"Physics of Auroral Phenomena", Proc. XIX Annual Seminar, Apatity, pp.85-86, 1996

Polar Geophysical Institute

MODELLING OF HIGH FREQUENCY RADIO WAVE PROPAGATION ALONG A HIGH-LATITUDE ROUTE

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Abstract. Peculiarities of HF radio wave propagation along the route Murmansk to St.Petersburg, in particular, the collision absorption of waves are investigated using a numerical model of the ionosphere and a two-dimensional ray-tracing computer program.

1. Introduction

High frequency radio waves can be partly absorbed during their propagation through the ionosphere. The absorption of HF radio waves can be essential at high latitudes due to specific features of the high-latitude ionosphere. To take into account the absorption in simulations of HF radio wave propagation it is necessary to possess the distribution of electron concentration at the level of the D-region. The purposes of this paper are to develop a numerical model of the high-latitude ionosphere, which contains the D-region, to improve the ray-tracing computer program by means of inclusion of the calculation of the collision absorption of waves, and to simulate HF radio wave propagation along a high-latitude route.

2. The ionosphere model

We have developed the non-stationary one-dimensional mathematical model of the high-latitude ionosphere. The model allows to calculate the composition of the ionosphere in the 50-500 km range. The important part of our model is the theoretical model of the D-region, which includes the effects of transport. The D-region model is based on the numerical solution of coupled continuity equations for 39 components, with electrons, positive and negative ions, and main, minor, and excited neutral constituents having been taken into account. The atmospheric composition, ionization processes, chemistries of positive and negative ions and neutral particles, eddy diffusion coefficients, and other details are consistent with models by *Torr and Torr* [1982] and *Shimazaki* [1984] and with the study by *Shimazaki* [1971]. Our model takes account of 139 chemical reactions and can describe behaviour of the lower ionosphere not only under quiet conditions, but also during disturbed periods at high-latitudes.

3. Calculations of HF radio wave propagation

Earlier we developed a two-dimensional ray-tracing computer program [*Orlova et al.*, 1988], which allows to determine the ionospheric propagation of HF radio waves, in terms of ray-tracing based on geometric-optics treatment. This computer program was based on the Haselgrove ray-tracing differential equations and Appleton - Hartree equation for the refraction index. Collisions between ionospheric plasma particles were neglected in this computer program.

In the present study, we improve the two-dimensional computer program developed earlier and include in it the capacity of the calculation of the collision absorption of HF radio waves. The improved version of the two-dimensional ray-tracing computer program allows to determine not only the ray-path trajectories of HF radio signals originated from distinct points of the earth's surface in the various directions for different values of the elevation angle and frequency of transmission, but also the absorption coefficient and the integral absorption along a ray-path trajectory.

4. Results of modelling

In this study we employ the oblique incidence sounding data obtained by Institute for Arctic and Antarctic Research in December, 1969. For the moment of obtaining these data, we simulated the two-dimensional distribution of electron concentration over the height range from 50 to 500 km between Murmansk and St. Petersburg using the mathematical model of the high-latitude ionosphere described above. We utilized the simulated electron concentration distribution for calculation of the ionogram of oblique sounding between Murmansk and St.Petersburg. It was found that the calculated ionogram of oblique sounding contains the tracks of five propagation modes: 1E, 2E, 1F2, 2F2, and 3F2. We compared the calculated ionogram with the experimental ionogram of oblique sounding and found rather good agreement. This fact indicates that the developed mathematical model of the high-latitude ionosphere is quite adequate.

Using the improved ray-tracing computer program, we calculated the ray-path trajectories of HF radio signals, originated in Murmansk and reached St.Petersburg, for different values of transmission frequency. Also, we calculated the integral absorption, designated by L, along each ray-path trajectory. Results of calculations are presented in Figure 1. It can be seen that the integral collision absorption depends on the frequency of transmission significantly. Maximum values of L may appreciably differ from each other for various propagation modes. The propagation mode 2E possesses the biggest maximum value of L; all the rest are disposed one after another in the following sequence: 1E, 3F2, 2F2, and 1F2. To elucidate the obtained sequence it is sufficient to allow for the length of the part of the ray-path trajectory that intersects the D-region in which the absorption coefficient achieves maximum values.

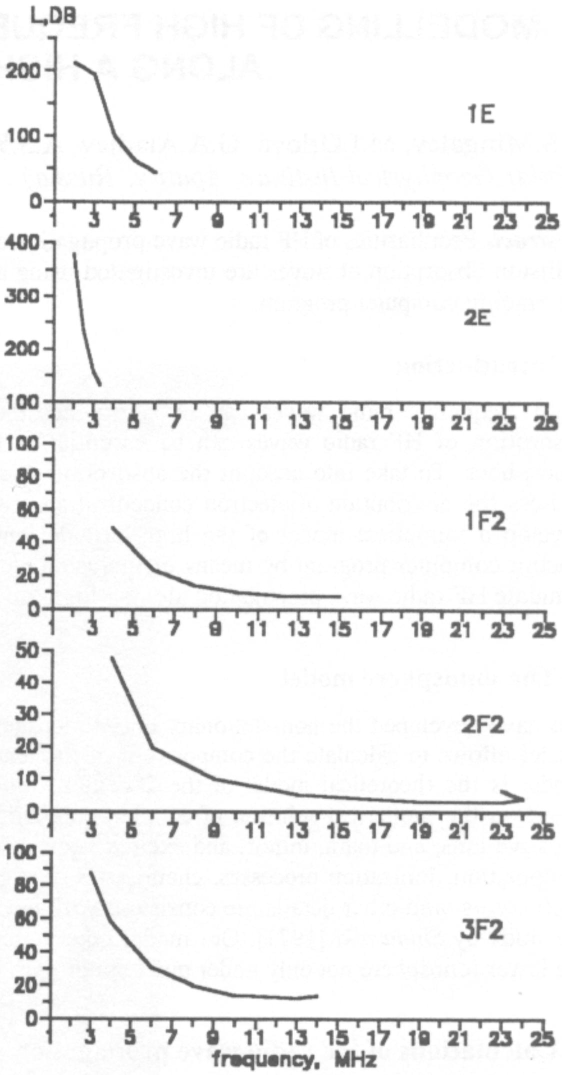

Fig.1. Dependence of the integral collision absorption, L (in decibel), on the transmission frequency for five propagation modes: 1E, 2E, 1F2, 2F2, and 3F2.

5. Conclusions

We have developed the mathematical model of the high-latitude ionosphere containing the D-region. We have improved the two-dimensional ray-tracing computer program by including in it the calculation of the collision absorption of HF radio waves. Using the developed mathematical model and the improved version of the ray-tracing computer program, we have simulated HF radio wave propagation along the route Murmansk to St.Petersburg. In particular, we have investigated peculiarities of the collision absorption of waves.

Acknowledgments. This work was partly supported by grant 94-05-16274 from the Russian Foundation for Basic Research.

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