This document describes the specification of the C-band Satellite Radio (CBSR) communication system developed at the Poznań University of Technology.

Contents

List of acronyms

CBSR	C-Band Satellite Radio
FER	Frame Error Rate
OBC	On-board Computer
PUT	Poznan University of Technology
SDR	Software Defined Radio
RGS	CBSR Ground Station
CGS	Control Ground Station
SS	Space Segment
SP	Session Plan
RS	Retransmission Schedule

1. System Concept

C-Band Satellite Radio is a state-of-the-art communication system developed specifically for Cubesat nano-satellites. The system will provide a broadband communication link between the satellite and the ground station operating in C-band and allowing for fast and efficient download of big data volumes from the orbit.

1.1. System Characteristics

The design goal is to reach a minimum throughput of 10Mbit/s in 10MHz channel at FER<1%. The ITU assigned the C-band frequencies 5830-5850MHz for amateur space-to-ground communication on the secondary basis, therefore the carrier frequency of 5840MHz has been selected as a default value. The channel bandwidth is limited to 20MHz, however, lower values down to 1MHz can be used as well. The transmit power is limited to 2W (+33dBm) due to the power constraints on-board the satellite. The system provides downlink connection only, however the transmitter is interfaced to other communication subsystems, operating e.g. in VHF/UHF/S bands as well as on-board computer, and it can receive control commands and ARQ information sent in the uplink.

1.2. Space Segment

The space segment of the CBSR communication system consists of a transmitter module and a transmit antenna. The transmitter module is connected to other satellite subsystems via a system connector providing power supply as well as control and data interfaces. The transmitter module will be designed as a single, easy-to-use module using SDR implementation. Such approach allows the user to freely select modulation types, channel coding schemes and transmission protocols by software upgrades only – no hardware modifications are required. This can be done even in space (during the mission) providing that the uplink can be used for uploading the bitstream to the satellite.

1.3. Ground Segment

The ground segment of the CBSR communication system consists of a high-gain parabolic antenna and a receiver module. The receive antenna is a part of a ground station which has been developed by PUT and located at its premises [1]. The receiver module will be developed in two versions, both of them based on SDR implementation, see below.

1.3.1. Hardware (Type-I) receiver

Type-I receiver can be used to receive and decode signals with bandwidth up to 20MHz. It uses an off-the-shelf Avnet Zynq mini-ITX platform [2], together with Analog Devices FMCOMMS3-EBZ board based SDR module [3] for down-converting and processing the received signal in on-line mode. Most of the receiver functionality (physical layer) is implemented in FPGA, only the control block and layers above the physical layer are implemented in software.

1.3.2. Software (Type-II) receiver

Type-II receiver can be used to receive and decode signals with bandwidth up to 20MHz. It uses an off-the-shelf USRP B210 SDR module [4] for down-converting the received signal and a PC for signal processing in off-line mode. Most of the receiver functionality (physical layer and above) is implemented in software, using GnuRadio

SDR platform [5]. Due to the lower costs, type-II receiver can be used by radio amateurs willing to experiment with satellite communication.

2. System Operation

A explained in Chapter 1, the CBSR communication system provides one-way high throughput link for uploading the data to the ground station. However, the transmitter on board the satellite requires some feedback information for efficient operation. For this purpose, the existing VHF/UHF/S band uplink control channel may be used.

During the visibility windows the distance between the satellite and the ground station in range can vary from roughly 2000 km to 500 km. However, for a specific pass the minimum distance may be higher, e.g. 1000 km, which limits the actual signal-to-noise ratios. In order to maximize the volume of data uploaded to the ground station during the pass, the transmitter has to adapt the transmission parameters continuously, based on the distance to the ground station. Since the return (uplink) communication channel may not be available during a specific pass or may introduce substantial delays, the adaptive scheme based on instantaneous SNR or other quality indicators is not suitable in the CBSR communication system. On the other hand most channel parameters may be predicted for every pass, therefore, transmission settings may be planned in advance.

2.1. Session Plans

CBSR communication system uses so called *session plans* (SP), specifying transmitter settings during every visibility window (i.e. session). The SP specifies session start time and duration, signal bandwidth and coding rate adapted to satellite position during the session as well as frame length and other parameters. The SPs are prepared by the CBSR system control functionality, running in RGS. The values of the parameters indicated in session plan file can be selected statically, based on the pre-calculated (expected) signal-to-noise ratios during a specific session and transmitted to the satellite via the return channel in advance for a number of visibility windows. However, we plan to use machine learning techniques to predict the values of the parameters based on the results gained during previous communication sessions and e.g. weather forecasts.

The files containing SP are uploaded to the satellite via the VHF/UHF uplink and the CBSR transmitter module uses an internal scheduler which interprets and runs specific actions, based on time stamps defined in the SP.

2.2. Ground Segment Architecture

The main reason for using the above mentioned session plans is the unavailability of the return channel in some cases (see Fig. 1). Typically, the CBSR receiver for downlink (belonging to RGS) is co-located with VHF/UHF transmitter for uplink as well as Cubesat control entity (i) (both belonging to CGS) and the return channel may be used for sending the feedback information to the satellite. However, the configuration where the CBSR receiver for downlink and the VHF/UHF transmitter for uplink and Cubesat control entity are separated (ii) is also possible (and, in fact, this is the case for both KPI-PUT and PUT-SatRev projects). The feedback information is not available when type-II software receiver, decoding the received data off-line, is used as well (iii).

Since the satellite channel is not 100% reliable medium, the VHF/UHF uplink is used for transmitting acknowledgment messages that confirm correct decoding of data in the ground station. Data is transmitted in chunks of specified length (depending on selected session parameters) and in case of incorrect decoding (wrong checksum) the chunk should be retransmitted to recover the original data. In general, the acknowledgment messages can be sent with a delay, e.g. during the next communication session. Therefore, the transmitted data is stored in a local buffer until all the chunks are correctly decoded in the ground station. When the communication session is over, the acknowledgment messages are aggregated and form retransmission schedule (RS) which is sent to the SS when possible.

The proposed architecture makes the system very flexible and helps to maximize the system throughput.

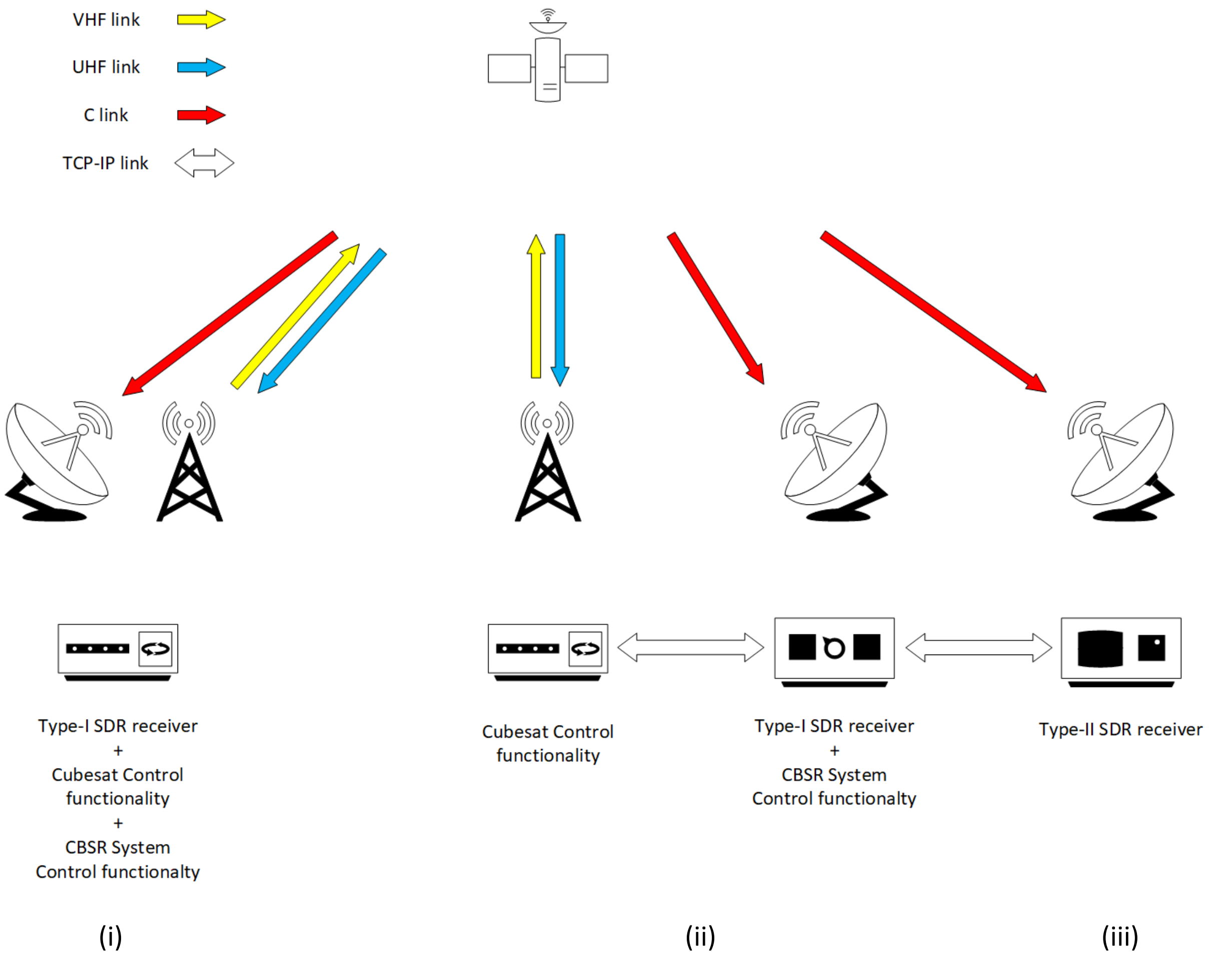

Fig. 1 CBSR ground segment architecture

2.3. Space Segment Architecture

Correct operation of the CBSR transmitter module requires exchange of information with the Cubesat OBC. The following classes of messages are specified (not exhaustive):

- control messages from the OBC (power-on, restart, power-off, clock synchronization, etc.)
- files containing SP (received in the uplink)
- files containing RS (received in the uplink)

- files containing payload data (uploaded to the ground station)
- status information from the transmitter module

Therefore, the interface between the OBC and the CBSR transmitter module (e.g. UART, ETH) must implement a communication protocol enabling reliable exchange of aforementioned messages.

Bibliography

[1] CS.S4.Gen