Design of Sheathed Dipole Antennas for Seawater Use

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1. Introduction

In recent years, the use of radio waves for underwater communication has been studied, and high quality wireless communications in seawater using radio waves is required. Besides, compared with wireless communications using acoustic waves and optical waves, radio waves could be expected for accurate location estimation of under-seawater divers in muddy seawater.

In our previous studies, the half-sheath dipole antenna for underwater communications was proposed [1]. The transmission factor between transmitting and receiving antennas was evaluated by the numerical analysis [2]. However, design method of sheath structure has not been clarified.

In this report, numerical design of sheathed dipole antennas in seawater is presented. The comparison of antenna characteristics between dipole antennas with sheaths of different length is performed. The impedance and the return loss behavior under the effect of different length of sheaths is discussed.

2. Model of sheathed dipole antenna

Fig. 1 shows the model of sheathed dipole antenna in seawater. Relative permittivity of ε_r=80 and conductivity of σ=4 S/m was used as seawater in this model. A dipole antenna is partially covered by the sheath contained pure water. Relative permittivity of ε_r=80 and conductivity of σ=0.01 S/m was used as pure water. L is the length of the antenna. l and d are length and thickness of the sheath, respectively. Since the antenna has a sheath, current flows through the conducting seawater and forms a path between the two ends of the sheath, which can be considered that the structure of sheathed dipole antenna is similar with the gamma-matched dipole antenna.

In this report, sheathed dipole antenna with L of 2050 mm and d of 100 mm has been discussed. The impedance and the return loss behavior have been observed under the situation of l changed from 0 to 1850 mm.

3. Results

Fig. 2 shows the reactance and resistance of sheathed dipole antennas in seawater under the situation of l changed from 0 to 1850 mm in a frequency range of 0 to 20 MHz. In the case without sheath, a current loop is formed through the conducting seawater. Therefore, resistance component of seawater and inductance component of loop appear. It can be observed that both reactance and resistance increase when the length of sheath increases in frequency rage f <6 MHz. As the frequency become higher, anti-resonance occurs. It can be observed that the anti-resonant frequency decreases as the length of sheath increases. At the anti-resonant frequency, the reactance becomes 0 and the resistance becomes the maximum, resulting in simple impedance matching circuit to the antenna.

Fig. 3 shows the return loss of sheathed dipole antennas in seawater under the situation of l changed from 0 to 1850 mm in a frequency range of 0 to 20 MHz. It can be observed that the minimum value of the curve decreases as the length of sheath increases, which corresponds to the anti-resonant frequency. It can also be observed that the return loss in the seawater at 1 MHz is about 0 dB when without sheath. When the length of sheath increases to 1850 mm, the return loss becomes -1 dB. It is considered that the increase of the length of the sheath-cover is conducive to signal transmission.

As the frequency decreases, the attenuation constant will decrease and the communicable distance will increase. It can be observed that the increase of the length of the sheath-cover contributes to increase both resistance and reactance at low frequency band. Therefore, this research is useful for future design at low frequency.

4. Conclusion

In this report, the effect of the length of sheath on the sheathed dipole antennas in seawater was clarified. It was shown that the structure of the sheathed antenna design is useful for decreasing the return loss and impedance matching.

Acknowledgement

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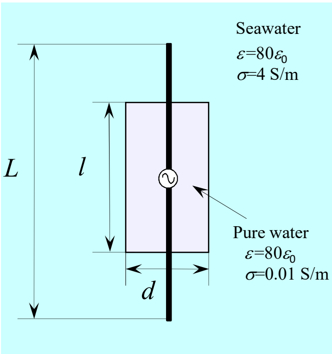
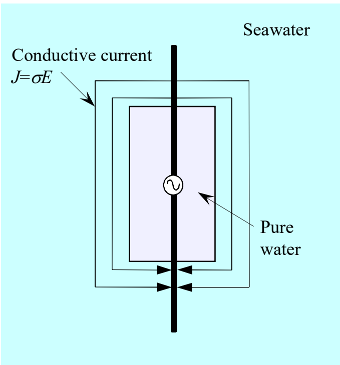
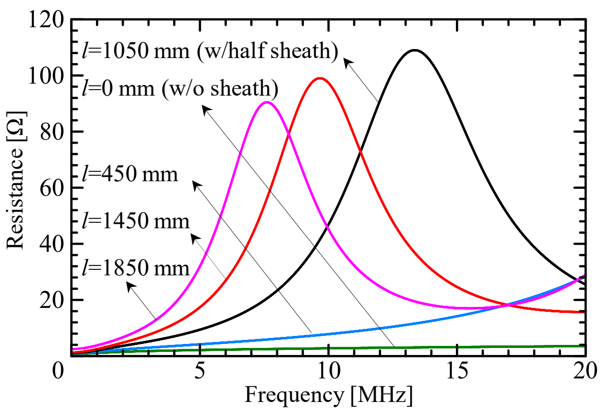


(a) Structure of sheathed dipole antenna in seawater.

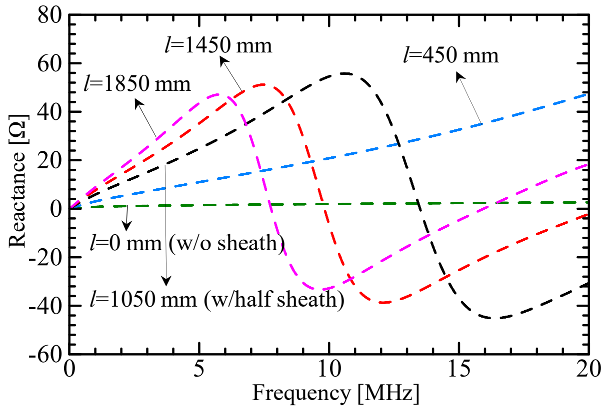


(b) Current loop formed through seawater

Fig. 1. Analysis model of sheathed dipole antenna in seawater.



(a) Resistance



(b) Reactance

Fig. 2. Impedance of sheathed dipole antennas in seawater with different lengths of sheath

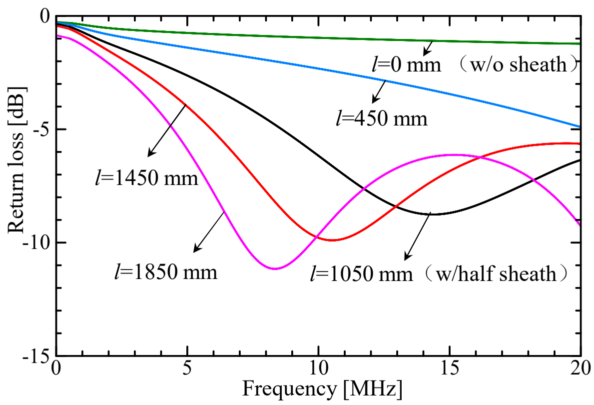


Fig. 3. Return loss of sheathed dipole antennas in seawater with different lengths of sheath.

[1] H. Sato, N. Fujii, Q. Chen, N. Ishii, M. Takahashi, R. Suga, K. Uesaka and H. Yoshida, "Dipole Antenna With Sheath-Cover for Seawater Use," International Symposium on Antennas and Propagation (ISAP2017), 1376, pp.1-2, Phuket, Thailand, Oct. 2017.

[2] Q. Chen, K. Ozawa, Q. W. Yuan, K. Sawaya, "Antenna Characterization for Wireless Power-Transmission System Using Near-Field Coupling", *IEEE Trans. Antennas and Propag. Magazine*, vol. 54, pp. 108-116, Aug. 2012.