

# A Compact Broadband MIMO Antenna for Mobile Handset Applications

Xiang Zhou\*<sup>1,2</sup>, RongLin Li<sup>1</sup>, and Manos M. Tentzeris<sup>2</sup>

<sup>1</sup>School of Electronic and Information Engineering,

<sup>1</sup>South China University of Technology, Guangzhou 510640, China

<sup>2</sup>School of Electrical and Computer Engineering

<sup>2</sup>Georgia Institute of Technology, Atlanta, GA 30332-0250, USA

E-mail: stephen\_chou\_zx@163.com

## I. INTRODUCTION

As the original multiple-input multiple-output (MIMO) paradigm assumed, the use of  $N_T$  antennas at the transmitter and  $N_R$  antennas at the receiver can achieve the capacity growth linearly with  $\min(N_T, N_R)$  through an independent and identically distributed (i.i.d.) Gaussian MIMO channel [1]. But poor diversity in the propagation multipath and mutual coupling between antenna elements will cause the sub-channel correlation, which subsequently leads to a loss of channel capacity as compared to the ideal i.i.d. Gaussian MIMO channel. Recently, the advantage of omni-directional antenna elements in MIMO applications has been proved in [2], for the ability of forming eigen-beams from any direction necessary in a rich multipath environment. But how to pack omni-directional antennas into a portable device is still an issue since the correlation becomes more serious for the short distance between the array elements. In this paper, we demonstrate a planar antenna array realized with two broadband omni-directional elements [4]. This array realizes a good performance under MIMO situations with low mutual coupling ( $<-11$  dB) and low correlation coefficient ( $\leq -15$  dB) in a very wide bandwidth (more than 40% at about 2.1GHz) and a compact size (50mm $\times$ 67.2mm $\times$ 0.254mm). That is more compactable than the array demonstrated in [1] with a wider bandwidth than the arrays shown in [1], [5], and [6].

## II. ARRAY DESIGN

As more antenna elements mounted into a limited space, the communication capacity for each antenna drops more heavily due to a higher correlation between adjacent elements. 2 $\times$ 2 MIMO configuration is more robust to the effect of mutual coupling than higher order MIMO configurations [1]. For the modern mobile handset design, the antennas always are concentrated together or at a corner. We propose three different cases consisting of two antenna elements as shown in Fig. 1, with the inter-element space ( $W_C$ ) varying from 25.5 mm to 38.3 mm (0.2~0.3 $\lambda$  at 2.35 GHz) to find out a suitable configuration. We call them Case 1, Case 2, and Case 3 (i.e., C. 1, C. 2, and C. 3). The gaps between two elements for each case are filled with ground plane at the backside in order to model a real printed circuit board (PCB). In this MIMO antenna design, we focus on the reduction of the mutual coupling and the correlation between the elements since a lower mutual coupling improves radiation efficiency while a lower correlation coefficient increases antenna diversity. All the simulation results are calculated by Ansoft HFSS.

## III. PERFORMANCE EVALUATION

The simulation results of scatter parameters are showed in Fig. 2 (a) ~ (c). The mutual coupling can be obtained directly from  $S_{21}$ . Those figures reveal that the  $S_{21}$  decreases as the inter-element space increases. By comparing the scatter parameters of different cases,

the C.2 array has a lower mutual coupling than the other cases with the same inter-element distance. So the C.2 structure will be the best choice. And if choosing C.2 at  $W_c = 38.3\text{mm}$  ( $0.3\lambda$  at 2.35 GHz), we will gain better mutual coupling at the cost of a width of 6.3 mm. Since there is no significant improvement of performance, we select the C. 2 with  $W_c = 32\text{mm}$  as the final configuration. The measured scatter parameters are shown in Fig. 2 (d). As the coaxial cable serves as a radiating part of the antenna, the measured scatter parameters are slightly different from the simulation.

The correlation coefficients of all the three cases at the inter-element space of  $0.25\lambda$  are shown in Fig. 3. They are calculated from S-parameter by the formula [7]

$$\rho = \frac{|S_{11}^*S_{12} + S_{21}^*S_{22}|^2}{(1-|S_{11}|^2 - |S_{21}|^2)(1-|S_{22}|^2 - |S_{12}|^2)} \quad (1)$$

The C.2 design demonstrates the lowest correlation coefficient. And we can find out the relationship between the mutual coupling and the correlation coefficient, i.e., that a lower mutual coupling corresponds to a lower correlation coefficient. Generally speaking, to obtain the characteristic of diversity, we need  $\rho < 0.5$  for the mobile handset applications [3]. So the correlation coefficient of C.2 indicates a very good diversity performance since it is less than -20 dB in the operating frequency band. The measured correlation coefficient for C.2 at  $W_c=32$  mm is also presented in Fig. 3. Though measured result is slightly higher than the simulation, it still shows a good diversity performance.

The capacity loss (in the case of high SNR) of all cases at  $W_c=32$  mm are calculated from the equation [8] shown below, and the detailed coefficient can get from [6]

$$C_{loss} = -\log_2 \det(\boldsymbol{\psi}^R) \quad (2)$$

As shown in Fig. 4, C.2 demonstrates the lowest capacity loss because of the lowest correlation coefficient. The measurement capacity loss is below 0.7 bits/s/Hz, similar to the simulation.

The calculated radiation pattern (Fig. 5) at 2.35 GHz of a single element in the MIMO array is compared to the pattern (Fig. 6) of an isolated antenna element. The effect of mutual coupling causes the change of antenna patterns. This change is good for diversity performance since signal channels are in different directions, and tends to decrease the correlation between two closely spaced antenna elements.

#### IV. CONCLUSION

A compact broadband MIMO antenna array is developed in this paper. The omnidirectional radiation pattern of the antenna elements allows the array to receive a wide range of multipath signals, thus increases the SNR of MIMO systems. It is found by simulation and measurement that the array has an excellent performance under the MIMO propagation environment in a wide bandwidth (more than 40% at 2.1GHz) with the correlation coefficient below -15 dB and the capacity loss less than 0.7 bits/s/Hz. The total size is only  $50\text{mm} \times 67.2\text{mm} \times 0.254\text{mm}$ , suitable for the mobile handset applications.

#### Acknowledgement

This work was supported by the NSFC (60871061), the GDSF (8151064101000085), and the SRFDP (20080561).

## References

- [1] Browne, D. W., M. Manteghi, et al. (2006). "Experiments With Compact Antenna Arrays for MIMO Radio Communications." *Antennas and Propagation, IEEE Transactions on* 54(11): 3239-3250.
- [2] Browne, D. W., J. Guterman, et al. (2007). *Experimental Validation of Capacity Preserving Design for MIMO Arrays. Antenna Technology: Small and Smart Antennas Metamaterials and Applications, 2007. IWAT*
- [3] Vaughan, R. G. and J. B. Andersen (1987). "Antenna diversity in mobile communications." *Vehicular Technology, IEEE Transactions on* 36(4): 149-172.
- [4] Li, R., B. Pan, et al. (2007). "A Compact Broadband Planar Antenna for GPS, DCS-1800, IMT-2000, and WLAN Applications." *Antennas and Wireless Propagation Letters, IEEE* 6: 25-27.
- [5] Cheng-Jung, L., M. Achour, et al. (2008). Compact metamaterial high isolation MIMO antenna subsystem. *Microwave Conference, 2008. APMC 2008. Asia-Pacific.*
- [6] Sung Ho, C., O. Se-keun, et al. (2007). "Analysis of Mutual Coupling, Correlations, and TARC in WiBro MIMO Array Antenna." *Antennas and Wireless Propagation Letters, IEEE* 6: 122-125.
- [7] S. Blanch, J. Romeu, and I. Corbella, "Exact representation of antenna system diversity performance from input parameter description," *Elec-tron. Lett.*, vol. 39, pp. 705–707, May 2003.
- [8] Hyundong, S. and L. Jae Hong (2003). "Capacity of multiple-antenna fading channels: spatial fading correlation, double scattering, and keyhole." *Information Theory, IEEE Transactions on* 49(10): 2636-2647.

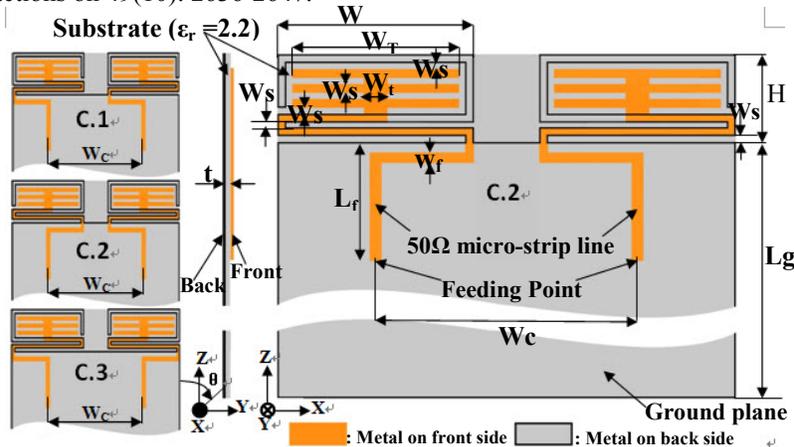
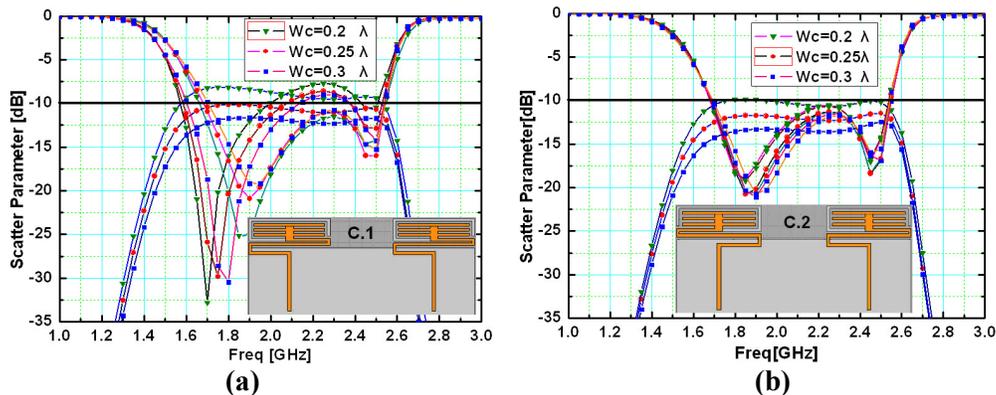
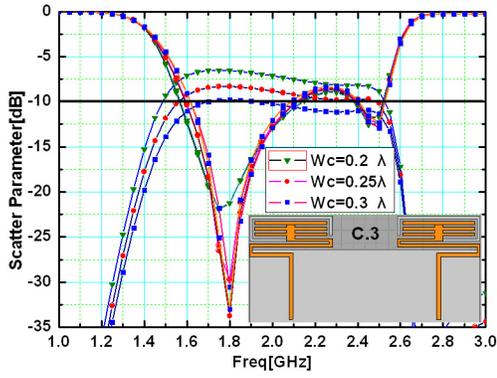
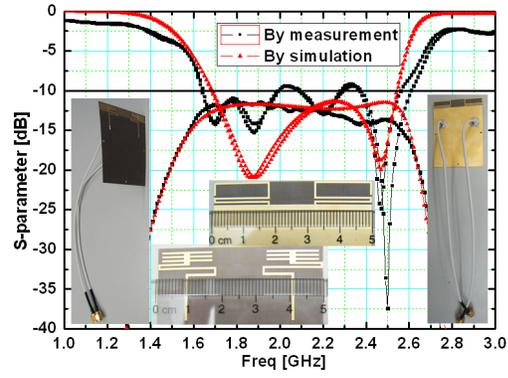


Fig.1. The configurations of C.1, C.2, and C.3. The inter-element space  $W_c$  varies from 25.6mm to 38.3mm ( $0.2\sim 0.3\lambda$  at 2.35 GHz), and the other geometrical parameters are  $H=7.2\text{mm}$ ,  $W=18\text{mm}$ ,  $W_f=15.6\text{mm}$ ,  $W_s=0.6\text{mm}$ ,  $w_t=1.8\text{mm}$ ,  $w_f=0.75\text{mm}$ ,  $t=0.254\text{mm}$ ,  $L_g=60\text{mm}$  and  $L_f=15\text{mm}$ .





(c)



(d)

Fig. 2. Simulated S-parameters of three different cases C.1 (a), C.2 (b), and C.3 (c), with measured S-parameter of C.2 at  $W_c = 32\text{mm}$  ( $0.25\lambda$  at  $2.35\text{GHz}$ ) (d).

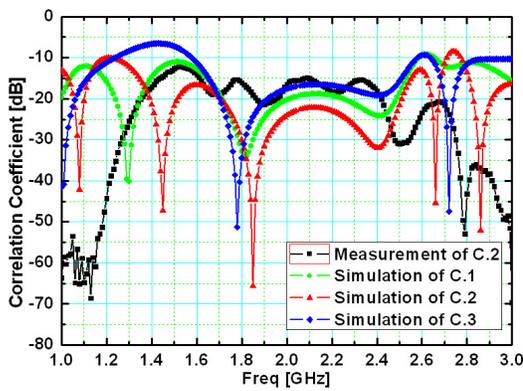


Fig. 3. Simulated correlation coefficient for C.1, C.2, and C.3 at  $W_c=32\text{ mm}$ , and measured result for C.2 at  $W_c=32\text{ mm}$ .

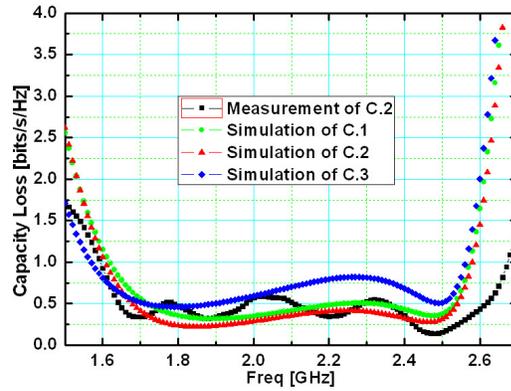


Fig. 4. Simulated capacity loss for C.1, C.2, C.3. at  $W_c=32\text{mm}$ , and measured result for C.2 at  $W_c=32\text{mm}$ .

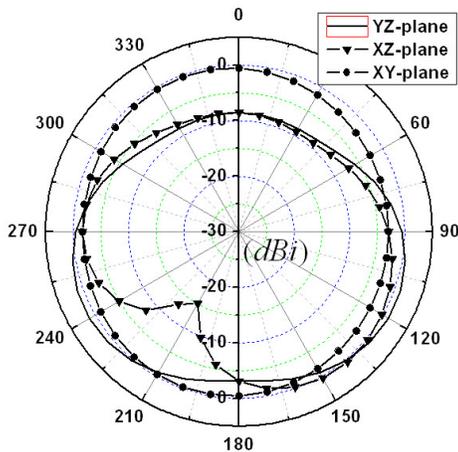


Fig. 5. Calculated radiation pattern at  $2.35\text{ GHz}$  of a single element in the MIMO array.

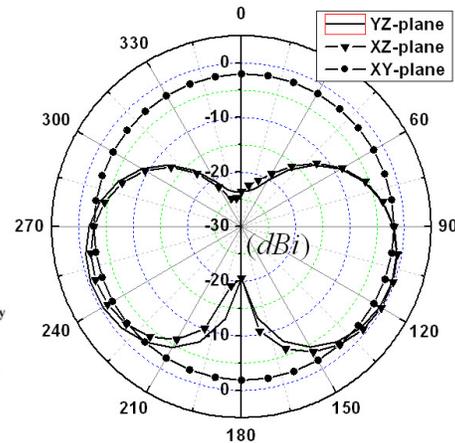


Fig. 6. Calculated radiation pattern at  $2.35\text{ GHz}$  of an isolated antenna element.