Mobile Ground Station for CubeSat Operations

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Abstract*—Operators of CubeSats often use Amateur Radio frequencies to get remote access to their small satellites. The frequency bands used are VHF (144-146 MHz), UHF (430-440 MHz) and sometimes also S-Band (2400-2450 MHz). For TT&C and data downlink a ground station is required, special attention has to be drawn on costs and regular maintenance. The lifetime of these antennas and ground station components is usually < 5 years and the service for the complete setup binds manpower. Furthermore, Central European locations for ground stations are not the best choice for LEO satellites on a sun synchronous orbit. This leads to 3-4 overpasses per day, 2 overpasses with a high elevation which results in longer contact time and closer distance. Other locations like Inuvik (CAN) provide more than 12 overpasses per day; northern regions are very interesting for long and more frequent communication times between earth and LEO Satellites. Therefore, the Institute of Space Systems (DLR) in Bremen is developing a remote controlled and mobile ground station for amateur radio frequencies, including antennas, servers and modern transceivers.

***Keywords*— CubeSat; ground station; space; operation;**

I. INTRODUCTION

The "CubeSat" is a type of miniaturized satellite for low earth orbit (LEO) space research and applications. One of these is typically made up of one or more 10x10x10 cm cubic units, and each unit has a mass of no more than 1.33 kilograms. In addition to being light and small, designers often use commercial off-the-shelf (COTS) electronic and structural components. Although bunches of CubeSats have been launched on dedicated rockets, they are most often put into orbit in small numbers via the International Space Station (ISS) or placed in orbit as secondary payloads. CubeSat applications usually involve experiments which can be miniaturized and provide services for earth observation and Amateur Radio applications. Some CubeSats are used to demonstrate spacecraft technologies or as feasibility demonstrators that can help to justify the cost of a larger satellite.

The aim of the project presented in this paper is to solve all known problems during CubeSat operations, it provides an all in one system including RF components, software and a remote access. Frequencies and bandwidths are restricted, especially if a ground station is operated in Amateur Radio frequencies. A key feature of this system is its mobility. So the ground station can easily be shipped to regions where optimum contact times can be achieved, e.g. to polar regions for sun synchronous orbits (SSO) or to equatorial regions for these very orbits.

A well-known challenge for CubeSat operators especially at universities or in an academic environment is the reliable and lasting operation as well as maintenance of their ground stations. Due to fluctuation in student body and research assistants, especially after the official ending of a mission, often responsibility for the ground station is not given any longer.
The L.A.R.S. ground station offers operations, service and maintenance from a single source.

Fig. 1. Satellite ground station placed in a sea container [1] with different antennas on an airport close to the city of Wilhelmshaven (GER)

II. SYSTEM DESCRIPTION

The complete ground station consists of the RF system and server computers beside utilities like ventilation, a convector heater and a 10 kW transformer, all inside a 20 feet sea container (see Fig. 1). This container features a special insulation against low outside temperatures. Furthermore the container is divided into two rooms. The first one is the technical compartment with the complete computer- and RF setup, the second one offers space for storage, service and stowing for transport (see Fig. 2). All antennas for the different applications are mounted on the top.

Fig. 2. DLR RF container interior view

The electrical power system guarantees a 230 Volts supply for all devices and utilities used inside the container, regardless of the installation site of the container and therefore the predominant line voltage of the corresponding country (110/115 Volts). The maximum power rating is approximately 10 kW. A temperature monitoring for all sensitive parts, a CCTV surveillance system as well as a control system for the heater unit is installed. All this facility management data is user accessible via web interface. Fig. 3 shows an exemplary temperature graph from three different temperature sensors recorded by the monitoring system. The database and graphical representation is realized with RRDtool [2].

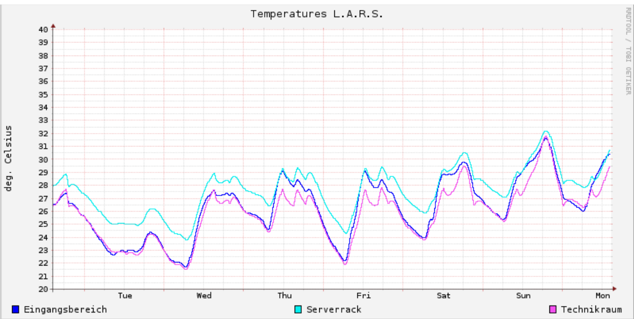

Fig. 3. Temperature diagram for both rooms and server rack

III. Server System and Remote Operation

As a link between the RF system and the outside world, a computer system is used, which will be briefly presented in this section. The ground station is equipped with a fully-redundant server system consisting of two server computers, each accompanied by an uninterruptable power supply (UPS). Moreover, all associated network appliances are redundant as well. The servers are each connected to the RF system to allow control and the manipulation of all settings and to provide data exchange for RX/TX. The ground station itself can be remotely accessed via a secure VPN connection. Fig. 4 shows a full view of the server rack, in Fig. 5 the remote control unit at DLR Bremen is shown.

Fig. 4. Redundant computer system

Fig. 5. Remote unit to control the ground station from DLR Bremen (left screen: RF configuration; center screen: user/satellite operator applications; right screen: graphical representation of satellite orbit)

IV. RF SYSTEM

The RF system consists of a redundant antenna system for the Amateur Radio VHF and UHF frequency range. For each band, two antennas, type "Eggbeater" [3], with approximately 5 dBi gain and a unidirectional antenna diagram are used. The simulated radiation patterns are shown in Fig. 6.

By using an antenna switching matrix, it is possible to choose between the required antennas, so both cross-band and in-band operations are realizable.

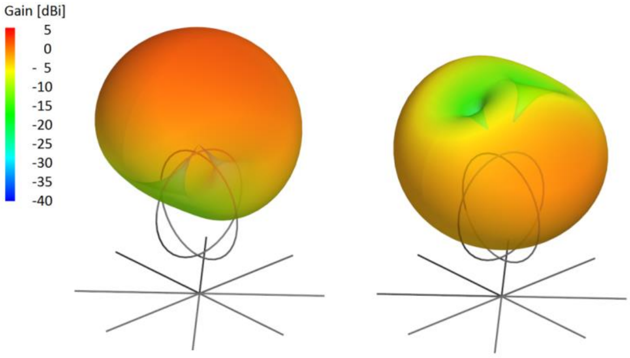

Fig. 6. Calculated radiation patterns with Antenna Magus [4]. Left: RHCP, right: LHCP

The transceiver system is redundant as well, that means two SDR transceivers, with high quality frequency transverters [5] and low noise amplifiers manage the frequency conversion towards IF (and vice versa) and guarantee the optimum signal levels. The maximum uplink power is approximately 100 W for all bands. Real tests with different cube satellites showed good results. The complete RF system is remote controlled and also monitored, so that one can keep track of all relevant parameters like system voltages, currents and temperatures of the system-critical modules like amplifiers.

Fig. 7. RF setup with switching matrix, power supply and RF racks

Fig. 7 shows the complete RF setup, including the three rack modules for the amateur radio bands. The S-Band frequency range is still under development.

V. OTHER OPTIONS IN SIGNAL DETECTION

Relating to the DLR activities in ADS-B (Automatic Dependent Surveillance - Broadcast) [6], AIS (Automatic Identification System) [7] and also the WSPR (Weak Signal Propagation Reporter), this system is able to receive and decode such kind of RF signals and make them available for academic purposes. The use of these three applications is complete independent of the primary purpose of the ground station, i.e. CubeSat operations.
Fig. 8 shows the redundant ADS-B rack unit, made of two independent receivers by Jäger EDV [8].

Fig. 8. ADS-B rackmount unit

REFERENCES

[1] CHS Container Handel GmbH, Bremen, Germany [Online]. Available: https://chs-containergroup.de/

[2] T. Oetiker, "RRDtool", 2018 [Online]. Available: https://oss.oetiker.ch/rrdtool/

[3] AnjoAntennen, Heinsberg, Germany [Online]. Available: http://www.joachims-gmbh.de/index.html

[4] Magus (Pty) Ltd, Stellenbosch, South Africa. *Antenna Magus.* (2018) [Online]. Available: http://www.antennamagus.com/

[5] Kuhne Electronic, Berg, Germany [Online]. Available: https://www.kuhne-electronic.de/

[6] K. Werner, J. Bredemeyer and T. Delovski, "ADS-B over satellite: Global air traffic surveillance from space," *2014 Tyrrhenian International Workshop on Digital Communications - Enhanced Surveillance of Aircraft and Vehicles (TIWDC/ESAV)*, Rome, 2014, pp. 47-52.

[7] Deutsches Zentrum für Luft- und Raumfahrt e.V. - Institute of Space Systems, Bremen, Germany [Online]. Available: http://www.dlr.de/irs/en/desktopdefault.aspx/tabid-11082/#gallery/26990

[8] Jäger EDV, Rodenbach, Germany [Online]. Available: http://www.jaeger-edv.de/