Mode Identification in the Design of Wideband Cylindrical Monopole Antenna

Joong-Chang Chun, Sang-Youl Kim, Deuk-Soo Jeung, *Member, KIMICS*

***Abstract*—**Cylindrical monopole antenna is one of most promising candidates for multi-band applications such as PCS, WLAN, DMB, and UWB wireless services. In this research, we demonstrate that there exist two types of current distributions according to the exciting frequency in a double band cylindrical monopole antenna, in which double resonance is achieved by adjusting the coupling structure of the antenna base. The operating modes of current distributions are identified from CST software simulations, the standing wave mode in a lower band and the traveling wave mode in a higher band. Also it is noticed that the mode behavior is quite similar to a helical antenna, a standing-wave (resonance) mode and a traveling-wave (non-resonance) mode according to the electrical dimensions of antenna. The effective ranges for operating modes and design formulas of the double band antenna are derived from simulation and measured results

***Index Terms*—**Cylindrical monopole, double resonance, wideband antenna, traveling wave antenna, UWB antenna

I. INTRODUCTION

WIDE band antennas are becoming more and more important for future wireless systems, and monopole antenna is one of most promising candidates for multi-band applications. So many approaches are investigated to improve the bandwidth of monopole antennas, in the forms of cylindrical [1],[2] and planar [3],[4] structures. Among them, the cylindrical monopole has more advantages for simple and sturdy structure in addition to omnidirectional radiation characteristic than planar types.

In reference [1], we have previously proposed a design procedure for a wide band monopole which has a stepped base part and a convex ground plane to achieve an additional frequency bandwidth of impedance matching. The antenna has shown an interesting feature having double resonance characteristic superficially. A further investigation has shown that the lower frequency band is caused by a fundamental quarter-wave resonance as a normal monopole, but the higher frequency band is formed by a traveling wave type of current distribution. Also it is revealed that the mode behavior is quite similar to a helical antenna, a standing-wave mode for the electrically small dimension and a traveling-wave mode for the electrically large dimension. In this paper, we show that two types of operating modes exist in current distributions on the base of CST software simulations, and the similarities for monopole and helical structures are compared for a further reference.

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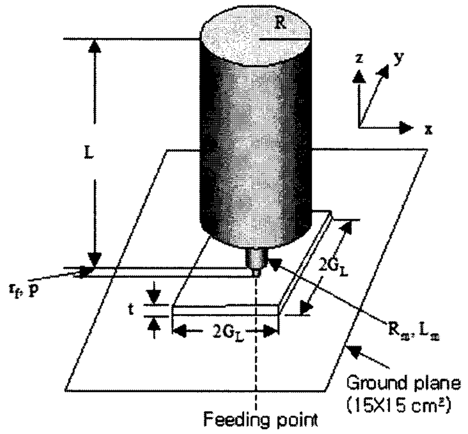
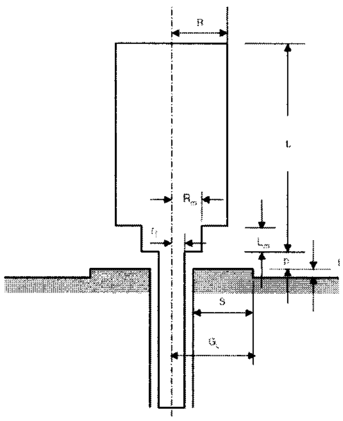
II. STRUCTURE AND IMPEDANCE OF A DOUBLE BAND MONOPOLE ANTENNA

Fig. 1 shows the geometry of the double band antenna.[1] Basic form of the antenna is a thick monopole, but it has some modification in the base part for an additional frequency band such as the stepped base part of the cylinder and the convex part of the ground plane, which result in a double band operation.



(a) Perspective view



(b) Cross sectional view

Fig. 1 Structure of the double band monopole.

The antenna dimensions are determined to cover PCS, WiBro, and UWB ranges. The optimized values are: L=3 cm, R=0.48 cm, p=0.2 cm, r_f=0.06 cm, t=0.17 cm, L_m=0.3 cm, R_m=0.15 cm, and G_L=0.635 cm. The measured result for the return loss is shown in Figure 2. 10 dB impedance bandwidths are 1.74 GHz-3.06 GHz (lower band) and 5.59 GHz-10.62 GHz (higher band).[1]

III. MODE IDENTIFICATION FOR SURFACE CURRENT DISTRIBUTIONS

Mode identification is performed from the CST simulation, and the effective ranges for operating modes and design formulas of the double band antenna are derived from simulation and measured results.

A. Standing Wave Mode

Fig. 3 shows the result of CST simulation for the current distribution at 2 GHz in the lower frequency band. From this result we can see that a standing wave is formed on the surface of cylinder as the phase is varying, which is caused by the open end of monopole. The condition for the standing wave is the effective length of the current path, $L_L = L + p + R - r_f$, is about quarter wavelength. That is, the whole monopole contributes to the radiation in the lower frequency band, so the resonant frequency f_L around at the center can be estimated as follows:

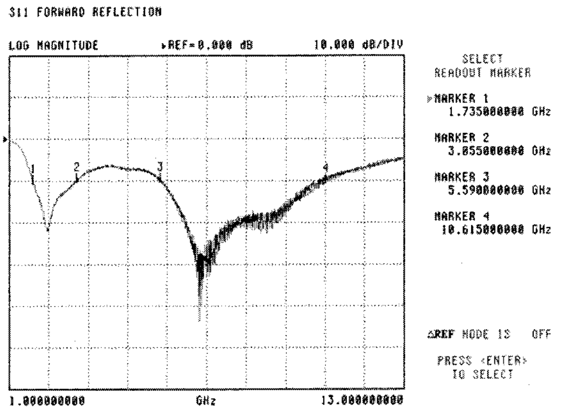


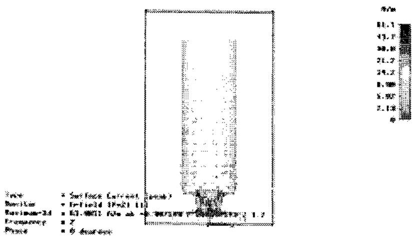
Fig. 2 Measured result of impedance characteristic. (lower band: 1.74 GHz-3.06 GHz, higher band: 5.59 GHz-10.62 GHz)

$$f_L = \frac{7.2}{L_L} = \frac{7.2}{L + p + R - r_f} \ (GHz). \qquad (1)$$

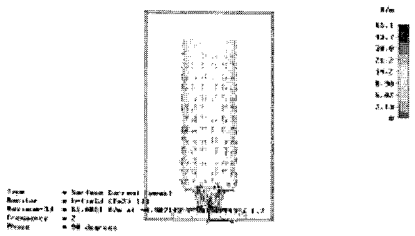
where all dimensions are in cm. Those parameters in Section II give $L_L = 3.62$ cm and the resonant frequency of f_L =1.99 GHz, which is in accordance with the measured result. The effective range for this resonant mode is

$$0.21\lambda \le L_L \le 0.37\lambda, \qquad (2)$$

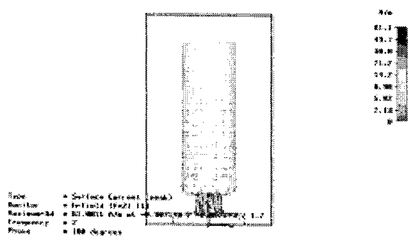
where λ represents the wavelength in the free space. The bandwidth is quite wide as 55.2 %, owing to the increased radius R of the cylinder.



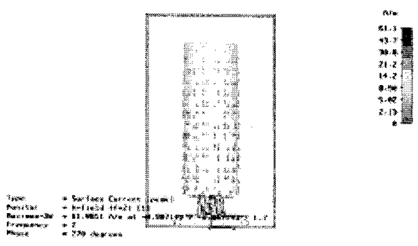
(a) phase: 0°



(b) phase: 90°



(c) phase: 180°

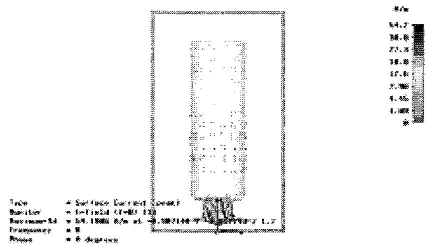


(d) phase: 270°

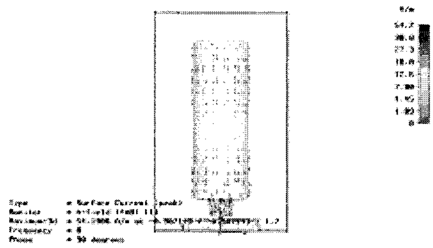
Fig. 3 Current distribution at 2GHz

B. Traveling Wave Mode

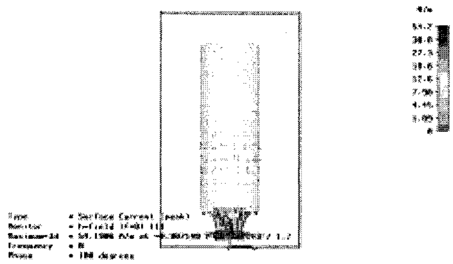
Fig. 4 presents the result of CST simulation for the current distribution at 8 GHz in the higher frequency band. From this result we can see that a traveling wave is formed on the surface of cylinder. The conditions for the traveling wave are that the length of the upper part of radiator, $L_\alpha = L - L_m$, is $\lambda \sim 2\lambda$ and the circumference, $C = 2\pi R$, is as long as λ.



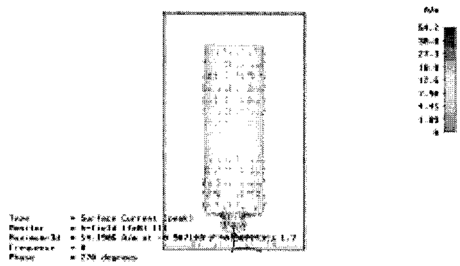
(a) phase: 0°



(b) phase: 90°



(c) phase: 180°



(d) phase: 270°

Fig. 4 Current distribution at 8 GHz

These conditions are in agreement with the explanation in [5] for a thick and long monopole. In this non-resonant mode, the radiation is caused for the most part by the surface current distributed along the stepped base part, of which effective length, $L_H = L_m + p + R - r_f$, is the determining factor for the operating frequency to be about quarter wavelength. So, the mid-frequency f_H of the higher band can be estimated as

$$f_H = \frac{7.2}{L_H} = \frac{7.2}{L_m + p + R - r_f} \ (GHz). \quad (3)$$

Those parameters in Section II give $L_H = 0.92$ cm and the frequency of f_H=7.83 GHz, which is consistent with the measured result. The effective range for this non-resonant mode is

$$0.17\lambda \le L_L \le 0.33\lambda, \quad (4)$$

where the bandwidth is as wide as 62.4 %, owing to the non-resonant current distribution along L_α.

As explained in [5], a thick and long monopole has a traveling wave characteristic. But one interesting point is that the thick monopole analyzed in this paper has two types of operating modes, the standing wave mode in a lower band and the traveling wave mode in a higher band. The traveling wave mode is formed near the third harmonics of the lower band, but not exactly. Also it is noticed that the mode behavior is quite similar to a helical antenna, a standing-wave (resonance) mode and a traveling-wave (non-resonance) mode according to the electrical dimensions of antenna.[5]

IV. CONCLUSION

A cylindrical monopole antenna with a modified base part has a double band characteristic, so it is a good candidate for multi-band wireless services. In this paper, it is demonstrated that there exist two types of current distributions according to the exciting frequency in the double band cylindrical monopole, a standing wave mode in a lower band and a traveling wave mode in a higher band. The mode identification is based on the simulation results using CST software at several frequencies. The traveling wave mode is formed near the third harmonics of the standing wave mode, but not exactly. So, it is more accurate in determining the antenna frequency of the higher band to apply the principle presented in this paper. Also it is noticed that the mode behavior is quite similar to a helical antenna, a standing-wave (resonance) mode and a traveling-wave (non-resonance) mode according to the electrical dimensions of antenna. The effective ranges for operating modes and design formulas of the double band antenna are derived from simulation and measured results.

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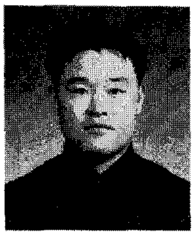

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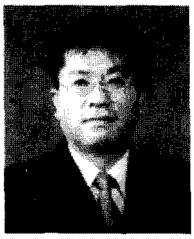

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