

WHISTLER WAVE RADIATION FROM AN ARBITRARILY ORIENTED LOOP ANTENNA LOCATED IN A CYLINDRICAL DENSITY DUCT IN A MAGNETOPLASMA

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ABSTRACT

An exact solution is obtained for the problem of a given source in the presence of a magnetic-field-aligned cylindrical density duct which is surrounded by a homogenous background magnetoplasma. It is shown that in the whistler range, the presence of a duct with enhanced plasma density can lead to a significant increase in the radiated power of a source in the form a loop antenna compared with the case where the same source is immersed in a homogeneous background magnetoplasma, regardless of the antenna orientation.

ANALYSIS AND RESULTS

Recent active experiments [1] in the Earth's ionosphere have showed that nonlinear effects due to intense electromagnetic fields of antennas on spacecraft can result in the formation of artificial density ducts aligned with the geomagnetic field [1]. It is now recognized that such plasma structures can affect significantly the electromagnetic radiation from sources located in the duct interior [2]. The purpose of this paper is to discuss the features of whistler wave radiation from an arbitrarily oriented loop antenna in a magnetoplasma in the presence of a cylindrical duct aligned with an external magnetic field.

At first, we study what types of guided whistler modes can exist in cylindrical density ducts surrounded by a background magnetoplasma. Then we obtain an exact eigenfunction expansion for the field excited by a circular loop antenna with a uniform electric-current distribution in the presence of a cylindrical density duct. The rigorous solution for the total field of the antenna comprises both the discrete and continuous parts of the spatial spectrum of excited waves. Expressions for the radiation pattern and total radiation resistance of the loop antenna have also been derived. As an example, Table 1 presents the results of calculations of the total radiation resistances $R_{||}$ and R_{\perp} for the cases where the antenna axis is respectively parallel and perpendicular to the axis of a duct with enhanced density \tilde{N} . The parameter values used for calculations were as follows: angular frequency $\omega = 1.88 \times 10^5 \text{ s}^{-1}$, antenna radius $b = 2.5 \text{ m}$, duct radius $a = 5 \text{ m}$, external magnetic field $B_0 = 0.5 \text{ G}$, and background plasma density $N_0 = 10^6 \text{ cm}^{-3}$. The radiation resistances of the same sources in a homogeneous background magnetoplasma amount to $R_{||,0} = 3.53 \times 10^{-3} \Omega$ and $R_{\perp,0} = 2.34 \times 10^{-3} \Omega$, respectively. The quantities $R_{||}^{(m)}$ and $R_{\perp}^{(m)}$, whose normalized values are also given in Table 1, are the partial radiation resistances into guided whistler modes with the azimuthal indices m for two limiting antenna orientations.

It follows from the results obtained that in the whistler range, the presence of such a duct can lead to a significant increase in the radiation resistance of the antenna as compared with the case where the same source is immersed in a uniform background magnetoplasma, regardless of the antenna orientation. Moreover, if the plasma density in the duct is high enough, then the guided whistler modes of the duct with the azimuthal indices equal to 0, +1, and -1 give the major contribution to the power radiated from a loop antenna of arbitrary orientation.

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REFERENCES

- [1] Yu. V. Chugunov and G. A. Markov, "Active plasma antenna in the Earth's ionosphere," *J. Atmos. Sol.-Terr. Phys.*, vol. 63, pp. 1775–1787, December 2001.
- [2] I. G. Kondrat'ev, A. V. Kudrin, and T. M. Zaboronkova, *Electrodynamics of Density Ducts in Magnetized Plasmas*. Amsterdam: Gordon and Breach, 1999.

Table 1. Radiation resistances as functions of plasma density in the duct

\tilde{N}/N_0	$R_{ }/R_{ ,0}$	$R_{\perp}/R_{\perp,0}$	$R_{ }^{(0)}/R_{ }$	$R_{\perp}^{(+1)}/R_{\perp}$	$R_{\perp}^{(-1)}/R_{\perp}$
30	22.6	25.8	0.91	0.61	0.30
50	33.7	40.5	0.91	0.65	0.25
80	47.3	56.1	0.92	0.71	0.22
100	54.9	66.5	0.92	0.71	0.19