3-1 A4

EXPERIMENTS ON ELECTRON PLASMA WAVE RADIATION AND RECEPTION BY SOME SIMPLE ANTENNAS

T. Ishizone, S. Adachi, Y. Mushiake, and K. Sawaya

Faculty of Engineering, Tohoku University
Sendai, Japan

Hitherto a number of theoretical papers have been written on the radiation of an electron plasma wave from antennas, especially from a dipole antenna in a warm plasma. While, the experimental studies on verification of these theoretical results are very scarce. In spite of many theoretical predictions, the electron plasma wave can not observed very easily, and seems to be buried in the electromagnetic wave.

It is the purpose of this experimental study to correlate existing theoretical results with experimental evidences and to provide a basis for further advancement of the theory.

Experimental Set-Up and Plasma

The experiments were performed in the space plasma chamber of the Research Institute of Electrical Communication, Tohoku University and partly in the similar one of the Institute of Space and Aeronautical Science, University of Tokyo. The space plasma chamber of the Tohoku University and the experimental set-up are illustrated schematically in Fig. 1. As a plasma source a back-diffusion type of hot cathode was used as shown in the figure. Argon was used as a discharging gas. The pressure was varied in the range of $3 \sim 12 \times 10^{-4}$ Torr. in the present experiments. The electron density and the electron temperature were measured by using the Langumuir single probe. Typical plasma parameters were $Te \simeq 1 \sim 6$ eV, the electron plasma frequency, $f_p \simeq 10 \sim 100$ MHz.

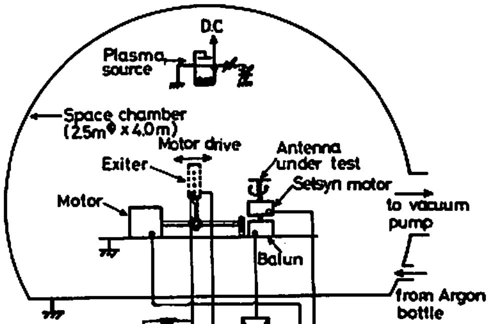

Fig. 1 Space plasma chamber and experimental set-up

Identification of Electron Plasma Wave

The characteristics of the electron plasma wave radiation and reception were obtained by the method of the propagation-measurement, namely the measurement of the variation of the received voltage versus the propagation distance from a transmitting antenna. A typical propagation pattern thus obtained is shown in Fig. 2. This pattern was obtained by using shielded circular grids (5 cmϕ) as transmitting and receiving antennas with floating d. c. potentials. Normally,

Fig. 2 Propagation pattern between two shielded circular grid antennas

both an electromagnetic wave and a plasma wave are received in certain frequency region. The damping standing wave pattern is believed to indicate the interference between the capacity-coupled electromagnetic field (fast wave) and the electron plasma wave (slow wave).

We first measured the dispersion characteristics of the slow wave superimposed on the near-exponentially damped electromagnetic field by varying a signal frequency and plasma parameters. One of the measured results is shown in Fig. 3 and is compared with the theoretical values of the electron plasma wave. These exhibit the proper characteristics of the electron plasma wave as a whole with respect to the phase velocity and the attenuation due to Landau damping.

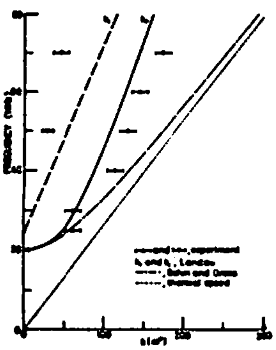

Fig. 3 Dispersion characteristics of received slow wave and theoretical dispersion of electron wave

Antenna Directional Pattern

The antenna directional patterns for the electron plasma wave were measured by the method described above. Antennas under test can be rotated by a selsyn-motor as shown in Fig. 1. For each fixed rotation angle the propagation measurement was carried out. Fig. 4 (a) shows the radiation pattern of the shielded circular grid antenna (5 cmϕ) together with the theoretical radiation pattern.

Fig. 4(b) shows the receiving field pattern of a top-loaded cylindrical dipole antenna. This receiving pattern is similar to the theoretical radiation pattern of a cylindrical dipole antenna. This experimental fact is of interest in connection with the reciprocity relation between transmitting and receiving antennas in a compressible plasma.

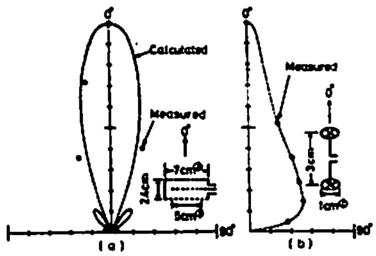

Fig. 4(a) Radiation field pattern of shielded circular grid antenna, (b) Receiving field pattern of top-loaded dipole antenna

Effect of D. C. Bias Voltage

The d. c. bias voltage applied to antennas can control the formation of the ion sheath around antennas. The ion sheath is directly related to the radiation or receiving properties of the electron plasma wave. Fig. 5 shows the measured relative transmitting and receiving efficiency of the electron plasma wave versus the applied d. c. bias voltage with respect to the earth. A similar tendency is seen for the transmitting and receiving antennas.

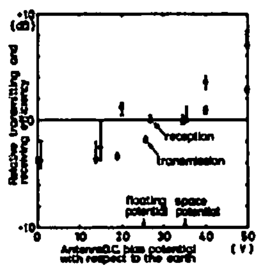

Fig. 5 Relative transmitting and receiving efficiency of shielded circular grid antenna versus d. c. bias voltage

Acknowledgement

The authors are indebted to Prof. K. Kamiryo for his advice and H. Ishikawa for his assistance in carrying out the experiments.