

# Connection One

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## Hybrid Metallo-Ferrite Ground Plane for Ultra-wide Bandwidth Antennas

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# Project Description

- **Goal:**

Develop a 2D or 3D textured ground plane that is a composite of good electrical conductor (PEC) and lossless ferrite to enhance radiations at high frequencies and suppress non-radiated transmission-line mode at low-frequencies for a UWB antenna – the long slot array developed by Raytheon.

- **Approach:**

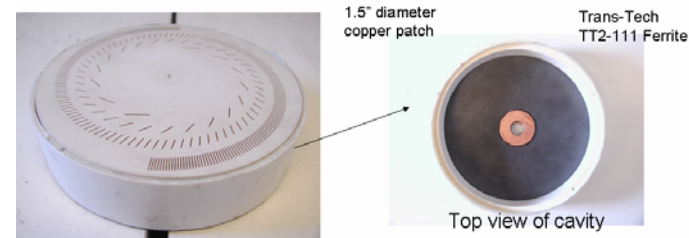
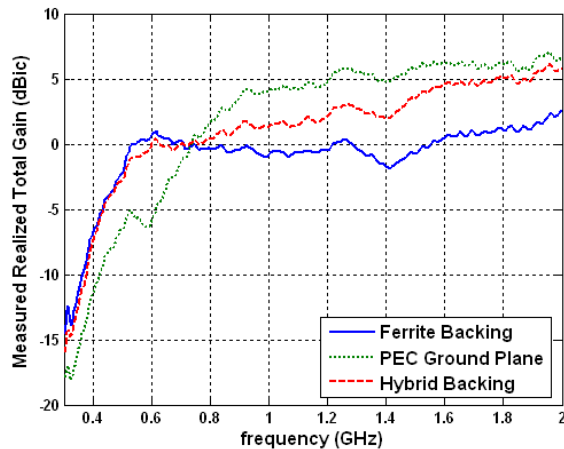
Utilizing metallo-ferrite or ferrite-dielectric material layer on top of the conducting ground plane to overcome the adverse effects caused by the ground plane.

- **Constraints/Assumptions:**

- Low Profile
- Ultra-wide Bandwidth

# Motivation

- The propose technology is addressing the key limitation in conformal antenna design with height  $< \lambda/20$
- PEC ground plane degrades antenna impedance, gain, pattern and bandwidth when height is less  $\lambda/15$  due to strong coupling with antenna.
- Existing methods are lacking because
  - EBG is performance is polarization dependent and require tuning.

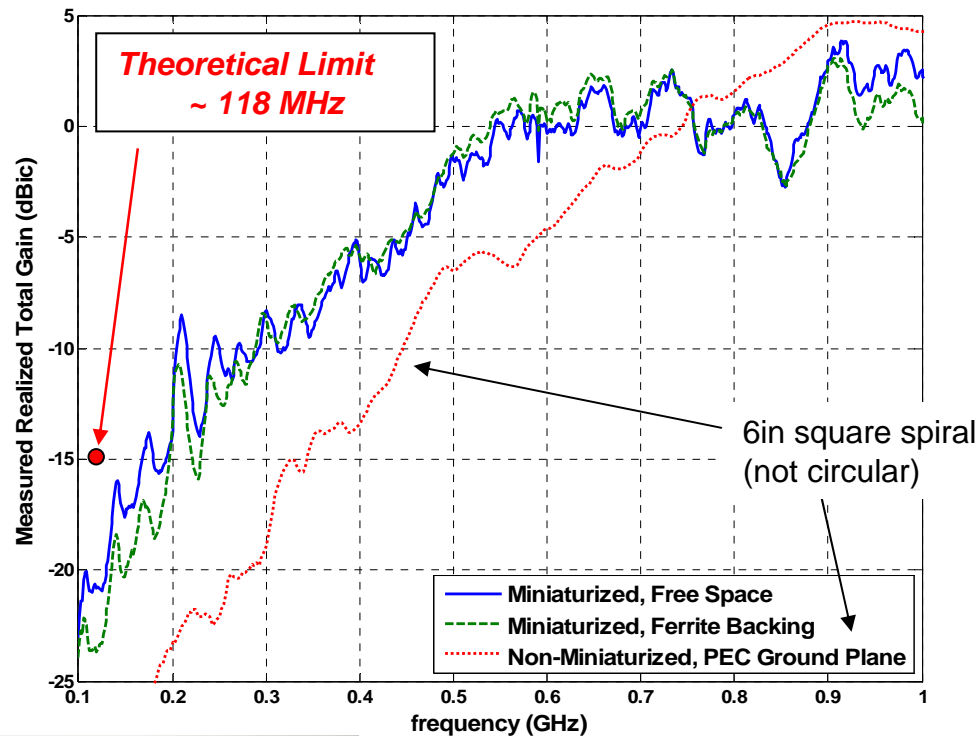
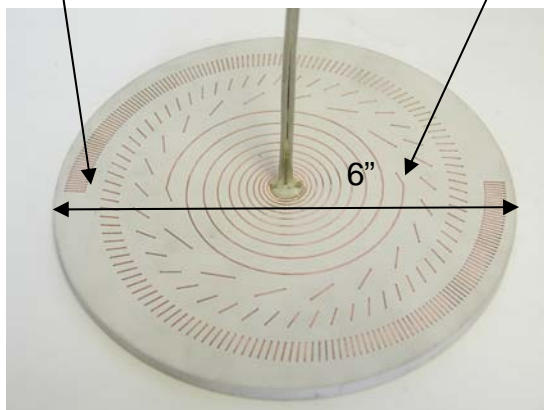


## "A Novel Reflective Surface for an UHF Spiral Antenna"

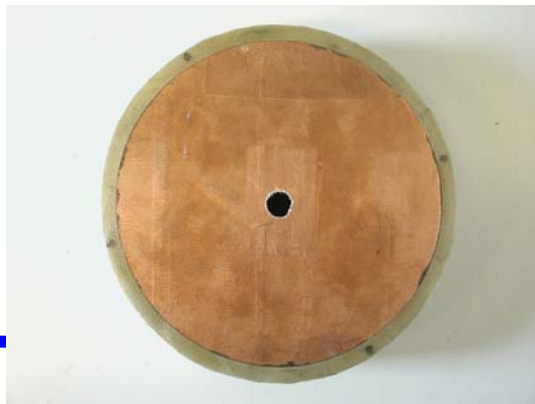
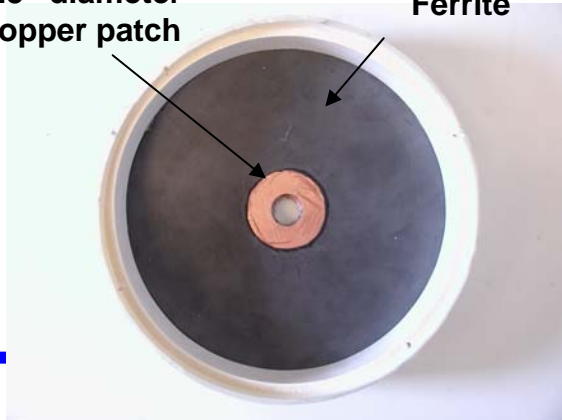
Kramer, B.A.; Koulouridis, S.; Chen, C.-C.; Volakis, J.L.; AWPL-5, No.1 pp. 32-34, Dec. 2006.

# 6" Miniature (1/4" thick) Weaved Spiral in Dielectric Substrate on Ferrite GP

Ending pitch  $p_e = 45$  mils  
Starting pitch  $p_i = 20 * p_e$



1.5" diameter copper patch  
Trans-Tech TT2-111  
Ferrite

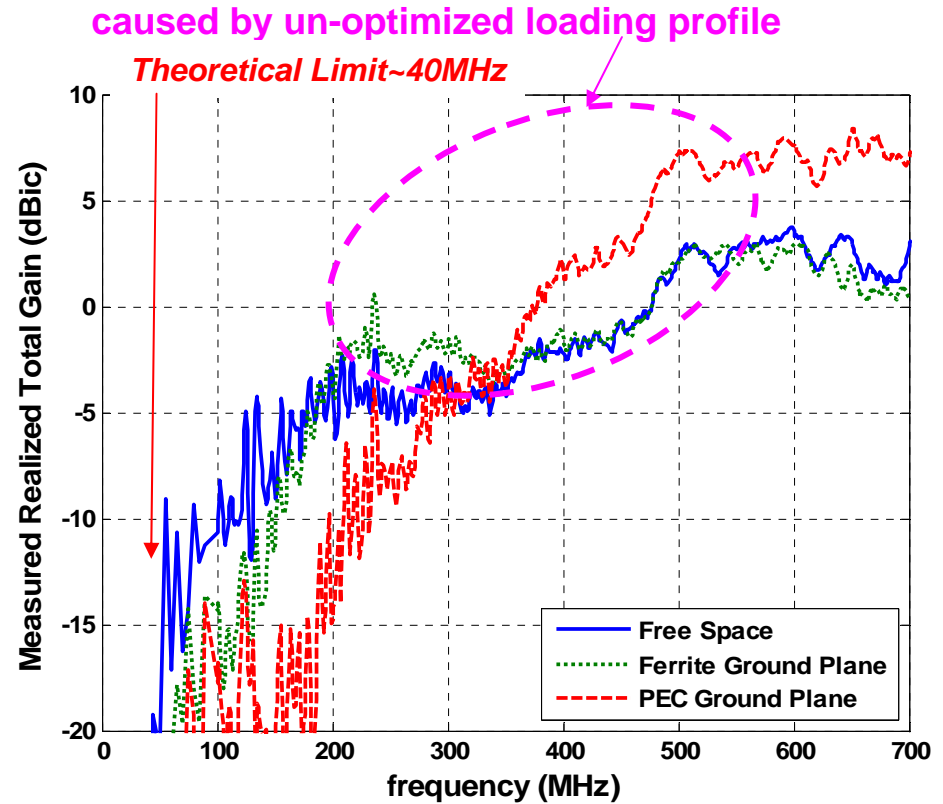
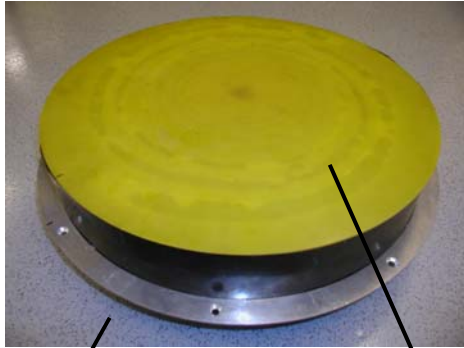


Top view of cavity

Bottom view of cavity

Final Packaged

# Demonstration of Ferrite GP Benefits 18" Spiral on Ferrite GP



- Ferrite ground plane overcomes issues with metallic GP
- Ferrite ground plane requires optimized profile to achieve free space gain below 150 MHz
- Need more suitable material for operation below 150 MHz

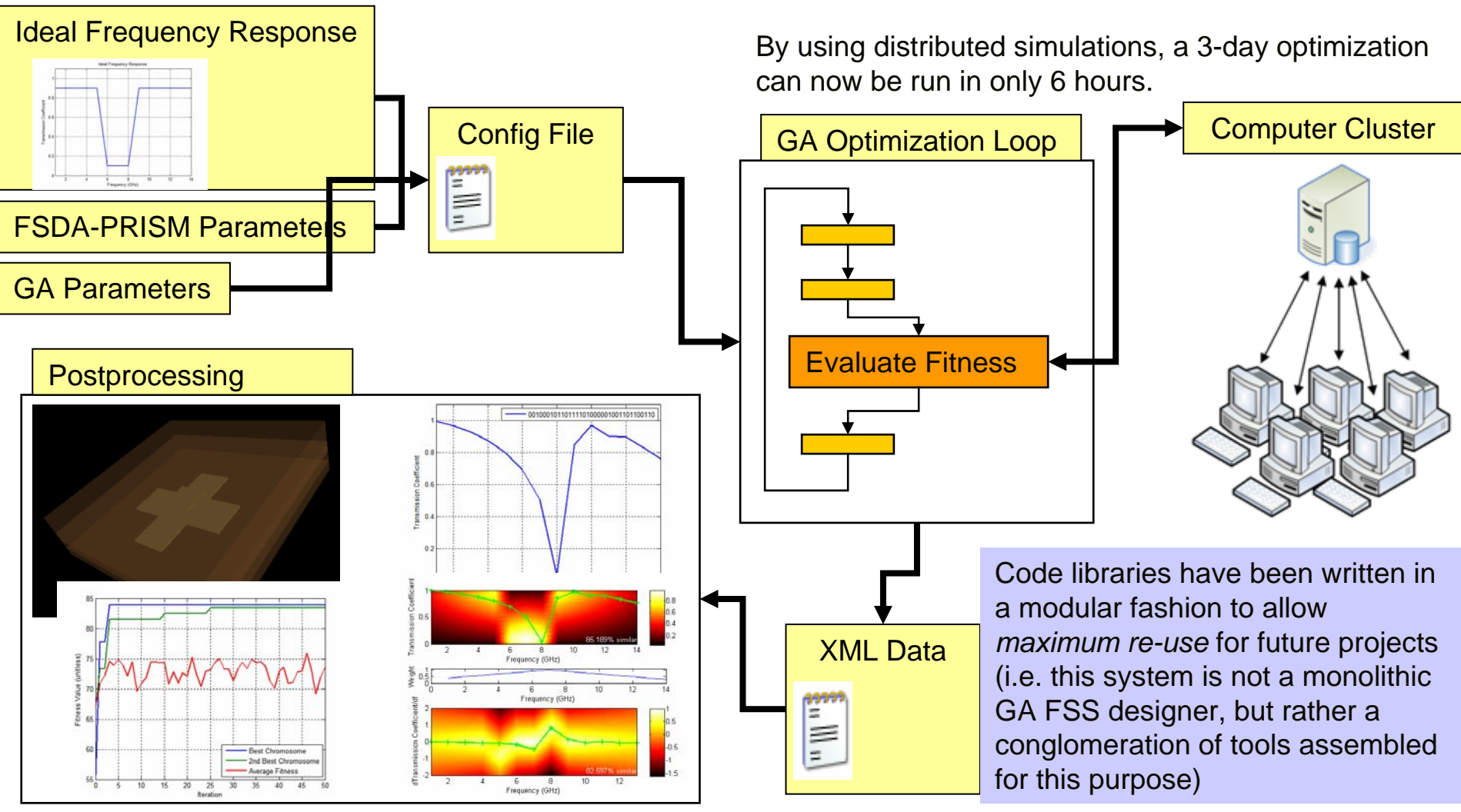
# Risks and Benefits

- **Novel aspects of this project:**
  - Study the utilization of novel ferrite-dielectric material as UWB ground plane in low-profile antenna design
  - Investigate the fabrication method of novel ferrite-dielectric material for low-profile ground plane treatment.
- **Risks/challenges in this project:**
  - Fabrication special ferrite materials with UWB properties.
  - Trade-off between optimal design and realizable material.
- **Potential benefits of this work:**
  - Enabling conformal ultra-wideband antennas has been a challenge for many years.
  - The recent availability of magnetic ground planes and low loss magnetic surfaces present us with an opportunity for truly conformal UWB antennas.
  - The proposed ground plane will be a metallo-magnetic composite and will be designed for variable reflectivity and surface properties subject to bandwidth requirements.

# Accomplishments to Date

- **Milestones achieved so far:**
  - Conducted theoretical study of a simple dipole element position closed to a finite-size ferrite-dielectric treated PEC ground plane. Various thicknesses and properties of the ferrite-dielectric layered were investigated.
  - Fabricating special ferrite-dielectric materials with equal permittivity and permeability (5) material by mixing Titanate powders and Ferrite Powders ( $\text{Co}_2\text{Z}$ ).
  - Alternative GP configuration using multilayer elements is being pursued
    - Completed optimization scheme using a farm of low-cost processors
    - Integrated optimizer with FSS design tools (FSDA-PRISM)
    - Preliminary results have been generated for specific FSS to demonstrate the optimizer
    - Multilayer FSS will serve as an alternative low weight ground plane for specific band operation

# Distributed FSS Ground Plane Optimizer



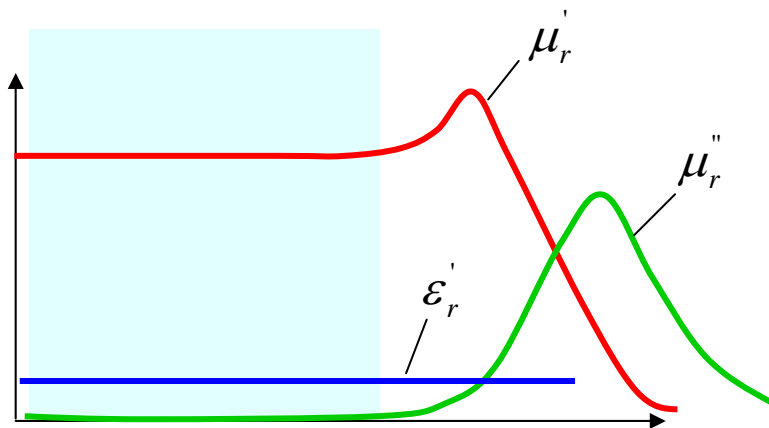
# Ferrite-Dielectric Ground Plane Treatment Concept

## Design A:

*High impedance layer*

That is

$$\sqrt{\frac{\mu_r}{\epsilon_r}} \text{ mainly real and } \gg 1$$

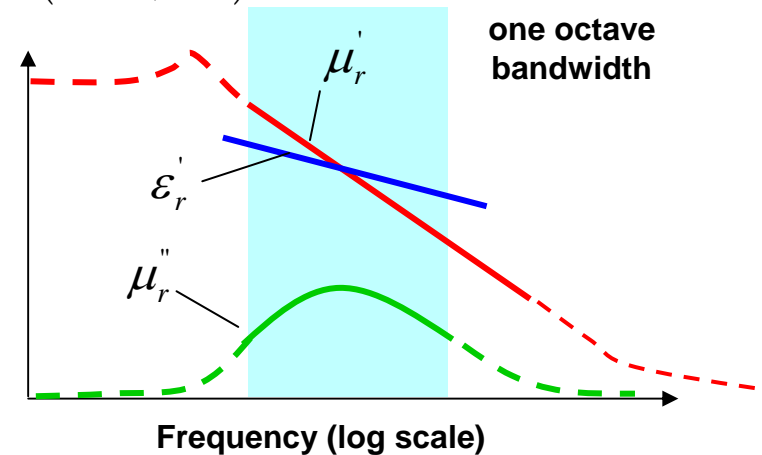


## Design B:

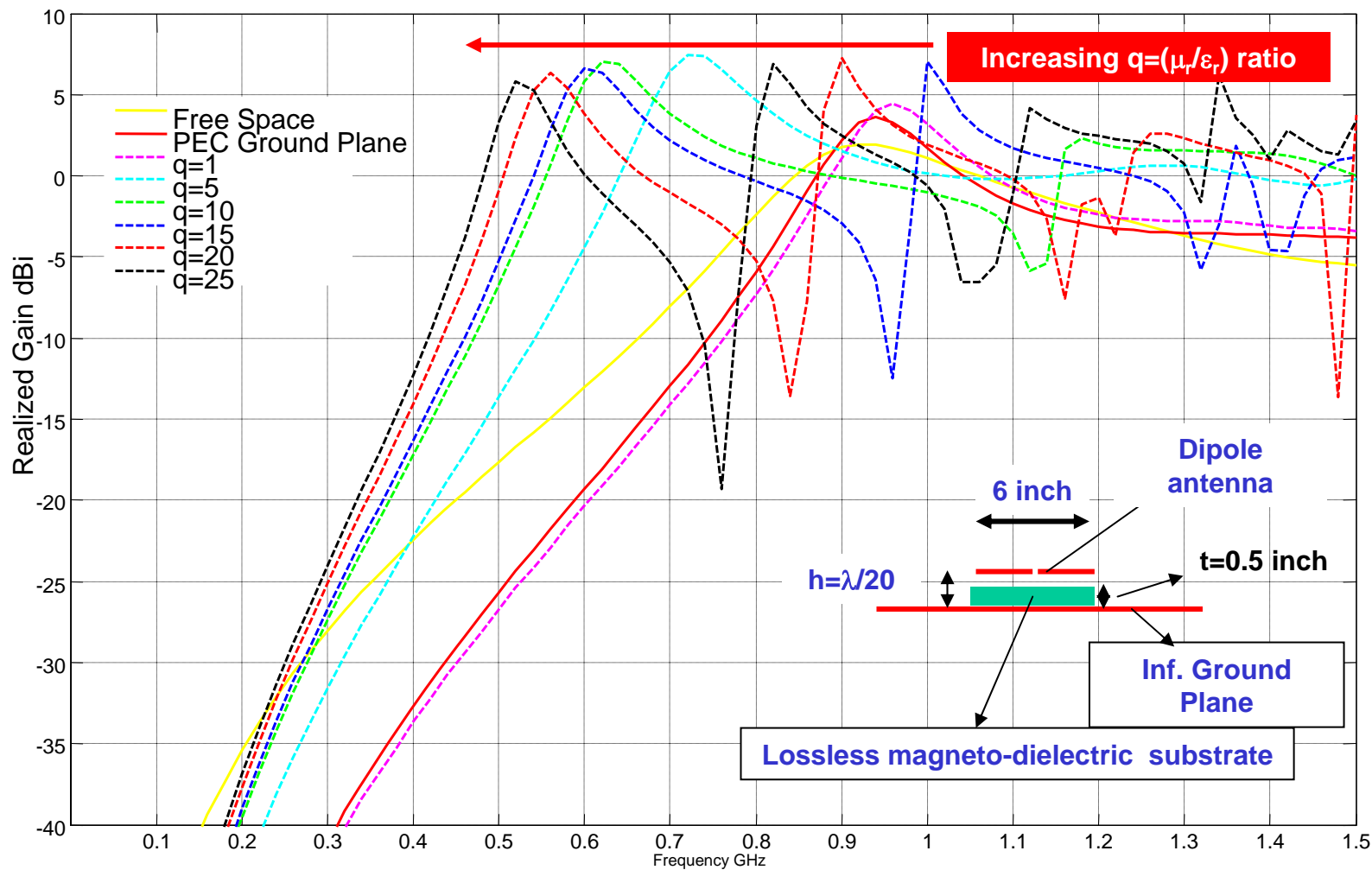
- *Impedance matched to free space*
- *Frequency dependent wavenumber*
- *Moderate material loss*

That is

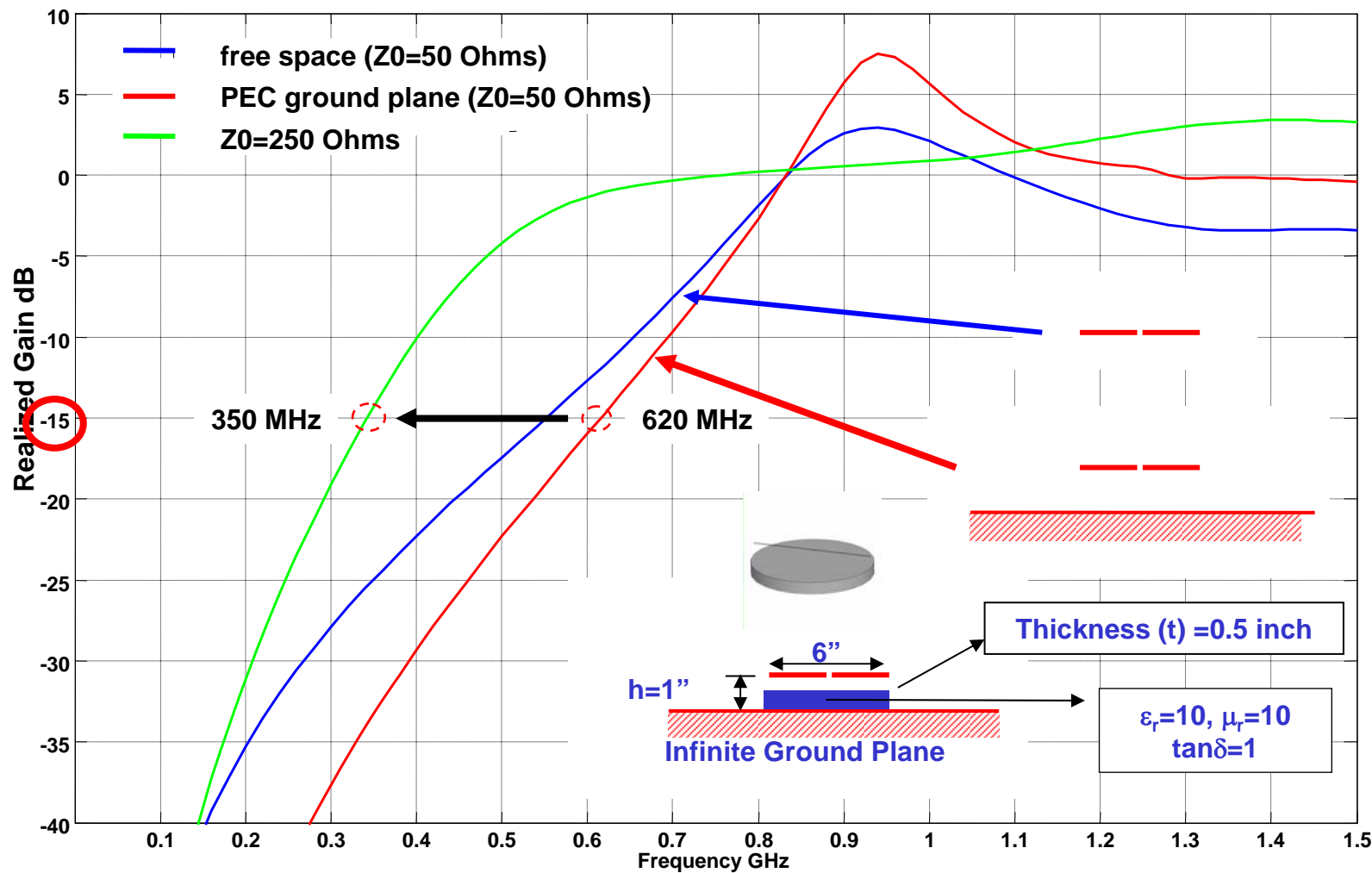
$$\left\{ \begin{array}{l} \sqrt{\mu_r} \approx \sqrt{\epsilon_r} \\ \text{Re}(\omega\sqrt{\mu\epsilon}) \approx \text{constant} \\ \text{Im}(d \cdot \omega\sqrt{\mu\epsilon}) > 1 \quad (\text{for } -17 \text{ dB attenuation}) \end{array} \right.$$



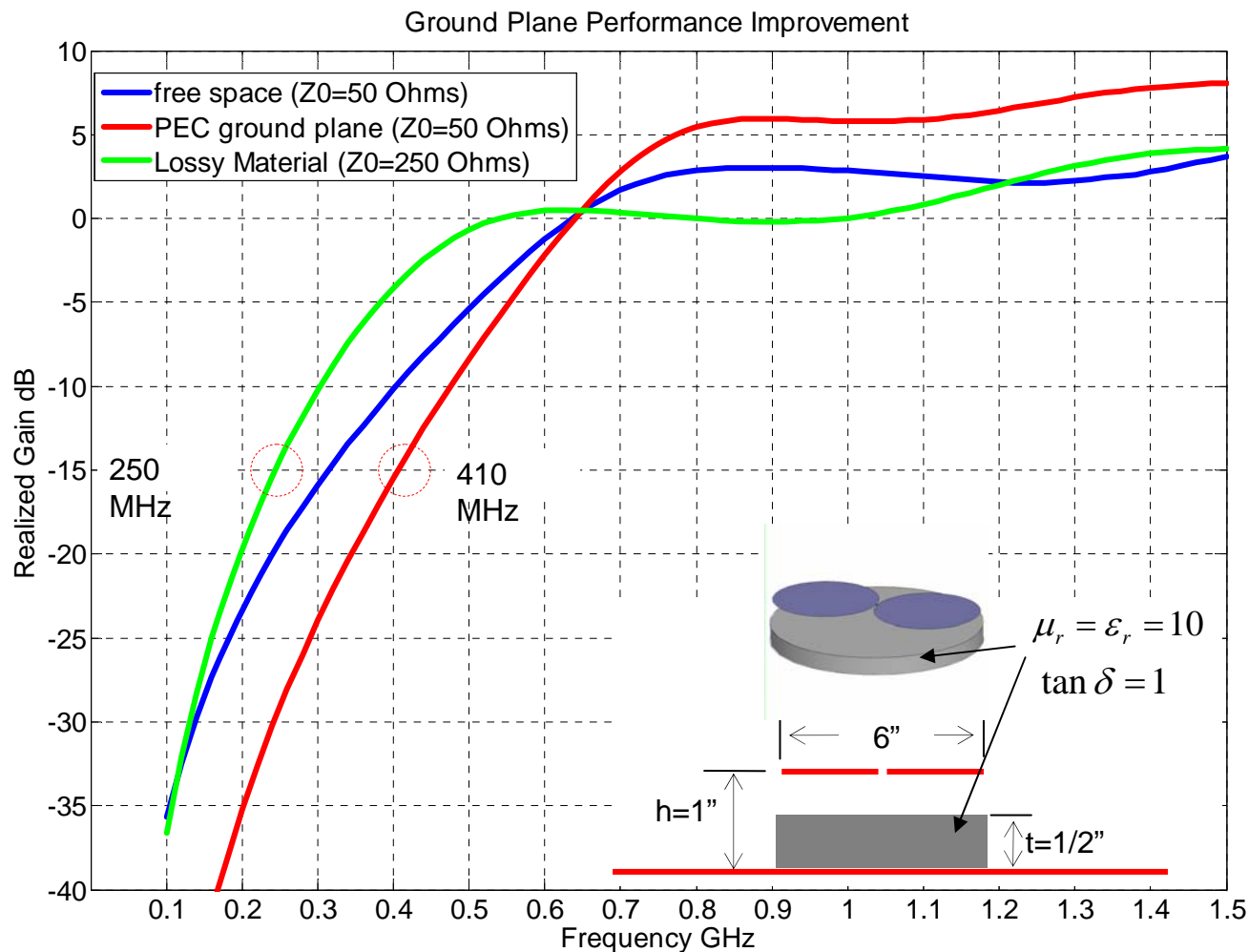
# Low-loss High-Impedance Ferrite Dielectric



# Lossy Impedance-Matched Ferrite Dielectric - Narrowband Antenna -



# Lossy Impedance-Matched Ferrite Dielectric - Broadband Antenna -



# What Remains?

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- Ground Plane design completion (6 months after start of project)
- Characterizations (9 months after start)
- Initial measurements (12 months after start)

## PROJECT OBJECTIVES

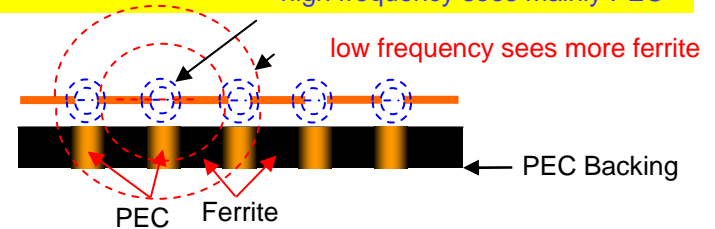
- Develop broadband ground plane for conformal wide band antennas. Ground plane must be as thin as possible, and the antenna bandwidth may exceed 2:1.
- Consider two approaches:

Frequency selective surfaces to serve as the ground plane, providing a reflection coefficient close to +1

2D and 3D textured ground plane formed as composite of good electrical conductor (PEC) and lossless ferrite to enhance radiations at high frequencies and suppress non-radiated transmission-line mode at low-frequencies for a UWB antenna.

## TECHNICAL APPROACH

Employ metallo-ferrite or ferrite-dielectric material layer on top of a conducting ground plane to overcome adverse effects caused by the ground plane. Alternatively, employ multi-FSS layers to generate the same effect (+1 Reflection Coeff. high frequency sees mainly PEC



## ACCOMPLISHMENTS

- Conducted a theoretical study of simple antennas on a finite-size ferrite-dielectric treated PEC ground plane. Various thicknesses and properties of the ferrite-dielectric layered were investigated.
- Fabricated ferrite-dielectric materials with equal permittivity and permeability (5) material by mixing Titanate powders and Ferrite Powders ( $\text{Co}_2\text{Z}$ ).
- Completed optimization scheme using a farm of low-cost processors
- Integrated optimizer with FSS design tools (FSDA-PRISM)
- Multilayer FSS will serve as an alternative low weight ground plane for specific band operation

## FUTURE TASKS

- Add metallization to the ferrite-dielectric layer
- Optimize metallization of antenna/ground plane combined configuration
- Generate multi-FSS designs and compare with ferrite GP approach.
- UWB antenna performance