CALCULATION OF PERFORMANCE PARAMETERS OF DGS STRUCTURED MICRO-STRIP ANTENNA ARRAY

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Abstract

This paper presents a dumbbell shape defected ground structure (DGS) implemented on two element patch micro-strip antenna array. The structure in this work is 2×1 micro-strip patch array antenna using substrate with h=1.6 mm and εr=4.4. Two patches are located on opposite side of PCB and spaced 80 mm apart by a small ground portion. The proposed DGS of dumbbell shape is placed in the ground plane. It does provide a method to improve antenna performance. In this way, return loss value is found to be i.e., S11≤-12.53dB, -14.51 dB and -21.58dB at resonant frequencies 3.72GHz, 4.76 GHz and 7.63GHz respectively. Moreover, stable radiation pattern with a peak gain of 6.54dB is obtained within the band. The proposed antenna is suitable for Wi-Max applications. The analysis has been done by using IE3D software based on MOM (Method of Moments).

Keywords: DGS, Microstrip Antenna, Array Antenna, Return Loss, Radiation Pattern, Gain, Directivity, Antenna Efficiency, Radiation Efficiency.

I. INTRODUCTION

With the development of base station for next generation mobile communication, compact micro-strip antennas have received much attention for their attractive features, such as light weight, low profile low cost, and ease to integrate with circuits. These features of micro-strip antenna attracted amounts of researchers to study and a series of literatures have been reported [1]-[5]. Although the micro-strip 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. However, a common disadvantage of micro-strip antenna is surface wave, which is excited whenever the substrate has dielectric permittivity greater than one (εr > 1). Surface waves can cause many disadvantages for micro-strip antenna such as mutual coupling effect between elements on an array [6]. In an antenna array, the mutual coupling effect will deteriorate the radiation properties of the array. 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 electromagn-etic 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. To suppress surface waves, several studies are conducted including defected ground structure (DGS). DGS is realized by etching the ground plane with a certain lattice shape which disturbs the current distribution of the antenna. Many shapes of DGS have been studied such as concentric ring [2], circle [3], spiral [4], dumbbells [5-8], elliptical [9] and U- and V-slots [10]. Each DGS shape can be represented as an equivalent circuit consisting of inductance and capacitance, which leads to a certain frequency band gap determined by the shape, dimension and position of the defect. DGS gives an extra degree of freedom in microwave circuit design and can be used for a wide range of applications. The shape of the defect may be changed from a simple shape to the complex one for the better performance.

In this paper the design of 2x1 array antenna with DGS structures with micro-strip feeding method is presented. The proposed array antenna is designed on FR4 substrate having dielectric constant of 4.4 and thickness of 1.6 mm, respectively.

II ANTENNA DESIGN

The geometry and detailed dimensions of 2×1 array antenna is shown in Fig 1.

![Fig 1: Proposed Array Antenna without DGS](image)

The antenna was implemented on two FR4 substrates (εr=4.4) of thickness 1.6 mm. The
spacing between two elements is 80 mm. The design of 2x1 planar array antennas with the edge feeding network is proposed. Then after, dumbbell-shaped DGS is inserted into the ground plane of the antenna with position between the two element patches as shown in figure 2.

![Fig: 2 Proposed Array Antenna With Dumbbell Shape DGS](image)

The purpose of using DGS as a technique to improve the isolation on the basis of basic parameters is to make use of the ground plane itself to prove a filter effect. This effect suppresses the mutual coupling between antennas.

III RESULT AND DISCUSSION

Microstrip antenna array with DGS presented in this paper has been designed and simulated using IE3D software. The simulation results of microstrip antenna array without and with DGS are shown in the figures 3-7.

**Performance Parameters of Antenna Array without and with DGS Structure**

(i) **S- Parameters**

It describes the amplitude of a reflective wave relative to that of incident wave. $S_{11}$ represents how much power is reflected from the antenna, and hence is known as the reflection coefficient (sometimes written as gamma or return loss).

![Fig: 3 (a) S Parameters of antenna array without DGS](image)

Fig. 3(a) shows that return loss of this design of patch antenna array without defected ground structure are at frequencies 3.72 GHz, 4.76 GHz, 7.63 GHz is -11.30 dB, -13.38 dB, -10.55 dB.

![Fig: 3 (b) S Parameters of antenna array with DGS](image)

Fig. 3(b) shows that return loss of this design of patch antenna array with defected ground structure are at frequencies 3.72 GHz, 4.76 GHz, 7.63 GHz is -12.53 dB, -14.81 dB and -21.58 dB.

(ii) **Gain**

As a transmitting antenna, gain defines how well the antenna converts input (electrical) power into radio (electro-magnetic) waves headed in a particular direction. As a receiving antenna, gain defines how well the antenna converts radio waves arriving from a specified direction into electrical power. Higher range antennas have the advantage of long range and better signal quality but must be aimed carefully in a particular direction.

![Fig: 4 (a) Gain of antenna array without DGS](image)

Figure 4(a) depicts the simulated graph of gain vs. frequency of proposed design without DGS.
According to the simulated results, value of gain is found to be 5.14dBi, 4.58dBi and 6.20dBi at 3.72 GHz, 4.76GHz and 7.63 GHz respectively.

Figure 4(b) depicts the simulated graph of gain vs. frequency of proposed design with DGS. According to the simulated results, value of gain is found to be 5.64dBi, 4.7dBi and 6.54dBi at 3.72 GHz, 4.76GHz and 7.63 GHz respectively

(iii) Directivity
Directivity is the ability of an antenna to focus energy in a particular direction when transmitting, or to receive energy better from a particular direction. It is defined as a ratio of power radiated by antenna in a particular direction to power radiated by an ideal isotropic radiator. Value of directivity varies from 1.76dBi for short dipole to 50 dBi for large dish antennas.

Fig: 5 (a) Directivity of antenna array without DGS
Simulated result of directivity of the microstrip antenna array system without DGS is shown in figure 5(a). According to the simulated results, value of directivity is found to be 6.02dBi, 6.25dBi and 6.77dBi at 3.72 GHz, 4.76GHz and 7.63 GHz respectively.

Figure 5(b) Simulated result of directivity of the micro-strip antenna array system with dumbbell-shaped DGS is shown in figure 5 (b). According to the simulated results, value of directivity is found to be 6.11dBi, 6.10dBi and 6.83dBi 77dBi at 3.72 GHz, 4.76GHz and 7.63 GHz respectively.

(iv) Efficiency
The antenna efficiency (or radiation efficiency) can be written as the ratio of the radiated power to the input power of the antenna. A high efficiency antenna has most of the power present at the antenna’s input radiated away. A low efficiency antenna has most of the power absorbed as losses within the antenna, or reflected away due to impedance mismatch.

Fig: 6 (a) Antenna Efficiency of antenna array without DGS
Fig: 6 (b) Antenna Efficiency of antenna array with DGS

Figs. 6(a)-(d) depicts variations of efficiency (antenna efficiency, radiation efficiency) characteristics with frequency of proposed design without and with DGS. According to simulated results value of antenna efficiency is found to be 91.7%, 68%, 89.41% and 93.43%, 72.18%, 96.68% at resonating frequencies without and with DGS respectively.

And value of radiation efficiency is found to be 100%, 71.87%, 100% and 100%, 74.5%, 100% at resonating frequencies without and with DGS respectively.

(v) Radiation Pattern

It is defined as mathematical function or a graphical representation of radiation properties of the antenna as a function of space coordinates. It is also known as antenna pattern. Radiation properties include power flux density, radiation intensity, field strength, directivity. It is of two types: field pattern, power pattern.

Fig: 7 (a) Radiation Pattern of antenna array without DGS

Fig. 7 (a) shows simulated results of radiation pattern of antenna array without defected structure. This result is taken at frequency of 3.6 GHz, which is -8.7dB. A negative radiation pattern is found at this frequency.

Fig: 7 (b) Radiation Pattern of antenna array with DGS

Fig. 7 (b) shows simulated results of radiation pattern of antenna array with defected structure. This result is taken at frequency of 3.7 GHz, which is 4dB. By applying a technique, named DGS
improves the radiation pattern of an antenna array and makes antenna highly directive.

Fig 7(c) Radiation Pattern of antenna array without DGS

Fig: 7(c) shows simulated results of radiation pattern of antenna array without defected structure. This result is taken at frequency of 4.7 GHz, which is -5dB.

Fig 7(d) Radiation Pattern of antenna array with DGS

Fig: 7(b) shows simulated results of radiation pattern of antenna array with defected structure. This result is taken at frequency of 4.7 GHz, which is 4dB.

Fig 7(e) Radiation Pattern of antenna array without DGS

Fig: 7(e) shows simulated results of radiation pattern of antenna array without defected structure. This result is taken at frequency of 7.6 GHz, which is -4.5 dB.

Fig 7(f) Radiation Pattern of antenna array with DGS

Fig: 7(f) shows simulated results of radiation pattern of antenna array with defected structure. This result is taken at frequency of 7.6 GHz, which is 6 dB.

Above results of radiation pattern shows that by using DGS there is an improvement in results of antenna array and enhances the performance of an antenna.

Table 1 Simulated Results

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Design without DGS</th>
<th>Design with DGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (GHz)</td>
<td>3.72</td>
<td>4.76</td>
</tr>
<tr>
<td>Return Loss (dB)</td>
<td>-11.30</td>
<td>-13.38</td>
</tr>
<tr>
<td>Directivity (dB)</td>
<td>6.02</td>
<td>6.25</td>
</tr>
<tr>
<td>Gain (dB)</td>
<td>5.14</td>
<td>4.58</td>
</tr>
<tr>
<td>Antenna Efficiency (%)</td>
<td>91.7</td>
<td>69.0</td>
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<tr>
<td>Radiation Efficiency (%)</td>
<td>93.43</td>
<td>89.41</td>
</tr>
</tbody>
</table>

Table 1 show the readings or variations of different performance parameters (return loss, gain, directivity, antenna efficiency, radiation efficiency and radiation pattern) with respect to frequency without and with DGS and we have noted these variations from the above graphs.
IV CONCLUSION
This paper presents a compact microstrip antenna array with defected ground for Wi-Max applications. An intentional defect of dumbbell-shape is inserted into ground plane which suppress the level of mutual coupling among antenna element. Suppressed level of coupling provides enhanced value of antenna performance parameters thereby showing improvement against results without DGS. Proposed antenna design has been analyzed with IE3D software. The technique may be useful in a number of technologies including patch array antennas.

References


Structure” IEEE transactions on antennas and propagation, vol. 60, no. 12, December 2012.


