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Metamaterial Antenna Using Split Semi-horse Shoe Structure

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Abstract : *In this paper a planar metamaterial antenna using split semi-horse shoe structure (SSHSS) is designed and analyzed. Equivalent circuit formula also developed. Prototype of the antenna is fabricated and experimental findings are also presented. Metamaterial property of the new structure is proved by using effective medium theory. Simulated results are compared with measured results. The antenna shows multiband characteristics while having a good agreement between simulated and experimental results.*

1. INTRODUCTION

Metamaterial in recent time received a lot of interest from scientific community nearly 40 years of the concept realized by Russian Prof. Veselago in 1968[1].These artificial materials have lots of interesting electromagnetic property as compared with naturally occurring materials that have opposite refractive index. Advancement in communication technology and the future research in wireless communication demands integrated system on chip systems [3]. Antenna designing therefore, is a challenging domain of research to meet the varied requirements. Metamaterials appears to be very useful in designing of future wireless communication devices. With the help of metamaterials, size of antenna can be reduced up to subwavelength of the operating frequency while enhancing the gain, bandwidth and directivity of antenna[4-5].In this paper, the authors aim at designing a reduced size, good gain and moderated bandwidth metamaterial antenna for wireless applications.

2. SSHSS Planar Antenna

In this section the physical dimensions of split semi-horse shoe structure (SSHSS) is presented. The antenna structure is simulated using IE3D electromagnetic simulator software. The geometrical dimensions of design are as; width of each ring W =2mm, spacing between two rings S= 1mm, split gap 'D'=1mm, strip vertical width w=4mm, outer length of outer strip L=23.47mm, r_1=6mm and r_4 =11mm. RT Duroid 5880 substrate of relative permittivity 2.20, loss tangent=0.0009 and thickness h = 1.575 mm is used to simulate and fabricate the antenna.

2.1. Geometry of SSHSS

Figure 1. shows the geometry of split semi-horse shoe structure with split cut in Y-axis.

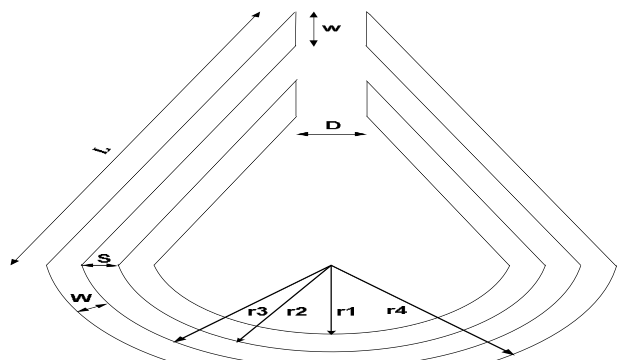


Figure 1. Geometry of Split Semi-Horse Shoe Structure (SSHSS)

3. SIMULATED RESULTS

The metamaterial antenna structure is coaxially excited at x=-7.0 mm, y=-7.1mm and x=3.6mm, y=6.9mm. Figure 2 one next page shows the reflection coefficient (S_{11}) and phase reversal (S_{12}) characteristics of SSHSS planar metamaterial antenna. As seen from the Figure 3(expanded view)**,** the return loss at 5.93 GHz frequency is -17.87 dB, it is also clear that structure exhibits phase reversal in the resonant frequency band which implying that the wave vector changes its phase by an angle of 180^0 at the interface. It is clear from the Figure

2 that it is a multiband antenna resonating at 5.93 GHz, 8.65 GHz, 12.69 and 15.25 GHz, at these resonating frequencies structure exhibits phase reversal in the resonant frequency band (return loss below -10dB).

Table 1. on next page shows the summary of the simulated results for proposed antenna

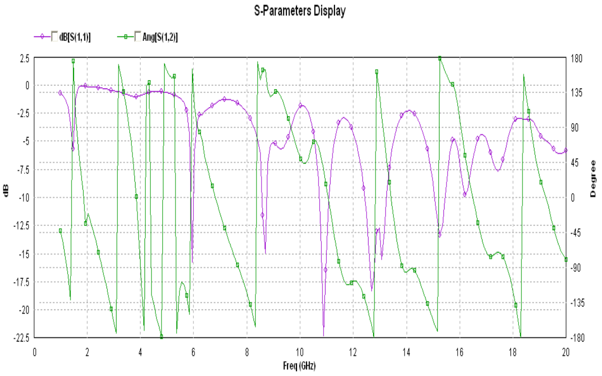


Figure 2. Reflection S_{11} (dB) and phase angle S_{21} of SSHSS

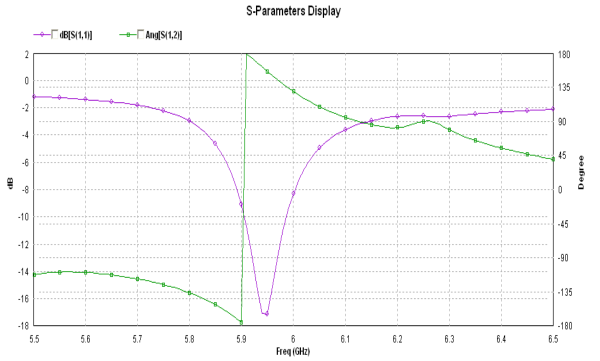
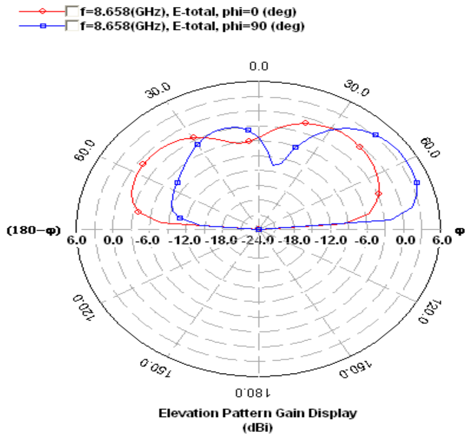


Figure 3. S_{11} (dB) and S_{21} of the SSHSS (expanded view)

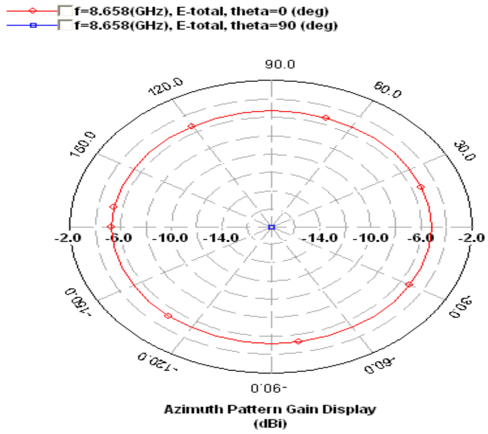
Table 1: Summary of the simulated results for design

Resonance Frequency(GHz)	Return Loss S_{11} (dB)
5.93	-15.59 dB (-17.87 dB expanded view)
8.65	-14.96
10.89	-21.56
12.69	-18.10
15.25	-13.30

Figure 4. depicts the azimuth and elevation plane radiation pattern of the SSHSS.



(a)



(b)

Figure 4. Radiation pattern (a) elevation (b) azimuth

Figure 5. shows the total filed gain versus frequency plot of the designed antenna.

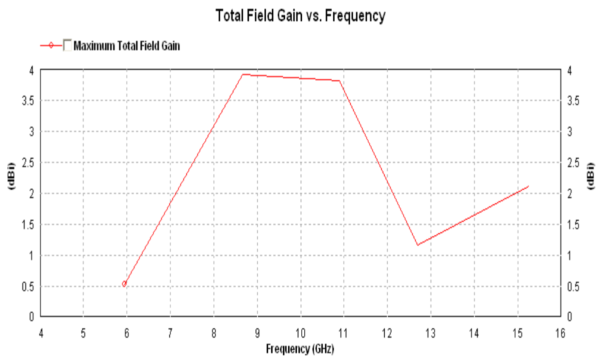


Figure 5. Total filed gain Vs Frequency plot of antenna

4. Verification of metamaterial property

MATLAB is used in the calculation of the permittivity and permeability of the designed structure. The NRW approach formulas[6-7] are used for numerical calculation of the electrical permittivity and magnetic permeability of the SSHSS. This is done by exporting the S-Parameters from IE3D software to MATLAB using the equations (1) & (2) [11],

$$\mu_r = \frac{2}{jk_0 d}\frac{1-V_2}{1+V_2} \qquad (1)$$

$$\varepsilon_r = \frac{2}{jk_0 d}\frac{1-V_1}{1+V_1} \qquad (2)$$

where k_o is the wave number, d is the height of the substrate. V_1 and V_2 are the composite terms which are defined in equation (3) & (4) [11],

$$V_1 = S_{21} + S_{11} \qquad (3)$$

$$V_2 = S_{21} - S_{11} \qquad (4)$$

Figure 6., Figure 7. Figure 8. Figure 9., Figure 10. ,&
Figure 11. shows the extracted permeability, permittivity and index of refraction from S-parameters for the SSHSS metamaterial antenna in ISM and X band respectively. From the figures it is clear that value of permeability, permittivity and index of refraction is negative over the resonant frequency band[6].

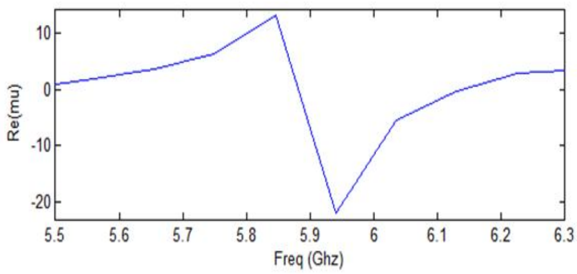


Figure 6. Extracted permeability from S- Parameters

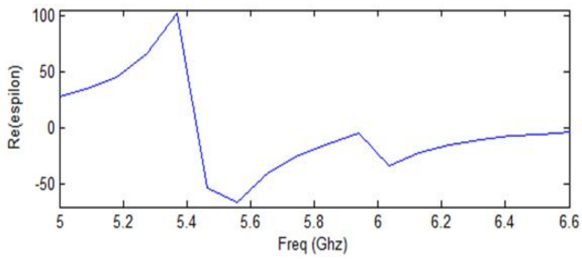


Figure 7. Extracted permittivity from S- Parameters

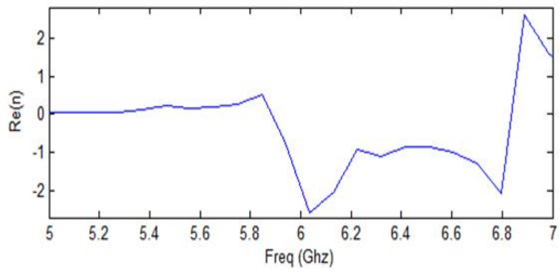


Figure 8. Extracted index of refraction from S-Parameters

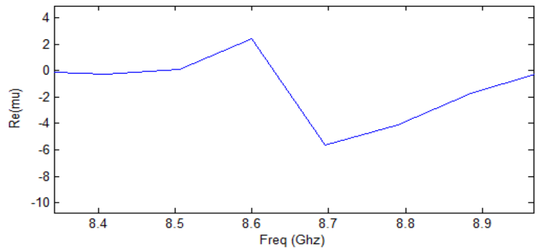


Figure 9. Extracted permeability from S- Parameters

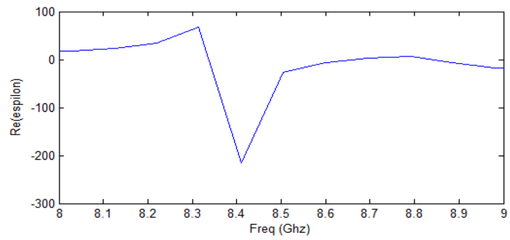


Figure 10. Extracted permittivity from S- Parameters

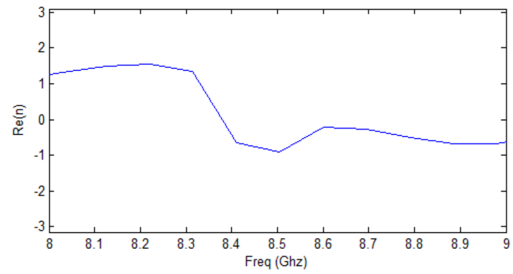


Figure 11. Extracted index of refraction from S-Parameters

5. FABRICATION AND EXPERIMENTAL RESULTS

Prototype of the Split Semi-Horse Shoe Structure metamaterial antenna is fabricated on RT Duroid 5880 substrate of relative permittivity 2.20, loss tangent=0.0009 and thickness h = 1.575 mm. Figure 12. shows the photograph of the radiating patch and ground plane of the fabicated SSHSS metamaterial antenna

(a) (b)

Figure 12. Photograph of the fabricated metamaterial antenna
(a) Radiating Patch (b) Ground Plane

Figure 13. shows the photograph of the VNA displaying the measured return loss for SSHSS metamaterial antenna. Summary of test result is presented in Table 2 on next page. Comparison graphs between simulated and measured results are made by exporting simulated S-parameters data as well as VNA data points to MATLAB. Figure 14. shows the comparison graphs between simulated & measured results for metamaterial antenna up to 20 GHz.

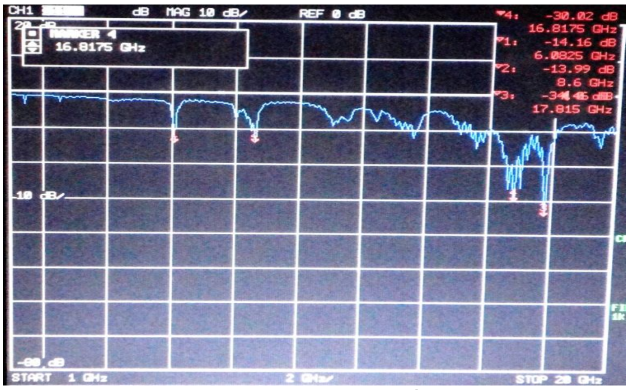


Figure 13. Measured return loss of SSHSS on VNA

Table 2: Experimental results by VNA

Resonance Frequency(GHz)	Return Loss S_{11} (dB)
6.0825	-14.16
8.60	-13.99
16.81	-30.02
17.815	-34.46

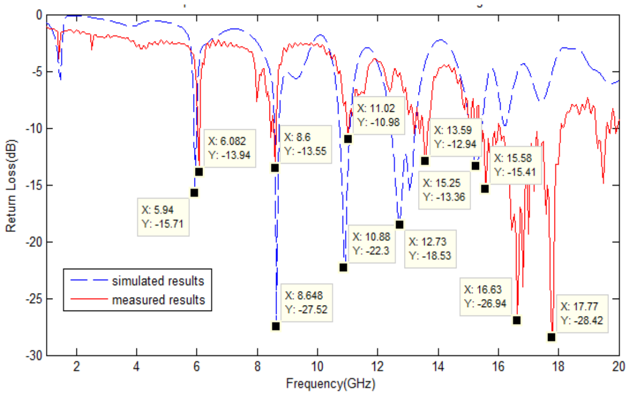


Figure 14. Comparison between simulated and measured return loss

6. CONCLUSION

In this paper a new metamaterial structure which is like horse shoe in shape is developed which exhibits metamaterial characteristics in ISM and X-band band. Radiation pattern, directivity and gain of the structure were illustrated which gives the possibility of using SSHSS as the antenna. Experimentally measured results show close resemblance to the simulated results.

7. REFERENCES

[1] V. G. Veselago, “The electrodynamics of substances with simultaneously negative values of ε and μ”, *Soviet Physics Uspekhi*, 10, 1968, pp.509–514.

[2] J. G. Joshi, Shyam S. Pattnaik, S. Devi, and M R Lohokare, “Frequency switching of electrically Small Patch Antenna using Metamaterial loading”, *Indian Journal of Radio & Space Physics*,40, 2011, pp.159-165.

[3] B.D. Bala, M.K.A . Rahim and N.A. Murad, "Small electrical metamaterial antenna based on coupled electric field resonator with enhanced bandwidth", *Electronics Letters*, 50, 2014, pp.138–139.

[4] Omar M. Khan, Zain U. Islam, Qamar U. Islam, and Farooq A. Bhatti, Multiband High-Gain Printed Yagi Array Using Square Spiral Ring Metamaterial Structures for S-Band Applications ,*IEEE Antennas and wireless Propagation letters*,13, 2014**,** pp. 1100-1103.

[5] Abdolmehdi Dadgarpur, Behnam Zarghooni, Bal S. Virdee, and Tayeb A. Denidni, "Beam Tilting Antenna Using Integrated Metamaterial Loading", *IEEE Transactions on Antennas and Propagation*, 62,2014**,** pp. 2874-2879.

[6] J. B. Pendry, A. J. Holden, D. J. Robbins, and W. J. Stewart, “Magnetism from conductors and enhanced nonlinear phenomena,” *IEEE Transactions on Microwave Theory and Techniques*, 47, 1999, pp. 2075–2084.

[7] D. R. Smith, D. C. Vier, Th. Koschny, and C.M. Soukoulis, “Electromagnetic parameter retrieval from inhomogeneous metamaterials”, *Physical Review E*,.71, 2005, pp. 1-11.

[8] Jiafu Wang, Shaobo Qu, etal, “A Controllable Magnetic Metamaterial: Split-Ring Resonator with Rotated Inner Ring”,

*IEEE Transactions on Antennas and Propagation,*56, 2008, pp.2018-2022.

[9] Filiberto Bilotti, Alessandro Toscano, Lucio Vegni, "Design of Spiral and Multiple Split-Ring Resonator for the Realization of Miniaturized Metamaterial Samples", *IEEE Transactions on Antennas and Propagation,* 55, 2007, pp. 2258-2267.

[10] J. G. Joshi, Shyam S. Pattnaik, S. Devi, and M.R. Lohokare, "Electrically Small Patch Antenna Loaded with Metamaterial", *Institution of Electronics and Telecommunication Engineers Journal of Research,* 56, 2010, pp.373-379.

[11] Richard W. Ziolkowski, "Design, Fabrication, and Testing of Double Negative Metamaterials", *IEEE Transactions on Antennas and Propagation*, 51, 2003, pp 1516-1529.