JOURNAL OF THE KOREAN INSTITUTE OF ELECTROMAGNETIC ENGINEERING AND SCIENCE, VOL. 10, NO. 4, DEC. 2010 JKIEES 2010-10-4-17

Improving the Isolation of MIMO Antennas Using Split Ring Resonators

Youngki Lee · Haeil Chung · Jaehoon Choi

Abstract

This paper proposes a method for improving the isolation characteristic of multi-input multi-output (MIMO) antennas using a split ring resonator (SRR) array structure between the two radiating elements. The fabricated antenna satisfies the 10 dB return loss requirement in the Mobile-WiMAX frequency band from 3.4 GHz to 3.6 GHz. The isolation between the two radiating elements is improved by approximately 20 dB at the center frequency by inserting a SRR array structure. The measured peak gains of the two elements are 2.3 dBi and 2.4 dBi, respectively.

Key words: MIMO, Split Ring Resonator, Isolation Characteristic, Metamaterial.

Ⅰ. Introduction

Current mobile communication systems require high data rates and large channel capacity in order to satisfy the various demands of users. A MIMO antenna system has a higher data rate and larger channel capacity compared with a conventional wireless system. A MIMO system is therefore a suitable candidate for fourth generation mobile communication systems requiring high speed and quality transmissions involving large amounts of data transfer. In the MIMO system, two or more antennas are used on both the transmitter and receiver sides. However, the antenna elements are strongly coupled with each other, as well as with the ground plane, because they share the common surface current [1]. Several techniques have been introduced to improve the isolation characteristic, such as using the resonating slot on the ground plane [2] and using the isolation elements between the radiating elements [3]. However, these techniques limit the available space for other system components and do not guarantee a uniform radiation pattern. A metamaterial technique [4] might be a good candidate for overcoming some of these drawbacks.

Metamaterials can be defined as man-made homogeneous electromagnetic structures with unusual properties that are not readily available in nature. When electrical property has negative permeability or negative permittivity ($\mu<0$ or $\varepsilon<0$), the medium has an evanescent wave. An evanescent wave is an electromagnetic wave that decays exponentially with distance. Negative permittivity and permeability materials can usually be obtained using the wire and split ring resonator (SRR) at a specific frequency band. The resonance frequency is determined by the capacitance and inductance of the structure [5].

This paper proposes a method for improving the isolation performance of a MIMO antenna for the Mobile-WiMAX frequency band using the negative permeability property of an SRR array structure.

Ⅱ. Antenna Design and Performances

2-1 Antenna Structure

The configuration of the proposed MIMO antenna is shown in Fig. 1. The antenna was implemented on two FR4 substrates (ε_r=4.4) of different thicknesses; it consisted of two radiating elements, the ground plane, and the SRR array structure. The radiating elements and ground plane were printed on a 0.8-mm-thick FR4 substrate (sub #1). The two radiating elements of the MIMO antenna were symmetrically printed with respect to the center and were placed near the corners of the top edge of the ground plane.

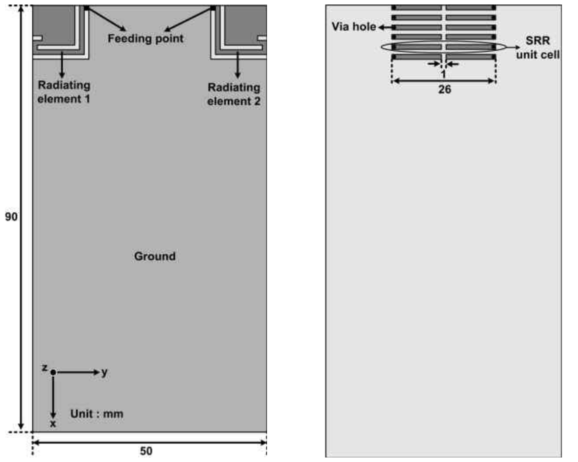
As shown in Fig. 1(d), each radiating element was a 9×10 mm rectangular shape with an L-shaped slit. The unit cell of the SRR is illustrated in Fig. 1(e). The SRRs were printed on the top and bottom surfaces of the 1.6 mm thick FR4 substrate (sub #2). The top and bottom surfaces of the SRRs were connected via holes. The SRR array structure consisted of six unit cells with dimensions of 1×26×1.6 mm. The distance between two adjacent unit cells was 1 mm. Sub #2 was located beneath sub #1, including the two MIMO antenna elements and the ground plane. The total antenna volume, including the two substrates, was 50×90×2.4 mm.

2-2 Impedance Bandwidth and Isolation

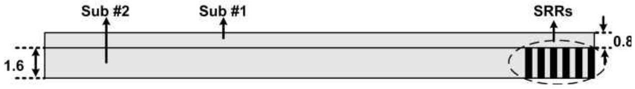
Fig. 2 shows the simulated return loss characteristics of

Manuscript received November 4, 2010 ; revised December 6, 2010. (ID No. 20101104-033J)

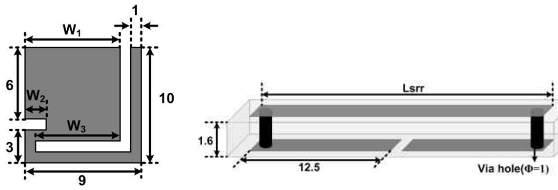
Dept. of Electronics and Computer Engineering, Hanyang University, Seoul, Korea
Corresponding Author : Jaehoon Choi (e-mail :choijh@hanyang.ac.kr)



(a) Top view (b) Bottom view



(c) Side view

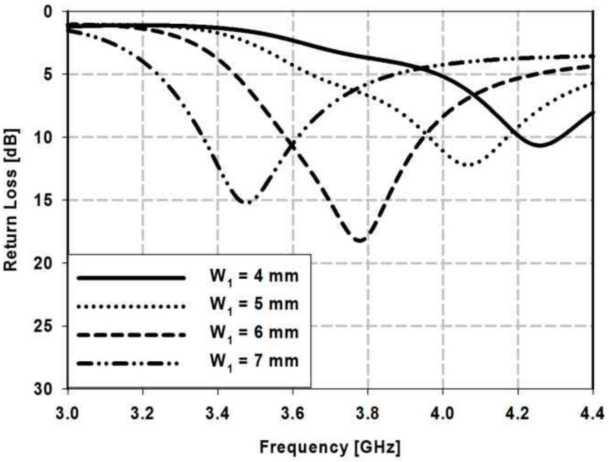


(d) Radiating element (e) SRR unit cell structure

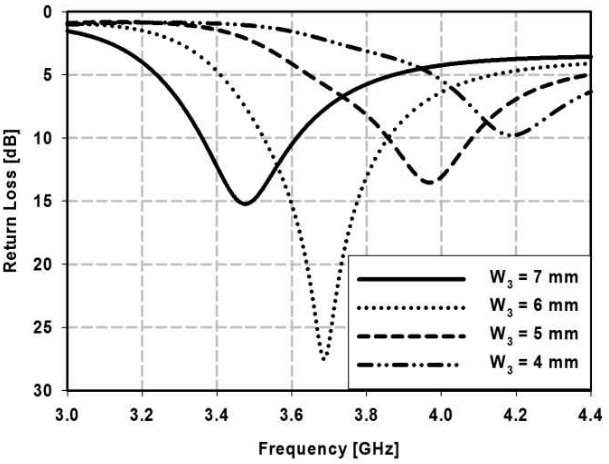
Fig. 1. Structure of proposed MIMO antenna.

the proposed antenna. When the slit width (W_1) of the patch and the width (W_3) of the L-shaped slit were increased, the resonance frequency shifted toward a lower frequency band. By adjusting the width (W_2) of the additional slit, the impedance matching was improved and the wideband operation characteristic was realized. Good impedance matching over the Mobile-WiMAX can be achieved by adjusting the sizes of the L-shaped slit and the additional slit.

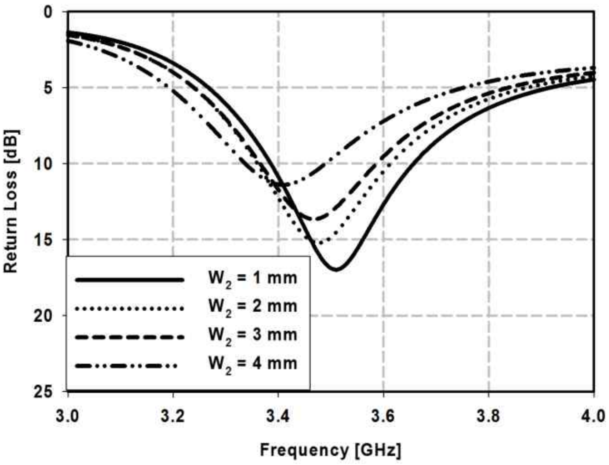
Fig. 3 (a) and (b) show the effective permeability of the SRR array structure and the isolation characteristics of a MIMO antenna for various lengths of SRR. The effective permeability was extracted using the method defined in [6, 7]. Choosing the correct size of the SRR array structure is very important because the resonant frequency is dependent on the length of the SRR array structure. As the length increaseds, the frequency band of negative permeability shifts to a lower frequency band. Also, the frequency band for isolation improvement shifts to the lower frequency side as the length of the SRR array was increased.



(a) Variation in W_1



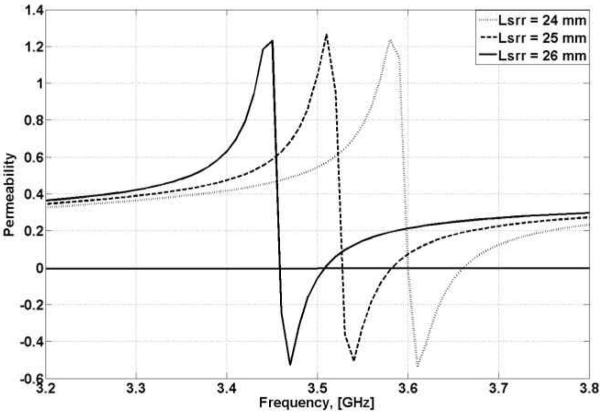
(b) Variation in W_3



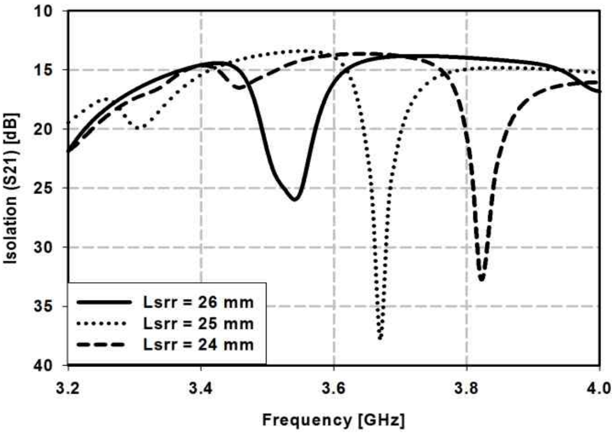
(c) Variation in W_2

Fig. 2. Simulated return loss characteristics for different design parameter values.

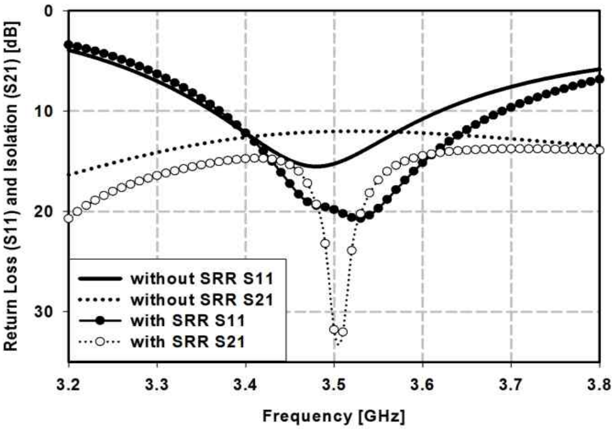
The simulated s-parameters with and without the SRR array structure are illustrated in Fig. 3(c). It is obvious that the addition of the SRR array structure improved the isolation characteristic. The designed antenna had a 10 dB return loss bandwidth from 3.38 GHz to 3.7 GHz, and an isolation of higher than 20 dB on the center frequency band. It had a negative permeability value at 3.5 GHz, so the wave could not propagate at this frequency.



(a) Effective permeability for variation in Lsrr



(b) Isolation for variation in Lsrr



(c) S-parameters for with and without SRR

Fig. 3. Simulated effective permeability and S-parameter characteristics.

Although the proposed antenna had an isolation higher than 12 dB without the SRR array structure, the isolation can be improved by approximately 20 dB at 3.5 GHz by adding it.

(a) With SRR array structure

(b) Without SRR array structure

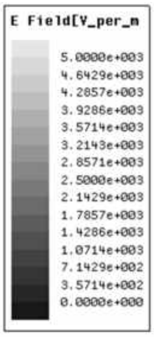


Fig. 4. Simulated field distribution.

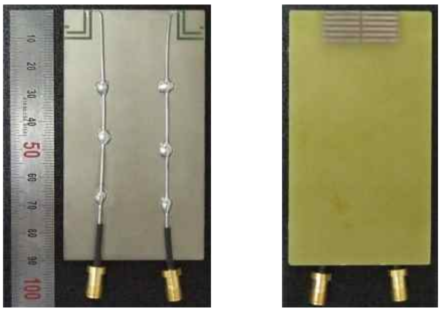
To investigate the effect of the SRR array structure on the isolation characteristic, the field distributions at 3.5 GHz with and without the SRR array structure were calculated and are shown in Fig. 4. When one of the two elements was excited, a strong field was induced at the other element in the absence of an SRR array structure. After the SRR array structure was added, the induced field on the non-excited element became very weak. The antenna structure was designed and analyzed using a high frequency structure simulator (HFSS V11.1) [8].

Ⅲ. Results

A photograph of the fabricated antenna is shown in Fig. 5. The measured and simulated return loss values in terms of frequency are compared in Fig. 6. The measured results were very similar to the simulated results. The fabricated antenna had a return loss greater than 10 dB and an isolation of higher than 15 dB over the whole Mobile-WiMAX band (3.4~3.6 GHz).

The measured radiation patterns of the two radiating elements of the designed MIMO antenna are shown in Fig. 7. The radiation patterns were symmetrical with respect to the x-axis, and each element had near omni-directional radiation patterns at the operating frequency.

As shown in Fig. 8, the measured peak gains of the two elements were 2.3 dBi and 2.4 dBi respectively at the operating frequency.



(a) Top view (b) Bottom view

Fig. 5. Photograph of fabricated MIMO antenna.

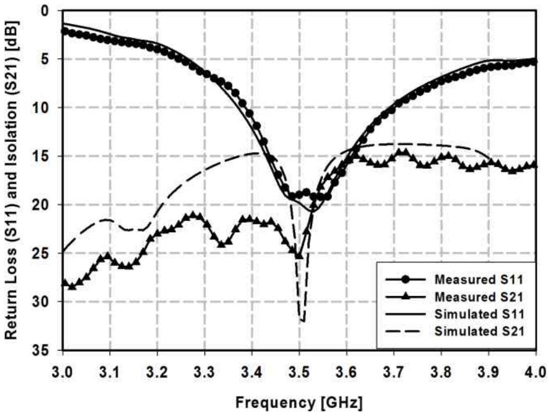
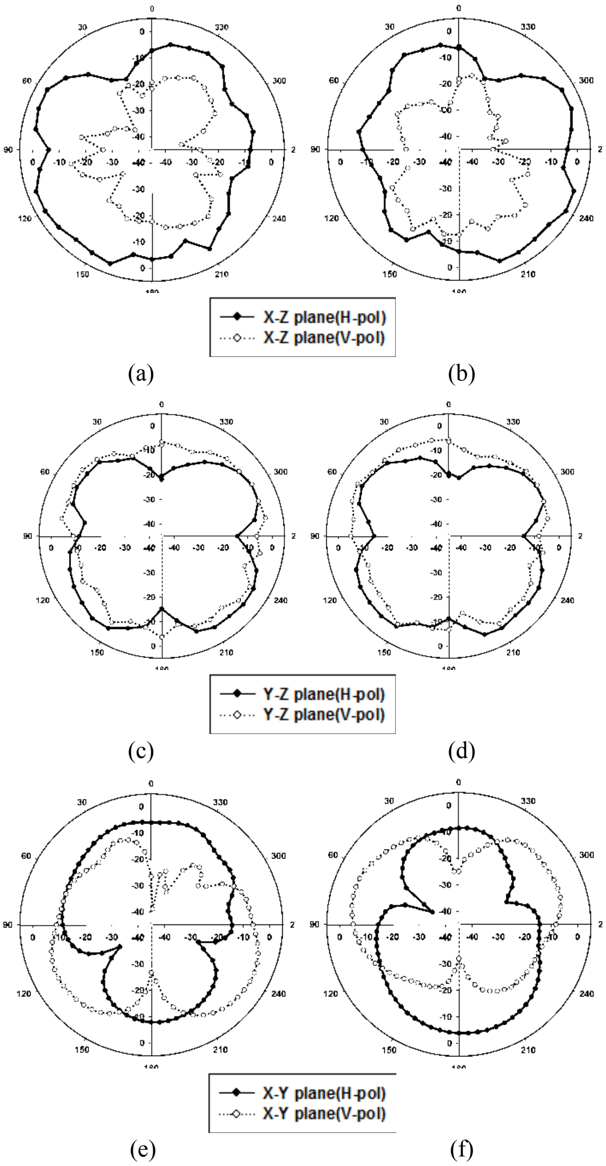


Fig. 6. Simulated and measured return loss and isolation characteristics.



(a) (b)

(c) (d)

(e) (f)

Fig. 7. Measured radiation pattern characteristic (a), (b), (c) radiation element 1 and (d), (e), (f) radiating element 2.

For diversity and MIMO application, the correlation between signals received at the same side of a wireless link by the involved antenna is an important figure of merit for the whole system. Usually, the envelope correlation coefficient (ECC) is used to evaluate the diversity capability of a multi-antenna system. This parameter should preferably be computed from 3D radiation patterns, but this method is laborious. Assuming that an antenna operates in a uniform multi-path environment, this parameter can alternatively be computed from its scattering parameters. The ECC of two antenna is given by [9].

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

Fig. 9(a) shows the ECC characteristics computed from scattering parameters. The ECC of two antenna was less than 0.08. Fig. 9(b) shows the measured mean effective gain (MEG) ratio of the proposed antenna. The measured MEG ratio was less than 1.12 dB over the whole Mobile-WiMAX band.

Ⅳ. Conclusion

In this paper, we proposed a method to improve the isolation characteristic of the MIMO antenna using an SRR. The proposed MIMO antenna consisted of two identical monopoles for Mobile-WiMAX (3.4~3.6 GHz) service. The SRR array structure was added between the two elements and placed beneath the ground plane to improve the isolation characteristic. The return loss was higher than 10 dB and the isolation characteristic was higher than 15 dB over the whole Mobile-WiMAX band. The measured peak gains of the two elements were 2.3 dBi and 2.4 dBi. The measured envelope correlation coefficient was less than 0.2, and the mean

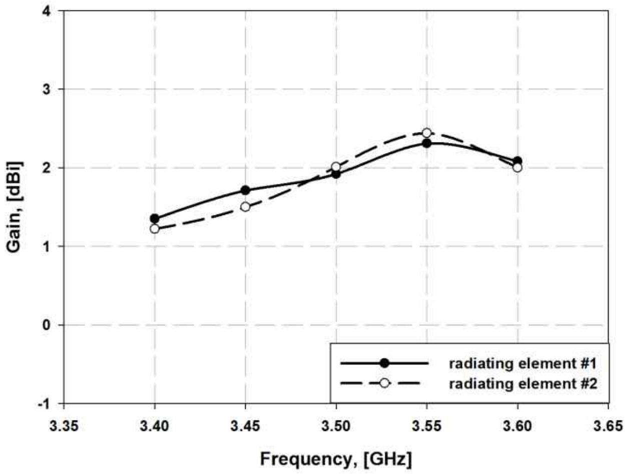
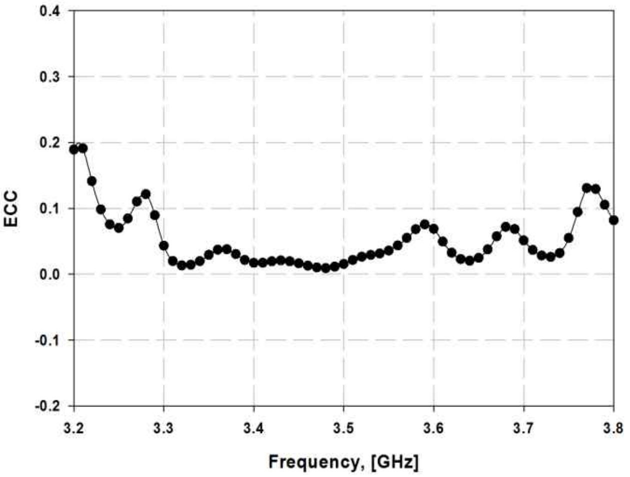
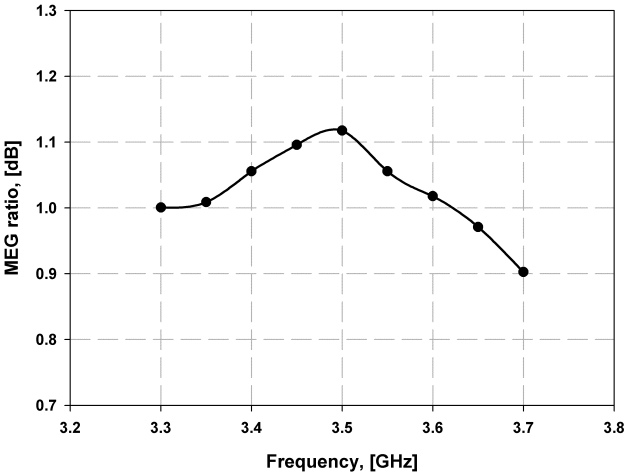


Fig. 8. Measured gain characteristics.



(a) ECC ration



(b) MEG ration

Fig. 9. Measured envelope correlation coefficient and mean effective gain ratio.

effective gain was less than 1.5 dB. Therefore, the SRR array structure can be used in MIMO antenna systems to obtain the high isolation characteristic necessary for mobile applications.

This work was supported by the IT R&D program of MKE/KCC/KEI. [KI002071, Study of technologies for improving the RF spectrum characteristics by using the meta-electromagnetic structure].

References

[1] D. A. Sanchez-Hernandez, *Multiband Integrated Antennas for 4G Terminals*, Artech House, Inc., 2008.

[2] K. Kim, K. Park, "The high isolation dual-band inverted F antenna diversity system with the small N-section resonators on the ground plane," *Microwave and Optical Technology Letters*, vol. 49, pp. 731-734, Mar. 2007.

[3] S. Hong, K. Chung, J. Lee, S. Jung, S. Lee, and J. Choi, "Design of a diversity antenna with stubs for UWB applications," *Microwave and Optical Technology Letters*, vol. 50, 1352-1356, May 2008.

[4] C. Hsu, K. Lin, H. Su, H. Lin, and C. Wu, "Design of MIMO antennas with strong isolation for portable applications," *Antennas and Propagation Society International Symposium*, pp. 1-4, 2009.

[5] R. Marqués, F. Martín, and M. Sorolla, *Metamaterials with Negative Parameters: Theory, Design and Microwave Applications*, Wiley Inter-Science, 2008.

[6] C. C. Courtney, "Time-domain measurement of the electromagnetic properties of materials," *IEEE Transaction on Microwave Theory and Techniques*, vol. 46, pp. 517-522, May 1998.

[7] R. W. Ziolkowski, "Design, fabrication, and testing of double negative metamaterials," *IEEE Transaction on Antennas Propagation*, vol. 51, pp. 1516-1529, Jul. 2003.

[8] Ansoft High Frequency Structure Simulator (HFSS), Ver.11.1, ANSYS Inc.

[9] S. Blanch, J. Romeu, and I. Cobella, "Exact representation of antenna system diversity performance from input parameter description," *Electronics Letters*, vol. 39, pp. 705-707, May 2003.

Youngki Lee

received a B.S. in Electrical Engineering from Ulsan University, Ulsan, Korea, in 2007. He also received an M.S. degree from the Department of Electronics and Computer Engineering at Hanyang University, Seoul, Korea, in 2009, where he is currently working toward his Ph.D. His research interests include antenna design, meta-material and wireless communication systems.

Haeil Chung

received a B.S. degree from Chungnam National University, Daejeon, Korea, in 2008. And he received an M.S. degree from the Division of Electrical and Computer Engineering at Hanyang University, Seoul, Korea, in 2010. His research interests include antenna design and wireless communication systems.

Jaehoon Choi

received a B.S. degree from Hanyang University, Korea, in 1980. He also received an M.S. degree and a Ph.D. degree from Ohio State University, Ohio, in 1986 and 1989, respectively. From 1989-1991, he was a research analyst with the Telecommunication Research Center at Arizona State University, Tempe, Arizona. He worked with Korea Telecom as a team leader in the Satellite Communication Division from 1991 to 1995. Since 1995, he has been a professor at the Department of Electronics and Computer Engineering, Hanyang University, Korea. His research is focused on the design of compact, multi-band antennas for mobile wireless communication, software defined radio (SDR) systems, and ultra-wideband (UWB) systems.