X-Band Directivity improvement using Reflector

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Abstract— **A metamaterial reflector resonating at 11.20 GHz measuring 8mm square shape structure is presented. An FR4 substrate was used and the incidental wave angles were varied from 0^0 to 60^0. The structure demonstrated above 80% reflection and was further tested with a microstrip patch antenna. The structure proves to increase the realized gain directivity of the antenna. The structure also demonstrated largest bandwidth to be 3.60 GHz and the lowest to be 1.79 GHz with percentage bandwidth of 32.14% and 15.98% respectively.**

Keywords— metamaterial, reflector, AMC, Microstrip patch antenna,

I. Introduction

The word metamaterial refers to structures artificially engineered to have properties not found in nature. These artificially engineered properties include having; both permittivity and permeability to be negative (DNG) or even combination of one negative and one positive (SNG) [1]. These unusual properties are desirable for certain applications such as EM filters [2], cloaking [3], low profile ground plane [4], sensing [5], focus antenna beam, phase shifting, reflectors [6] Electromagnetic wave reflectors or Artificial magnetic conductors (AMC)s are structures purposely designed with unusual boundary conditions that are "selective" in supporting surface wave currents. [7].

Conventional metallic conductors and perfect electric conductor (PEC) used for antenna ground planes have their drawbacks of reversal or out of phase image currents and propagation of surface current which is radiation caused by infinite ground plane. AMCs counter these drawbacks and even exhibits the ability to reduce back-radiation as well as increase gain. [7].

II. Design and simulation

A. Proposed structure.

The proposed MTM structure unit cell substrate measures 8.235mm by 8.235mm and the patch measures 8.00mm by 8.00mm on an FR4 with dielectric constant of 4.7 and loss tangent of 0.019. The substrate has a thickness of 1.6mm and a full ground plane was used, thus transmittance is zero. Fig. 1a shows the top view of the structure. Reflection is taken to be S11 and incidence angle is considered to be theta for the entire simulations.

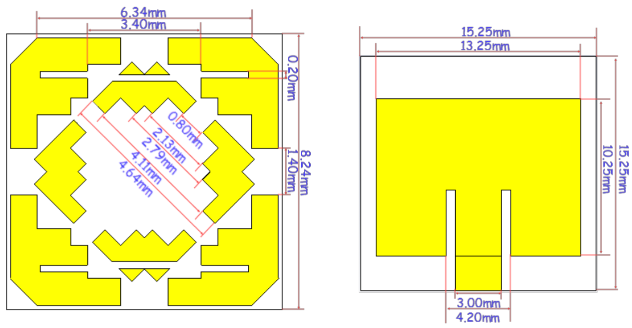


Fig. 1. (a) Proposed MTM Structure (b) Microstrip Antenna

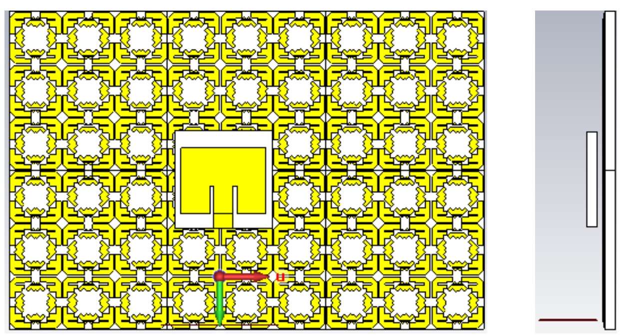


Fig. 2. (a) Proposed MTM Structure and microstrip antenna (b) Side

B. Simulations.

Microwave Studio of Computer Simulation Technology CST® 2015 was used for simulations. Floquet periodic boundary conditions were set to Xmin, Xmax, Ymin &Ymax set to "unit cell" whereas Zmin & Zmax were set to "open add space". Phi and Theta were set to "0".

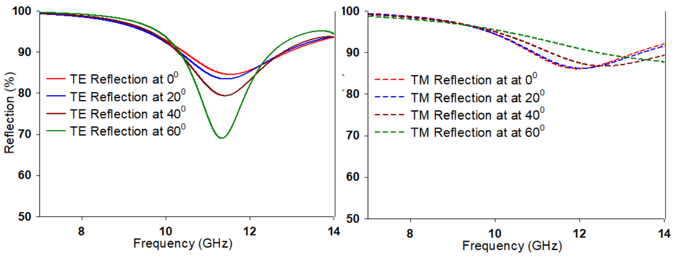
The reflector was designed to operate at 11.20 GHz and has tendency of being made to be switchable or frequency selectable structure after some modifications and optimizations. Its performance in respect to reflection magnitude, phase and effect on an antenna were tested. Incident angle was varied for

(0^0, 20^0, 40^0 & 60^0), also it was tested for polarization sensitivity.

III. Results and Discussions (MTM Reflector)

A. Reflection Magnitude

Under this heading, the reflection magnitude of the structure is tested. For both TE and TM mode, it performed excellently with above 80% reflection for angles below 40 degrees. For angles above 60 degrees, the performance dropped to about 72 degrees for the TE mode. Overall for the TE mode, there isn't any shift in frequency where as for the TM mode there is slight shift in resonance frequency. However, the shift in TM mode for angle above 60 degrees is very high and thus no resonance at the designed frequency.

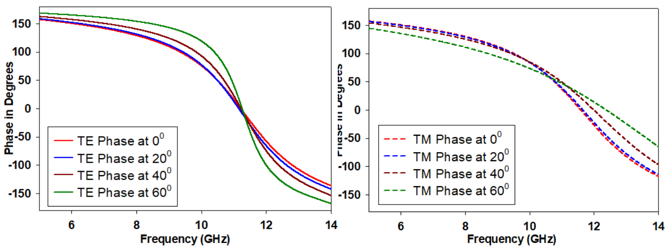


(a) (b)

Fig. 3. Reflection Magnitudes for (a) TE and (b) TM modes.

B. Reflection Phase.

Similarly, in this section, the phase is being studied and reported. For TE mode, for all the four angles simulated, the phase was consistent with the designed resonance frequency. Where as for TM mode, the structure had little but acceptable shift in resonance frequency across angles less than 60 degrees. Unfortunately, the structure didn't perform well in TM mode for angles above 60 degrees, the shift was large there by not having resonance within the designed frequency range. The structure demonstrated largest bandwidth of 3.60 GHz and the lowest to be 1.79 GHz.



(a) (b)

Fig. 4. Reflection Phase for (a) TE and (b) TM modes.

C. Antenna's Return loss and Radiation pattern.

In order to fully efficiency or improvement the reflector could offer, a microstrip patch antenna shown in fig 1(b) was designed using the same substrate properties. The reflector was put into an array of 6x9 = 54 and then the antenna was place close to the top surface at a distance of 24.5mm.

The return loss of the antenna and the realized gain with and without the reflector are presented in Fig. 5 and 6. From Fig. 5, even though the return loss reduced, when the reflector is added, the side loops of the antenna was greatly reduced. Gain improvement is mostly affected by the distance at which the reflector is placed.

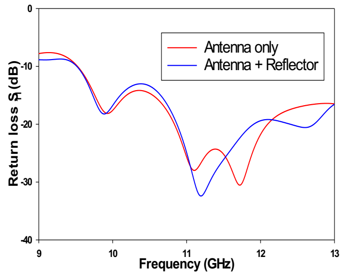


Fig. 5. Return loss of the microstrip antenna only and antenna & Reflector

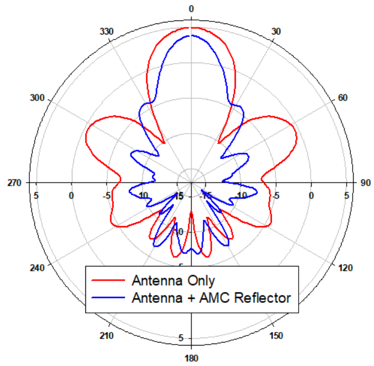


Fig. 6. Antenna's radiation pattern

IV. Conclusions

A Metamaterial Reflector is presented, the performance under different incident angles (0° to 60°) were tested and reported. The structure demonstrated above 80% reflection at resonance frequency. The structure was tested with a microstrip antenna and it reduced the side loops of the antenna. The structure is polarization sensitive, structure has potentials for X-band applications and has percentage bandwidth of 32.14%.

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