



DESIGN OF LEFT-HANDED MATERIAL BASED MICROSTRIP ANTENNA FOR WIRELESS APPLICATIONS

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ABSTRACT

This paper represents the design of a reconfigurable and tunable multiband patch antenna integrated with Left-handed material (LHM) for achieving high directivity and high gain. The antenna designed to be considered for wireless application. It can be used for various combinations of wireless application such as WLAN, Wi-Fi, wi-max, within a microwave S and C frequency bands in Electromagnetic Spectrum. The antenna consists of a main patch, four sub-patches, and a ground plane achieving reconfigurability. However, the design of microstrip yields low gain and low bandwidth. To overcome this issue, left-handed materials are used along with patch antenna so as to increase the bandwidth and gain with achieving tunability. Therefore, a single compact antenna is used for different applications thus saving the cost and the size of the antenna.

Keywords: Directivity, Left-handed material, Return loss Reconfigurability, Tunability.

I. INTRODUCTION

Microstrip patch antenna preferred over other antennas in today's modern word scenario for their compatibility to be fit in Mobile Aircraft Satellites owing to very small sizes. Hence design and development of superior and cost effective microstrip patch antenna has become an active research area. Devices used in such communication are required to be small in size and also operate at as many frequencies as possible to as to provide a seamless way of communication to users. Nowadays mobile handsets are miniature in size and are also required to operate at multiple-frequency bands in order to provide the enhanced and multifunctional performances. Further, due to the device convergence trend antenna structure, very limited space is available in available for the antenna structure. The design of an efficient wide band small size antenna, for recent wireless applications, is a major challenge. Microstrip patch antenna is a resonant element [1].

Tunable multiband antennas are becoming popular for use in the multifunctional handsets due to their significant advantages in terms of weight, volume and performance [2]. Tunability is utilizing the same antenna aperture for different frequencies. If size and efficiency are the issues in particular engineering disciplines, here, we focus on



engineering applications related to the important area of wireless communications, and how LHM can have a strong impact on the performance of microstrip antennas [5].

Design then tunable narrowband antennas are the best solution for it. Tunability is always done in the same operating band of frequency. Another alternative for multiband antenna is reconfigurable antennas. The concept of reconfigurability means changing the operating band of frequency. It reduces the complexity as well increase the capability of the system. Frequency- reconfigurable antennas are those antennas in which operating frequency can be classified into two categories: Switched and continuous, in the switched frequency – tunable antennas, the centre frequency is changed in discrete steps whereas the continuous frequency- tunable antennas allow continuous change in the centre frequency. Both types of antennas in general share a common theory of operation and reconfiguration mechanism – the main difference being the extent of the effective length change that enable operation over different frequency bands and the switching mechanism used to achieve these changes.

II. LEFT-HANDED MATERIAL

Metamaterials [3] are artificial materials synthesized by embedding specific inclusions in host media and they exhibit the properties of either negative permittivity or permeability, if both negative permittivity and negative permeability happen at the same time, then the composite exhibits an effective negative index of refraction and is referred to as left handed left-handed materials (LHMs). The idea of metamaterial was first proposed theoretically by Veselago in 1968 [3].

Left-handed materials are in essence electrically small resonators. A structure that is electrically small implies that the size of the structure is much smaller than the wavelength in free space. The resonance that takes place in these structures in the result of an applied field that generates either a magnetic dipole moment, electric dipole moment or both in the small resonators. In addition to providing enhance magnetic or dielectric properties, left-handed material are fundamentally dispersive due to the inherent laws of physics governing the magnetization and seen applications in wide Areas of the SRR structure proposed by Pendry et al. consists of two concentric rings separated by a gap, an both the rings have splits on opposite sides The splits behave like a parallel plate capacitor. The capacitance due to splits will decrease, with an increasing split width, which in turn will decrease the total capacitance of the system. The resonance frequency will increase with decrease in the capacitance of the system. Changing the distance between the inner and outer rings will change the mutual capacitance and the mutual inductance between the rings. Increasing the gap distance decreases both mutual capacitance and mutual inductance of the SRR system and therefore an increase in resonance frequency. Metal width affects all capacitances and inductances, the mutual inductance and mutual capacitance will decrease with increase in the metal width. Therefore SRRs made of thinner rings will have smaller resonant frequencies. Increasing the number of splits drastically increases the magnetic resonance frequency, since the amount of decrease in the capacitance of the system is very large [7].

III. PROPOSED ANTENNA DESIGN

This paper presents design of multiband microstrip patch antenna which covers S and C band in electromagnetic spectrum. To increase the gain and bandwidth left-handed material is added to the antenna. The base patch of

microstrip antenna includes main radiator and four sub-patches placed on FR-4 substrate with relative permittivity = 4.4 and height of a substrate $h = 1.57$ mm. The left-handed material substrate is placed on top of this patch leaving an air gap of 1 mm. The total volume of the microstrip antenna design is $50 \times 50 \times 1.57$ mm³. Software used for simulation of antenna design is Agilent Advanced Design System (ADS) 2011.05. It supports Momentum as well as FEM mode of simulation. The design of patch antenna is as shown in Fig. 2 and the dimensions of the patches are as shown in TABLE-1. The width (w) of the patch can be calculated by equation (1).

$$w = \frac{c}{2f \sqrt{\frac{(\epsilon_r + 1)}{2}}} \quad (1)$$

With ' c ' is the free space velocity of light, ' f ' is the frequency of operation, ϵ_r is the dielectric constant. The actual length of patch (L) is calculated by equation (2).

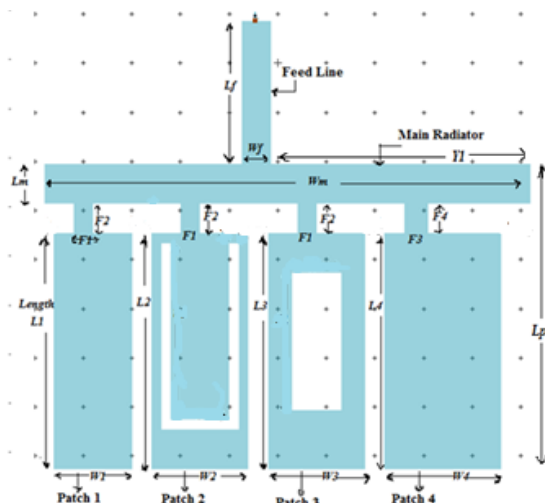
$$L = L_{\text{reff}} - 2\Delta L \quad (2)$$

Whereas, the effective length of the patch (L_{eff}) and finally, calculation of ground plane parameters of the patch antenna is given below in the equation (3) and (4).

$$L_g = 6h + L \quad (3)$$

$$W_g = 6h + W \quad (4)$$

Table-1: Dimensions of proposed antenna design
(Units are in mm)



L1	L2	L3	L4
24mm	24	24	24
W1	W2	W3	W4
8	8	10	12
F1	F2	F3	F4
2	3	2.5	3
Lf	Wf	Lm	Lp
14.6	3	4	31
h	Y1	Wm	Total Volume
1.57	26.7	50	$50 \times 50 \times 1.57 \text{ mm}^3$

Fig.1: Proposed design of Microstrip antenna

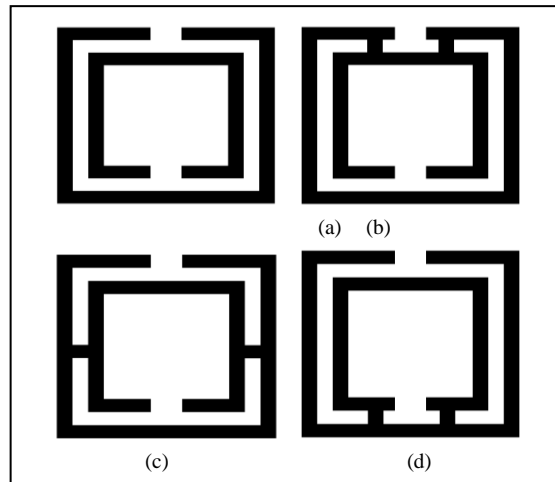


Fig-2: Proposed Left-handed material SSR structure a) LHM without load b) LHM with loading 1 c) LHM with loading 2 d) LHM with loading 3

The SRR structure as shown in Fig-2 is the left-handed material substrate on the microstrip patch for tuning. The outer ring of the structure measures 7 mm in length as well as the width. Similarly, the inner ring measures 5 mm in length and width. The opening measures 1 mm in width and 0.5 mm in length. Each microstrip patch has three SSR structure placed on it and then the antenna is simulated. The loadings placed in the SRR structure are small square measuring 0.5 mm each which helps in tuning.

IV. SIMULATED AND EXPERIMENTAL RESULTS

The proposed multiband antenna structure is as shown in Fig. 3 using ADS. The simulated results are as shown in the Fig. 4 and Table - 1. The return loss (s11) should be as low as possible for the transmission of maximum power ideally less than -10dB.

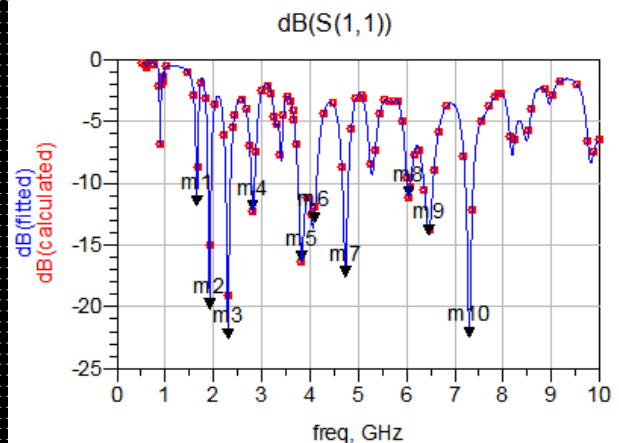
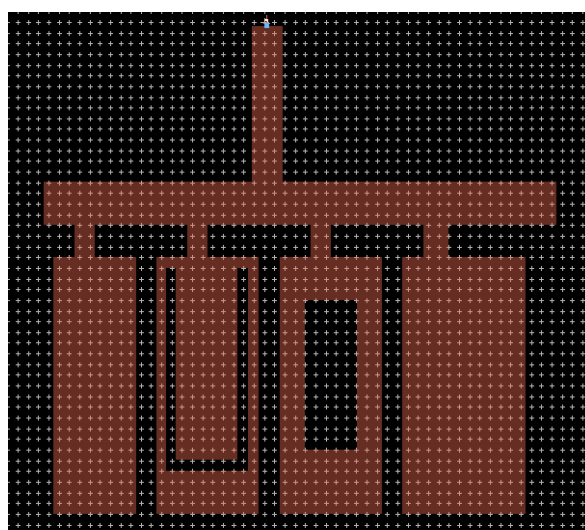


Fig. 3: design of Microstrip antenna in ADS Software

Fig. 4: Simulation results of antenna in Fig. 3

The antenna exhibits ≤ 10 dB reflection coefficient giving the multiband frequency band of 1.656, 1.915, 2.3, 2.814, 3.821, 4.083, 4.735, 6.042, 6.464 and 7.299 as shown in Table-2.

Table-2: Frequency and Return Loss of the simulated antenna

Frequency (GHz)	Return Loss (dB)
1.656	-11.795
1.915	-20.159
2.300	-22.564
2.814	-12.250
3.821	-16.294
4.083	-13.183
4.735	-17.538
6.042	-11.114
6.464	-14.152
7.299	-22.464

Individual patches are also simulated so as to see the resonant frequencies given by each patch. The results of the simulation are shown in Fig. 5. The tuning as well as the reconfigurability of the frequencies is not achieved in this multiband antenna. To achieve the tuning and reconfigurability the left-handed material patch is placed on the microstrip patch and simulated results are shown in Fig. 6.

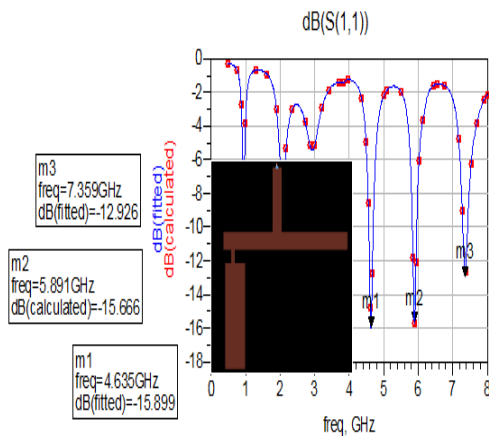


Fig. 5: Simulation results of sub-patch 1

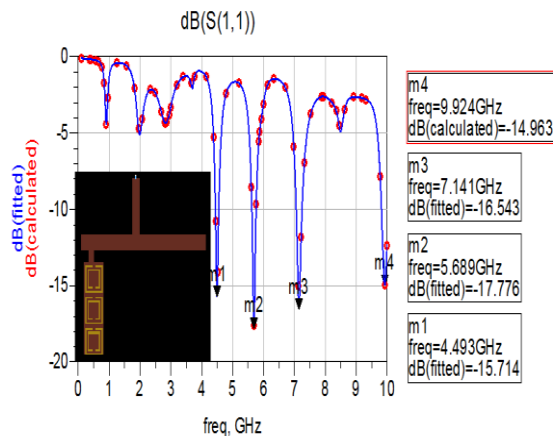


Fig. 6: Simulation results with LHM for patch-1

Loadings are placed between the rings of SRR structure to obtained tuning of frequencies. The loadings are placed only one at a time and the corresponding obtained frequencies are studied. Table-3 shows the obtained frequencies for the sub- patch 1. Similarly LHM is placed as a superstrate on the remaining patches too and frequency-tuning is obtained. It is observed that the frequencies are tuned and also reconfigurability is achieved which was not observed in the microstrip patch without LHM.

Table – 3: Frequency and Return Loss of sub- patch 1 with Left-handed material loadings

	Frequency (GHz)	Return Loss (dB)
Load 1	4.48	-18.578
	5.71	-16.606
	7.16	-14.487
Load 2	4.48	-16.446
	5.69	-14.669
	7.145	-15.527
Load 3	4.480	-23.364
	5.69	-17.654
	7.1	-16.660

The corresponding results of directivity efficiency and gain are given in Table-4. As observed the gain and directivity increase with the LHM structure on the patch antenna.

Table-4: Gain and Directivity with corresponding Resonant Frequencies

	Resonant Frequencies (GHz)		Gain (dBi)	Directivity (dBi)	Efficiency (%)
	Simulation	Measured			
Without Left-handed material	4.61	4.6	5.1	6.74	69.51
	5.81	5.8	5.69	7.81	61.19
	7.2	7.3	5.38	7.621	59.67
With Left-handed material	4.47	4.45	4.8	6.38	69.1
	5.69	5.7	5.9	8	61.18
	7.13	7.11	6.3	8.3	63.5

As seen at frequency 7.2 GHz of the patch antenna the gain and directivity increases considerably at frequency 7.13 GHz of the patch antenna with LHM. Multiband antenna design shown in Fig.-3 has been implemented as shown in Fig.7. It has been tested using Vector Network Analyzer (VNA) and measured results are shown in Fig.-8.

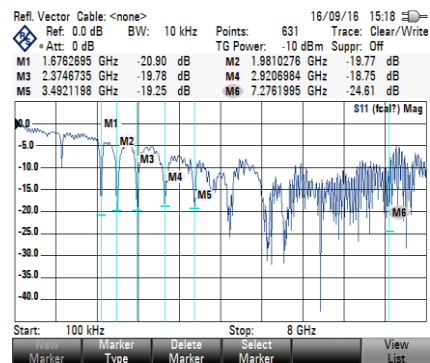
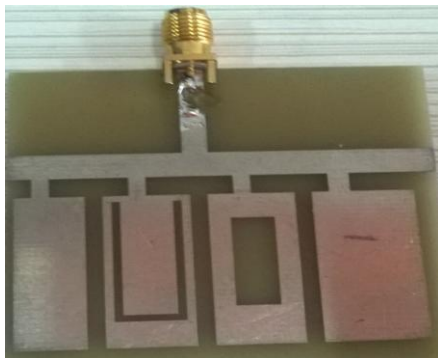


Fig. 7: Hardware of microstrip antenna shown in Fig. 3

Fig. 8: Measured results for Fig. 7 using VNA

There is a deviation between simulated and measured frequencies due to following reasons:

Fr4 substrate is sensitive to frequency, cable losses while testing an antenna.

Measured results of microstrip patch antenna with Left - handed material layer are shown in the Fig.-9.

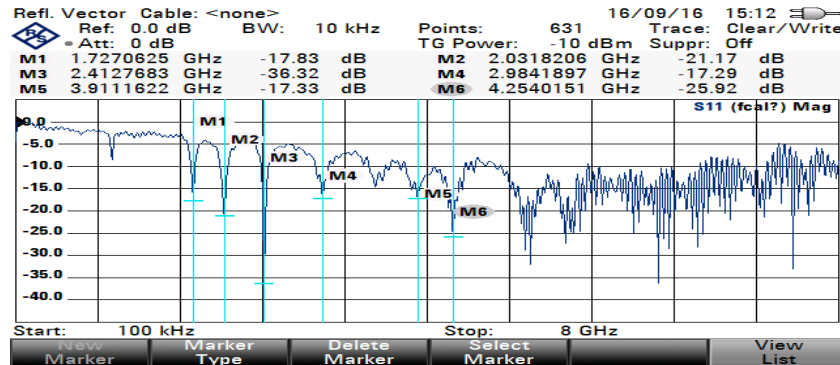


Fig. 9: Measured results of Microstrip antenna with LHM

V. CONCLUSION

Thus with the use of left-handed material the gain and bandwidth of a microstrip patch antenna can be increased. From observations, we can see that with the loadings of the left-handed material, frequency-tuning takes place. Also the patch antenna gives a multiband frequency covering the frequencies of S and C band. Fabrication designs also have near about same results like software simulation. For 4 to 8 GHz patch 1 and 3 will be used and for all frequencies patch 2 will be useful. Hence only one antenna can be used for all the wireless applications thus saving space and time with improved characteristics like gain and directivity and minimize the return loss of the microstrip antenna.

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