Sleeve Antenna with Left-handed Choke Structure

Takatsugu Fukushima, Naobumi Michishita, Hisashi Morishita
Department of Electrical and Electronic Engineering, National Defense Academy
1-10-20 Hashirimizu Yokosuka Kanagawa 239-8686 Japan

***Abstract* - In this paper, the composite right/left-handed (CRLH) transmission line has been applied to a choke structure of the sleeve antenna. The dispersion relation of the CRLH transmission line is designed as the left-handed (LH) branch becomes at around 700 MHz. To verify the operation as the choke structure, radiation patterns and current distributions on the outer conductor of the coaxial cable are calculated. These characteristics are compared with those of the conventional sleeve antennas. The length of the inner conductor and the LH choke are 0.12 and 0.06 wavelength at 716 MHz, respectively.**

***Index Terms* — Sleeve antennas, choke, composite right/left-handed transmission line, leakage current.**

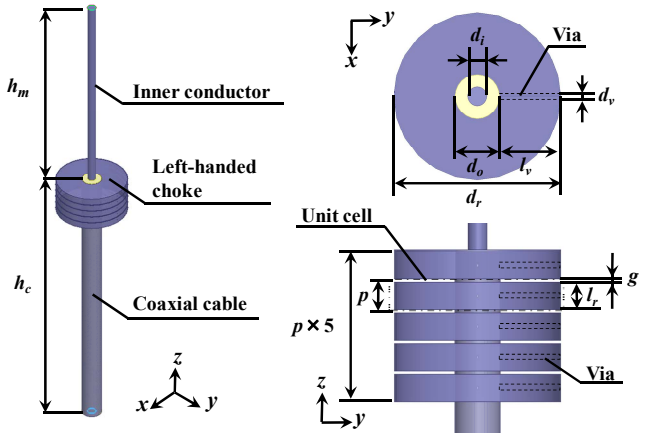
1. Introduction

A sleeve antenna has been employed for experiment due to its simple structure. The sleeve antenna is composed of the extension of quarter wavelength from the center conductor of a coaxial cable. To reduce the leakage current flowing on the outer conductor, the choke structure with quarter wavelength is attached to the surface of the outer conductor. The radiation pattern of the sleeve antenna with choke structure is similar to that of the dipole antenna. When the operational frequency band becomes low frequency, the antenna size becomes large due to the resonant length corresponds to the physical length of the antenna configuration. Therefore, a miniaturized sleeve antenna and a wideband sleeve antenna have been proposed [1],[2].

On the other hand, the composite right/left-handed (CRLH) transmission line has been proposed as the one of the study of metamaterial [3]. The CRLH transmission line has been applied to miniaturize the monopole antenna [4]. The length of the CRLH monopole antenna is a quarter of the conventional monopole antenna. In this paper, the CRLH transmission line has been applied to a choke structure of the sleeve antenna. The dispersion relation of the CRLH transmission line is designed as the left-handed (LH) branch becomes at around 700 MHz. To verify the operation as the choke structure, radiation patterns and current distributions on the outer conductor of the coaxial cable are calculated. These characteristics are compared with those of the conventional sleeve antennas.

2. Configuration

Fig. 1(a) shows the proposed sleeve antenna. This antenna is composed of a coaxial cable, a extension of an inner conductor and a LH choke. The LH choke is attached on the outer conductor of a coaxial cable. Upper and lower ends of the choke are short- and open-circuited, respectively.



(a) (b)

Fig. 1. Configurations of (a) sleeve antenna with left-handed choke structure, and (b) left-handed choke structure.

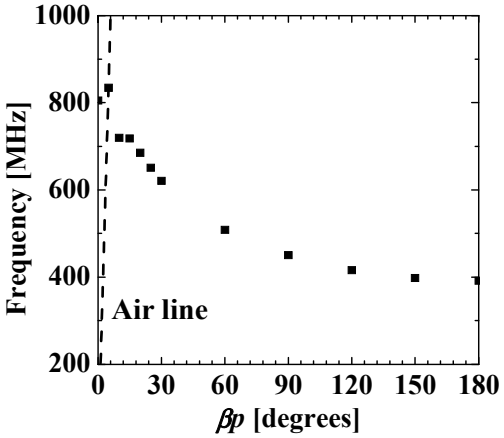
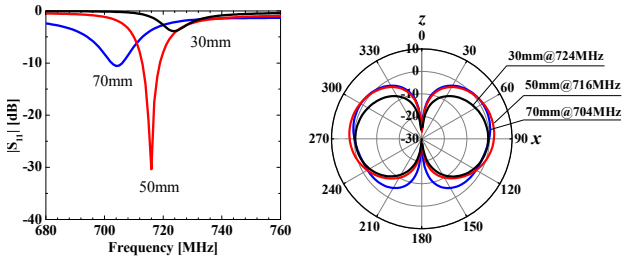


Fig. 2. Dispersion relation with d_r = 50 mm, d_o = 14 mm, l_r = 4.5 mm, g = 0.5 mm, d_v = 0.5 mm, l_v = 18 mm, p = 5.0 mm.

Fig. 1(b) shows the LH choke structure. The unit cell structure is composed of metal ring, via and gaps, and is arranged in the z direction periodically. The metal ring is connected to the outer conductor of the coaxial cable through via. The LH choke structure is composed of 5 unit-cells. The gaps between metal rings work as series capacitance. The vias work as shunt inductance.

3. Simulated results

Fig. 2 shows the simulated dispersion relation of the proposed CRLH transmission line. Since the phase velocity has the different sign from the group velocity, the LH branch is confirmed at around 700 MHz.



(a) (b)

Fig. 3. (a) $|S_{11}|$ and (b) radiation patterns of sleeve antennas with left-handed choke structure with h_c = 200 mm, d_i = 2.9 mm, when h_m is varied.

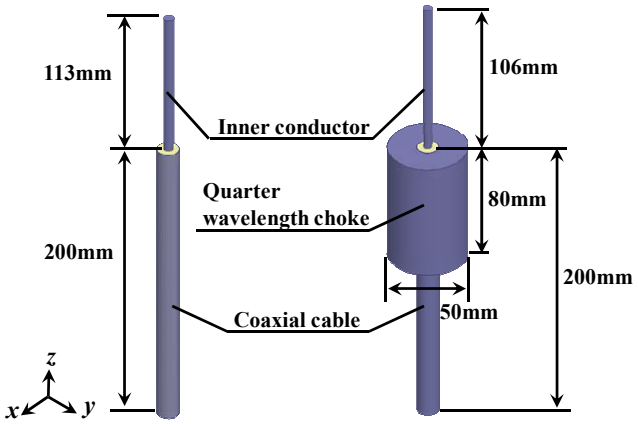
$|S_{11}|$ and radiation patterns of the sleeve antennas with the LH choke are simulated. The length of the inner conductor h_m is varied with 30 mm, 50 mm, and 70 mm. Fig. 3(a) shows $|S_{11}|$ characteristics. The resonant frequencies are 704 MHz, 716 MHz, and 724 MHz at each length. These frequencies are in the range of the dispersion relation in Fig. 2. Fig. 3(b) shows the radiation patterns in *zx* plane. When h_m = 50 mm, the gain in the horizontal direction becomes high. In this case, the length of the inner conductor and the choke are 0.12λ and 0.06λ at 716 MHz, which correspond to 48% and 24% of the conventional sleeve antenna.

4. Comparison with conventional sleeve antennas

To verify the effect of the LH choke structure, the conventional sleeve antenna without choke and with quarter wavelength choke are compared. Fig. 4 shows the configurations of the sleeve antenna without choke and with quarter wavelength choke. Fig. 5 shows the radiation patterns at 716 MHz. The length of the inner conductor of the sleeve antenna with the LH choke is h_m = 50 mm. In the case without choke, the radiation toward upper part of the antenna is suppressed due to the undesired leakage radiation. The radiation patterns of the sleeve antennas with quarter wavelength and LH chokes are shaped as a figure eight. Fig. 6 shows the current distributions on the outer conductors of the coaxial cable at 716 MHz. As shown in Fig. 6(a), the current of 1.2 A/m is confirmed on lower part of the outer conductor. The quarter wavelength and LH chokes can suppress the leakage current on the outer conductors in Fig. 6(b) and (c). The current on lower part of the outer conductor becomes smaller than 0.8 A/m.

5. Conclusion

The CRLH transmission line on coaxial cable has been proposed as a choke structure. The dispersion relation of the CRLH transmission line was designed as the LH branch becomes at around 700 MHz. The radiation pattern of the sleeve antenna with the LH choke is similar to that of the conventional sleeve antenna with quarter wavelength choke. The LH choke suppress the leakage current on the outer conductor of the coaxial cable. The length of the inner conductor and the choke are 0.12λ and 0.06λ at 716 MHz.



(a) (b)

Fig. 4. Configurations of conventional sleeve antennas (a) without choke, and (b) with quarter wavelength choke.

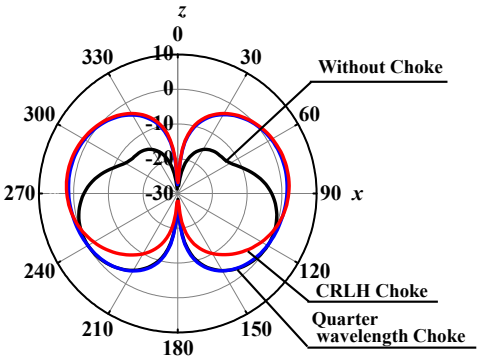
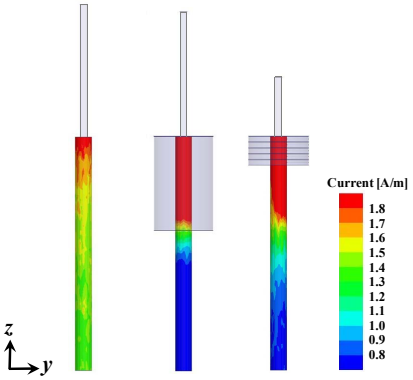


Fig. 5. Radiation patterns of sleeve antennas.



(a) (b) (c)

Fig. 6. Current distributions on outer conductor of coaxial cable (a) without choke, (b) with quarter wavelength choke, and (c) with left-handed choke.

References

[1] K. Nishimoto, R. Umeno, T. Fukasawa, M. Ohtsuka, H. Miyashita, Y. Konishi, "Tunable Sleeve Antenna Using Variable Capacitors," *IEICE Trans. Commun. (Japanese Edition)*, vol.J93-B, no.9, pp.1322-1330, Sept. 2010.

[2] M. Kitamura, M. Sakuma, K. Tanaka, M. Taguchi, "Wideband Sleeve Antenna," *IEICE Tech. Report.,* AP2005-11, pp.13-16, May. 2005 (in Japanese).

[3] A. Sanada, C. Caloz, T. Itoh "Characteristics of the Composite Right/Left-Handed Transmission Lines," *IEEE Microwave and Wireless Components Letters*, vol.14, no.2, pp.68-70, Feb. 2004.

[4] C. Lin, H. Arai, "A λ/4 Monopole Antenna by Left-Handed Coaxial Structure," *IEICE Tech. Report*, AP2006-92, pp.91-94, Oct. 2006 (in Japanese).