Design and Analysis of Dual Split Rings Metamaterial Based Antenna for Wireless Communication

Dinanath Singh[1], Suresh G. Gawande[2], Satyarth Tiwari[3]

[1]PG Scholar, [2]Professor, [3]Assistant Professor

[1,2,3]Department of ECE, BERI Bhopal, M.P, India

Abstract- In wireless communication systems such as satellite and radar communication, their systems are mostly antenna for transmission and reception. Microstrip antennas play very important roles in wireless or mobile communication systems. The presentedpaperis a dual split ring metamaterial based antenna with modified ground planemicrostrip structure,used for wireless communication applications from 1GHz to 10GHz. We presents two microstrip antenna out of which one having single split ring patchon the other hand second design having dual split ring patchbut with same ground plane. On the basis of proposed design we investigate the effect of dual split ring antenna on return loss, VSWR bandwidth and gain. The proposeddesign with properties of dual split ring,increase the operating band of antenna with better bandwidth.

Keywords— Multiband Microstrip Antenna (MBMA), Split Ring Resonator (SRR), Strip Line.

I. INTRODUCTION

As the technology changes rapidly, there is a greatdemand of compact size, high selectivity, low cost, and high performance components in any modern wireless communication system. Antenna is an essential component inmodern communication system. In response to this plea,in recent times many planar antennas with better performances parameters have received extensive attention. Many more techniques and methodologies have been investigated indesigning such antennas. As microstrip patch antenna (MPA) emerge as one of the key component in modern communicationsystem. It plays a major role of signal transmissionat different frequencies andreceiving the desired signal [1]. Active devices such as mixer and oscillator are often followed by MPA for signal transmission and reception at desired frequency. MPA can be used for WiFiand Bluetoothapplication and in many low earth orbit satellites, military satellites, and terrestrial wireless connections like GSM mobile phones [2].

The contents of the paper are organized in following manner. Section II, describe the basic concepts of EBG specially SRR technique. Section III presents twoSSRdesigns proposed for microstrippatchantennawith different patchShapes. Section IV demonstrates the simulation results and performance parameters using HFSS software for the proposed design, and finally, a conclusion is reached in section V.

II. CHARACTERISTIC OF EBG

Diversetypes of metamaterial structures are exploited in collected works to upgrade the implementation of a microstrip patch antenna. The objective of the metamaterial based patch is to realize contraction of shape, low VSWR, low reflection loss and larger bandwidth. As the EBG is introduced in the ground plane of the patch antenna, the resultantof final capacitance and inductance introduce amendment and these as a result will change the resonant frequency of the microstripantenna. For keeping this theory in mind we introduce SRR technique for single and dual split ring, the basic of SRR is presented in fig 1. Due to the amalgamation of SRR, there will be deviation in inductance and capacitance. The quality factor will also transform due to variation in inductance and capacitance. The quality factor can be transcribed as: $Q = \frac{f_o}{BW}$ Here, f_o is the resonating frequency, BW is the bandwidth of operating devices, and Q is the quality factor. If the quality factor decreases, bandwidth will increase but circuit performance is degraded because of increased losses. Therefore, there is a tradeoff between the value of L and C in such a manner that the performance of the antenna s is not reduced. The inductance and capacitance depend on the lattice dimensions and slot gap of the SRR.

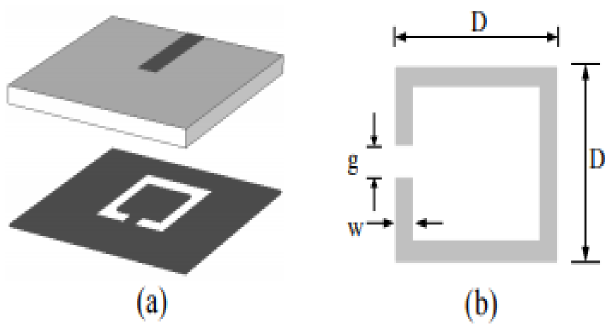

Figure 1: EBG resonator configuration

Fig. 1 demonstrates a SRRsetup.The resonator resembles a folded half wavelength resonator.

III. PROPOSED MICROSTRIP ANTENNA

This section we are presenting two different designs of microstrip patch antenna the proposed design is a split ring resonator based microstrip antenna with different SSR patch and modified ground plane, the substrate thickness of all two designsare keeping fixed as 1.6 mm. the detailed proposed designs are shown below.

A. G-Shape SRR antenna Design

First proposed design is a Split Ring Patch basedMicrostripantenna , made-up of Split Ring PEC removalfrommetallic patch which is grown on a FR-4 dielectric substrate of thickness 1.6 mm.The total area of ground plane and substrate is 32 mm × 26 mm. which is shown in the Figure 2.

The physical dimension of the proposed microstrip antennas are designed through ansys-HFSS software. The analysis of design is performed of frequency range of 1 to10 GHz. With oneinput/output port as lumped port and their dimensions are 4mm ×4 mm. dimension of substrateis 32 mm × 26 mm × 1.6 mm.and dielectric constant of 4.4.

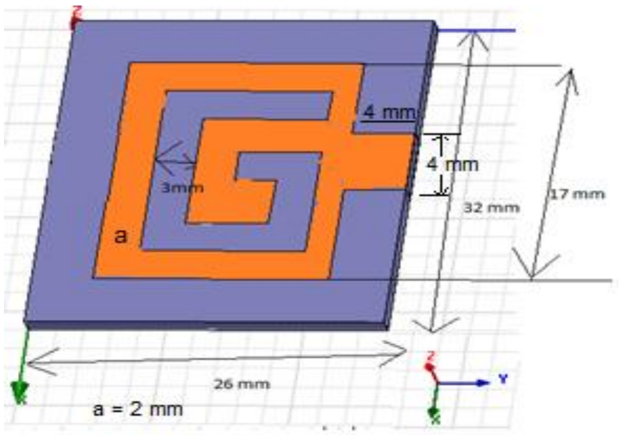

Figure.2 Top view of 1st Design model.

On the other hand we can classify the shape and dimension ground plane for the first design in fig 3.here we can see that the overall dimension of the ground plane is same as that of the substrate structure i.e 32 mm × 26 mm. The H-Shape is symmetrical in design and having an opening of 3 mm.

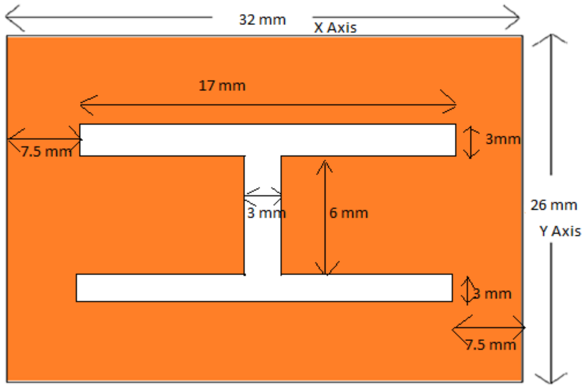

Figure.3 Bottom view of 1st Design ground plane.

B. Dual Split Ring Antenna Design

The proposed second design is a dual split ring structure on the same dimension of substrate as used in first design i.e 32 x 26 mm^{2}and thickness of 1.6 mm. the dimension of dual SRR is shown in fig 4. Thefeed line of this design is having dimension of 3mm× 4 mm. The ground plane of the proposed design has same area of dimension 32 mm ×26 mm as that of 1st design.

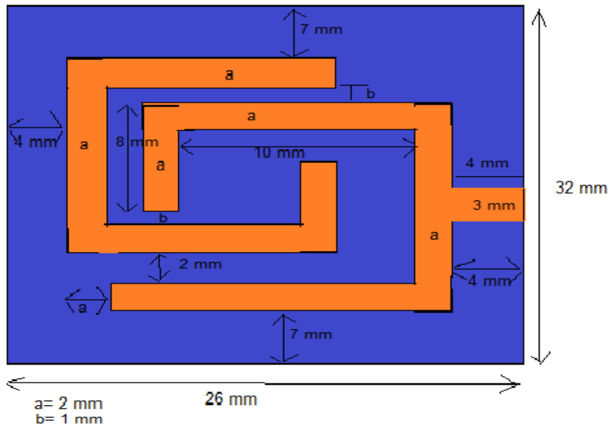

Figure.4 Top view of 2nd Design.

IV. RESULTS

Theforemost performance parameter of proposed antenna design presented here are Return Loss, Bandwidth,VSWR, radiating band and peak Gain. For first design we achieve two operating band, we also get two very small band but due to its narrow bandwidth we ignore them and hence calculated the numerous performance parameter for only two band of operation with center frequency 8.49 and 9.21 GHz. On the other hand for second design we attainfive multiple band of radiation, the inclusive results achieved by all two designs are shown in table 1.

Table I: Result analysis of Patch antenna.

Design	Radiating Frequency (GHz)	BW (-10dB) (MHz)	Gain (dB)	Return Loss	VSWR
A	8.49	181	5.59	-12.50	1.63
	9.21	306	6.33	-19.97	1.21
B	1.11	273	-11.70	-19.47	1.24
	4.50	142	2.45	-13.10	1.59
	4.80	316	3.28	-12.92	1.59
	8.52	197	4.49	-13.07	1.56
	9.23	392	7.50	-17.35	1.30

The figure 5, 6 and 7 represents the mentioned parameter viz. return loss S11, impedance Bandwidth, gain and VSWR respectively for first design.

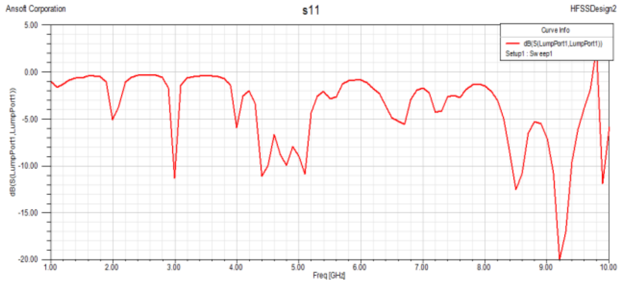

Figure 5. S11 for 1stDesign

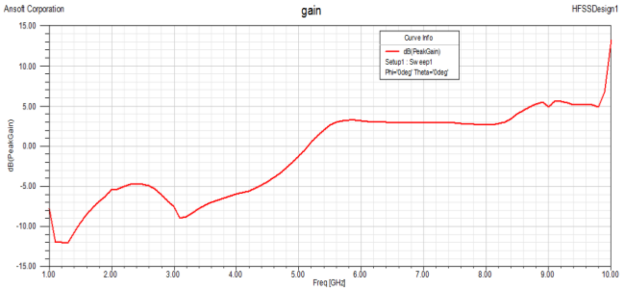

Figure 6. Gain for 1stDesign

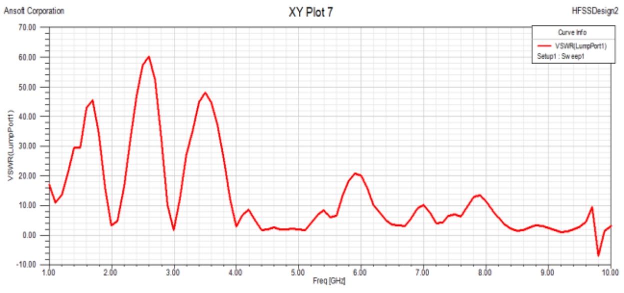

Figure 7. VSWR for 1stDesign

The figure 8, 9 and 10 represents the mentioned parameter viz. return loss S11, impedance Bandwidth, gain and VSWR respectively for second design respectively for design C.

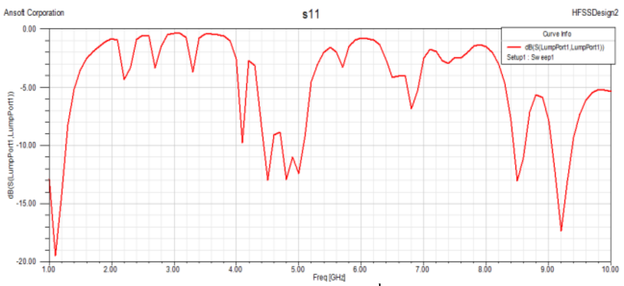

Figure 8. S11 for 2nd design

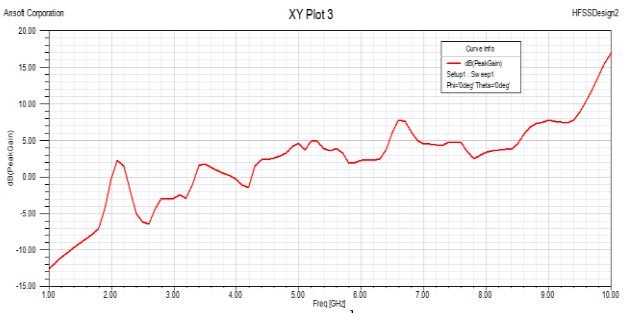

Figure 9.for 2nd design

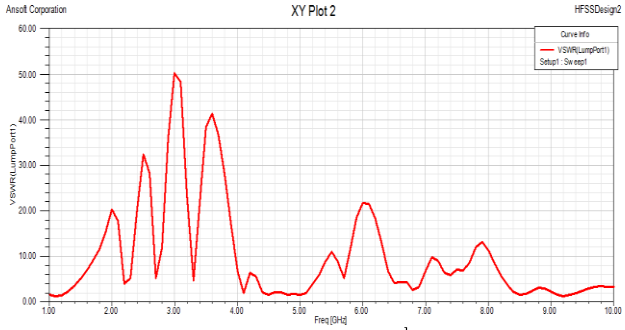

Figure 10. VSWR for 2nd design

V. CONCLUSION AND FUTURE WORK

In this paper a dual SRR patch antenna is proposed, the final proposed antenna which is design by taking outthe idea of first design without changing the dimension of ground plain and substrate. We observed that the 2nd design producesfive-bands of radiation with bandwidth of 273 MHz, 142 MHz, 316 MHz, 197 MHz and finally 392 MHz at center frequency of 1.11 GHz, 4.50 GHz, 4.80 GHz, 8.52 GHz and 9.23 GHz as center frequencies respectively. We also observed that the peek Gain is achieved at 9.23 GHz that is 7.50dB. After analyzing the results in table 1 we can conclude that the introduction of dual SRR EBG structure improve the multi-band operation of antenna along with the gain improvement as well. Here the antenna gain is improved by around 18.5%as compare of single SRR patch antenna.So far is band of operation is concern again dual SSR gives a far better result as compare of single SRRantenna with five bands of radiation with satisfactory bandwidth and return loss. In future the research can be extended in field of circular SRR and physical realization of the proposed design can also be carried out.

REFERENCES

[1] Hamed E.A and N. N. Kisel, “Evaluation of the Efficiency of the Metamaterial in the Development of Microstrip patch Antennas using LTCC Technology”, Moscow Workshop on Electronic and Networking Technologies (MWENT), 2020.

[2] Md. Asaduzzaman, ReefatInum, Md. SabbirHossain, Muhammad Abdul Goffar Khan "On the Design of Effective EBG Structures to Model Highly Efficient Rectangular Patch Antenna for Wireless Applications', IEEE International Conference on Robotics,Electrical and Signal Processing Techniques (ICREST) 2019.

[3] Guo-Ping Gao, Bin Hu*, Shao-Fei Wang, and Chen Yang, “Wearable Circular Ring Slot Antenna with EBG Structure for Wireless Body Area Network”,. Antennas and Wireless Propagation Letters IEEE on 2018

[4] CristianFiallos-Silva, and R´aulHaro-Baez. “On the Design, Simulation and Fabrication of Multiple Section Split ring metamaterialPatch Antennas at C-band using Microstrip Technology”, CHILECON, IEEE International Conference 2017.

[5] Konradjanisz and Robert Smolarz “Compensated 3-dB Lange Patch Antenna in Suspended Microstrip Technique”, IEEE International Symposium on Microwave, Antenna, Propagation, and EMC Technologies (MAPE)2017.

[6] K. Wincza, S. Gruszczynski, S. Kuta, “Approach to the Design ofAsymmetric Split ring metamaterialPatch Antennas With the MaximumAchievable Impedance-Transformation Ratio“. IEEE Transactions onMicrowave Theory and Techniques, Vol. 60 (5), pp. 1218-1225, May2012.

[7] P. Bhakhar, V. Dwivedi, P. Prajapati, “Directivity Enhancement ofMiniaturized Patch Antenna using Defected Ground Structure“.Advances in Intelligent Systems Research, Vol. 137, pp. 739-746.ICCASP/ICMMD-2016.

[8] H. R. Ahn, M. M. Tentzeris, “Novel Generic Asymmetric and SymmetricEquivalent Circuits of 90 Coupled Transmission-Line Sections Applicable to Marchand Baluns”, IEEE Transactions on Microwave Theory andTechniques , VOL. 65 (3), pp. 746-760, 2007.

[9] H. Bastidas Vallejo, & X. Gracia Cervantes, “Design and constructionof a three-section MicrostripPatch Antenna for the 2.4 GHz bandwith HMI to PC - Dise˜no y construcci´on de un AcopladorDireccionalMicrostrip de tresseccionespara la banda de 2.4 GHz con HMI a la PC,” Bachelor thesis, Universidad de lasFuerzas Armadas-ESPE, Sangolqu´ı, Ecuador, 2015.

[10] Amish Kumar Jha, Bharti Gupta and Preety D Swami “Iterative Analysis of Dielectric Constant of Patch Antenna Substrate at UHF Band”. International Journal of Engineering and Technology (UAE), Vol. 7, No. 2.16, 2018.

[11] P. S. Kildal, E. Alfonso, A. Valero-Nogueira and E. Rajo-Iglesias, ”Local Metamaterial-Based Waveguides in Gaps Between Parallel Metal Plates,” in IEEE Antennas and Wireless Propagation Letters, vol. 8, no. , pp.84-87, 2009.

[12] D. Sievenpiper, Lijun Zhang, R. F. J. Broas, N. G. Alexopolous and E.Yablonovitch, ”High-impedance electromagnetic surfaces with a forbidden frequency band,” in IEEE Transactions on Microwave Theory and Techniques, vol. 47, no. 11, pp. 2059-2074, Nov 1999.

[13] Yang, Ning, Chen, ZhiNing, Wang, Yun Yi, and Chia, M. Y. W., "A two-layer compact electromagnetic bandgap (EBG) structure andits applications in microstripantenna design,” in Microwave and Optical Technology Letters, vol. 37, no. 1 , pp. 62-64, 2003.

[14] L. Inclan-Sanchez, J.L. Vazquez-Roy, and E. Rajo-Iglesias “Considerations on designing microstrip gap waveguide slot arrays”, 9th EuropeanConference on Antennas and Propagation, april 2015.

[15] H.Kiumarsit, K.Wasa, H.Itot, N.Ishiharat, and K.Masu,” E-band antenna s based on substrate integrated waveguide octagonal cavities loaded by complementary split-ring resonators,” in 2015 IEEE MTT S Int. Microwave Symp., USA, 2015.

[16] Jia Sheng Hong and M.J.Lancaster, MicrostripAntenna s for RF / Microwave Applications, 2nd ed. New York: Wiley, 2011.

[17] Y. K. Singh ,P. Abdulla P, A. Chakrabarty "Miniaturized microstripantenna using a dual-mode octagonal patch resonator,” in Proc. APMC 2009 Asia Pacific Microwave Conf., Singapore, 2009, pp. 2511-2514.

[18] X. L. Lu *et al.*, “Design of a high-order dual-band superconducting antenna with controllable frequencies and bandwidths,” *IEEE Trans. Appl. Supercond.*, vol. 24, no. 2, pp. 3–7, Apr. 2014.

[19] H. Liu, B. Ren, F. Liu, X. Guan, P. Wen, and Z. Ma, “Dual-band high temperature superconducting microstrip antenna using dual-mode hairpin ring resonator,” *IEEE Trans. Appl. Supercond.*, vol. 26, no. 7, Oct. 2016, Art. no. 1501704.

[20] E. G. Cristal and S. Frankel, “Hairpin-line and hybrid hairpin-line/halfwave parallel-coupled-line antenna s,” *IEEE Trans. Microw. Theory Techn.*, vol. MTT-20, no. 11, pp. 719–728, Nov. 1972.

[21] J.-S. Hong and M. J. Lancaster, ‘‘Couplings of microstrip square open-loop resonators for cross-coupled planar microwave antenna s,’’*IEEE Trans. Microw. Theory Tech.*, vol. 44, no. 11, pp. 2099--2109, Nov. 1996.