Status of on-board radiocommunication system of OUFTI-1 nanosatellite as of mid-2012: design, implementation, and tests

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Abstract

We describe the space-segment component of the radiocommunication system of the OUFTI-1 nanosatellite system, providing D-STAR digital voice & data communication, AX.25 telecommand & telemetry, and OOK beacon transmissions.

The educational OUFTI-1 nanosatellite features three distinct radiocommunication (COM) capabilities: D-STAR voice/data communications; AX.25 telecommands and telemetry (TC/TM); and OOK (emergency) beacon transmissions. D-STAR is an amateur-radio, digital, voice and data (radio)communication protocol, and is the primary motivation for the OUFTI-1 project.

The COM system has much evolved since the fall of 2007, and we have now a “final” design. Along the way, there have been uncertainties about the use of VHF or UHF for downlink, and thus about the downlink budget, the corresponding radiofrequency (RF) power required, the availability/choice of appropriate RF power-amplifiers (PA) integrated circuits (IC's), and the voltages and currents to be provided. The uplink is now at UHF (435 MHz), and the downlink at VHF (145 MHz). The Doppler-compensation strategy also evolved. The COM system has two parts: (1) a transmitter (Tx) and a receiver (Rx) capable of operating either in D-STAR mode (main payload) or in AX.25 mode (TC/TM); (2) a beacon Tx continuously sending vital parameters (mainly voltages, currents, and temperatures).

On the Tx side, one significant design constraint is the single Tx antenna. The two RF signals produced the two parts above thus need to be combined. Furthermore, because of the critical role of the beacon, we opted for two maximally-independent beacon chains, operating in alternation. This meant combining three distinct RF signals into a single output RF signal. Furthermore, our budget links indicated that the power levels required for the D-STAR/AX.25 and the beacon were different. We thus had to solve the problem of properly power-amplifying the three low-power RF signals (produced by their own processor and modulator), and of combining them into a single output RF signal. We found very few RF PA IC's at the frequency of interest and with the proper gains (even when using several stages). The best compromise found calls for: (1) having two redundant beacon chains up to the modulators; combining the resulting low-power RF signals into a single low-power RF signal; and power-amplifying it to the proper level; (2) producing a low-power D-STAR or AX.25 RF signal and power-amplifying it to the proper level; and (3) combining the two resulting “high-power” RF signals (for a total of about 0.66 W), and sending the resulting RF signal to the antenna. We ended up using two distinct PA IC's. Each combiner has a 3dB loss, and the loss in the combiner before the antenna (3dB of 0.66 W) leads to possible overheating, which we studied.

On the Rx side, regulations indicate that we must be able to command the satellite to stop transmitting at any time (e.g. if it creates interference). This forces the satellite to constantly listen for AX.25 telecommands, even during the reception of a D-STAR transmission. The AX.25 and D-STAR frames being different, we were forced to have two parallel Rx chains, each consisting of a demodulator and a digital processor. Our algorithms for de/encoding D-STAR and AX.25 signals have been operational for a while.

The COM electronics also includes several bandpass filters, impedance-matching circuits, and overcurrent protections. We have built and successfully tested prototypes of the various parts of the COM system. The 3 (de)modulators for D-STAR/AX.25 are Analog Device ADF7021's, the 2 modulators for the beacon are RFMD RF2516's, and the 4 digital processors are TI MSP430's. Although we had initially planned to place the complete COM electronics on a single PC104-format (about 10x10 cm), six-layer board, we may need to use part of a second board.

We will present a block diagram of the COM system and explain the constraints and compromises that led to it. We will also present the state of implementation and the preliminary tests.