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RESEARCH PAPER

Variable length SDP antenna using SRR for dual-band operation

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Abstract

The performance of SDP antenna can be improved significantly by using SRR. A conventional SDP antenna comprises a ground reflector and two dipoles of different lengths, which are connected in serieswith a transmission line. In this work, a design is proposed to improve the performance of the conventional SDP antenna by adding SRR. Firstly, a traditional SDP antenna which is devised by adjusting the length of dipole and the distance between both the dipoles to function in the range of 1.8-2.62 GHz. Further, a pair of split ring resonator (SRR) is mounted above the first dipole to improve the antenna performance. Then the effects of SRR on different parameters like bandwidth, impedance and gain are examined. The proposed design is developed using FR4 glass epoxy substrate having a dielectric constant value of 4.4. The simulation results show that the gain of the proposed antenna design is increased. The antenna is simulated and parameter measurement is performed using CST microwave studio. The designed antenna can be used for GPS, WIFI, WiMAX and other multiband applications.

1. Introduction

Microstrip antennas (MSA) are one of the best suitable examples of such radiating systems. The Microstrip Antenna can be optimized using various methods. Optimization is centered around either reducing the dimensions of MSA to maintain the similar gain over a similar impedance band or by increasing the different parameters of MSA like, impedance, beam-width, efficiency, gain, multiple band and bandwidth [1]. Also optimization of microstrip antenna can be obtained by using Split Ring Resonator (SRR). But all designing techniques of microstrip antenna give small bandwidth. Therefore, to increase the antenna performance in terms of dimensions, functionality and applications, various printed antennas design has been proposed [2]. Printed antenna designs are widely used in radio systems and wireless applications because these antennas have simple structure, cheap and high bandwidth. Among distinct printed antennas, series fed dipole pair antennas are widely used because antenna using integrated balun provides high bandwidth and stable gain. Series fed dipole pair antenna are connected in series due to its serially feeding mechanism they produced endfire radiation. Split Ring Resonator is a couple of concentric annular rings, both the rings are split opposite to each other. Split ring resonator behaves such as a small magnetic dipole, which is used to increase the magnetic response of an antenna. SRR is utilized to enhance the performance of an antenna in many applications [3]. Antenna using SRR can be tuned to different frequencies inside the constrained band by changing the number of SRR Unit Cells. Using this property sub-wavelength antenna can be designed easily [4]. Multi band operation can be obtained using SRR. A double-band SDP with SRR working in the GPS (global positioning system) L1 (1.563– 1.587 GHz) and 1.7–2.8 GHz frequency range was implemented and the effect of SRR was presented [5]. Multiple bands were achieved by designing a monopole SRR antenna which access different application of wireless communication by adjusting the point SRR [6]. Triple band operation is achieved by designing the asymmetric monopole SRR antenna. The use of coupling between radiating element and SRR is responsible for multi band operation [7].

In the first part of the proposed work, a conventional series fed dipole pair antenna implemented for a frequency range of 1.8-2.62 GHz by adjusting the length of the dipoles and the space between them. Analysis of obtained results shows that the antenna has low gain and small bandwidth. In the next part, a couple of SRR is used to enhance the performance of SDP antenna in terms of bandwidth and gain. The proposed design has dual band operation as compared to single band conventional antenna.

2. Antenna Design

The designed antenna using Split Ring Resonator (SRR) is represented in fig.1. A traditional series-fed dipole pair antenna comprises of two dipoles represented as P1 and P2 respectively and a ground reflector named as Ro. Both the dipoles are of distinct length. The length and width of P1 are $\mathrm{Y_1}$ and $\mathrm{N_1}$, respectively, and those of P2 are $\mathrm{Y_2}$ and $\mathrm{N_2}$, respectively. The length and width of reflector are $\mathrm{P_g}$ and $\mathrm{P_0}$, respectively. The separation distance between reflector and P1 is $\mathrm{X_1}$ and that between P1 and P2 is $\mathrm{X_2}$. The components of the conventional antenna are associated in series using a CPS line. An incorporated balun between the microstrip (MS) line and CPS line is actualized on the CPS line to coordinate the input impedance of the antenna with the 50 Ω feed line and the end of the MS line is shorted with a shorting pin at the feeding point. The width of the CPS line and slot line are denoted as $\mathrm{N_{cps}}$ and

P_s respectively. The length and width of the MS feed line is N_f and Y_f, respectively and the MS feed is offset from the center at a distance of P_f.

In the proposed work, a couple of split ring resonator is affixed above the dipole 1 of the conventional antenna. The distance between ring and P1 is D_s .The ring is splitted along the P1. The length and width of outer ring is Ld and Wd respectively and the gap between each ring is g_d. FR4 glass epoxy substrate having a thickness H = 1.6 mm and a dielectric constant of 4.4 is used for the proposed design. L and W are the length and width of substrate respectively.

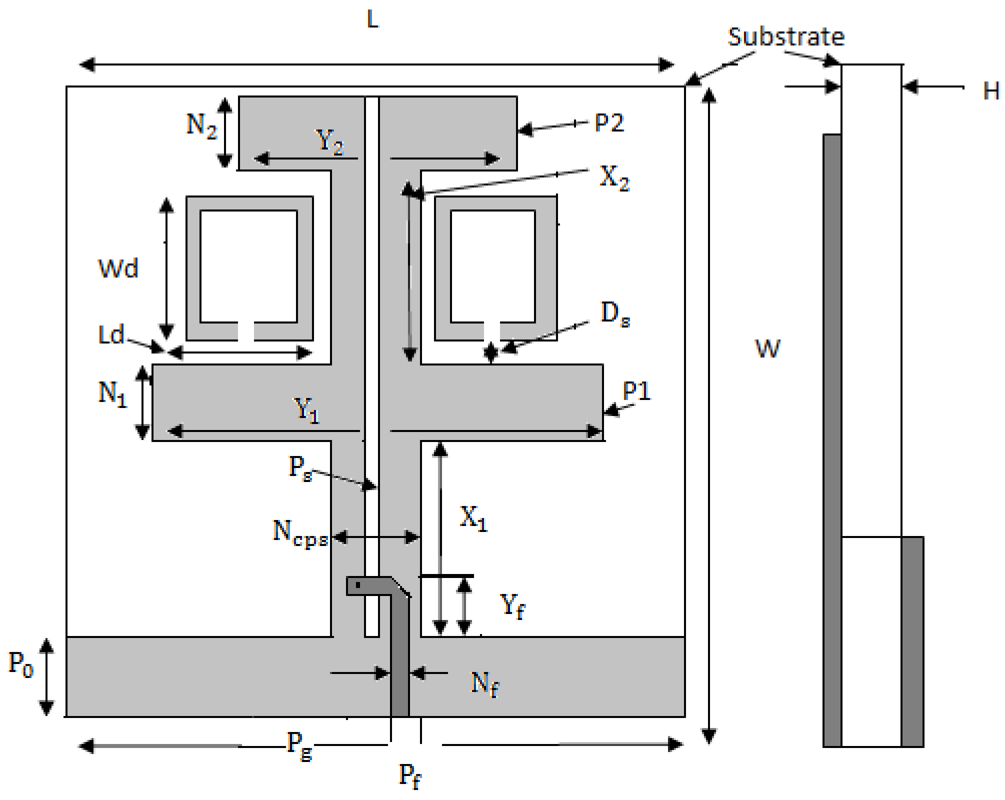

Fig: 2.1 Design of conventional antenna using SRR

At first, a traditional antenna, which will be utilized as a base antenna, is intended for operation in a frequency band of 1.8-2.62 GHz. Then, the measurements of the split ring resonator director are enhanced to give double band operation in the 1.53-1.61 GHz and 2.01-2.74 GHz frequency range. Table 2.1 shows the parameter values of the conventional SDP and SDP using SRR design. For the Conventional antenna, the frequency range for a VSWR < 2 is 1.69– 2.80 GHz and gain ranges 5.99-5.13 dB in this frequency range. For the proposed work, the value of gain is 7.75 dB and 6.49 dB at 1.58 GHz and 2.6 GHz, respectively.

Mathematical expression-

There are a number of calculations step that are useful when simulating the antenna-

1. **width calculation-**

$$\text{Width (W)} = \frac{C_0}{2f_r}\left(\frac{\varepsilon_r+1}{2}\right)^{-1/2}$$

2. **Calculation of Dielectric Constant**

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+12\frac{h}{W}\right)^{-\frac{1}{2}}$$

Where ε_r- Dielectric constant of the substrate

h- Height

w- Width of the substrate

3. **Length of the rectangular patch**: -

$$L = \frac{c}{2f_r\sqrt{\varepsilon_r}}$$

Where c represents speed of light

f_r- Resonant frequency of the antenna

4. **Extension Length (ΔL)**

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)}$$

5. **Actual length of the patch**

$$L = L_{eff} - 2\Delta L$$

Table 2.1 design Parameter values of conventional and proposed antenna design

Parameter	Value [mm]		Type
	Conventional Antenna	Proposed Antenna	
H	1.6	1.6	Substrate Height
Y_1	72	72	Length of dipole 1
Y_2	50.4	50.4	Length of Dipole 2
P_g	90	90	Reflector Length
X_1	36	36	Distance between reflector and dipole 1
X_2	36	36	Distance between dipole 1 and dipole 2
W	115	115	Width of substrate
N_1	7.5	7.5	width of dipole 1
N_2	7.5	7.5	Width of dipole 2
R_0	0.5	0.5	outer radius of feed
Ncps	20	20	Width of solid
g_d	-	3	Distance between D_s1and D_s2
Wd	-	18	Width of outer ring
Ld	-	18	Length of inner ring
w_d	-	15	Width of inner ring
l_d	-	15	Length of inner ring
Po	15	15	Width of reflector
D_s	-	13	Distance between outer Ring and dipole 1
P_s	0.7	0.7	Width of centre line
N_f	-	3	Width of MS
P_f	-	3	MS offset distance from centre
Y_f	-	23	Width of MS

3. Results and Discussion

The proposed work is simulated and measured on CST software.

3.1. S- Parameters:-

It describes the relationship of input and output between the terminals in the electrical system. It shows how much power has reflected at the transmitter and also known as return loss. All the power is transmitted back when the value of s-parameter is equal to zero. The antenna resonates at 1.8 GHz and 2.62 GHz and the values of s-parameter at these two frequencies are -13.192 dB and -29.273 dB respectively. The s-parameter graph of a conventional antenna is as illustrated in fig: 3.1 which show that less power is transmitted to the antenna and more transmitted power is reflected back from the antenna.

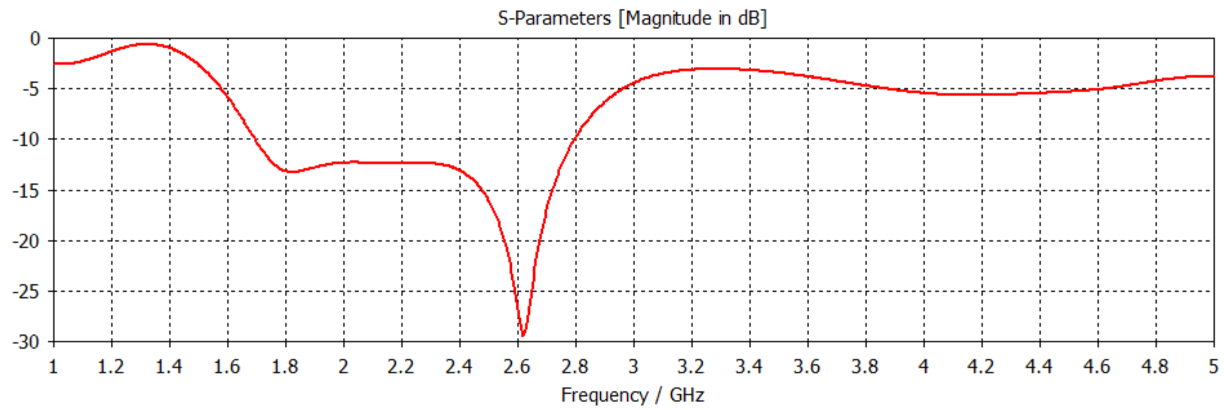

Fig: 3.1 return loss graph for conventional antenna

The proposed design resonates at 1.58 GHz and 2.6 GHz and the values of the reflection coefficient at these frequencies are -31.15 dB and -15.35 dB, respectively. The graph of s-parameter for proposed design is as illustrated in fig: 3.2 which show that more power is transmitted to the antenna and less transmitted power is reflected back from the antenna.

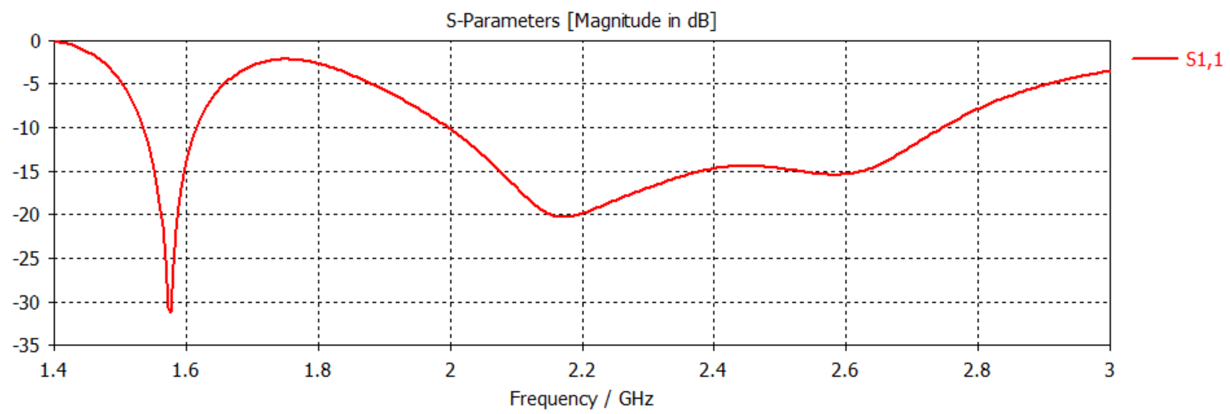

Fig: 3.2 return loss graph for proposed antenna

3.2. VSWR (Voltage Standing Wave Ratio)

It is defined as a voltage measured along a transmission line. Antennas have a real and positive value of VSWR. If the value of voltage standing wave ratio is small then the antenna is coordinated with the transmission line and power is reflected from the antenna is less. When the receiver end antenna is not matched most of the power is reflected. The ideal value of VSWR is 1.0 for which no power is reflected from antenna and voltage has a constant magnitude. The value of VSWR should be less than 2.0. If VSWR is greater than 2.0, then more power will be reflected which can damage the radio also it cause signal distortion. For a conventional antenna, the values of VSWR are 1.56 and 1.07 at 1.8 GHz and 2.62 GHz frequency, respectively as illustrated in fig: 3.3. For these values of voltage standing wave ratio, the power reflected from the antenna is more and delivered power at the receiver point is less.

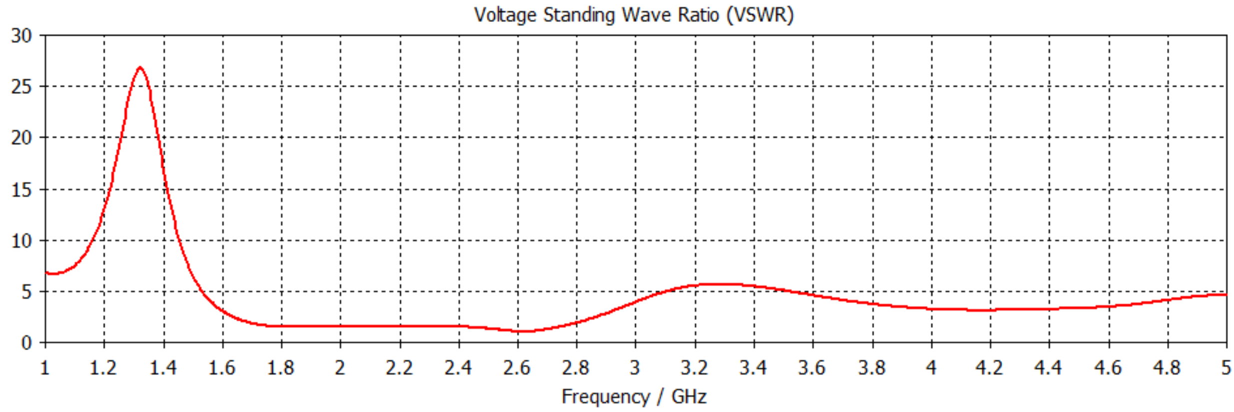

Fig: 3.3 Graph of VSWR for conventional antenna

For the proposed work, the values of VSWR are 1.05 and 1.4 at 1.58 GHz and 2.6 GHz frequency, respectively as illustrated in fig: 3.4. For these values of voltage standing wave ratio, the antenna is coordinated with the transmission line and the power delivered to the receiver is more and reflected power to the transmitter is less.

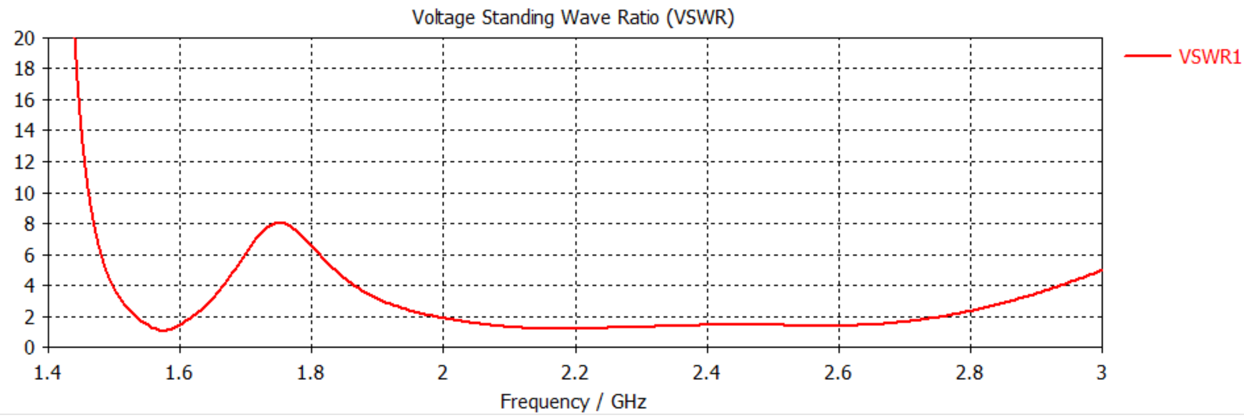

Fig: 3.4 Graph of VSWR for proposed antenna

3.3. Far-field

Most of the antennas are operated in this region. This is the region where radiation pattern does not change shape with distance. In this field radiated field is dominated and E and H-field both are orthogonal to each other. It represented the gain and directivity of the antenna.

3.3.1. Gain

The gain of an antenna is described as how much power is transmitted in the direction of maximum radiation to that of the isotropic source. Sometimes it is considered as a function of angle where the magnitude of the pattern is measured in antenna gain. The 3-d plot of gain is also known as radiation pattern. It is a key performance which combines electrical efficiency and antenna directivity. For conventional antenna design it is 5.99 dB and 5.13 dB at 1.8 GHz and 2.62 GHz frequency, respectively as illustrated in fig: 3.3 and fig: 3.4 -

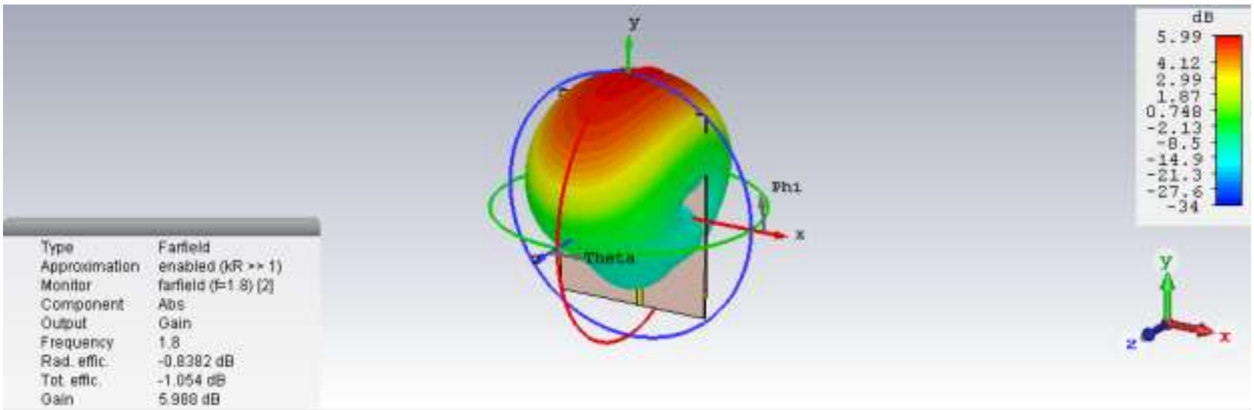

Fig: 3.5 Gain plot for conventional antenna at 1.8 GHz

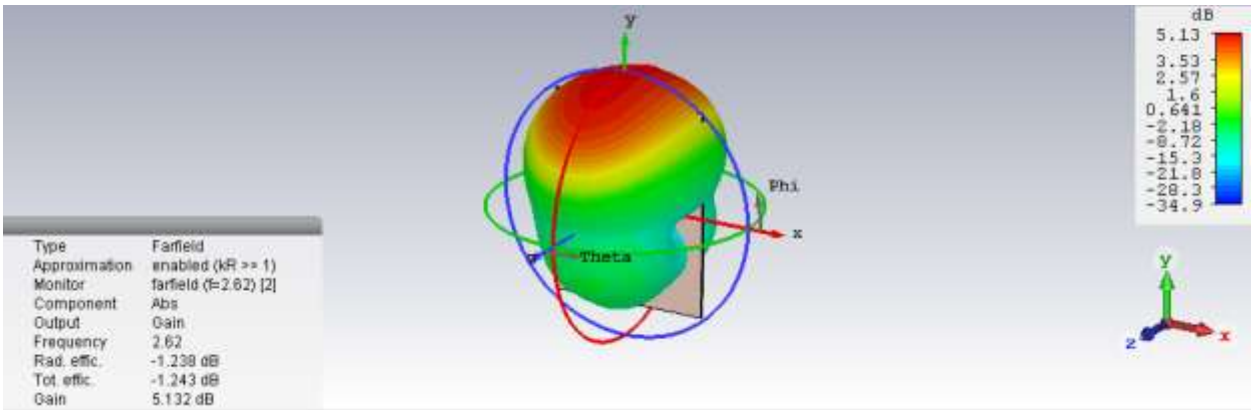

Fig: 3.6 Gain plot for conventional antenna at 2.62 GHz

For the proposed antenna design it is 7.75 dB and 6.49 dB at 1.58 GHz and 2.6 GHz frequency, respectively as illustrated in fig: 3.7 and fig: 3.8-

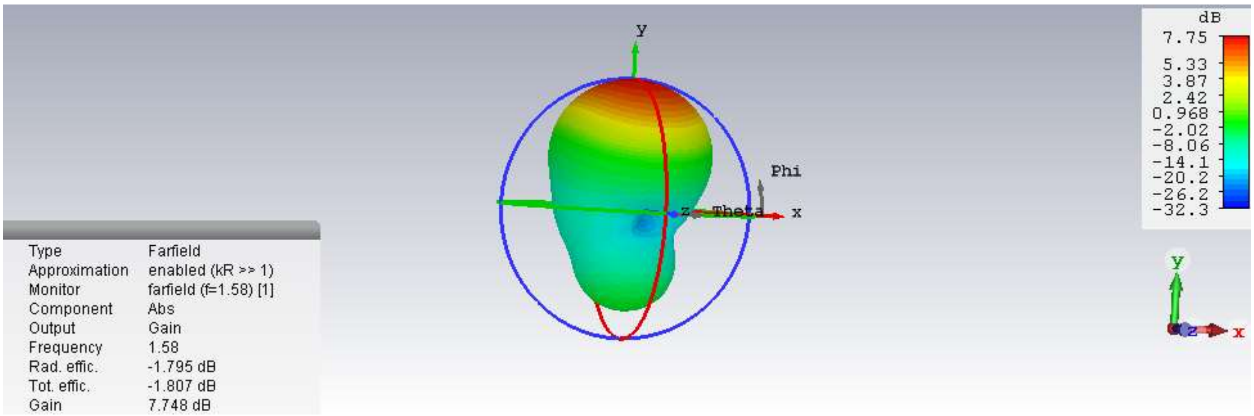

Fig: 3.7 Gain plot for proposed antenna at 1.58 GHz

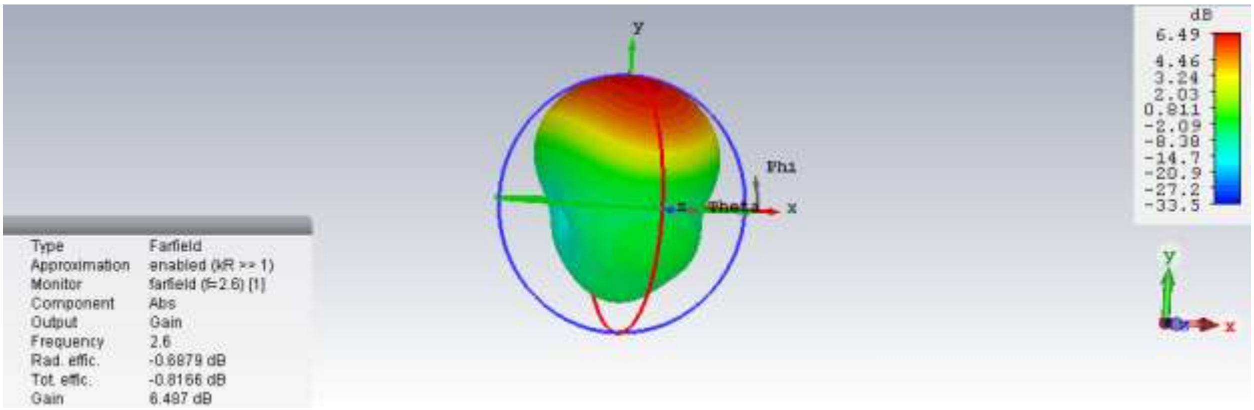

Fig: 3.8 Gain plot for proposed antenna at 2.6 GHz

3.3.2. Directivity

The directivity of an antenna is the ratio of radiation intensity averaged all over the direction to the radiation intensity in a given direction from the antenna. The directivity, in a measure of radiation of the antenna in preferred direction than a mythical isotropic radiation than both, is fed with the same total power. For the conventional design, directivity is 6.83 dBi and 6.37 dBi, respectively. The result in fig: 3.9 and fig: 3.10 show that the radiated power in the desired direction is very small.

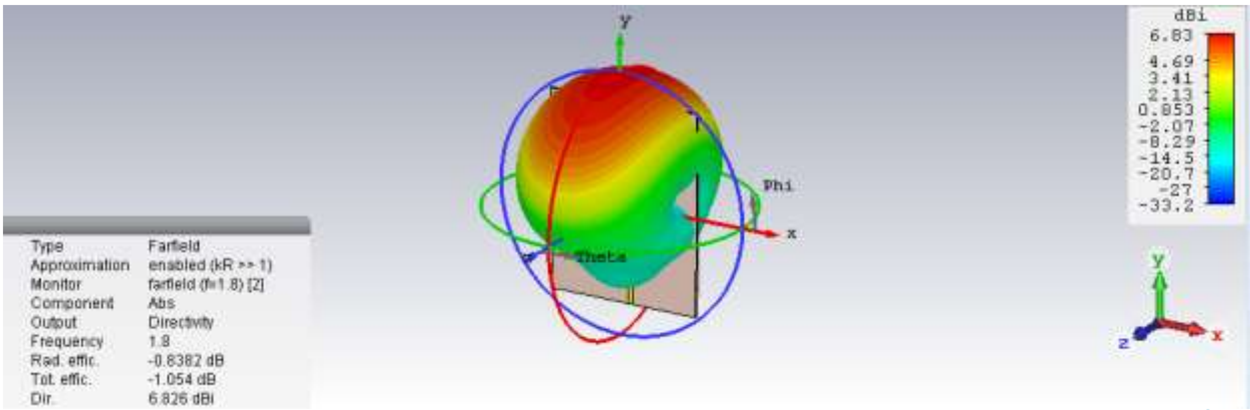

Fig: 3.9 Directivity plot for conventional antenna at 1.8 GHz

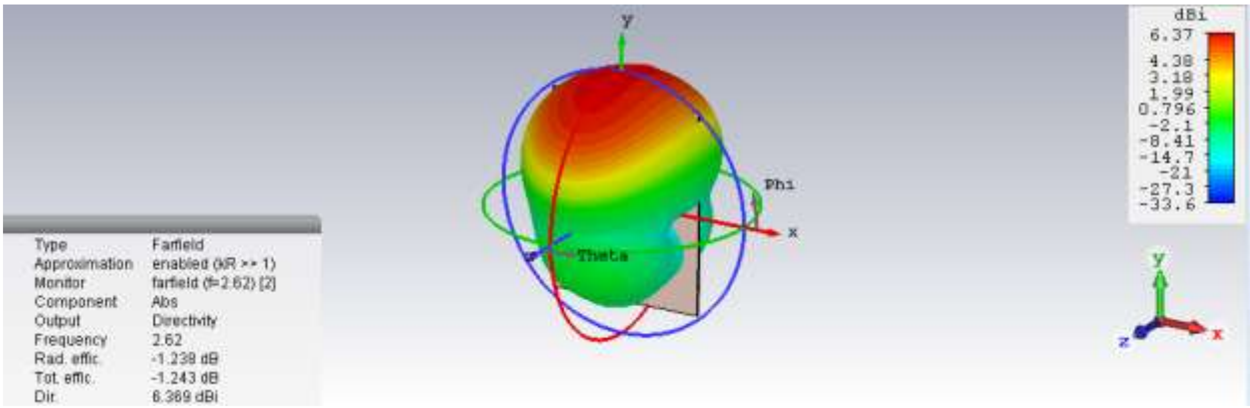

Fig: 3.10 Directivity plot for conventional antenna at 2.62 GHz

For the proposed design, directivity is 9.54 dB and 7.17 dB, respectively. The result in fig 3.11 and fig: 3.12 show that the radiated power in the desired direction is maximum.

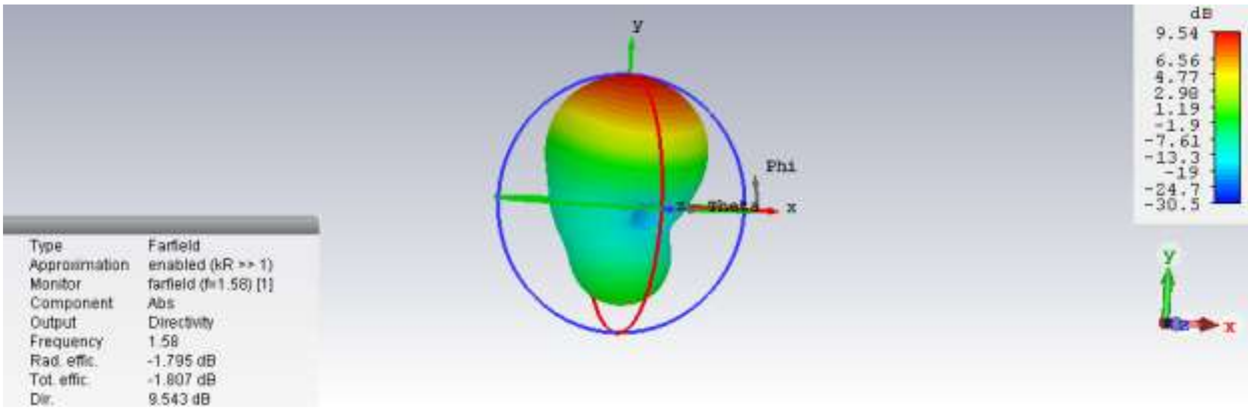

Fig: 3.11 Directivity plot for proposed antenna at 1.58 GHz

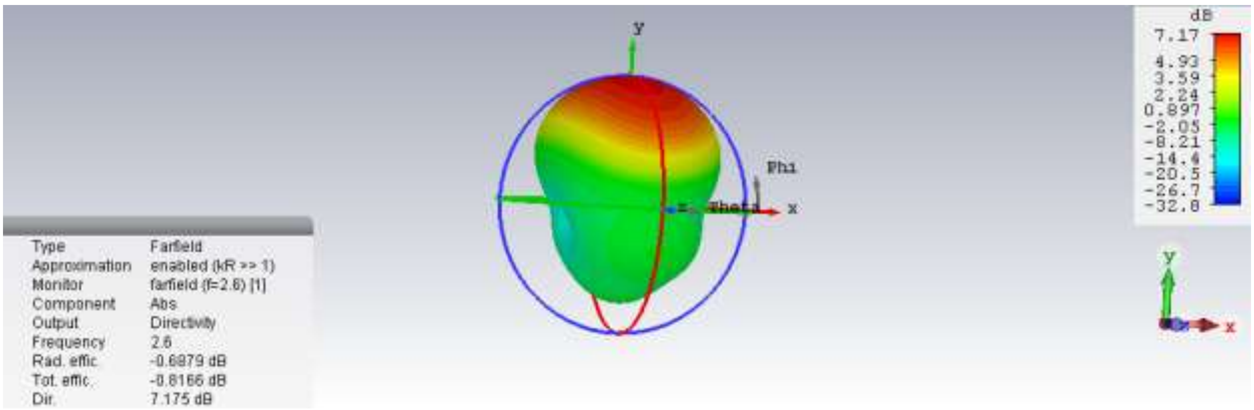

Fig: 3.12 Directivity plot for proposed antenna at 2.6 GHz

3.4. Polar plot

Polar plot shows how an antenna performs. The magnitude of the response in any direction is represented by using polar plot. Their values must be positive for better results. One key truth about polar plot and antenna radiation pattern is that the receiving pattern. For the conventional design, the value of side lobe is maximum for both the resonate frequency as illustrated in fig: 3.13 and fig: 3.14-

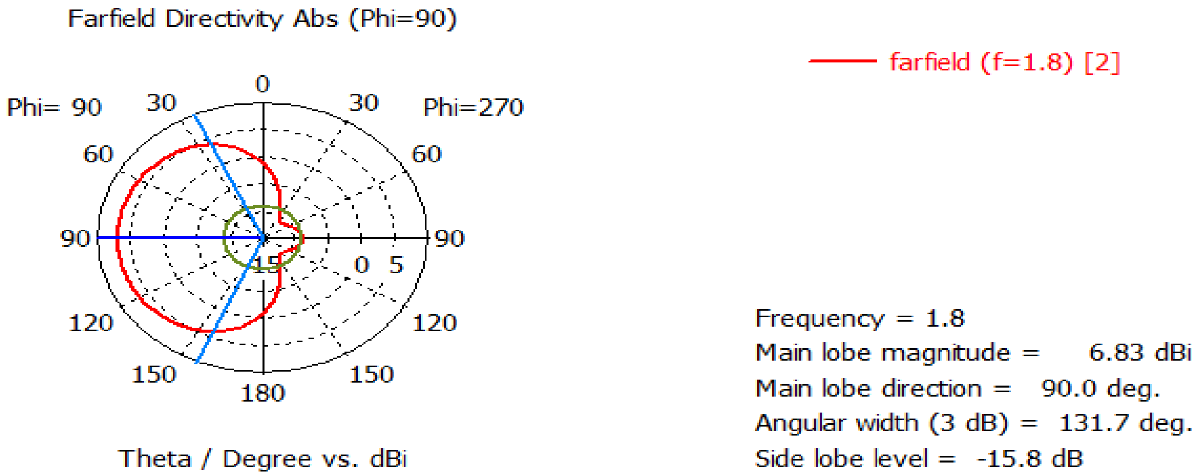

Fig: 3.13 Polar plot for conventional antenna at 1.8 GHz

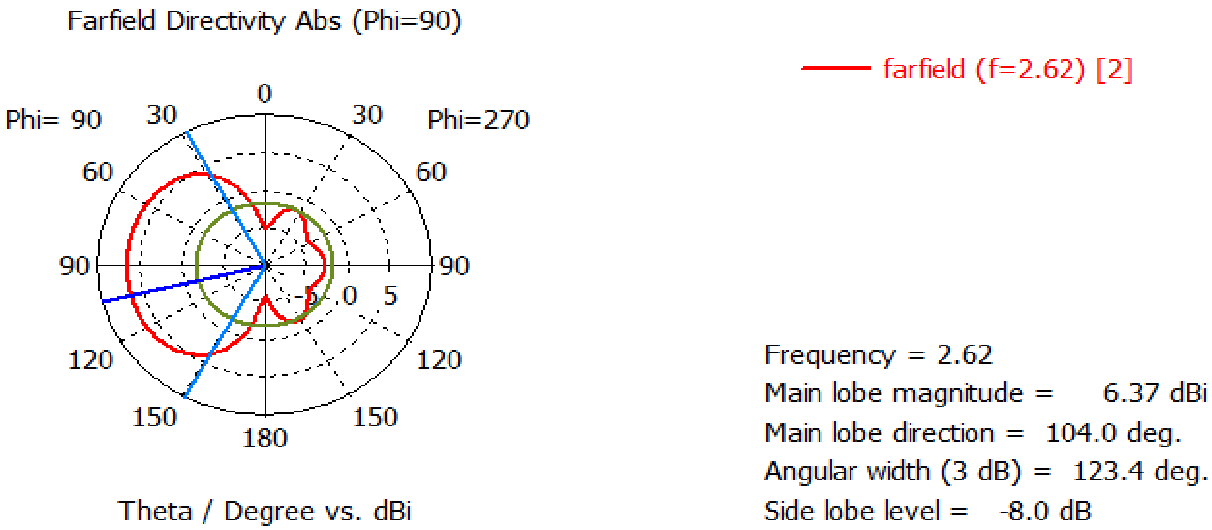

Fig: 3.14 Polar plot for conventional antenna at 2.62 GHz

The value of side lobe is minimum for the proposed work at both the resonate frequency as shown in fig: 3.15 and 3.16 below –

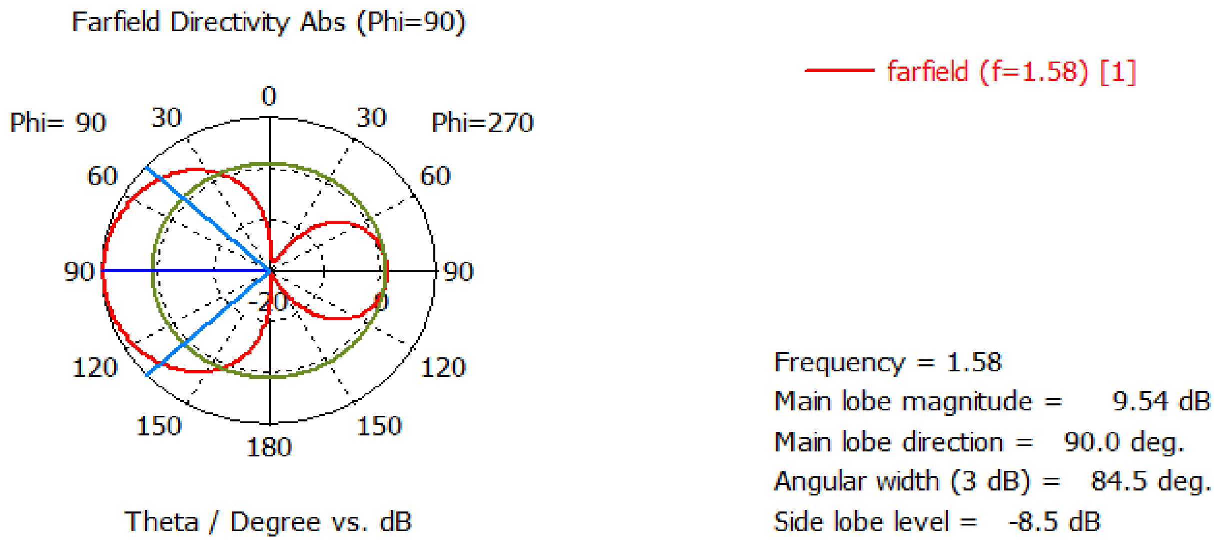

Fig: 3.15 Graph of polar plot for SDP with SRR antenna at 1.58 GHz

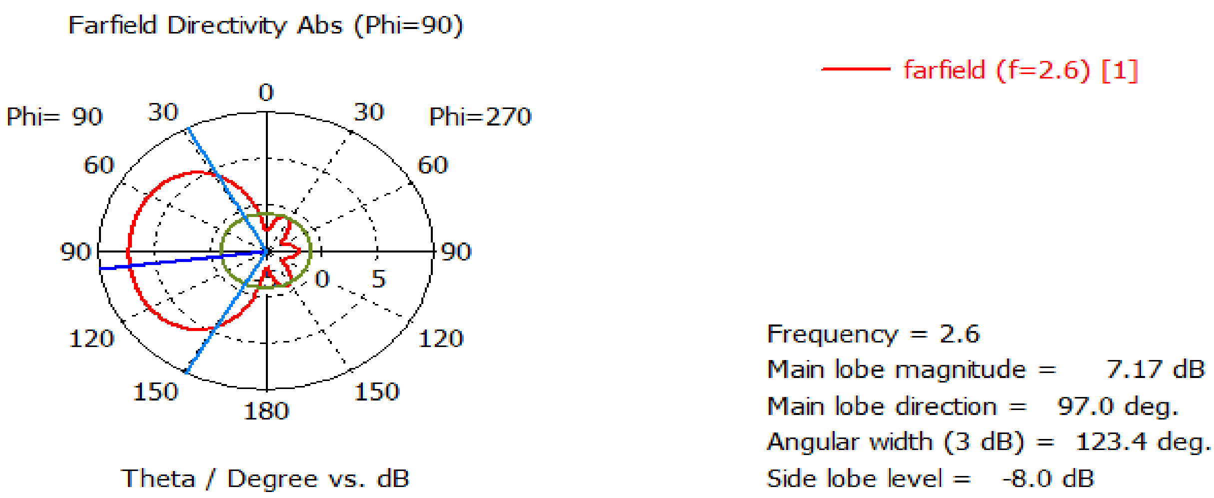

Fig: 3.16 Graph of polar plot for SDP with SRR antenna at 2.6 GHz

3.5. Smith chart

It is a useful tool to measure and analyze the impedance of a transmission line and its behavior with the matching circuits, as a function of frequency. Smith chart can be used to demonstrate concurrently the graphical representation of multiple parameters of antenna systems. The unity radius region is regularly utilized to draw the Smith chart. In two dimensions (2-D) smith chart is plotted on the complex reflection coefficient plane. It is scaled in normalized impedance (most commonly at 50 ohm), normalized admittance or both and different colors are used to make a distinction between them. Normalized scaling is useful in solving any kind of problems associated with characteristic or system impedance by use of smith chart as these are represented by the centre of the chart. In scaling of wavelength and degrees, smith chart exhibits circumferential scaling. The separation along the transmission line between source and the load under concern is measured using wavelength scaling. The unit less parameters in the chart represents the reflection coefficients. Degree scaling is used to obtain the angle of reflection coefficient at any point. The smith chart is also useful in analysis of lumped elements and their matching. Smith chart of conventional and proposed design is shown in fig: 3.17 and fig: 3.18-

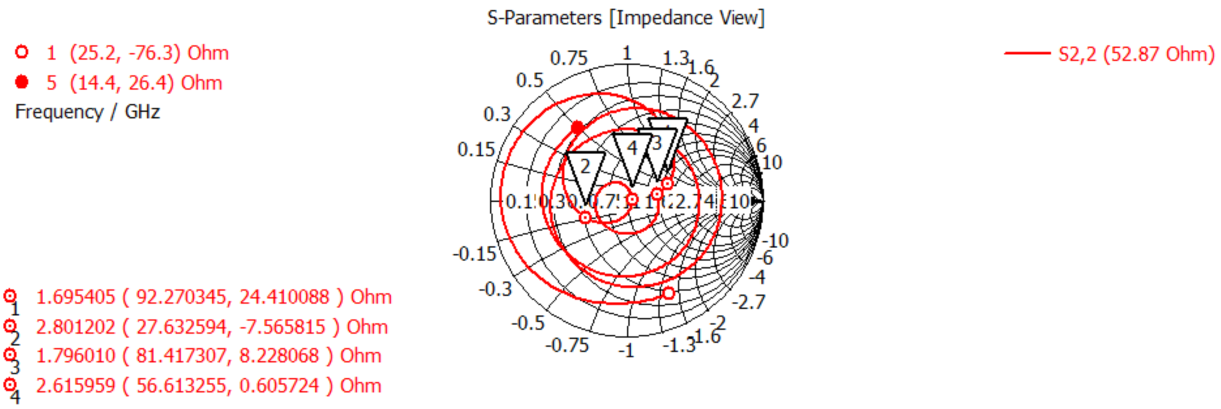

Fig: 3.17 Smith chart for conventional antenna

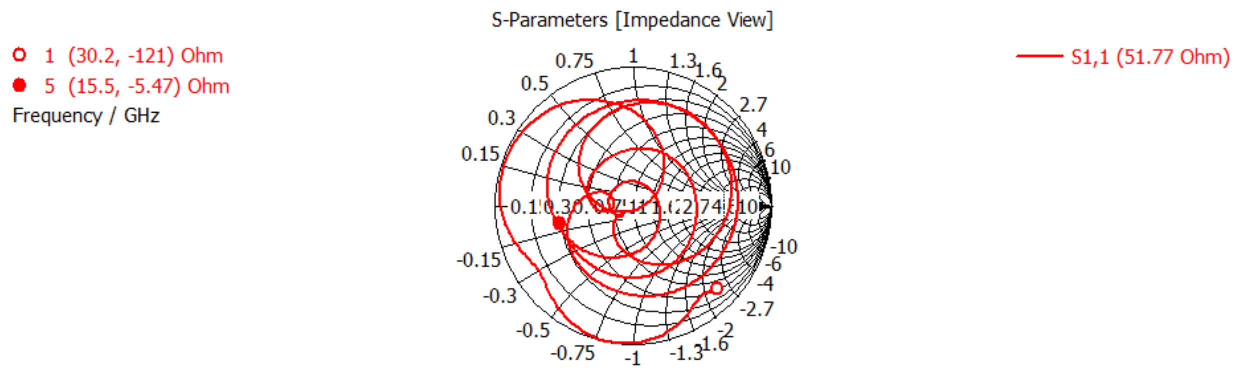

Fig: 3.18 Smith chart for proposed design

Conclusion

In this proposed work, designing of a double band series- fed dipole pair antenna using split ring resonator and examined the simulated results. To obtain double band operation and to enhance the performance of a traditional antenna, a couple of split ring resonator is affixed above the dipole1 (P1) of conventional SDP antenna. In view of a parametric investigation of the impacts of the design parameter of the split ring resonator, a design of a double band series-fed dipole pair antenna working in the 1.53-1.61 GHz and 2.01-2.74 frequency bands was simulated and measured on an FR4 glass epoxy substrate having a dielectric constant of 4.4. It is found from measured and simulation results that the proposed work has double band characteristic at 1.8 and 2.6 GHz frequency for a value of VSWR less than 2. The value of gain at these frequencies is 7.75 dB in the main band and 6.49 dB at 2.6 GHz frequency. The proposed work is used in many wireless communication and mobile communication applications.

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