A Compact multi band MIMO antenna

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Abstract

This paper presents a compact dual band two element MIMO array covering the 2.4GHz and 5.2GHz bands for the modern mobile wireless LAN applications. The dual band antenna element is structured as a two-branch tree-type inverted-L monopole, where, the two collinear inverted-L radiators have been purposely organized such that an oblique element radiation pattern is obtainable. The MIMO array is then incorporated with two tree-type monopoles and a simple narrow band isolator to achieve an excellent mutual coupling performance. Besides, the characteristics of small size and nearly omnidirectional array radiation pattern make the proposed MIMO array entirely compatible with the mobile wireless network applications. The measurement results of the prototype antenna array demonstrate the success of the suggested design topology.

***Index terms* — MIMO Antenna, WLAN, Mutual Coupling, Inverted-F Antenna, Envelope Correlation Coefficient ECC**

1. Introduction

A wireless radio system equipped itself with multiple antennas in both terminals of link is referred to as the multiple-in-multiple-out (MIMO) configuration. The use of multiple antennas has been recognized as one of the most promising techniques to enhance the quality of modern mobile broadband wireless access communication. The benefits obtained from the MIMO structures include the link reliability improvement, the data throughput growth, and the spectral efficiency enhancement. However, it is noted that the mutual coupling between array elements can be a destructive factor degrading the performance of the MIMO wireless system [1]. As a result, in order to fully exploit the advantages of MIMO wireless systems, the study of reducing coupling effect has become one of the most significant subjects in the array structure design. Various array decoupling techniques have been proposed [2-7]; in [2], it uses two parallel meander lines between array elements as a reflector to obtain -17 dB degradation in S_{21}; in [3] and [4], they create an extra crossing path between two element array by using either a physical line or a parasitic coupling device respectively so as to cancel out the existing mutual coupling. The technique in [5] and [6] uses the shaped ground plane with slits to form a bandstop filter to suppress the mutual coupling in a closely packed planar inverted-F antenna array. In [7], instead of using isolation element, it judiciously utilizes two parallel feed lines that cause a capacitive coupling so as to induce a reverse polarity current in the opposite element to cancel out the mutual coupling, and thus to obtain better than 13 dB isolation on a Long Term Evolution MIMO array at 700MHz band.

In this paper, a creative design topology which is capable of decreasing the degree of complexity in isolation mechanism of a multiband MIMO array is presented. The proposed approach intentionally deploys an antenna element layout that is organized to produce a slightly oblique outward radiation pattern, and the produced asymmetrical pattern is therefore not only decreasing the antenna mutual coupling but also reducing the complexity of decoupling mechanism. Following with this design principle, a high isolated two element dual band planar MIMO array is demonstrated, where, the oblique radiation pattern is obtained by using the layout of an asymmetrical tree-type monopole. The tree-type monopole is incorporated with two purposely organized collinear inverted-L radiators which produce the frequency bands of 2.3-2.6GHz and 5-5.5GHz to correspond to the mobile WLAN standard. Two asymmetrical tree-type monopoles both having oblique outward radiation patterns are then closely spaced to form a small size and high isolation WLAN MIMO array. Besides, it can be demonstrated that further reducing the coupling effect can be easily done once the oblique antenna radiation pattern obtained. As demonstrated in this paper, the additional isolation is achieved with a simple structure such as inverted-T stripe placed between array elements. The prototype of the two element MIMO array has been fabricated on the FR4 substrate with occupation of 50mm×20mm in size, 1.6 mm in thickness, 4.4 in dielectric constant and 0.02 in loss tangent. The array structure, the design topologies and the fabricated prototype measurement are given in the following sections respectively.

2. ARRAY STRUCTURE DESCRIPTION

Figure 1 gives the geometrical structure and the physical dimensions of the proposed dual band two element MIMO array. Where, the tree-type array element is incorporated with two inverted-L radiators, and the two inverter-L branches are lengthened with the effective quarter wavelengths of the WLAN frequency bands of 2.4GHz and 5.2GHz respectively. The layout of the tree-type array element is intentionally organized in the way such that the longer inverted-L branch is constructed not only to produce the 2.4GHz band but also to act as an obstacle to the 5.2GHZ band. Conceivably, the radiation pattern of the 5.2GHz band can be oblique outward. The interelement distance of MIMO array is gauged about one-twelfth of the lower frequency band, and the inverted-T strip which is colored in yellow and situated on the opposite side of the substrate works as an isolator to the 2.4GHz band.

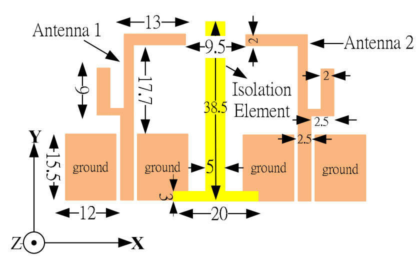


Figure 1. The array geometry structure and dimensions (unit: mm)

3. ARRAY DESIGN AND SIMULATION

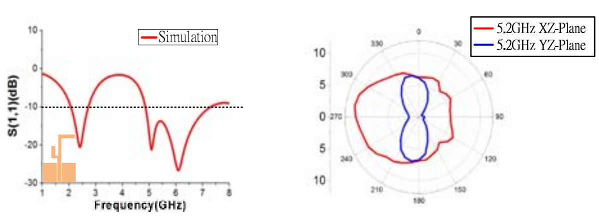
The preliminary performances of the depicted two element MIMO array have been evaluated by using the Ansoft-HFSS software package, and the outcomes are given in the following subsections.

3.1 Asymmetrical tree-type antenna element

As shown in Figure 1, the tree-type antenna element is incorporated with two collinear inverted-L strips and the coplanar waveguide (CPW) feeding network. The simulated S_{11} of the antenna element and the radiation pattern at 5.2GHz are given in Figure 2. From Figure 2(a), the two frequency bands of the tree-type antenna are ranged from 2-2.7GHz and 4.85-7.27GHz respectively based on the -10dB S_{11} measurement. However, the bandwidth in 5.2GHz band is much wider than that of anticipated, and this result can be contributed to the non-uniform geometrical structure in the shorter inverter-L branch. Further, as exhibited in Figure 2(b), an expectable slightly oblique outward radiation pattern at 5.2GHz band has successfully created that is theoretically caused by the asymmetrical layout of the two inverter-L branches, and the consequence can be useful to reducing the coupling effect to an MIMO array.

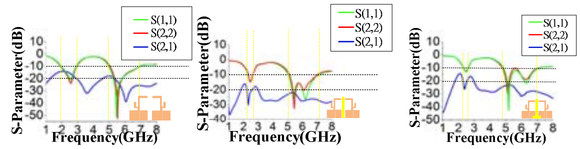
3.2 MIMO array and mutual coupling investigation

By using the antenna element studied in subsection 3.1, two identical tree-type antennas were placed closely to form a two element MIMO array, where, the interelement distance is given by 9.5mm which is about one-twelfth of the wavelength of the 2.4GHz band. At the outset, the array mutual coupling is simulated in the case of lacking isolator, and the outcome is given in Figure 3(a), where, the S_{21} across over the two frequency bands are better than -14dB and -19 dB respectively. It is clear that the purposely produced oblique outward radiation pattern at 5.2GHz band does have the benefit in the improvement of mutual coupling effect for a closely spaced MIMO array. Further investigation of the decoupling mechanisms have been made by adding a simple structure of I-shape or inverted-T shape isolator between the array elements, however, they are situated at the opposite side of the substrate with respect to the main radiator. The decoupling performances with isolators are simulated and the results are given in Figure 3 (b) and 3(c) respectively, where, the S_{21} provided by the I-shape isolator is better than -19db and -20dB and that provided by inverted-T shape isolator is better than -20dB and -24dB across over the two frequency bands. It is obvious that the mutual coupling of the MIMO array can be greatly reduced by using a simple structured isolator. Moreover, in order to match the inverted-T isolator and the 2.4GHz inverted-L radiator, the length of the inverted-T is set approximately to be the half-wavelength of 2.4GHz (58.5mm), and its line width (W_u) at the horizontal part has been used as a tuning parameter to optimize the array S_{11} performance. The optimization result is given in Figure 4, and from the result, it is figured out that the optimal width of w_u for both frequency bands is given by 5mm.



(a) (b)

Figure 2. The simulated (a) S_{11} and (b) 5.2GHz radiation pattern



(a) (b) (c)

Figure 3. The simulated S parameters of the two element array (a) without isolator, (b) I-shape isolator,(c) inverted -T shape isolator

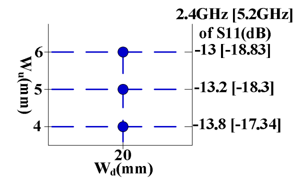
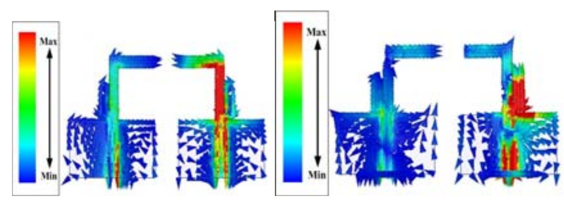


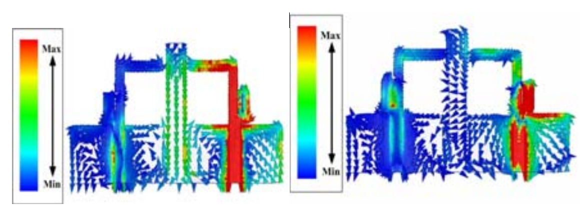
Figure 4. Optimization of inverter-T isolator width Wu

It is meaningful to further investigate the effect of the isolation mechanism by examining the surface current distributions on the array elements. The simulated surface currents of the dual band two element MIMO array in cases of lacking isolator and incorporated with isolator are given in Figure 5 and 6 respectively. It can be realized from the results that the strength of isolation in 5.2GHz band is comparably better than that that in 2.4Gz, this exactly shows that the asymmetrical oblique antenna radiation pattern caused by an asymmetrical layout of the antenna element does provide a valuable mechanism to effectively reduce the mutual coupling for a closely spaced MIMO array.



(a) (b)

Figure 5. The simulated surface current distribution without isolator at (a) 2.4GHz, (b) 5.2GHz



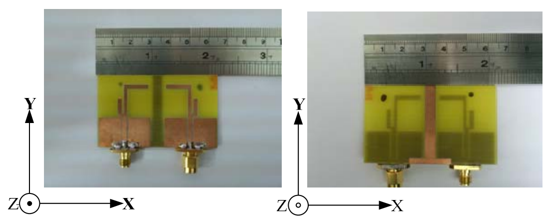
(a) (b)

Figure 6. The simulated surface current distribution with inverter-T isolator at (a) 2.4GHz, (b) 5.2GHz

4. ARRAY MANUFACTURE AND EASUREMENT

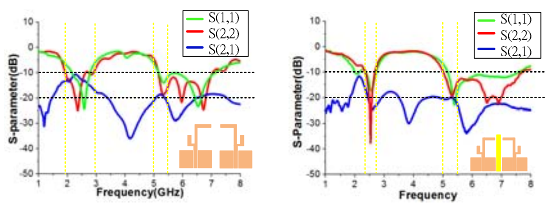
Three prototypes of two element MIMO array, including the array without isolator, the array with I-shape isolator and that with inverted-T isolator, were fabricated on a FR4 substrate. However, only two of them, the one without isolator and that with inverted-T isolator, are demonstrated in Figure 7. The measured S-parameter with respective to the three prototypes are shown in Figure 8(a), 8(b) and 9(a) respectively, and the quantified detail measurement results are summarized in Table 1, where the simulation correspondences (quantities within brackets) are also included for comparison. By examining the measurement results, it is clear that a good mutual coupling performance has been obtained by merging the creative technique of asymmetrical antenna element layout and a simple isolator. The isolation indicated by S_{21} in the MIMO array with an inverted-T shape isolator has shown to be lower than -20dB and -24dB at the two frequency bands. The noticeable discrepancy found between simulation and measurement is believed to be caused by the manufacturing skill of the designer.

The Envelope Correlation Coefficient ECC [8] has been adopted as an effective merit of index to demonstrate the MIMO diversity performance, and it can be calculated by using the S-parameters. The ECC of the two-element MIMO array with inverter-T isolator has been calculated based on the simulated and measured S-parameters, and the result is given in Figure 9(b). The ECC should be less than 0,5 to assure a good diversity performance, and that provided by the proposed MIMO array is lower than 0.08 in both the simulation and the measurement over the 2.4GHz and 5.2GHz frequency bands.



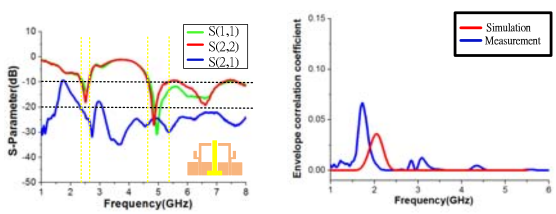
(a) (b)

Figure 7. The fabricated two-element MIMI array
(a)without isolator, (b) with inverted-T isolator



(a) (b)

Figure 8. The measured S parameters of the antenna array without isolator. (a) without isolator, (b) I-shape isolator



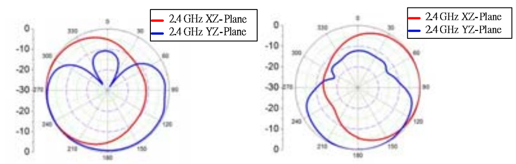
(a) (b)

Figure 9. The measured (a) S parameters and (b) ECC of the two-element MIMO array with inverted-T isolator

Table 1. The measured (simulated) S_{21} with different isolators

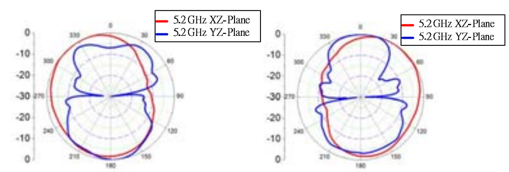
Frequency bandwidth	2.3GHz-2.6GHz		5GHz-5.5GHz	
	Minimum	Maximum	Minimum	Maximum
without isolator	-13dB (-16dB)	-10dB (-14dB)	-22dB (-22dB)	-18dB (-17dB)
I-shape isolator	-24dB (-30dB)	-16dB (-19dB)	-22dB (-22dB)	-19dB (-21dB)
Inverted T-shape isolator	-24dB (-26dB)	-20dB (-20dB)	-29dB (-24dB)	-24dB (-23dB)

The radiation patterns of the prototype dual band MIMO array with inverted-T isolator are measured in a time-domain antenna measurement system, they are shown in Figured 10 and 11 respectively, where, the individual element pattern is measured by connecting the alternative element with a 50 terminal load. It is worthwhile to be noted that the two individual antenna elements exactly produce an oblique outward radiation pattern at the horizontal plane (X-Z plane), which is obtainable by organizing the layout of the two collinear inverted-L branches. Nevertheless, the dual band MIMO array produces a nearly omnidirectional radiation pattern by merging the two oblique element patterns. This is fully compatible with the requirement of the mobile wireless access network applications.



(a) (b)

Figure 10. The measured antenna radiation pattern at 2.4GHz
(a) element 1, (b) element 2



(a) (b)

Figure 11. The measured antenna radiation pattern at 5.2GHz
(a) element 1, (b) element 2

5. Conclusion

A compact and good isolation two element dual band MIMO array operating in the 2.4GHz and 5.2GHz frequency bands has been presented. The MIMO array is incorporated by two tree-type monopoles with an inverted-T isolator. The tree-type antenna element is purposely figured out in an asymmetrical structure in order to produce an oblique outward radiation pattern that is useful to simplify the decoupling structure in the design of high isolation MIMO array. Moreover, the proposed MIMO array exhibits the additional characteristics of small size and nearly omnidirectional radiation pattern has lent itself particularly suitable to the mobile wireless network applications so as to fully exploit the advantages of spatial diversity and multiplexing.

References

[1] Chen-Nee Chuah, David N. C. Tse, Joseph M. Kahn, and Reinaldo A. Valenzuela, "Capacity Scaling in MIMO Wireless Systems Under Correlated Fading", *IEEE TRANSACTIONS ON INFORMATION THEORY*, VOL. 48, NO. 3, MARCH 2002.

[2] Jae-Min Lee, Ki-Baek Kim, Hong-Kyun Ryu, and Jong-Myung Woo, "A Compact Ultrawideband MIMO Antenna With WLAN Band-Rejected Operation for Mobile Devices", *IEEE Antennas and wireless propagation letters*, Vol. 11, 2012.

[3] V. Ssorin, A. Artemenko, A. Sevastyanov, R. Maslennikov , " Compact Bandwidth-Optimized Two Element MIMO Antenna System for 2.5 – 2.7 GHz Band", P*roceedings of the 5th European Conference on Antennas and Propagation (EUCAP).*

[4] J.N. Hwang and S.J Chung, "Isolation Enhancement Between Two Packed Antennas With Coupling Element," *IEEE Antennas and wireless propagation letters*, Vol. 10, 2011

[5] C.-Y. Chiu, C.-H. Cheng, R. D. Murch, and C. R. Rowell, "Reductionof mutual coupling between closely-packed antenna elements," *IEEETrans. Antennas Propag.*, vol. 55, no. 6, pp. 1732–1738, Jun. 2007

[6] FuGuo Zhu, JiaDong Xu and Qian Xu, "Reduction of Mutual Coupling Between Closely-Packed Antenna Elements Using Defected Ground Structure", ELECTRONICS LETTERS 4th June 2009 Vol. 45 No. 12

[7] B.k Kim, Y.S Park, H. Wi, M.J. Park, Y.Y Choi, J.k Lee, W. J., D.W. Kim, and B.G Lee*, "*Isolation Enhancement of USB Dongle MIMO Antenna in LTE 700 Band Applications," *IEEE Antennas and wireless propagation letters*, Vol. 11, 2012.

[8] S. Blanch, J. Romeu, and I. Corbella, "Exact representation of antenna system diversity performance from input parameter description," *Electron Lett.*, vol. 39, no. 9, May 2003.