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A J-shaped Element Planar Inverted-F MIMO Antenna for 4G/5G Communication

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ABSTRACT

A small two element planar inverted-F MIMO antenna (PIFA) is presented in this paper for 4G Long Term Evolution (LTE) and 5G wireless standard. The structure of the proposed antenna is compact with the dimensions (length x width x height) as 100 mm × 50 mm × 4 mm. The dimensions of the radiating element is 22 mm x 15 mm. The frequency band covered by the proposed MIMO antenna is around 3.5 GHz. The proposed design shows good MIMO characteristics with good isolation between elements. Simulated results are presented and discussed.

Key words: 4G LTE, 5G, MIMO, PIFA.

1. INTRODUCTION

In the last decade or so the mobile radio communication industry has grown rapidly [1]. With the advancements in communication sector especially mobile communication has led to increase in compact and light mobile phones and several wearable gadgets. As the number of bands has increased there is evolving trend of miniaturization and use of multiple element to support high data rate. For making the antennas compact so that other components can easily be accommodated in a mobile device there has been a lot of research on planar antennas such as patch, PIFA, printed monopole etc. [1]-[7].

The advancements in the mobile communication technologies is being done at a fast pace. Fifth-Generation (5G) communication is the latest addition to the mobile communication technologies. The focus in 4G and 4G LTE technologies is to provide high data rates to the users which resulted in significant increase in video-on-demand services, online entertainment portals, live games and live video sharing on social media platforms, augmented and virtual reality etc. [8]. With 5G there will be various emerging areas which will come into picture such as Massive MIMO, Internet of Things (IoT), mobile broadband, macro-cell technology etc. It is estimated that millions of devices will be able to connect and communicate simultaneously [9]. The vision for smart cities, smart transport, smart shopping, machine to machine communication etc. will become reality in the coming years. [10] [11].

In the past few years there are many antenna designs proposed by researchers worldwide for 5G wireless communication. In [12] a MIMO antenna is proposed working on 4G communication bands with dual function ground slots. A patch antenna with circular polarization is proposed in [13] with metallic block cavity. The patch formed a folded shaped with slots loading to reduce size of the patch. Few more papers presented different types of PIFA and patch antennas working on the candidate bands for 5G communication [14]-[18].

A MIMO PIFA is proposed in this paper for 4G LTE/ 5G communication devices. The overall geometry of the proposed antenna is 100 mm × 50 mm × 4 mm resulting in a low profile structure. The band of operation is 3.5 GHz with wide bandwidth coverage. High Frequency Structure Simulator (HFSS) is used to simulate the proposed MIMO structure.

The proposed antenna geometry is discussed in Section II, Section III presents and discusses the simulated results. The presented research work is concluded in Section IV.

2. ANTENNA GEOMETRY

The proposed design of MIMO PIFA is shown in Figure 1 which consists of two J-shaped radiating elements of size 22 mm × 15 mm each. FR4 is used as the substrate material having thickness of 1 mm and dielectric constant (εr = 4.4). The feed to the radiating elements is from the edge which is easier to construct. The profile of the proposed antenna is of dimensions 100 mm × 50 mm. Table I lists the dimensions of proposed antenna structure.

The antenna is particularly designed to support sub-6GHz 5G communication band at 3.5 GHz which supports higher data rate due to wider channel bandwidth. The simulation results are presented and discussed in the next section.

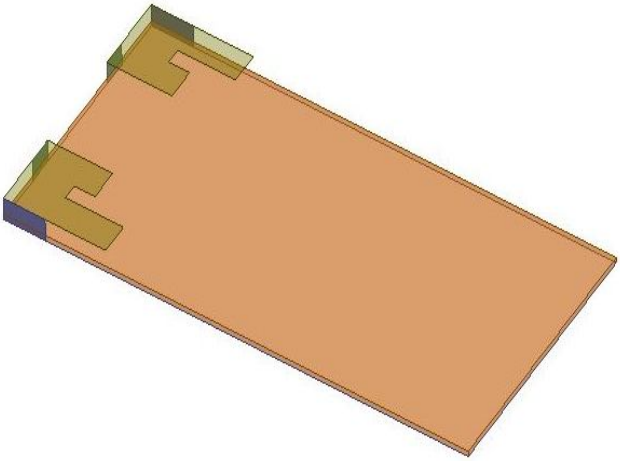

Figure 1: 3D View of MIMO antenna system

The shorting plate is along the width of the substrate and the feed plate is along the length of the substrate. The height of antenna elements is just 4 mm above the ground plane which makes the proposed structure low profile and suitable for mobile devices. The modification of the rectangular shape of the radiating patch to J-shaped element resulted in size reduction of the patch while resonating at the same frequency.

Table 1: Dimensional details of MIMO antenna

PARAMETER	VALUE (mm)
Length of Ground Plane	100
Width of Ground Plane	50
Length of Radiating Element	22
Width of Radiating Element	15
Shorting Plate Length	9
Shorting Plate Width	4

3. SIMULATION RESULTS

A. S-Parameters

From Figure 2 it can be observed that the resonant frequency for both antenna elements is 3.5 GHz. The return loss value at the resonance is -18.54 dB and the frequency band covered is 3.27 GHz to 3.72 GHz. The bandwidth covered by the proposed antenna is 450 MHz supporting 4G and 5G communication bands. The correlation between the antenna elements can be observed as isolation parameter i.e. S21 or S12. The acceptable level of isolation is -15dB and the obtained value is below this level throughout the operating band. At resonance, the isolation level is below -17 dB.

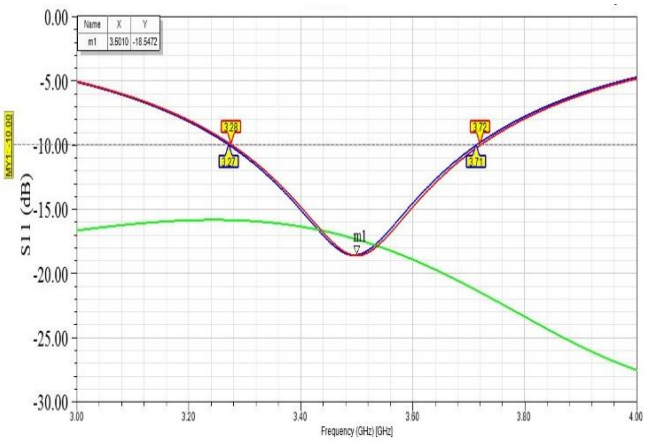

Figure 2: S-Parameters Plot of MIMO Antenna

B. Radiation Pattern

Figure 3 presents the simulated 2D radiation plot which shows that the MIMO antenna is a good radiator with almost omnidirectional radiation. The peak can be observed between 20^0 and 30^0.

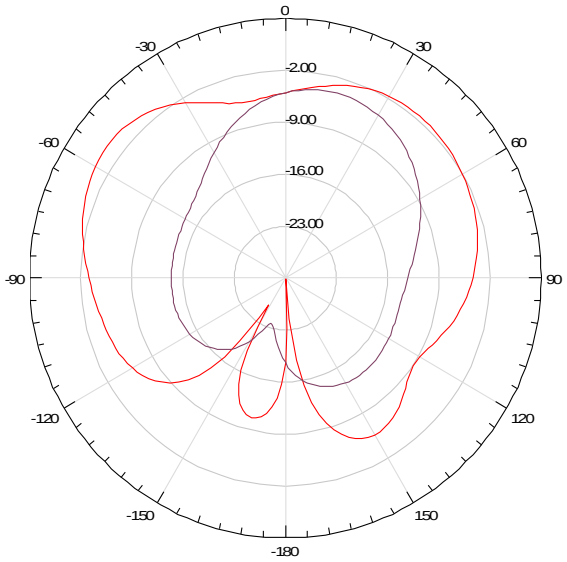

Figure 3: Radiation plot for phi 0 and 90 degrees.

C. Diversity Gain (DG)

This is an important parameter for MIMO antenna performance analysis. It can be obtained from S-parameters of the MIMO antenna for which ECC should be calculated first as given in equation 1. From Figure 4 it can be observed that diversity gain value remains near to 10 dB level in the band of operation. Good MIMO performance is exhibited. The calculation of diversity gain is performed as per equation 1.

$$DG = 10\varepsilon_p \quad (1)$$

where $\varepsilon_p = \sqrt{(1 - |0.99\rho_e|^2)}$

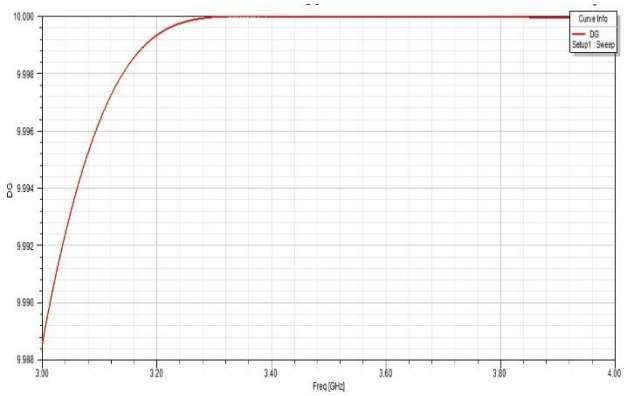

Figure 4: Diversity Gain Plot (Simulated)

D. Envelope Correlation Coefficient (ECC)

Figure 5 presents the ECC plot of the MIMO antenna. The calculation of ECC can be done using S-parameters and radiation efficiencies of the antenna ports in the MIMO system. The acceptable level of the ECC should be below 0.5. As it can be observed from Fig. 5 the ECC level for the band of operation is below 0.005. This reflects that the proposed MIMO antenna has excellent MIMO performance.

Calculation of ECC from S-parameters can be done by the following equation. The equation is given for N-element MIMO system [8].

$$\rho_e(i,j,N) = \left| \frac{\sum_{k=1}^{N} S_{i,k}^{*} S_{k,j}}{\prod_{k=1,j} \left(1 - \sum_{k=1}^{N} S_{i,k}^{*} S_{k,k}\right)^{1/2}} \right|^2 \frac{1}{\eta_{ir}\eta_{jr}\eta_{kr}} \quad (2)$$

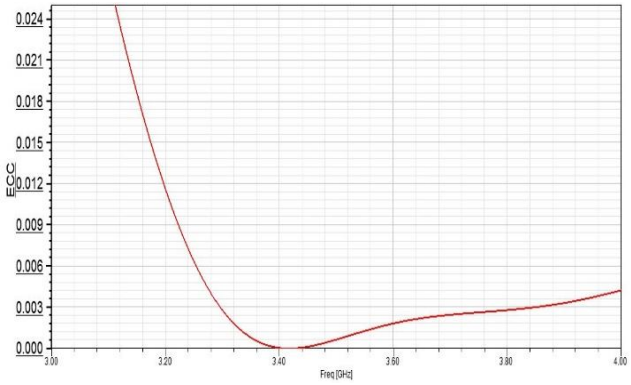

Figure 5: Simulated ECC plot of MIMO PIFA

5. CONCLUSION

In this work, a J-shaped element based MIMO PIFA has been proposed for 4G LTE/5G bands. The resonance occurs at 3.5 GHz and the isolation is below -16 dB between the elements. The MIMO performance parameters i.e. ECC and diversity gain also confirms that the proposed MIMO antenna exhibit good diversity performance. The overall size of the proposed antenna makes it a good candidate in the mobile devices where component space is becoming a major issue now-a-days.

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