A–7–2

EXPERIMENTS ON SUPERCONDUCTING ELECTRIC DIPOLE AND ITS ARRAY

Saburo Adachi, Yoshihiro Mohri, Shigeo Ohnuki
and Kazuhide Ashida
Department of Electrical Engineering,
Tohoku University, Sendai, Japan

Introduction

Successful experiments on superconducting antennas have been carried out so far only for loop antennas by Walker and Haden [1], [2] and our group [3]. The first experiment on the cryogenic electric dipole antenna was tried by Moore and Traverse [4]. However the improvement of the radiation efficiency was very moderate due to non-superconducting state. In the present experiments a single electric dipole antenna fed by a 50-ohms coaxial cable has been tested successfully at the frequency band of 300 MHz. Then, an endfire array antenna consisting of two such electric dipoles has been found to be the first unidirectional and superdirective antenna even tested successfully.

Single Electric Dipole

The whole configuration of the electric dipole antenna system including the balance-unbalance transducer (Ys) and the impedance matching section is shown in Fig. 1. The matching section consists of the series lumped-constant inductance coil (Z_L) and the parallel distributed-constant inductance (Y_M).

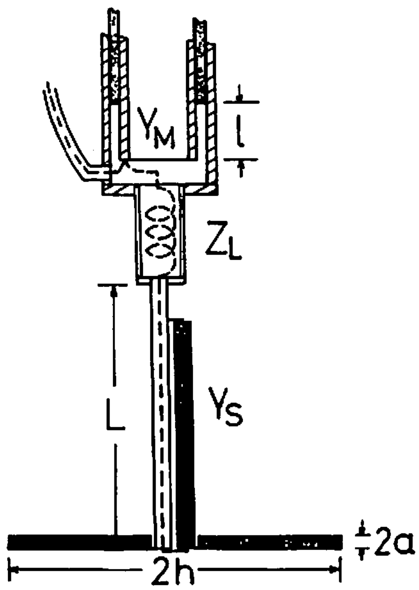

Fig. 1. Structure of single electric dipole antenna. 2h = 6 cm, L = 6.5 cm.

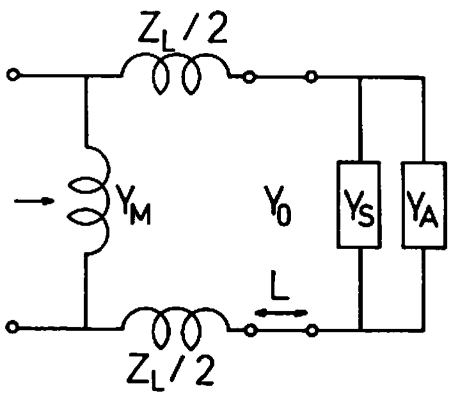

Fig. 2. Equivalent circuit of single electric dipole.

The radiation resistance of the dipole (2h = 6 cm, i.e., 1/17 wavelengths) is calculated as $Rr \simeq 0.71\Omega$ at f = 300 MHz. The number of turns of the coil is 20. The parallel admittance value Y_M for the 50Ω-matching has to be very large ($\ell \simeq 9.6$ mm). All the conductive surface was Pb-plated (the critical temperature of Pb, $Tc \simeq 7.2$ K). The whole antenna set was submerged in He-liquid ($T \simeq 4.2$K) which is poured into an unsilvered Pyrex Dewar.

The input admittance locus of the antenna is shown in Smith chart, Fig. 3 (for 50Ω-cable). The optimum VSWR for this case is about 2.3. The optimum VSWR of the Cu-antenna in a room temperature was about 1.08 at f = 310 MHz. Figure 4 shows the radiated field intensity measured at a distance of 2λ apart from the transmitter versus the frequency for the superconducting dipole and the normal Cu dipole at a room temperature respectively.

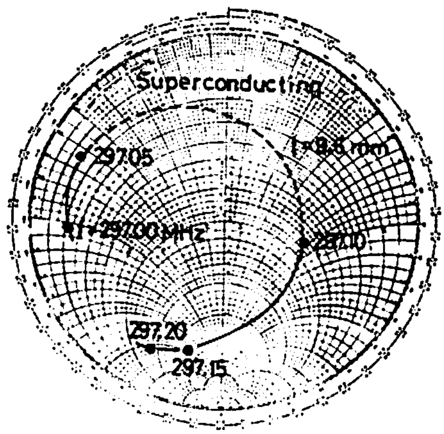

Fig. 3. Normalized input admittance of superconducting single electric dipole for 50Ω-cable.

The total improvement of the field intensity due to the superconduction is found from Fig. 4 to be about 17.6 dB. The Q values obtained from the resonance curves are about 3,700 and 100 for these antennas, respectively. The impedance matching condition in case of the superconduction changes considerably from that in a room temperature mainly because of the vanishing of the loss resistance of the coil Z_L. The impedance matching is optimized by adjusting the stub (Y_M) and the frequency. The frequency shift indicated in Fig. 4 is resulted from the above frequency adjustment for obtaining the optimum impedance matching. The 8-figured radiation pattern was obtained for the horizontal polarization in the superconducting state. The working gain of the antenna was measured by comparing the radiated field strength to that of a half-wave dipole, and was estimated as about -10.4 dB (absolute gain), which is 5.4 dB less than the gain, -5 dB of the superconducting loop with 3 cm in diameter [3]. The low efficiency compared to a loop antenna is due to the reason

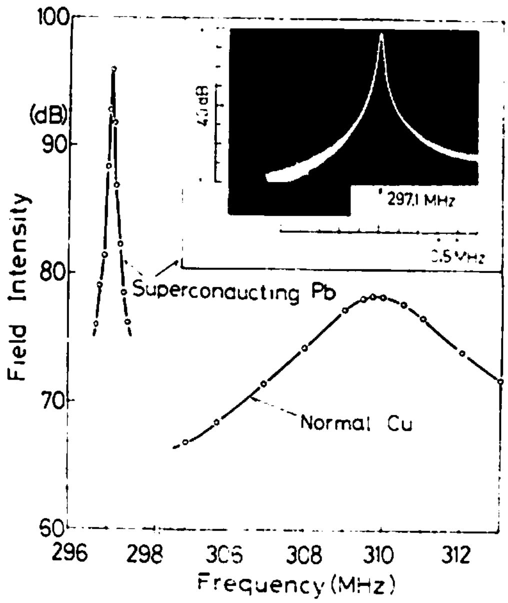

Fig. 4. Radiated electric field intensity of single electric dipole.

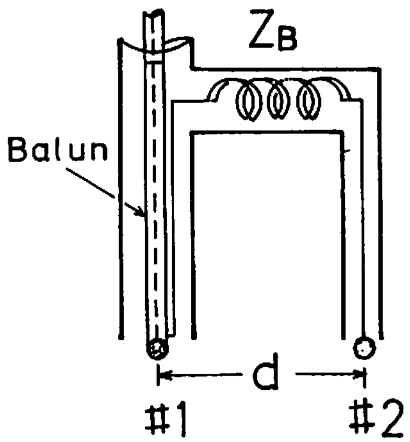

Fig. 5. Structure and feeding configuration of 2-elements dipole array. d ≃ 3.3 cm.

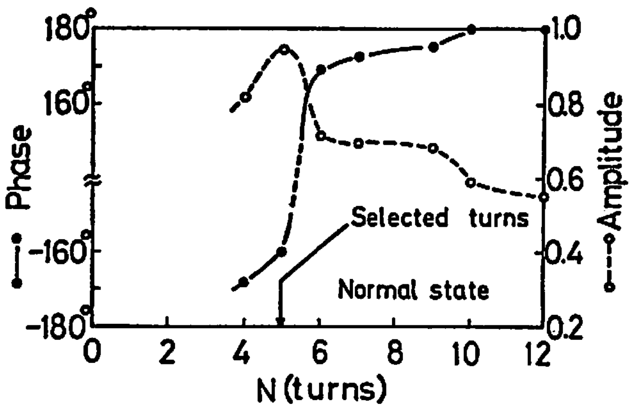

Fig. 6. Relative amplitude and phase of two dipoles versus number of turns of bifilar coil.

that the series inductance (Z_L) has to be much larger than that in case of the loop for the matching. The reduction of the gain may be covered by arraying the dipoles.

Dipole Array

We are going to achieve a supergain antenna by arraying the superconducting dipoles. As is well known, the gain is essentially determined by the number of dipole elements whatever small the array length is. The 2-elements endfire dipole array was constructed. The feeding configuration is schematically shown in Fig. 5. The second element (#2) is fed via a bifilar coil (Z_B). The amplitude and the phase of the #2 element was adjusted by changing the number of turns of the coil to obtain the optimum gain for the prescribed element-spacing (3.3cm) in a room temperature. The characteristics of the coil in a room temperature are illustrated in Fig. 6.

The input admittance locus is shown in Smith chart, Fig. 7. The radiated electric field strength is plotted in Fig. 8 with comparison to the single Cu dipole antenna with #2 dipole removed and to the Cu 2-elements dipole array in a room temperature. The improvement of the

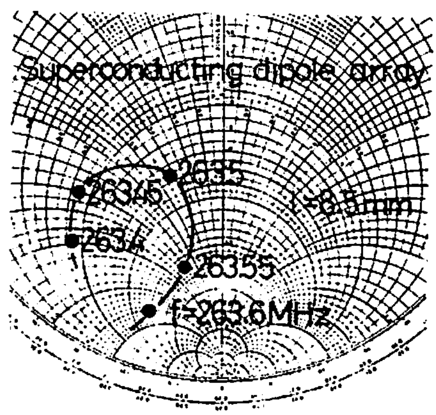

Fig. 7. Normalized input admittance of superconducting dipole array for 50 Ω -cable.

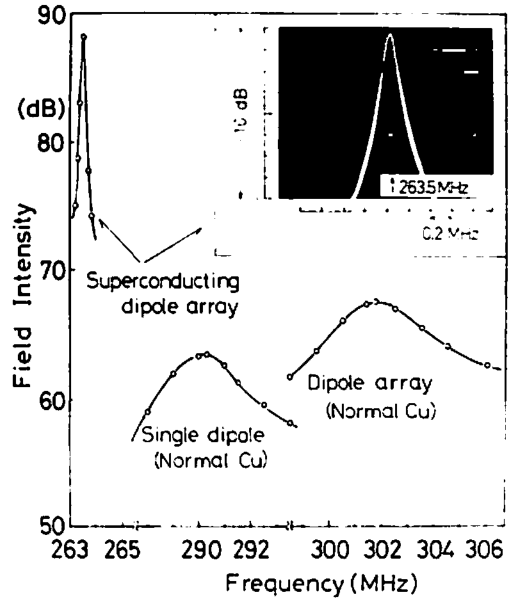

Fig. 8. Radiated electric field intensity of single and 2-elements dipoles.

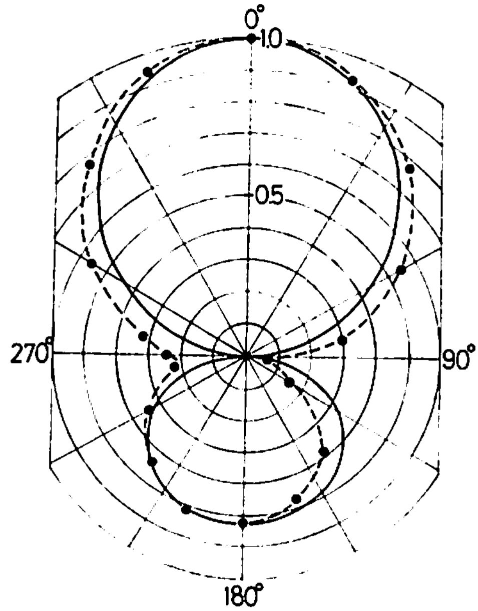

Fig. 9. Radiated electric field pattern of superconducting dipole array. —— ; calculated, - - - measured.

working gain is about 21 dB compared to the normal 2-elements array. The radiated field pattern at the state of superconduction is approximately unidirectional as shown in Fig. 9, where the calculated pattern is for the assumed excitation of the equal amplitude and the phase difference of 150 degrees for the two dipoles.

Conclusion

A superdirective supergain antenna has been achieved by using 2-elements superconducting dipole array. The improvement of 21 dB in the working gain has been obtained by the superconduction.

References

1. Walker, G. B. and C. R. Haden, J. Appl. Phys. 40, p. 2035 (April 1969).
2. Walker, G. B., C. R. Haden and O. G. Rawer, IEEE Trans., AP-25, No. 6, p. 885 (Nov. 1977).
3. Adachi, S., S. Kimura, S. Ohniki, Y. Mohri and Y. Onodera, IECE of Japan, 59-B, No. 5, p. 299 (May 1976).
4. Moore, J. D. and D. N. Travers, IEEE Trans., AP-14, p. 246 (March 1966).