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Investigation of two port Ultra-wideband MIMO antenna with improved inter-port isolation

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Abstract - *In this paper, two port Ultra-wide band Multiple Input Multiple Output (UWB-MIMO) with high isolation feature is presented. The overall structure of proposed antenna is compact with the size of 62×30mm². The fundamental unit, measuring 30×30 mm², consists of a hexagonal ring-shaped patch connected to a stepped feed line, ensuring a 50Ω impedance matching. In addition, the feed line is modified with inset feed cutting and the partial ground is defected by three rectangular shaped slots which culminated to enhanced the bandwidth range. The frequency range of proposed model is 3.7-14.20GHz with satisfy ability of UWB range and beyond. High isolation is achieved without implemented complex decoupling structure. As a results, the isolation is achieved below -20dB level with envelope correlation coefficient < 0.015 and diversity gain > 9.98 dB. Also, it exhibits maximum radiation efficiency and gain 50.78% and 3.81 dBi respectively in the working band.*

Key Words: Ultra-wide band, inset feed, orthogonal, MIMO, Defected ground plane

1. INTRODUCTION

Wireless communication technology has witnessed rapid advancements in recent years, driven by the need for higher data rates, improved reliability, and enhanced efficiency. Notably, Ultra-Wideband (UWB) antennas play a crucial role in modern wireless communication, offering high-speed data transmission, precise localization, and low power consumption. Unlike conventional narrowband antennas, UWB antennas operate over a broad frequency spectrum (typically 3.1–10.6 GHz), enabling efficient and interference-resistant communication [1]. UWB technology is increasingly being combined with MIMO (Multiple Input Multiple Output) systems to overcome challenges in modern wireless networks. When MIMO combined with UWB, this synergy enables high-speed, low-latency communication, making it highly suitable for applications such as 5G networks, Internet of Things (IoT), radar systems, medical imaging, and indoor positioning systems [2]. In spite of all benefits, MIMO antenna design suffer from, interference and correlation issues among the elements [3]. In addition mutual coupling, and higher complexity in design to fabrication is also a major concern. Here, diverse approaches have been examined till date to minimize the mutual coupling or expansion the isolation techniques include, positioning the structure in between the antenna element [4], defected ground plane [5], EBG structure [6], metamaterial [7] , neutralization lines[8] and to name the few.

F. Guichi et al. [9] proposed two element MIMO antenna with a simple structure and small size of 24 ×35 mm2.They were able to achieve -20dB isolation by inserting a simple rectangular shaped ground isolation stub. In another approach, U. felix et.al. Studied a UWB MIMO antenna with port, they were incorporated a set of three quad G-shape metamaterial between two port antenna design. However, it enhanced bandwidth in the lower frequency range of the UWB spectrum (below 5.567 GHz) while simultaneously minimizing mutual coupling within this expanded band [10]. Additionally, the exploration of defected ground in multi-port antennas remains at the forefront of ongoing research. A. Iqbal et al. [11] discussed a decoupling structure in the form of an F-shape isolator positioned between the patch. They presented a UWB-MIMO antenna comprising two monopoles fed by microstrip lines. The inclusion of F-shaped stubs in the ground plane enhances multiple resonances and ensures high isolation between the radiating elements. The simulated and measured results align well, demonstrating that the proposed antenna is an excellent choice for modern portable wireless front-end applications. A lots of research has been done in past few years, which encounters some limitations, such as complex in circuit, large in size, low gain etc. Designing a MIMO antenna system with more than two antennas while enhancing isolation and simultaneously keeping the wireless device compact is also a challenging task [12-18].

In this paper, a novel compact 2×2 UWB MIMO antenna with high inter-port isolation is presented. The significant enhancement in isolation has been achieved by placing the antenna element in orthogonal manner. The frequency band extending from 3.7-14.20GHz is above -10dB reflection level. Here, the bandwidth has been extended from 7.92 to 10.22GHz by utilizing the hexagonal slot and inset feed in the radiating element. Hence, the achieved bandwidth percent is achieve by 130%. Besides above, The proposed UWB MIMO antenna performance parameters like the S-parameters, VSWR, gain, surface current, efficiency and radiation pattern are evaluated. Despite of this the diversity parameter is evaluated by examine the diversity matrix such as diversity gain (DG) and effective correlation coefficient (ECC). The above MIMO antenna is applicable for UWB frequency band satellite systems as well as, Wi-MAX, WLAN, ISM, LTE, sub-6 GHz 5G, and X- and Ku bands.

2. Design of Single UWB Antenna Element

Fig. 1(a) and 1(b) illustrates the top and bottom view of model of planar monopole antenna configuration feature with ultra-wideband characteristics. The antenna design is implement on a FR-4 substrate having dielectric constant of 4.3 and thickness of 1.6mm.The size of the single element is 30×30mm².The UWB antenna design consists of hexagonal ring shape radiator with stepped feedline. Further, the partial ground plane miniaturized by three rectangular slots employing a wide bandwidth. Therefore, this whole sum structure is responsible for covering the extreme bandwidth beyond the range of UWB antenna parameters of antenna design is demonstrated in table-1. All parameters are measured unit in mm.

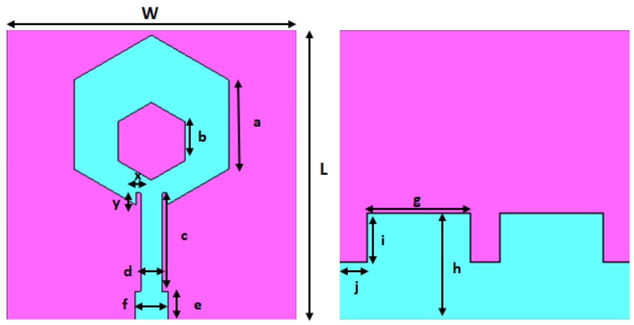
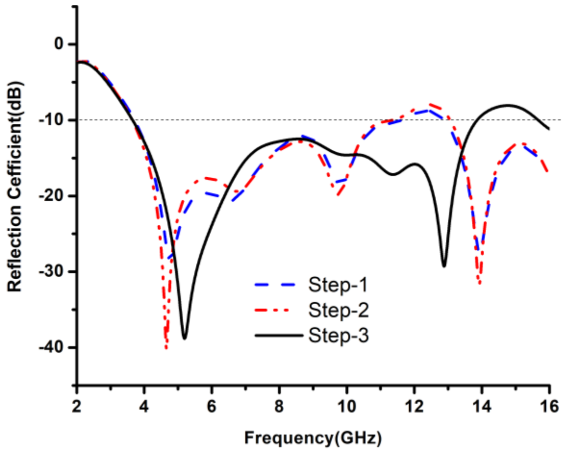


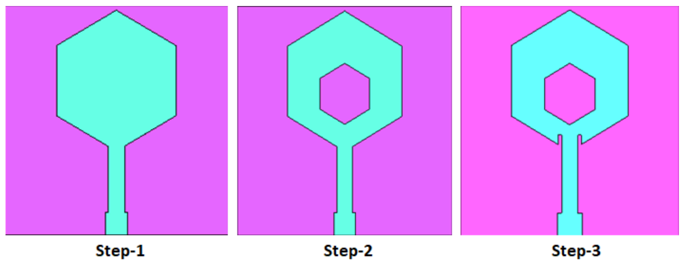
Fig.1. The single element UWB antenna configuration (W=30, L=30, a=9.20, b=4.00, c=10.13, d=2.20,

e=3, f=3.40, x=0.50, y=1.21, g=10.50, h=11, i=5.00,j=3)(all measurement in mm)

The progressive evolution at different stages is demonstrated in Fig.2.The reflection coefficient of suggested antenna model having bandwidth of 3.7-14.20GHz is above -10dB over three different steps as illustrated in fig. 2(a). The antenna design starts with ordinary hexagonal shaped patch with stepped shape feed and slotted ground called as step-1. It can be observed that this design gives poor impedance matching and low in bandwidth. In order to apply hexagonal ring in step-2 and further apply inset feed on patch with 50Ω impedance matching in step-3 gives the wide bandwidth as compared to previous one. Finally, the reflection coefficient of proposed design in step-3 gives the wide bandwidth of 3.7-14.20GHz in terms of novelty. All step by step procedure to achieve the final monopole antenna layout is demonstrated as Fig. 2(b). The inset feed plays an important role to achieve the improved impedance matching and enhancing bandwidth. The modifications in shape is performed by using the Computer Simulation Technology Microwave Studio (CST-MWS-2022).The shape modifications such as slotting, cutting edge, partial ground has results enhancing the bandwidth and miniaturized the size towards the UWB monopole antenna.



(a)



(b)

Fig.2 The step wise progress evolution of proposed antenna model (a) Reflection coefficient (b) Three steps at different stage

3. Two Port Planar UWB MIMO Antenna Design

The layout of the proposed two port MIMO antenna design is depicted in Fig.3. The front and back view is consisted of two single element as discussed as earlier. Two single UWB monopole antenna placed orthogonally to each other comprises of high isolation factor. The overall size of proposed MIMO antenna is 62×30mm²(W1×L1) constructed on same material FR-4 substrate. The MIMO antenna consisted of two element of same size of monopole design placed on distance of I=7.66 mm in orthogonally manner. It can be observed that the proposed model of two port MIMO antenna confirmed the maximum isolation between the inter-elements and provide the better enhancement characteristics which satisfied the parameters of MIMO configuration. Additionally, achieved the isolation between the port is less than -20dB isolation level. The isolation level S-parameters such as S_{21} and S_{22} are shown in Fig.4. However, provides results are compared to available previous literature .It is found that the proposed antenna model gives the higher isolation with compact in size .Also the proposed model gets the better ECC and diversity gain.

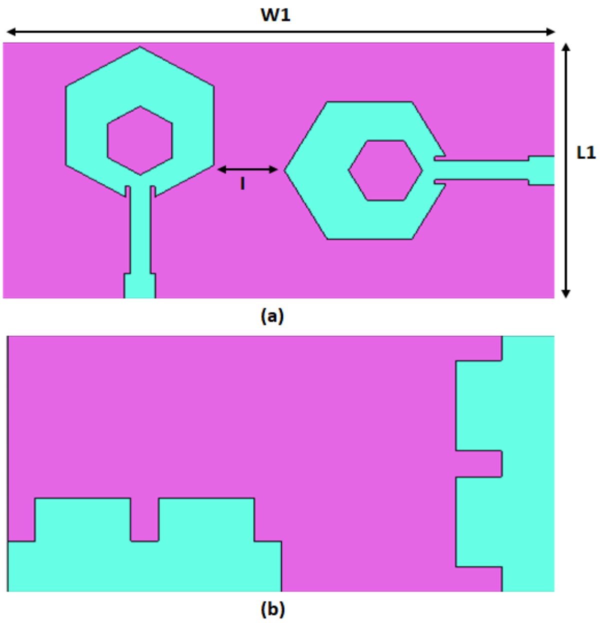


Fig.3 Geometry of the two port UWB MIMO antenna configuration (a) The front view (b) Back view

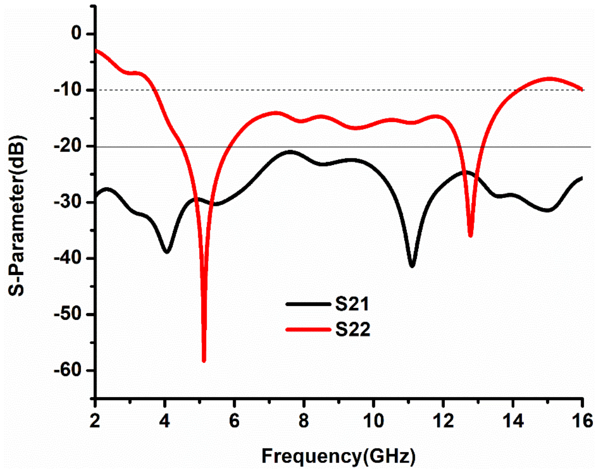


Fig.4 Simulated S-parameters of proposed two port antenna model

4. Simulated Results and Discussion

a. Voltage Standing Wave Ratio

In essence, VSWR quantifies the impedance mismatch between the antenna and the transmission line by calculating the ratio of the maximum to minimum voltage standing wave along the line. In practical, the value of VSWR is less than 2.So, however, the vswr of the proposed antenna model less than 2 is demonstrated as Fig.5 satisfied the characteristic parameter.

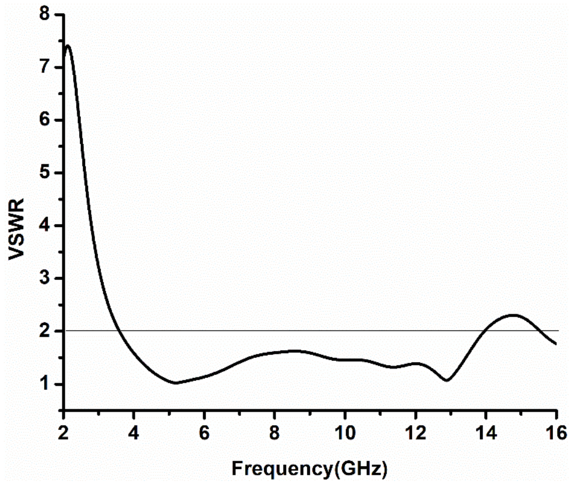


Fig.5 The simulated VSWR of proposed single monopole UWB antenna model

b. Radiation Pattern

Fig.6 demonstrates the simulated radiation patterns at two different resonant frequencies at 5.12 and 12.79GHz. The 2-dimensional radiation pattern has obtained by exciting port 1.The co-polarization at 5.12 and 12.79GHz explain the unidirectional in left side whereas the cross polarization at 5.12 and 12.79GHz are demonstrated as omnidirectional in shape explain in right side as Fig. 6(a) and Fig.6(b) respectively. Also both figure could be explain the isolation between the elements.

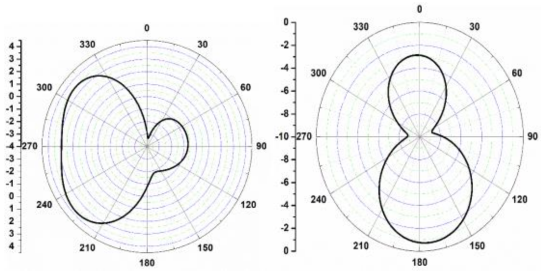


Fig.6 (a) Co and cross polarization radiation pattern at 5.12GHz

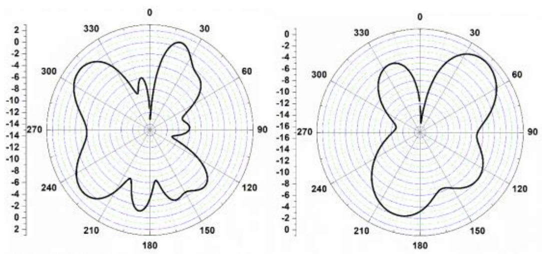
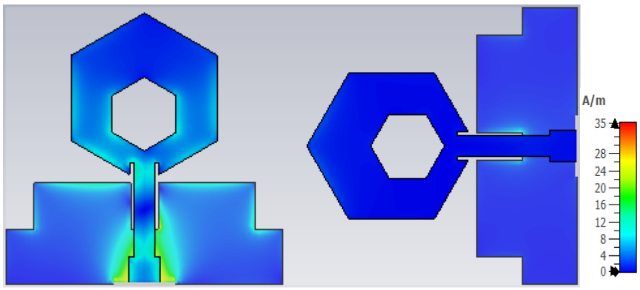


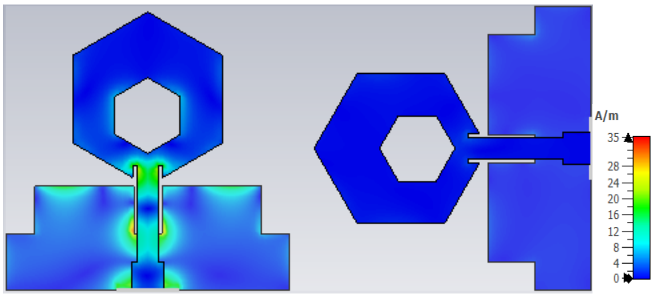
Fig.6 (b) Co and cross polarization radiation pattern at 12.79GHz

c. Surface Current

Fig. 7(a) and Fig. 7(b) illustrates the surface current distribution at two different frequencies at 5.12and 12.79GHz. Notably, port-1 was excited during taken the distribution. It can be observed that second element is isolated form first port. There is no current distribution at second port in the case of both resonant frequencies. In addition, there is no need of complex isolation structure to isolate the port .It is well decoupled only from arrangement the element in orthogonally manner.



(a)



(b)

Fig.7. Surface Current Distribution over the antenna (a) at 5.12GHz (b) 12.79GHz

d. Gain and Radiation Efficiency

Gain and radiation efficiency plot of proposed two port UWB MIMO antenna are demonstrated in Fig. 8. It can be observed that the maximum gain is obtained 3.81 dBi at 12.25GHz.Next, the simulated radiation efficiency is obtained 50.78% at 12GHz in the working frequency band from 1-16GHz.

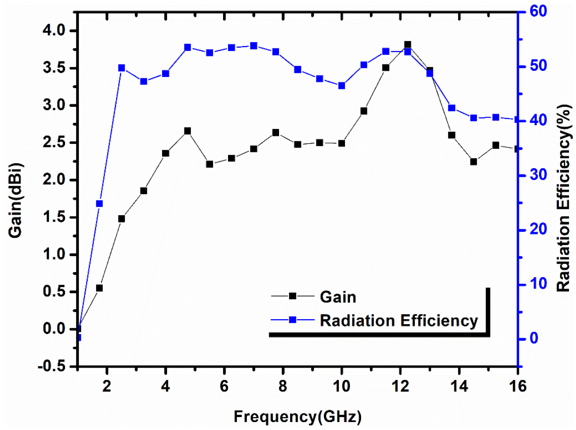
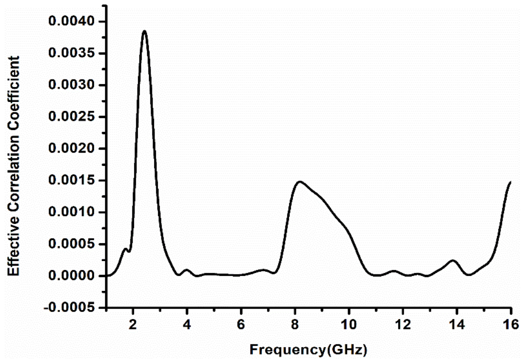


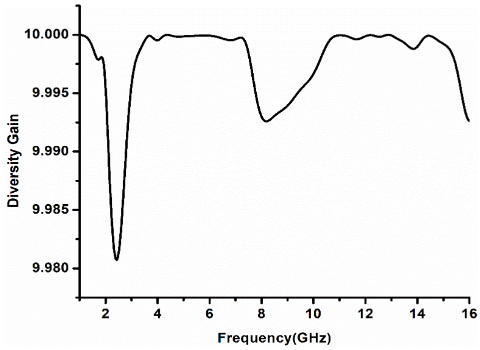
Fig.8. The simulated Gain and radiation efficiency of proposed UWB MIMO antenna design

e. Effective correlation coefficient (ECC) and Diversity Gain(DG)

The diversity performance of a MIMO antenna is evaluated using the envelope correlation coefficient (ECC) and diversity gain (DG). ECC measures the level of correlation between signals received by adjacent antenna elements [19]. Lesser the value of ECC quantifies the better signal quality. It is clearly observed that the value of ECC is lower than 0.0015 except at 2.3GHz frequency of the recommended MIMO antenna. Also DG satisfy the value of 9.98, which is nearly less than 10 demonstrate the acceptable value.



(a)



(b)

Fig.9. The simulated (a) ECC and (b) DG of recommended MIMO antenna

5. Conclusion

A two port UWB MIMO antenna with improved isolation is investigated in this paper. In yields a ultra-wide frequency ranges from 3.7-14.20GHz comprise bandwidth of 10.5GHz ability to covering beyond the UWB antenna. Apart from this, the single antenna element convert into two port MIMO antenna for increasing the data rate. The two element MIMO antenna are placed orthogonal manner for improving the inter-port isolation above -20dB.It is observed that there is no need of complex isolator element to improve the isolation. In addition, it is capable to achieve radiation efficiency and gain as high as 50.78% and 3.81 dBi, respectively with consistent radiation pattern in principal planes. The diversity gain and ECC are found in acceptable range. The peculiar properties of the proposed antenna makes it well suited for the smart devices operating in sub-6 GHz 5G, WLAN, ISM, LTE, Wi-MAX, UWB frequency bands; and X- & Ku-band satellite systems.

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