Design of Wideband Cylindrical Monopole Antenna

Joong-Chang Chun[1] · Jaeruen Shim[2] · Tae-Soo Kim[3]

Abstract

A new wideband cylindrical monopole antenna is presented for multiple band applications. Multiple band property of the proposed antenna is achieved by adjusting the coupling structure with steps between the antenna base and the ground plane. The measured −10 dB impedance bandwidths are 1.74∼3.06 GHz and 5.59∼10.62 GHz, which can cover various kinds of wireless services, such as PCS(1.75∼1.87 GHz), IMT-2000(1.92∼2.17 GHz), WiBro(2.3∼2.39 GHz), WLAN(2.412∼2.483 GHz, 5.725∼5.825 GHz), DMB(2.63∼2.655 GHz), High-band UWB(7.2∼10.2 GHz).

Key words : Cylindrical Monopole, Wideband Antenna, UWB, PCS, WLAN.

Ⅰ. Introduction

Wide band antennas are becoming more and more important for future wireless systems, so many approaches are investigated to increase the bandwidth of antenna, such as loading a small disk on the semi-circular disk[1], electromagnetically coupling shorting pins[2], and using orthogonal inverted triangular plates[3]. On the other hand, the planar types of monopole antennas are alternative structures due to its simplicity and efficiency. Typical types of planar monopole designs reported so far are circular disk[4], square plate[5], beveled square[6], and notched square[7]. Among them the notched square structure is most promising in the criterion of wide-band property.

It is well known that the larger the radius of monopole is, the wider the bandwidth becomes. But there exists the physical limitation. In this paper, we propose a new type of a cylindrical monopole antenna for multiple band wireless applications. The proposed monopole has a modified structure in the feeding part similarly as the notching for planar monopole antennas, so that the multi-band property is achieved by adjusting the coupling structure between the antenna base and the ground plane.

The measured results show that −10 dB impedance bandwidths are 1.74∼3.06 GHz and 5.59∼10.62 GHz, which can cover various kinds of wireless services, such as PCS(1.75∼1.87 GHz), IMT-2000(1.92∼2.17 GHz), WiBro(2.3∼2.39 GHz), WLAN(2.412∼2.483 GHz, 5.725∼5.825 GHz), DMB(2.63∼2.655 GHz), high-band UWB in South Korea(7.2∼10.2 GHz).

Ⅱ. Antenna Design and Fabrication

The proposed antenna structure is depicted in Fig. 1. New features are the stepped base part of the cylinder and the convex part of the ground plane. Basically, the radius of the monopole should be increased for the property of wide bandwidth. In this case, the lowest resonant frequency can be calculated as follows[8]:

$$f=\frac{7.2}{L+L_m+R+p}\ \text{(GHz)} \tag{1}$$

where L is the length of the cylinder including the modified base part with length L_m, R is the radius of the cylinder, p represents the gap at the feeding point, and

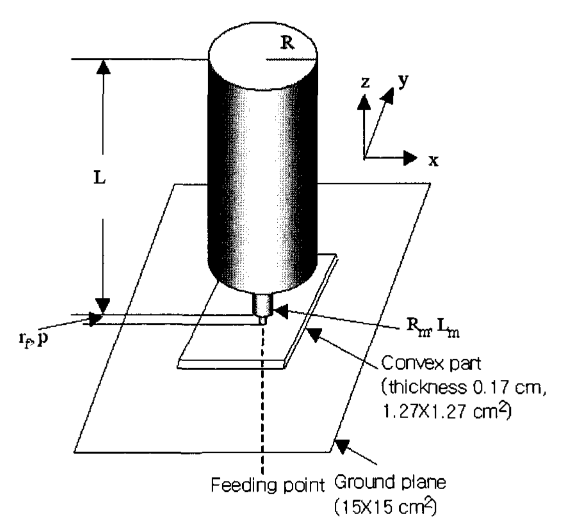

Fig. 1. Perspective view of the proposed cylindrical monopole antenna.

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[1]Department of Electronic Engineering, Jinju National University, Jinju, Korea.
[2]School of Digital Media, Pusan University of Foreign Studies, Busan, Korea.
[3]Department of Information Engineering, Uiduk University, Gyeongju, Korea.

all dimensions are in cm. In our work, we set L=3 cm, R=0.48 cm, p=0.2 cm, and r_f=0.06 cm where r_f is the radius of the feeding probe. These parameters give the resonant frequency of about 2.06 GHz. The convex part of the ground plane has the size of 1.27×1.27 cm with thickness 0.17 cm.

Parameters, L_m and R_m, are optimized through iterated simulations with the commercially available CST software, where R_m is the radius of the stepped part of the monopole. The simulation results for the variation of L_m with a fixed radius R_m=0.15 cm are shown in Fig. 2. Fig. 3 depicts the effect of R_m on the return loss when the length L_m is fixed as 0.3 cm. We can see that dimensions of L_m and R_m play an important role in determining the impedance bandwidth, particularly for the higher frequency band. Finally, we have obtained the optimum values of L_m=0.3 cm, R_m=0.15 cm. and the fabricated antenna with brass is shown in Fig. 4.

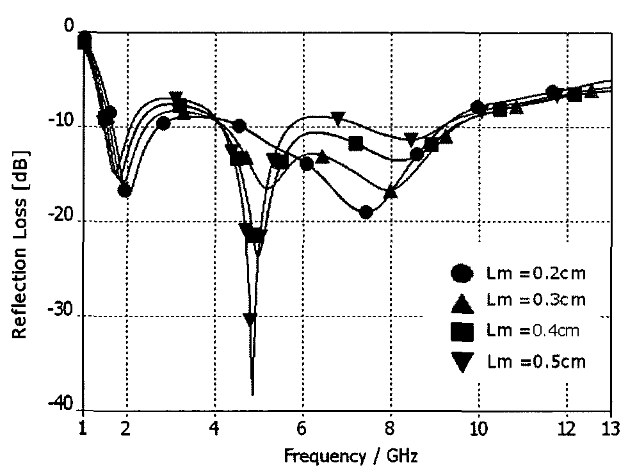


Fig. 2. Simulation results for the variation of the length L_m with R_m=0.15 cm.

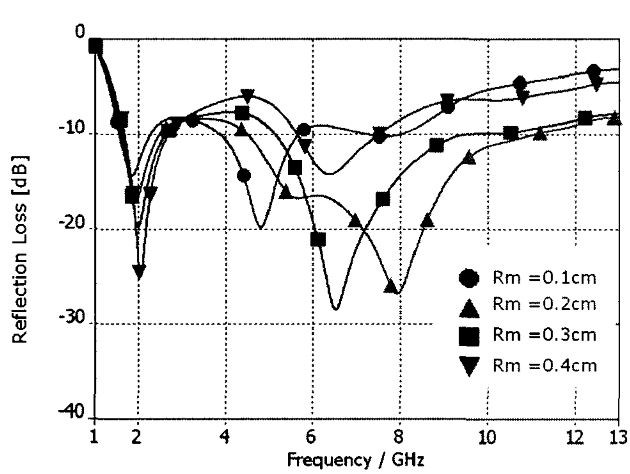


Fig. 3. Simulation results for the variation of the radius R_m with L_m=0.3 cm.

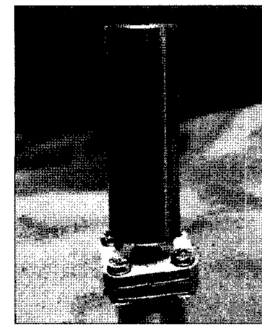
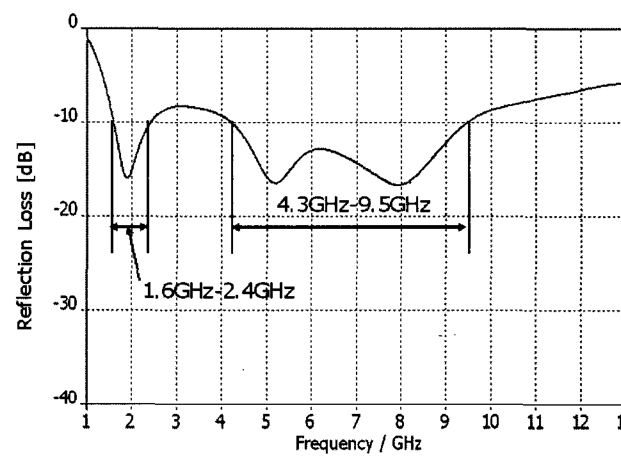


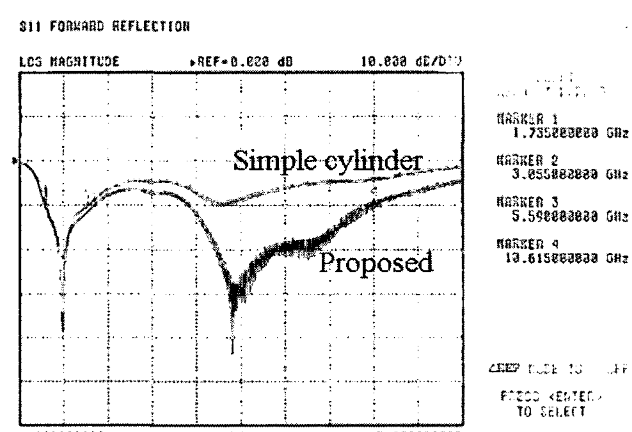
Fig. 4. Picture of the fabricated antenna.

III. Experimental Result

The fabricated antenna is mounted on the ground plane with dimensions 15×15 cm to demonstrate the proposed bandwidth enhancement technique. Fig. 5 shows



(a) Simulated result for the proposed antenna



(b) Measured result
(Proposed: L=3.0 cm, R=0.48 cm, p=0.2 cm, r_f=0.06 cm, L_m=0.3 cm, R_m=0.15 cm;
Simple cylinder: L=3.0 cm, R=0.48 cm, p=0.2 cm, r_f=0.06 cm, L_m=0)

Fig. 5. Simulation and measurement results for the reflection loss.

the simulated result and the measured return loss. The impedance bandwidths for the proposed and a simple cylinder monopole antenna are plotted simultaneously for comparison in Fig. 5(b). The simple cylinder monopole has dimensions: L=3 cm, R=0.48 cm, p=0.2 cm, r_f =0.06 cm, and L_m=0. From Fig. 5(b), we can see that 10 dB impedance bandwidths of the proposed monopole are 1.74~3.05 GHz(54.7 %) and 5.6~10.6 GHz(61.7 %), whereas the simple cylinder shows the bandwidth of 1.72~2.9 GHz(51.1 %) only in the lower frequency band. So, the modification of the coupling structure in a cylinder monopole produces an additional frequency range available with quite a wide band-width. The measured antenna gain for the propose geometry is presented in Fig. 6. The gain is about 2.0 dBi in the lower band(1.74~3.05 GHz), and about 5.0 dBi in the upper band(5.6~10.6 GHz).

The measured results for radiation patterns are presented in Fig. 7. Even in the high frequency as 10 GHz, the radiation characteristic of figure-8 peculiar to the quarter-wave monopole is conserved.

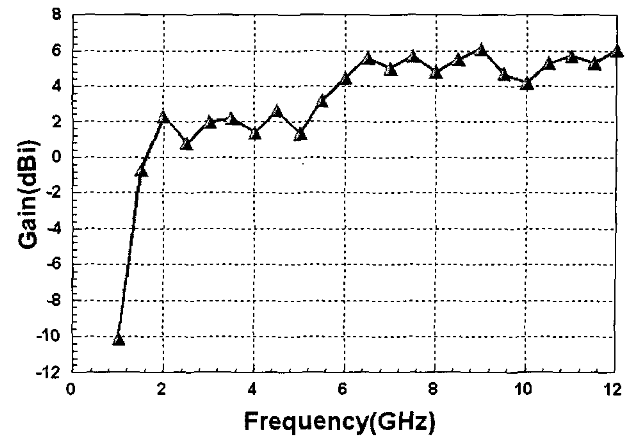
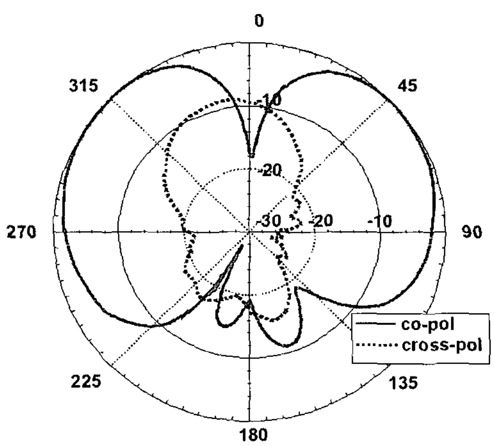


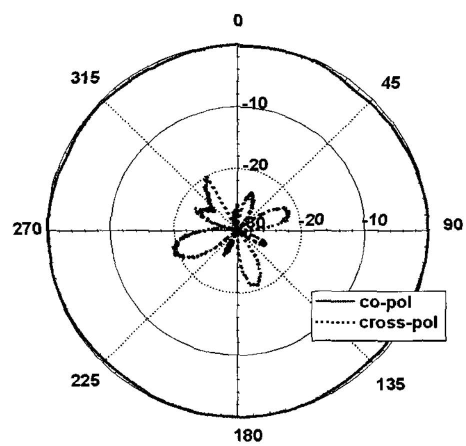
Fig. 6. Measured antenna gain for the proposed geometry.

Ⅳ. Conclusion

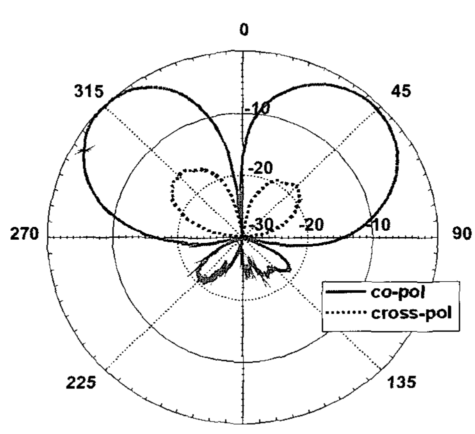
A new design principle for cylindrical monopole antennas is presented on a basis of a modified feeding geometry. The fabricated antenna according to the scheme



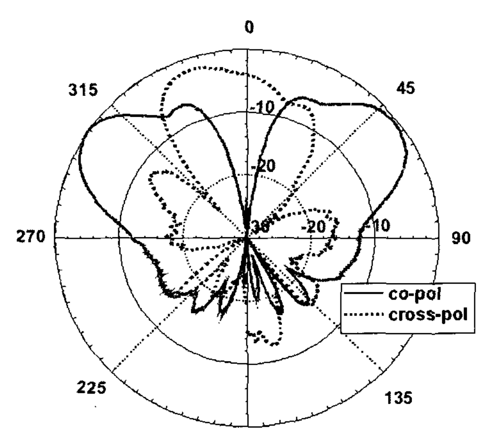
(a) Elevation pattern at 2.5 GHz



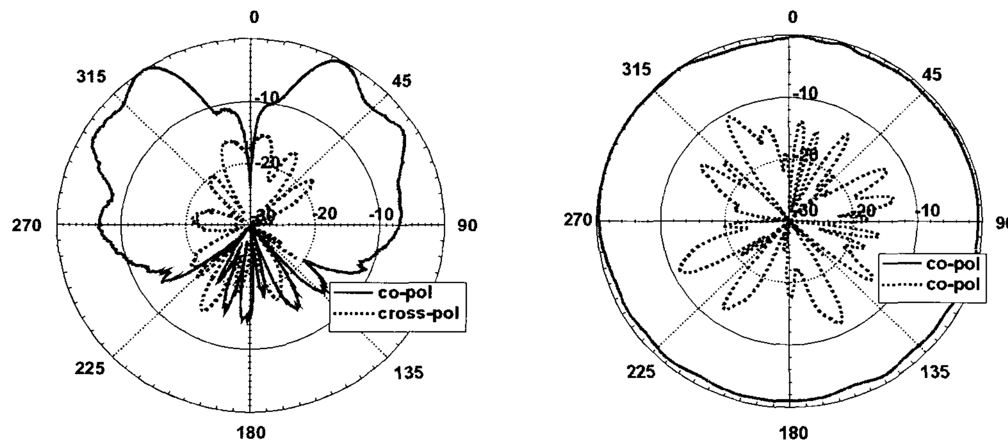
(b) Azimuth pattern at 2.5 GHz



(c) Elevation pattern at 6 GHz



(d) Elevation pattern at 8 GHz



(e) Elevation pattern at 10 GHz

(f) Azimuth pattern at 10 GHz.

Fig. 7. Measured radiation patterns of the proposed monopole.

shows that −10 dB impedance bandwidths are 1.7∼3.1 GHz and 5.6∼10.6 GHz, and gains are 2∼5 dBi. Inherently, the thick cylindrical monopole can cover the frequency range of 1.7∼2.9 GHz. But the modification in the antenna base and the ground plane produces an additional frequency range suitable for the high-band UWB(7.2∼10.2 GHz). Thus the proposed antenna cannot only cover wireless services operating in the vicinity of 2 GHz, but also be used for the higher range applications. The measured results for antenna gain and radiation patterns at several frequencies are also presented.

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Joong-Chang Chun

received the B.E. degree in electronic engineering from Kyungbuk National University in 1984, and M.S. and Ph.D. degrees in electronic and electrical engineering from POSTECH(Pohang University of Science and Technology) in 1991 and 1995, respectively. He has been with Wireless Communications Research Center of Korean Telecom from February 1995 to February 1997. Before he joined the department of electronic engineering at Jinju National University in March 2003, where he is currently an associate professor, he has been with Uiduk University for six years. His research interests include antennas, mixers, and oscillators, and microwave sensors.

Tae-Soo Kim

received the B.E. degree in electronic engineering from Kyungbuk National University in 1987, and M.S. and Ph.D. degrees in electronic and information engineering from Yokohama National University in 1991 and 1995, respectively. Since 1996, he has been with Division of Information and Communication Engineering at Uiduk University where he is now an associate professor. His research interests include digital signal processing, image recognition, and human interface, and wireless Lan.

Jaeruen Shim

received the B.S. degree in electrical engineering from Korea Advanced Institute of Science and Technology(KAIST) in 1990. He received M.S. degree and the Ph.D. degree in electronic and electrical engineering from Pohang University of Science and Technology(POSTECH) in 1992 and 1999, respectively. Since 2000, he joined the faculty of Pusan University of Foreign Studies(PUFS). His research interests are in the areas of antenna design, EM scattering, and wireless communications.