A Hexagonal MIMO Antenna System With Defected Ground Structure to Enhance Bandwidth and Isolation

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***Abstract*— In this paper, a compact planar MIMO antenna system of size 36 mm × 40 mm with two hexagonal monopole elements is proposed. The impedance bandwidth and isolation are enhanced by a hexagonal shaped Defected Ground Structure (DGS). Simulated results show that the MIMO antenna with DGS has 10-dB return loss from 4.4 GHz to 9.57 GHz, yielding 75% improvement in impedance bandwidth over that of the traditional MIMO antenna system without DGS. Isolation also is enhanced by the DGS. S_{21} results show that isolation exceeds 15 dB within the required band and 20 dB in most of the band.**

***Index Terms*—Multiple-input-multiple-output (MIMO), defected ground structure (DGS), isolation, impedance bandwidth, mutual coupling.**

I. Introduction

MULTIPLE-INPUT-MULTIPLE-OUTPUT (MIMO) technology has attracted attention in modern wireless communication systems. A significant increase in channel capacity is achieved without the need of additional bandwidth or transmit power by deploying multiple antennas for transmission to achieve an array gain and diversity gain, thereby improving the spectral efficiency and reliability. MIMO antenna systems require high decoupling between antenna ports and a compact size for application in portable devices.

Many methods have been proposed for reducing mutual coupling between the antennas. Various structures are introduced in the ground plane to achieve low mutual coupling [1]–[3]. A T- shaped stub in the ground plane was used to increase isolation between antennas [1]–[2]. In [3], wideband isolation was achieved through a tree- like structure on the ground plane. Low mutual coupling can also be achieved through neutralization techniques [4]–[5], and through a decoupling network [6]. Additionally, it has been found that mushroom- like EBG structures [7]–[8] reduce the mutual coupling by suppressing surface wave propagation.

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Recently, Defected Ground Structures (DGS) are introduced to improve antenna performance characteristics like size reduction, gain and bandwidth enhancement, and it is also used in reduction of mutual coupling between antenna elements [9]–[12]. The cross- polarized radiation of a microstrip antenna was reduced by 8 dB by introducing a circular DGS [10]. In [11], a double U- shaped DGS was proposed to broaden impedance bandwidth of a monopole antenna by 112%. Enhanced isolation of more than 40 dB is achieved by a dumbbell like DGS [12], but with very low impedance bandwidth. However, to the best of our knowledge, simultaneous enhancement of isolation and impedance bandwidth using a single DGS has yet not been proposed in existing studies.

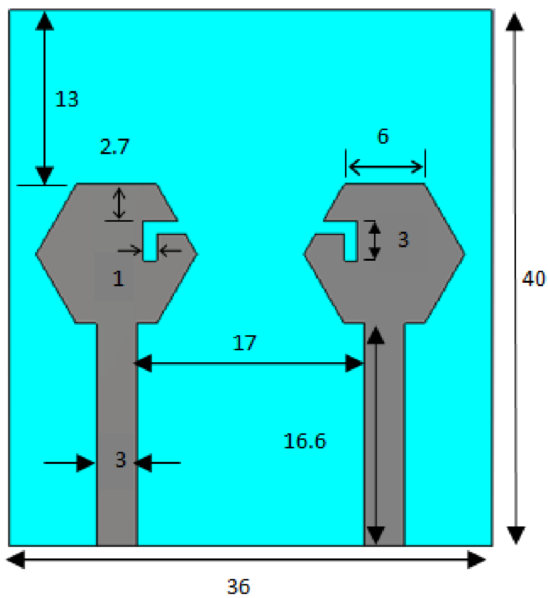
In this paper, a single hexagonal- shaped DGS is introduced in the ground plane of a two- element compact MIMO antenna system. Different from the traditional DGS, the hexagonal shaped DGS enhances isolation and at the same time broadens the impedance bandwidth of the proposed antenna system.

II. MIMO Antenna Design With DGS

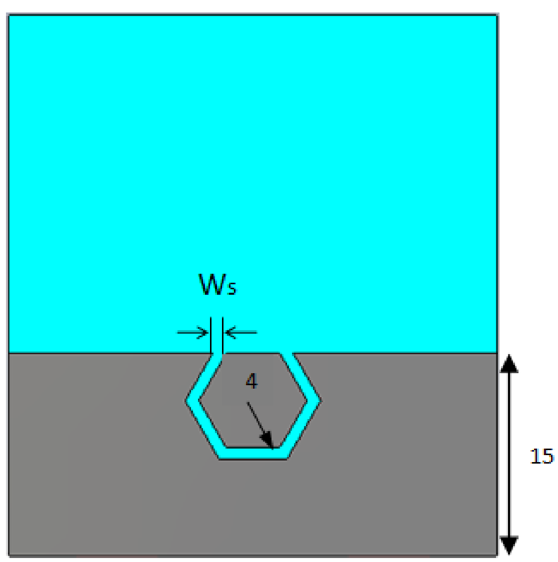
The two- element MIMO antenna system of a compact size of 36 mm × 40 mm with the proposed DGS is shown in Fig. 1. The antenna system is printed on a FR4 substrate with a dielectric constant of 4.4 and thickness of 1.6 mm. Each radiator is fed through a 50-Ω microstrip line. The length and width of the microstrip line is 16.6 mm and 3 mm respectively. The distance between the two feedlines is optimized at 17 mm so as to minimize the surface current flowing to the other port, thereby reducing the coupling between the elements. The radiators have a similar, regular hexagonal geometry of side 6 mm, offering more impedance bandwidth than the antennas with rectangular, square or triangular geometries. A slot of 1 mm width is etched on each of the hexagonal antenna elements to adjust the bandwidth, which is determined by the length of the slot.

A defected ground structure (DGS) is introduced as shown in Fig. 1(b), to enhance the bandwidth and to reduce the coupling between the antennas. A hexagonal slot of uniform width W_s = 1 mm is etched on the ground plane. The distance between hexagonal radiator and the hexagonal DGS is optimized at 1.6 mm. Varying this gap, adjusts the impedance bandwidth of the antenna system. The proposed hexagonal –

shaped DGS offers a high order matching network for enhancing the bandwidth and at the same time acts as an isolation structure by suppressing the ground current flowing between the two ports, thereby enhancing isolation between the antenna elements.



(a)

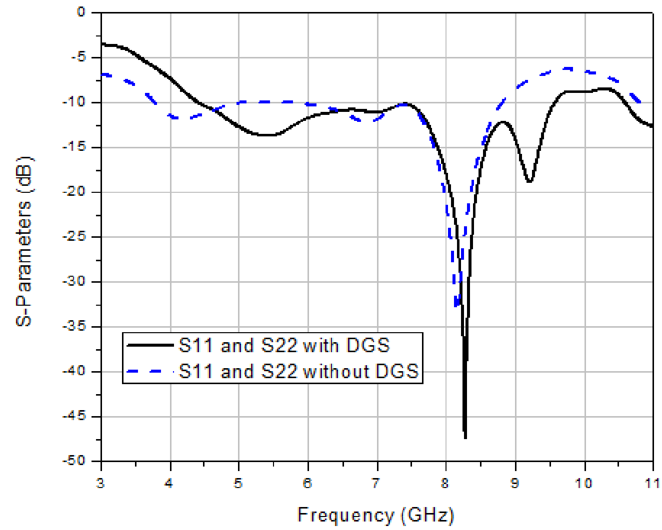


(b)

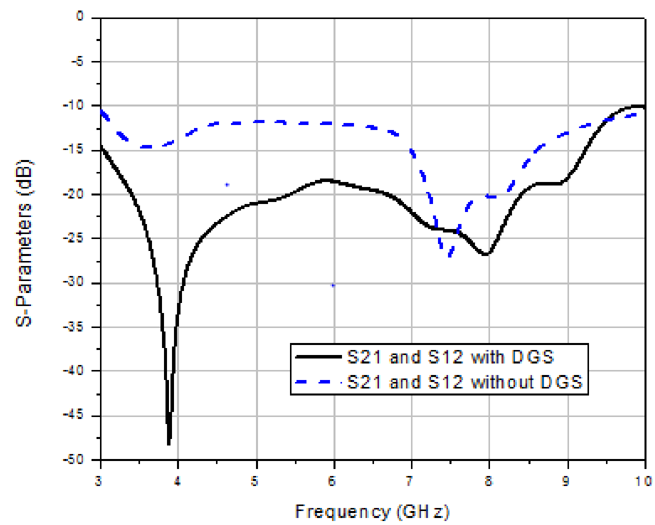
Fig. 1. Geometry of the proposed MIMO antenna with DGS (a) front view, (b) rear view. Dimensions are in mm.

III. Results and Discussions

Isolation and return loss characteristics of the MIMO antenna system with and without DGS are analyzed to find out the effectiveness of the proposed DGS.



(a)



(b)

Fig. 2. Simulated S-parameters with and without DGS: (a) S_{11} and S_{22}, (b) S_{21} and S_{12}.

Simulated results of S- parameters with and without DGS are shown in Fig. 2. S_{11} is less than -10 dB from 5.85 to 8.8 GHz for the MIMO antenna with single ground plane. After introducing the DGS, it is found that the antenna has 10 dB return loss over an extended band from 4.4 GHz to 9.57 GHz, thus providing a bandwidth enhancement of 75%.Simulated results of S_{21} and S_{12} are shown in Fig. 2(b). It is observed that isolation has increased after incorporating the hexagonal DGS. S_{21} is less than -15 dB throughout the operating band of the antenna system and also a maximum isolation of more than 25 dB is achieved.

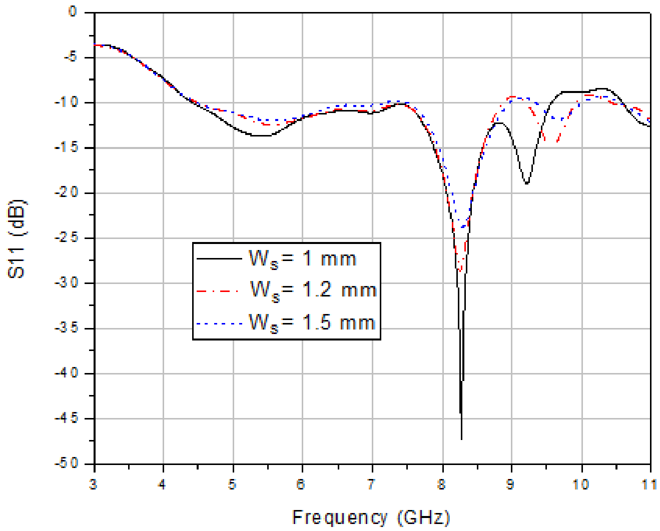


Fig. 3. Width W_S variation against S_{11}.

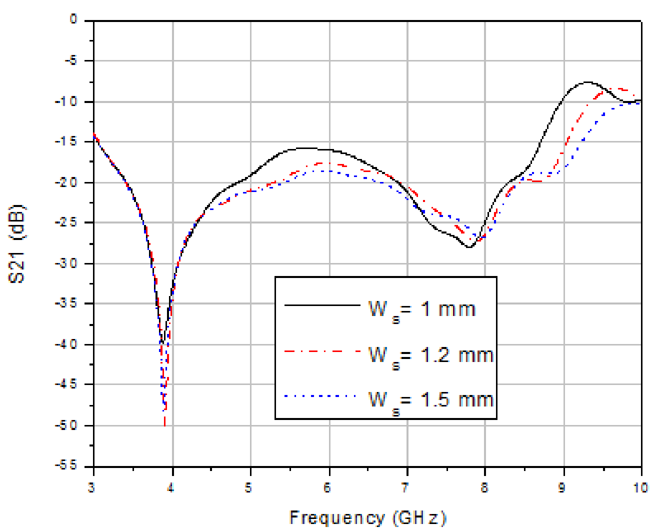


Fig. 4. Width W_S variation against S_{21}.

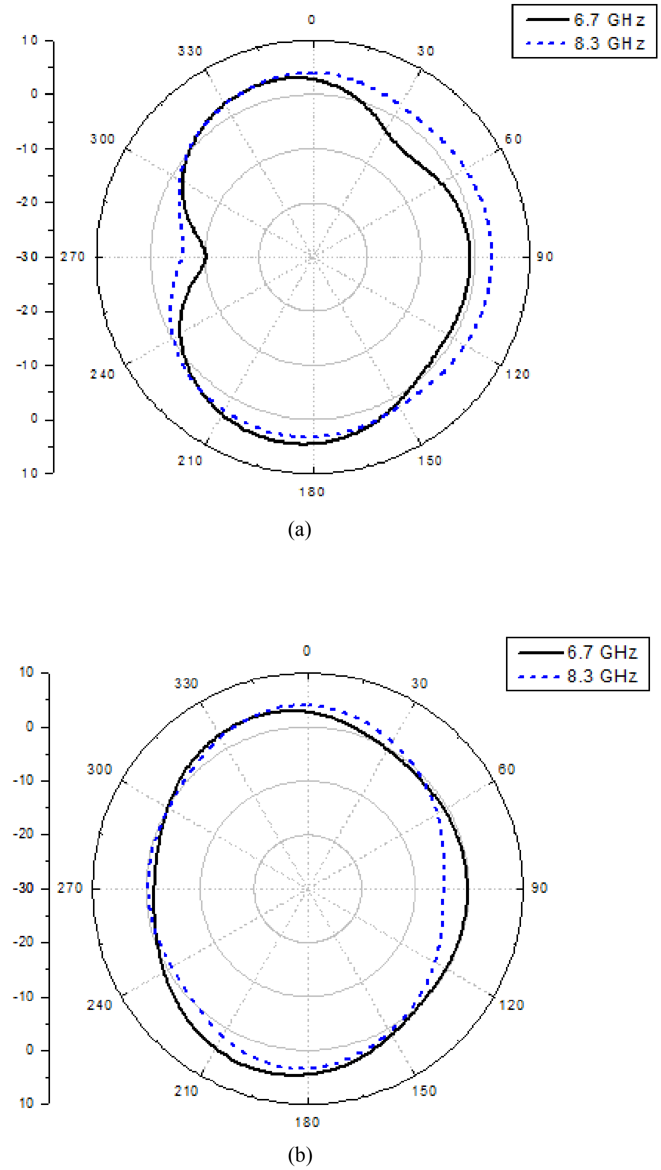


Fig. 5. Simulated radiation patterns: (a) y-z plane, (b) x-z plane.

The isolation and bandwidth behavior of the MIMO antenna with DGS is studied by varying one of the design parameters. Fig. 3 shows the variation of return loss obtained by varying the width of the slot W_s of the hexagonal DGS from 1mm to 1.5 mm. It is apparent that a wider bandwidth is achieved corresponding to a narrow width, W_s= 1 mm. But, on the contrary, isolation increases when W_s is varied from 1 mm to 1.5 mm as shown in Fig. 4. Hence better isolation performance corresponds to a wider slot of width 1.5 mm. High isolation of more than 20 dB is achieved in this case.

Radiation patterns of the antenna system are obtained when only one of the ports is excited, while the other is terminated with a 50-Ω load. When one port is excited, the flow of current from the antenna through the ground plane to the other element will be obstructed by the defected ground structure. The same effect is achieved when the other port alone is excited. Simulated radiation patterns are shown in Fig. 5, for frequencies of 6.7 GHz and 8.3 GHz in the y-z (φ= 90^0) and x-z (φ= 0^0) planes. The antenna exhibits a stable radiation behavior across the required operating band. Simulated results of antenna gain are shown in Fig. 6 and the variation of antenna gain was found to be 3 dB across the band.

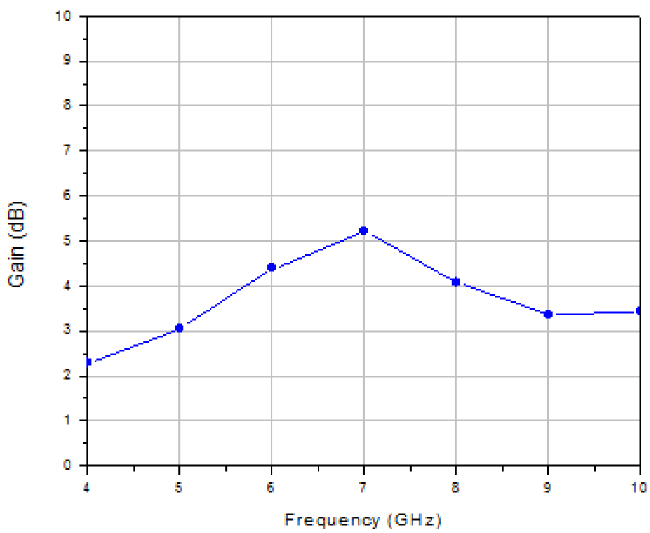


Fig. 6. Antenna gain.

IV. Conclusion

The proposed antenna system shows good MIMO/ diversity performance by achieving isolation of – 20 dB, facilitated through a hexagonal shaped DGS. Bandwidth also is enhanced by the DGS so as to have an operating frequency range from 4.4 GHz to 9.57 GHz, which covers almost the entire UWB (3.1 – 10.6 GHz band). Hence wideband isolation is achieved in the proposed compact antenna system with DGS and it is found suitable for portable MIMO applications.

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