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Features of the Jovian DAM radiation dynamic spectra as observed by modern receivers with high frequency-temporal resolution

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Abstract

One of the promising approaches to investigating features of the Jovian decameter radio emission (DAM) is application of novel experimental techniques with a further detailed analysis of the obtained data using both well-known and modern mathematical methods. Several observational campaigns were performed in November 2009 with the use of the UTR-2 radio telescope (Kharkov, Ukraine) and efficient registration systems with high frequency and temporal resolutions (the antenna effective area is about 10^5 m^2, the frequency resolution is 4 kHz, the temporal resolution is 0.25 ms, and the dynamic range is 70 dB) [1]. The main goal of these campaigns was to experimentally investigate new properties of the Jovian DAM emission which could be detected using the above mentioned equipment. Also an original software package was developed for control the digital receiver and for off-line data analysis at the post-processing stage.

1. Introduction

Researches into physical processes that take place in space objects are largely based on analysis and interpretation of dynamic spectra of the object electromagnetic radiation measured from ground-based stations and satellites. The Jupiter decameter emission (DAM) represents an extraordinary astrophysical phenomenon which is characterized by an unusual complexity of the frequency-temporal structure of its dynamic spectra. It should be noted that since of its discovering in 1955 many problems in the theory of the Jovian decameter emission have been successfully investigated and solved [2, and references therein]. Nevertheless, a great number of physical features of this phenomenon still remain unclear. The present paper is devoted to a preliminary analysis of the specific properties of the Jupiter DAM emission which appear in dynamic spectra within the frequency range from units to tens of kHz and on the temporal scales of order microseconds.

1.1 Instrumentation

An enormous amount of wide-band data about the radiation from different Io-dependent sources has been obtained using a high frequency and temporal resolution digital receiver (DSP) [3] installed into the world's largest decameter band radio telescope UTR-2 [1]. The DSP is a fully digital baseband device which satisfies all modern requirements for investigation of the Jovian decameter emission and provides the ultimate spectral analysis capability by allowing digital signal processing in real time. The receiver has two input channels and can operate in two main modes: as a spectrum analyser and as a waveform recorder. In the spectrum analyser mode it can perform a Fourier transformation of the real signal in the continuous frequency band up to 70 MHz in two independent data streams (summing and subtracting channels, ON/OFF regimes). In the waveform mode the device is capable of recording the signal waveforms, i.e., "catching" the ADC's output signals (analogue-to-digital converter).

1.2. Data processing algorithm

As was mentioned above an original software package consisting of two parts was developed to control the digital receiver and for off-line data analysis at the post-processing stage. The first part of the software package is the real-time software WRSA (Waveform Receiver and Spectral Analyzer). This controls the receiver parameters, the data acquisition process, and on-the-fly data displaying. The WRSA performs automatic adjustment of the digitally controlled analogue filter bank and attenuators to the ADCs which contributes to an effective solution of the RFI mitigation task, which is the critical point for astronomical observation in the decameter waveband. The second part of the software package which is named AESA (Astronomical Enhanced Spectral Analyzer) is designed for the post-processing of the recorded data. The main goal of this software is the construction and optimal visualization of the Jovian radiation dynamic spectra. The software provides flexible control for a number of dynamic spectra visualization parameters.

2. Some observational results

It is clear that with changing the scale over time and frequency we will find new effects in the dynamic spectra of the Jovian decameter emission.

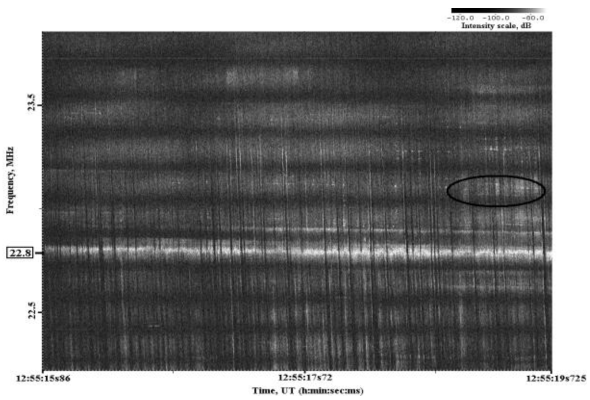

Figure 1: Dynamic spectrum of Io-B emission demonstrating the different unusual effects.

Figure 1 shows an example of the Jovian DAM radiation dynamic spectra, which was obtained for the Io-B source on November 27, 2009 using the high performance equipment described in the previous section (waveform regime, Fourier analysis). The spectrum is presented for the time interval 3.95 sec and frequency range about 1.5 MHz. It should be specially emphasized that due to the new quality level of the receiving facilities the recorded spectra demonstrate such features which were invisible in the DAM emission before the new instrumentation has been used. For instance, in Figure 1 one can see at least three unusual effects which have still not been considered in detail. These are i) quasi-harmonic variations in the power of the narrow-band signal at separated frequencies (see radiation at 22.8 MHz frequency in Figure 1); ii) sequence of alternating increases and decreases in the intensity of wideband short-time bursts; and iii) a structure of thin horizontal lanes (see fragment in Figure 1 marked by oval). In addition, it is clear seen in the Figure 1 that the narrow-band emission is modulated by the absorption bursts.

3. Summary and Conclusions

Application of the world’s largest radio telescope and novel receiving equipment with high time-and-frequency resolution has allowed identifying a lot of new specific details of such well known phenomenon as the Jupiter decameter radiation. The used technique could be useful for clarifying the Jovian DAM radiation fine structure and determining physics of Jupiter radio emission. Undoubtedly, theoretical and experimental investigations of Jovian decameter emission phenomena are necessary and should be continued. On the next stage of the DAM radiation investigation it is planned to process the recorded waveform data using the wavelet transform analysis to provide a nanosecond temporal resolution of the signals.

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