Diagnostics of ionospheric turbulence by pulse wideband signals

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New results on diagnostics of HF-pumped ionosphere by means of powerful ($\sim$ 20 MW ERP) and short ($\tau \lesssim 200$ μs) pulses are presented. The pulse duration τ was chosen to be less than a period of multiple ionospheric reflections ~ 2 ms. Specially elaborated algorithms of signal processing allowed to analyze amplitude and phase evolution of different spectral components of recorded signal in a bandwidth of order of 200 kHz. Experiments were handled at the "Sura" facility (Russia) in 2004–2005. One or two Sura transmitters with 20–80 MW ERP radiated the pump wave at a frequency f_0 including a range far from and close to forth electron gyroharmonic $4f_{ce} \sim 5390$–5440 kHz. The third transmitter at a frequency $f_d \approx f_0 \pm (0$–$1150)$ kHz was used for ionosphere sounding by diagnostic pulses with $\tau = 20$–200 μs and an interpulse period $T = 20$–40 ms. Stable 5 MHz generator was used to synchronize the transmitter and receiver equipment. The signal spectral components shifted by 1 kHz were processed using digital mixer and narrow Bessel 10 Hz filter in Labview and Matlab environments.

As a rule, a positive values of the doppler frequency shift Δf for different spectral components were observed during the pumping. This corresponded to an increase of plasma density and can be related to an additional ionization and/or temperature dependence of recombination coefficient under diurnal conditions and heights below 220 km. Besides, a fine structure of the turbulence region, corresponding to abrupt changes of Δf as dependent on time and frequency were observed. A dependence of the anomalous absorption of different spectral components on the pump power, on a displacement from the center of the perturbed volume, and on the closeness of a component to the 4-th gyroharmonic were also obtained.

In case of well developed striations the short pulses excite upper hybrid plasma waves at $f \sim f_d$, and, therefore, stimulated electromagnetic emission (SEE). The SEE spectrum around f_d after the pulse trailing edge lasts much longer than τ and allows to study SEE spectrum (and, therefore, the upper hybrid wave spectrum) in a whole bandwidth, without interference of the diagnostic wave at $f = f_d$. Such a diagnostics has shown that SEE spectral maximum is observed to be downshifted from f_d by 2–4 kHz at the development stage of striations, and up to 4–6 kHz at their relaxation stage. Typical SEE e-folding decay time after the trailing edge was found to be shorter that estimated collisional one for upper hybrid wave intensity (2–3 ms). Notice. that the use of the short pulses at different frequencies f_d allows to study features of HF-driven upper hybrid turbulence by SEE at different altitudes.

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