Investigations of HAARP emission on super long radio paths (review)

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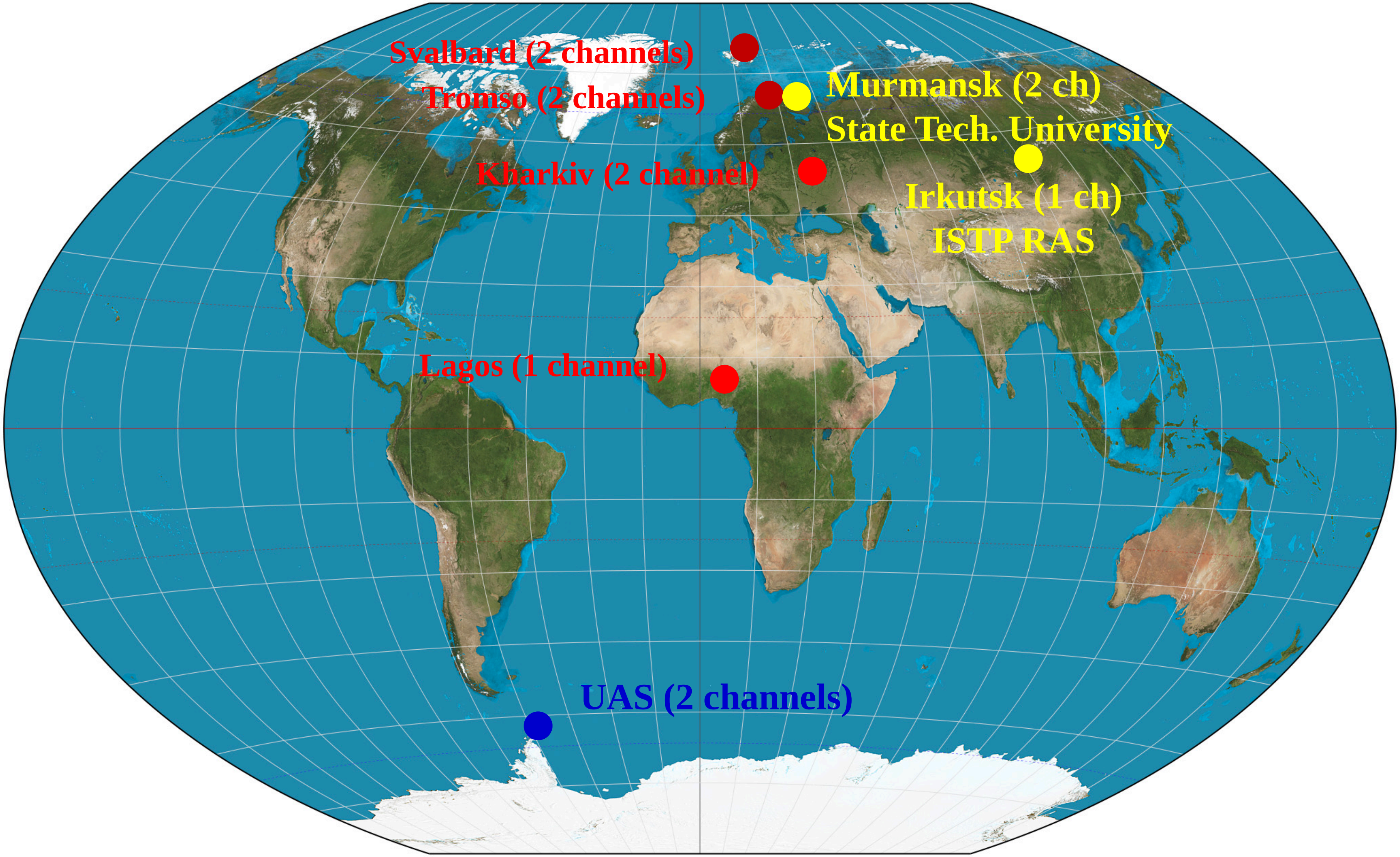
Outline

- Network of HF receivers
- Experiment of 2002 – self-scattering
- Experiments with HAARP
  - 2008 – confirmation of self-scattering
  - 2010 – receiving in Antarctica the signals from HAARP
  - 2013 – excitation of the ionospheric interlayer duct
  - 2014 – correlation of HAARP signals received in Antarctica with SEE DM

Network of the HF receivers



Internet-controlled Manually-controlled Partner instruments

Experiments of October, 2002 (EISCAT)

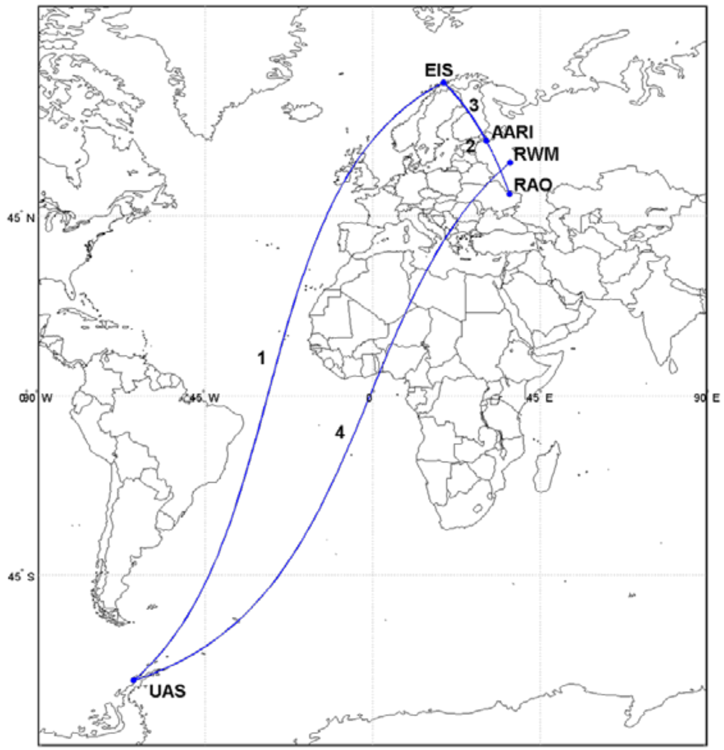


Figure. Layout of the experiment. EIS, AARI, RWM, RAO, and UAS signify, respectively, EISCAT (European Incoherent Scatter Scientific Association) HF transmitter, Arctic and Antarctic Research Institute, RWM Station of the Moscow Time and Frequency Service, Radio Astronomical Observatory (of the Institute of Radio Astronomy), and Ukrainian Antarctic Station *Akademik Vernadsky*.

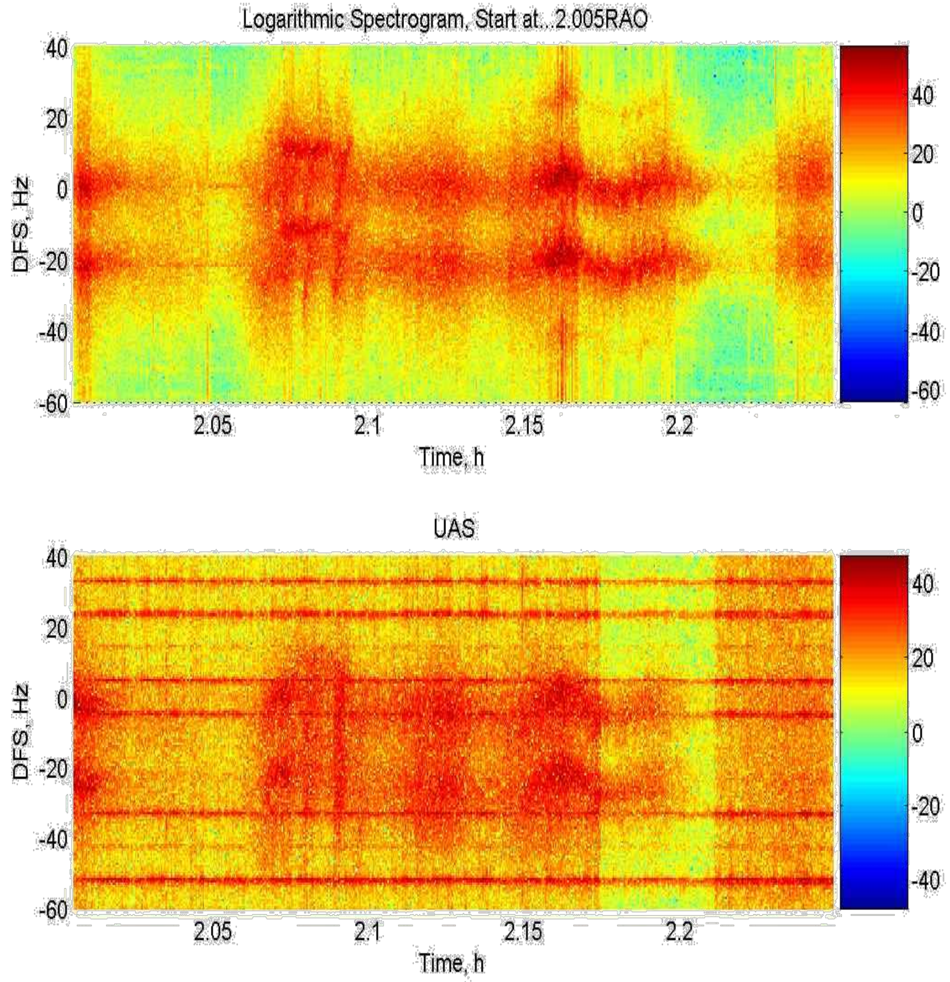


Figure. Spectrograms of EISCAT heater signal received on October 29, 2002 at 02:00:30-02:15:00 UT at RAO (top panel), and at UAS (bottom panel). The transmission frequencies were 4.040,717 and 4.040,695 MHz

Experiments of February, 2008

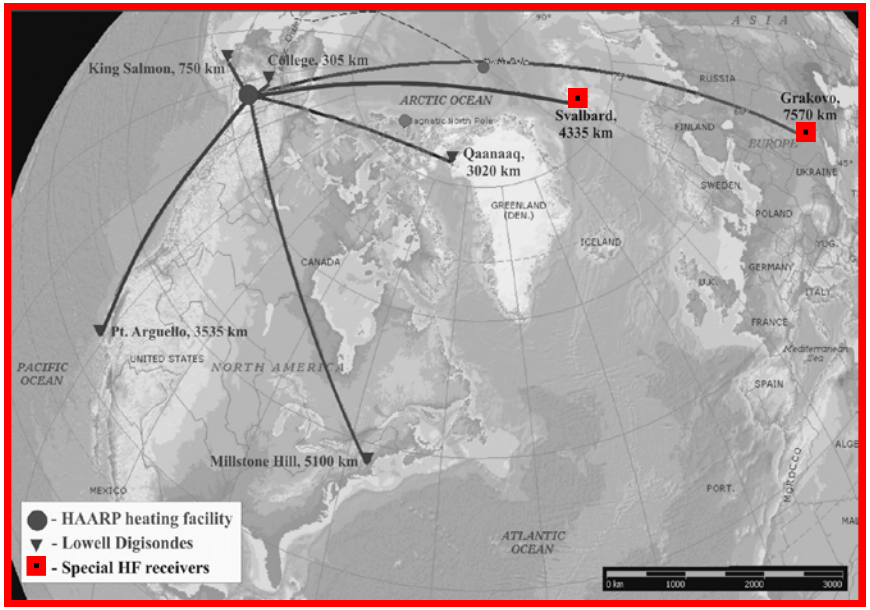


Figure. Scheme of experiments

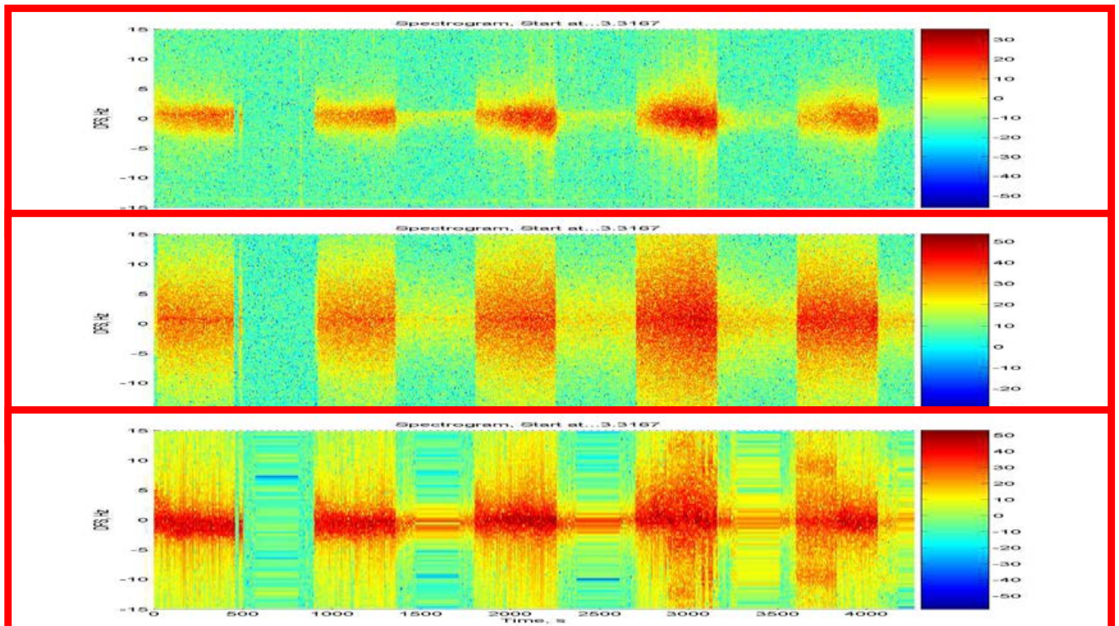


Figure. Spectrogram of the HAARP heating signal at the RAO, Svalbard, and Millstone Hill. 2008/02/26, 03:19…04:30 UT.

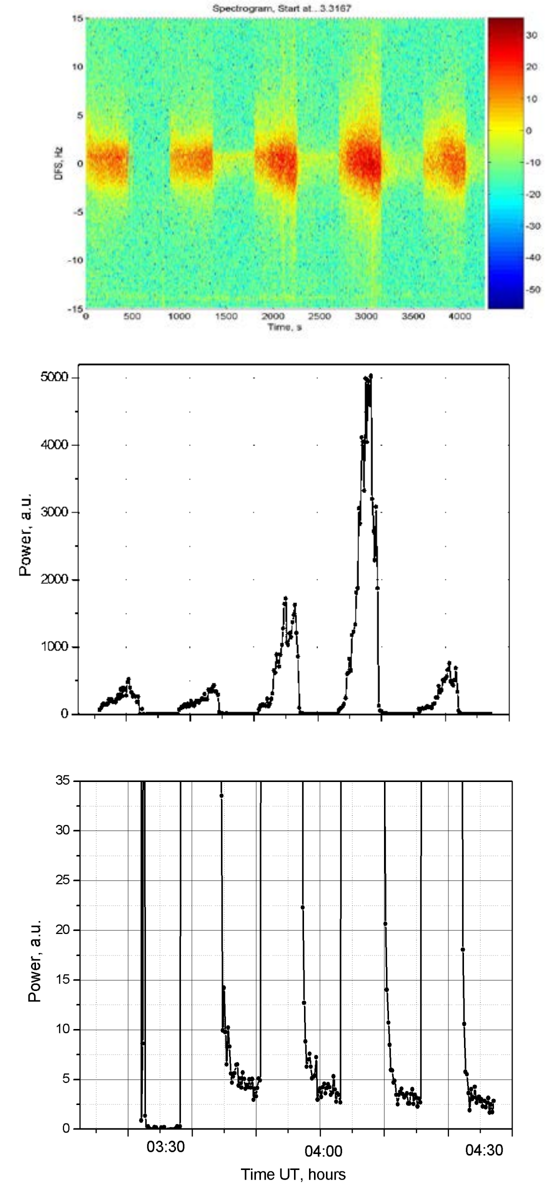
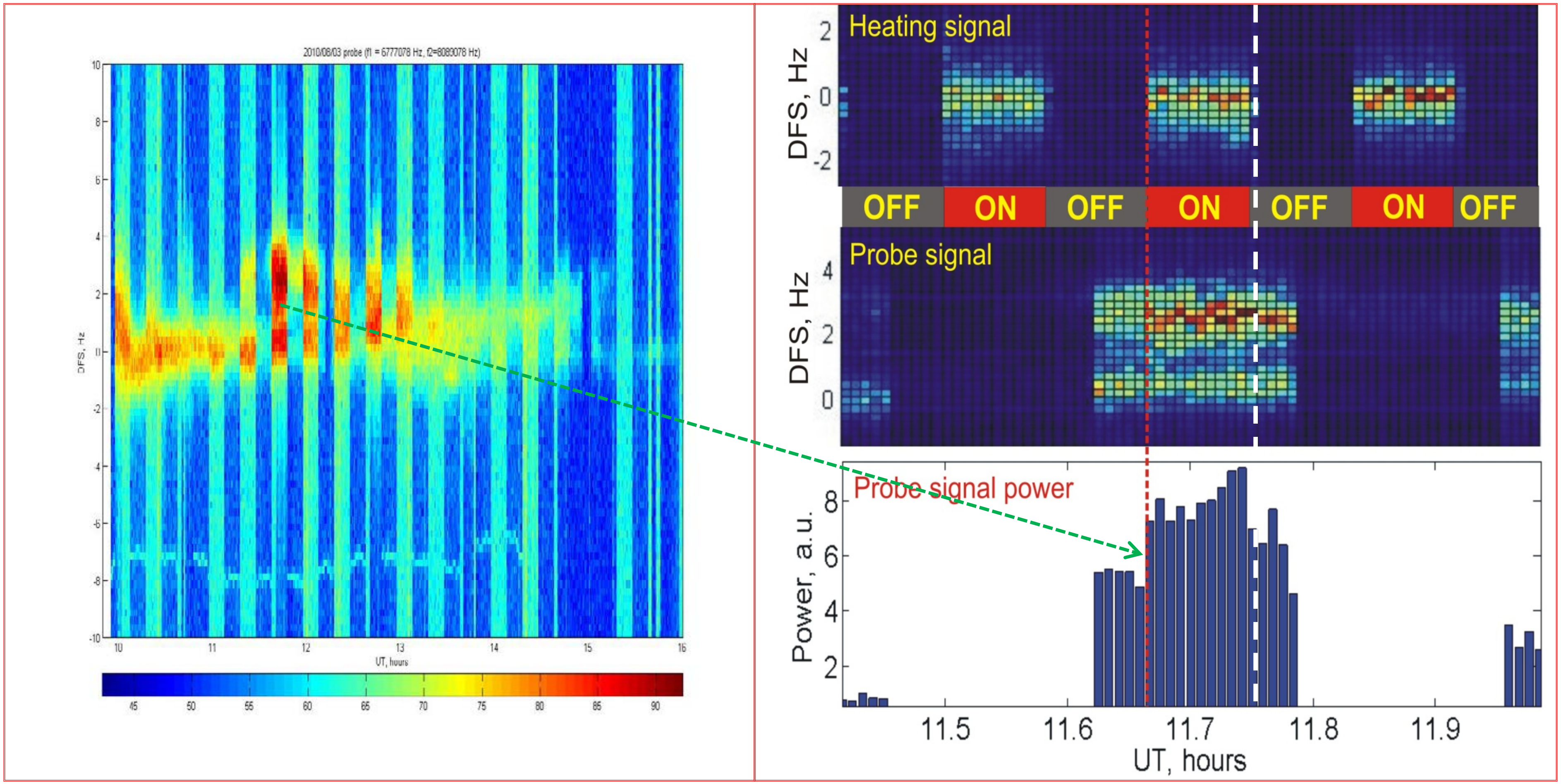


Figure. Spectrogram and variations of the scattered signal power after the heater was switched to radiate the full power and relaxations of probe signal as observed at RAO positions on February 26, 2008 at the HAARP transmission frequency of 2.755,056 MHz

Experiments of May and August, 2010

A specific of the August, 2010 campaign is the presence of two frequency-separated components in the probe signal spectra. These components can be associated with signals propagating along different trajectories. Of special interest is the increase and decrease in the intensity of the frequency-shifted component of the probe signal observed at the time moment when the heater was turned on/off.

August 3, 2010



Experiments of November, 2012

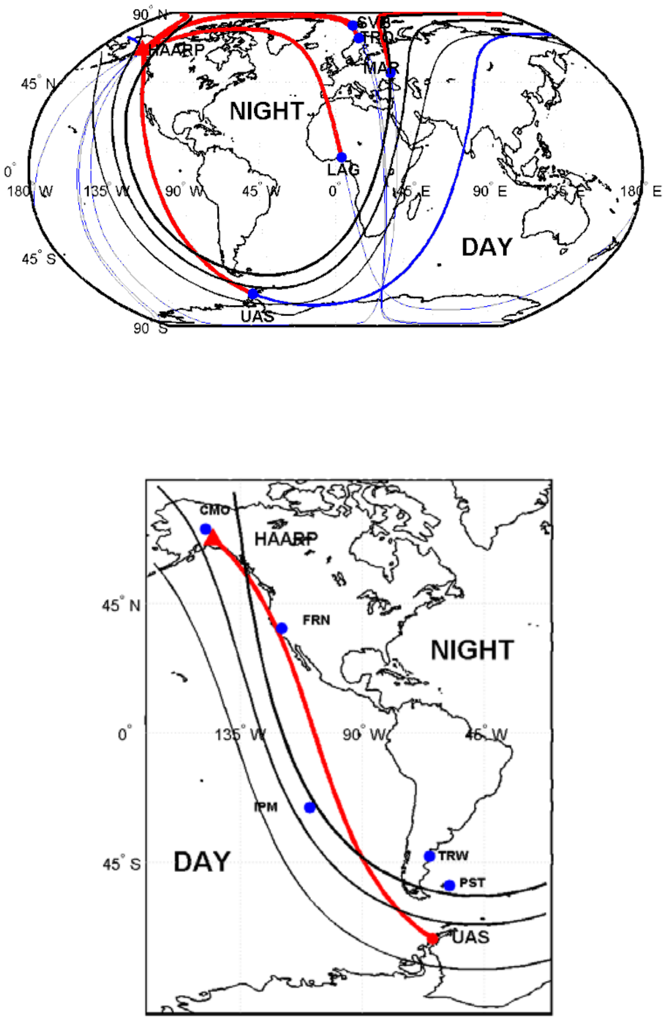


Figure. Layout of the experiment in different scales and the solar terminator boundary at the Earth’s surface and at the heights of 100 and 300 km

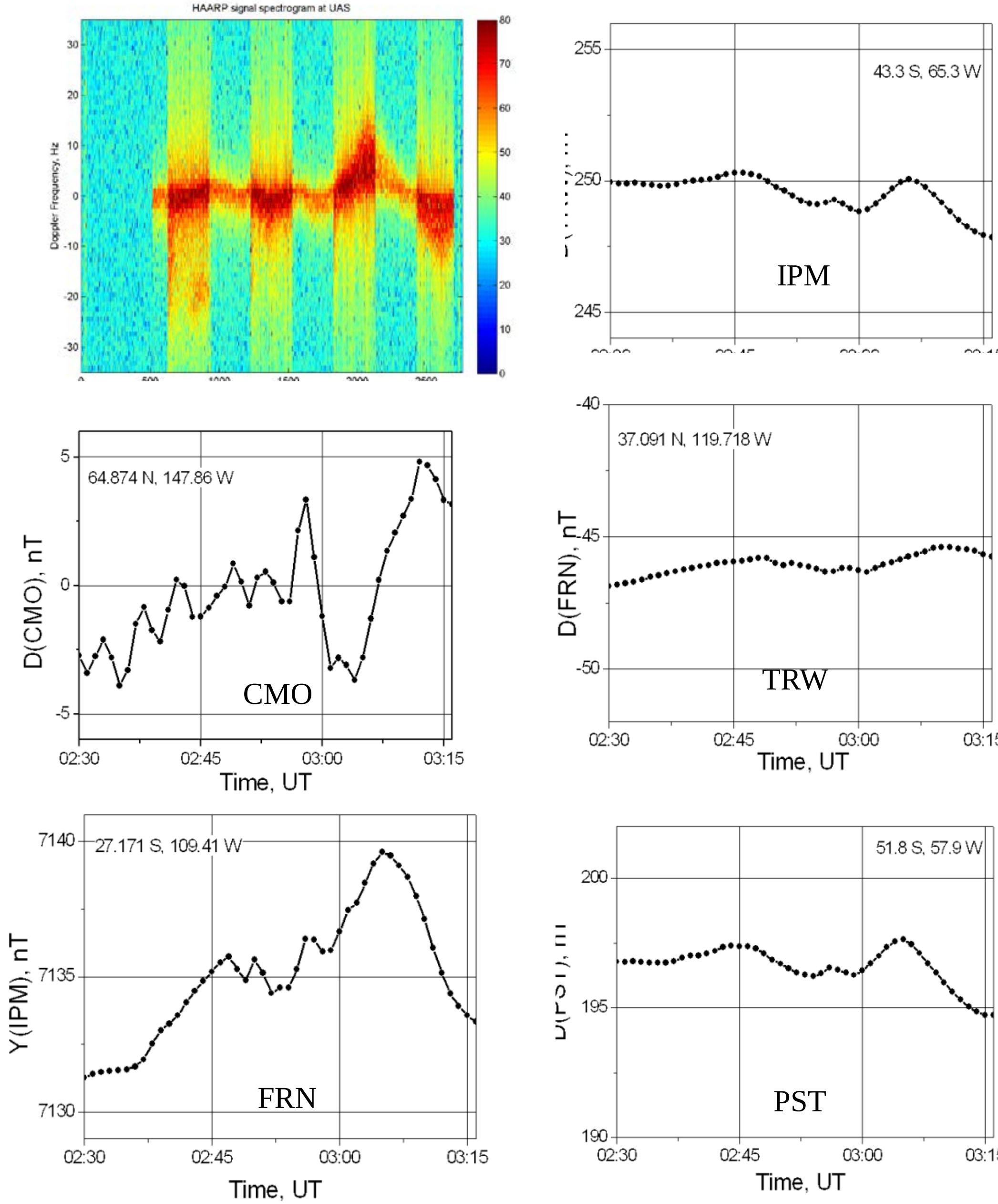


Figure. Variations of DFS of HAARP signal and the magnetic field D or Y component near the HAARP position (CMO observatory) and along the HAARP-UAS radio path at the observatories of the INTERMAGNET network

Experiments of June, 2014

The peak of the amplitude of the HF signals detected by UAS correlates with the peak of DM

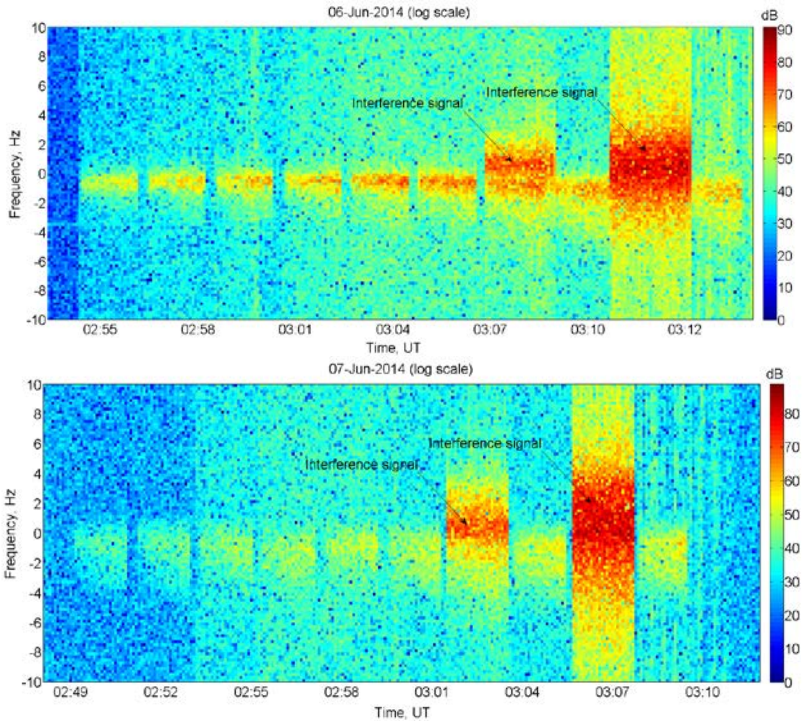


Figure. Spectrogram of received HF signal at UAS a) June 6th, b) June 7th.

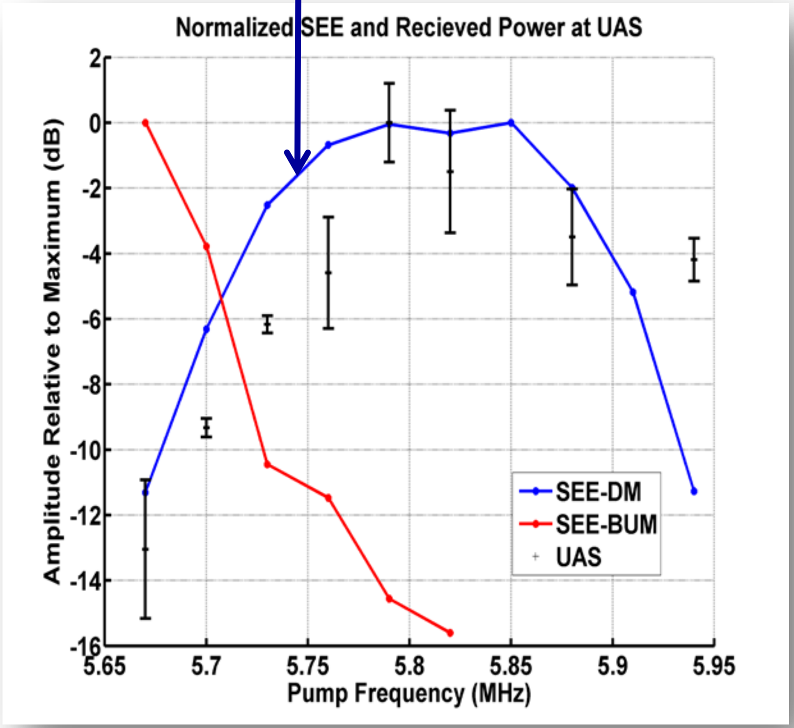


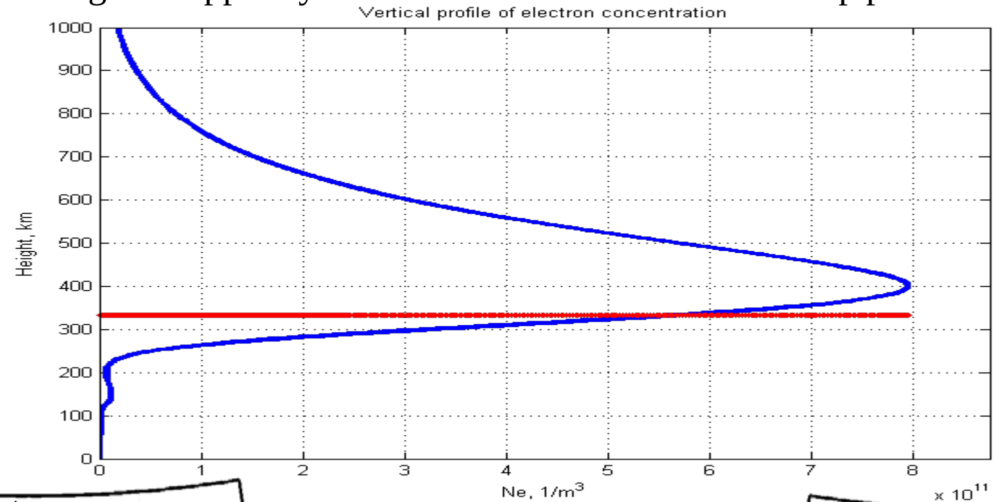
Figure. Amplitudes of DM, BUM, and received power at UAS relative to maximum values, as a function of heating frequency.

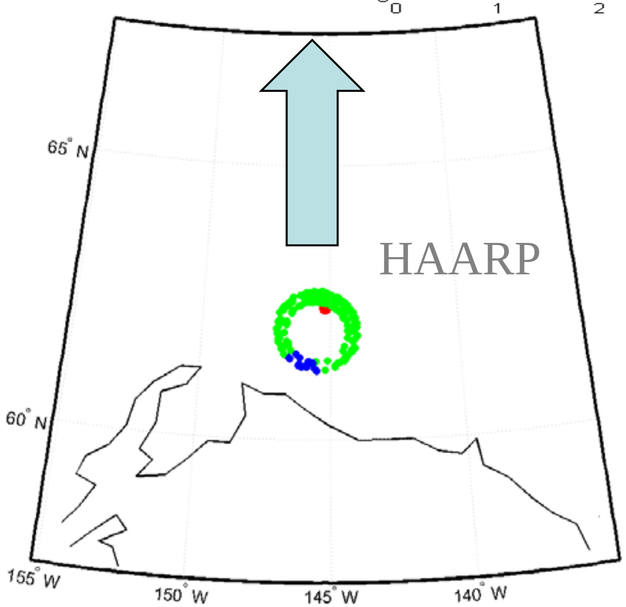
The BUM is associated with 10 cm scale striations, called super small striations (SSS) while the DM is associated with decameter scale striations.

SSS are inefficient scatters of the HF waves compare to the decameter scale striations.

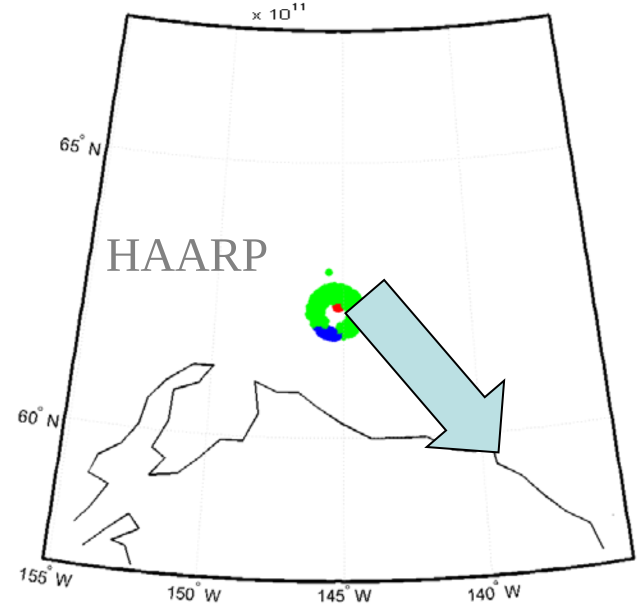
The mirror reflection does not play an important role since the existing nonlinear dependence of the amplitude of HAARP signals on the ERP cannot be induced by the weak side lobe radiation.

Ionospheric areas responsible for excitation of the interlayer waveguide to channelize the scattered pump energy toward the UAS and Arctic-Europe positions for the conditions of the experiment of November 13, 2013 between 2:30 and 3:15 UT. The intersections of the areas with antenna pattern projection at the scattering level are shown by blue color. The model electron density profile and the height of upper hybrid resonance are shown on the top panel





From HAARP
to Tromso, Svalbard, Ukraine



From HAARP
to UAS *Akademik Vernadsky*

Conclusions

- Self-scattering effects were observed simultaneously at greatly dispersed receive sites for several intervals of heating during the HAARP campaign of February, 2008. The similar behavior of the signals received at sites located in the USA, Europe, and Arctic following the changes in the power of the heater can be regarded as direct evidence that the pump wave is scattered by ionospheric irregularities produced by the same wave. Signal analysis has allowed estimating the relaxation and rise times of the HAARP-stimulated ionospheric inhomogeneities which are responsible for the self-scattering. The observed relaxation time was equal to several tens of seconds, while the rise time extended to a few minutes.
- During the measurement campaign of November 2012 the highest signal-to-noise ratio was observed for the HAARP-UAS propagation path. The signal level in the Antarctic showed essential increase when the sunset solar terminator passed simultaneously over the receiving and transmitting sites. A high amount of correlation was observed between Doppler frequency shift variations at the UAS and D-component of geomagnetic field fluctuations measured close to the HAARP heater (the correlation coefficient was about -0.89) that can be considered as indirect evidence of ionospheric waveguide propagation of pump emission.
- According to the results of the measuring campaign of June 2014 it was shown that the intensity of the signal received at UAS strongly depends on the heating frequency and on the intensity of the pumping wave. Thus the HAARP signals detected at UAS originated by the HF-pumping of the artificial striations which in turn scatters HF radiation into the ionospheric channel. The usual multi-hop propagation mode of the HAARP side lobe parasite radiation does not play an important role.

ACKNOWLEDGEMENTS

This work has been done under partial funding of EOARD-STCU partner projects P-330 and P-524,
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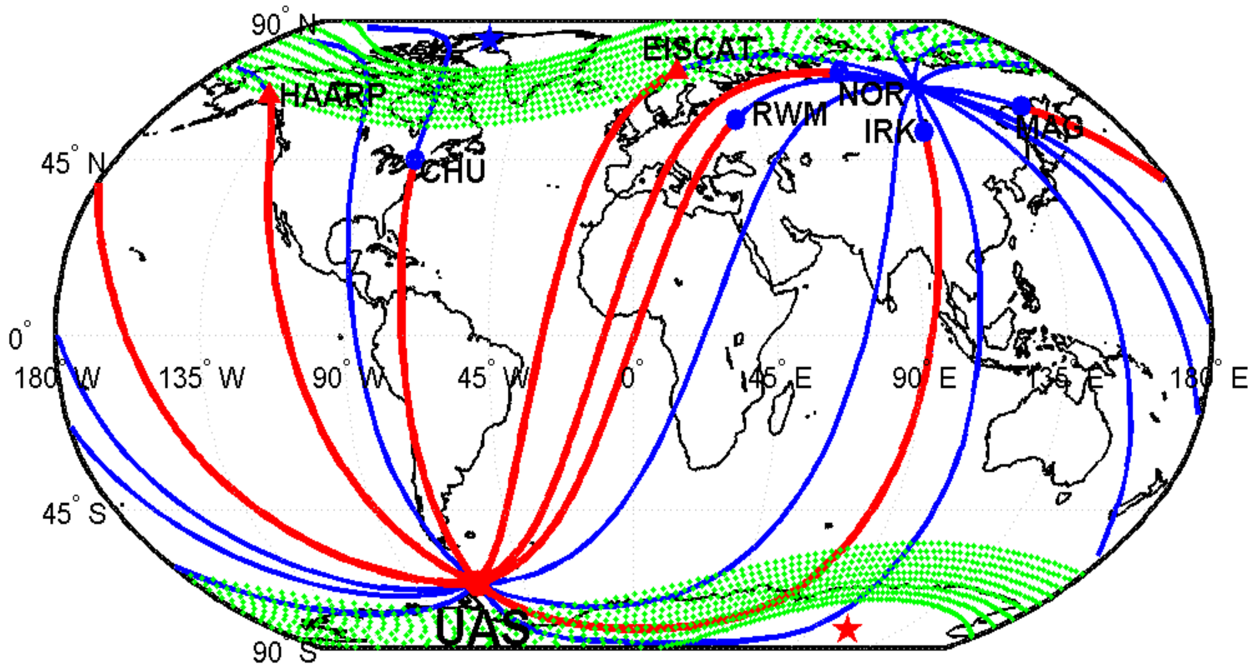
Thank you!

Extra slides

Map of radio paths with receiving site at the *Akademik Vernadsky* station



Abstract

HAARP facility is unique research instrument, which can be used both for investigations of the interaction between high-power electromagnetic waves and ionospheric plasma and for studying of propagation effects on long-distant HF radio paths. The observation of HAARP signals at several geographically dispersed radio sites are carried out in the Institute of Radio Astronomy, National Academy of Sciences of Ukraine (IRA NASU) for about ten years. They are performed using the network of digital HF receivers developed by the IRA NASU team. It worth to note that access to the data and remote control by the acquisition systems are implemented via Internet network. In this study we will discuss results collected at the observational sites located near Kharkov (Ukraine), Tromsø (Norway), at Svalbard (Norway) and at the Ukrainian Antarctic Station (UAS, Antarctic Peninsula, 65.25 S, 64.25 W). The results of data processing show that heater signal simultaneously recorded at several spaced observation points can be used to study the "self-scattering" on ionospheric irregularities produced by the same HF pumped wave. This effect was firstly observed for EISCAT heater at sites located, near Kharkiv, St. Petersburg and at UAS. High level of correlation of the temporal variations of the self-scattered spectra at different sites was detected. The observations of HAARP signal were used to calculate relaxation and rise times for the self-scattered signals. The average relaxation were shown to be several tens of seconds (40-60 s), while the observed risetime was much longer, up to a few minutes. The power and spectral width of the scattered signals depend on the HAARP beam orientation and local ionospheric conditions were studied as well. Another effect, which is discussed here, is enhancement of HAARP signal detected at UAS located 15.6 Mm from the heater. The possible explanation of this effect is propagation of the HAARP signal in the ionospheric interlayer waveguide. This effect was commonly observed when the solar terminator passed simultaneously over the transmitting and receiving sites. The regular gradients of the electron density appears in the ionosphere during the solar terminator passage near the observer can be responsible for signal output from the interlayer waveguide. The exaltation of the waveguide may be produced by wave scattering on artificial or natural ionospheric plasma irregularities. In both cases, area of the ionosphere near the heating facility will produce the dominant contribution to the variations of spectra parameters recorded at UAS, because propagation in the interlayer waveguide occurs with small losses and minimal spectral distortions. This effect was confirmed by good correlation between variations of Doppler frequency shift observed at UAS and D component of magnetic field measured close to HAARP. A clear correlation of the signal intensity recorded at UAS with amplitude of downshifted maximum and anticorrelation with strength of broad upshifted maximum of SEE observed near HAARP were detected.