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# Design of MIMO Antenna at Various Bands for Wireless and Mobile Communications

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**ABSTRACT:** : A planar compact MIMO antenna with coplanar waveguide (CPW) feed is designed using HFSS software. The proposed antenna is composed of two symmetrical radiating elements which are connected by a neutralization line. This neutralization line plays a vital role in the improvement of isolation between the antennas. The proposed antenna has slits that are etched to avoid interference and thereby used at multiple bands. The proposed antenna is fed by a coplanar waveguide transmission lines having characteristic impedance of 50 ohms. The simulated results show that the proposed antenna has good isolation. The diversity gain and the antenna efficiency at the operating frequencies are very appreciable. The proposed antenna has acceptable TARC and ECC values. The proposed antenna can be operated at different frequencies such as LTE-E 2300 MHz, LTE-D 2600 MHz and WiMAX 3400MHz.

**KEYWORDS:** Multi Input Multi Output (MIMO) antenna, Total Active Reflection Coefficient(TARC), Envelope Correlation Coefficient(ECC).

## I. INTRODUCTION

Very often radio signals reaching the receiver faces signal degradation due to multipath propagation .This results in the degradation of link capacity and link reliability. So in order to cope with this degradation Multi Input Multi Output (MIMO) systems are used. There are many techniques involved in MIMO systems. Spatial diversity technique is used to enhance the link performance. Spatial Multiplexing technique is used to improve the link efficiency. Generally, the principle of diversity is to provide the receiver with multiple versions of the same signal which results in the reduction of signal degradation considerably and effectively improves the link performance. This can be achieved by three methods. First method involves time diversity technique. In this technique, the same message is transmitted at different time slots. Second method includes frequency diversity technique. In this technique, the same message is transmitted at multiple distinct frequency slots. Third method involves Space diversity technique. In this technique, separate antennas are used to send messages which are located at different positions in order to take advantage of different radio paths that exist in a typical terrestrial environment. In most of the cases, Space diversity technique is used in MIMO systems. Up until 1990's, Space diversity is used in the systems that switches between two antennas or combined the signals in order to provide the best possible signal. To get such best possible signals, high level of signal processing is required which is limited then. However as the years go by, with the improvement of processing power it is possible to implement MIMO systems. Signals can take multiple paths between transmitter and receiver due to obstacles and objects in the medium. Traditionally these various multiple paths will introduce interference. By the introduction of MIMO, with these various multiple paths can be used to provide additional robustness to the radio link by spatial diversity or to enhance the link data capacity by spatial multiplexing. Consider a stream of data [010011] is transmitted through a channel with deep fades. Due to fluctuations in channel quality, the data stream may get lost or corrupted severely so that the receiver is unable to recover it. The best solution to reduce rapid channel fluctuations is to add independent fading channels by increasing the number of transmitting as well as receiving antennas or both. In spatial diversity techniques the same information is sent or received across various multiple paths to combat fading of signal. In this concept, the diversity gain is the multiplication of number of transmitting antennas and the number of receiving antennas. For example, if the number of receiving antennas is increased by 1, the chances of proper delivery of the data across link-2 will be very high. Fig 1 represents a typical multi input multi output system.

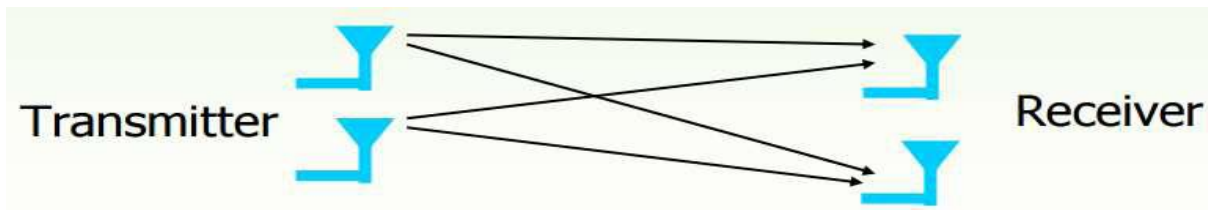


Fig. 1 A Multi Input Multi Output System

## II. EARLIER WORK

Immense research is going on in the field of Multi input Multi output (MIMO) systems. Many people have developed MIMO systems which have complex design analysis. Also signals involved in MIMO demand high level of signal processing but the systems processing were limited then. Also in many existing methods there is no provision for shorting line which has a negative impact on isolation between the antennas. This will lead to coupling effect which drastically reduce the system gain and thereby reducing the channel capacity. One of the most important challenges in designing a MIMO antenna is to reduce the complexity involved in the design of MIMO antenna. So in order to get best possible results, a shorting line is provided to get isolation to a safer level. Etching of slits are also done in our method in order to get band rejection filters so that interference is not there at the service frequencies.

## III. PROPOSED METHOD

A compact planar multiband MIMO antenna along with two symmetrical radiating elements has been designed for LTE, WiMAX AND Wireless LAN applications. The radiating element consists of a folded monopole and a bevelled rectangular metal patch. The substrate of antenna has  $60 \times 80 \times 0.8 \text{ mm}^3$  dimensions. The substrate is made up of FR4 epoxy material with a dielectric constant  $\epsilon_r = 4.4$ . The loss tangent is about  $\tan\delta = 0.02$ . The software used to simulate the proposed antenna is High Frequency Structure Simulator (HFSS). HFSS involves finite element method in order to analyse the electromagnetic structures. This software is used to simulate 3D full-wave EM fields. Fig 2 shows the bottom view and isometric view of the proposed antenna design.

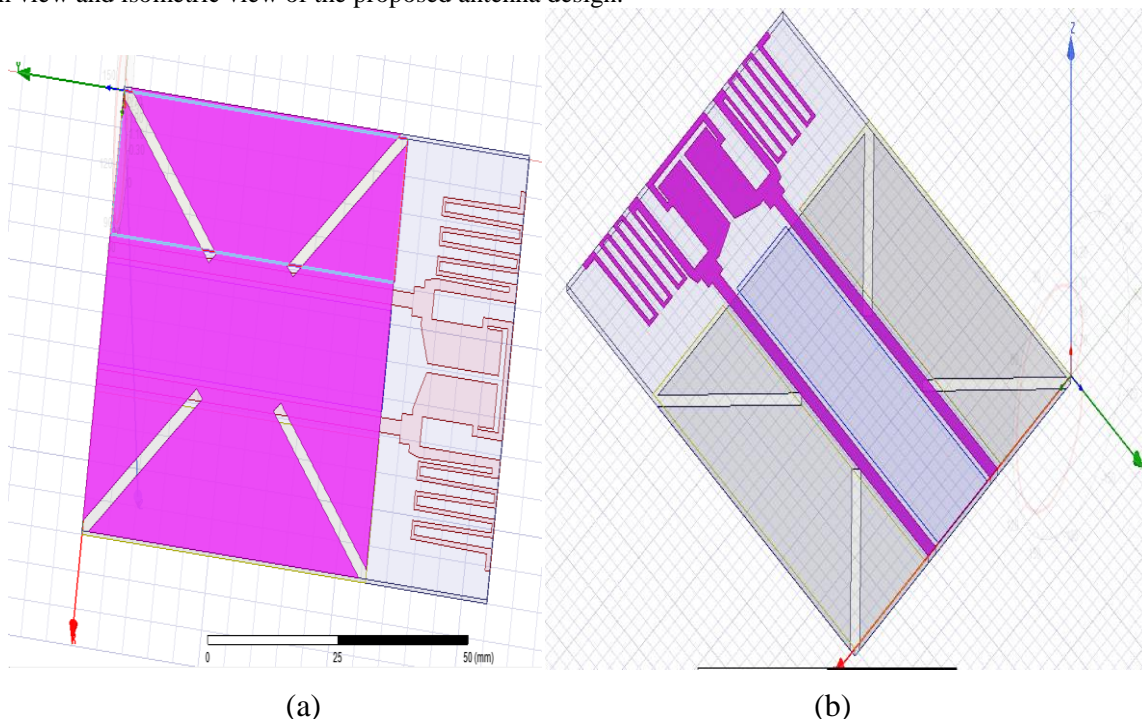


Fig.2 Configurations of the proposed antenna. (a) Bottom view. (b) Isometric view.



Coplanar waveguide feed is used in this method. The radiating elements are fed by the coplanar waveguide (CPW) transmission lines of 50 ohms. The radiating elements are connected by the shorting line which is of 1mm wide. The shorting line acts as a neutralization link which allows the signals picked up from one radiating antenna to the other and produces an opposite coupling to the other antenna to get low mutual coupling at the service frequencies. This proposed antenna is used at LTE, WiMAX and Wireless LAN applications. So in order to avoid interference, slits are etched. Depending upon the usage of antenna, the length of the slits will change. These slits act as band rejection filters and hence used for multiple applications. The operating frequencies of the proposed antenna are 1900MHz (LTE Band2), 1700-2100 MHz (LTE Band5) and, 2.3-2.4 GHz, 2.5-2.7 GHz, 3.4-3.6 GHz (WiMAX).

IV. RESULT AND ANALYSIS

The proposed compact planar multiband MIMO antenna has operating frequencies in the range 0.5-6 GHz. The parameters required to analyse the proposed antenna are Total Active Reflection Coefficient(TARC), Envelope Correlation Coefficient(ECC) and Diversity Gain(DG). It is necessary to analyse Return loss , Coupling loss and VSWR plots of the proposed antenna. The following are the results of the proposed antenna.

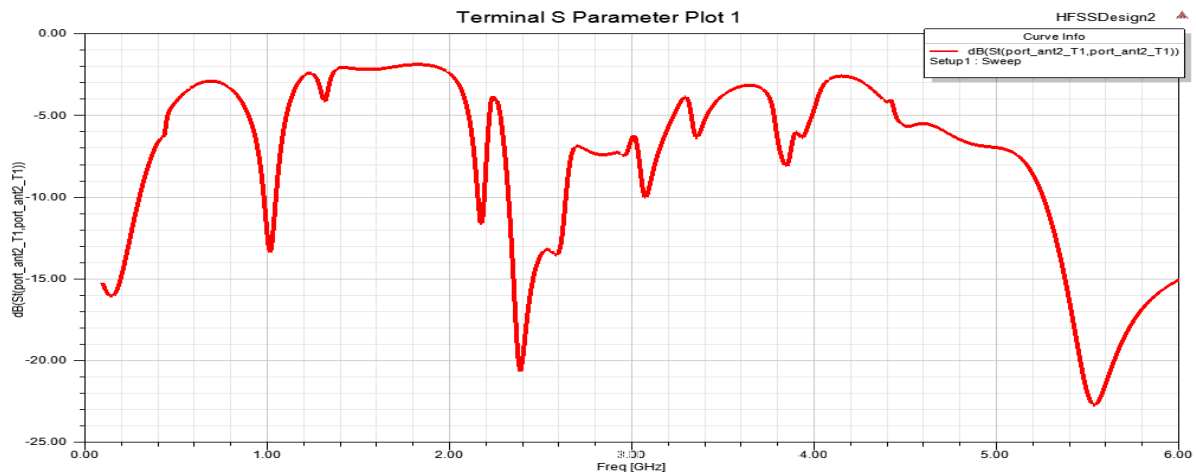


Fig. 3 Return loss (S<sub>11</sub>) plot

The above plot indicates the return loss of the proposed antenna. Generally the return loss of below -10dB is considered for the better performance of the antenna. The power accepted by the antenna is given as  $(1-|S_{11}|^2)$  the power fed to the antenna. So if we consider S<sub>11</sub> of -10dB the power accepted by the antenna is 90% the power fed to the antenna. Hence it is necessary to consider S<sub>11</sub> below -10dB. In the above plot the resonant frequencies are 1.1 GHz, 2.18GHz, 2.45GHz and 5.58 GHz. In between some frequencies, the return loss is greater than -10dB. This is achieved by etching the slits on the radiating elements. This indicates that at those frequencies the performance of the antenna is deteriorated. Those bands act as rejection bands and hence there is no interference. So our proposed antenna works around those service frequencies which can be used at LTE, Wireless LAN and WiMAX applications.

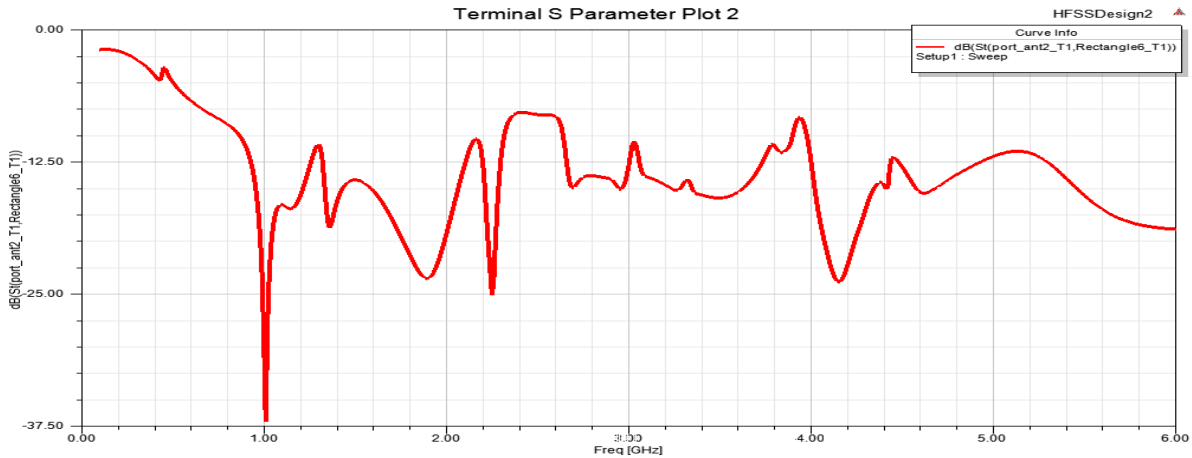


Fig. 4 Coupling loss ( $S_{12}$ ) plot

The above figure represents the coupling loss plot of the proposed antenna. This plot indicates how tightly the two antennas are coupled. In the proposed antenna there is a provision of neutralisation link. This will reduce the coupling effect between the two antennas. The diversity and the primary cellular antennas that share the common ground plane needs to be isolated. Otherwise there will be a significant drop in the efficiency of the antenna. Isolation can be increased in many ways. One way is to increase the separation between the antennas. Another way is to use different polarizations for the antennas. Generally the coupling loss of below -10 dB is considered for the better performance of the antenna. The power to antenna-2 is given as  $(|S_{12}|^2)$  the power to the antenna-1. So if we consider  $S_{12}$  of -10dB the power to the antenna-2 is 10% the power fed to the antenna-1. Hence it is necessary to consider  $S_{12}$  below -10dB. In the above plot the frequencies which are having below -12.5dB are serviceable.

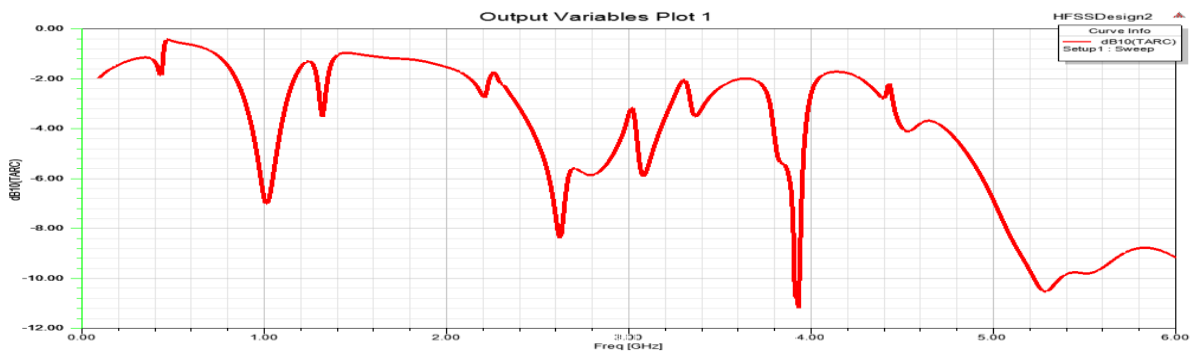


Fig. 5 Total Active Reflection Coefficient (TARC) plot

The above graph indicates the TARC values of the proposed antenna. Suppose there are two antennas placed adjacently to each other. So the radiation field of one antenna is bound to interfere with the radiation field of another antenna. The overall system response will be different whenever we consider each antenna independently. In order to quantify at what degree the interference is going on in the system TARC parameter is necessary. It is given as:

$$TARC = \frac{\sqrt{(S_{11}+S_{12})^2+(S_{21}+S_{22})^2}}{\sqrt{2}} \dots\dots\dots(1)$$

For a MIMO communication system , TARC should be <0dB

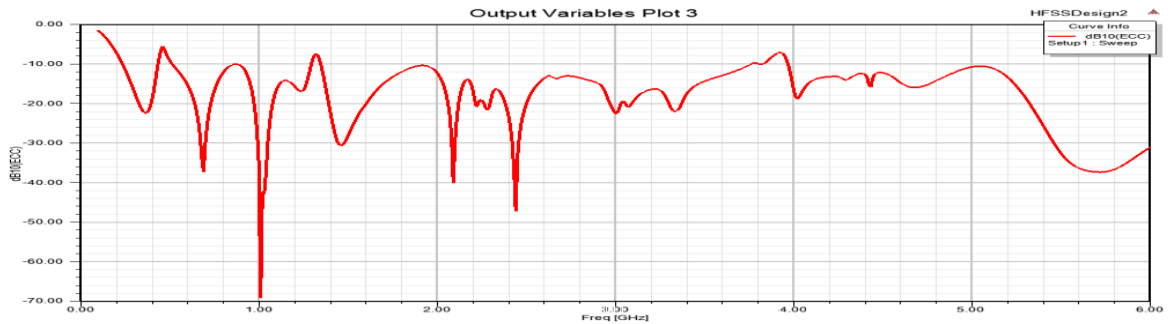


Fig. 6 ENVELOPE CORRELATION COEFFICIENT (ECC) plot

The above figure shows the Envelope Correlation Coefficient (ECC) plot. It is defined as the degree of the correlation between the radiation patterns between the two antennas. The less correlated the radiation patterns are, the higher the gain is and thus the capacity of the system. ECC ranges from 0 to 1. If the value of ECC is 0 then it indicates that there is no correlation between those radiation patterns and hence the best is the gain. If the value of the ECC is 1 then the radiation patterns are identical which indicates there is no gain.

It is given as:

$$ECC = \frac{|S_{11}^* S_{12} + S_{21}^* S_{22}|^2}{(1 - (|S_{11}|^2 + |S_{21}|^2))(1 - (|S_{12}|^2 + |S_{22}|^2))} \dots\dots\dots(2)$$

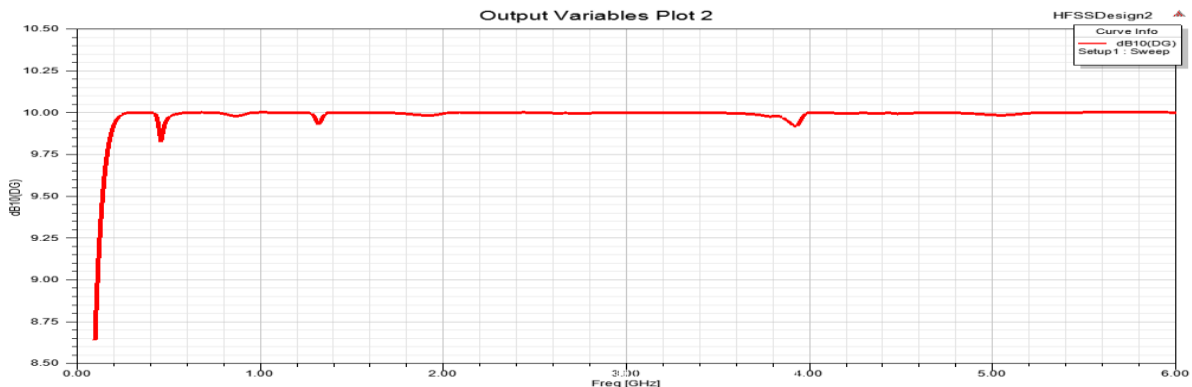


Fig.7 DIVERSITY GAIN (DG) plot

The above figure shows the Diversity gain plot of the proposed antenna. Diversity gain involves transmitting the multiple versions of the same or slightly modified signal through different antennas in order to improve the reliability of the signal. For example if there are two or more radio links carrying same amount of information if there is a deep channel fading in one radio link, the probability of having a deep channel fading in the other radio link is very low. It is given as:

$$DG = 10(\sqrt{1 - ECC^2}) \dots\dots\dots(3)$$

For a MIMO communication system , DG should be > 9dB.

V. CONCLUSIONS AND FUTURE SCOPE

In this proposed work, a compact planar MIMO antenna with neutralization link is designed using HFSS software. There is an improvement in TARC, ECC and DG parameters. With the provision of neutralization link the isolation between the antennas is improved. Etching slits on the radiating elements of the antenna reduce the interference. These slits act as band rejection filters which can be operated in different frequency bands such as LTE bands, WiMAX and Wireless LAN. Many studies are going on MIMO antenna system design in order to use them at 5G applications.

From the above observations, it is observed as follows:



- TARC value which is -2.4 dB in the existing work has been improved to -7.4 dB.
- DG value which is 8.35 dB in the existing work has been improved to 9.75 dB.
- EGG value which is 0.81 in the existing work has been reduced to 0.24 which is significant.

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