Wideband Microstrip Patch Antenna with Metamaterial (Spiral Resonator) on Ground

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Abstract
A novel wideband patch antenna designed to resonate at public band is presented in this paper. The model besides tradional modeling implements spiral resonators in its ground plane. A conventional patch is designed and then a SR is designed. To get a band enhanced antenna resonating at predefined spectra six such Spiral resonators are etched in its ground plane besides Patch portion being etched with four triangles on its radiating as well as non-radiating edges similar to first iteration of a fractal antenna. The detailed analysis is also presented.

Keywords: *Microstrip patch antenna, linear polarization, wireless applications, h shaped slot, radar, SATCOM applications*

INTRODUCTION

The planar printed planar antenna with the advent of Metamaterials in early 2000 has undergone a remarkable change in its design making it a widely prefered wireless antenna. K. F. Lee and K. F. Tong explained the historic growth of MPA, different methods of creating slots, various design criteria for creating slots that cause dual , triple band resonances, different band width enhancement technique as well as the overall growth of such planar antennas are elaborately explained [1].

R. Marques *et al.* simulated two types of SRRs that is edge coupled- and broadside coupled SRRs in which a comparative analysis of these two structures have been carried and their suitability for the design of metamaterials in antennas have been suggested [2].

To know the recent progress in MTM, an article by G. V. Eleftheriades is also referred. The author discussed /reviewed all facts about MTM like negative refractive index, negatives permittivity and permeability. Particularly, the author has explained all about SRR, equivalents, methods to extract parameters and about the MTM lens which may find application in antenna domain [3]. Use of lens for antenna design is also an emerging field of research now.

L. Anthony *et al.* explained very clearly the concept of CRLH TL and different equivalents when a TL is loaded with capacitor and inductor separately as well as together. They have given various equivalents and derived relevant expression for parameter extractions. This paper forms a core paper of reference for analyzing such structures for antenna application [4].

A MTM antenna with five Spiral resonators on both sides is proposed by J. Zhu and G. V. Eleftheriades [5]. Thus, they have utilized CRLH structures as elements for bandwidth enhancement. In their work, they have used two different patches with staggered unit cells of spiral resonator energized together by some common feed. Y. Kwon Jung and B. Lee have clearly established an approach by which a microstrip RFID reader antenna features are improved with size reduction and they also respond at dual frequencies. For this they have utilized CRLH technique, in designing directional couplers to feed a slotted patch and thereby they have shown the bandwidth enhancement, dual resonances [6].

The use of artificial magnetic conductors (AMC) structures that is capacitive loaded loops (CLL) on one of the layers of a printed dipole antenna is studied by E. Aycan *et al.* [7]. The CLL is found to create increased FBR or larger directivity value creating a highly focused antenna. Following these, Gayathri *et al.* proposed many types of Metamaterial based antennas, wireless application antennas [8–13]. In this paper a wideband antenna with spiral resonators in its ground plane is presented.

DESIGN OF PROPOSED ANTENNA

A conventional patch is designed using RT Duroid substrate with relative permittivity of 2.2 with a thickness of 62 mils. The antenna is fed with coaxial cable [14]. The size of the ground is 45 X 38 mm. A five turn rectangular Spiral resonator (SR) is etched on ground plane. Six such resonators are etched on its ground plane making it resonate at required public band frequency. Rectangular SR is as shown in Figure 1. Its equivalent circuit is also a parallel combination of inductance and capacitance.

The spiral resonators are found to create miniaturization up to λ/30. The design equations presented in this section holds good only if value of *N*, *which* is the number of turns of resonator, does not exceed a predefined integer value as given below.

$$N_{SR\max} = Integer\left[\frac{l-(w+s)}{2(w+s)}\right] \quad \ldots \quad (1)$$

The design equations for the spiral resonators are as follows

$$L_{SR} = \frac{\mu_0}{2\pi} l_{SRavg}\left[\frac{1}{2} + \ln\left(\frac{l_{SRavg}}{2\omega}\right)\right] \quad \ldots \quad (2)$$

$$C_{SR} = C_o \frac{l}{4(\omega+s)} \frac{N^2}{N^2+1} \sum_{n=1}^{N-1}\left[l - \left(n+\frac{1}{2}\right)(\omega+s)\right] \quad (3)$$

Where ω stands for width, s for spacing , N is an integer, n stands for number of turns, l stands for length while the expressions for l_{SRavg} and C_o are available in [15].

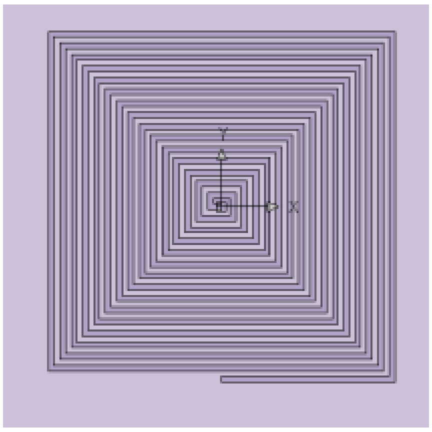

Fig. 1: *Spiral Resonator.*

The top view as well as its ground plane are seen in Figures 2 and 3. The dimensions of SR are shown in Table 1 for the sake of clarity to readers.

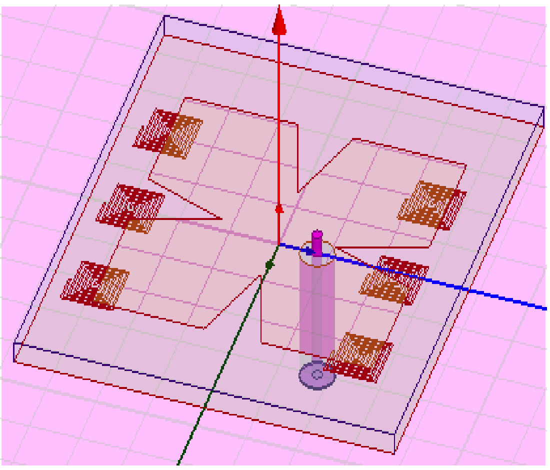

Fig. 2: *Top View of the Proposed Antenna.*

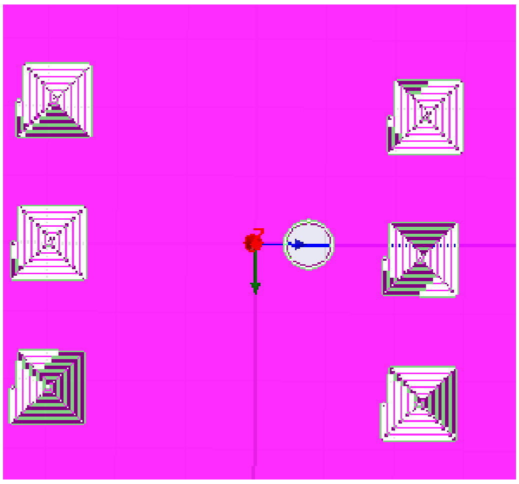

Fig. 3: *Ground Layer of the Proposed Antenna.*

Table 1: *Dimension of the Proposed Antenna.*

Parameters	**Size**
Substrate	62 mils
Relative permittivity	2.17
Ground	45 x 38 mm
SR	5 turns 0.2 mm width 0.5 distance Thickness 1 micron

ANALYSIS OF THE PROPOSED ANTENNA

The Coaxial fed antenna is optimized to resonate at 6.76 GHz and its return loss characteristics are shown in Figure 4. The value of S_{11} is -16 dB indicating good match. The simulated antenna parameters are seen in Table 2.

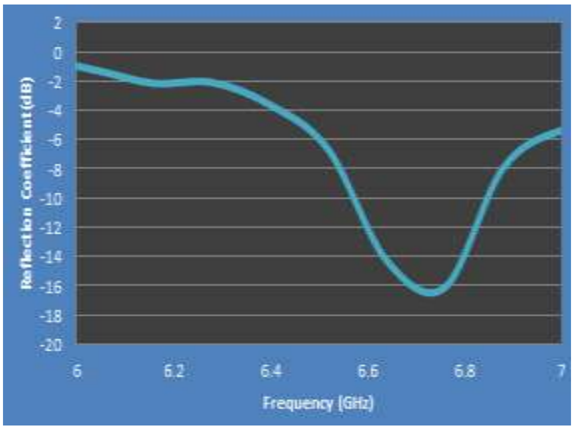

Fig. 4: *Reflection Coefficient of the Proposed Antenna.*

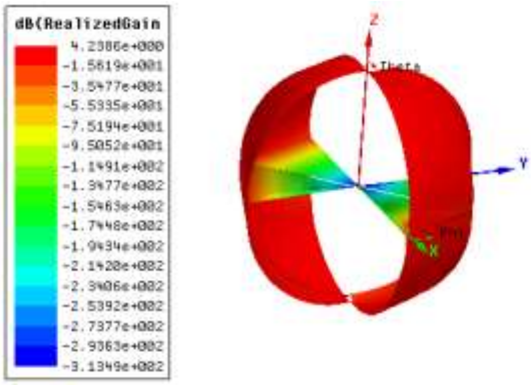

Fig. 5: *Polar Plot (Gain) of the Proposed Antenna.*

The Polar Plot of the Proposed Antenna at its discrete frequency of resonance is noted in Figure 5. The Magnitude of its Directivity, VSWR is seen in Figures 6 and 7. The ludwig radiation pattern and the magnitude of current density distribution on patch and ground are shown in Figures 8–10. The simulated parametrs are tabulated in Table 2.

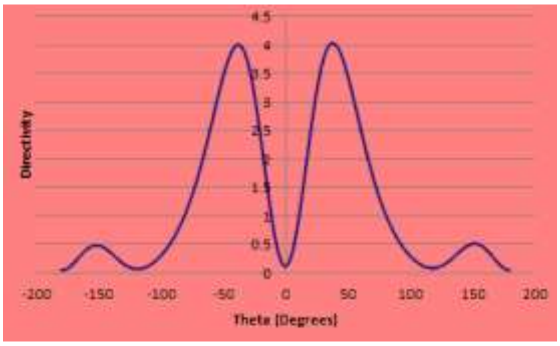

Fig. 6: *Directivity of the Proposed Antenna.*

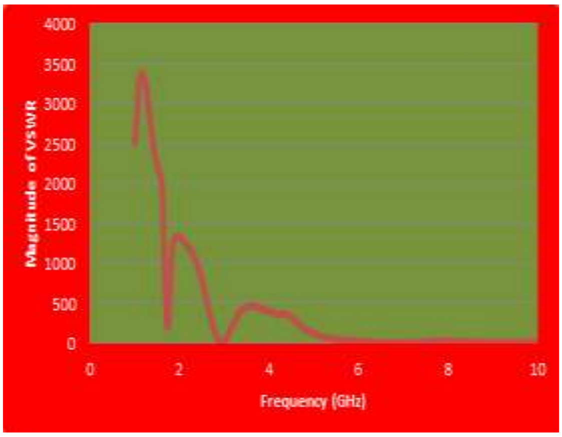

Fig. 7: *VSWR of the Proposed Antenna.*

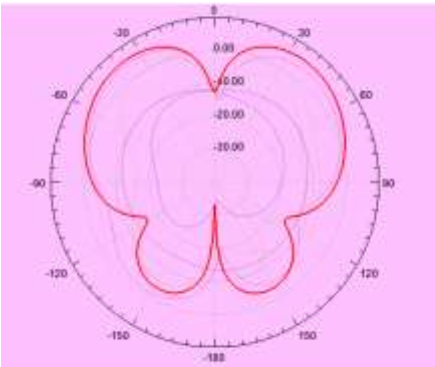

Fig. 8: *Radiation Pattern of the Proposed Antenna.*

Table 2: *Antenna Parameters at 6.76 GHz.*

Quantity	**Value**
Directivity	4.03
Gain (dB)	4.02
Efficiency	99.85
VSWR	1.37

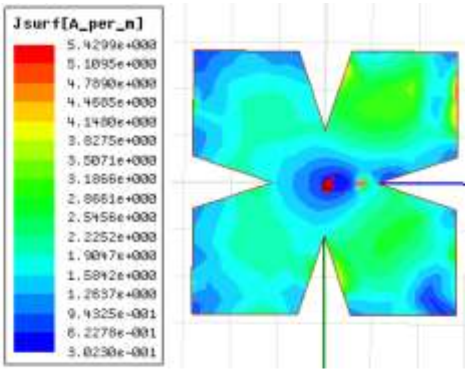

Fig. 9: *Current Distribution on Patch of the Proposed Antenna.*

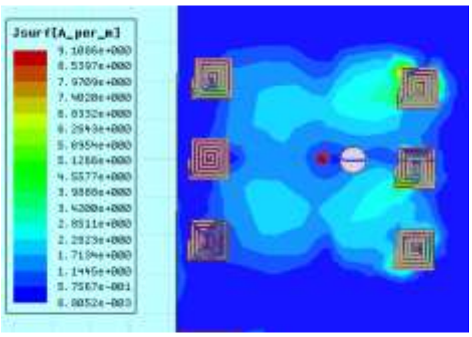

Fig. 10: *Current Distribution on Ground of the Proposed Antenna.*

CONCLUSION

A wide band antenna with gain of 4.03 dB at fixed bands for public utility is presented. The antenna has a conserved pattern, good return loss and directivity with linear polarization. The antenna also has a improved bandwidth of 238 MHz. The efficiency of the antenna is 99.85 which means more or less its 100% effective in its transmission and reception making it a best option for the suggeted application.

ACKNOWLEDGEMENTS

The author wishes to thank the authorities of Annamalai university for permittting her to carry out this work. The author also wishes to acknowledge her Guru, The Great Scientist of ISRO, Dr. Khagindra Kumar Sood, Group Head, Satcom Systems and Technology Group (SSTG) & Satcom and Navigation Applications Area (SNAA), Space Applications Centre, Indian Space Research Organization, Ahmedabad.

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