4-Shaped MIMO Antenna with Enhance Isolation

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Abstract*-A compact 4-shaped multiple-input-multiple-output (MIMO) antenna is proposed with parasitic element and DGS. The overall size of proposed MIMO antenna system is 50×50×1.6 mm*^{3}*. A defected ground plane structure (DGS) etched into the ground plane to improve mutual coupling effect between two antennas is reduced and isolation is increased. It covers two frequency bands, lower frequency band was 3.18-3.92 GHz and higher frequency band was 4.9-5.89 GHz.The reflection coefficient of antenna is less than -10dB at resonant frequencies. The isolation observed at lower band and higher band is below -25 dB which indicated there is good isolation in between two antenna element. The maximum gain of an array antenna is found 2.9dBi .*

Key Words- mutual coupling, isolation, diversity gain, multiple-input multiple output (MIMO) antenna, radiation pattern, Correlation coefficient

1. INTRODUCTION

Multiple-input-multiple-output (MIMO) is a new technology used for obtaining higher data rates in wireless communications system. In this technology, multiple antennas at both ends are utilized to enhance the transmission performance without increasing power at sources. The importance of MIMO technology is that they provide the opportunity to form parallel orthogonal transmission channels. MIMO has become an important element of wireless communication standard including IEEE802.11n (Wi-Fi), IEEE802.11ac (Wi-Fi), 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. Two inverted-L-shaped branches and a rectangular slot having circular end, etched into the ground plane to improve isolation [5]. The mutual coupling is reduced by introducing novel bent slits into the ground plane [6].

A complementary split-ring resonator introduced into the ground plane are effectively reduce the antenna size[7]. A built in filter method is also used to enhance the isolation between closely packed MIMO antennas. 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 providing polarization diversity [8].Three effective radiators used such as S and F-shaped radiators and driven monopole antenna printed on top surface of dielectric substrate which gives pattern diversity [9]. 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 lower and upper frequency bands for WLAN application.

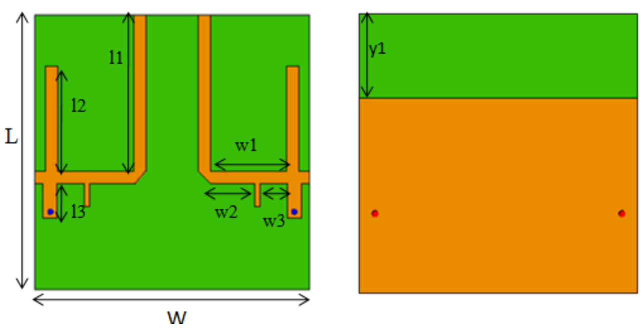
Defected ground plane structure is one of method used for increasing isolation between antenna elements. Ground was defected by a simple dumbbell like structure so that mutual coupling between antennas was reduced. For addressing low band, spirals were introduced into the primary rectangles of DGS in [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.

2. DESIGN AND SIMULATION

A. MIMO ANTENNA WITH PARTIAL GROUND

The optimized layout with dimensional details of the proposed MIMO antenna is illustrated in Fig. 1. This MIMO antenna system consists two dumbbell shape slots is substracted from the ground surface to reduce the mutual coupling effect. The slots act as a band stop fiter which helps to improve isolation. The dimension of dumbbells is very much important. Here, the dimension of 22×2mm^2 dumbles is cut from ground plane. A square shape slots having dimension of 8×8mm2 is subtracted from middle of ground surface as mention in fig. 3.28. By inserting slots into the ground plane helps to improve isolation. By changing the dimension, the resonant peak will be changed.

. The dimensions are in millimetre (mm): W=50, L=50, l1=28.5,l2=19.2,l3=6.3,w1=13.8,w2=8,w3=5 & y1=19.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.



(a) Top layer (b) Bottom layer

Fig. 1. Geometry of the MIMO antenna system

After simulation, two frequency bands are observed i.e. 3.48-3.73GHz with resonant frequency 3.63GHz and from 5.26-5.78GHz with resonant frequency 5.54GHz. The reflection coefficient (S11) observed at 3.63GHz is -12.83dB and at 5.54GHz is -23.8dB with isolation of -4.484dB and -13.67dB respectively as shown in fig 2.

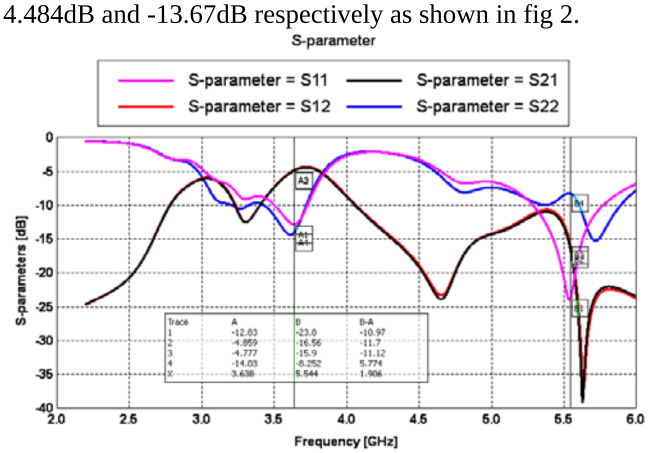
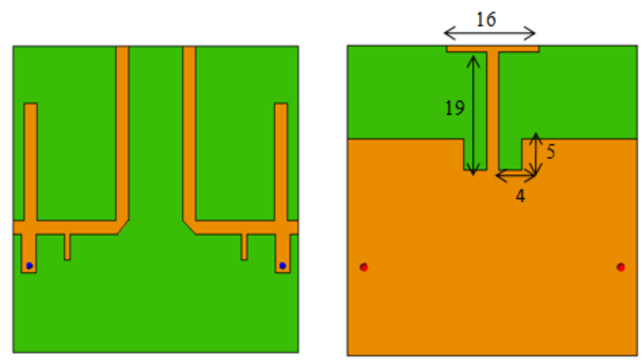


Fig.2 Simulated S-parameter with partial ground surface

B. MIMO ANTENNA WITH T-SHAPE METAL STRIP

A T-shaped metal strip with cutting slots is introduced into the back side substrate. Slots are used to reduce the mutual coupling effect caused by ground surface. After using T-strip on the bottom surface of ground, isolation is improved and the bandwidth is increased. The dimension of T-shaped metal strip is shows in figure 3.



(a)Top layer (b) Bottom Layer

Fig.3 Geometry of 4-shape MIMO antenna with T-shaped metal strip

The T-shaped metal strip gives two frequency bands from 3.18-3.59 GHz which is useful for WiMAX application and from 4.84-5.8 GHz frequency for WLAN/ WiMAX application with resonant frequency at 3.32GHzand 5.234GHz. The reflection coefficient (S11) is observed at 3.32GHz is -14.35dB and -14.44dB at 5.234GHz is shown in fig.4. The rectangular cutting slots are subtracted from ground surface located at both side of T-strip. After introducing cutting slots, the isolation is increased. The minimum isolation is observed -21dB at middle band and -15dB at upper band.

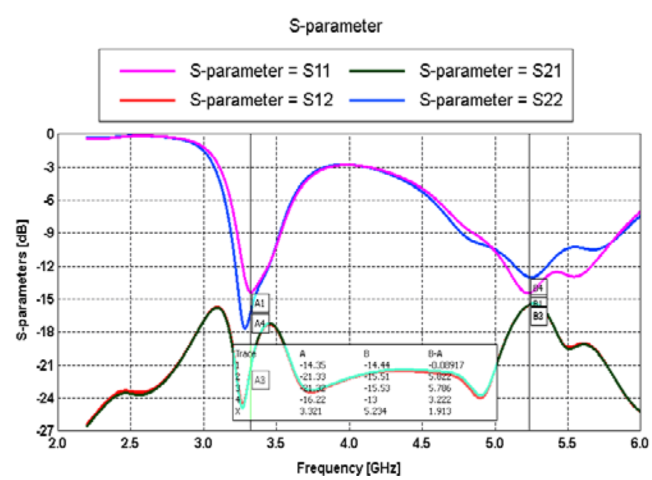
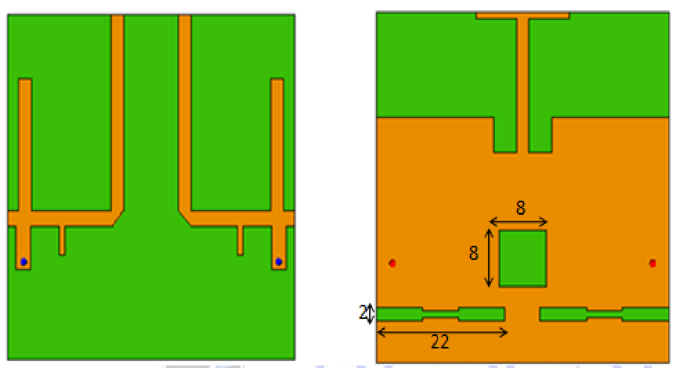


Fig.4 Simulated S-parameter with T-shaped metal strip

The VSWR is 1.92 at 3.29 GHz and 1.55 at 5.26 GHz. The gain observed at 3.29 GHz is 1.4dBi and at 5.26 GHz operating frequency is 2.3 dBi

C. MIMO ANTENNA WITH INSERTING SLOTS

Instead of using ordinary slots, two dumbbell shape slots is subtracted from the ground surface to reduce the mutual coupling effect. The slots act as a band stop filter which helps to improve isolation. The dimension of dumbbells is very much important. Here, the dimension of 22×2mm^2 dumbbell is cut from ground plane. A square shape slots having dimension of 8×8mm^2 is subtracted from middle of ground surface as mention in fig. 5. By inserting slots into the ground plane isolation is improve. By changing the dimension, the resonant peak will be changed.



(a)Top layer (b) Bottom Layer
Fig.5 Geometry of 4-shape MIMO antenna with inserting slots

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.

The simulated S-parameter results shows that there are two frequency bands middel band has frequency range from 3.26-3.6 GHz which covers WiMAX frequency range and upper band of frequency range from 4.98-5.8 GHz which covers WLAN/ WiMAX frequency range is shown in fig. 6.

The reflection coefficient observed at resonance frequency 3.39 GHz is -23.92 dB and 5.38 GHz is -32.78 dB. The minimum isolation observed below -15dB from 2.4GHz-6.0GHz frequency after using dumb-bell and square shaped slots as shown in figure 5. The VSWR is below 2 at lower band and higher band.

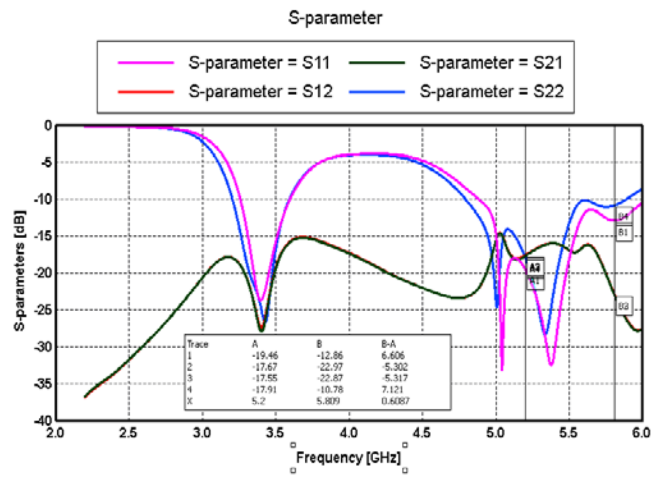
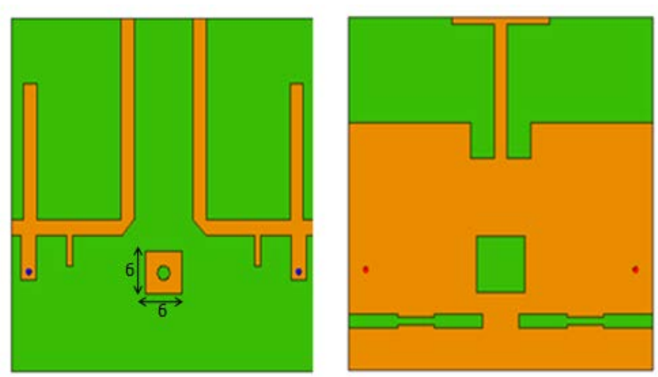


Fig.6 Simulated S-parameter using dumbbell slots

The overall gain of an antenna is varies in between 1.7dBi to 2.3 dBi for operating frequency range. Large surface current distribution is occurred near to the feed position at top surface while At the bottom surface, very small surface current found near the dumbbells and T-strips. After using the square shaped slots with square slots, the surface current at bottom also increased.

D. MIMO ANTENNA WITH EBG STRUCTURE

The EBG structure is specially used for improving gain/radiation pattern of an antenna and for reducing losses in transmissions. It is also known as high impedance surface because it has an ability to suppress the surface wave at certain operational frequency. Due to the used of square shaped EBG structure, isolation and gain is increased.



(a)Top layer (b) Bottom Layer
Fig.7 Geometry of 4-shape MIMO antenna with EBG structure

With insertion of EBG structure, the frequency band is increased, middle band range is from 3.2-3.62GHz and upper band ranges from 4.9-5.89 GHz. The reflection coefficient observed at resonant frequency is -23.22dB and -32.33dB at 3.44 GHz and 5.01 GHz respectively is as shown fig 8. The VSWR is found to be less than 2 for both frequency .

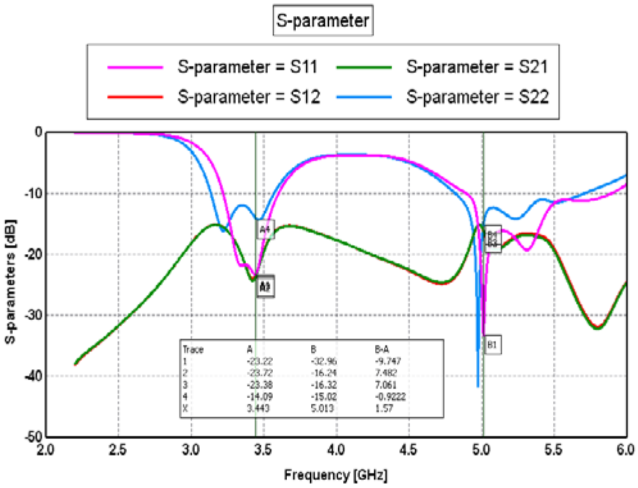


Fig.8 Simulated S-parameter using EBG

The overall gain of an antenna varies in between 1.9dBi and 2.9dBi at resonance frequencies. After introducing EBG structure, the gain of an antenna is increased. The figure 9 & 10 shows the 3D & 2D radiation pattern respectively. The surface current observed in figure 11, it indicate that the surface current desity is improved due to use of dumbbell shape DGS and EBG structure.

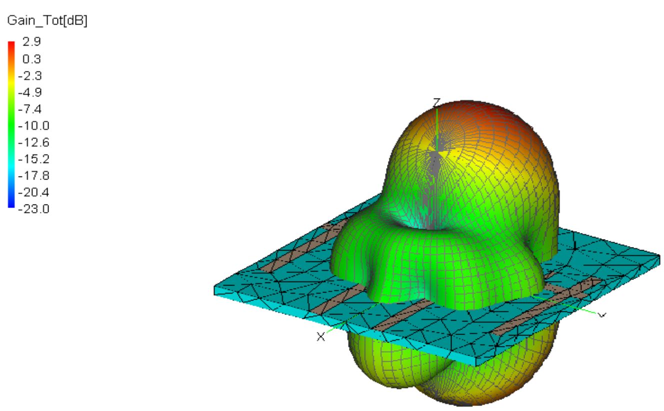
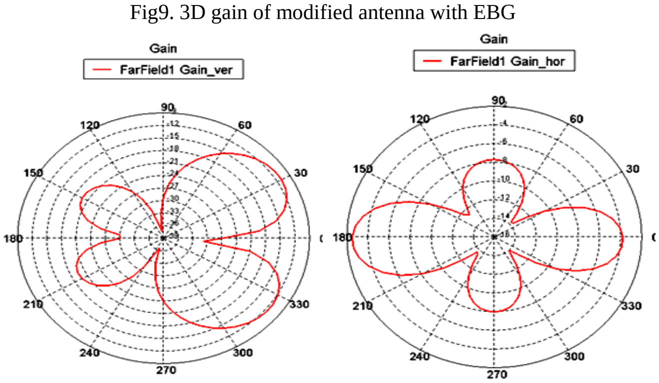


Fig9. 3D gain of modified antenna with EBG



(a) Vertical far field gain (b) Horizontal far field gain

Fig.10 2D gain with EBG

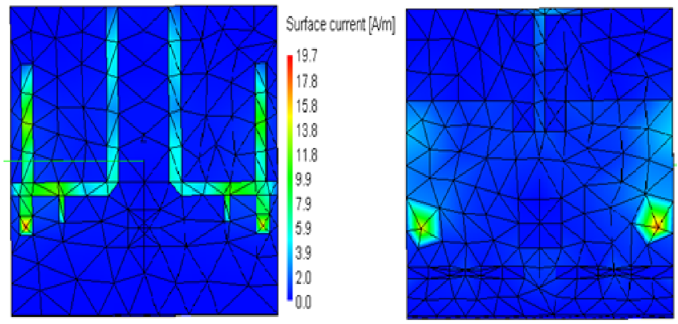


Fig.11 Current distribution of MIMO antenna

3. RESULTS AND DISCUSSIONS OF PROTOTYPE

The Antenna Prototype is shown in fig.12. The antenna parameters are measured with Rohde & Schwarz VNA.

(a)Front view (b) Back view

Fig. 12 Fabricated Antenna

Two bands are found at 3.72- 4.13 GHz and 5.2 - 5.45 GHz. The lower side band. The measured reflection coefficient S11 is at -12.91dB and -26.70 dB observed at resonant frequency 3.92GHz and 5.35GHz respectively similarly S22 is at -23.26 dB and -16.05 dB at same resonance frequency as shown in fig. 13.

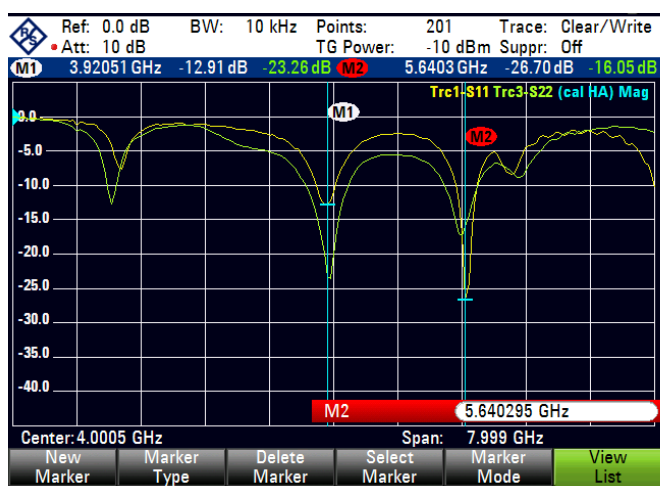


Fig.13 Measured S11 and S22

The measured transmission coefficient shown in fig.14 , S12 and S21 is found to be -28.72 dB and -29.02 dB respectively at same resonant frequency which is less than -25 dB. The measured VSWR is found to in between 1 and 2 as shown if fig.15. The impedance of the antenna is found near to the 50 Ω in both frequency bands.

Fig.14 Measured S21 and S12

Fig.15 Measured VSWR

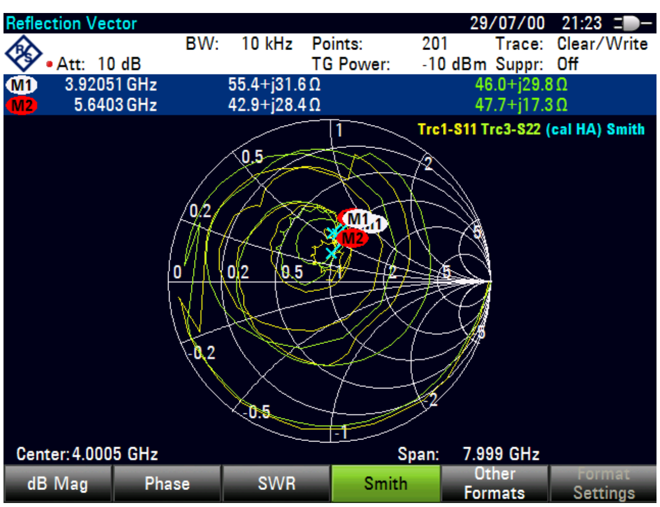


Fig.16 Measured Impedance

4. Conclusion

A 4-shaped MIMO antenna is designed for WLAN/ WiMAX application. It works on frequency bands of 3.18-3.92 GHz which is useful for WiMAX application and from 4.9-5.89 GHz frequency for WLAN/ WiMAX

An antenna is designed and simulates with T-shaped parasitic element, dumbbell slots and EBG structure which was accomplished and various parameters such as return loss, VSWR, Input impedance, gain. A T-shaped metal strip and slots are used for enhancing isolation and reduced mutual coupling effect. An EBG structure is used to increase the gain of an antenna.The reflection coefficient of antenna is less than -10dB at resonant frequencies. The transmission coefficient is observed less than -25 dB which indicated there is good isolation in between two antenna element. The maximum gain of an array antenna is found 2.9dBi .

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