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SPECIAL ISSUE ON RECENT RESEARCH CHALLENGES IN BIO-MEDICAL APPLICATIONS

Novel Splitring Resonator Antennas for Biomedical Application

B. Anandhi Meena[1]*, P. Thiruvalar Selvan[2],
B. Nagaraj[3], S. Raghavan[4], S. Suganthi[5] and V. Karthiyayini[6]

[1]Teaching Faculty, Department of Electronics and Communication Engineering, University College of Engineering, Dindigul - 624 622, India.
[2]Department of Electronics and Communication Engineering, TRPEC –Trichy, India.
[3]Department of Electronics and Communication Engineering, Karpagam College of Engineering, Coimbatore - 641 032, India.
[4]Department of Electronics and Communication Engineering, National Institute of Technology – Trichy, India.
[5]Department of Electronics and Communication Engineering, Christ University, Bangalore, India.
[6]University College of Engineering, Dindigul, India.

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Our paper presents the design and development of split ring resonator based metamaterial antenna for biomedical i.e., Industrial, Scientific and Medical(ISM-2.45GHz) applications and also used in biosensors. Now a day the biological changes in the human body such as glucose content in blood, heart rate, respiratory rate, brain tumor are monitored by the use of wireless body area networks. In such networks the main part of the system is antenna with compactness and wider bandwidth. We have designed gain enhanced and wide bandwidth antennas with size reduction of more than 95% compared to the conventional patch antenna. The design methodology is based on Metamaterial which is an emerging technology uses split ring resonators for size reduction. We have designed double square split ring shape superstrate antenna and circular ring resonator antenna with stub for 2.48GHz. Also they have better return loss (>12dB). Our antennas are fed with microstrip feeding and Coplanar Waveguide (CPW) feeding for better impedance matching and easy fabrication. The fabricated antennas are tested using Network analyzer. The measured results are good in agreement with simulated results.

Key words: Metamaterials, Patch antenna, Square split ring resonators, Circular split ring resonators, Superstrate, Stub.

"Metamaterial" coined in the late 1990's. The "meta" refers to the resulting effective properties whose electromagnetic responses are "be-yond" those of their constituent materials[1-3]. Metamaterial demonstrated by the negative index of refraction[4].

Recently many properties and potential applications of metamaterials have been explored and analyzed. Pendry proposed that left-handed Metamaterials could be used to build a perfect lens with sub-wavelength resolution[5] at a given frequency range, multiple modified Split ring resonator (SRR) structures have been reported in the literature.[6–8]

A common characteristic of all the SRR used in the realization of metamaterials so far is that they need to be combined with a periodic arrangement of rods in order to exhibit left-handed properties. [10-12]

Nowadays microstrip patch antenna is mainly used in ON body and OFF body wireless

* To whom all correspondence should be addressed.
E-mail: anandhimeena@gmail.com

communication in human health monitoring because of their low profile, light weight, low price, compactness, etc.[13]. But major disadvantage is narrow bandwidth and low gain. To overcome these disadvantages[14,15]. This paper proposed a new design of enhanced gain by using c shape micro strip patch antenna.

Feeding mechanism plays an important role in this patch antenna. Several works have been aimed to improve the performance in the range of 2.4GHz frequency[16,17]. The 'C' shape Superstrates have increasingly attracted great attentions and recent efforts were thrown into investigating their fundamental electromagnetic responses and potential applications[18]. The refraction index of unit cell and 6×7 array of double split ring Metamaterial Superstrates using CRR were more accurate than SRR[19]. The Microstrip Ring Resonator for characterizing microwave materials shows that resonant frequency depends on the outer, inner ring radius[20-22].

By the means of the commercial software ADS which uses designing and optimizing RF and microwave circuits to calculate the 'S' parameters for a single unit cell with the mentioned boundaries along the wave propagation[23], the effective material parameters are given. From the simulation results, the real part of the refractive index is found to be negative at frequencies where both real parts of the permittivity and permeability are negative. Thus we show that there is a frequency band where the effective refractive index of the medium is negative.

For high radiation efficiency and reduced surface wave propagation it is convenient to choose air dielectric[24]. In particular, the recent advances in the fabrication processes of ceramic oxide materials with high/low dielectric constants make the material tapering an effective technique to improve the performances of miniaturized antennas. Substrate thickness and permittivity are optimized for radiation efficiency[25-27].

Nowadays the demand for compact radiators with sufficiently high gain is rapidly increasing in many application areas. In particular, modern wireless telecommunication systems and space communications require compact antennas with high gain[28, 29]. Use of the electromagnetic band-gap (EBG) and frequency selective surface (FSS) as a superstrate has been proposed by Pirhadi et al. Planar MNZ- or ENZ-MTMs is used as a superstrate for an antenna; the radiation beam would be combined resulting in gain being enhanced. The use of FSS superstrates to enhance directivity was proposed, but only gain enhancement has been achieved[30, 31].

Antenna for Body area network, Glucose monitoring, and Respiratory monitoring[32] are some of the areas where planar antennas play a vital role to play with their changes in return loss.

METHODS AND MATERIALS

Among several substrates the FR4 is chosen because of its low profile and low cost. Both the antennas are fabricated on a 1.6 mm-thickness FR4 substrate, with relative permittivity $\mathring{a}_r$ of 4.6 and the loss tangent factor of 0.001. The workflow of the antenna design is shown in figure 1. It is clear that after the simulation part is successfully performed then then the fabrication process starts. The design formulas are given below in equations 1-7.

Formulae

$$w = \frac{c}{2f_r}\sqrt{(\frac{2}{\varepsilon_r + 1})} \quad ...(1)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+10\frac{h}{w}\right]^{-1/2} \quad ...(2)$$

$$\Delta L = h \times 0.412\frac{(\varepsilon_{reff}+0.3)[\frac{w}{h}+0.264]}{(\varepsilon_{reff}-0.258)[\frac{w}{h}+0.8]} \quad .(3)$$

$$L = \frac{\lambda}{2} - 2\Delta L \quad ...(4)$$

Where L, w= Length and width of the patch,
εreff = Effective dielectric constant

$$r = 3\sqrt{\frac{3wc^2}{4\pi^4\varepsilon_r}} + (2t+w) \quad ....(5)$$

$$L_g = 6h + L$$
$$W_g = 6h + W \quad ...(7)$$

Where r = radius of the ring in mm
C = velocity of light m/s
L_g = length of ground plane in mm
W_g = Width of ground plane in mm
h = Thickness of the substrate

Design of Square shape double split ring resonator antenna (SDSRR)

This antenna consists of two layers one with patch antenna and another with metasurface. The constructional details are given in Figure 2.

In this structure square shape ring is used as a frequency selective structure i.e., it act as a lens to improve the gain of the conventional antenna. The final dimension of this antenna is 46.7mm x 41.1mm which is in reducible size of conventional patch antenna. It has microstrip feeding of optimized width of 27.2mm.

The equivalent circuit diagram of the antenna is shown in Figure 3. Since the split ring act as resonator the equivalent consists of Inductor and Capacitor to obtain the resonance.

Design of Circular shape double split ring resonator antenna (CDSRR)

The shape of ring is taken as circular. The constructional details diagram is shown in figure 4 and the dimension parameters are given in table 1.

The feeding of this antenna is CPW based, since the impedance matching is better in this type than microstrip feeding. And also the fabrication is easier.

RESULTS AND DISCUSSION

In figure 5 the parametric study of the patch width is performed for SDSRR antenna. It shows that width of 27.2mm is the optimized value to get resonance frequency as 2.45GHz. The figure 6 shows the fabricated antenna and measurement setup with the *Agilent's Network Analyzer N9926A*.

Figure 7 and 8 shows the simulated and measured return loss of the SDSRR antenna. It is observed that resonance frequency is about 2.4GHz with return loss of -19.65dB and the impedance bandwidth is 49 MHz. Both measured and simulated results are good in agreement.

Table 2 gives the details about comparison between the antenna with SDSRR and antenna without SDSRR. Comparing the

Table 1. Dimension details of circular split ring resonator antenna

Parameters	Size (mm)	Parameters	Size (mm)	Parameters	Size (mm)
r1	6.18	L3	24.9	G2	0.9
r2	2.89	T1	1.4	S1	3.2
w1	7.7	T2	1.4	S2	1.98
L1	20	T3	1.4	M1	1.56
L2	29.4	G1	0.75	M2	2.16

Table 2. Comparison of Conventional patch (without SDSRR) and Antenna with SDSRR

Antenna Characteristics	Without SDSRR (only conventional patch)	With SDSRR
Gain (dB)	1.65096	3.72693
Length (mm)	22	22
Width (mm)	48	43
Operating frequency (GHz)	2.5	2.42
Impedance Bandwidth (MHz)	18	49

Table 3. Comparison of Reference antenna with Proposed Antenna

Parameters	Reference Antenna	Proposed Antenna
Frequency(GHz)	2.4	2.45
Number of Rings	3	2
Number of Stub	4	2
Ring Radius(mm)	8.3,6.25, 3.4	6.18,2.89
Ground Plane Width(mm)	10.65	7.7
Ground Plane Length(mm)	21	20
Length of the Stub(mm)	30,30,15,15	29.4,24.9

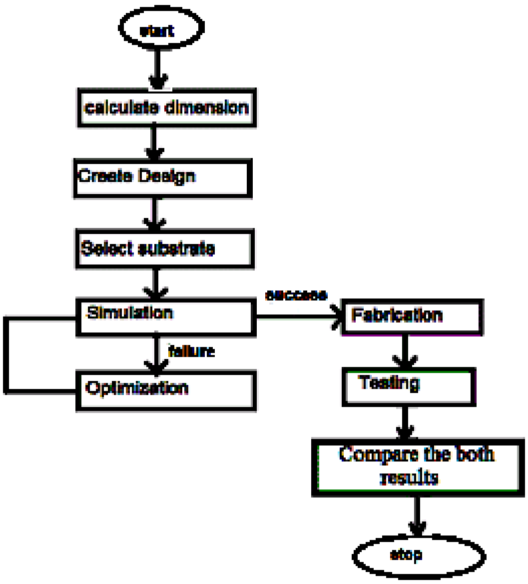

Fig. 1. Methodology Diagram Antenna Analysis

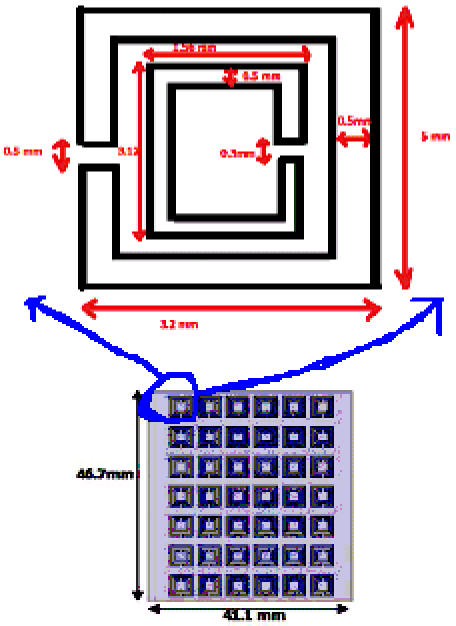

Fig. 2. Constructional detail diagram of SDSRR superstrate

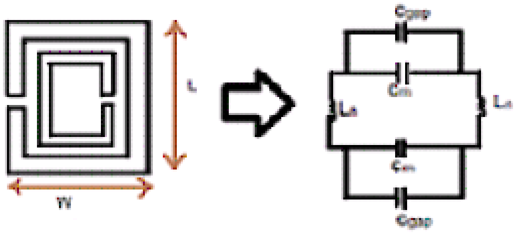

Fig. 3. Equivalent Circuit diagram of SDSRR single cell

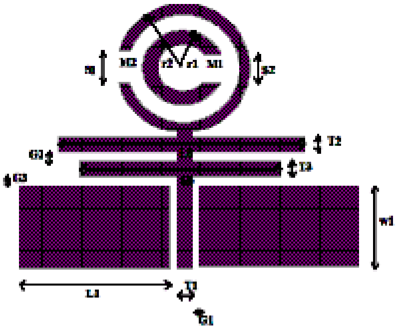

Fig. 4. Dimensions of CDSRR Antenna

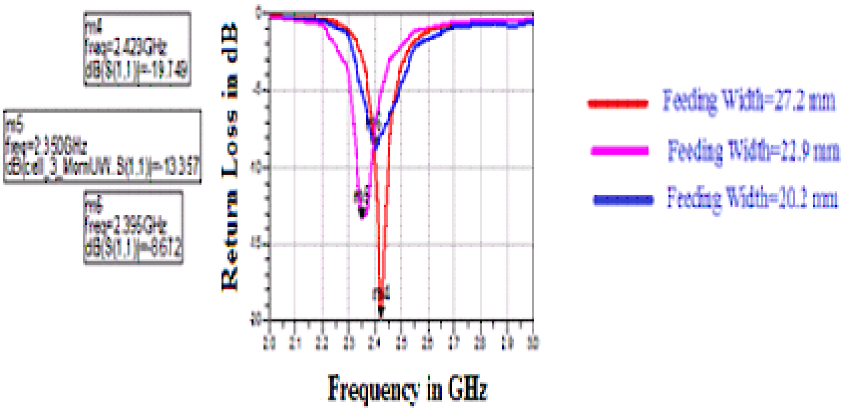

Fig. 5. Parametric study of feed width of SDSRR

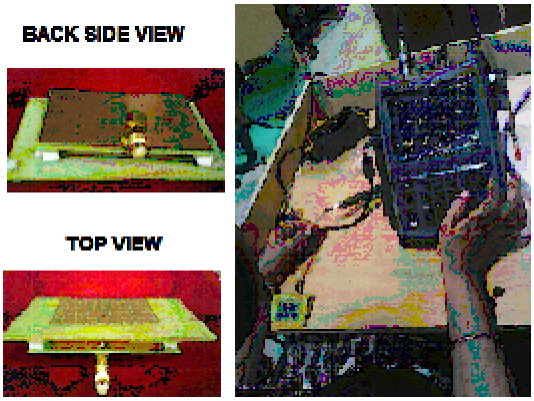

Fig. 6. Fabricated Antenna and Measurement setup of SDSRR antenna

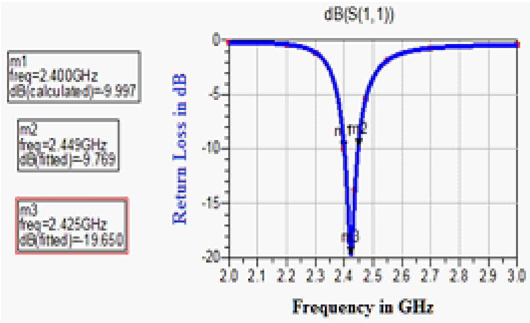

Fig. 7. Simulated return loss of SDSRR antenna

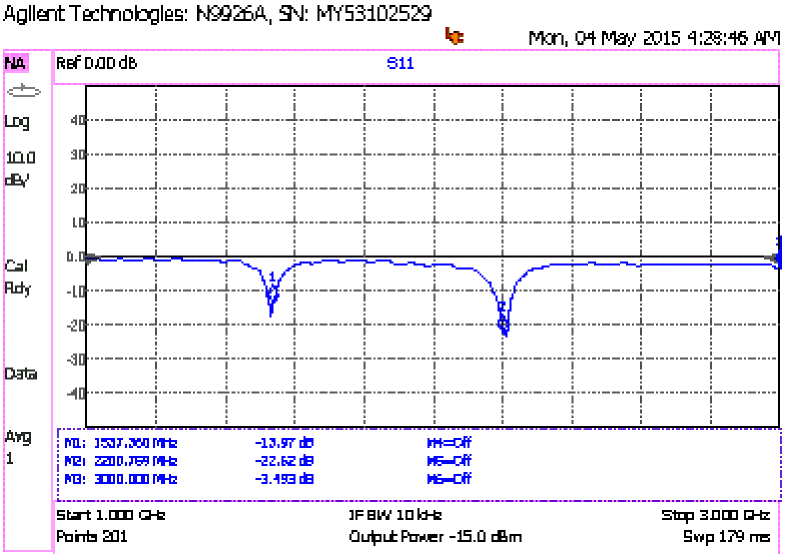

Fig. 8. Measured return loss of SDSRR antenna

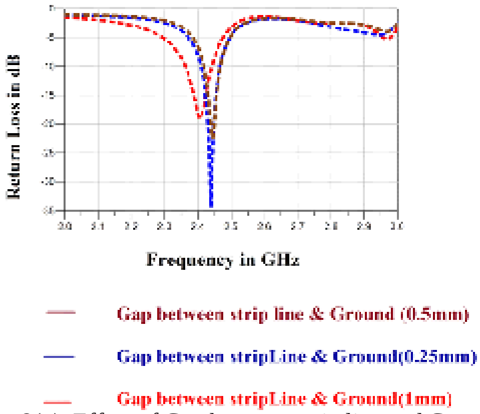

Fig. 9(a). Effect of Gap between strip line and Ground of CDSRR Antenna

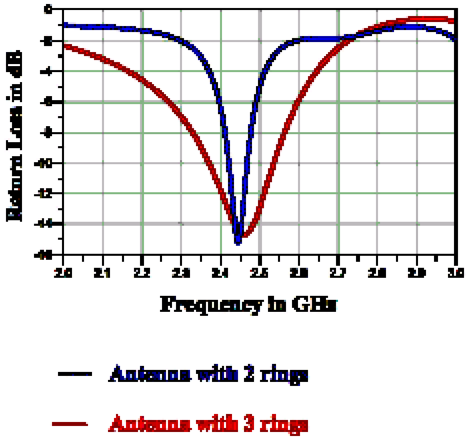

Fig. 9 (b). Effect of variation in number of ringsof CDSRR Antenna

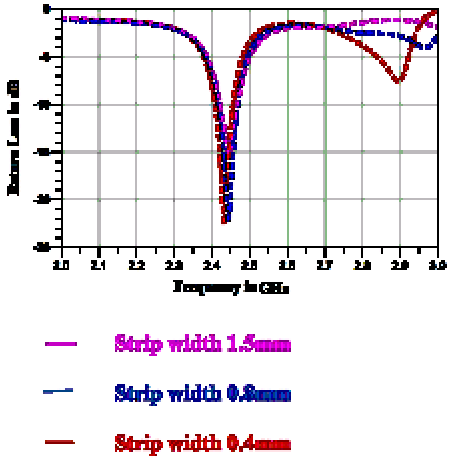

Fig. 9(c). Effect of strip widthof CDSRR Antenna

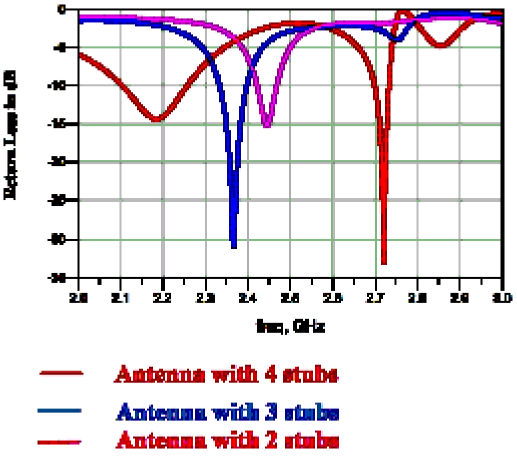

Fig. 9(d). Effect of number of stubsof CDSRR Antenna

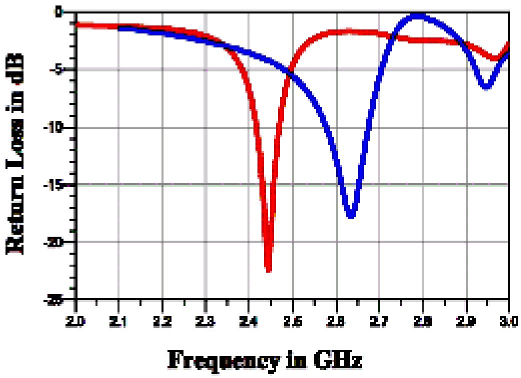

Fig. 10. Comparison of Simulated return loss of reference antenna and proposed antennaof CDSRR Antenna

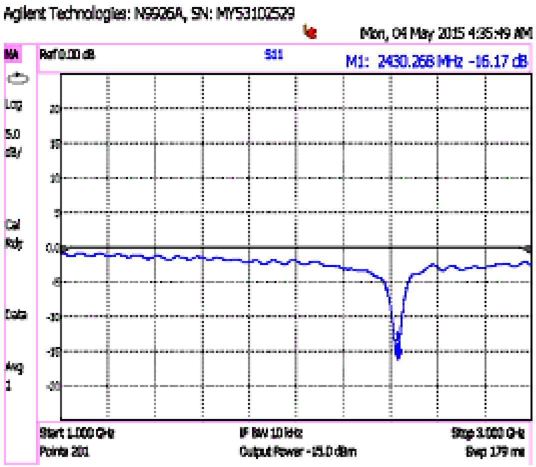

Fig. 11. Measured return loss of proposed CDSRR antenna with stub

Fig. 12. Fabricated CDSRR antenna with stub

conventional patch without SDSRR the gain and bandwidth are good in proposed antenna. The size also significantly reduced than the reference antenna.

From figures 9(a) to 9(d) we can say the optimized gap between the stripline and the ground plane is 0.25mm, the optimized number of rings is two , the optimized strip width is 0.8mm and the optimized number of stubs is two. With these optimized values the proposed antenna is simulated and the return loss is compared with the reference antenna as shown in figure 10.

The measured return loss value as shown in figure 11 is good in agreement with simulated result. The fabricated antenna is shown in figure

12. Comparison between the various antenna parameters of reference antenna and proposed antenna is given in table 3. From the table we can say the proposed antenna has better performance characteristics at resonance frequency of 2.45GHz with compact size.

CONCLUSION

In our paper we have designed and developed split ring resonator based metamaterial antenna for biomedical i.e., Industrial, Scientific and Medical(ISM-2.45GHz) applications and also used in biosensors. These antennas will be used in wireless body area networks. We have fabricated gain enhanced and wide bandwidth antennas with size reduction of more than 95% compared to the conventional patch antenna. We have designed double square split ring shape superstrate antenna and circular ring resonator antenna with stub for 2.48GHz. Also they have better return loss (>12dB). Our antennas are fed with microstrip feeding and Coplanar Waveguide (CPW) feeding for better impedance matching and easy fabrication. The fabricated antennas are tested using Network analyzer N9926A. The measured results are good in agreement with simulated results. In future the measured radiation pattern will be obtained from Anochoic Chamber testing.

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