EOT Antenna Radiation Pattern

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ONDAS NETWORKS

1. General

   The EOT utilizes a whip antenna which behaves as a monopole.

2. Ideal Monopole
   a. The radiation pattern of an ideal monopole is shown in figure 1 below. It is comprised of a whip radiator mounted and fed perpendicular in the center of a large ground plane and the radiation pattern is omnidirectional in azimuth.
   b. The ground plane is expected to be at least a few wavelengths (67 cm @ 450 MHz)

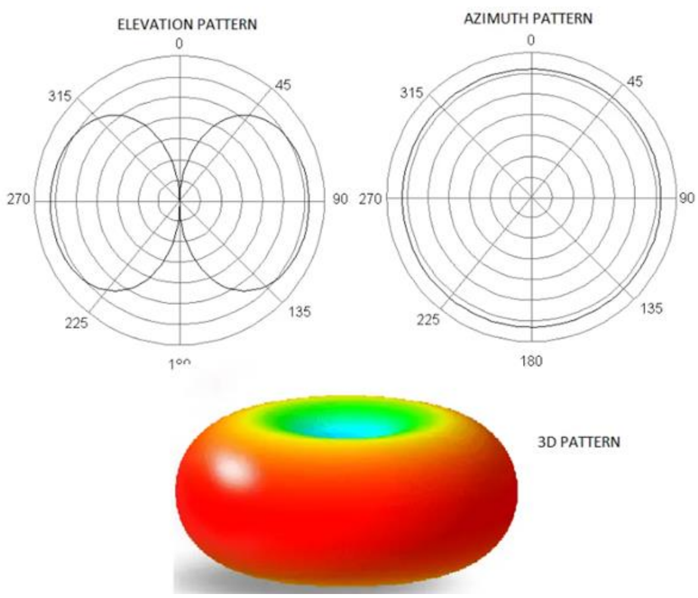

Figure 1: Radiation pattern of an ideal omni-directional antenna

3. EOT antenna behavior when mounted at the rear of the train

   a. Figure 2 below shows the HOT and EOT antenna on the train. There is no line of sight between the HOT and EOT when the train is at a straight line. Communication is enabled by reflections from wayside objects.

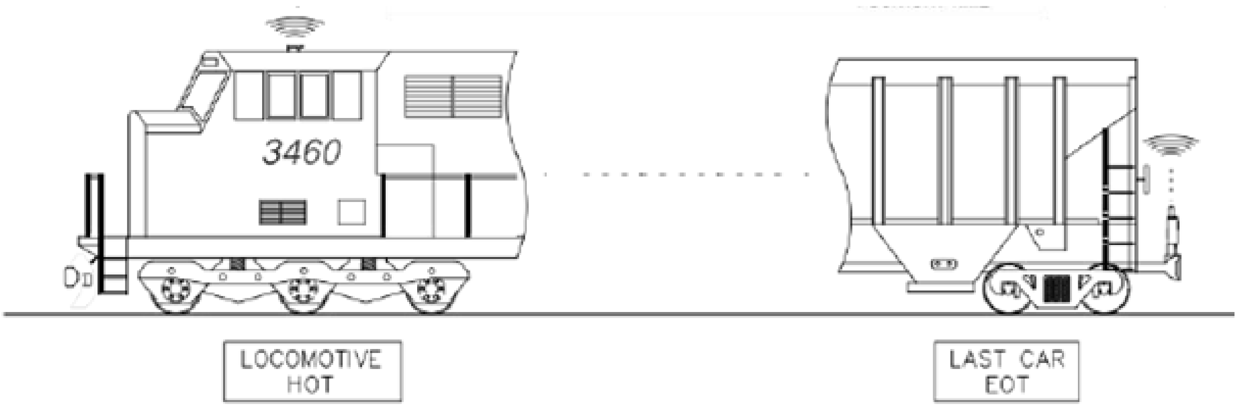

Figure 2: HOT and EOT Antenna Location on the Train

   b. When the EOT is mounted at the rear of the train, the rear wall of the last car acts as a reflector and the EOT antenna radiation pattern changes. From an omni antenna in open space, it becomes a directional antenna.
   c. An antenna simulation tool (Wipl-D) was used to simulate the radiation pattern of the EOT antenna in the presence of an 8'x 8' reflector, separated by 1' from the EOT. The actual results will vary, depending on the actual dimensions and shape of the last car rear wall but the general behavior is expected to be in the same direction.
   d. The simulated antenna pattern is shown in figures 3 and 4 below. The EOT antenna becomes directional with 9 dBi gain in both azimuth and elevation, pointing backwards, away from the car.

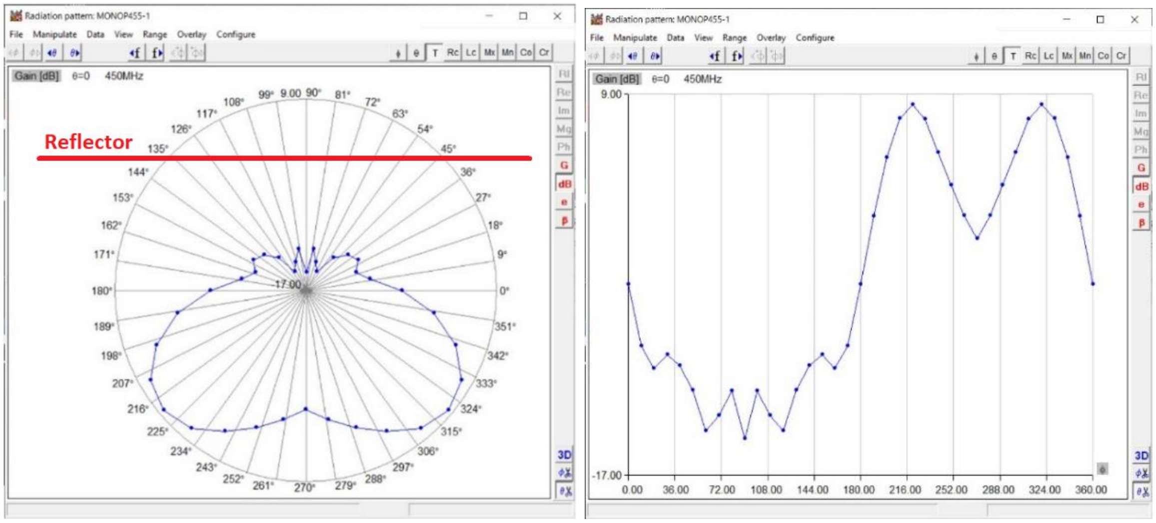

Figure 3: Azimuth Pattern -> Peak Gain 9 dBi

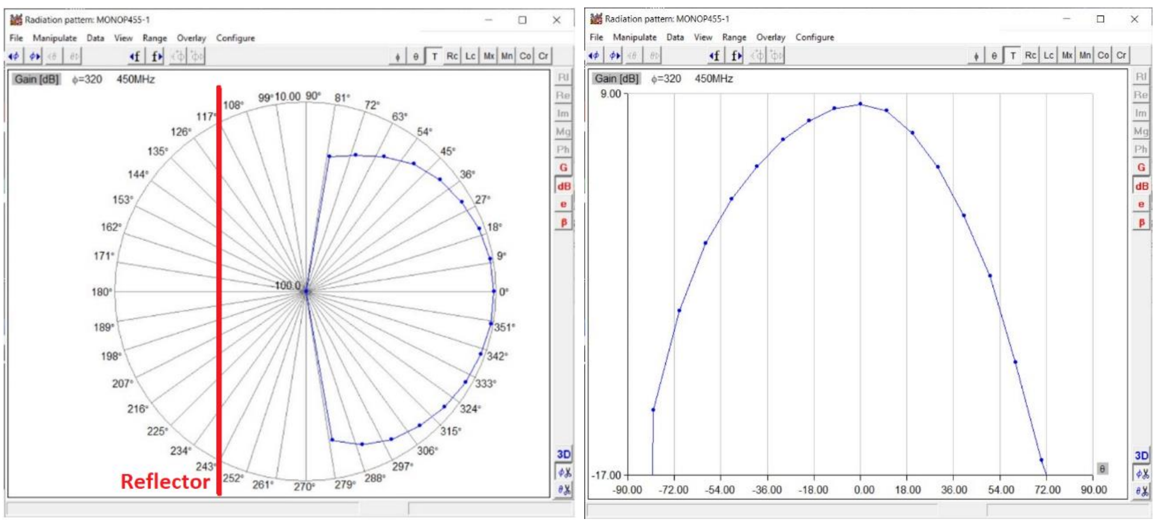

Figure 4: Elevation Pattern -> Peak Gain 9 dBi

Recommendations

1. Explore possible improvement to the EOT antenna radiation [pattern when the EOT is mounted in the train. This may be difficult given the physical constraints.
2. Assuming the problem is a "fact of life", it can be addressed by increasing the transmit power and/or repetition/combining factor, in the F to R direction as compared to the R to F direction. Here are possible configurations to make the link symmetrical:
    a. Use 10 dB higher transmit power at HOT. The EOT transmits at 8 Watts (39 dBm) so this implies transmitting at 49 dBm (80 Watts) from the HOT.
    b. Use repetition factor 8 for F to R communication and no repetitions in R to F communication. This is equivalent to increasing the TX power by 9 dB.
    c. Increase both TX power and repetitions at the HOT. For example, if the HOT TX power is increased by 4 dB to 20 Watts (43 dBm) and repetition factor 4 is used for F to R communication to buy the equivalent of 6 dB extra power, the total increase is 10 dB as required.
    d. Note that the HOT TX power is not subject to the EOT TX power constraints and therefore increasing the power at the HOT is more feasible. Also, the F to R message length is shorter than the R to F status message, especially when positioning is used. As such, the impact of using repetitions in F to R direction on duty cycle is smaller.

Appendix A: Antenna Radiation Planes

1. Antenna Radiation Planes: Azimuth (AZ) and Elevation (EL) are terms used to describe the radiation patterns of an antenna in different directions. Refer to Figure 10 for Azimuth and Elevation plane.
   a. **Azimuth plane**: The horizontal plane, or x-y plane, which measures the energy radiated from the antenna as if you were looking at it from directly above. Azimuth is measured in degrees and ranges from 0° to 360°, with 0° being north, 90° being east, 180° being south, and 270° being west. The azimuth plane pattern is measured when the measurement is made by traversing the entire x-y plane around the antenna under test.
   b. **Elevation plane**: The vertical plane, or y-z plane, which measures the energy radiated from the antenna as if you were looking at it from the side. Elevation is also measured in degrees, with 0° being just above the horizon and 90° being directly overhead. The elevation plane is a plane orthogonal to the x-y plane. The elevation plane pattern is made by traversing the entire y-z plane around the antenna under test.

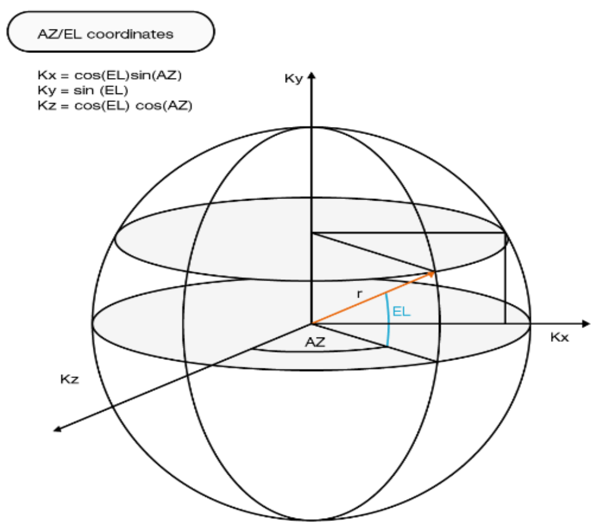

Figure 10: Antenna Azimuth (AZ) and Elevation (EL) Plane

   c. Phi (Φ) Angle: The ϕ angle is the angle from the positive *x*-axis to the vector's orthogonal projection onto the *xy* plane, moving in the direction towards the y-axis. The azimuth angle is between –180 and 180 degrees (See Figure 11).
   d. Theta (θ) Angle: The θ angle is the angle from the positive *z*-axis to the vector itself. The θ angle is in the range 0 degrees and 180 degrees (See Figure 11).

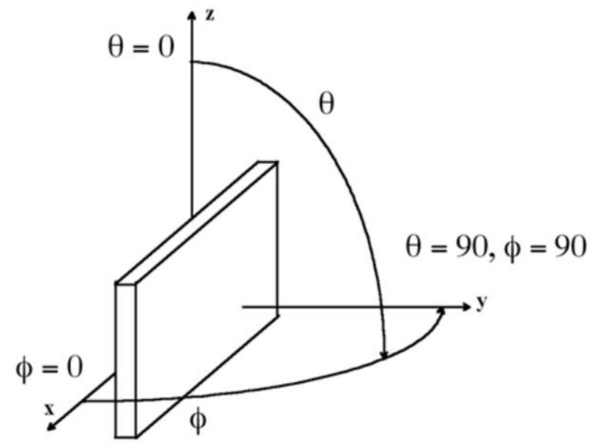

Figure 11: Antenna Phi (Φ) Angle and Theta (θ) Angle