Radiation Hazard Analysis

SoNY Miralite 3.7m

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 an 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:	3.7 meters
Antenna Surface Area:	10.8 meters
Antenna Isotropic Gain:	52.6 dBi
Number of Identical Adjacent Antennas:	1
Nominal Antenna Efficiency (ε):	60%
Nominal Frequency:	14.25 GHz
Nominal Wavelength (λ):	0.0211 meters
Maximum Transmit Power / Carrier:	45 Watts
Number of Carriers:	1
Total Transmit Power:	45Watts
W/G Loss from Transmitter to Feed:	0.0 dB
Total Feed Input Power:	45 Watts
Near Field Limit:	$R_{nf} = D^2/4\lambda$ =162.5 meters
Far Field Limit:	$R_{ff} = 0.6\ D^2/\lambda$ = 390 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:

$PD_{refl} = 4P/A =$ **1.674** 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:

$PD_{nf} = (16\varepsilon P)/(\pi D^2) =$ 1.004 mW/cm² (2)
from 0 to 162.5 meters

Evaluation
Uncontrolled Environment: Complies to FCC Limits
Controlled Environment: Complies to 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: $162.5 < R < 390$ 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}: 163.3 meters
Controlled Environment Safe Operating Distance,(meters), R_{safec}: 32.6 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: $R > R_{ff} =$ 1396 meters
PD_{ff} = **0.430** 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 FarField 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:

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

$PD_{1\text{ deg off-axis}} = PD_{ff} x\ 1585/G =$ **0.0037** mW/cm² (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:

$PD_{nf(off\text{-}axis)} = PD_{nf} /100 =$ **0.01004** mW/cm² at D off axis (6)

See Note 1 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 have received training specifying this area as a high exposure area. Procedures have been established that will assure that all transmitters are rerouted or turned off before access by maintenance personnel to this area is possible.

8.0 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:

$S = (D/ \sin \alpha) + (2h - D - 2)/(2 \tan \alpha)$ (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 = 7.0 meters
h = 2 meters

Then:

α S

El Angle	Distance to Safe Area	
6.5	25.2	m
20	8.5	m
25	6.9	m
30	5.9	m
35	5.2	m

Suitable fencing or other barrier is installed to prevent casual occupancy of the area in front of the antenna within the limits prescribed above at the lowest elevation angle required.

9.0 Summary of Results

The table below summarizes all calculations:

Summary of All RadHaz Parameters		SoNY Miralite 3.7m		
Parameter	Abbr.	Value	Units	Formula
Dish #		Miralite		
Antenna Diameter	Df	3.7	meters	
Antenna Centerline	h	2.4	meters	
Antenna Surface Area	Sa	10.8	$meters^2$	$(\pi * D^2)/ 4$
Antenna Ground Elevation	GE	0.0	meters	
Frequency of Operation	f	14.25	GHz	
Wavelength	λ	0.0211	meters	c / f
HPA Output Power	P_{HPA}	45.0	watts	
HPA to Antenna Loss	L_{tx}	0.0	dB	
Transmit Power at Flange	P	16.5	dBW	$10 * Log(P_{HPA}) - L_{tx}$
		45.00	watts	
Antenna Gain	G_{es}	52.6	dBi	
		182911.8	n/a	
PI	π	3.1415927	n/a	
Antenna Aperture Efficiency	eff	60%	n/a	$G_{es} / (PI * Df / \lambda)^2$
1. Reflector Surface Region Calculations				
Reflector Surface Power Density	Was	16.74	W/m^2	$(16 * P)/(\pi * D^2)$
		1.674	mW/cm^2	
2. On-Axis Near Field Calculations				
Extent of Near Field	Rn	162.57	meters	$D^2 / (4 * \lambda)$
		533.23	feet	
Near Field Power Density	Wn	10.04	W/m^2	$(16 * eff * P)/ (\pi * D^2)$
		1.004	mW/cm^2	
3. On-Axis Transition Region Calculations				
Extent of Transition Region (min)	Rtr	162.57	meters	$D^2 / (4 x \lambda)$
Extent of Transition Region (min)		533.23	feet	
Extent of Transition Region (max)	Rtr	390.17	meters	$(0.6 * D^2) /\lambda$
Extent of Transition Region (max)		1279.74	feet	
Worst Case Transition Region Power Density	Wtr	10.04	W/m^2	$(16 * eff * P)/ (\pi * D^2)$
		1.004	mW/cm^2	
Uncontrolled Environment Safe Operating Distance	Rsu	163.29	m	=(Wn)*(Rnf)/Rsu
Controlled Environment Safe Operating Distance	Rsc	32.66	m	=(PDnf)*(Rnf)/Rsc
4. On-Axis Far Field Calculations				
Distance to the Far Field Region	Rf	390.2	meters	$(0.6 * D^2) /\lambda$
		1279.74	feet	
On-Axis Power Density in the Far Field	Wf	4.30	W/m^2	$(G_{es} * P) / (4 * \pi * Rf^2)$
		0.430	mW/cm^2	
5. Off-Axis Levels at the Far Field Limit and Beyond				
Reflector Surface Power Density	Ws	0.037	W/m^2	$(G_{es} * P) / (4 * \pi * Rf^2)$*(Goa/Ges)
Goa/Ges at example angle θ 1 degree		0.009		Goa = 32 - 25*log(θ)
		0.0037	mW/cm^2	
6. Off-axis Power Density in the Near Field and Transitional Regions Calculations				
Power density 1/100 of Wn for one diameter removed	Ws	0.1004	W/m^2	$((16 * eff * P)/ (\pi * D^2))/100$
		0.01004	mW/cm^2	
7. Region Between Antenna and Ground Calculations				
Reflector Surface Power Density	Ws	4.19	W/m^2	$(4 * P)/(\pi * D^2)$
		0.419	mW/cm^2	
8. Safe Distances from Earth Station				S = (D/ sin α) + (2h - D - 2)/(2 tan α)
α = minimum elevation angle of antenna		16.5	deg	
h = maximum height of object to be cleared, meters		2	m	
elevation angle	6.5	25.2	m	
	20	8.5	m	
	25	6.9	m	
	30	5.9	m	
	35	5.2	m	
Note: Maximum FCC power density limits for 6 GHz is 1 mW/cm^2 for general population/uncontrolled exposure as per				
FCC OE&T Bulletin No. 65, Edition 97-01 August 1997, Appendix A page 67.				

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.

Radiation Hazard Analysis

SoNY Prodelin 3.8m

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 an 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:	3.8 meters
Antenna Surface Area:	11.3 meters
Antenna Isotropic Gain:	53.2 dBi
Number of Identical Adjacent Antennas:	1
Nominal Antenna Efficiency (ε):	65%
Nominal Frequency:	14.25 GHz
Nominal Wavelength (λ):	0.0211 meters
Maximum Transmit Power / Carrier:	40.0 Watts
Number of Carriers:	1
Total Transmit Power:	40.00 Watts
W/G Loss from Transmitter to Feed:	0.0 dB
Total Feed Input Power:	40.00 Watts
Near Field Limit:	$R_{nf} = D^2/4\lambda$ =171.48 meters
Far Field Limit:	$R_{ff} = 0.6\ D^2/\lambda$ = 411.5 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:

$PD_{refl} = 4P/A =$ **1.411** mW/cm^2 (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:

$PD_{nf} = (16\varepsilon P)/(\pi D^2) =$ **0.917** mW/cm^2 (2)
from 0 to 171.48 meters

Evaluation
Uncontrolled Environment: Complies to FCC Limits
Controlled Environment: Complies to 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: $171.48 < R < 411.54$ 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}: 157.25 meters
Controlled Environment Safe Operating Distance,(meters), R_{safec}: 31.45 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: $R > R_{ff} =$ 411.5 meters
$PD_{ff} =$ **0.393** mW/cm^2 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:

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

$PD_{1\ deg\ off\text{-}axis} = PD_{ff} x\ 1585/G =$ **0.0030** mW/cm² (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:

$PD_{nf(off\text{-}axis)} = PD_{nf} /100 =$ **0.00917** mW/cm² at D off axis (6)

See Note 1 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 have received training specifying this area as a high exposure area. Procedures have been established that will assure that all transmitters are rerouted or turned off before access by maintenance personnel to this area is possible.

8.0 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:

$S = (D/ \sin \alpha) + (2h - D - 2)/(2 \tan \alpha)$ (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 = 3.8 meters
h = 2 meters

Then:

α S

El Angle	Distance to Safe Area	
6.5	25.7	m
20	8.6	m
25	7.1	m
30	6.0	m
35	5.3	m

Suitable fencing or other barrier is installed to prevent casual occupancy of the area in front of the antenna within the limits prescribed above at the lowest elevation angle required.

9.0 Summary of Results

The table below summarizes all calculations:

Summary of All RadHaz Parameters		SoNY Prodelin 3.8m		
Parameter	Abbr.	Value	Units	Formula
Dish #		Miralite		
Antenna Diameter	Df	3.8	meters	
Antenna Centerline	h	2.5	meters	
Antenna Surface Area	Sa	11.3	$meters^2$	$(\pi * D^2)/4$
Antenna Ground Elevation	GE	0.0	meters	
Frequency of Operation	f	14.25	GHz	
Wavelength	λ	0.0211	meters	c / f
HPA Output Power	P_{HPA}	40.0	watts	
HPA to Antenna Loss	L_{tx}	0.0	dB	
Transmit Power at Flange	P	16.0	dBW	$10 * Log(P_{HPA}) - L_{tx}$
		40.00	watts	
Antenna Gain	G_{es}	53.2	dBi	
		209010.2	n/a	
PI	π	3.1415927	n/a	
Antenna Aperture Efficiency	eff	65%	n/a	$G_{es} / (PI * Df / \lambda)^2$
1. Reflector Surface Region Calculations				
Reflector Surface Power Density	Was	14.11	W/m^2	$(16 * P)/(\pi * D^2)$
		1.411	mW/cm^2	
2. On-Axis Near Field Calculations				
Extent of Near Field	Rn	171.48	meters	$D^2 / (4 * \lambda)$
		562.44	feet	
Near Field Power Density	Wn	9.17	W/m^2	$(16 * eff * P)/(\pi * D^2)$
		0.917	mW/cm^2	
3. On-Axis Transition Region Calculations				
Extent of Transition Region (min)	Rtr	171.48	meters	$D^2 / (4 x \lambda)$
Extent of Transition Region (min)		562.44	feet	
Extent of Transition Region (max)	Rtr	411.54	meters	$(0.6 * D^2)/\lambda$
Extent of Transition Region (max)		1349.85	feet	
Worst Case Transition Region Power Density	Wtr	9.17	W/m^2	$(16 * eff * P)/(\pi * D^2)$
		0.917	mW/cm^2	
Uncontrolled Environment Safe Operating Distance	Rsu	157.25	m	=(Wn)*(Rnf)/Rsu
Controlled Environment Safe Operating Distance	Rsc	31.45	m	=(PDnf)*(Rnf)/Rsc
4. On-Axis Far Field Calculations				
Distance to the Far Field Region	Rf	411.5	meters	$(0.6 * D^2)/\lambda$
		1349.85	feet	
On-Axis Power Density in the Far Field	Wf	3.93	W/m^2	$(G_{es} * P) / (4 * \pi * Rf^2)$
		0.393	mW/cm^2	
5. Off-Axis Levels at the Far Field Limit and Beyond				
Reflector Surface Power Density	Ws	0.030	W/m^2	$(G_{es} * P) / (4 * \pi * Rf^2)*(Goa/Ges)$
Goa/Ges at example angle θ 1 degree		0.008		$Goa = 32 - 25*log(\theta)$
		0.0030	mW/cm^2	
6. Off-axis Power Density in the Near Field and Transitional Regions Calculations				
Power density 1/100 of Wn for one diameter removed	Ws	0.0917	W/m^2	$((16 * eff * P)/(\pi * D^2))/100$
		0.00917	mW/cm^2	
7. Region Between Antenna and Ground Calculations				
Reflector Surface Power Density	Ws	3.53	W/m^2	$(4 * P)/(\pi * D^2)$
		0.353	mW/cm^2	
8. Safe Distances from Earth Station				$S = (D/ \sin \alpha) + (2h - D - 2)/(2 \tan \alpha)$
α = minimum elevation angle of antenna		16.5	deg	
h = maximum height of object to be cleared, meters		2	m	
elevation angle	16.5	10.3	m	
	20	8.6	m	
	25	7.1	m	
	30	6.0	m	
	35	5.3	m	
Note: Maximum FCC power density limits for 6 GHz is 1 mW/cm^2 for general population/uncontrolled exposure as per				
FCC OE&T Bulletin No. 65, Edition 97-01 August 1997, Appendix A page 67.				

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.

Radiation Hazard Analysis

SoNY S-A 7m

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 an 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:	7.0 meters
Antenna Surface Area:	38.5 meters
Antenna Isotropic Gain:	58 dBi
Number of Identical Adjacent Antennas:	2
Nominal Antenna Efficiency (ε):	58%
Nominal Frequency:	14.25 GHz
Nominal Wavelength (λ):	0.0211 meters
Maximum Transmit Power / Carrier:	112 Watts
Number of Carriers:	1
Total Transmit Power:	112 Watts
W/G Loss from Transmitter to Feed:	0.0 dB
Total Feed Input Power:	112 Watts
Near Field Limit:	$R_{nf} = D^2/4\lambda$ =581 meters
Far Field Limit:	$R_{ff} = 0.6\ D^2/\lambda$ = 1396 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:

$PD_{refl} = 4P/A =$ **1.164** mW/cm^2 (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:

$PD_{nf} = (16\varepsilon P)/(\pi D^2) =$ **0.675** mW/cm^2 (2)
from 0 to 581 meters

Evaluation
Uncontrolled Environment: Complies to FCC Limits
Controlled Environment: Complies to 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: $581 < R < 1396$ 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}: 392 meters
Controlled Environment Safe Operating Distance,(meters), R_{safec}: 78.5 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: $R > R_{ff}$ = 1396 meters
PD_{ff} = **0.289** mW/cm^2 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 FarField 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:

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

$PD_{1\ deg\ off\text{-}axis} = PD_{ff} x\ 1585/G =$ **0.0007** mW/cm² (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:

$PD_{nf(off\text{-}axis)} = PD_{nf} /100 =$ **0.00675** mW/cm² at D off axis (6)

See Note 1 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 have received training specifying this area as a high exposure area. Procedures have been established that will assure that all transmitters are rerouted or turned off before access by maintenance personnel to this area is possible.

8.0 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:

$S = (D/ \sin \alpha) + (2h - D - 2)/(2 \tan \alpha)$ (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 = 7.0 meters
h = 2 meters

Then:

α S

El Angle	Distance to Safe Area	
6.5	39.9	m
20	13.6	m
25	11.2	m
30	9.7	m
35	8.6	m

Suitable fencing or other barrier is installed to prevent casual occupancy of the area in front of the antenna within the limits prescribed above at the lowest elevation angle required.

9.0 Summary of Results

The table below summarizes all calculations:

Summary of All RadHaz Parameters		SoNY S-A 7m		
Parameter	Abbr.	Value	Units	Formula
Dish #		Miralite		
Antenna Diameter	Df	7	meters	
Antenna Centerline	h	4.6	meters	
Antenna Surface Area	Sa	38.5	$meters^2$	$(\pi * D^2)/4$
Antenna Ground Elevation	GE	0.0	meters	
Frequency of Operation	f	14.25	GHz	
Wavelength	λ	0.0211	meters	c / f
HPA Output Power	P_{HPA}	112.0	watts	
HPA to Antenna Loss	L_{tx}	0.0	dB	
Transmit Power at Flange	P	20.5	dBW	$10 * Log(P_{HPA}) - L_{tx}$
		112.00	watts	
Antenna Gain	G_{es}	58.0	dBi	
		632864.9	n/a	
PI	π	3.1415927	n/a	
Antenna Aperture Efficiency	eff	58%	n/a	$G_{es} / (PI * Df / \lambda)^2$
1. Reflector Surface Region Calculations				
Reflector Surface Power Density	Was	11.64	W/m^2	$(16 * P)/(\pi * D^2)$
		1.164	mW/cm^2	
2. On-Axis Near Field Calculations				
Extent of Near Field	Rn	581.88	meters	$D^2 / (4 * \lambda)$
		1908.55	feet	
Near Field Power Density	Wn	6.75	W/m^2	$(16 * eff * P)/(\pi * D^2)$
		0.675	mW/cm^2	
3. On-Axis Transition Region Calculations				
Extent of Transition Region (min)	Rtr	581.88	meters	$D^2 / (4 x \lambda)$
Extent of Transition Region (min)		1908.55	feet	
Extent of Transition Region (max)	Rtr	1396.50	meters	$(0.6 * D^2) / \lambda$
Extent of Transition Region (max)		4580.52	feet	
Worst Case Transition Region Power Density	Wtr	6.75	W/m^2	$(16 * eff * P)/(\pi * D^2)$
		0.675	mW/cm^2	
Uncontrolled Environment Safe Operating Distance	Rsu	392.87	m	=(Wn)*(Rnf)/Rsu
Controlled Environment Safe Operating Distance	Rsc	78.57	m	=(PDnf)*(Rnf)/Rsc
4. On-Axis Far Field Calculations				
Distance to the Far Field Region	Rf	1396.5	meters	$(0.6 * D^2) / \lambda$
		4580.52	feet	
On-Axis Power Density in the Far Field	Wf	2.89	W/m^2	$(G_{es} * P) / (4 * \pi * Rf^2)$
		0.289	mW/cm^2	
5. Off-Axis Levels at the Far Field Limit and Beyond				
Reflector Surface Power Density	Ws	0.007	W/m^2	$(G_{es} * P) / (4 * \pi * Rf^2)*(Goa/Ges)$
Goa/Ges at example angle θ 1 degree		0.003		$Goa = 32 - 25*log(\theta)$
		0.0007	mW/cm^2	
6. Off-axis Power Density in the Near Field and Transitional Regions Calculations				
Power density 1/100 of Wn for one diameter removed	Ws	0.0675	W/m^2	$((16 * eff * P)/(\pi * D^2))/100$
		0.00675	mW/cm^2	
7. Region Between Antenna and Ground Calculations				
Reflector Surface Power Density	Ws	2.91	W/m^2	$(4 * P)/(\pi * D^2)$
		0.291	mW/cm^2	
8. Safe Distances from Earth Station				$S = (D/ \sin \alpha) + (2h - D - 2)/(2 \tan \alpha)$
α = minimum elevation angle of antenna		16.5	deg	
h = maximum height of object to be cleared, meters		2	m	
elevation angle	6.5	39.9	m	
	20	13.6	m	
	25	11.2	m	
	30	9.7	m	
	35	8.6	m	
Note: Maximum FCC power density limits for 6 GHz is 1 mW/cm^2 for general population/uncontrolled exposure as per				
FCC OE&T Bulletin No. 65, Edition 97-01 August 1997, Appendix A page 67.				

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.