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Plasma Travelling Wave Antenna

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Abstract—The possibility of using plasma column as linear travelling wave antenna is studied. It is shown that surface current waves propagating in plasma column of finite length are a source of paraxial electromagnetic radiation of decimeter band. Influence of dielectric waveguide, which surrounds cold isotropic plasma, on dispersion properties of plasma column is investigated. The corresponding dispersion equation for eigenwaves of circular dielectric waveguide filled with plasma is derived and solved numerically. Plasma and waveguide parameters are determined under which the surface wave slowing-down is close to unity leading to antenna's radiation primarily in axial direction. It is shown that in case of plasma density around 10^{12}–10^{13} cm^{-3} dispersion of the considered wave is close to dispersion of waves propagating in metal travelling wave antenna.

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INTRODUCTION

In papers [1, 2] a column of low-temperature isotropic plasma maintained in dielectric tube using a surface wave was used as transmitting antenna for a signal whose power ranged from one to several tens of watts on frequencies from ten to several hundreds of megahertz. In paper [2] a non-symmetrical quarter-wave plasma vibrator was studied. In this antenna the power is transferred from a generator to coaxial feeding waveguide, through the side of which HF discharge in a quartz tube and excitation of axially symmetrical surface wave occur. In this case only a small fraction of supplied power, around 10%, is consumed for plasma maintenance. The surface wave induces HF current, which is a source of electromagnetic radiation. It was shown that under the same 100 W power injected into metal and plasma vibrators both antennas have approximately the same radiated power in case of plasma density $n = 10^{12}$–10^{13} cm^{-3} and plasma column radius equl to 1 cm. Besides under such density dispersive properties of waves in plasma column approach the properties of Zommerfeld wave. This proves that a plasma column with sufficient density may operate as antenna. One of plasma antenna's advantages mentioned in [2] is their capability of the best impedance matching with feeder due to plasma self-tuning of antenna's input impedance. The present paper studies the possibility of creating linear transmitting plasma travelling wave antenna where a plasma column serves as conductor. Traditional designs of travelling wave antennas that use vacuum and dielectric waveguide systems are described in [3].

DISPERSION EQUATION

In order to analyze dispersive properties of waves in a plasma column we consider an infinite in longitudinal direction cylinder dielectric tube with radius b_1, thickness $\Delta b = b_2 - b_1$ and relative dielectric permittivity ε_d. A cylinder plasma column made of cold isotropic plasma with radius $a \le b_1$ and dielectric permittivity $\varepsilon_p = 1 - \omega_p^2 / \omega^2$, is located inside the dielectric, where $\omega_p^2 = 4\pi n e^2 / m_e$ is a square of plasma frequency, n is plasma electrons density, e, m_e are charge and mass of electron. The cross section of plasma column antenna is depicted in Fig. 1.

We consider a surface azimuth-symmetrical slow E-wave that contains components E_z, E_r, and H_φ. We assume there is the following dependence of field components on coordinates and time: E_z, E_r, H_φ ~ $\exp[i(k_z z - \omega t)]$, where frequency ω and wave vector k_z satisfy the condition $\omega/c < k_z < \sqrt{\varepsilon_d}\,\omega/c$. Using boundary conditions for field components under $r = a, b_1, b_2$, the following dispersion equation is obtained: