Paper ID: 67718
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IAF SPACE COMMUNICATIONS AND NAVIGATION SYMPOSIUM (B2)
Advances in Space-based Communication Technologies, Part 1 (5)

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RECONFIGURABLE SOFTWARE DEFINED RADIO (SDR) TRANSCEIVER WITH SELECTIVE FREQUENCY ALGORITHM FOR ATMOSPHERIC RADIO SENSING MEASUREMENTS ON SMALL SATELLITES

Abstract

The atmospheric measurements of water vapor and ionosphere electron density are critical for global climate modeling and scientific research. Incorrect predictions of atmospheric conditions can lead to disruptive and hazardous weather patterns such as storms, hurricanes and tornadoes, which endanger infrastructure, humans and other living species. Geostationary satellites, polar-orbiting satellites, stratospheric balloon sounding, instrumented aircraft and radiosonde networks provide data for atmospheric radio sensing measurements. The possibility of taking atmospheric measurements using radio signals is being considered for small satellites that use amateur and non-amateur frequency bands for transmission. Small satellites are cheap, fast to develop and affordable to new space actors, especially developing countries. Onboard the satellite, Software Defined Radio (SDR) hardware, Raspberry Pi 4 (RPi-4) Model B , Chip Scale Atomic Clock (CSAC), and Global Positioning System (GPS) are mounted. The SDR hardware serves as the radio signal transceiver; the RPi-4 does the digital signal processing; the CSAC provides the time signal; and the GPS receiver predicts the location of the satellite. The Universal Software Radio Peripheral (USRP b200mini-i), which is a space-grade model of an SDR transceiver, was selected due to its high signal sensitivity, scalability, modular design, programmability and software reconfigurability that support evolution over time. To ensure high signal processing gain, increased tolerance to multipath, low interference, and increased ranging capabilities of the SDR transceiver, Spread Spectrum Binary Phase-Shift Keying (SS-BPSK) modulation and demodulation were implemented. Furthermore, a reconfigurable frequency selection algorithm was implemented on the RPi-4 using open source GNU radio software and the Python programming language. The algorithm enables the SDR to switch frequencies so as to distinguish between water vapor and Total Electron Content (TEC) measurements. Test results clearly demonstrated the possibility of reconfiguring the frequency onboard the satellite with the implemented algorithm. In addition, the SS-BPSK has shown good reception of transmitted signals in the time and frequency domains. Moreover, the results obtained during the SDR sensitivity test ensured a good communication link budget for effective and efficient communication between the satellite and terrestrial ground station, which makes USRP-SDR a good choice in radio sensing applications. In this paper, the configuration results of this study indicate that the selected SDR can be used for future atmospheric measurements and other radio sensing applications using onboard manipulation of frequencies on SDR transceivers.

Keywords: Atmospheric Measurements, Software Defined Radio, Small Satellites, Frequency Reconfiguration, GNU Radio.