

Microstrip Planar Array Antenna with Improved DGS Structure for single band Operation

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Abstract:The goal of this paper is to use defected ground structure (DGS) in microstrip planar array antenna for single band operation. The DGS structures are introduced to improve the performance of planar array antenna in terms of return loss, gain, directivity and voltage standing wave ratio. The array of two by one (2x1) planar array antenna with edge feed based on quarter wave impedance matching technique is designed and simulated using IE3D electromagnetic simulation software. The results of planar array antenna with DGS structure is taken into account. The array antenna is designed on GML 1000 having dielectric constant (ϵ_r) of 3.2 and thickness of 0.762mm, respectively. Further, results show that the proposed array antenna with DGS structure has the gain of 6.5 dB, directivity of 7 dBi and the return loss of -33.05 dB at 9.7 GHz.

Index Terms— Laminate, array antenna, defected ground structures, mobile communication

I. INTRODUCTION

Patch antennas play a very important role in today's world of wireless communication systems. There is always a very large demand for high performance, small size and low cost wireless communication systems. In order to meet these requirements, planar patch antenna is preferred because of their various advantages such as lightweight, low volume, low cost and ease for fabrication [1]. Although the microstrip patch antenna has various advantages it also has various disadvantages which are low gain, narrow bandwidth and low efficiency. These disadvantages can be overcome by constructing many patch antennas in array configuration.

Recently there has been increasing demand in the use of DGS for performance enhancement of microstrip patch antennas and planar array antennas [2]. There are basically two types of structures which are used for the design of compact and high performance wireless communication systems named as defected ground structures (DGS) and electromagnetic band-gap structures (EBG) which is also known as photonic band-gap structures (PBG). These Structures have been

used to obtain the functions such as unwanted frequency rejection and circuit size reduction. Recently defected ground structures have been introduced; DGSs are realized by simply etching off simple shape (called as defect) from the ground plane [3]. Depending upon the shape and the dimensions of the defect, the current distribution in the ground plane is disturbed and resulting in a controlled excitation and propagation of electromagnetic waves through the substrate. The shape of the defect may be changed from a simple shape to the complex one for the better performance. DGSs have more advantages than PBG or EBG structures such as: (1) For implementing EBG structures, a large area is needed to implement the periodic patterns and it is also difficult to define the unit element of EBG whereas DGS structures has similar properties like EBG and the geometry of DGS can be one or few etched structures which is simpler and also does not require large area for implementation. (2) DGS is more easily to be designed and implemented and has higher precision with regular defect structures. Therefore it is very extensive to extend its practical applications.

In this paper the design of single antenna, 2x1 array antenna with DGS structure with edge feeding method [3] is presented. The proposed array antenna is designed on GML 1000 having dielectric constant of 3.2 and thickness of 0.762 mm, respectively. The proposed array antenna with DGS structure offers the gain of 6.5 dB, directivity of 7 dBi and the return loss of -33.05 dB at 9.7 GHz.

II. ANTENNA DESIGN

For designing a high-performance planar array antenna, the exact dimension of each patch element is very important. In this section, we firstly describe the design of single element antenna, followed by the array antenna design. The design specifications of single patch antenna are shown in Table 1.

TABLE I. DESIGN SPECIFICATION OF PATCH ANTENNA

Parameters	Dimensions
Substrate type	GML 1000

Dielectric constant	3.2
Substrate height	0.762mm
Centre frequency	9.7 GHz
Patch thickness	0.035 mm

Microstrip planar array Antenna design

The structure of the two element antenna array is shown in Figure 1. The element is composed of patch, ground plane, substrate and the feeding line. The performance of planar patch antenna array depends on their dimension that also influences the operating frequency, radiation efficiency, directivity, return loss and other post processing parameters. The microstrip patch antenna was designed by determining its patch dimensions. The width (W) and length (L) of patch was calculated from following mathematical expressions:

Width of the patch is given by

$$w = \frac{c}{2f_r} \left(\frac{\epsilon_r + 1}{2} \right)^{-0.5} \quad (1)$$

Length of the patch is given by

$$L = \frac{c}{2f_r \sqrt{\epsilon_{eff}}} - 2\Delta l \quad (2)$$

Where

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(1 + \frac{12h}{w} \right)^{-0.5} \quad (3)$$

And

$$\Delta l = 0.412h \left(\frac{0.262h + (w/h)}{0.813h + (w/h)} \right) \left(\frac{\epsilon_{eff} + 0.3}{\epsilon_{eff} - 0.258} \right) \quad (4)$$

Characteristic Impedance of Patch is given by

$$Z_a = 90 \frac{\epsilon_r^2}{\epsilon_r + 1} (L/W)^2 \quad (5)$$

Characteristic Impedance of Transition section is given by

$$Z_T = \sqrt{50 * Z_a} \quad (6)$$

Inset feed length is given by

$$y_o = \frac{L}{\pi} \cos^{-1} \sqrt{\frac{50}{Z_T}} \quad (7)$$

Width of 50 ohm feed line is given by

$$Z_o = \frac{120\pi}{\sqrt{\epsilon_{eff}} \left(1.393 + \frac{W}{h} + \frac{2}{3} \ln \left(\frac{W}{h} + 1.444 \right) \right)} \quad (8)$$

Where f_0 is the centre frequency of the patch, c is speed of light in free space, h is the substrate thickness and ϵ_r is the dielectric constant of substrate. The array antenna consists of a branching network of two-way power dividers. Quarter-wavelength transformers (70 Ω) are used to match the 100 Ω lines to the 50 Ω lines.

The design of 2x1 planar array antennas with the corporate feeding network is proposed. The shape of the defect may be changed from a simple shape to the complex one for the better performance.

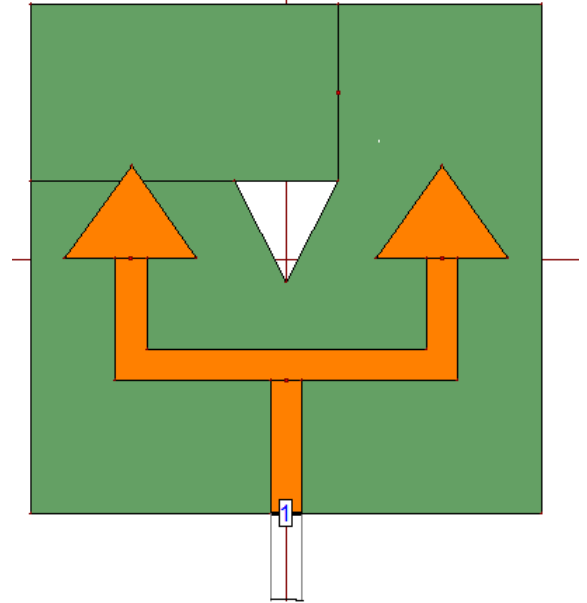


Fig: 1 Top view of the proposed antenna array with DGS

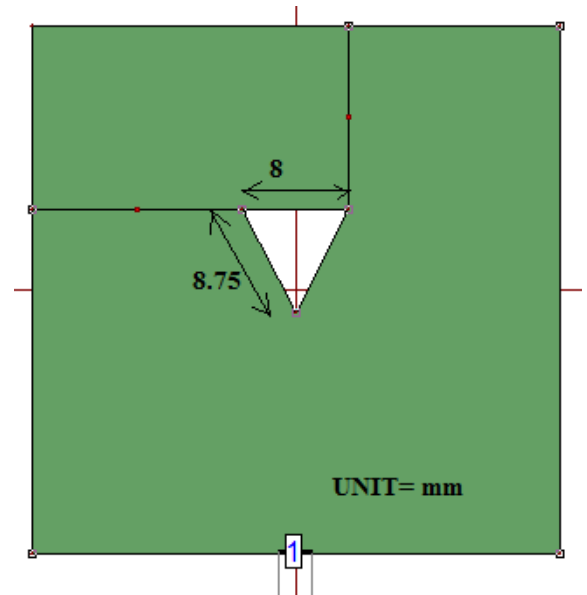


Fig: 2 Bottom view of the proposed antenna array

As shown in Fig.1, since the planar array antenna is designed using 2 triangular patches with the DGS structure cut on the ground plane arranged in 2x1 (columns x rows) formation, thus the corporate feeding network is chosen to feed all patches. The main goal of using DGSs in the ground plane is to reduce the antenna size and to enhance the performance in terms of gain, directivity, return loss, radiation pattern and voltage standing wave ratio. DGSs are realized by simply etching off simple shape (called as defect) from the ground plane. The array antenna consists of a branching network of two-way power dividers. Quarter-wavelength transformers (70 Ω) are used to match the 100 Ω lines to the 50 Ω lines. After some

parametrical study, separation between patches is set to be 0.6 of wavelength to avoid grating lobes. The design of 2x1 planar array antennas with the corporate feeding network is proposed. The dimension of each planar patch antenna is calculated using equations (1) and (2). The length of substrate is 40mm and width of substrate is 40mm, respectively.

In this paper we will discuss the influence of triangular-shaped DGS structure and the result shows that the triangular-shaped DGS structure has better performance in terms of gain, directivity and return loss.

III. RESULTS AND DISCUSSION

Fig. 3 shows the return loss plot of two element patch antenna array with triangular-shaped DGS, The simulation results shows that 2x1 patch antenna array gives the return loss of -33.05dB at the resonance of 9.7 GHz.

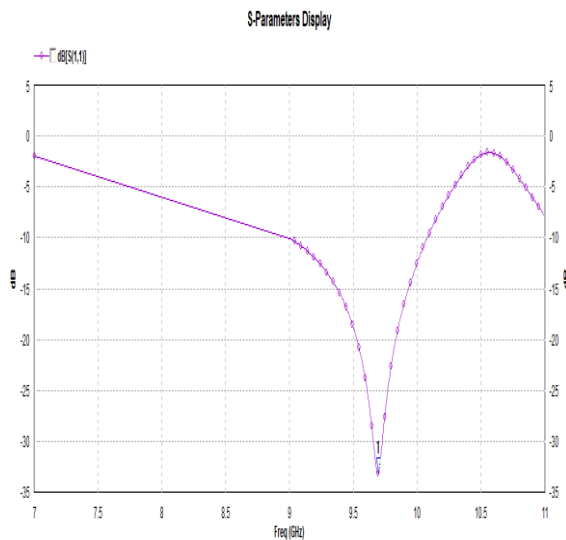


Fig.3 Return loss plot of 2x1 planar array antenna with triangular-shaped DGS

Fig. 4 and 5 shows the gain and directivity of 2x1 planar array antenna with triangular-shaped DGS structure. Gain of 2x1 planar array antenna with triangular-shaped DGS structure is 6.5 dB and directivity of 2x1 planar array antenna with triangular-shaped DGS structure is 7 dB.

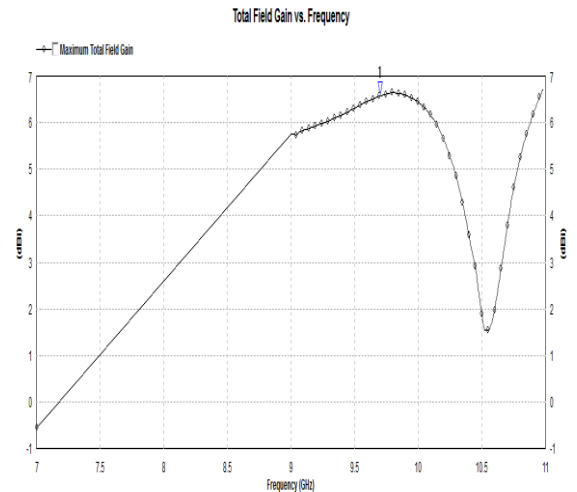


Fig.4 Gain of 2x1 planar array antenna with triangular- shaped DGS

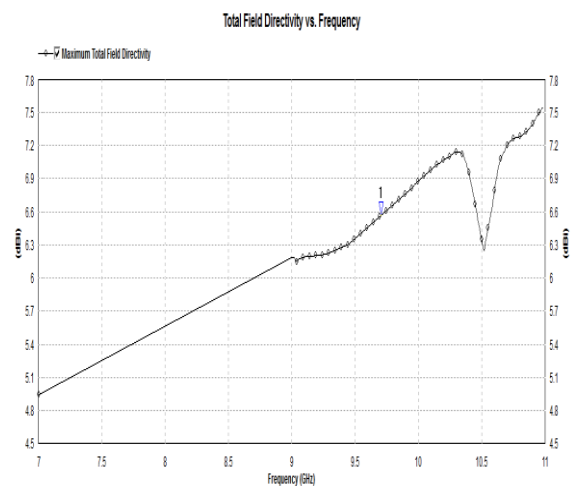


Fig. 5 Directivity of 2x1 planar array antenna with triangular- shaped DGS

Fig.6 shows the 3D geometry of the proposed antenna array with DGS structure.

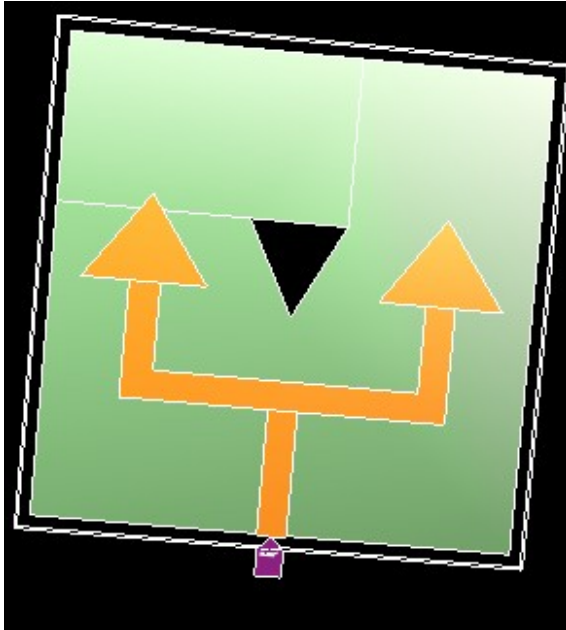


Fig .6 3D view of the 2x1 planar array antenna with DGS

TABLE II: SUMMARY OF OUTCOME

Parameters	Value
Return loss	-33.05 dB
Gain	6.5 dB
Directivity	7dB
Efficiency	92%
Bandwidth	987 MHz

IV. CONCLUSION

A 2x1 planar array antenna with DGS structure has been designed and simulated. The proposed planar antenna array with DGS resonates at 9.6 GHz. DGS is the advantageous approach for the size reduction. This simulation results have shown that the 2x1 planar array antenna with triangular shaped DGS has gain of 6.5 dB, directivity of 7 dB and the return loss of -33.05 at centre frequency of 9.7 GHz.

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