Isolation enhancement of MIMO system using metamaterial zeroth-order resonant antennas

#Hojun Choi , Bomson Lee
Department of Electronics & Radio engineering, Kyung Hee University
1 Seochun-dong, Giheung-gu, Yongin-si, Gyeonggi-do 446-701, Republic of Korea
bomson@khu.ac.kr

Abstract

In this paper, a MIMO antenna system consisting of two types of MTM (Metamaterial) ZOR (Zeroth-Order Resonant) antennas is proposed and its performances are evaluated in terms of isolation between antenna elements and envelope correlation between the two radiation patterns. The resonant frequency of the each antenna element is 2.22 GHz. The isolation of the proposed MIMO antenna is 28.2 dB at 2.22 GHz and the envelope correlation is 0.0002. Owing to these relatively good performances, each antenna may be regarded to operate almost independently. Furthermore, the sizes of the proposed antenna elements are significantly small due to the use of ZOR antennas. The ENG (Epsilon-NeGative) ZOR antenna size is 16.5×7.1 mm ($0.121\times0.052\ \lambda$ at 2.2 GHz) and the MNG (Mu-NeGative) ZOR antenna size is only 7.5×7.1 mm ($0.055\times0.052\ \lambda$ at 2.2 GHz). These results are also compared with those of other representative MIMO antennas.

1. Introduction

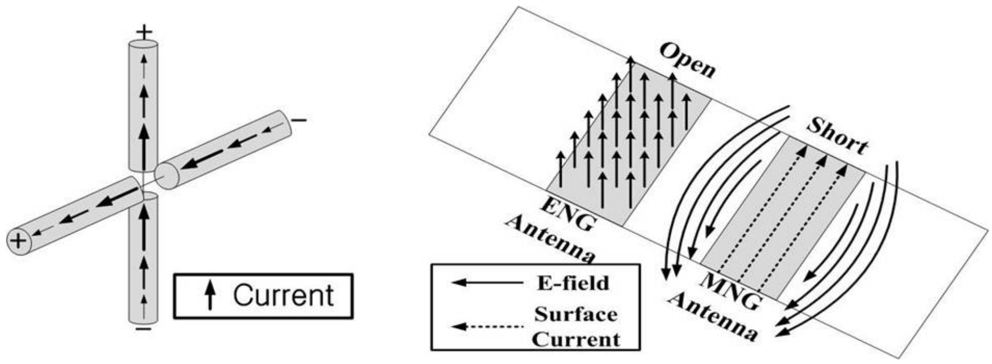
Isolation between multiple antenna elements has been considered as one of the most important issues in the design of Multi Input Multi Output (MIMO) antenna system [1]. Conventionally, a lot of research for improving the isolation has focused on using the space between antenna elements and the components such as isolators, decoupling networks, and so on. To achieve a high isolation, antennas must be placed far away from each other [2]. The isolation can be improved using an isolator that employs single-negative magnetic metamaterial based on SRR between two antennas [3] or using a decoupling network [4].

In this paper, a MIMO antenna system using different types of the zeroth-order resonant (ZOR) antennas is proposed. One ZOR antenna type is the epsilon negative (ENG) and the other one is the mu negative (MNG). The ZOR antennas have the advantage of compact size. It is well known that a ZOR metamaterial line can be made as small as possible. The proposed antenna is designed on a PCB, using only two ZOR antennas without additional components or circuits. The proposed antenna is shown to have very low envelope correlation and high isolation.

This paper is organized as follows. Section 2 gives a motivation, methodology, and design of the proposed MIMO antenna. In Section 3, the performances of the MIMO antenna are evaluated by S-parameters, radiation patterns, and envelope correlations [5-6]. Finally, conclusion and summary follow in section 4.

2. MIMO antenna design

Figure 1 (a) shows two dipole antennas positioned orthogonally in order to increase the isolation between them. Since the polarization states of two dipole antennas are orthogonal, interference of between two antennas is very small. We expect to have a similar effect with much smaller antenna elements than the dipole ones. Figure 1 (b) shows the MIMO antenna system implementing the almost identical methodology. Since the ENG antenna has an open termination and propagation constant β is zero, the series current levels stay low and the electrical fields in the entire area vertically oscillates in the same manner. The MNG antenna has a short termination and the current flows horizontally. The electric fields generated by this current oscillate horizontally as shown in figure 1 (b). For this reason, the interference between two antenna elements becomes very small. Figure 2 shows the geometry of the proposed antennas. The left one is the open terminated ENG ZOR antenna designed at 2.4 GHz. The right one is the short terminated MNG ZOR antenna designed at 2.4 GHz. The antennas are fed by two 50 Ω microstrip lines of width 7.5 mm on a Teflon substrate (ε_r: 2.2, height: 2.37 mm). The electrical length *kd* of the unit cell is π/6 radians and the characteristic impedance (Z_c) is 50 Ω. Using the design equations [7-9], L_0 = 6.2 nH for ENG antenna and C_0 = 2.5 pF for MNG antenna.



(a) (b)

Figure 1: (a) Two dipole antennas positioned orthogonal
(b) Electric field and surface current on the proposed MIMO system

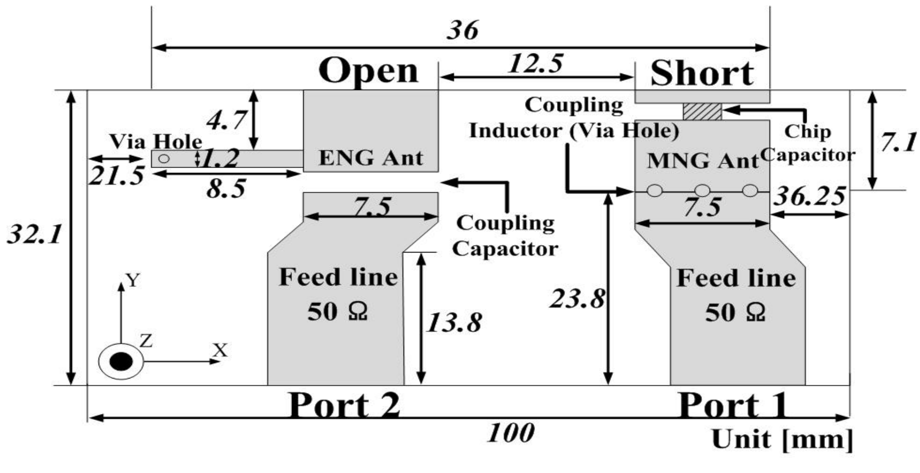


Figure 2: Geometry of the proposed MIMO antenna

3. Performances of proposed MIMO antenna system

The proposed ENG and MNG antennas are fed by microstrip lines using a gap capacitor and via holes in order to satisfy the matching condition, respectively. A new resonant frequency (f_1) of the proposed antennas is 2.2 GHz [7-9]. We compared the proposed antenna with other three type antennas. 'A' antenna is a dual inverted-F one included in a MIMO system [2]. 'B' antenna is using single-negative magnetic metamaterials for MIMO applications [3]. 'C' antenna uses a decoupling method [4]. The characteristics and specifications of these antennas and the proposed antenna are summarized in Table 1.

Table 1: Comparison of MIMO antenna characteristics

	A type [2]		B type [3]		C type [4]		Proposed antenna	
	Port 1	Port 2	Port 1	Port 2	Port 1	Port 2	Port 1	Port 2
Antenna size	0.5X0.25X0.05 λ_0		0.125x0.77x0.27 λ_0		0.32X0.04 λ_0		0.26X0.23 λ_0	
Antenna spacing	0.5 λ_0		0.125 λ_0		0.16 λ_0		0.09 λ_0	
f_R [GHz]	3		1.24		2.4		2.22	
$\|S_{11}\|$ [dB]	Near -25		Near -11		Near -18		-11.1	
$\|S_{21}\|$ [dB]	-16.5		Below -40		-20		-28.2	
ρ_e (Envelope correlation) [5-6]	Not mentioned		Near 0		Below 0.05		0.0002	
Gain [dBi]	4.85 (each antenna)		5.6	5.6	3.39	3.51	3.92	2.82
Radiation Efficiency [%]	Not mentioned		60	60	Not mentioned		83.1	97.7

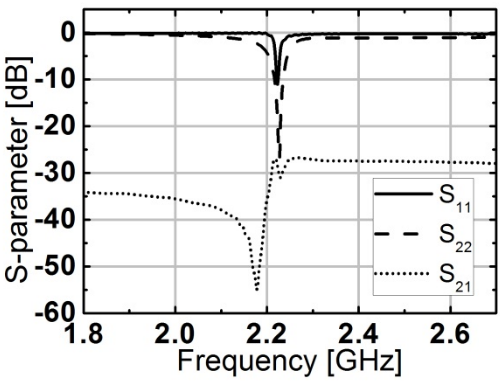


Figure 3: EM-Simulated S-parameter of the proposed MIMO antenna

Figure 3 shows $|S_{11}|$, $|S_{22}|$, and $|S_{21}|$ based on the EM-simulated results. Their new resonant frequencies are 2.22 GHz. The isolation of the proposed MIMO antenna is shown to be 28.2 dB. Compared with A-type antenna, the isolation of the proposed antenna is 11.7 dB higher. In addition, the proposed antenna size is smaller than A-type antenna. Although the isolation of the B-type antenna is 11.8 dB higher than the proposed antenna, the structure of the B-type antenna is very bulky. Compared with C-type antenna, the isolation of the proposed antenna is 8.2 dB higher. The envelope correlation [5-6] of proposed antenna is 0.0002. Because the polarization state of each proposed is almost orthogonal, these phenomena happen. The radiation efficiencies of the proposed antenna elements are shown to be high (83.9% for MNG and 97.7% for ENG).

In Figure 4, the radiation pattern (in XZ plane) of ENG (or MNG) element together with the other one (but treated with a matched load) is shown to be similar to the radiation pattern of only the ENG (or MNG) element.

4. Conclusion

In this paper, a MIMO antenna with isolation enhancement using two different types of the ZOR antennas for mobile handsets is presented. The polarization states of the proposed two antenna elements have been evaluated to be almost orthogonal. The isolation of the proposed antenna is 28.2 dB and the envelope correlation is 0.0002. Lower envelope correlation and higher isolation will help antenna elements provide independent channels in the MIMO applications. The size of the proposed antennas is small. The ENG ZOR antenna size is only 16.5×7.1 mm ($0.121\times0.052\ \lambda$ at

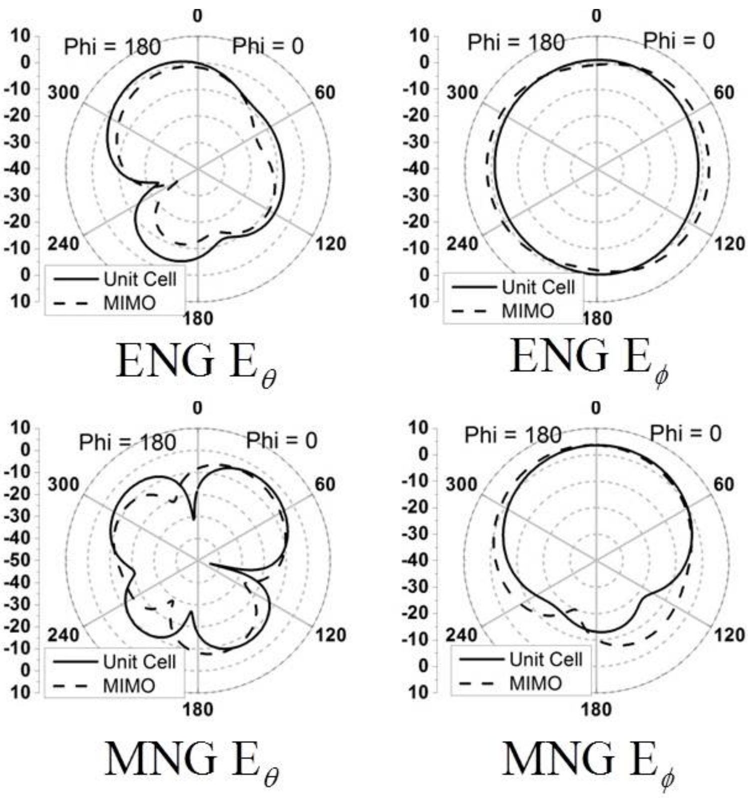


Figure 4: EM-simulated radiation patterns (E_θ,E_ϕ) of the proposed MIMO antenna in XZ plane

2.2 GHz) and MNG ZOR antenna size is only 7.5$\times$7.1 mm (0.055$\times$0.052 λ at 2.2 GHz). Besides, the proposed MIMO system doesn't require any additional components and circuits between antenna elements. We may expect a great potential for the proposed MIMO antennas based on MTM ZOR phenomenon.

References

[1] R. G. Vaughan, J. B. Andersen "Antenna diversity in mobile communications", IEEE Transactions on Vehicular Technology, vol. 36, No. 4, pp. 149-172, November, 1987.

[2] Mustafa K. Taher Al-Nuaimi, William G. Whittow "Performance Investigation of a Dual Element IFA array at 3GHz for MIMO Terminals", Antennas and Propagation Conference(LAPC), pp. 1-5, November, 2011.

[3] Bait-Suwailam. M. M, Boybay M. S, Ramahi. O. M "Electromagnetic Coupling Reduction in High-profile Monopole Antennas Using Single-Negative magnetic Metamaterials for MIMO Applications", IEEE Transaction on antennas and propagation, vol. 58, No. 9, pp.2894-2902, September, 2010.

[4] Juman Kim, Minseok Han, Changho Lee, Jaehoon Choi "Dual band MIMO antenna using a decoupling network for WLAN application", ICACT 2011, pp.624-627, February, 2011.

[5] R. G. Vaughan "Signals in Mobile Communications: A review", IEEE Transactions on Vehicular Technology, vol. 35, No. 4, pp.133-145, 1986.

[6] J. Blanch, J. Romeu and I. Cordella "Exact Representation of Antenna System Diversity Performance from Input Parameter Description", Electronics Letters, vol. 39, pp.705-707, 2003

[7] Christophe Caloz, Tatsuo Itoh, Andre Rennings "CRLH metamaterial leaky-wave and resonant antennas", Antennas and propagation magazine, Vol. 50, No. 5, pp.25-39, October, 2008.

[8] T.-G. Kim, B. Lee "Metamaterial-based compact zeroth-order resonant antenna", Electronics Letters, Vol.45 , No. 1, pp.12-13, January, 2009.

[9] S. Jang, B. Lee "Modelling and design of resonant one-dimensional metamaterial-based trans mission lines for antenna applications", IET Microwaves, antennas & propagation, Vol.5, No. 13, pp.1529-1536, October, 2011.