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USING IRI-95 IN FMCW SIGNAL SIMULATION

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ABSTRACT

A ray tracing code for long distance propagation via the ionosphere has been established and applied with electron density profiles taken from IRI-90 and -95. The theoretical results for different distances were compared with experimental ones obtained by Chirp ionosonde techniques. When comparing maximum observable frequencies good agreement was found even with a transequatorial path.

INTRODUCTION

The International Reference Ionosphere (IRI) is one of the most dynamically evolving and widely used model of the ionosphere. Numerous studies on the verification and improvement of this model were based on data from vertical-incidence ionospheric sounding stations, and from IS radars and GPS. Not so many comparisons with systematic HF propagation experiments have been reported. When predicting the characteristics of a radio channel ray tracing must be applied imposing some requirements to the ionospheric model used. In order to interpret oblique incidence Chirp sounding experiments (Brynko et al., 1987) the Institute of Solar-Terrestrial Physics (ISTP) has established simulation codes for different path lengths and orientations based on different IRI versions (Kotovich et al.,1997). The model was tested with oblique-incidence ionospheric sounding (OIS) data obtained in the Russian network of chirp-ionosondes located at Irkutsk, Khabarovsk, Magadan, Nizhny Novgorod and on the Russian-Australian transequatorial Alice-Springs - Irkutsk experiment.

Using the IRI-95 code we compare in this paper OIS ionogram simulations with experimental data for paths ranging from 3000 km to round-the-world. Signal characteristics were calculated the normal-mode approach (expansion in terms of eigenfunctions of the propagation waveguide) (Altyntseva et al., 1990), and of the geometrical optics method (Kiyanovsky et al., 1990). Both methods yield comparable results.

SELECTION OF THE IRI MODEL VERSION

For the peak characteristics IRI-95 admits two options. We used the one based on the URSI set of coefficients. The N(h) profile was calculated with the base of the F2-layer as reference level, applying one or the other of two techniques to calculate the electron density profile:

a standard technique (Rawer et al., 1981; Bilitza. and Rawer, 1990), and

the technique of T.Gulyaeva (Gulyaeva, 1987).

In our comparisons we used technique 2.

Though it is unimportant in the present context we note that our code also determines the attenuation by absorption in lower layers; the collision frequency needed to this end is derived from the neutral composition\concentration data given in the MSIS model (Hedin, 1991).

COMPARISON RESULTS

We compared the model results with experimental data obtained in winter and equinox for high as well as low solar activity and different geomagnetic activities. A most important parameter is the so-called "MOF" (Maximum Observable Frequency) which is compared with the corresponding result of our theoretical computations called "MUF" (Maximum Usable Frequency). We use the daily mean of the absolute difference $\Delta = |(\overline{MOF} - MUF)|$ as test quantity, where $\overline{MOF}$ is the value obtained by averaging every hour over the time interval of observations. Table 1 shows some results obtained on the Magadan-Irkutsk path (3000 km). The agreement is rather good, in particular for low solar activity.

Table 1. Survey: the daily mean of the absolute difference Δ, obtained on Magadan-Irkutsk path for different geomagnetic activity

Time interval of observation	$\overline{\sum K_p}$	$F_{10.7}$	hop	Δ,MHz
February 15 - 23, 1989	19+	196	2F2	2,9
October 20 - 26, 1989	30+	215	2F2	1,6
February 15 - 18, 1994	23	104	1F2	1,9
			2F2	1,0
November 2 - 25, 1993	19+	98	1F2	1,1
			2F2	0,8
September 11 - 14, 1994	16	74	1F2	0,9
February 25 - 28, 1998	10	99	1F2	0,7
March 1-5, 23-27, 1998	18+	108	2F2	0,4
February 24 - 28, 1999	14+	138	1F2	2,0
March 1 - 13, 1999	23+	125	2F2	0,6

Note that for the decisive mode (the one with the minimum number of hops) the choice of the IRI parameter B0 determines in fact the reference level and so largely influences the usable frequency band. We obtained comparable results with the above techniques (1) and (2). An example for the path Magadan-Irkutsk is shown in Fig. 1 , where for comparison (solid and dashed lines) MUFs were calcullated either with IRI-95 or IRI-90 (Bilitza, 1990). Both compare quite well with mean experimental MOFs (dots).

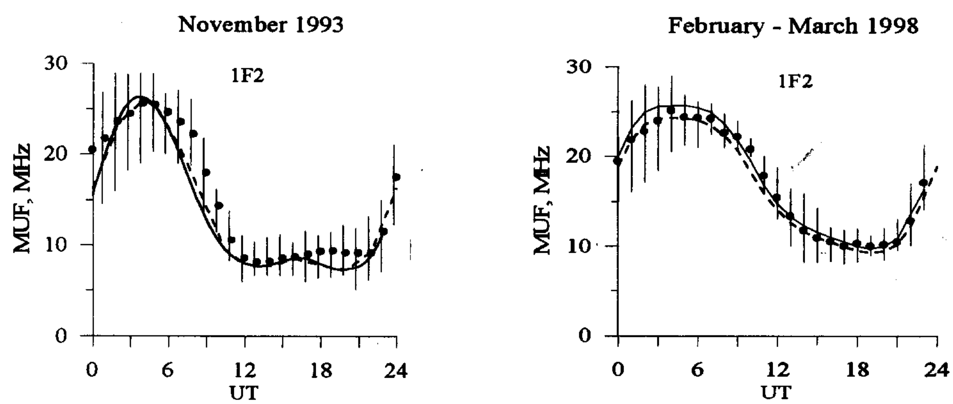

Fig.1. Diurnal variation of MUFs calculated with IRI-95 (solid line) and IRI-90 (dashed) for the 3000 km path Magadan - Irkutsk. The variation range of corresponding experimental OIS data is shown by bars with the mean as a dot.

In addition we analysed diurnal variations of simulation error K=MOF-MUF for different dates. Under quiet conditions K is the maximum values during sunrise and sunset hours. At disturbed time the largest negative errors are at the day. Fig. 2 presents the typical examples of K diurnal variations under quiet (November 24, 1993) and disturbed days (November 19, 1993).

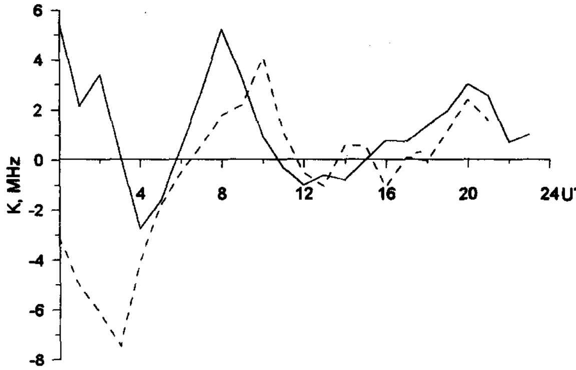

Fig.2. Diurnal variation K on quiet (solid line) and disturbed days (dashed).

When the electron density at the reference level was seriously variable along the path we often encountered problems with low and high angle ray tracing. In these cases our simulation allowed a broad frequency band only for the high angle (Pedersen-ray) while the experimental data were interpreted as low angle ray propagation. This might be explained by one of the following reasons: strong horizontal gradients at the reflecting level or inadequacy of the theoretical simulation.

In order to see what happened in the critical hours before sunset we compared the vertical incidence ionograms recorded at both ends with the observations and found that for these particular hours near the Magadan end the theoretical reflection height (based on the IRI) was different by as much as 100 km from the height needed to explain the observations.

From the viewpoint of propagation transequatorial paths have particular interest. When applying our code to the transequatorial path from Alice Springs (Australia) to Irkutsk (Siberia) we found most interesting results. Fig. 3 shows MOF\MUF intercomparison for a few days in August 1998 for which we have data. The path with three reflections (3F2) must have been decisive during all 24 hours. Though the difference between both IRI models is not too great better agreement was obtained with the more recent IRI-95. Serious deviations found at night (16-21 UT) can be explained by the appearance of a sporadic Es-layer and this was confirmed by the vertical incidence ionograms.

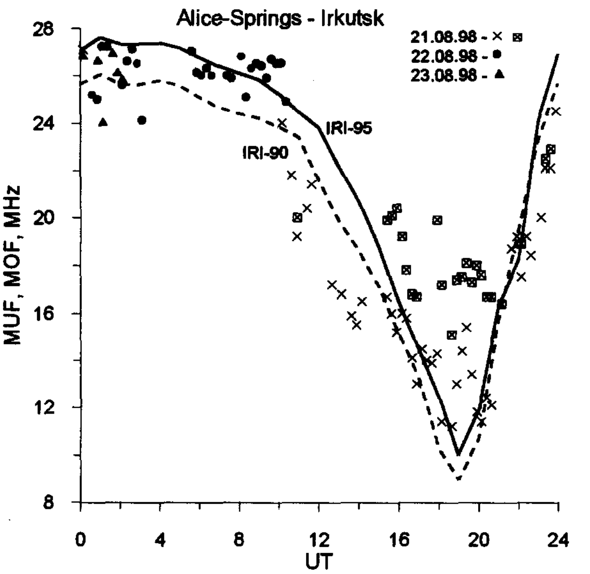

Fig. 3. Diurnal variations of MUFs and MOFs as in Fig. 1 for the transequatorial path Alice-Springs - Irkutsk for the 3F2 mode in August 1998.

Finally, we tried to simulate round-the-world propagation. With our code based on the IRI-model we found short time intervals that should be suited for this rather rare type of propagation. These intervals were confirmed experimentally. It must be noted that in this context the degree of development of the equatorial anomaly and its dependence on longitude plays a decisive role.

CONCLUSIONS

Experimentally obtained oblique-incidence ionospheric sounding ionograms were compared with a theory based on ray tracing in the IRI model ionosphere. With the IRI-95 model the maximum transferred frequencies agreed generally well. Problems occured in particular hours when large horizontal gradients are known to be present; this holds in particular for a few hours before sunset.

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