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Design and Evaluation of Two Port UWB Antennas for efficient MIMO Communications

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***Abstract*— A compact UWB MIMO antenna system with high isolation has been proposed and investigated. A compact planar UWB MIMO antenna system of size 36 mm × 40 mm with two hexagonal monopole elements is presented. . The radiators have a similar, regular hexagonal geometry of side 6 mm, offering more impedance bandwidth. A slot of 1 mm width is etched on each of the hexagonal antenna elements to adjust the bandwidth. A hexagonal slot of uniform width Ws = 1 mm is etched on the ground plane. Good isolation performance was achieved through this proposed DGS structure. Simulated results using commercial software I3D 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 4.5 GHz to 9.6 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.**

***Index Terms*— MIMO Antenna, UWB Antenna, DGS, Two port.**

I. INTRODUCTION

There is a constant demand for compactness or miniaturization of wireless electronic devices, as well as an increase in speed and data rate for these devices. The potential of UWB technology is enormous owing to its tremendous advantages such as the capability of providing high speed data rates at short transmission distances with low power dissipation. In this regard, UWB MIMO antenna systems are being considered for better performance, and they present antenna engineers with many design challenges. Designing a UWB antenna is to attain wide impedance bandwidth with high radiation efficiency. UWB antennas achieve a bandwidth, greater than 100% of the center frequency to ensure sufficient impedance so that only less than 10 % of incident signal is lost due to reflections at the antenna's input terminal [1]. A return loss of greater than 10 dB is necessary in order to obtain high radiation efficiency. It is required as UWB transmission is of very low power (below the noise floor level) and with high sensitivity [2].

Digital communication using Multi-Input Multi-Output (MIMO) processing has emerged as a breakthrough for wireless systems of revolutionary importance. All wireless technologies face the challenges of signal fading, multipath, increasing interference and limited spectrum. MIMO technology exploits multipath to provide higher data throughput, and simultaneous increase in range and reliability all without consuming extra radio frequency. MIMO systems exploit the antenna diversity (spatial, polarization or pattern diversity) to increase the strength of the transmitted signals and therefore to improve the Signal Noise Ratio (SNR). Spatial multiplexing in MIMO systems helps in increasing data rate. Beam forming is used either to increase data rate or to strengthen the signal. The main applications of UWB technology are found for WPAN and WBAN (Wireless body area network) in indoor environments where the dense multipath propagation leads to generally detrimental Inter Symbol Interference (ISI). Therefore, to turn this drawback into an advantage, multiple antennas or MIMO techniques can be employed to exploit such rich scattering environments. The more important is that the applications of UWB are limited to the short distance communication due to very low transmission power allowed by the FCC. Hence, using MIMO together with UWB helps in extending the communication range as well as offers higher link reliability. The benefits of UWB-MIMO can be summarized as following [3]-[4]: interference mitigation/suppression, higher data rates, improved link quality, extended coverage, reduced analog hardware requirements, and concurrent localization.

A compact UWB MIMO antenna system with low mutual coupling among the antennas is desired for UWB applications. Various methods and isolation structures can be introduced for simultaneous enhancement of bandwidth and isolation in a UWB MIMO antenna system. , Defected Ground Structures (DGS) are introduced to improve antenna performance characteristics like size reduction, gain and bandwidth enhancement, and they are also used in reduction of mutual coupling between antenna elements. the defected ground structure (DGS) is also able to provide a band stop effect due to the combination of inductance and capacitance [5]. The defects on the ground plane store a fraction of propagating energy and that can be modeled in terms of a simple equivalent reactive circuit as was explained in detail in [6]. DGS has been applied to antenna designs to suppress harmonics, cross polarization of a patch antenna, and to increase the isolation between antennas.

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II. ANTENNA DESIGN

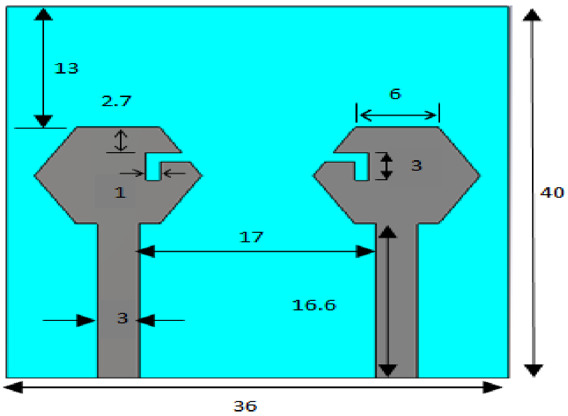


Fig. 1. Geometry of the proposed MIMO antenna system-Front view

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 feed lines 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.

III. PROPOSED ISOLATION - DGS:

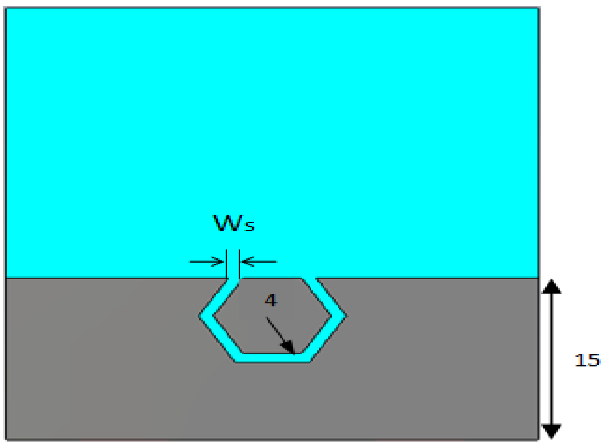


Fig. 2. Geometry of the proposed DGS

A defected ground structure (DGS) is introduced as shown in Fig 2, to enhance the bandwidth and to reduce the coupling between the antennas. A hexagonal slot of uniform width Ws = 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.

IV. SIMULATION AND RESULTS

The proposed antenna with the various ground plane structures is simulated using the commercial software I3D. The simulated results of S-parameters and radiation pattern are obtained in the frequency range of 3-11 GHz and analyzed for isolation and bandwidth performance characteristics.

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.

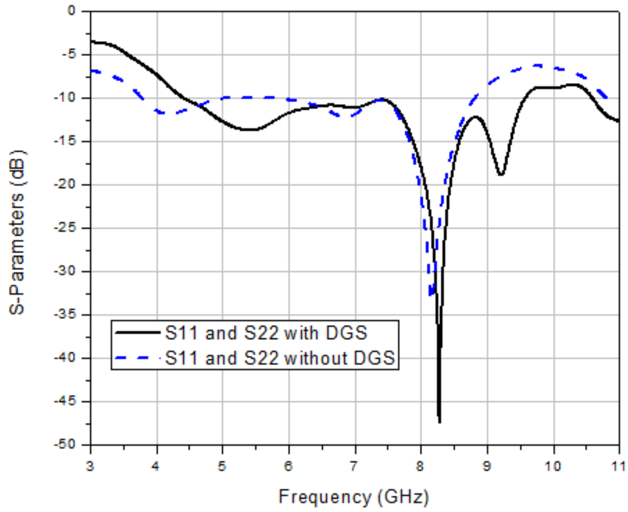


Fig.3 Simulated S-parameters with and without DGS - S11 and S22

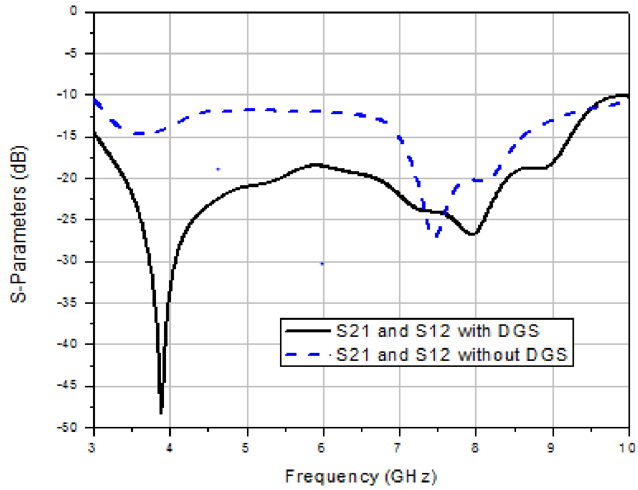


Fig 4. Simulated S-parameters with and without DGS -- S21 and S12.

V. PARAMETRIC STUDY :

The isolation and bandwidth behavior of the MIMO antenna with DGS is studied by varying one of the design parameters.

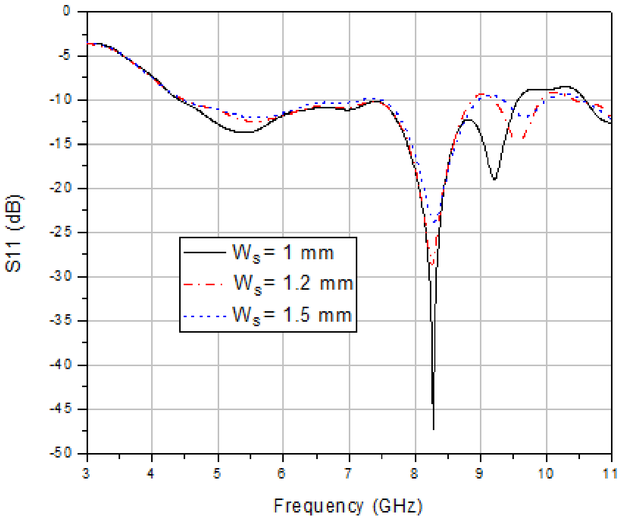
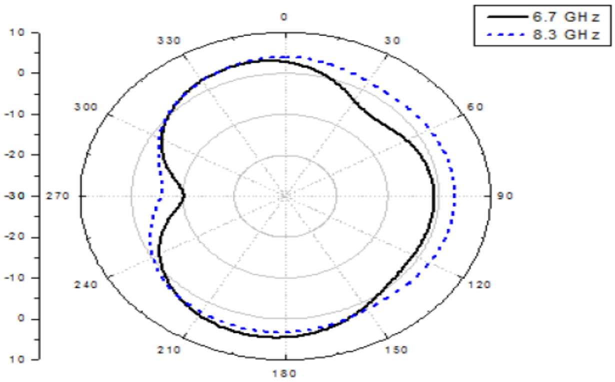


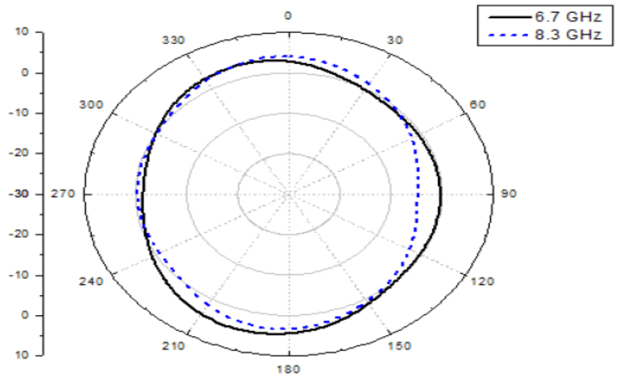
Fig.5. Width Vs variation against S11.

The isolation and bandwidth behavior of the MIMO antenna with DGS is studied by varying one of the design parameters. Fig.5 shows the variation of return loss obtained by varying the width of the slot Ws of the hexagonal DGS from 1mm to 1.5 mm. It is apparent that a wider bandwidth is achieved corresponding to a narrow width, Ws= 1 mm

VI. RADIATION PERFORMANCE:



(a)



(b)

Fig. 6. Simulated radiation patterns: (a) y-z plane, (b) x-z plane.

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.6, for frequencies of 6.7 GHz and 8.3 GHz in the y-z ($\phi = 90^0$) and x-z ($\phi = 0^0$) planes. The antenna exhibits a stable radiation behavior across the required operating band.

VII. CONCLUSION

A novel compact UWB MIMO antenna system with high isolation has been proposed and investigated . Good isolation performance was achieved through the proposed DGS structure. It 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 4.5 GHz to 9.6 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. . The obtained results of isolation and bandwidth characteristics show that the proposed MIMO antenna system can work well in extremely wideband range and it is found suitable for application in UWB portable devices.

The performed simulation results and investigations proved sufficient port-to-port isolation in the UWB and the designed antenna systems can be used, where high data rate and support for MIMO transmission is required.

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