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HF DUCTING CONTROL DUE TO MODIFICATION OF THE IONOSPHERE BY POWERFUL RADIATION

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Abstract. - By the method of oblique chirpsounding on Khabarovsk - "Sura" - Temryuk - distance the effect of powerful ground radio emission on long-range HF propagation has been investigated. It is shown that HF aspect scattering by artificial ionospheric turbulence (AIT) is responsible for the appearance of additional modes reqistered on the oblique sounding (OS) ionograms in the period of the heating facility operation.The modelling of long distance HF propagation with account of the aspect scattering by AIT is carried out. It is shown that with small negative gradients of the critical frequency f_0F_2 along the path the aspect mode (AM) is associated with the hop propagation and at the values grad f_0F_2 < -0,03...0,04 MHz/100 km AM is associated with ducting. The waveguide mode escaping from the ionospheric channel due to the aspect scattering by AIT occupies the frequency range of Δf~2-3 MHz and is observed at frequencies exceeding the maximum observed frequency (MOF) hop of 2F2 direct signal mode.Time-frequency characteristics of AM have been investigated and their relation with geomagnetic-ionospheric disturbance has been established.

Introduction.

It is known (Gurevich and Tsedilina,1979) that there are raised channels in the Earth - ionosphere waveguides the propagation in which at long distance is characterized by a number of advantages in comparison with the hop propagation. They are: small losses at the absorption and the possibility of propagation at frequencies above MOF hop propagation. At the ground location of sounding means the main problem is the excitation of the ionospheric duct (ID) (Kravtsov et al.,1979). For the undisturbed ionosphere the most effective mechanism of ID excitation is the radio wave refraction at the horizontal gradient of the electron density. The creation of irregularities of different scales (1 ~ 0.01....1 km) in the ionosphere under the action of powerful radio emission opens new possibilities for the control of ID excitation at the expence of scattering by AIT.This report presents the experimental results on the control of HF long distance propagation due to radio wave aspect scattering (ASR) by AIT.

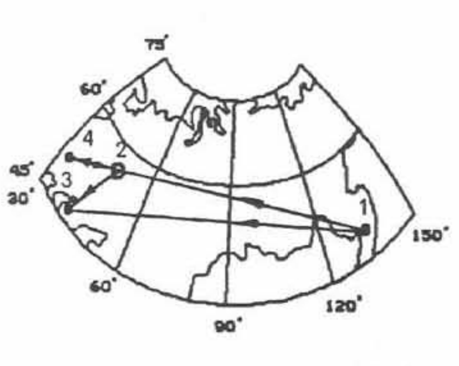

Fig.1. The Scheme Of The Experiment.
1 - Khabarovsk 2 - "Sura"
3 - Temryuk 4 - Dimer

Experiment

The scheme of the experiment is shown in Figure.1. The chirp sounder located in Khabarovsk is used in the capacity of sounding means (Ivanov et al.,1991).The transmitter radiats linear frequency modulated (LFM) signals in the frequency range 6-28.4 MHz by the antenna

$RG\frac{65}{4}1$ ($\lambda_0 = 19m$) oriented to the heating facility "Sura" located in N.Novgorod region (azimuth radiation $A=315^{0}$ distance ~ 5700 km). The power of the signal at the entrance of the antenna amounts ~ 200 W, the sweep rate ~ 380 kHz/s. Observations were carried out in the period from 18 to 23 March 1991 from 22.00 to 06.00 of the local time at the reception point ($LT=UT+3^{h}$) when the maximum of the negative gradient of the electron density provided the radio wave trapping in ID was registered for the given season (equinox). Chirpsounding is continuously carried out during the observation time.The disturbance of the ionosphere is accomplished by the powerful HF radiation facility "Sura". The transmitter operated with effective power PG = 100 MW and the radiated O-mode polarization at the frequency f_H below the F region critical frequency f_0F_2 ($f_H < f_0F_2$) by cycles: 5 min-heating,5 min-pause. The reception point Temryuk is located to the south from Khabarovsk - "Sura" path at the distance ~ 1300 km from the heating facility (the angle of scattering $\theta s \sim 30^{0}$).The reception of LFM signal is carried out by the antenna $RG\frac{65}{4}1$ ($\lambda_0 = 19m$) oriented to the artificial ionospheric disturbance. The ionosphere at the point of radiation and heating is controlled by the vertical sounding, the geopmagnetic activity is controlled in Khabarovsk. For the control of the efficiency of AIT excitation the HF radar was used located in Dimer,Kiev region at the distance~1200 km from the heating facility.The radar transmitter power is 25 kW, operated in pulse at several frequencies in the range 16.6 - 19.9 MHz by the antenna $RG\frac{65}{4}1$($\lambda_0 = 18m$) oriented to the domain of the ionospheric disturbance.The reception of HF backscattering from AIT is carried out by the phased array.

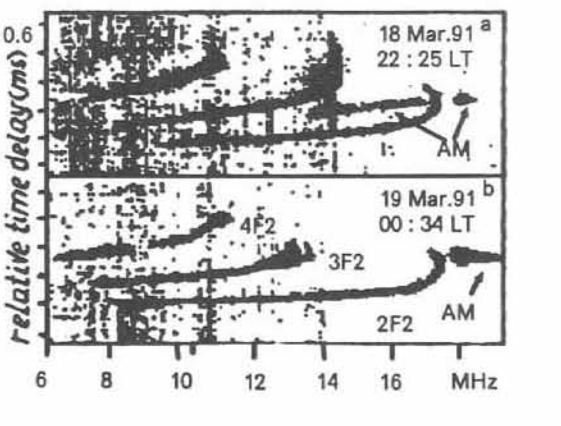

Fig.2.Samples oblique ionograms Khabarovsk to Temryuk with AM correlated with the heating facility operation.

The Results and Discussion.

The additional modes are registered in Temryuk in OS ionograms at the heating time. Small time of the development of additional modes ($\tau_h <$ 1min) indicates to its relation with excitation of artificial small-scale field-aligned irregularities with a crossed field dimension $l = \lambda/2 \sin(\theta s/2)$ (for $\lambda = 15$ m, $\theta s = 30^{0}$, $l = 30$ m) responsible for ASR. Figure 2 shows a samples oblique ionograms with AM correlated with the heating facility operation. It is seen that AM is observed both at the frequency below MOF 2F2 (Fig.2a) and at the frequency above MOF 2F2 (Fig.2b) direct signal at Khabarovsk-Temryuk path .

The observational results are compared with ionospheric/geomagnetic conditions.Figure 3 illustrates 3 hour value K_p of the geomagnetic activity and the level of ionospheric disturbance $\Delta f_0F_2 = (f_0F_2 - \langle f_0F_2 \rangle)/\langle f_0F_2 \rangle$ during the period of the experiment at the transmitter point. The intervals of the observations are noted in the same place. The period of AM observation correlated with the heating facility operation are shaded.It

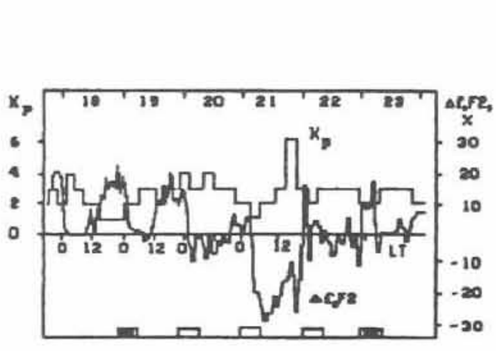

Fig.3. Daily variation of K_p, Δf_0F_2 and appearance of the aspect mode

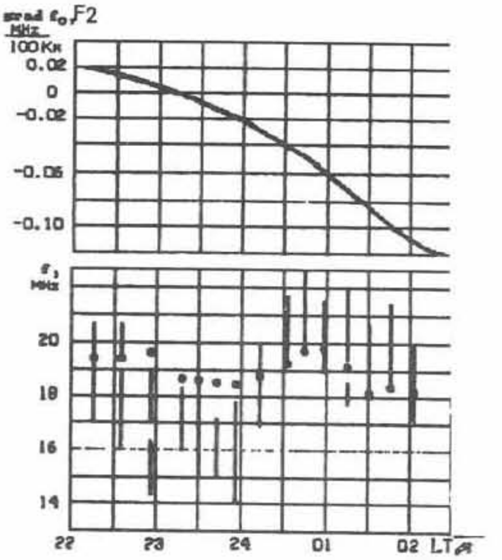

Fig.4.Daily dependency MOF 2F2, frequency range AM and gradient critical frequency f_0F2 from the transmitter side averaged along path from 0 to 4000 km.

should be noted that AM is observed only in the period of low geomagnetically quiet day with $K_p \sim$ 1-2. The absence of the effect of 21 March when $K_p \sim$ 1-2 is connected obviously with negative ionospheric disturbance at the distance. The sounding results of AIT with the help of HF radar indicate also to the dependence efficiency of the AIT excitation from the level of geomagnetic and ionospheric disturbance.According to the data obtained the HF back scattering by AIT is observed in the period 22^h13^m on 18 March to 00^h20^m on 19 March at the frequency f ~ 18-20 MHz.The radar cross section back scattering was in the maximum $\sigma \sim 8*10^7\ m^2$ on 23^h30^m 18 March. HF back scattering by AIT was not observed both in the period of geomagnetic activity ($K_p \sim$ 3-4) and negative ionospheric disturbance.

The observational data of AM permit us to investigate its dynamics with time. Figure 4 (lower panel) presents the observational results of AM on 18-19 March. MOF 2F2 at Khabarovsk-Temryuk path is marked by points, vertical lines indicate the frequency range of AM in the last minute of the heating facility operation.Note,that AM is not observed after 03^h00^m LT.Probably it is connected both with the decrease of the heating efficiency at the ionosphere and with the change of the aspect scattering conditions for the given geometry of the experiment.

For the interpretation of the data in Figure 4 (upper panel) the daily dependence is given for the critical frequency gradient from the transmitter side averaged along the path from 0 to 4000 km.It is seen that in cases when grad f_0F_2> -0.03 MHz/100km the AM is observed at frequencies less than MOF 2F2. By reverse inequality AM is observed mainly at frequencies above MOF 2F2.

For the analysis of the experimental data the modelling of HF propagation with account of ASR on AIT has been carried out.The ray tracing and the synthesis of the direct signal and AM ionogram using the ionospheric forecast were carried out.It is shown that conditions for ASR on AIT can be realized both for hop and waveguide modes.If the negative gradient of the electron density caused by the terminator is insufficient then the aspect signal hop mode arrives at the reception point at frequencies low than MOF 2F2. With growth of he negative gradient of the electron density the radio wave trapping occurs in the ID at frequencies above MOF 2F2 and AM is registered at the reception point being of a waveguide origin.Figure.5 illustrates the ray tracing of waveguide propagation calculated by the ionospheric forecast at the frequency above maximum usable frequency (MUF) hop propagation.The isolines of the plasma frequency are noted in the same place.

Conclusion

As a result of investigations carried out a possibility is shown for the control of HF waveguide propagation at frequencies above MOF hop propagation due to escape of the waveguide mode from the ID with the help of ASR on artificial ionospheric irregularities created inside the channel of the powerful radiation.

It is shown that HF trapping in the ID takes place for grad f_0F_2 < - 0.03..- 0.04 MHz/100 km.The waveguide mode escaping from the ID at the expence of ASR on ATI occupies the frequency range Δf=2-3 MHz and is observed at the

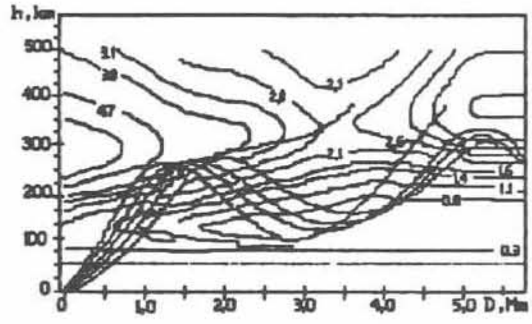

Fig.5.Ray tracing from Khabarovsk to "Sura" March 91 01^hLT Frequency 15 MHz. The angles of radiation: $6^o...10^o$.

frequency above MOF 2F2 for the direct signal.It is obtained that escape of the radio wave from ID is effective when $K_p \sim$ 1-2 and the negative ionospheric turbulence is absent.

References

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