International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING

ISSN:2147-6799 www.ijisae.org Original Research Paper

# Compact MIMO Antenna Design with Enhanced Isolation and Bandwidth

**B.Venkateshwar Rao*[1], Sunita Panda[2]**

**Submitted:** 10/09/2022 **Accepted:** 20/12/2022

***Abstract:*** This article regards to a compact shaped MIMO antenna array using planar structure for a range of ultra wideband (UWB) frequencies. This configuration comprised of four element system covered within the area of $0.16\lambda_o^2$ ($\lambda_o$ being highest operating wavelength). The proposed MIMO antenna structure aimed to achieve adequate bandwidth and acceptable isolation level which consisting of inverted L-shaped elements with partial interconnected ground plane. Final design provides to achieve an impedance bandwidth ($S_{11}$< -10dB) that covers entire UWB frequency range (3.1-10.6 GHz). A satisfactory isolation among interelements about 19 dB is achieved to the maximum range of UWB. Besides this, envelope correlation coefficient (ECC<0.1) is also attained. The results obtained from the simulation is carried out using Ansoft HFSS (High Frequency Structure Simulator) provides sufficient bandwidth and isolation levels covering almost entire of UWB frequencies.

***Keywords:*** *envelope correlation coefficient (ECC), Inverted L antenna (ILA), impedance bandwidth, multiple input multiple output (MIMO), ultra wideband(UWB)*

## 1. Introduction

Nowadays, multiple input multiple output (MIMO) antenna technology attracting extensively in wireless communication systems. These are necessarily associated with 4G and 5G communication networks to enhance spectral efficiency, bandwidth, gain and thereby limiting multipath signaling among the available power levels[1-2].

However, it is extremely a difficult task to design a compact structure maintaining high isolation among the MIMO elements within the limited space available[3]. From the existing literature, various MIMO antennas have been devised such as wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) supporting to build a 4x4 antenna systems[4-7]. The electromagnetic interactions between the array elements having common ground induces currents as a result, high mutual coupling among the interelements are produced. This may lead to raise antenna correlation effecting antenna impedance and radiation pattern [8].

Concept of reducing mutual coupling among the MIMO antennas is adopted using neutralization lines[9,10], Same is achieved using modified ground plane[11], by using electromagnetic bandgap structure[12], also done using artificial magnetic conductor(AMC)[13]. Similarly, bandwidth enhancement bandgap from inverted L-monopole antenna[14], electromagnetic bandgap structure[15], half loop monopole antennas (HLMAs) [16]. In [17] the antenna design rejects existing WLAN, WiMAX, X-band downlink frequency channel arrangements to avoid interference among compact antenna systems for a fixed wireless system.

There have been several techniques devised in literature for compact MIMO antenna system that can operate efficiently through entire UWB band thereby providing a good isolation between the elements. Two parallel coupled line resonators (PCRs) are used for achieving a good isolation among the elements [18]. In [19] isolation between the antenna systems is done by using complementary split ring resonator (CSSR). In [20] isolation within UWB range is achieved upon introducing a novel shaped stop band using a cross shaped DGS(CSDGS). EBG structures of any regular shapes having equal area will exhibit similar performance [21]. The process of reducing mutual coupling compact EBG structure [22-23]. In [24], investigations on compact monopole antenna are highlighted.

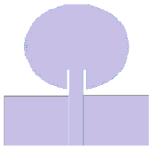
The article presented having a compact four elements MIMO antenna system spreading within the area of $0.16\lambda_o^2$ (where $\lambda_o$ being highest operating wavelength) together with inverted L-shaped partial ground plane. The design proposed reduces the mutual coupling effect among the antenna systems for a given UWB applications. Section II is detailed with antenna design. Results and discussion of the proposed structure is exposed in section III. Finally, the paper is concluded in section IV.

## 2. Antenna Design

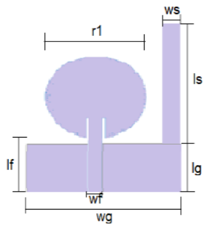
A miniaturized circular patch antenna design of radius 4.75mm is implanted on FR4 substrate material of thickness (h=0.8mm) with partial ground. The design is fed with an inset arrangement of wide transmission line. Fig 1(a) shows the individual antenna system with a partial ground arrangement. Similarly, fig 1(b) shows an inverted L-shaped ground plane together with the antenna system. This arrangement enhances the impedance

[1]*Research Scholar of GITAM School of Technology, GITAM, Bengaluru*
[1]*Assistant Professor, Dept. of ECE, CMR College of Engineering & Technology, Kandlakoya, Hyderabad-501401, Telangana, India.*
*ORCID ID : 0000-0002-7515-1773*
[2]*Assistant Professor, Dept. of ECE, GITAM School of Technology, Doddaballapura, Bengaluru-561203, Karnataka, India.*
*ORCID ID : 0000-0002-8280-5261*
** Corresponding Author Email: bvrao.be@email.com*

bandwidth of the antenna which will be relevant to operate at UWB frequencies.



**(a) Individual partial ground plane antenna**




**(b) Inverted L-shaped antenna**

**Fig 1: Structure of individual antenna system with different ground planes**

The dimensions of the structure associated with fig 1(b) are shown in I.

| Parameter | Dimension (mm) |
|---|---|
| r1 | 9.5 |
| ws | 2.8 |
| ls | 11.4 |
| wf | 1.25 |
| lf | 5.7 |
| wg | 15.4 |
| lg | 5.1 |
| h | 0.8 |

**I: Design parameters of the proposed antenna system**

Fig 2 shows the design of compact four element MIMO antenna system with inverted L-shaped partial ground plane which is suitable to operate at UWB range of frequencies. The structure comprised of all four individual antennas arranged closely and facing crosswise to each other.

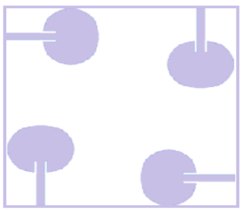


**Fig 2: Compact 4-element MIMO antenna system**

## 3. Results and Discussion

The structure of proposed compact 4-element MIMO antenna is designed and simulated using Ansoft HFSS software. The antenna design in which ground plane was included with stub results in enhancement of impedance bandwidth. This can be further improved by choosing standard dimensions obtained by parametric analysis. From fig 3 it is clearly observed that, the plot showing an impedance bandwidth of 5.7-8.3 GHz.

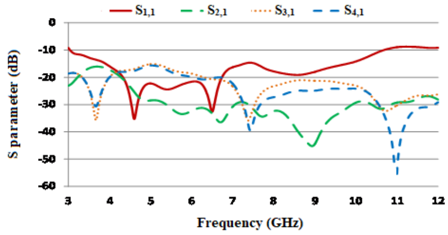



**Fig 3: S parameter response of proposed MIMO antenna system with partial ground plane**

Similarly, the plot shown in fig 4 is related to the compact antenna design with inverted L shaped partial ground plane. The plot obtained shows enhancement in impedance bandwidth covering a maximum range of UWB frequencies when compared with previous ground plane based stub system. The graph also shows of achieving a good isolation of 18 dB between the elements of the compact structure.

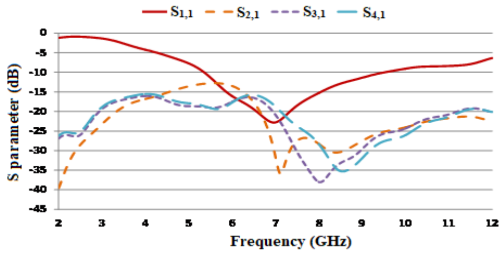
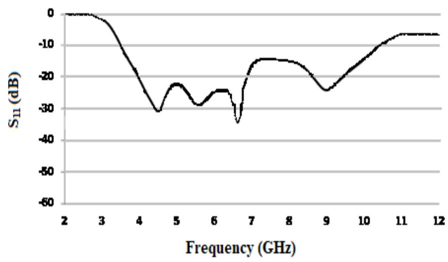
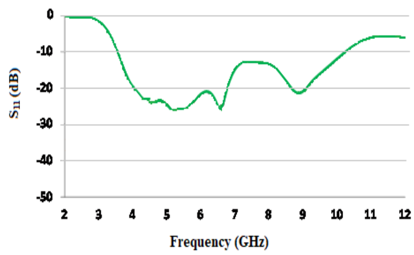



**Fig 4: S parameter response of proposed MIMO antenna system with inverted L ground plane**

Fig 5(a) and 5(b) represents the reflection coefficient at respective optimum values of ls=11.4mm and ws=2.8mm which obtained through parametric analysis. It is observed from the plot that there is not much differences seen with the modifications in the dimensions of parameters used, but these are well maintained with reflection coefficients almost lying below -10dB benchmark covering UWB frequency range.



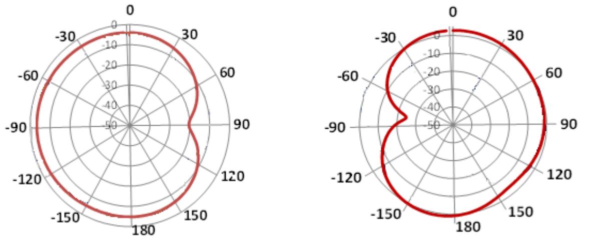

(a) For ls=11.4 mm




(b) For ws= 2.8mm

**Fig 5: Reflection coefficient for respective dimensions**

Simulation results of radiation pattern in two dimensional formats both in XY Plane and YZ plane are shown in fig 6 (a) and 6 (b) at 3.9 GHz respectively. The pattern model obtained from the simulation results of MIMO antenna system is performed when port 1 is excited by keeping other ports terminating at matched load. It is noticed from the plots that a good approximation is said to be achieved related to the directional properties of proposed antenna setup.




(a) XY-Plane pattern (b) YZ-Plane pattern

**Fig 6: 2-Dimenstional radiation pattern response at 3.9 GHz**

Another parameter named envelope correlation coefficient (ECC) for estimating the distinctive performance of a compact MIMO antenna system is introduced. ECC is calculated using the far-field pattern method as recommended in [25-27]. Thus, ECC is recorded to be less than 0.07 as shown in figure 7 respectively.

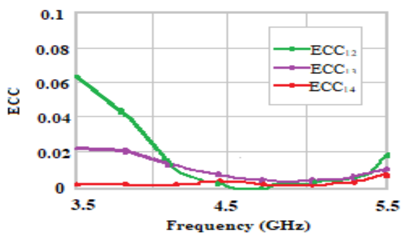



**Fig 7: Frequency variations of ECC for i =1and j = 2, 3, 4**

A brief comparison of parameters pertaining to the proposed antenna to other existing compact MIMO antenna systems is tabulated in II. The parameters compared are likely to be number of antennas, total area, impedance bandwidth and isolation.

| Reference | Number of elements | Total area ($\lambda_o^2$) | IBW ( %) | Isolation (dB) |
|---|---|---|---|---|
| 2 | 4 | 2.132 | 22.5 | 14 |
| 3 | 4 | 1.588 | 49.7 | 11 |
| 4 | 4 | 0.706 | 60.6 | 10 |
| 5 | 4 | 1.587 | 96.2 | 14 |
| 14 | 4 | 0.131 | 58.6 | 11 |
| 16 | 4 | 0.476 | 34.3 | 19 |
| 26 | 2 | 2.5 | 63.4 | 17 |
| 27 | 4 | 0.84 | 72.4 | 17 |
| This work | 4 | 0.16 | 92.3 | 18 |

**II: Comparison chart of parameters with respect to other MIMO systems**

## 4. Conclusion

Analysis of compact four-element MIMO antenna system operating at UWB frequencies is proposed in the article. The antenna structure is designed using a low cost FR4 substrate material which is composed limiting to the area of $0.16\lambda_o^2$ covering entire UWB frequency band achieving a high impedance bandwidth ($S_{11}$<-10dB). A good isolation level (>18dB) is resulted among the elements of compact design proposed and is estimated for a maximum coverage of UWB frequencies. An efficiency around 82% for the proposed structure is recorded. A very minimum envelope correlation coefficient (ECC< 0.07) is recorded for the proposed structure. Hence, a satisfactory performance can be ruled from the proposed MIMO antenna structure which can be considered as excellent model for various wireless communication system applications under UWB range.

## Acknowledgements

I thank [Sunita Panda, Asst.Prof.] for assistance with [particular technique, methodology], and [Sunita Panda, Asst. Prof. GITAM School of Technology, GITAM] for comments that greatly improved the manuscript.

## Author contributions

**Venkateshwar Rao1 Basuthker1:** Conceptualization, Methodology, Software, Field study, Writing-Original draft preparation, Validation. **Sunita2 Panda2:** Visualization, Investigation, Writing-Reviewing and Editing.

## Conflicts of interest

The authors declare no conflicts of interest.

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