Radiation Hazard Analysis for Experimental Obstacle Detection Radar for Caterpillar Inc.

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Description of Experimental Radar Unit

1. Central frequency of transmitter: 77.0 GHz
2. Bandwidth of transmission: 300 MHz centered in above frequency
3. Maximum continuous transmission power: 20 mW (13 dBm)
4. Maximum antenna aperture: 23 cm.
5. Typical antenna aperture 15 cm
6. Type of transmitter: continuous wave
7. Antennas are typically connected to the transmitter.
8. Disassembly of equipment is ALWAYS done by knowledgeable personnel and with power off.

Assumptions:

1. Type of exposure: Occupational/controlled
2. Antenna efficiency: 0.65 (due to polarization filter and inefficient planar antenna)

Power Calculations:

1. Antenna gain (Ref: Eq (15) in page 28 of OET Bulletin 65)

$$G = \frac{4\pi\eta A}{\lambda^2} = \frac{4\pi(0.65)(15cm*23cm)}{(0.398cm)^2} = 17790 \quad \text{(~43 dBi)}$$

Experimental value provided by manufacturer G=40 dBi (Antenna Performance Summary, Millitech)

2. Near field range up to (Ref: Eq (12) in page 27 of OET Bulletin 65):

$$Rnf = \frac{D^2}{4\lambda} = \frac{(23cm)^2}{4*0.39cm} = 332cm$$

3. Power density in the near field region (Ref: Eq (13) in page 28 of OET Bulletin 65)

$$Snf = \frac{16\eta P}{\pi D^2} = \frac{16*0.65*20mW}{\pi D^2} = 0.125mW/cm^2$$

4. Transition field up to (Ref: Eq (16) in page 29 of OET Bulletin 65)

$$Rnf = \frac{0.6D^2}{\lambda} = \frac{0.6(23cm)^2}{0.39cm} = 813cm$$

5. Power density in the transition zone (Ref: Eq (17) in page 29 of OET Bulletin 65)

$$Stf = \frac{Snf * Rnf}{R} = \frac{0.125mW / cm^2 * 332cm}{812cm} = 0.05mW / cm^2$$

6. Power density in far field zone (Ref: Eq (18) in page 29 of OET Bulletin 65)

$$Sff = \frac{PG}{4\pi R^2} = \frac{20mW * 17790}{4\pi 833^2} = 0.041mW / cm^2$$

Exposure Calculations:

The power density has a maximum of 0.125 mW/cm^2 for distances within the near field of the antenna, that is, 332 *cm*. The power decreases proportional to the inverse of the distance within the transition zone to 0.05 mW/cm^2 at 813 *cm* from the sensor. Farther than that, the power density decreases proportional to the square of the distance. These numbers apply for positions in the main axis of the antenna. The antenna exhibits sidelobes around 20 dB lower than the main lobe; therefore, the power density levels for sidelobe exposure are at least 100 times lower than the aforementioned values.

Conclusions:

The levels of power density are below the Limits for Maximum Permissible Exposure (MPE) indicated in the Table 1 in page 67 of OET Bulletin 65, which are: 5 mW/cm^2 for the frequency range of 1,500–100,000 MHz (77 GHz is in this range).

The levels of power density are ALSO below the General Population/Uncontrolled Exposure limit of 1 mW/cm^2. This is not the typical type of exposure, however.

The type of antennas used and the experimental procedures allow transmitter power of 40 times more (~30 dBm) under the Occupational/Controlled Exposure Standards.