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Dumbbell-shaped asymmetric DGS-based dual band 3*3 MIMO for WLAN/ WiMAX applications

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Abstract

The work presents a design of 3*3 MIMO (Multiple Input Multiple Output) wireless dual-band antenna which supports two frequency ranges i.e. 2.4 GHz - 2.5 GHz and 5.725 GHz - 5.85 GHz for WLAN/ WiMAX applications. The method of construction thereof allow transmission and reception of electromagnetic signals with high gain, high isolation ($\geq$ 20 dB) and low VSWR (< 2). In this design, the antenna elements are etched on a compact low-cost FR4 (ε_r =4.4, tan δ = 0.02) PCB board. The design is based on combination of dumbbell-shaped asymmetric DGS (Defected Ground structure) and L-shaped monopole antenna.

1. Introduction

MIMO systems have attracted significant attention as they have the potential to achieve significant increase in wireless channel capacity without the need for additional transmit power or spectrum. One important requirement for MIMO antenna systems is the requirement for good isolation between antenna elements. In addition, for WLAN/WiMAX applications in portable devices very small form factors are an important requirement and therefore good isolation between antennas with closely packed antenna elements is necessary.

There are various methods that can be utilized to improve antenna isolation. For example mushroom-like EBG structures can suppress the surface wave between antenna elements [1]. However, a number of mushroom-like structures are needed to be put under the antenna elements and this occupies a large area. A compact integrated diversity antenna with two feed ports has been proposed as well [2]. Since they are based on patch antennas, the size may not be suitable in very small form factors. Then slot-cutting on the antenna elements to improve isolation is introduced [3], but there is no general solution to provide isolation. Recently, there has been an increasing interest in the use of DGSs for performance enhancement of microstrip antennas [4-7]. These structures are realized by etching off a simple shape defect from the ground plane of the microstrip patch antenna. The shape may vary from a simple geometry to a complicated geometry.

Based upon the foregoing, it is a main objective of the present work to provide a stable alternative method for field cancellation between a pair of closely-packed antenna elements within a very small form factor. So a dumbbell-shaped asymmetric DGS is introduced to provide a cost-effective MIMO construction which suppresses harmonics, cross polarization and increases gain, isolation with low VSWR of the antenna over two frequency bands: (2.4 GHz - 2.5 GHz) and (5.725 GHz - 5.85 GHz), with minimum aberration or distortion and maximum efficiency. The design and simulation of the proposed dual band 3*3 MIMO for WLAN/WiMAX applications have been carried out using 3D full-wave EM simulator HFSS [8].

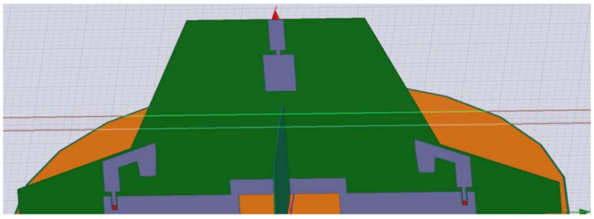


Figure 1a. Configuration for 2.4 GHz antenna.

2. Design Methodology

The purpose of this work is to develop design to enhance the isolation and VSWR between two closely packed antennas operating at two different frequency bands: (2.4 GHz - 2.5 GHz) and (5.725 GHz - 5.85 GHz). The idea is to use field cancellation to enhance isolation by putting a coupling element which artificially creates an additional coupling patch between the L-shaped monopole antenna elements.

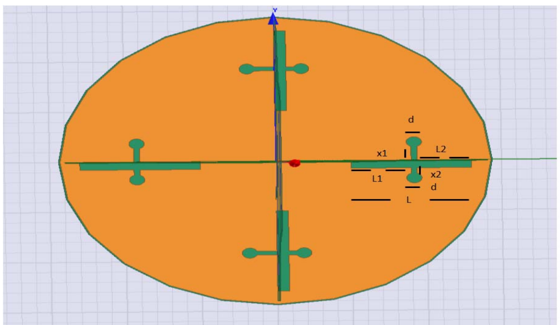


Figure 2b. Configuration for 5.8 GHz antenna.

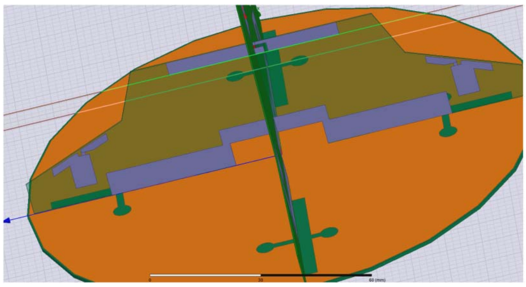
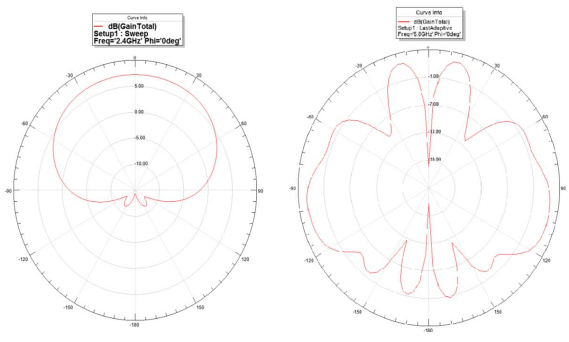


Figure 3c. Dumbbell - shaped asymmetric DGS introduced to improve isolation.

So a dumbbell-shaped asymmetric DGS is introduced to dual band 3*3 MIMO, to provide a band-stop effect by suppressing the ground current flowing between antenna elements. When this DGS is applied to the ground plane of the L-monopole antennas, it increases the series inductance to the microstrip line [6]. This effective series inductance introduces the cutoff characteristic at a certain frequency. There are attenuation poles on the etched dumbbell-shaped asymmetric DGS. These attenuation poles can be explained by parallel capacitance with the series inductance. This capacitance depends on the etched gap below the conductor line.

The designs of dual band 3*3 MIMO using dumbbell-shaped asymmetric DGS configuration to improve isolation and VSWR are shown in Fig. 1a for 2.4 GHz and Fig.1b for 5.8 GHz respectively. The design in Fig. 1c shows a pair of closely-packed antenna elements with dumbbell-shaped asymmetric DGS within a very small form factor. The L-monopole antenna elements are etched on a compact low-cost FR4 (ε_r =4.4, tan δ=0.02) PCB board.

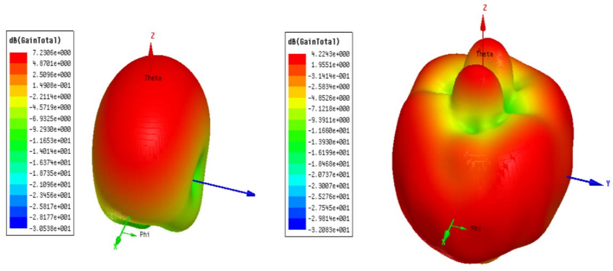


(a) (b)

Figure 2. Radiation pattern for : (a) 2.4 GHz, and (b) 5.8 GHz.

3. Results and Discussions

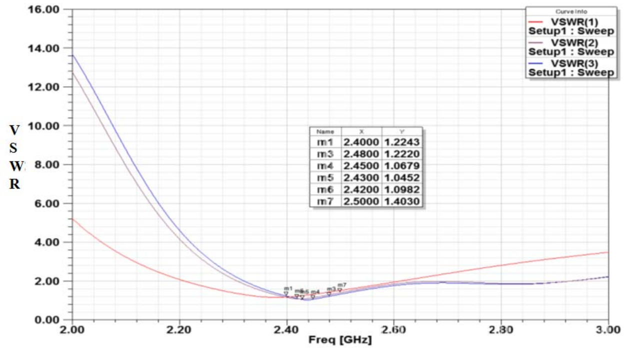
The design and simulation of the proposed dumbbell-shaped asymmetric DGS- based dual band 3*3 MIMO has been carried out using 3D full-wave EM simulator HFSS [8]. Fig. 2 is showing the radiation pattern of the antenna for both the frequency bands. Fig. 3 is showing 3D polar plot for total gain of antenna which is 7.23 dBi for 2.4 GHz and 4.22 dBi for 5.8 GHz respectively.



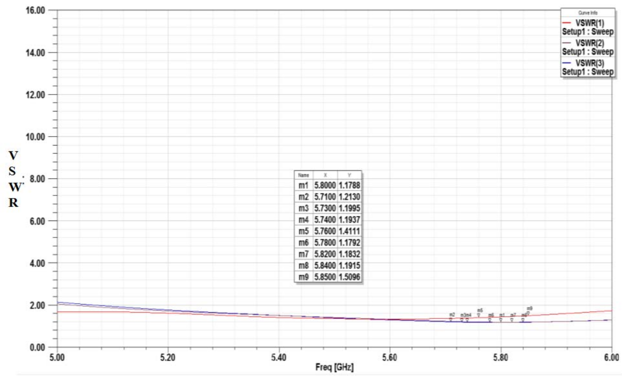
(a) (b)

Figure 3. 3D Polar plot for antenna gain :(a) 2.4 GHz, and (b) 5.8 GHz.

Fig. 4 shows the VSWR characteristics for both the frequency band which is < 2 throughout the range. Similarly Fig. 5 shows the isolation and reflection characteristics of antenna for both the bands. It can be clearly seen that for both the frequency bands isolation is ≥ 20dB.



(a)

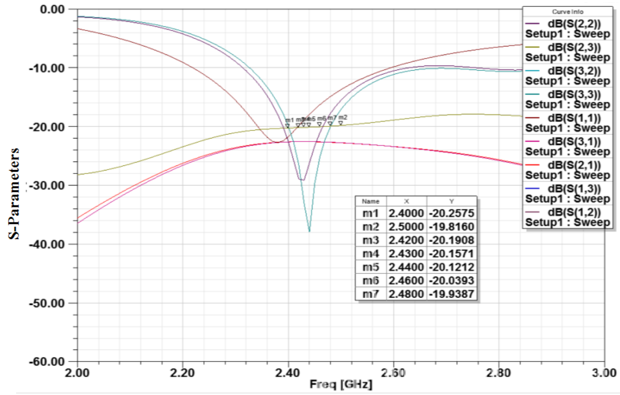


(b)

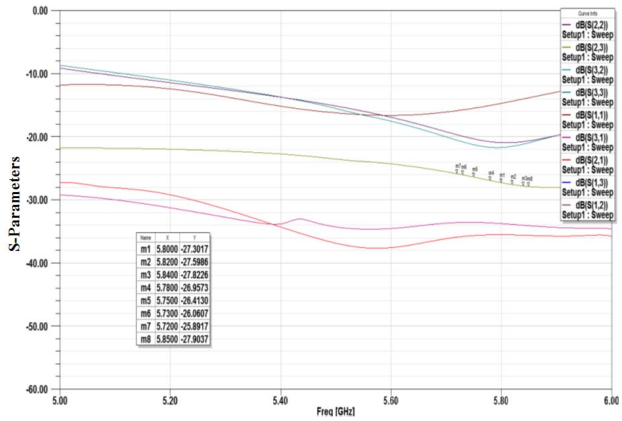
Figure 4. VSWR characteristics for :(a) 2.4 GHz, and (b) 5.8 GHz.

The dielectric constants, loss tangents, and thicknesses of the various materials to be used in the configuration construction of the asymmetric DGS-based dual band 3*3

MIMO antenna are designed to provide excellent transmission and reception efficiency over the frequency ranges desired. It produces an optimized performance design for applications based on WLAN/ WiMAX range.



(a)



(b)

Figure 5. Isolation and Reflection characteristics for : (a) 2.4 GHz and (b) 5.8 GHz.

From the point of view of the electromagnetic performance of antenna, it can be said that the overall result can be the achievements of the dumbbell-shaped asymmetric DGS-based 3*3 MIMO for dual band with high gain and isolation and low VSWR.

4. Conclusions

The present work is related to design of dual-band 3*3 MIMO for the wireless channel to send and receive signals and to suppress the channel fading. It is a wireless dual-band antenna which supports two frequency ranges i.e. 2.4 GHz - 2.5 GHz and 5.725 GHz - 5.85 GHz for WLAN/ WiMAX applications. The proposed structure consists of two antenna elements and a coupling element which is located in between the two antenna elements. The method of construction thereof allow transmission and reception of electromagnetic signals with high gain, high isolation (≥ 20 dB) and low VSWR (< 2). In this design, the antenna elements are etched on a compact low-cost FR4 (ε_r =4.4, tan δ=0.02) PCB board. The design is based on combination of dumbbell-shaped asymmetric DGS and L-shaped monopole antenna. The design is cost-effective and highly efficient which is a boon for wireless coverage.

5. Acknowledgements

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6. References

1. F. Yang, and Y. R - Samii, “Microstrip Antennas Integrated With Electromagnetic Band-Gap (EBG) Structures: A Low Mutual Coupling Design for Array Applications,” *IEEE Trans. on Antenna and Propagation*, **51**, 10, October 2003, pp. 2936-2946.

2. S.C.K. Ko, and R.D. Murch, “Compact integrated diversity antenna for wireless communications,” *IEEE Trans. on Antenna and Propagation*, **49**, 6, June 2001, pp. 954-960.

3. H.-T. Chou, H.-C. Cheng, H.-T. Hsu, and L.-R. Kuo, “Investigations of Isolation Improvement Techniques for Multiple Input Multiple Output (MIMO) WLAN Portable Terminal Applications,” *PIER*, **85**, 2008, pp. 349-366.

4. A. K. Arya, A. Patnaik, and M. V. Kartikeyan, “Gain Enhancement of Micro-strip patch antenna using Dumbbell shaped Defected Ground Structure,” *International Journal of Scientific Research Engineering & Technology (IJSRET)*, **2**, 4, July 2013, pp. 184-188.

5. A. K. Arya, A. Patnaik, and M. V. Kartikeyan, “Microstrip Patch Antenna with Skew-F Shaped DGS for Dual Band Operation,” *Progress In Electromagnetics Research M,* **19**, 4, 2011, pp. 147-160.

6. M. K Khandelwal, B. K. Kanaujia, and S. Kumar, “Review Article: Defected Ground Structure: Fundamentals, Analysis, and Applications in Modern Wireless Trends,” *International Journal of Antennas and Propagation,* **85**, 2017, pp.1-22, *https://doi.org/10.1155/2017/2018527*.

7. A. K. Arya, A. Patnaik, and M. V. Kartikeyan, “Back to Back Combined Single Feed Proximity Coupled Antenna with Dumbbell Shaped DGS,” *Journal of Electromagnetic Analysis and Applications,* **3**, 2, 2011, pp. 43-46.

8. HFSS Ansoft Designer HFSS v12.0, Ansoft USA 2005, http://www.ansoft.com/HFSS.