Synthesis of Goblet shape defected ground slotted microstrip patch antenna

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Abstract. This paper presented for investigation, how the defects as well as slots of different shapes and sizes on the ground of microstrip patch antenna (MPA) improve its characteristics like VSWR, Return Loss, efficiency, etc. This has been done by cutting a rectangular shape of defect on the ground and cut a slot on the goblet shaped patch of designed antenna structure. This microstrip antenna is suitable for tracking data, satellite communication, etc. The performance and advantages of microstrip antenna such as low cost, low profile, low weight made them the perfect choice for communication systems. In the proposed defected ground microstrip patch antenna (DG – MPA), a rectangular slot (1.25mm x 3.75mm) is cut on the Goblet Patch (10.71mm x 41.5mm x 1.5mm) of the structure. An inset feed (-11mm x 6mm) is introduced in this microstrip antenna. The antenna designed to function at 2.2 GHz. The proposed antenna not only operate at 2.2 GHz frequency, but also offers Return loss -26.86, VSWR 0.78, with frequency 12.85 GHz (Ku-band).

1. Introduction

Communication plays a very important role in today’s world as the switching of communication systems from “wired to wireless” has been very rapid. The antenna is one of the most important elements of wireless communication systems, allowing the transmission and reception of electromagnetic waves in free space. The design of an efficient, small size antenna providing large operating bandwidth for recent wireless applications is a major challenge. Thus, antenna design has become one of the most important and demanding aspect in the field of wireless communication [1]. Conventional microstrip antennas had some limitations, that is, single operating frequency, low impedance bandwidth, low gain, larger size, and polarization problems. There are a number of techniques which have been reported for enhancing the parameters of conventional microstrip antennas that is, using stacking different feeding techniques, Frequency Selective Surfaces (FSS), Electromagnetic Band Gap (EBG), Photonic Band Gap (PBG), Metamaterial, and so forth. Microwave component to Defected Ground Structure (DGS) has been gaining popularity among all the techniques reported for enhancing the parameters due to its simple structural design. The etched slots or defects on the ground plane of microstrip circuits are referred to as Defected Ground Structure. Single or multiple defects on the ground plane may be considered as DGS [2].
Recently, a growing demand of microwave and wireless communication systems in various applications, resulting in an interest to improve antenna performances. Therefore, the selection of microstrip antenna is suitable to apply at various fields such as telecommunication, medical application, satellite, military system, etc. Many kinds of miniaturization techniques, such as using of dielectric substrate of high permittivity, slot on the patch, DGS at the ground plane or a combination of them have been proposed and applied to microstrip patch antennas [3].

In the present work, a defect has been produced in the ground plane to reduce the antenna size and trying to make the antenna structure simple and effective. The proposed antenna design is incorporated with rectangular shaped defect on the ground and a slot on the patch of the conventional microstrip antenna. Etching this defect underneath the simple microstrip feedline, the impedance, bandwidth and other technical parameter can be obtained [3]. In this communication, the geometry of the rectangular shape of the slot on the microstrip patch antenna (MPA) has been introduced to improve the performance of conventional MPA. The simulation studies are carried out by using HFSS simulation software.

2. Design and simulation of the proposed antenna

The designed structure consists of a rectangular patch microstrip antenna with a defected ground as shown in ‘figure 1’.

The rectangular, slotted patch antenna with DGS is designed on a commercially available FR 4 epoxy substrate of dielectric constant ($\varepsilon_r$) 4.4 and height (h) 1.5 mm, respectively [4]. The dimensions and parameters of the rectangular microstrip patch antenna can be calculated as follows for the central resonance frequency (Fr) of 2.2 GHz [5], [6]. The width (W) of the patch antenna is calculated by

$$W = \frac{v_0}{2f_r}\left(\frac{2}{\varepsilon_r+1}\right)^{1/2}$$  

Where, $v_0$ is the velocity of light in free space.

The actual physical length (L) of the patch antenna is calculated by

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

Where, $L_{eff}$ is the effective length of patch antenna caused by fringing field and $\Delta L$ is extended length due to fringing field. The $L_{eff}$ and $\Delta L$ is given by

$$L_{eff} = \frac{v_0}{2f_r}(\varepsilon_{reff})^{-1/2}$$

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And, the value of $\Delta L$ can be calculated using the following equation

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

(4)

Where, $\varepsilon_{ref}$ is effective dielectric constant of microstrip patch antenna on dielectric substrate

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

(5)

Length of active patch (L) is more responsible for better antenna performance. Ground patch is with good conducting material takes the dimensions of the dielectric substrate. However, it may be partial or full ground with slots according to their requirement. To improve the performance of microstrip patch the inset feeding technique is used. The main advantage of using this mechanism is that, impedance matching can be done easily by adjusting the position of inset feed [7].

**Table 1.** A General structure specification for designed antenna.

| Sr. No. | Specification          | Measurement (mm) |
|---------|------------------------|------------------|
| 1.      | Material of substrate  | FR4 epoxy        |
| 2.      | Dielectric constant of substrate | 4.4             |
| 3.      | Dimension of Ground (mm$^3$) | 4.5 x 50.5 x 1.5 |
| 4.      | Dimension of Substrate (mm$^3$) | 41.21 x 50.5 x 1.5 |
| 5.      | Dimension of Patch (mm$^3$) | 10.71 x 41.5 x 1.5 |
| 6.      | Dimension of Inset Feed (mm$^3$) | -11.0 x 6.0 x 1.5 |
| 7.      | Defected Area (mm$^2$)  | 45.5 x 41.5      |
| 8.      | Slotted Area (mm$^2$)   | 3.75 x 1.25      |

To have better performance in terms of radiation or bandwidth, the dielectric constant ($\varepsilon_r$) of substrate should be low and thickness (h) of the substrate should be more. Generally, the value of $\varepsilon_r$ lies between 2.2 to 12 [6]. If the value of $\varepsilon_r$ is small, then the radiation from an antenna is good. If it is high, then the fields are more tightly contained in the substrate which results in less radiation. To obtain high efficiency and high bandwidth the thickness of the substrate should be more as possible; however, the antenna pattern and the polarization characteristics may be degraded due to higher thickness of the substrate. The value of substrate thickness should be $0.003 \lambda_0 \leq h \leq 0.05 \lambda_0$. Where, $\lambda_0$ is wavelength in the free space [8].

In the present work, defected ground technique is used to improve bandwidth, return loss and other parameter of antenna and it is also useful to reduce weight, shape and size of the Microstrip Patch Antenna.

**3. Result and Discussion**

The simulation tool used for designing and evaluating the performance of proposed antenna is HFSS software. This model simulates and obtained results for the antenna parameters, S11, Gain, Directivity and Voltage Standing Wave Ratio, etc. Defected ground structure (DGS) plays an important role in the microstrip antenna. This is frequency sensitive antenna because in such kind of patch antenna multiple frequencies may assign at same dimension. With the help of DGS the effective inductance and capacitance has been increased, therefore, the return loss, gain and bandwidth show better results as compared to non-DGS.
The return loss is shown in the ‘figure 2’ and it must be less than -10 dB. The return loss (in dB) of the single-band patch antenna is -26.86 at operating frequency 12.85 GHz. The return loss shows a good matching between the antenna and the feed line.

![Figure 2. Graph frequency Vs Return loss.](image1)

The voltage standing wave ratio (VSWR) of proposed antenna is 0.78 at frequency 12.85 GHz is shown in ‘figure 3’.

![Figure 3. Graph frequency Vs VSWR.](image2)

To find the perfect input impedance matching VSWR should be minimal. The maximum gain of proposed antenna is 0.736 at 12.85 GHz and it has been presented in ‘figure 4’.

![Figure 4. Graph frequency Vs Gain.](image3)
In this proposed work the directivity of the antenna is 4.55 dB, at 12.85 GHz. In spacious form, the value of directivity is from 1 to $\infty$ for various operated frequency. The better directivity gives high radiation efficiency in all possible directions and it has been shown in ‘figure 5’.

![Figure 5. Graph frequency Vs Directivity.](image)

The radiation pattern at resonance frequency at 2.2 GHz, for $\theta = 0^\circ$ and $\theta = 90^\circ$ has been shown in ‘figure 6’ and it is omnidirectional.

![Figure 6. Radiation pattern at frequency 12.85 GHz.](image)

4. Conclusion

This antenna has been designed using FR4 substrate and having an exoteric shape and simple manufacturing technique. The proposed slotted DGS antenna has significance for good directivity and return loss. This structure is operating at frequency 12.85 GHz under Ku-band. The impedance of this slotted DGS antenna is around 34.68 $\Omega$ and axial ratio is 1.4 at 12.85 GHz. The designed antenna is supporting for different Ku-band application, for example; microwave towers, radio astronomy services, mobile services and satellite communications in tropical regions like Indonesia.

5. References

[1] Khan N A and Singh B A 2014 Microstrip antenna design with defected ground structure IOSR J. Elect. Com. Eng. 9(2) 46-50.
[2] Khandelwal M K, Kanaujia B K and Kumar S 2017 Defected ground structure: fundamentals, analysis and applications in modern wireless trends Int. J. Ant Pro. 1-22.
[3] Singh G, Rajni and Momi R S 2013 Microstrip patch antenna with defected ground structure for bandwidth enhancement Int. J. Com. App. 73(9) 14-8.
[4] Caliskan A, Belen M A, Mahouti P, Demirel S and Gunes F 2015 Design of a multiband microstrip patch antenna with defected ground structures 1-4.

[5] Arya A K, Patnaik A and Kartikeyan M V 2013 Gain enhancement of micro-strip patch antenna using Dumbbell shaped defected ground structure Int. J. of Sci. Res. Eng. Tec. 2(4) 184-8.

[6] Bankey V and Kumar N A 2015 Design and performance issues of microstrip antennas International Journal of Scientific and Engineering Research 6(3) 1572–80.

[7] Kaur P, Nehra R, Kadian M, De A, Aggarwal S K 2013 Design of improved performance rectangular microstrip patch antenna using peacock and star shaped DGS International Journal of Electronics Signals and Systems (IJESS) 3 (2) 33-37.

[8] Kumar P and Srivastava D K 2015 Design of triangular monopole UWB microstrip patch antenna with SRR International Journal of Advanced Research in Electronics and Communication Engineering 4(12) 2830–35.