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Compact Dual Band MIMO Antenna Design

Megha Ann Jacob[1], Ria Maria George[2]

PG Student, Dept of E.C.E, Amal Jyothi College of Engineering, Kottayam, India[1]

Assistant Professor, Dept. of E.C.E., Amal Jyothi College of Engineering, Kottayam, India[2]

ABSTRACT: A two element MIMO antenna system with Planar Inverted-F Antenna (PIFA) as the element for dual band operation in GPS and WIMAX applications is proposed. A folded slit in the top plate is used to get the dual band operation for 1.5 GHz GPS and 3.3 GHz WIMAX. In order to enhance the higher band, a parasitic element is used. Three different orientations for elements of MIMO system were studied. Among the different possible orientations pattern diversity is achieved when the elements are orthogonally placed. The -10 dB return loss is obtained for 1.427 - 1.507 GHz and 3.25 - 3.49 GHz. The isolation for lower and upper bands is -2.92 dB and -18 dB respectively. The gain at lower band is 2.9 dB and at higher band is greater than 3.9 dB. The correlation coefficient of the system is near zero at both bands.

KEYWORDS: Correlation Coefficient, Dual band, Folded slit, PIFA, MIMO

I.INTRODUCTION

The growing demands for higher data rates in wireless systems led to the development of Input Multiple Output (MIMO) systems. It is an important technique in the fourth generation communication systems, such as Long Term Evolution (LTE) systems. For an environment sufficiently rich in multipath components, the wireless channel capacity can be increased using multiple antennas at transmitter and receiver. MIMO is considered as an attractive technology which can provide higher receiver gain, increased data rate, improved link quality and reliability through antenna diversity.

Many applications require low profile antennas, especially portable devices such as laptops and mobile phones. Patch antennas and their derivatives are the best candidates for low profile application. When patch antennas are used as the element of MIMO, the resulting size is very large to be included in portable devices. Planar Inverted-F Antenna (PIFA) is quarter wavelength in size and is suitable for portable devices. But the main limitation is narrow bandwidth. A folded slit on the top plate of PIFA is used to obtain a dual band antenna operating at 1.5 GHz GPS and 3.3 GHz WIMAX [1]. In this paper, a parasitic element is added to the compact structure in [1] to enhance the higher frequency bandwidth in order to incorporate 3.5 GHz WiMAX. Two element MIMO is designed and compared for different orientations.

II.RELATED WORKS

In order to incorporate different standards into a single device, multi band and broadband antennas are required. Many techniques are available for bandwidth enhancement. In [2], parallel excitations of PIFA and slot radiators are used for bandwidth enhancement. In [3], bandwidth enhancement is achieved by changing the width of two isolated feeding ports and shorting plates of PIFA. In [4], bandwidth is enhanced using a pair of slant slits and L-shaped patch. MIMO systems for WLAN applications are proposed in [5] - [6]. In [5], two PIFA elements with operating frequencies 2.38 - 2.78 GHz and 5.69 - 5.99 GHz is proposed. PIFA is designed over an FR-4 substrate with height of 4.8 mm. A J-shaped slot is used for obtaining dual band performance. The separation between MIMO elements is 0.25λ. In [6], a single band compact MIMO system for LTE 13 band is proposed. Two symmetrical elements are placed 0.046λ apart. Diagonally orthogonal radiation pattern is achieved.

III. SINGLE ELEMENT PIFA

PIFA with folded slit provides GPS and 3.3 GHz WiMAX [1]. A parasitic element is placed near to the shorting plate as shown in Fig.1 to enhance the higher band. It is electromagnetically coupled to the main radiating element.

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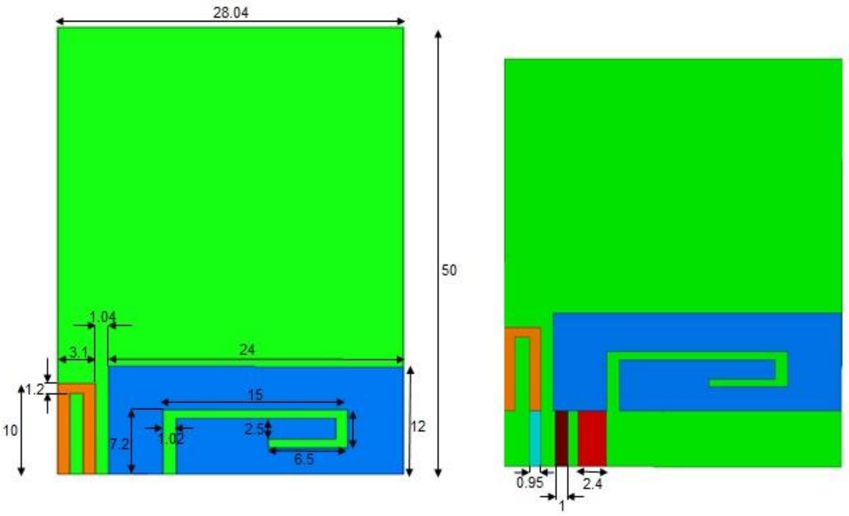


Fig.1. Structure of Single Element PIFA

The plot for reflection coefficient is shown in Fig.2. The antenna resonates at 1.489 GHz with -11.4 dB return loss indicating more than 90% of power is radiated. The bandwidth at lower band is 1.479 - 1.499 GHz. The upper bandwidth is enhanced to3.25 - 3.49 GHz because of parasitic patch.

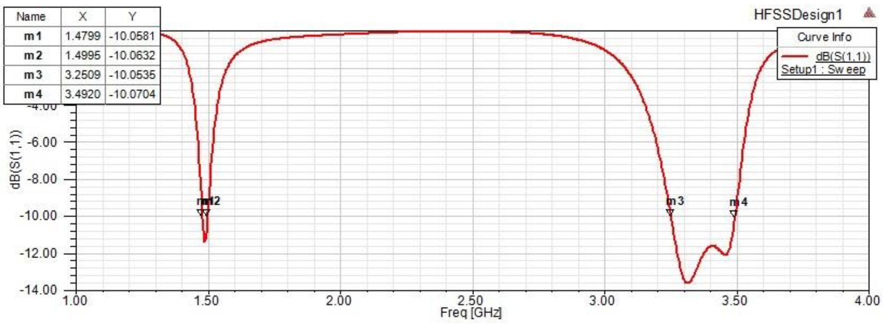
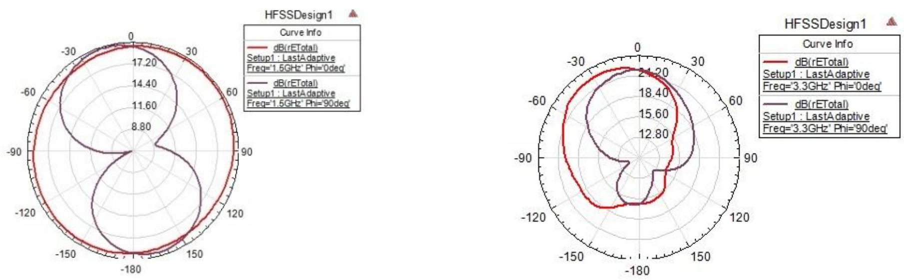


Fig.2. Reflection Coefficient



a) b)

Fig.3. Radiation Pattern of Single Element PIFA a) at 1.5 GHz and b) at 3.3 GHz

The radiation pattern at 1.5 GHz and 3.3 GHz is shown in the Fig.3. The pattern is same as in the case of dual band PIFA without parasitic element [1]. The gain at 1.5 GHz is 2.55 dB and at 3.3 GHz is 5 dB.

The current distributions at 1.5 GHz and 3.3 GHz are shown in Fig.4. A high current density is also found around the parasitic element, since it is also responsible for the higher band along with the slit in the main radiator.

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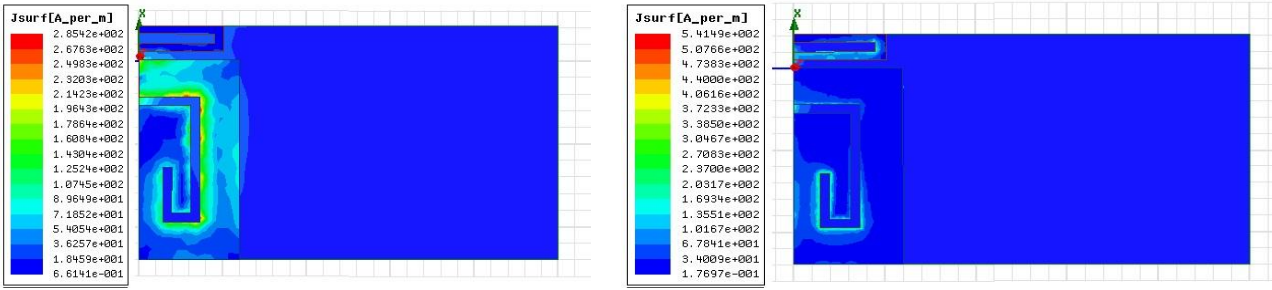

a) b)

Fig.4. Current Distribution of PIFA with Parasitic Element at a) 1.5 GHz and b) 3.3 GHz

IV.MIMO ANTENNA DESIGN

Three different orientations of MIMO for the close separation of 4mm (0.02λ) are shown below.

A. MIMO Antenna-1

A close separation of 4 mm is provided between two symmetrical elements with the main radiating patches close to each other. The main radiating PIFAs, which are responsible for lower resonant frequencies are close to each other. The S11 and S22 plots are shown in Fig.6 and 7. An additional resonant frequency with a return loss of less than -10 dB for 1.39 GHz is obtained. At the higher band the system can operate at 3.2 GHz and 3.5 GHz with greater than -12 dB return loss. A high isolation of -12.92 dB is obtained at higher band as shown in Fig.7. The isolation at lower band is -3.65 dB.

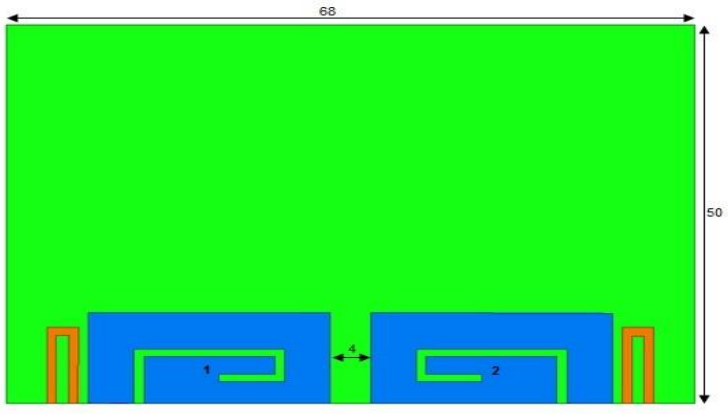

Fig.5. Structure of MIMO Antenna-1

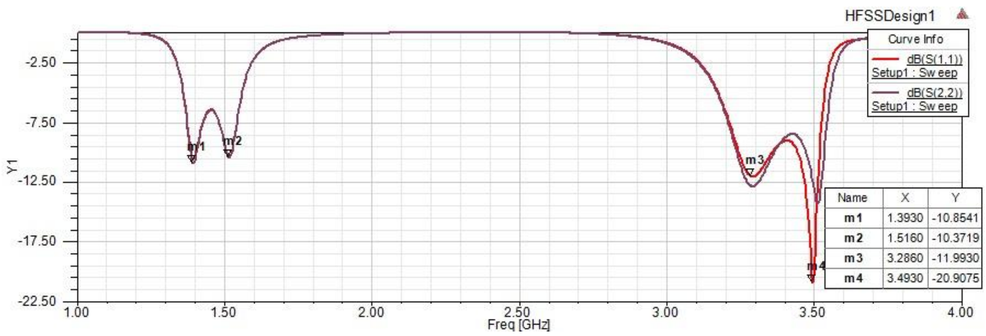

Fig.6. Reflection Coefficient of MIMO Antenna-1

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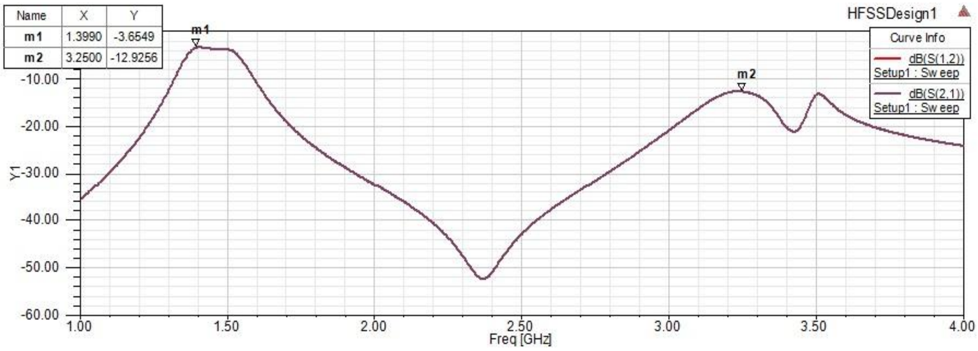
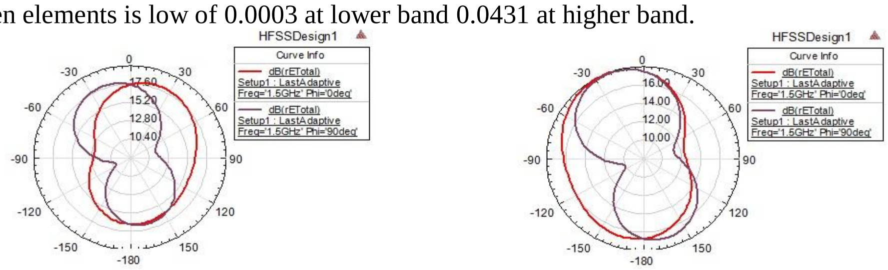


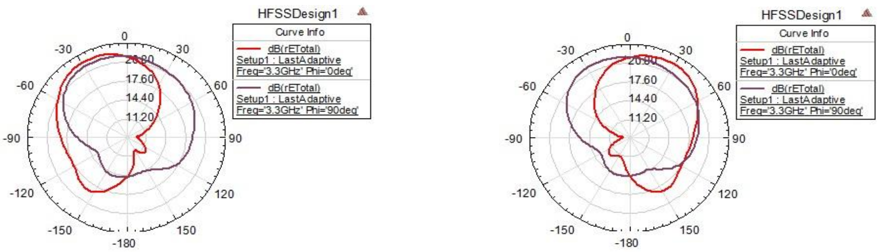
Fig.7. Isolation of MIMO Antenna-1

Radiation pattern at 1.5 GHz for element 1 and 2 is shown in Fig.8 and for 3.3 GHz is shown in Fig.9. The radiation patterns are distorted since the elements are close to each other. At 3.3 GHz the patterns are symmetrical. Hence the correlation between elements is low of 0.0003 at lower band 0.0431 at higher band.



a) b)

Fig.8. Radiation Pattern at 1.5 GHz for a) element-1 and b) element-2



a) b)

Fig.9. Radiation Pattern at 3.3 GHz for a) element-1 and b) element-2

Gains at 1.5 GHz for element 1 and 2 are 3.66 dB and 3.61 dB respectively. At 3.3 GHz the gain obtained are 5.15 dB and 5.16 dB respectively for elements 1 and 2.

B. MIMO Antenna-2

Two elements are placed symmetrical with parasitic element close to each other as shown in Fig.10. The plots for reflection coefficient and isolation are shown in Fig.11 and Fig.12. Since parasitic elements are close to each other with very small separation, the S11 and S22 plots at upper band have additional radiation frequency of 3.64 GHz. But this band can be neglected since its return loss is -4.4 dB. A large isolation of -22.5 dB is obtained at 1.5 GHz. The other two resonant frequencies are 3.16 GHz and 3.37 GHz. High isolation of -20.58 is obtained in the lower band. The isolation is near -6.32 dB in upper band.

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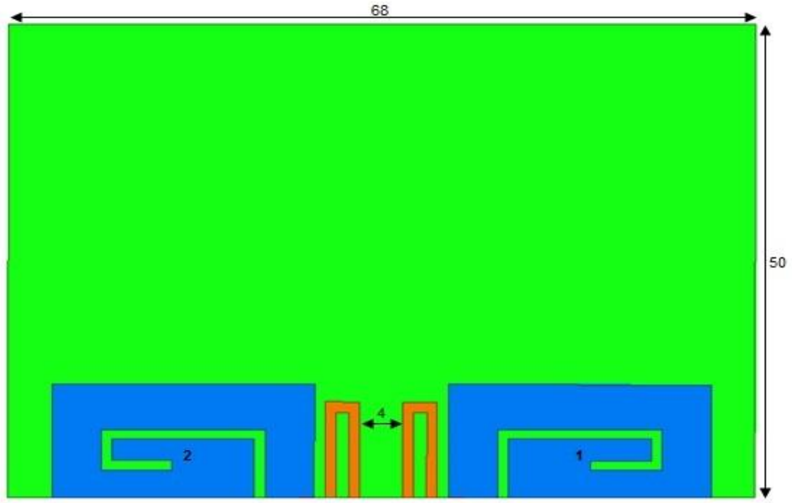

Fig.10. Structure of MIMO Antenna-2

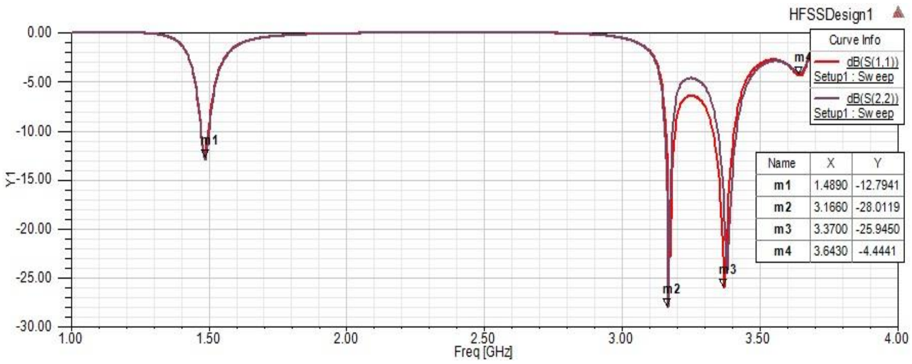

Fig.11. Reflection Coefficient of Dual Band Antenna-2

Radiation pattern at 1.5 GHz for element 1 and 2 is shown in Fig.13 and for 3.3 GHz is shown in Fig.14. The radiation patterns are symmetrical and the correlation between elements is low. The obtained correlation at 1.5 GHz is 0 and at 3.41 is 0.0024. Correlation coefficient between 3.2 GHz to 3.3 GHz is greater than 0.3. The gain obtained at 1.5 GHz for element 1 and 2 are 3.17 dB and 3.02 dB respectively. At 3.3 GHz the gain obtained are 5.97 dB and 6 dB respectively.

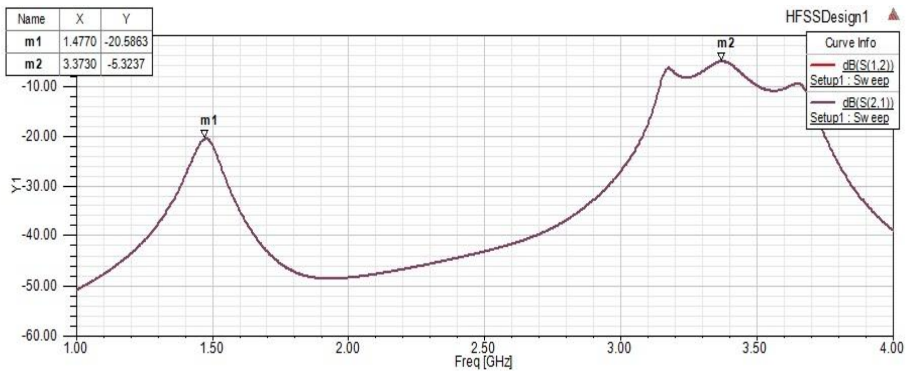

Fig.12. Isolation of Dual Band Antenna-2

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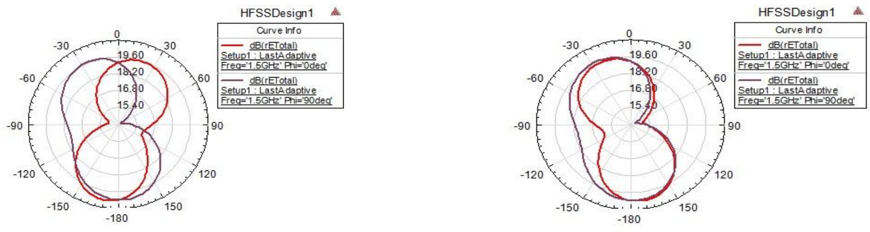

Fig.13. Radiation Pattern at 1.5 GHz for a) element-1 and b) element-2

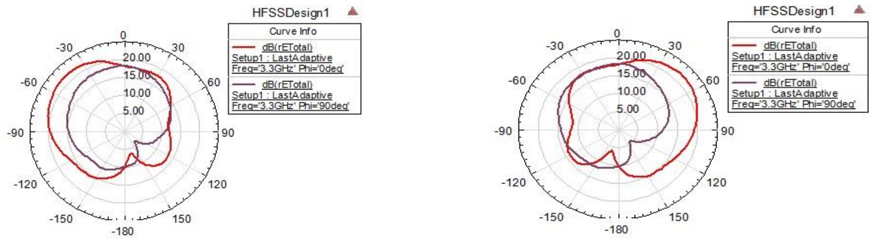

Fig.14. Radiation Pattern at 3.3 GHz for a) element-1 and b) element-2

C. MIMO Antenna-3

The two identical elements of MIMO are placed orthogonally, with the main directly fed PIFA elements close to each other as shown in Fig.15. A 4 mm separation is maintained between the elements. The reflection coefficient plot is shown in Fig.16. S11 and S22 graphs are identical. This arrangement of MIMO gives nearly same band widths as in the case of single element system. The lower band resonates at 1.473 GHz and the higher band extends from 3.25 GHz to 3.45 GHz. The plot for isolation is shown in Fig.17. A good isolation of -18.63 dB is obtained for higher band. At lower band isolation is -2.92 dB.

Radiation pattern at 1.5 GHz for element 1 and 2 is shown in Fig.18 and for 3.3 GHz is shown in Fig.19. The radiation patterns are symmetrical and orthogonal due to orientation of MIMO elements. The distortion in the omni-directional pattern is due to the interaction of neighbouring element in MIMO system. The orthogonal radiation pattern provides pattern diversity in addition to spacial diversity provided by the MIMO elements.

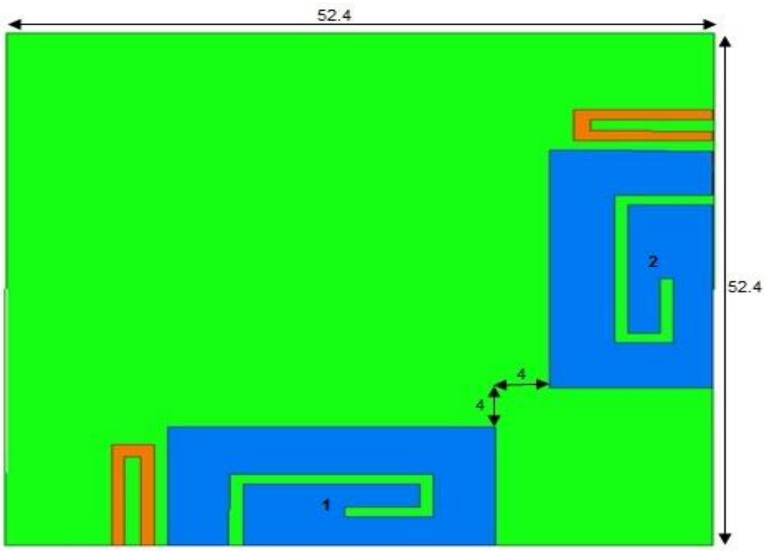

Fig.15. Structure of MIMO Antenna-3

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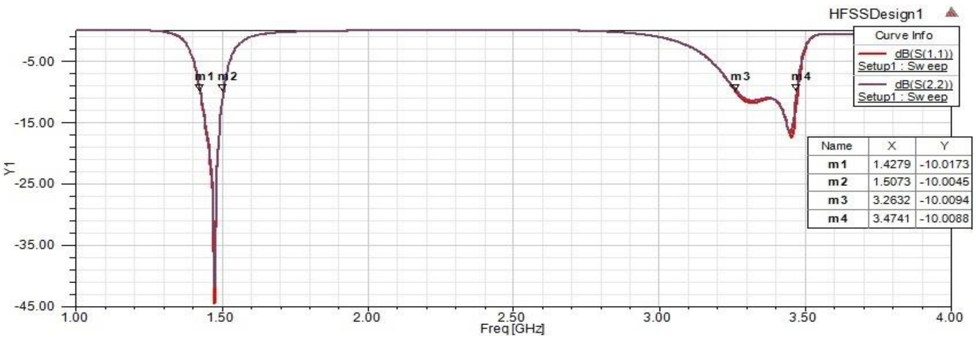


Fig.16. Reflection Coefficient of MIMO Antenna-3

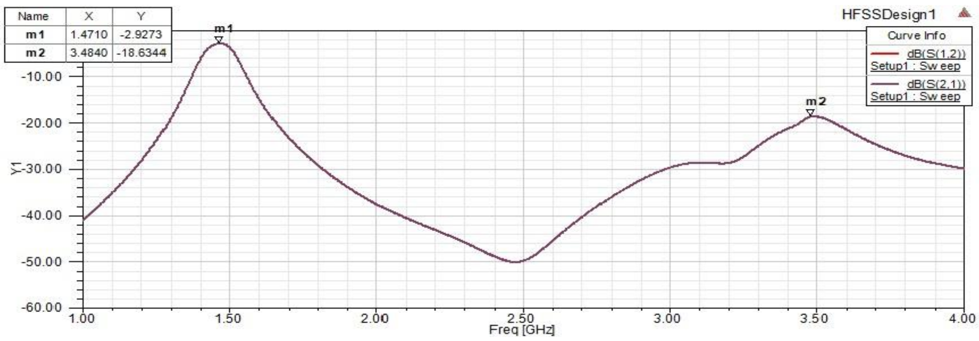
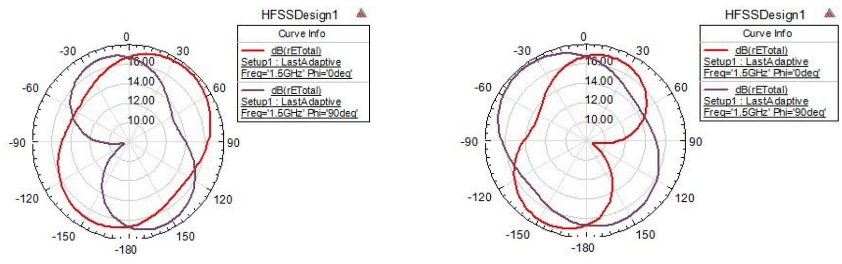


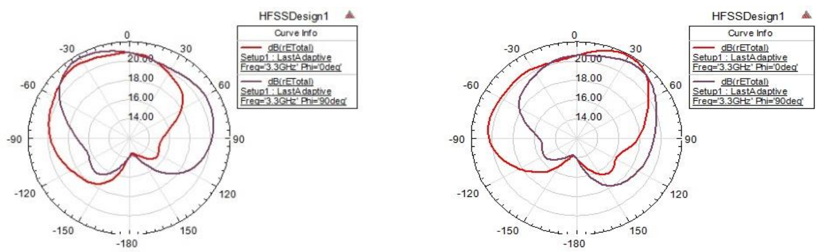
Fig.17. Isolation of MIMO Antenna-3

The gain obtained at 1.5 GHz for element 1 and 2 are 2.96 dB and 2.9 dB respectively. This difference between gains for identical elements for the same frequency can be attributed to the ground plane dimension and the position of elements on the ground plane. At 3.3 GHz the gain obtained are 3.97 dB and 4.2 dB respectively. The obtained correlation at lower band is 0 at 1.477 GHz and at 3.3 GHz in the higher band is 0.0005.



a) b)

Fig.18. Radiation Pattern at 1.5 GHz for a) element-1 and b) element-2



a) b)

Fig.19. Radiation Pattern at 3.3 GHz for a) element-1 and b) element-2

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V.CONCLUSION

In this paper, a compact dual band Planar Inverted-F Antenna (PIFA) with enhanced bandwidth is designed. Bandwidth of 3.25 -3.49 GHz is obtained by adding a parasitic element near to the compact PIFA. Three different orientations for the elements in the MIMO system were studied. Additional reflections may occur when the elements are symmetrically placed. The most suitable orientation for elements is when the elements are orthogonally placed. In this case, pattern diversity can be achieved in addition to spacial diversity. Isolation at lower and upper bands is -2.92 dB and -18.63 dB respectively. Isolation at lower band need to be enhanced, which is the required future work. Correlation coefficients are less than 0.0005 in both bands.

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