Design of Defected Ground Structure S-Shaped Multiband Microstrip Patch Antenna Using Complementary Split Ring Resonator

Jigar M. Patel[1], Shobhit K. Patel[2], Falgun N. Thakkar[3]
[1] B. & B. Institute of Technology, V. V. Nagar, Gujarat, India,
[2] Charotar University of Science and Technology, Changa, Gujarat, India
[3] G. H. Patel College of Engineering and Technology, V.V.Nagar, Gujarat, India
Email: [1] jmp_ec@yahoo.com, [2] shobhit_65@yahoo.com, [3] falgungcet@gmail.com

***Abstract*—In this paper Defected Ground Structure (DGS) S-shaped microstrip patch antenna using Complementary Split Ring Resonator (CSRR) is designed and analyzed. The aim to design this antenna is to achieve multiband applications which are required in today's scenario. Here S-shaped meandered patch of dimension 50×50mm^2 is analyzed. This design has four working bands centered around 1374 MHz, 2468 MHz, 3070 MHz and 4632 MHz which can be used for multiband application purposes. Design results of VSWR, Return loss S_{11}, Total Gain plot and Total Directivity Plot are shown in this paper. Design results are obtained by a HFSS (High Frequency Structure Simulator) which is used for simulating microwave passive components.**

***Index Terms*—Microstrip, Multiband, S-Shaped, DGS, CSRR.**

I. Introduction

A microstrip antenna contains very extensive applications in recent times because of its light weight, small size, easy reproduction and integration ability with the circuitry [1-10]. The rapid development of electronics and wireless communications led to great demand for wireless devices that can operate at different standards such as the universal mobile telecommunications system UMTS, Bluetooth, wireless local-area network (WLAN) and also satellite communications. However, frequency steering capability shows that it is difficult to keep the frequency fixed without any changes [11]. In addition, compact small size is a demand factor for several applications as mobile devices. These two requirements have triggered research on the design of compact and single or multiband antennas operation [12]. Microstrip patch antennas are widely used because of their many merits, such as the low profile, light weight and conformity. However, patch antennas have a main disadvantage: narrow bandwidth. Researchers have made many efforts to overcome this problem and many configurations have been presented to extend the bandwidth [13].

Microstrip patch antennas are widely used in wireless devices and other compact sizes with multiband antenna operation. The techniques for reducing the size of Microstrip patch antenna are reported extensively and include capacitive loading [1], LC resonator [2], meander configuration [9, 10]; however, these techniques usually trade off the antenna bandwidth or antenna efficiency to achieve the reduction in antenna size. Different techniques [14] for creating multiband Microstrip patch antennas with metamaterial have been published, such as adding SRR elements in substrate [15] to reduce the size of the patch antenna. There is a tradeoff between number of operating bands and antenna size. Reconfigurable antennas represent a recent innovation in antenna design that changes from classical fixed-form, fixed-function antennas to modifiable structures that can be adapted to fit the requirements of a time varying system. Advances in microwave semiconductor technologies enabled the use of compact, ultra-high quality RF and microwave switches in novel aspects of antenna design.

The S-shaped Patch antenna [16] was designed and simulated which gave only three bands. Now to enhance the bands, Defected Ground Structure with Complementary Split Ring Resonator (CSRR) is used in this proposed design.

Recently a defected ground structure (DGS) [17] have been introduced, DGS is realized by etching off a simple shape in the ground plane, depending on the shape and dimensions of the defect, the shielded current distribution in the ground plane is disturbed, resulting a controlled excitation and propagation of the electromagnetic waves through the substrate layer. The shape of the defect may be changed from the simple shape to the complicated shape for the better performance.

Very recently, complementary split-ring resonator (CSRR), which is the negative image of split-ring resonators (SRR) [16], has been reported by some authors. It has been demonstrated that CSRR etched in the ground plane or in the conductor strip of planar transmission media provides a negative effective permittivity to the structure. CSRR has been successfully applied to the narrow band filters and diplexers with compact dimensions.

II. Design and Modeling

This section, we will introduce the design of our antenna. First the conventional patch length and width is designed. After designing the patch, we have taken out two slits from the patch to make it Defected Ground Structure (DGS) S-shape patch using Complementary Split Ring Resonator (CSRR). Basic length and width is designed with the use of following equations.

$$w = \frac{c}{2 f_0 \sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (1)$$

Width of the patch can be designed using the equation (2), here f_0 is the center frequency, ε_r is relative permittivity and c is speed of light.

$$L_{eff} = \frac{c}{2 f_0 \sqrt{\varepsilon_{reff}}} \quad (2)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left(\frac{1}{\sqrt{1 + \frac{12t}{w}}} \right) \quad (3)$$

$$\Delta L = 0.412t \frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{t} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{t} + 0.8\right)} \quad (4)$$

$$L = L_{eff} - 2\Delta L \quad (5)$$

Length of the patch can be designed by using the equations (1-5). Here t is the thickness of substrate. Using these equations we have designed length and width of conventional patch here.

Here we designed square patch so length and width are same and it is 50 mm, so a square patch is 50×50 mm^2 over here which is shown in Figure 1. We have taken out two slits from the patch to make it S-shape and to improve the results Complementary Split Ring Resonator (CSRR) is used in ground which is called Defected Ground Structure (DGS) as shown in figure. The slits taken out have dimension of 30×10mm^2. The top view and side view of the design is shown in Figure 1(a) and 1(b) respectively.

The space between two SRR is 4mm as shown in figure 1(a).

Table 1 shows details about the material. Patch is of copper material. Substrate is of FR4 epoxy material with ε=4.4. The base material is also of copper.

Table: 1 Material used for patch antenna

	Material
Patch	Copper
Substrate	FR4 epoxy with ε=4.4

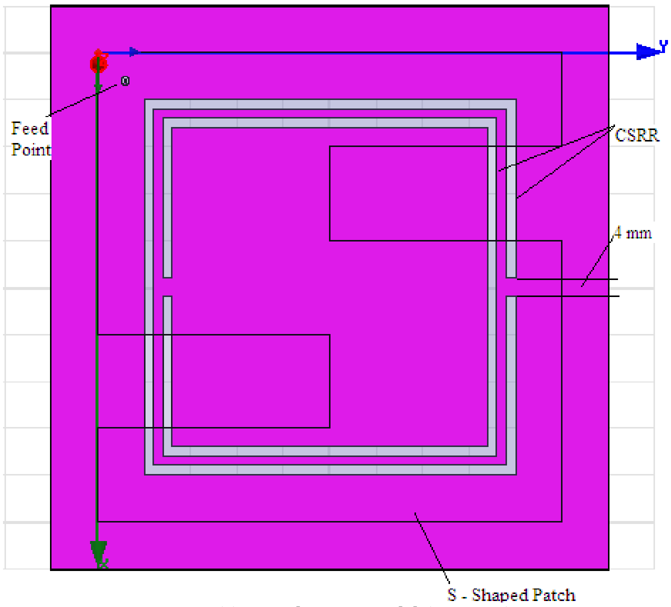

Fig. 1 (a) Actual HFSS Model (top view)

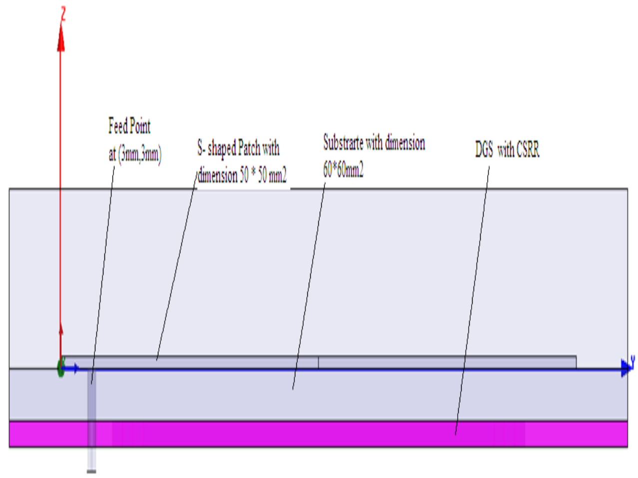

Fig.1 (b) Actual HFSS Model (side view)

III. Simulation Results and Discussions

For simulation we used HFSS 11 of Ansoft, which is very good simulator for RF antennas. After simulating the design the result we got is as follows.

Figure 2 shows the Return Loss (S_{11}) plot of the design and Table 2 shows values of Return Loss (S_{11}) in dB for different bands with their frequency. The minimum return loss which we are getting for this design is -42 dB for the second band centered around 2.46 GHz

Table: 2 Return Loss (S11) values

Band	Frequency in GHz	Minimum Return Loss (S_{11}) in dB (Negative Values)
1st	1.3740	28.0632
2nd	2.4688	42.2802
3rd	3.0702	20.6456
4th	4.6322	20.7692

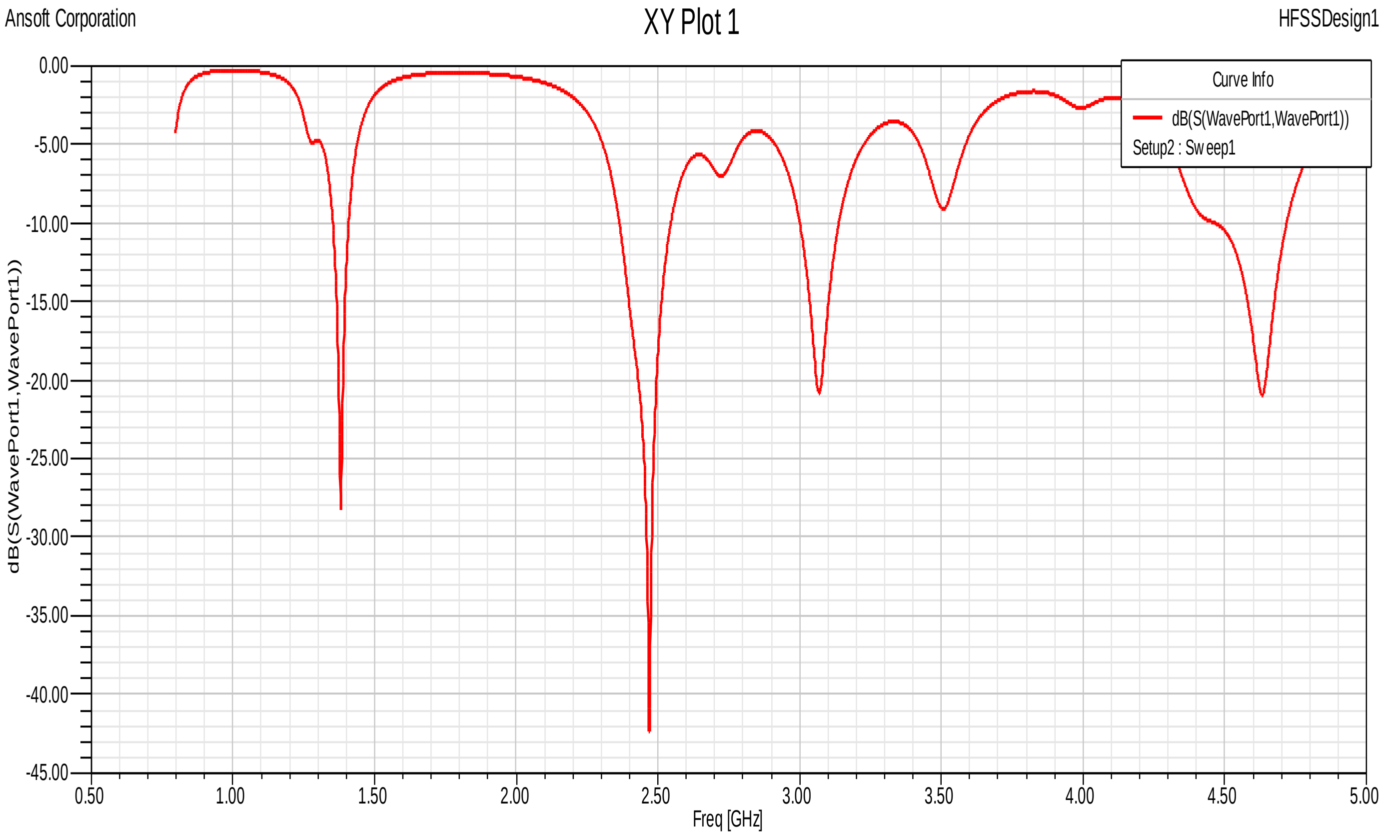

Fig.2 Return Loss (S_{11}) parameter of the antenna

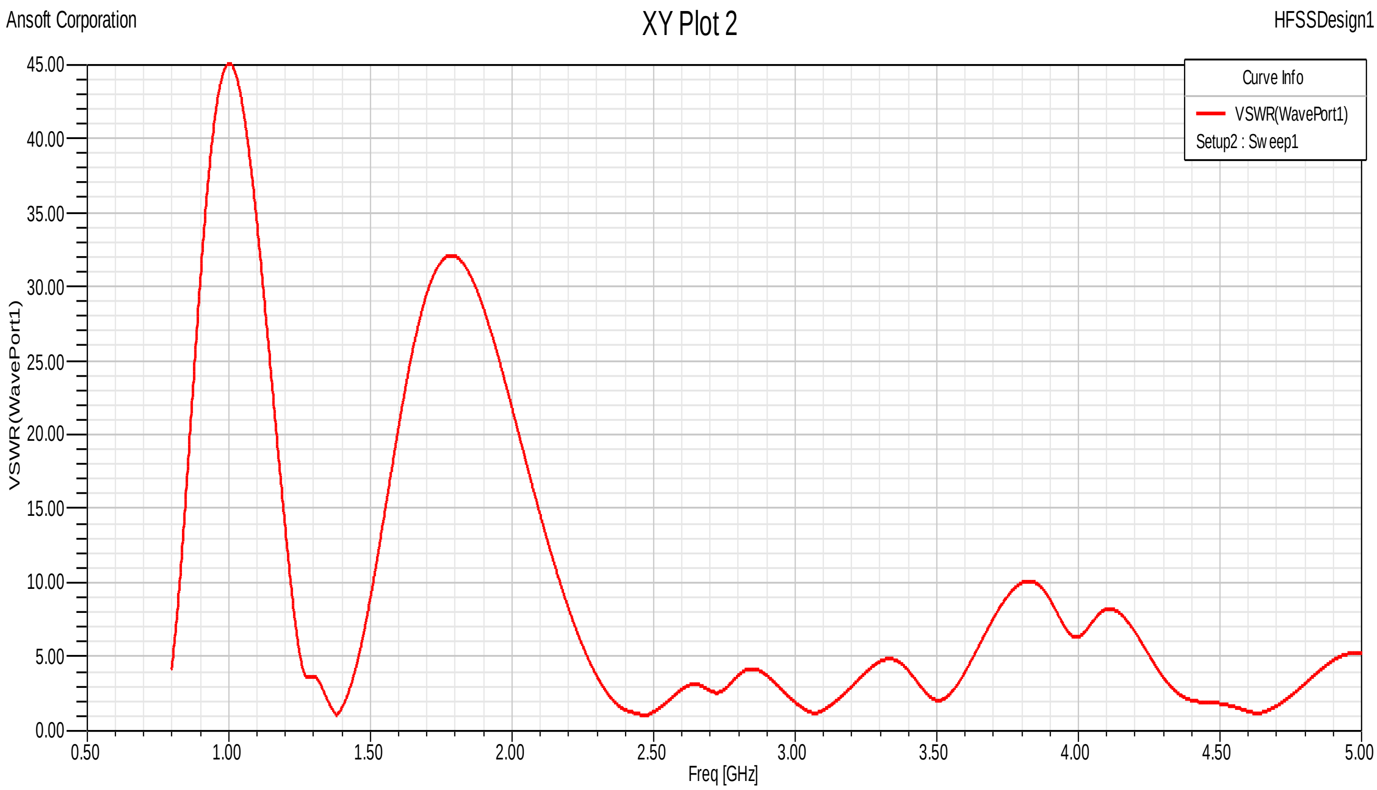

Fig. 3 VSWR of Antenna

Figure 3 shows the VSWR plot of the design and Table 3 shows values of VSWR for different band with frequencies. For the entire band VSWR is less than 2 and lowest VSWR for the design is 1.1 for the second band centered around 2.46 GHz.

Table: 3 VSWR Values

Band	Frequency in GHz	VSWR
1st	1.3740	1.1126
2nd	2.4688	1.1126
3rd	3.0702	1.3599
4th	4.6322	1.2363

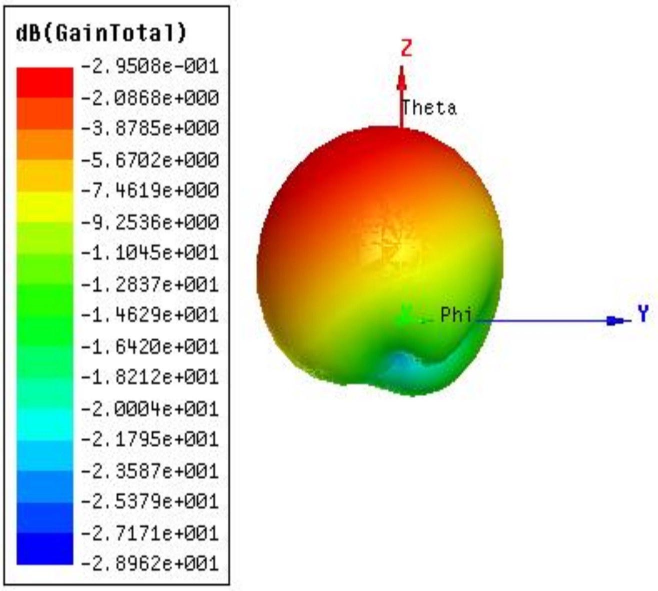

Fig. 4 Total Gain Plot of the proposed antenna

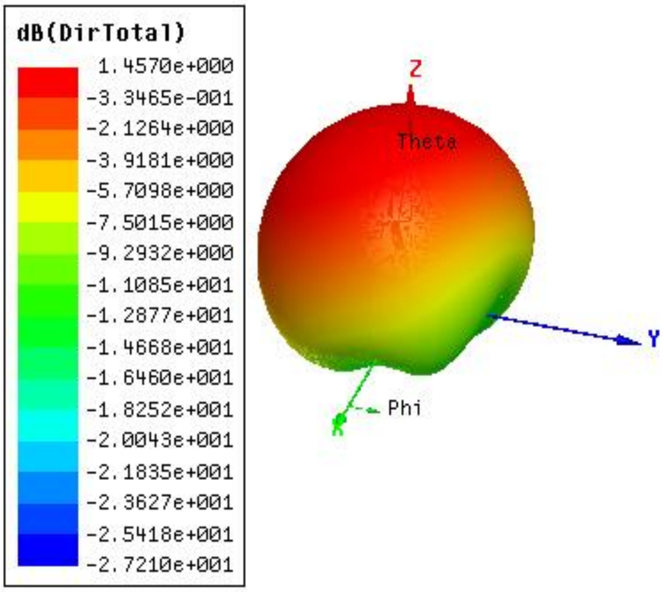

Fig. 5 Total Directivity Plot of the proposed antenna

Figure 4 shows the Total Gain plot of the proposed antenna with value of -0.295 dB and figure 5 shows the Total Directivity plot of the proposed antenna with value of 1.457 dB.

IV. Conclusion

Microstrip antennas have become a rapidly growing area of research. Their potential applications are limitless, because of their light weight, compact size, and ease of manufacturing. Here Defected Ground Structure (DGS) S-shaped microstrip patch using Complementary Split Ring Resonator (CSRR) is designed for multiband applications. The modeling and iterative simulations are carried out at center frequency of 2.5 GHz. The result indicates the four bands so the antenna can used for L Band and S Band Applications. Further design can be modified to have multiband for other applications in C Band, X Band and other bands. The results are in very good agreement with the industry and standard published antenna-requirements with respect to ease of fabrication, compactness and volume miniaturization compared to other antennas so far designed for similar applications.

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