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Split Ring Resonator Based Wide Bandwidth Planar Inverted-F Antenna for Wi-Fi/WLAN Applications

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ABSTRACT

In order to accomplish the requirement of the wireless communication networks, a compact coaxial fed planar inverted-F antenna (PIFA) is designed and fabricated for Wi-Fi (5.15-5.825 GHz) applications. Fabricated antenna resonates at the operating frequency of 5.3 GHz with -10 bandwidth range of 4.7-6.24 GHz. The volume of fabricated antenna is 20mm × 20mm × 4mm. FR-4 used as substrate with $\varepsilon r = 4.4$ and copper sheet used as a patch and shorting port. SRR embedded on PIFA for bandwidth enhancement of antenna. High frequency structure simulator software is used for the simulation of antenna design. Antenna properties like bandwidth, gain and return loss are used for the performance comparison of design. Performance analysis of split ring resonator (SRR) is also simulated with two slots at same and both axis on the double ring.

Keywords: HFSS, PIFA, Return loss, Slots SRR, VSWR

1. INTRODUCTION

Antennas are a structure which works as a transducer. It converts voltage and current in the electric and magnetic field, act as a bridge between the transmission line and air. Working principle of the antenna is similar to speaker or microphones with acoustic energy. Growths of portable devices and small equipment are forcing to focus on size and bandwidth of antennas [1]. So, in order to meet the requirements, a high bandwidth miniaturized antenna should be designed. Applications such as Wi-Fi, navigation, speed detection, and weather monitoring are a compact light weighted required an antenna with high bandwidth [2].

Planar inverted-F antenna is widely used in the mobile phone because of its qualities as low profile, light weight, low cost, ease of fabrication. PIFA has also more advantage microstrip patch antenna like high gain, wide bandwidth and low SAR. SAR is specific absorption rate which defines that the interaction of antenna is less with the human body. SAR is an important quality of PIFA which boost the implementation of this antenna in mobiles and other equipment [3]. The designed antenna operates in C band range from 4-8 GHz of electromagnetic spectrum defined by IEEE standards.

PIFA is also known as quarter monopole antenna due to the shorting plate which reduces the length of the antenna. The main advantage of planar inverted F antenna is that the input impedance of antenna depends on the distance of feed point from the ground due to this the input impedance of antenna matched by adjusting the height of the shorting plate. The planar inverted F antenna has the advantage of compactness and impedance matching capacity due to air gap/shorting [3, 4].

There are various methods and techniques used to enhance the bandwidth of the antenna such as slotting, defected ground structure, meandering, defining different shapes and size of the radiating element. Antenna performance can also be improved using different electromagnetic materials with their specific dielectric

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values [5]. The bandwidth of planar inverted-F antenna is more due to air gap presence because of this air gap antenna has two dielectric medium. The bandwidth of the antenna can be enhanced by loading split rings/slots or both [7].

Split ring resonator is a set of two or more rings with the same centre coordinate made up of non-magnetic materials such as copper. There is gap provided between rings. Slits are etched on the rings preferably opposite sides. SRR can be in any shapes like square, rectangular, ring, triangular and ohm-shaped structure [6]. It has the property of negative reflective index similar to the metamaterials. Reflective index depends on permittivity εr and permeability μr. If either εr or μr is negative value then the material is known as epsilon negative metamaterial (ENG) or mu negative metamaterial (MNG), also known as single negative metamaterial (SNG) [4]. If μr and εr both have negative values then the material is known as double negative material (DNG).

Complimentary split ring resonator (CSRR) can also be used in place of split ring resonators (SRR). CSRR/SRR reduces the quality factor Q of design by which bandwidth of the antenna is enhanced [7, 13]. There is an inverse relation between quality factor and bandwidth.

In this paper, a compact coaxial fed planar inverted-F antenna is proposed. Split ring resonator is embedded on it to enhance the bandwidth of antenna design. This paper has several parts with different work. Section I for the introduction, Section II for antenna design structure, section III for result and discussions and Section IV for the conclusion of final work.

2. ANTENNA DESIGN STRUCTURE

2.1. Conventional Antenna Design

Planar inverted F antenna design contains four layers, ground, substrate, air gap in the form of shorting port and patch. The thickness of the substrate is 1.6mm with the dielectric property of εr = 4.4. Antenna has an air gap of 2.4 mm. So the total height of antenna design is H=4mm. The length, width of patch and height of shorting port are calculated from following equation written below

$$L_1 + L_2 - W = \frac{\lambda}{4} \tag{1}$$

$$fr = \frac{c}{4(L - W)} \tag{2}$$

$$L = L_1 + L_2 \tag{3}$$

The size of length L_1 and width L_2 of patch and height of shorting plate H optimized for the 5 GHz of operating frequency are 12mm, 8mm and 4mm. Coaxial feed uses with radius 0.7 mm for the antenna. Feed point is 5 mm away from the shorting plate denoted by D in Figure 1. The width of the shorting port is 6mm. The total size of the antenna is 20mm × 20mm × 4 mm shown in Figure 1. The dimension of the conventional simulated antenna design is mentioned in Table 1 with is notation which is used in Figure 1.

Table 1
Conventional Antenna Dimension

Parameter	*Value (mm)*	*Parameter*	*Value (mm)*
L_s	20	D	5
W_s	20	W	6
L_1	8	H	4
L_2	12		

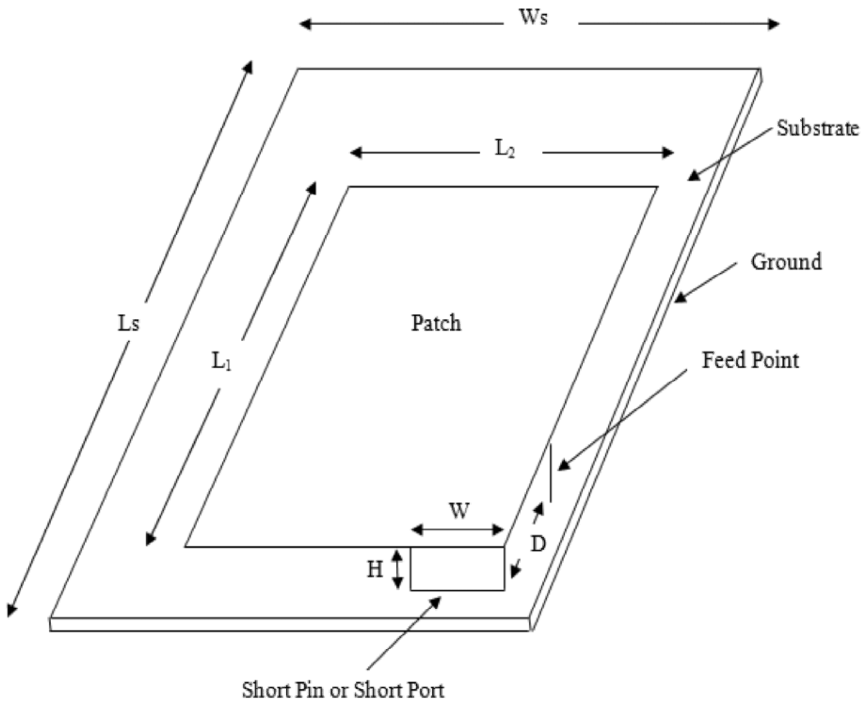


Figure 1: Conventional PIFA Design

2.2. Proposed Antenna Design

The proposed antenna has identical to conventional antenna design. In the proposed antenna design split ring resonator embedded for the enhancement of bandwidth. Antenna parameter of the proposed antenna analyzed with double and four slit on the double ring. The radius of the inner ring is r_1, r_2 and the radius of the outer ring is r_3, r_4. The centre of rings is identical. There is small gap d is provided between the rings. There is double slot present on each ring at same side. The size of the slot is g=2 mm. The thickness of rings is c=1 mm. The radius of rings are r_1=2 mm r_2=3 mm r_3=4 mm and r_4=5 mm. Rings are centered at the position 2mm × 2mm from the centre point of the antenna. Proposed antenna resonates at the frequency of 5.05 GHz. The top view and 3D view of proposed antenna are shown in Figure 2 and in Figure 3.

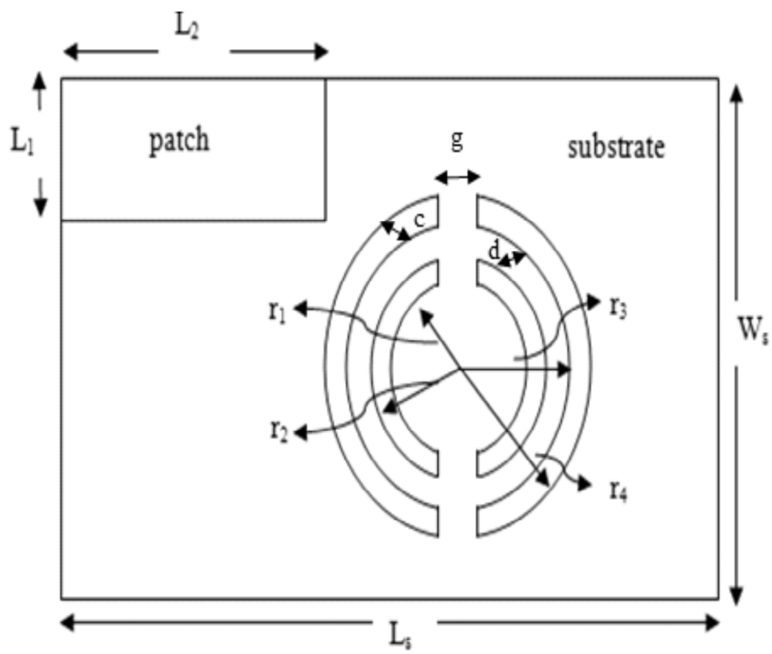


Figure 2: Top view of proposed antenna design

The operating frequencies of proposed and conventional planar inverted F antenna are 5.05 GHz and 5.1 GHz shown in Figure 4.

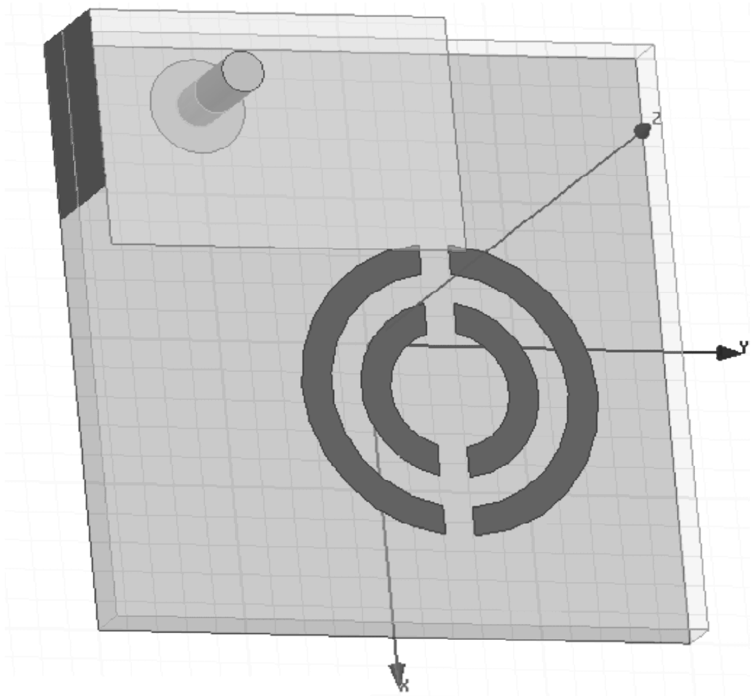


Figure 3: 3D view of proposed antenna design

Figure 3. shows the 3D view of proposed planar inverted F antenna embedded with two SRR rings in which total four slots are introduced. The proposed antenna also fabricated with substrate FR-4 which has a resonating frequency of 5.3 GHz and 6.04 GHz.

3. RESULTS AND DISCUSSIONS

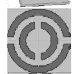
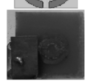
Conventional and the proposed structure of planar inverted F antenna are simulated with the help of high frequency Structure simulator. Antenna parameters such as bandwidth, gain and return loss are used for the comparison of the simulated antenna designs and fabricated antenna structure mentioned in Table 3. Dual ring structure with two slots used to enhance the bandwidth of planar inverted F antenna. Conventional PIFA has a bandwidth of 1.68 GHz with a gain of 7.18 dB and it has a return loss of -29.93 dB.

PIFA load with two slots at both axis has a bandwidth of 1.49 GHz. There is a decrement in bandwidth compare to conventional antenna design because the increase of capacitance due to ring and mutual coupling effect. Split ring resonator is embedded on conventional PIFA for bandwidth enhancement. For this double ring is introduced in the antenna design. Two slots at the same axis and two slots at both axis are etched on the double ring.

The proposed antenna design is fabricated with the help of FR-4 substrate with the dielectric property of 4.4 mm and height of substrate is 1.6mm. 2.4 mm air gap is provided to antenna between substrate and patch layers. The measured antenna resonates at the frequency of 5.3 GHz and 6.04 GHz shown in Figure 4. The fabricated antenna has a bandwidth of 1.54 GHz.

Degradation in bandwidth and frequency shift in fabricated antenna as compared to the conventional and proposed antenna is because of fabrication error, SMA connector mismatching with patch and shorting defect with the ground plane. Measured antenna has a return loss of -28.6 dB marked in Figure 4. Measured antenna has 28.15% bandwidth of centre frequency. Fabricated antenna is shown in Figure 6.

Table 2
Comparision Between Antenna Structures

Antenna design	*Ring structure*	*Band width (GHz)*	*Gain (dB)*	*Return loss (dB)*
Basic PIFA		1.68 (4.24-5.92)	7.18	-29.93
slot at both axis		1.49 (4.2-5.69)	7.17	-34.78
slot at same axis		1.95 (3.9-5.85)	7	-22.75
Measured value		1.54 (4.7-6.24)	-	-28.6
[12]	-	0.30 (5.15-5.35 & 5.725-5.825)	-	-

From Table 2, comparison of different designs of an antenna made on the basis of antenna parameters such as bandwidth, gain and return loss. Fabricated antenna also compared from [12] which operates in 5 GHz frequency band. It has a bandwidth of 300 MHz which is a summation of two frequency bands, 200 MHz bandwidth of band 5.15-5.35 GHz and 100 MHz bandwidth of band 5.725-5.825 GHz. These values show that the measured antenna has wider bandwidth compared to the paper antenna design.

Return loss for the conventional antenna, proposed antenna and measured antenna structures are compared through graph shown in Figure 4. In Figure 4. The solid line graph shows the conventional antenna design, dotted used for proposed antenna and dashed line is used for the measured antenna design. There is gain frequency plot of proposed antenna design for the resonating frequency 5.05 GHz shown in Figure 5. The gain of the antenna at the additional frequency is 4.82 dB.

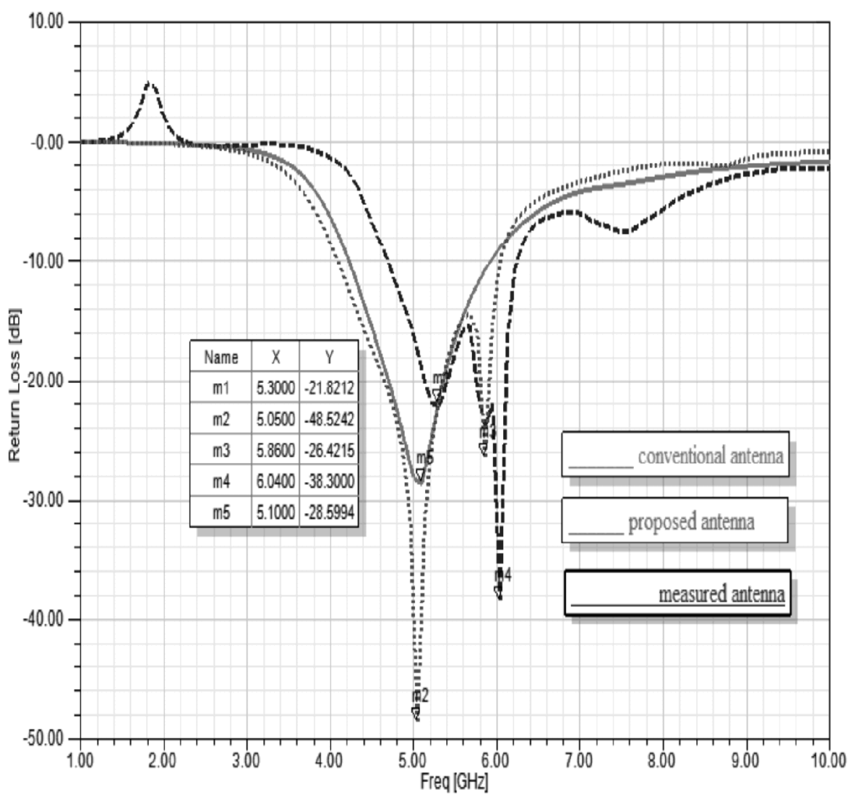


Figure 4: Comparison of return loss and bandwidth for conventional, proposed and fabricated antenna design

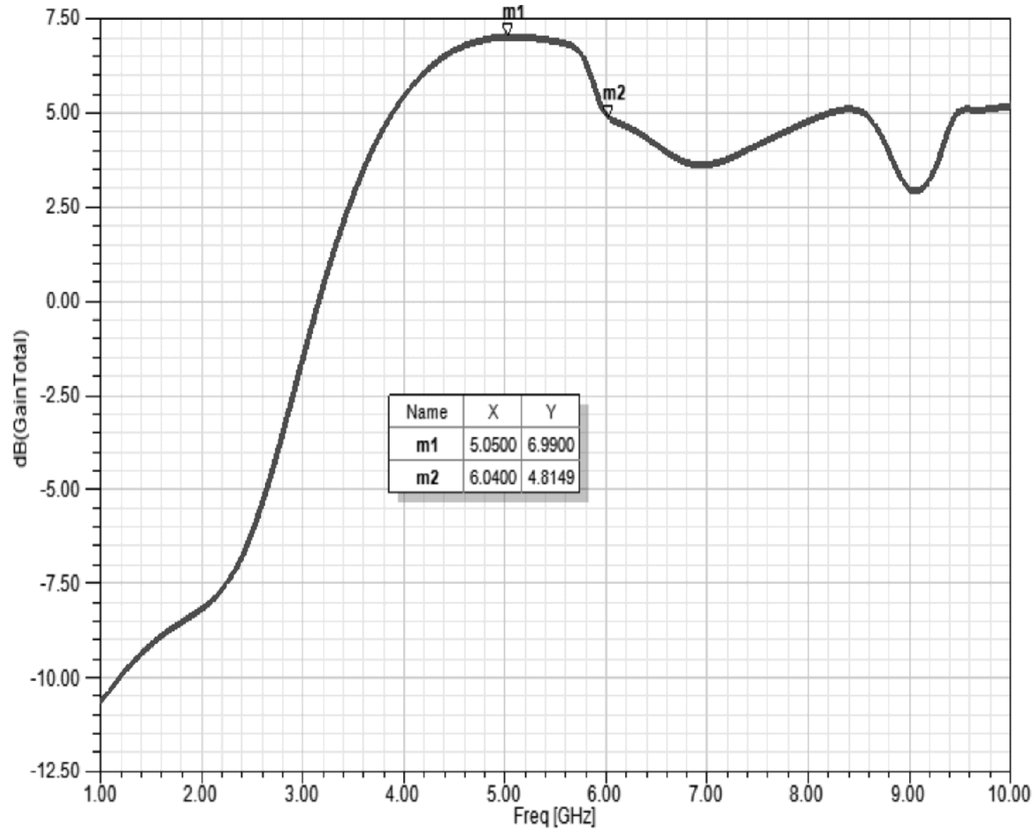


Figure 5: Frequency vs. Gain plot for proposed antenna design

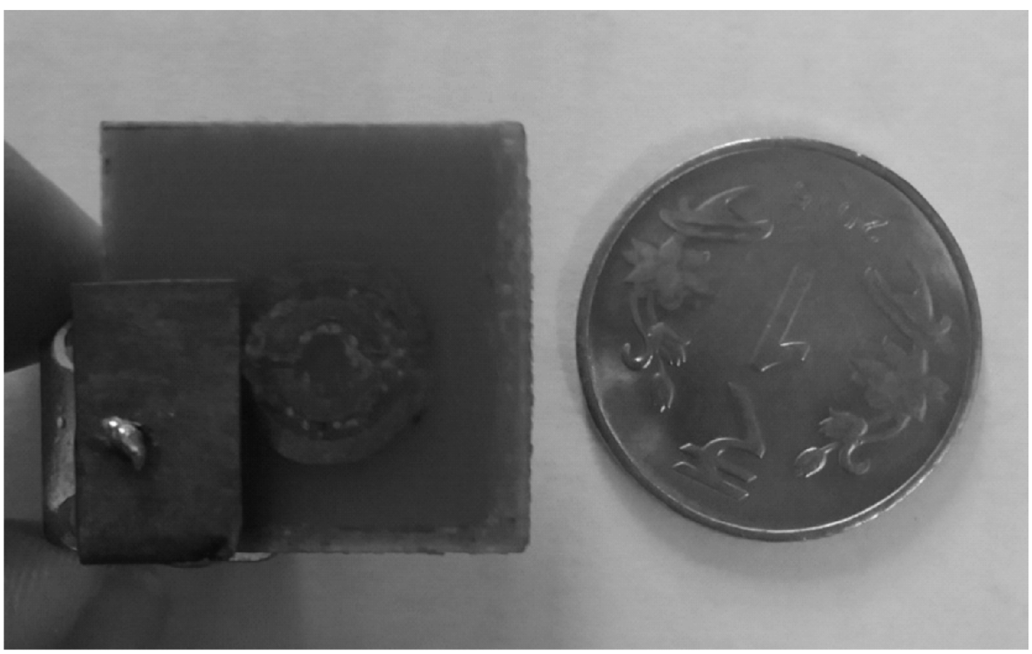


Figure 6: Fabricated Antenna Design

Figure 7. shows the vector current distribution over the patch area. Red arrows show strong current distribution area and blue arrows show weak current distribution area. Strong current distribution is near the feed point and it is due to the feed of antenna on the patch and split ring resonator. Because inserting slots in antenna design increases the electrical length which increases current distribution.

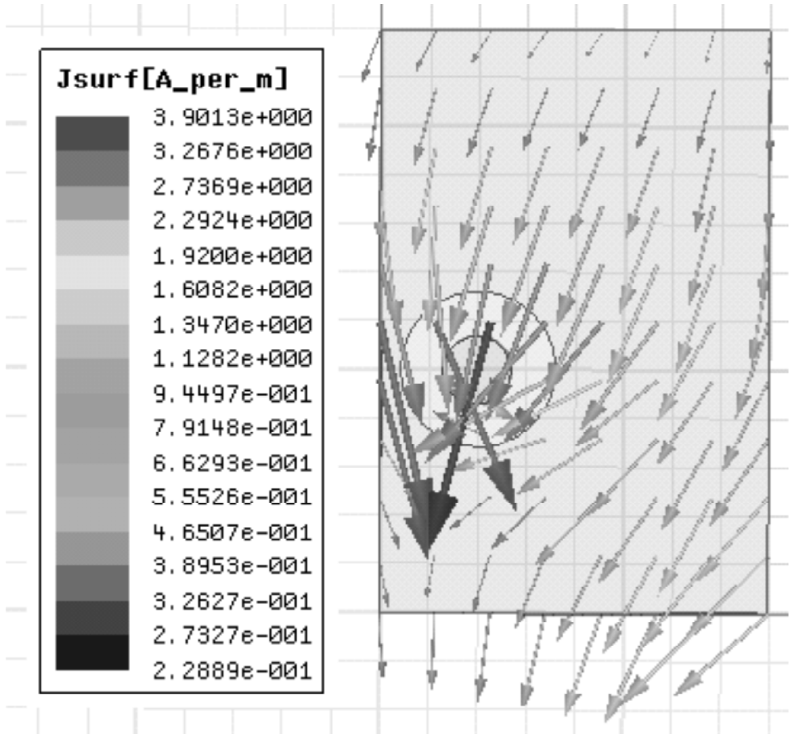


Figure 7: Vector current distribution on patch

4. CONCLUSION

In this paper, a compact antenna is designed and fabricated for Wi-Fi (5.15-5.825 GHz) applications. Fabricated antenna resonates at the operating frequency of 5.3 GHz with -10 dB bandwidth range from 4.7-6.24 GHz. Split ring resonator is embedded on the planar inverted F antenna. The proposed antenna has a gain of 7 dB. Two and four slots on the dual ring are for the antenna parameters such as gain, bandwidth and return loss. Vector current distribution is also finding over the patch for proposed antenna structure. Measured value of PIFA embedded with SRR design is also compared with paper which shows that antenna has a wide bandwidth.

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