Left-Handed Material Based Directive Microstrip Antennas

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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 wi-fi, wi-max, Bluetooth 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.*

Key Words**:** Reconfigurability, Tunability, left-handed material, directivity, return loss.

1.INTRODUCTION

Compact the broadband antenna is the need of the hour in many communication systems since they can interface with any communication standards and also occupy less space. Microstrip patch antenna re 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.

1.1 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 material (LHMs). The idea of metamaterial was first proposed theoretically by Veselago in 1968 [4].

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. This resonance phenomenon is in sharp contrast to the constructive interference between waves bouncing back and forth along or within a traditional resonator such as transmission line or cavity. For instance, in the artificial magnetic material type LHMs, the frequency range of interest will be immediately before the resonance frequency, whereas for single–negative type of LHMs, the interest would be in frequency range immediately above resonance. 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 Ares 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 SSR has capacitance due to the rings but the mutual capacitance between the two rights enables the flow of the current through the structure. It is possible to model and individual SRR as an L-C circuit system. The capacitances are due to the splits and the gap between the two concentric rings; Inductances are due to the conducting rings and gap between inner and outer rings. The effect of the certain geometrical parameters such as split width, metal width, gap between the rings etc. on the resonant frequency were investigated [6].

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]. The schematic views of the LHM unit cell Split Ring resonator (SRR) structures are given in Fig-1.

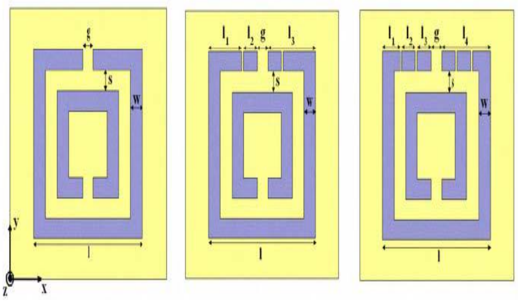


Fig -1: Schematic views of SRR structure.

2. 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. The left-handed material substrate is placed on top of this patch leaving an air gap of 1mm. The total volume of the microstrip antenna design is 50×50×1.57 mm3. Software used for simulation of antenna design is Agilent Advanced Design System (ADS) 2011.05. The width (w) of the patch can be calculated as

$$w = \frac{c}{2f\sqrt{\frac{(\varepsilon_r+1)}{2}}} \qquad 2.1$$

The actual length of patch (L) is calculated by equation 2.3.

$$L = L_{reff} - 2\Delta L \qquad 2.2$$

Finally, calculation of ground plane parameters of the patch antenna is given below in the equation 2.3 and 2.4.

$$L_g = 6h + L \qquad 2.3$$

$$W_g = 6h + W \qquad 2.4$$

The SRR structure as shown in Fig-2 is the left-handed material substrate used as a superstrate on the microstrip patch for tuning. The outer ring of the structure measures 7mm in length as well as the width. Similarly, the inner ring measures 5mm in length and width. The opening measures 1mm in width and 0.5mm 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.

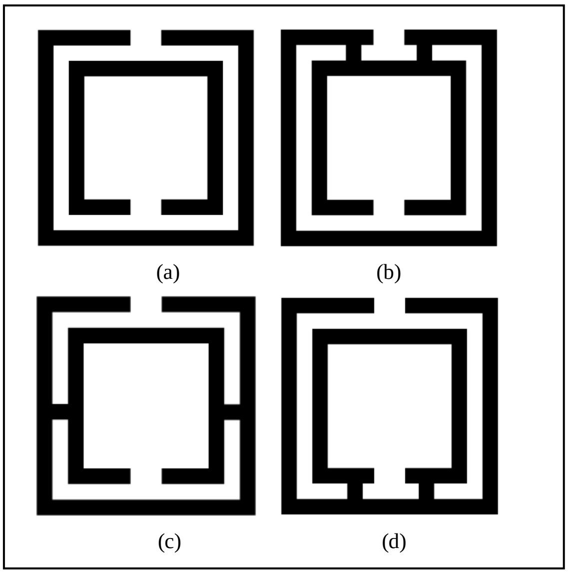


Fig-2: Proposed Left-handed material SSR structure a) LHM without load b) LHM with loading 1 c) LHM with loading 2 d) LHM with loading 3

3. SIMULATED AND EXPERIMENTAL RESULTS

The proposed multiband antenna structure is as shown in Fig- 3 using ADS. The simulated results are as shown in 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.

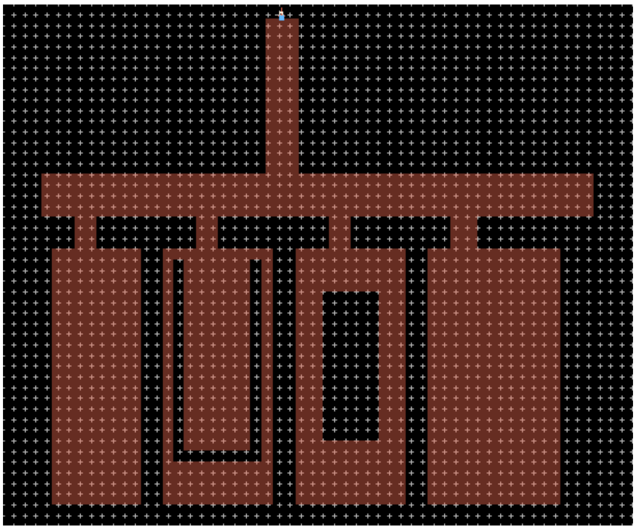


Fig-3: Modified structure for multiband antenna in ADS Software

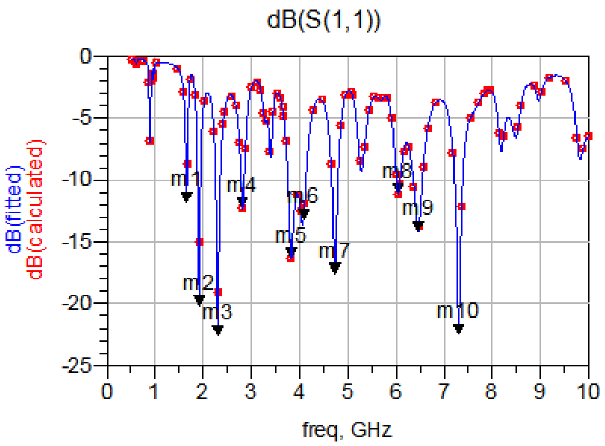


Fig-4: Simulation results of antenna in Fig -3

The antenna exhibits ≤10dB 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-1.

Table-1: 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 and Table-2. The tuning as well as the reconfigurability of the frequencies is not achieved in this multiband antenna.

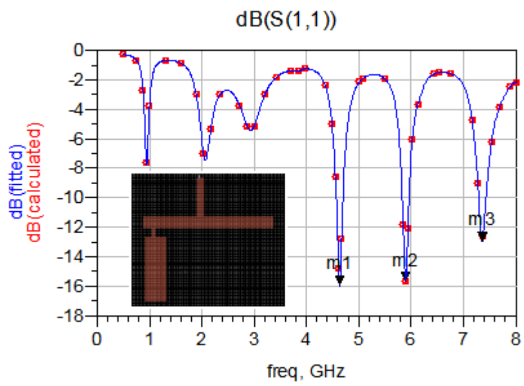


Fig - 5: Simulation results of sub-patch 1

Table-2: Frequency and Return Loss of sub-patch 1

	Frequency (GHz)	Return Loss (dB)
Patch 1 (Without Left-Handed Material)	4.61	-15.949
	5.8	-15.917
	7.3	-11.230

To achieve the tuning and reconfigurability the left-handed material patch is placed as a superstrate on the microstrip patch and simulated as shown in Fig- 6. The frequencies obtained are as given in Table-3.

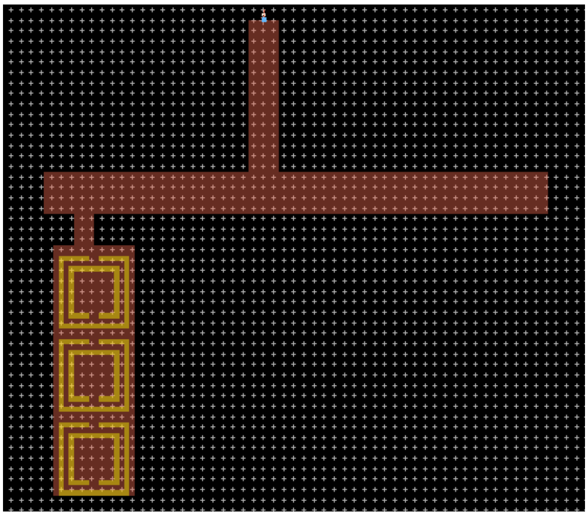


Fig-6: Microstrip antenna with Left-handed material for patch-1 in ADS

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

	Frequency (GHz)	Return Loss (dB)
Patch 1 (Without load)	4.49	-15.714
	5.68	-17.776
	7.14	-16.543
	9.92	-14.93

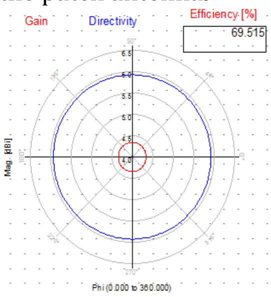
Loadings are placed between the rings of SRR structure to obtained tuning of frequencies. The loadings are placed only one at a time and the corresponding obtained frequencies are studied. Table-4 shows the obtained frequencies for the sub- patch 1.Similarly LHM is placed as a superstrate on the remaining 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 – 4: Frequency and Return Loss of sub- patch 1 with Left-handed material loadings

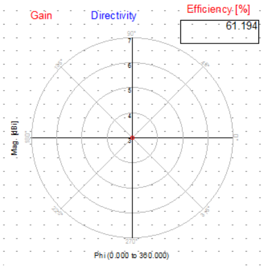
	Frequency (GHz)	Return Loss (dB)
Load 1	4.5	-18.578
	5.71	-16.606
	7.2	-14.487
Load 2	4.45	-16.446
	5.7	-14.669
	7.1	-15.527
Load 3	4.4	-37.640
	5.6	-26.734
	7	-25.394

The Gain and Directivity plots for the antenna structure are as given below in Fig. 7 and Fig. 8 at the corresponding resonant frequency in ADS.

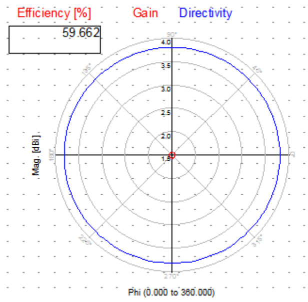
The corresponding results are given in Table-5. As observed the gain and directivity increase with the LHM structure on the patch antenna.



(a)

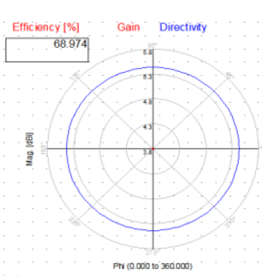


(b)

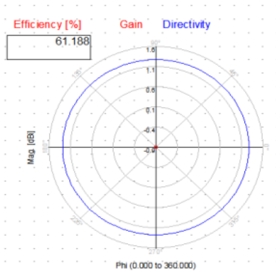


(c)

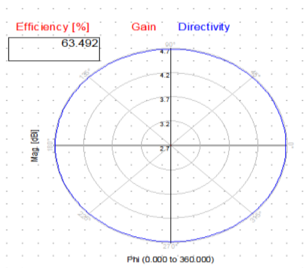
Fig- 7: Gain and Directivity plot of sub-patch 1 without LHM (a) at 4.61 GHz (b) at 5.81 GHz (c) at 7.2 GHz



(a)



(b)



(c)

Fig- 8: Gain and Directivity plot of sub-patch 1 with LHM (a) at 4.61 GHz (b) at 5.81 GHz (c) at 7.2 GHz

Table-5: Gain and Directivity with corresponding Resonant Frequencies

	Resonant Frequencies (GHz)		Gain (dBi)	Directivity (dBi)	Efficiency (%)
Without Left-handed material	Simulation	Measured			
	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.

4. CONCLUSIONS

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. As from the observation, for the higher bands patch 1 and 4 can be used. For the band 4-8 GHz patch 3 can be used and for all the bands patch 2 can be used. Hence only one antenna can be used for all the wireless applications thus saving space and time.

REFERENCES

[1] G. Kumar, and K.P. Ray, "*Broadband Microstrip Antennas*," Artech House, Inc. 2003.

[2] Constantine A. Balanis, "Antenna Theory Analysis and Design", 3rd edition 2005.

[3] C. Caloz and T. Itoh, "*Electromagnetic Metamaterials: Transmission line theory and application*," John Wiley & Sons, Inc. 2006.

[4] Huda A. Majid, Mohamad Kamal A. Rahim and Thelaha Masri, "Left Handed material designed for microstrip antenna application," *IEEE International RF And Microwave Conference proceedings* Kuala Lumpur, Malaysia, Dec 2008.

[5] V. I. Slyusar, "Metamaterials on Antenna Solutions," in Proc. *International Conf. on Antenna Theory and Techniques*, pp. 19-24, 6-9 Oct 2009.

[6] K. LEE and S. YANG, "High Gain Patch Antenna for 2.4 GHz using Metamaterial Superstrate," *J. Measurement Science and Instrumentation,* vol.1, no. 5, pp. 1674-1678, May 2010.

[7] P. K. Singhal, Bimal Garg, "A High Gain & Wide Band Rectangular Microstrip Patch Antenna loaded with "Interconnected SRR" Metamaterial Structure" *International Journal of Engineering and Technology,* 335-346, Apr 2012.

[8] Bashir D. Bala, Mohamad Kamal A. Rahim, N. A. Murad, "Bandwidth Enhanced Microstrip Patch Antenna Using Metamaterials," *IEEE Asia-Pacific Conference on Applied Electromagnetics (APACE)*, Dec 2012.

[9] George Casu, Cătălin Moraru, Andrei Kovacs, "Design and Implementation of Microstrip Patch Antenna Array," IEEE 2014

[10] Muhammad Waqas, Shahid Bashir, Muhammad Junaid Khan, Zeeshan Akbar, "High Directivity of Microstrip Patch Antenna using Metamaterial" *IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)* Vol 9, Issue 1, Ver. III Jan 2014.

[11] Atul Kumar, Nitin Kumar, Dr. S.C. Gupta, "Review on Microstrip Patch Antennas using Metamaterials," *International Journal of Engineering Research and General Science* Vol 2, Issue 4, June-July, 2014.