Differential and Single Ended Elliptical Antennas for 3.1-10.6 GHz Ultra Wideband Communication

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Outline and Goals

- Introduction
- Specifications and Considerations
- Discrete System Implementation
- Antenna Designs
- Antenna Results
  - Frequency
  - Time Domain
  - Anechoic Chamber
Motivation for UWB?

- Revolutionary approach to wireless communication
- Pulse based waveforms compressed in time
- 3.1-10.6 GHz, -41.3 dBm/MHz
- Low power levels allow for coexistence
UWB Impact on Antenna Design

Impedance Matching Requirements
- Bandwidth +100% of $f_c$
  - $|\Gamma| = |S_{11}| < 1/3$
  - VSWR < 2
  - $-10\log|S_{11}^2| = \text{Return Loss} > 10 \text{ dB}$

Wave Reception
- Linear Phase
- High Radiation Efficiency
- Omnidirectional Radiation Pattern
- Time Domain Pulse Fidelity

Physical Constraints
- Compatible with Portable Devices
- Small, Compact, Planar
Discrete System Implementation

Discrete System Implementation
Transmit Pulse Power Density

Power Spectrum vs. Frequency

FCC Spectral Mask

Frequency (GHz)

Power Density (dBm/MHz)
Discrete System Implementation

A wideband impedance match indicates optimal reception for a wideband pulse.
Diamond Dipole

Time Domain Diamond Dipole

- **A**: 1.18 GHz
- **B**: 1.24 GHz
- **C**: 2.9 GHz

Graphs showing VSWR versus frequency with labeled peaks at 1.18 GHz, 1.24 GHz, and 2.9 GHz.
Circular Disc Monopole

VSWR < 1.5 ➔ Power loss < 4%

Single Ended and Differential Elliptical Antennas

\[ f_L = \frac{c}{\lambda} = \frac{30 \times 0.24}{L + r} \text{GHz} \]
Antenna Results - Frequency

VSWR = 2
Phase and Group Delay Comparison

Phase vs. Frequency

Group Delay vs. Frequency
Antenna Results - Time Domain

Single Ended Elliptical Antenna

Tx pulse (Red)
Rx pulse (Blue)

Differential Antenna

Negative Terminal (Yellow)
Positive Terminal (Red)

10 mV/div 500 ps/div 500 ps/div
Absolute Value of Differential Pulses
Antenna Results - Chamber

Photos courtesy Lincoln Labs

Spherical Coordinates:
Azimuth = Rotation in $\phi$
Elevation = Rotation in $\theta$
Antenna Results - Chamber

Spherical Coordinates:
Azimuth = Rotation in $\phi$
Elevation = Rotation in $\theta$

Lincoln Laboratory Measured Azimuth Pattern
Max Gain 2.11 dB

Measured Elevation Pattern
Max Gain 2.7 dB
HPBW = 73°
Gain vs. Frequency for Azimuth and Elevation Planes

![Graph showing Gain vs. Frequency for Azimuth and Elevation Planes](image-url)
Radiation Patterns for Varying Frequency - Elevation Co-polarized

- 3.5 GHz
- 4 GHz
- 5 GHz
- 7 GHz
- 9 GHz
- 10 GHz
Radiation Patterns for Varying Frequency- Azimuth Co-Polarized

3.5 GHz 4 GHz 5 GHz

7 GHz 9 GHz 10 GHz
3-D Radiation Pattern

Farfield Simulated
Measurement
Frequency = 4 GHz
Radiation Efficiency = 99.58%
Total Efficiency = 92.90%
Gain = 3.22 dB

Measured
Frequency = 4 GHz
Radiation Efficiency = 93%
Impedance Efficiency = 99.3%
Total Efficiency = 92.3%
HPBW = 73°
Summary

- UWB Antenna Designs
  - VSWR < 2 for 3.1- 10.6 GHz
  - Near Omnidirectional Pattern
  - High Radiation Efficiency
  - Physically Small Size
- Discrete System Implementation
- Future Work: System Considerations