Antenna Techniques to Optimize Pseudorange Measurements for Ground Based Ranging Sources

Jeff Dickman
Ohio University
Avionics Engineering Center

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Outline

- Background
- Stage 1 - Siting Study
  - » Ground transmitting antenna locations investigated
- Stage 2 - Pattern Investigation
  - » Important regions of the pattern refined
  - » Design considerations
- Stage 3 - Prototype Antenna Analysis
  - » Pattern characteristics
  - » Theoretical coverage

Dynamic Range

- Receiver Dynamic Range refers to the range of power levels that can go into a receiver and still get an accurate output. This is highly dependant upon the receiver design.
- It is limited by receiver components such as AGC, A/D converter, mixers, and amplifiers.
- Typical GPS receivers have a range of 30 dB before the A/D saturates.
- It is still possible to get linear output up to 45 dB while in A/D saturation.
- Above this level, nonlinearity occurs.

Exceeding the Dynamic Range

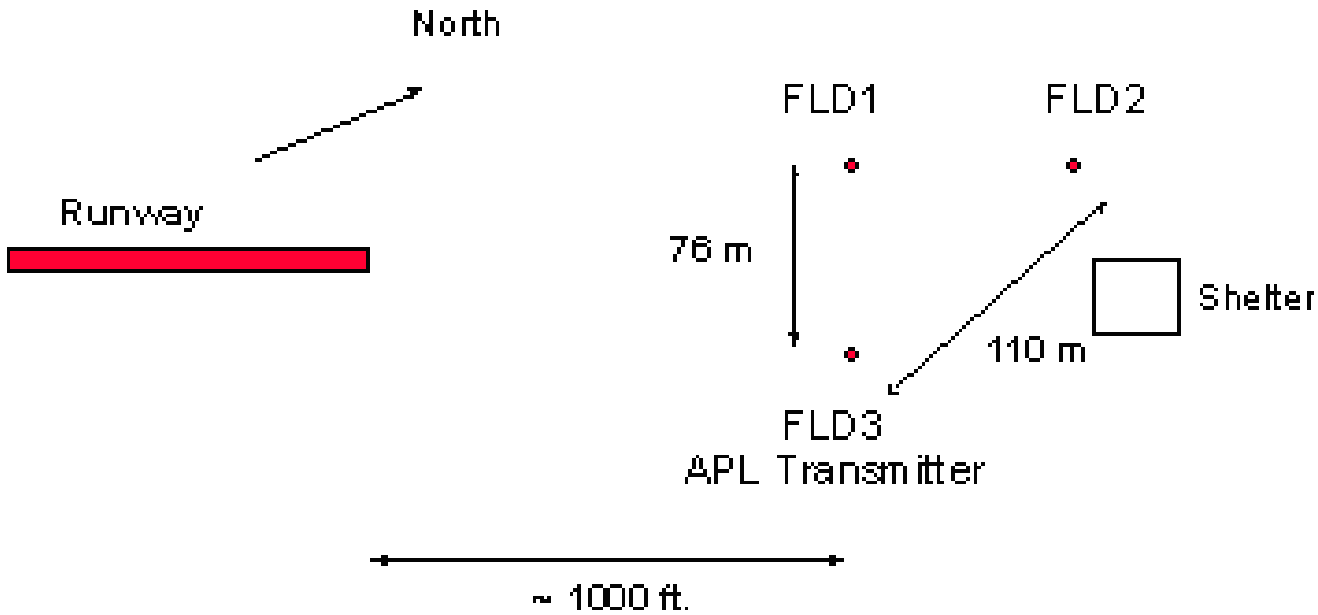
- 3 - 3.5 meter biases are possible when using a wideband code for power level variations of 40 dB.
- Bias is a function of the receiver, the signal bandwidth and the correlator spacing.
- Along with ground multipath, this can be one of the largest error sources in DGPS/DAPL systems.

* Van Dierendonck, A.J., "Report on APL Receiver Pseudorange Bias Investigation", GPS Silicon Valley

Motivation for Research

- Reduce known error sources for WBAPL integration into DGPS/DAPL LAAS installations.
- Dynamic range requirement reduction through antenna siting.
- Dynamic range requirement reduction through antenna design.
- Optimize APL transmission pattern characteristics.
  - » Expanded coverage – Above 35 degrees
  - » Remove excessive gain variation “hump” at low elevations
  - » Maintain or improve multipath performance (sharp gain rolloff)
- These techniques serve to reduce potential GPS pseudorange biases resulting from receiver saturation or multipath.

LAAS Ground Facility (LGF) at Ohio University Airport



Prototype LAAS Installation

- Consists of multiple integrated multipath limiting antennas (IMLA).
- Each IMLA uses two antennas to provide full hemispherical coverage.
  - » Vertical Linear Array - Multipath Limiting Antenna (MLA)
  - » Helibowl - High Zenith Antenna (HZA)
- Pseudolite transmission via an MLA.
- Located at the beginning of runway 25.
  - » Aircraft must fly over the APL during an approach.
  - » Selected due to logistic considerations

Integrated Multipath Limiting Antenna (IMLA)

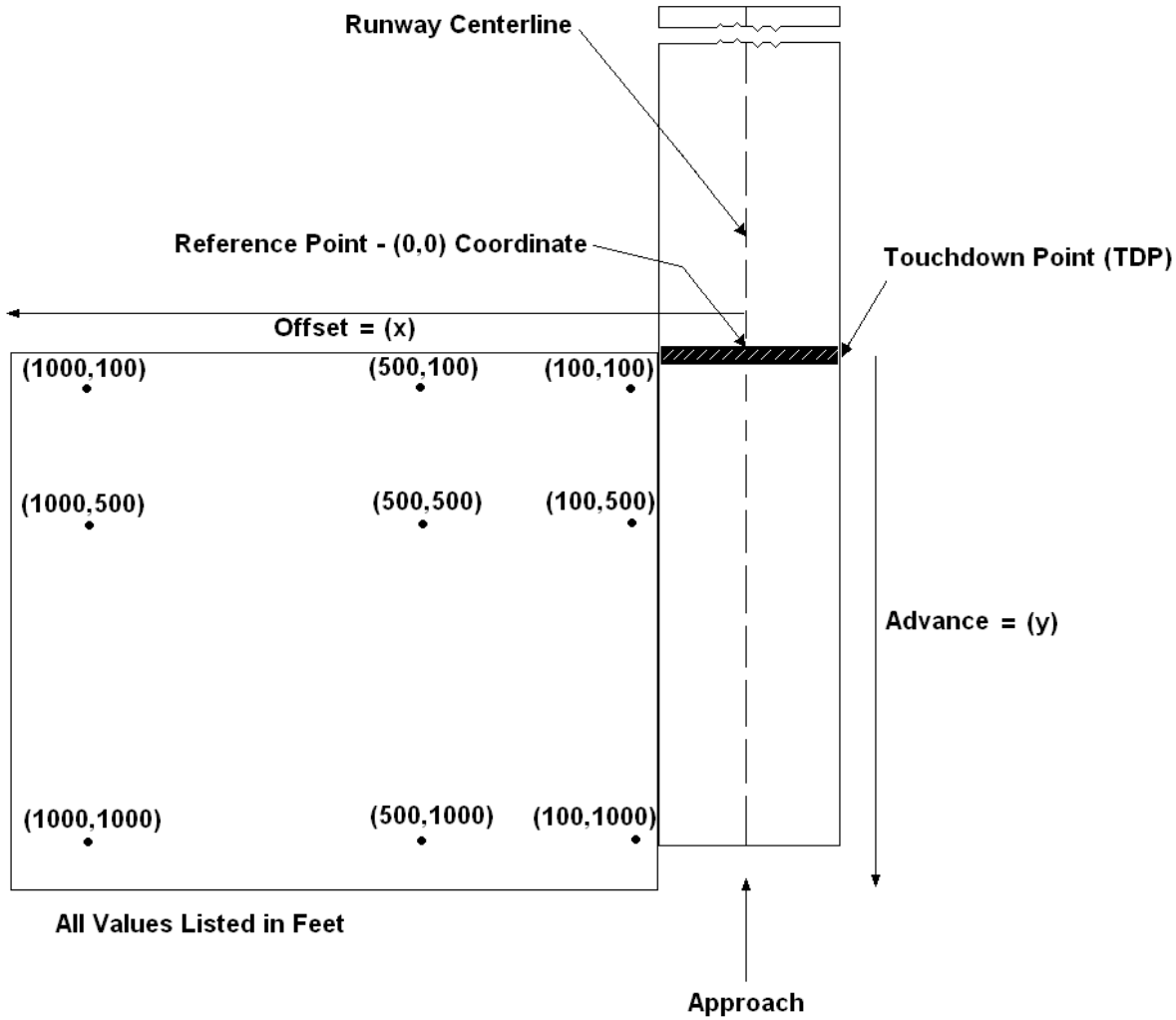
Known GPS/APL Error Sources

- **Multipath**
  - » **Ground reflections from signals transmitted by the pseudolite.**
- **Power Level Induced Bias**
  - » **Rapidly varying gain levels can cause the receiver to go into saturation and induce potential biases.**
  - » **Antenna gain “hump” causes radiation in undesired directions while increasing the dynamic range requirements by 5 dB.**

Stage 1 - Siting Investigation

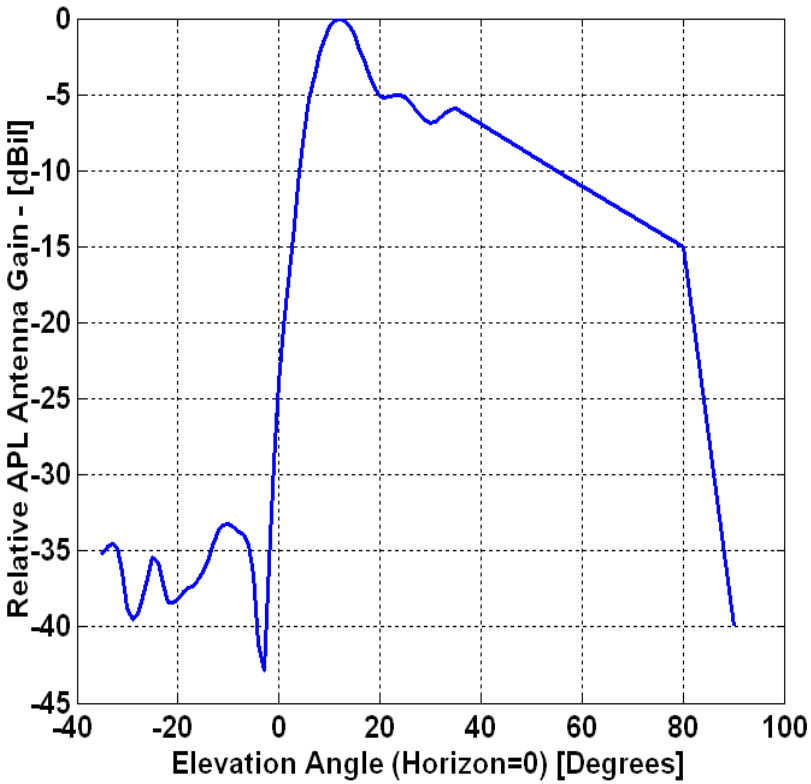
- **A Model was developed to determine how moving the APL transmission antenna effected the airborne receiver dynamic range requirements.**
  - **Varied the *Offset* (Distance to the side of the runway) - 100 ft, 500 ft, and 1000 ft**
  - **Varied the *Advance* (Distance in front of the runway) - 100 ft, 500 ft, and 1000 ft**
- **Surface plots were created showing a composite of the received power as a function of APL location.**

APL Location Variation

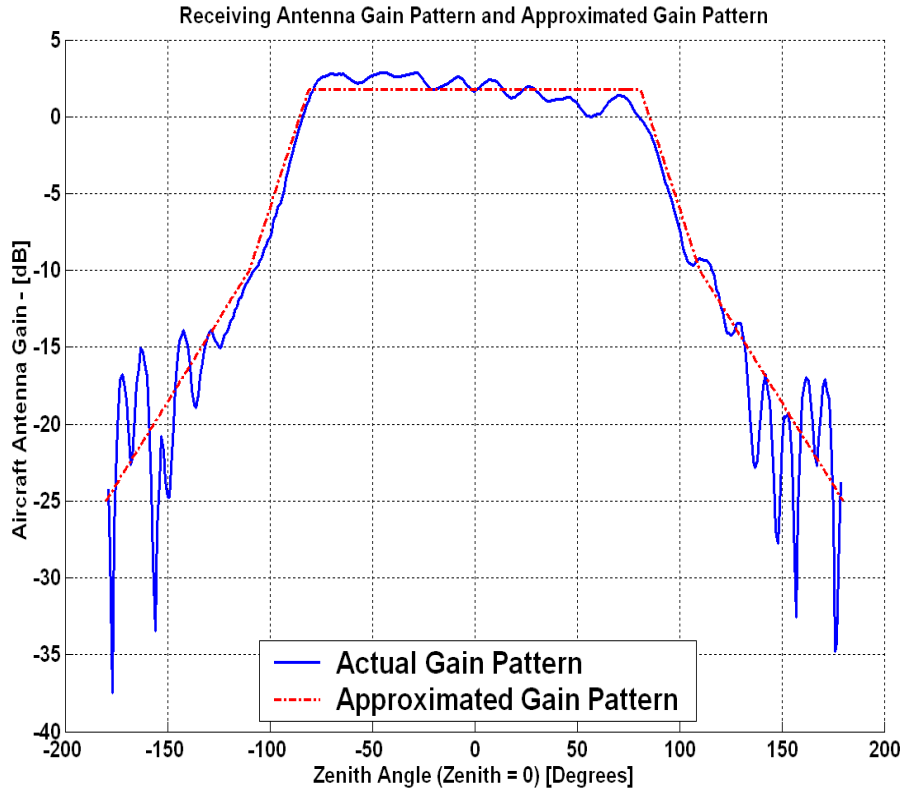


Antenna Gains Used in Simulations

Ground Station MLA - G_t

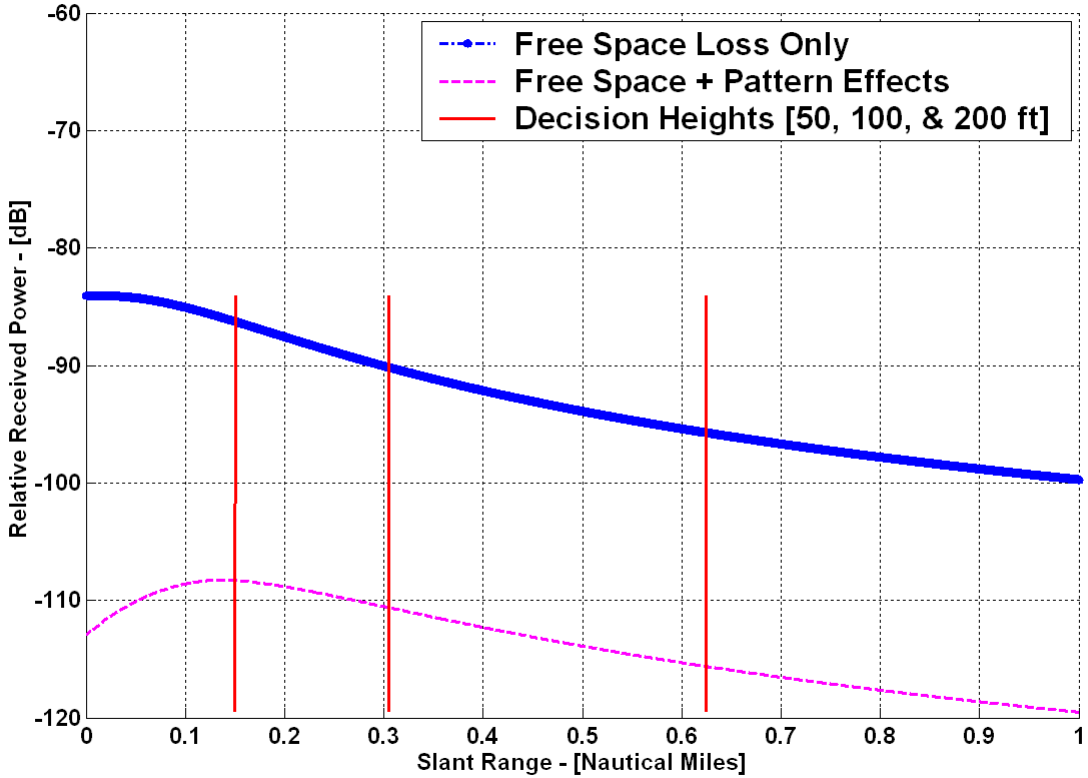


Aircraft Antenna - G_r



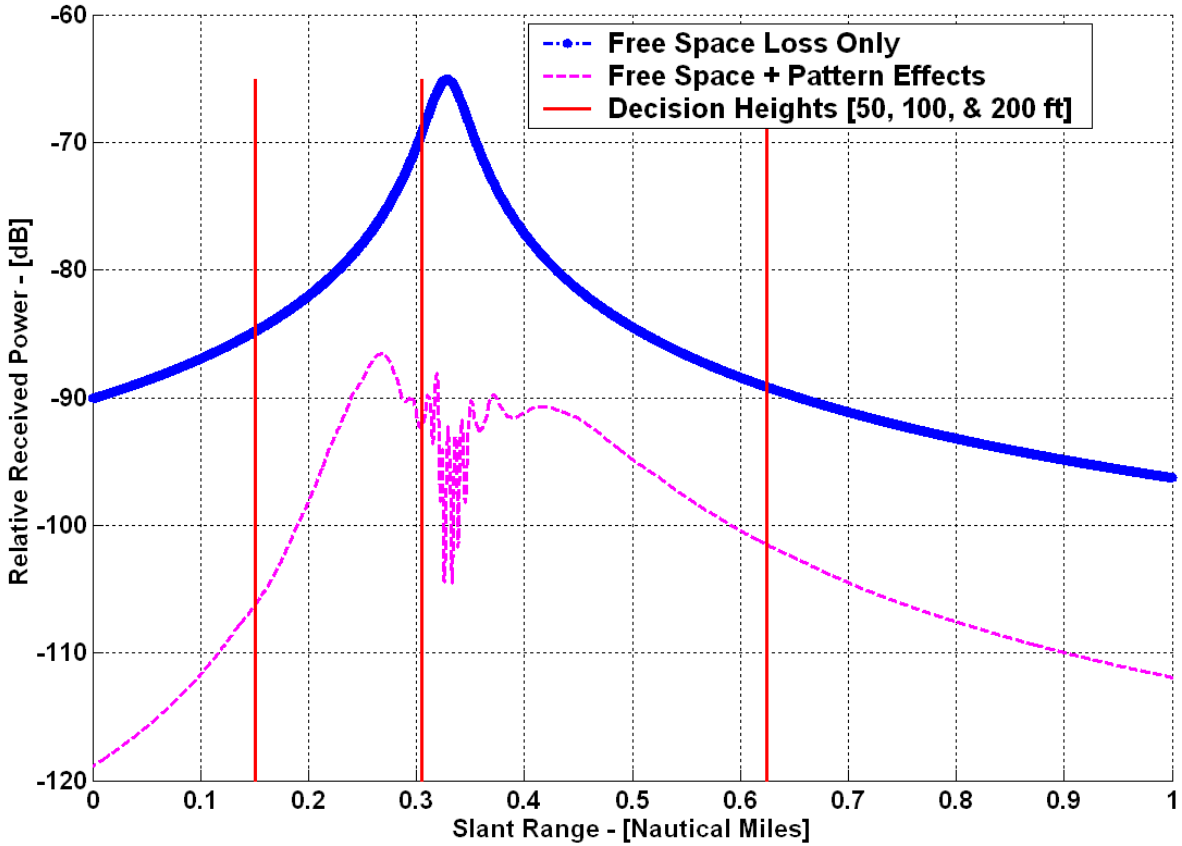
Power Profile Analysis

- **What to look for:**
  - » Overall flatness of the curve
  - » Location of the peak
  - » Distortions in the curve
  - » Differences between the two curves



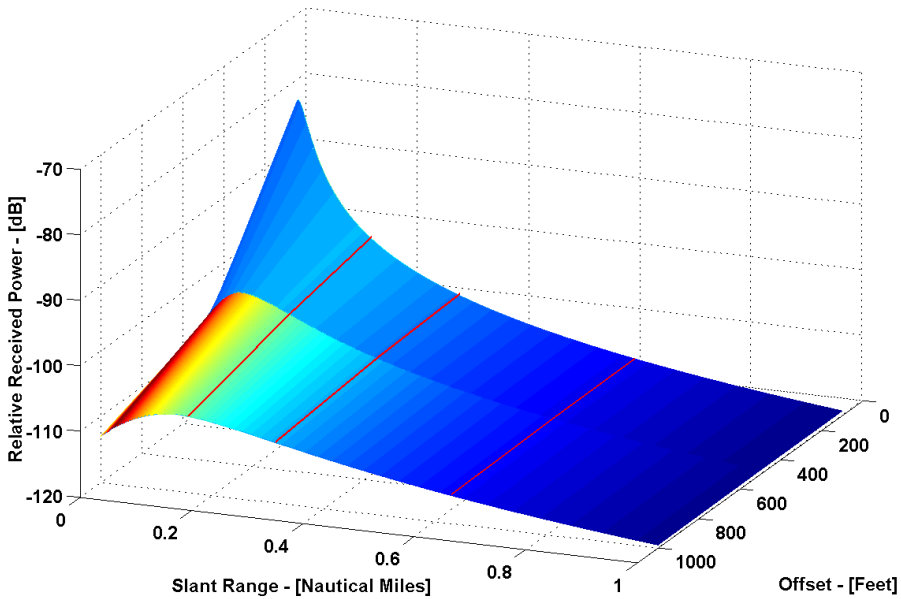
Offset = 1000 Ft , Advance = 100 Ft

Received Power Profile For Current LGF at UNI

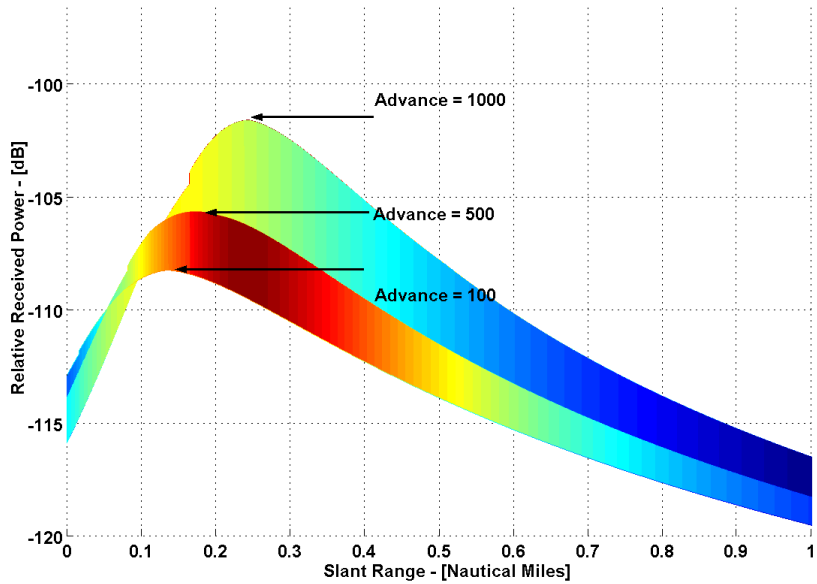


Offset = 0 Ft, Advance = 2000 Ft

Composite Power Profiles

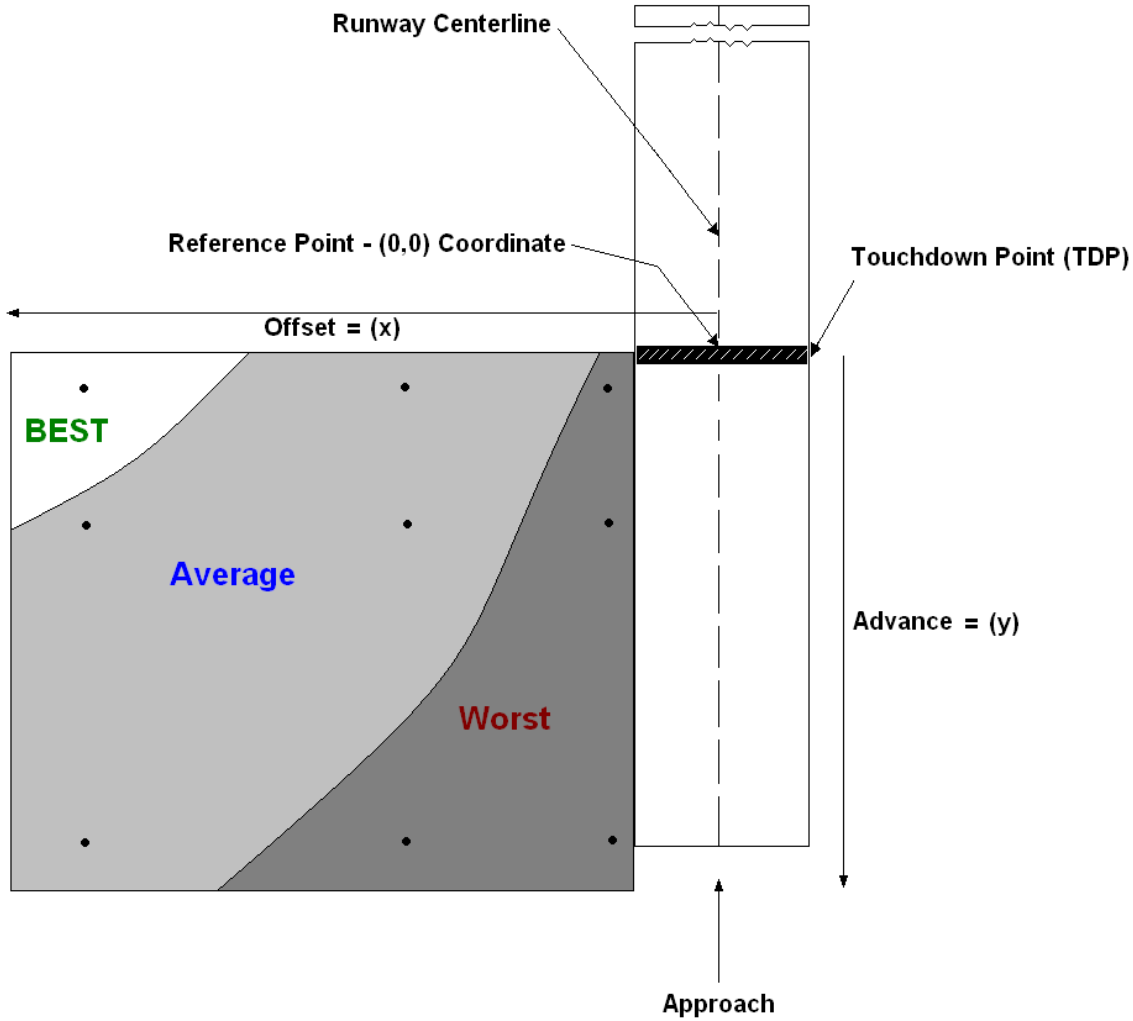


Fixed Advance = 100 Ft



Fixed Offset = 100 Ft

“Best” APL Antenna Locations



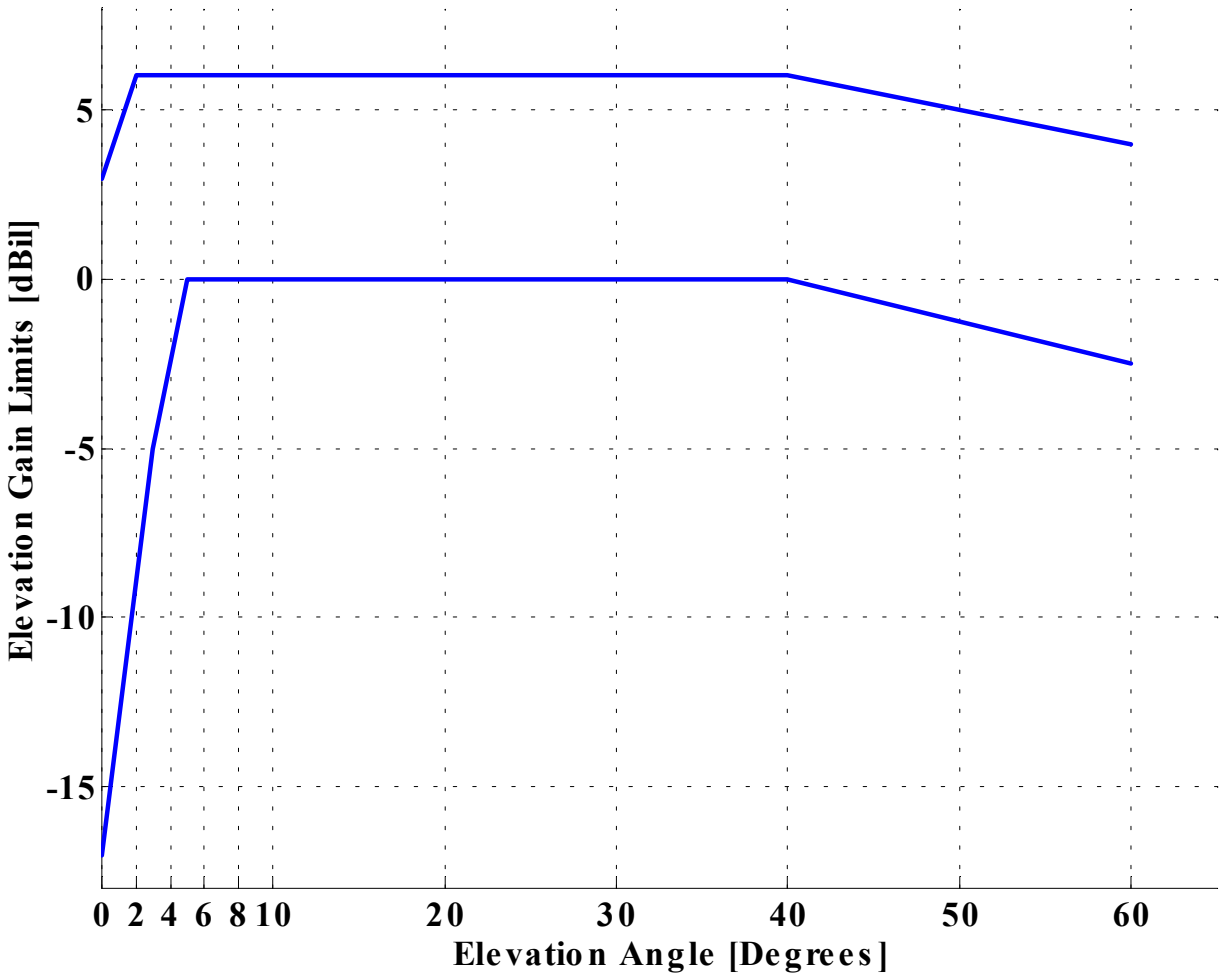
Stage 2 – Pattern Investigation

- Identify required gain for the important regions of the transmission pattern
- Objectives
  - » Minimize ground multipath
  - » Provide enough gain to support APL to LGF link
  - » Provide sufficient APL transmission range to airborne users
- Theoretical APL antenna pattern
- New WBAPL development

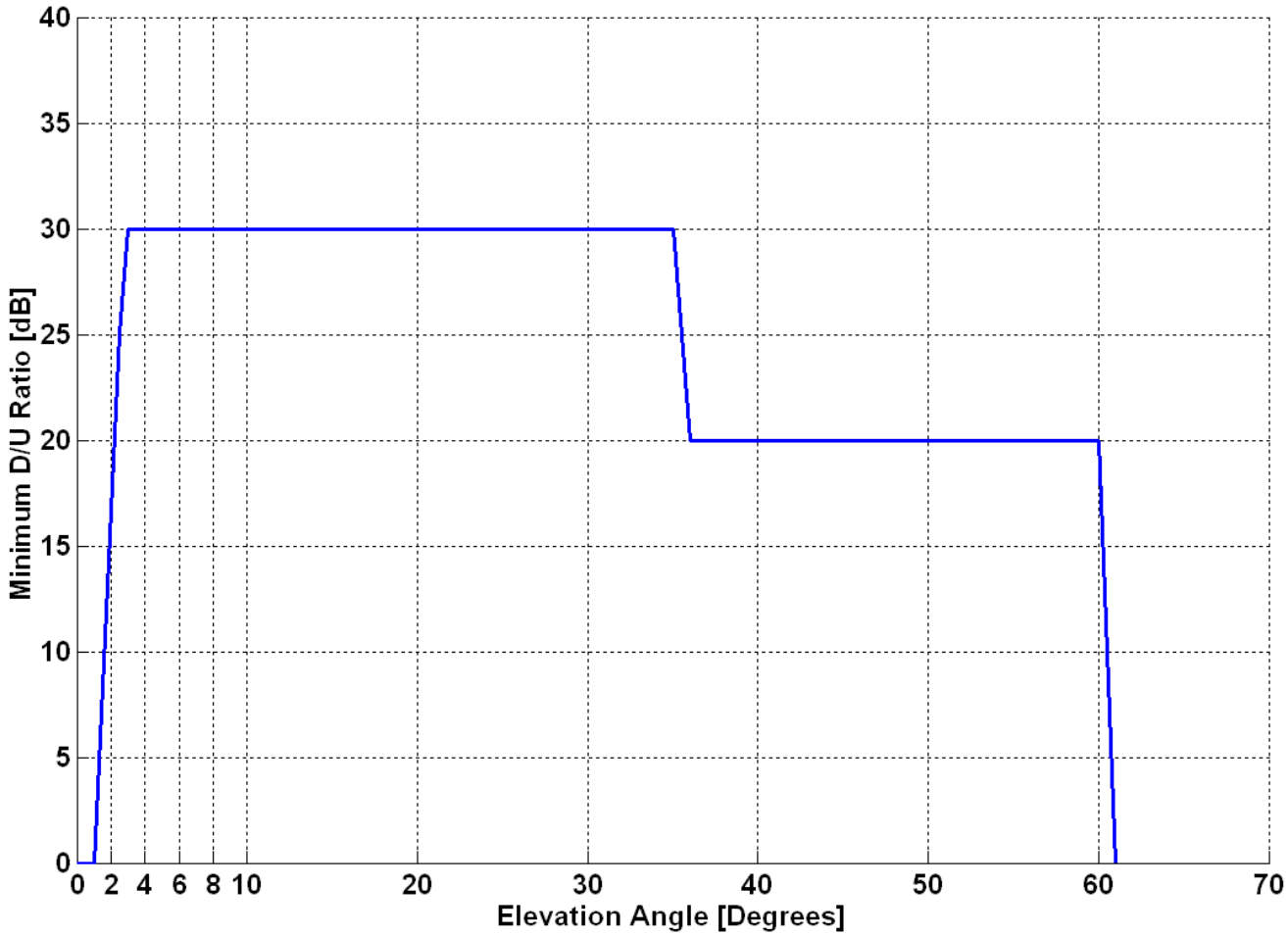
Pattern Regions

- **Each region of the pattern has objectives and tradeoffs.**
  - » **Below the Horizon**
    - ➤**A/C and LGF multipath rejection**
  - » **Near the Horizon**
    - ➤**Adequate gain to LGF vs. minimum multipath**
  - » **Above the Horizon**
    - ➤**Adequate gain coverage for approaches**
    - ➤**Adequate gain coverage for en route navigation**

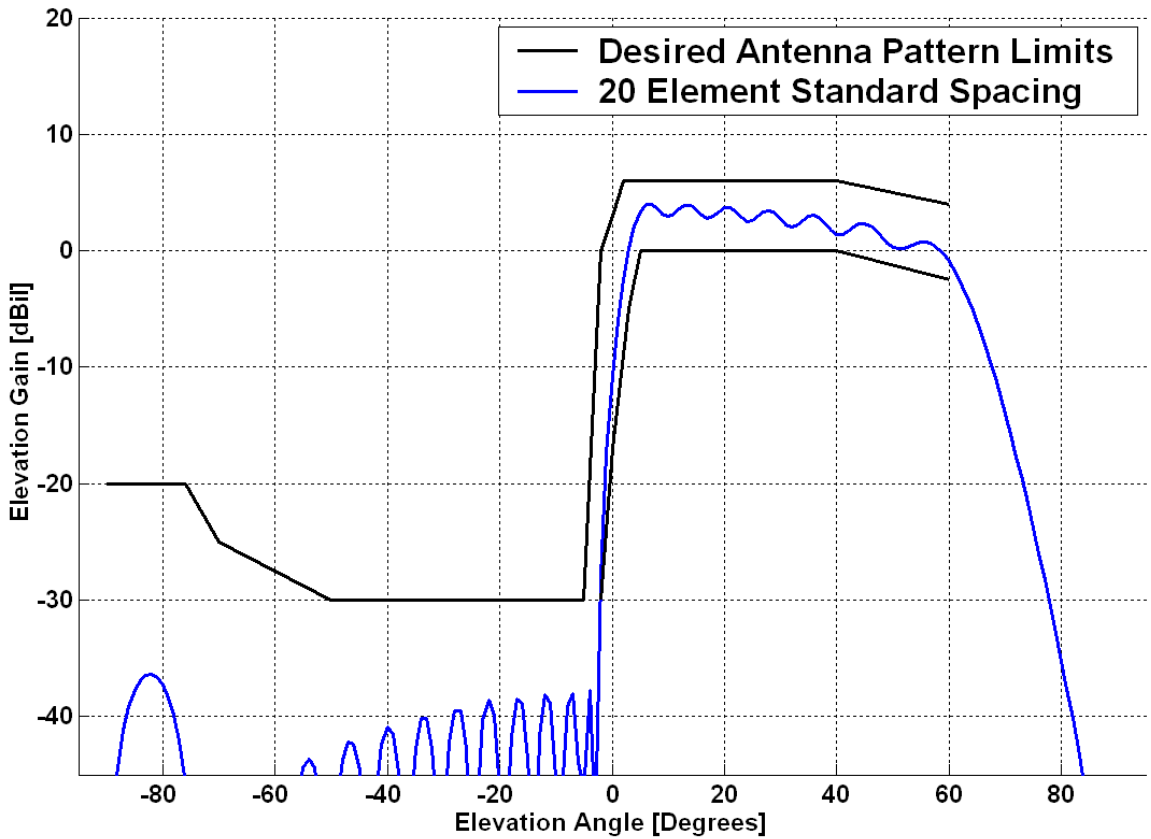
Elevation Gain Envelope



Minimum D/U Ratio



Theoretical Elevation Radiation Pattern vs. Envelope

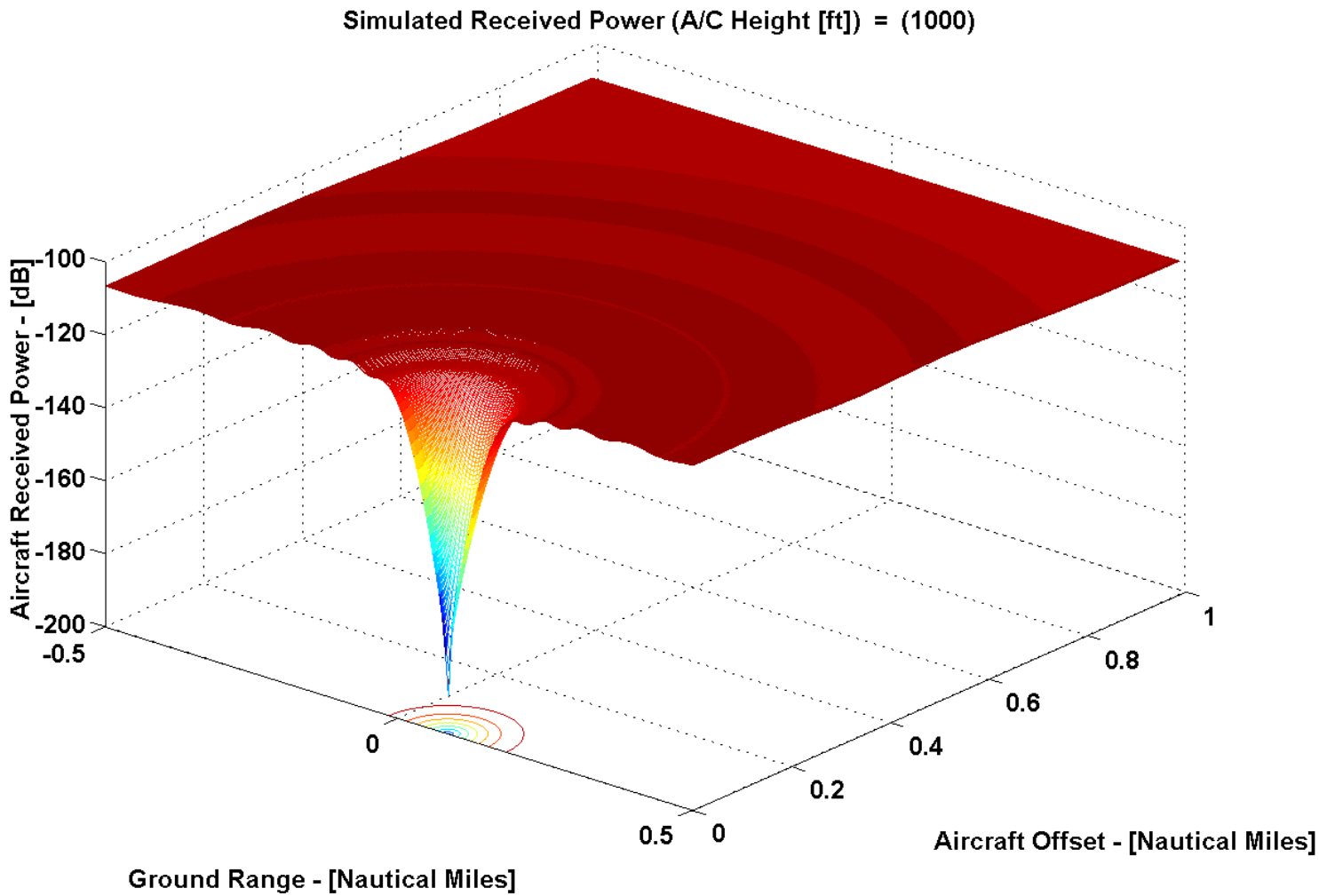


*Ohio University Contract 144G368801 – Technical Data Package, 2/24/01

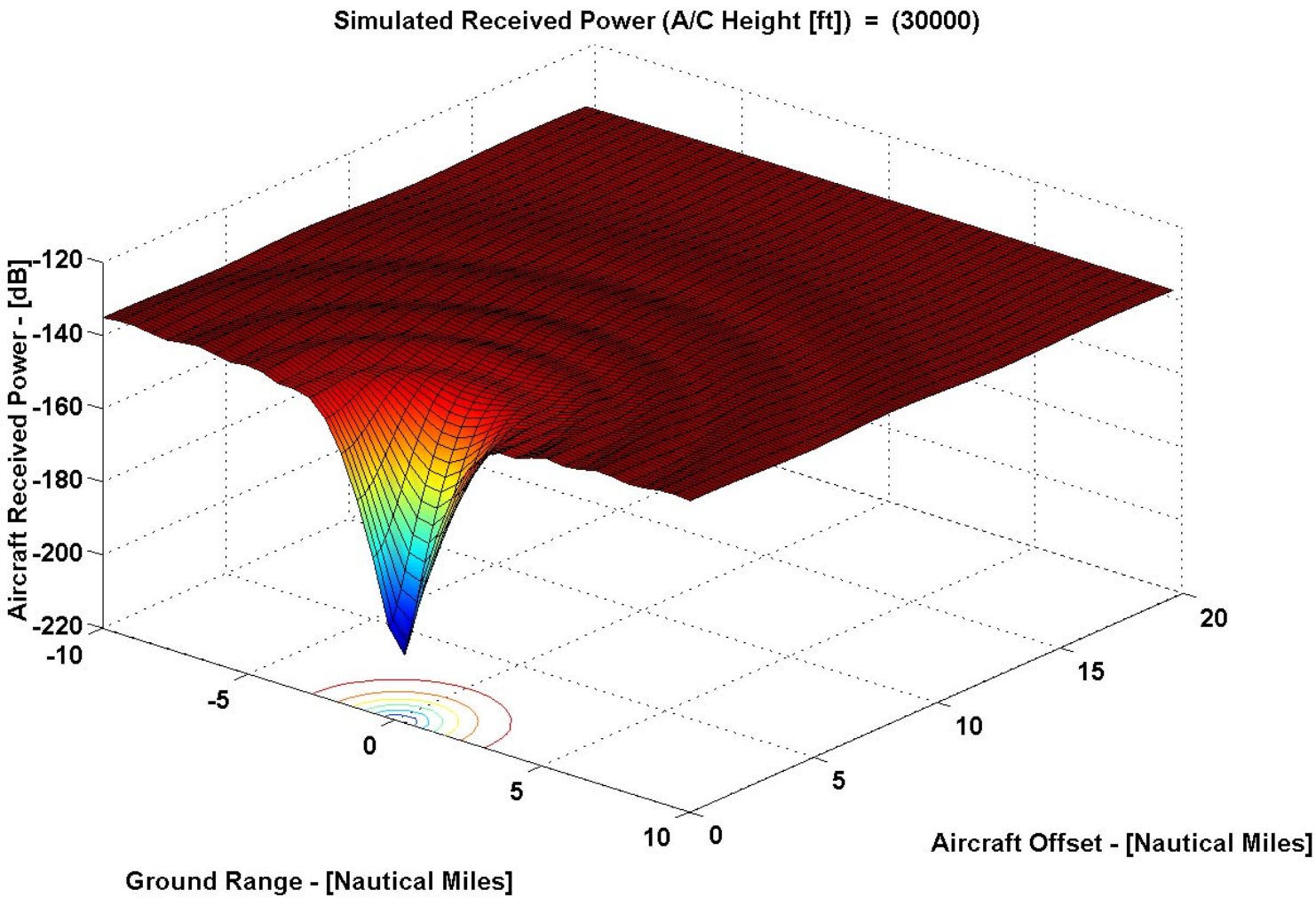
Stage 3 - APL MLA Coverage

- The APL antenna was designed to provide sufficient coverage for aircraft approaches and landings as well as en route navigation.
- A zone of silence exists directly above the antenna.
- This zone of silence is small for low aircraft heights.
  - » Less than 0.2 nmi at an aircraft height of 1,000 ft.
- For en route navigation, the zone of silence is larger.
  - » Less than 2.5 nmi at an aircraft height of 30,000 ft.

Zone of Silence at 1,000 Feet



Zone of Silence at 30,000 Feet



Conclusions

- Exceeding the dynamic range of a receiver can lead to biases in the GPS navigation solution but this can be reduced or eliminated by using antenna siting and pattern development techniques.
- Some antenna sites are better suited for airport pseudolite transmission than others.
- An antenna with a gain pattern tailored to reducing dynamic range requirements can also reduce multipath problems and still maintain a reasonable coverage volume.
- Even with a zone of silence, the proposed WBAPL antenna still provides adequate coverage for en route navigation.