Design of Printed Monopole Antenna with Resistive Loading for UWB Applications

Koji Kanemoto [1], Takayuki Sasamori [2], Teruo Tobana [2], and Yoji Isota [2]
[1] Graduate School of Systems Science and Technology, Akita Prefectural University
Yurihonjyo, Akita, 015–0055 Japan, m10b003@akita-pu.ac.jp
[2] Faculty of Systems Science and Technology, Akita Prefectural University
Yurihonjyo, Akita, 015–0055 Japan

1. Introduction

Recently, there has been enormous interest in ultra-wideband (UWB) wireless systems for short-range and high-speed wireless communications. The Federal Communication Commission (FCC) has released three basic areas of applications, in the areas of communication, positioning and imaging. Currently, a resistively loaded dipole antenna has been proposed as one of the antennas with a broadband characteristic. By using a dipole antenna with continuous resistive loading, it is possible to create a small traveling wave antenna with a broadband characteristic [1]– [3]. However, it is not easy to produce the necessary continuous resistance distribution.

In this paper, a printed monopole antenna with resistive loading is developed for UWB applications. First, a loading technique of lumped resistor on the antenna element based on the well-known Wu-King profile is proposed. This technique enables the fabrication of the resistively loaded printed monopole antenna using surface mount chip resistors. Next, after evaluating the simulated and the measured results of the return loss characteristics, the gain and the measured results of the radiation patterns are presented and discussed.

2. Antenna Design

Wu and King obtained a profile for the loading that produced an outward-traveling wave on the antenna over a broad range of frequencies [1]. Fig. 1 shows the cylindrical monopole driven through an image plane by a coaxial transmission line. The conductors of the coaxial line and the image plane are assumed to be perfect, while the monopole is formed from a thin-walled resistive tube. Following Wu and King's method, the internal impedance per unit length of this tube will be chosen so as to produce an outward-traveling wave along the monopole.

The resistive internal impedance per unit length for the Wu-King profile is

$$r(x/h) = \frac{\xi_0 \phi_0}{2\pi h(1 - x/h)} \tag{1}$$

where, x/h is the relative distance along the monopole from the coaxial aperture, and ξ_0 is the intrinsic impedance of free space given by $\xi_0 = \sqrt{\mu_0/\varepsilon_0} \approx 120\pi$. Moreover, if this resistance is obtained using a thin-walled metallic tube of outer radius a and wall thickness d, as in Fig. 1, the conductivity of the tube must vary with x/h as

$$\sigma = (1 - x/h)\sigma_0 \tag{2}$$

where

$$\sigma_0 = \frac{h/a}{d\xi_0 \phi_0}. \tag{3}$$

Fig. 2 shows the dipole antenna with lumped resistive loading. The element of length h is divided into two sections whose lengths are L_1 and L_2. The value of the loaded resistances R_1 and R_2 are obtained by integrating the Wu-King profile in the sections L_1 and L_2, respectively. Here, the length of the two sections is chosen as the value of each resistance corresponds to the other. Fig. 3 shows the value of the lumped resistance with the distributed resistance derived from the Wu-King profile. As can be seen here, $L_1 > L_2$ and $R_1 \approx R_2$.

Fig. 4 shows the configuration of the resistively loading printed monopole antenna. The antenna is printed on a dielectrical substrate with a relative permittivity of 2.25, $\tan\delta$ = 0.00038(@10 GHz), a length and width of 65 mm and 20 mm respectively and a thickness of 1.6 mm. The antenna consists of a microstrip feed line, taper balun and a radiation element with resistive loading on the topside of the substrate and a rectangular ground plane on the bottom side. The microstrip line has a width of 4.8 mm and is fed through an SMA connector and it is designed for 50 Ω. The shape of the ground plane is chosen to be rectangular and has dimensions of 20 mm × 35 mm. The antenna is fabricated by using the surface mount chip resistor of the commercialized product whose resistance is the nearest to an analytical value.

3. Results and Discussion

Fig. 5 illustrates the simulated and the measured frequency characteristics of the return loss of the resistively loaded print monopole antenna. The return loss is simulated by using the FDTD method. It may be noted in Fig. 5 that the simulated return loss reasonably agrees with the experimental result. The simulated and measured bandwidth where the return loss is less than −10 dB are 48 % and 87 % respectively. It is considered that the discrepancy between the values in the simulation and the experiment is due to the frequency characteristics of the chip resistor. Fig. 6 shows the measured result of the frequency characteristic of the chip resistor of 1.8 kΩ. The maximum and the minimum measured values of resistance are 560 Ω and 40 Ω in the UWB band respectively.

Fig 7 shows the frequency characteristics of the actual gain of the resistively loaded printed monopole antenna for *x* direction in the UWB band. It is observed that the measured gain is over 0 dBi in the frequency band from 5.0 to 7.0 GHz. Figs. 8 show the measured radiation patterns of the resistively loaded printed monopole antenna in the *xy* plane and *xz* plane at 5.0 GHz, 6.0 GHz and 7.0 GHz respectively. The patterns were measured using a network analyzer in an anechoic chamber. Note that the patterns in the *xy* plane are reasonably omnidirectional from 5.0 to 7.0 GHz, and the main beams are tilted in the *xz* plane.

4. Conclusion

In this paper, a novel design of a printed monopole antenna with resistive loading has been proposed for UWB applications. First, the method of realizing the Wu-King profile by using the lumped resistor was examined. The geometry of the resistively loaded printed monopole antenna using the surface mount chip resistor was explained. By comparing the measured result with the calculated result of the return loss, it was shown that the simulated return loss reasonably agrees with the experimental result. The frequency characteristics of the actual gain and the radiation pattern were also discussed.

References

[1] T. T. Wu and R. W. P. King, "The cylindrical antenna with nonreflecting resistive loading," IEEE Trans. Antenna Propag., vol.13, pp.369-373, May 1965.

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[3] K. P. Essele and S. S. Stuchly, "Pulse-Receiving Characteristics of Resistively Loaded Dipole Antennas," IEEE Trans. Antenna vol. 38, No.10, pp.1677-1683, Oct1990.

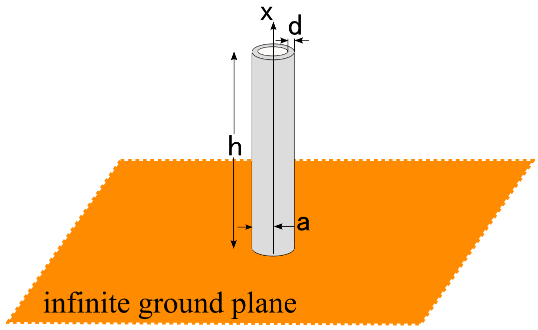


Figure 1: The resistively loaded monopole antenna.

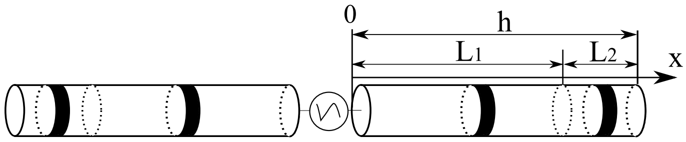


Figure 2: The dipole antenna with lumped resistive loading.

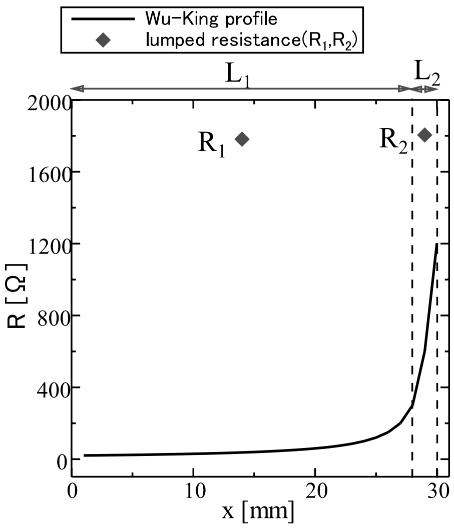
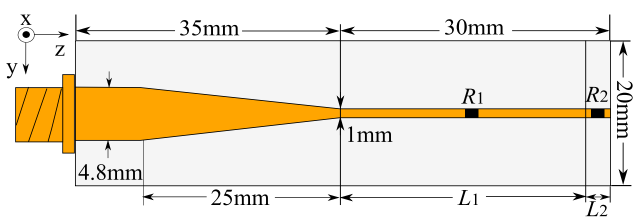
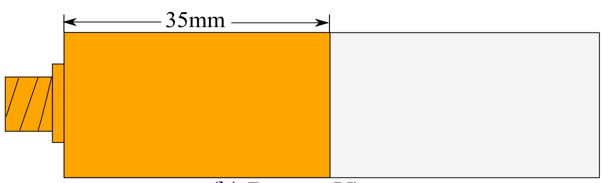


Figure 3: Discretization of resistive loading.



(a) Top View.



(b) Bottom View.

Figure 4: The resistively loaded printed monopole antenna.

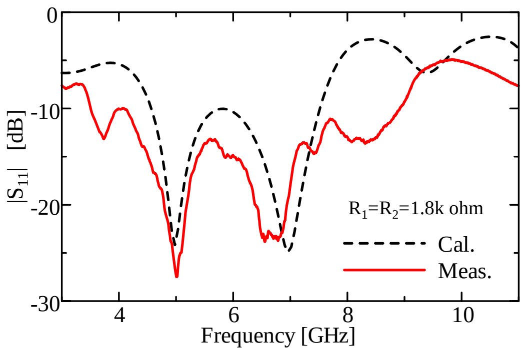


Figure 5: Measured and calculated return loss.

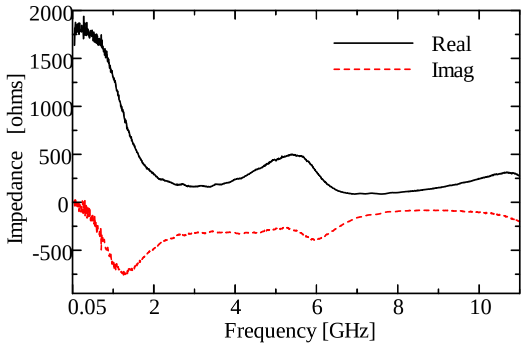


Figure 6: Measured impedance of the chip resistor of 1.8 kΩ.

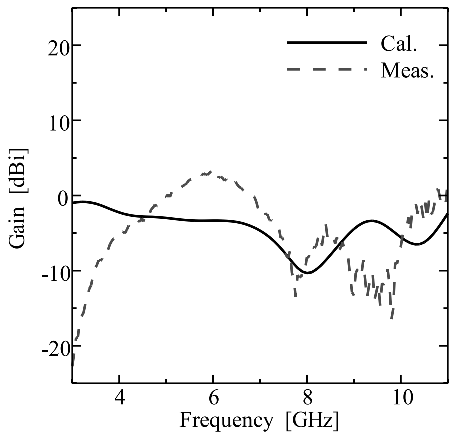
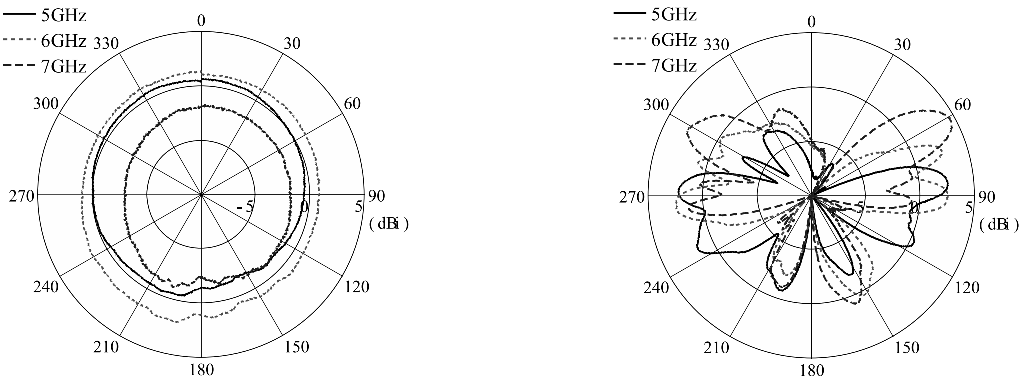


Figure 7: Frequency characteristics of actual gain for *x* direction.



(a) *xy* plane

(b) *xz* plane

Figure 8: Measured radiation patterns.