Analysis of Bent Ground plane on MIMO Antenna

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Abstract
This paper presents the analysis of bent ground plane antennas for multiple-input-multiple-output (MIMO). Here, antenna array with three elements are proposed to evaluate the diversity performance of MIMO antennas systems. Then a three-element suspended plate antenna array with a bent ground plane is analyzed. The diversity performance of the design is analysed with the simulation results. At suspended angle α = 0^o, the reflection coefficient of antenna is found to be -26.58 dB with an isolation of -47.53dB at resonance frequency 5 GHz. While At suspended angle α = 45^o, the reflection coefficient of antenna is found up to -29.69 dB with a maximum isolation of -56.65dB.

Key Words
Correlation coefficient, diversity antenna, diversity gain, multiple-input multiple output (MIMO) antenna, phone antenna, total radiation power.

INTRODUCTION

Conventional Microstrip antenna consist a conducting patch printed on a grounded microwave substrate. It has the attractive features of light weight, small size, easy fabrication, low profile and conformable.

In this paper the performance evaluation of antennas in MIMO system is presented. After that, a three-element suspended plate antenna design with a bent ground plane is designed and analysed.The recent development of wireless technology has increased the capacity and reliability requirements of wireless communication systems. It is difficult to fulfil these requirements with traditional SISO (single-input single-output) systems, due to its limitations of less channel capacity. By using transmitting-diversity, diversity-reception, and channel-coding techniques, MIMO (multiple-input multiple-output) systems are able to transmit multiple signals, with the same power level, simultaneously through parallel channels. These signals are then received and combined using diversity techniques. MIMO becomes a popular technology due to its potential to achieve low bit error rate (BER) and larger capacity by multiplexing. MIMO multiplexing has been widely adopted due to its high speed data Communications [1-6].

Multiple-Input and Multiple-Output consists of multiple antennas at both the transmitter and receiver to improve communication performance. One of the major benefits of MIMO systems over traditional SISO systems are their improved capacity and reliability, without increasing bandwidth or transmitted power.

In a MIMO system, the antennas have a great impact on the channel capacity, also it plays an important role in system stability. Antenna arrays used in MIMO systems are required to have high gain, wide lobe pattern, and high isolations between antenna elements. Now, the performance of MIMO antenna is degraded due to mutual coupling between elements. There are different strategies have been devised to achieve decoupling (or improve isolation) among the antennas[2,5].

The RF performance of antennas are evaluated by using various parameters such as gain, directivity, radiation patterns, matching impedance, and polarization, the envelope correlation coefficient between antennas. The envelope correlation coefficient calculated using S-parameters or radiated electric fields with assumption that the antennas are lossless and the channels are uniform and random [4].

Using the S-parameters of N elements, the envelope correlation coefficient, $\rho_{e,ij}$ can be given in equation1.1:

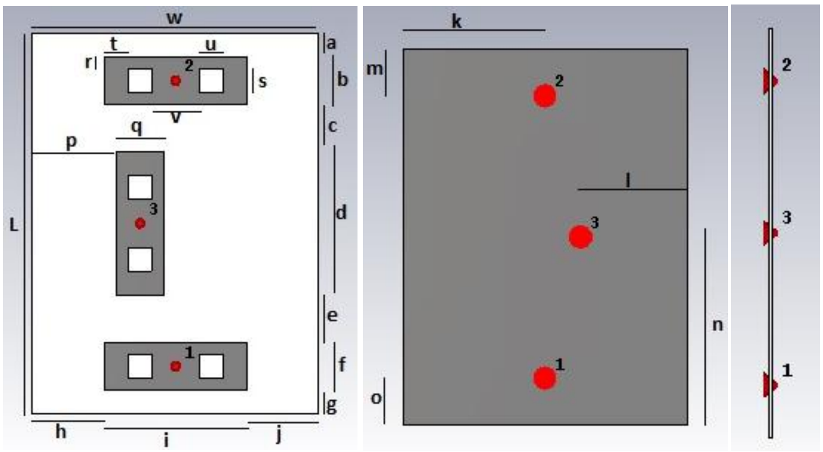
$$\rho_e(\mathbf{i},\mathbf{j},\mathbf{N}) = \frac{\left|\sum_{n=1}^{N} S_{i,n}^{*} S_{n,j}\right|^2}{\prod_{k=i,j}\left[1-\sum_{n=1}^{N} S_{k,n}^{*} S_{n,k}\right]} \text{---------1.1}$$

Where, i and j indicate the i^{th} and j^{th} elements, respectively. It can be observed that the correlation is affected by the inter-element mutual coupling, the phase difference between S_{ii} and S_{ij} and impedance matching. From the denominator term it can be observed that S_{ii} and S_{ij} also affect the overall radiated power from all the elements. As a result, both factors affect the antenna efficiency. The variation in the envelope correlation coefficient is caused by the phase change in the numerator term [4, 6].

design and simulation

a. MIMO antenna with $\alpha = 0^0$

The optimized design with dimensional details of the proposed MIMO antenna is illustrated in Fig. 1.The dimensions are in millimetre (mm): W=120, L=160, a=10, b=20, c=20, d=60, e=20, f=20, g=10, h=30, i=60, j=30, p=35, q=20, r=5, s=10, t=10, u=10, v=30, k=60, l=45, m=20, n=80, o=20.The thickness of substrate is 1.6mm. A dielectric constant was 4.3. The overall size of MIMO antenna system is 120×160× 1.6mm^3.



(a) Top layer (b) Bottom layer (c) side view

Fig. 1. Geometry of the MIMO antenna system α=0^o

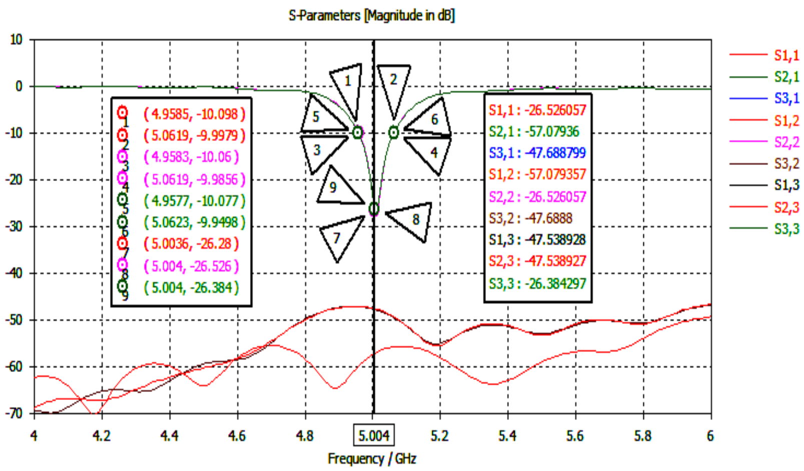
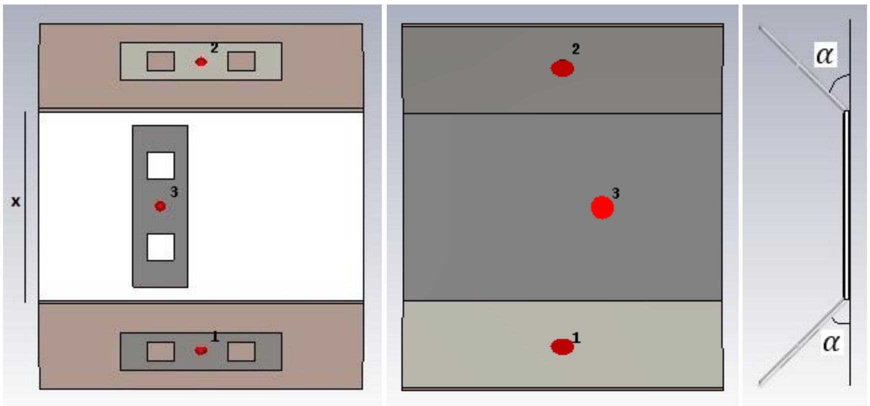


Fig.2 Simulated S-parameter with α=0^o

After simulation, one frequency band is observed i.e. 4.95-5.06GHz with resonant frequency 5GHz. The reflection coefficient (S11) observed at 5GHz is -26.38dB with isolation varies between -47.53dB to -57.09dB as shown in fig 2.The VSWR is 1.09 at 5 GHz. The gain observed at 5 GHz is 2.84dBi

B. MIMO antenna with $\alpha = 45^0$

In iteration2, the portions of the ground plane are bent i.e $\alpha = 45^0$ as shown in figure 3, the mutual coupling between Elements 1 and 2 is found to be reduced such that the lowest coupling is achieved. The similar trend is also demonstrated for Elements 1 and 3. However, the mutual coupling between Elements 2 and 3 is also reduced. The value of correlation coefficient can be significantly reduced between Elements 1 and 2 as well as Elements 1 and 3 when $\alpha=45^0$.



(a)Top layer (b) Bottom Layer
(c) side view
Fig.3 Geometry of MIMO antenna with $\alpha=45^o$

The $\alpha = 45^0$ gives one frequency band observed between 4.94-5.04 GHz with resonant frequency of 5GHz, The value reflection coefficients (S11, S22, S33) at 5GHz are found up to -29.67dB is shown in fig.4. After introducing $\alpha = 45^0$, and the transmission coefficients are change in the range of -48.56 dB to -58.65dB which indicate the good isolation between elements. The VSWR is 1.06 at 5 GHz. The gain observed at 5GHz operating frequency is 1.03dBi.

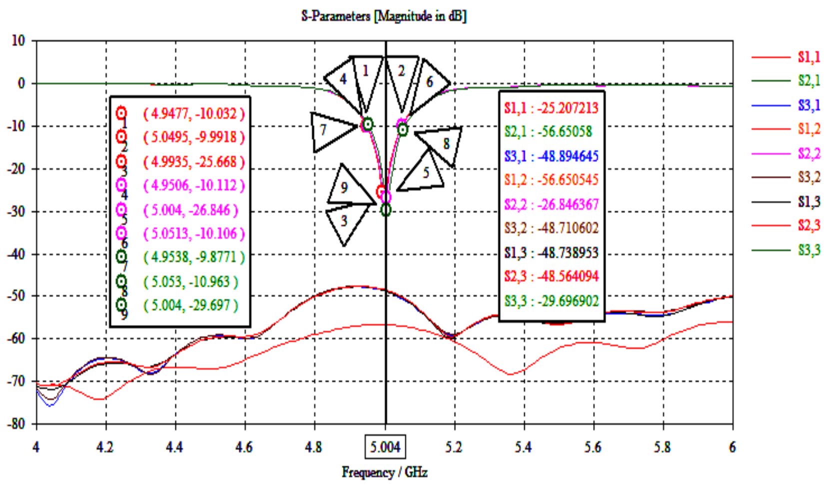
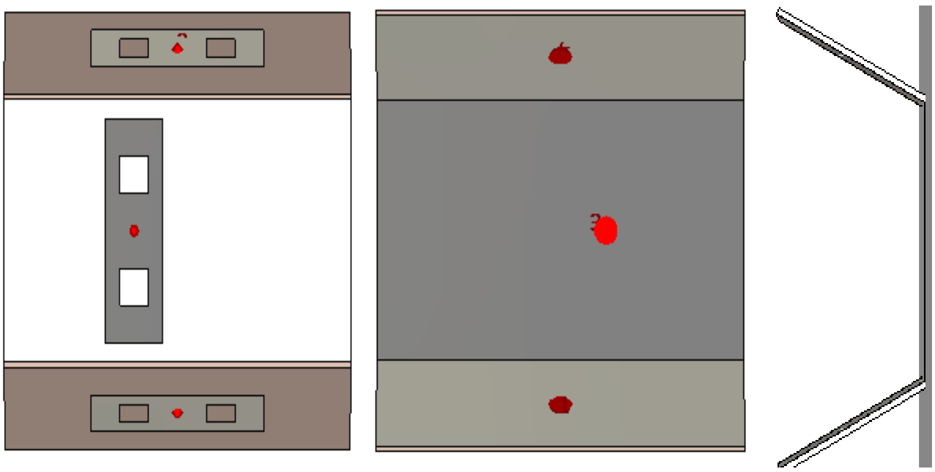


Fig.4 Simulated S-parameter with $\alpha = 45^0$

C. MIMO antenna with $\alpha = 60^0$

In iteration 3, the portions of the ground plane are bent i.e $\alpha = 60^0$ as shown in figure 5. The correlation is significantly reduced between Elements 1 and 2 as well as Elements 1 and 3 when $\alpha = 60^0$.The value of correlation coefficient is found below 0.0002 in both cases.



(a)Top layer

(b) Bottom Layer (c) side view

Fig.5 Geometry of MIMO antenna with $\alpha = 60^o$

The $\alpha = 60^0$gives one frequency band observed between 4.91-5.01 GHz with resonant frequency of 4.96GHz but resonance frequency of element 3 is shifted to 5 GHz. The value reflection coefficients (S11, S22, S33) are range between -26.94dB to -28.27 dB as shown in fig.4. After introducing $\alpha = 60^0$, and the transmission coefficient found in the range of -50.50 dB to -58.46 dB which indicate the good isolation between elements. The VSWR is observed below 2 at 5 GHz. The gain observed at 5GHz operating frequency is 1.87dBi.

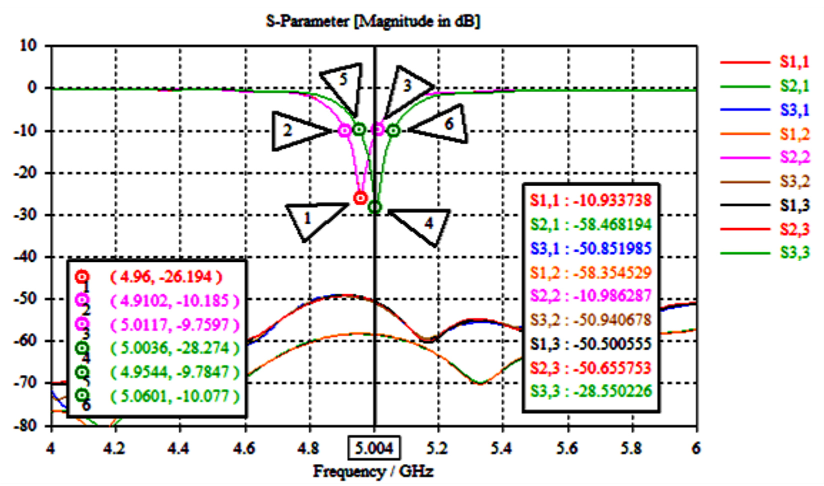
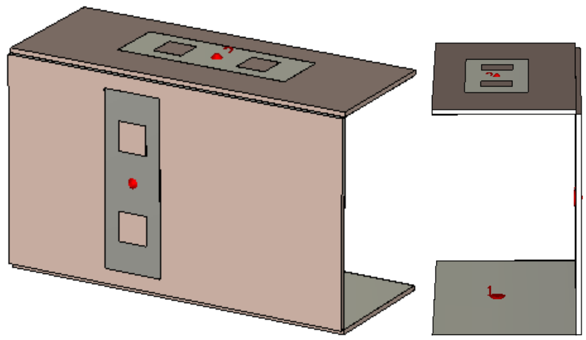


Fig.6 Simulated S-parameter with $\alpha = 60^o$

C. MIMO antenna with $\alpha = 90^0$

In iteration 4, the portions of the ground plane are bent i.e $\alpha = 90^0$ as shown in figure 7, the mutual coupling between Elements 1 and 2 is found to be reduced such that the lowest coupling is achieved. The similar trend is also demonstrated for Elements 1 and 3. However, the mutual coupling between Elements 2 and 3 is also reduced. The correlation can be significantly reduced between Elements 1 and 2 as well as Elements 1 and 3 when α=90^0.



(a)Top layer (b) side view

Fig.7 Geometry of MIMO antenna with α=90°

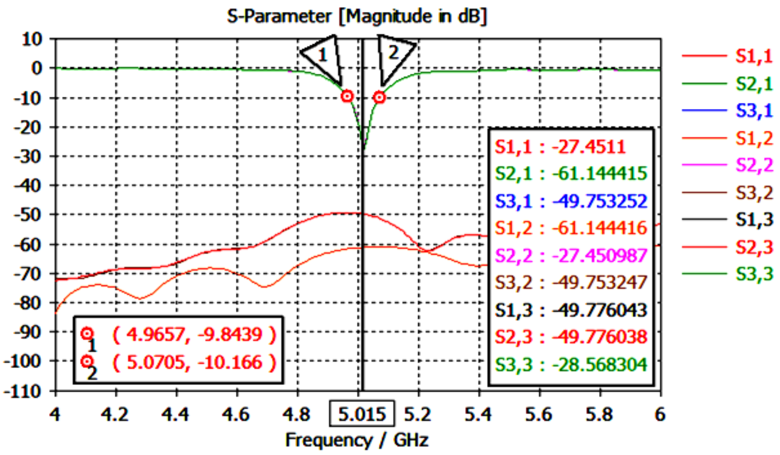
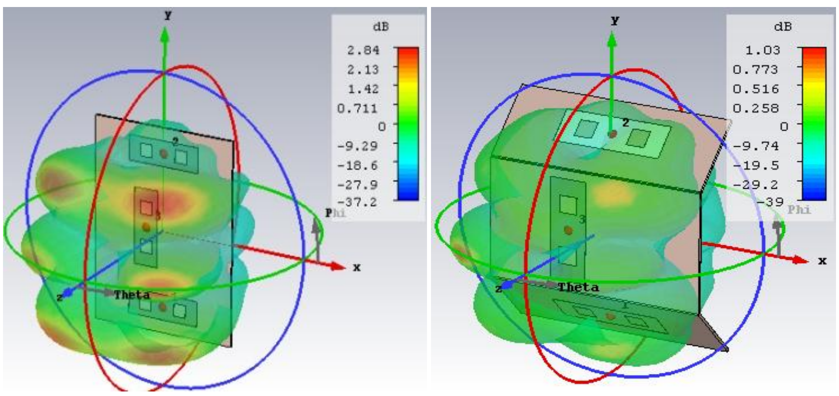
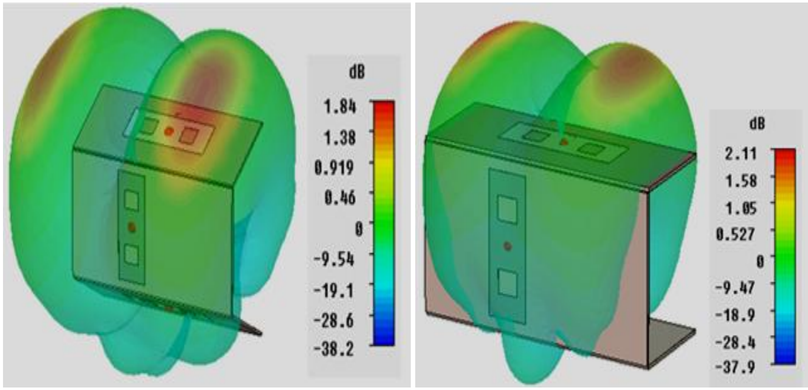


Fig.8 Simulated S-parameter with α=90°

The $\alpha = 90^0$gives one frequency band observed between 4.96-5.07 GHz with resonant frequency of 5 GHz. The value reflection coefficients (S11, S22, S33) are range between -27.94dB to -28.56 dB as shown in fig.8. After introducing $\alpha = 60^0$, and the transmission coefficient found in the range of -50.50 dB to -58.46 dB which indicate the good isolation between elements. The VSWR is observed 1.08 at 5 GHz. The gain of antenna at 5GHz operating frequency is found up to 2.09dBi. The value of correlation coefficient is found below 0.00006.

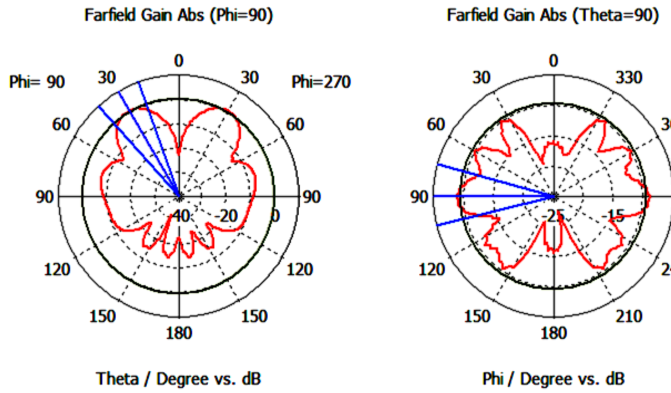


(a)α=0° (b) α=45°



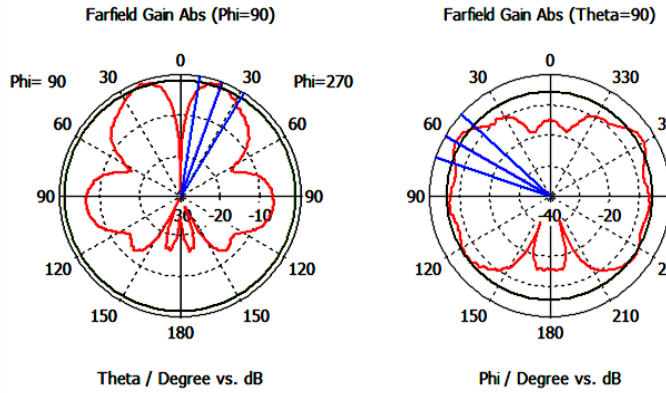
(a)α=60° (b) α=90°

Fig.9 Simulated 3D gain



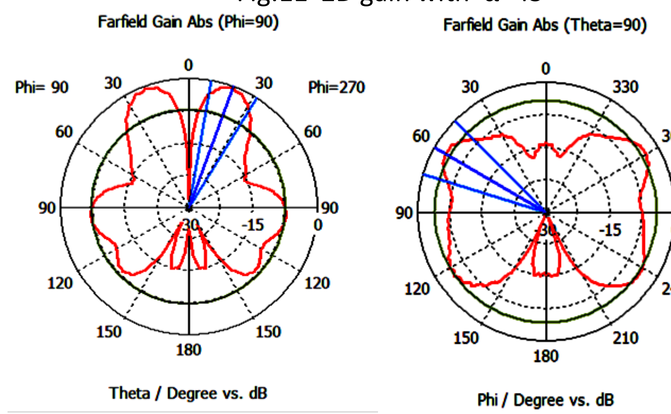
(a) Vertical far field gain (b) Horizontal far field gain

Fig.10 2D gain with α=0°



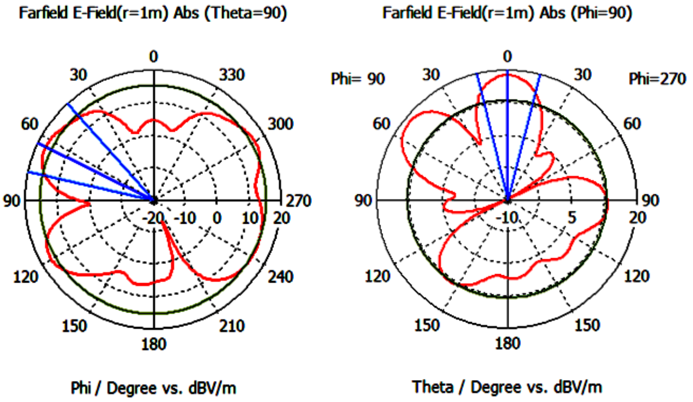
(a) Vertical far field gain (b) Horizontal far field gain

Fig.11 2D gain with α=45°



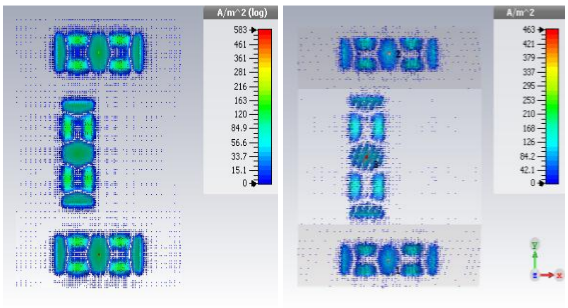
(a) Vertical far field gain (b) Horizontal far field gain

Fig.12 2D gain with $\alpha=60^o$

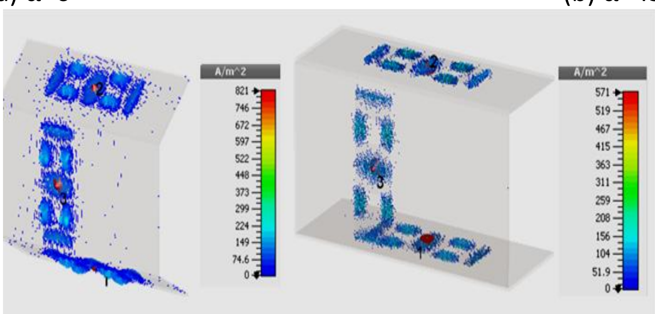


(a) Vertical far field gain (b) Horizontal far field gain

Fig.13 2D gain with $\alpha=90^o$



(a) $\alpha=0^o$ (b) $\alpha=45^o$



(c) $\alpha=60^o$ (d) $\alpha=90^o$

Fig.8 Current distribution of MIMO antenna

RESULTS AND DISCUSSIONS

From above diagram it is found that the results are link with mutual coupling factor. For better result, we fixed some parameters like feed position, dielectric constant, height of dielectric, patch size at optimum level. By changing the angle of ground plane further analysis can be done. Figure 9 shows 3D radiation pattern of MIMO antenna with and without bending the ground plane.

First, we simulate antenna system without bending ground plane i.e. $\alpha = 0^0$ and It is observed that the structure hardly affects the impedance matching. Also check the effect of mutual coupling between antenna elements at resonance frequency 5 GHz.

In iteration 2, the portions of the ground plane are bent i.e. $\alpha = 45^0$ as shown in figure 3, the mutual coupling between Elements is found to be reduced such that the lowest coupling is achieved. The correlation can be significantly reduced between Elements 1 and 2 as well as Elements 1 and 3 when $\alpha=45^0$.

In iteration 3, the portions of the ground plane are bent by $\alpha = 60^0$ as shown in figure 5. The correlation can be significantly reduced below 0.0002 between Elements 1 and 2 as well as Elements 1 and 3 when $\alpha=60^0$.

In iteration 4, the portions of the ground plane are bent by $\alpha = 90^0$ as shown in figure 7. The correlation can be significantly reduced below 0.00006 between Elements 1 and 2 as well as Elements 1 and 3 when $\alpha=90^0$. Also the gain achieved by antenna is above 2dBi.

Conclusion

Antenna array with 1.6 mm thick FR4 substrate is investigated in this paper. The analysis of bent plane with angle $\alpha=0^0,45^0,60^0,90^0$ is carried out. Besides the conventional assessment of performance of MIMO antennas, the two- and three-dimensional patterns for envelope correlation coefficients have been proposed to evaluate the performance of the antenna designs. It has been found that for the given ground plane size and antenna configuration, the three-element antenna array on the 90^o bent ground plane give better isolation than others. While the gain of antenna is found above 2 dBi for 0^0& 90^0. The results show that the proposed antenna can be used for wireless internet access application, which include WLAN. Here multipath fading avoid by providing spatial and pattern diversity.

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