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# Microwave Radiation of Cylindrical Plasma Column

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**Abstract**—The travelling wave antennas representing a column of isotropic plasma and a plasma column placed into external infinitely large magnetic field have been theoretically and numerically investigated and compared. The relationships of radiation patterns as a function of the plasma density, geometrical parameters of the plasma cylinder and the radiation wavelength were also investigated. We considered both the linear antennas and the radiating antennas with wavelengths close to the antenna radius. An axially symmetric *E*-wave was studied. The need of taking into account the radial distribution of antenna current was shown. The dependence of normalized radiation patterns on the wave-slowing was analyzed. The characteristic value of plasma density was found; if this value is exceeded, the normalized radiation patterns are sharp directional and have the main lobe located at small angle towards the antenna axis. For the magnetized plasma this characteristic value of density is much smaller than for the isotropic one. With the rise of the plasma density the level of side lobes gets smaller.

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## INTRODUCTION

Experimental studies [1–5] reveal that the low-temperature plasma column can be used as a transmitting or receiving microwave antenna. A nonsymmetrical plasma dipole and the linear travelling wave antenna are considered in papers [2, 6], where it was theoretically and numerically shown that with plasma density of $10^{12}$–$10^{13}$ cm$^{-3}$ the dispersion properties of the above antennas are close to those of metallic antennas.

The above cited papers made use of isotropic plasma. Linear antennas are usually considered in such cases, where the radiation wavelengths are much larger than the antenna radius. The analysis of radiating antenna with wavelengths close to its lateral dimension involves specific difficulties arising in the case of taking into account the radial structure of antenna current. The investigation of plasma antennas with longitudinal magnetic field $B_0$ is also of interest.

The present paper presents the theoretical and numerical analysis and comparison of the travelling wave antennas representing a column of isotropic plasma and a plasma column placed into an external infinitely large magnetic field. The plasma is assumed to be cold and collisionless. The paper analyzes the dependence of the normalized radiation patterns (NRP) on the plasma density, geometric parameters of plasma cylinder, and the radiation wavelength. In this case we consider both the linear antennas and the antennas radiating waves with lengths close to the antenna radius.

## RADIATION PATTERN

Let us consider an infinite cylindrical plasma column of radius $b$. The plasma confinement is achieved by using an external dielectric cylinder. As shown in [6], the impact of sufficiently thin dielectric envelope on plasma radiation is insignificant. That is why the present study deals with an open plasma column.

As is known (see for example [7]), in this case only slow *E*-waves exist in both isotropic ($B_0 = 0$) and magnetized ($B_0 = \infty$) plasmas with frequencies satisfying the following condition

$$\omega < \omega_p, \tag{1}$$

where $\omega$ is the wave frequency, $\omega_p = \sqrt{4\pi n_e e^2 / m_e}$ is the plasma frequency, $n_e$ is the plasma density, $e$ and $m_e$ are the charge and mass of electron.