TITLE: The Technique for Calculating of HF-Signals Characteristics Taking into Consideration Ionosphere Waveguide Propagation

THE TECHNIQUE FOR CALCULATING OF HF-SIGNALS CHARACTERISTICS TAKING INTO CONSIDERATION IONOSPHERE WAVEGUIDE PROPAGATION

Alexey V. Oinats, Vladimir I. Kurkin, Sergey N. Ponomarchuk

Institute of Solar-Terrestrial Physics
of Russian Academy of Science Siberian Division
E-mail: oinats@iszf.irk.ru

ABSTRACT

The technique based on waveguide approach for calculating of ionosphere oblique-incidence sounding signal characteristics taking account of ionosphere waveguide excitation is offered. The comparison of given technique calculation results and experimental ionograms on the path Alice-Springs (Australia) - Irkutsk (Russia) is given.

INTRODUCTION

Within the framework of waveguide approach in ISTP SD RAS the technique for calculating of characteristics of signals that propagate on an inhomogeneous path in any of the existing Earth-ionosphere waveguides (for example, waveguide between the ground and E-layer of the ionosphere or waveguide between the ground and F-layer of the ionosphere) was designed. The stationary condition that allows defining interference properties of a series of normal modes and the structure of a field in waveguide is the basis of this technique. It is equivalent to a requirement:

$$L_n^{\pm}(\vec{r},f)=\frac{1}{2\pi}(\Phi_n^{\pm}-\Phi_{n+1}^{\pm})=l^{\pm} \qquad (1)$$

- the phase difference of the neighboring normal modes is multiple 2π. Here f is a frequency, n is a number of normal mode, $\Phi_n^{\pm}$ is its phase in a point $\vec{r}$, $l^{\pm}$ is an integral nonnegative numbers (number of hops). For given number of normal mode the stationary condition determines the geometric localization of a field of group of normal modes with this central number, i.e. propagation trajectory of packet of phased normal modes.

Really there are cases, in which the modes of propagation spreading at first in one waveguides, and then transferring in other one. In particular there are the ionosphere propagation modes, i.e. which propagate in the ionosphere waveguide on a part of a path.

To calculate the characteristics of the ionosphere propagation modes, it is necessary to take into account transitive groups of the normal modes, which were not considered in the standard scheme. Those are such groups of normal modes, which propagate in one waveguide on a part of the path, and in other waveguide on another part of the path. Such an account is possible, if we introduce the continuity condition for propagation trajectory of packet of phased normal modes as is in geometric optics.

In the report the approximate scheme of the calculation of the ionosphere propagation mode characteristics based on such hybrid approach is given. All characteristics of a signal field in the Earth-ionosphere and ionosphere waveguides are calculated using the above-mentioned standard technique. In points of transition from one waveguide to other one weaving is made, based on continuity condition for propagation trajectory of packet of phased normal modes.

THE SCHEME OF CALCULATION

The scheme of calculation is as follows. First, the group of normal modes, which is effectively incited by receiver and weakly penetrates through the ionosphere, is selected. From this group the subgroup is separated, which propagate in the Earth-ionosphere waveguide on all path. For this group of modes the calculation of the signal characteristics is carried out using a standard technique.

Further the rest group of normal modes, which participates in transitions between waveguides, is considered. The number of normal modes in this group is determined by variation of maximum and minimum waveguide numbers along a path of propagation and can reach several thousand for equatorial paths.

The calculation is carried out in a cycle on central numbers with some step. Central number of a packet of phased normal modes is adiabatic invariant and does not vary at propagation in the waveguide except for transition points. Therefore for each of them the transition point from one waveguide to other one is determined using dependences of maximum and minimum waveguide numbers on the longitudinal coordinate. Using (1) in the transition point, the height of localization and propagation delay of the normal mode packet in this waveguide is calculated. On these data the waveguide is defined, in which this packet of normal modes transfers. The condition of the propagation trajectory continuity actually means that the angle α between tangent to a trajectory of the packet and horizontal should vary continuously. As it is follows from equation

$$\alpha = \arccos\left(\frac{\gamma_n}{y\sqrt{\varepsilon(y,\theta)}}\right), \tag{2}$$

where γ_n - spectral parameter, y relative radial and θ angular - spherical coordinates, $\varepsilon(y,\theta)$ - permittivity of the ionosphere, the dependence of spectral parameter on coordinate along the path $\gamma_n(\theta)$ should be continuous too. This requirement in view of the normal modes spectral equation gives that central number of the packet at transition from one waveguide in other one changes by bound. The value of this bound is determined by volume of adjacent waveguides (for example, ionosphere waveguide will be an adjacent waveguide at transition from E to F waveguide).

After central number of the packet in the new waveguide is obtained, the new transition point is determined and the calculation for the new waveguide is iterated or, if the end of the path achieves, the characteristics are calculated using standard scheme.

In a point of the receiver arrangement the resulting interference function and resulting propagation delay of the normal mode packet are determined by the formulas

$$L_n(\theta, y) = \sum_k \Delta L_{n_k}, \tag{3}$$

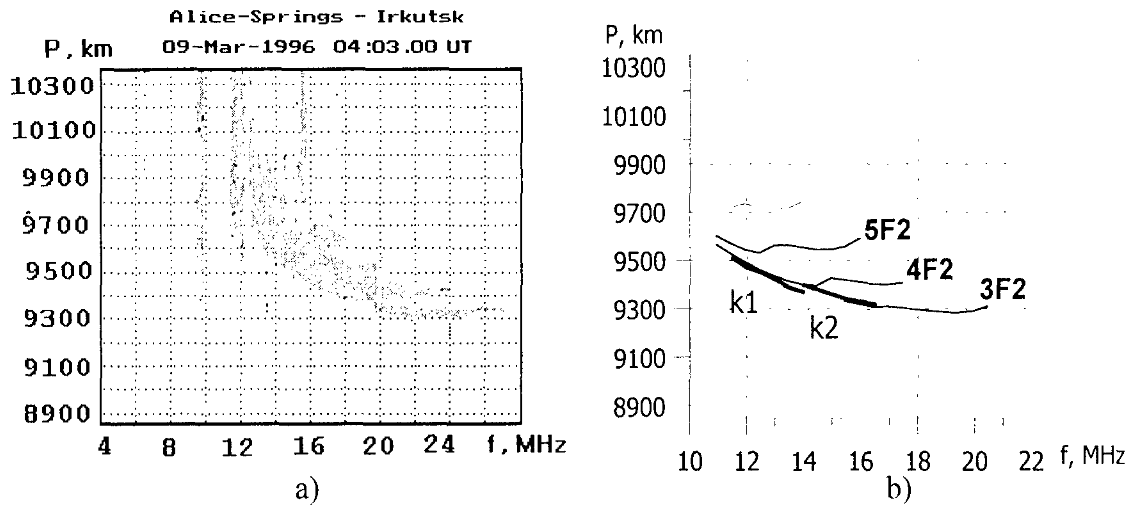

Fig.1. Experimental ionogram (a) and results of the calculation (b).

$$\tau_n(\theta, y) = \sum_k \Delta\tau_{n_k} \, . \tag{4}$$

Here ΔL_{n_k}, $\Delta\tau_{n_k}$ are additives to interference function and delay at propagation of the packet in k waveguide under the account along the path.

The obtained dependence of interference function on central numbers in the point of the receiver arrangement (3) is approximated by splines, and using the stationary condition central numbers of packets giving the contribution to a signal field near the ground are determined.

Making similar calculation for a series of frequencies, we obtain a standard ionogram with distance-frequency dependences of transition modes of propagation.

RESULTS OF CALCULATION

As an illustration on figure 1 the results of the calculation (b), which has been, carried out using the designed approximate scheme, and experimental ionogram (a) for equatorial path Alice-Springs (Australia) - Irkutsk (Russia) 04 UT on March 9, 1996 are shown.

The frequency range of the experimental ionogram and of the calculation results don't coincide. It is possible to explain this by the underestimated maximum F-layer frequency along the propagation path of the used ionospheric model.

On the figure 1b one can see two transition propagation modes (k2 - three-hop and k1 - four-hop), which propagate a part of the path in the ionosphere waveguide. They qualitatively explain a bend of 3F2 mode curve in the low-frequency area, which we can see on the experimental ionogram.

REFERENCES

[1] V.I. Kurkin, I.I. Orlov, and V.M. Popov. Normal-mode approach in the problem of HF radio communication. Moscow: Nauka, 1981.

[2] A.V. Gurevich, E.E. Cedilina. Superdistant radiowave propagation. Moscow: Nauka, 1979.