Measurement of Sonobuoy Transmitting Antenna System for Anti-Submarine Warfare

Kyeong-Sik Min

Abstract

This paper describes the measured results of sonobuoy transmitting antenna system for anti-submarine warfare (ASW). 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 for sonobuoy system performance. Matching circuit is designed by Smith chart using control of *L* and *C*. In standing wave ratio(SWR) measurement using Network Analyzer, SWR of antenna with matching circuit observed 1.5 below at the assigned VHF band. It shows very excellent performance comparison with conversional product that is used for the same object. The measured vertical and horizontal radiation patterns are also shown the satisfaction of military specifications. A drop out of sonobuoy system on the sea is happened when angle of elevation direction is over 10 degrees, and it is conformed that it takes less than 1 second return to original signal level. The required electric power density is 83 mW/m^2 in the military specification, and measured electric power density is observed over average 110 mW/m^2 at all frequency bands.

Key words : Sonobuoy, Radiation Pattern, Drop Out, Power Density, Spurious Radiation.

Ⅰ. Introduction

The sonobuoy transmitting system has been used for ASW in navy. This system is composed of a transmitting antenna, a RF transmitting circuit, a converting circuit sound source into VHF radio frequency and a hydrophone sensor system for receiving of a sound source generated by submarine. Many kinds of sonobuoy system are used for ASW. These systems are classified by frequency range limitation, single and/or bi-direction communication, repeating or transmitting function and so on. In this paper, a sonobuoy transmitting system with the $\lambda/4$ vertical ground plane antenna operating at VHF band is considered and measured at anechoic chamber. Fig. 1 shows a concept of sonobuoy transmitting antenna system used in the sea. A purpose of this system is transmission from the location, speed and direction information of a sound source generated by submarine to the receiving antenna system mounted on the ship or airplane. A received supersonic wave generated by submarine is converted to RF signal in sonobuoy system. The frequency range assigned for this system is 136 MHz to 173.5 MHz[1],[2]. This paper is organized as follows. In section 2, the anechoic chamber equipped with antenna measurement system required by military specification is simply described. In section 3, the developed radiation pattern measurement software using graphic user interface (GUI) technique for this system is introduced. This software offers automatic normalization of measured data and reduction of 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

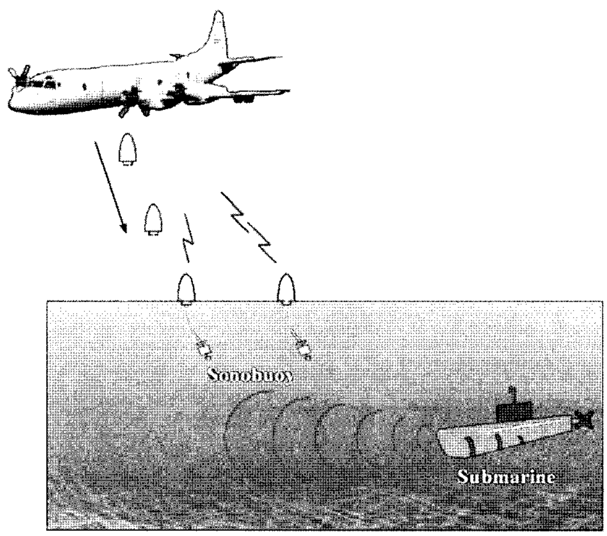

Fig. 1. Concept of sonobuoy transmitting antenna system on maritime.

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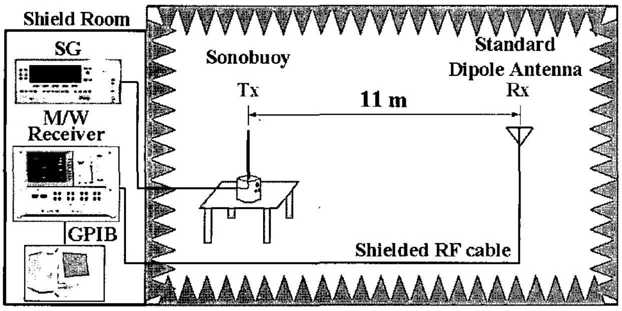


Fig. 2. Configuration of sonobuoy transmitting antenna measurement in anechoic chamber.

compared with ones of conventional type. In section 5, the characteristics of sonobuoy system such as drop out, electric power density and spurious radiation level were measured and discussed. Finally, section 6 concludes the summary of this paper.

Ⅱ. Antenna Measurement System in Anechoic Chamber

Fig. 2 shows a system configuration for sonobuoy transmitting antenna measurement in anechoic chamber. The fabricated antenna is connected to the transmitting RF circuit and a standard dipole antenna as a receiving antenna is set at anechoic chamber. Microwave receiver and computer are directly connected to monitor by the GPIB cable for real time data transmission. Typical equipments used for this measurement are a 8530A microwave receiver, a 8511B frequency converter, a 83650L CW generator, a AL-4806 position controller, a computer within GPIB board and a seawater tank[3],[4].

Ⅲ. Visual Graphic Software for Antenna Measurement

Development of software for accurate measurement of this system is very important thing. Because this system requires not only general radiation patterns but also the specific measurements such as drop out, electric power density and spurious radiation level. However commercial antenna measurement software is very expensive and general. Therefore, needs of software with specific functions that can satisfy the general antenna characteristics such as radiation patterns, gains and polarizations as well as an advanced communication protocol have been increased. In software development, since the GPIB command depends on difference from manufacturing companies of measuring instruments, types of GPIB board and so on, it is required the software suitable for measurement environment. Fig. 3 shows an

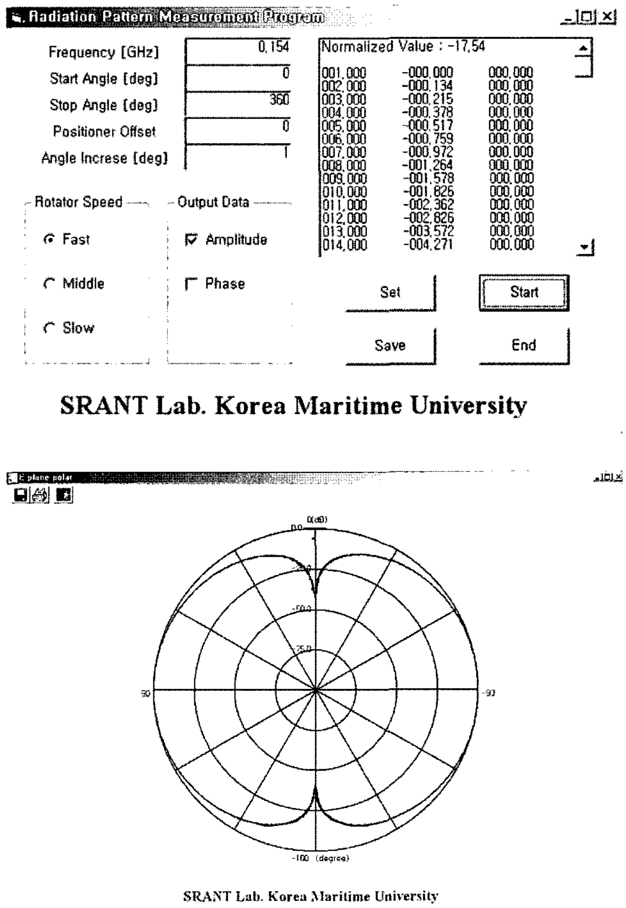


Fig. 3. Example of the developed software window.

example of the developed visual graphic software window 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 results expressed by polar graph.

Ⅳ. Radiation Pattern Measurement

The impedance matching between antenna and transmitter plays an important role in a system performance. 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 problems and considered for matching of impedance between antenna and transmitter as shown in Fig. 4. The operating frequency band of sonobuoy considered in this paper is from 136 MHz to 173.5 MHz on 99 separate channels. In the absence of modulation, the transmitter

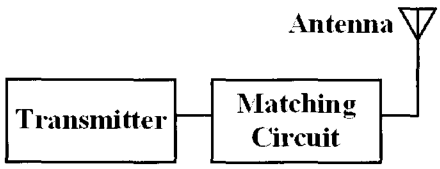


Fig. 4. Block diagram with impedance matching circuit between transmitter and antenna.

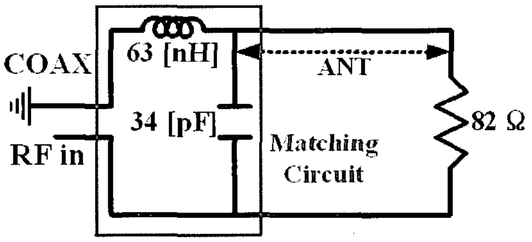
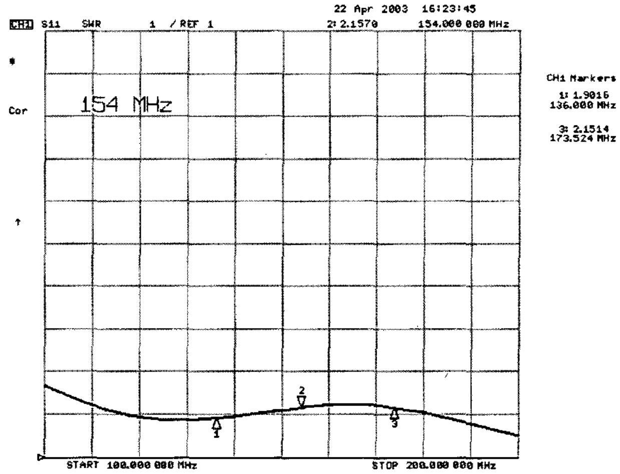


Fig. 5. Antenna structure with impedance matching circuit.

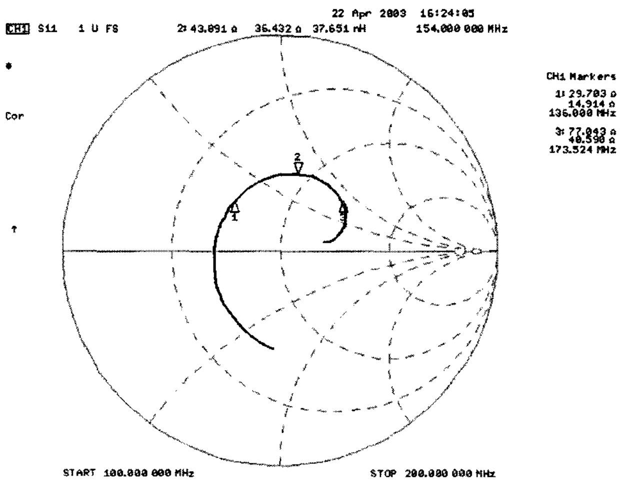
carrier frequency shall be within ±25 kHz of the assigned channel frequency.

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. Resistance value is determined by using time of sonobuoy system threw on sea from airplane. Therefore, Resistance value is changed by monitor region environment. The element values of *R*, *L* and *C* expressed at Fig. 4 are the calculated test value for a power output of at least 1.0 watt RMS on the assigned channel frequency to the antenna.

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 50 Ω 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[5]. The measured SWR and impedance on Smith chart show about 1.4 below and about 46 Ω at VHF bands assigned by military specification, respectively. The lowest SWR appears 1.13 at



(a) Measured SWR curve



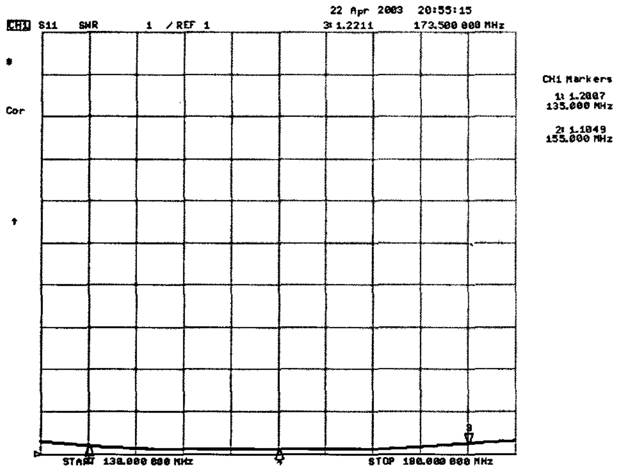
(b) Measured curve of impedance locus

Fig. 6. Measured SWR of antenna without impedance matching circuit.

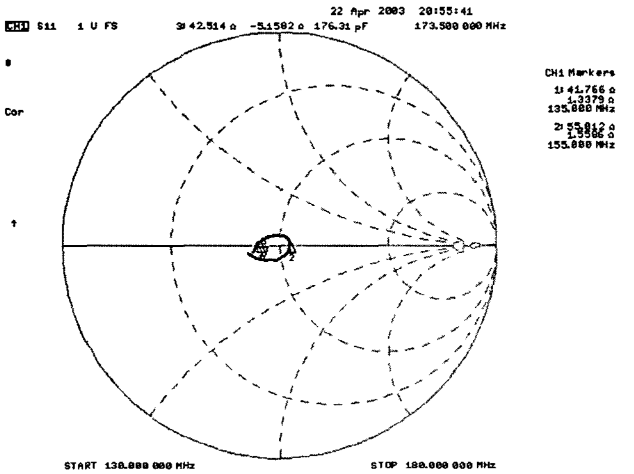
162.4 MHz. We confirmed that a linear antenna with impedance matching circuit has broad bandwidth and better SWR characteristic comparison with one without impedance matching circuit.

Fig. 8 shows vertically polarized radiation patterns of a proposed antenna with matching circuit and the conventional antennas that are manufactured by foreign company(Ant A, Ant B) at 135 MHz. These antennas are practically used for the sonobuoy system of the naval military. Two foreign products have null point in 82.5°. The measured null point angle of a proposed antenna radiation pattern is about − 18.5 dB at 85°. The relative amplitude level of Fig. 8 is normalized by the measured maximum one. A radiation pattern of the proposed antenna is similar to one of foreign A and has generally higher than one of the foreign companies.

Fig. 9(a) and (b) show the vertically polarized radiation pattern of the proposed antenna and the conven-



(a) Measured SWR curve



(b) Measured curve of impedance locus

Fig. 7. Measured SWR of antenna with impedance matching circuit.

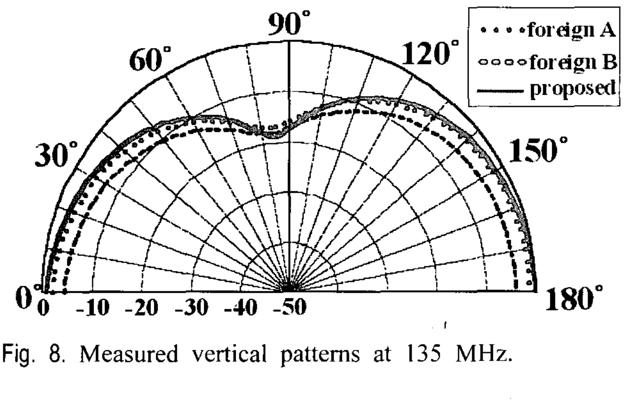
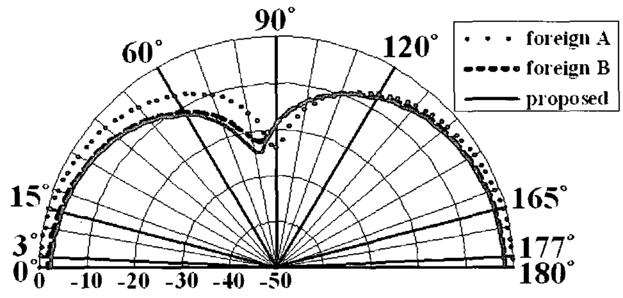
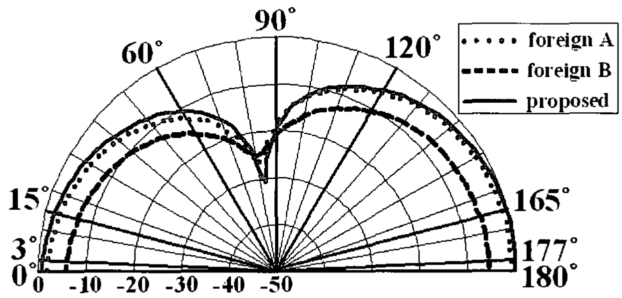


Fig. 8. Measured vertical patterns at 135 MHz.

tional 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



(a) 154 MHz



(b) 173.5 MHz

Fig. 9. Measured vertical patterns at 154 MHz and 173.5 MHz.

and amplitude of the proposed antenna with impedance matching circuit are measured 82.5° and −23 dB, respectively. Even if null pointing angle is slightly shifted, an observed amplitude level of the proposed antenna at 90° appears about −20 dB. In the measured radiation patterns at 154 MHz, even though the foreign product A is observed the best performance with the symmetry pattern, the foreign product B and the proposed antenna are also shown to satisfy the required military specification. The similar phenomena are also 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 ±1 dB for all elevation angles within the vertical beam pattern defined by the −3 dB. The measured horizontal beam patterns are shown reasonable characteristics of comparison with military specification. The omni-directional beam within ±0.8 dB is observed at 136 MHz and 173.5 MHz.

V. Measurement and Estimation of Sonobuoy Transmitter

5-1 Radiation Pattern

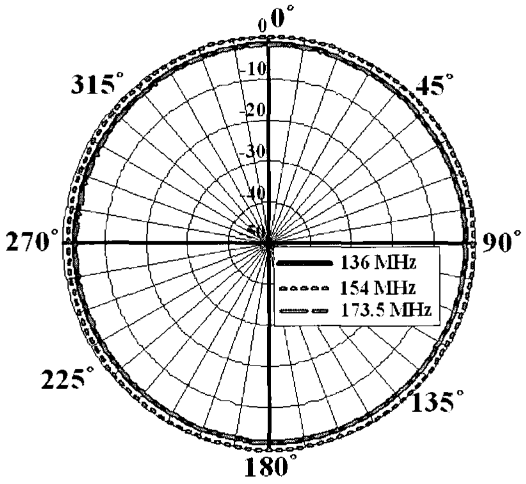


Fig. 10. Measured horizontal patterns of the proposed antenna.

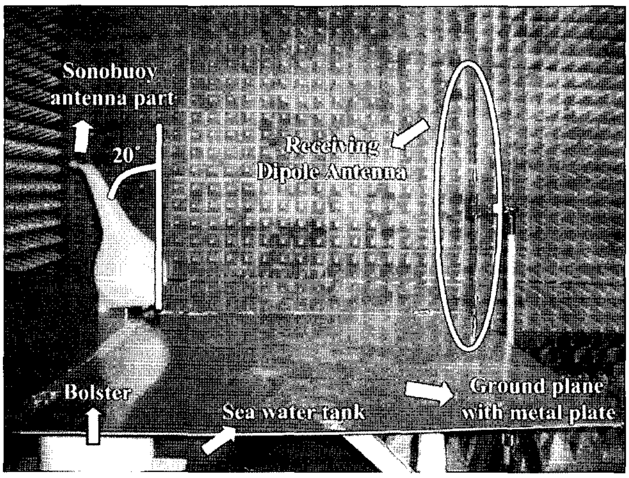
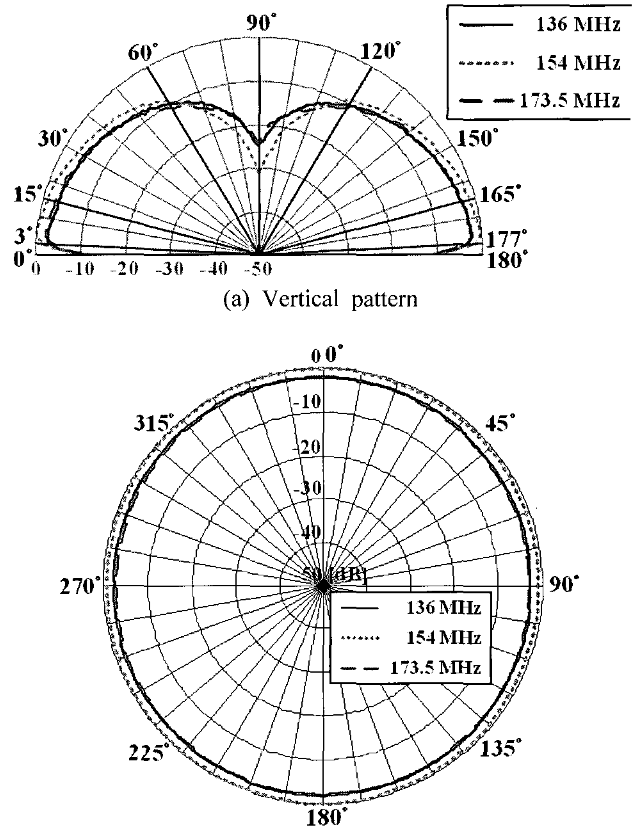


Fig. 11. Sonobuoy transmitting system in seawater tank.

Fig. 11 shows a photograph of sonobuoy transmitter used in measurement with seawater tank. Electromagnetic wave absorber on floor of anechoic chamber was removed to have a reflection effect from surface of the sea. Sonobuoy transmitter was supplied the power by a source of electric power supply. Fig. 12 shows vertical and horizontal radiation patterns of sonobuoy transmitter installed the fabricated antennas. In the measurement result of vertical polarization as shown in Fig. 12(a), the best reasonable power and pattern are observed at 154 MHz of center frequency. Also, radiation patterns measured at three frequencies show a typical radiation pattern of vertical ground plane antenna. In the measurement result of horizontal polarization as shown in Fig. 12(b), omni-directional characteristics at allocated frequency are observed. The measured beam patterns of comparison with the maximum power direction value were distributed within ±1 dB. Thus, the measured radiation patterns showed good characteristics and satisfied the MIL Spec.[6].



(a) Vertical pattern

(b) Horizontal pattern

Fig. 12. Radiation patterns of sonobuoy.

5-2 Drop Out

Drop out occurs when sonobuoy transmitter was putted on sea and slanted by waves or wind. A drop out time prescribed in the MIL Spec., must be within 3 seconds. The sonobuoy transmitter was measured a signal reduction time from drop out. As see in Fig. 11, the distance between a sonobuoy transmitter and a receiving antenna was 1 m and slanted sonobuoy transmitter by 5, 10, 15, 20 degrees. Drop out does not happen in 5～10 degrees. Drop out happens when angle of elevation over 10 degrees, and it takes less than 1 second to return to original signal level. Therefore, sonobuoy transmitter satisfies the MIL spec. that should be reconstructed by original signal level within 3 seconds in more than 3 degree angle of elevation.

5-3 Electric Power Density of Radiation Signal

Fig. 11 shows measurement photograph of electric power density of a radiation signal from sonobuoy transmitter. Distance between a sonobuoy transmitter

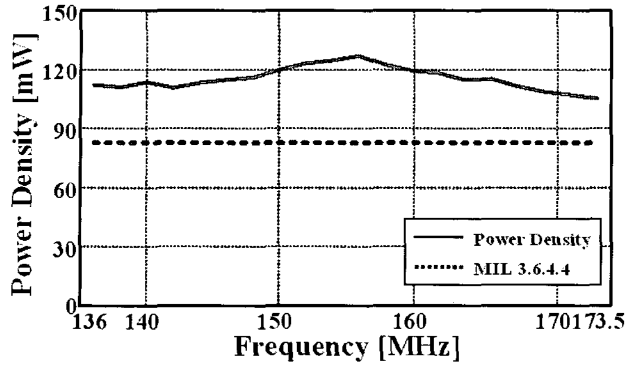


Fig. 13. Measured electric power density.

and a receiving antenna is 1 m and the maximum power supplied by power supply is 1.3 W. Electric power density of sonobuoy transmitter was measured by sweeping all frequency bands. In the MIL Spec., electric power density should be over 83 mW/m^2 at all frequency bands. Fig. 13 shows the measurement result of electric power density of the sonobuoy transmitter and it satisfies the MIL Spec. The maximum power density is observed at 154 MHz and its value is 126 mW/m^2.

5-4 Spurious Radiation

Fig. 14 shows an example of the measured spurious pattern with the main lobe direction at 154 MHz. The MIL Spec. provides that no components of the spurious radiation spectrum shall be greater than a level of −40 dB relative to the main lobe power density of the signal radiated on the VHF-band carrier frequency. The spurious radiation can appear when the vertical and horizontal radiation patterns are measured. But there is no side lobe in Fig. 12. Therefore, the spurious radiation did not appear in this experiment. Also, when it is searched a main lobe direction with the maximum power for antenna or sonobuoy transmitter using spectrum analyzer, spurious characteristic can appear at neighbor frequency. However, the spurious radiation spectrum components did not appear because there was no interference from neighbor frequency as shown in Fig. 14. The measured spurious level difference between the maximum and the minimum value is obsetved about −60 dB below.

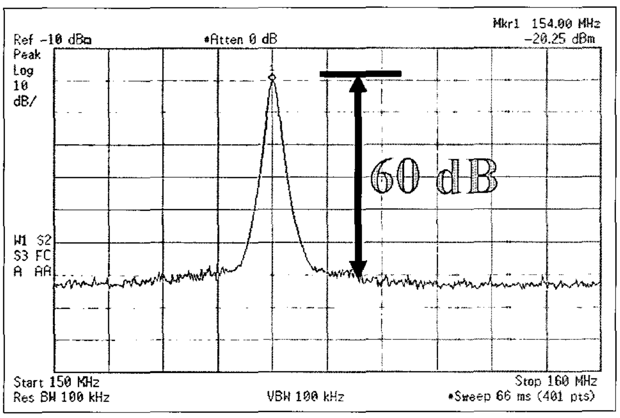


Fig. 14. Measured spurious pattern.

Ⅵ. 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 antenna matching circuit is very important for this system. 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 have been used for the same object. The measured vertical and horizontal radiation patterns of the proposed antenna are also shown −20 dB below at 90° apnd the omni-directional beam within ±0.8 dB. In a scale-down seawater environment, the radiation patterns of sonobuoy transmitter installed the fabricated antenna were measured, and it satisfied the MIL Spec. A drop out was happened when angle of elevation over 10 degrees, and it took less than 1 second to return to original signal level. The measured electric power density is observed over 83 mW/m^2 at all frequency bands. Spurious radiation is observed −60 dB below at the assigned frequency band. Therefore, sonobuoy transmitter with the proposed antenna structure shows a good performance, and it satisfies the MIL Spec. perfectly.

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