



Angle Independence of Metafilms

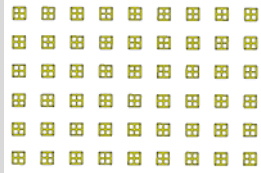
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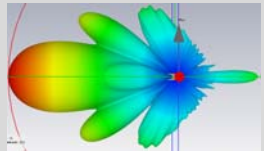


Computer Simulation

CST Microwave Studio was used to develop simulation models of the metamaterial structure and experimental setup.

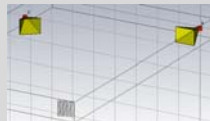


Models of actual laboratory equipment were used in simulation to eliminate as many possible sources of error as possible. The farfield pattern at left represents an accurate depiction of the radiation pattern of the horn antennas used in the lab.



Horn farfield pattern

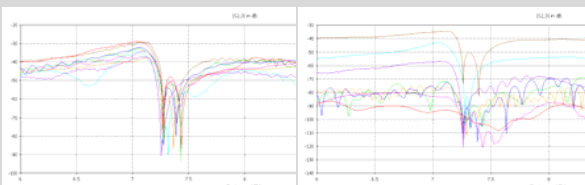
The figure at right illustrates the model of the entire experiment in CST MWS. The entire system was simulated to mitigate sources of error between theory, simulation and measurement.



Simulated System

Preliminary Simulation Results

The plot below left depicts the resultant reflection coefficient of an incident wave upon a PEC sheet to verify the validity of the CST simulation space. The plot below right shows the reflection coefficient with no material in the experimental space. The various line colors represent differing angles of incidence.



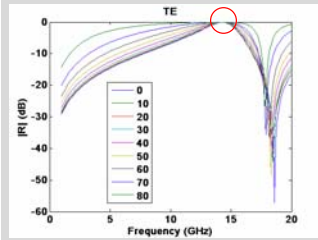
Reflected off of PEC

Reflected off of space

Project Goal

Investigate the effect of Metamaterial structures on the behavior of electromagnetic waves at specific frequencies and confirm angle independence of reflection coefficient.

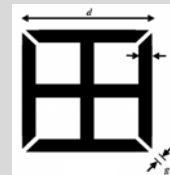
Angle Independence



The figure at left illustrates the expected result of a reflection coefficient independent of incident angle at a frequency of about 14 GHz. Note that the reflection coefficient of all angles of incidence is identical at that frequency (circled in red).

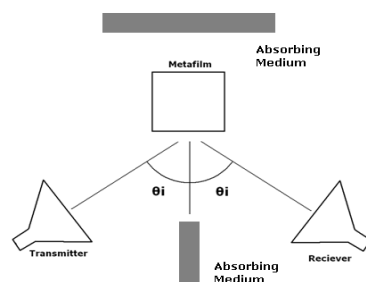
Metamaterial Structure

The unique geometry of these conductive elements interferes with incoming plane waves to change the effective material properties of the overall film. For this particular structure, the wave is reflected across all angles of incidence as though it were incident at the Brewster Angle. This creates a theoretical zero-transmission surface in which all of the power incident is reflected at the resonant frequency. This particular structure is the structure we are investigating. The outer conductive elements act as charge sources, and incident fields cause the charge to move through the narrow conductors in the middle, which slow the response due to self inductance.



$d = 5\text{mm}$
 $w = 0.5\text{mm}$
 $g = 0.1875\text{mm}$
 $f_0 = 14.4\text{GHz}$
thick = 17.5μm Rogers 5880

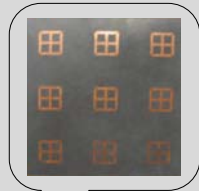
Bistatic Measurement



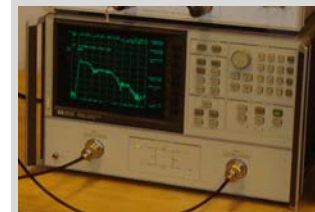
The bistatic measurement strategy permits a direct measurement of angle-dependent material properties like the reflection coefficient. The diagram at left depicts the concept of the measurement setup technique. This setup was chosen due to the directional nature of the antennas being used as well as the need to measure properties based upon their variation across a range of incident angles.

Physical Setup

An enlargement of a section of the metamaterial array is shown at right. The array consists of copper conductive elements on Rogers 5880 High Frequency Laminate.

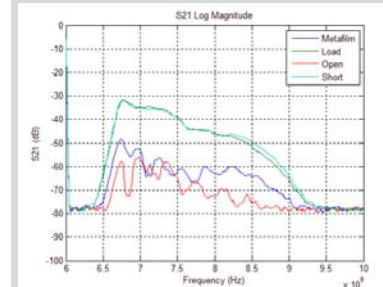


The experimental bistatic measurement setup is shown at right. Absorbing cones are placed behind the array to reduce reflections not originating from the metamaterial array.

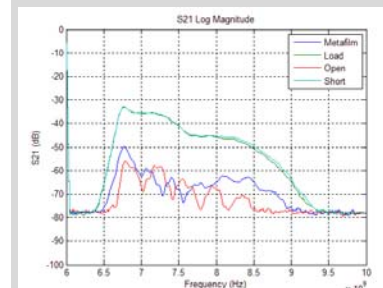


The HP8720A VNA used to collect data in the experiment is shown at left. The VNA is connected to both antennas and is used to measure the reflection coefficient as a function of frequency.

Preliminary Physical Results



Raw, uncalibrated data for a 10 degree angle of incidence is shown at left on a logarithmic scale. The different lines represent results for open, load, short, and film.



Raw, uncalibrated data for a 20 degree angle of incidence is shown at left on a logarithmic scale. The different lines represent results for open, load, short, and film.