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Design of Microstrip Antenna with Defected Ground structure for UWB Applications

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Abstract: In this paper a design of compact size microstrip antenna is presented that have its applications in UWB frequency range. The ground element of the proposed antenna is taken in the form of defected ground structure(DGS). The antenna is fed by a microstrip feeding technique and printed on a dielectric Fr4 substrate of dimension (30mm X 32 mm) permittivity εr =4.4 and height h = 1.59 mm. The optimization on the microstrip has been done to accomplish an -10 dB return loss criterion. Moreover, in comparison with a simple ground, the proposed design enhances the bandwidth and improves input return loss. The antenna design parameters and performances have been investigated through a number of design simulations. Design parameters like substrate variation, feed size and defected ground plane which affect the performance of the antenna in terms of its frequency domain and time domain characteristics are investigated.

Keywords: Microstrip line feed, microstrip antenna, Omni-directional patterns, UWB.

I. INTRODUCTION

Ultra wide band range covers 3. 1GHz-10.6GHz is released by FCC in 2002[1]. From then on, the ultra-wideband (UWB) systems have attached much attention recently because of its advantages including high speed data, small size, low cost, low complexity [2-4]. As the important part of the UWB systems, the antenna has received increased attention due to its impedance bandwidth, simple structure and onmi-directional radiation pattern. The simplest way to implementing planar forms of the antenna is using the microstrip feeding technology. Microstrip antenna in its simplest form consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side of the substrate. Defected Ground Structure is one of the methods which is used for this purpose[5-8].The defect in a ground is one of the unique techniques to reduce the antenna size. So design the antenna with the defected ground structure, the antenna size is reduced for a particular frequency as compared to the antenna size without the defect in the ground[9-10]. 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 CST MICROWAVE STUDIO is a specialized tool for the fast and accurate 3D EM simulation of high frequency problems[11]. UWB applications owing to the features of low cost, light weight, ease of fabrication and nearly omni-directional radiation pattern. Some of these monopole UWB antennas only cover partial spectrum of the UWB band because of their large size. It is found that by introducing a rectangular slot on the ground plane, the return loss and radiation pattern characteristic is improved. A wide impedance bandwidth from 3 to 10.6 GHz is also obtained. The effects of the rectangular slot on the ground plane have been analyzed using commercially available CST Microwave Studio 2010 and an experimental structure of proposed antenna has been fabricated and measured to verify the simulated result.

TABLE I. THE ANTENNA PARAMETERS

Sr.No.	Description	Value/mm
1	Antenna length	30
2	Antenna width	32
3	Width of the ground plane	10
4	Sise of slot	2
5	Substrate thickness h	1.59
6	Feed Size	3

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II. ANTENNA GEOMETRY AND SIMULATION RESULTS

A. Antenna Geometry:

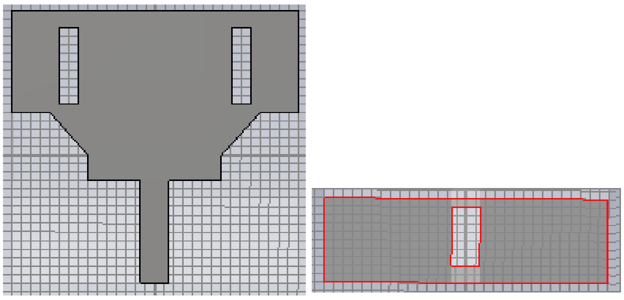

Fig. 1 illustrates (a) the evolution of the proposed Microstrip Antenna on the FR4 substrate.

(b)Defected ground structure

B. Impedance Bandwidth

Fig.2 shows the simulated return losses (S parameter) of the proposed antenna. It can be clearly seen that the proposed antenna has a multi-band characteristic in the UWB spectrum. Three resonant frequencies locate at about 6.5GHz,7.97GHz and 9.3GHz with the return losses reach -28dB, -62dB, and -43dB respectively. The antenna bandwidth that is lower than -10dB occupies from 3.1GHz to 10.6GHz. It can operate well in UWB applications. The ground plane size selection is also based on the study presented in [12], [13] on the microstrip slot antennas. Antenna designs are simulated on CST microwave studio 2010.

CST Result:

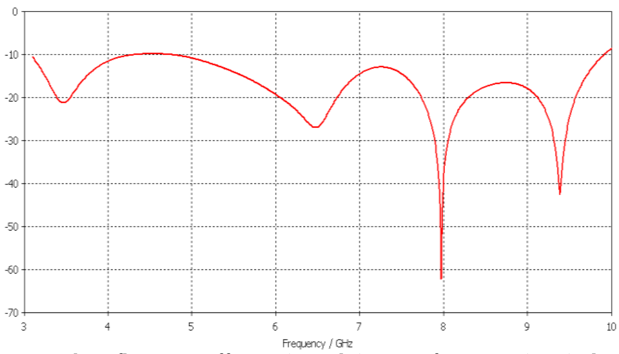

Fig.2.The reflection coefficient (S11, dB) versus frequency (GHz) plot for antenna design.

(a)Calculation of width of patch:

The width of the antenna is calculated by equation

$$w = \frac{1}{2 f_r \sqrt{\varepsilon_o \mu_o}} \sqrt{\frac{2}{\varepsilon_r + 1}}$$

(b) **Calculation of effective dielectric constant**:

The effective dielectric is calculated by equation[6]

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

(c) **Calculation of the effective length:**

The effective length is calculated using equation

$$f_r = \frac{1}{2L\sqrt{\varepsilon_r \varepsilon_o \mu_o}} = \frac{v_o}{2L\sqrt{\varepsilon_r}}$$

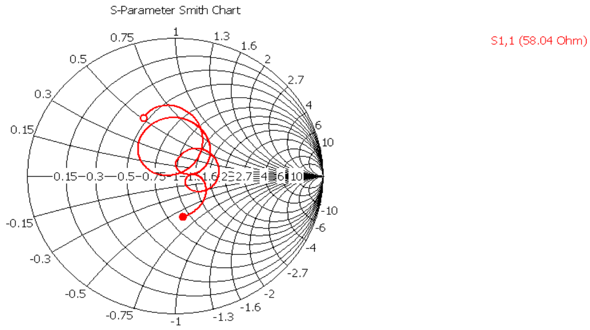

Fig.3.Port Impedance In terms of Smith Chart

III. FREQUENCY Vs VSWR GRAPH:

VSWR is defined in terms of the input reflection coefficient r as:

$$VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

r is defined in terms of input impedance *Z*in of the antenna and the characteristic impedance *Z*0 of the feed line as given below:

$$r = \frac{Zin - Zo}{Zin + Zo}$$

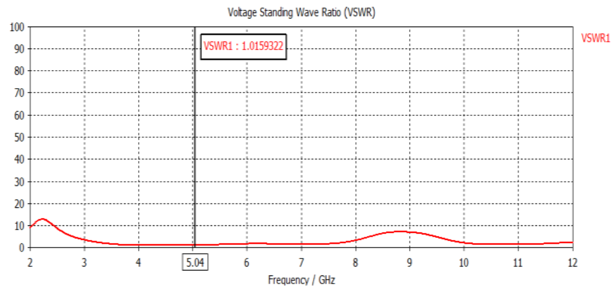

Fig. 4 The frequency (GHz) versus VSWR plot

IV. EFFECT OF PARAMETER VARIATION ON ANTENNA PERFORMANCE:

Substrate material Variation

In this case there are comparisons of return loss with the variation in the materials of substrate. In this investigation of effect generally Roger 4003 & Fr4 are considered. With Fr4 first lobe of -62dB occur at 7.5GHz whereas with

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Roger4003 the first lobe of return loss of -32dB at a frequency of 8GHz. The use of Fr4 as a substrate provides the max.. return loss of -62 dB at 8GHz whereas with Roger4003 the min. loss of -32dB at 7GHz. So it can be concluded that Fr4 act as better substrate material for satisfying the return loss.

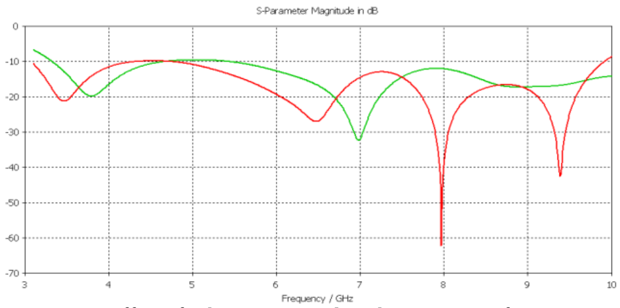

Fig.5: Effect of substrate material on the antenna performance

Effect of slot on Radiator : In this antenna design we are taking the different slot sizes to analyse its effect on performance of antenna.In this as the number of slots increases more energy will radiate out of the antenna[14]. In this antenna design only one slot of 2 mm is cutted. With more number of slots the antenna design requirement of -10dB return loss does not met.

Fig.6.Effect of single and double slot cut on radiator

Effect of defected ground slot width: In this design variation of defect ground has a large effect on the return loss. From the below graph it has been concluded that the effect of defected ground size has large effect on antenna performance. The microstrip antenna without DGS, the bandwidth is narrow and the return loss is high. On the other hand, microstrip antenna with DGS will provide higher operating bandwidth and less return loss. Therefore, the DGS can be integrated onto the ground plane of such antenna in order to improve its radiation, besides not requiring additional circuits are for implementation.

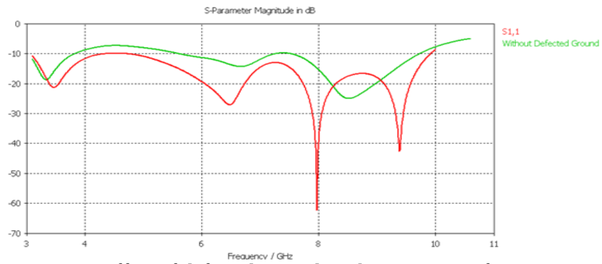

Fig.7: Effect of defected ground on the antenna performance

Effect of feed Width:

In this design of microstrip antenna we are taking the different feed size[15] to calculate their effect on performance. The feed size of antenna influences the impedance of antenna. In this antenna design the feed size of 3mm satisfy the requirement of -10dB. The feed size has inversely proportional effect with the port impedance. With increase in feed size of antenna the input impedance of antenna decreases.

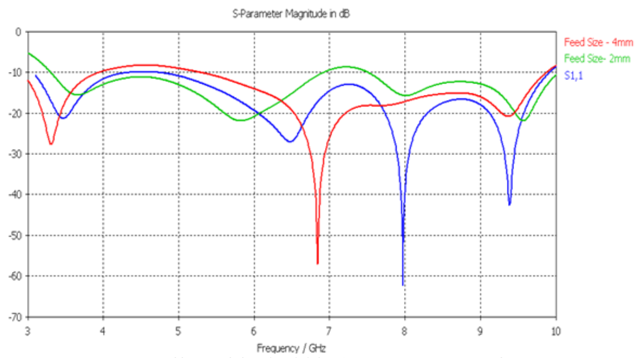

Figure 8 – Effect of feed width (ε_r) on antenna performance characteristics

Radiation pattern: This work is to design a small antenna suitable to be used in mobile devices, where a three-dimensional (3D) omni-directional radiation and high radiation efficiency are desirable. [15]where the red colour indicates the stronger radiated E-fields and the blue colour the weaker ones.

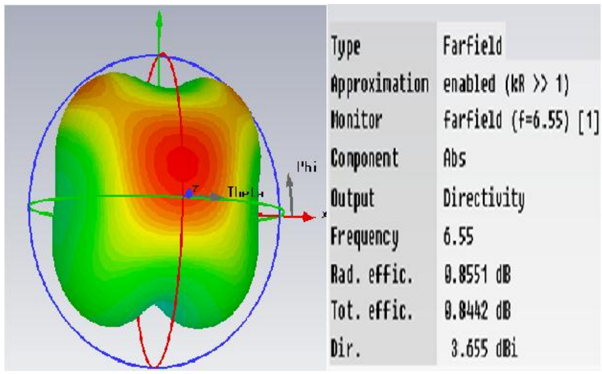

Fig.9: The electric field curve in theta and phi direction.

V. CONCLUSION

This new patch antenna with defected Ground Structure (DGS) demonstrate properties: improved return loss, VSWR bandwidth, gain of the antenna as compared to the conventional antenna. These fundamental parameters are modeled with the equations and estimated with CST software. By this microstrip antenna 85% total efficiency is achieved. The effects of introducing DGS into the ground plane of the antenna have been successfully investigated. The antennas operate well at their corresponding frequencies of operations. The rectangular patch antenna designed with slotted DGS shows directivity 3.65 dB. Moreover, the radiating patch area is smaller as compared to the conventional antenna without DGS. So, this antenna design with DGS not only improve the parameters of the antenna without DGS but also can [17] provide a smaller size of radiating patches, which will cause an overall reduction in antenna size.

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