Stimulated plasma emission at the second harmonic of the pump wave

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Abstract

The possibility of generating of the electromagnetic radiation at harmonics of the pump wave in the ionospheric plasma is still open because of complexity of the experiments on its detection. The fact is that the parasitic generation of harmonics can occur in the output circuit of the transmitter, and separate it technically from the possible ionospheric effects is very difficult. To solve the problem of release the 2nd harmonic which excited in the ionosphere the special scheme of the experiment was proposed that based on using the stable low-power probe wave on the frequency near the second harmonic of the pump wave for inspecting the propagation conditions of parasitic radiation. The conclusion about the ionospheric generation of the 2nd harmonic was done by comparing of its parameters with the probe signal.

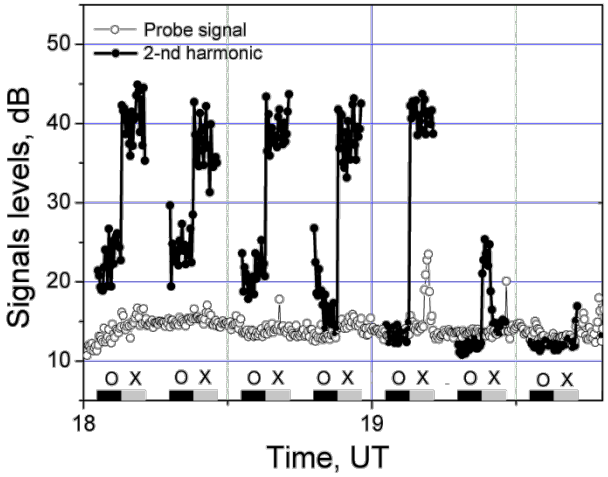
Two special measuring campaigns organized jointly by the Institute of Radio Astronomy, National Academy of Sciences of Ukraine (IRA NASU), and EISCAT Scientific Association were held on 29-31 October 2013 and 17-18 November 2014. During the campaigns the EISCAT heating facility and UHF incoherent scatter radar, as well as IRA NASU coherent HF receiving systems located in Tromsø, Svalbard (Norway), and at the S.Ya. Braude's Radio Astronomy observatory and Low-frequency observatory of IRA NASU (Kharkov region, Ukraine) were used. At the time of experiments the carrier frequency of the pump wave was constant and equal 3989942 Hz. One transmitter of the heater radiated the probe pulse signal with power of about 100 kW at carrier frequency Hz. The level and frequency of the probe signal during the measurement remained constant. The synchronous registration of the signals at the frequencies of the pump, probe, and 2nd harmonic were conducted. At the time of effective interaction between the pump wave and the plasma (according to the data of EISCAT UHF incoherent scatter radar) on October 31, 2013 and November 17, 2014 the signal at the 2nd harmonic of the pump wave has been observed in Tromsø at the significantly higher level in comparison with the probe signal near the 2nd harmonic. At the other receiving sites the 2nd harmonic of the pump wave has not been registered. Ratio between the levels of 2nd harmonic and probe signal in Tromsø grew up on 50 dB during the effective interaction of the pump wave and the plasma, and it was equal zero in the absence of interaction. The effect of the pump frequency doubling has been observed under the influence on the ionosphere by the waves of both "O" and "X" polarizations.

The strong dependence of the 2nd harmonic signal parameters on the conditions of the interaction between pump wave and ionospheric plasma, as well as the absence of its correlation with the parameters of the probe signal indicate that the signal at the 2nd harmonic of pump wave is generated in the ionosphere.

Scheme of the experiment

Two special measuring campaigns organized jointly by the Institute of Radio Astronomy, National Academy of Sciences of Ukraine (IRA NASU), and EISCAT Scientific Association were held on 29-31 October 2013 and 17-18 November 2014. During the campaigns the EISCAT heating facility and UHF incoherent scatter radar, as well as IRA NASU coherent HF receiving systems located in Tromsø, Svalbard (Norway), and at the S.Ya. Braude's Radio Astronomy observatory and Low-frequency observatory of IRA NASU (Kharkov region, Ukraine) were used. At the time of experiments the carrier frequency of the pump wave was constant and equal 3989942 Hz. One transmitter of the heater radiated the probe pulse signal with power of about 100 kW at carrier frequency Hz. The level and frequency of the probe signal during the measurement remained constant.

October 31, 2013



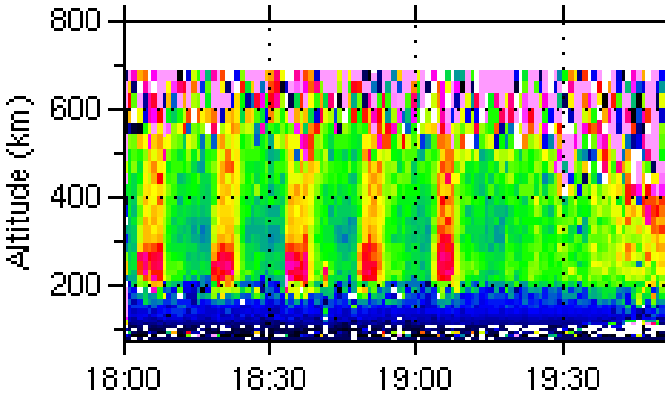


Figure. Variations of the 2nd harmonic and probe signal levels in Tromso, and electron temperature variations according to UHF EISCAT IS radar 31 October 2013.

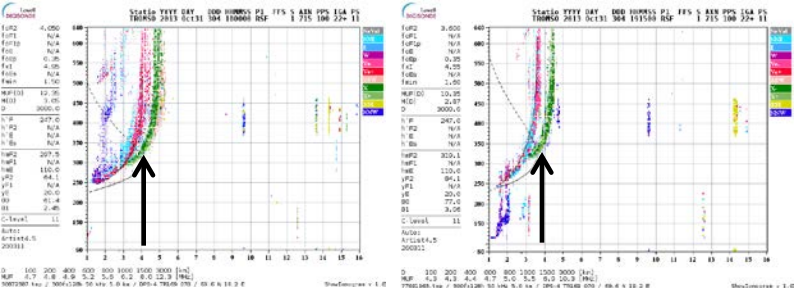


Figure. The ionograms registered at Tromso 31 October 2013 at 18:00 (a) and 19:00 (b)

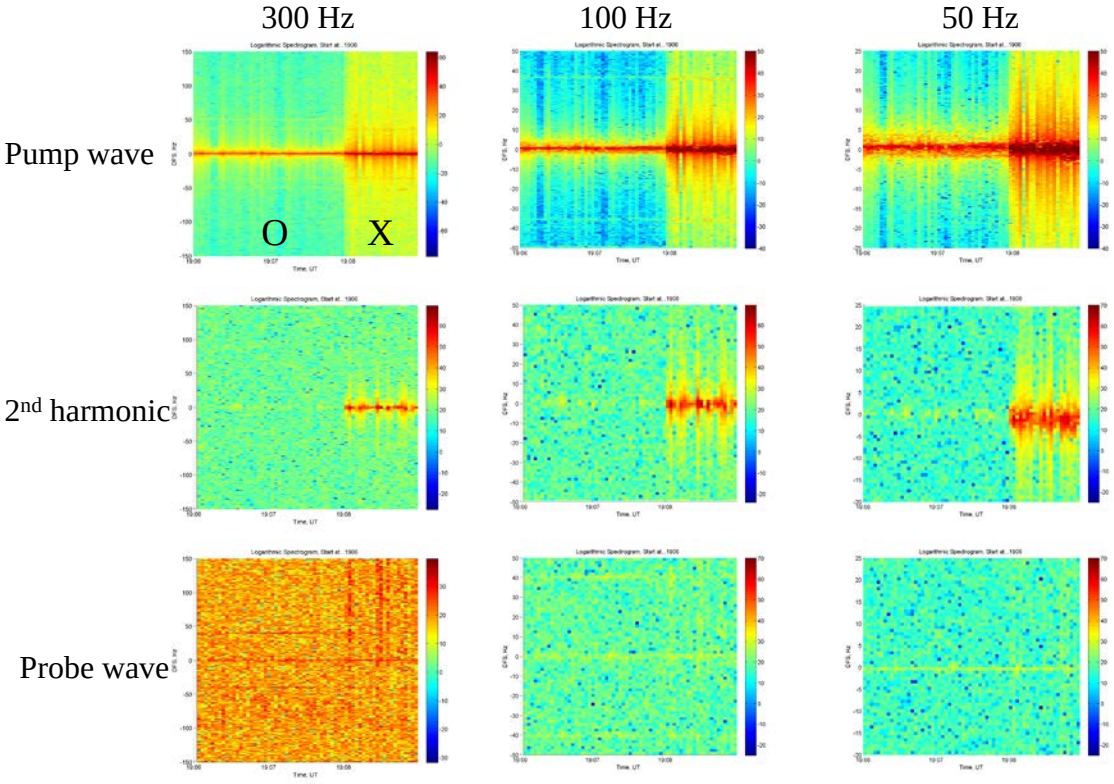


Figure. The spectrograms of pump wave, signal at the 2nd harmonics of heating, and probe signal that were received October 31, 2013 19:06-19:09 UT at Tromso receiving site in frequency bands of 300 Hz, 100 Hz, and 50 Hz, correspondently.

The strong dependence of the 2nd harmonic signal parameters on the conditions of the interaction between pump wave and ionospheric plasma, as well as the absence of its correlation with the parameters of the probe signal indicate that the signal at the 2nd harmonic of pump wave is generated in the ionosphere.

November 17, 2014

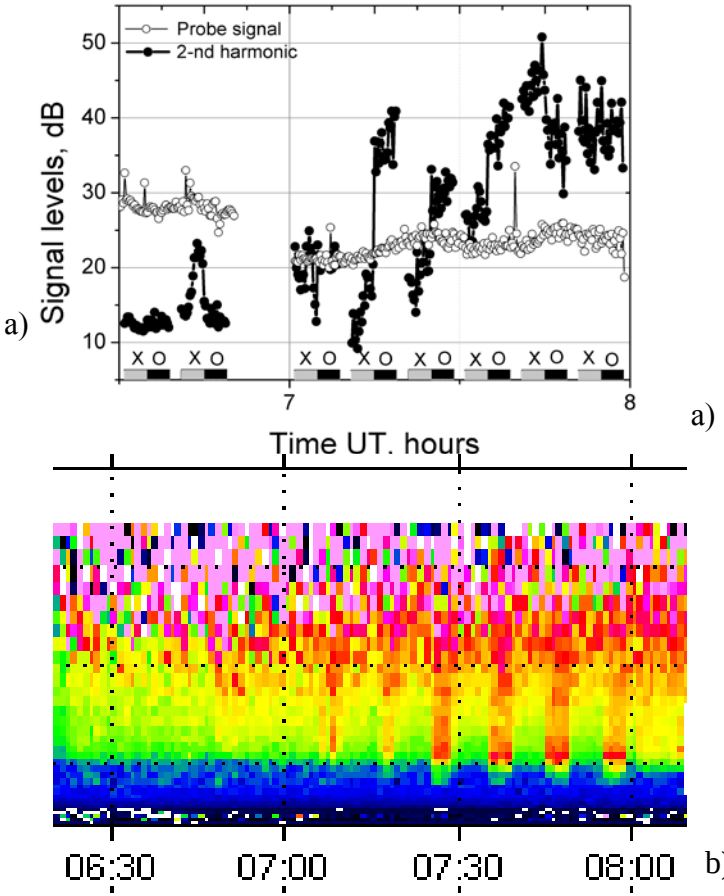


Figure. Variations of the 2nd harmonic and probe signal levels in Tromso (a), and electron temperature according UHF EISCAT radar (b) on 17 November 2014.

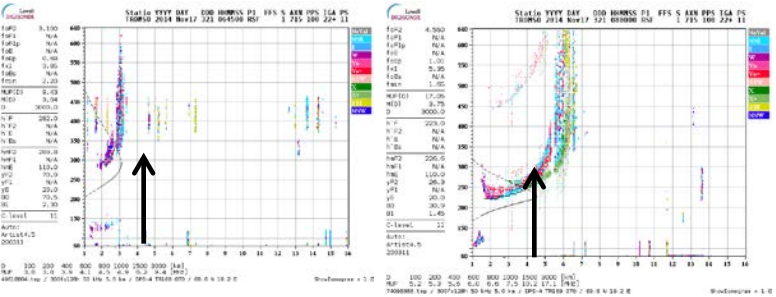


Figure. The ionograms registered at Tromso on November 17, 2014 at 6:45 UT, and 8:00 UT

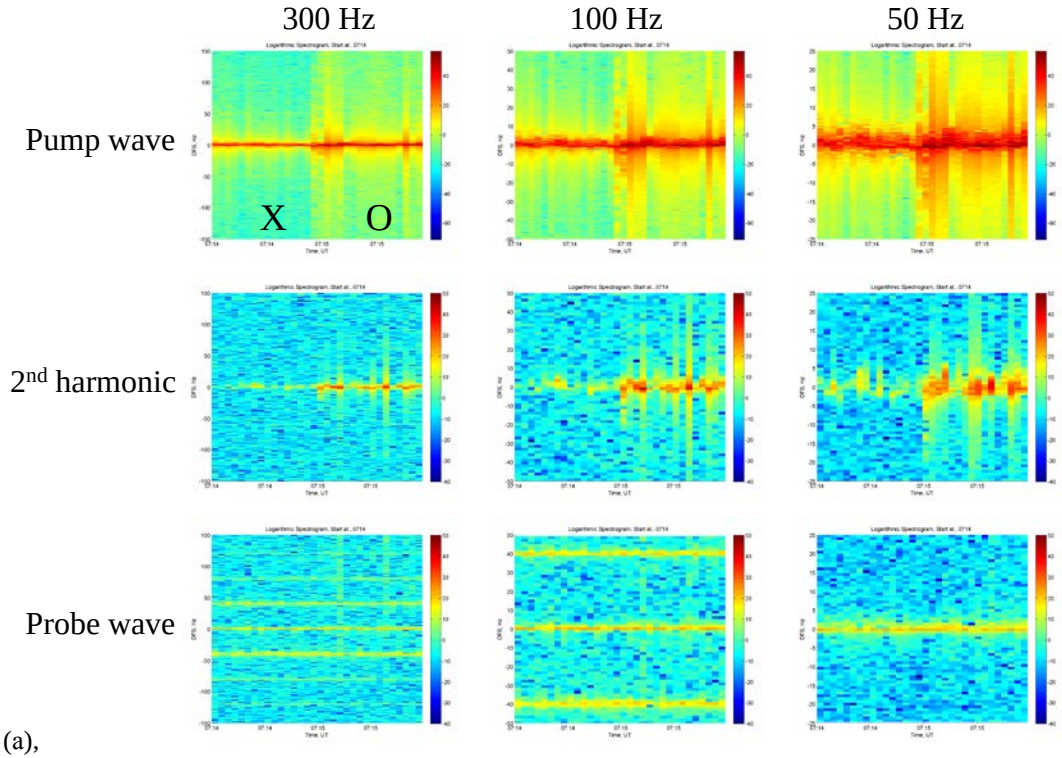


Figure. The spectrograms of pump wave, signal at the 2nd harmonics of heating, and probe signal that were received November 17, 2014 07:14-07:16 UT at Tromso receiving site in frequency bands of 300 Hz, 100 Hz, and 50 Hz correspondently.

Conclusions

Generation of electromagnetic wave at frequency of the second harmonic appearing because of interaction of powerful electromagnetic radiation of heating facility with the ionospheric plasma has been discovered. The 2^{nd} harmonic signal has been detected only in close vicinity of the heater. It was absent at the receiving sites located at a distance 1000 km and more from the heater. The 2^{nd} harmonic emission is observed during both O- and X-mode heating. The effect is stronger on the polarization for which the better conditions of reflection from the ionosphere are realized. Hence, the 2^{nd} harmonic signal that recorded at the Earth surface is excited with participation of pump wave specularly reflected from the ionosphere.

THANK YOU!