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UWB and miniaturized meandered stripline fed metamaterial loaded antenna for satellite applications

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Abstract. A novel metamaterial surface-inspired patch antenna is proposed, wherein different parameters, e.g. dimension of ground plane, no. of slots on radiating patch, shape of the feed and distance between the patch and metamaterial surface, have been optimized for maximum gain, bandwidth and miniaturization .It is observed that the pair of slots on radiating patch generate multiple resonances giving 400% miniaturization while varying ground plane and feed results in wide bandwidth of nearly 600%..

1. Introduction

Nowadays, the trend is developing devices for wireless communication systems which have inherent high bandwidth, gain and multi-resonance. Rectangular Microstrip Patch Antenna i.e. RMPA is not a good candidate as it has narrow bandwidth, in sufficient gain and directive properties. Thus, various optimization techniques have been introduced to make patch antenna as successful candidate in wireless communication applications.

With the development of metamaterials, came the concept of attaining altered behaviour of electromagnetic radiations, i.e. μ, ε, η. Thus, providing better solution for attaining enhanced antenna‟s performance

In this paper, a novel antenna structure is proposed with enhanced performance parameters and miniaturization. By using different dimensions of ground plane and by changing the dimension of feed line wider bandwidth is obtained. Also, by inserting slots on the radiating patch different resonant frequencies are observed. Further the performance is improved by introduction of metamaterial surface at an optimum spacing from the radiating patch.

2.Antenna Design

Transmission line representation of RMPA is by two slots of width, w, and height, h, separated by transmission line of length, l. It resonates at 38.5GHz frequency with dielectric constant (εr) = 2.2, substrate thickness h = 3.2mm, L = 24.3mm, W = 30.8 mm on a ground plane [1-4]. Nearly, ground plane is finite with size greater than the patch by six times the substrate thickness, with length, Lg=108mm and width, Wg=140mm. Figure 1 gives the constructional details.

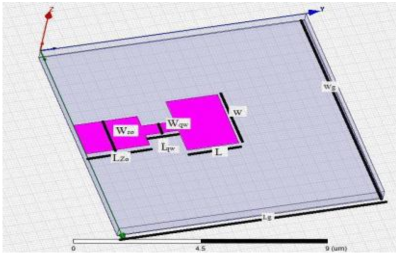


Figure 1. Rectangular microstrip patch antenna: constructional details

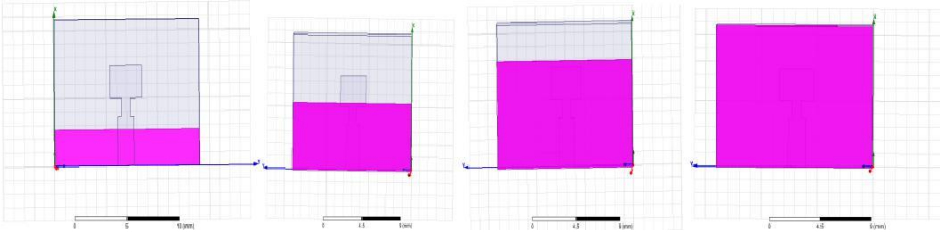
The input impedance at the base of microstrip feed line is 50Ω i.e. Zo. „Wqw" and „Lqw" represent the width (=16.3mm) and length (13.8mm) of the quarter wave transformer.

3.Paramateric Analysis of Patch

The antenna parameters e.g. size, feed position, gain and radiation characteristics are not considered in parametric study. The different design parameters of the antenna (number of slots, feed shape, size of ground plane and spacing between the patch antenna and metamaterial surface) are optimized using Ansoft HFSS software.

3.1. Analysis of size of ground plane

The size of the ground plane [5] is varied as 1/2, 1/4, 3/4 and full as shown in figure 2.



(a) (b) (c) (d)

Figure 2. Size of ground plane a) 1/2 ground b) 1/4 ground c)3/4 ground d)full ground

The size of ground plane affects the excitation modes and thus, the operational bandwidth. The curve in figure 3 depicts the effect of dimension of ground plane on S_{11} of radiating patch.

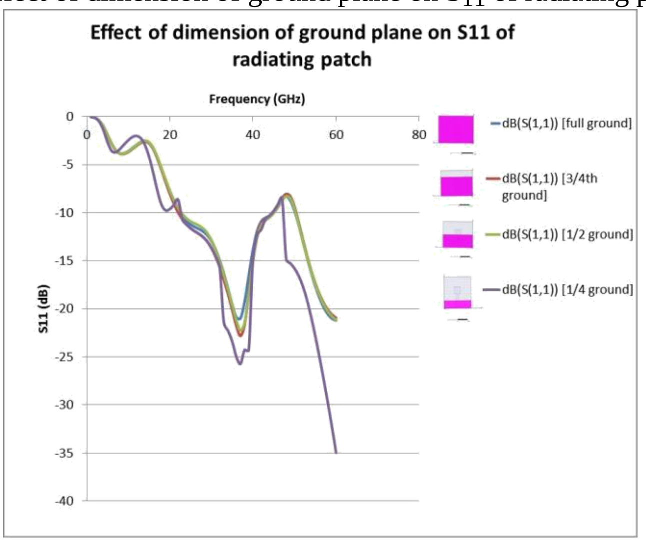
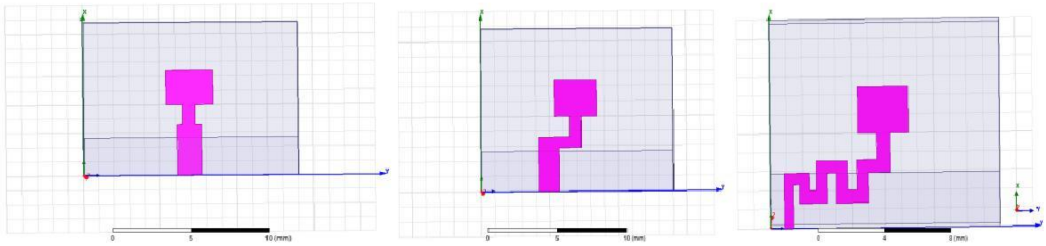


Figure 3. Effect of dimension of ground plane on S11 on radiating patch

It can be observed that using partial ground plane (1/4th) better reflection and bandwidth is obtained.

3.2. Analysis of different feed shape

The different feed shapes effect the input impedance mismatch of patch antenna [6]. Micro strip, L-strip and meander stripline has been used as feed in figure 4. .



(a) (b) (c)

Figure 4. Different feeding techniques: a) microstrip b) L-strip c) Meander stripline feed

The curve in figure 5 depicts the response of different feeding techniques on S_{11}.

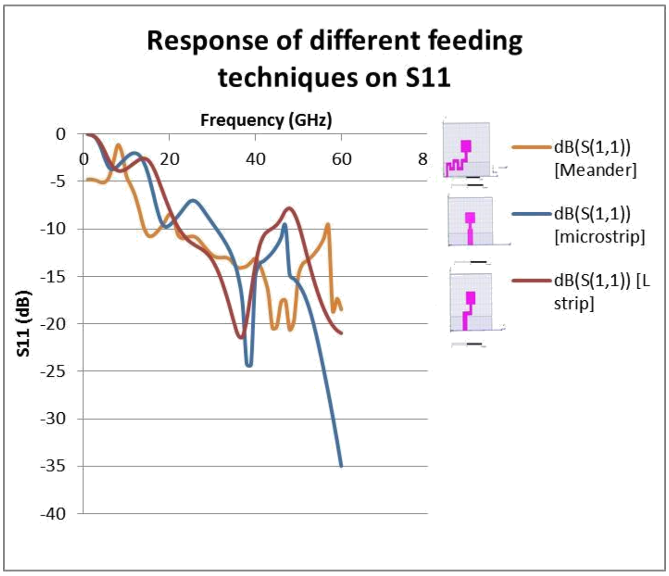
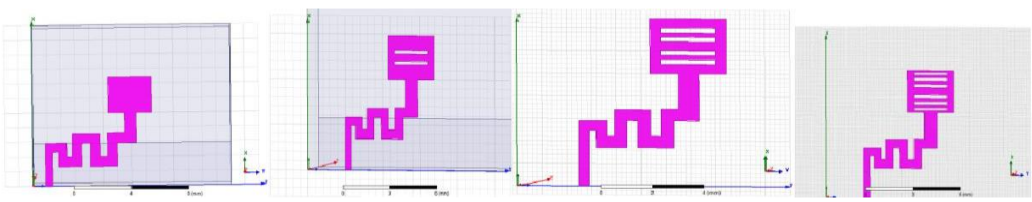


Figure 5. Response of different feeding techniques on S11 of patch

It can be seen that the meander strip-line feed structure has helps in attaining better impedance matching and thus wider bandwidth of 40GHz which is 400% enhancement over the conventional microstrip feed line.

3.3 Analysis of number of slots

The cutting of slots (in symmetrical pairs) [7] on the radiating patch has been done as shown in figure 6. Three pairs of equal size and spacing have been cut which leads to altered flow and direction of current. Thus, reducing the impedance of patch and introducing lower resonant frequencies.



(a) (b) (c) (d)

Figure 6. Inserting different no. of slot pairs: a) No slot b) one slot pair c) two slot pair d) three slot pairs

The curve in figure 7 depicts the effect of inserting different no. of slots on radiating patch on the resonant frequencies.

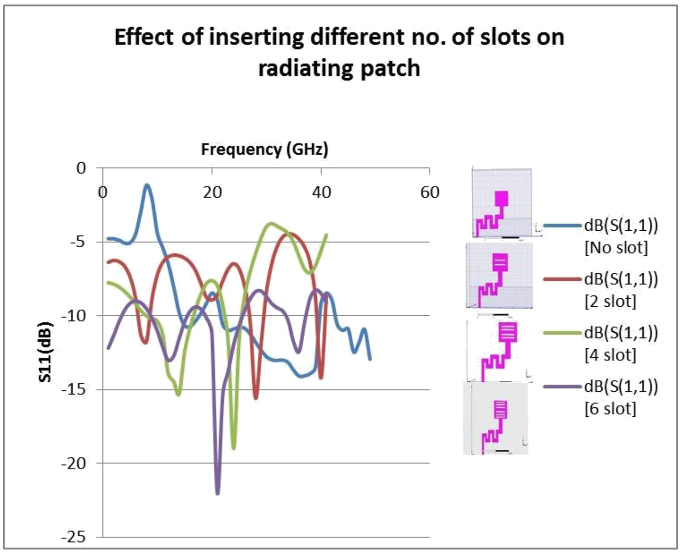


Figure 7. Effect of Inserting different no. of slot pairs on S_{11}

It can be observed that 50% miniaturization occurs with 6 slots on the patch.

3.4 Analysis of spacing between patch antenna and metamaterial surface

The metamaterial array of 2X2 swastika is used as reflector surface [8-9] by placing it at „ds" spacing below the patch antenna as shown in figure 8.

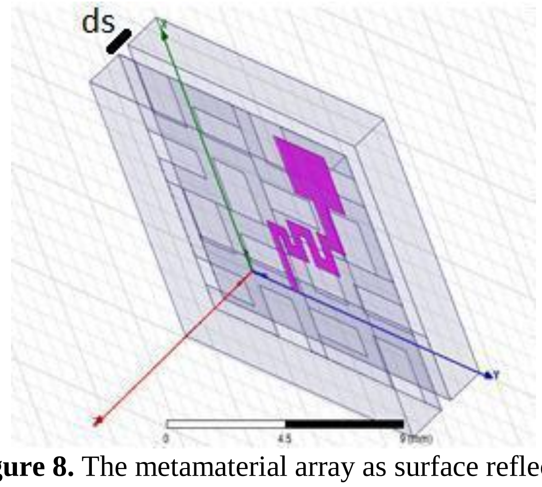


Figure 8. The metamaterial array as surface reflector

The 'ds' is varied as 0mm, 0.5mm, 0.75mm, 1mm, 1.5mm.The curve in figure 9 depicts the effect of spacing on the antenna"s performance parameters.

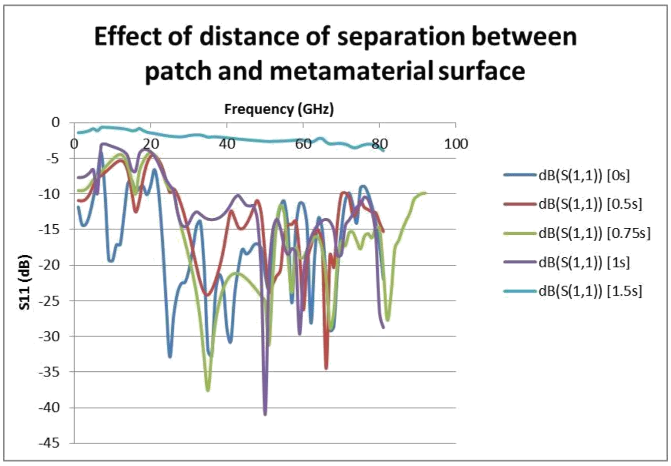


Figure 9. Effect of distance of separation between patch and metamaterial surface

It can be seen that the optimized value of ds is 0.75mm for maximum bandwidth improvement of nearly 600% over the conventional microstrip patch antenna [10].
The curve in figure 10 combines the effect of slots for obtaining both miniaturization and maximization of bandwidth.

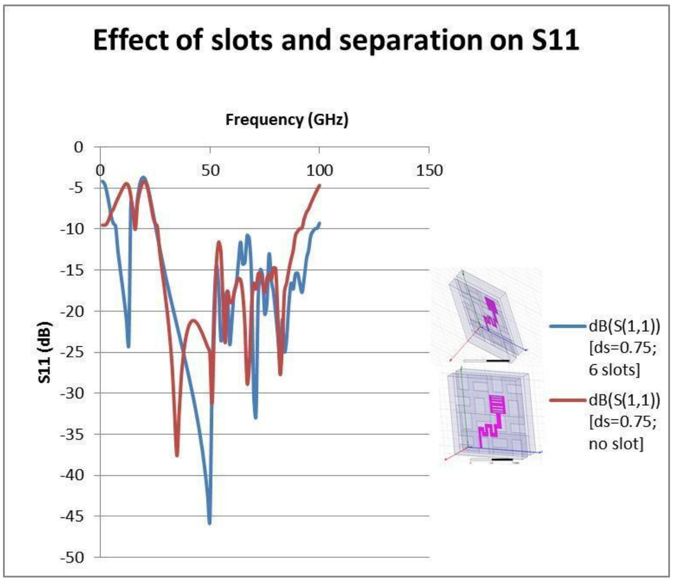


Figure 10. Effect of slots and separation distance on S11

It can be seen that the miniaturization of nearly (1/4th) of the conventional patch is obtained.

4.Experimental validation of simulation results

In order to validate the above results, the patch antenna is fabricated by scaling the dimensions by a factor of 10 and frequency is scaled by (1/10). Thus, the new resonant frequency is 3.85GHz.
The fabricated antenna with meandered strip line and six slots is shown in Figure 11. The fabricated antenna is then embedded with metamaterial array in the middle of the substrate and is shown in Figure 12.

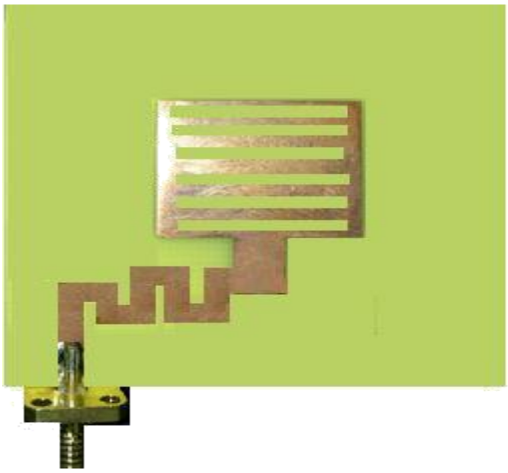


Figure 11. Fabricated Meandered patch antenna

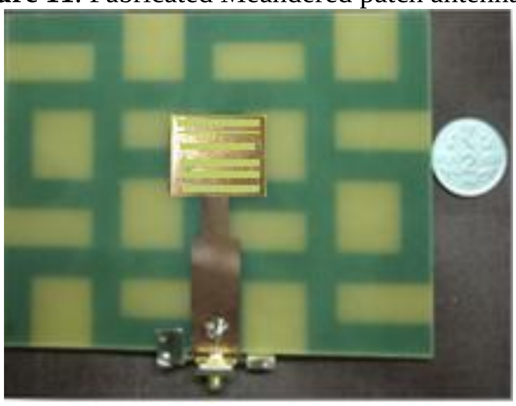
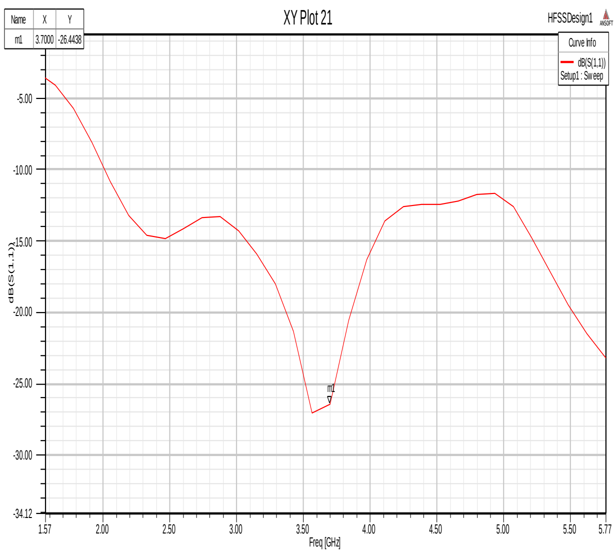


Figure 12.Fabricated metamaterial patch antenna

The simulation results are shown in figures 13 a, b, c and figure 14 a, b, c. below.



(a)

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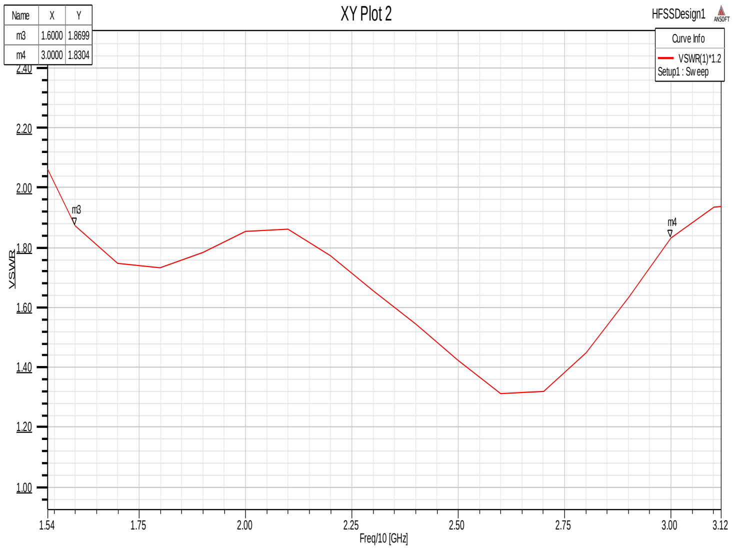
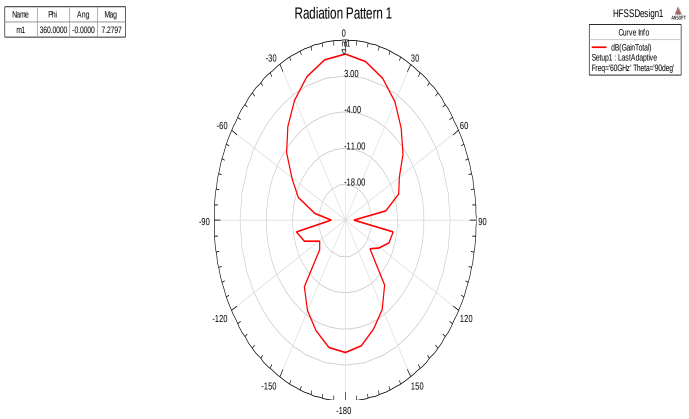


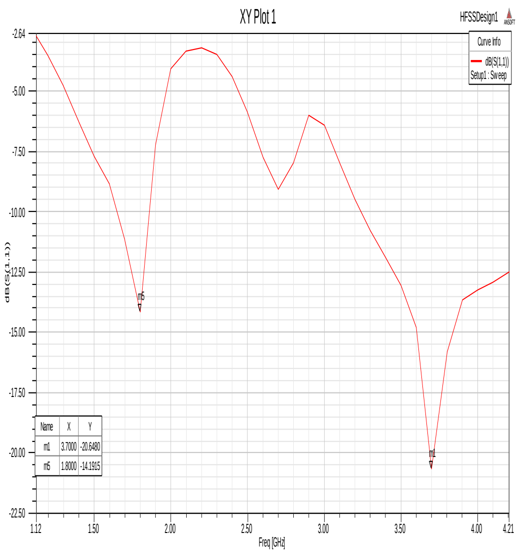
(b)



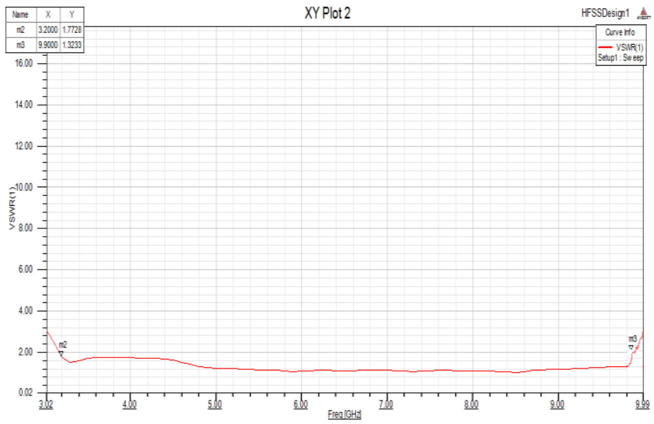
(c)

(c)

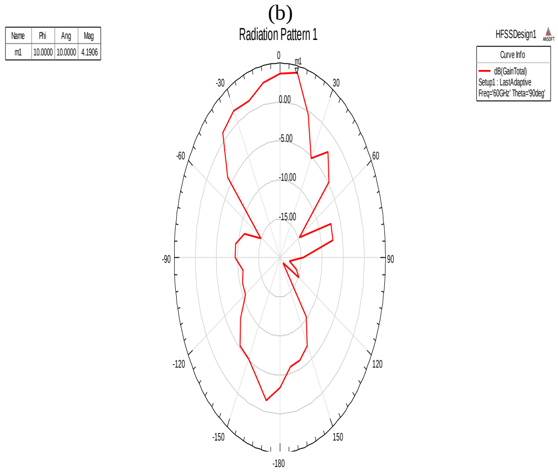
Figure 13 . Meandered stripline Patch Antenna :a)Return Loss b)VSWR c)Gain



(a)



(b)

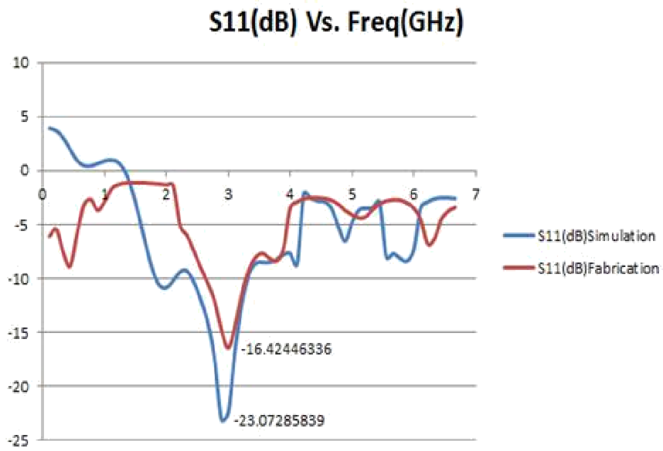


(c)

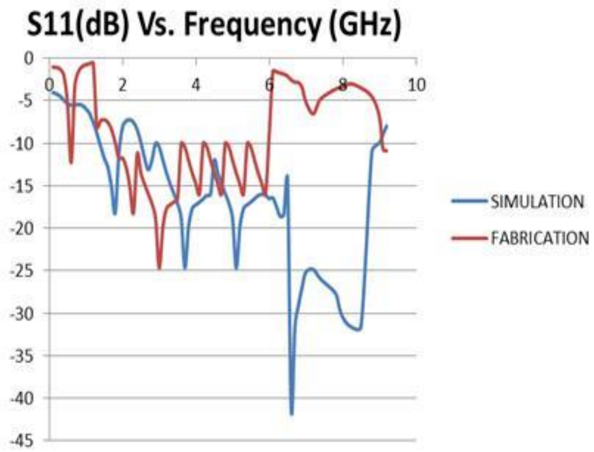
Figure 14. Meandered stripline Metamaterial Patch Antenna: a) Return Loss b) VSWR c) Gain

Using Keysight RF Fieldfox Network Analyser as shown in Figure 15, we compared the fabrication results in figure 16.

Figure 15. Keysight Fieldfox RF Network Analyser



(a)

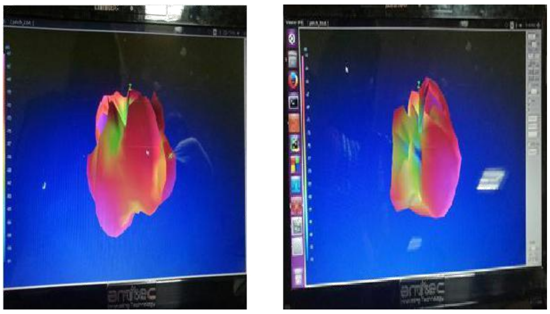


(b)

Figure 16. Comparison of simulation and fabrication results: a) Meandered Stripline Patch Antenna b) Meandered stripline metamaterial Patch Antenna

Using AMITECH gain measurement set-up as shown in figure 17, gain and radiation pattern have been obtained in figure 18.

Figure 17. AMITECH Gain measurement set-up



(a) (b)

Figure 18. Gain and Radiation Pattern measurement: a) Meandered Stripline Patch Antenna b) Meandered Stripline metamaterial patch Antenna

The above results have been tabulated in Table 1.

Table 1. Fabrication results of RMPA

Configurations	Gain(dB)	Directivity(dB)	Miniaturozation (%)	Return Loss(dB)
Meandered stripline Patch Antenna	3	5	51	20
Meandered stripline metamaterial Patch Antenna	3	4	84	25

Thus, "fabricated and simulated antennas" helps in achieving miniaturization and bandwidth enhancement which is in coherence with the proposed antenna configurations

5.Conclusion

In this paper, a proposed novel microstrip antenna attains miniaturization by nearly 400% and maximization in bandwidth of nearly 600% with ds=0.75mm between the metamaterial surface as reflector and patch , quarter ground plane, meander stripline feed and three slot pairs on the radiating patch. The simulation results are in coherence with the fabrication results.

6.References

[1] Schantz, H., "The Art and Science of Ultra Wide Band Antennas", Artech House, 2005.
[2] Balanis, C. A., "Antenna Theory," John Wiley & Sons, Inc., 1997.
[3] Pozar, D. M., "Microstrip antenna," Proc. IEEE, Vol. 80, 79–81, 1992.
[4] Volakis, "Antenna Engineering Handbook", McGraw Hills, Chapter-7, pp: 147574-5.
[5] Wang S, Feresidis AP, Goussetis G, Vardaxoglou JC, " Low-profile resonant cavity antenna with artificial magnetic conductor ground plane", Electronics Letters ,2004,40: 405–406.
[6] Ahsan MR, Islam MT, Ullah MH, Misran N , "Bandwidth Enhancement of a Dual Band Planar Monopole Antenna Using Meandered Microstrip Feeding.",The Scientific World Journal 2014.
[7] Lee KF, Luk KM, Mak KM, Yang SLS , " On the Use of U-Slots in the Design of Dual-and Triple-Band Patch Antennas",IEEE Antennas and Propagation Magazine,2011, 53: 60–74.