Fast Doppler Technique of Observations of Aspect Sensitive Signals Backscattered from the Ionosphere Heated by Powerful HF Radio Waves

***V.A.Puchkov*[1], *A.V.Branitsky*[2], *V.Yu.Kim*[3], *V.A.Panchenko*[4], *and V.P.Polimatidi*[5]**

[1]Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Waves Propagation of the Russian Academy of Sciences, IZMIRAN, Troitsk, Moscow region,142190, Russia (puchkovint@mail.ru)

[2]As (1) above (branitsk@mail.ru)

[3] As (1) above (vkim@izmiran.ru)

[4] As (1) above (panch@izmiran.ru)

[5] As (1) above (vppolima@izmiran.ru)

Abstract

Fast Doppler measurements technique of observation of small-scale, magnetic field aligned inhomogeneities produced in the Ionosphere by powerful HF radio waves is developed. This technique is based on evaluation of "momentary" Doppler shift of received signal frequency with the help of phase measurements in individual pulse responses. Observations of backscattered aspect sensitive signals show that individual modes in multi mode signals have different dynamics at the time intervals less than 1 second.

1. Introduction

The Doppler technique is a very informative tool used in investigations of various kinds of non-stationary processes in the Ionosphere. One of the most important point of Doppler measurements is the problem of spectral and temporal resolution. This problem becomes especially important when we investigate artificial perturbations produced in the Ionosphere by powerful HF radio waves, as in this case both high temporal and frequency resolution is required due to fast dynamics of non-linear processes. In the Doppler techniques based on fast Fourier Transform (FFT) of received signal the frequency resolution is in inverse proportion to the time resolution. For example, measurements of Doppler frequency shift within the accuracy of 0.1 Hz require 10 s integration interval. In this paper we propose a new technique that affords sufficiently high frequency resolution (~ 0.1 – 0.2 Hz) at time intervals sufficiently less than 1s. This technique is applied to observations of aspect sensitive signals backscattered from small-scale, magnetic field aligned artificial density irregularities.

2. Results

In our experiments we used repeated pulses of probe waves illuminating the region of the Ionosphere modified by the Sura heating facility (Nizhniy Novgorod, Russia). The probe pulses with the frequency 9.15 MHz and the repetition frequency F_R = 25 Hz were sent by HF diagnostic facility at IZMIRAN, near Moscow. The backscattered pulses were received by the same diagnostic facility. The full waveforms of the received signal and direct probe wave were recorded, and the phase shift of the waves in each pulse was evaluated by finding the intersection points of the waveform with zero axis. Comparing phase shifts of the signals in neighboring pulses we could evaluate the phase change $\Delta\varphi_S$ at the time interval $T_R = 1/F_R$ equal to repetition period of the pulses. The same procedure for the direct wave gives the phase shift $\Delta\varphi_D$ which is independent of the ionospheric motions and should be subtracted from $\Delta\varphi_S$. Therefore the resulting Doppler shift f_D will be given by the equation $f_D = (\Delta\varphi_S - \Delta\varphi_D) / 2\pi T_R$. In the conditions of our experiments the accuracy of phase measurements was 4,5°, the time resolution (equal to T_R) was 0.04 s, and the Doppler shift accuracy was 0.25 Hz.

Analysis of the experimental data shows that waveforms of backscattered signals have some fine structure reflecting fast dynamics of artificial inhomogeneities. The received signals consist of several (normally 3 - 5) modes or pulses. The lifetime of these pulses is of the order of 1 s, and within this period of time we can see evolution of the pulses including their interaction and their individual Doppler shift. The Doppler shift of the frequency inside these pulses can be a combination of ambient Doppler shift caused by large scale plasma motions and fast changing Doppler shift reflecting evolution of inhomogeneities. In the report possible dependence between inhomogeneities dynamics and the received waveform properties is discussed.

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