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Design and Improvement of Microstrip Patch Antenna Parameters Using Defected Ground Structure

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ABSTRACT
In this paper simple RMPA is designed and its performance parameters are compared with RMPA having defected ground plane. The antenna is simulated at 2.4 GHz using CAD-FEKO simulation software .This work mainly includes modification of antenna ground plane called as Defected Ground Structure (DGS). The parameters of antenna such as Reflection coefficient, Gain, VSWR and Band width, with and without DGS are measured. The main focus of this paper is to improve band width so that patch antenna is used for wide band applications and study effect of DGS on antenna parameters.
***Keywords* -** CAD-FEKO, Defected Ground Structure (DGS), Reflection coefficient, Rectagular Microstrip Patch Antenna (RMPA), VSWR .

I. INTRODUCTION

Microstrip patch antennas are more popularly used now a days due to its various advantages such as light weight, low volume, compatibility with integrated circuits ,easy to install on the rigid surface and low cost. Microstrip patch antennas are design to operate in dual-band and multi-band application either dual or circular polarization. These antennas are used in different handheld communicating devices [5]

The simple Microstrip patch Antenna [16] consists of a dielectric substrate having fixed dielectric constant . Radiating patch is present on one side of a dielectric substrate and a ground plane is present on other side of a substrate . The metallic patch may take any geometrical shapes like rectangular, triangular ,circular , helical, ring, elliptical etc. The dimensions of the patch are corresponds to the resonant frequency of antenna .

However, microstrip patch antennas are having narrow bandwidth and bandwidth enhancement is necessary for most of the practical applications, so for increasing the bandwidth different approaches have been utilized. Defected Ground Structure is one of them . In addition most of the applications which uses microstrip antenna in communication systems like mobile handheld communicating devices require smaller antenna size . Different advance tools to the design of very compact microstrip patch antennas have been introduced over the last few years. [5]

Meaning of DGS is , in ground plane of patch antenna some defected shape is introduced and depending on the different dimension ,shape and size of the defect the shielded current distribution will get disturb [13] . Input impedance and the current flow of the antenna will get affected due to disturbance at the shielded current distribution. It can also control the excitation and electromagnetic waves which are propagating through the substrate layer.

II. LITERATURE REVIEWS

According to [11] the substrate material plays significant role determining the size and bandwidth of an antenna. Increasing the dielectric constant decreases the size but lowers the bandwidth and efficiency of the antenna while decreasing the dielectric constant increases the bandwidth but with an increase in size. Some research papers reviews are mentioned below.

In [3] antenna is feed using microstrip feeding technique and simulated using IE3D software The antenna shows single band bandwidth of 2 GHz for the working band of 4-6 GHz. The proposed antenna is useful for IEEE 802.11 WLAN standards in the 5.2/5.8 GHz band and WiMAX standards in the at 5.5 GHz band.

In [4] defected ground plane is in the form of L shaped slot and the rectangular parasitic patches and diagonal cuts at top corners can increase the bandwidth. for the first and second resonant frequencies Return losses of −17dB and −30 dB respectively, can be achieved when the the diagonal cut is at optimum value.

In [5] a rectangular microstrip patch antenna with DGS has been simulated using High Frequency Simulation Software (HFSS) at 2.45 GHz frequency , antenna is fed by Quarter Transformer feeding . The rectangular patch antenna designed with swastik shaped DGS structure, shows gain of 7 dB. Patch antenna with Defected Ground Structure (DGS) demonstrate properties like improved returning loss, VSWR, bandwidth, gain of the antenna as compared to the conventional antenna.

In [6] a single frequency microstrip patch antenna feed using microstrip line fed and simulated using CST Microwave Studio software. Antenna operates at the frequency 5.2 GHz WLAN standard. Resultant impedance bandwidth is around 190 MHz with the having value of return loss as -47 dB has been obtained. The antenna also shows impedance of 50.89 ohm.

In [9] circular patch antenna is designed with defect in ground plane.

In [10] antenna operating at 2.4 GHz frequency band for WLAN applications uses rectangular slot in the ground plane is located at different locations in the bottom of the substrate are considered and results of optimized patch antenna were obtained . Return loss improvement is from -17.72dB to -26.92dB . Gain improvement is from-5.1dB to -5.9 dB.

In [11] antenna Simulated At 4.30 GHz frequency. and it is proved that when defect is introduced in ground plane of the single band antenna then the resulting antenna has its resonant frequency at lower side that is at 2.5GHz , which shows that the antenna has compact in size and showing improvement in gain and bandwidth. Here multiband operation of antenna is also obtained .

In [12] very compact antenna was designed, the antenna for WLAN operating in band of 2.4 and 5GHz. Various results are obtained by varying different dimensions of patch. Antenna is feed using microstrip-feed. Different defected ground structures (DGS) have been developed analyzed.

In [13] and is is concluded that although the DGS has applications in the field of the, microwave oscillators , microwave filter design, microwave couplers to increase the coupling, microwave amplifiers, etc., it can be used in the microstrip antenna design for various advantages such as antenna size reduction mutual coupling reduction, harmonic suppression, cross polarization reduction, in antenna arrays etc.

In [14] microstrip patch antenna for GSM and Wi-Max application was proposed. The proposed antenna shows promising characteristics for WLAN ,Wi-Max, and Satellite application at resonant frequencies of 5.5 GHz for WiMax, 5.2 GHz and 5.8 GHz for WLAN and 6-7 GHz for satellite application respectively.

III. Indentations and Equations

Three basic parameters for the RMPA design are,

1.Operating frequency (f_0):

The operating frequency of the antenna is very important factor. The ISM frequency band is 2400MHz to 2483.5MHz, which is used for Bluetooth , WLAN and other applications . Hence , the resonant frequency selected for design is 2.4 GHz.

2. Dielectric constant of the substrate (ε_r):

The dielectric material selected for design is FR4_epoxy having dielectric constant of 4.4. A substrate having high dielectric constant should be selected because higher the dielectric constant smaller the dimensions of the antenna. [11],[16] As shown in table 1.

Table 1: Different Materials and dielectric constants [15]

Dielectric constant ε_r	Material	Patch Length (in mm)	Patch Width (in mm)
2.1	Teflon	41.41	50.20
3.2	Taconic_TLC	33.37	43.12
4.4	FR4_epoxy	28.30	38.03
5.7	Mica	24.72	34.14
6.15	Rogers R03006	23.76	33.05
7	Silicon_nitrate	22.19	31.25
8.3	Marble	20.28	28.98
9.2	Alumina_92pct	19.20	27.67
10	Sapphire	18.37	26.65
11.9	Silicon	16.73	24.60
12.9	Gallium_arsenide	16.02	23.70
16.9	Diamond	13.84	20.89

Note : L and W are calculated for frequency of 2.4 GHz.

3. Height of dielectric substrate (h):

For the microstrip patch antenna which are used in cellular phones or other hand held devices it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate should be small, effect of height is discussed in [16]. Here FR4_epoxy substrate of standard height 1.59 mm is selected .
Hence, the essential parameters for the design are:

- Frequency of operation f_o = 2.4 GHz
- Dielectric constant of the substrate ε_r = 4.4
- Height of dielectric substrate h = 1.6 mm

The transmission line model is used [16] and following steps are followed to design the antenna

1: Width calculation (W):

The width W of the Microstrip patch antenna is calculated as :

$$W = \frac{C}{2 f_r \sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (1)$$

Where c = free space velocity of light . Substituting c = 3.0e8 m/s, ε_r = 4.4 and f_o = 2.4 GHz,
we get: W = 0.03803 m = 38.03 mm

2:Effective dielectric constant calculation (ε_{reff} **):**

The effective dielectric constant is:

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

Substituting : ε_r = 4.4, *W* = 38.03 mm and *h* = 1.6 mm,
we get: **ε_{reff} = 4.3996**

3: Effective length calculation (L_{eff}**):**

The effective length is:

$$L_{eff} = \frac{C}{2 f_r \sqrt{\varepsilon_{reff}}} \quad (3)$$

Substituting : ε_{reff} = 4.3996, *c* = 3.0e8 m/s and f_o = 2.4 GHz we get:

L_{eff} **= 0.028569 m = 28.569mm**

4:Length extension calculation (ΔL):

The length extension is given by:

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

Substituting : ε_{reff} = 4.3996 , *W* = 38.03 mm and *h* =1.6 mm we get

Δ*L* **= 7.4800e-4 = 0.748 mm**

5: Actual length of patch calculation (*L*):

The actual length is obtained by:

$$L = Leff - 2\Delta L , \quad (5)$$

Substituting L_{eff} = 4.3996 mm and Δ*L* = 0.7243 mm
we get: ***L* = 28.30mm**

6: Ground plane dimensions calculation (L_g and W_g):

Only for infinite ground planes , transmission line model is applicable , but for practical considerations finite ground plane is required . Same results for finite and infinite ground plane are obtained if ,in case of infinite ground plane the size of the ground plane around the periphery is greater than the patch dimensions by six times thickness of substrate . Hence, for proposed design dimensions of ground plane would be given as:

$$\mathbf{L_g = 6h + L = 37.9\ mm} \quad \mathbf{(6)}$$
$$\mathbf{W_g = 6h + W = 47.63mm} \quad \mathbf{(7)}$$

7: Inset feed depth determination (y_0):

An inset-fed type feed is to be used in this design. As shown in Figure 1, y_0 is the inset feed point depth which must be located at point on the patch, where the input impedance is exactly 50 ohms for the resonant frequency.

In this case we obtain the optimum feed depth, where the reflection coefficient is at the minimum value. Minimum reflection coefficient indicates minimum return loss and there exists a point along the length of the patch which gives the minimum return loss .

$$\mathbf{Rin|_{(y = y\,0)} = Rin|_{(y = 0)} \cos^2(\pi * y_0/L)} \quad \mathbf{(8)}$$

Here , Rin$|_{(y\ =\ 0)}$ =243 Ohm.[17]
and Rin| ($_{y\ = y0)}$ = 50 Ohm. is required

Y_0= 8.1016 mm

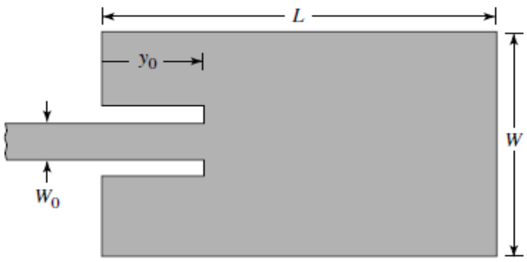

Fig. 1 :Dimensions of rectangular microstrip patch antenna [RMPA]

Table 2:Design parameters

Sr No.	Parameter	Value
1	Dielectric Constant (εr)	4.4
2	Thickness (h)	1.6 mm
3	Operating Frequency (fr)	2.4 GHz
4	Length of Ground(Lg)	37.9012 mm
5	Width of Ground(Wg)	47.6363 mm
6	Cut Width	5 mm
7	Cut Depth (y_0)	8.1016 mm
8	Path Length (L_p)	28.30 mm
9	Path Width (w_p)	38.03 mm
10	Width of Feed (w_o)	3.00mm

IV. SIMULATION RESULTS

Considering design parameters of table 2 and operating frequency as 2.4 GHz ,following simulation results are obtained using CAD FEKO software [18] .

Fig. 2 shows dimensions of patch for rectangular microstrip antenna .

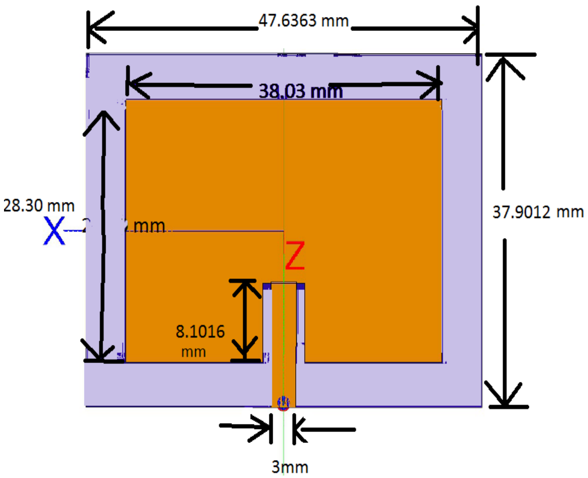

Fig. 2 Dimensions of patch for rectangular microstrip antenna .

4.1 Return loss (Reflection coefficient)

Fig. 3 shows graph of reflection coefficient in dB verses frequency of RMPA . At 2.4 GHz frequency simulated Rectangular Microstrip Patch Antenna alone exhibits reflection coefficient of -15.5dB

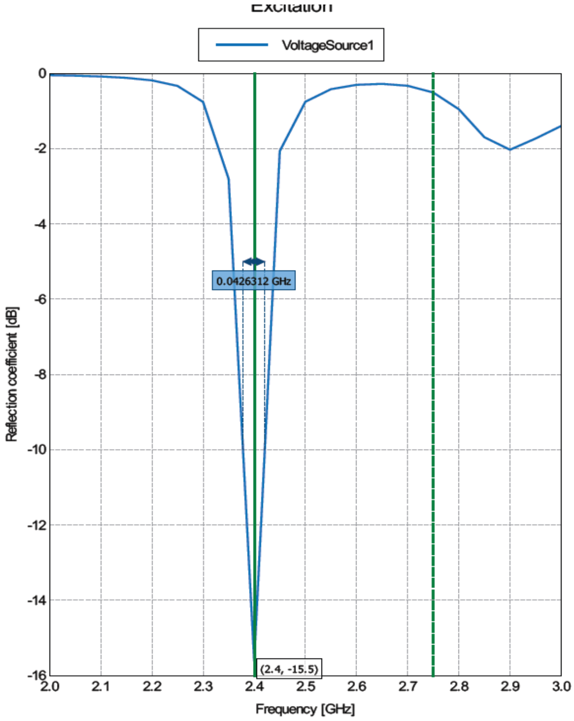

Fig. 3 : Reflection coefficient of RMPA

4.2VSWR :

Simulation results of VSWR are obtained using CAD FEKO software. Fig. 4 shows graph of VSWR verses frequency of RMPA. At 2.4 GHz frequency simulated RMPA alone exhibits the VSWR of 1.435

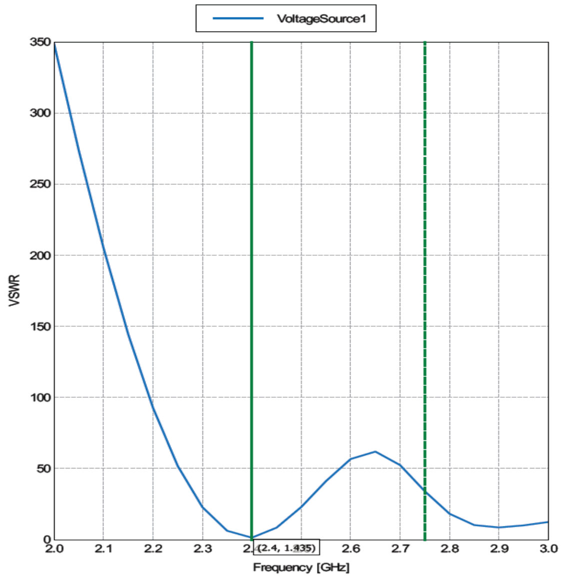

Fig. 4: VSWR Graph of RMPA

4.3 Radiation pattern

Fig. 5 shows radiation pattern of RMPA having maximum gain of 4.2dB and beamwidth of 93.613^0

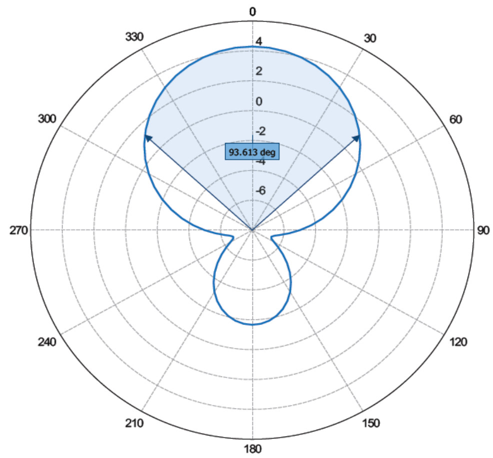

Fig. 5 : Radiation pattern of RMPA

4.4 Input impedance

Fig. 6 shows smith chart of RMPA which shows that impedance equal to 54.587 Ohm at 2.4 Ghz which is not exactly matched with 50 Ohm.

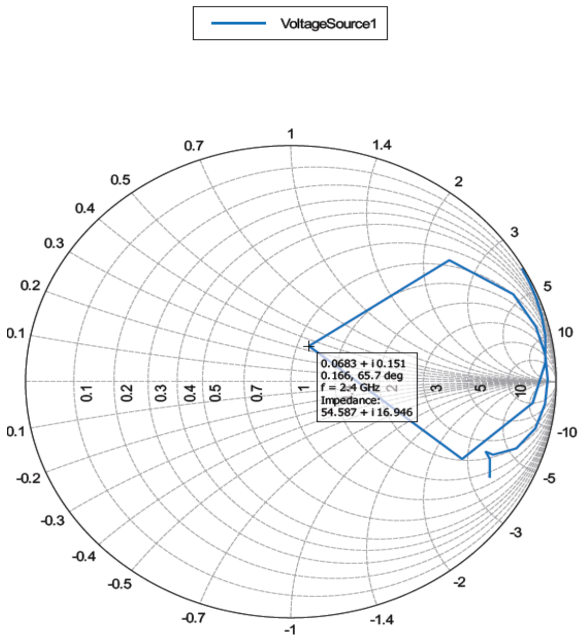

Fig. 6 : Smith Chart of RMPA

V. Simulated Results of RMPA with DGS

A same RMPA with dual H shaped defect in ground is proposed. The dual H shaped defect is placed in ground plane in order to study its influence, and the results are compared with those of the antenna alone without DGS .

The bandwidth of proposed antenna has been improved by 34.1846 MHz Fig.7 shows RMPA with dual H shaped DGS structure.

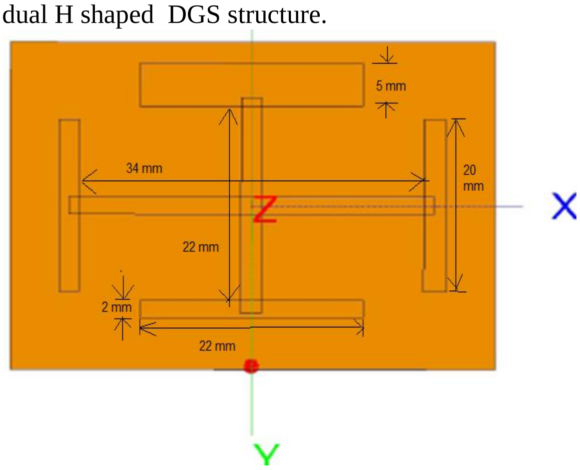

Fig. 7 :Rectangular Microstrip patch antenna with dimensions of DGS

5.1 ReturnLoss (Reflection coefficient)

Simulation results RMPA with DGS structure are obtained using CAD FEKO software . Fig.8 shows graph of reflection coefficient in dB verses frequency of RMPA with DGS . At 2.4 GHz frequency simulated RMPA with DGS structure exhibits the reflection coefficient -33.73 dB along with bandwidth improvement up to 76.8158MHz.

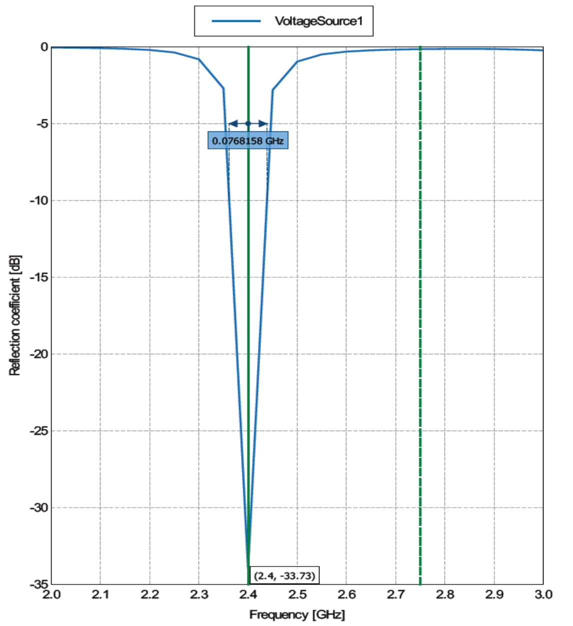

Fig. 8: Reflection coefficient of RMPA with DGS

5.2 VSWR

Simulation results RMPA with DGS structure are also obtained using CAD FEKO software . Fig. 9 shows graph of VSWR verses frequency of RMPA with DGS . At 2.4 GHz frequency simulated RMPA with DGS structure exhibits VSWR of 1.06

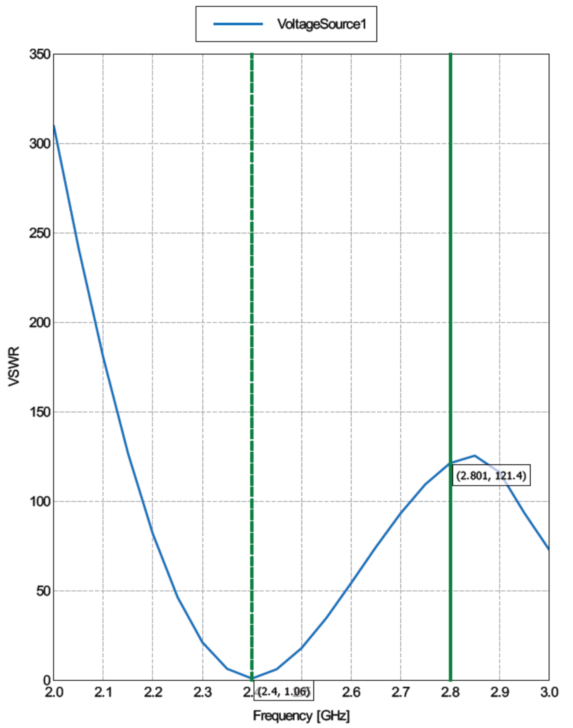

Fig.9: VSWR of RMPA with DGS.

5.3 Radiation pattern :

Fig. 10 shows radiation pattern of RMPA having gain of 4.3dB and maximum beam width of 93.2883^0 which is not much change from 93.613^0

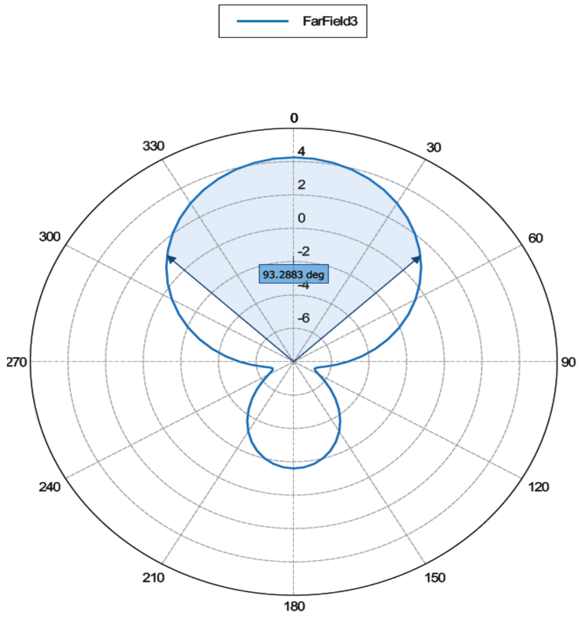

Fig. 10: Radiation pattern of RMPA with DGS

5.4 Surface currents

Fig. 11 shows Surface current distribution with DGS. This shows uniform current distribution over entire surface of patch as compair to RMPA without DGS.

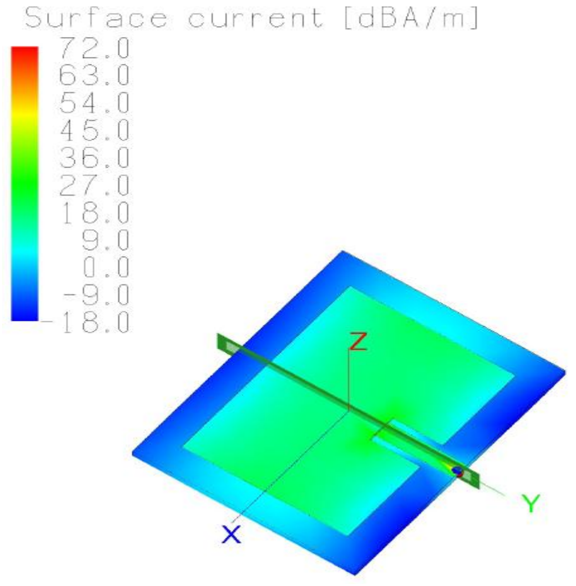

Fig. 11 : Surface current distribution

5.5 Input impedance

Fig. 12 shows Smith Chart of RMPA which shows that impedance is 50.18Ohm at 2.4 GHz which is nearly equal to 50 Ohm hence impedance matching is achieved .

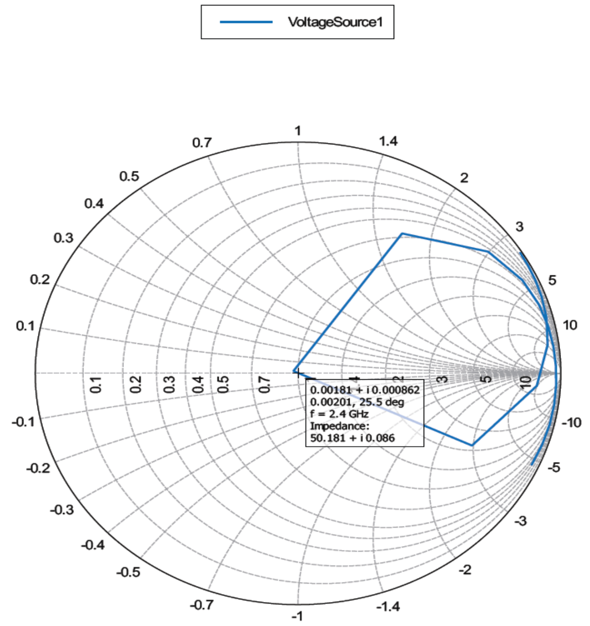

Fig. 12 : Smith Chart of RMPA with DGS

VI. Results

The RMPA defect on ground plane resonates at frequencies 2.4 GHz . This shows that when defect is introduced in the ground plane of the antenna then performance parameters of antenna like bandwidth , reflection coefficient ,gain are improved . The bandwidth enhancement is near about 34.1846 MHz was achieved and antenna can be used for wideband applications.

Simulated results RMPA alone and RMPA with DGS are shown are summarized in table 3.

Table 3: Result table

Parameter	RMPA without DGS	RMPA with DGS
Reflection coefficient	-15.5dB	-33.73dB
VSWR	1.435	1.06
Bandwidth	42.6312MHz	76.8158MHz
Beamwidth	93.613^0	93.288^0
Resonant Frequency	2.4 GHz	2.4 GHz

VII. Conclusion

It is observed that, by introducing some defected shape in ground plane we can overcome the drawbacks of RMPA . Defected ground plane can be used for improving the bandwidth which was the main drawback of patch antenna. Bandwidth improvement of 34.1846 MHz is achieved here so that antenna can be used for wide band applications. Reduced reflection coefficient indicates that most of the power will be radiated from the patch and only small amount of reflection waves were returned back to the source. Although improvement in parameters is small but it can be further improved by using different geometrical shapes, dimensions and locations of DGS.

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