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Ultra-Compact 1.8GHz Microstrip Antenna Using Defected Ground Structure

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***Abstract*—In this letter, we have presented an ultra-compact microstrip patch antenna. Physical size reduction and low cost are the trends that are centralized in today's developing technology. The simulated and fabricated results of an ultra-compact antenna that operates in 1.8GHz is discussed. Even though a lot of compromises are made such as low gain, narrow bandwidth etc., still this antenna provides promising features and parameters that are suitable for certain applications depending upon their requirements. The ultra-compact size is achieved by introducing DGS in the ground plane. The antenna including the ground plane has a total dimension of 17.78 mm × 17.78 mm × 1.6 mm. The proposed antenna is designed and fabricated with FR4 substrate with a dielectric constant of 4.4.The antenna operates at 1.8GHz with a reflection co-efficient of -17.04dB. A size reduction of 68% is achieved when compared to the traditional 1.8GHz narrowband antenna that is obtained through the design equations and a radiating efficiency of 76% is achieved. This compact narrowband antenna has a wide scope in wireless communication system applications.**

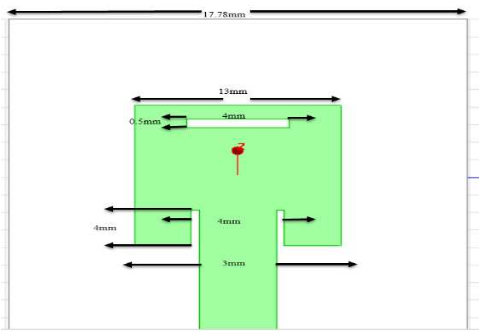
***Index Terms*— 1.8GHz, Antenna, Compact antenna, Defected ground structure, Microstrip, Narrowband antenna.**

I. INTRODUCTION

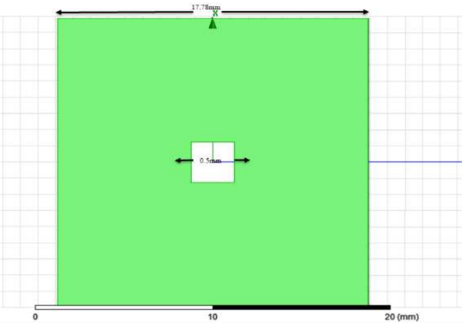
Wireless communication, recently has focused its researchin the miniaturization of the devices utilized. Antenna is an integral part of any wireless communication system as it transmits and receives the radio waves that is input or output by the system. The trend in the development of any new electronic devices or the optimization of the old will come out with the default criteria of size reduction ratio. The designers are motivated to design the antenna with small dimensions as possible as it finds huge applications in the areas where size and cost are hurdles. Compact sizes always gives rise to low cost devices that can be manufactured in large quantities unless and until it provides some acceptable disadvantages.

There are huge number of techniques to achievecompact size. Every compact antenna design, either modifies the regular structure or adopts a particular miniaturization technique, but each has its own pros and cons. The compact size can be achieved by a simple antenna design together with inset feed. Due to the inset structure, the impedance of the feed matches with the impedance of the radiating structure and therefore the desired result can be achieved with minimum dimensions when compared to the traditional design structure [2], [3].Any defect etched in the ground plane will change the current distribution which in turn increases the storage of effective capacitance and inductance. This accordingly decreases the reflection co-efficient and the required output is met together with compact size [4]. Other techniques such as meander lines is also adopted. Meander lines are nothing but the random fold of lines etched in the patch which greatly affects the current distribution. These randomly folded increases the distance travelled by the current which in turn is equal to the dimensions that is required for the antenna to resonate in frequency bands such as L- band, C-band etc.[5], [6]. Complementary split ring resonator is one of the miniaturization technique that is followed in order to get a compact size. They are either incorporated in the patch or ground [7], [8]. A very common technique is either to etch slots in the patch in the appropriate positions or designing the patches in the form of slots which is adopted for almost all designs. This greatly helps in achieving a compact size [9] - [13].

In this paper, we have proposed and fabricated a simple design that incorporates a rectangular slot in the patch together with a defected ground structure. The antenna operates in 1.8GHz frequency and can be used in 1.8GHz band application. Fig.1. shows the proposed antenna.



(a)



(b)

Fig.1.Proposed design (a) Patch (b) Ground

II. Antenna Design

The antenna designed is a square patch and makes use of FR4 substrate with permittivity 4.4. The antenna has an inset feed in order to match the impedance with radiating structure. The slot etched in the patch helps to increase the return loss a little and also helps in tuning the antenna to 1.8GHz by adjusting its length, width and position. When DGS is included in the ground plane the reflection co-efficient is greatly reduced. This helps in building up a compact size antenna.

Rectangular patch design equations

a) *Calculation of the Width (W)*

$$W = \frac{v_o}{2f_o}\sqrt{\frac{2}{\varepsilon_r+1}}$$

b) *Calculation of Effective dielectric constant ($\mathcal{E}_{reff}$)*

$$\mathcal{E}_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+\frac{12h}{W}\right]^{\frac{-1}{2}}$$

c) *Calculation of the Effective length (L_{eff})*

$$L_{eff} = \frac{v_o}{2f_o\sqrt{\varepsilon_{reff}}}$$

d) *Calculation of the length extension (ΔL)*

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

e) *Calculation of actual length of patch (L)*

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

f) *Calculation of the ground plane dimensions($L_g$and W_g)*

$$L_g = 6h + L$$

$$W_g = 6h + W$$

Table I shows the calculated dimensions of the patch antenna for 1.8GHz which is obtained through the above design equations. The compact dimensions achieved for the patch antenna is also shown which operates in a narrowband band.Fig.2. shows the fabricated antenna.

TABLE I. Calculated Vs Reduced Values

Parameters	**Calculated values(mm)**	**Reduced values(mm)**
Patch length	40	13
Patch width	52	13
Ground length	49.60	17.78
Ground width	61.60	17.78

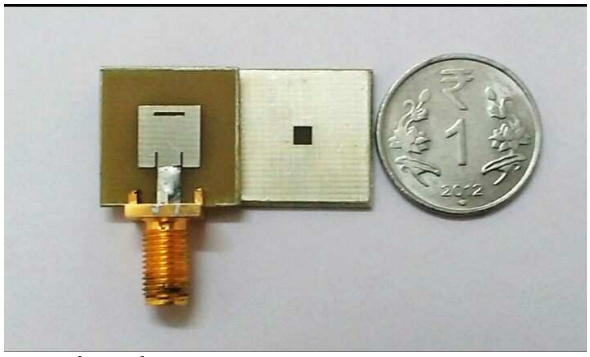


Fig.2. Fabricated antenna

III. Results and Discussions

A) S parameter Performance

a) *Without rectangular patch slot and DGS:*

The antenna is simulated without the patch slot and DGS. By simply adjusting the inset feed and feed gap the center frequency is pushed more or less to 1.8GHz. A reflection co-efficient of -7dB is achieved for 1.8GHz and has its center frequency at 1.84GHz. Fig.3. depicts the return loss graph of the antenna without patch slot and DGS.

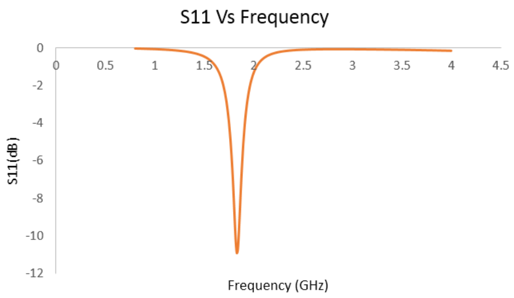


Fig.3. S11 parameter without patch slot and DGS

b) With rectangular patch slot and without DGS:

The antenna is simulated with the patch slot but without DGS. The slot in patch disturbs the current distribution in the patch which in turn provides the center frequency at 1.82 GHz and a reflection co-efficient of -10.04dB is obtained for 1.8GHz. Fig.4. shows the reflection co-efficient graph of the antenna with patch slot and without DGS.

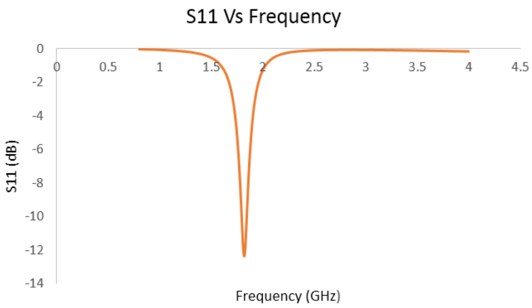


Fig.4. S11 parameter with patch sot without DGS

c) With rectangular patch slot and with DGS:

The antenna is simulated and fabricated with rectangular patch slot and DGS. Both, slot in the patch and ground are adjusted in order to obtain a better result. The defect in the ground plane increases the effective inductance and capacitance which greatly reduces the reflection co-efficient. A reflection co-efficient of -17.03 is achieved in simulation with a bandwidth of 1.77-1.84GHz. But due to losses and discrepancies in fabrication, a reflection co-efficient of -10.01dB is achieved for 1.8 GHz with a bandwidth of 1.8-1.87GHz. Fig.5. shows the simulated and fabricated reflection co-efficient of the antenna with both the patch slot and DGS.

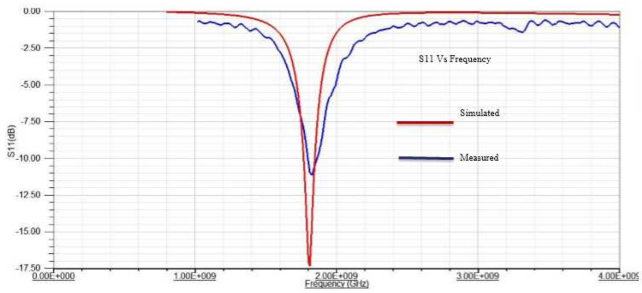


Fig.5. S11 parameter of the antenna both simulated and fabricated

B) *VSWR Performance*

The VSWR graph is shown in Fig.6.The VSWR is always a real and positive number for antennas. The smaller the VSWR is, the better the antenna is matched to the transmission lineand themore power is delivered to the antenna. The minimum VSWR is 1.0, no power isreflected from theantenna, which is ideal. VSWR should be in the range of 1-2 for the better performance of the antenna. VSWR of 1.33 is achieved for 1.8GHz.

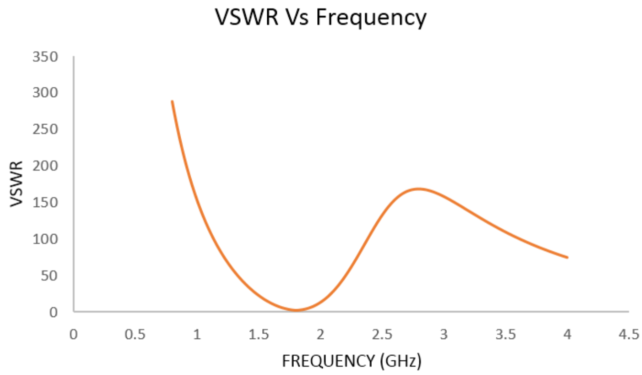
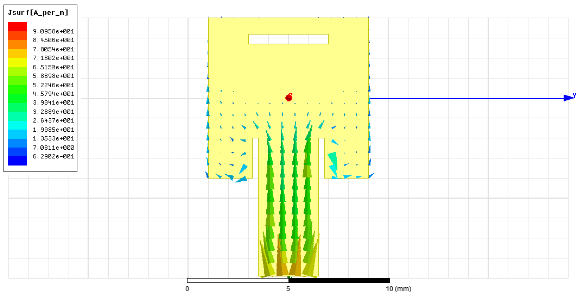


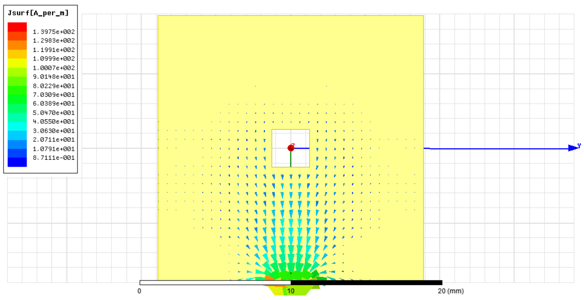
Fig.6. VSWR graph

C) *Surface Current Distribution*

Fig.6. shows the surface current distribution of the patch and the ground plane. The slot in the patch makes the current to take a longer electrical path than the one taken without the slot. Similarly in the ground plane the defect changes the current distribution which reduces the return loss of the antenna and is compact.



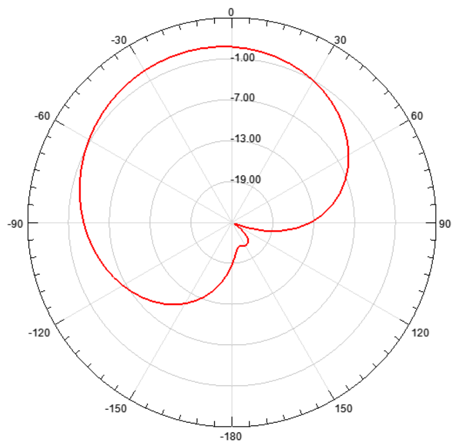
(a)



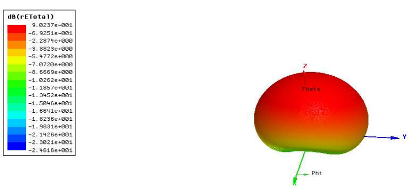
(b)

Fig.6. Surface current distribution for 1.8GHz (a) Patch (b) Ground

D) *Radiation Pattern Performance*



(a)



(b)

Fig.7. Directional radiation pattern (a) 2D (b) 3D

Fig.7. shows the directional radiation pattern for 1.8GHz. Though the radiation efficiency of the antenna is 76%, and the bandwidth is fairly increased in the fabricated result, the gain and directivity always remains as a criteria that needs to be given up because of the advantages gained from compact size. The front to back ratio is 165.78 which is also an important criteria that is met and to be discussed.

IV. CONCLUSION

In this letter, an ultra-compact narrow band antenna is designed and fabricated. The design is very simple and DGS is employed which greatly helps in reducing the size of the antenna structure. The structure uses Fr4 epoxy, which is a commonly available substrate and can be fabricated easily with less cost. This antenna can be manufactured in large quantities which can be easily integrated with ICs though it suffers from disadvantages like narrow bandwidth, low gain and directivity. The antenna can be used in low profile 1.8 GHz band applications depending on the requirement of the application that takes return loss, radiation efficiency and radiation pattern alone as criteria.

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