Dynamic and Spectral Features of the Decameter Artificial Irregularities and the Stimulated Electromagnetic Emission over the ”Sura” Heating Facility near the Fourth Electron Gyroharmonic

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***Abstract*—The results of simultaneous studies of the dynamic and spectral characteristics of radio signals scattered off the decameter artificial striations with transverse scales $l_\perp \sim 10$-100 m to the geomagnetic field and the stimulated electromagnetic emission by a powerful action on the ionospheric plasma in the fourth harmonic region of the electron gyrofrequency on the Sura facility are presented.**

***Index Terms*—powerful radio waves, artificial turbulence of ionospheric plasma, stimulated electromagnetic emission, radio wave back scattering, electron gyroharmonics**

I. Introduction

Since the beginning of experiments on powerful modification on ionosphere plasma, methods for its remote sounding have been widely used to diagnose the properties of excited plasma turbulence. The paper presents the results of the integrated use of radio wave back scattering off the artifiial small-scale irregularities and measurements of the stimulated electromagnetic emission from the ionosphere to study the processes of the excitation of the irregularities of the decameter scales under modification of the ionosphere plasma by powerful pump wave in the vicinity of the fourth electron gyroharmonic frequency $4f_c$.

II. Problem Statement and Measurement Technique

Simultaneous studies of the dynamic and spectral characteristics of artificial decameter irregularities in the range of transverse to the geomagnetic field scales $l_\perp \sim 10$-100 m and the stimulated electromagnetic emission (SEE) with a powerful modification of the ionospheric plasma in the frequency range $f_0 \sim 4f_c$ were first performed on June 20-21, 2011 on Sura heating facility (Vasil'sursk, the SEE measurements). The measurement of the back scattering of radio waves were performed in the Signal laboratory of the Southern Federal University (UFU, Rostov-on-Don, ∼1100 km from the Sura, the frequency range of 10-15 MHz) and Zelenodolsk Ionosphere Observatory of the Kazan Federal University (KFU, Kazan, ∼170 km from the Sura, the frequency range of 2-7 MHz).

The measurement program consisted of day (14:30-16:30 LT) and night (22:00-24:00 LT) observation cycles. The duration of heating during the day was 2 minutes, at night, 1-1.5 minutes with a period of 5 minutes. Additionally, during a pause of heating, diagnostic pulses with a duration of 20 ms (100 mks in the last hour of observations) with a period of 1 s (or 100 ms in the last hour of observations) were emitted. From session to session, the heating frequency changed by 20 kHz in the frequency range of the pump wave: $f0 = 5440$-5520 kHz (20.06 day, $4f_c = 5440$ kHz), $f_0 = 5400$-5480 kHz (21.06 day, $4f_c = 5440$ kHz), $f_0 = 5320$-5400 kHz (20.06 night, $4f_c = 5315$-5330 kHz) and $f_0 = 5310$-5390 kHz (21.06 night, $4f_c = 5320$ kHz). The effective transmitter power for O-mode radiation to zenith was $P_{eff} \sim 60$-120 MW. The SEE measurement by the suppression of the Downshifted Maximum, DM, at $f_0 = 4f_c$ and the appearance of Broad Upshifted Maximum, BUM, in the emission spectrum at $f_0 > 4f_c$ [1] allowed to determine the position of the pump wave frequency relative to the fourth gyroharmonic $4f_c$, the dynamics of the diagnostic SEE after turning off the heating was compared with the relaxation dynamics signals.

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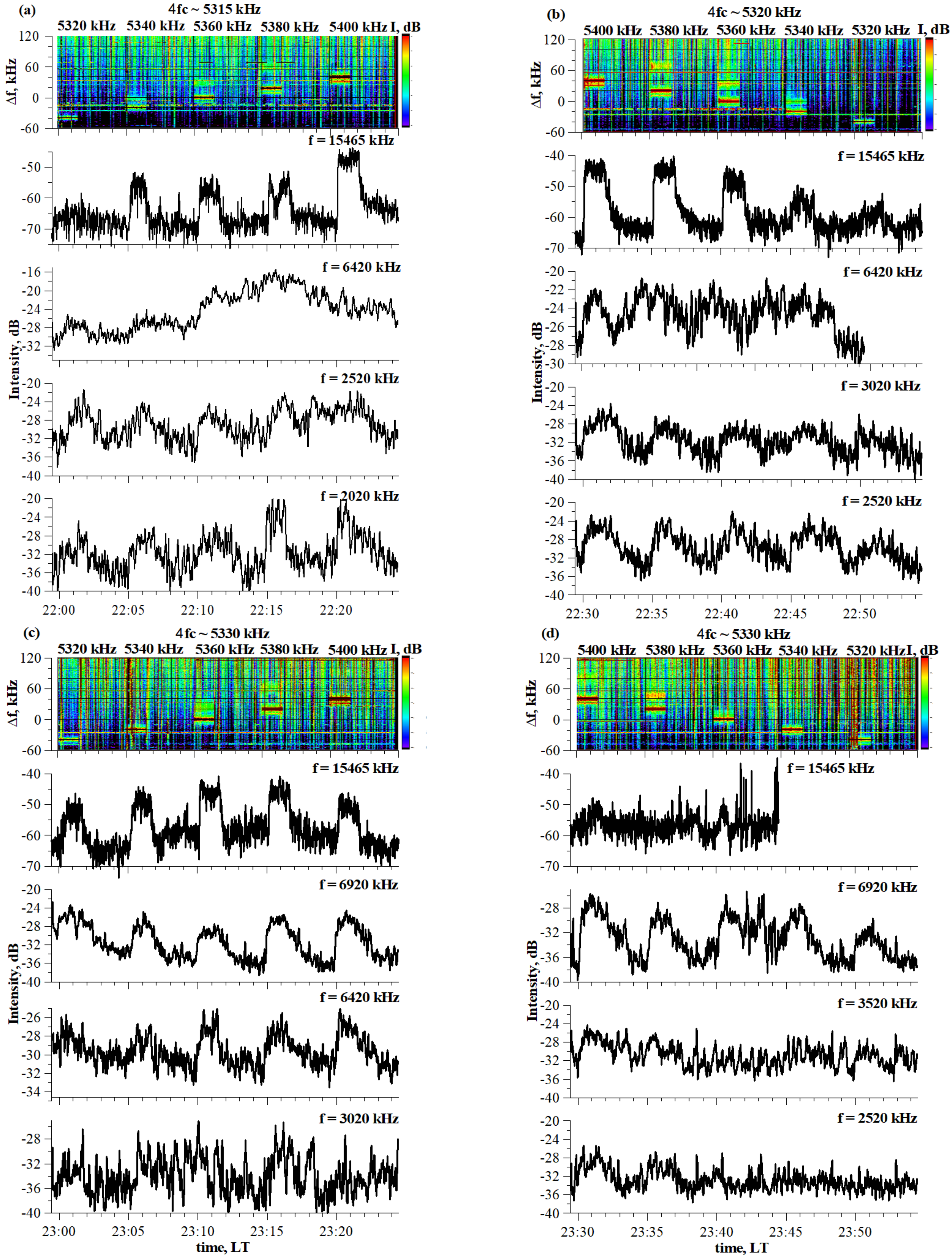

Fig. 1. The SEE spectrograms (color panels, f_0 above the panels) and the scattered signal from the disturbed region on the frequency grid corresponding to scattering on decameter irregularities with $l_\perp \sim$ 10-100 m for four half-hour measurement cycles (a-d). $4f_c \sim$ 5315-5330 kHz. 20.06.2011, 22:00-24:00 LT.

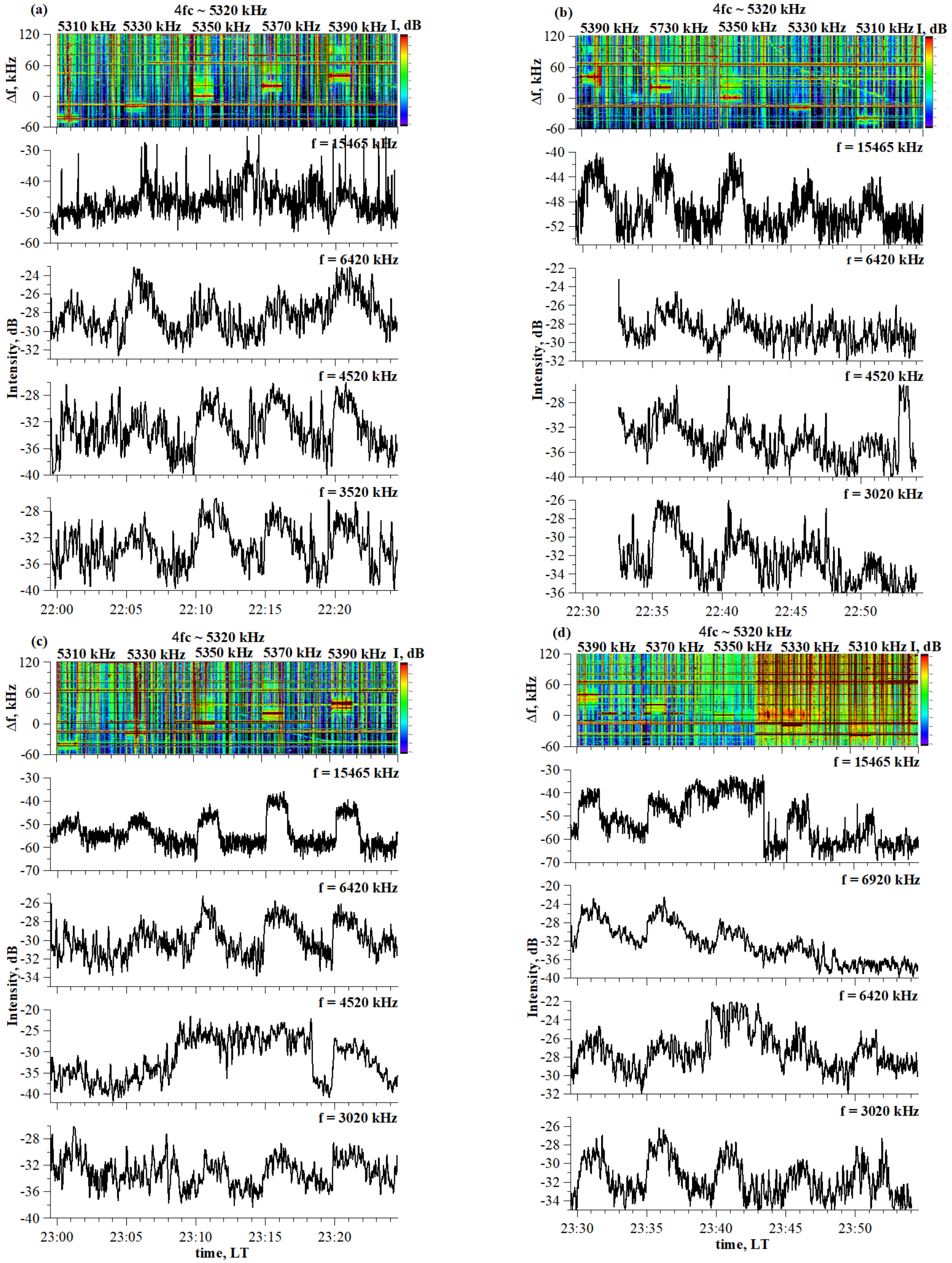

Fig. 2. The SEE spectrograms (color panels, f_0 above the panels) and the scattered signal from the disturbed region on the frequency grid corresponding to scattering on decameter irregularities with $l_\perp \sim$ 10-100 m for four half-hour measurement cycles (a-d). $4f_c \sim$ 5320 kHz. 21.06.2011, 22:00-24:00 LT.

Similar signals were observed at frequencies of $f = 9996$, 14996 and 15465 kHz (radio stations in the Moscow region) in the SFU, responding to the scattering scales of $l_\perp \sim 10$ m, and the grid of the frequencies $f = 2020$, 2520, 3020, 3520, 4020, 4520, 5360, 5920, 6420 and 6920 kHz on the Cyclon ionosonde in the KFU, corresponding to the scattering scales $l_\perp \sim 40$-120 m. If studies of the scattering dynamics for scales $l_\perp \sim 40$ m near the gyroharmonics were carried out earlier [2], [3], for larger decameter scales such measurements held for the first time.

III. The Experimental Results

For daytime hours of experiments, scattered signals were observed only at SFU site for maximum sounding frequencies. Only singe scattering sessions were recorded for $f = 6920$ kHz in KFU site when the pump wave frequencies were above the 4th gyroharmonic.

Figures 1-2 present the measurement data of the SEE and probing waves at night of June, 20-21, 2011. The values of $\Delta f = f - f_0$ for the top panels of the SEE spectrograms correspond to $f_0 = 5360$ kHz for 20.06.2011 and $f_0 = 5350$ kHz for 21.06.2011. In nighttime measurements, the scattered signal was almost always observed for the entire grid of recorded sounding frequencies, had maximum values at the maximum positive offset of the pump wave frequency from the gyroharmonic frequency $f_0 - 4f_c \sim$ 60-80 kHz, and significantly decreased in intensity (up to 20 dB for $l_\perp \sim 10$ m and up to 5-10 dB for $l_\perp \sim 100$ m) with the passing of the pump wave frequency through the gyroharmonic frequency and below it. In general, these results are consistent with the data of [3]. In the measurements, an increase in the e-folding decay times of the largest decameter irregularities and of the diagnostic SEE was observed from 10-15 s in the afternoon to 2-2.5 min at night, previously observed in experiments [4], [5].

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