HF ANALYSER FOR THE TARANIS SATELLITE

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ABSTRACT

We present a preliminary design of the High Frequency (HF) analyzer for the French satellite TARANIS (Tool for the Analysis of RAdiations from lightNIngs and Sprites) scheduled for the launch in 2011. This satellite will study high altitude electric discharges above thunderstorms and their associated electromagnetic emissions. Besides the Transient Luminous Events (TLEs) in optical range like sprites a special interest will be paid to terrestrial gamma ray flashes (TGFs) or X-ray flashes and production of energetic electrons. The main scientific objective of the HF analyzer is recording of the electromagnetic radiation generated during these phenomena. Because of the limited telemetry volume (~ 40 kb/s) and high sampling frequency (80 MHz) the main challenge in designing the HF analyser is a correct onboard detection of an event of interest. Such a correct detection lies in the selection of proper time interval which should be stored into the onboard memory and transmitted to the ground, thus effectively reducing the amount of input data.

1. INTRODUCTION

In the past years there has been a growing interest in the detection and understanding of phenomena occurring above thunderstorms (Rodger, 1999; Cummer, 2006; and references therein). The observations are performed from ground, aircrafts, balloons and space. The impact of these recently discovered dischargers on the chemistry of the high altitude atmosphere and global electrical circuit (Pasko, 2003; Rycroft et al., 2000) is still subject of intense investigation. These discharges can also be accompanied by terrestrial gamma ray flashes (TGFs) or X ray flashes and production of energetic electrons (Fishman et al., 1994; Inan et al., 1996). Although many authors (Gurevich et al., 2007 and references therein) try to explain how these high energy electromagnetic radiation can be produced by bremsstrahlung of relativistic electrons, the detailed generation mechanisms of these phenomena are still not well understood.

The observation of electromagnetic radiation in HF range from space can provide important information about the causative lightning properties, mainly in the case of intra-cloud discharges, which are difficult to detect optically (Light et al., 2001). Jacobson (2003) performed extensive recordings of electromagnetic emissions of lightning discharges on FORTE satellite and reported that the most emission arise from intracloud electrical breakdown, which is usually recognizable by a pulse followed by a delayed echo from the ground reflection. The interpulse separation within each pulse pair yields the discharge height above the reflective ground. There is a strong statistical increase of effective radiated power of intracloud discharges, for increasing capping height of the parent storm. Shao et al. (2005) used the HF frequency measurements on FORTE satellite to investigate the initiation of return stroke.

On French satellite TARANIS, to be launched 2011, there will be instruments for measurements of LF, MF, HF electromagnetic waves (covering all frequencies from 0 to 30 MHz), optical detectors and cameras, detectors of X and gamma-ray emission and energetic electrons, which are generated or associated with lightning discharges. In the following we present a preliminary design of HF Analyser and discuss its properties.

2. DESCRIPTION OF HF ANALYSER

The sensitivity of the HF receiver installed on the TARANIS satellite will be ~ 10 $nVm^{-1}Hz^{-1/2}$ at 10 MHz. The analyzed frequency band will be from 100 kHz to 30 MHz. A sampling frequency of 80 MHz, and 12 bit resolution will be used. Basically, there will be two modes of operation.

In the survey mode, only 40 kbit/s of telemetry will be available for the HF analyzer. Thus, a crucial point is a reliable detection and selection of interesting events. Because we are interested in a waveform of the selected events, only short time intervals, typically of 0.5ms will be transmitted to the ground receiving station for further analysis. Considering 80 MHz sampling of input signal (~30 MHz bandwidth) and 3.6 W limit of power consumption for the whole analyser, it is obvious that the selection algorithm could not require too much of computational power. We suppose that the selection will be mainly based on rough frequency filtering, amplitude detection of the signals passing these filters and checking whether the dispersive properties of the signal in frequency-time space correspond to the impulsive signal coming through the ionosphere. A combined analogue and digital data processing will be used to perform this task in real time. The functional scheme of the HF analyser is presented in Figure 1. After the amplification and anti-aliasing filtering, the signal is simultaneously fed from antenna to a fast 12bit/80MHz ADC converter and to a chain of passive analogue band-pass filters. The digitized 80 MHz signal is passed to a circular buffer memory with a capacity corresponding to ~33 ms. The parts of the signal which are passed through the filter bank are demodulated, separately in each frequency channel. Thus, we obtain information about the amplitude in each frequency band. These signals are sampled at much lower frequencies. We assume sampling at 200 kHz or 100 kHz. Such information, running at much lower data rate, is then processed and checked for changes and dispersion properties. If an event is recognised, the corresponding HF part is then transferred from the circular buffer into the Data memory. In this memory, it is stored until it is read out into the telemetry. It can also be overwritten with a newly detected event with higher mark. The marking will be based on the amplitude of the event and will be artificially lowered during the time; the new events with similar amplitudes will have higher priorities. Alternatively, we consider a histogram method for event selections. This is supposed to be based on the occurrence of different amplitudes in the input HF data stream.

Besides the selected parts of waveform, information of amplitude in frequency bands with time resolution of ~0.1s will also be continuously transmitted to the ground to obtain a map of global distribution of intensity of HF waves.

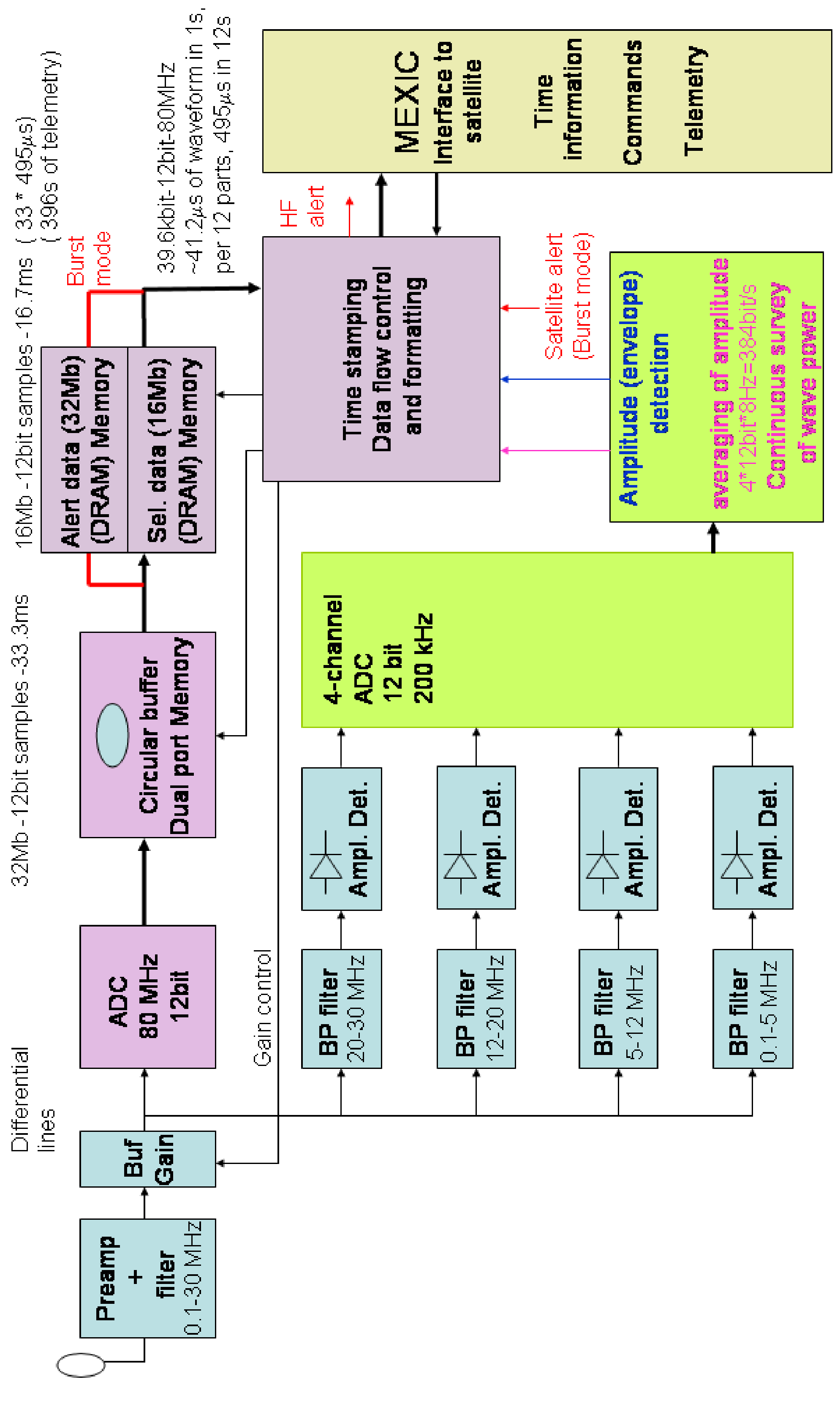

Fig.1. Functional scheme of HF analyzer

The second mode of operation is the so called burst mode. If an interesting event is detected and evaluated onboard the satellite by any instrument, the burst mode can be initiated by a satellite central unit. An alert signal is received via the MEXIC interface. In this case, 36 Mbits, which is approximately 33 ms of waveform, will be stored and subsequently transmitted to the telemetry. There will be a programmable time shift, which determines which 33ms with respect to the beginning of burst mode (alert signal) are stored.

Because there is an uncertainty about the optimum amplification, the gain of the input amplifier can be set by command from the ground control station after previous analysis of data. We avoid the usage of automatic gain control because we are interested in very fast transient phenomena.

3. CONCLUSION

We have presented a preliminary conception of HF analyser for TARANIS satellite. After the computer simulations and debugging of event detection algorithm, we are going to build a universal simulator. We will download this simulator with various waveforms based on the analysis of pulse propagation through the ionosphere and on experience from previous similar experiments and we will test the efficiency of selection algorithm (event detection). Unfortunately, the similar experiment on FORTE satellite worked in 25-50MHz bandwidth; signal was processed after down-conversion. We have to extrapolate or calculate the dispersion to our frequency range which is 0.1-30 MHz; the dispersion in our range will be obviously larger, because our frequency range covers the maximum plasma frequency in the ionosphere. The noise background and unwanted signals from ground transmitters will be different as well. The engineering model is supposed to be ready for testing in 2008.

4. REFERENCES

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