WIDEBAND SLEEVE ANTENNA

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Abstract: The wideband sleeve antenna is numerically and experimentally analyzed and its return loss characteristics are examined. This antenna is fed by the coaxial transmission line and has two sleeves. The outer conductor of the transmission line and the hollow larger conductor form the lower sleeve and the inner conductor of transmission line and the hollow larger conductor form the upper sleeve. This antenna is calculated by the electromagnetic simulator Fidelity based on the FDTD method. The return loss characteristics become wider near the resonant frequencies of two sleeves.

1. INTRODUCTION

The sleeve antenna is used as the base station antenna of mobile communication system. It is essentially a half-wave dipole antenna fed by a coaxial transmission line [1]. This antenna consists of a thinner radiator and a tubular conductor sleeve shown in Figure 1. The thinner radiator is the inner conductor of a coaxial transmission line. The sleeve attached around the coaxial transmission line provides effective choking of the RF currents at its own open end and also one-half of the radiating dipole. This conductor is shorted to the outer conductor of the coaxial transmission line feeding the sleeve [2]. The choke works most effectively if the length of sleeve transmission line formed by the outer conductor of the coaxial line and the inner surface of the sleeve is a quarter wavelength. Therefore the bandwidth of this antenna is narrow.

In this paper, the wideband sleeve antenna, which has two tubular sleeves, is numerically and experimentally analyzed [3]. The outer conductor of the transmission line and the hollow larger conductor form the lower sleeve and the inner conductor of transmission line and the hollow larger conductor form the upper sleeve. This antenna is called as the coaxial sleeve antenna with a decoupling choke in the reference [4]. In the reference [4], its input impedance was calculated. However, it was concluded that its bandwidth is narrow. In this paper, the broadband operation of this antenna is shown by the numerical calculation and the measurement. In the numerical analysis, the electromagnetic simulator Fidelity based on the FDTD method is used [5].

2. ANALYTICAL MODEL

Figure 2 shows the analytical model of proposed sleeve antenna. This antenna has two sleeves. The lower sleeve woks as the sleeve attached on the surface of coaxial transmission line of the conventional sleeve antenna. The upper sleeve is attached around the inner conductor of the transmission line. The parameters of antenna are as follows.   p=0.455 mm, q=1.5 mm, r=1.79 mm, w=3mm, t=4 mm, and S=20 mm. The relative permittivity of dielectric material between the inner and outer conductors of the coaxial transmission line is 2.05. The dielectric material is leaved around the radiating element for protection.

The return loss characteristics of this antenna are analyzed at the frequencies from 1 GHz to 3 GHz. In the numerical calculation by Fidelity, the minimum and maximum cell sizes are 0.1045 mm and 1 mm, respectively. The minimum cell size 0.1045 mm is 0.00418 wavelength at the highest frequency 3 GHz. The perfectly matched layer of six-layer and fourth-order is used as the absorbing boundary condition.

3. RESULTS AND DISCUSSION

The wavelength within the lower sleeve λ_c is expressed by

$$\lambda_c = \lambda. \quad \left(\lambda : \text{wavelength in free space}\right) \qquad (1)$$

Then, the resonant frequency f_c of the lower sleeve is defined by the frequency when the length of sleeve is a quarter wavelength $\left(c = \lambda_c / 4\right)$.

Assuming the dielectric material is filled within the upper sleeve, the effective wavelength λ_b within the upper sleeve is given by

$$\lambda_b = \frac{\lambda}{\sqrt{\varepsilon_r}} = \frac{\lambda}{\sqrt{2.05}}. \qquad (2)$$

Since the radius of feed aperture of coaxial transmission line q-p (=1.045 mm) is much smaller than the distance between the outer and inner radius of upper sleeve w-p (=2.545 mm), the upper sleeve is assumed to be shorted at the feeder side. Then, resonant frequency f_b of the upper sleeve is
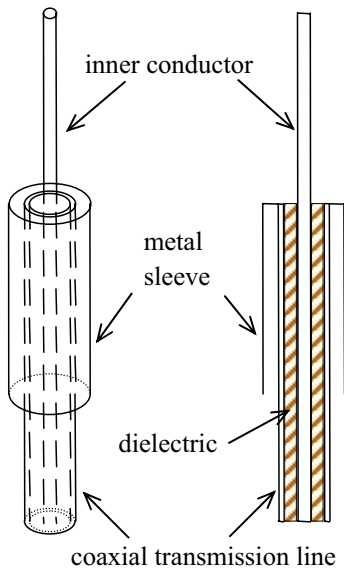
(a) Sketch   (b) Cross sectional view
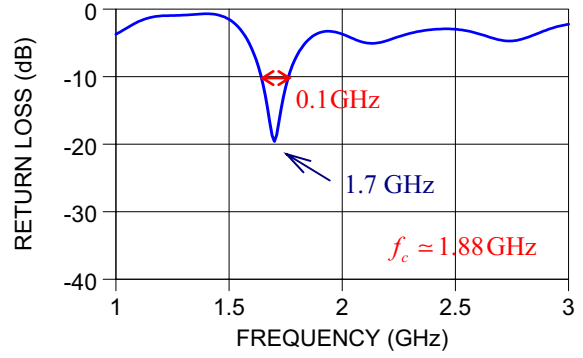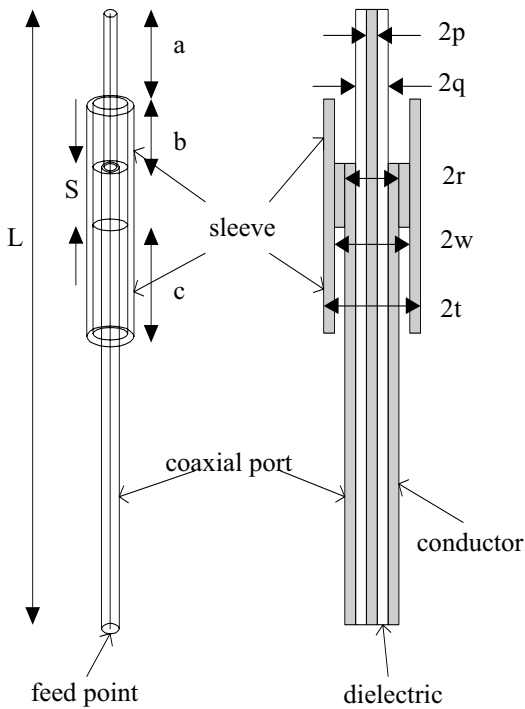Figure 1 Conventional sleeve antenna.

(a) Sleeve antenna   (b) Cross sectional view
Figure 2 Structure of proposed sleeve antenna
p=0.455 mm, q=1.5 mm, r=1.79 mm, w=3mm,
t=4 mm, and S=20 mm.

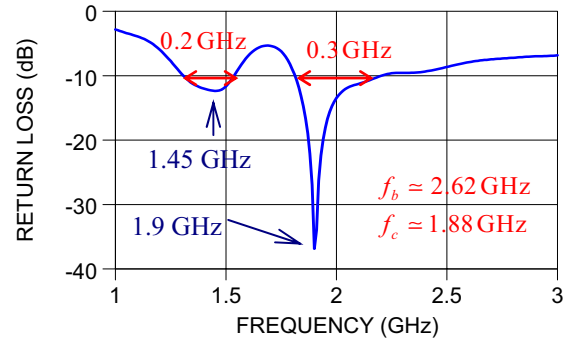Figure 3 Calculated return loss of sleeve antenna
without upper sleeve.
L=240mm, a=40mm, b=0mm, c=40mm

Figure 4 Calculated return loss characteristics.
L=240mm, a=40mm, b=20mm, c=40mm
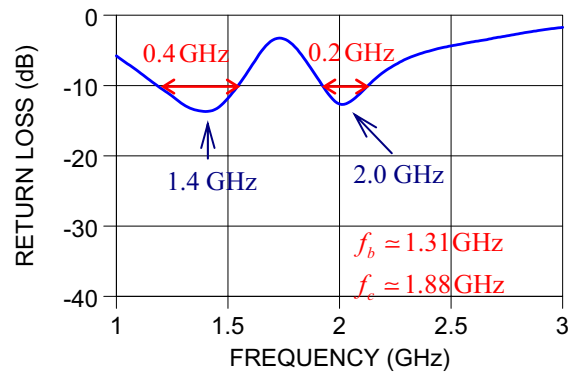

Figure 5 Calculated return loss characteristics.
L=240mm, a=40mm, b=40mm, c=40mm
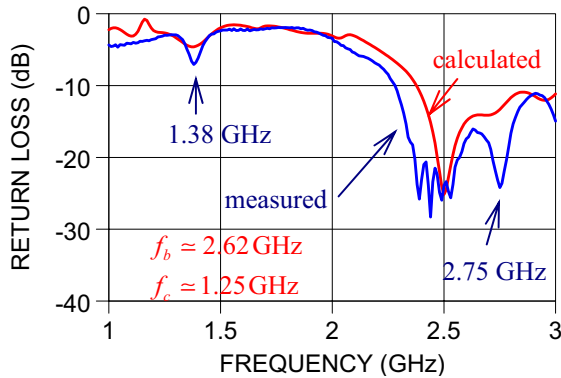
Figure 6 Comparison between calculated and
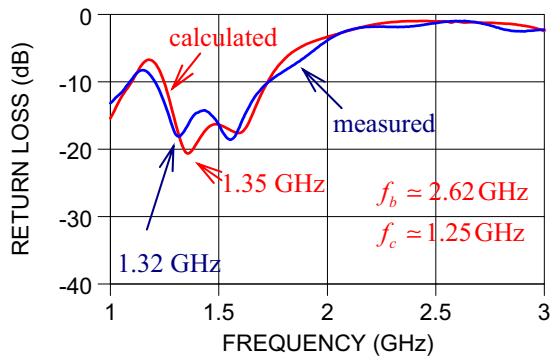measured return loss characteristics.
L=290mm, a=80mm, b=20mm, c=60mm

Figure 7 Comparison between calculated and
measured return loss characteristics.
L=290mm, a=60mm, b=40mm, c=60mm

approximately defined by the frequency when $b = \lambda_b/4$.

Figure 3 shows the calculated return loss characteristics of the sleeve antenna without the upper sleeve. The bandwidth of return loss less than -10 dB is about 0.1GHz.

Figure 4 and 5 show the calculated return loss characteristics of the proposed sleeve antenna in the case of b = 20 mm and b = 40 mm, respectively. On these figures, the resonant frequency f_c and f_b of lower ad upper sleeves are shown for comparison. The length of upper radiator a is same as that in Figure 3. By adding the upper sleeve to the antenna in Figure 3, the two resonances occur. Although, the resonance at f_b is not observed in Figure 4, two resonances are observed near f_c and f_b in Figure 5.

Figure 6 and 7 show the comparison between the calculated and measured return loss characteristics. The calculated return loss characteristics agree well with the measured results. In both figures, the

bandwidth of return loss becomes wider around resonant frequencies of upper and lower sleeves.

Figure 8 show the measured return loss characteristics for different length of lower sleeve. By adjusting the length of lower sleeve, the bandwidth of return loss becomes wider.
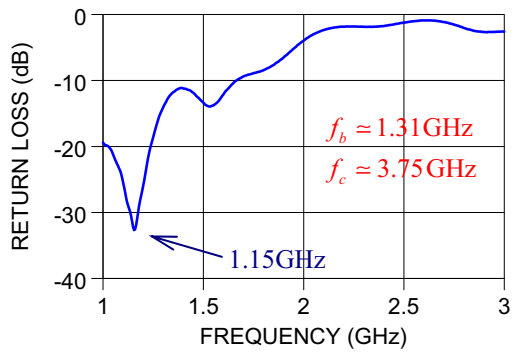
Figure 9 shows the example of calculated electric field radiation pattern for a=60 mm, b=40 mm, c=60mm at the frequency of 1.35GHz. Due to the current distribution on the upper and lower sleeve, the main lobe direction becomes downward.
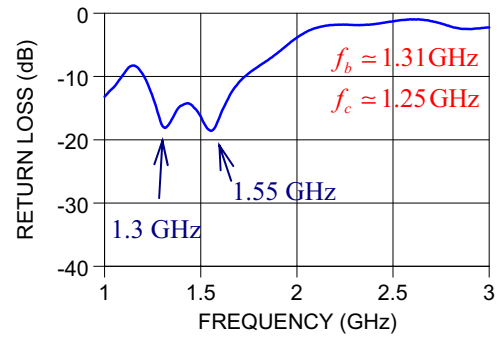
4. CONCLUSION

The return loss characteristics of a sleeve antenna with two sleeves have been analyzed numerically and experimentally. This antenna shows the broadband operation of return loss at around the resonant frequencies of two sleeves. Here, the effect of the length of inner radiator on the return loss characteristics has not been considered. This may be the next subject. The radiation characteristics of this antenna also will be reported at the next opportunity.

REFERENCES
[1] Q. Balzano, *Design Techniques for Portable Phone Antennas* in *Mobile Antenna Systems Handbook*, pp. 313-320, edited by K. Fujimoto and J. R. James, Boston: Artech House, 2001.
[2] G. Sato, H. Kawakami and M. Taguchi: *Modern Antenna Engineering*, Tokyo: Sogo-denshi shuppan, 2004 (*in Japanese*).
[3] M. Sakuma, "Wideband sleeve antenna", Japan Patent Application, No. S291001002, Sept. 2003.
[4] L. W. Rispin and D. C. Chang, *Wire and Loop Antennas*, in *Antenna Handbook*, Chapter 7, edited by Y. T. Lo and S. W. Lee, New York: Van Nostrand Reinhold, 1993.
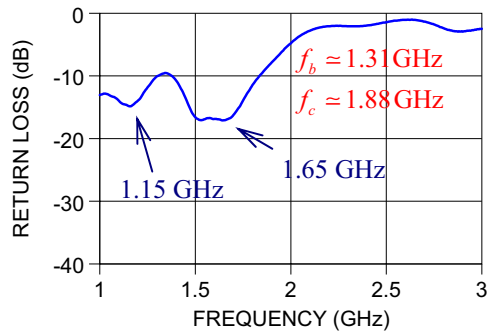[5] "Fidelity User's Manual", Zeland Software, Inc., April 2000.

$f_b \simeq 1.31 \text{GHz}$
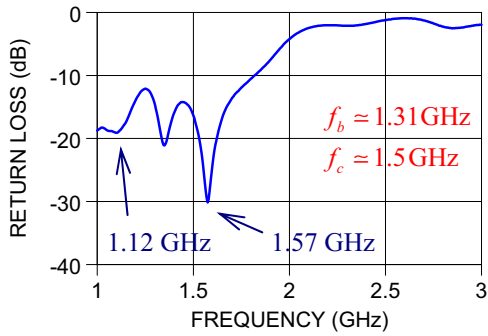$f_c \simeq 3.75 \text{GHz}$

1.15GHz

(a) c=20mm

$f_b \simeq 1.31 \text{GHz}$
$f_c \simeq 1.25 \text{GHz}$

1.55 GHz

1.3 GHz

(d) c=60mm
Figure 8 Measured return loss characteristics.
L=290mm, a=60mm, b=40mm

$f_b \simeq 1.31 \text{GHz}$
$f_c \simeq 1.88 \text{GHz}$

1.65 GHz

1.15 GHz

(b) c=40mm

θ=0

-5   0 dB

90°

180°
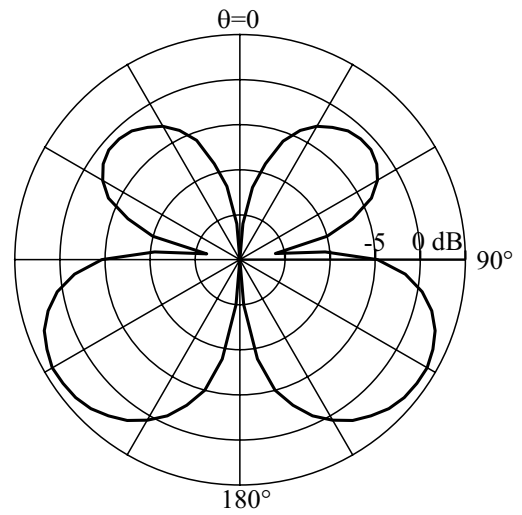
Figure 9 Calculated electric field radiation patterern.
L=290mm, a=60mm, b=40mm, c=60mm, 1.35GHz.

$f_b \simeq 1.31 \text{GHz}$
$f_c \simeq 1.5 \text{GHz}$

1.12 GHz   1.57 GHz

(c) c=50mm