

# **MOBILE GROUND TRACKING STATION DESIGN MODIFICATIONS AND PLACEMENT PREPARATION FOR CROWDED AIRSPACE**

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## **ABSTRACT**

As the frequency spectrum becomes more crowded each day, preparation for placement of tracking ground station in tracking environment gains more importance. Existence of high power weather ground radars, airport approach equipment, and various other RF sources in the environment necessitates the test teams to be more cautious. This paper discusses, implemented design changes to an S-band antenna system to reduce the in-band interfering power, calculation of the effects from nearby interferers, analysis of the environment during placement of the mobile ground system by Honeywell telemetry teams.

## **KEY WORDS**

Interference, antenna modifications, mobile ground tracking system preparation

## **INTRODUCTION**

Each time the mission support teams receive a new mission support requirement with Honeywell designed and built transportable antenna systems, they need to adjust not only their schedule but their thinking for a placement of the antenna for the best tracking location. As the tracking requires an S-band (2200-2400 MHz frequency band) reception and UHF (400-450 MHz frequency band) transmission support the antennas must have clear Line Of Sight (LOS) support. However, the clear LOS is not the only issue the teams must address. A clean reception environment is crucial to the mission success as well protection of the antennas. Especially with the concern of obtaining highest G/T (Gain/System Noise Temperature) ratios design of the antenna front-end requires more attention. While placement of the band limiting filters prior to LNAs (Low Noise Amplifiers) in the feed increases the noise temperature of the system, causing G/T to drop, it makes the system more immune to out of band signals from near by emitters such as weather band radars, GPS transmitters and various other high power transmission equipment in the area of the tracking. Especially in the tracking ranges where coordination (of frequency, power levels, and timing of transmission) is required prior to tracking functions start, the preparation cycle with boresight tests leaves the teams vulnerable to environmental “clutter.”

- Closest available tracking location with the coordinates (usually the customer decides)
- The environment

- The positioning of the dual antennas vs. each other (Honeywell’s transportable tracking systems use 5.4 meter dual tracking parabolic antennas with Left and Right Circular Polarizations (LHCP / RHCP) reception of the same carrier with the command destruct, UHF transmit capability built into the feeds, Figure 1)
- Physical location (nearby obstacles for a clear Line Of Sight (LOS))
- Nearby emitters (frequency, power, direction of transmissions, frequency of transmissions, masking – if any and their distance to tracking antenna location) become critical. In the following sections we will discuss briefly of the placement issues while some modification implementation due to further protection need.



**Figure 1 Two opposite circular polarized antennas tracking a launch**

## IMPLEMENTATION

### **A. Placement of the dual antennas vs. each other:**

In order to assure that the antennas do not affect each other’s field, it is imperative that the two antennas are separated by the distance of meeting the requirements of the FRESNEL region while the boresight antenna distance meets the minimum requirement for the Franhoufer region. (Appendix A). Per the calculation, the minimum separation between two 5.4 meter S-band antennas should be 22 meters (approximately 72 ft.)

In addition, applying Huygens’s principle (Appendix B) to a plane wavefront around an edge, it is possible that wavelet cancellation on the received and diffracted signal by the antenna in the front may occur. (We have observed this phenomenon in some close placement tests of the antennas analyzing the data received on both antennas and comparing the two AGC values.) In the case of the multipath, with the circular polarization, the reflected and the incident waves will

be in opposite polarizations. Based on the time of arrival the reflected wave may cancel the incident wave. (Honeywell systems use receivers with diversity combiners to eliminate this effect to the extent possible.)

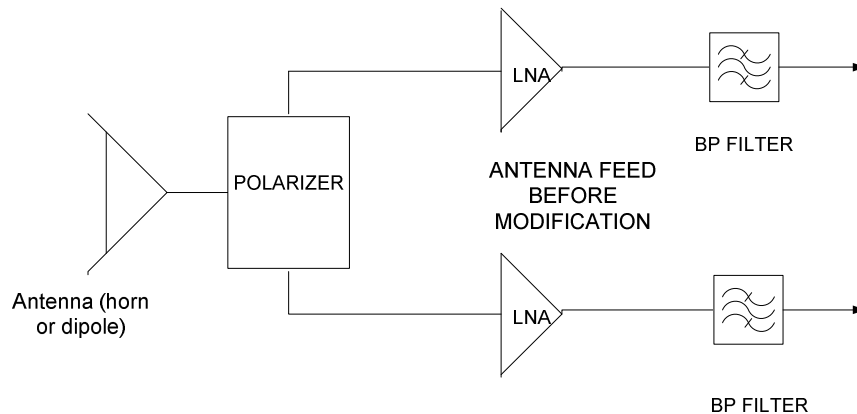
**B. The study of the environment:**

A close study of the environment that has the weather, GPN or other airport radars reveals the possible hazards from the high EIRP (Effective Incident Radiated Power) emitters in the area. Any equipment that can provide enough power in the antenna bandwidth is a candidate for destruction of the front end of the LNA systems. (Appendix C).

$$P_{LNA}(dBm) = EIRP(of - emitter) - Space\_Loss(dB)$$

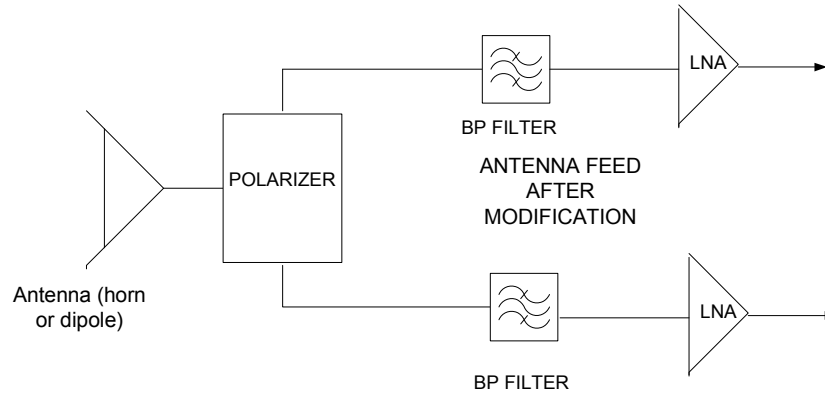
In Honeywell’s 5.4 meter antenna case, the LNAs can not endure more than 10 dBm of input power level (in probably micro or milliseconds). If the LNAs endure the signal, if it is in band, then the receiver tuner input amplifiers could not tolerate it above +10 dBm level at their inputs. Some suggested antenna modifications to lower the effect of high power emitters always come at the expense of lowered G/T:

a. At the input to antenna feeds we have the LNAs immediately following the antenna dipole or cone and the polarizer (Figure 2). This increases the gain without adding further noise into the system (in compliance with Friis’s theory for system noise temperature). The band limiting filters come after the LNAs, influencing the G/T much less, or almost none at all, while NOT protecting the LNAs from the effects of high power out-of-band signals’ effects.



**Figure 2 Antenna Feed Prior to Modification (higher G/T)**

A modification that moved the LNAs in the feed after the filters provided approximately 60 db attenuation for all out-of-band emitter signals (Figure 3). This was more than enough to eliminate the problem for out of band signals. (However, this provided no protection for the in-band signals that are off-frequency but within the S-band telemetry antenna’s operational band.) The G/T was lowered by about 1 dB to 16 dB/K (as measured at 5 degree above the horizon looking into the clear sky.) In-band signal protection is managed by way of operational precautions. (Arranging on-air timing of local emitters, sharing the RF airspace or masking the antenna in the direction of HP emissions.)



**Figure 3 Antenna Feed After the Modification (Better Out-of-Band Protection)**

b. An input PIN diode limiter can be installed into the RF input circuit of the LNA. This passive PIN limiter can offer RF overload protection of one (1) to two (2) watts. This level of protection has typically proven adequate protection for extraneous emitters that may be encountered. One input PIN diode is expected to impact the noise temperature of the LNA about ten (10) degree K. PIN diodes can absorb the initial blow, divide the voltage, discharge the energy to the termination of the isolator. (Diode avalanches, dividing the power down, reflects to the load of the isolator.) Increase in the LNA noise temperature by about 10 Kelvin degrees (in our case from about 28-30 degree K to 38-40 degree K) translates to new noise figure of 0.561 dB (an increase in the noise figure approximately of 0.13 dB which is acceptable in most cases.) This update requires a modification (board layout change) to the LNA circuitry which can be costly. A less expensive approach is to modify the board with two 50-mil holes and making solid cut and jumpers to add the diodes. One LNA manufacturer indicated that they have used pin diodes for protection up to 4-5 watt over-power dissipation across the input to the LNA. In our case 1-2 watt protection (meaning protection against development of voltages up to 7 to 10 V at the 50 ohm input) would be enough for the input levels, at the distances we worked (with an average 40 dB pre-filter antenna gain up to 6 GHz.)

## CONCLUSION

Placement of mobile antennas and their shelters in an environment requires additional care as each location of mission may bring RF hazards and obstructions that can be detrimental to the accomplishment of the task with success. Protection of the antennas start with the design phase placing the filters in the front of the LNAs in the feed or adding protection diodes in the LNA input circuits with a small sacrifice in the system G/T. Otherwise, the LNA gain can either suddenly disappear (down to a loss!) or LNA can deteriorate in time, with the abusing power of high power emitters in the environment.

It is impossible to design an antenna / receiver system that is completely protected from the environment. However, learning the mission characteristics early in the support preparation

phase and staging the antennas in a good position for the mission, while understanding the environment completely, prepares the mission support personnel for hazards in the environment. Mission support personnel can mask or limit the antenna from pointing those hazardous areas and / or possibly adding protective equipment (attenuators and / or filters) to the system thus avoiding unpleasant and costly failures in the field.

Author sees the need and wishes for more direct discussion / recommendation from the IRIG, or similar groups, on the placement of the multiple and transportable tracking antennas.

Ref 1: Wayne Tomasi, Electronic Communications Systems, ISBN 0-13-049492-5

Ref 2: Richard C. Johnson, Henry Jasik, Antenna Engineering Handbook, ISBN 0-07-032291-0

## APPENDIX A

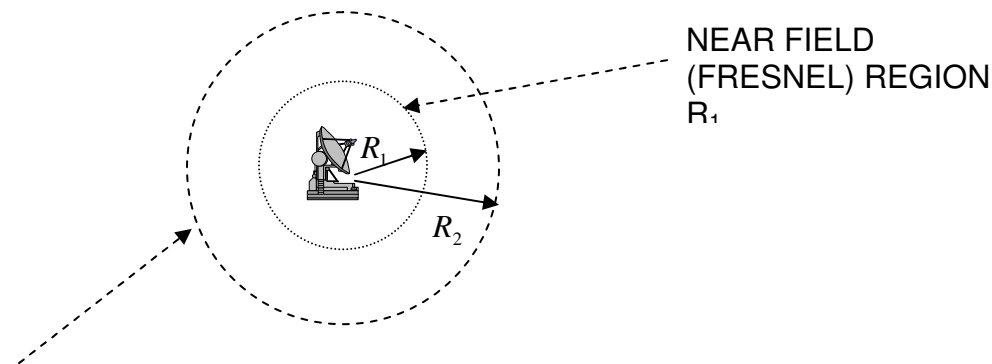
### Near field / far field considerations for Honeywell's mobile tracking antennas – for frequency range of 2200MHz – 2400 MHz

#### NEAR FIELD (FRESNEL) REGION $R_1$ -

While placing the two antennas nearby each other, the near-field region should be clear of any structures (including the other antenna.) The near field region is called Radiating Fresnel region. In this region as the antenna acts like an inductor, some energy may return to the antenna itself. While antenna parabolic reflector diameter is  $D=5.4$  m:

$\lambda = \frac{C}{f}$  while  $C$  = speed of light ( $3 \times 10^8$  m/sec) and  $f$  = frequency = 2200 - 2400 MHz our  $\lambda \cong 13$ cm.

$$R_1 = 0.62 * \sqrt{\frac{D^3}{\lambda}} = 22 \text{ meters (approximately 72 ft.)} \quad D(m)=\text{antenna diameter}$$

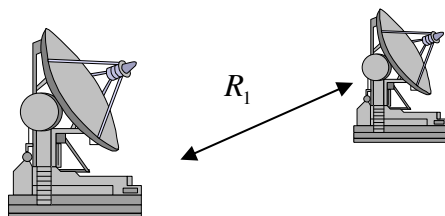


#### RADIATING FAR FIELD (FRAUNHOFER) REGION $R_2$ :

$$R_2 = 2 * \frac{D^2}{\lambda} = 467\text{m (for worst case of } f=2400 \text{ MHz) approximately 1530 ft. (Reference 2)}$$

Whatever energy reaches the  $R_2$  region is radiated. This is the **minimum** distance where one can (and should) place the test (boresight) antennas. (At this distance antenna looks as a single source of radiation and the antenna pattern is insensitive to range.) To the extent possible this area in front of the antennas (and boresight antenna path) should be clear.

When the two RHCP and LHCP antennas are close to each other or other structures at a tracking

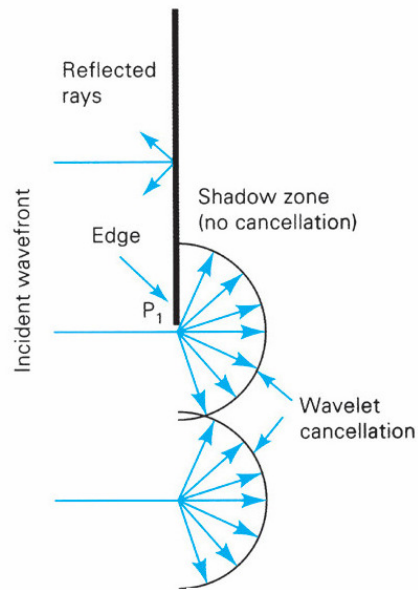


site, one must pay attention to these regions.

## APPENDIX B

### HUYGENS'S PRINCIPLE

Principle Statement: Every point on a given spherical wavefront can be considered a secondary point source of electromagnetic waves from which secondary waves (wavelets) are radiated outward. This causes diffraction which is the modulation or redistribution of energy within a wavefront when it passes near the edge of an opaque object. Diffraction allows the radio waves to propagate (peek) around the corners. (Reference 1). Due to the phase differences at different times of arrival, the wavelets can add to or cancel the received signal.



## APPENDIX C

### A Sample Preparation for Delta II Swift Launch support

PAFB antenna locations at the time of the support:

A antenna: N28deg 12 min 50.8 sec, W80 35 54.2

B antenna: N28 deg 12 min 50.8 sec, W80 35 55.3

Launch is from Complex 17 in Cape Canaveral, 16.22 miles north of the antenna position. (at approximately +10 degrees from north, in horizon at position N 28 26' 45" W80 33' 29")

There are three known hazardous emitters in the area:

WSR 74 C Weather radar: Continuous operation, min op angle is 0.5 degrees, Not masked, f= 5625 MHz, position is at N28 15' 20", W80 36' 21", distance from our antennas is 2.7 miles. NW of the antennas, at angle of 9.3 deg from North. EIRP is 130.8 dBm creating a level of 48.25 dBm at the LNA input, polarization is Linear, Horizontal.

GPN 20 radar: Continuous operation from 6AM to 11:30PM, supporting PAFB and skid strip. Scans at 15 RPM, not masked, f=2750-2840 MHz, at N28 14 24, W80 36 30, distance from antenna is 1.85 miles north, NW at angle of 20 deg from North, EIRP is 119 dBm creating a level of 46.24 dBm at the LNA input, polarization is Linear, Vertical

WSR 88 D Weather radar, Melbourne Airport: Continuous operation at the rate of 2 RPM. It is not masked, min operational angle is 0.5 degrees, f= 2879 MHz at N28 6 46, W80 39 14, distance from the antenna is 7.9 miles SW at 151.6 degrees from North, EIRP is 130.8 dBm creating a level of 45 dBm at the LNA, polarization is Linear, Horizontal

1. Map of the area with sample emitters:

