Analysis of the Effects of Atmospheric Noise on Loran-C

Presented by Curtis Cutright
to the International LORAN Association
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Outline

- Purpose
- Data collection system overview
- Flight test overview
- Data processing
- Initial flight test results
- Conclusions
- Future work

Purpose

- Effects of noise on Loran signals
- Precipitation static (p-static)
- Atmospheric noise
  - » Man-made noise
    - – Cross-rate
    - – CW
  - » Lightning

Purpose

- Compare airborne vs. ground environments
- E-field vs. H-field performance
  - » Bandwidth
  - » SNR
  - » Saturation
- P-static mechanisms
- Thunderstorm phenomena

Data Collection System

- **Simultaneous ground and aircraft RF data collection (Using Reelektronika DataGrabber)**
  - **2 channels, 16-bits samples, 400 kSamples/s**
- **LORAN receivers for performance assessment**
- **GPS WAAS for position reference**

Data Collection System

- **Aircraft**
  - » **King Air C-90B**
  - » **Pressurized twin turboprop**
  - » **240 knot cruise speed**

Data Collection System

- **Equipment**
  - » **Novatel OEM4 GPS receiver**
  - » **LORADD-DS DataGrabber**
  - » **WX-500 StormScope**
  - » **Apollo 618**
  - » **Data collection PC**

Data Collection System

- **Ground Equipment**
  - » **Novatel OEM4 GPS receiver**
  - » **LORADD-DS DataGrabber**
  - » **Apollo 618**
  - » **Data collection PC**

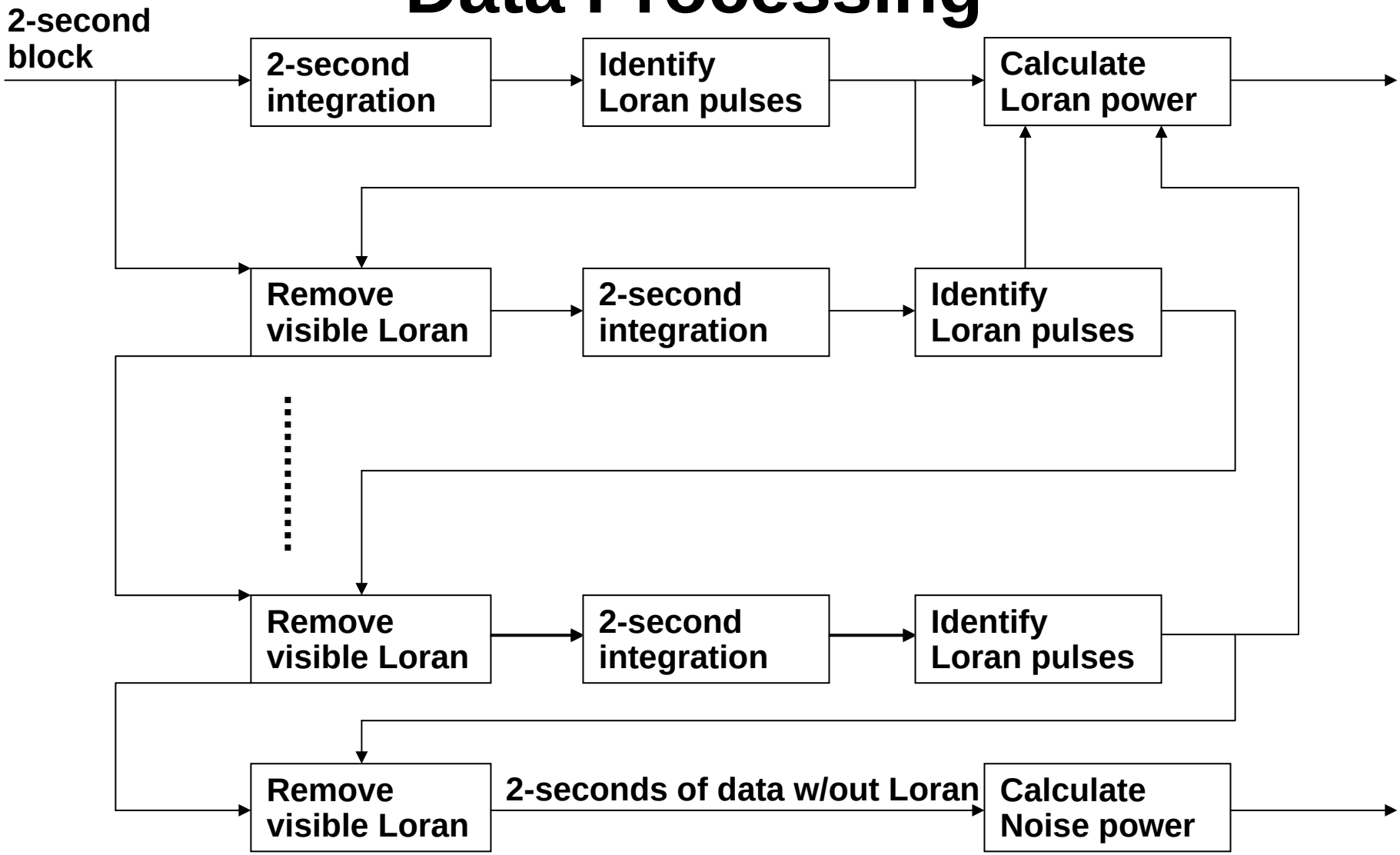
Flight Test Overview

- July 13-17, 2004
- Kendall-Tamiami Executive Airport (TMB)
  - » Frequent t-storm activity
  - » Familiarity with the area
  - » As a “benefit” the area has poor coverage/geometry
- ~10 hours flown
  - » Varied weather conditions
  - » Ground system on battery or AC power

Data Processing

- Processed in 2-second blocks
- No attempt at tracking or position solution
  - » Noise is the data of interest
  - » Visible Loran signals are located
    - – Identified in integrated signal
  - » Loran signal energy found
    - – I and Q channel processed over 2-seconds
  - » Chain is removed and next is processed
  - » Noise energy is calculated

Data Processing



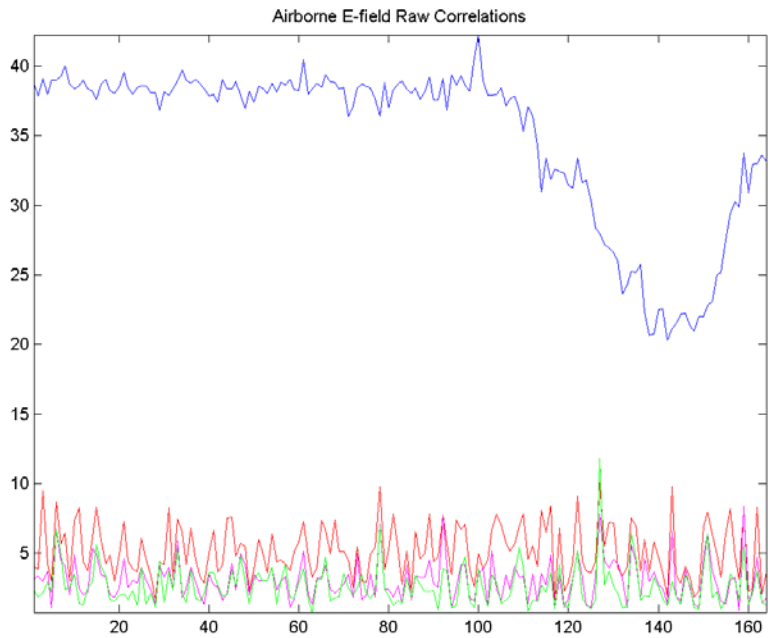
Initial Flight Test Results

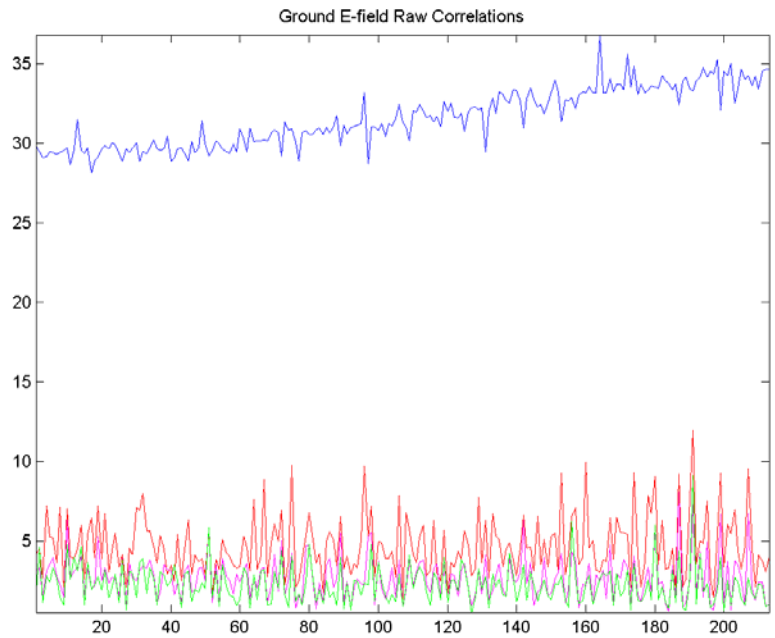
- **5 sets of data**
  - **Different ground equipment power sources**
  - **Varied weather conditions**
- **Plots**
  - **Correlation results**
  - **Noise PDF**
  - **Noise CDF**
  - **Loran energy (E) vs. noise energy (N_o)**
  - **Airborne vs. ground E/ N_o ratio**

Initial Flight Test Results – Set 2

- **Set 2**
  - **Aircraft takeoff**
  - **Ground van using AC power**
  - **No significant weather**

Initial Flight Test Results – Set 2





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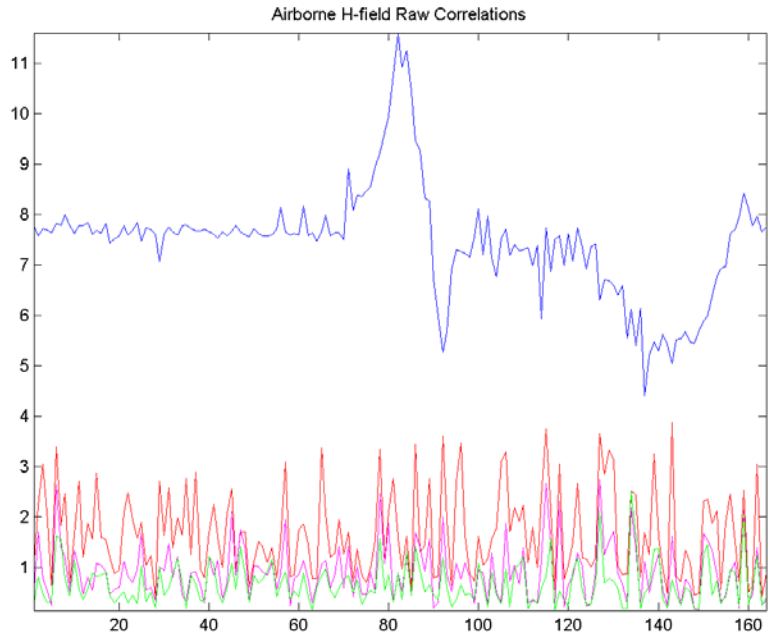

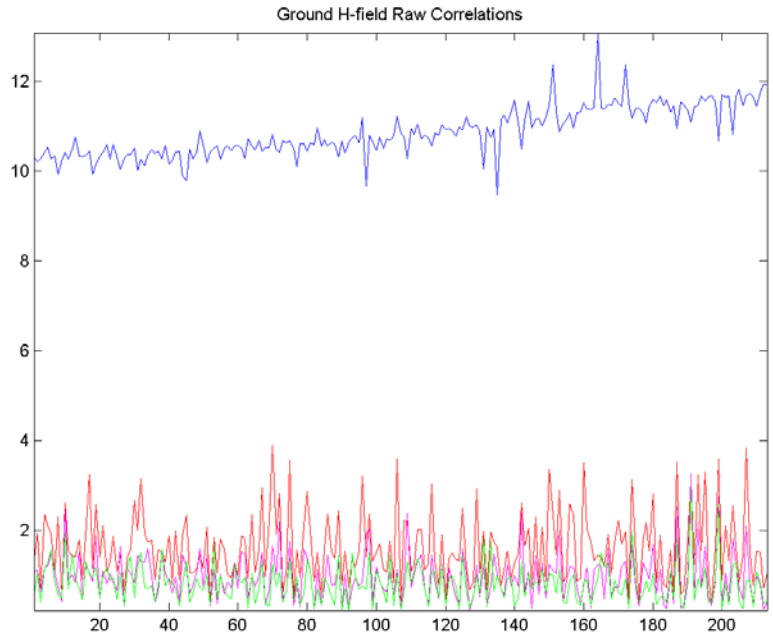

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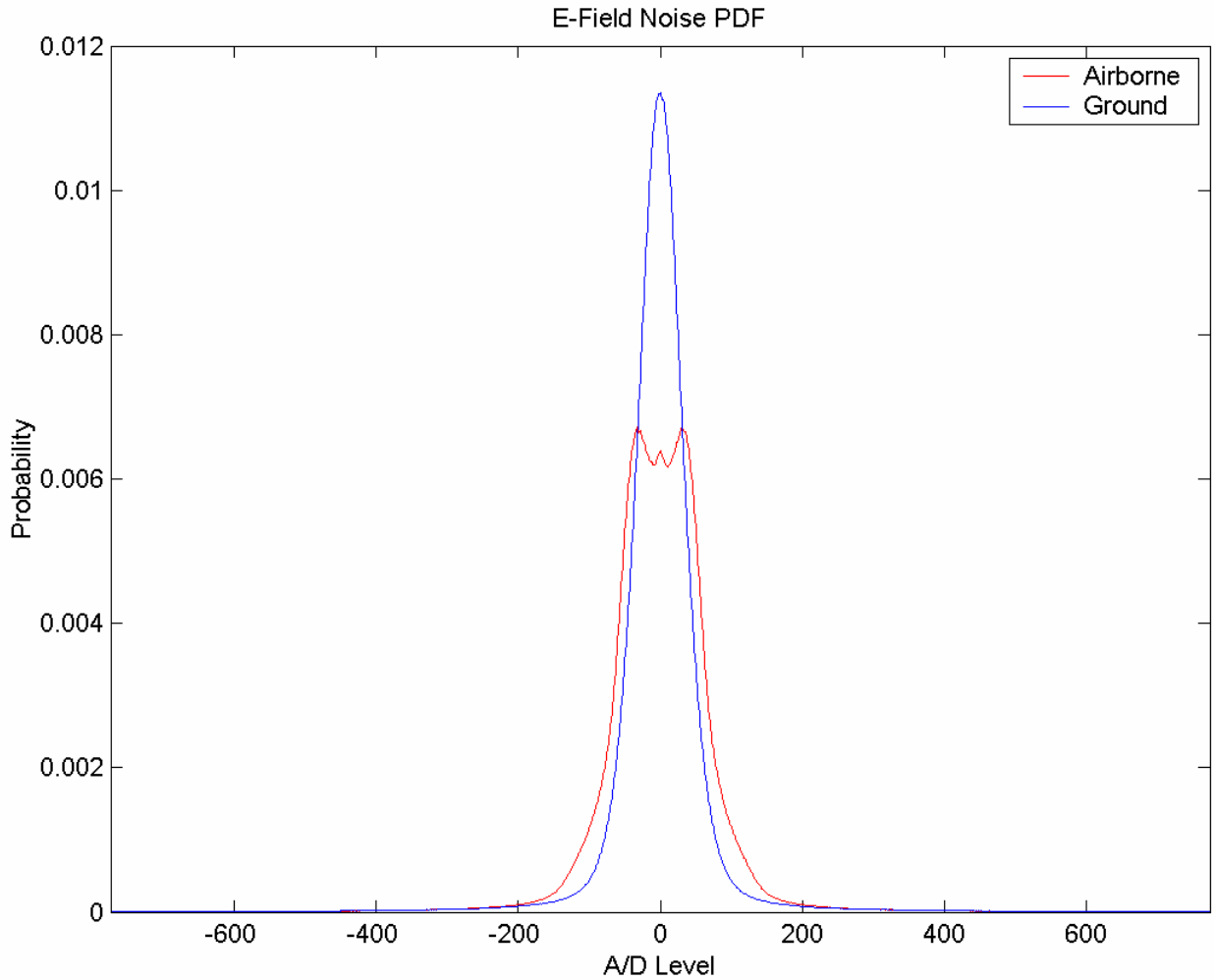

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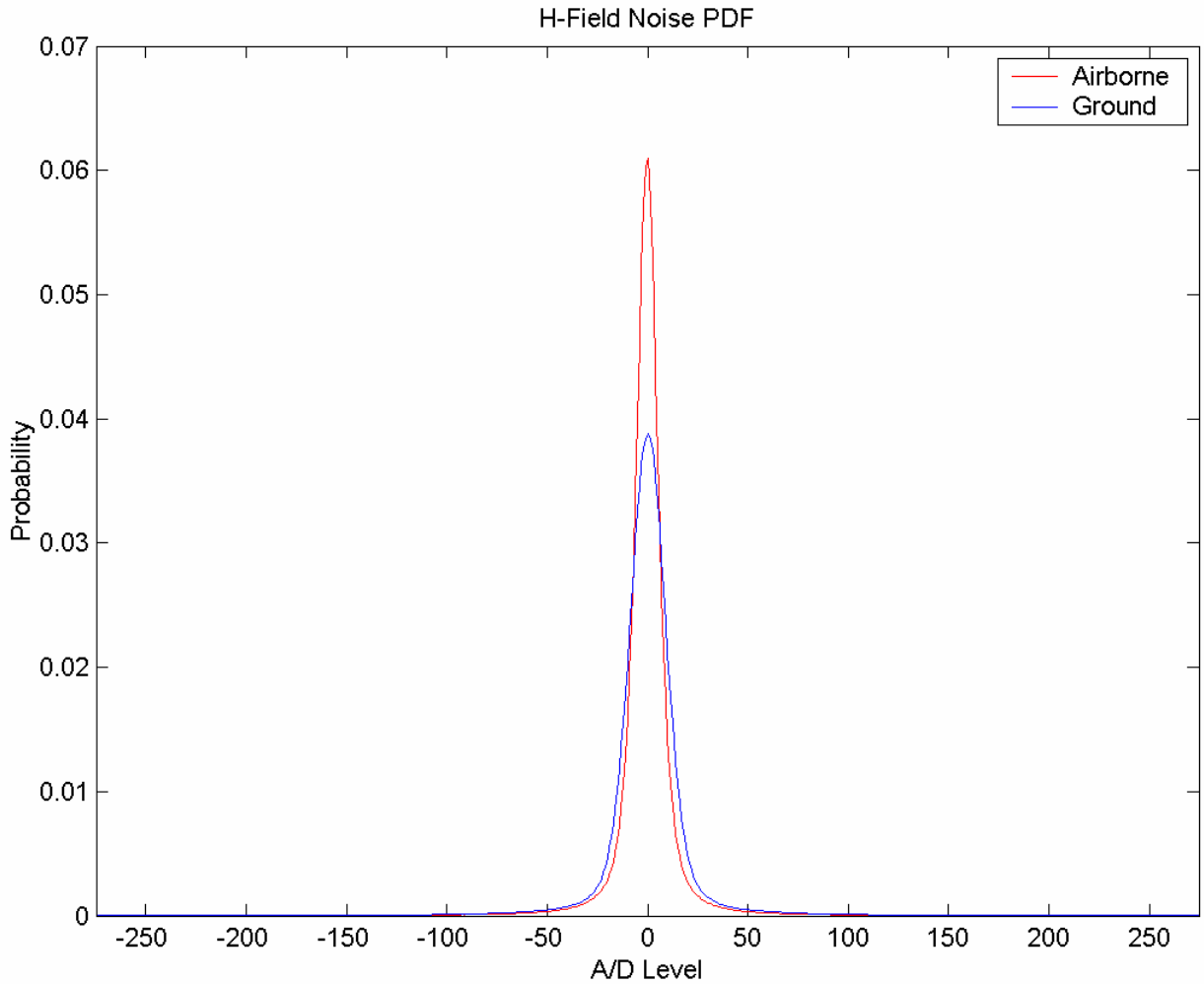

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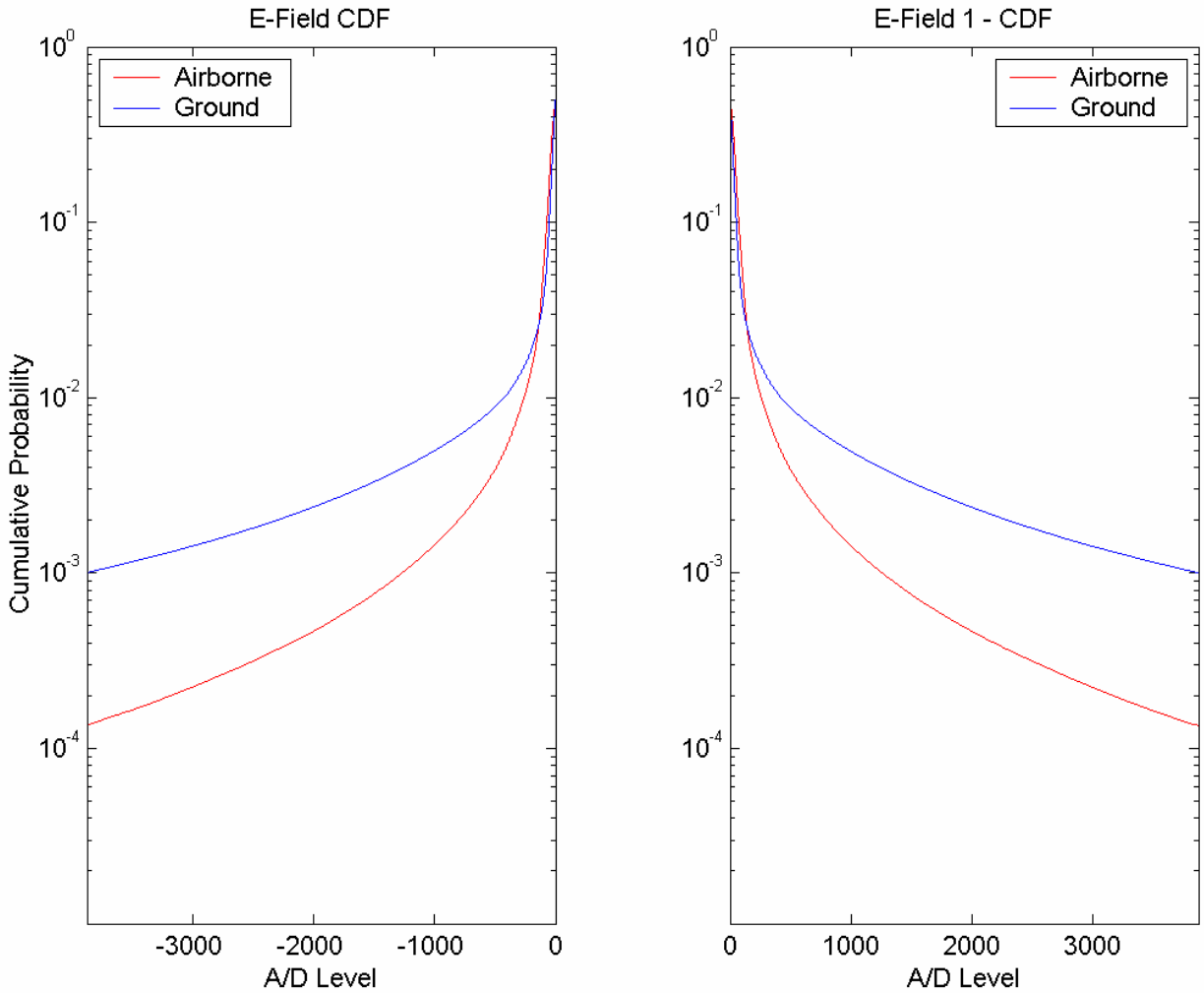

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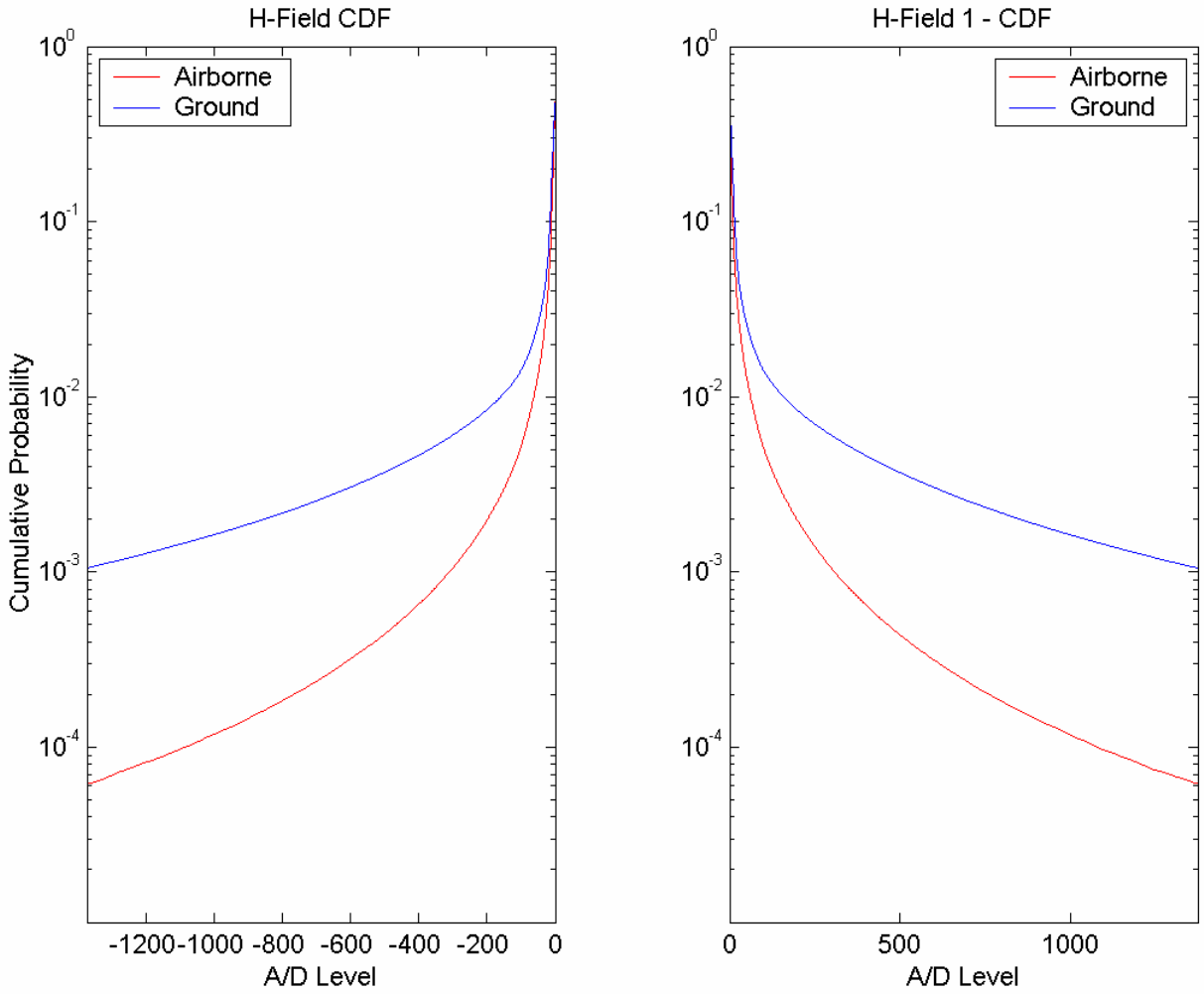

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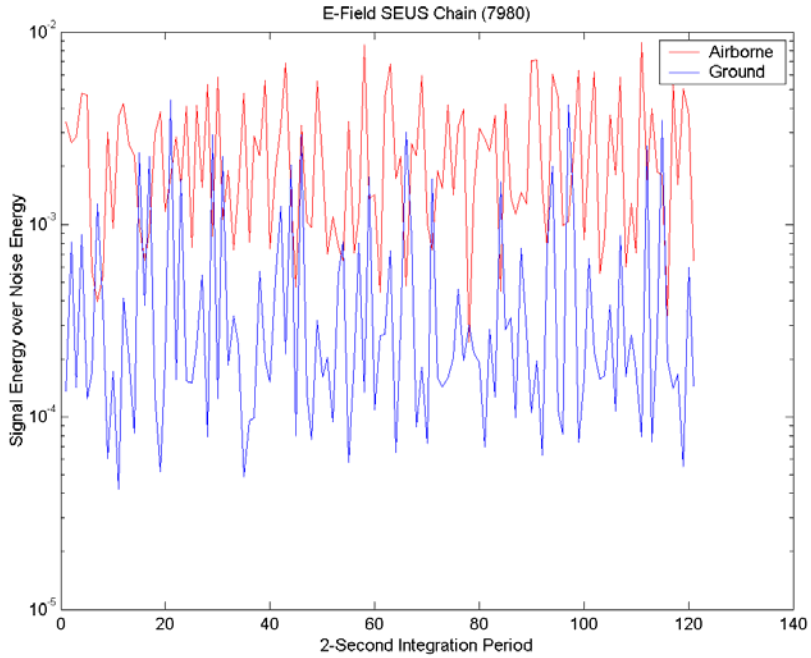

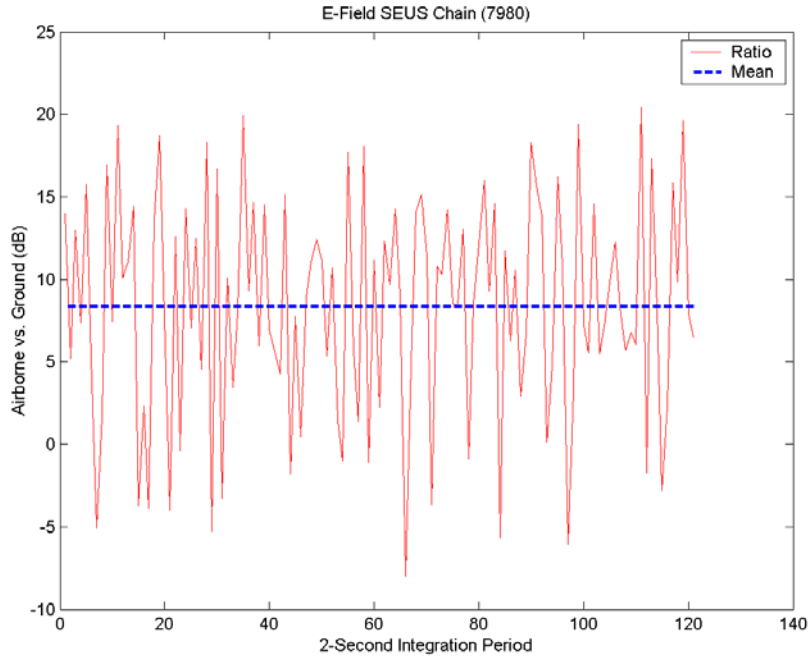

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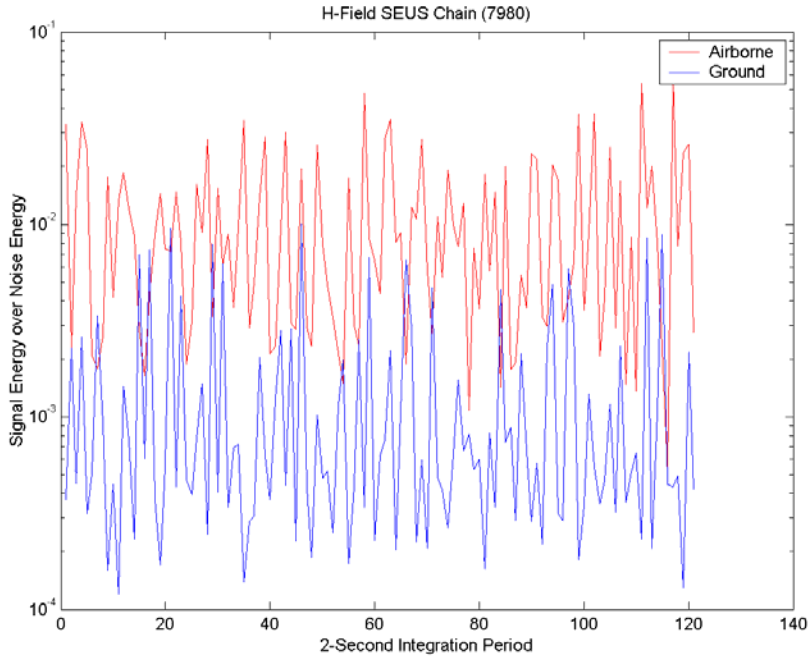
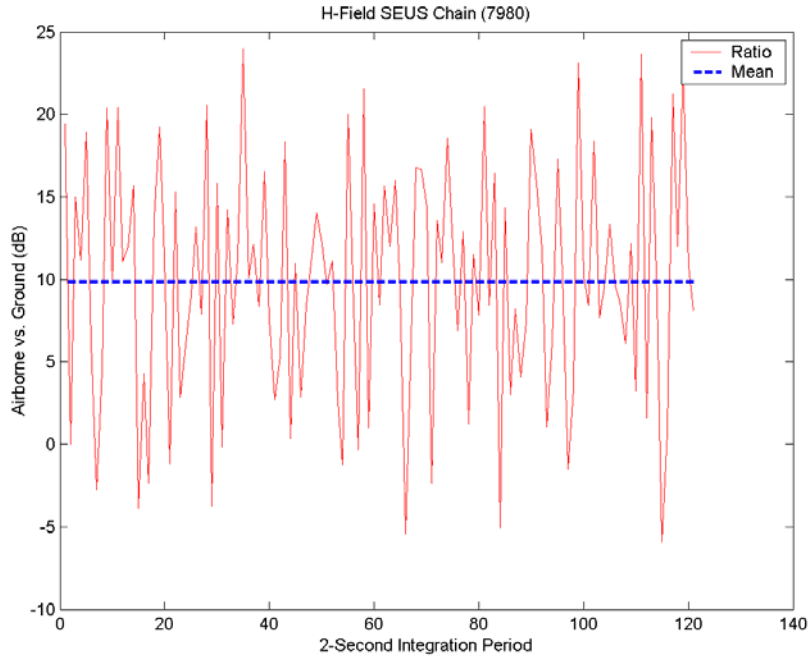
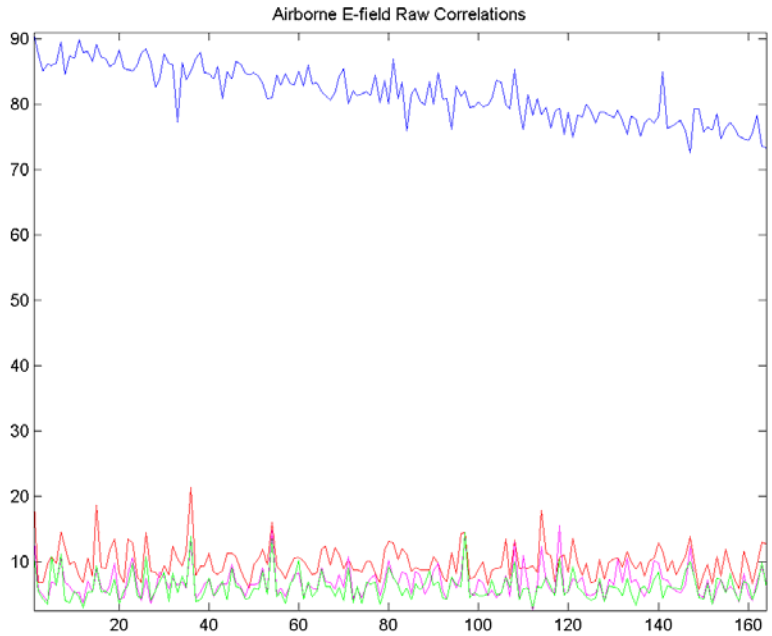


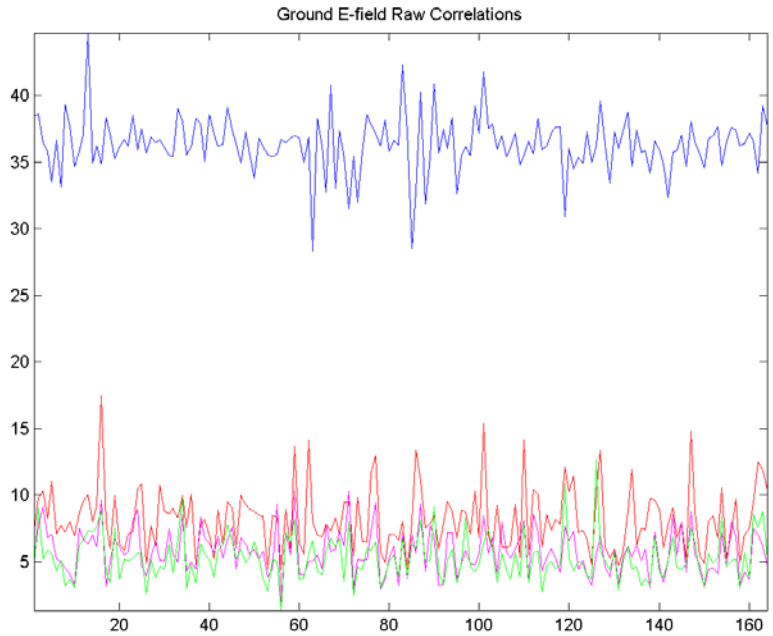


Initial Flight Test Results – Set 3

- **Set 3**
  - **Aircraft parked at TMB FBO**
  - **Van on AC power**
  - **T-storms directly over TMB**

Initial Flight Test Results – Set 3





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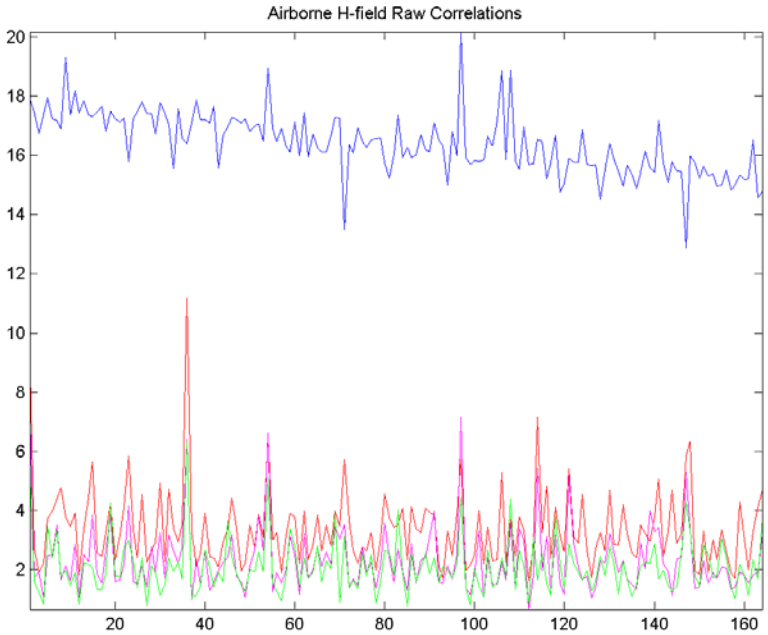

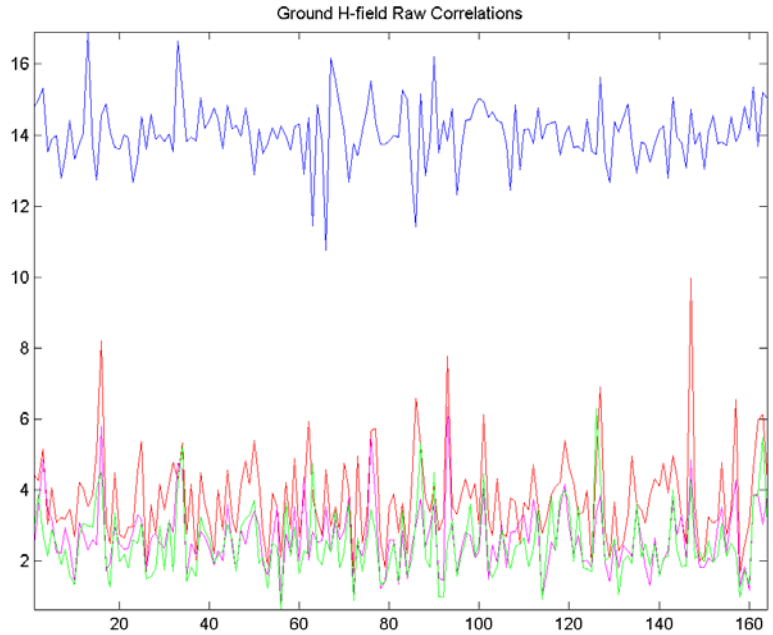

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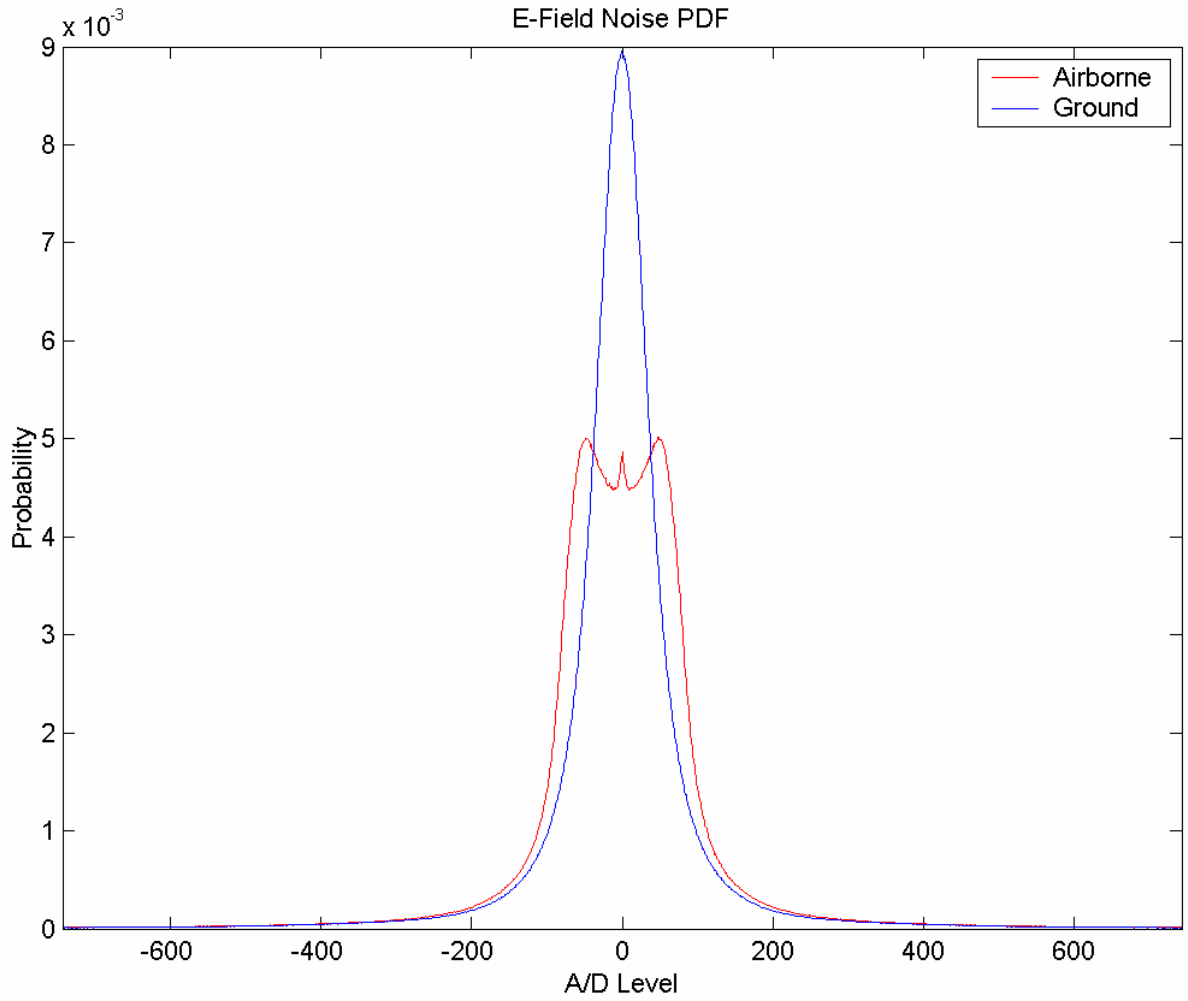

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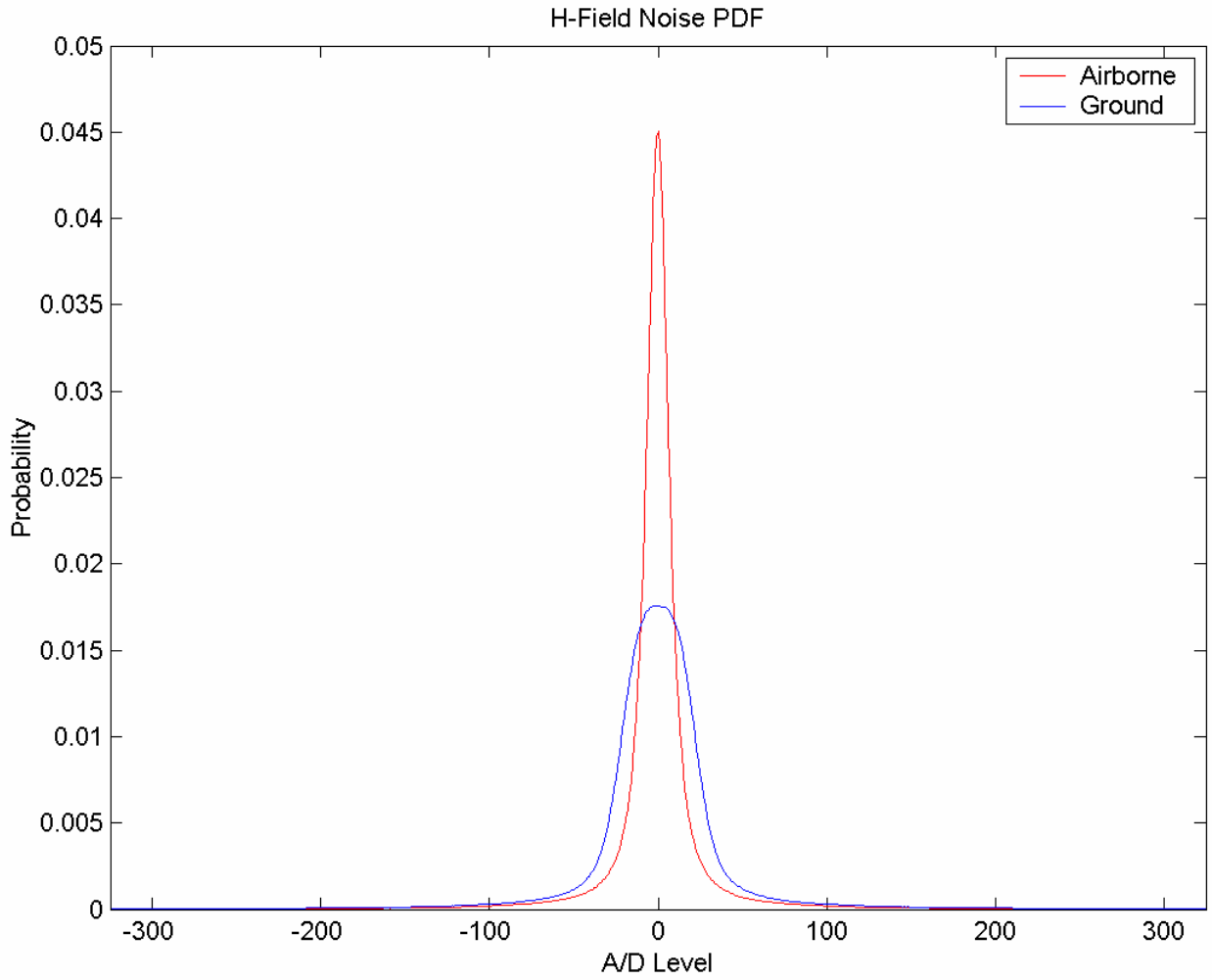

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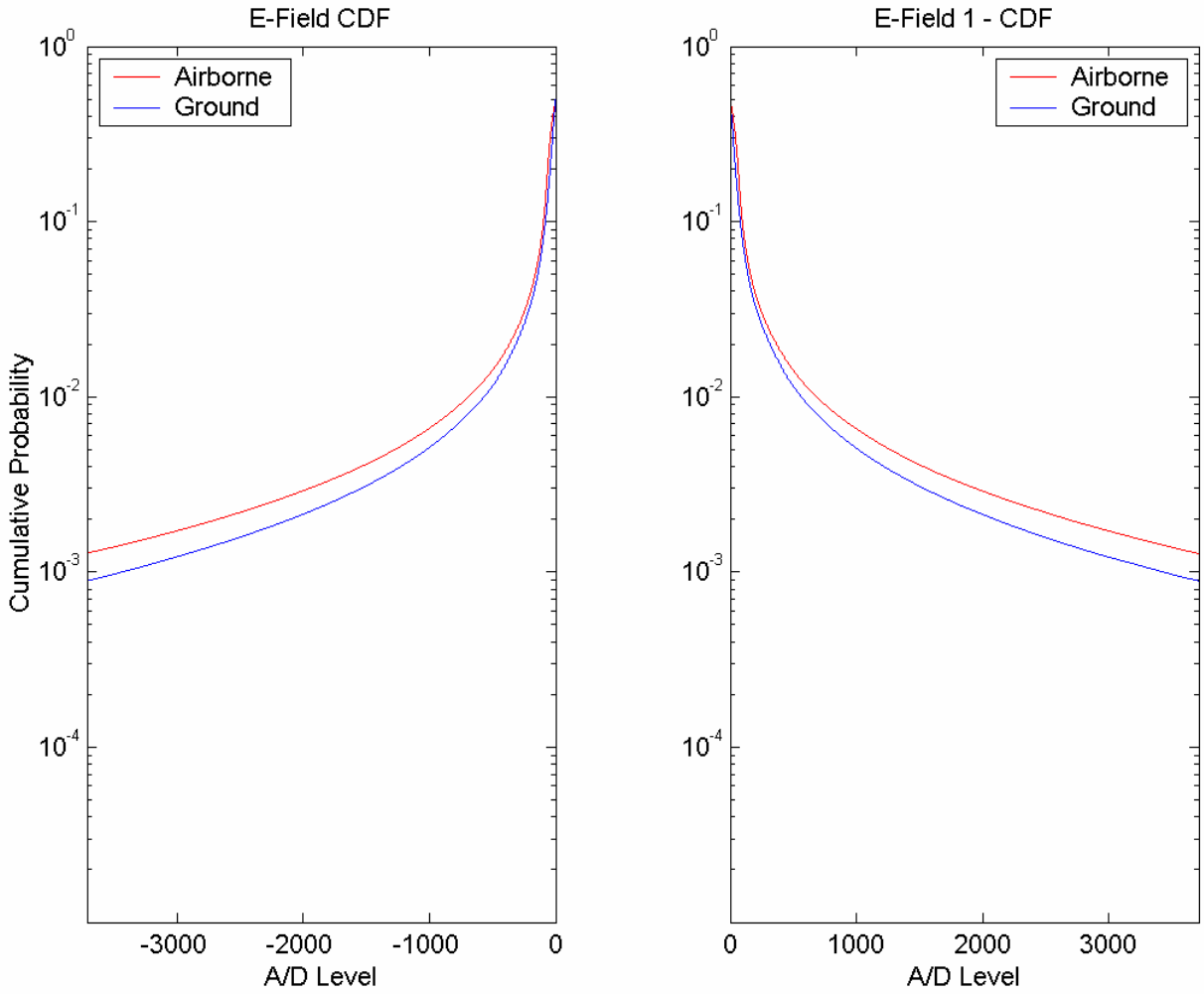

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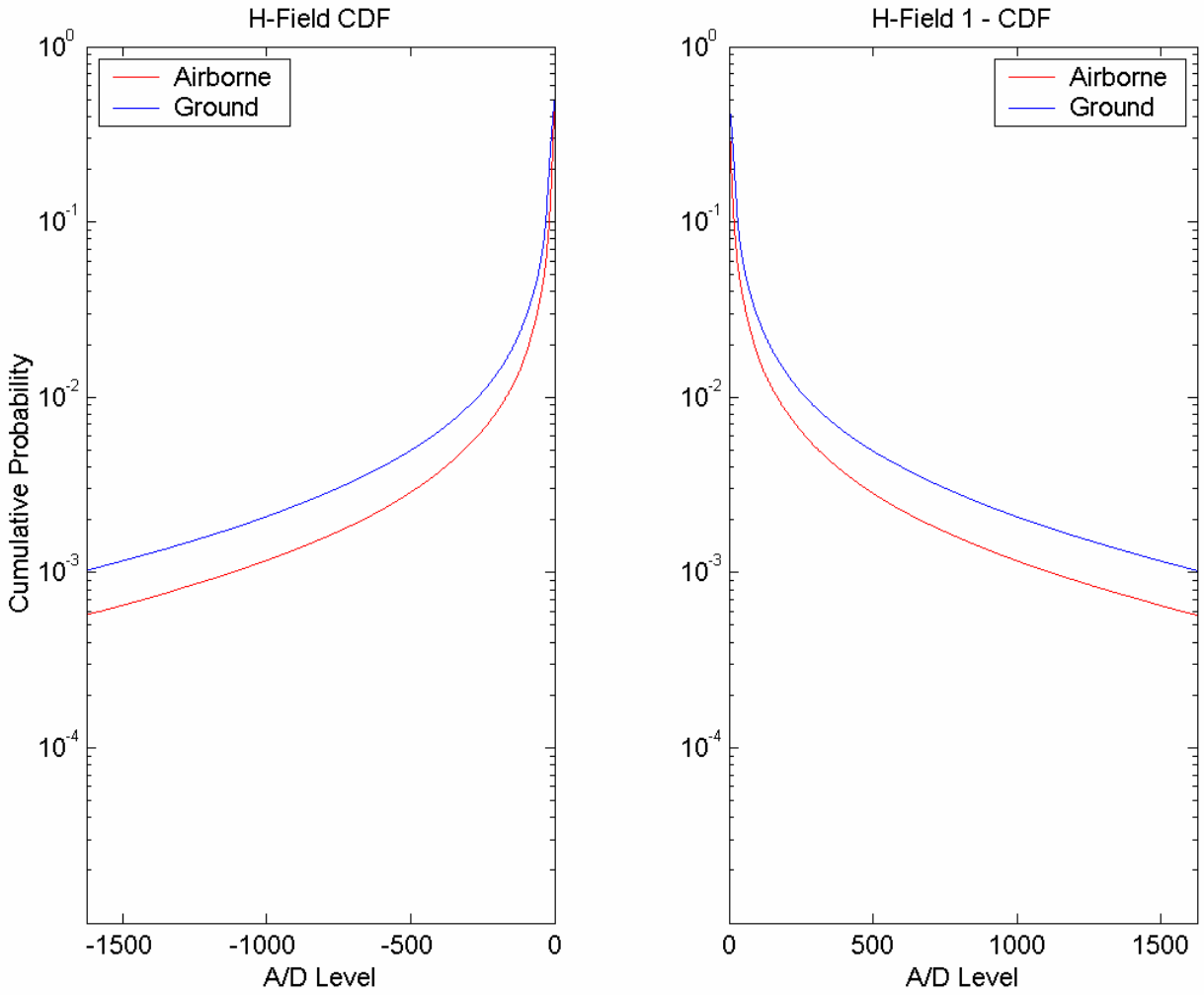

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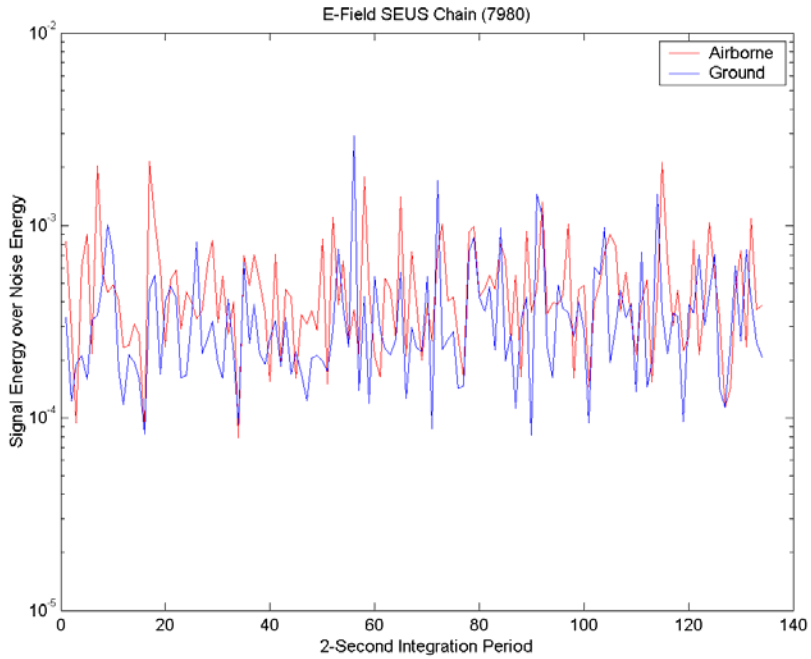

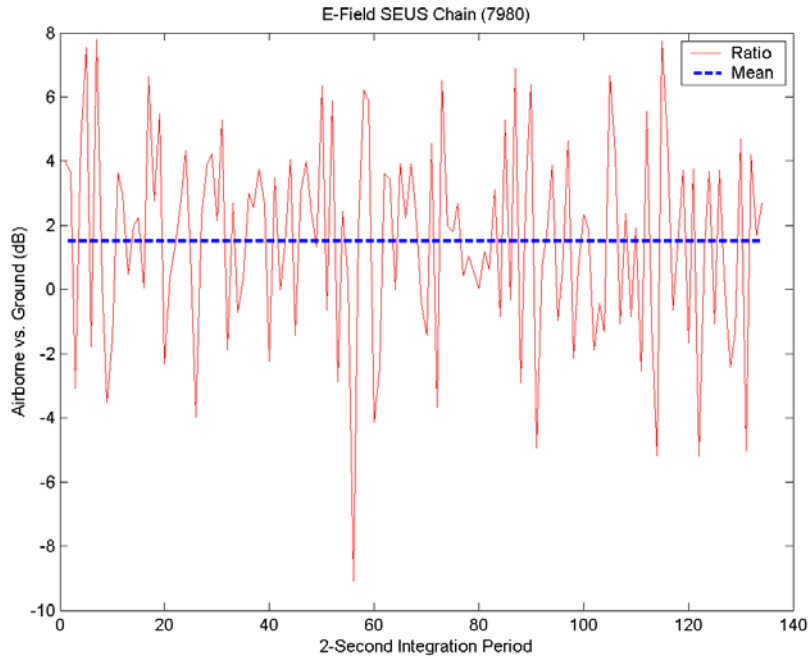

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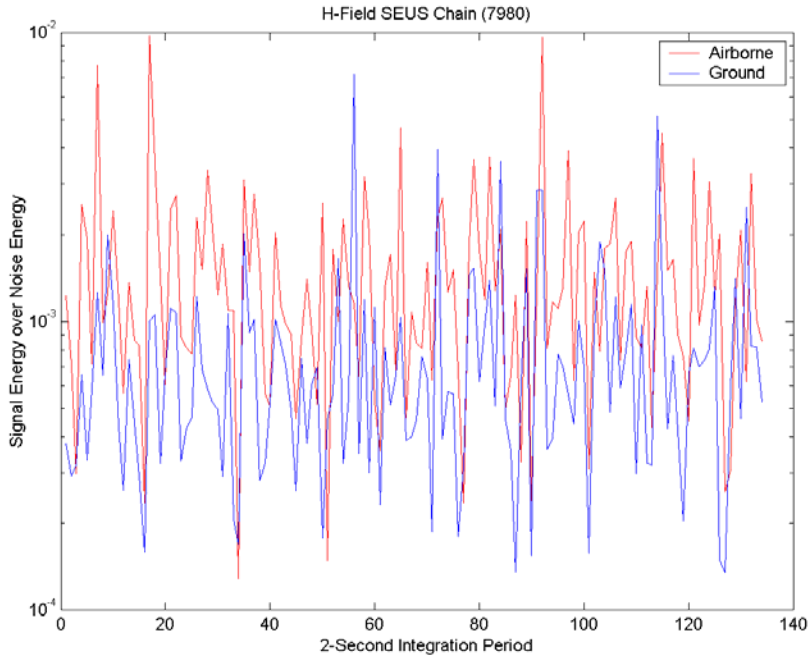
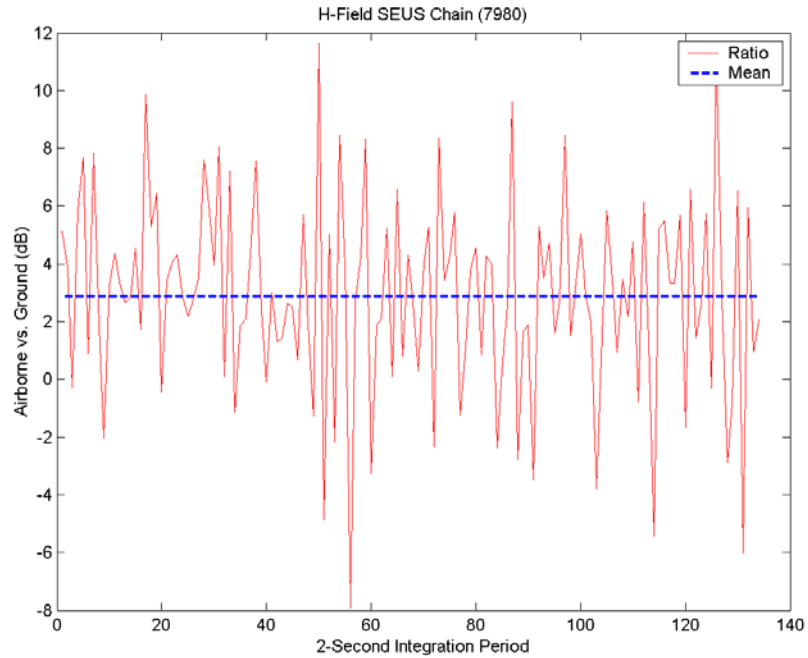
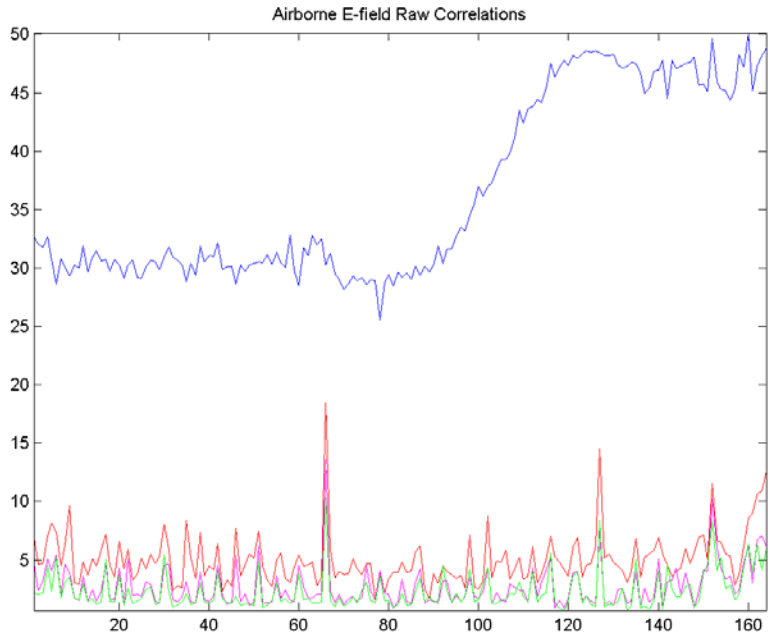


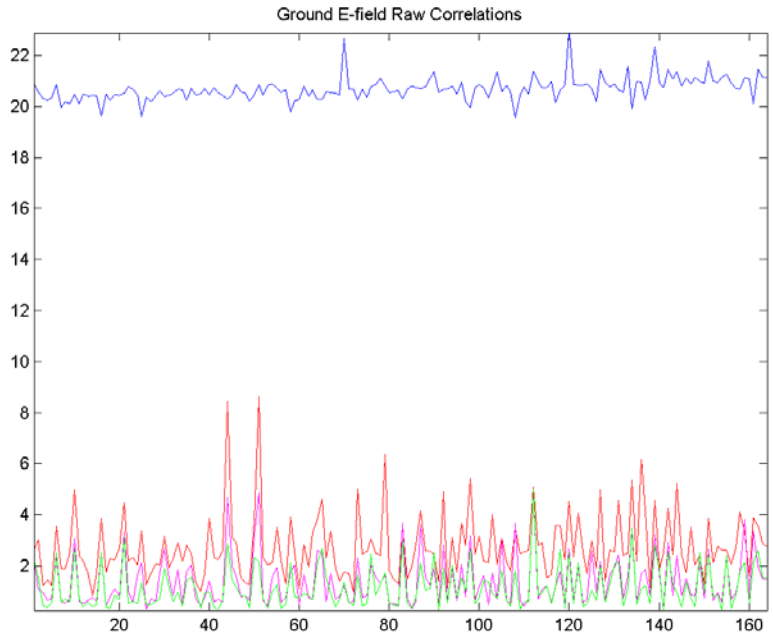


Initial Flight Test Results – Set 4

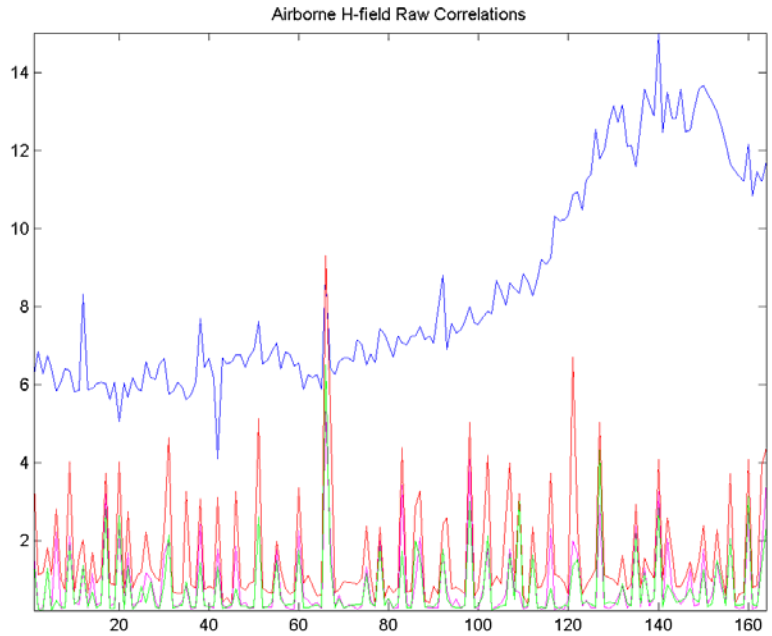
- **Set 4**
  - **Aircraft flying near moderate t-storms**
  - **Van on battery power**
  - **Light-to-moderate lightning activity**
  - **No significant weather over TMB**

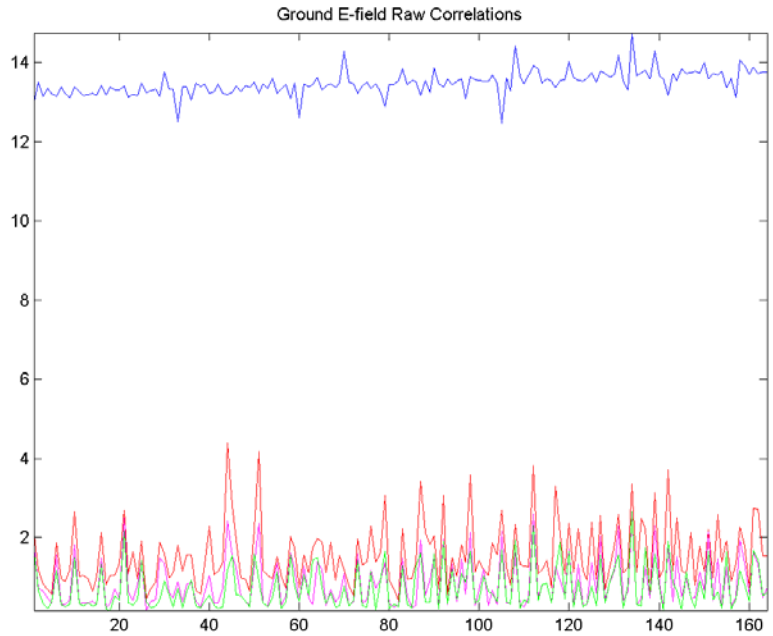
Initial Flight Test Results – Set 4





Initial Flight Test Results – Set 4





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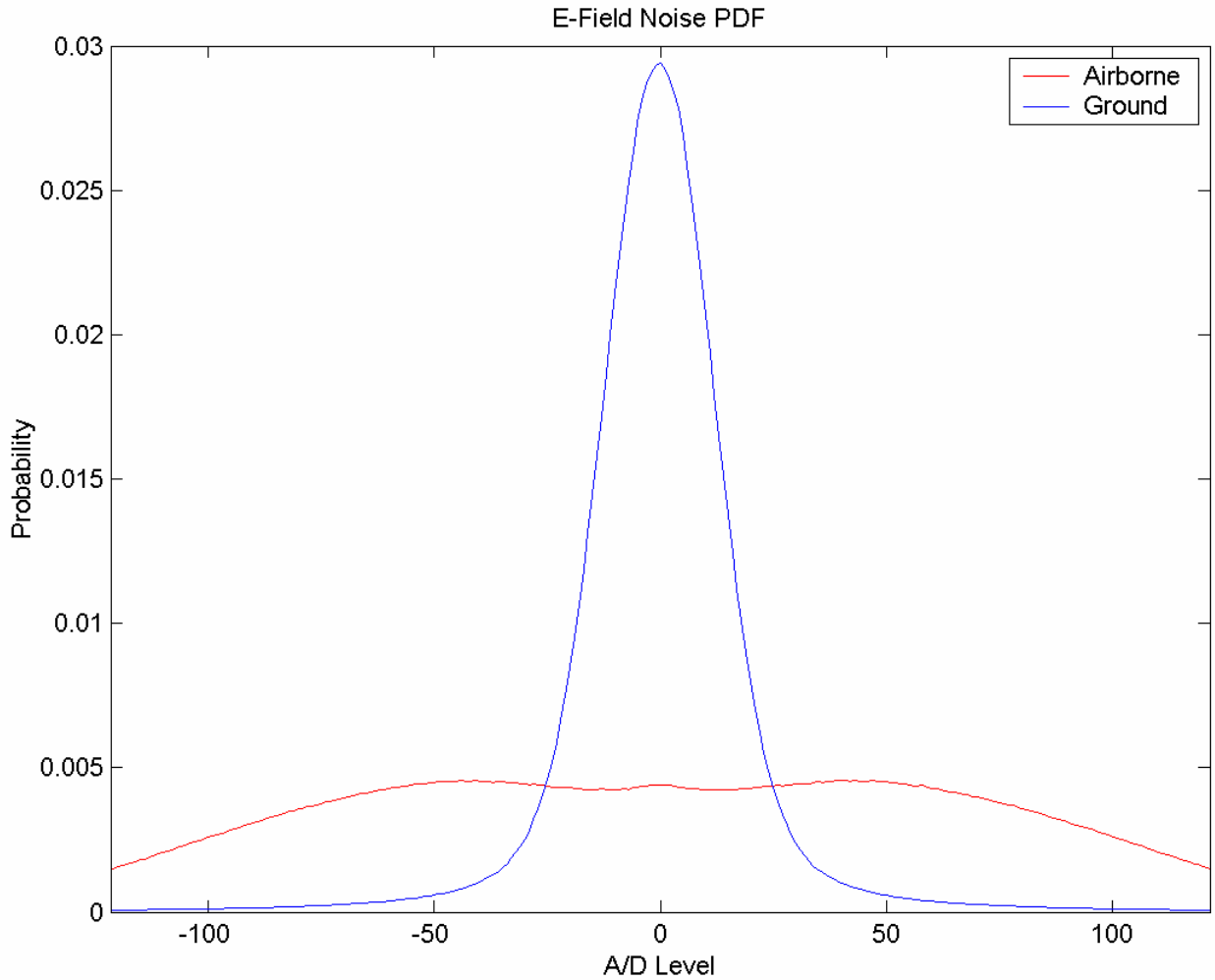

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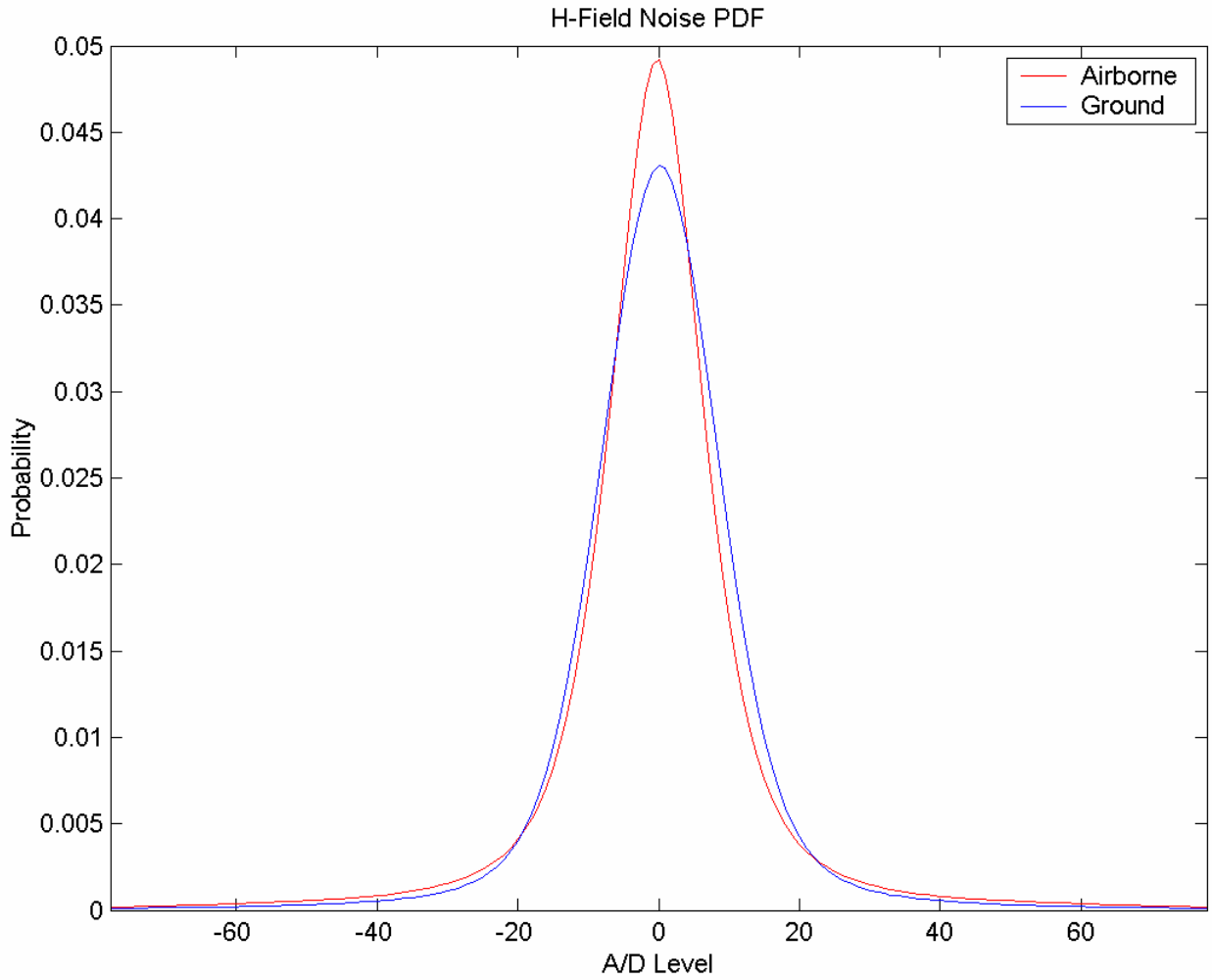

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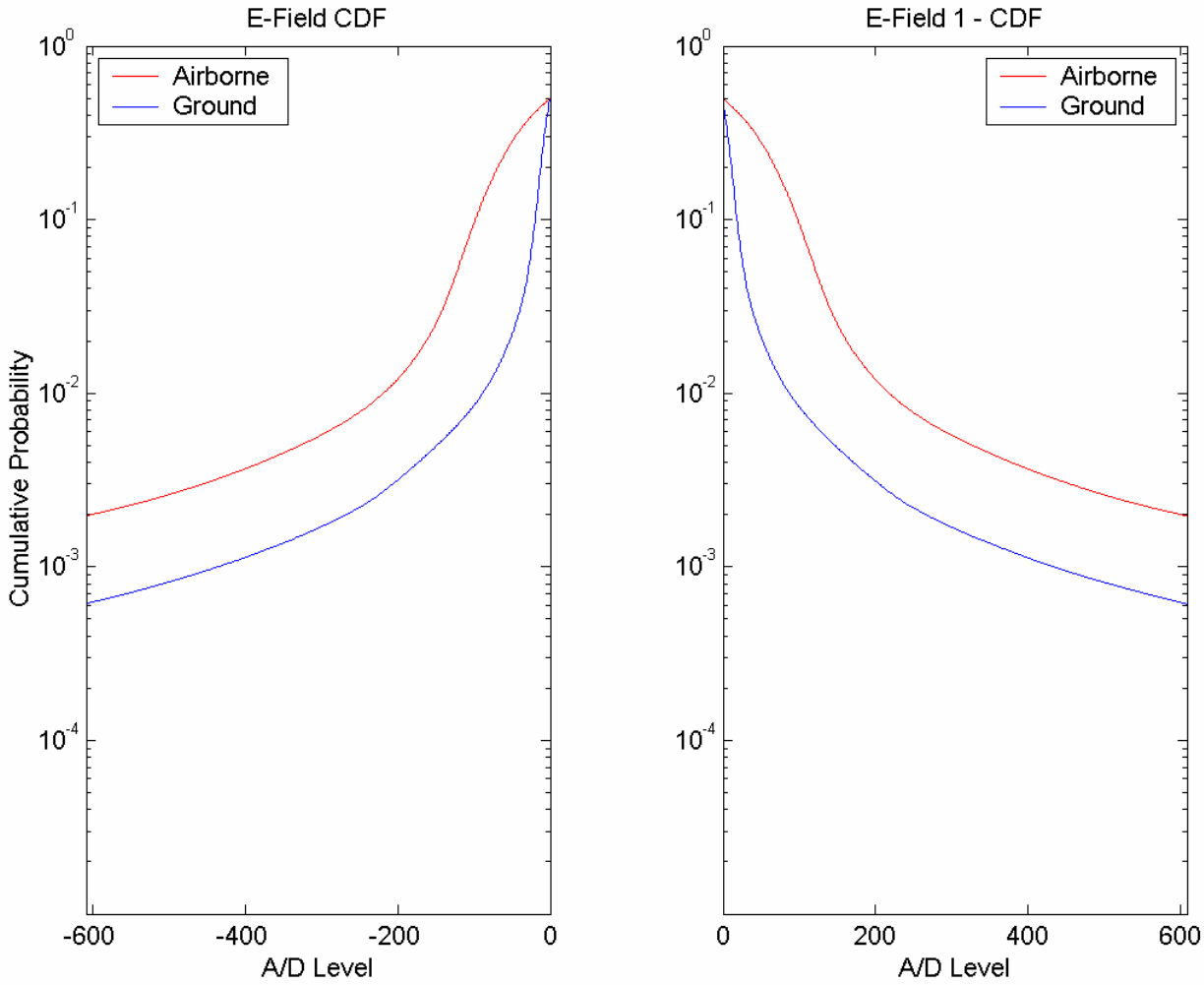

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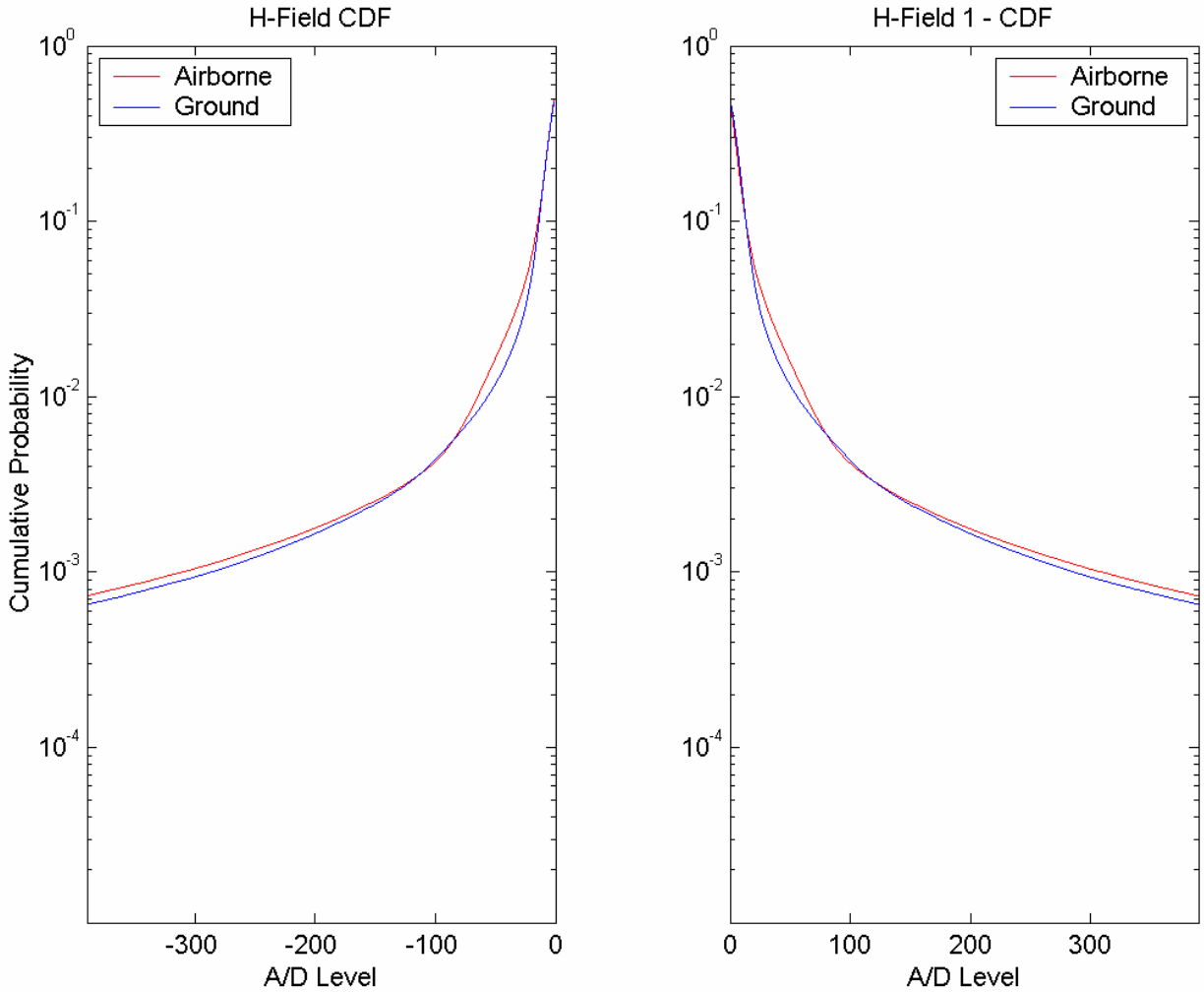

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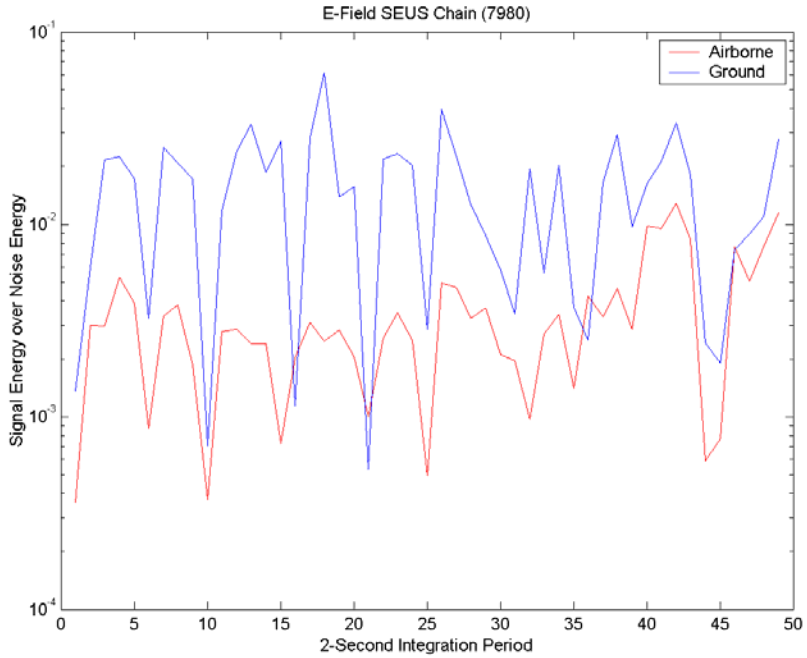

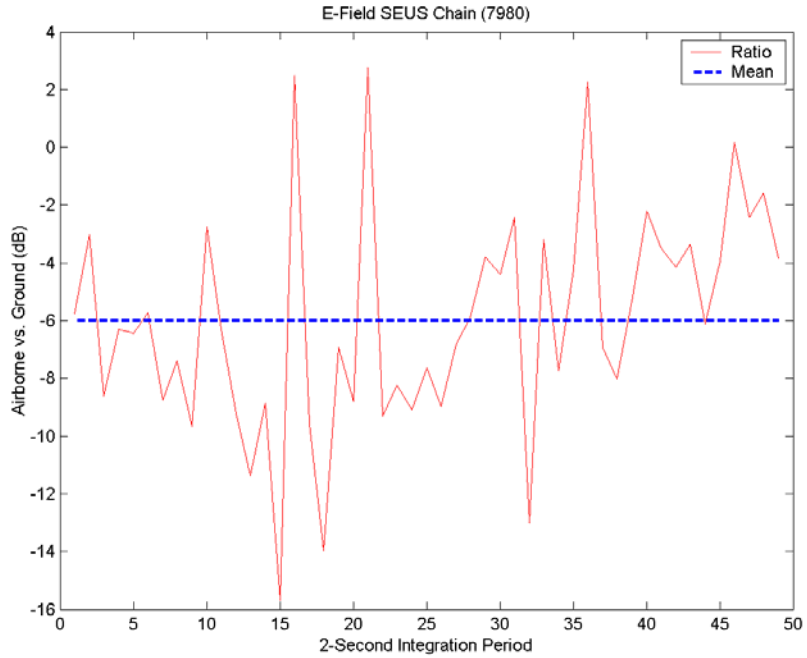

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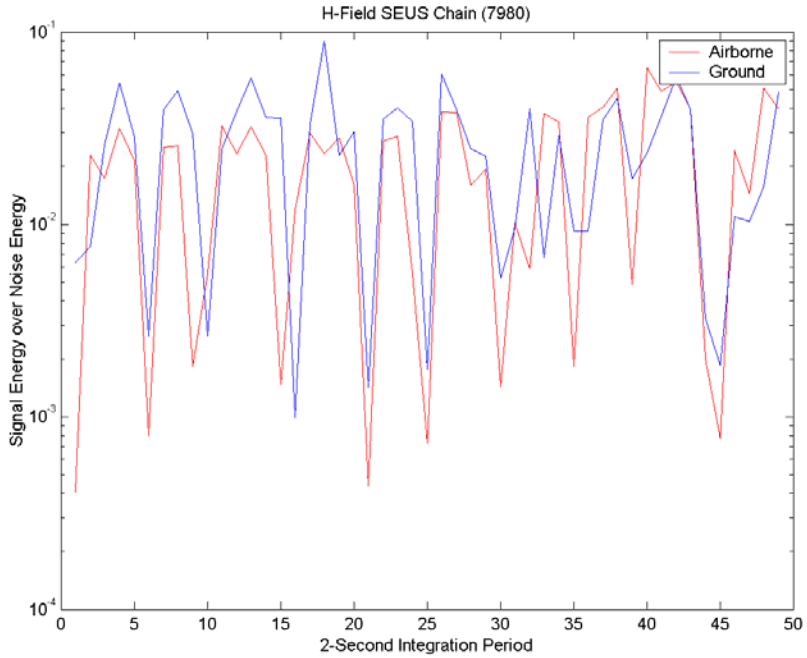

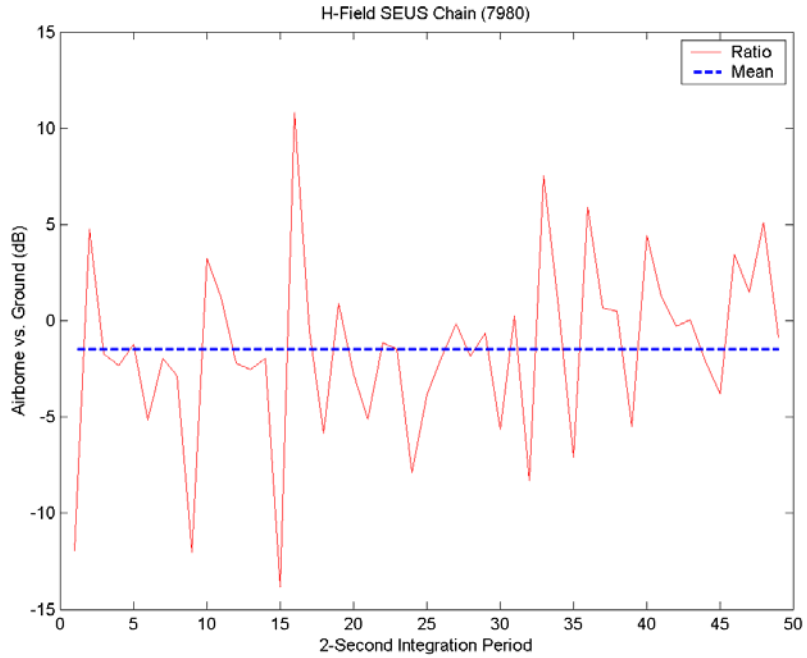

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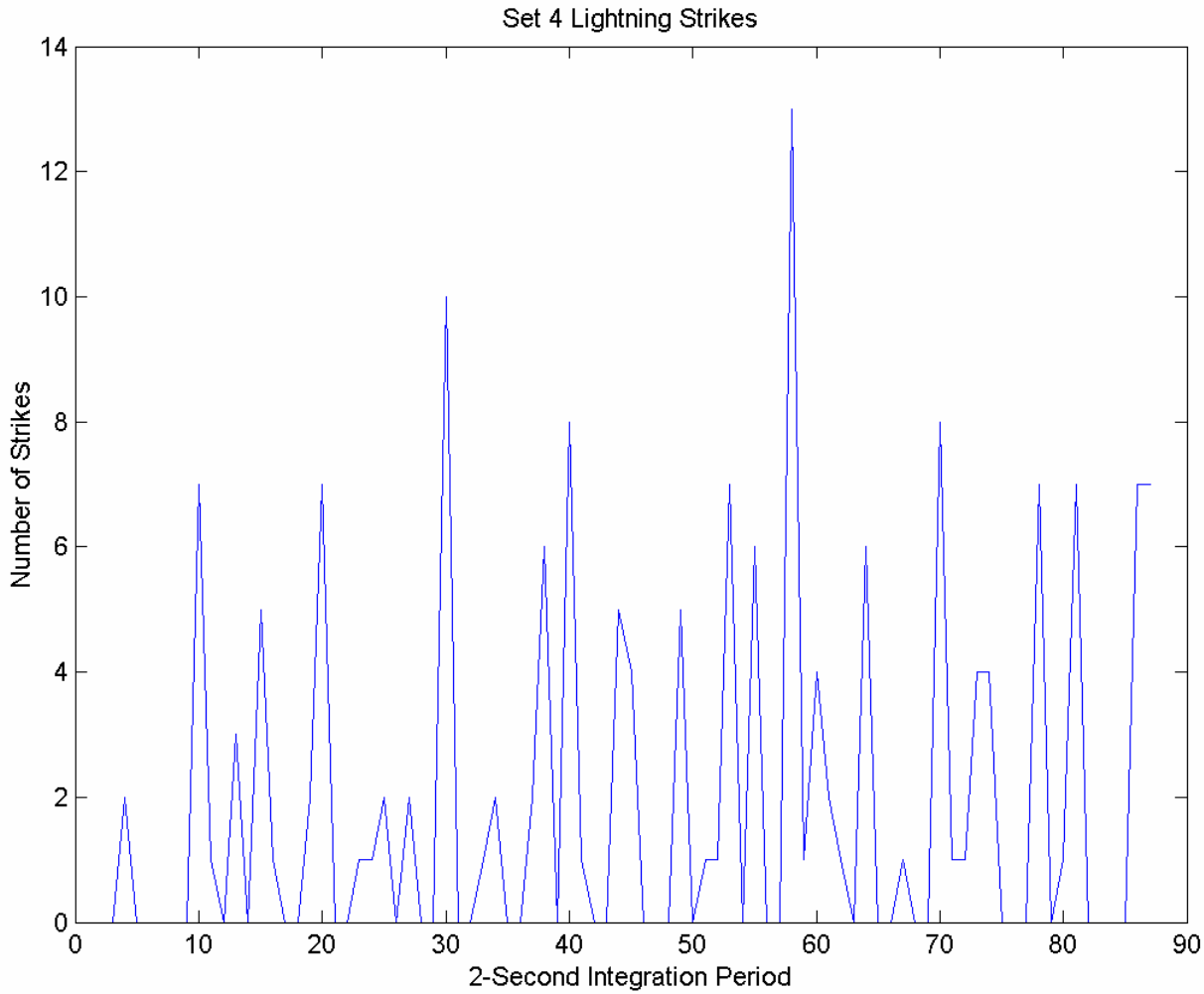
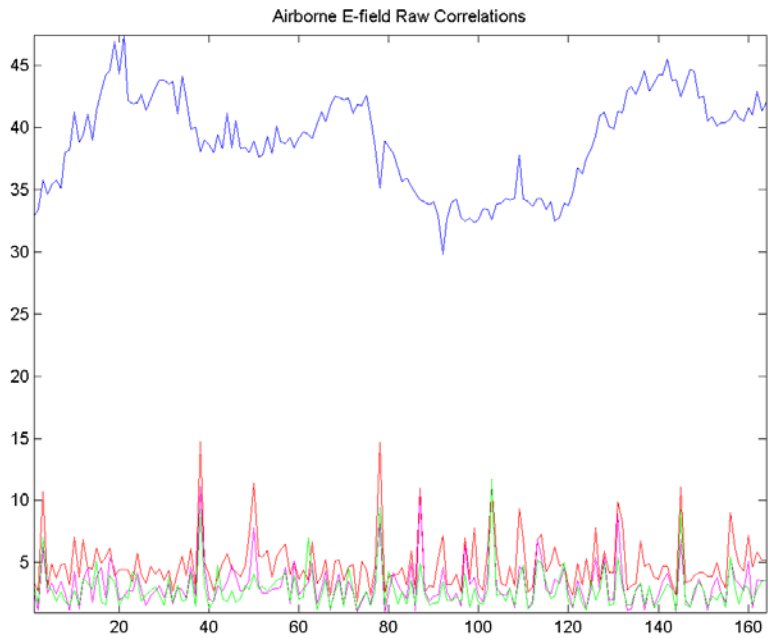
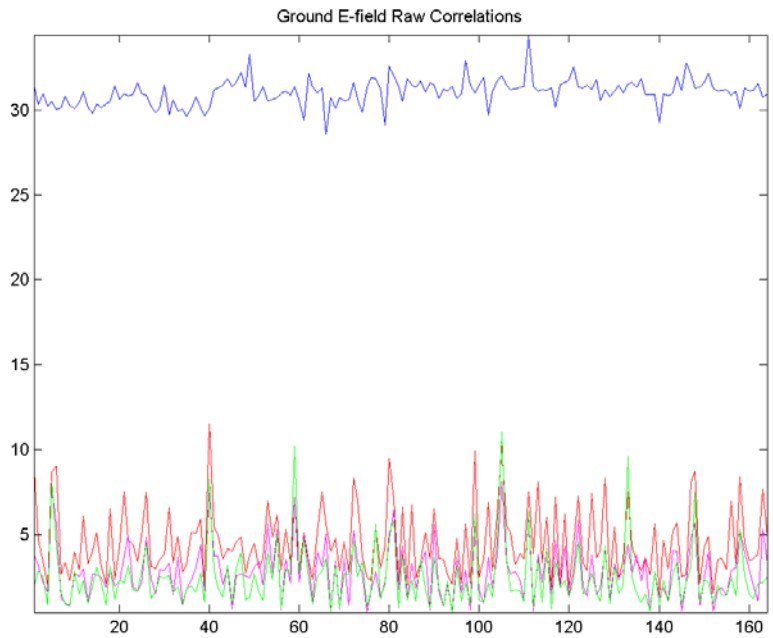


Initial Flight Test Results – Set 5

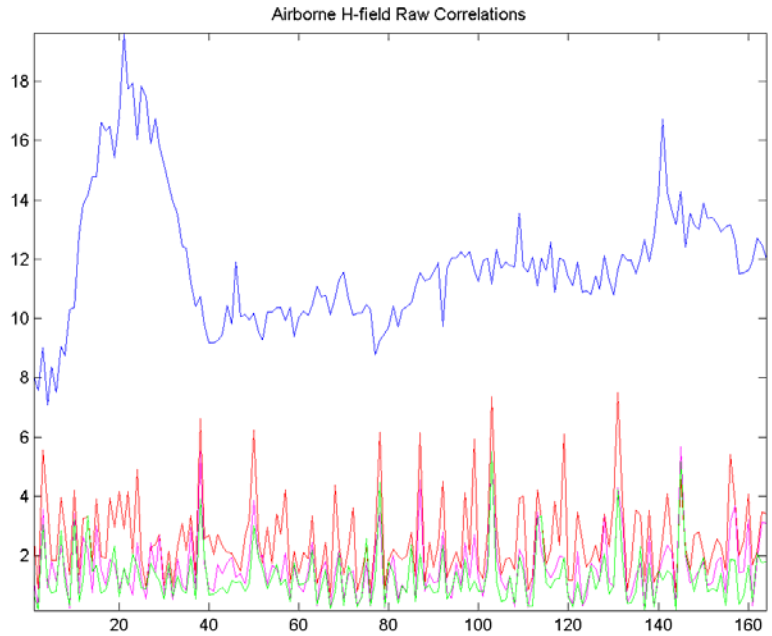
- **Set 5**
  - **Aircraft flying near moderate-to-severe t-storms**
  - **Van on AC power**
  - **Moderate-to-heavy lightning activity**
  - **No significant weather near TMB**

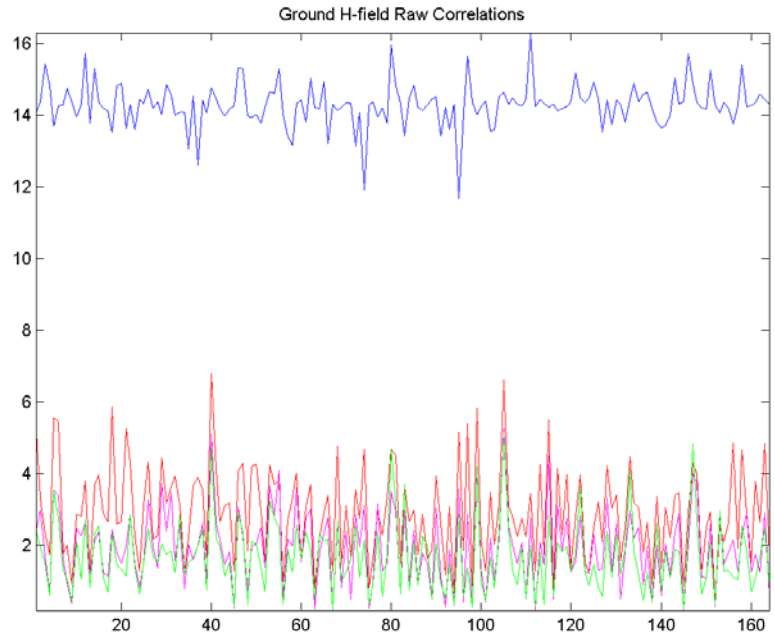
Initial Flight Test Results – Set 5





Initial Flight Test Results – Set 5





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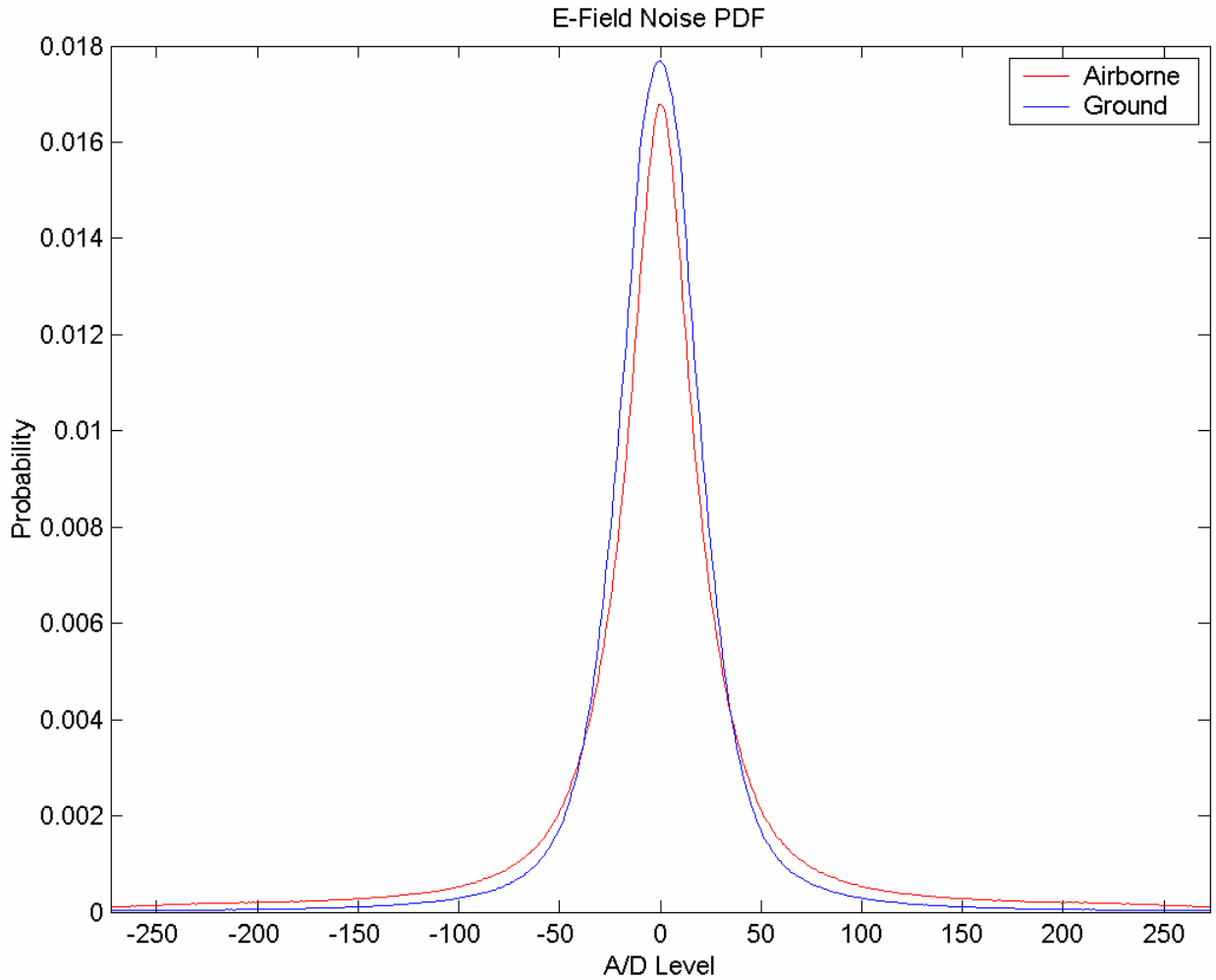

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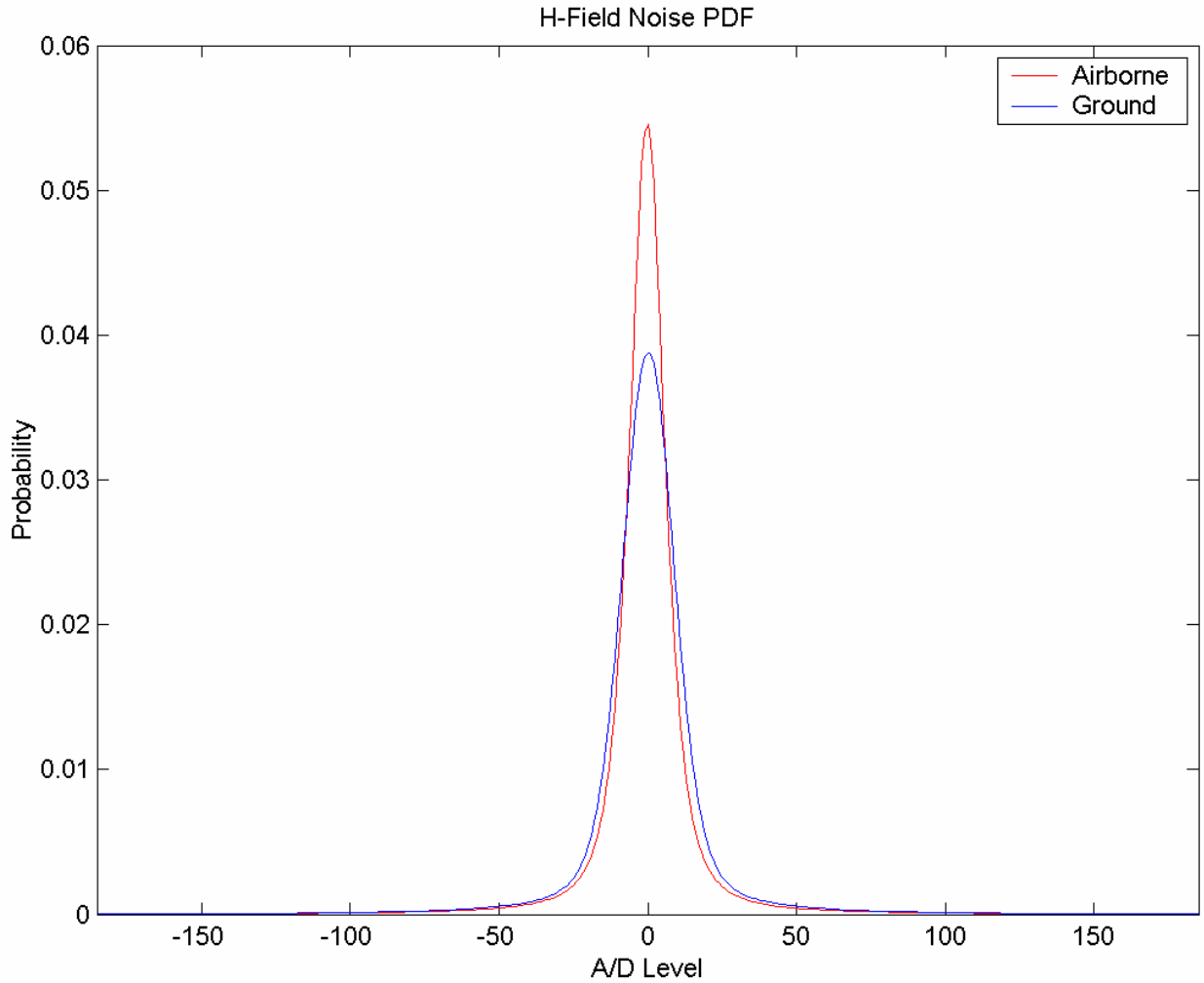

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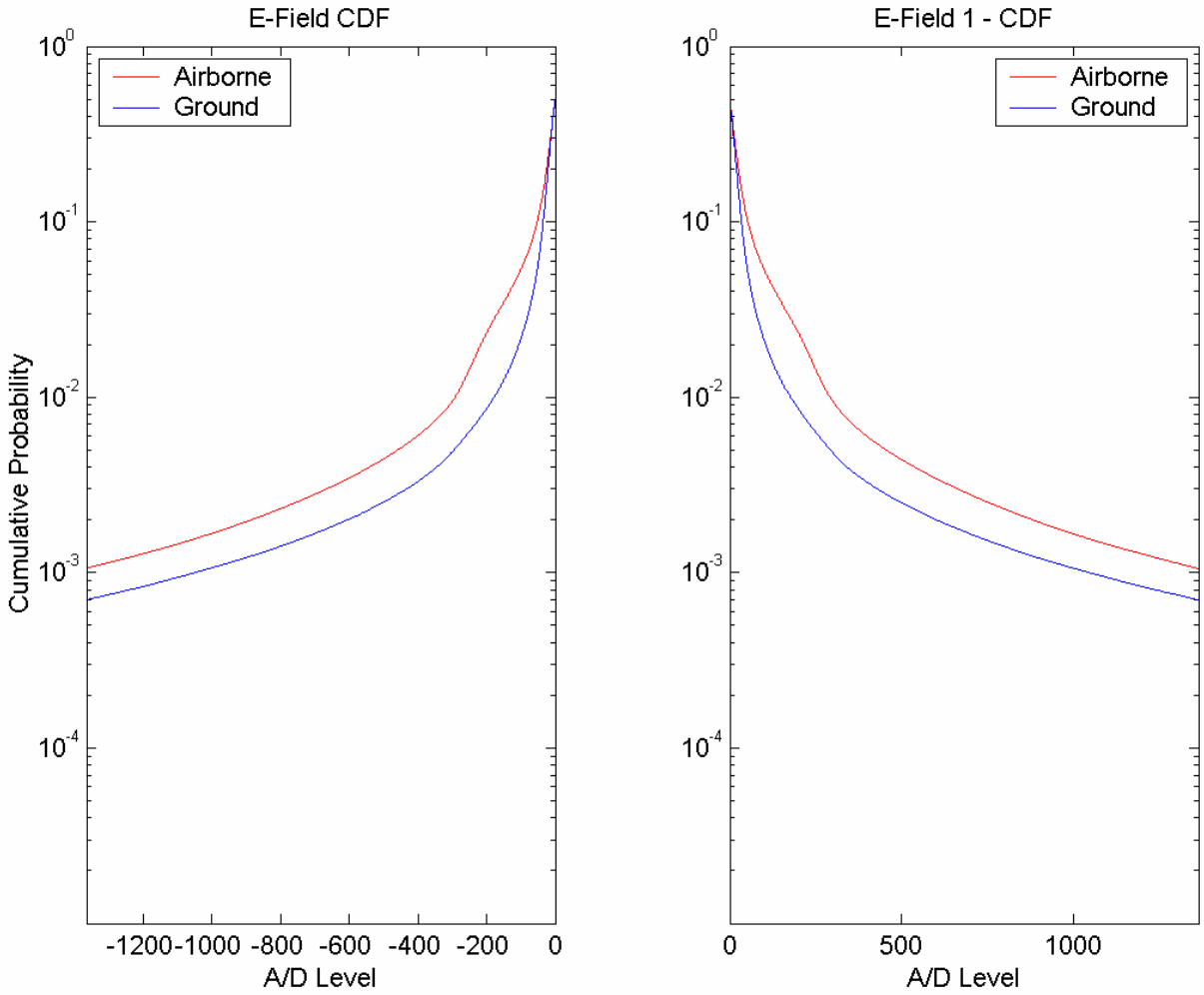
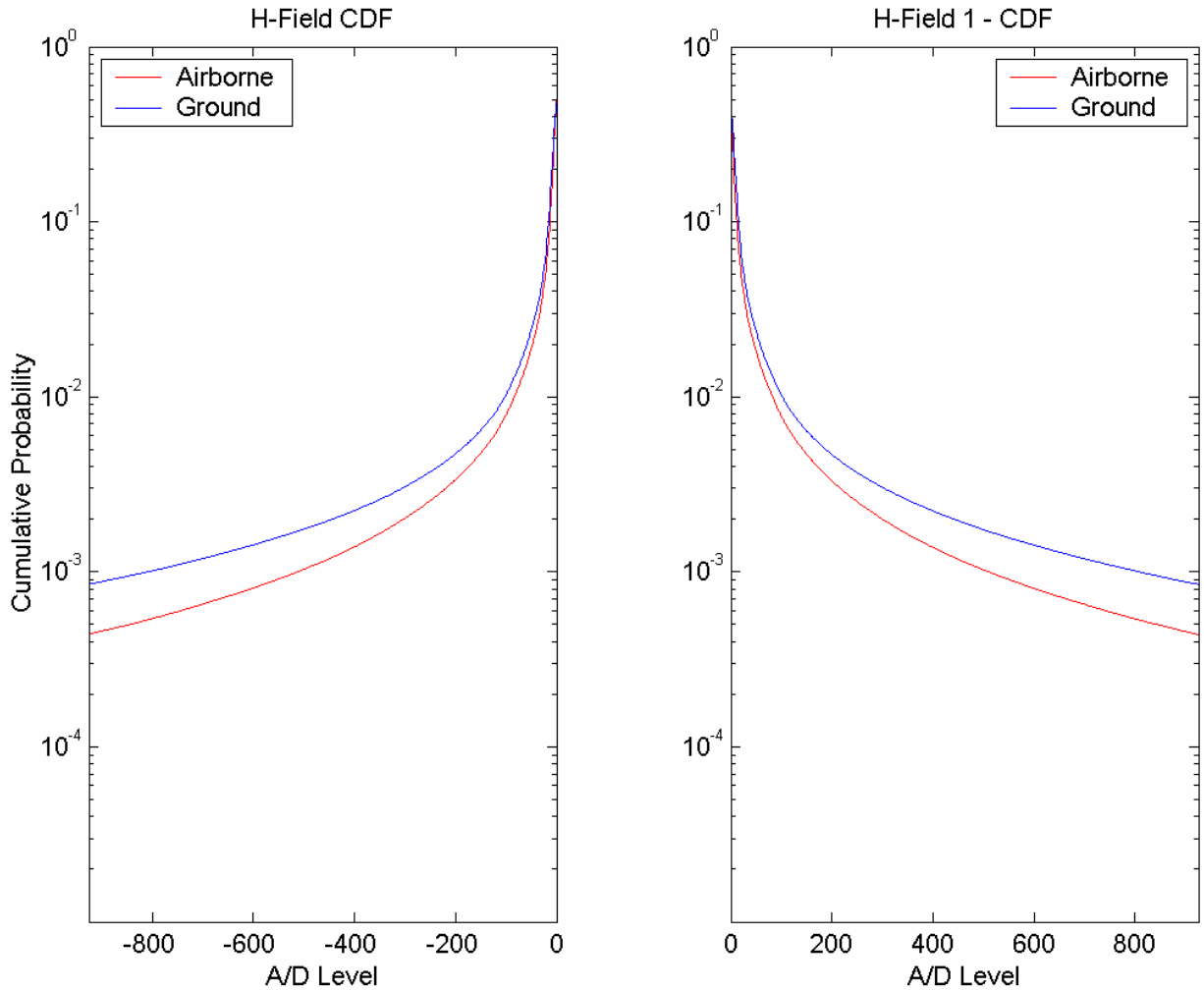
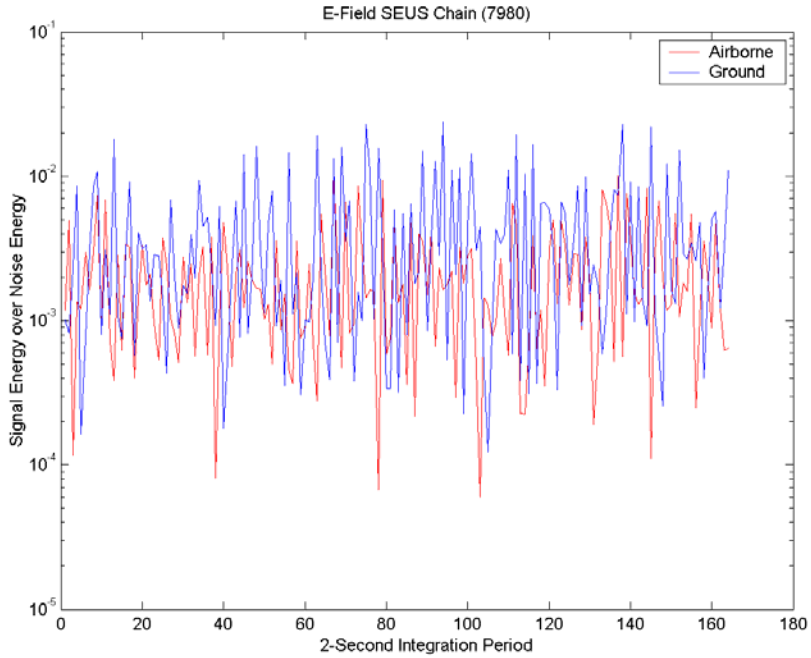
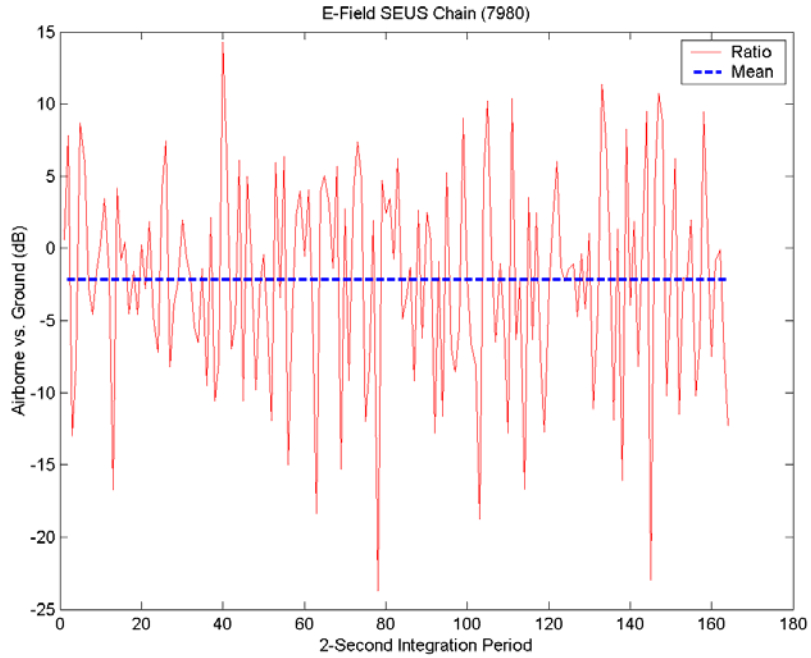


Initial Flight Test Results – Set 5



Initial Flight Test Results – Set 5





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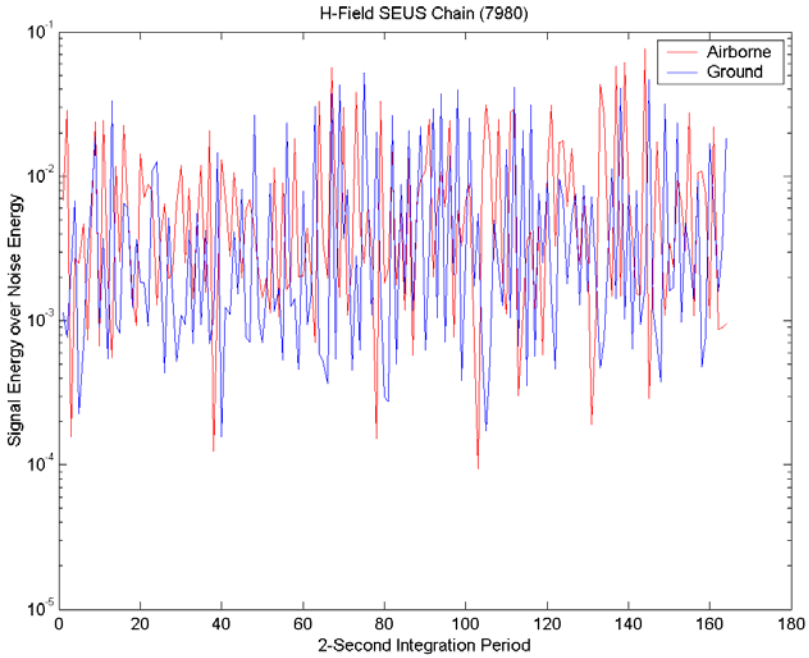

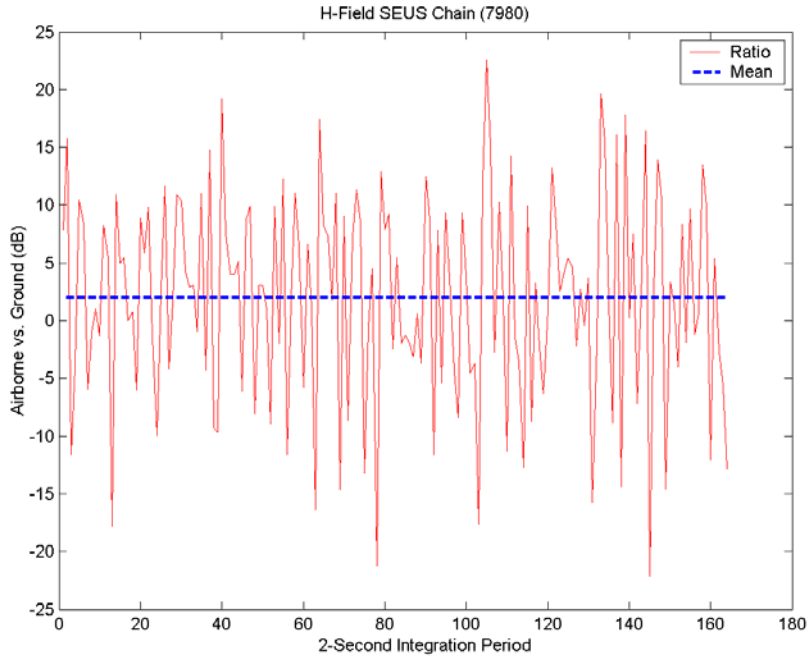

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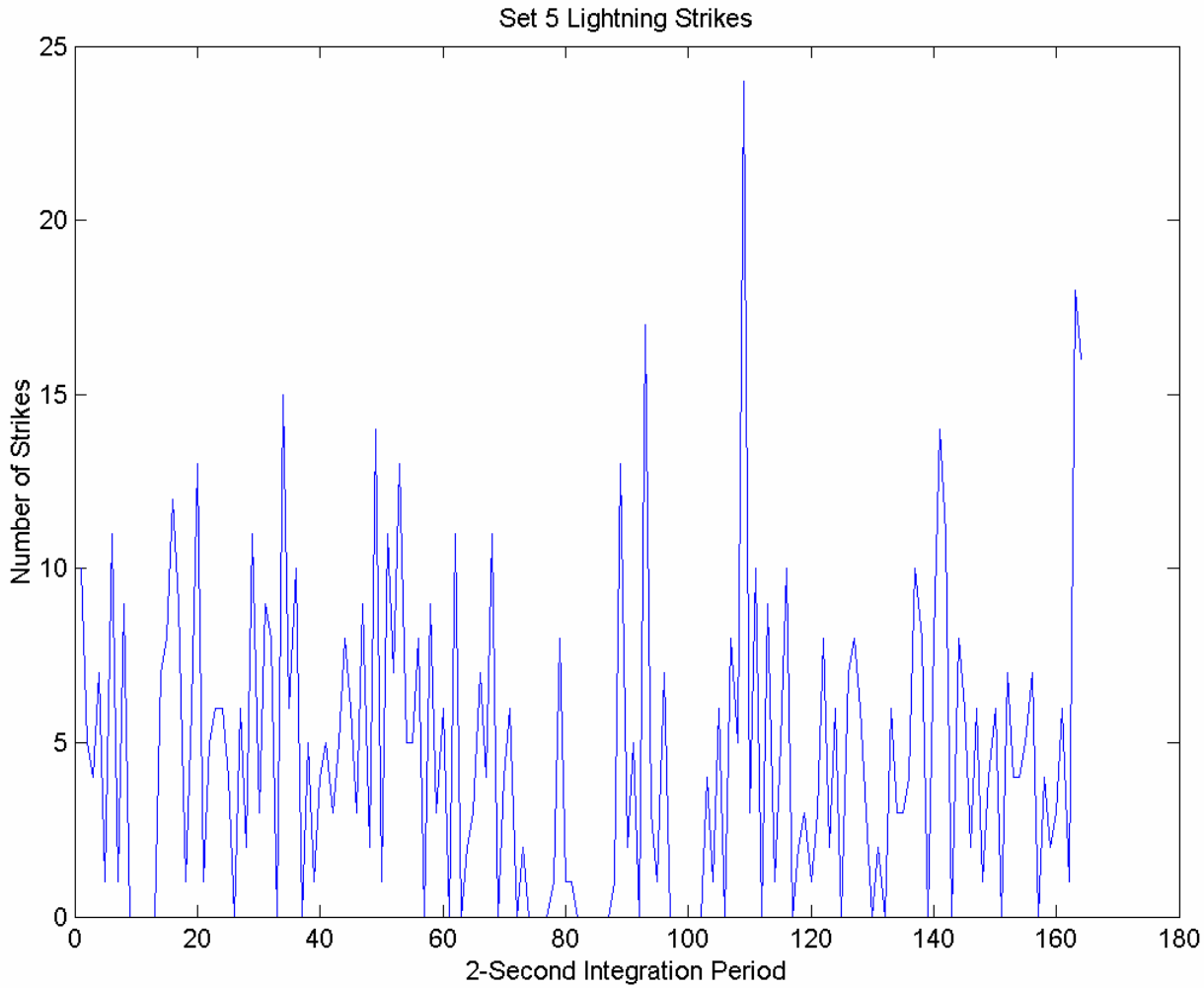
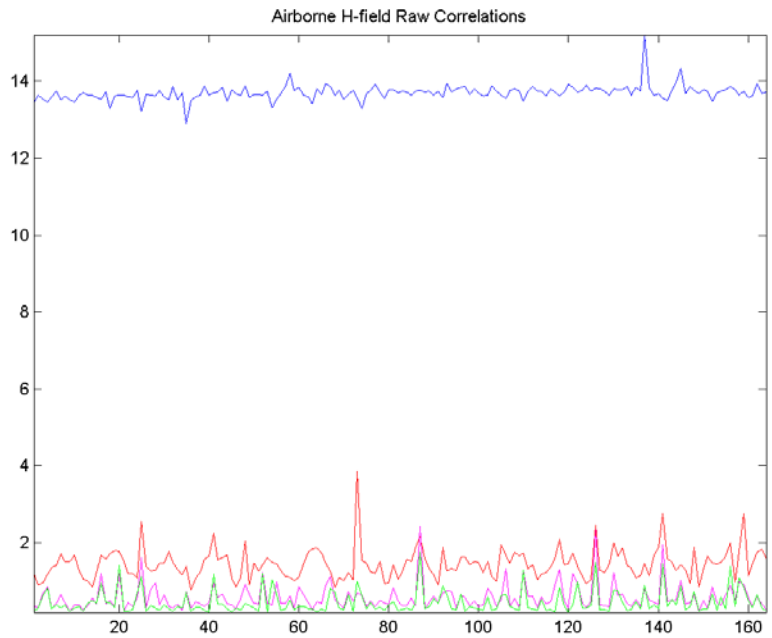


Initial Flight Test Results – Set 6

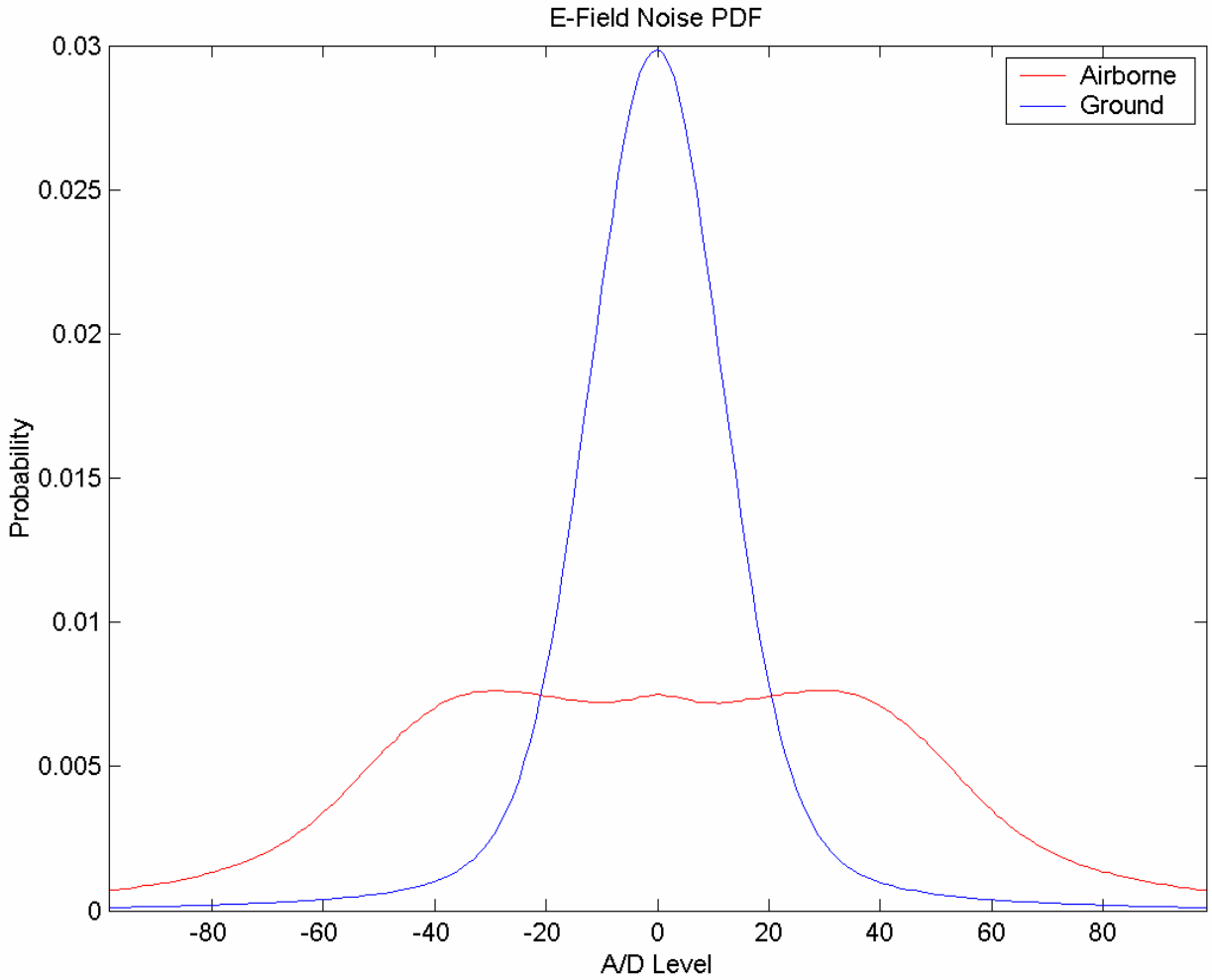
- **Set 6**
  - **Aircraft parked in the TMB RWY9L run-up area approximately 200m from the van**
  - **Van on battery power**
  - **No significant weather in the area**

Initial Flight Test Results – Set 6

Initial Flight Test Results – Set 6



Initial Flight Test Results – Set 6



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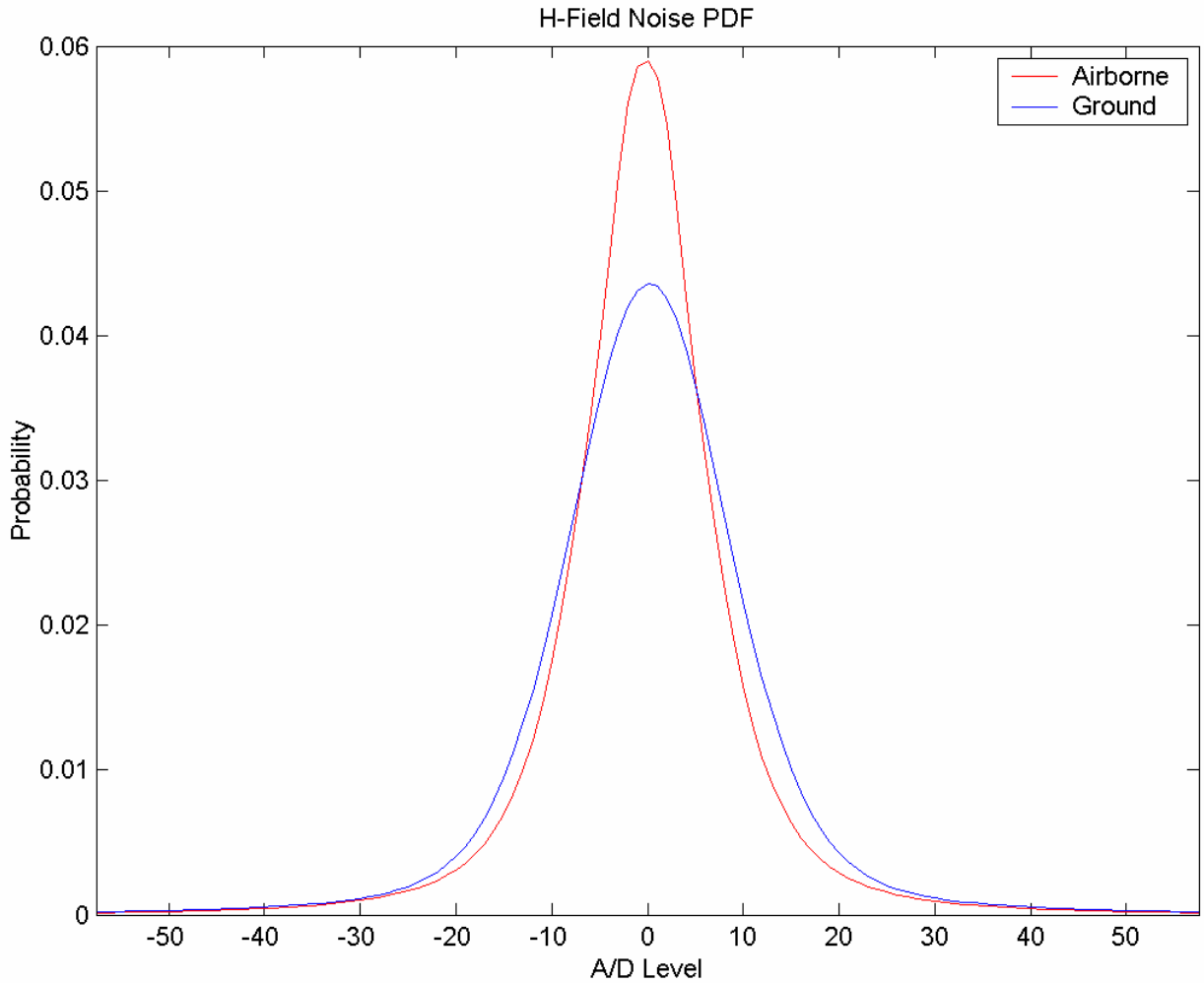

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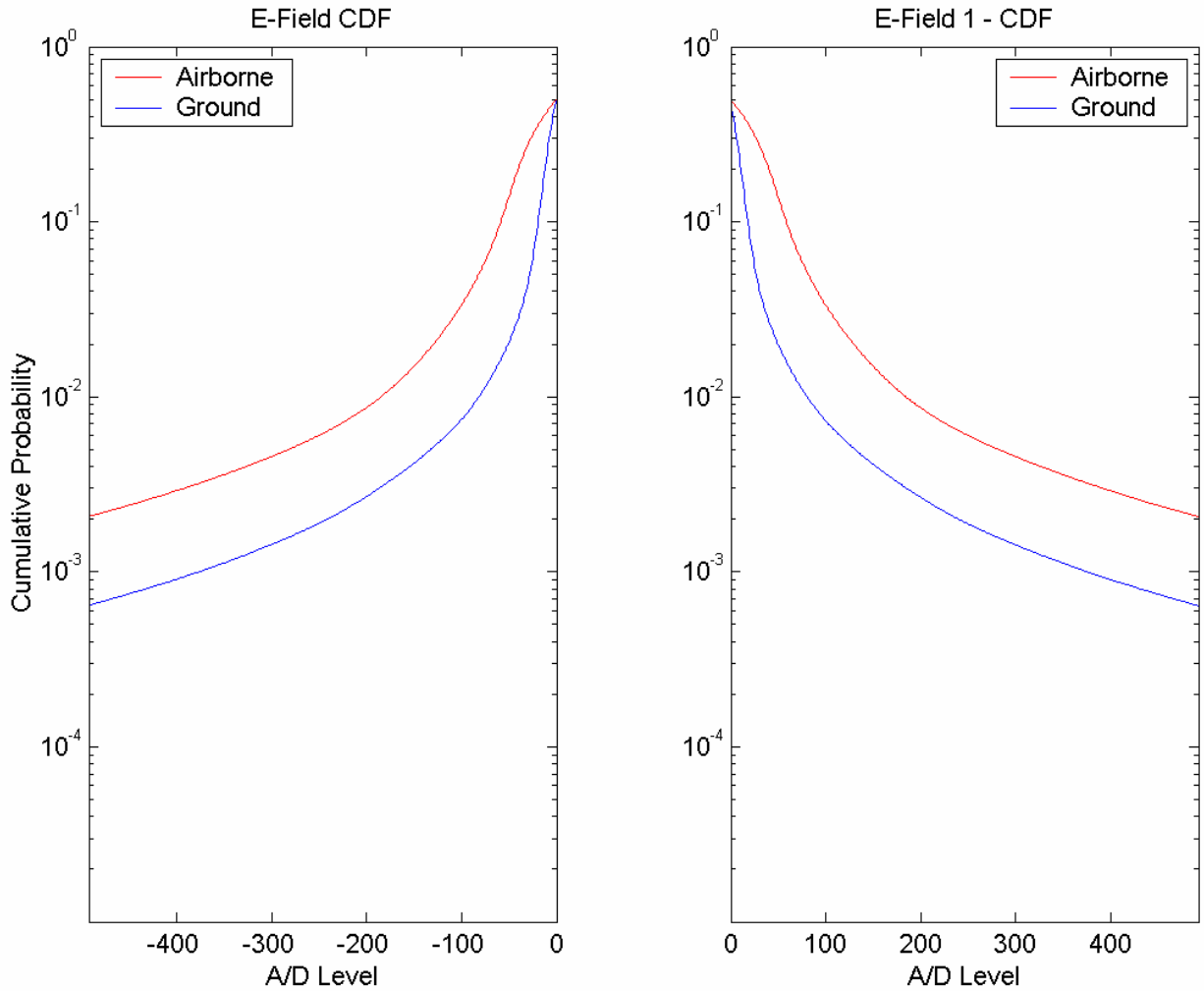

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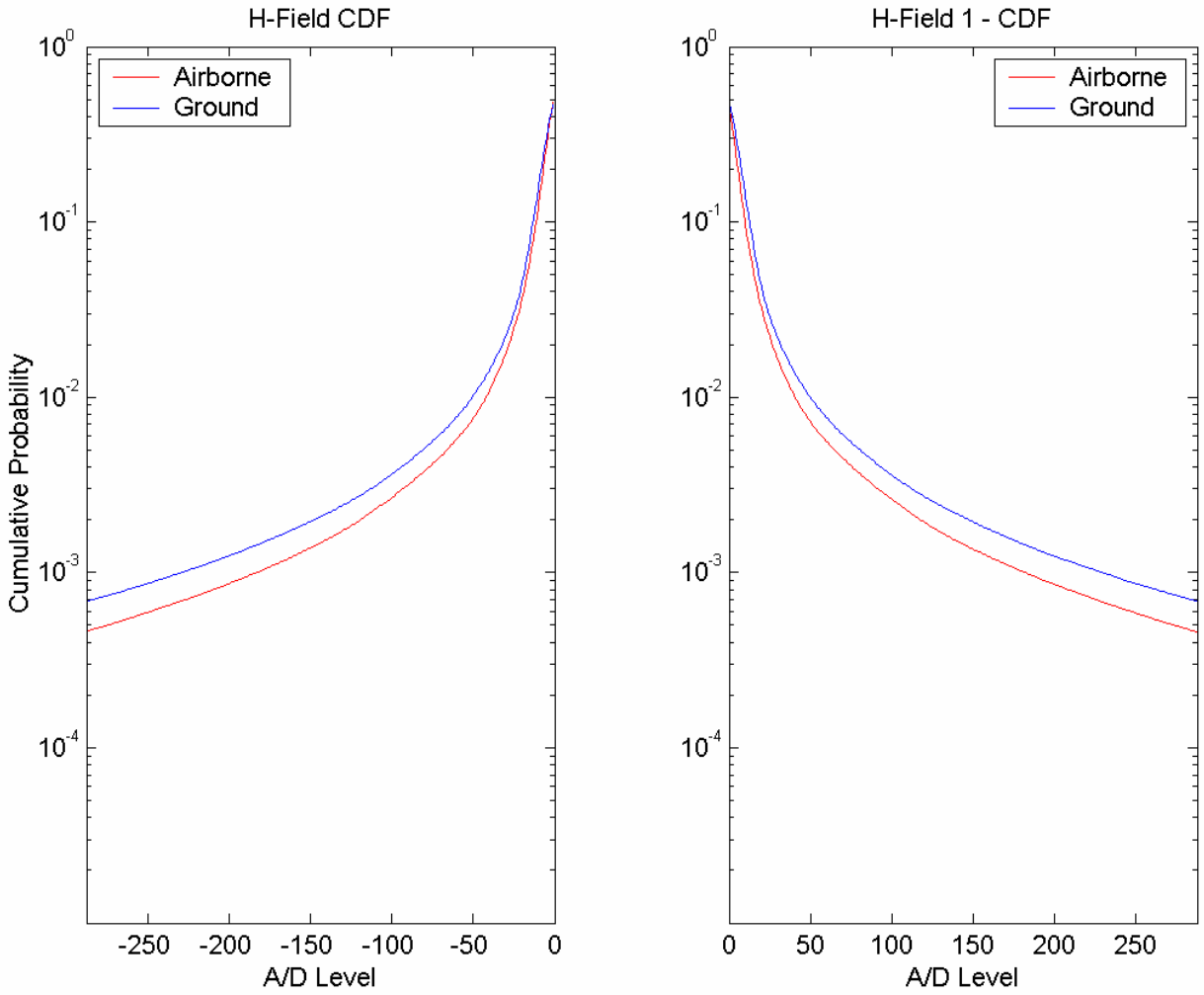

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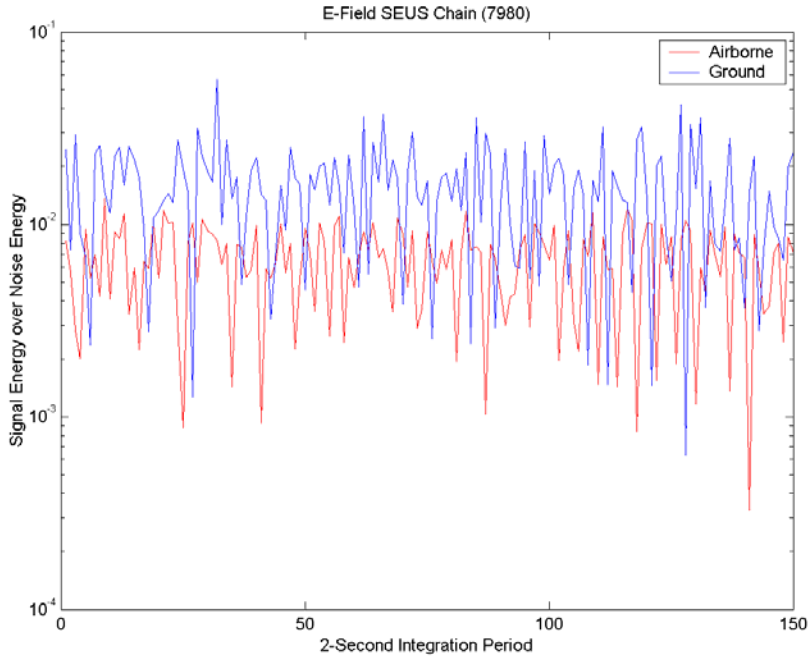
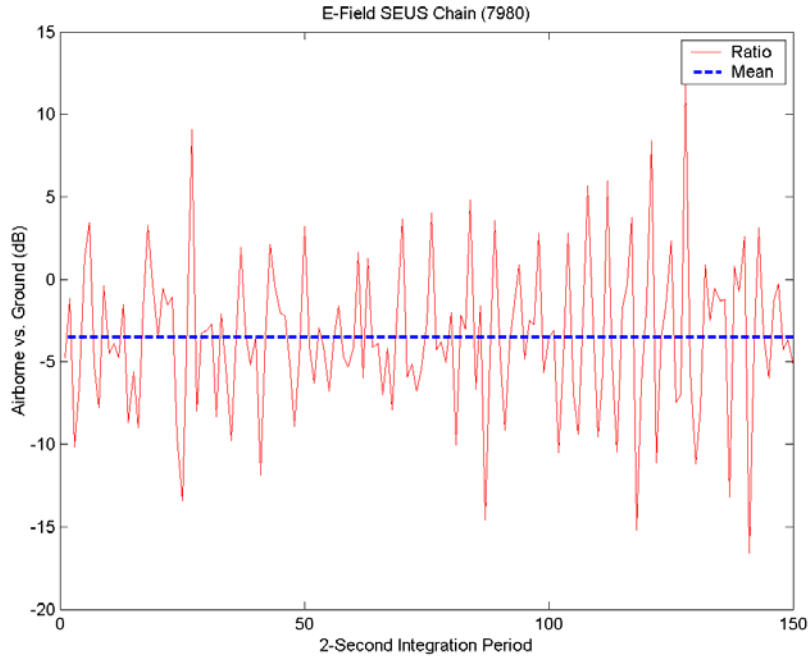
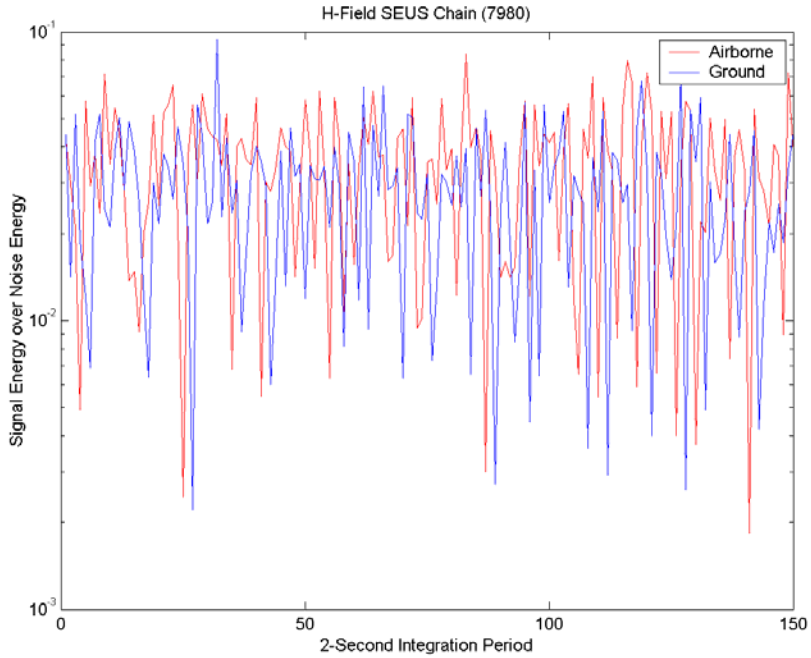
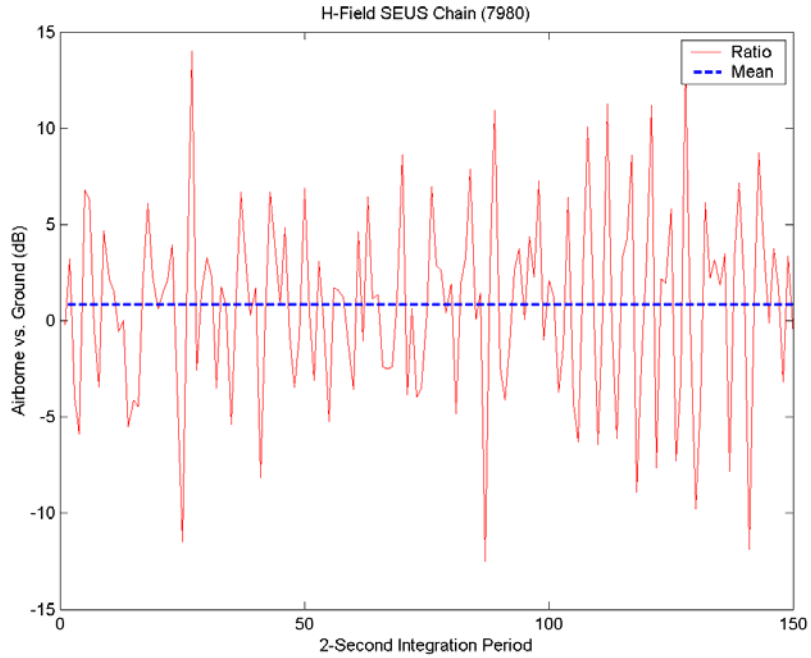




Initial Flight Test Results – Set 6





Conclusions

- **H-field provides better performance in both the airborne and ground-based systems**
- **Van performance degrades when using AC power**

Future Work

- Determine the effect of altitude on E/N_o for both E-field and H-field
  - » Data was collected on multiple approaches at TMB
- Complete processing of the TMB data
- Continue p-static data analysis
  - » Mechanism
  - » Effect on each antenna

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Questions?