D-STAR digital amateur communications in space with OUFTI-1 CubeSat

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Abstract – OUFTI-1 is a nano-satellite currently being constructed by the students of the University of Liège, Belgium. Its main payload is the D-STAR amateur-radio telecommunication protocol. In this paper, we explain how hams will be able to operate OUFTI-1 for D-STAR space communications. The large footprint of OUFTI-1 results in a larger number of users being able to communicate via D-STAR.

1. Introduction

OUFTI-1 is a nano-satellite entirely developed by the students of the University of Liege (ULg), Belgium, along with two other engineering schools. The students develop the different subsystems of OUFTI-1, including the power system, the on-board computer, the thermal system, the communication system, and the ground station. Details about all these subsystems can be found in [1]. OUFTI-1 will carry two payloads; the first on-board D-STAR-dedicated repeater and new generation solar cells. This paper describes the different aspects of the D-STAR payload. Section 2 briefly presents the D-STAR protocol. Section 3 details the classical D-STAR ground communications. Section 4 presents the possible communications using the D-STAR repeater aboard OUFTI-1. Section 5 details the management of the Doppler shift. Section 6 concludes.

2. D-STAR amateur-radio protocol

The D-STAR amateur-radio protocol has been developed by the Japanese Amateur-Radio League (JARL). Its main features are the simultaneous transmission of voice and digital data and callsign-based roaming through the Internet. A D-STAR frame is composed of a header, digital data, and digital voice, as shown in Fig. 1. The header contains information such as callsigns of the users and of the repeaters used for the communication. Both the header and the digital data undergo various error-correction algorithms, including a scrambler, an interleaver, and a convolutional coder. The input voice is coded on the ICOM transceivers using the AMBE codec [2]. Details about the structure of a D-STAR frame can be found in [3].

The digital frame passes then through a Gaussian filter and an FM modulator in order to be GMSK-modulated. The operating frequencies used on OUFTI-1 are the 145 MHz and 435 MHz ham bands.

3. D-STAR for ground communications

In order to establish a D-STAR communication, a user must set the four following callsigns: its own callsign, the callsign of the ham he wants to reach (companion callsign), the callsign of the repeater he uses to enter the D-STAR network (departure repeater callsign), and the callsign of the repeater needed to reach the companion ham (destination repeater callsign). Please note that, due to the roaming and routing capabilities of the D-STAR network (exactly as for mobile phone networks), the destination repeater callsign can simply be set as the callsign of the gateway of the departure repeater. Event though callsigns are needed, a user must still use the appropriate frequencies.

4. D-STAR for satellite communications

The reasons for having a space-based D-STAR repeater is that ground repeaters are not present everywhere, and that their footprints are limited. The OUFTI-1 D-STAR repeater will be available either as a direct communication repeater between two users, and as an extension of the ULg D-STAR repeater. Figure 2 shows the case of two users communicating through OUFTI-1, thus used as a repeater in space. The distance between the two users can be large, since OUFTI-1's footprint is foreseen to be around 2000 km, depending on its final orbit.

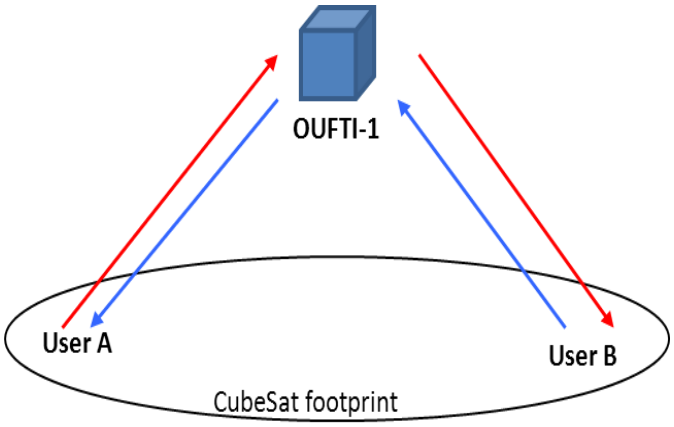


Figure 2: OUFTI-1 as a direct space-based repeater for two ham users.

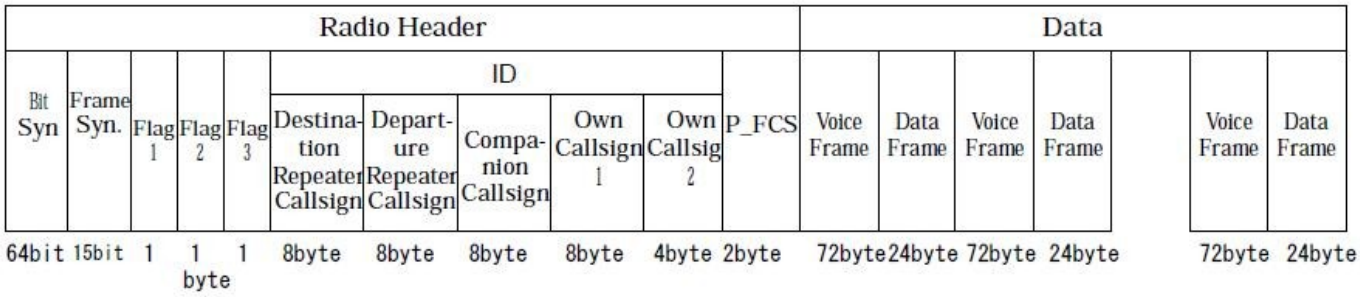


Figure 1: Structure of a D-STAR frame [3].

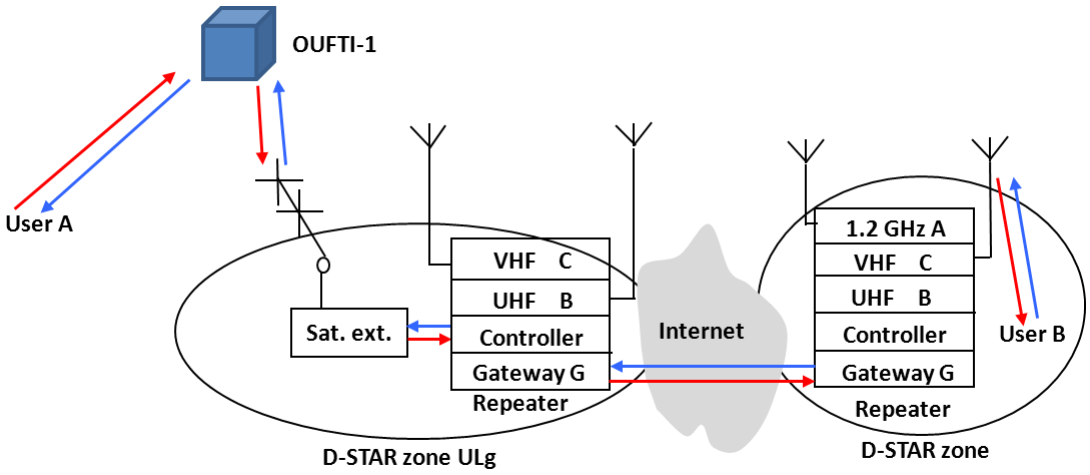


Figure 3: OUFTI-1 as an extension of the ULg ground-based D-STAR repeater.

Figure 3 shows the case where OUFTI-1 is used as an extension of a ground D-STAR repeater, here again augmenting the range of communication between two users. In this case, any user A located within OUFTI-1's footprint is able to communicate with any user B located within the footprint of any D-STAR repeater in the world.

5. Management of the Doppler shift

A major issue in the design of a D-STAR radiocommunication system for a satellite is the Doppler shift compensation. The constraints that we face are that (1) the Doppler shift ranges from -3 kHz to +3 kHz at 145 MHz (used for downlink), and from -9 kHz to +9 kHz at 435 MHz (used for uplink), and (2) the commercial D-STAR transceivers have a tolerance of 1 kHz and a frequency step of 5 kHz. Therefore, as illustrated in Fig. 4, there are blind frequency regions, in which commercial transceivers are unable to compensate the Doppler shift correctly.

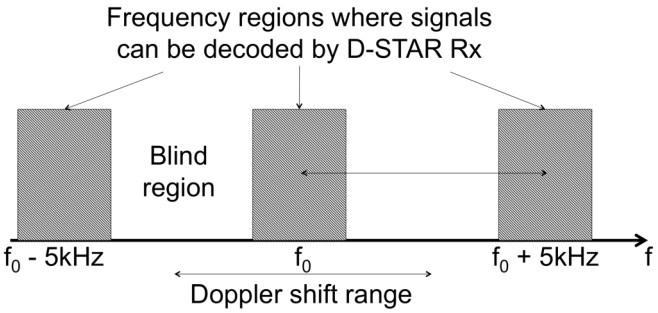


Figure 4: Illustration of the inability of commercial D-STAR repeaters to compensate the Doppler shift.

Two solutions are implemented for OUFTI-1, in order to compensate the Doppler shift without having hams buying new, perhaps expensive, equipment. First, we implement an original on-board solution, which consists in the compensation of the Doppler shift for two different geographical areas, as illustrated in Fig. 5. Any user that will want to use OUFTI-1 for D-STAR communications will have to book the repeater for a particular pass, at a particular time instant. The OUFTI-1 ground station will then compute the Doppler shift for this pass, and send it to OUFTI-1. The user will then be able to communicate as if the OUFTI-1 repeater was ground-based. Any user who would be able to compensate the Doppler shift for D-STAR communications would then need to compensate the Doppler shift compensation. Details of implementation can be found in [4].

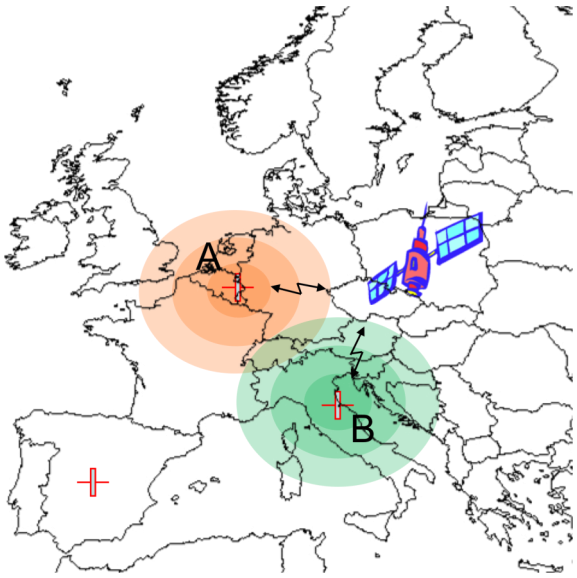


Figure 5: Illustration of the compensation of the Doppler shift for two geographical areas.

The second solution is ground-based. It consists of two parts. The first part consists in the addition of D-STAR capabilities to conventional, non-D-STAR, ham-radio transceivers ready for satellite communications. This work is detailed in [5]. The second part, currently being implemented, is to adapt a ground-based D-STAR repeater to satellite communications. The adaptation consists in the Doppler compensation and in the frequency adaptation. Indeed, while a D-STAR repeater module, e.g. UHF as illustrated in Fig. 6, works on a single frequency band, OUFTI-1 receives and transmits on two different frequency bands, which are 145 MHz for the downlink and 435 MHz for the uplink. We therefore

need to compensate the Doppler shift for both the uplink and downlink signals, and to shift the downlink 145 MHz signal to 435 MHz The plan is to drive frequency converters with the appropriate Doppler-compensated frequency. Details about this frequency conversion can be found in [6].

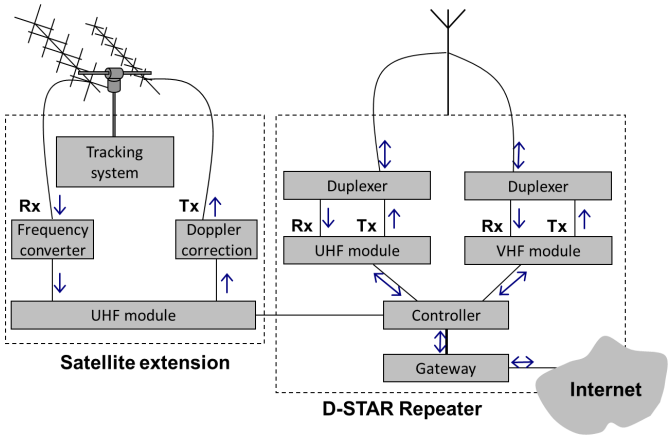


Figure 6: Complete D-STAR repeater, including the extension for satellite communications.

6. Conclusion

OUFTI-1, the CubeSat built by the students of the University of Liege, Belgium, will carry the first space-based, D-STAR-dedicated repeater. In this paper, we briefly reviewed the digital D-STAR ham-radio protocol, allowing hams to transmit simultaneously voice and data. We then presented the two communication modes users will use OUFTI-1 in, which are either as repeater, or as extension of a ground-based repeater. We eventually presented both the ground-based and the space-based solutions implemented to face the issue of Doppler shift.

References

[1] *OUFTI-1 nanosatellite website*, http://www.leodium.ulg.ac.be/, May 2013.

[2] Digital Voice Systems, INC., AMBE-2020 Vocoder Chip User's Manual, version 4.9, 2008.

[3] Pisane J., Design and implementation of the terrestrial and space telecommunication elements of the student nanosatellite of the University of Liege, MS thesis, 2008.

[4] Crosset N., Implémentation du relais D-STAR à bord du nanosatellite OUFTI-1, MS thesis, 2010.

[5] Werner X., Implémentation du protocole D-STAR sur un transceiver radioamateur classique, MS thesis, 2011.

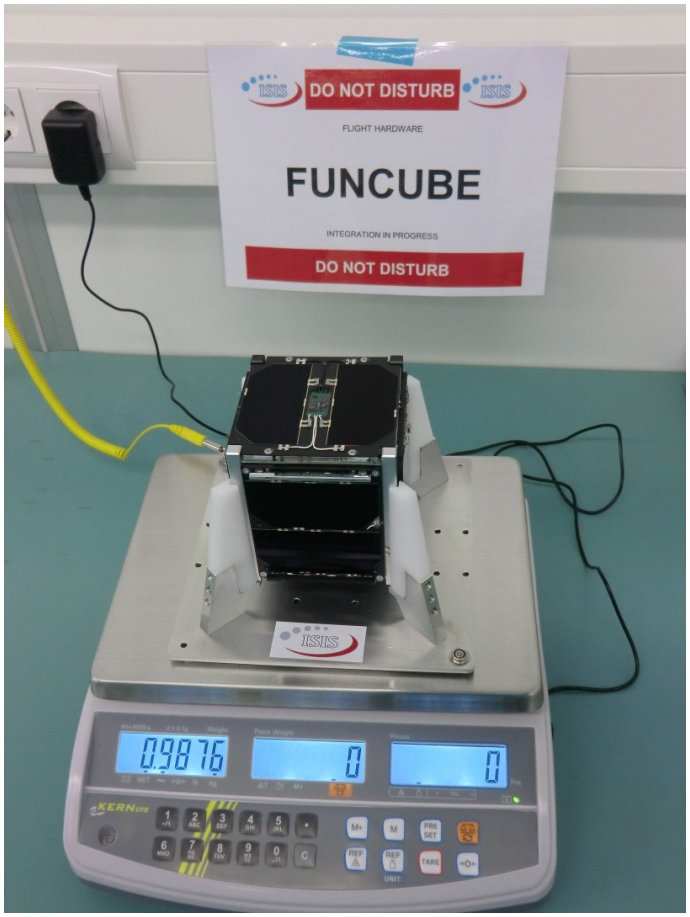
[6] Melchior J., Réalisation d'un convertisseur de fréquence pilotable dans le cadre du projet OUFTI-1, MS thesis, 2011.

FUNcube Report

Jim Heck G3WGM

So here we are, May 2013, some four years after we started the project in 2009. I recall discussing at the Colloquium of that year, a possible tie up with our friends at ISIS bv in Holland, which resulted in a contract between them and AMSAT-UK being signed in Oct 2009. Basically this contract covered the supply of several sub-systems and parts for the spacecraft, eg solar panels, structure, Electronic Power Supply (EPS), Attitude Control System (PMASS), and the antenna deployment system (AntS). It also covered the all important testing and integration of the completed spacecraft. Some of the things we anticipated all those years ago, have not come to pass, but suffice it to say that our relationship with ISIS has remained extremely friendly. They have been extremely generous by making available to us many resources which we didn't see we might need at the beginning of the project

So where are we now? As previously reported, the building, integration and testing of the spacecraft is completed, and as our picture shows, it is now sitting peacefully in the clean room at ISIS, waiting for its launch opportunity. We are still able to reload the flight software, if needed, but this is the only change we can make, and we are extremely loathe to make any



FUNcube-1—the completed hardware—well within mass budget!