**Scientific Research**

# Dual Band MIMO Antenna Composed of Two Low Profile Unbalanced Fed Inverted L Antennas for Wireless Communications

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## Abstract

A low profile dual-band multiple-input-multiple-output (MIMO) antenna system is proposed. The proposed MIMO antenna consists of two low profile unbalanced fed inverted L antennas with parasitic elements to resonate at 2.45 GHz and 5 GHz. The structure is uncomplicated by locating two ultra low profile inverted L antennas on the finite conducting plane. The proposed MIMO antenna is numerically and experimentally analyzed. When the size of conducting plane is 55 mm by 55 mm and the height of antenna is 9 mm, the directive gain of 4.11 dBi and the $S_{11}$ bandwidth of 5.71% are achieved for lower frequency of 2.45 GHz. At the upper frequency of 5 GHz, the directive gain of 8.22 dBi and the $S_{11}$ bandwidth of 6% are obtained. The proposed antenna has good diversity gain, shown by the correlation coefficient becomes less than 0.005 at the frequency of 2.45 GHz and 5 GHz band when the distance between inverted L elements is 41 mm. A good agreement between calculated and measured results is obtained. The results show that the weak mutual coupling of the proposed antenna and this feature enables it to cover the required bandwidths for WLAN operation at the 2.4 GHz band and 5 GHz band.

## Keywords

## 1. Introduction

The dual band antennas have been investigated with the development of wireless communication systems in re-

cent years [1]-[8]. Most of these dual or multiple band antennas have an omnidirectional radiation pattern. In some applications such as wireless base station or access point, the unidirectional radiation pattern is needed. In order to realize the unidirectional radiation pattern, the antenna size becomes larger [4] [6] [8]. A higher order mode maybe excited in such antenna and large ripples may exist in the radiation pattern at the upper frequency bands [4]-[6]. The interference and the antenna gain reduction may occur due to the large ripple for base station or access point applications. Therefore the compact dual band antenna with unidirectional radiation pattern is desired. The dual or multiple band MIMO antennas are widely used for wireless communication because they become as an effective solution to enhance the channel capacity [9] [10]. One of authors has proposed the dual band antenna composed of the unbalanced fed inverted L antenna for 1.4 GHz and 2.2 GHz bands [11]. In [11], the parasitic element was located above an unbalanced fed inverted L antenna for higher band excitation. This antenna is promising as the candidate of the dual band antenna because it provides two distinct resonant modes for achieving dual-band operation. Furthermore, the authors have studied the advantages of inverted L antennas for wireless communication systems [12] [13], and proposed the simple design and low cost material antenna for single band MIMO antenna systems [14] [15].

In this paper, a dual band MIMO antenna composed of two parallel identical ultra low profile inverted L antennas located on square conducting plane. The proposed antenna has a simple design and works at frequency bands of 2.45 GHz and 5 GHz. In order to satisfy the MIMO antenna system requirements, the proposed antenna is investigated on mutual coupling between two inverted L elements and diversity gain through correlation coefficient value [16]-[19]. The electromagnetic simulator WILP-D based on the method of moments is used for numerical analysis for the reason of shorter computation time compared with other simulation methods [20]. Then its results are validated with the measurement.

## 2. Antenna Structure

**Figure 1** shows the proposed dual band MIMO antenna. The proposed structure is configured by two low profile inverted L antennas located on finite conducting plate with dimension 55 mm by 55 mm ($0.45 \lambda_{2.45}$ by $0.45 \lambda_{2.45}$). $\lambda_{2.45}$ is the wavelength at the frequency of 2.45 GHz. The parasitic element is placed above the horizontal element of low profile inverted L antenna. The feed points are located at the distance $L_1$ from the bend of horizontal elements of the inverted L antennas. Both the lengths of $L_1$ and $L$ are adjusted to obtain the 50 Ohm impedance matching. In the calculation, the height of inverted L antenna $h_1$ is set as 5 mm or 6 mm. The length of parasitic elements $L_p$ is determined so that the upper resonant frequency becomes to be 5 GHz. In the previous study in [12], the optimum distance between two inverted L antennas was 41 mm in the case of the conducting plane was 55 mm by 55 mm. Therefore the distance between inverted L antennas $d$ is set to be 41 mm. The inverted L antenna is composed of the semi rigid coaxial cables with the radius of inner and outer conductors are 0.255 mm and 1.095 mm, respectively. The radius of parasitic elements is 1.095 mm. The distance between the vertical element of inverted L antennas and the edge on backside $pym$ is set as 10 mm. The distance between the vertical element of inverted L antennas and the edge on front side $pyp$ is set as 45 mm. The distances between vertical element of inverted L antennas and outer edge on right and left side $pxp$ are fixed as 7 mm.
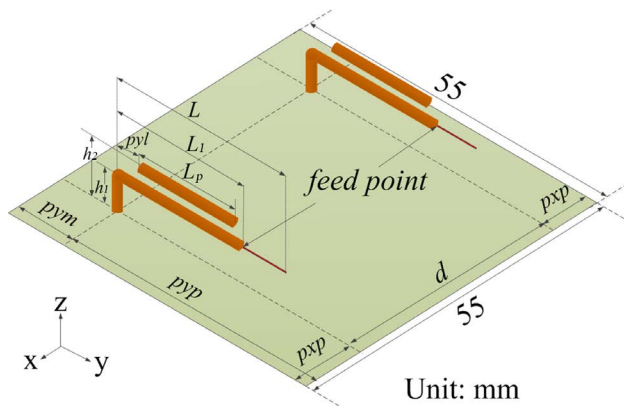


| Antenna parameters | Unit:mm | |
| --- | --- | --- |
| $L$ | 28.9 | 29.9 |
| $L_1$ | 14.4 | 16.8 |
| $L_p$ | 27.1 | 27.3 |
| $h_1$ | 6 | 5 |
| $h_2$ | 9 | 8 |
| $pyl$ | 4.6 | 4.0 |
| inner radius of wire | 0.255 | |
| outer radius of wire | 1.095 | |
| conducting plane dimension | 55 x 55 | |
| $d$ | 41 | |
| $pxp$ | 7 | |
| $pym$ | 10 | |
| $pyp$ | 45 | |

**Figure 1.** The structure of proposed MIMO antenna.

## 3. Results and Discussion

**Figure 2** show the calculated scattering parameters of proposed MIMO antenna. The $S_{11}$ bandwidth less than −10 dB of the proposed antenna are 5.71% (2.38 - 2.52 GHz) for lower frequency band and 6% (4.87 - 5.17 GHz) for higher frequency band. The mutual coupling between two ports is less than −21 dB in the lower band and less than −23 dB in the higher one.
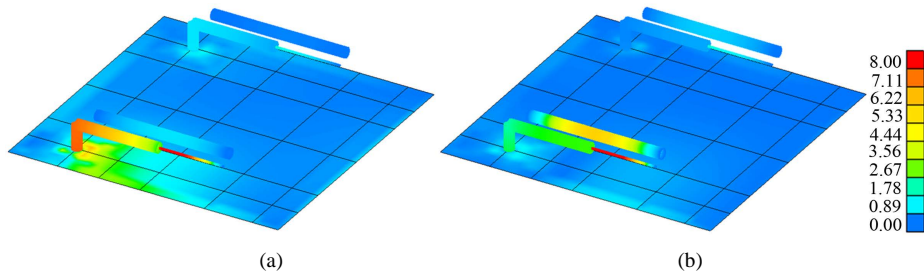
   **Figure 3(a)** and **Figure 3(b)** show the calculated current distributions at lower frequency of 2.45 GHz and higher frequency of 5 GHz. The height of inverted L antenna and parasitic element are $h_1$ = 6 mm and $h_2$ = 9 mm, respectively. **Figure 4(a)** and **Figure 4(b)** show the calculated current distributions when $h_1$ = 5 mm and $h_2$ = 8 mm. A surface current on the conducting plane between two inverted L antennas is small. This means that the proposed structure achieves a good isolation. When the height of inverted L antenna is 5 mm, a large surface current flows on the conducting plane under the inverted L antenna. Due to the strong mutual coupling between inverted L antenna and the conducting plane, the frequency bandwidth becomes slightly narrow.
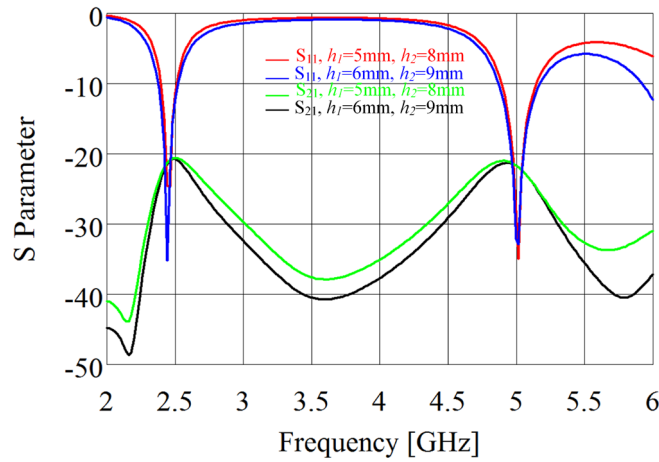


**Figure 2.** Calculated scattering parameter of proposed antenna. *pyp* = 45 mm, *pxp* = 7 mm, *pym* = 10 mm, *d* = 41 mm.



(a)          (b)
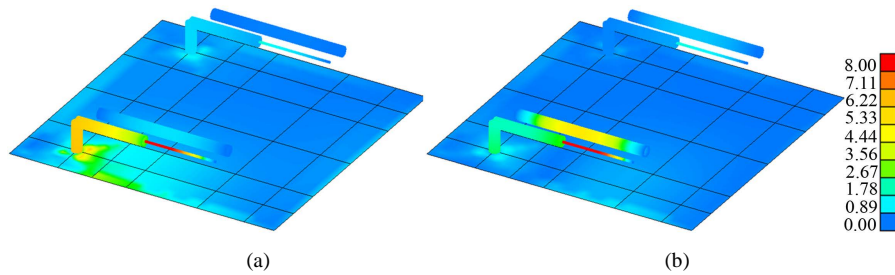
**Figure 3.** Current distributions of proposed antenna. $h_1$ = 6mm, $h_2$ = 9 mm, *pyp* = 45 mm, *pxp* = 7 mm, *pym* = 10 mm, *d* = 41 mm. (a) 2.45 GHz; (b) 5 GHz.



(a)          (b)

**Figure 4.** The calculated current distributions of proposed antenna. $h_1$ = 5 mm, $h_2$ = 8 mm, *pyp* = 45 mm, *pxp* = 7 mm, *pym* = 10 mm, *d* = 41 mm. (a) 2.45 GHz; (b) 5 GHz.
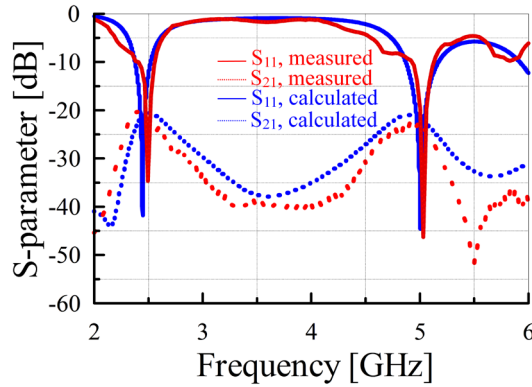
**Figure 5** show the comparison of calculated and measured scattering parameters of proposed MIMO antenna when the height of inverted L antenna and parasitic elements are $h_1 = 6$ mm and $h_2 = 9$ mm, respectively. The scattering parameters are measured by the 6 GHz board network analyzer R3760 by Advantest. The measured scattering parameters agree well with the calculated ones.

**Figure 6** shows the directive gain of proposed MIMO antenna in the $z$ direction. In both of cases of antenna height, the almost the same directive gain 4.11 dBi is obtained at 2.45 GHz. At 5 GHz, the current on the parasitic element is strongly excited. Since the equivalent size of antenna becomes large, the directive gain more than 8.11 dBi is obtained at this frequency.

The MIMO antenna system correlation factor will be significantly degraded with high coupling levels. It can be calculated from the scattering parameters in isotropic/uniform signal propagation [21]. The correlation coefficient $\rho_e$ is important to achieve the required diversity gain of the MIMO antenna systems. When $\rho_e$ becomes lower, the higher diversity gain is obtained. The value of $\rho_e$ can be calculated by using [22];

$$\rho_e = \frac{\left| S_{11} * S_{12} + S_{21} * S_{22} \right|^2}{\left( 1 - \left( \left| S_{11} \right|^2 + \left| S_{21} \right|^2 \right) \right) \left( 1 - \left( \left| S_{22} \right|^2 + \left| S_{12} \right|^2 \right) \right)} \tag{1}$$

**Figure 7** show the calculated correlation coefficients in two cases of antenna height. It is evident that the proposed antenna with enhanced isolation satisfies the MIMO requirements for spatial diversity with the value of $\rho_e$ are less than 0.005 at both of lower and upper frequency bands. **Figure 8** shows the calculated and meas-
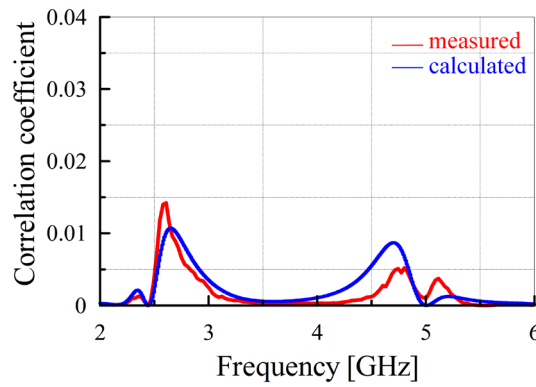


**Figure 5.** Calculated and measured scattering parameter. $h_1 = 6$ mm, $h_2 = 9$ mm, $pyp = 45$ mm, $pxp = 7$ mm, $pym = 10$ mm, $d = 41$ mm.
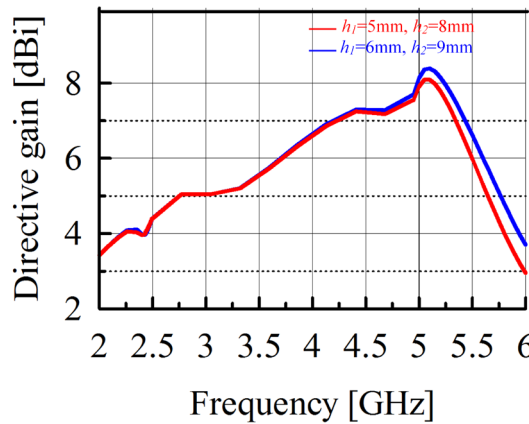


**Figure 6.** The directive gain of the proposed antenna in $z$ direction. $pyp = 45$ mm, $pxp = 7$ mm, $pym = 10$ mm, $d = 41$ mm.
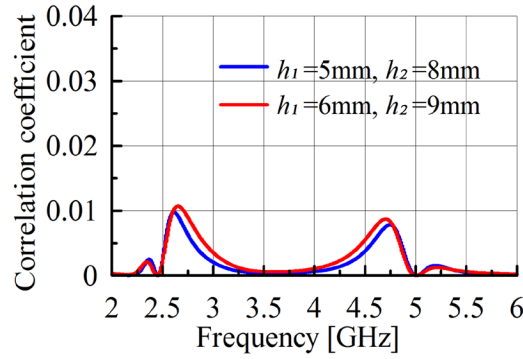
**Figure 7.** Correlation coefficient. *pyp* = 45 mm, *pxp* = 7 mm, *pym* = 10 mm, *d* = 41 mm.



**Figure 8.** Correlation coefficient. $h_1$ = 6 mm, $h_2$ = 9 mm, *pyp* = 45 mm, *pxp* = 7 mm, *pym* = 10 mm, *d* = 41 mm.

ured correlation coefficient of the proposed MIMO antenna when the height of inverted antenna and the height of antenna elements are 6 mm and 9 mm, respectively. A good agreement between calculated and measured results is obtained.

**Figure 9** show the calculated electric field radiation pattern in *xy*-plane, *xz*-plane and *yz*-plane at 2.45 GHz and 5 GHz when the height of inverted L antenna is $h_1$ = 6 mm and height of parasitic element is $h_2$ = 9 mm, respectively. When the height of inverted of inverted L antenna is reduced to 5 mm, the calculated electric field radiation pattern are shown at **Figure 10**.

As a result, the radiation patterns of the proposed antenna tends to cover complementary space region, which can provide pattern diversity to overcome the multipath fading problem and enhance the system performance.

**Figure 11** shows the calculated near field distribution of the proposed antenna in *xz*-plane including the feed point in the case of $h_1$ = 6 mm and $h_2$ = 9 mm. The weak mutual coupling between two inverted L antennas is archived. It clearly illustrates that the spatial coupling is dominant at operation frequency bands since the small current are flowing on the conducting plane between two inverted L antennas.
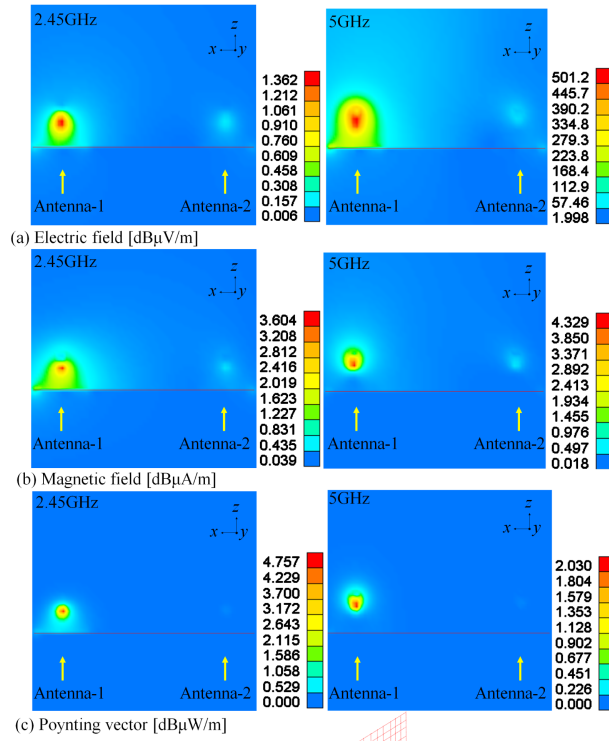
## 4. Conclusion

In this paper, a simple design and fabrication of dual band MIMO antenna composed of two ultra low profile inverted L antenna has been presented. The proposed antenna satisfies the MIMO system requirements with correlation coefficient less than 0.005 at both frequency bands. When the antenna size is 55 mm by 55 mm by 9 mm, the $S_{11}$ bandwidth of 5.71% (140 MHz) at lower band of 2.45 GHz and 6% (300 MHz) at upper band of 5 GHz are obtained. The directive gains are 4.11 dBi at 2.45 GHz and 8.22 dBi at 5 GHz. The good agreement of calculated and measured scattering parameters and the correlation coefficients are obtained. The presented design is suitable for MIMO communication applications.
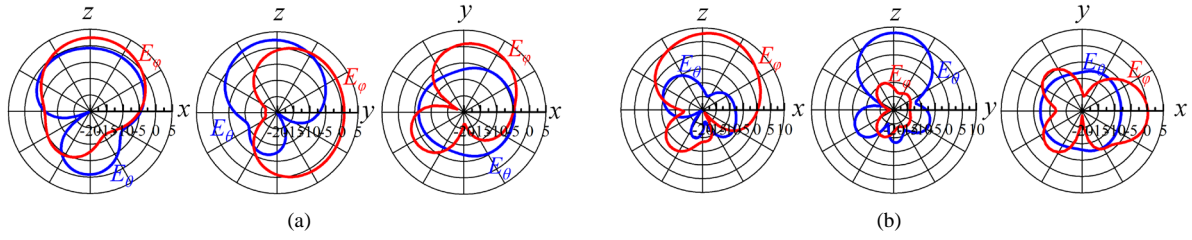
**Figure 9.** Electric field radiation pattern. $h_1 = 6$ mm, $h_2 = 9$ mm, $pyp = 45$ mm, $pxp = 7$ mm, $pym = 10$ mm, $d = 41$ mm. (a) 2.45 GHz; (b) 5 GHz.
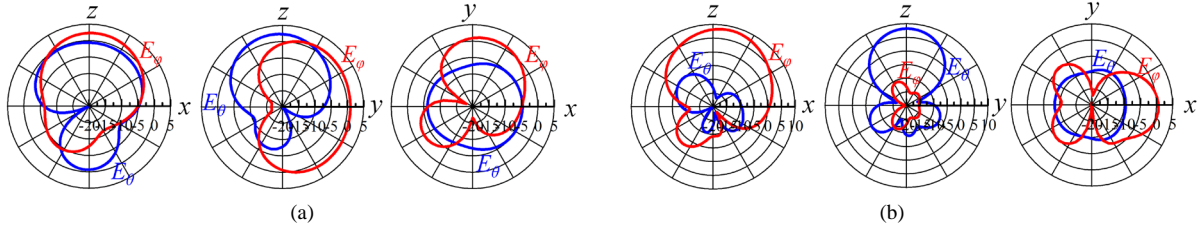


**Figure 10.** Electric field radiation pattern. $h_1 = 5$ mm, $h_2 = 8$ mm, $pyp = 45$ mm, $pxp = 7$ mm, $pym = 10$ mm, $d = 41$ mm. (a) 2.45 GHz; (b) 5 GHz.



(a) Electric field [dBµV/m]

(b) Magnetic field [dBµA/m]

(c) Poynting vector [dBµW/m]

**Figure 11.** The near field distribution at 2.45 GHz and 5 GHz ($h_1 = 6$ mm, $h_2 = 9$ mm, $d = 41$ mm, $pxp = 7$ mm, $pym = 10$ mm, $pyp = 45$ mm, $L = 28.9$ mm, $L_1 = 14.2$ mm, $L_p = 27.1$ mm).

## Acknowledgements

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