Design of Split-Ring Resonator Embedded Metamaterial Monopole Antenna for Short Range Communication.

Dalfiah.J[1] Dabu Karuppasamy[2] Bhanumathi.K[3]
[1]Assistant Professor [2,3]UG Students
Department of Electronics and Communication Engineering,
Velammal College of Engineering and Technology, Viraganoor, Madurai District.
jd@vcet.ac.in email2dabu95@gmail.com bhanumathi76@gmail.com

Abstract

In recent years, antenna and its feed system in wireless communications need to be inexpensive and ease of fabrication. Using stub wideband antenna with frequency notched function at Industrial, Scientific and Medical (ISM) band is designed with novelty. Coplanar Waveguide (CPW) fed ring antenna is designed using Advanced Design System (ADS) software by means of several parametric studies and fabricated using wet etching method of fabrication. The resultant antenna is working at short communication such as ISM band frequency 2.45GHz. FR4 Glass Epoxy material is used as a substrate. Even though it produces low bandwidth signal, using stub the bandwidth is slightly improved up to 100MHz. The return loss characteristics is less than -10dB level.

Key words: Ring Antenna, Coplanar Waveguide, Stub, ISM band.

1. Introduction

Ring antenna shape is derived from Metamaterial which is an artificial material that exhibits negative characteristics in permittivity value and permeability value such that these characteristics are not present in nature. These unique characteristics are used in antenna, filters and power dividers in such a way to reduce the size and to enhance the existing characteristics. Some of the examples are, the electromagnetic/photonic band gap (EBG/PBG) and artificial magnetic metamaterials are applied in antenna design.

Single antenna working for several frequencies is a desired key feature required presently, which is classified as band notch characteristics [1]. An Ultra wide-band (UWB) system has special advantages, such as low complexity and low cost, resistant to severe multipath and jamming, and also uses a low-power spectral density and a short pulse radio signal to send high data-rate information [2].

In [3], a bi-arm rolled monopole antenna is used for the UWB applications but they are not planar structures as they were placed above a big ground plane, and not compatible with RF integrated circuit. For a dual frequency application of antennas, an annular ring slot structure is adopted in [4] and [5].

In literature [6], Chen *et al.* briefs about planar wideband antennas with different shapes exhibiting good impedance matching, stable radiation patterns, and high efficiency over a various band of frequency. The frequency range of an UWB antenna system is 3.1–10.6 GHz approved by Federal Communications Commission (FCC) [7]. In this paper, the ring resonator is constructed as a resonant antenna by increasing the width of the microstrip [8–10].

The ring antenna is already been analyzed using Galerkin's method [11, 12]. It was concluded that the TM12 mode is the best mode for antenna applications, whereas TM11 mode is best for resonator applications. Another rigorous analysis of probe feed ring antenna was introduced in [13]. In [14], a numerical model based on a full-wave spectral-domain method of a moment is used to model the connection between the probe feed and ring antenna. The slot ring antenna is a dual microstrip ring antenna. It has a wider impedance bandwidth than the microstrip antenna. Therefore, the bandwidth of the slot antenna is greater than that of the microstrip antenna [15–17].

Split-ring resonator (SRR) consists of two concentric metal rings separated by a gap, each with a split at opposite sides. In spite of nonmagnetic conductor (like copper) radiators, it can yield negative effective magnetic permeability, which was introduced by Pendry et al.in 1999 [18] and experimentally confirmed by Smith et al.in 2000. Coplanar waveguide (CPW) transmission lines have been broadly used for antenna feed system because of its wide bandwidth, planar structures, and easy integration with monolithic microwave integrated circuits (MMIC) [19–21]. In this work, we have designed a CPW fed ring antenna with concentric rings as resonators with stubs

2. Design Methodologies:

Ring antenna comes under the category of ring resonators which are one of the types of metamaterials. Since the UWB antennas occupy a wider band of frequencies, the specific application band is needed in between this range. In order to achieve this band, notch operation is performed by the use of split rings as shown in figure 1.

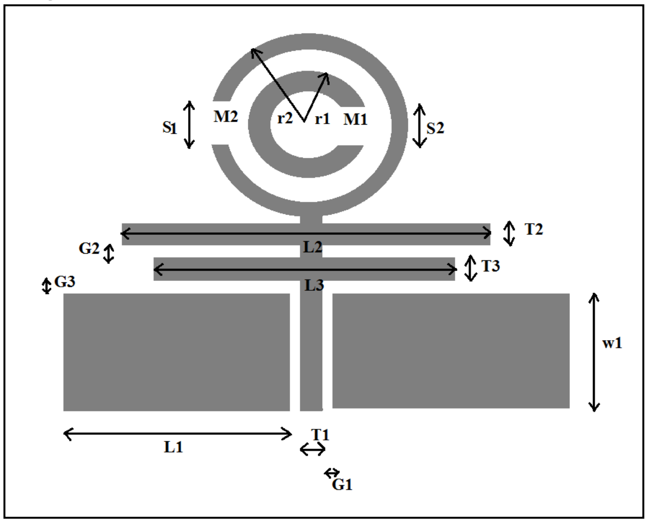

Figure 1: Proposed Antenna Structure.

Notation	Dimension in mm
S_1	3.2
S_2	1.98
M1	1.56
M2	2.16
r1	2.89
r2	6.18
G_1	0.75
G_2	0.9
G_3	0.75
T_1	1.4
T_2	1.4
T_3	1.4
L_1	20
w1	4.7

Table 1: Optimized Dimensions

The SRR (Figure 1) is constructed by two conducting rings, i.e., two metal rings which is made up of copper and are separated by a gap, each with a split at opposite sides. Pendry and co-workers [18] formulated a fundamental magnetic resonant frequency of SRR

$$f_{SRR\_m} = \frac{c}{2\pi^2}\sqrt{\frac{3\omega}{\epsilon_r(r-2t-\omega)^3}} \quad \text{-------- (1)}$$

Where f_{SRR_m} is a fundamental magnetic resonant frequency of SRR, ε_r is relative permittivity of a dielectric substrate, r is the radius of the outer ring, t is the width of the metal lines, and ω *is* the gap between the inner and outer ring. In this work, the ring shape is used for radiating antenna and the stub is used to enhance the impedance matching.

In the reference paper the feed is in a tapered manner wherein proposed design straight feed is used and also curved ground plane is modified as rectangular shape ground.

3. Results and Discussion:

The parametric study is implemented at the various length of the ground plane, various number of ring structures, various number of stubs and a various gap between the ground plane and strip line.

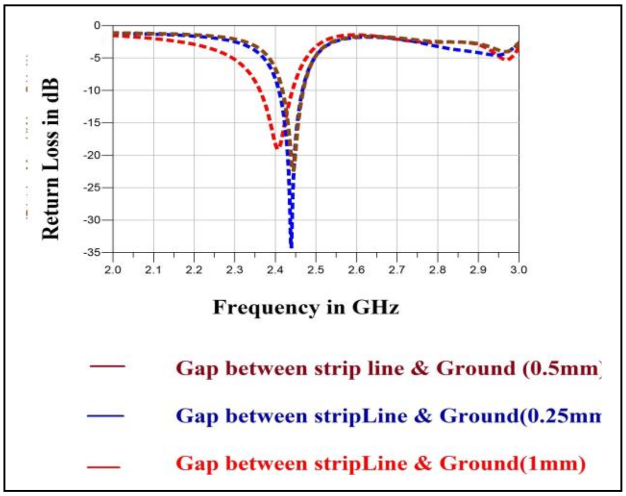

Figure 2: Effect of gap between strip and ground

The frequency is dependent with respect to the gap between the ground plane and center strip. From figure 2 it is clear that 0.5mm is the optimized value of the gap to resonate at 2.45GHz.

Similarly, the number of stubs also gives their impact on resonant frequency and bandwidth. It is shown in figure 3. The required operating frequency and wider bandwidth is obtained from two stub structure.

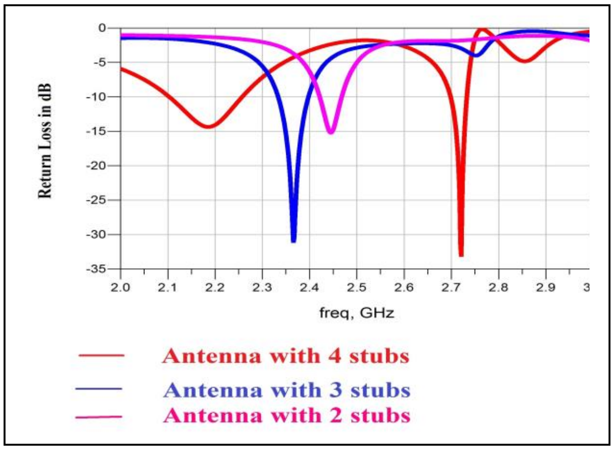

Figure 3: Changes while using different number of stubs

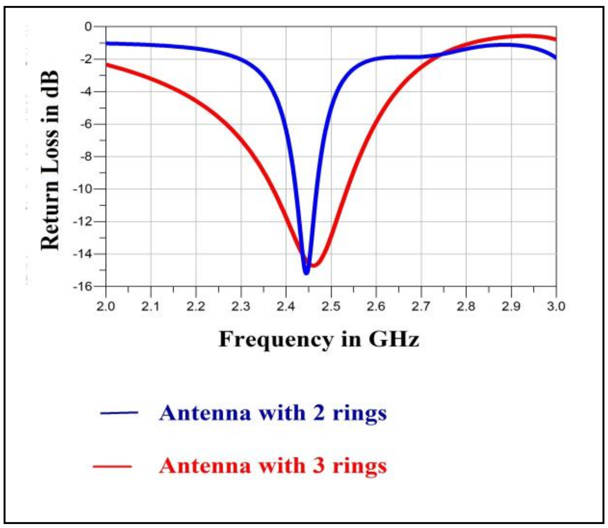

Figure 4: Comparison between Antennas with different number of rings

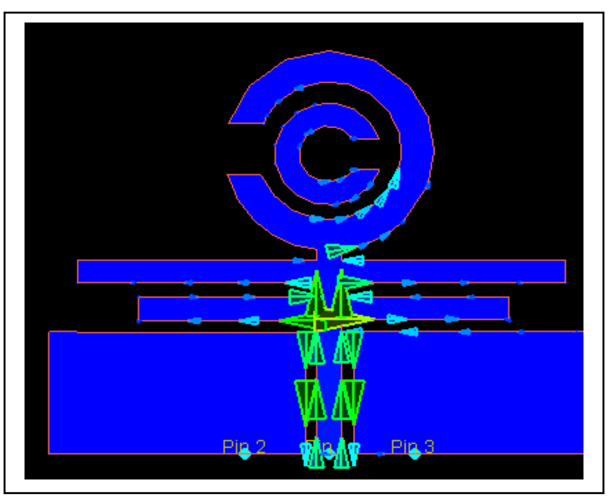

Figure 5: Current Distribution of Rectangular Ground Structure

The figure 4 reveals that as a number of rings increases the bandwidth coverage increases since the rings are resonators. From figure 5 the current is distributed mainly along the outer rings and at the center of the feed system, however, the colors are green which indicates that peak current distribution is maximum at the center of the antenna.

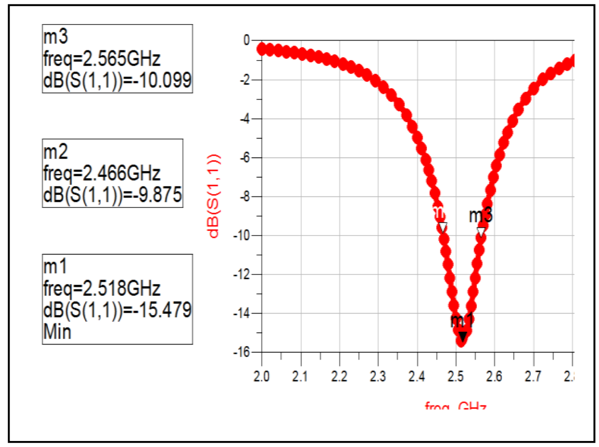

Figure 6: Simulation Result of Antenna

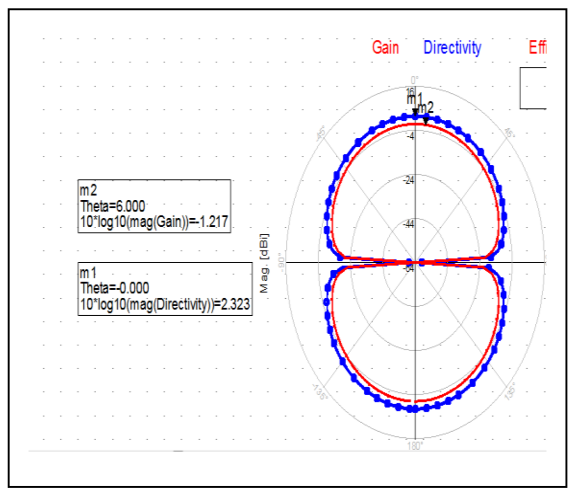

Figure 7: Gain and Directivity of the Antenna

Figure 6 and 7 shows the return loss, gain and directivity of the proposed antenna respectively. The bandwidth is about 100MHz and the resonance frequency is 2.45GHz which is ISM band frequency. Since the antenna is focused for medical application, the gain is very poor in this antenna. The directivity is comparatively better than gain since the efficiency is about 50% for the proposed antenna.

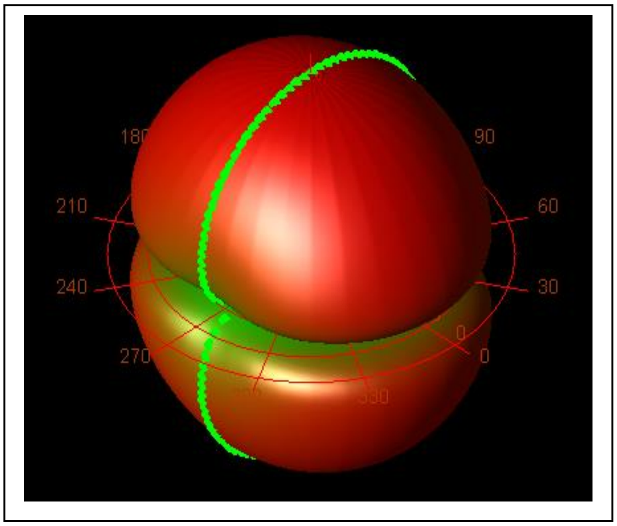

Figure 8: 3-D Radiation Pattern

Figure 9: Fabricated Antenna

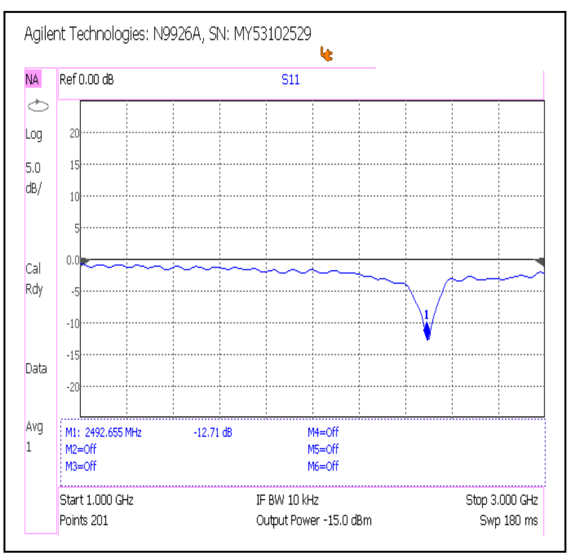

Figure 10: Return loss (dB) Measurement.

Figure 8 shows the 3D radiation pattern. The red color indicates maximum radiation, green color as average radiation. The prototype of the antenna and its measured result using Agilent's Keysight Technology Network analyzer is shown in figures 9 and 10 respectively. Since the measured result is similar to that of simulated results, it is clear that the designed antenna have less return loss even though the fabrication soldering gives impact on the antenna performance.

4. Conclusion:

A new compact ring resonator based antenna is designed and fabricated using FR4 glass epoxy material. This antenna is used at the frequency of 2.45GHz(ISM band) with reduced return loss. It can be applicable for short range communication between doctor and patient and Commanders and soldiers etc., Since the antenna have low gain it can be used in OFF- body communication also. In future, we might design in RT duroid material for better radiation performance and further size reduction.

5. References:

[1] Kim, Y. and D. H. Kw on, "*CPW-fed planar ultra-wideband antenna having a frequency band notch function*", ***Electronics Letters***, Vol.40, No.7, 403–405, 2004.

[2] I. Oppermann, M. Hamalainen, and J. Iinatti, *"UWB Theory and Applications*", New York: Wiley, 2004, ch. 1, pp. 3–4.

[3] Z. N. Chen, *"Novel bi-arm rolled monopole for UWB applications"*, **IEEE Trans. Antennas Propag**., vol. 53, no. 2, pp. 672–677, Feb. 2005.

[4] K. Chang, *"Microwave Ring Circuits and Antennas",* New York:Wiley, 1996.

[5] J. S. Chen, *"Dual-frequency annular ring slot antennas fed by CPW feed and microstrip line feed"*, **IEEE Trans. Antennas Propag.,** vol. 53, no. 1, pp. 569–571, Jan. 2005.

[6] Z. N. Chen, M. J. Ammann, X. M. Qing, X. H.Wu, T. S. P. See, and A. Cai, "*Planar antennas*", **IEEE Microw.** ***Mag***., vol. 7, no. 6, pp. 63–73, Dec. 2006.

[7] "*Federal Communications Commission-Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems"*, **FCC**, 2002, First Report and Order FCC, 02.V48.

[8] Kong, J. A., *"Electromagnetic wave interaction with stratified negative isotropic media"*, **Progress In Electromagnetic Research,** PIER 35, 1–52, 2002.

[9] Pendry, J. B., "*Negative refraction makes a perfect lens*" **Physical Review Letters**, Vol.85, 3966–3969, 2000.

[10] Srivatsaava, S.K. and S.P .Ojha, "*Enhancement of Omni-directional reflection bands in one-dimensional photonic crystals with left-handed materials*" **Progress in Electromagnetics Research**, PIER 68, 91–111, 2007.

[11] Schurig, D., J.J. Mo ck, B.J. Justice, S.A. Cummer, J.B. Pendry, A.F. Starr, and D.R.Smith, "*Metamaterial electromagnetic cloak at microwave frequencies*", *Science*, Vol.314, Vol.58010, 977–980, 2006.

[12] Fu, Y.Q, Q.R. Zhang, Q. Gao, and G.H. Zhang, "*Mutual coupling reduction between large antenna arrays using electromagnetic bandgap (EBG) structures*", **Journal of Electromagnetic Waves and Applications**, Vol.20, No.6, 819–825, 2006.

[13] Pirhadi, A., M. Hakkak, and F. Keshmiri, "*Using electromagnetic bandgap superstrate to enhance the bandwidth of probe-fed microstrip antenna"*, **Progress In Electromagnetics Research**, PIER 61, 215–230, 2006.

[14] Nader, E.and R.W.Ziolk owski, "A positive future for double negative metamaterials," **IEEE Transactions on Microwave Theory and Techniques**, Vol.53, No.4, 1535–1556, 2005.

[15] Jong-Hyuk Lee, Young-Chul Oh, Noh-Hoon Myung, "*A Novel Compact Micro strip Band stop Filter Based on Complementary Split-Ring Resonators*", **Proceedings of Asia-Pacific Microwave Conference 2006,** pg- 305- 701.

[16] W. -S. Chen, C. -K.Wu, and K. -L Wong, *"Square-ring microstrip antenna with a cross strip for compact circular polarization operation"*, **IEEE Trans. Antennas Propagat.,**Vol. 47, No. 10, pp. 1566–1568, October 1999.

[17] P. M. Bafrooei and L. Shafai, "*Characteristics of single- and double-layer micro strip square-ring antennas"*, **IEEE Trans. Antennas Propagat.,** Vol. 47, No. 10, pp. 1633–1639, October 1999.

[18] Pendry, J.B., A.J.Holden, D.J.Robins, and W.J.Stew art, *"Magnetism from conductors and enhanced nonlinear phenomena"*, **IEEE Transactions on Microwave Theory and Techniques**, Vol.47, 2075–2084, 1999.

[19] Kim, Y.and D.H.Kw on, *"CPW-fed planar ultra-wideband antenna having a frequency band notch function"*, **Electronics Letters**, Vol.40, No.7, 403–405, 2004.

[20] Liu, W.C.and C.F. , Hsu, "*CPW-fed notched monopole antenna for UMTS/IMT-200/WLAN applications*", **Journal of Electromagnetic Waves and Applications,** Vol.21, No.6, 841–851, Progress In Electromagnetics Research, PIER 83, 2008

[21] Liu, W.C.and H.J.Liu, "*Miniaturized asymmetrical CPW-fed meandered strip antenna for triple-band operation*", **Journal of Electromagnetic Waves and Applications**, Vol.21, No.8, 1089– 1097, 2007.