Long-distance propagation effects in the HF signals from different Heating facilities observed with using passive Doppler sounding equipment at Irkutsk

Berngardt O.I.[1], ***Abramov V.G.***[1], ***Blagoveschenskaya N.F.***[2], ***Frolov V.L.***[3], ***Kurkin V.I.***[1], and ***Ponomarchuk S.N.***[1]

[1] Institute of Solar-Terrestrial physics SB RAS, Irkutsk, Russian Federation, e-mail:berng@iszf.irk.ru
[2] Arctic and Antarctic Research Institute, St.Petersburg, Russian Federation
[3] Radiophysical Research Institute (NIRFI), Nizhny Novgorod, Russian Federation

Abstract

We present the first observation results of long-distance propagation effects of short radio waves at pump frequency, observed by passive Doppler sounding equipment at Irkutsk during heating facilities operation. We demonstrate two effects: dependence of the received signal amplitude on the propagation path during power-stepping mode and difference between experimental observations and propagation expectations according to our model.

1 Introduction

The ways of long-distance propagation of short wave (SW) radiosignals and theirs creation mechanisms during heating facilities operation is investigated intensively. The basic principles, operation modes, physical mechanisms and references can be found for example in [1]. The use of doppler sounding data at pump frequency at long-distance radio pathes for diagnostics of the processes, that accompany heating processes, is also under investigation [2]. In the work we analyze the effects of the propagation conditions on the radiowaves propagation from heater facility at pump frequency. The passive Doppler sounding equipment at Irkutsk - is a multichannel narrow-band (up to 1kHz bandwidth) system for receiving short-wave (SW) radiosignals (1-30MHz) with quadrature (IQ) components registration. The system was built in Institute of Solar-Terrestrial Physics (ISTP SB RAS) in 2007-2009 years. For the following analysis we have used 3 heater facilities (EISCAT,SURA,HAARP), 1 HF broadcasting station (Moscow) and two receiver locations(Irkutsk and St.Petersburg). All of these locations and propagation paths are shown at Fig.1.

2 Peculiarities of the received signal in power-stepping mode

The one of the basic mode of the EISCAT heater during 6/11/2009 campaign was power-stepping mode. During this experiment the power of pump frequency was changed from minimal (20%) to maximal (100%) value, without changes of other transmitter parameters. Registration of the signal at pump frequency during this experiment has been made at two locations: St.Petersburg and Irkutsk. The analysis allowed us to detect the following peculiarity of the signal propagation over these paths: the power of the received signal at different locations changes non-proportionally to each other when changing pump radiowave power. At Fig.2A we have shown the time dependence of the received signal amplitude of time, at Fig.2B we have shown the relation between signal power received at St.Petersburg and Irkutsk at the same time. During the experiment, only pump radiowave power has been changed, the antenna pattern of the heater facility has not been modified. Due to this, the non-linear relation between received signal power at two different locations allows us to suggest an existence of nonlinear mechanism, that changes amplitude of signal received at pump frequency far from the heater facility. It is thought that basic mechanisms of signal generation at pump frequency at long distance from the heater are: propagation of the heater radiowaves from sidelobes of the antenna pattern over the different radio paths, including multi-hop propagation (with reflecting from the ionosphere and the ground) and interlayer channel propagation (between E- and F-layers) with feeding the channel by the heater and receiving the signal at solar terminator or artificially modified regions[3,4]; scattering of the signal from the irregularities, generated by the heater (or self-scattering mechanism)[2,5]. One

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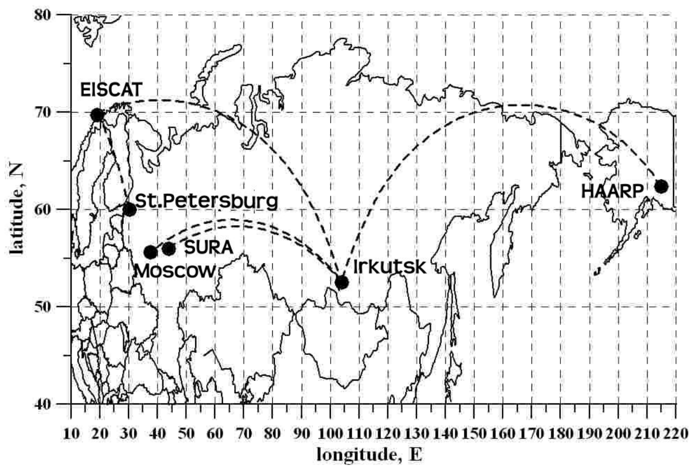

Figure 1: Experimental geometry

possible mechanism, related with the heater radiowave propagation over the distorted media is propagating the pump wave in presence of the electron density cavern, created during the heating. Due to long (over 5000 km) propagating path the ionospheric region making the most powerful response to the received signal (for slight difference of the ionosphere from its spherically-symmetrical model) should be located near the region of the first reflection from the ionosphere (and located about 700-1000 km from the heater facility). In this case the signal must be generated by lower sidelobes of the heater facility antenna pattern. For the described nonlinear effect takes place, the first reflecting region should be located near the heater-generated electron density cavern (in the region about 100-150km size). According to this, the signal should be generated by mainlobe of the heater antenna pattern. This cause propagating path changes due to heated region presence and arising new radiowave propagation modes that travels through th heated region. The one of these modes, for example, is interlayer channel propagation of the heater radiowave [3,4].

3 Signal propagation peculiarities and propagation model predictions

For the following analysis we have used the propagation model, developed in ISTP SB RAS. The model is based on waveguide approach, and on technique of the adiobatic approximation of the eigenwaves [6]. The technique is based on the approximation of the electromagentic field by eigenfunctions of the radial problem in the Earth-ionosphere waveguide. In [7] the schemes and algorithms are described in details, that allows one to calculate radiosignal parameters over the wide frequency limits and large spatial regions, with taking into account the nearly real parameters of the waveguide. We have used international reference ionosphere (IRI-2007) to get the ionospherical parameters. The approach is the most used propagation prediction technique in ISTP SB RAS.

At Fig.3 there is shown comparison between signal amplitude received at pump frequency from SURA facility at Irkutsk, and amplitude of the signal from Moscow public radiostation at Irkutsk. The experiment was made 26/08/2010. The propagation paths SURA-Irkutsk and Moscow-Irkutsk are very close to each other (the distance between them is about 50-100km in South-North direction), but Moscow-Irkutsk path is about 1000 km longer. The frequencies are almost the same (the difference is about 200kHz). As one can see, the signal from SURA at pump frequency arises about 1 hour earlier than signal from Moscow radiostation. According to the modeling results, the delay should not exceed 15 minutes. According to the model, the start of the stable observation of the signal for Moscow-Irkutsk path is 18:00UT, and for SURA-Irkutsk path - 17:45UT. As one can see, the Moscow-Irkutsk observations are predicted by our propagation model sufficiently well, but SURA-Irkutsk signal is observed about 30-45 minutes earlier. We think, that observed difference can be caused by non-standard propagation path of the SURA radiowave in presence of the

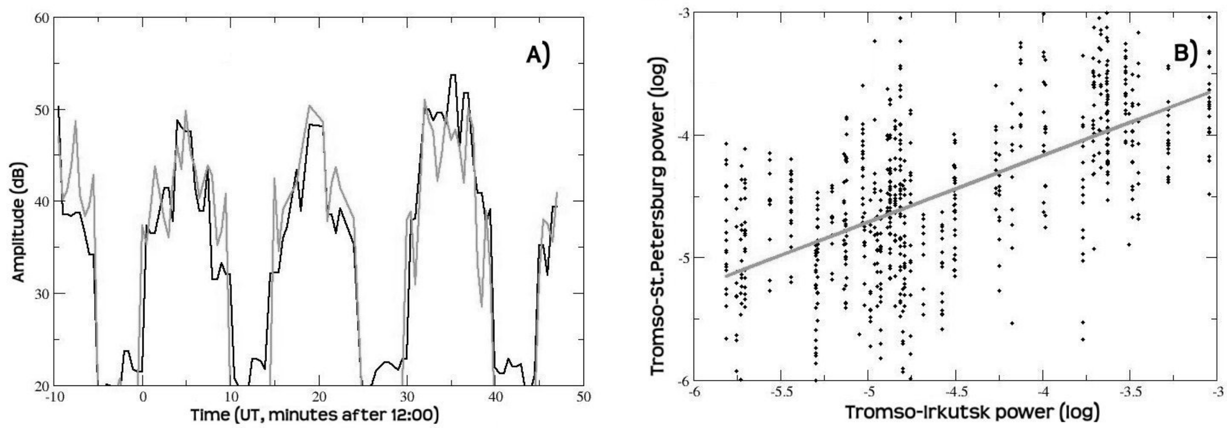

Figure 2: A) Tromso-St.Petersburg (black line) and Tromso-Irkutsk (grey line) received signal power during power-stepping experiment B) St.Petersburg logarithmic power vs. Irkutsk logarithmic power (black dots) and linear fit with 0.54 coefficient (grey line)

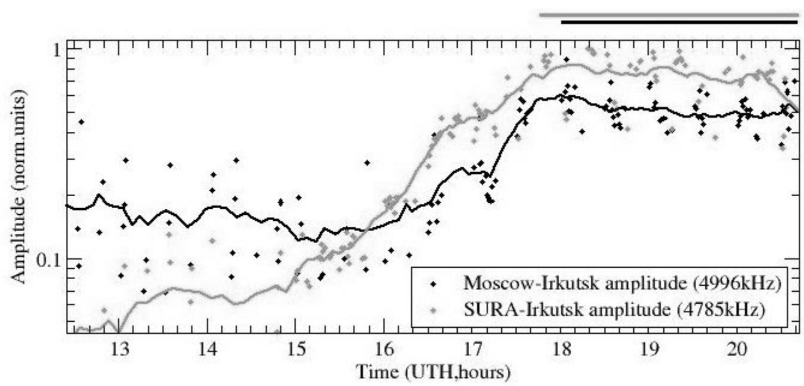

Figure 3: Moscow-Irkutsk and SURA-Irkutsk received signal power,26/08/2010 campaign, lines above - ISTP SB RAS model prediction for observations (grey - for SURA-Irkutsk, black - for Moscow-Irkutsk path)

disturbed region. At Fig.4. there is shown a comparison between HAARP observations during 02/08/2010 campaign at approximately 3MHz pump frequency. According to our propagation model, used for previous modeling, the radiowaves at frequencies below 5 MHz from the heater location should not be detected at Irkutsk. But according to the experiment, from 12:00 to 14:00UT we stably observe the signal at pump frequency.

4 Conclusion

Summarizing all the described facts, we can conclude that for interpreting the experimental observations of the heater facilities at pump frequency we need to modify our model of the radiowave propagation in presence of the heated region. The possible additional schemas are: interlayer channel propagation (between E- and F-layers) with feeding the channel by the heater, according to the [3,4]; propagation of the signal, scattered from the irregularities, generated by the signal itself [2,5]; modification of the propagation paths due to formation of the 3-dimensional ionospheric cavern during the heating, with significant horizontal and vertical electron density gradients. Our analysis has shown that at long paths the propagation of the radiowave from heater facility at pump frequency can depend on propagation effects, caused by changes of the media near the heater due to its functioning.

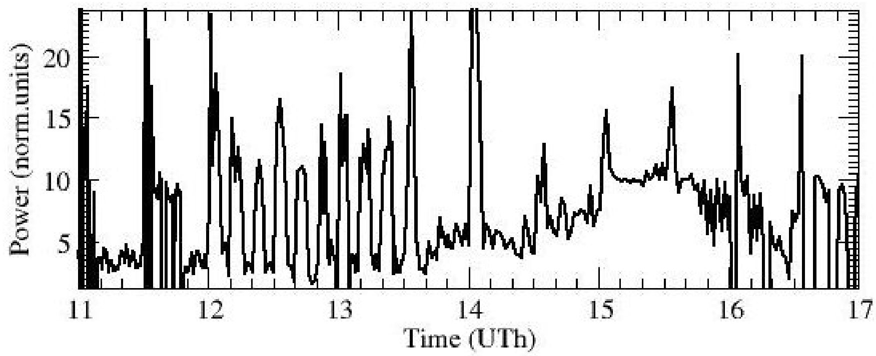

Figure 4: HAARP-Irkutsk received signal power, 02/08/2010 campaign, pump frequency 2750 kHz

5 Acknowledgements

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