V/UHF 대역에서 방향탐지를 위한 광대역 능동 복합 다이폴 안테나

A Broadband Active Composite Dipole Antenna for Direction-finding Applications at V/UHF-band

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ABSTRACT

A compact broadband active composite dipole antenna for direction finding system at the V/UHF-band is presented. It uses the composite structure which improves the antenna gain and the active circuit for broadband operation. This type of antenna has a high gain more than that of one dipole antenna within limited length(1m). The basic design and performance of both antenna structure and integrated active circuit are presented.

주요기술용어(주제어) : Electronic Support(ES), Electronic Intelligence(ELINT), Correlative Vector Direction Finding (CVDF), Direction Finding(DF), Fast Fourier Transform(FFT), Angle of Arrival(AOA)

1. Introduction

A direction finding system is great important for variety applications such as electronic support (ES), electronic intelligence(ELINT), communications, and also personal locating service. For the ES, the accurate direction finding(DF) detection is required for measuring and analyzing the physical parameters of the RF signals in the dense signal environment. These parameters provide the number, type, strength and location of the enemy units[1]. The detection ability for the ES system generally needs 5 degrees using the amplitude comparison method and 2 degrees using the interferometer method[2]. The correlative interferometer method, correlative vector direction finding(CVDF) technique is preferred in the V/UHF DF system. Because it is possible to earn the high DF accuracy and processing speed[3,4].

As shown in Fig. 1, the DF system is composed of the five electrically short vertical dipole antennas which are placed in an equilateral circle, the 5-channel DF receivers, the high speed digital FFT receiver, DF processor, and the display/control unit which provides as the operator interface.

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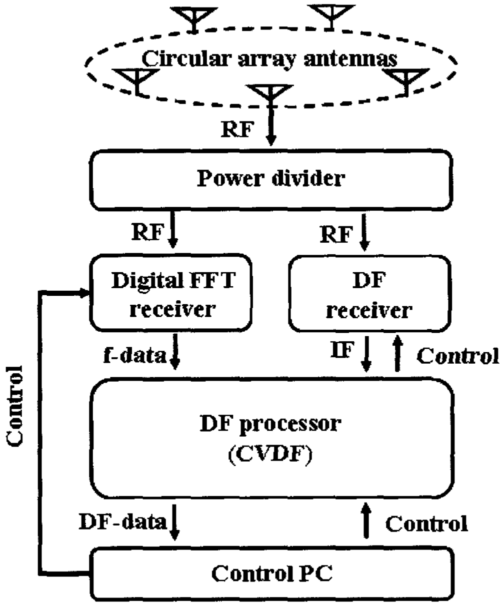
The main element of the DF system is antenna unit. It has to be carefully designed because the sensitivity of the DF system is dependent on the gain and the radiation patterns of the antenna and the characteristics of the antenna arrays. One of the common forms of the antenna arrays is a circular array(see Fig. 1). This circular array provides the potential advantages of the equal radiation coupling and the minimum coupling between the antenna and the supporting mast. The antenna type is selected as the active dipole antenna. Although it has disadvantages of the internal noise and distortion of the active circuit, it provides the broadband operation and short radiation length compared with the passive antenna at the same frequency range[5].

This paper presents the broadband active composite dipole antenna for applications requiring a low profile, lightweight and compact direction finding array. This antenna plays a role in two dipoles functionally and also one dipole physically to improve the gain in the V/UHF-band.



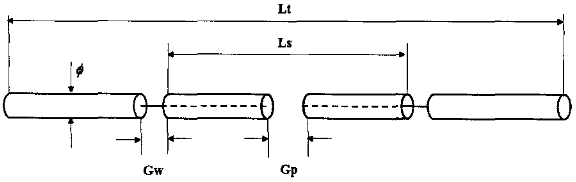
[Fig. 1] V/UHF direction finding system

2. Direction-finding techniques

A DF is the process of estimating the angle-of-arrival(AOA) of one or multiple signals using the information received by the multiple receivers. Most DF techniques used on the ES system are the amplitude comparison methods[5], the interferometer methods[5] or the correlative interferometer methods[3,4]. The first methods measure the amplitude of the RF signals through the antennas and then calculate the differences of the amplitude between two crossed-loop antennas. They are converted to the direction of the incident signal. The second methods measure the relative phase differences of the same incoming signal by placing the antenna at different positions. The third methods compare the measured complex voltage vectors with the obtained complex voltage vectors for a DF system of known configuration at a given wave angle. The comparison is made by correlating the two data sets. Specially, the correlative interferometer methods, CVDF techniques are preferred to the DF system at V/UHF band because of higher accuracy than that of the other DF techniques.

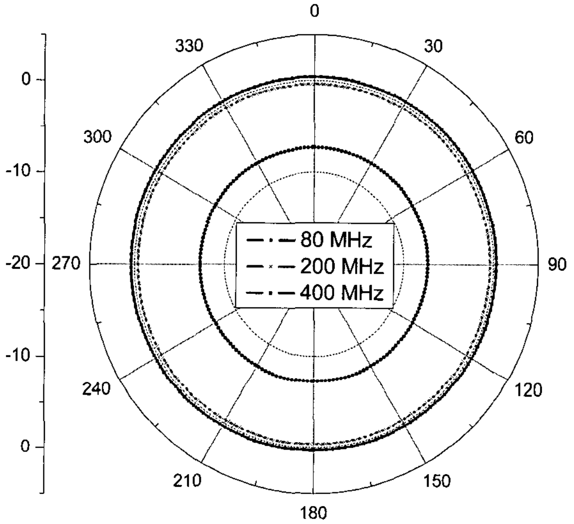
3. Antenna design and configuration

The type of the designed V/UHF antenna is the composite two-range axial dipole, as shown in Fig. 2. It consists of the long dipole, short dipole and inner wire which provides the separation both of them. The maximum length of the total dipole is restricted by 1 m to reduce the size and weight. The simulation is carried out using the Ansoft HFSS, a commercial 3-D electromagnetic simulator based on a finite element method to compare the composite dipole antenna with the one dipole antenna.

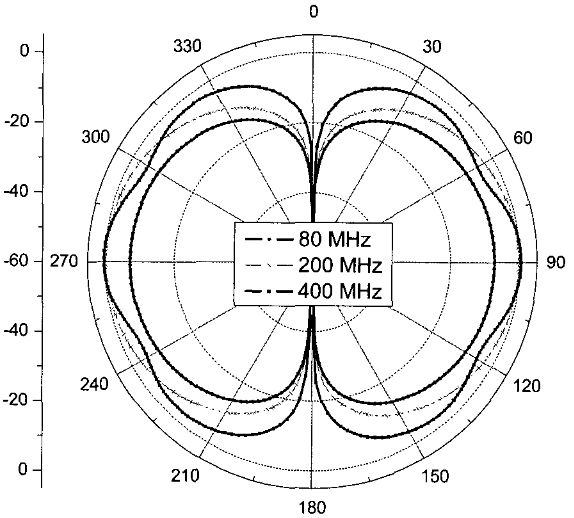


[Fig. 2] Configuration of the composite dipole antenna

The simulated results are presented in Fig. 3, Fig. 4 and Fig. 5. As shown in Fig. 3 and 5, the long dipole antenna provides acceptable gain and radiation patterns for the low frequency range. However, the distortion of the vertical radiation pattern in the high frequency range is appeared and also the low gain is obtained due to the

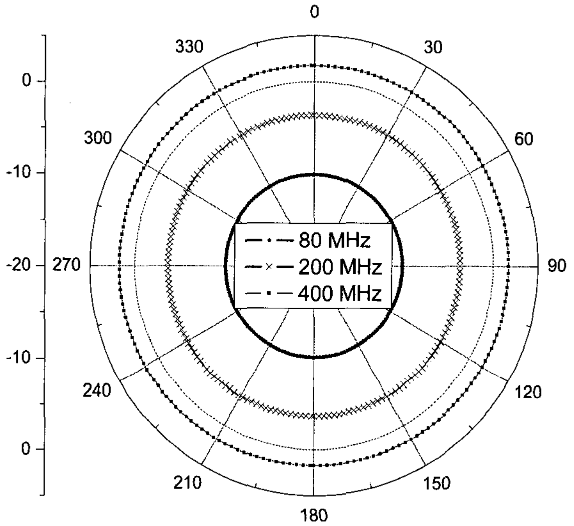


(a) Horizontal radiation patterns

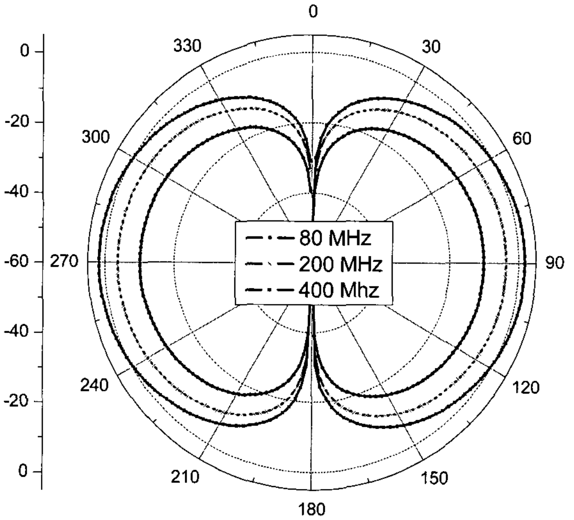


(b) Vertical radiation patterns

[Fig. 3] Radiation patterns of the long dipole

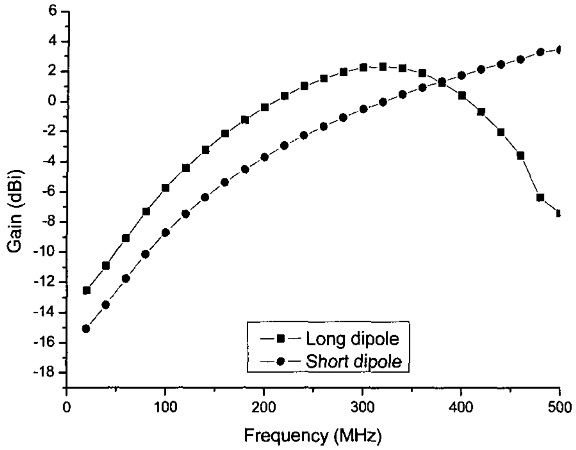


(a) Horizontal radiation patterns

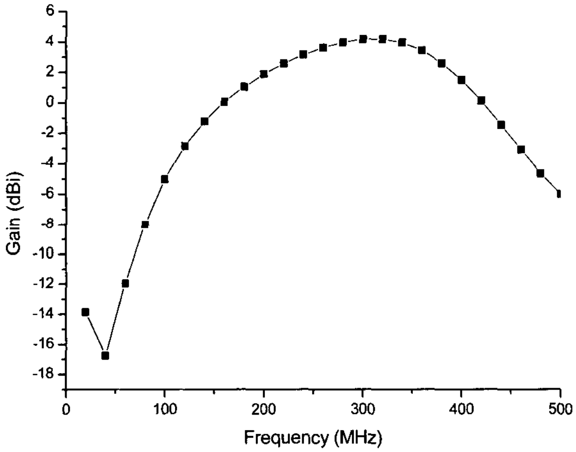


(b) Vertical radiation patterns

[Fig. 4] Radiation patterns of the short dipole



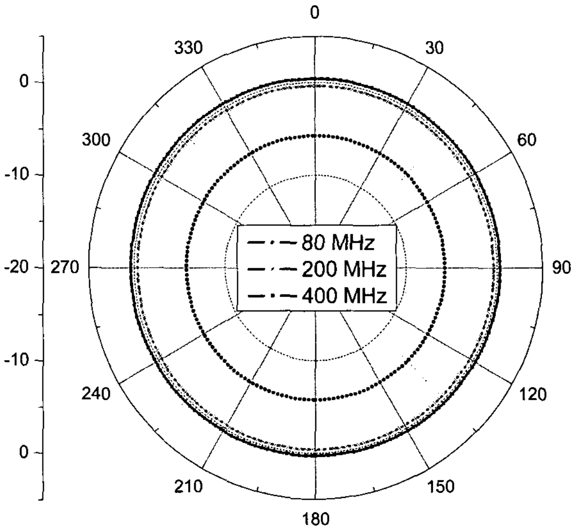
[Fig. 5] Gain characteristics of the short and long dipole



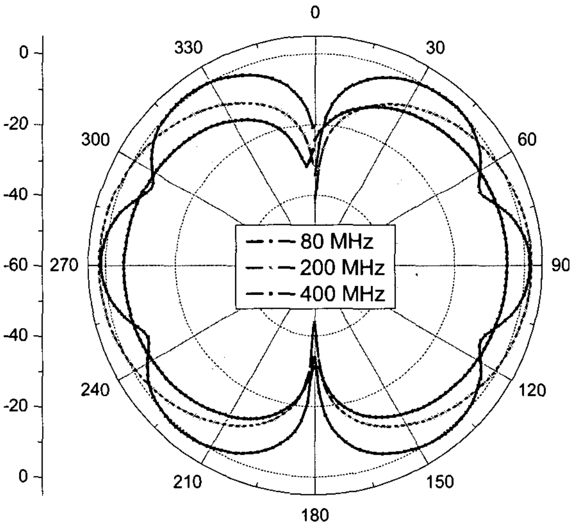
[Fig. 6] Gain characteristics of the composite dipole

unwanted higher order mode. The short dipole antenna provides the good vertical radiation pattern and high gain in the high frequency range while the low gain is achieved in the low frequency range because of shortening radiation length(see Fig. 4 and 5).

These results make a decision to use composite dipole to obtain good performances at the whole frequency range. The design parameters are defined as total dipole length Lt, short dipole length Ls, port gap Gp, thin wire gap Gw and dipole diameter ϕ(see Fig. 2). The short dipole is designed for 470MHz and the long dipole is designed for 140MHz to improve the gain. The simulated gain is presented in Fig. 6. This structure provides higher gain than that of the long and short dipole within the frequency range of 100~400MHz. However, the low gain is



(a) Horizontal radiation patterns



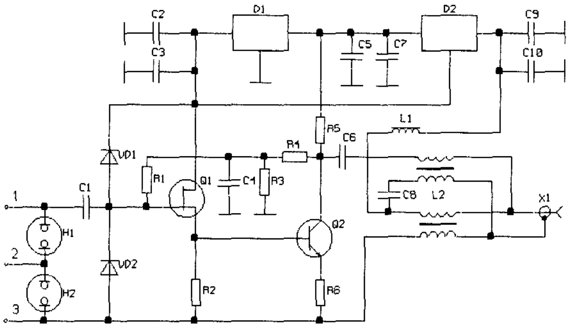
(b) Vertical radiation patterns

[Fig. 7] Radiation patterns of the composite dipole obtained near the 50MHz. The simulated radiation patterns are shown in Fig. 7.

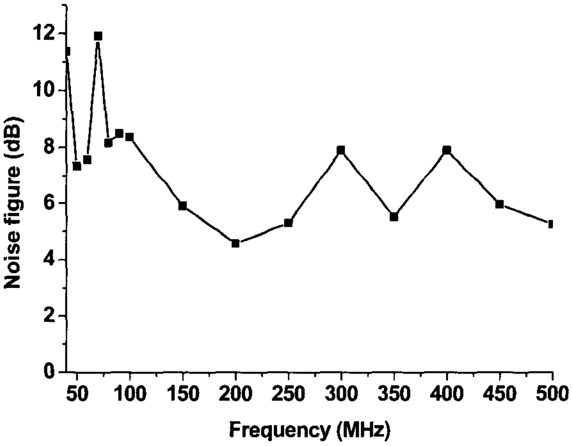
4. Active circuit design

The preamplifier of the active circuit should have high input resistance and low input capacitance to provide the matching of the large impedance change of the dipole. So the preamplifier should be mounted directly at the terminal of the dipole. It acts as an impedance converter and often as an amplifier.

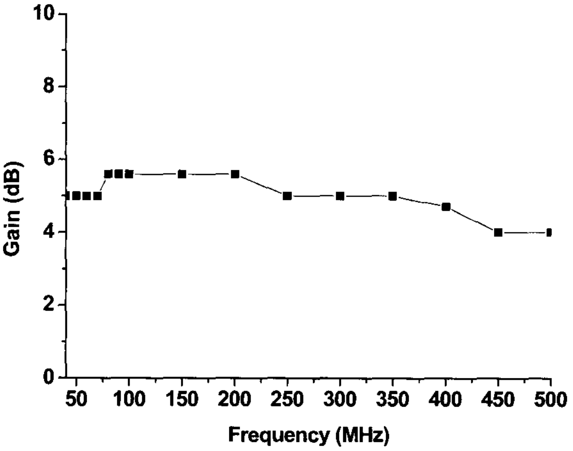
As shown in Fig. 8, the active circuit is composed of two cascade amplification circuits with total transfer constant of +5.5dB at the 50 Ohm load. The first cascade, Q1 is source-following amplifier which provides high input resistance and low input capacitance. The second cascade, Q2 is common-emitter amplifier with gain of +12dB at the 100Ohm load. The transfer constant on RF signal of the cascade amplifier is stabilized by consecutive feedback resistor, R6 and determined by the ratio of 100/(2*R6). The bias voltage of the transistors is stabilized by parallel feedback of the resistance R1, R3, and R4. The capacitor, C4 is inserted to eliminate the influence of parallel feedback to the RF parameters. The output transformer, L2 provides electrical balancing of the dipole and the matching of both the amplifier output impedance(200Ohm) and RF output cable(50Ohm). The diodes, VD1 and VD2 support protection of the input transistor from voltage exceeding 0~+5V. The surge arrestors, H1 and H2 provide protection of the amplifier circuit from static electricity induced on the dipole. The measured performances of the active circuit are shown in Fig. 9, and Fig. 10. The noise figure is measured by the noise figure meter and the gain is measured by the Network Analyzer. The noise figure and gain are around 8



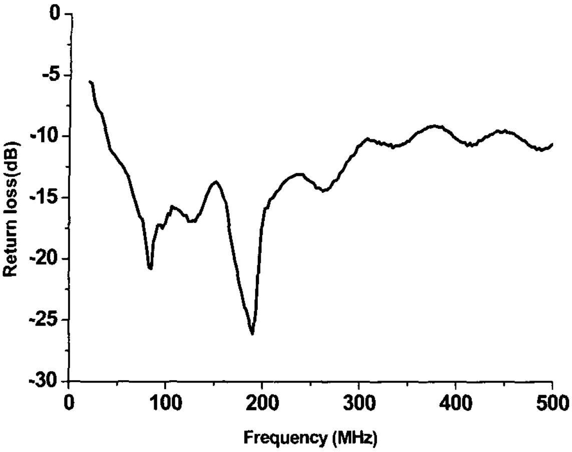
[Fig. 8] Circuit diagram of active circuit



[Fig. 9] Measured noise figure of the active circuit



[Fig. 10] Measured gain of the active circuit

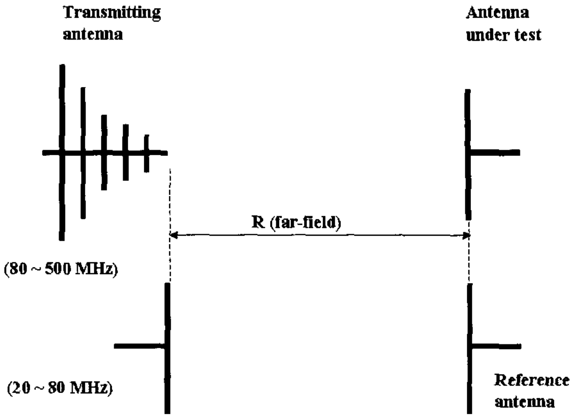


[Fig. 11] Measured return loss of the active circuit

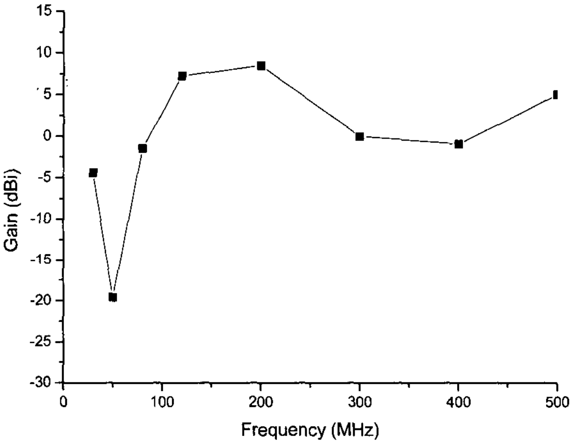
dB and 5dB respectively. As shown in Fig. 11, the output return loss of the active circuit is achieved by around -10dB.

5. Measured results of the active composite dipole antenna

As shown in Fig. 12, the radiation patterns and gain of the active composite dipole antenna are measured by using the methods as used for the passive antenna in outdoor places because the low frequency results in unpractical dimension of the anechoic chamber to satisfy the far-field condition[6]. Two transmitting antennas are used to cover the frequency range of 40~500MHz. To calculate the gain characteristics, one reference antenna is located in the antenna under test. The data points of the horizontal radiation patterns are taken every 4 degrees on the 0 degree elevation as the antenna mast is rotated through full 360 degrees azimuth. The vertical radiation patterns are also measured by using the equal method.



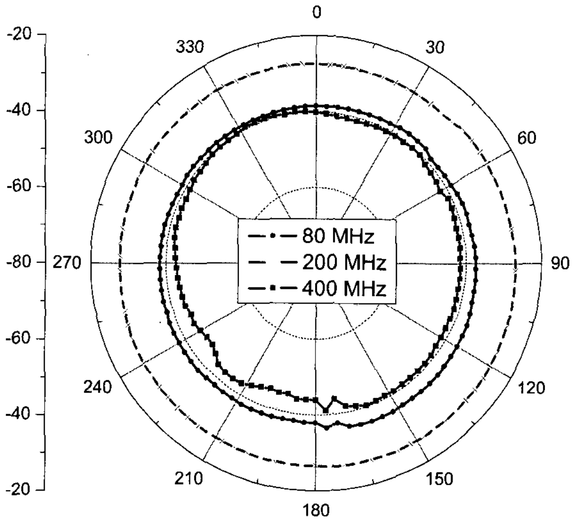
[Fig. 12] Measurement setup of the active composite dipole antenna



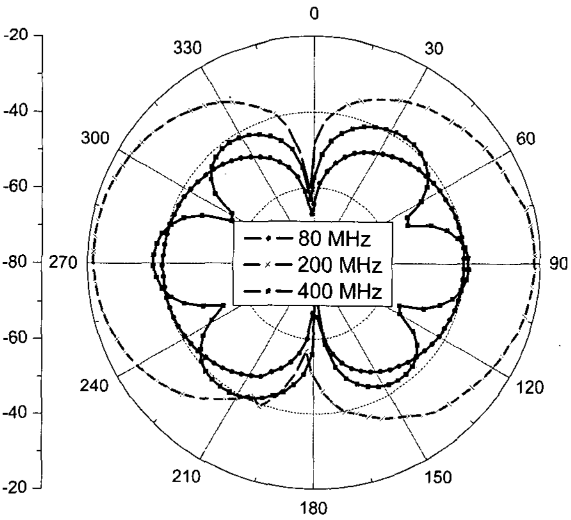
[Fig. 13] Measured gain of the active composite dipole antenna

Fig. 13 shows the measured gain characteristics. It has good gain in the frequency range of 100 ~300MHz while the low gain is obtained in the frequency range of 40~100MHz and 300~500MHz. These differences between gain characteristics can be caused by the unwanted resonance of the low frequency range and the high order mode of the high frequency range.

The measured radiation patterns are presented in Fig. 14. These results are similar to the simulated results. Although the distortion of the vertical radiation patterns is appeared at 400MHz, if they are symmetrical, these results are acceptable for direction finding applications which only use azimuth angle data.



(a) Horizontal radiation patterns

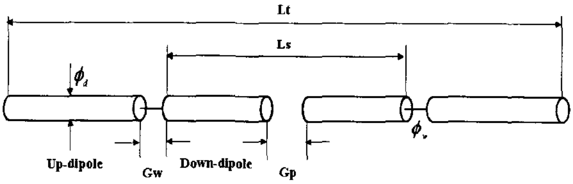


(b) Vertical radiation patterns

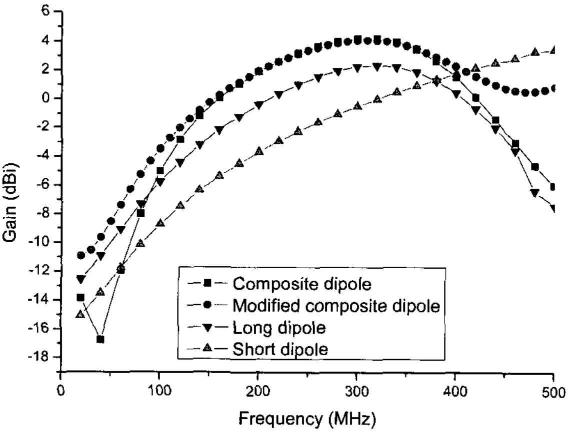
[Fig. 14] Measured radiation patterns of the active composite dipole antenna

6. Performance discussion

The active composite dipole antenna have the low gain in the frequency range of 40~100MHz and 300~500MHz. It may decrease the DF sensitivity. To improve the gain in the low and high frequency range, the structure of the composite dipole antenna is modified. Fig. 15 shows the modified composite dipole antenna. The inner long wire is replaced by the short wire which is directly connected between up-dipole and down-dipole. This structure plays a role in two dipole, long and short dipole. The design parameters are slightly adjusted. The simulated results are presented in Fig. 16. The gain characteristics in the low and high frequency range are improved by above 2dBi.



[Fig. 15] Modified composite dipole antenna



[Fig. 16] Gain characteristics of the modified composite dipole antenna

7. Conclusion

A compact broadband active composite dipole antenna at the V/UHF-band is presented. The gain is increased by using the composite structure which plays role in two dipoles. To improve the gain of the low and high frequency range, the composite dipole antenna is modified by directly connecting between up-dipole and down-dipole. This type of antenna has a high gain more than that of one dipole antenna within limited length. It is useful for the direction finding system because of compact, broadband and high gain.

8. References

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