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# Bandwidth Enhancement of a Microstrip Patch Antenna Using Inverted-F Shaped Defected Ground Structure

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**Abstract**

In this paper, a rectangular microstrip patch antenna with a defected ground structure is proposed. Bandwidth is improved with a good impedance matching which is suitable to use in various applications. Inverted-F Shaped defected ground structure (DGS) is proposed in this paper to achieve this enhancement. With the proposed design method, using a simple single layer structure, an enhanced bandwidth of 650 MHz ranging from 8.07 GHz to 8.72 GHz is achieved for C and X bands respectively. Besides that, compares the performance of the proposed antenna over a traditional rectangular patch antenna. The microstrip patch antenna is designed and simulated using the high frequency simulation software FEKO.

***Keywords:*** Defected Ground Structure (DGS); Microstrip Patch Antenna (MPA); C-band, X-band.

## 1. Introduction

To survive in the world of digital communication there is a massive necessity of antenna [1]. The Microstrip Patch Antenna receiving more popularity due to low profile structure, low fabrication cost and easy to design and fabrication [2]. Microstrip patch antennas are popular because of its shape can be modified easily to match resonant frequency, signal pattern, polarization and impedance [3]. Surface waves are one of the drawbacks of the microstrip antennas because when a patch antenna radiates, a portion of the total available radiated power is trapped along the surface of the substrate. Surface waves increase the level of side lobes, reduce the efficiency and antenna gain, limit the bandwidth and increase cross polarization [4,5].

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To enhance the Bandwidth (BW) of the patch antenna one possible method is the adjustment of the width of patch and height of the substrate [6]. In that case, proper optimizations need to be done for maintaining the desired center or resonant frequency.

One of the ways of the removed by using a DGS structure in microstrip patch antennas, which supports multi-band and can operate at different frequencies in a single device [7]. Different shapes of defected ground structures provide many advantages like reducing the size of the antenna and improving the bandwidth [8]. In this paper, Inverted-F Shaped DGS is used to enhance the bandwidth at the resonant frequency of 7.16 GHz in the range of C-band (4 to 8 GHz), which is used in the applications of long-distance radio telecommunications and at the 8.25 GHz in the range of X-band (8 to 12 GHz) which is used for the applications of satellite communications, radar, terrestrial broadband, space communications, amateur radio. The antenna is designed with the dielectric substrate having dimensions 32 x 28.1 x 0.794 mm with dielectric constant 2.2. An Inverted-F Shaped slot is applied on the ground plane as DGS. Fig.1 shows the side views of the antenna and structure of the Inverted- F Shaped Microstrip Antenna. There are four types of Feeding techniques (Microstrip line feed, Coaxial feed, Aperture Couple feed, Proximity couple Feed). In our work we have used Microstrip line feed as far as Spurious feed Radiation is concern it is more, reliability is better, easy to fabricate and easy to matching the impedance.

This paper discusses about the antenna design methodology and formulas for parameters calculation in the next section. Section 3 describes the result and discussion with several figures, comparison table of having and not having DGS and achievements of the design with benchmarking table. In section 4 the paper ends with conclusion.

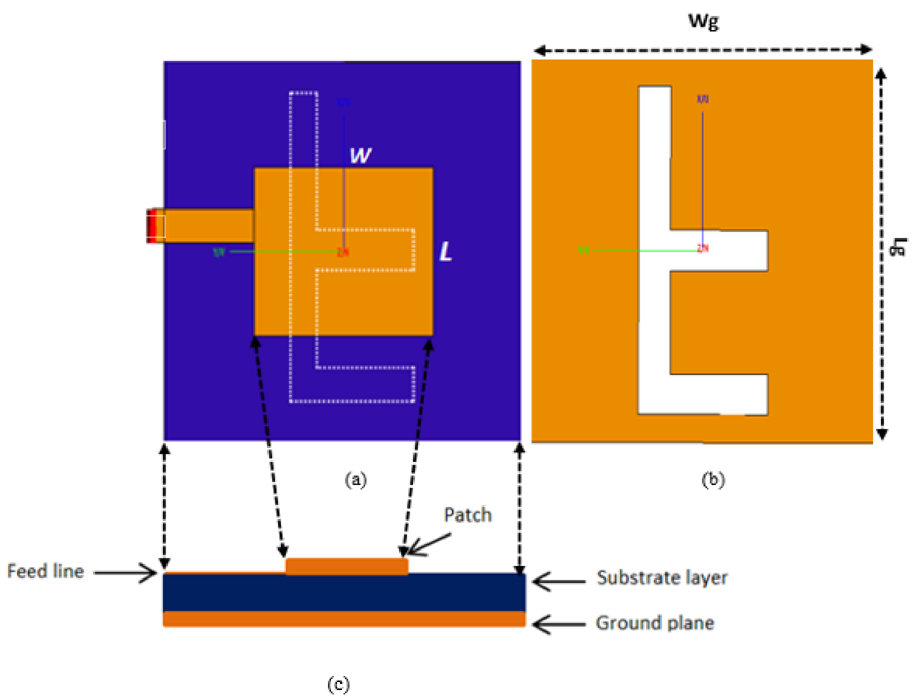
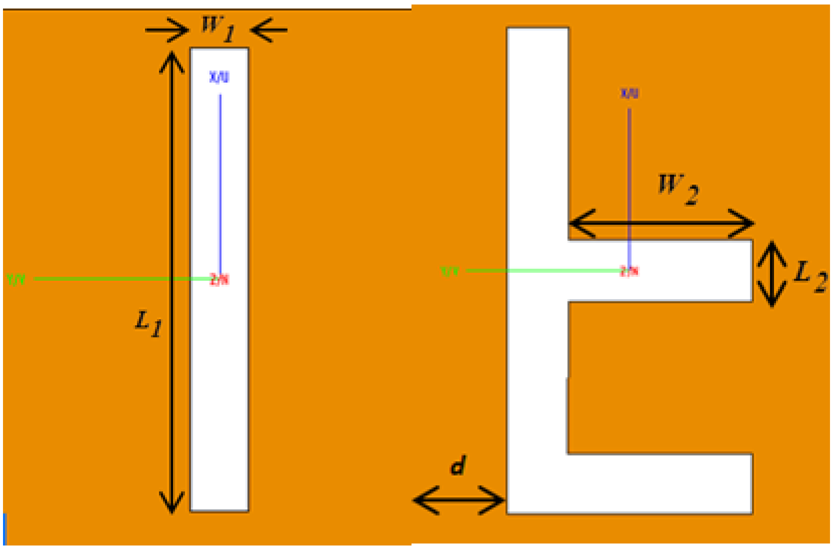



**Figure 1:** (a) Top view of the antenna (b) Bottom view of the antenna (c) Side view of the antenna

## 2. Antenna Design

Geometry of the antenna consists of a patch antenna with dimensions 12.45 x 16 mm, a substrate dielectric material of relative permittivity 2.2 with thickness 0.794 mm. Fig. 2 shows the ground plane with I Shaped [9] and the Inverted- F Shape DGS.




(a) (b)

**Figure 2:** (a) I Shaped DGS (b) Inverted- F Shape DGS

Microstrip feed line is used as a feeding method. The design parameters are given in Table 1. Antenna is designed and simulated in FEKO 5.5 software.

**Table 1:** design parameter of microstrip patch antenna

| **Parameter** | **Value** |
|---|---|
| Patch width | 16 mm |
| Patch length | 12.45 mm |
| Substrate dimensions (Lg x Wg x h) | 32 x 28.1 x 0.794 mm |
| Dielectric constant | 2.2 |
| Feed line width | 2.46 mm |
| Feed line length | 8 mm |
| Center of the Feed point | (1.9,12)mm |

The design procedure for the essential parameters is explained based on the transmission line model.

Step 1: Determination of the Patch Width (W)

The width of the microstrip patch antenna is given by (1)

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

Step 2: Determination of effective dielectric constant ( $\varepsilon_{reff}$ )

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}(1 + 12\frac{h}{w})^{-\frac{1}{2}} \tag{2}$$

where h is the thickness of the substrate.

Step 3: Determination of the effective length ( $L_{eff}$ )

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \tag{3}$$

Step 4: Determination of the length extension (ΔL)

$$\Delta L = \frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{w}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{w}{h} + 0.8\right)} \tag{4}$$

Step 5: Determination of the actual patch length (L)

$$L = L_{eff} - 2\Delta L \tag{5}$$

Similar results for finite and infinite ground plane can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery [10]. FEKO software is a comprehensive computational electromagnetics (CEM) software used widely in the telecommunications, automobile, aerospace and defense industries [11].

The geometry of the Inverted-F Shaped DGS consist of vertical arm with the dimensions of 24 x 3 mm which is located at a distance *d* from patch edge and two horizontal arms as shown in Table 2.

**Table 2:** Design parameter of inverted-f shaped dgs

| **Parameter** | **Value** |
|---|---|
| Vertical arm Length ( $L_1$ ) | 24 mm |
| Vertical arm Width ( $W_1$ ) | 3 mm |
| Horizontal Arm Length ( $L_2$ ) | 3 mm |
| Horizontal arm Width ( $W_2$ ) | 9 mm |
| Distance from the ground edge ( $d$ ) | 10 mm |

## 3. Simulated Results

### *A. Return Loss*

Table 3 shows the return loss results for the patch antenna with and without DGS.

**Table 3:** Return loss of the microstrip patch antenna

| **Case** | **Resonant frequency (GHz)** | **S-parameter (dB)** |
|---|---|---|
| Without DGS | 7.44 | -13.77 |
| I Shaped DGS | 8.07 | -36.34 |
| Inverted- F Shaped DGS | 7.167 | -52.77 |
| | 8.25 | -23.12 |

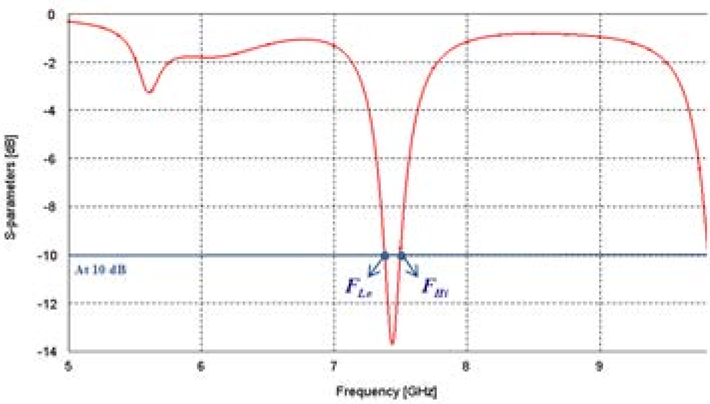



**Figure 3:** Return loss of the microstrip patch antenna without DGS

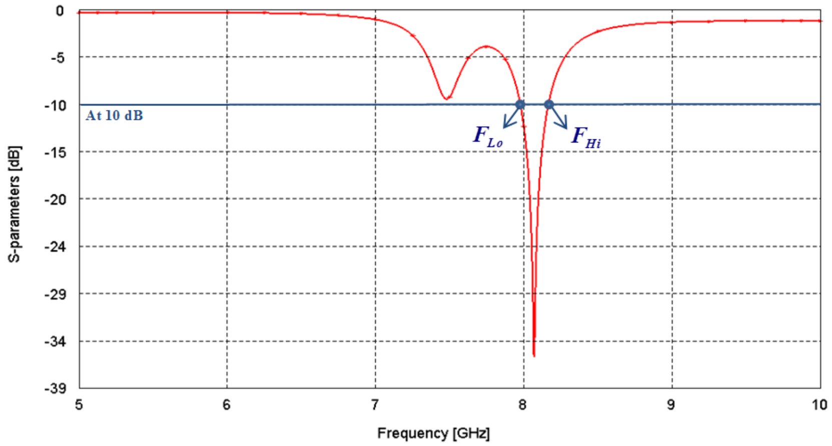



**Figure 4:** Return loss of the microstrip patch antenna with I Shaped DGS

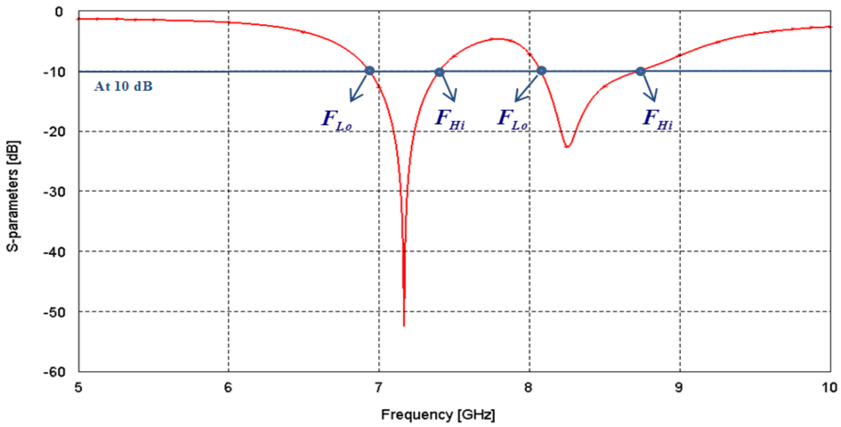



**Figure 5:** Return loss of microstrip patch antenna Inverted- F Shaped DGS

*B. Bandwidth*

In the case of Inverted- F Shaped DGS, the bandwidth is increased by 470 MHz in the C-band at the resonant frequency 7.167 GHz and 650 MHz in the X-band at the resonant frequency 8.25 GHz. The bandwidths for each case are shown in in Table 4.

**Table 4:** antenna Bandwidth for the microstrip patch antennas

| **Case** | $F_{Lo}$ **(GHz)** | $F_{Hi}$ **(GHz)** | **Bandwidth (MHz)** |
|---|---|---|---|
| Without DGS | 7.38 | 7.49 | 110 |
| I Shaped DGS | 7.97 | 8.16 | 190 |
| Inverted- F Shaped DGS | 6.93<br>8.07 | 7.40<br>8.72 | **470**<br>**650** |

After that, Inverted- F Defected arms are examined for different dimensions step by step to achieve a better broadband as shown in Fig. 6 and Fig. 8. The impedance for each case is tested to obtained good matching impedance close to 50Ω at the resonant frequencies as shown in Fig. 7 and Fig. 9.

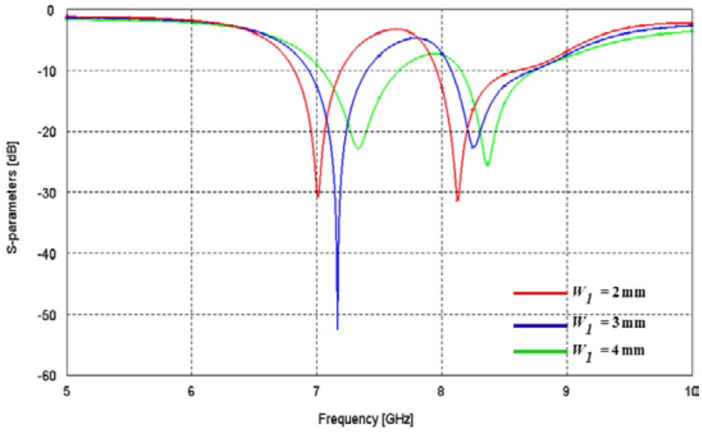



**Figure 6:** Return loss results at different values of $w_1$

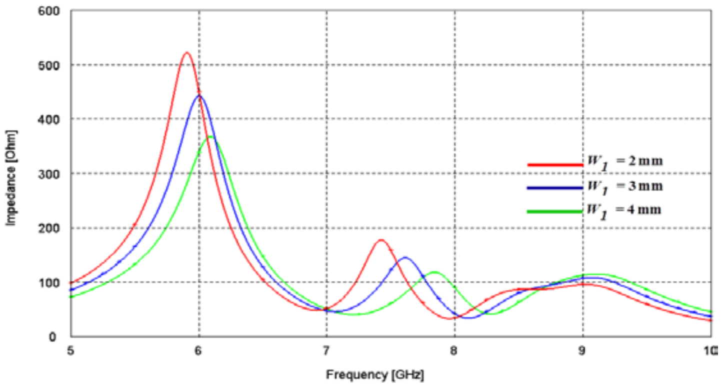



**Figure 7:** Relation between the resonant frequency and the impedance for different values of $w_1$

**Table 5:** Parameters for different $w_1$ values

| $w_1$ | Band | Resonant frequency (GHz) | S-parameter | Bandwidth (MHz) | Impedance (Ohm) |
|---|---|---|---|---|---|
| 2 mm | C-band | 7.0 | -30.99 | 380 | 49.84 |
| | X-band | 8.12 | -31.47 | 650 | 49.84 |
| 3 mm | C-band | 7.167 | -52.77 | 470 | 49.38 |
| | X-band | 8.25 | -23.12 | 650 | 49.38 |
| 4 mm | C-band | 7.33 | -22.91 | 620 | 42.64 |
| | X-band | 8.36 | -25.74 | 610 | 44.21 |

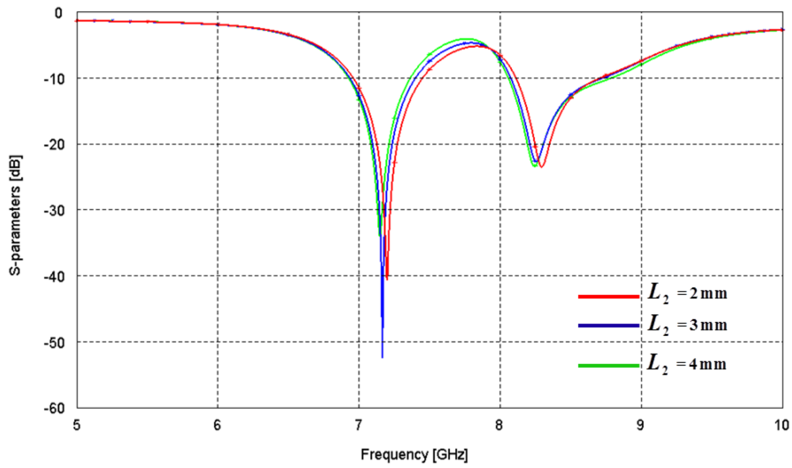



**Figure 8:** Return loss for different values of $L_2$

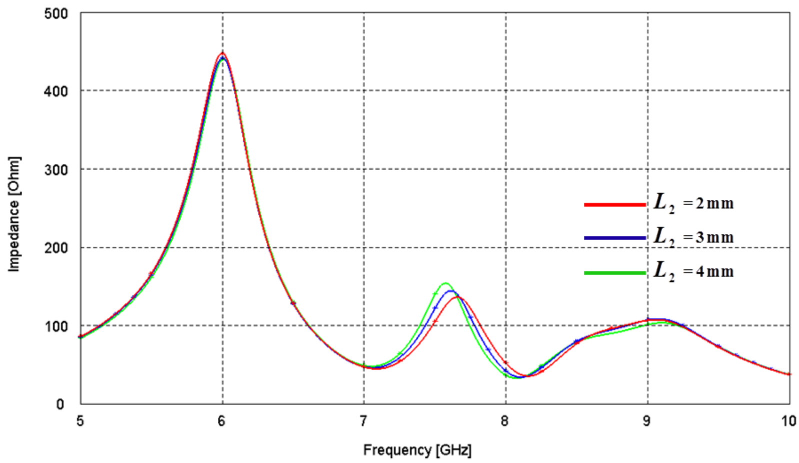



**Figure 9:** Relation between the resonant frequency and the impedance for different values of $L_2$

Table 6 shows the values of return loss, impedance and bandwidth for different $L_2$ values.

**Table 6:** Parameters for different values of $L_2$

| $L_2$ | Band | Resonant frequency (GHz) | S-parameter | Bandwidth (MHz) | Impedance (Ohm) |
|---|---|---|---|---|---|
| 2 mm | C-band | 7.19 | -40.9 | 500 | 48.4 |
| | X-band | 8.29 | -23.70 | 610 | 47.42 |
| 3 mm | C-band | 7.167 | -52.77 | 470 | 49.38 |
| | X-band | 8.25 | -23.12 | 650 | 49.38 |
| 4 mm | C-band | 7.14 | -34.21 | 440 | 50.3 |
| | X-band | 8.24 | -23.71 | 770 | 48.4 |

## 4. Conclusion

An Inverted-F shaped structure of defected ground was treated and simulated by using FEKO software. The comparison of the simulated results of the proposed antenna with the conventional antenna without DGS and the antenna with I shaped defected ground structures in terms of the return losses and bandwidth enhancement is clearly explained and discussed. The proposed antenna is designed for the applications covering the C-band and X-band. Bandwidth is significantly increased up to 620 MHz and 740 MHz respectively and a good impedance matching close to was recorded.

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