while RF is being transmitted. This may be accomplished by setting the tracking system to not allow the antenna be pointed below certain elevation angles. Other techniques, such as shielding may also be used effectively.

Evaluation of Safe Occupancy Area in Front of Antenna

The distance (S) from a vertical axis passing through the dish center to a safe off axis location in front of the antenna can be determined based on the dish diameter rule (Item 6.0). Assuming a flat terrain in front of the antenna, the relationship is:

$$S = (D/ \sin \alpha) + (2h - D - 2)/(2 \tan \alpha) \qquad (7)$$

Where: α = minimum elevation angle of antenna
D = dish diameter in meters
h = maximum height of object to be cleared, meters

For distances equal or greater than determined by equation (7), the radiation hazard will be below safe levels for all but the most powerful stations (> 4 kilowatts RF at the feed).

For	D =	2.0	meters
	h =	2	meters

Then:

α	S	
5	22.9	meters
10	11.5	meters
15	7.7	meters
20	5.8	meters
25	4.7	meters
30	4.0	meters
45	2.8	meters

Radiation hazard warning signs are posted at all access points to the roof of the vehicle to prevent anyone occupying the area in front of the antenna while it is operating. Due to the height of the antenna location no occupancy is expected within the area in front of the antenna within the limits prescribed above at the lowest elevation angle required.