

Design for Sonobuoy Transmitting Antenna for Anti Submarine Warfare

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1. Introduction

The sonobuoy transmitting system has been used for anti-submarine warfare. This system is composed of the transmitting antenna, the RF transmitting circuit, the converting circuit sound source into VHF radio frequency and the hydrophone sensor system for receiving of a sound source generated by submarine. In this paper, a sonobuoy transmitting system with the $1/4$ vertical ground plane antenna is designed and measured at anechoic chamber. Fig. 1 shows a concept of $1/4$ vertical ground plane transmitting antenna system used in the sea. A purpose of $1/4$ vertical ground plane transmitting antenna system is transmission from the location information of a sound source generated by submarine to the receiving antenna system mounted on the ship or airplane. A received supersonic wave is converted to RF signal. The frequency range assigned for this system is 136 MHz to 173.5 MHz. This paper is organized as follows. In section 2, the anechoic chamber construction of antenna measurement system required by military specification is described. In section 3, radiation pattern measurement software using GUI (Graphic User Interface) technique is developed. This software offers automatic normalization of measured data and shortening measurement time. In section 4, the radiation patterns and the standing wave ratio (SWR) characteristics of the fabricated antenna with impedance matching circuit are measured and estimated. The measured radiation patterns of a proposed antenna are also compared with ones of conventional type. Finally, Section 5 concludes the summary of this paper.

2. Antenna measurement system in anechoic chamber

Fig. 2 shows a photograph of system configuration for measurement of ground plane antenna. The fabricated antenna is connected to the transmitting RF circuit and the standard dipole antenna with microwave receiver is set up at anechoic chamber. Between microwave receiver and computer are connected by the GPIB cable to monitor real time data. Equipments used for measurement are 8530A microwave receiver, 8511B frequency converter, 83650L CW generator, AL-4806 position controller and computer within GPIB Board.

3. Development of visual graphic software for antenna measurement

Development of software for accurate radiation pattern measurement is very important thing. Commercial software is very expensive and is required the specified equipments. Therefore, needs of general software for antenna measurement have been increased with an advanced communication protocol. However, because GPIB command depends on different according to manufacturing company of measuring instruments, types of GPIB board and so on, software development which is suitable for measurement environment is required.

Fig. 3 shows an example of the developed visual graphic software for antenna radiation pattern measurement using GUI technique. For rapid processing of the measured data, antenna measurement software using commercial compiler of a visual basic 6.0 is developed. This software has some merits that the automatic normalization of measured data reduces the measurement time and visual display window is comfortable for estimation of output expressed by polar graph.

4. Fabrication and measurement of antenna

The impedance matching between antenna and transmitter plays an important role in a system. Since the conventional antenna has not the impedance matching circuit, an increase of the SWR, a

narrow bandwidth and a low efficiency of antenna are occurred. The fabricated antenna is designed to solve above problem and considered for matching of impedance between antenna and transmitter as shown in Fig. 4[1][2].

Fig. 5 shows the proposed structure of antenna with matching circuit. In order to match the impedance, the matching circuit between antenna and RF output is employed, and it is composed of a capacitor and an inductance. Resistance of R as shown in Fig. 4 performs a termination role as a heating element by over current.

Fig. 6 (a) shows the measured SWR of sonobuoy linear antenna without impedance matching circuit using the network analyzer. It is observed the SWR 1.9, 2.16 and 2.15 at 135 MHz, 155 MHz and 175 MHz, respectively. The SWR required by military specification at the assigned VHF band is 2 below. Fig. 6 (b) shows the impedance characteristic of antenna without matching circuit by Smith chart. There is not satisfaction of 50Ω circuit. In order to solve the narrow bandwidth problem occurred by the impedance mismatching, the values of L and C of Fig. 4 are varied. These values can be obtained by control of impedance locus curve of each element on Smith chart. Fig. 7 (a) and (b) show the SWR and the impedance characteristics of antenna with matching circuit, respectively. The measured SWR and impedance on Smith chart show about 1.4 below and about 46Ω at VHF band assigned by military specification, respectively. The lowest SWR appears 1.13 at 162.4 MHz. We confirmed that a linear antenna with impedance matching circuit has broad bandwidth and better SWR characteristic comparison with one without impedance matching circuit.

Fig. 8 (a) shows vertically polarized radiation patterns of the conventional antennas that are manufactured by foreign company (Ant A, Ant B) at 135 MHz [3][4]. These antennas are practically used for the sonobuoy system of the naval military. Two foreign products have null point in 82.5° . Fig. 8 (b) shows the vertically polarized radiation pattern of the fabricated antenna with matching circuit. The measured null point angle of radiation pattern is about -18.5 dB at 85° . The relative amplitude of Fig. 8 (a) and (b) is normalized by the measured maximum amplitude. From the comparison of amplitude of Fig. 8 (a) and (b), one of the fabricated antenna of Fig. 8 (a) has larger than one of Fig. 8 (b). It is similar to requirement pattern of the military specification.

Fig. 9 (a) and (b) show the vertically polarized radiation pattern of the fabricated antenna and the conventional ones at 154 MHz and 173.5 MHz, respectively. In Fig. 9 (a), null point angles of the proposed antenna and the conventional types are observed at 82.5° and 90° , respectively. The required null point angle of military specification is 90° and the relative amplitude at this angle has to satisfy -20 dB below. The null point angle and amplitude of the proposed antenna with impedance matching circuit are measured 90° and -23 dB , respectively. In the measured radiation patterns, both of the foreign products A and B are asymmetry, but the proposed antenna is symmetry. The similar phenomena are observed at 173.5 MHz as shown in Fig. 9 (b). Even though null point angle of the proposed antenna is shifted about 6° , the relative amplitude of -20 dB below at 90° is kept.

Fig. 10 shows the horizontally polarized radiation pattern of the proposed antenna with matching circuit. In military specification, the horizontal beam pattern at the assigned frequency shall be omni-directional within $\pm 1 \text{ dB}$ for all elevation angles within the vertical beam pattern defined by the -3 dB . The used frequencies for measurement are 136 MHz, 154 MHz and 173.5 MHz. The measured horizontal beam patterns are shown reasonable characteristics of comparison with military specification. The omni-directional beam within $\pm 0.8 \text{ dB}$ is observed.

5. Conclusion

This paper describes a performance of sonobuoy antenna compensated with impedance matching circuit for anti submarine warfare system. Since radiation pattern and power density depend on impedance matching between transmitting RF part and antenna with termination resistance, design of matching circuit is very important. The measured SWR of antenna with matching circuit is observed 1.5 below at the assigned VHF band. It shows very excellent performance comparison with conventional types that are used for the same object. The measured vertical and horizontal radiation patterns are also shown -20 dB below at 90° and the omni-directional beam within $\pm 0.8 \text{ dB}$. These results of the proposed antenna agree well with comparison of military specification.

Acknowledgement

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References

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- [2] M. Mizutani, "A Study on Antenna of Matching Circuit Integrally," Thesis, Yokohama National University, Feb. 2003.
- [3] H. Arai, "Measurement of mobile antenna systems," Artech House, 2001.
- [4] Constantine A. Balanis, "Antenna theory analysis and design," John Wiley & Sons, New York, 1997.

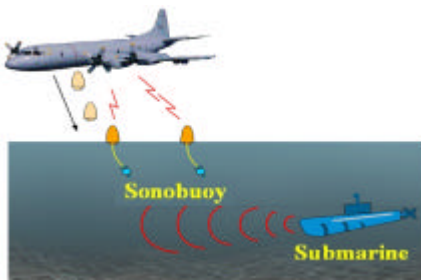


Fig. 1 Concept of $1/4$ vertical ground plane transmitting antenna system on maritime.

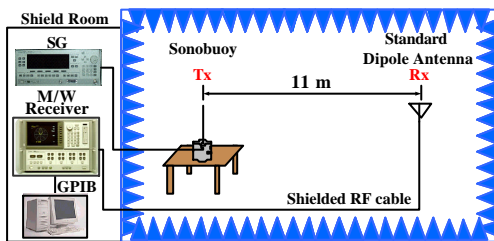


Fig. 2 Configuration of $1/4$ transmitting antenna measurement in anechoic chamber.

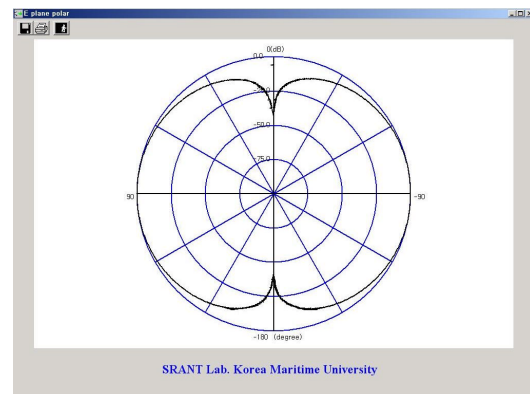
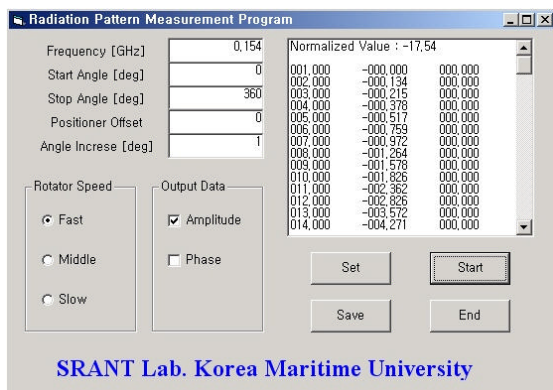


Fig. 3 Example for input and output window of the developed software.

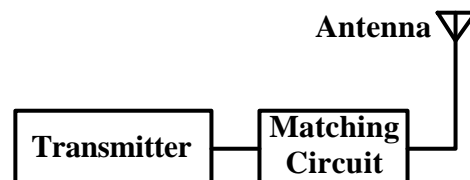


Fig. 4 Block diagram with impedance matching circuit between transmitter and antenna.

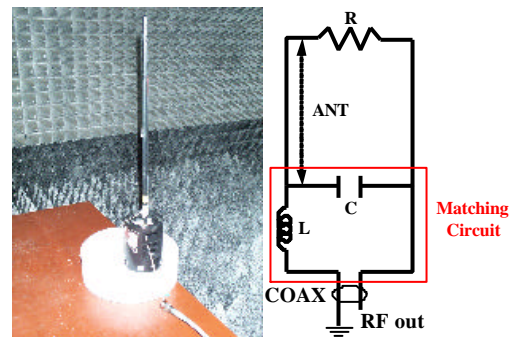
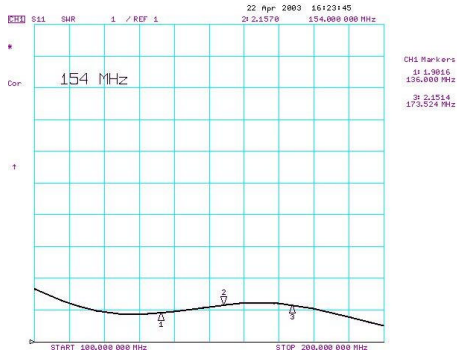
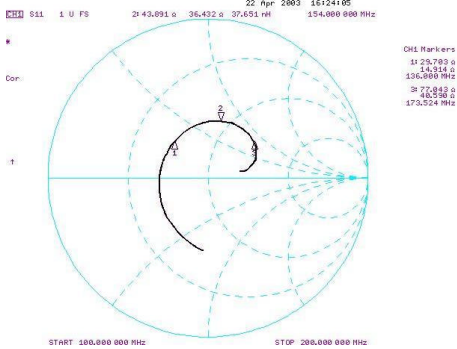


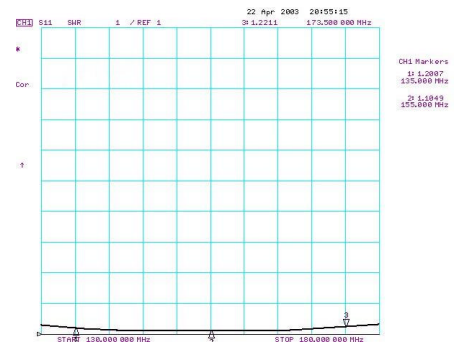
Fig. 5 Antenna structure with impedance matching circuit.



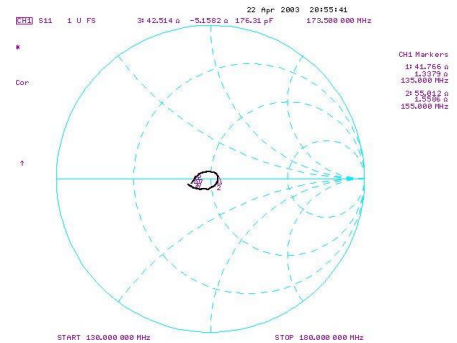
(a) Measured SWR curve



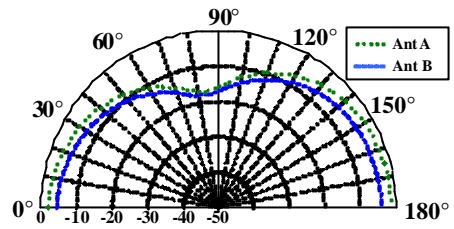
(b) Measured curve of impedance locus
Fig. 6 Measured SWR of antenna without impedance matching circuit.



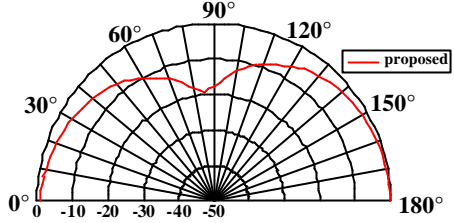
(a) Measured SWR curve



(b) Measured curve of impedance locus
Fig. 7 Measured SWR of antenna with impedance matching circuit.

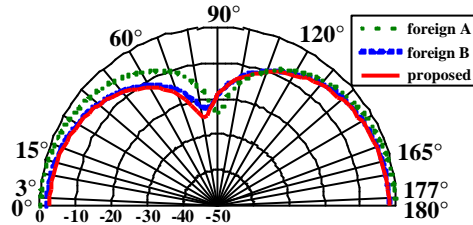


(a) The conventional antenna

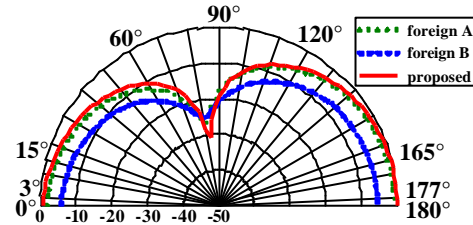


(b) The proposed antenna

Fig. 8 Vertically polarized radiation patterns of the measured antenna at 136 MHz.



(a) 154 MHz



(b) 173.5 MHz

Fig. 9 Vertically polarized radiation patterns measured at 154 MHz and 173.5 MHz.

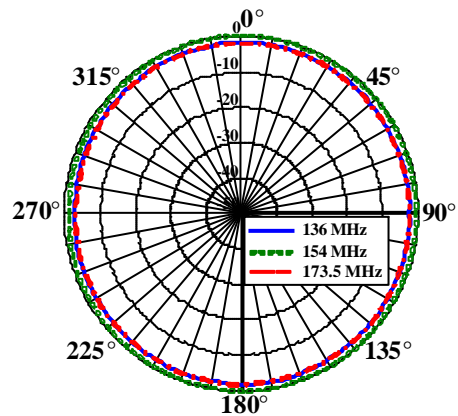


Fig. 10 The measured horizontal patterns of the proposed antenna.