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DESIGN OF MULTIBAND MICROSTRIP PATCH ANTENNA USING SPLIT RING RESONATOR FOR APPLICATION IN C, X AND K_U BAND

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ABSTRACT

In this work three different microstrip antenna designs are investigated. The first design is a simple microstrip patch antenna. The second design is a multiband antenna and consists of the first structure microstrip patch antenna having a circular slot with one arm. The third design is also a multiband antenna. It is a modification of the second one and consists of a split ring resonator (SRR) loaded in the ground plane exactly behind the patch. The first structure resonates at 14 GHz. The second and third structures show four frequency bands at 5.8 GHz, 11 GHz, 13.4 GHz and 15.4 GHz, but there is an improvement in gain, bandwidth, return loss and VSWR by using an SRR in the third structure.

KEYWORDS: Microstrip patch antenna, metamaterial(MTM), split ring resonator (SRR).

INTRODUCTION

Antennas are indispensable component of any wireless communication device. An antenna is a transducer between the transmitter and the free space waves and vice versa. They efficiently transfer electromagnetic energy from a transmission line into free space. In recent years, demand for small antennas on wireless communication has increased the interest of research work on compact patch antenna design among communication engineers [1-3]. To support the high mobility necessity for telecommunication devices a small and light weight compact patch antenna is one of the most suitable applications. Microstrip patch antennas are fabricated on a dielectric substrate. These antennas can be embedded along with other components in a system. These antennas are widely used in communication systems because of their ease of analysis, less cost, light weight, easy to feed and their attractive radiation characteristics.one of the major disadvantage of patch antenna is narrow bandwidth and low gain.

To overcome these drawbacks we used an artificial homogeneous material called metamaterial. Metamaterials (MTM) are represented in terms of their medium properties, *viz*., DNG (double negative -both ε & μ are negative), DPS (double positive –both ε & μ are positive), ENG (epsilon negative) and MNG (μ negative). Metamaterials found applications in various fields including sensor detection, remote aerospace applications, public safety, high frequency battle field communication, improving ultrasonic sensors, solar power management and for high gain antennas (pendry, 2003; raj, 2007).

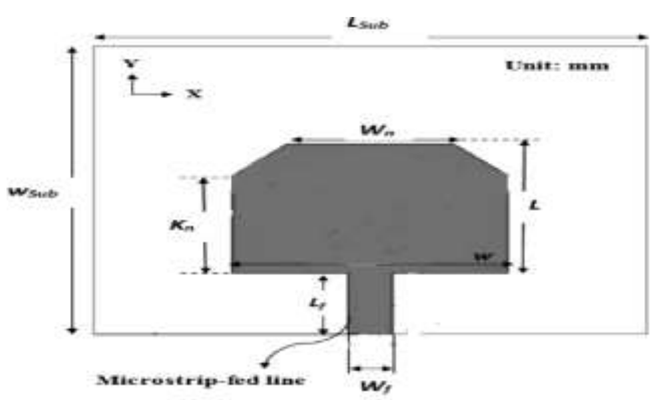


Fig 1. Geometry of the proposed antenna

So, the design methods of the miniaturized patch antenna with metamaterial technology have been reported by some authors, recently [4]. These would include the SRR or CSRR on the microstrip patch or in the ground plane. In other words, the achievement of size reduction of antenna with the SRR and CSRR has special meaning in the field of microstrip antenna [5-6]. In this paper, the miniaturized microstrip patch antenna with SRRs is presented.

LITERATURE SURVEY

In 1953, Deschamps first proposed the concept of the patch antenna [7]. Practical antennas were developed by Munson [8,9] and Howell [10] in the 1970s. The idea of metamaterials started with the veselago's proposal in 1968 [11]. He proposed a new type of material in which permittivity and permeability have simultaneously negative value and he showed the general electromagnetic properties of such material. J. In 2003 J. B. Pendry [12] in his paper exclaimed that Light bends the wrong way in materials where both ε and μ are negative. Smith et.al [13] demonstrate that a composite medium, based on a periodic array of interspaced conducting nonmagnetic split ring resonators and continuous wires, that exhibits a frequency region in the microwave regime with simultaneously negative values of effective permeability and permittivity. Singh et al. [14] focused on the use of metamaterials for the performance enhancement of microstrip patch antennas.

ANTENNA DESIGN AND METHODOLOGY

Design parameters

Figure 1. show the front view geometry and the structure designed on CST Microwave Studio software of proposed microstrip line fed patch antenna. The dimensions and feed point location for proposed antenna have been optimized so as to get the best possible impedance match to the antenna. The following parameters are used for design of proposed antenna.

Substrate permittivity = 4.9
Substrate used = FR4
Thickness of substrate =0.8 mm
Length of patch (L) = 9 mm
Width of patch (W) = 10 mm
Length of substrate = 20 mm
Length of substrate = 20 mm
Length of Ground (L_g)= 20 mm
Width of Ground (W_g)= 20 mm
Thickness of patch = 0.1mm
Thickness of ground plane = 0.1mm

Basic antenna design

The proposed slot antenna fed by a 50-Ω microstrip line is as shown in fig. 1, which is printed on an fr4 substrate, with dimensions of 20 (x -axis)× 20 (y -axis)× 0.8 mm^3 , permittivity 4.9, and loss tangent of 0.018 (structure 1). It can be fed by different methods like microstrip line feed, coaxial probe feed, aperture coupling, electromagnetic coupling and coplanar waveguide (CPW). In this work, microstrip line (50 ohm) feed has been used. The width of the microstrip feedline is fixed at W_f =1.3 mm.

Basic antenna with slots

The structure 2 consists of a modified rectangular radiation patch in structure 1, with novel shapes of slots as shown in fig. 2. A single-armed circular slot has been etched on the patch (structure 2). The dimensions of the patch are as shown in the table 1.

Table 1. Dimensions of the patch

Patch	
r1= 2.5	ps= 0.6
r2 =3	Rs= 8.5
W_n=6	W=10
K_n=6.75	L_f=4.25
L=9	Lg =20
W=10	Wg=20

Basic antenna with slots and SRR

The third structure consists of the same slotted antenna described above but the difference is in the groundplane, which is loaded with a split ring (structure 3).

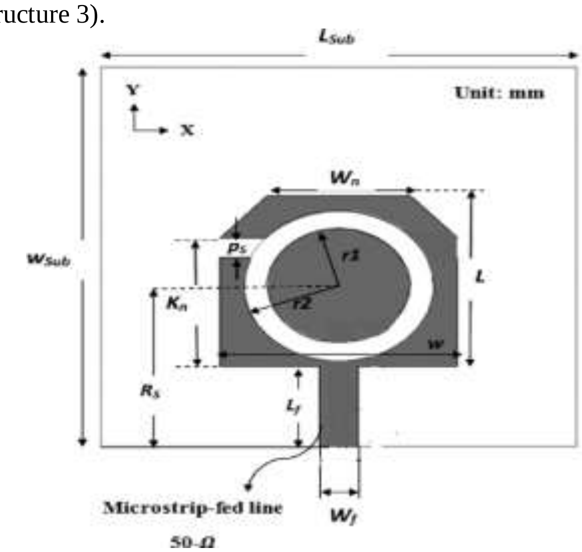


Fig 2. Geometry of the proposed antenna with novel shapes of slots

resonator (SRR). Metamaterial have an important role to improve the performance in devicessuch as antenna [15]. Metamaterial such as a split ring resonator (SRR) structure had been categorized as the structure or design that has simultaneously negative permeability and permittivity value[16]. The SRR is placed in the ground plane exactly behind the radiating patch. The metamaterial SRR loading reduces the mutual coupling between the slots of microstrip patch antenna [17]. The SRR consists of two circular or square rings with splits on opposite sides. The other shapes available are rhombic, spiral, Minkowski, open shape, H-shape, and omega shape[15]. The length and width of the SRR are length 9 mm and 10 mm respectively and the split gap width 1 mm. The gap between outer and inner ring is 1mm. Thickness of the ring is 0.5mm and material used for the ring is copper. The SRR is as shown in fig 3. The ground plane containing the SRR is as shown in fig 4.

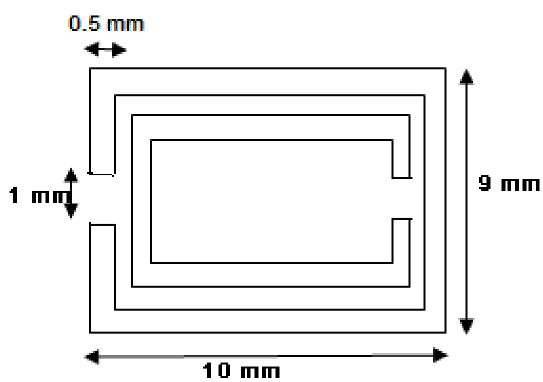


Fig 3. Structure of SRR ring

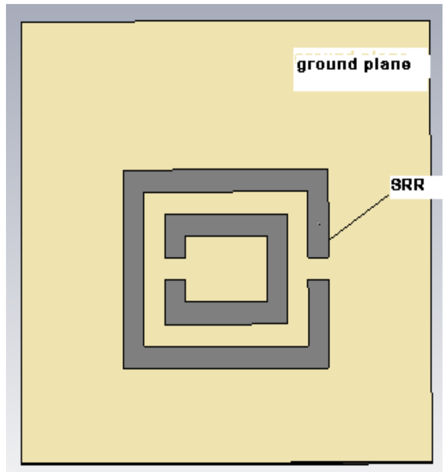
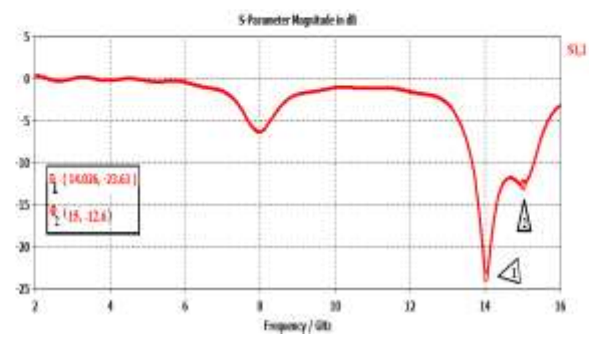


Fig 4. Ground plane containing SRR

RESULTS AND DISCUSSION

This experimental setup is designed and simulated in CST microwave studio. Capability of operating over wide frequency bands and good radiation characteristics lead to choosing a rectangular radiation patch as a basic structure of the slot antenna[16].



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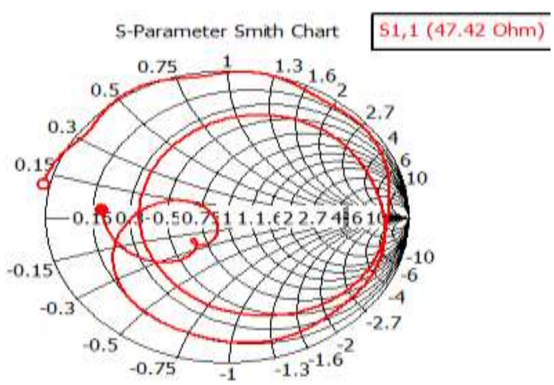

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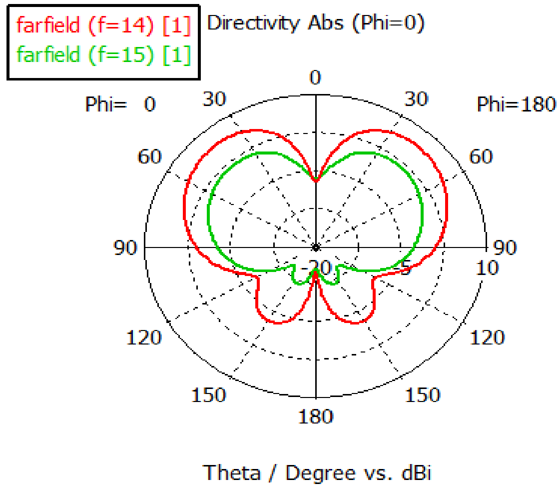

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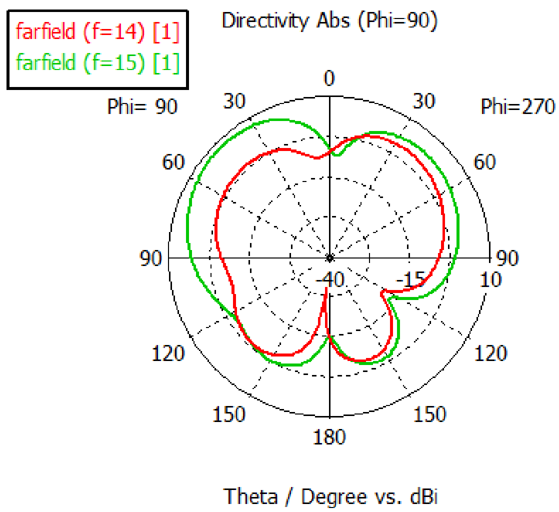

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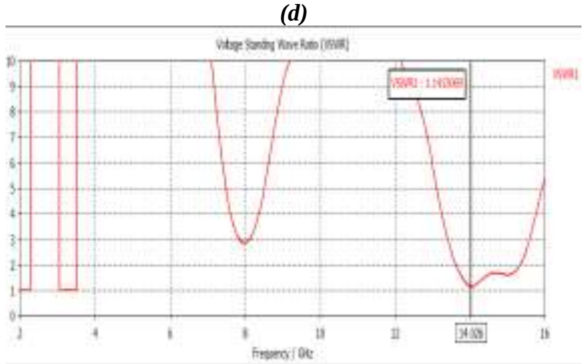
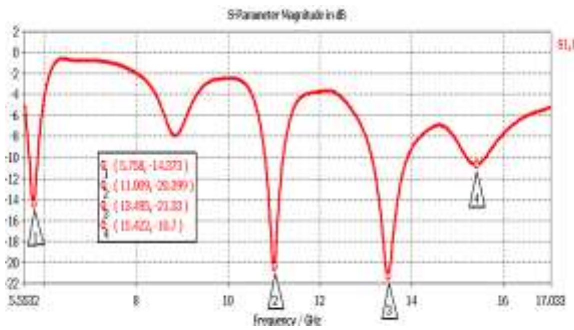


(e)

Fig 5. Structure 1 (a) return loss (s-parameter) plot, (b) smith chart (c) radiation pattern (elevation) at phi=0^0, (d) radiation pattern (elevation) at phi=90^0, (e) VSWR.

The simulated return loss (s-parameter) plot of the structure 1 is shown in fig 5 (a). As can be seen from fig 5(a) the antenna in structure 1 operates at 14 GHz and 15 GHz with a return loss of -23.61GHz and -12.6 dB. The bandwidth of the antenna is found to be 1.6 GHz. The smith chart for structure 1 is also shown in fig 5 (b) and shows that the input impedance is 47.42 ohm which is quite close to required impedance of 50 ohm, which is the ideal input impedance of the microstrip line feed. The elevation radiation patterns at phi=0^0 and phi=90^0 are shown in fig 5 (c) and (d). The gain of the antenna is found to be 3.634 dB. The VSWR ratio is 1:1.14 and 1:1.6 for 14 GHz and 15 GHz respectively is shown in Figure 5(e), which should lie in between 1 and 2.



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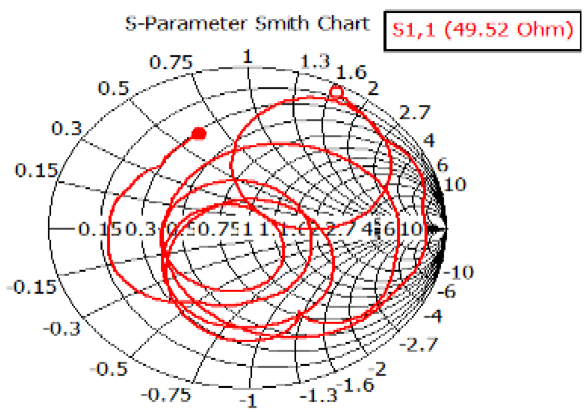

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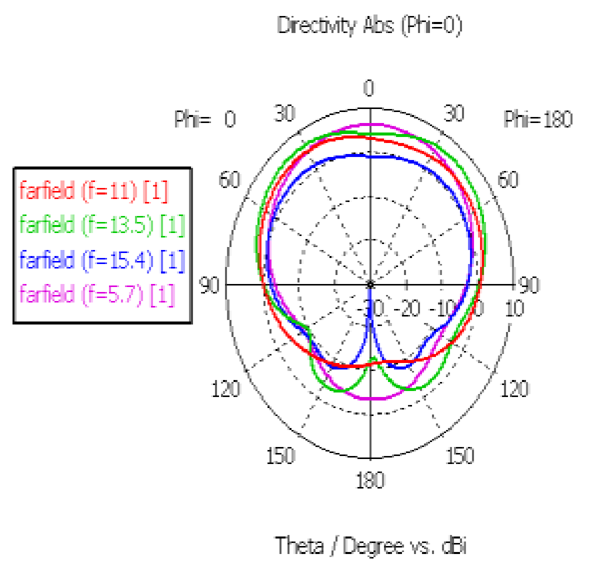

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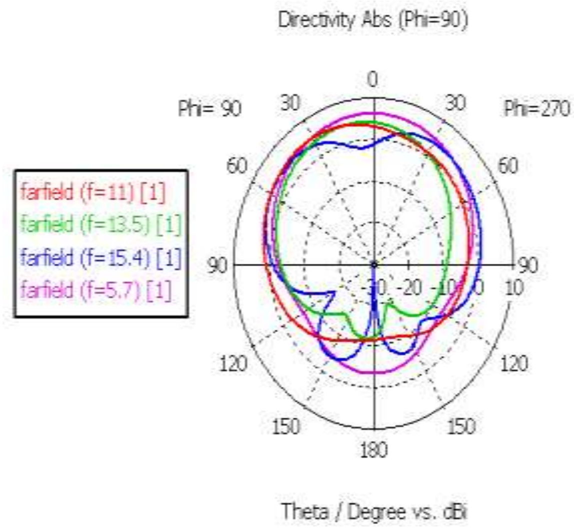
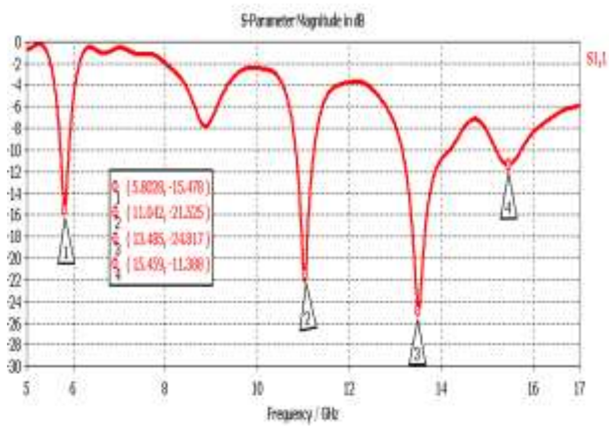


(d)

Fig 6. Structure 2 (a) return loss (s-parameter) plot, (b) smith chart (c) radiation pattern(elevation) at phi=0^0, (d) radiation pattern (elevation) at phi=90^0.

In structure 2 we added a circular slot with an arm to the patch. The simulated return loss (s-parameter) plot of the structure 2 is shown in fig 6 (a). As can be seen from figure the antenna in structure 2 operates at four frequency bands i.e. 5.8 GHz, 11 GHz, 13.5 GHz and 15.4 GHz .The smith chart for structure 1 is also shown in fig 6 (b) and shows that the input impedance is 49.52 ohm which is quite close to required impedance of 50 ohm, which is the ideal input impedance of the microstrip line feed. The elevation radiation patterns at phi=0^0 and phi=90^0 are shown in fig 6 (c) and (d).



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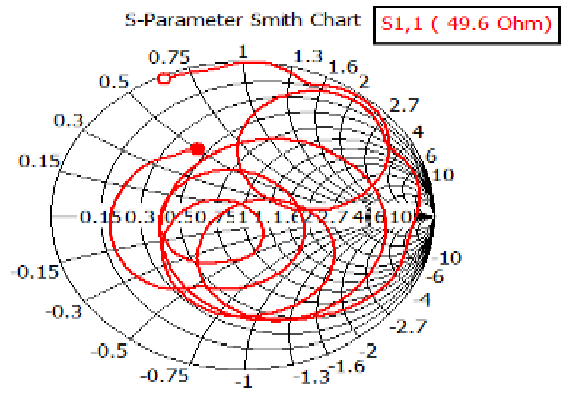

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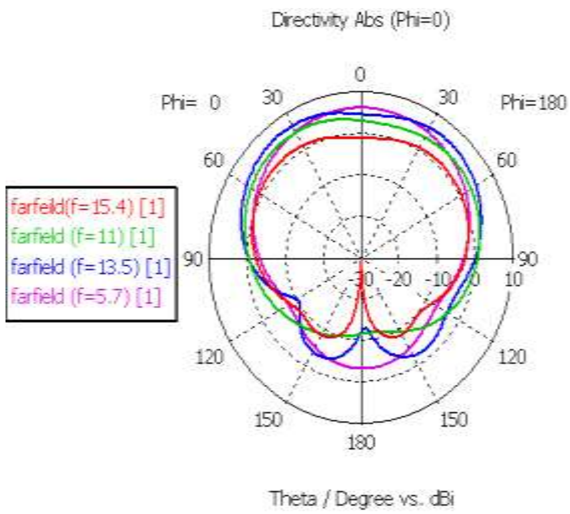

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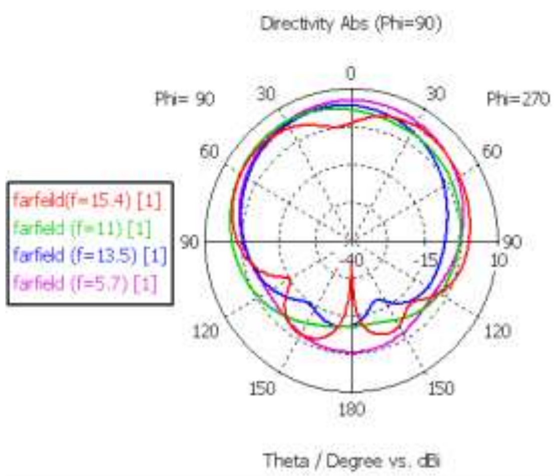

(d)

Fig 7. Structure 3 (a) return loss (s-parameter) plot, (b) smith chart (c) radiation pattern(elevation) at phi=0^0, (d) radiation pattern (elevation) at phi=90^0.

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Then we loaded the proposed antenna with SRR in the ground plane of the antenna giving the structure 3. Metal split-ring resonator (SRR) structure is positive-ε/negative-μ MTM. The return loss (s-parameter) for the structure 2 is shown in fig.7 (a). The structure 3 also resonates at the same frequencies as that of structure 2 but with improved antenna parameters. The
metamaterial SRR loading reduces the mutual coupling between the slots of microstrip patch antenna to obtain good impedance matching at the resonant frequencies. The smith chart for structure 3 is also shown in fig 7(b) and shows that the input impedance is 49.6 ohm. The elevation radiation patterns at phi=0^0 and phi=90^0 are shown in fig 7 (c) and (d).

Table 2. Comparative analysis of various antenna Parameters

Antenna type	**Frequency (GHz)**	**Return loss (dB)**	**Bandwidth (MHz)**
Structure 1	14.026	-23.6	1600
Structure 2	5.8 11.009 13.5 15.4	-14.3 -20.4 -21.3 -10.7	188 400 780 412
Structure 3	5.8 11.04 13.5 15.4	-15.5 -21.5 -24.9 -11.5	188 400 1040 545

Table 3. Comparative analysis of various antenna Parameters

Antenna type	**Frequency (GHz)**	**VSWR**	**Gain (dB)**
Structure 1	14.026	1.14	3.634
Structure 2	5.8 11.009 13.5 15.4	1.4 1.3 1.27 1.94	-1.1 0.09 3.65 2.1
Structure 3	5.8 11.04 13.5 15.4	1.45 1.2 1.19 1.8	0.05 0.24 3.9 2.4

As can be seen from table 2 and table 3 the bandwidth of the structure 2 at 13.5GHz and 15.4 GHz has improved from 780 MHz to 1040 MHz (7.7%) and 412 MHz to 545 MHz (3.6%) respectively. Also the gain has increased from negative to positive side for 5.8GHz band (-1.1dB to 0.5dB) and for other frequency bands too. The VSWR plot is also calculated for structure 2 and 3 as shown in fig 8. The VSWR is also improved in structure 3 than that in structure 2. Lower values have been attained for VSWR for the structure with SRR. The VSWR for all the three structures lie in between 1 and 2 which is the need for the antenna to radiate.

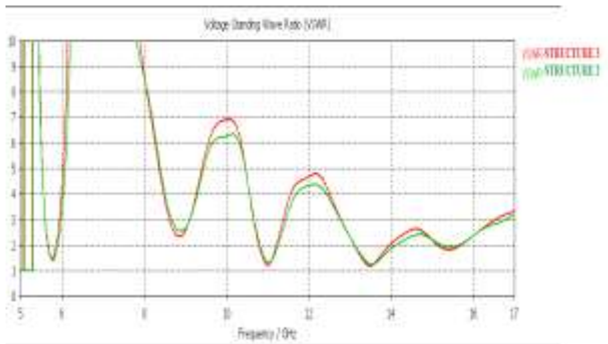

Fig 8. VSWR plot structure 1 and structure 2

CONCLUSION

The work focused on the analysis and design parameters of metamaterial inspired microstrip patch antenna. A compact multiband band microstrip antenna with improved bandwidth and gain using a split ring resonator design based on metamaterial technique has been presented. The proposed design helps to achieve improvement in the gain, bandwidth and VSWR. The results presented in this paper are promising design of compact antennas without having to sacrifice the antenna bandwidth.

The antenna has applications in the C (4-8 GHz), X (8-12 GHz) and Ku (12-18 GHz) band. The C-band contain frequency ranges that are used for many satellite communications transmissions, some Wi-Fi devices, some cordless telephones, and some weather radar systems. The X band is used for short range tracking, missile guidance, marine, radar and airborne intercept. The Ku band application include satellite communications, most notably for fixed and broadcast services, and for specific applications such as NASA's tracking data relay satellite used for both space shuttle and international space station (ISS) communications.

Future scope of metamaterials holds great Promise for new applications in the megahertz to terahertz bands, as well as optical frequencies This design can also further be improved by using the different structures of split ring resonator. We can also apply SRR rings to the patch of the antenna to improve the antenna Parameters in better way.

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