Experimental check of technique for calculation of critical frequency and peak height values from oblique sounding data

Anton G. Kim*, Galina V. Kotovich, Viktor P. Grozov, Constantine G. Ratovskiy
Institute of Solar-Terrestrial Physics, Russian Academy of Sciences/Siberian Branch,
126 Lermontova Ave., p/o box 291, Irkutsk, Russian Federation 664033

ABSTRACT

The work is devoted to experimental check of operative technique for calculation of F2-layer parameters in path's mid-point (critical frequency and peak height) using oblique sounding data. In this work experimental data obtained in 2003-2006 by FMCW-ionosounder in Irkutsk (over different paths with different length and orientation) were used. The IRI data and experimental vertical sounding data (nearest to path's midpoint) were used for verifying of calculated values. Experimental oblique sounding data recalculation into the path's midpoint parameters was performed on the basis of the modified Smith method without consideration of Earth's magnetic field.

Keywords: ionogram, ionosonde, oblique incidence, oblique sounding, ionosphere diagnostics, IRI

1. INTRODUCTION

For in-line diagnostics we should be experienced in obtaining information about environment in various points of investigated region and also in the points where vertical sounding (VS) stations are not installed. Research of relations between VS and oblique sounding (OS) data plays an important role in solution of this problem.

A lot of works were devoted to questions of diagnostics and forecasting of HF parameters according to OS data, for example [1-3]. However, experimental check-up of methods of HF parameters obtaining according to OS data is complicated by absence of experimental VS data along OS path. At best real information about environment during the OS session can be obtained in transmitter or receiver points.

In works [4-6] a simple approach for determination of critical frequency in midpoint of OS path on the basis of Smith method was proposed. This technique can be applied to distance-frequency characteristic (DFC) measured on single-hop path for height-frequency characteristic (HFC) calculation. Previously the technique was checked by simulation over OS path with distance 2300 km [6] and applied to experimental OS data obtained during March-April of 2004 [5], where calculated f_0F2 values have been compared with IRI model f_0F2 values.

This work is devoted to complex experimental checking of operative technique for f_0F2 and $hmF2$ calculation. The checking bases on the ISTP SB RAS FMCW-ionosounder [3] observations during 2003-2006 in Irkutsk (52°N, 104°E) over different (by distance and orientation) OS paths (Norilsk—Tory, Usolie—Tory, Magadan—Tory). IRI data and experimental VS stations (nearest to path's midpoint) data were used for verifying of f_0F2 and $hmF2$ values. Experimental VS data of ionospheric station in Podkamennaya Tunguska were used for checking calculated data derived from Norilsk—Tory path, Yakutsk station VS data were used for checking calculated data derived from Magadan—Tory path (Fig. 1), digisonde DPS-4 in Irkutsk data were used for verifying calculated f_0F2 and $hmF2$ values derived from weakly OS Usolie—Tory path data.

2. HFC ESTIMATION FOR MID-POINT OF OS PATH

As during OS the signal is reflected near to the path' middle point, then according to obtained OS data the determination of some environment parameters is possible in this point. Technique of VS parameters obtaining according to the OS data supposes corresponding accuracy of the obtained information of measured signal delay (group path) value.

* kim_anton@mail.ru; phone +7 (3952) 56-45-59

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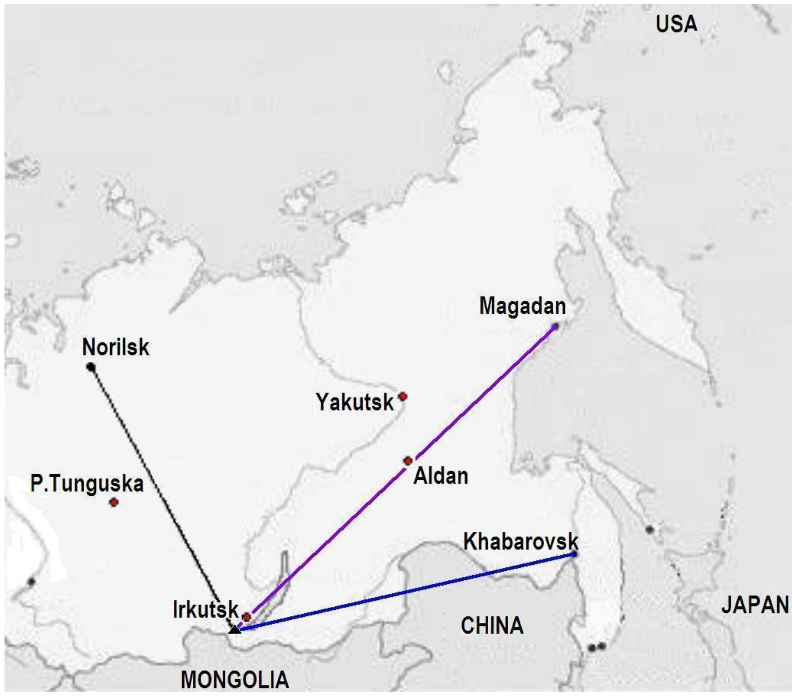

Fig. 1. The map of the long distance paths and nearest to path's midpoints VS stations.

In the OS experiments carried out in the ISTP SB RAS in Irkutsk (52°N, 104°E) using the FMCW signal [7] absolute time of decameter signal propagation in selected path is changing (receiving point of FMCW ionosounder is located close to the Tory settlement in ~ 95 km to the south-west from Irkutsk). GPS system time synchronization allows obtaining the true data of absolute time of propagation with high reliability and accuracy.

Having the dependence of absolute time of propagation on the OS frequency (i.e. DFC) we can obtain the height-frequency characteristic (HFC) in the path' middle point and, consequently, also critical frequency in this path' point. Method of environment parameters determination according to DFC is described in details in [6]; it is based on the Smith method [8] that is an approximated analogue for the sphere-layer medium of the method of the «curves transfer» in flat-layer environment. Necessary input data are the OS path length, OS frequency and the absolute time of propagation corresponding to this frequency. During experimental OS data processing in DFC the track is singled out by the operator related to the 1F2 mode of usual component. This track is saved as massive of frequencies and delays. Then these frequencies and delays of OS are recalculated into frequencies and acting heights of VS (as a result we have HFC). At the Fig. 2 the result of work of experimental DFC recalculation (on the example of the Khabarovsk—Tory path) into the efficient HFC, which can be approximately related to the path' midpoint, is shown.

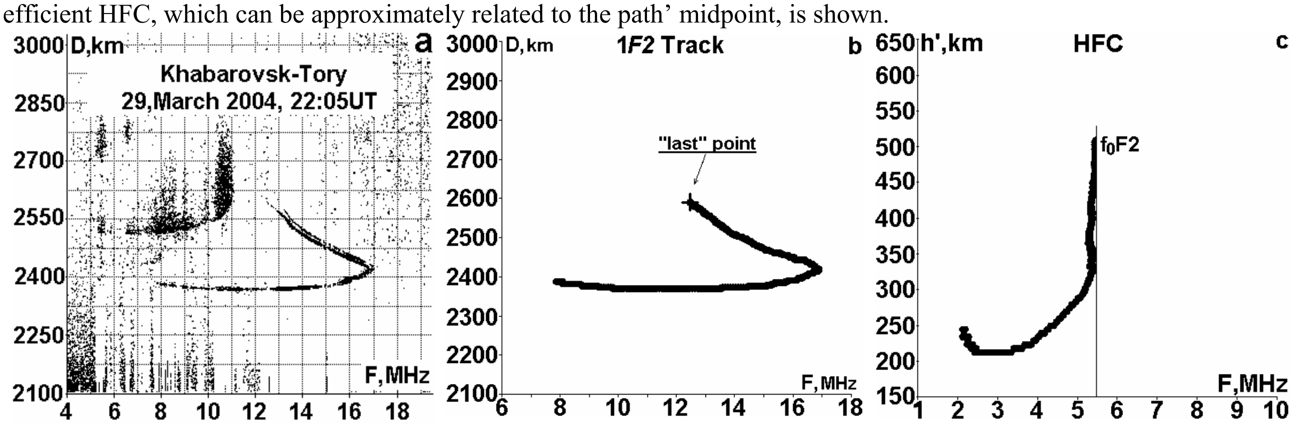

Fig. 2. Example of experimental DFC recalculation into the HFC in the Khabarovsk—Tory path's midpoint, 29.03.2004, 22:05 UT.

3. CRITICAL FREQUENCY CALCULATION FOR OS PATH' MID-POINT

For determination of the critical frequency we need to (and that is enough) fix the OS frequency and the delay of the most upper ray («last» point, at the Fig. 2b it is shown by cross) which trajectory before the reflection is closed to the Pedersen ray passing through the peak height region in area of path' midpoint. This frequency and delay of the «last» point of experimental DFC in the given path length by the operation opposite to the Smith method are recalculated into the critical frequency and effective height of reflection from the layer maximum.

In modified method of «transfer curves» the linear relation between the VS and OS frequencies is determined by the coefficient $(k \cdot \sec\varphi)$ where k – is the Smith coefficient. For the Norilsk—Tory path k = 1,06983 (path length D = 2088 km). Values of k for other paths lengths are shown in [9]. Angle of ray falling φ on the layer according to the equivalent theorem is related to the acting height h' by the following formula [8]:

$$\varphi = arctg\left(\frac{\sin(D/2R)}{x-\cos(D/2R)}\right), \text{ where } x = \frac{R+h'}{R},\ R \text{ – Earth radius.} \tag{1}$$

Absolute time of propagation of t_{OS} decameter signal by the oblique propagation according to [8] is determined as follows:

$$t_{OS} = \frac{2R}{c}\cdot\frac{\sin(\Omega-\varphi)}{\sin\varphi}, \text{ where } \Omega = \arcsin(x\cdot\sin\varphi),\ c \text{ – speed of the light.} \tag{2}$$

To determinate the desired value h' which should correspond to the delay of the most upper ray of the single-hop propagation, obtained by data processing of the "last" point of DFC, the selection of effective heights with the step 200 m is carried out from the start value 70 km. For every value, according to the formulas (1) and (2), the value of the group path is determined. It compares then with the experimental value. The selection is carrying out till reaching the desired agreement with the marked accuracy between comparing values. According to the law of session the OS frequency f_{OS} is related to the VS frequency f_0 by the equation $f_{OS} = f_0 \cdot k \cdot \sec\varphi$. Then $f_0F2 = f_{OS}/(k\cdot\sec\varphi)$. Where the f_{OS} frequency corresponds to the one marked by cross at the Fig. 2b the «last» DFC point. This simple way of recalculation allows fast determination of f_0F2 value for the OS path' middle point.

4. PEAK HEIGHT CALCULATION FOR OS PATH' MID-POINT

If critical frequency is quite easy and quickly determined according to the OS data with the help of described method then for peak height determination we need more complicated approach.

To determine *hmF2* is possible from *N*(h)-profile of electron density (or from *fp*(h)-profile of plasma frequency), characterizing ionosphere in the region of the path center. In this case any type of profiles is reconstructed from HFC, obtained as a result of DFC recalculation (the absence of information in DFC about the E-layer can be replaced by data from ionosphere model, for example, according to the IRI). If the value *M(3000)F2* can be obtained, then the value *hmF2* can be calculated from the values f_0F2, f_0E and *M(3000)F2* according to the simplified Dudeney formula [10-11], which is:

$$hmF2 = \frac{1490}{M(3000) + \dfrac{0{,}253}{f_0F2/f_0E - 1{,}215}} - 176\,. \tag{3}$$

5. CHECK ON THE USOLIE—TORY PATH

Ionosounder transmitting point working with frequency modulated continuous wave (FMCW) signals is located near Usolie-Sibirskoye to the north-west of Irkutsk (Fig. 3), receiving point is near village Tory ~98 km to the south-west of Irkutsk (path length is about ~126 km). Under quiet and weakly disturbed conditions weakly OS ionograms (DFC) are not much different from VS ionograms (HFC) received in Irkutsk [12].

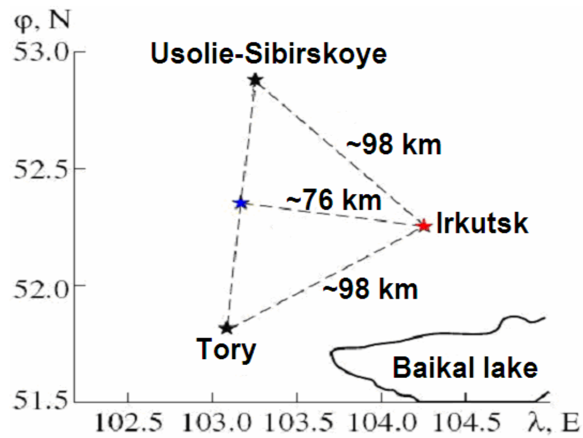

Fig. 3. The map of the Usolie—Tory path (weakly OS path).

For peak height value (in path's midpoint) determination *fp*(h)-profile was reconstructed by Huang-Reinisch method which was integrated in software «SAO-Explorer» of digisonde DPS-4 (working in Irkutsk since 2002), it helps to process VS ionograms of digisonde. DFC of FMCW-ionosounder obtained over weakly OS Usolie—Tory path was recalculated into HFC which one used for *fp*(h)-profile reconstruction.

Calculated values of parameters f_0E, f_0F2, $hmF2$ (through the use of weakly OS data) in Usolie—Tory path's midpoint were compared with experimental f_0F2, $hmF2$ values obtained by digisonde in Irkutsk and with f_0F2, $hmF2$ values obtained from IRI model. The comparison shows that it has good agreement between calculated values and experimental ones (Fig. 4).

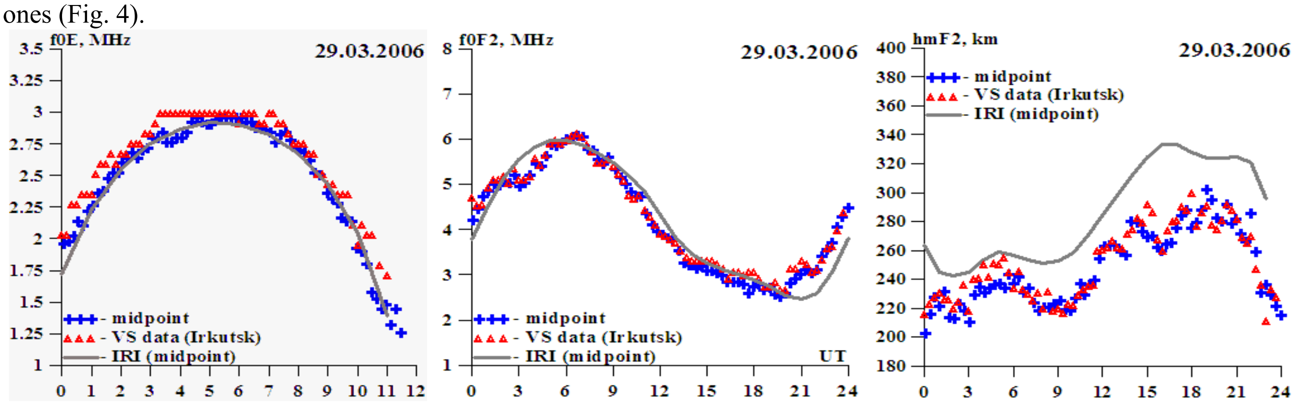

Fig. 4. Diurnal variation of f_0E, f_0F2 and $hmF2$ near midpoint of Usolie—Tory path and in Irkutsk.

6. CHECK OF f_0F2 ON THE NORILSK—TORY PATH

For the new experimental check-up of the method the data were chosen from the accumulated radiophysical observation data that were obtained during the mild solar activity (in order for the maximum usable frequency (MUF) not to cross the limits of the sounding frequencies range). Observations over Norilsk—Tory path (Tory: 51.8°N, 103°E; Norilsk: 69.2°N, 88°E) were organized by separate series since 2003. The path is located in meridian direction (Fig. 1) and it is located by one side in polar and in close-polar zone (path length ~2088 km). Coordinates of the path' midpoint: φ = 60.7°N, λ = 97.5°E. The closest VS station is located in Podkamennaya Tunguska (61.6°N, 90°E). Unfortunately, there is no total coincidence of this point and the path' midpoint coordinates (distance between them ~416 km.

Hour values of critical frequencies F2- and E-layers and also of the coefficient $M(3000)F2$ of the station Podkamennaya Tunguska in a type of table data were given by station employees. Comparing of more than 250 hour values of f_0F2 obtained at the station Podkamennaya Tunguska with the values of f_0F2 calculated according to the OS data and characterizing ionosphere in the path' midpoint was carried out [13]. In the Fig. 6 daily run f_0F2 is shown during one day from the observation series for each season of year in 2003-2004.

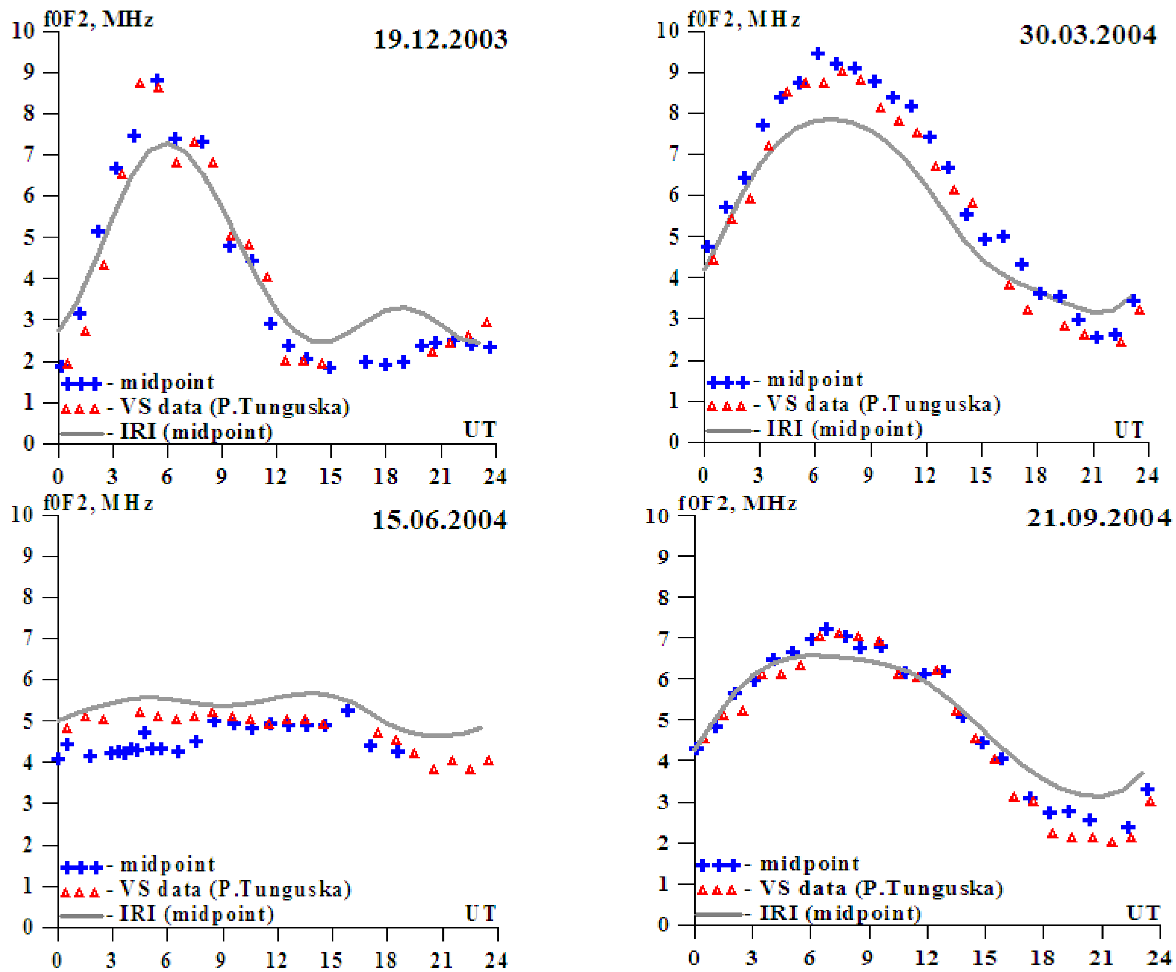

Fig. 5. Diurnal variation of f_0F2 near midpoint of Norilsk—Tory path and in Podkamennaya Tunguska.

Compared sets of calculation and experimental values of f_0F2 were led to Universal Time (UT) format taking into account a longitudinal effect. Podkamennaya Tunguska data when transferring into UT faced the shift of half an hour because of the difference of longitudes of path' midpoint and Podkamennaya Tunguska. It is seen from the Fig. 5 that values obtained from recalculation agree well with experimental values.

Carrying out the experimental works requires quite larger resources unlike the carrying out numerical experiments with the use of various types of environment models the most wide-spread of which is the IRI model. In addition at the Fig. 5 the daily run of critical frequencies in the path' midpoint calculated according to the IRI model with the adaptation with the average-monthly index of solar activity is shown by the bold line. Coefficients for the critical frequency calculation correspond to URSI as to the recommended standard for the models users. Comparing with the IRI model shows the difference of median model values and everyday values. In spite the satisfactory agreement of the model with experiment, in conditions of experimental VS data absence is preferably to use the recalculated data of OS experimental observations than the model ones (even after the model adaptation carrying out according to the index F10.7).

Experimental check-up of f_0F2 values calculating technique in the OS path' midpoint according to observations data in 2003-2004 over Norilsk—Tory path and in Podkamennaya Tunguska VS station showed that absolute middle quantity of f_0F2 values deviation in Podkamennaya Tunguska from calculation values in the path' midpoint according to OS data was 0,34 MHz. Average relative deviation ~8 % (maximal value ~25 % in separate hours), and a correlation coefficient was 0,96. But the largest error is observed at the day time in summer and that can be explained by the Smith method peculiarity where effects related to wave delay in the lower layers are not taken into consideration. Deviations of f_0F2 values can be explained by media gradients because of coordinate's differences of investigated points.

At the Table 1 the daily average values of Ap and F10.7 indices are presented, as well as absolute and relative deviation of f_0F2 according to IRI and observations in Podkamennaya Tunguska and according to the results of f_0F2 calculation for the Norilsk—Tory path's midpoint from experimental OS data in 2003-2004.

Table 1. Absolute and relative deviation of f_0F2 according to IRI and observations in Podkamennaya Tunguska and according to the results of f_0F2 calculation for the Norilsk—Tory path's midpoint from experimental OS data in 2003-2004.

year	month	day	Δ*f*, MHz	δ*f*, %	<Ap>	F10.7
2003	12	16	0.39	12.6	10.25	103
		17	0.36	11.8	6.625	113.8
		18	0.41	11.1	3	119.1
		19	0.25	6.9	1.375	118.6
		20	0.22	8.1	16	125.9
		16-20	0.33	10.1	–	–
		IRI	0.04	0.7	–	–
2004	03	09	0.30	4.9	27.875	107.2
		10	0.16	3.5	**45.125**	111.1
		11	0.20	3	**40**	111.7
		13	0.28	5.5	14.25	102.6
		29	0.30	5.8	10.5	128.3
		30	0.47	8.9	13.625	126.4
		31	0.60	9.5	9.25	121
		09-31	0.33	5.9	–	–
		IRI	0.08	1.7	–	–
	06	15	-0.17	-3.3	17.5	112.9
		16	-0.07	-0.78	7.25	115.1
		17	-0.10	-1.4	6.75	114.9
		15-17	-0.11	-1.83	–	–
		IRI	-0.01	-0.3	–	–
	09	21	0.47	12.5	7.625	95.6
		22	0.23	4.1	16.25	92
		21-22	0.35	8.3	–	–
		IRI	0.05	1.26	–	–

7. CHECK OF *hmF2* ON THE NORILSK—TORY PATH

At the Fig. 6 daily run of hour peak height *hmF2* values obtained by various ways is shown for the same days as at the Fig. 5. Bold line — according to the IRI model, triangles — according to the simplified Dudeney formula (3) from station Podkamennaya Tunguska data, oval circles — from *N*(h)-profile reconstructed according to Guliaeva method [14] from HFC calculated according to the experimental DFC. For June 15, 2004 according to OS data we can calculate HFC only during night hours (in LT) because of the cause of total DFC absence during the day. Almost in all DFC of this period only upper rays and screening sporadic *Es* layer are represented and that allowed calculating only f_0F2 in the path' midpoint and *hmF2* value are impossible to obtain according to this method. Out from the Fig. 6 it is seen that *hmF2* values are well-agreed between each other. As the procedure of *hmF2* value obtaining according to the proposed algorithm via *N*(h)-profile is quite bulky but it can be realized, then in operative goals and in cases when according to OS data it is impossible to calculate *hmF2* value we can use *hmF2* value from the IRI model.

For simplification of peak height calculations a fast approach of peak height determination was tried according to the formula (3). For this case we need to know the parameters of only two DFC points (points corresponding to MUF), and to the «last» point). The critical frequency is calculated according to the «last» point and according to the described method, f_0E value is taken from the IRI model and *M*(3000) is calculated according to the formula *M*(3000)= *MUF*(3000)/f_0F2, where *MUF*(3000) — MUF in the path of 3000 km length.

As the Norilsk—Tory path length differs from 3000 km then according to the formulas (1) and (2) the recalculation of experimental MUF into the HFC point is carried out, and then according to the same formulas (but for *D* = 3000 km) and out from the ratio $f_{OS} = f_0 \cdot k \cdot \sec\varphi$ the frequency is determined that is supposed to be equal to MUF in the path of

3000 km length. A supposition is used in calculation that the media is spherically symmetric and the region of signal reflection from environment and at the MUF frequency for the given paths length (2088 km and 3000 km) is the same.

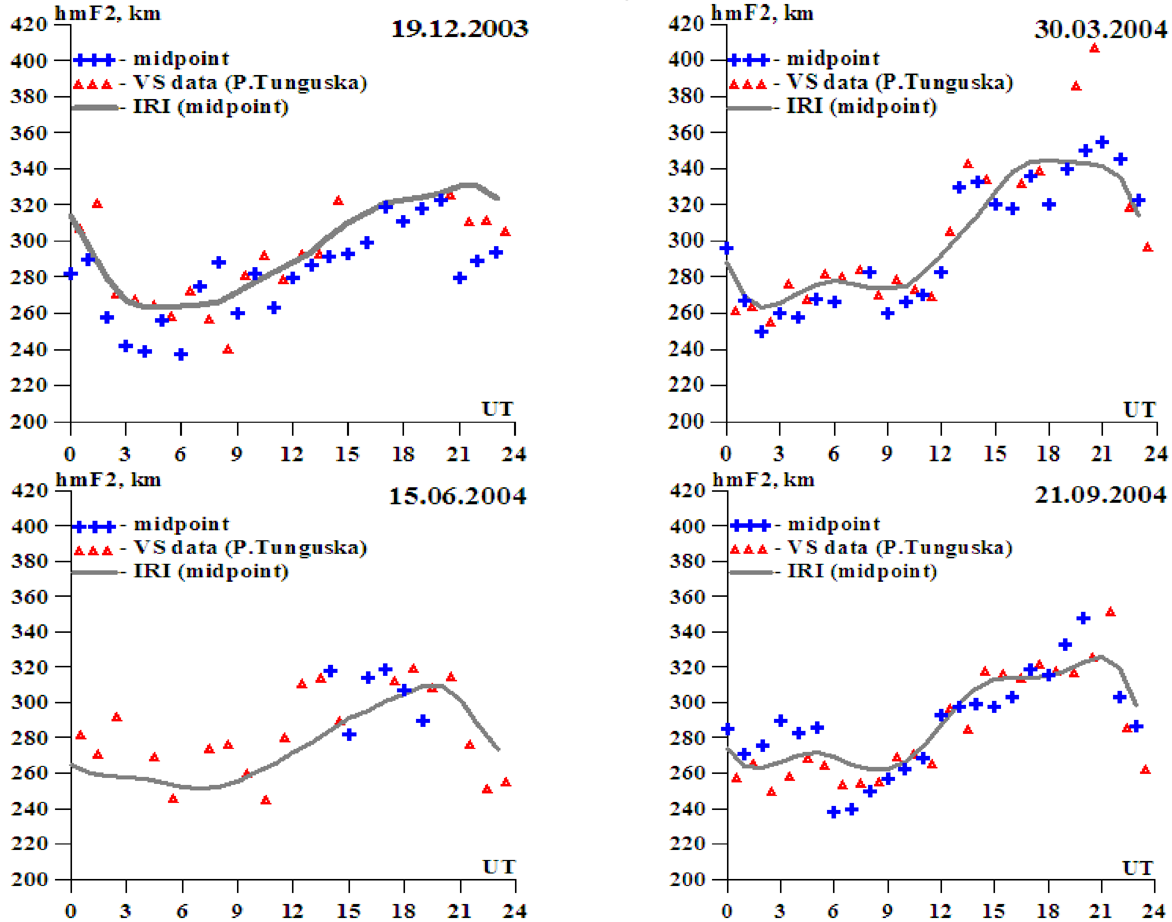

Fig. 6. Diurnal variation of *hmF2* near midpoint of Norilsk—Tory path (derived from OS data) and in Podkamennaya Tunguska (experimental data).

Results of such recalculation are shown at the Fig. 7 by crosses. It is seen that the *M(3000)F2* and height maximum values are well-agreed with the Podkamennaya Tunguska data and with the calculation data according to *N*(h)-profile. As the calculations are simple and we need to obtain only two points (instead of he total track) this calculation approach is simpler and faster than the calculation approach according to the *N(h)*-profile. But in the case of opportunity absence of obtaining the parameters of «last» point or MUF the use of this calculation approach is impossible.

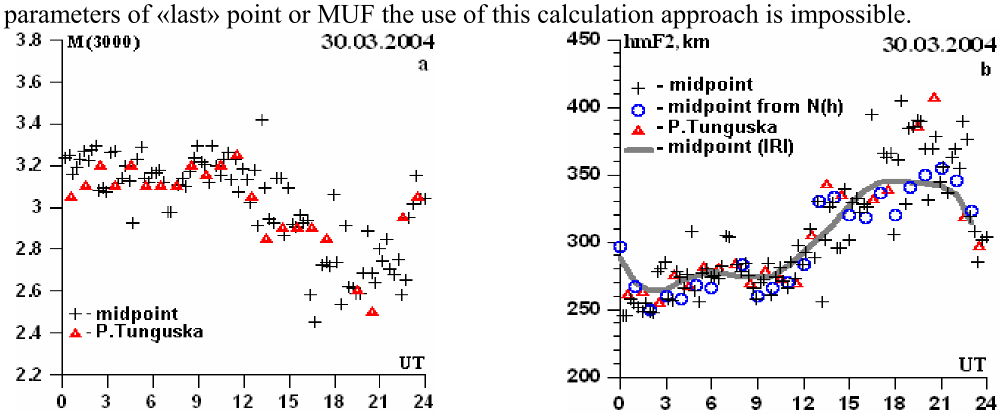

Fig. 7. Daily run of *M(3000)F2* obtained from Podkamennaya Tunguska data and from DFC (a); daily run of calculated peak height values in the Norilsk—Tory path's midpoint and at the Podkamennaya Tunguska (b).

8. CHECK ON THE MAGADAN—TORY PATH

Efforts of experimental check-up of ionosphere parameters calculation according to VS data had been tried earlier [4] for Magadan—Tory path (path length ~3034 km) in 1989, at that time in the path' middle point (58.2°N, 124.2°E) during experiment time ionospheric VS station in Aldan (58.48°N, 125.24°E) was specially installed. But, unfortunately, range limit of OS working frequencies (up to 29 MHz) at that period of solar activity maximum (F10.7 ≈ 217) had not allowed obtaining a total DFC, i.e. up to MUF. Maximum observed frequency (MOF) limited by 29 MHz was sufficiently lower than calculative MUF. Also because of technical failures it has not observations data obtained during complete 24-hour period. Nevertheless, limited set of DFCs during those hours (night and transitive period) when we could determine MOF (as crossing frequency of upper and lower rays) allowed us making conclusions of determining influence of VS parameters in the path' midpoint when determining MUF by the calculative approach. Errors in comparing MUF as also the calculated critical frequency according to DFC were in average 5 %.

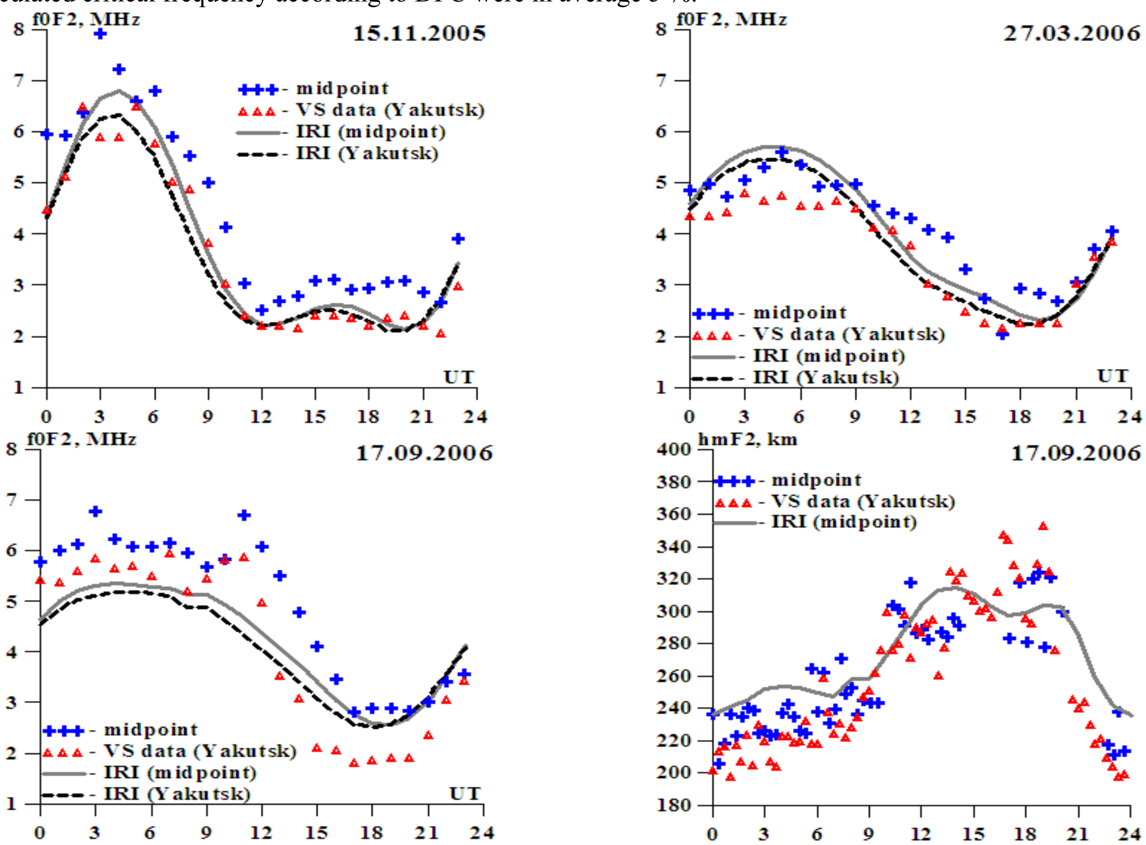

Fig. 8. Diurnal variation of f_0F2 and *hmF2* near midpoint of Magadan—Tory path and in Yakutsk.

Experimental checking through the use of 2005-2006 data (Fig. 8) had shown that data of ionospheric VS station in Yakutsk (62°N, 129.6°E), nearest VS station to Magadan—Tory path's midpoint (distance between them ~516 km or ~4° latitude gradient), cannot be used for such supervisory checking with calculated data for path's midpoint (spatial gradient is too large). It was proved by comparison VS data obtained during February and March of 1989 in Yakutsk and in Aldan, which situated in Magadan—Tory path's midpoint directly. For this purpose experimental VS data obtained in Aldan in 1989 and storing on films were scanned and processed again. VS data obtained in Yakutsk were kindly given by ionospheric station employers. Also we used modeled data from IRI-2001 model.

Differences of IRI model used to be less than differences obtained in the result of experimental OS data recalculation (at night hours latitude gradient for Aldan and Yakutsk according to IRI model is absent) that means, that the IRI describes the ionosphere an that region not enough well. In Tables 2-3 we can see the values of absolute relative deviation of f_0F2 according to IRI and according to observations in Aldan (nearest to the Magadan—Tory path midpoint) and in Yakutsk in February and October of 1989.

Table 2. Absolute and relative deviation of f_0F2 according to IRI and observations in Aldan and Yakutsk in February of 1989.

date \ interval			0-8 UT (day)		8-12 UT (transitional hours)		12-20 UT (night)		20-24 UT (transitional hours)	
year	**month**	**day**	**Δf, MHz**	**δf, %**	**Δf, MHz**	**δf, %**	**Δf, MHz**	**δf, %**	**Δf, MHz**	**δf, %**
1989	02	5	1.2	12.5	1.04	15.6	1.06	38	0.38	17
		6	0.92	6.25	-	-	-	-	-	-
		8	-	-	1.19	18.3	1.7	61	1.8	79
		9	1.05	10.4	1.34	20.3	1.06	23.8	-	-
		13	1.44	13.3	1.99	35.1	2.56	883	-	-
		17	1.48	15.7	1.05	14.1	0.3	6	0.79	17.9
		18	1.5	12.5	0.94	9.3	0.83	19.2	0.22	7
		19	1.72	16.5	0.5	5.5	0.19	3.6	0.22	12.5
		20	1.2	11.1	0.69	6.3	0.65	14	0.59	10.1
		21	1.0	8.7	0.91	9.7	1.18	40.9	0.72	17.8
		22	0.43	3.5	1.51	22.7	1.4	34	0.8	24.1
		23	0.16	1.35	0.56	6.1	0.34	6-	-	-
		26	1.1	9.6	0.77	8.7	-	-	-	-
		5-26	1.1	10.1	1.04	14.3	1.03	30.5	0.73	23.1
		IRI	0.43	4.3	0.18	2.4	-0.01	-0.21	0.17	2.75

Table 3. Absolute and relative deviation of f_0F2 according to IRI and observations in Aldan and Yakutsk in October of 1989.

date \ interval			0-24 UT (day and night)	
year	**month**	**day**	**Δf, MHz**	**δf, %**
1989	10	23	0.82	15.5
		24	0.85	15
		25	0.98	18
		26	0.65	13.3
		27	0.72	12.3
		28	0.53	8.2
		29	0.72	11.8
		30	0.91	17.6
		23-30	0.78	13.9
		IRI	0.23	2.4

It does not allow us to use Yakutsk VS station data for reliant experimental check-up of technique for media parameters derivation from OS data, how it was checked in 1989 when VS station had worked near Magadan—Tory path's midpoint (in Aldan, Yakutiya region). In order to demonstrate differences of ionospheric parameters for coordinates of Yakutsk and Magadan—Tory path's midpoint at the Fig. 9 daily run of MOF values (from OS experiment over Magadan—Tory path) and MUF values obtained through the use of Yakutsk data with the help *M(3000)F2* coefficient. It's seen that experimental OS data are good correlated with calculated values (via Yakutsk data). However quantity analysis shows deviation value more than 20 %. Values of absolute and relative deviation of f_0F2 according to IRI model and according to data of observations in Yakutsk and according to the results of calculation of values f_0F2 for path' mid-point from OS data on Magadan—Tory path in 2005-2006 are shown at the Tables 4-5.

Table 4. Absolute and relative deviation of f_0F2 according to IRI and observations in Yakutsk and according to the results of f_0F2 calculation for the Magadan—Tory path's midpoint from experimental OS data in 2005.

date \ interval			0-8 UT (day)		8-12 UT (transitional hours)		12-20 UT (night)		20-24 UT (transitional hours)	
year	**month**	**day**	**Δf, MHz**	**δf, %**	**Δf, MHz**	**δf, %**	**Δf, MHz**	**δf, %**	**Δf, MHz**	**δf, %**
2005	11	15	1.0	18.74	0.89	28.6	0.7	30.6	0.84	33.3
		16	0.65	12.14	0.78	30.2	0.24	10.6	–	–
		17	0.82	15.1	0.83	31.5	0.56	24.2	1.05	43.4
		18	0.66	11.8	0.64	25.4	0.62	27.6	0.89	38.6
		19	0.46	9.2	0.72	27.4	1.07	48	0.91	37.7
		15-19	0.7	13.25	0.77	28.5	0.61	27.02	0.9	38.4
		IRI	0.4	7.5	0.21	7.0	0.08	3.1	0.04	1.22

Table 5. Absolute and relative deviation of f_0F2 according to IRI and observations in Yakutsk and according to the results of f_0F2 calculation for the Magadan—Tory path's midpoint from experimental OS data in 2006.

date \ interval			0-10 UT (day)		10-15 UT (transitional hours)		15-20 UT (night)		20-24 UT (transitional hours)	
year	**month**	**day**	**Δf, MHz**	**δf, %**	**Δf, MHz**	**δf, %**	**Δf, MHz**	**δf, %**	**Δf, MHz**	**δf, %**
2006	03	26.	0.59	11.8	0.52	15.6	0.83	36.6	0.56	19.3
		27	0.59	13.1	069	22.2	0.43	18.8	0.32	10.5
		28	0.58	12.35	0.61	20.8	0.63	32.5	0.36	12.7
		29	0.55	11	0.25	7.3	0.43	19.7	0.6	21.3
		30	0.52	10.1	0.43	13.11	1.17	52	0.22	7.47
		26-30	0.56	11.7	0.5	15.8	0.7	31.9	0.41	14.3
		IRI	0.24	4.6	0.24	6.8	0.18	6.9	0.02	0.41
	09	17	0.58	10.60	1.29	35.96	1.2	61.83	0.35	13.10
		18	0.52	12.79	–	–	–	–	0.39	11.21
		19	0.50	11.82	1.22	36.45	–	–	0.46	15.81
		20	0.69	14.67	0.42	12.89	0.71	35.59	0.48	15.47
		21	0.69	14.45	0.78	24.24	1.10	56.45	0.59	21.10
		22	0.60	11.93	0.56	14.46	–	–	0.84	27.62
		23	0.72	14.91	0.87	26.76	1.36	72.36	0.76	30.69
		24	0.73	16.80	–	–	–	–	0.59	19.38
		25	0.59	12.68	0.98	36.5	–	–	0.57	14.84
		26	0.58	11.95	0.64	19.5	–	–	0.35	8.69
		27	0.60	12.31	0.58	16.82	–	–	0.24	6.20
		28	0.57	11.03	0.76	22.8	–	–	–	–
		17-28	0.62	13.0	0.81	24.64	1.1	56.56	0.51	16.74
		IRI	0.18	3.6	0.31	7.81	0.13	4.5	0.03	0.57

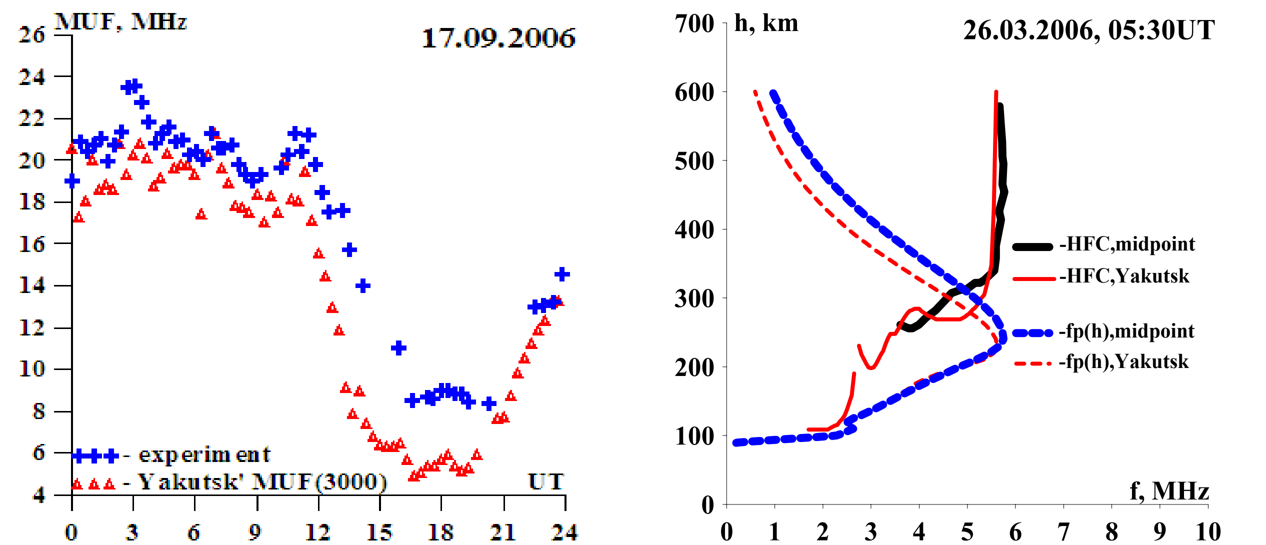

Fig. 9. Diurnal variation of experimental MOF and MUF values derived from VS station data in Yakutsk (in left). HFC and *fp*(h)-profiles reconstructed from HFC in Yakutsk and recalculated for midpoint from experimental DFC (in right).

At the Fig. 10 diurnal variation of absolute deviation and ratio error between calculated f_0F2 value in Magadan—Tory path' midpoint and experimental f_0F2 value in Yakutsk during few days of different months in 2005-2006 are presented.

9. CONCLUSIONS

Experimental checking of operative technique for calculation of f_0F2 and $hmF2$ values in OS path's midpoint (carried out on the base of experimental data obtained during 2003-2006 over different length and orientation paths) shows satisfying approbation between experimental and calculated values.

Also the checking showed that Yakutsk station VS data correlate with estimated Magadan—Tory values in path's midpoint, but deviation can be more than 20 % (different daytime have an effect) that accords to theory [15].

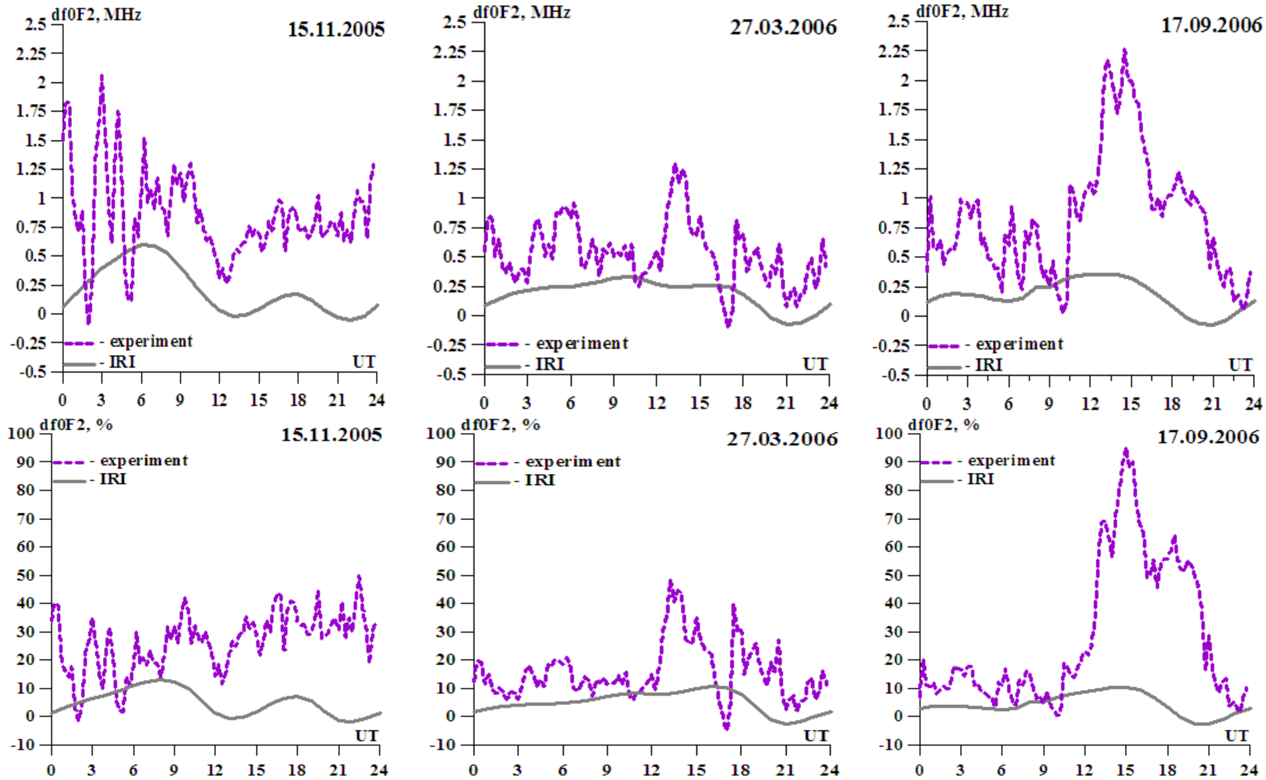

Fig. 10. Diurnal variation of absolute deviation (in top) and ratio error (in bottom) between calculated f_0F2 value in Magadan—Tory path' midpoint and experimental f_0F2 value in Yakutsk.

IRI allows determining the ionosphere parameters in every point of the Earth at any time. Obtained averaged values of medium can totally differ from the real values, especially on the Russia territory. However, the possibility of IRI model adaptation according to the real values allows some-how compensating this disadvantage. Carried out analysis of the IRI model adaptation possibilities according to the critical frequency and peak height values has shown that for the obtaining of values close to the real ones we need the adaptation in one parameter – critical frequency. IRI adaptation in both parameters (critical frequency and peak height) does not give a sufficient improvement in calculation of *N*(h)-profile, because the changes of peak height values are low in comparison with the critical frequency variations.

Comparison with IRI model shows that latitude gradients between critical frequencies in Magadan—Tory path's midpoint and Yakutsk larger than IRI model expects. Differences speak that IRI describes ionosphere in this region (East Siberian high and middle latitudes) not enough sufficiently.

The operative technique of f_0F2 definition (also HFC which can be used for *hmF2* definition) have satisfying accuracy, and its simple algorithm opens good perspectives for using the technique in real-time for operative diagnostics. OS data recalculation into the HF parameters in the path' midpoint can be useful as an opportunity to obtain additional information of environment in regions where the VS stations are absent. We need only the presence of true experimental OS data and a possibility of the 1F2 mode upper ray parameters obtaining. Besides diagnostics it can be useful for short-term forecasting in development of regional ionosphere models, for adapting and correcting of different ionosphere references to real conditions.

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