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Design of 4-shaped MIMO Antenna for Wireless Communication

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Abstract:In this work, a 2×1 compact 4-shaped multiple-input-multiple-output (MIMO) antenna is designed by implementing parasitic element and DGS. A defected ground plane structure (DGS) etched into the ground plane so that mutual coupling effect between two antennas is reduced and isolation rate is increased. It covers two frequency bands, lower frequency band was 2420-2520MHz and higher frequency band was 4920-5110MHz.The minimum isolation was observed at lower band and higher band was 17dB and 21dB after using parasitic element. The overall size of MIMO antenna system was $50 \times 50 \times 0.8 mm^3$. Results indicate that proposed MIMO antenna has a bandwidth which covers the 2.4G-WLAN and WiMAX applications. The overall gain of an antenna is -0.5dBi at low frequency and 2.0dBi at high frequency.

Key Words Multiple-input-multiple-output (MIMO) antenna, defected ground plane structure, parasitic element, mutual coupling.

I. INTRODUCTION

Multiple-input-multiple-output (MIMO), a new technology is used for obtaining higher data rates in wireless communications system. In this technology, multiple antennas at both ends of link are utilized in order to enhance the transmission performance without extra frequency and power resources. The importance of MIMO technology is that they provide the opportunity to form parallel orthogonal transmission channels, especially in environment with rich scattering. MIMO has become an important element of wireless communication standard including IEEE802.11n (Wi-Fi), IEEE802.11ac (Wi-Fi), HSPA+ (3G), WiMAX(4G), and Long Term Evolution(4G).

The MIMO technology uses multiple antennas for data transmission and reception. To design multiple antennas on PCB is a difficult task for MIMO application. There are two challenges faced by MIMO. First, antenna should be compact in size. Second, all the antenna elements should have good isolation rate. But the coupling between closely-packed antenna elements affects the performance of antennas. If the isolation within multiple antennas system is reduced, system performance in terms of gain and correlation is degrade due to the mutual coupling effect.

To overcome these limitations, there are various techniques that are used to reduce mutual coupling effect and increase isolation. Two folded monopole slot antenna placed both the side of the substrate and a parasitic element is placed in between two antennas is described in [1]. A mushroom like electromagnetic structure (EBG) and several ground branches are added for increasing isolation in [2]-[3].Similarly in [4], two techniques are performed by introducing EBG and defected ground plane structure. In [5], two inverted-L-shaped branches and a rectangular slot having circular end, etched into the ground plane. Two novel bent slits etched into the ground plane which helps to reduce mutual coupling effect in [6].

In [7], a complementary split-ring resonator introduced into the ground plane for antenna miniaturization to reduce the antenna size. A built in filter method is also used to enhance the isolation between closely packed MIMO antennas. In this antenna system, four Microstrip fed quarter wavelength slot antenna was introduced into the ground plane, with each antenna was orthogonally polarized with its neighbouring antenna and several slits etched on the ground plane [8].In [9], three effective radiators used such as S and F-shaped radiators and driven monopole antenna printed on top surface of dielectric substrate. High isolation between two antenna elements achieved by imprinting T-shaped slot in the radiator and extending a stub from ground in [10]. In [11], two tree type monopole antenna having inverted T-shaped isolator used for reducing mutual coupling effect which covered 2.4GHz and 5GHz frequency bands for WLAN application.

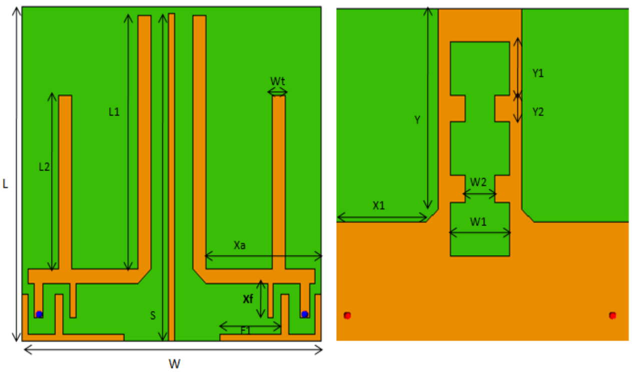
Defected ground plane structure is one of method used for increasing isolation between antenna elements. Ground was defected by a simple dumbbell like structure so that mutual coupling between antennas was reduced. For addressing low band, spirals were introduced into the primary rectangles of DGS in [12]. In [13], a aperture coupled Microstrip antenna was designed which was included with DGS and parasitic element. Four dumbbell shaped DGS etched on the ground plane which was sandwiched between upper and lower substrate for reducing back radiation.

The rest of the paper is described as follows: Section II presents the design of the DGS structure for enhancing isolation. Section III describes simulation and comparison results and section IV concludes the paper.

II. PRINTED MIMO ANTENNA DESIGN

The optimized layout with dimensional details of the proposed MIMO antenna is illustrated in Fig. 1. This MIMO antenna system consists of two compact 4-shaped antennas at top layer and dumbbell shaped DGS is etched on the ground plane. The dimensions are in millimetre (mm): W=50, L=50, L1=38,L2=26,Xa=19.3,Xf=5,S=49,F1=10.2, X1=16,Y=32, Y1=8,Y2=4,W1=10,W2=5.The thickness of substrate is 0.8mm. A dielectric constant was 4.4. The overall size of MIMO antenna system is 50×50× 0.8mm^3.The antenna was designed and simulated using CADFEKO software.

The structure consists of simple dumb like pattern cut from the ground plane. It defects in the ground plane which acts as a stop-band filter. This is an important property which is used to reduce mutual coupling effect and increase isolation rate. By introducing dumbbell DGS improved the isolation between the two antenna elements which act as a dual-band stop filter.



(a) Top layer (b) Bottom layer

Fig. 1. Geometry of the MIMO antenna system

The structure size is also important so that it should cover all the coupling area between the antenna elements. The centre frequency of original dumbbell antenna can be changed by increasing the length of dumbbells. It was observed that width of rectangles increased, operating frequency increased. Increasing the length of the DGS decreased the operating frequency. There is another technique is used by introducing parasitic element. Rectangular strip and F-shaped strip is used as parasitic elements. Single rectangular strip in between two antenna elements and F-shaped strip at the corner. Both rectangular strip and F-shaped strip are electromagnetically coupled to each other.

III. RESULTS AND DISCUSSIONS

Fig. 2 shows the S-parameter measurements for these 4-shaped dumbbell antennas before adding parasitic element. Measured reflection coefficient of an antenna at 2.5GHz is -16 dB and -37.81dB at 5.04GHz frequency. Isolation between antenna elements is -16.8dB at 2.5GHz and -20.51dB at 5.04GHz frequency. If the length of dumbbell decreased the operating frequency and width of dumbbell increased, operating frequency increased. By using only DGS method, isolation rate is small so that coupling rate is increased. Therefore, two parasitic elements are added which act as an isolator so mutual coupling effect is reduced.

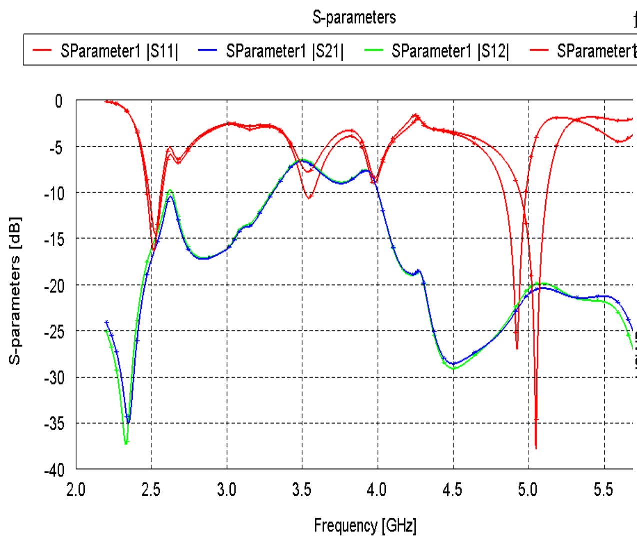


Fig. 2. Simulated S-parameter before introducing parasitic element.

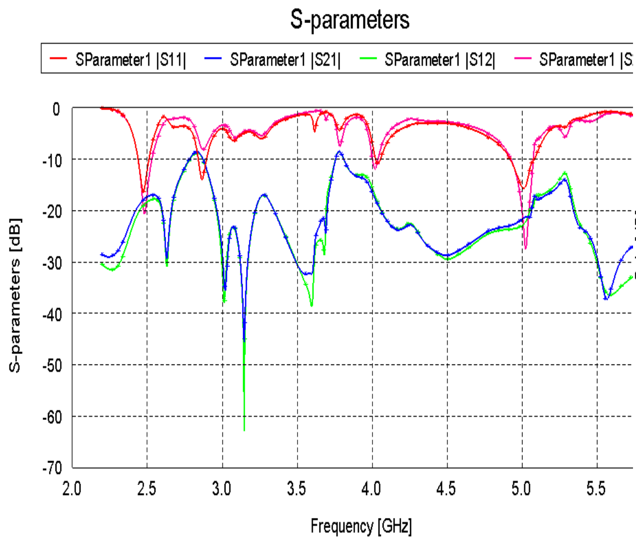


Fig. 3. Simulated S-parameter after introducing parasitic element.

After adding parasitic element, the measured reflection coefficient (S11) of an antenna at 2.47GHz frequency is
-16.16dB and -15.68dB at 5.01dB. Isolation (S21) between antenna elements is -17.91dB at 2.47GHz and -21.41dB at 5.01GHz frequency as shown in fig.3. The measured VSWR of the proposed MIMO antenna is 1.84 at 2.47GHz and 1.86 at 5.01GHz frequency is as shown in fig.4. The measured S12 and S22 parameter of an antenna is -19.07 and -20.87dB at 2.47GHz frequency. At 5.01GHz frequency, the measured S12 and S22 parameter is -19.07 and -20.87dB.

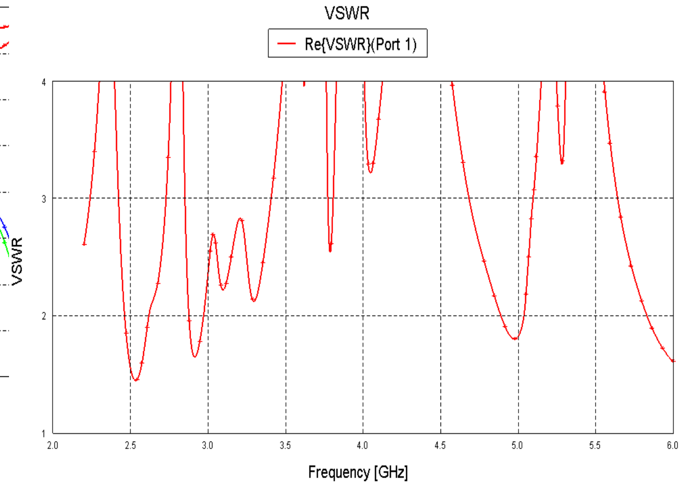


Fig. 4. Simulated VSWR of 4-shaped MIMO antenna.

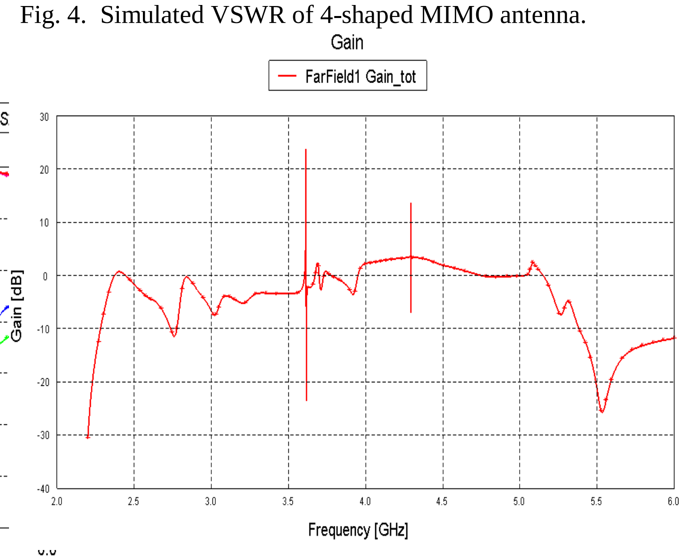
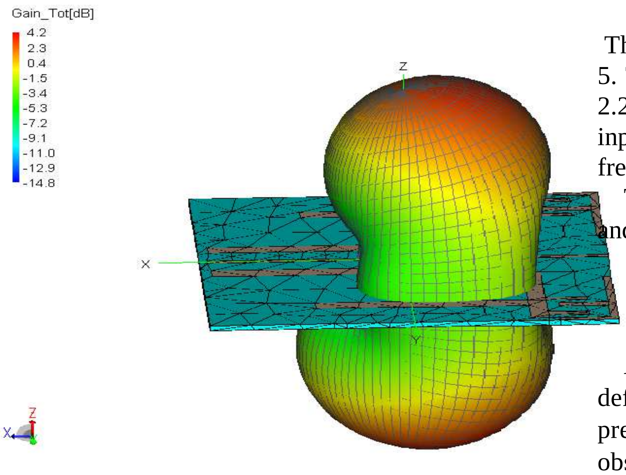
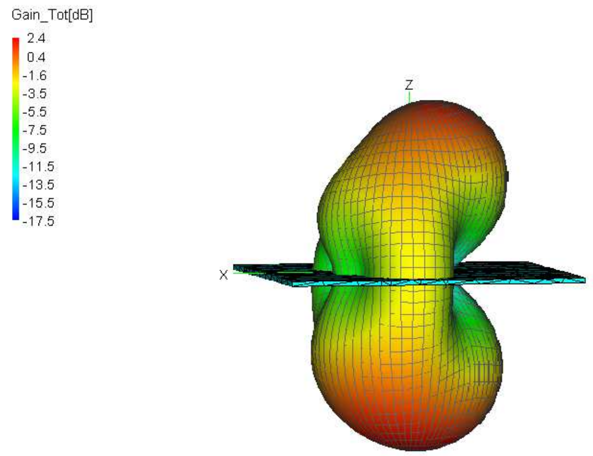


Fig. 5. Total Gain of 4-shaped MIMO antenna.



a) Total gain of an antenna



b) Gain at 5GHz frequency

Fig.6 . Measured 3D radiation patterns of an antenna

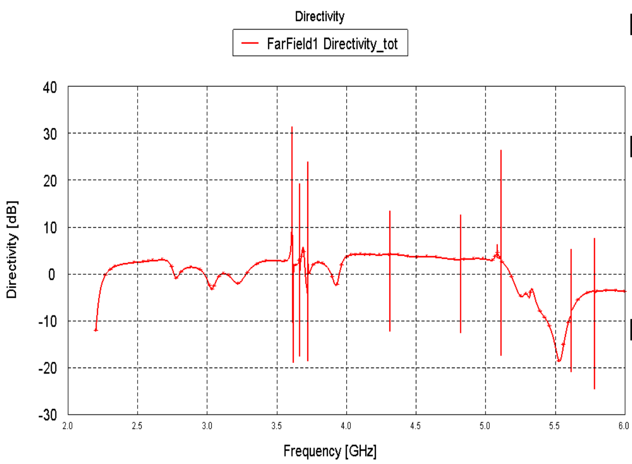


Fig. 7. Directivity of an antenna

The total gain of an antenna is 4dBi shows in fig. 4 and 5. The gain obtained at 2.47GHz frequency -0.8dBi and 2.2dBi at 5.01GHz frequency is shows in fig. 6.The input impedance is observed as 76.47-5.51j at 2.47 GHz frequency and 84.47+1.11j at 5.01GHz frequency range.

The directivity of an antenna was 2.49dB at 2.49 GHz and 3.47dB at 5.01GHz frequency is as shown in fig. 7.

IV. CONCLUSION

A 4-shaped dual band MIMO antenna having defected ground structure with parasitic element is presented in this project work. The minimum isolation is observed at low band and high band was 17dB and 21dB. Rectangular strip and F-shaped strip is used as parasitic elements improve isolation. The total gain of an antenna is 4dBi. The proposed MIMO antenna covers the band which covers the 2.4G WLAN and WiMAX system.

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