Design of a Microstrip Antenna using a High Dielectric Superstrate Lens and an Artificially Reduced Permittivity Surrounding Substrate

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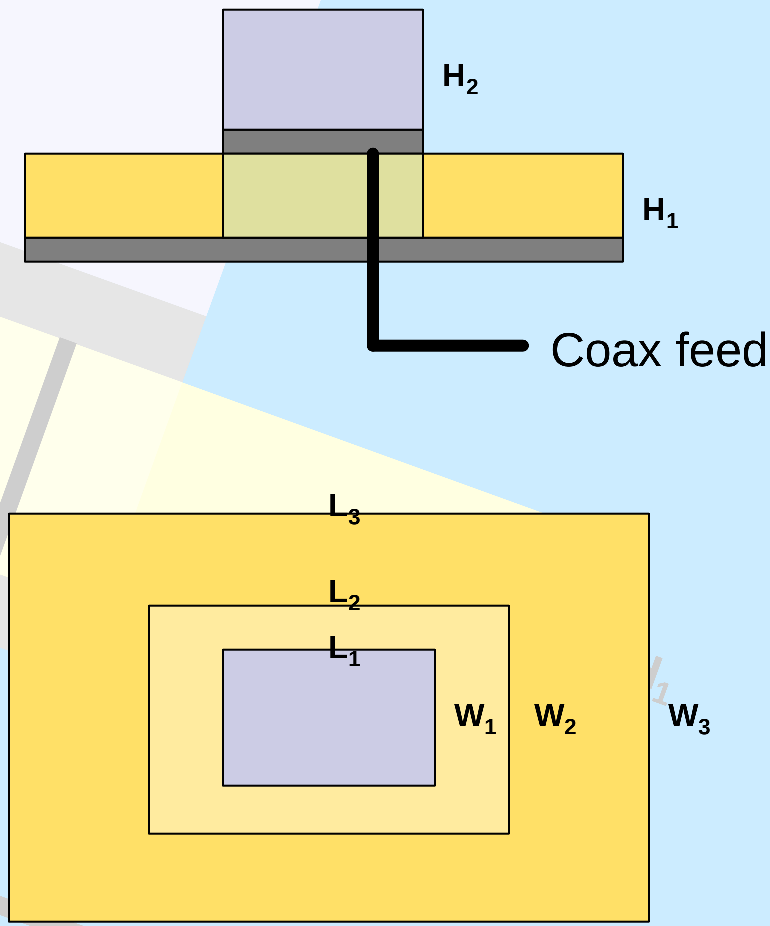
- **Problem Statement:** The goal of this project is to design, fabricate and test a microstrip antenna that is physically smaller than a standard antenna while maintaining similar electrical properties.
- **Methodology:** This goal is to be achieved by the use of different techniques involving dielectrics. These include the use of a high dielectric lens and reduction of the permittivity of the substrate exterior to the patch.

Design Specifications

- Patch size <25% of standard low permittivity patch
- Broadside directivity improvement of >1dB compared to non-reduced substrate antenna
- Lower surface wave excitation
- Center frequency of 917.88 MHz
- Probe fed with impedance of 50 Ohms
- Substrate ε_r=10.2
- Superstrate ε_r=84
- Ground Plane 9”x12”
- Surrounding substrate reduction >25% by volume



Motivation

- **Advantages of Patch Antennas**
  - Planar, low profile
  - Ease of construction
  - Flexible shapes
  - Near isotropic patterns achievable
- **Disadvantages**
  - Narrow bandwidth
  - Large size
  - Large loss due to surface wave excitation
  - Coupling
- **Recent Developments**
  - Shorting pins
  - Different printed shapes
  - Dielectric covers
  - Artificial reduction of surrounding substrate, photonic-bandgap effects
- **Dielectric Covers**
  - Miniaturization of the patch
  - Directivity drop in broadside direction
  - Excitation of surface waves
- **Photonic-Bandgap Effects**
  - Reduce surface waves
  - Improve directivity

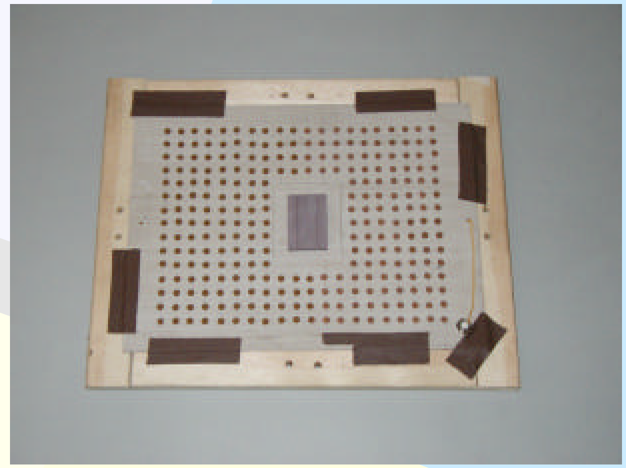
Design Decisions and Testing

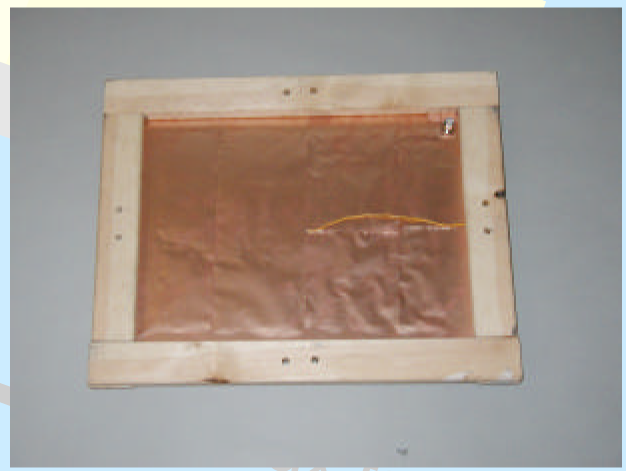
- **Superstrate of Barium Tetratitanate**
  - High permittivity
  - Temperature stable
  - Low loss
- **Hole size and placement**
  - Small enough to use the volumetric average approximation
  - Remove enough material to create a boundary effect
  - Leave enough material for sufficient mechanical support
- **Frequency**
  - UCR owns testing equipment for 917.88 MHz
  - Practical applications would be at higher frequencies, but the effects should scale

- **Testing Apparatus**
  - Ritron DTX-450 transceiver
  - Icom communications receiver
  - Transmitting antenna on mast
  - Mast to mount patch antenna
  - All measurements performed at Grassy Knoll during low traffic hours
- **Measurements of Interest**
  - Radiation Pattern (360^{o})
    - Directivity and gain
    - Measurements take at 11.25^{o} intervals

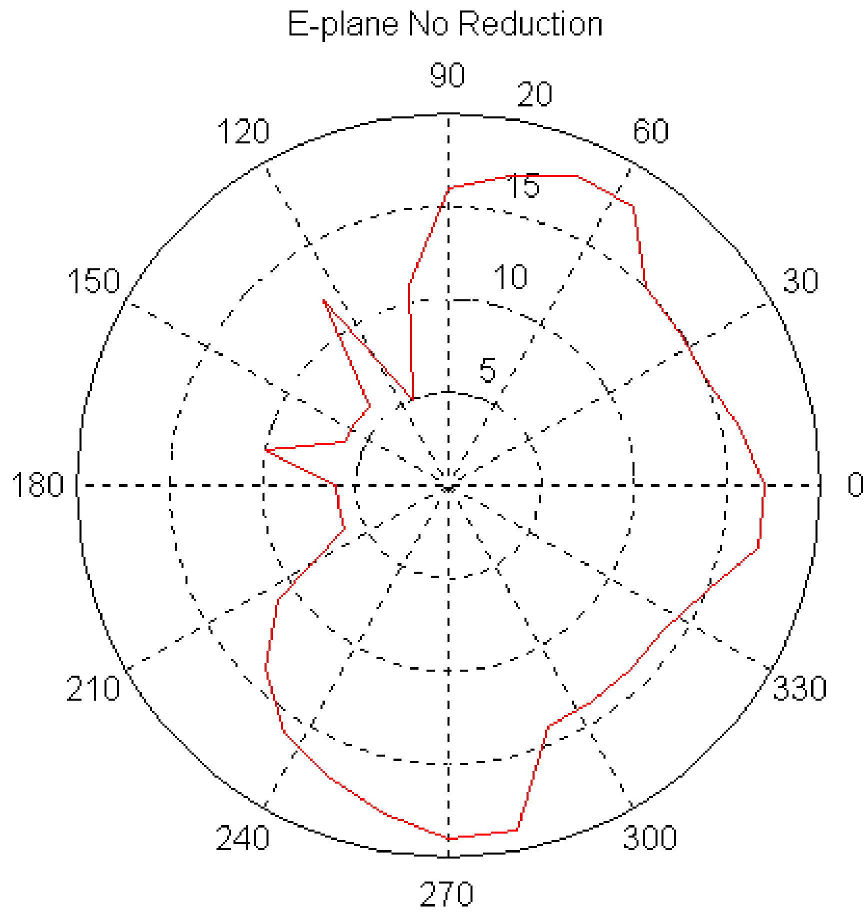
Stage One

Stage Two

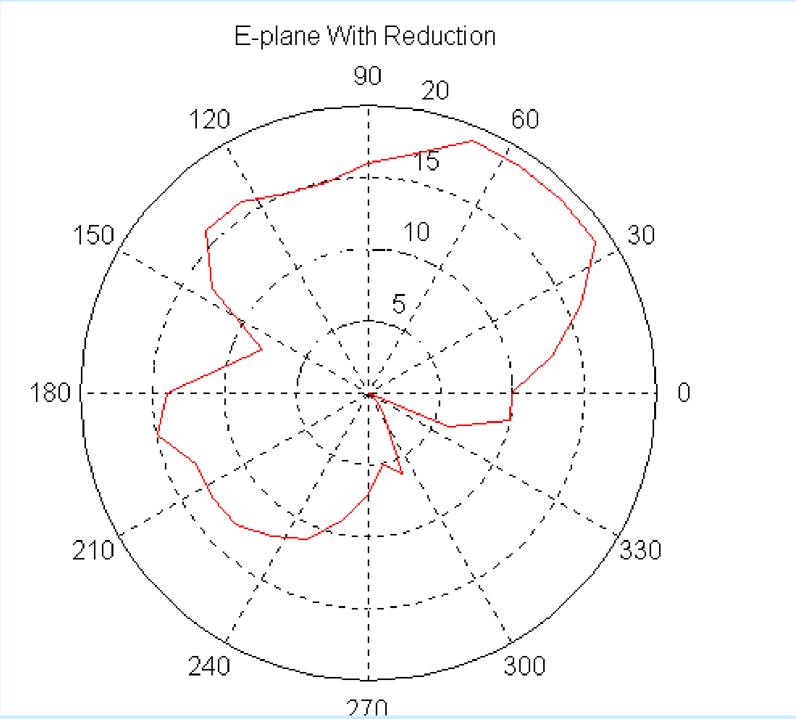


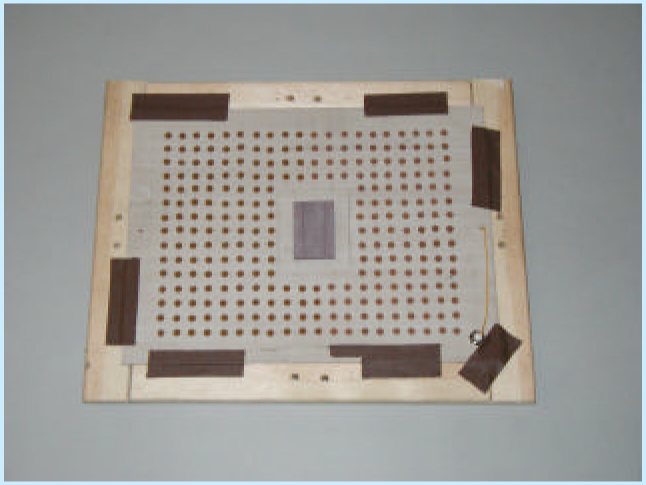


Stage One Results



Stage Two Results





Results

•Using beamwidth as a figure of merit, it can be seen that the unreduced antenna **does** appear to be physically larger than it is.

- –Models used to predict microstrip antenna beamwidth, indicate that a **much larger** antenna would be required to achieve the measured beamwidth
- –The aperture antenna model also indicates that an antenna of larger size would be needed to achieve the measured beamwidth

•Direct measurement of surface wave levels was unachievable and the effects on the radiation pattern are inconclusive.

•Accuracy of results is questionable do to testing equipment and set-up.

E-plane beamwidth	**2.356 rads**
Directivity	**3.4**
Size from Microstrip Model method 1	**5.2 cm x 36.8 cm**
Size from Microstrip Model method 2	**17.8 cm x 36.7 cm**
Real Size	**3.8 cm x 3.1 cm**
Improvement range	**16x – 55x area**