Improve Antenna Performances by DGS Techniques

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***Abstract* — This paper presents the design of microstrip circular patch antenna with Defected Ground Structure (DGS) for wireless communication. The proposed antenna has been simulated at 2.45 GHz frequency using Computer Simulation Tool (CST) Design Environment software. The substrate using Frame Retardant 4 (FR-4) with ε_r = 4.7 and thickness 0.8mm. Copper with thickness 0.035mm is used as a patch and ground. DGS with various sizes and shapes is build below the circular patch. The resultant antenna with DGS and without DGS was analyzed in term of return loss, bandwidth, gain, Voltage Standing Wave Ratio (VSWR), and radiation pattern. The fabricated antenna was then to be measured by Vector Network Analyzer (VNA) to carry out its S_{11} and VSWR result. The result from simulation and measurement will be compared.**

***Keywords*: DGS, patch antenna, wireless, (CST) Design Environment, Vector Network Analyzer (VNA).**

I. INTRODUCTION

A microstrip patch antenna is a type of a antenna that offers a low profile, conformable to planar and nonplanar surface, easy manufacturability, simple and inexpensive to manufacture using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces. When the particular patch shape and mode are selected, they are very versatile in term of resonant frequency, polarization, pattern, and impedance [1]. However, major operational disadvantages of microstrip antennas are their low frequency, low power and low gain.

Defected Ground Structure (GDS) is one of the methods which are used for this purpose. The defect in a ground is one of the unique techniques to reduce the antenna size. So design the antenna with the DGS, the antenna size is reduced for a particular frequency as compared to the antenna without the defect in the ground. DGS is realized by introducing a shape defected on a ground plane thus will disturb the shielded current distribution depending on the shape and dimension of the defect. The disturbance at the shielded current distribution will influence the input impedance and the current flow of the antenna. It can also control the excitation and electromagnetic waves propagating through the substrate layer [2].

In this paper, using microstrip circular patch antenna with DGS is very suitable for the applications in the wireless communication. DGS are widely used in microwave devices to make the system compact and effective. On the other hand, microstrip antenna with DGS will provide higher operating bandwidth, gain, less return loss, improve its radiation pattern and VSWR.

II. METHODOLOGY

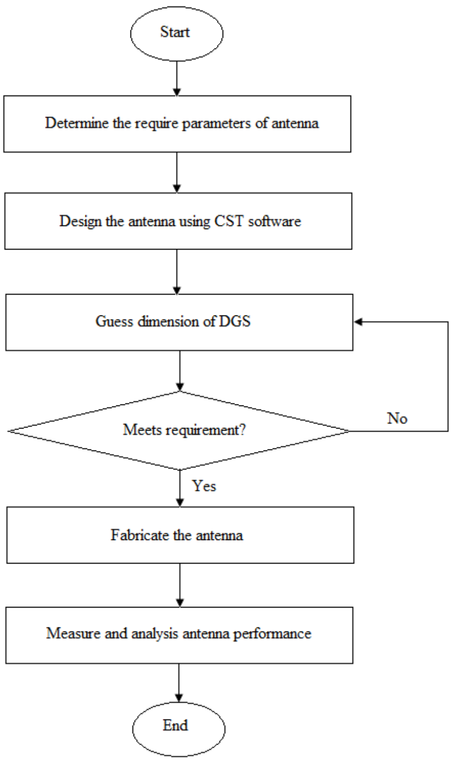


Fig.1: Flow chart to design Microstrip Patch Antenna with DGS

Figure 1 shows the flowchart how to design an antenna. It start with obtaining the required parameters, followed by designing the proposed antenna and guess dimension of DGS using Computer Simulation Technology (CST) software.

Next, if the frequency response acceptable, antenna can be fabricated. If not, the optimizing step should be done again until meets the antenna's necessity. After finished fabricating process, the antenna is measured using VNA. The result between simulation and measurement is compared and analyzed.

III. ANTENNA STRUCTURE

In order to design the frequency reconfigurable microstrip circular patch antenna, there are several related equations that should be used. The procedure assumes that the specified information includes the dielectric constant of the substrate (ε_r), the resonant frequency (f_r) and the height of the substrate h. The procedure is as follow:

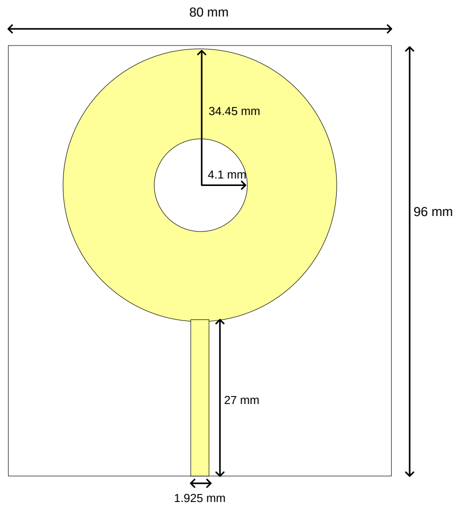
ε_r, f_r (in Hz), and h (in cm)

The actual radius, a of the patch

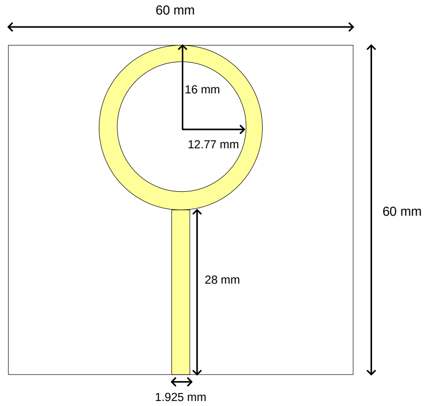
$$a = \frac{F}{\left\{1+\frac{2h}{\pi\varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}}$$

where

$$F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}}$$



(a)

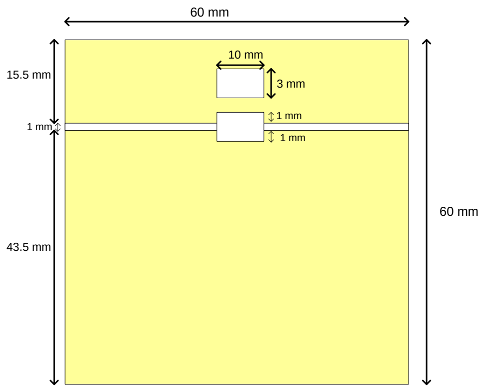


(b)

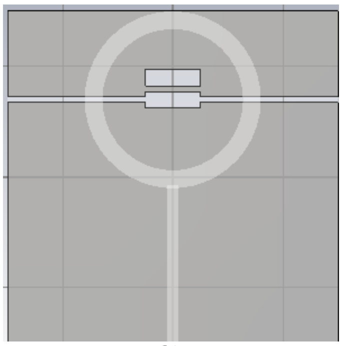
Fig.2: Patch parameters (a) without DGS (b)with DGS

The geometry and parameter of the antenna without and with DGS is shown in Fig.2. The antenna is designed with a single microstrip patch antenna consists of a circular microstrip patch of outer and inner radius, supported by a substrate, ground, feed line and waveguide. Material used for the substrate is Flame Retardant, FR-4 (loss free) having dielectric constant ε_r = 4.7, thickness h=0.8mm and tangent loss 0.019. FR-4 is chosen instead of cost limitation, ease of fabrication and reduce of weight. Thickness of the patch and ground is 0.035mm above and below the substrate.

In Fig.2 (a) and 2(b) shows a circular patch antenna without and with DGS. Antenna with DGS (substrate 60mm x 60mm) has small size compare to antenna without DGS (substrate 80mm x 96mm). There also an huge improvement in optimize parameter when the radius between this antenna is adjusted. Optimization width of feeding required for obtaining 50Ω line impedance and radius of circular also need to optimized to achieve the frequency band at 2.45GHz.



(a)



(b)

Fig.3: The shape of the DGS

Parameters DGS with 2 different slot is shown in Fig.3 (a). This figure shows the process of building the new shaped DGS patch antenna. In Fig.3 (b), DGS is loaded rightly under the circular patch to compare antenna performances in terms of return loss, gain, radiation pattern, VSWR and bandwidth.

IV. RESULT AND DISCUSSION

A Simulation Result

Fig.4 shows the return loss of microstrip circular patch antenna without DGS and with DGS. The antenna which is designed shows return loss at 2.45GHz frequency. The return graph shows the result with DGS is 19.49dB and antenna without DGS is 10.62dB.

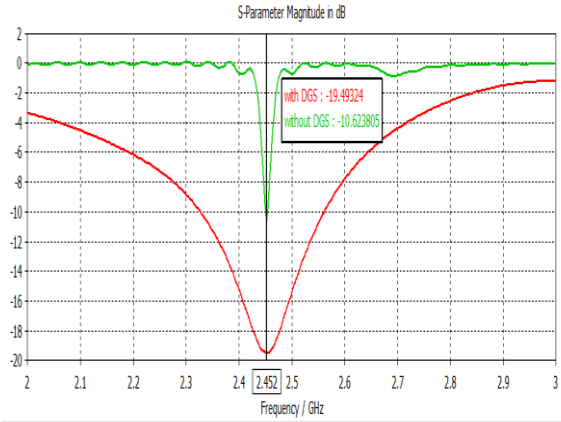


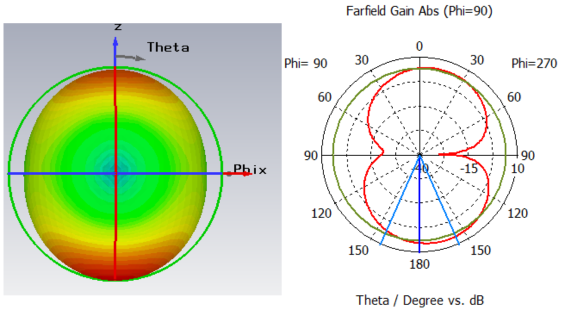
Fig.4: S_{11} vs Frequency without DGS and with DGS

The bandwidth can be calculated from the return loss plot. The bandwidth of the antenna in return loss is less than -10dB. The voltage standing wave ratio (VSWR), is not strictly an antenna characteristic, but is used to describe the performance of an antenna when attached to a transmission line. In this case, the VSWR has a value greater than one. The VSWR is easily measured with a device and VSWR of 1.5 is considered excellent, while values of 1.5 to 2.0 is considered good, and values higher than 2.0 may be unacceptable. Table 1 shows the improvement of bandwidth, VSWR and gain with DGS.

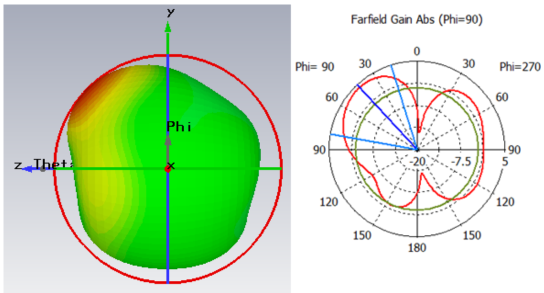
Table 1

	Without DGS	With DGS
Bandwidth	15.8 MHz	233.4 MHz
VSWR	1.83	1.24
Gain	3.897 dB	5.575 dB

Fig.5 (a) and 5 (b) shows the simulation result of radiation pattern the resonant frequency at 2.45GHz with and without DGS.



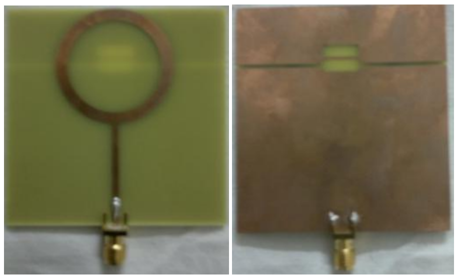
(a)



(b)

Fig.5: The radiation pattern for 2.45GHz (a) with DGS (b) without DGS

B Simulation and Measurement Result



(a) (b)

Fig. 6: Fabricated antenna (a)Top view (b) Back view

Fig.6 shows the fabricated antenna of DGS using FR-4 (loss free) as a substrate and copper as a patch and ground.

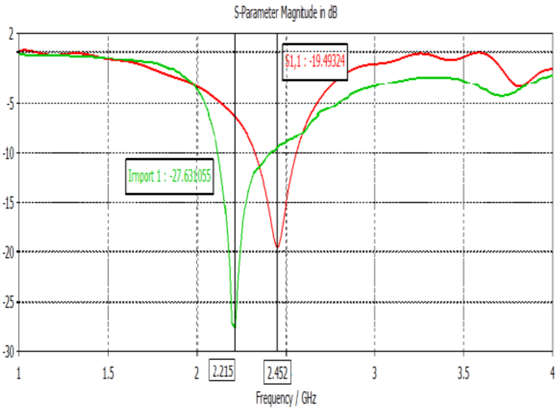


Fig.7 S-parameter between simulation and measurement result of DGS.

Fig.7 shows the differences between simulation and measurement result of DGS for thickness of substrate 0.8mm.The red line represent simulation result and the green line represent measurement result. Frequency and return loss of measurement result totally different from the simulation result because of environment and equipment error. Besides that, error occurs during fabrication, soldering and measurement process. The measurement result shifted 9.67% to the left from actual frequency, 2.45GHz. Otherwise, return loss have an improvement compare to the simulation result from 19.49dB to 27.63dB.

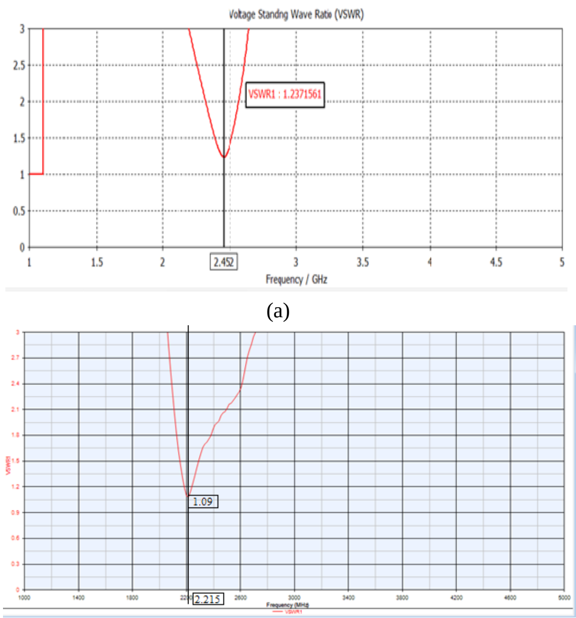


Fig.8: VSWR for DGS (a) simulation result (b) measurement result

From Fig.8, the result of VSWR for both simulation and measurement in an excellent range that is between 1 to 1.5. It can observed that the measured VSWR of 1.09 is better than the simulated VSWR. A perfectly matched antenna would have a VSWR of 1:1 that indicates how much power is reflected back or transferred into a cable. This mean that the frequency of measured antenna is closer to a perfect matching of 50 Ω compared to the simulated frequency. Difference results between simulation and measurement occurs because of environment error.

V. CONCLUSION

In this paper, microstrip circular patch antenna with Defected Ground Structure (DGS) are modeled with the equations and estimated with CST software and measured the result of the antenna designing with DGS using VNA. The effect of introducing DGS into ground plane of the antenna improved returning loss, VSWR, bandwidth, gain and radiation pattern compared to the antenna without DGS at the central frequency of 2.45GHz. Moreover, the radiating patch area is smaller as compared to the antenna without DGS. This antenna design with DGS not only improve the parameters of the antenna but also can provide a smaller size of radiating patches, which will cause an overall reduction in antenna size. The proposed antenna showed improvement in parameters and size reduction which can make them of potential to be used in various microwave circuits.

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