Design of an ENG-ZOR multiband antenna for GPS and WLAN MIMO system

Jeongpyo Kim, Haeil Chung, and #Jaehoon Choi
Div. of Electronics and Computer Engineering, Hanyang University,
17 Haengdang-dong, Seongdong-gu, Seoul, Korea, 133-791, choijh@hanyang.ac.kr
(#corresponding author)

1. Introduction

The rapid progress in personal and computer communication technologies demands integration of more than one communication system into a single compact module. To comply with this requirement compact high-performance multiband antennas with good radiation characteristics are needed. Various antennas were introduced for the global positioning system (GPS), the wireless local network area (WLNA) and mobile communication services [1-3]. The GPS and WLAN antennas are usually fabricated on a substrate with high dielectric constant to achieve the compact size. Recently, small antennas using meta-material techniques were introduced [4-5]. These antennas were constructed by a double negative zeroth order resonator (DNG-ZOR) [4] or an epsilon negative zeroth order resonator (ENG-ZOR) [5]. The performance of a ZOR utilizing the ENG unit cell was demonstrated by using an infinitesimal circuit model. The ENG-ZOR and the DNG-ZOR have the same zeroth-order resonance frequency where the permittivity of each ZOR is zero [5].

We propose an ENG-ZOR multiband antenna for GPS and WLAN MIMO systems. The proposed antenna consists of a dual band antenna for GPS and WLAN bands, a single band antenna for WLAN band, and a hairpin resonator to improve the isolation characteristic between the two antennas. Two antennas are fabricated by utilizing three ENG-ZOR unit cells with size of 5 mm × 5 mm. The dual band antenna has very compact size of 5 mm × 5 mm × 5 mm and the total volume of the antenna including the second WLAN antenna for MIMO is 40 mm × 5 mm × 5 mm.

2. Antenna Design

Fig. 1 shows the ENG-ZOR unit cell. The unit cell consists of two inductors for negative epsilon performance and a transmission line between the two inductors. The resonant frequency of the unit cell is fixed by two inductors and equivalent capacitor of transmission line and the impedance characteristic is controlled by adjusting the ratio of inductance values of two inductors [4]. The basic structure of the ENG-ZOR antenna is shown in Fig. 2. Because the length of the unit cell is fixed as 5 mm, the resonant frequency is determined practically by two inductors, L_{01} and L_{02}. Fig. 3 shows the structure of the proposed antenna. The antenna consists of a dual band antenna for WLAN and GPS services at port #1 and a single band antenna for WLAN service at port #2. For GPS band, L_{01} = 56 nH, L_{02} =150 nH and for WLAN band, L_{01} = 27 nH, L_{02} = 50 nH. Then, the dual band antenna at port #1 satisfies 10 dB return loss requirement from 1.557 GHz to 1.577 GHz and from 2.42 GHz to 2.45 GHz. The single band antenna at port #2 has the bandwidth from 2.4GHz to 2.45 GHz.

For the MIMO system in WLAN band, the good isolation performance between the two WLAN antennas is required. Fig. 4(a) shows the current distribution without a hairpin resonator at 2.4 GHz. Since the signal excited at port #1 flow to the WLAN antenna at port #2 through the ground edge, the value of isolation become about -11 dB, which is not enough for the MIMO system. In order to improve the isolation characteristic, a hairpin resonator with the line width of 0.5 mm and the gap of 0.2 mm over the ground edge is added between the two WLAN antennas. Fig. 4(b) shows that the current flow through the ground edge is interrupted by the added hairpin resonator. The isolation characteristics for the variable lengths of the hairpin resonator, W, are shown in Fig. 5. The isolation performance is improved more 10 dB at the resonant frequency of the hairpin resonator. When W = 20.5 mm, the isolation characteristic for the WLAN band is lower than -17 dB. The S-parameters of the designed antenna are shown in Fig. 6. The proposed antenna is simulated by CST-MWS [6].

3. Experimental Results

Fig. 7 shows the photograph of the fabricated antenna. The antenna was printed on FR-4 substrate with the relative permittivity of 4.4 and the thickness of 0.6 mm. The antenna was constructed on the upper portion of the substrate with the volume of 40 mm × 5 mm × 5 mm and the ground has size of 40 mm × 95 mm. Fig. 8 shows the measured S-parameters of the fabricated antenna. At port #1, the impedance bandwidths of the dual band antenna are from 1.555 GHz to 1.575 GHz at the GPS band and from 2.328 GHz to 2.45 GHz at the WLAN band for S_{11} lower than -10 dB, respectively. The single band antenna at port #2 has the impedance bandwidth of 130 MHz from 2.39 GHz to 2.52 GHz for S_{11} lower than -6dB. Although the two WLAN antennas use the same valued inductors, the resonant frequency of the antenna at port #1 is lowered due to effect of GPS antenna. The optimized antenna has L_{01} = 33 nH, L_{02} = 100 nH for GPS band and L_{01} = 12 nH, L_{02} = 47 nH for WLAN band. The isolation at WLAN band is lower than -16 dB, which is improved about 5 dB by using the hairpin resonator over the isolation value without resonator. The measured peak gain of the fabricated antenna is -3.5 dBi at GPS band and -0.8 dBi ~ 1.5 dBi at WLAN band as shown in Fig. 9. Fig. 10 shows the measured radiation patterns of the designed antenna. Large cross polarization is observed for each operating frequency. It should be noted that this characteristic can be an advantage for indoor wireless communication applications.

4. Conclusions

We proposed an ENG-ZOR multiband antenna for GPS and WLAN MIMO systems. The proposed antenna consists of a dual band antenna for GPS and WLAN bands, a single band antenna for WLAN band, and a hairpin resonator to improve the isolation characteristic between the two antennas. Two antennas are fabricated by utilizing three ENG-ZOR unit cells with size of 5 mm × 5 mm. The dual band antenna has very compact size of 5 mm × 5 mm × 5 mm and the total antenna including the second WLAN antenna for MIMO has the volume of 40 mm × 5 mm × 5 mm. Because the hairpin resonator is printed between the two antennas, extra space is not required to improve the isolation characteristic. The measured peak gain of the designed antenna is -3.5 dBi at GPS band and -0.8 dBi ~ 1.5 dBi at WLAN band. The gain enhancement at GPS band needs to be studied further.

Acknowledgement
This work was supported by the IT R&D program of MKE/IITA. [2006-S-018-03, Design of a compact and multi band antenna for a mobile broadcasting service]

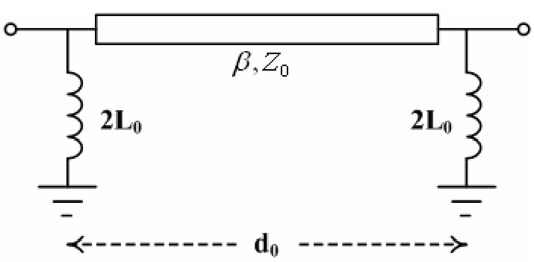


Fig. 1 ENG unit cell structure

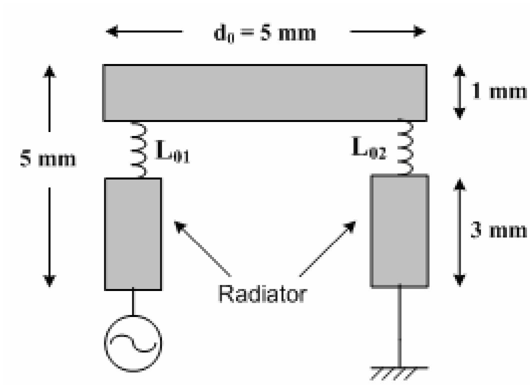


Fig. 2 Basic structure of the ENG-ZOR antenna

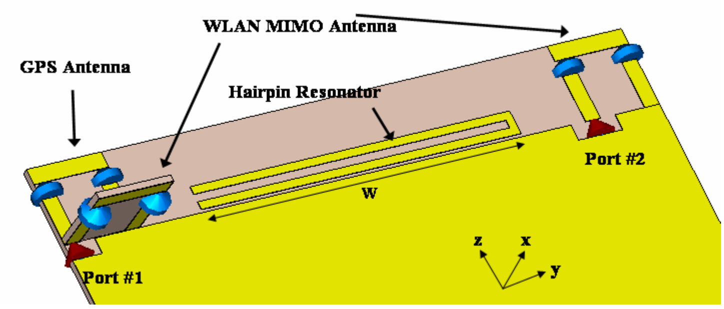
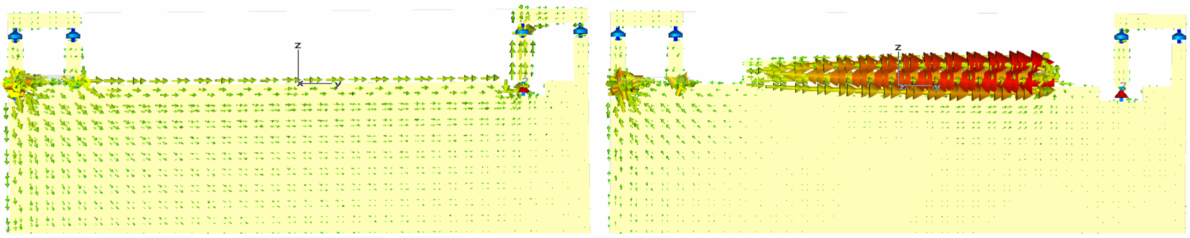


Fig. 3 Proposed antenna structure



(a) without a hairpin resonator (b) with a hairpin resonator

Fig. 4 Current distribution without / with a hairpin resonator

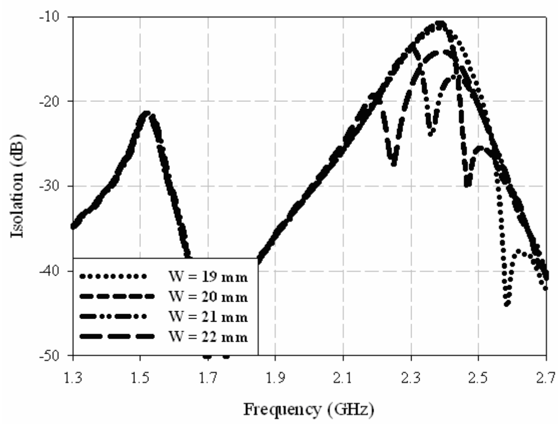


Fig. 5 Isolation characteristics for variable length W

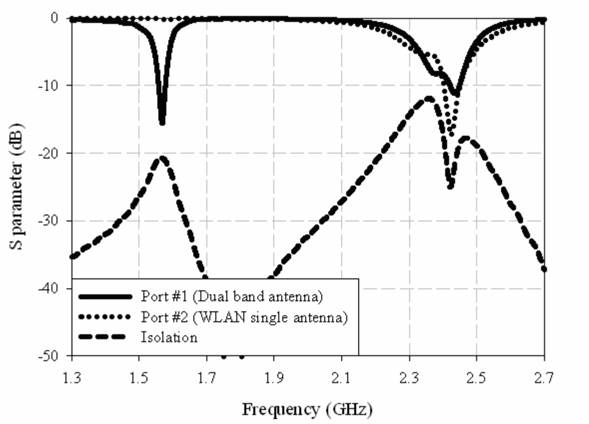


Fig. 6 S-parameter of the designed antenna

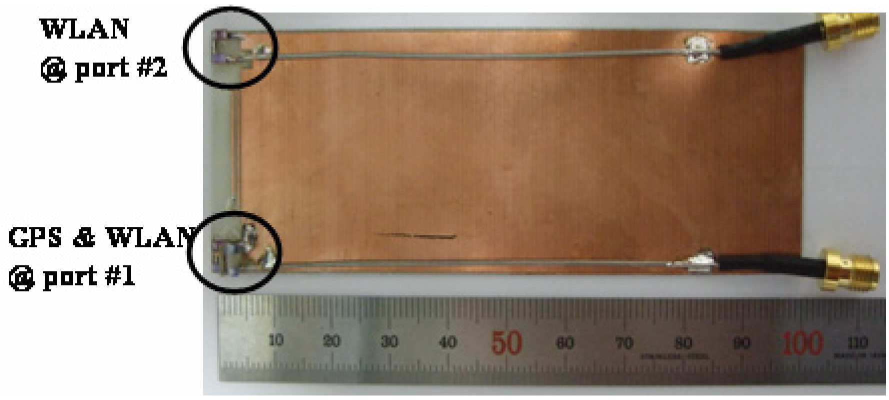


Fig. 7 Photograph of the fabricated antenna

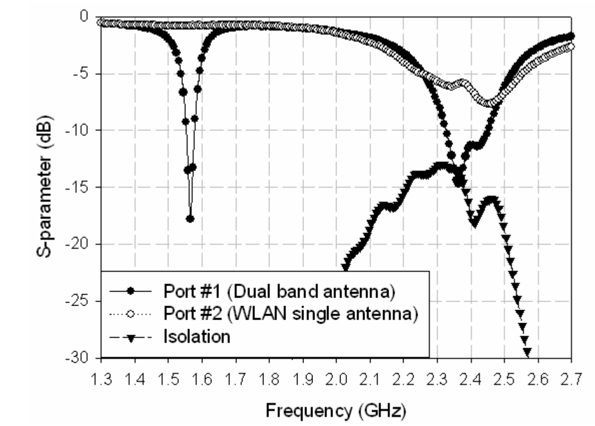


Fig. 8 Measured S-parameters of the fabricated antenna

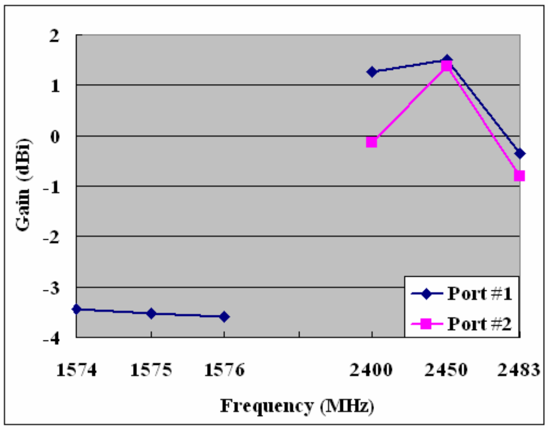
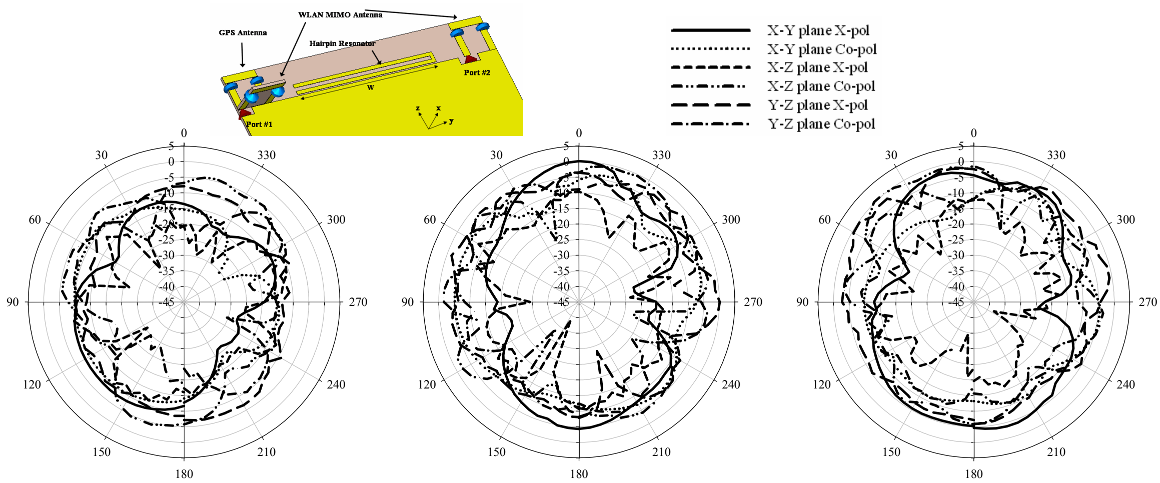


Fig. 9 Measured gain characteristics



(a) GPS @ port #1 (b) WLAN @ port #1 (c) WLAN @ port #2

Fig. 10 The measured radiation patters of the designed antenna

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