to tune out the large capacitive reactance of the input impedance of a small antenna.

The effect of the thickness of the plasma layer on the phenomenon of enhanced radiation is shown in Fig. 2(b). The same antenna (0.635-cm radius) is driven at 0.4 GHz, and the electron collision frequency is assumed to be 0.003 GHz. The antenna radiation is plotted as a function of ω_p^2/ω^2 for various values of the plasma layer thickness. For a thin plasma layer the enhancement of radiation is small. When the thickness of the plasma layer is around $1\frac{3}{4}$ inches, a maximum enhancement of radiation is obtained. This indicates the existence of an optimum thickness of the plasma layer for the maximum enhancement of antenna radiation. As the thickness of the plasma layer increases, the enhancement of radiation decreases correspondingly. When the thickness of the plasma layer approaches infinity, the antenna radiation remains zero after passing the cutoff point. This point is expected since the phenomenon of enhanced radiation does not occur if the antenna is placed in a plasma of infinite extent.

The effect of the antenna size on the phenomenon of enhanced radiation is indicated in Fig. 2(c). The antennas of various radii are assumed to be covered by a plasma layer of 2-inch thickness and driven at 0.4 GHz. The electron collision frequency is assumed to be 0.003 GHz. The antenna radiation is plotted as a function of ω_p^2/ω^2. In this figure it is observed that the phenomenon of enhanced radiation becomes less significant if the antenna size is increased. This indicates that for a large antenna the phenomenon of enhanced radiation may not be observed.

Experimental Results and Comparison with Theory

The experimental results of the radiation from a spherical antenna of radius 2.54 cm driven by various frequencies are plotted in comparison with the corresponding theoretical results in Fig. 3. At each driven frequency the antenna radiation is measured as a function of the plasma density, and the radiated power is normalized to the value when no plasma is present (free-space radiation). The antenna radiation is measured at $r = 0.915$ meter in the broadside direction of the radiating antenna. A similar experimental setup used in [2] has been employed in this investigation.

The corresponding theoretical results are calculated from $E_{\theta 2}$ ($r = 0.915$ meter, $\theta = 90$ degrees) in (1) under the assumption that the electron collision frequency is 0.12 GHz. The theoretical value of the radiated power is also normalized to the free-space radiation. The comparison of theoretical results (lines) with the experimental results (dots) indicates very good agreement.

In the experiment, the antenna radiation was observed to be enhanced about 15 dB over the free-space radiation when the antenna frequency was 0.3 or 0.4 GHz and the plasma frequency was at least twice higher than the antenna frequency. It was also observed in the experiment that when the antenna frequency was higher than 0.8 GHz, no enhancement above the free-space radiation could be obtained after passing the cutoff point. All these phenomena are well predicted by the theory. Also in the experiment the dc potential of the antenna was varied between ± 20 volts to see the effect of the plasma sheath on the phenomenon of enhanced radiation. Except for a slight effect due to the bias circuit, negligible effect by the plasma sheath had been observed.

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Measurement of Antenna Current Distribution in an Anisotropic Plasma

Abstract—**The current distribution along a cylindrical antenna immersed in a magnetized plasma has been measured. It has been observed that the standing wavelength along the antenna wire is substantially shortened to a greater degree with increasing plasma frequency under the presence of the dc magnetic field. The gyroresonance has also been observed in the current distribution.**

Introduction

The current distribution along a cylindrical antenna immersed in an isotropic plasma was measured by Judson and Chen [1], Ting *et al.* [2], and the present authors [3]. In the measurement by the present authors a large volume of plasma ($1.4 \times 1.4 \times 0.7$ m^3) was used. By using the same experimental setup the current distribution along a cylindrical antenna in an anisotropic plasma magnetized in the direction parallel to the antenna axis has been measured for the first time. Variation of the wavelength along the antenna has been obtained from the measured current distributions for various gyro and plasma frequencies.

Experimental Setup

The experimental setup used in this experiment is almost the same as that of the previous experiment [3] except that a magnetizing coil with a diameter of 1 meter is placed beneath the image plane. The direction of the static magnetic field at the monopole antenna is set parallel to the antenna axis. It should be noted that the anisotropic plasma generated by this system is not quite uniform in the plasma density and also in the static magnetic field intensity.

The plasma density was derived from the measured results of the antenna current distribution at a sufficiently high frequency satisfying the condition of $f > f_P$ and $f^2 \gg f_H^2$, where f is the radio frequency, f_P the plasma frequency, and f_H the electron gyrofrequency corresponding to the static magnetic field. The justification for using this method was confirmed in the recent experiments, that is, the antenna current distribution in an isotropic plasma is essentially determined by the well-known equivalent dielectric constant for an electromagnetic wave in the case of $f > f_P$ [3], and also the antenna current distribution in an anisotropic plasma differs very little from that in an isotropic plasma if $f^2 \gg f_H^2$ holds [4]. This measuring method for a plasma density is considered as convenient for determining the average plasma density in the direct vicinity of the antenna since no other measuring instruments are required.

Experimental Results and Discussion

The monopole antenna was driven at the frequency of 108 MHz. The antenna current distribution for various ambient plasma frequencies was measured when the magnetizing coil current is kept to constant at $I_B = 0$, 100, 150, and 200 amperes, respectively. Fig. 1 shows some typical examples of the measured antenna current distributions in an axially magnetized plasma. These curves show the following two interesting features. First, as indicated by curves f, g, h, k, and l, when the plasma frequency is relatively low, a traveling-wave current and an attenuating-wave current are observed along the part of the antenna wire including the feedpoint and the remaining part of the antenna, respectively. Fig. 2 shows this typical antenna current distribution. The traveling type of current and the attenuating type of current exist in the regions of $f < f_H$ and $f > f_H$, respectively. One or a few resonance peaks are observed at the vicinity which is a little lower than the point of the electron gyrofrequency $f = f_H$. This phenomenon may be well explained by the gyroresonance of the propagating wave or current along the antenna which occurs when the radio

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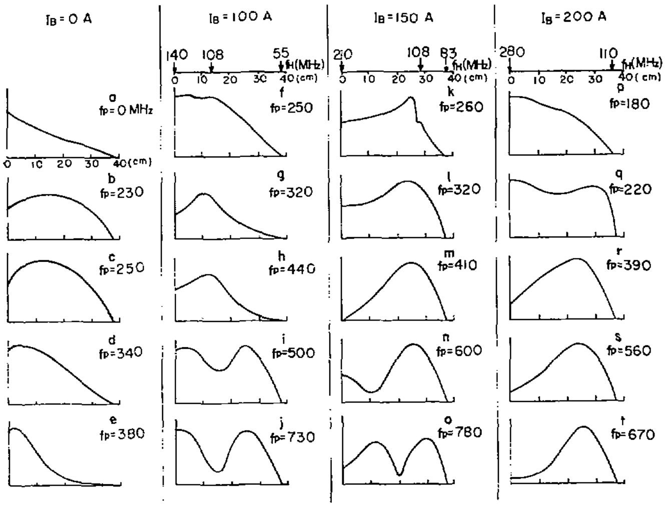

Fig. 1. Antenna current distributions in axially magnetized plasma, f = 108 MHz.

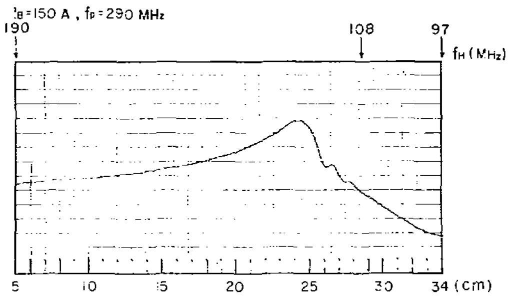

Fig. 2. Antenna current distribution showing gyroresonance, f = 108 MHz.

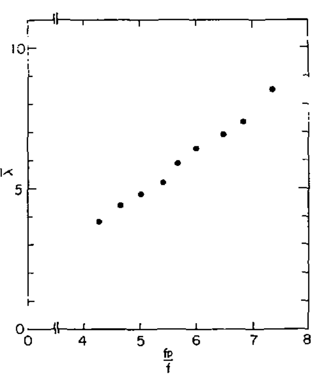

Fig. 3. Wavelength along antenna wire in axially magnetized plasma versus plasma frequency, f = 108 MHz, I_B = 150 amperes.

frequency of the propagating wave approaches the local electron gyrofrequency. Because of the wave absorption at the resonance point the traveling-wave type of current is resulted on the part of the antenna including the feedpoint.

Second, as indicated by curves j, m, n, o, r, s, and t in Fig. 1, when the plasma frequency is relatively high, it is observed that the gyroresonance disappears, and that the standing wavelength is shortened considerably more than that in free space to a greater degree with increasing plasma frequency. Fig. 3 shows the variations of the wavelength versus the plasma frequency for I_B = 150 amperes. The tendency that the wavelength ratio increases almost linearly with increasing plasma frequency is in good agreement with the theory by Mushiake [5] for $f < f_H$. A reasonably complete theoretical explanation for the above experimental result has not been made yet, but it is now under investigation by the authors.

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On Radar Pulse Scattering from Ionized Media

***Abstract*—Some preliminary work relating to the pulse radar return from ionized media, such as fireballs resulting from nuclear explosions and the wakes of high-speed reentry vehicles, is reported. In all cases the objective is to retrieve the envelope of the backscattered signal correctly related in time to the transmitted pulse.**

Introduction

The scattering of dc and radar pulses from underdense and overdense plasma spheres and clusters of spheres is of considerable practical as well as theoretical interest. Several members of the staff of the Sandia Laboratories have devoted some time to such problems, specifically radar return from fireballs and reentry vehicle wakes. The study is conveniently carried on by persons versed in electrodynamics, as well as communication theory, i.e., signal processing, transmission, and reception. Of course a numerical analyst is indispensable. This communication, though brief, is intended to be of a tutorial nature.

Retrieval of the Envelope of the Backscattered Radar Pulse from a Plasma Profile Using the Fourier Integral Approach

The description of the impinging pulse in the time domain employed in this section is

$$e^i(t) = A \exp\left[-\frac{1}{2}\left(\frac{t}{t_1}\right)^2\right] \cos 2\pi f_0 t \tag{1}$$

where A is the value of $e^i(0)$, t is the time, t_1 is a measure of the pulsewidth, and f_0 is the radar frequency. The frequency-domain representation of the pulse is obtained by taking the Fourier transform of (1). Thus

$$E^i(f) = A \int_{-\infty}^{\infty} \cos 2\pi f_0 t \exp\left[-\frac{1}{2}\left(\frac{t}{t_1}\right)^2\right] \exp(-j2\pi f t)\, dt. \tag{2}$$

Using the integral [1]

$$\int_0^{\infty} e^{-ax^2} \cos xy\, dx = \frac{1}{2}\sqrt{\frac{\pi}{a}} \exp\left(-\frac{y^2}{4a}\right) \tag{3}$$

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