International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 **Issue:** IV **Month of publication:** April 2023

DOI: https://doi.org/10.22214/ijraset.2023.50875

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

Design of Sub-6 GHz Antenna using Negative Permittivity Metamaterial for 5G Applications

Sambaldevi Chandra Bhaskar[1], Tejavathu Dheeraj Kumar[2], Boda Naveen[3], Pendli Pradeep[4]
[1, 2, 3]UG Scholar, [4]Associate Professor, Department of Electronics and Communication Engineering, Sreenidhi Institute of Science and Engineering, Telangana, India

***Abstract:** The objective of the presented article is to design a compact metamaterial-based dual-band antenna that meets the frequency requirement of 5G. The antenna consists of a Circular Split Ring Resonator structure with a defective ground plane and slots to enhance the bandwidth and gain parameters. Metamaterial-based Microstrip patch antenna produces unique electromagnetic properties that allow us to control over the antenna parameters with a compact size. FR-4 epoxy is used as a substrate its dielectric constant is 4.4 and its loss tangent is 0.02. Dimensions of the antenna are 20 x 12 x 1.6mm^3 with a very compact size and cost-effective. The proposed metamaterial-based antenna resonates at dual bands at 3.24GHz and 5.46 GHz respectively. The peak gains at resonant frequencies 3.45GHz and 5.46 GHz are 0.9 dB and 2dB respectively. The proposed antenna shows S-parameters at S_{11}, which is -12.13dB at frequency of 3.45 GHz and -15.165 at a frequency of 5.46 GHz. The proposed antenna can effectively work for WLAN and WiMAX applications. The antenna covers the frequency spectrum from 2 GHz to 8 GHz with a centre frequency of 5 GHz. The proposed antenna is cost-effective.*
***Keywords:** Negative permittivity, Meta material, HFSS and Dual-band*

I. INTRODUCTION

The advancement of wireless communication requires a compact size antenna with high performance. The traditional approach of using a normal patch is not recommended to obtain a compact-sized antenna along with high performance. Instead, integrating split ring resonators provides high antenna parameters [3]. The compact-sized antenna provides a homogeneous radiation pattern, wider bandwidth, and a low gain, to enhance that we use different techniques like metamaterials [5]. As there are many shapes of split ring resonators like circular, Rectangular, Square etc., each shape provides various advantages. Square and Rectangular shaped resonators provide a high gain and better return loss [1]. In this paper, we designed a compact metamaterial-based Microstrip patch antenna with FR-4 epoxy as the substrate. This antenna has a defective ground structure which helps to avoid mutual coupling between neighbour elements and helps to enhance bandwidth and gain. A circular ring resonator structure is integrated into the patch along with a slot. This structure provided the negative permittivity, which is verified through the MATLAB script [5]. This antenna provides a dual-band with a peak gain of 0.9 dB and 2 dB at the resonant frequencies 3.45 GHz and 5.46 GHz respectively covering the WLAN and WiMAX applications [2]. All the relevant data for design analysis is used from papers [14-16].
Section II presents the details of metamaterial-inspired antenna geometry and design for the proposed antenna. Section III presents a detailed analysis of the proposed antenna with returns plot, Radiation characteristics and current distribution to explain the performance of the antennas. Finally, conclusions are given in section IV followed by acknowledgement and references.

II. PROPOSED ANTENNA GEOMETRY

The proposed compact microstrip monopole metamaterial-inspired antenna is shown in Fig.1. The antenna is imprinted on FR-4 epoxy substrate whose dielectric constant i.e; effective relative permittivity **εr** = 4.4 and contains a thickness of 1.6mm and is fed with microstrip line.
The proposed antenna has a circular split ring resonator-shaped radiation strip along with a partial ground structure along with some slots to improve the impedance matching and also to provide isolation between antennas when placed in the form of arrays [4]. We have calculated the length of radiating element length by using equation (1)

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} \qquad (1)$$

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue IV Apr 2023- Available at www.ijraset.com

Here denotes the lowest frequency at which VSWR =2 and is the velocity of light.

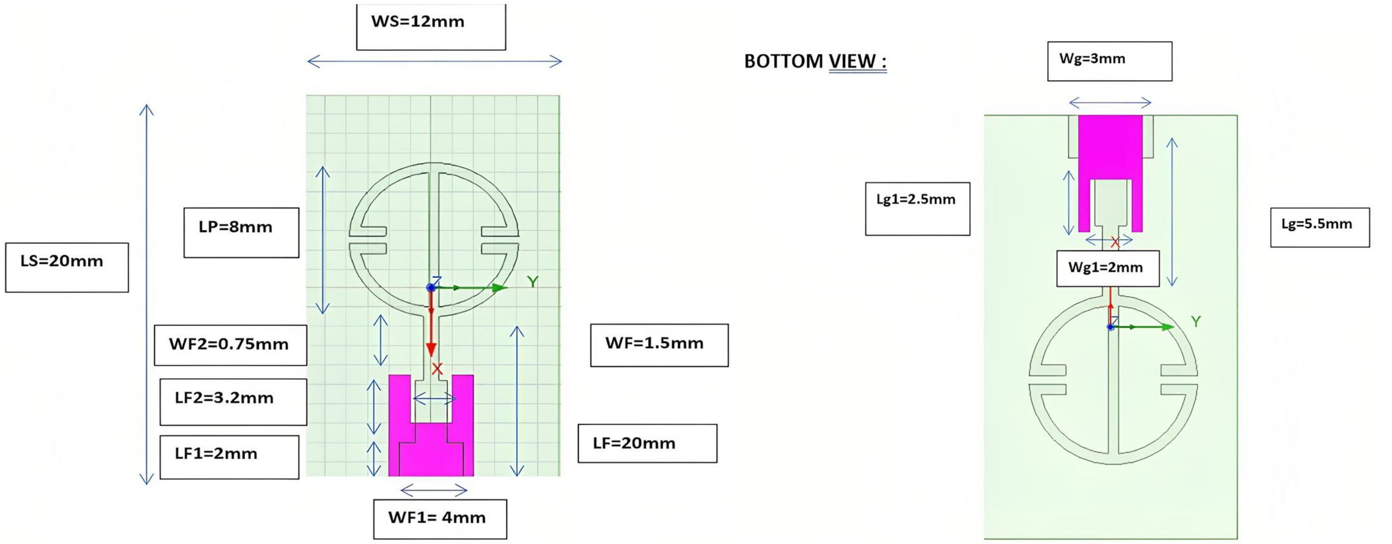


Fig.1a. Front view Fig.1b. Back view

Fig 1. Proposed antenna Design

The Design which is shown above contains a metamaterial-inspired structure which exhibits different electromagnetic properties when the structure is designed in a specific manner. The above-shown red colour patch is metamaterial which shows negative permittivity in Circular Ring Resonator. It is metamaterial inspired because its property of negative permittivity is slightly off. Our design dimensions are 20 x 12 x 1.6mm^3, we used FR4 epoxy as a substrate whose dielectric constant is 4.4 and whose loss tangent of 0.02. The ground contains the dimensions of Lg=5.5mm, Wg1=2mm, Lg1=2.5mm, and Wg=3mm. They will provide more impedance matching and gives us less return loss. The patch contains a circular ring resonator metamaterial-inspired structure whose dimensions Lp=8mm, a=0.5mm, b=0.5mm, c=0.5mm, d=0.5mm, e=1.4mm and the microstrip feed line dimensions are Lf=8mm, Wf=1.5mm, Lf1=2mm, Wf1=4mm. Here metamaterial properties are verified through another method and results are verified.

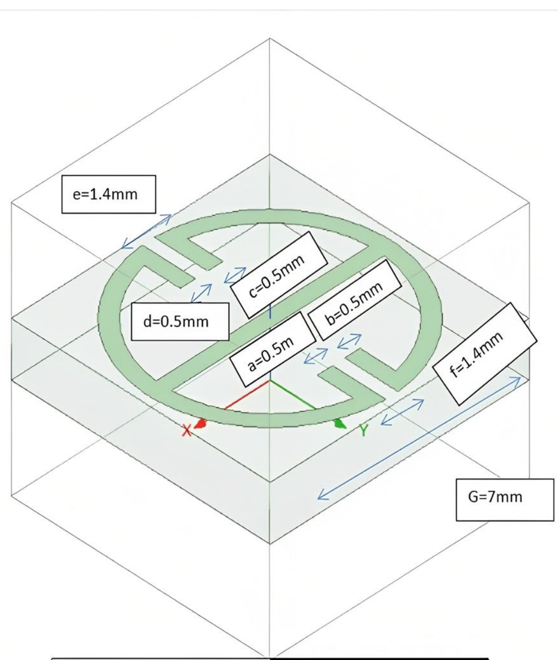


Fig 2. Unit cell Boundary conditions.

III. RESULTS AND DISCUSSION

The proposed antenna is simulated in HFSS, and results are drawn in which the return loss is plotted which is shown in Fig. 4. Antenna radiates with nearly 84% efficiency.

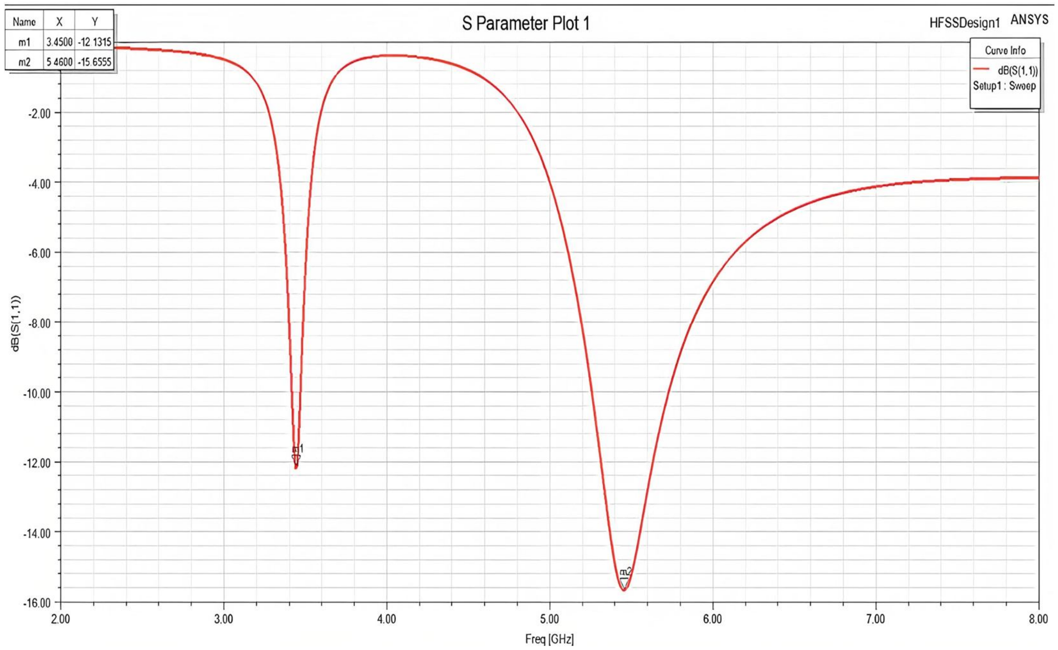


Fig 3. Return loss of Antenna

S11 is a measure of how much power is reflected back at the antenna port due to a mismatch from the transmission line.

The proposed antenna shows S-parameters at S_{11}, which is -12.13dB at a frequency of 3.45GHz and -15.165 at a frequency of 5.46GHz.

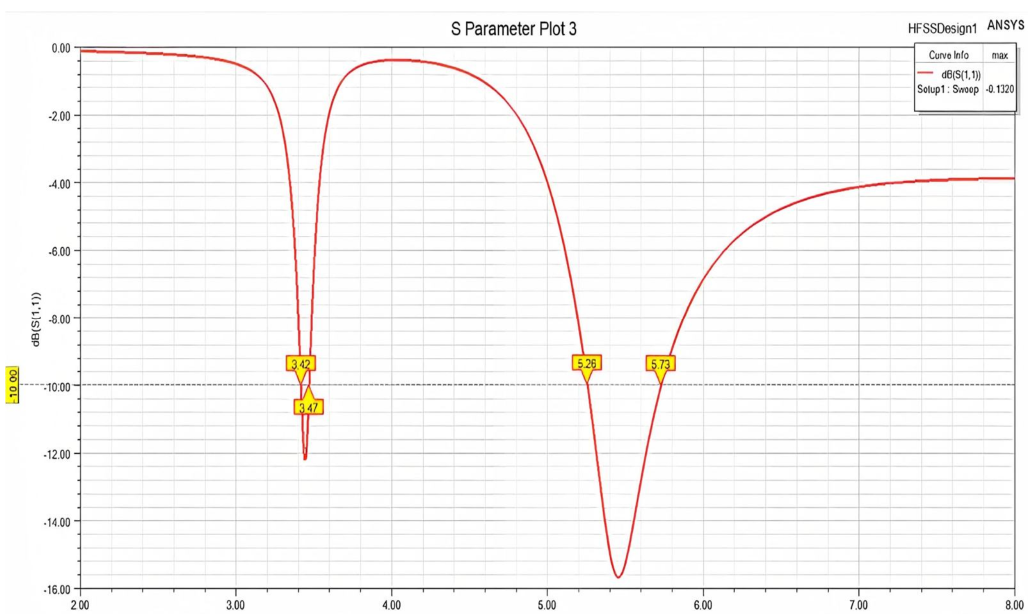


Fig 4. S11 parameter of the unit cell

For the proposed antenna, S1 parameters resonate at dual bands at 3.24GHz and 5.46 GHz. The peak gains at resonant frequencies 3.45GHz and 5.46 GHz are 0.9 dB and 2dB respectively.

The impedance bandwidth of (|S11|<-10 dB) 3.42 to 3.47GHz (50MHz) and 5.73 to 5.26ghz(470MHz).

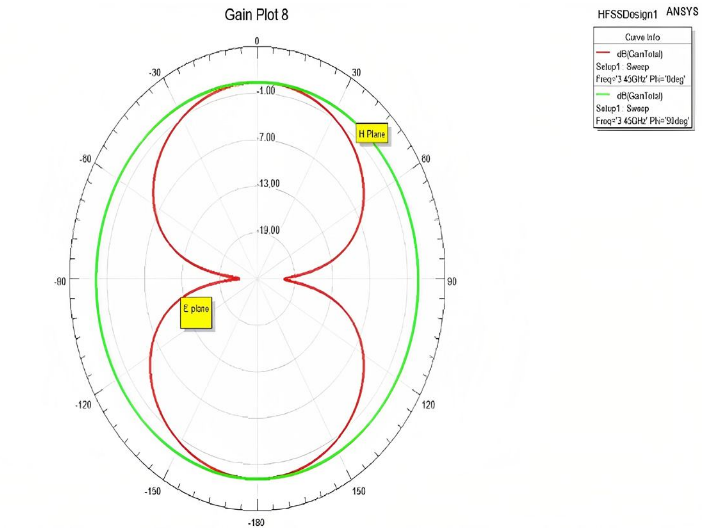


Fig.5a. Radiation pattern at 3.45 GHz

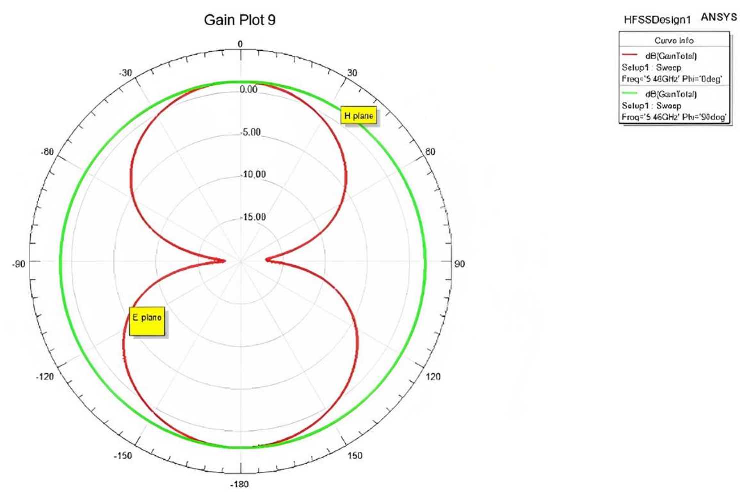


Fig.5b. Radiation pattern at 5.46 GHz

Fig 5. Radiation Patterns in the XY plane and YZ plane

For the proposed antenna, Gain at frequency 3.45GHz is 0.9dB and gain at frequency 5.46GHz is 2db.

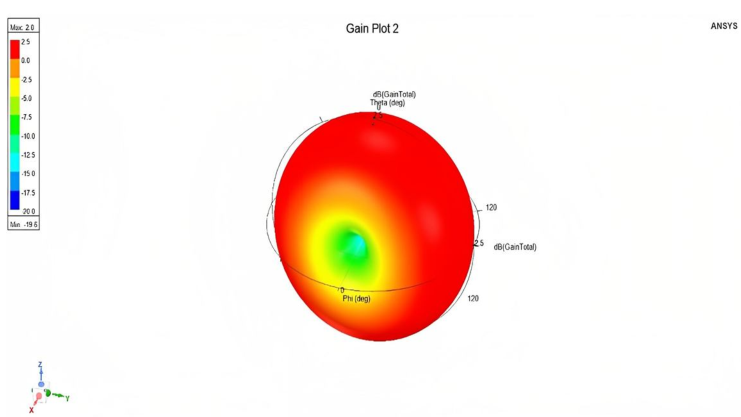


Fig.6a. Gain at 5.46 GHz

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue IV Apr 2023- Available at www.ijraset.com

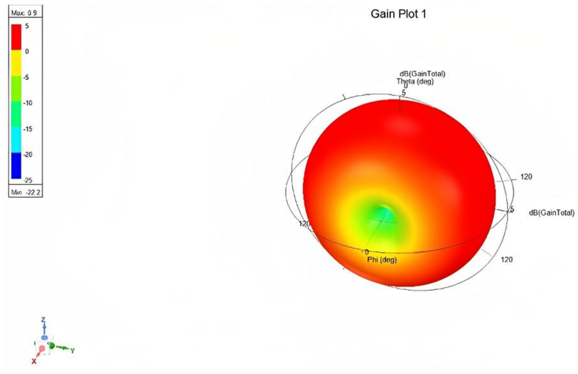


Fig.6b. Gain at 3.45 GHz

Fig 6. Gain plot distribution at Resonant frequencies.

The radiation pattern depends on the structure of the antenna which changes when the current distribution changes on the antenna's radiating element.

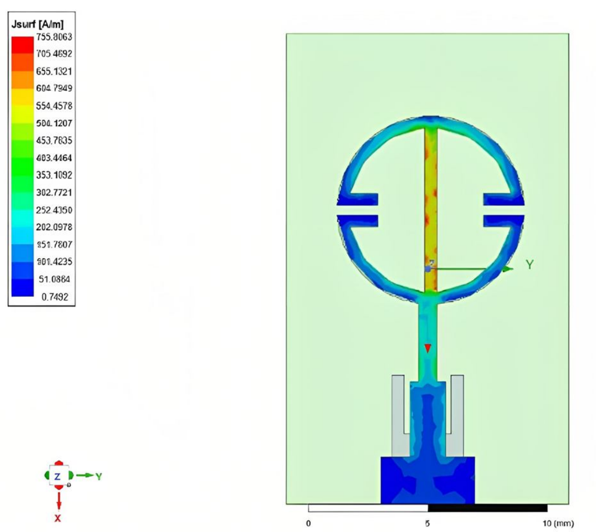


Fig.7a. Current Distribution at 3.45 GHz

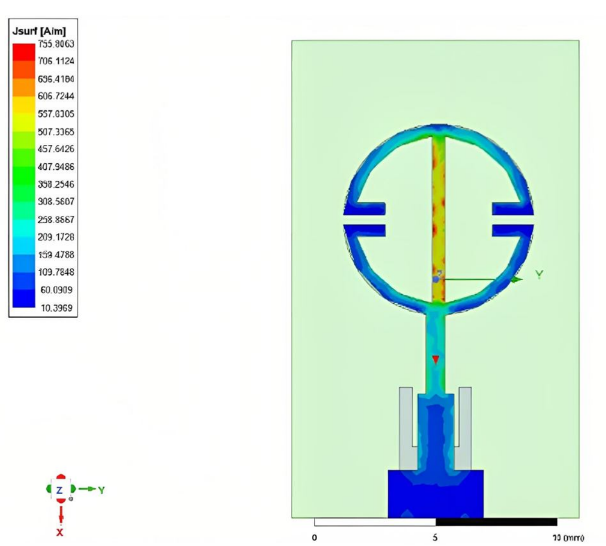


Fig.7b. Current Distribution at 5.46 GHz

Fig 7. Current distribution at Resonant frequencies.

IV. CONCLUSIONS AND FUTURE SCOPE

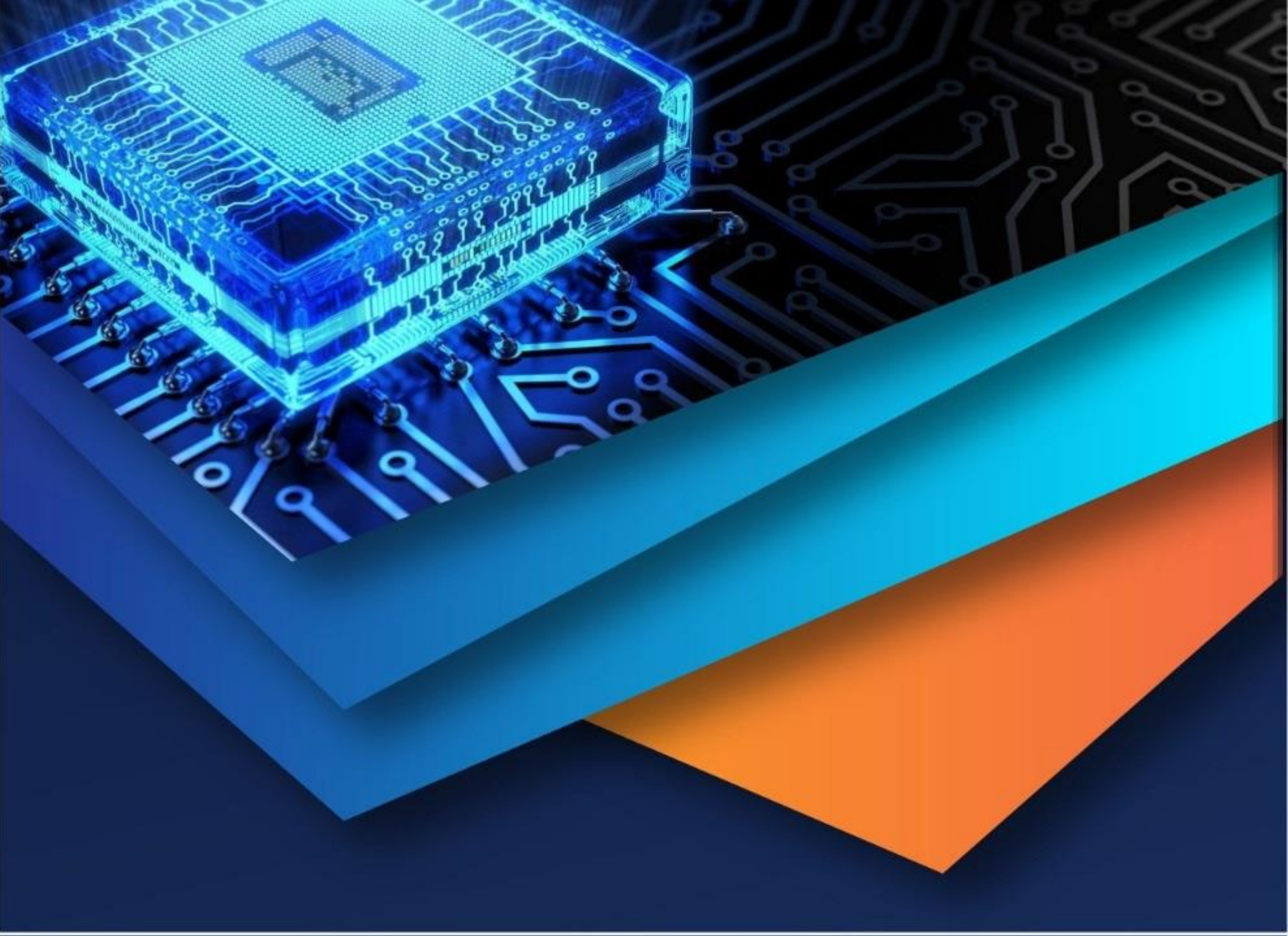
A compact metamaterial-inspired dual-band monopole antenna is designed and validated on a 20 x 12 x 1.6mm^3 FR-4 epoxy substrate. The proposed design contains a circular split ring resonator which is a metamaterial inspired and whose permittivity value is negative. The proposed antenna can radiate at dual band frequencies at 3.45 GHz and 5.46 GHz with a return loss of -12.13dB and -15.165dB respectively. This compact antenna has a gain of 0.9 dB and 2 dB at respective resonant frequencies. Due to its compact size, the achieved gain is moderate, and external devices like Cellular signal boosters maintain constant gain throughout the transmission. We can achieve better results when the antenna is arranged in the shape of arrays and arrays will increase the gain and directionality of the antenna.

V. ACKNOWLEDGEMENT

Firstly, we are grateful to the Sreenidhi Institute of Science and Technology for allowing us to work on this project. We are fortunate to have worked under the supervision of our guide Mr. Pradeep. His guidance and suggestions helped us a lot in this work. We are also thankful to Mr. S. N. Chandrashekar for being the In Charge and Coordinator for this project and its reviews. We are also thankful to the HOD of Electronics and Communication Engineering [ECE], Dr. S. P. V. Subba Rao for giving constant support and encouragement.

REFERENCES

[1] Kaur, Parwinder, and Mandeep Kaur. "Gain and Bandwidth of Micro-strip Patch Antenna with Split Ring Resonator (SRR)."
[2] Attia, H., Siddiqui, O., Yousefi, L. and Ramahi, O.M., 2011, April. Metamaterial for gain enhancement of printed antennas: Theory, measurements, and optimization. In 2011 Saudi International Electronics, Communications and Photonics Conference (SIECPC) (pp. 1-6). IEEE.IEEE.
[3] Ortiz, N., Falcone, F. and Sorolla, M., 2012. Gain improvement of dual band antenna based on the complementary rectangular split-ring resonator. International Scholarly Research Notices, 2012.M. Wegmuller, J. P. von der Weid, P. Oberson, and N. Gisin, "High resolution fiber distributed measurements with coherent OFDR," in Proc. ECOC'00, 2000, paper 11.3.4, p. 109.
[4] Abdel-Rahman, Adel B., and Ahmed A. Ibrahim. "Metamaterial enhances microstrip antenna gain." (2016). (2002) The IEEE website. [Online]. Available:http://www.ieee.org/
[5] Murugeshwari, B., Daniel, R.S. and Raghavan, S., 2019. A compact dual band antenna based on metamaterial inspired split ring structure and hexagonal complementary split-ring resonator for ISM/WiMAX/WLANapplications. Applied Physics A, 125(9), pp.1-8.FLEXChip Signal Processor (MC68175/D),Motorola, 1996.
[6] Krzysztofik, W.J. and Cao, T.N., 2019. Metamaterials in application to improve antenna parameters. Metamaterials and Metasurfaces.
[7] Daniel, R. Samson, R. Pandeeswari, and S. Raghavan. "Dual-band monopole antenna loaded with ELC metamaterial resonator for WiMAX and WLAN applications." Applied Physics A 124, no. 8 (2018): 1-7
[8] Yasar-Orten, P., Ekmedkci, E. and Turham-Sayan, G., 2010, July. Equivalent circuit models for split-ring resonator arrays. In PIERS Proceedings.
[9] Numan, A.B. and Sharawi, M.S., 2013. Extraction of material parameters for metamaterials using a full-wave simulator [education column]. IEEE Antennas and Propagation Magazine, 55(5), pp.202-211.
[10] Hasan, Md Mehedi, Mohammad Rashed Iqbal Faruque, and Mohammad Tariqul Islam. "Dual band metamaterial antenna for LTE/bluetooth/WiMAX system." Scientific reports 8, no. 1 (2018): 1-17.
[11] Kowsalya, M., Muthu, T.R. and Murugan, S., 2017, March. Design and implementation of flexible microstrip antenna for ISM band applications. In 2017 International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS) (pp. 1-4). IEEE.
[12] Rastogi, Namrta, and Rakhi Kumari. "Improved characteristics of microstrip patch antenna using reactive impedance surface." In 2017 3rd International Conference on Computational Intelligence & Communication Technology (CICT), pp. 1-6. IEEE, 2017.
[13] Sahithi, S., Kumar, S.A. and Shanmuganantham, T., 2017, December. A U-slot microstrip patch antenna for Wi-Max applications. In 2017 IEEE International Conference on Circuits and Systems (ICCS) (pp. 109-111). IEEE
[14] Pendli Pradeep,Akkenapally Hemanth,Gundu Kavya Sri,Sama Vinisha, "A COMPACT FREQUENCY RECONFIGURABLE ANTENNA WITH ENHANCED BANDWIDTH FOR WLAN APPLICATIONS", International Journal of Creative Research Thoughts (IJCRT), ISSN:2320-2882, Volume.9, Issue 6, pp.c6-c12, June 2021.
[15] Pradeep, P., Satyanarayana, S.K. and Mahesh, M., DESIGN AND ANALYSIS OF A CIRCULARLY POLARIZED OMNIDIRECTIONAL SLOTTED PATCH ANTENNA AT 2.4 GHZ. ICTACT IJCT_Vol_11_Iss_3_Paper_5_Pages-2234_2238.
[16] "Design of dual band Flexible Microstrip Patch Antenna for WLAN/X-band applications", International Journal of Emerging Technologies and Innovative Research (www.jetir.org), ISSN: 2349-5162, Vol.8, Issue 6, page no.b157-b160, June-2021.



10.22214/IJRASET

INDEX COPERNICUS 45.98

ISRA JIF IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

ISI

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY