

# **Radiation Hazard Analysis**

## **Fixed Customer Premises Earth Station Terminal**

### **Introduction**

This analysis calculates the non-ionizing radiation levels for a WB Holdings 1, LLC (“WB Holdings”) fixed customer premises earth station terminal (“CP terminal”). The calculations performed in this analysis comply with the methods described in FCC Office of Engineering and Technology Bulletin, Number 65 (Edition 97-01) (“Bulletin 65”). This analysis demonstrates that WB Holdings' CP terminals are compliant and will not result in exposure levels exceeding the applicable radiation hazard limits.

Bulletin 65 and section 1.1310 of the Commission's rules specify two separate tiers of exposure limits: one for Occupational/Controlled Exposures and one for General Population/Uncontrolled Exposures. Limits for Occupational/Controlled Exposures apply in situations when persons are exposed as a consequence of their employment and are fully aware of and can control their exposure. These limits also apply in situations when a person is transient through a location where such limits would otherwise apply provided the person is made aware of the potential for exposure. The limits for General Population/Uncontrolled Exposure apply in situations in which the general public may be exposed, or in which persons that 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. WB Holdings will typically deploy its CP terminals in General Population/Uncontrolled Environments. Accordingly, this analysis discusses only the Maximum Permissible Exposure (“MPE”) limit for those types of exposures, which is a power density equal to 1 milliwatt per centimeter squared averaged over a thirty minute period.

As described in the definitional section of Appendix A, this report analyzes the maximum power density levels in the vicinity of a CP terminal antenna in five regions: (1) the far field, (2) the near field, (3) the transition region between near field and far field, (4) near the main reflector surface, and (5) between the main reflector and the feed. These radiation regions were analyzed using the definitions and formulas in Bulletin 65 for aperture antennas. The results of this analysis are summarized in Tables 1 and 2 in Appendix A, which identify the potential exposure under nominal operating conditions and worst-case conditions, respectively.

### **CP Terminal Description**

The CP terminal transmits bursts of information at designated times that are assigned to the terminal by the network. The length and carrier frequency of each transmission burst depend on the CP terminal's mode of operation. There are three modes of operation (a) Idle Mode, during which the CP terminal is not in active use; (b) Normal Mode, when there terminal is actively used under typical network loading conditions; and (c) High Capacity Mode, When the terminal is actively used under maximum uplink data transfer conditions.

In Idle Mode, the CP terminal transmits only timing and system information to the network for 0.4 millisecond every 640 ms seconds. The average duty cycle (ratio of transmitter on to transmitter off time) in Idle Mode is 0.06%. In Normal Mode, the CP terminal transmits burst traffic to the network with a nominal duty cycle of 10%. To support heavy data upload requirements such as file transfer, current network configuration allows CP terminals to increase their transmit duty cycle to 30% in High Capacity Mode.

Tables 1 (clear sky condition) and Table 2 (heavy rain condition) provide a summary of the radiation exposure analysis for each of the three WildBlue operating modes, as well as 100% duty cycle – which in practice will not happen.

The CP terminal uses transmitter power control system to reduce uplink interference and mitigate the effects of changing atmospheric conditions. Under clear sky and cloudy conditions, all WildBlue 0.7 m CP terminals will transmit at a nominal power level of 1.25 watts or less. This includes terminals at the edge of beam locations. In rainy conditions, a CP terminal may increase its transmit power up to a maximum power level of 2.8 watts. This maximum power level is only reached when the link experiences extreme attenuation during periods of heavy rain or other extreme link fade conditions.

The CP terminal incorporates two “fail safe” features that limit the potential for human exposure. First, the transmitter is not enabled until the receive down link connection to the satellite has been established and an acceptable down link bit error rate has been achieved. The transmitter is disabled very quickly, in less than 40 milliseconds, if a loss of down connectivity occurs. Transmissions will not resume until approximately 10 seconds after downlink communications have been reestablished. Secondly, the terminal's transmitter is not capable of operating in a continuous transmit mode of operation. The CP terminal's outdoor unit incorporates a watchdog timer that will shut down the transmitter if it remains in a continuous transmit state for more than 10 seconds. Under these conditions, the transmitter will be turned off for 3 ms then resume normal operation after an internal reset has occurred.

### **Explanation of the Analysis**

The “Calculated Values” in Tables 1 and 2 (clear sky condition and heavy rain condition) are the exposure rates calculated using the formulae from the Office of Engineering and Technology Bulletin Number 65 (Edition 97-01) for a system with continuous (100% transmit duty cycle) transmission. The WildBlue network, however, is based on so-called “shared pipes”. WildBlue terminals transmit short bursts of data periodically as instructed by the network and are neither designed for nor capable of continuous transmission. Therefore, in order to compute the effective radiated energy of a WildBlue CP terminal, the terminal's transmitter duty cycle has been used to adjust the values calculated from Bulletin Number 65.

The columns in the tables labeled “Idle Mode,” “Normal Mode,” and “High Capacity Mode” reflect the total potential for human exposure based on the length of time that the CP terminal transmits energy during a rolling 30 minute period. In Idle Mode, the maximum transmitter duty cycle is 0.06% and therefore the values in the column labeled “Idle Mode” are equal to the calculated values multiplied by 0.0006. Similarly, in Normal Mode the maximum transmitter duty cycle is 10% and the values in the column labeled “Normal Mode” are equal to the Calculated Values multiplied by 0.1. And finally, in High Capacity Mode the transmitter duty cycle is 30% and the values in the column labeled “High Capacity Mode” are equal to the Calculated Values multiplied by 0.3.

The MPE level calculations for each of the three operating modes for conditions labeled “Between feed and reflector” are calculated based on the “fail safe” features of the WildBlue CP Terminal. When the receive signal is lost due to signal blockage, the transmitter is shut down until the receive downlink is restored. The transmitter is shutdown in less than 40 milliseconds of the loss of the downlink. Since the areas of high field strength near the reflector and the feed are very sensitive to blockage of the down link, this “fail safe” feature minimizes the potential for human exposure. If the

blockage due to human exposure occurs in these areas, the down link will be interrupted causing the transmitter to turn off almost immediately and it will remain off until the blockage is removed. After the blockage is removed, the CP terminal will have to reacquire the receive downlink and wait to be invited back into the network before the transmitter will be enabled. The complete downlink recovery time is 10 seconds. The values in the column labeled “Idle”, “Normal”, and “Worst Case” are multiplied by 0.004 because the transmitter cannot transmit more than 0.4% of any rolling 30 minute period with significant blockage near the sub reflector and between the sub-reflector and the feed.

### **Results of Analysis**

This analysis demonstrates that WB Holdings' CP terminal is not a radiation hazard because the terminal does not exceed the MPE limit of 1 milliwatt per centimeter squared averaged over a thirty minute period. As demonstrated in Tables 1-2, the area with the greatest field concentrations is between the feed and the reflector surface. The area in which these high field concentrations exist is very small in size, which limits the risk of human exposure to a person's hands or arms. If the down link (receive signal) is interrupted by an object in an area of high field concentration, the uplink (transmit signal) is shut down in less than 40 milliseconds and the receiver down link recovery time is 10 seconds. The uplink will remain off until the blockage is removed and the downlink recovery is complete. This feature, coupled with the terminal's use of uplink power control and non-continuous operation, ensures that the general population will not be exposed to harmful levels of radiation.

### **Conclusion**

This radiation hazard analysis demonstrates that WB Holdings' CP terminals will not result in exposure levels exceeding the applicable radiation hazard limits.

## Definitions

### 1) Far Field Region

The far field region extends outward from the main reflector, beginning at a distance of  $\frac{0.6 \cdot D_{maj}^2}{\lambda}$  meters where the larger diameter of the elliptical antenna is  $D_{maj}$ . The maximum power density is calculated using the equation recommended in Bulletin 65.

### 2) Near Field Region

The near field region is an elliptical volume co-incident with the boresight of the main beam extending outward from the main reflector the length of the near field  $\frac{D_{maj}^2}{4 \cdot \lambda}$  meters. The larger dimension ( $D_{maj}$ ) of the elliptical antenna is used in place of the diameter of a circular antenna to calculate the worst case length of the near field.

### 3) Transition Region

The transition region is located between the near field region and the far field region. This region has a power density that decreases inversely with increasing distance. Therefore the power density in the transition region will be less than the power density in the near field for the purpose of evaluating potential exposure.

### 4) Region Near the Main Reflector Surface

The power density near the main reflector surface can be estimated as equal to four times the power divided by the area of the main reflector surface, assuming that the illumination is uniform and that it would be possible to intercept equal amounts of energy radiating towards and reflected from the antenna surface.

### 5) Region between the Main Reflector and the Feed

The power radiated from the feed toward the reflector is conical in shape with the vertex at the feed. The maximum power is at the feed mouth and can be estimated as four times the transmit power divided by the area of the feed mouth.

**Table 1: Radiation from 0.7 m Fixed Terminal (Clear Sky)**

**Input Parameters**

Antenna Aperture Major Axis:	$D_{maj} := 77 \cdot cm$
Antenna Aperture Minor Axis:	$D_{min} := 72 \cdot cm$
Diameter of Feed Mouth:	$D_{feed} := 5.461 \cdot cm$
Frequency of Operation:	$F_{\text{ww}} := 30 \cdot GHz$
Max Power into Antenna:	$P := 1.25 \cdot W$
Aperture Efficiency:	$\eta := 0.5$

**Calculated Values**

Wavelength:	$\lambda := \frac{c}{F}$	$\lambda = 0.01 \cdot m$	
Area of Reflector:	$A_{ref} := \frac{\pi \cdot D_{maj} \cdot D_{min}}{4}$	$A_{ref} = 0.435 m^2$	
Area of Feed Mouth:	$A_{feed} := \pi \cdot \frac{D_{feed}^2}{4}$	$A_{feed} = 0.002 \cdot m^2$	
Antenna Gain:	$G_{\text{ww}} := \frac{\eta \cdot 4 \cdot \pi \cdot A_{ref}}{\lambda^2}$	$G = 2.74 \times 10^4$	$10 \cdot \log(G) = 44.377 \text{ dBi}$
Length of Near Field:	$R_{nf} := \frac{D_{maj}^2}{4 \cdot \lambda}$	$R_{nf} = 14.833 m$	
Beginning of Far Field:	$R_{ff} := 0.6 \cdot \frac{D_{maj}^2}{\lambda}$	$R_{ff} = 35.599 m$	

**Power Density Calculations**

Far Field:	100% Duty Cycle	Idle Mode	Normal Mode	High Capacity Mode
$S_{ff} := \frac{P \cdot G}{4 \cdot \pi \cdot R_{ff}^2}$	$S_{ff} = 0.215 \cdot \frac{mW}{cm^2}$	$S_{ff} \cdot 06\% = 0.013 \cdot \frac{mW}{cm^2}$	$S_{ff} \cdot 10\% = 0.022 \cdot \frac{mW}{cm^2}$	$S_{ff} \cdot 30\% = 0.065 \cdot \frac{mW}{cm^2}$
Near Field:	100% Duty Cycle	Idle Mode	Normal Mode	High Capacity Mode
$S_{nf} := \frac{4 \cdot \eta \cdot P}{A_{ref}}$	$S_{nf} = 0.574 \cdot \frac{mW}{cm^2}$	$S_{nf} \cdot 06\% = 0.034 \cdot \frac{mW}{cm^2}$	$S_{nf} \cdot 10\% = 0.057 \cdot \frac{mW}{cm^2}$	$S_{nf} \cdot 30\% = 0.172 \cdot \frac{mW}{cm^2}$

Transition Region: Power density is less than the maximum near field region power density and greater than the minimum far field region power density.

Main Reflector:	100% Duty Cycle	Idle Mode	Normal Mode	High Capacity Mode
$S_{ref} := \frac{4 \cdot P}{A_{ref}}$	$S_{ref} = 1.148 \cdot \frac{mW}{cm^2}$	$S_{ref} \cdot 0.6\% = 0.007 \cdot \frac{mW}{cm^2}$	$S_{ref} \cdot 10\% = 0.115 \cdot \frac{mW}{cm^2}$	$S_{ref} \cdot 30\% = 0.344 \cdot \frac{mW}{cm^2}$

Feed Mouth <sup>1</sup> :	100% Duty Cycle	Idle Mode	Normal Mode	High Capacity Mode
$S_{feed} := \frac{4 \cdot P}{A_{feed}}$	$S_{feed} = 213.47 \frac{mW}{cm^2}$	$S_{feed} \cdot 0.0024\% = 0.01 \frac{mW}{cm^2}$	$S_{feed} \cdot 0.04\% = 0.09 \frac{mW}{cm^2}$	$S_{feed} \cdot 0.12\% = 0.26 \frac{mW}{cm^2}$

**Table 2: Radiation from 0.7 m Fixed Terminal (Heavy Rain)**

**Input Parameters**

Antenna Aperture Major Axis:	$D_{maj} := 77 \cdot cm$
Antenna Aperture Minor Axis:	$D_{min} := 72 \cdot cm$
Diameter of Feed Mouth:	$D_{feed} := 5.461 \cdot cm$
Frequency of Operation:	$F := 30 \cdot GHz$
Max Power into Antenna:	$P := 2.8 \cdot W$
Aperture Efficiency:	$\eta := 0.5$

**Calculated Values**

Wavelength:	$\lambda := \frac{c}{F}$	$\lambda = 0.01 \cdot m$	
Area of Reflector:	$A_{ref} := \frac{\pi \cdot D_{maj} \cdot D_{min}}{4}$	$A_{ref} = 0.435 m^2$	
Area of Feed Mouth:	$A_{feed} := \pi \cdot \frac{D_{feed}^2}{4}$	$A_{feed} = 0.002 \cdot m^2$	
Antenna Gain:	$G := \frac{\eta \cdot 4 \cdot \pi \cdot A_{ref}}{\lambda^2}$	$G = 2.74 \times 10^4$	$10 \cdot \log(G) = 44.377 \text{ dBi}$
Length of Near Field:	$R_{nf} := \frac{D_{maj}^2}{4 \cdot \lambda}$	$R_{nf} = 14.833 m$	
Beginning of Far Field:	$R_{ff} := 0.6 \cdot \frac{D_{maj}^2}{\lambda}$	$R_{ff} = 35.599 m$	

**Power Density Calculations**

Far Field:	100% Duty Cycle	Idle Mode	Normal Mode	High Capacity Mode
$S_{ff} := \frac{P \cdot G}{4 \cdot \pi \cdot R_{ff}^2}$	$S_{ff} = 0.482 \cdot \frac{mW}{cm^2}$	$S_{ff} \cdot 06\% = 0.029 \cdot \frac{mW}{cm^2}$	$S_{ff} \cdot 10\% = 0.048 \cdot \frac{mW}{cm^2}$	$S_{ff} \cdot 30\% = 0.145 \cdot \frac{mW}{cm^2}$
Near Field:	100% Duty Cycle	Idle Mode	Normal Mode	High Capacity Mode
$S_{nf} := \frac{4 \cdot \eta \cdot P}{A_{ref}}$	$S_{nf} = 1.286 \cdot \frac{mW}{cm^2}$	$S_{nf} \cdot 06\% = 0.077 \cdot \frac{mW}{cm^2}$	$S_{nf} \cdot 10\% = 0.129 \cdot \frac{mW}{cm^2}$	$S_{nf} \cdot 30\% = 0.386 \cdot \frac{mW}{cm^2}$

Transition Region: Power density is less than the maximum near field region power density and greater than the minimum far field region power density.

Main Reflector:	100% Duty Cycle	Idle Mode	Normal Mode	High Capacity Mode
$S_{ref} := \frac{4 \cdot P}{A_{ref}}$	$S_{ref} = 2.572 \cdot \frac{mW}{cm^2}$	$S_{ref} \cdot 0.6\% = 0.015 \cdot \frac{mW}{cm^2}$	$S_{ref} \cdot 10\% = 0.257 \cdot \frac{mW}{cm^2}$	$S_{ref} \cdot 30\% = 0.772 \cdot \frac{mW}{cm^2}$

Feed Mouth <sup>1</sup> :	100% Duty Cycle	Idle Mode	Normal Mode	High Capacity Mode
$S_{feed} := \frac{4 \cdot P}{A_{feed}}$	$S_{feed} = 478.17 \frac{mW}{cm^2}$	$S_{feed} \cdot 0.0024\% = 0.01 \frac{mW}{cm^2}$	$S_{feed} \cdot 0.04\% = 0.19 \frac{mW}{cm^2}$	$S_{feed} \cdot 0.12\% = 0.57 \frac{mW}{cm^2}$