A Miniaturized Microstrip Patch Antenna Array with Enhanced Bandwidth and Reduced Mutual Coupling for Wireless Application

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Abstract—The design of a novel miniaturized microstrip patch antenna array has been presented. The antenna consists of a single layer of Split Ring Resonators around the rectangular patch. The patch sizes are less than conventional designs. Simulations are performed to study the return loss, resonant frequency, bandwidth and mutual coupling between the antenna elements. The technique to reduce the return loss of the patches is also presented. The antennas are designed using the simulation tool HFSS and are suitable to use in IEEE 802.11 WLAN frequency band.

Keywords— array antenna, metamaterials, microstripantenna, miniaturization, mutual coupling

I. INTRODUCTION

This paper presents the modeling, simulations and analysis of microstrip patch antenna and its feed lines. Microstrip antennas are of high importance because of the advantages at their modest profile and less expensive printed circuit design and fabrication for various applications.

Developing broadband and small size antenna for wireless mobile communication systems has become big challenge and many methods are being incorporated by researchers across the world to get over the problem [1]. The design of a miniaturized patch antenna was discussed in [2-8]. Techniques to reduce the size of the patch include letting in slots on the patch or ground plane [2-4], incising electro-magnetic bandgap structures in the neighborhood of the patch [5-6], slit loaded ground plane [7], strip loaded microstrip patch antenna [8], employ high permittivity di-electric substrates [9]. These literatures brought clearly into focus the single element design and have narrow bandwidth. Multiple element antennas for several applications were discussed in [10-13]. The small separation between the antenna element had increased consequences for mutual coupling which was reduced using Ring Resonator [14], di-electric slab EBG [15] and metamaterials [16]. Inorder to reduce the size of the patch and mutual coupling between the antenna elements metamaterial is used.

In this paper, we propose a novel design of microstrip patch antenna array loaded with Split Ring Resonator (SRR) metamaterial. The effects of this inclusion on the array performance are also studied. The characteristics parameters like dielectric constant (ε_r) is 4.4, thickness of the substrate (h) is 1.57mm and antennas dominate-mode resonant frequency (f_r) is transformed into the patch dimensions that is length (l) is 11.74mm and width is of 9.16mm of the patch.

II. ANTENNA DESIGN

A. Microstrip Array Design

The two element rectangular microstrip patch etched on common ground plane is depicted in Fig. 1. Widely available, less expensive FR4 epoxy is used as a substrate with ε_r =4.4 and height =1.57mm using the formulas given below are used in the design.

$$w = \frac{V_0}{2f_r}\left(\sqrt{\frac{2}{\varepsilon_r+1}}\right) \quad (1)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+12\frac{h}{w}\right)^{-1/2} \quad (2)$$

$$,\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{w}{h}+0.8\right)} \quad (3)$$

$$L_{eff} = \frac{V_0}{2f_{r\sqrt{\varepsilon_r}}} \quad (4)$$

$$L = L_{eff} - 2\Delta L \quad (5)$$

Where, w - width of the patch, fr - resonant frequency, εr - dielectric constant of the substrate. Vo - velocity of light in free space=3e8 m/s, h – height of the substrate, w – width of the patch, εreff – effective dielectric constant of the patch, and L is the length of the patch antenna.

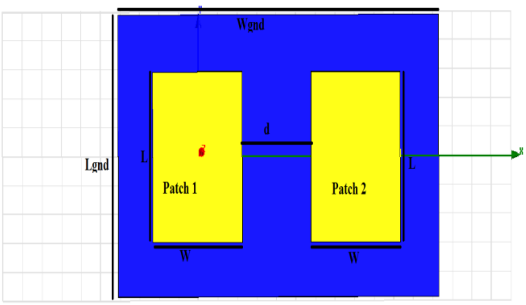


Fig.1. Rectangular Patch Antenna array simulated on FR4 substrate using HFSS tool

The antenna array dimension, material properties and operating frequency are listed in Table. 1

TABLE.1. ANTENNA SPECIFICATIONS

Parameters	**Specification**
Resonant Frequency	6.8GHz
Substrate	FR4 epoxy
Di-electric constant	4.4
Height of the substrate	1.57mm
Dimension of Patches	11.74mm x 9.16mm
Distance between antennas	7mm

The antenna elements are separated by a distance of 7mm. This small separation is selected to demonstrate the effect of mutual coupling between the antennas.

B. Microstrip Patch Antenna Array loaded with Split Ring Resonator

Wireless communication devices require more compact antenna designs to enhance portability. Designing such a compact antenna is a challenge due to mutual coupling and size dependency of antennas on wavelength of operation.

In this section, microstrip patch antenna array loaded with SRR metamaterial is proposed to combat this problem as shown in Fig. 2.

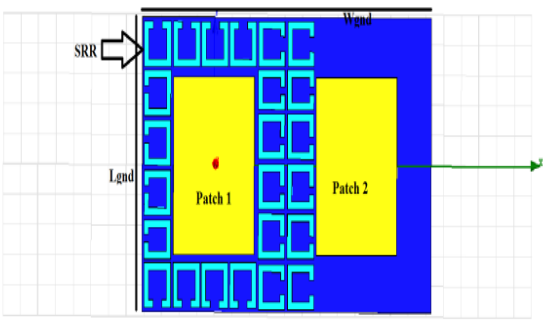


Fig.2. Microstrip Patch Antenna array loaded with SRR simulated using HFSS.

As shown in Fig.2, the proposed design consists of in-plane SRR loaded around patch 1. The dimension of the ring is 3mm x 3mm. The 1mm gap in the ring gives the capacitive effect to the SRR.

C. Slotted (Patch1)Microstrip Patch Antenna Array with SRR

With regard to decrease the return loss of the patches with SRR, a slot is included on patch 1 as shown in the Fig. 3.

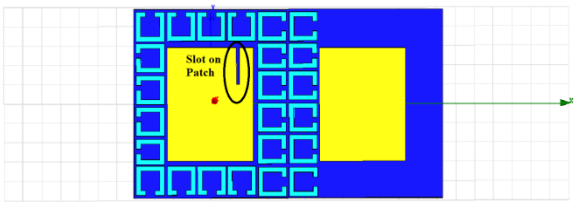
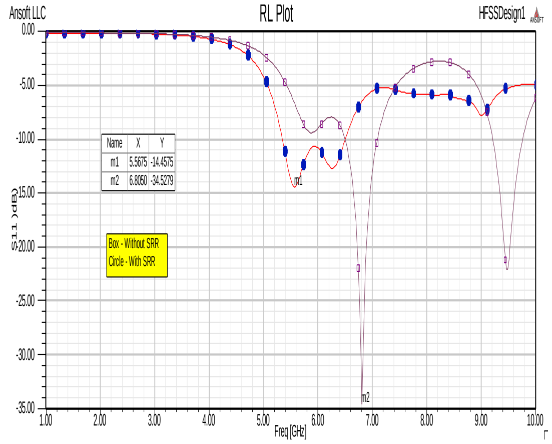


Fig.3. Proposed antenna array geometry with SRR and slot on patch1 simulated using HFSS.

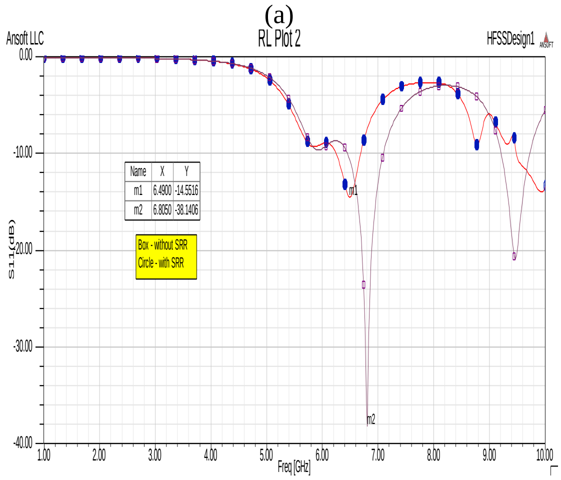
III. SIMULATION RESULTS AND DISCUSSION

A. Microstrip Patch Antenna Array loaded with Split Ring Resonator

The simulations was executed on the antenna design tool HFSS. The simulated return loss plot for microstrip patch antenna array with and without SRR is as shown in Fig. 4



(a)



(b)

Fig.4. Simulated return loss plot for patch array antenna with and without SRR (a) return loss plot of patch 1 (b) return loss plot of patch 2

As depicted in Fig. 4 the resonant frequencies of both the patches decreases. In particular, the resonant frequency of patch 1 surrounded by SRR shifts to 5.5 GHz from 6.8 GHz with a bandwidth of 21.2 % and that of patch 2 shifts slightly to 6.4 GHz from 6.8 GHz. The bandwidth in the former is significantly increased. Since, the dimensions of the patches required to resonate at lower frequencies is larger the designed array geometry shows the potential for miniaturization.

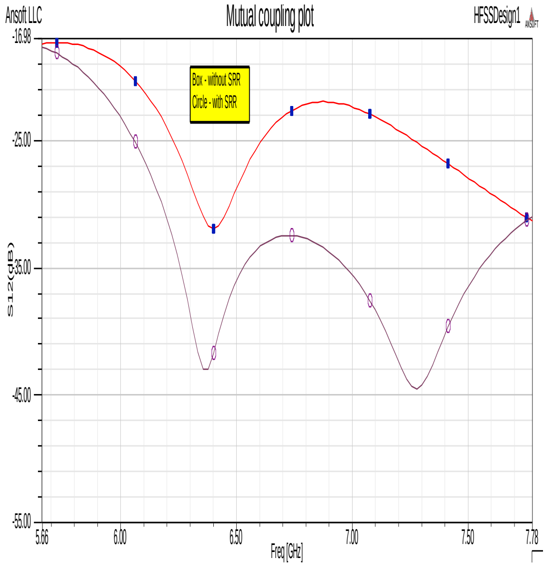


Fig.5. Simulated mutual coupling plot for microstrip patch antenna array with and without SRR.

As seen in Fig. 5 the mutual coupling between the patches separated by 7mm is decreased by about 10dB within the frequency range of 6 to 7.5 GHz.

B. Slotted (Patch1)Microstrip Patch Antenna Array with SRR

The simulated return loss of the slotted microstrip patch antenna array with SRR is shown in Fig. 6

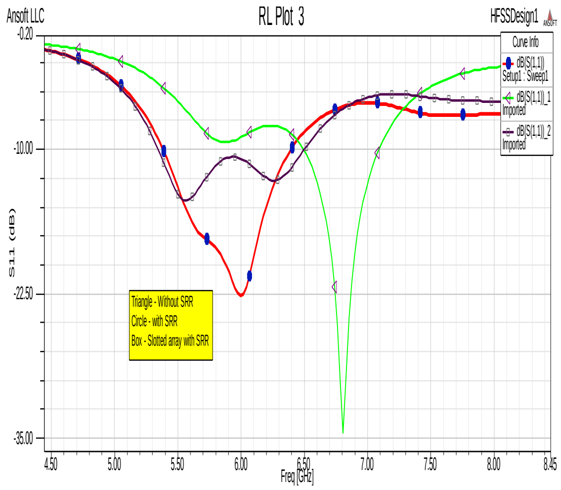


Fig.6. Simulated return loss plot for slotted microstrip patch antenna array with SRR

As seen from Fig. 6 when a slot of 3.5mm x 0.3mm is introduced on patch 1 the return loss of patch1 decreases to -22.5dB at 6GHz. The resonant frequency in slotted patch antenna array with SRR shits to 6 GHz from 6.8 GHz which is less compared to SRR loaded array without slot.

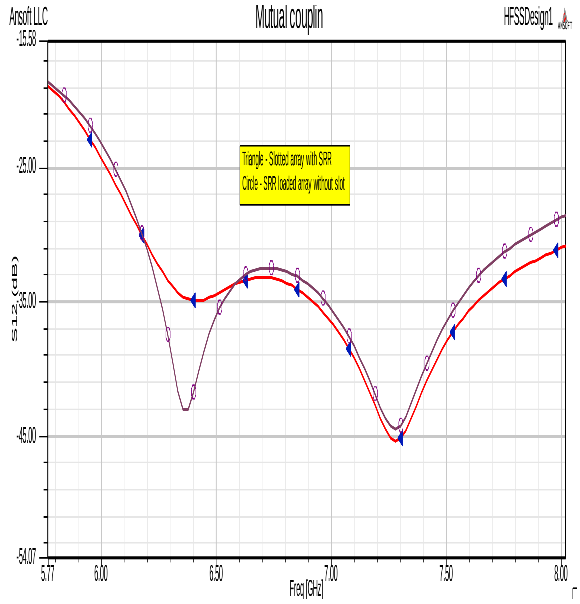


Fig.7. Mutual coupling plot for slotted microstrip patch array with SRR

As seen in Fig. 7 the mutual coupling in case of slotted patch array with SRR increases in 6.2 to 6.5 GHz frequency range and is lower elsewhere.

The summary of the simulation results is shown in Table. 2

TABLE.2. SIMULATION SUMMARY

Parameters		**Without SRR**	**With SRR**	
			Without slot	**With Slot on P1**
Resonant frequency (GHz)	P1	6.8	5.5	6
	P2	6.8	6.4	6.4
Bandwidth %	P1	10.1	21.2	17.3
	P2	10.1	6.25	7.8

Comparison between the array with and without SRR is shown in Table. 2. The resonant frequency of patch1 and patch2 decreases to 5.5 GHz and 6.4 GHz respectively from 6.8 GHz when SRR are included around patch1. The dimension of the patch required to resonate at 5.5 GHz frequency is 12.219mm x 16.59mm and that at 6.4 GHz is 10.5mm x 14mm for given substrate and height which is large compared to the dimension used in the simulation. So, the proposed antenna array shows miniaturization by about 42 % and 27.5 % in size of patch1 and patch2 respectively. The bandwidth achieved in array with SRR is 21.2% for patch1 and 6.25% for patch2. The former shows significant improvement in bandwidth. The mutual coupling between the antenna elements separated by 7mm in array showed 10dB decrement when SRR was included around patch1. The return loss decreased by significant amount when slot was incised on patch1.

IV. CONCLUSION

The design of miniaturized microstrip patch antenna array has been presented. The antenna consists of single layer SRR around patch1. Simulation has been used to study the antenna performance in terms of return loss and mutual coupling. Result shows that by employing SRR the size of the patches decreased by 42% and 27.5% respectively with significant improvement in bandwidth by 22%. There is reduction in mutual coupling by 10dB. Slotted array geometry with SRR is proposed to decrease the return loss of the antenna elements.

REFERENCES

[1] Huang, Y. and Boyle, K. (2008) Popular Antennas, in Antennas: From Theory to Practice, John Wiley & Sons, Ltd, Chichester, UK. doi: 10.1002/9780470772911.ch5

[2] S. Dey and R. Mittra, ”Compact Microstrip patch antenna”, OTL, Vol. 13, Sept. 1996, p. 12.

[3] K. L. Wong and W. S. Chen,”Compact Microstrip Antenna with dual frequency operation”, Electronics Letters Vol. 33, no. 8, April 1997, p. 646.

[4] R. M. Vane aet.al,”A shorted Rectangular Microstrip Antenna with slots in ground plane”, IE(I), Journal-ET, Vol. 87, July 2006, pp. 19-20.

[5] Suntives, A.; Abhari, R., "Design of a compact miniaturized probe-fed patch antenna using electromagnetic bandgap structures," Antennas and Propagation Society International Symposium (APSURSI), 2010 IEEE , vol., no., pp.1,4, 11-17 July 2010 doi: 10.1109/APS.2010.5562071

[6] Korkontzila, E.G.; Papafilippou, D.B.; Chrissoulidis, D.P., "Miniaturization of microstrip patch antenna for wireless applications by use of multilayered electromagnetic band gap substrate," Antennas and Propagation, 2006. EuCAP 2006. First European Conference on , vol., no., pp.1,6, 6-10 Nov. 2006 doi: 10.1109/EUCAP.2006.4584994

[7] Bao, X.L.; Ammann, M.J., "Small patch/slot antenna with 53% input impedance bandwidth," Electronics Letters , vol.43, no.3, pp.146,147, Feb.12007

[8] S.E. Lauro, A. Toscano, and L. Vegni, Symmetrical coupled microstrip lines with epsilon negative metamaterial loading, IEEE Trans Magn 45 (2009), 1182–1185.

[9] Martin, L.J.; Sooliam Ooi; Staiculescu, D.; Hill, M.D.; Wong, C.P.; Tentzeris, M.M., "Effect of Permittivity and Permeability of a Flexible Magnetic Composite Material on the Performance and Miniaturization Capability of Planar Antennas for RFID and Wearable Wireless Applications," Components and Packaging Technologies, IEEE Transactions on , vol.32, no.4, pp.849,858, Dec. 2009

[10] Ahmad A. Gheethan, Paul A. Herzig, Gokhan Mumcu, “Compact 2x2 Coupled Double Loop GPS Antenna Array Loaded With Broadside Coupled Split Ring Resonators,” IEEE Transactions On Antennas And Propagation, Vol. 61, No. 6, June 2013

[11] Christos Masouros, Mathini Sellathurai, Tharm Ratnarajah, “Large- Scale MIMO Transmitters in Fixed Physical Spaces: The Effect of Transmit Correlation and Mutual Coupling,” IEEE Transactions On Communications, 2013

[12] Dong-Jin Kim, Kyeong-Sik Min, Young-Min Moon and Young-Eil Kim, “Compact 2-channel MIMO Antenna for WiBro Handy Terminal Application,” Proceedings of Asia-Pacific Microwave Conference 2006.

[13] Jagadish M, T Ramya, Pradeep A S . " Design and Performance Analysis of Compact MIMO Antenna by Mutual Coupling Suppression between Elements ", Vol. 3 - Issue 12 (December - 2014), International Journal of Engineering Research & Technology (IJERT) , ISSN: 2278-0181 , www.ijert.org

[14] Yoonjae Lee, Yang Hao, and Clive Parini, “Applications of Electromagnetic Bandgap (EBG) Structures for Novel Communication Antenna Designs,” Proceedings of the 36th European Microwave Conference, Manchester UK, September 2006

[15] Ripin, N.; Saidy, W.M.A.W.; Sulaiman, A.A.; Rashid, N.E.A.; Hussin, M.F., "Miniaturization of microstrip patch antenna through metamaterial approach," Research and Development (SCOReD), 2013 IEEE Student Conference on , vol., no., pp.365,369, 16-17 Dec. 2013