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Study of Saturn electrostatic discharges with high time resolution

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Abstract

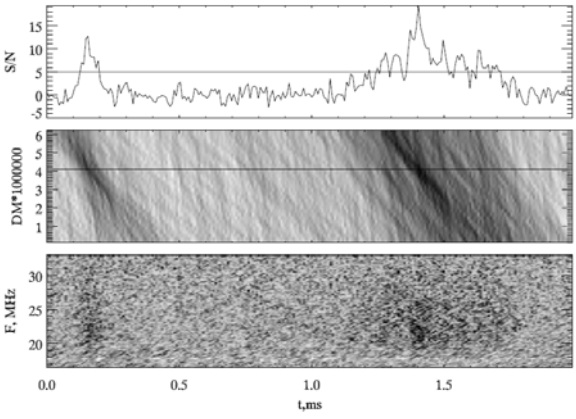
Ground-based observations of SED (Saturn Electrostatic Discharges) with high time resolution are the next stage of extraterrestrial atmospheric processes study. Due to extremely high intensity of Saturn's storm J (2010) [1] we have obtained the records with high signal-to-noise (S/N) ratio with the time resolution of 15 ns. It permitted us to investigate the microsecond structure of lightning and clearly distinguish SED in the presence of local interference in virtue of a dispersive delay of extraterrestrial planetary signals.

1. Introduction

High time resolution study of SEDs can be achieved by means of coordinated observations of the Cassini spacecraft and the ground-based decameter radio telescope with highly sensitive receiving equipment such as UTR-2 [2,3,4,5].
This is confirmed by the reliable ground-based detection of Saturn's lightning despite strong terrestrial interference. First high time resolution SED records were obtained in the frequency range 18-21 MHz during the storm F (2007) [6] by means of broadband receiver [7]. In those records the microbursts with duration of several hundreds of microseconds were found. But the sensitivity that is proportional to $(\Delta f \cdot \tau)^{-1}$, with frequency range $\Delta f \approx 3$ MHz, allows to obtain a sufficient S/N ratio (≈ 10) only in the case of time resolution $\tau \sim 20...40$ us.
More significant results were obtained during the next observation (storm J [1], December 2010). It was provided by modernization of equipment [3], allowing to perform synchronous recording by several receivers [8] in different modes of operation. The observations were taken by three receivers: two in the spectral mode (for ON and OFF beams) with $\tau \approx 20$ ms and one in the waveform mode (ON beam, $\tau \approx 15$ ns, $\Delta f = 33$ MHz). Fast visual analysis revealed the portion of records that contains SED. In order to save the disc space only the informative part of the recorded waveform data was kept for further analysis.

2. Results

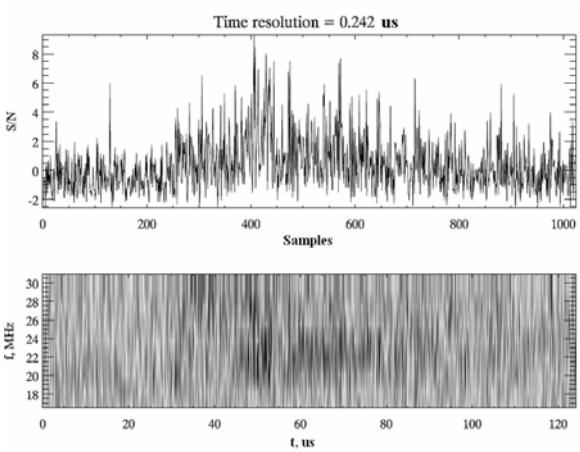
The obtained records with a time resolution of 15 ns and a bandwidth of 33 MHz permitted for the first time to observe the dispersion delay of the SED signal on the way to Earth. [9] The estimated delay between the frequencies of 33 and 15 MHz (below this frequency terrestrial ionosphere blocks the SED signals) is few hundreds of microseconds. This corresponds to the dispersion measure (DM) ≈ $(2…5)\cdot10^{-5}$ pc·cm^{-3}. Fig. 1 shows microbursts within one lightning with $\tau \approx 8$ us.



The bottom panel shows dynamic spectrum of two microbursts after the compensation of dispersion delay. The middle panel illustrates the results of dispersion measure search. The point where total (integrated by frequency) signal has the maximum S/N ratio corresponds to the true value of DM. The total signal is presented on the upper panel. Our

search algorithm selects the samples with S/N exceeding 5 standard deviations. The selected microbursts are recorded in the database for further processing.

Fig. 2 shows the results of analysis of the most powerful events. The time resolution on the spectrogram after coherent dedispertion [10] was chosen as 242 ns.



In the records there are peaks occupying just 1...3 samples. However, the average duration of the microburst is a few tens of microseconds.

3. Conclusions

The obtained results (the duration and intensity of the microbursts) will allow us to make a significant progress in the investigations of physical processes in Saturn's atmosphere. A huge amount of data is now being processed on this subject.

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