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eXchange RF Radiation Safety Analysis

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1 INTRODUCTION

In compliance with the U.S. Code of Federal Regulations, Title 47, Section 1.1307, this study analyzes RF radiation levels around the Connexion eXchange tail-mounted antenna. The FCC maximum permitted exposure level limits (MPE_{limit}) are based on limits recommended by the National Council on Radiation Protection and Measurements (NCRP), the limits developed by the Institute of Electrical and Electronics Engineers (IEEE) and adopted by the American National Standards Institute (ANSI).

2 RF RADIATION EXPOSURE LIMITS

Researchers have considered the biologic effects of radiofrequency (RF) energy for over 40 years. Various organizations and countries have developed recommended safe exposure standards for RF and microwave energy. In the U.S, the FCC guidelines for human exposure to RF electromagnetic fields were derived from the recommendations of two expert organizations, the Institute of Electrical and Electronic Engineers (IEEE) [1] and the National Council on Radiation Protection and Measurements (NCRP) [2]. The FCC adopted these guidelines on August, 1 1996, amending Part 1 and 2 of Title 47 of the Code of Federal Regulations [47 C.F.R. 1.1307(b), 1.1310, 2.1091, 2.1093].

Expert scientists and engineers developed both the NCRP and the IEEE exposure standards after extensive reviews of the scientific literature related to biologic effects of human exposure to radiofrequency (RF) electromagnetic fields. The exposure guidelines are based on thresholds for known adverse effects, and they incorporate appropriate margins of safety.

The ANSI standard in Reference [1] specifies the MPE_{limit} of non-ionizing radiation for the general public as a power density of 10 Watts-per-square-meter (10 W/m^2) averaged over any 30-minute period. Higher power density levels and reduced averaging times are permitted for RF and microwave trained workers, but it is not assumed in this report that the aircraft maintenance workers near the eXchange system have been trained in RF safety, and so the more conservative 10 W/m^2 power density level and 30 minute averaging time will be used in this analysis.

3 EXCHANGE FREQUENCY RANGE AND RADIATED POWER LIMITS

The pertinent characteristics of the eXchange system for RF Safety analysis are as follows:

- Transmit Frequency = 14.0 – 14.4 GHz
- Aperture size = 11.4” (28.956 cm)
- EIRP = 40.7 dBW
- Antenna 3dB beamwidth = 5.5^0

- Minimum antenna elevation angle = 0^0
- Power delivered to the antenna = 7.6W
- Antenna height on tail of Bombardier G5000 = 24.83' (7.57m)

The following calculations provide the RF radiation levels of the eXchange system.

4 CALCULATION OF EXCHANGE POWER DENSITY AND EXPOSURE LEVELS

4.1 Far-Field Region

Free-space power density is maximum on-axis and may be calculated from equation (1)

$$PFD_{ff}\ (W/m^2) = EIRP / 4\pi R_{ff}^2 \qquad \textbf{(1)}$$

Where PFD_{ff} = the power flux density on-axis in the far field,

EIRP (dBWi) = total power radiated from the antenna,

R_{ff} (meters) = distance to the beginning far field region and is found from equation (2)

From reference [1], a realistic practical distance for a large antenna, i.e., an antenna diameter larger then a wavelength of its operating frequency, where the far-field zone begins is:

$$R_{ff} = 0.6\ D^2 / \lambda \qquad (2)$$

$$= 0.6\ (0.2896)^2 / (0.0210)$$

$$= 2.4\ m$$

Where R_{ff} = distance to the beginning of the far-field region, in meters (m)

D = diameter of antenna in longest dimension, in meters (m)

λ = transmitter wavelength, in meters (m).

The PFD_{ff} at the beginning of the far-field region 2.4 meters from the antenna, using the maximum EIRP of 40.7 dBW, is found from equation (1) as follows:

$$PFD_{ff} = 162.3\ W/m^2$$

The minimum on-axis distance, r_{min} , from the antenna where the exposure does not exceed the 10 W/m^2 maximum exposure level for the general public is calculated by rearranging equation (1):

$$r_{min} = [EIRP / 4\pi MPE_{limit}]^{0.5}$$

$$= [10^{4.07} / 4\pi * 10]^{0.5}$$

$$= 9.67\ m$$

This minimum distance is in the far-field zone of the antenna, on boresight, and therefore the use of equation (1) for power density levels is valid.

4.2 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, therefore, it is assumed that the on-axis flux density is at its maximum value throughout the length of the region. The length of this region, i.e., the distance from the antenna to the end of the near field, is from [1]:

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

$$= (0.2896)^2/ 4*(0.0210)$$

$$= 1.0 \text{ m}$$

The maximum power density for commonly used horn and reflector antennas in the near field region from reference [1] is:

$$PD = 4P_T n/A \quad W/m^2 \qquad \textbf{(3)}$$

Where P_T = is the net power delivered to the antenna, in Watts (W)
n = antenna efficiency
A = physical area of the antenna aperture, in meters^2
$A = \pi D^2/4 = 0.0658 \text{ m}^2$

And $PD = 4P_T n/A \quad W/m^2$
$= 4 * 7.6 *0.8 / (0.0658) \text{ W/m}^2$
$= 369.6 \text{ W/m}^2$

This value exceeds the maximum safe exposure level of 10 W/m^2.

4.3 Transition Region

The transition region is located between the near and the far field regions of the antenna, or between 1.0 and 2.4 meters in the eXchange system. The power density in the transition region decreases inversely with distance from the antenna, while density in the far-field region of the antenna decreases with the *square* of the distance, as indicated by equation (1). The maximum power density in the transition region will not exceed that calculated in the near field region, which as shown above is 369.6 W/m^2.

Table 4-1 Summary of eXchange RF Radiation Levels

Region	Calculated Maximum Radiation Level (W/m^2)	Hazard Assessment
1. Near Field, R_n= 1.0m	369.6	Exceeds ANSI
2. Transition Region, $R_n < R_t < R_f$	369.6< PD<162.3	Exceeds ANSI
3. Far Field, R_f = 2.4m	162.3	Exceeds ANSI

4.4 Off-axis Radiation Levels

As calculated in section 4.1, the on-axis RF radiation levels exceed safe levels within the antenna main-beam out to a distance of 9.7 meters from the antenna. However, due to the narrow beamwidth of the antenna, the 3dB beamwidth was measured to be 5.5^{o}; the hazardous area is contained in a very small volume.

The antenna pattern of the eXchange antenna is shown in Figure 1. As shown in the figure, 4^{o} or more away from the antenna main-beam axis the power levels will be reduced by at least 10dB. On the Bombardier G5000 airplane, the antenna will be mounted on the top of the aircraft tail 25 feet above the ground and the power levels from the CBB antenna in this area will be at insignificant levels. For example, at typical antenna elevation angles to satellites in the GSO arc of 25^{o} or more the power levels at the antenna height or below are at least 25dB lower then in the antenna main-beam.

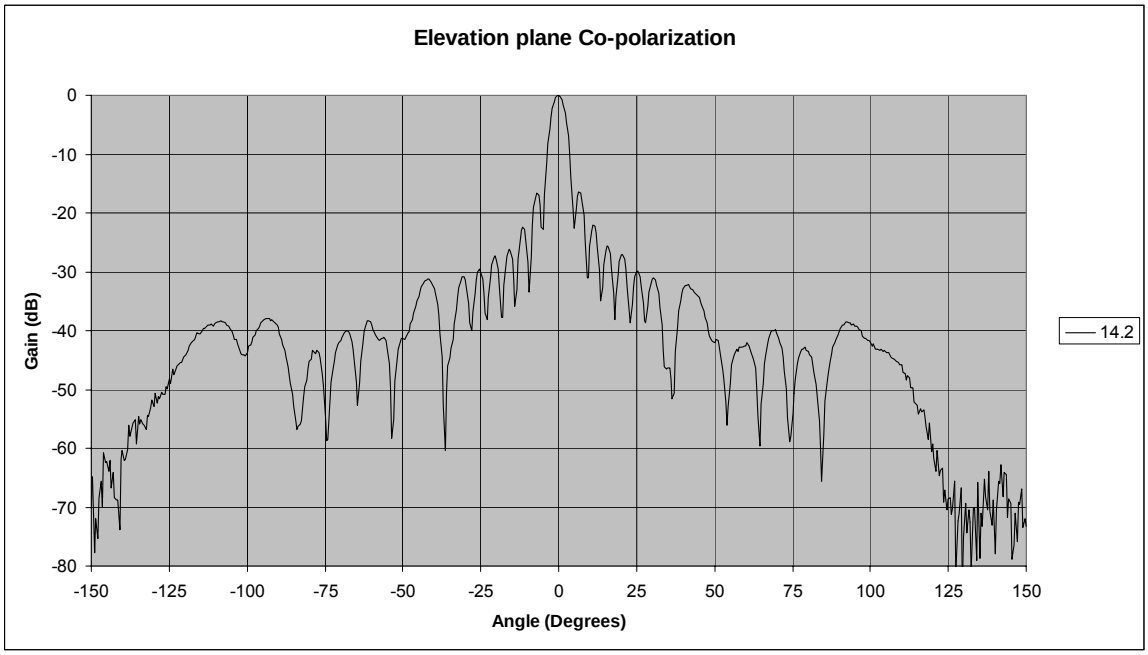

Figure 4-1 CBB eXchange antenna pattern at 14.2 GHz

5 CONCLUSION

Based on the above analysis it is concluded that harmful levels of radiation will not exist in regions normally occupied by the public or airplane maintenance workers. The antenna will be turned off during maintenance work near the antenna installation in the tail so that the ANSI standard of 10 W/m^2 will not be exceeded.

6 REFERENCED DOCUMENTS

1 IEEE C95.1, *IEEE Standards for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3kHz to 300 GHz, 1999*

2. International Commission on Non-Ionizing Radiation Protection, *Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300GHz), Health Physics, 1998*