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Reading of the Jovian decametric radio-storm

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Abstract

Based on the 2D-correlation analysis of synthetic and real dynamic spectra of Jovian narrowband emissions at decametric wavelengths, the methods are created for a measurement of the dispersion of radio emission and an estimate of the parameters of Alfvén wave in the jovian low magnetosphere. We apply these methods to extract the valuable data from the tangled pattern of highly sporadic emissions in the dynamic spectrum of August 2, 2002.

1. Introduction

It has been shown in our previous paper [1] that the main phenomenology of Jovian decametric radio bursts at timescales between 0.03 s and 0.3 s (S/NB-emissions) can be reduced to three main ingredients which are: the dispersion delay of the radio emission; the motion of the radio source (a clump of emitting electrons) in the parallel electric field of a standing Alfvén wave, and the shadow effect. We used these components to calculate the synthetic dynamic spectra of S/NB-bursts. Usually, we used only one radio source in our models. However, the case of several radio sources seems an interesting but unstudied possibility.
The purpose of the new study is the reproduction of all details of the zebra-pattern in the 2D-correlation plot (Fig. 1) using several radio sources in our dynamical model. We compare the model result with experimental data and use this comparison to extract the physical information from the highly tangled dynamic spectra of DAM.

2. The parameter set

To calculate the synthetic dynamic spectrum of S/NB-bursts, we numerically integrate the equation of motion of the electron clump (the radio source) along the magnetic field in the parallel electric field of the standing Alfvén wave, which has been

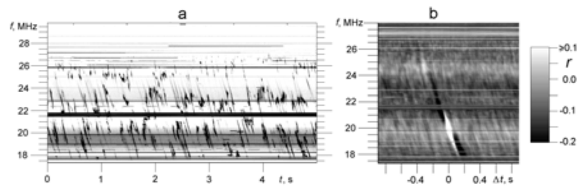

Figure 1: The regular 2D-correlation pattern with a zebra is revealed in the chaotic S-storm: **a)** the fragment of analyzed dynamic spectrum (2002 August 2, 9:30 UT; UTR-2 radio telescope); **b)** the raw pattern of linear correlation coefficient $r(f, \Delta t)$ between spectral intensity in the current (f) and the reference (f_o=20 MHz) frequency channels with Δt time shift.

derived in our previous paper [1]:

$$V(t_i, f_i) = -A_v \sin[(2\pi/P)t_i+\varphi] \cos[(2\pi/\lambda_f)(f_i - f_o)] + \delta V(t_i), \quad (1)$$

where $V(t_i, f_i)$ is the frequency drift rate of the source which is a function of the time t and frequency f; the index i is the number of a step of numerical tracking of the source trajectory; A_v is the amplitude of the drift rate in the long-wave approximation; P is the time period of the Alfvén wave; λ_f is the Alfvén wavelength in the frequency scale; f_o is the electron gyrofrequency in the reference antinode of the Alfvén wave. To simulate the excitation of an ionosphere/magnetosphere resonator with accidental wave impulses, the phase φ is included. This phase is constant during the period P_φ, but φ jumps to another random value for the next cycle. Another noise term δV_i simulates the electrostatic disturbances and/or running Alfvén waves. Additionally, the parameter D_d is the frequency drift of the spectral features rate due to the dispersion of radio emission. The parameter D_m is the frequency drift rate of the shadows (the regions of damped radiation; [2]) in the dynamic spectrum.

3. Manifestations and estimates

Figure 2a shows the typical synthetic spectrum in our simulations which resembles the real S-bursts.

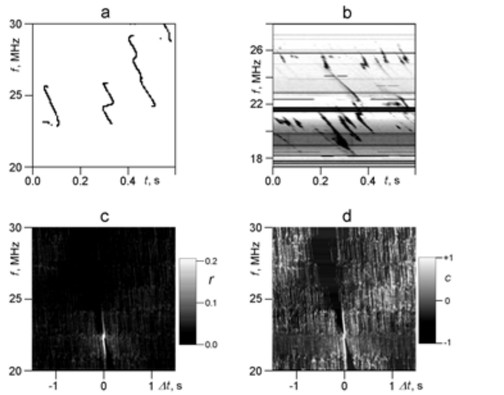

Figure 2: The modeling with a single radio source: **a)** the fragment of calculated synthetic spectrum; **b)** the real dynamic spectrum; **c)** the *r*-pattern; **d)** its visualization with $C(f, \Delta t) = [Y(f, \Delta t) - \langle Y \rangle_f]/(3\sigma_f)$, where: $Y(f,\Delta t) = \lg[r(f,\Delta t)+1]$; $\langle Y \rangle_f$ and σ_f are the average value and its standard deviation for each frequency channel.

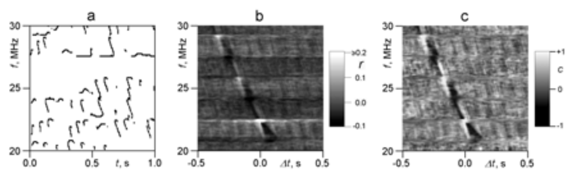

Figure 3: The modeling with 5 radio sources: **a)** the fragment of calculated synthetic spectrum; **b)** the *r*-pattern like in Fig. 1b (f_o = 22.4 MHz); **c)** the *C*-visualization.

However, one can see that the zebra pattern, visible in Fig. 1b, is absent in the single source model (Fig. 2c,d) although λ_f=3.3 MHz.

The zebra pattern is reproduced only with a model of several radio sources that do not affect each other's shadow (Fig. 3). Although these radio sources move in the common parallel electric field of the same standing Alfvén wave, but the noise perturbation (δV) is individual for every source.

The successful modeling allows us to understand how the model parameters could be extracted from the two-dimensional correlation pattern. For example, Fig. 4 shows the manifestations of some model parameters in the correlation pattern of the synthetic spectrum from Fig. 3. The measured frequency bands and drift rates (arrowed in Fig. 4) practically coincide with the parameter set of our model.

Hence, applying the proposed methods to the real

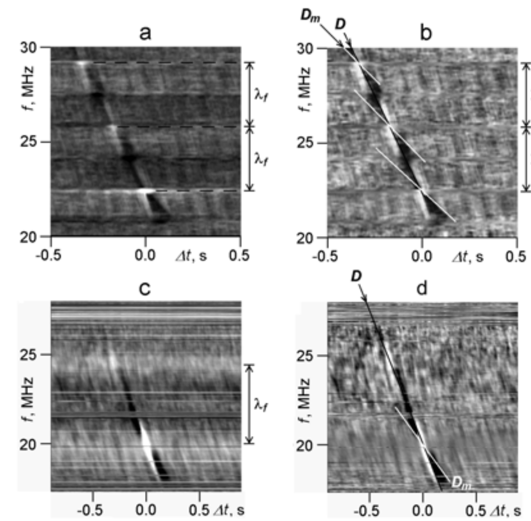

Figure 4: Extraction of some of model parameters from the 2D-correlation patterns of the synthetic (**a**, **b**) and real (**c**, **d**) dynamic spectra of jovian S/NB-emissions. Left and right plots depict *r* and *C* patterns respectively.

patterns, e.g., in Fig. 4c-d, we estimate the main parameter set for the real dynamic spectrum (Fig. 1): λ_f =4.45 ±0.2 MHz; D = –15.0 ±0.6 MHz/s; D_m = –8.2 ±1.3 MHz/s; $P_\varphi \approx P$=0.12±0.02 s; A_v~92±14 MHz/s. Obtained values are not far from the model.

6. Summary and Conclusions

1. The zebra in Fig. 1b is a clear 'fingerprint' of standing Alfvén wave. Therefore, the proposed technique can be used in studies of Alfvén resonances in the low magnetosphere of Jupiter.

2. For the first time, the dispersion and the dynamic effects were separated in the S-burst storm. As $A_v \sim D$, the dispersion must be taken into account in estimating the typical energy of emitting electrons which control the source drift rate.

References

[1] Arkhypov, O. V., Rucker, H. O.: Dynamics of decametric radio-sources and standing Alfvén waves in jovian magnetosphere. Icarus. Vol. 212, pp. 714–718, 2011.

[2] Arkhypov, O. V., Rucker, H. O.: Shadows in S/NB-events of jovian decametric emission. Icarus. Vol. 211, pp. 603-608, 2011.