Experimental Band Monitor for PSAT Satellite

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Abstract — **During changing sun activity, the ionosphere is responding accordingly and therefore it is interesting to observe the propagation behavior of shortwave bands. For the above mentioned purpose we are designing a monitoring payload for an experimental cubesat satellite called PSAT. The payload consists of a receiver, which is able to receive SSB modulated narrowband signals in 28 MHz uplink band and a transmitter with FM modulation in UHF downlink frequency band. The receiver frequency is selected to be at the center of radio amateur activity with low data rate digital modulations.**

Keywords- CubeSat, band monitor, BPSK31 modulation, PSAT, transponder.

I. INTRODUCTION

During last years, members of the Laboratory of Experimental Satellites at Brno University of Technology were involved in projects related with experimental satellites [2][3][5]. Since early nineties we participate on satellite program of international organization AMSAT [1][4]. In 2010, we were asked by the US Naval Academy Satellite Laboratory to develop a HF band monitoring payload for an experimental CubeSat-type satellite called PSAT (ParkinsonSat) [6]. The receiver is used for demodulating SSB modulated slow-data-rate BPSK signals in 28 MHz band in 3 kHz audio channel. This 3 kHz baseband including BPSK signals is then FM modulated on UHF carrier in 435 MHz band.

II. RECEIVER

A block diagram of the HF receiver part of the band monitor is depicted in Fig. 1. We use a double conversion super heterodyne, proven in PCSAT2 receiver, with several modifications - especially the BPSK31 signal sensing circuits.

The receiver includes low noise preamplifier in order to compensate electrically short receive antenna, which must be shorter than quarter of wavelength. The LNA is followed by high quality LC filter for the out of band signal suppression. Then there is first mixer to intermediate frequency followed by a crystal filter, which defines actual bandwidth 3 kHz of monitored HF band. The intermediate frequency amplifier with the gain setting ability for automatic gain control then amplifies the received signal and it is followed by the last mixer, which converts the signals to the audio band.

The baseband signal is then splitted into three ways. The first signal is rectified and the obtained DC voltage controls the gain of the intermediate amplifier. The second signal is rectified to get 31.25 Hz frequency from the received signals. This spectral component is a part of the BPSK31 signal modulation which is most frequently used digital mode in the monitored radio-amateur band. After passing through the narrow bandwidth tone decoder, binary signal carrying information about presence of BPSK31 modulation is obtained. It is monitored by a control microprocessor of transmitter in order to recognize useful signal and switch the power amplifier on. The last signal is directly connected to the transmitter modulation input to modulate the UHF carrier.

III. TRANSMITTER

The transmitter produces FM modulated signal in UHF frequency band. Output RF power of the transmitter is 27 dBm at 435 MHz. A BPSK modulator with data rate 31.25 bit/s on a sub carrier with frequency 312.5 Hz is implemented in order to transmit telemetry data from built-in sensors. Block diagram of the transmitter is depicted in Fig. 2.

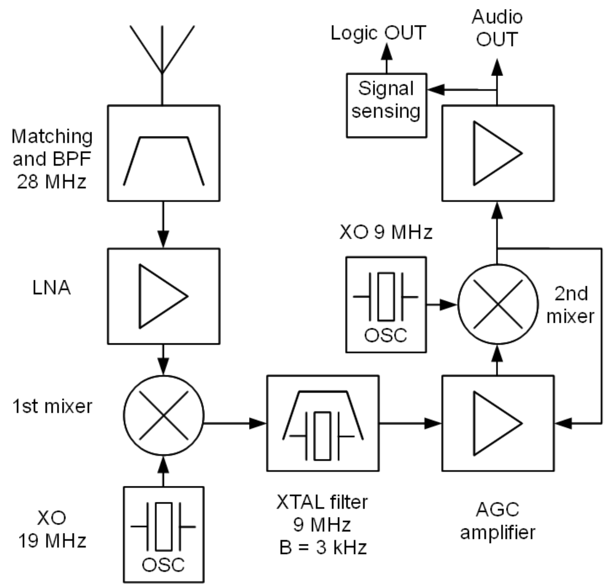

Figure 1. Receiver block diagram.

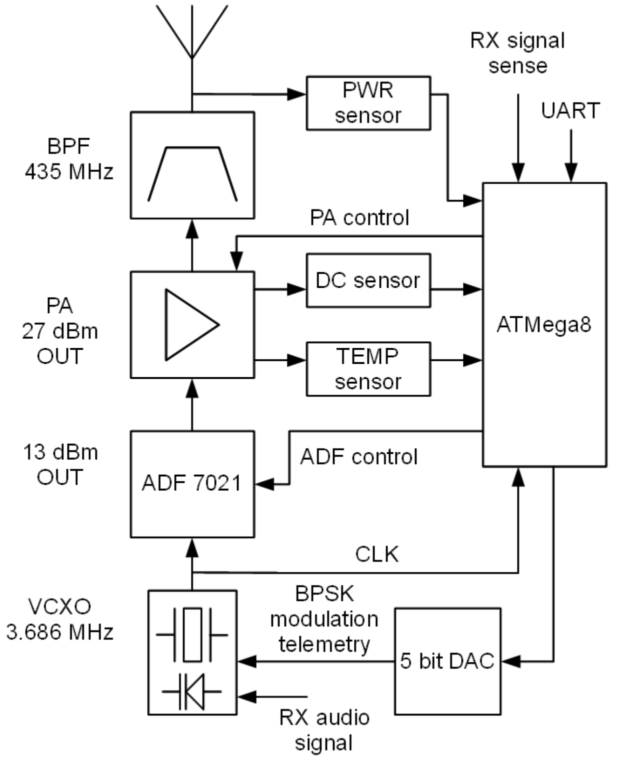

Figure 2. Transmitter block diagram.

The core of the transmitter is integrated transceiver IC produced by Analog Devices. This solution with minimum number of external components results in minimal dimensions of the PCB board. The IC quartz oscillator is directly modulated by a varicap in order to achieve FM modulation. Output power is amplified by one-stage PA with a Mitsubishi MOSFET transistor. On the board are implemented sensors which measure drain voltage, current and temperature of the PA transistor and also the output RF power. All sensors and the transceiver IC are controlled by microcontroller ATmega8. The microcontroller also drives a 5-bit parallel DA converter, which provides BPSK modulation of the telemetry data.

The described monitoring payload is implemented on one double sided PCB with the outer dimensions 90x90mm. In the center of the board there is simple heater consisting of a set of resistors connected in parallel. The purpose of the heater is that the thermal model of satellite and its orientation in respect to the Sun predict that the monitor board will be possibly freezing.

IV. Realization and Measurement

Recently we have built the prototype and we perform some basic tests and tuning. Fig. 3 and 4 show spectrograms of the output signal of the transmitter. Wideband spectrum is clean, in narrowband spectrum are observed spurs from the reference signal of the PLL, however they are well suppressed by 65 dBc.

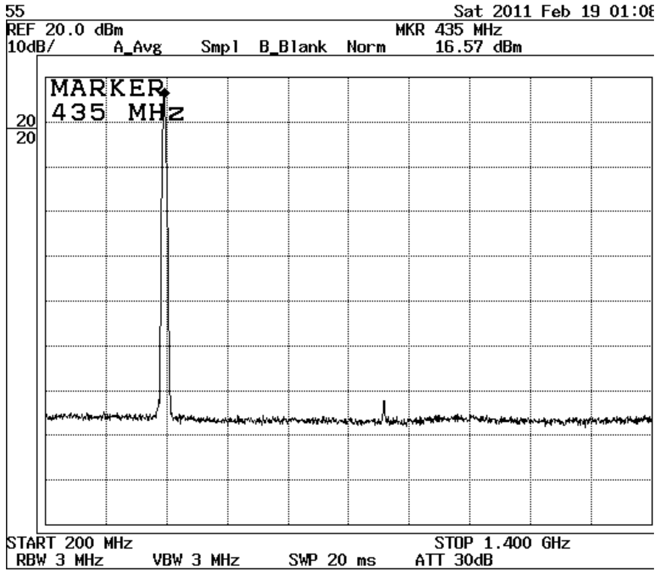

Figure 3. Wideband output spectrum of the transmitter.

Fig. 5 shows a photograph of one side of the board during tests. This side contains the major parts of the transmitter and receiver AGC amplifier with filters. The PA transistor is placed in the upper right corner near the metal pole to guide away the dissipated heat. Some parts, as the voltage, temperature and power sensors are not assembled yet.

The receiver was tested for the dynamic range of automatic gain control circuit. The results of the measurement can be seen in Fig. 6. The measurement results can be divided into several parts. First part has input signals below -127dBm, there the signal is growing from the noise and gain is at its maximum, the approximate value of the receiver gain is estimated to be 100dB. Then up to the input level -73dBm, the level of the output signal is kept quite constant ant in this region AGC takes control. Above that value output signal increases to the level, where implemented limiter takes care of the amplitude and signal is distorted therefore. The minimum signal, which can be decoded through the receiver, goes to the estimated level -141dBm, so the usable dynamic range of the receiver is around 70dB.

As shown in Fig. 7, we tested the BPSK31 telemetry modulator together with the receiver. Fig. 6 shows a part (0 to 2 kHz) of the baseband spectrum, recorded from a UHF receiver using a PC soundcard. There is BPSK31 modulated signal at the subcarrier 312.5 Hz, which is directly synthesized by the control microprocessor. Approximately at 1800 Hz there is obvious a test signal (unmodulated carrier) received in 28 MHz band. The upper part of the figure shows the spectrum change in time.

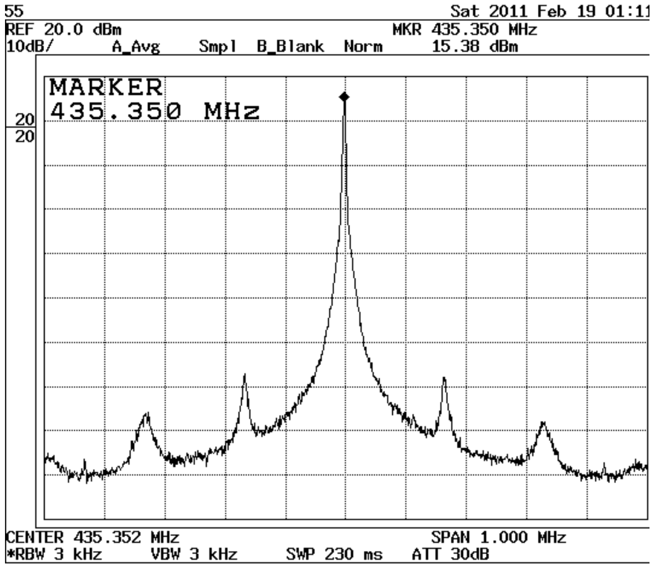

Figure 4. Reference spurs in output spectrum of FM modulated carrier in 1 MHz bandwidth.

Fig. 8 depicts screenshot of the BPSK31 decoding software. The signal from OK2AQ is transmitted in 28 MHz band and OK2CPV signal is generated by the transmitter microprocessor. It can be seen, that received signal is strong and AGC corrected the gain of IF stage.

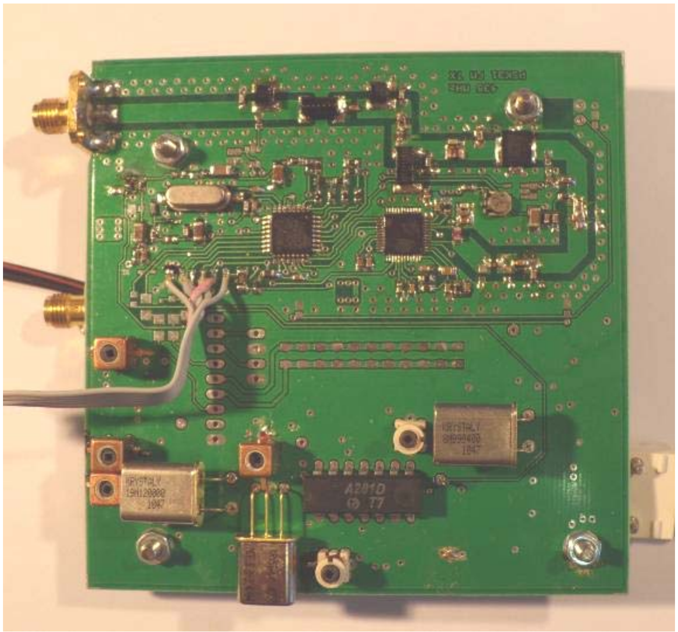

Figure 5. Photograph of one side of the board. The transmitter is in the upper half of the board.

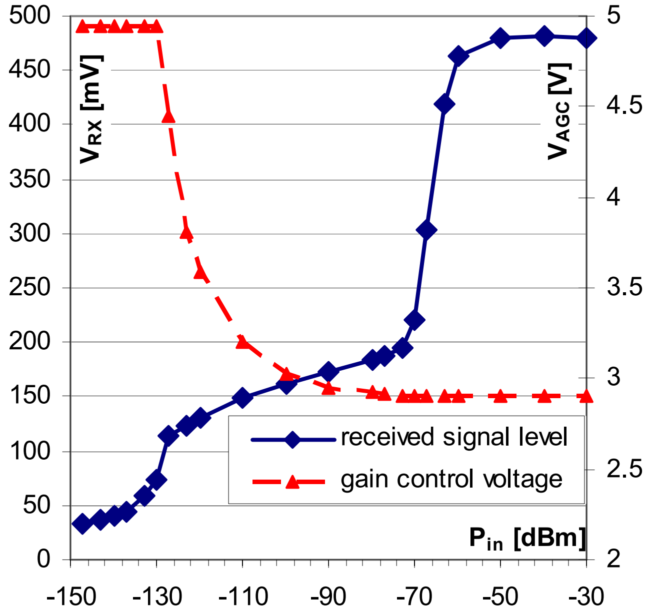

Figure 6. Output signal amplitude and AGC voltage vs. input signal.

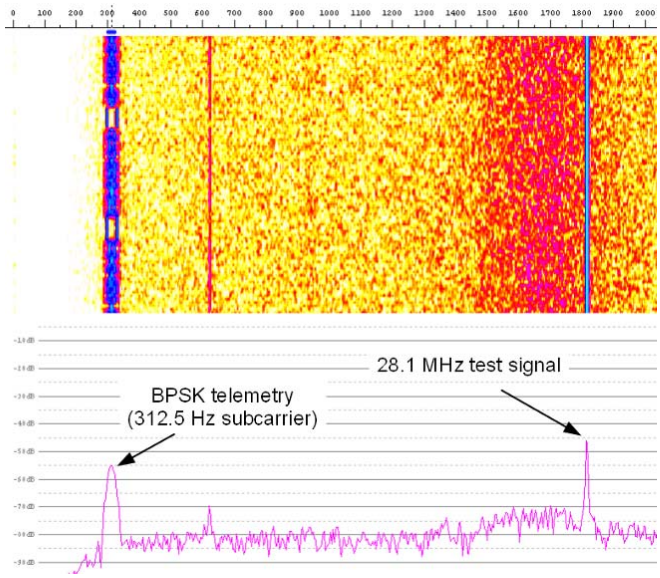

Figure 7. Baseband spectrum (and spectrum in time) of demodulated signal from 0 to 2000 Hz. Horizontal axis - frequency in Hz.

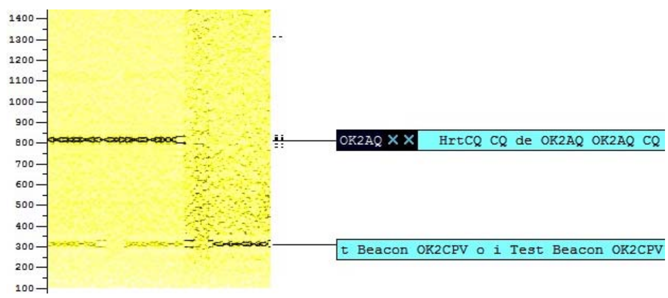

Figure 8. Test with a real BPSK31 signal and its decoding by PC. Horizontal axis - time, vertical axis - frequency in Hz.

V. Conclusion

The receiver bandwidth allows us monitoring dozen of signals at once and therefore, it is possible to obtain the ionosphere conditions from the various directions under the satellite. Moreover, the plan is to deploy two identical PSAT satellites with identical payload onboard for the more complex view on the signals. The satellites should be deployed during the year 2011.

Acknowledgement

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