LATVIAN JOURNAL OF PHYSICS AND TECHNICAL SCIENCES
2012, N 6 (II)
DOI: 10.2478/v10047-012-0038-9

RECEIVING SYSTEM FOR IONOSPHERE RESEARCH

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The RT-32 radio telescope at Irbene has been used in the VLBI experiments for studying the ionosphere by its transradiation with the signals from Navstar GPS and GLONASS satellites. The VLBI station at Irbene is equipped with a modular receiver system operating on 1.6 GHz and consisting of off-the-shelf RF components (*Mini Circuits* Ltd.). In the secondary focus of RT-32 a four-helix antenna array is installed. The implemented receiver system has successfully been employed in the experiments as a part of multi-element radiointerferometer, with interferometric echoes registered from all the observed satellites.

Key words: *Radioastronomy, VLBI, Ionosphere, Navstar GPS, GLONASS*.

1. INTRODUCTION

The very long base interferometry (VLBI) method has been successfully used for space debris observation and specification of their orbits. In the interferometric experiments it was revealed that the precision at coordinate determination is heavily dependent on the ionosphere.

In the work, radio interferometric methods are applied in the research into the state of the Earth's ionosphere transradiated with navigational radio signals from Navstar GPS and GLONASS satellites (see [1–3]). The results allow studying the processes in the Earth's atmosphere and achieving better functional reliability for the navigation systems as well as for ground and space communications in general.

The signal power spectrum of the radio interferometer is modulated with different fluctuations in the trans-ionospheric radio signals. The electron concentration variations in the observed area make the most important contribution to the signal phase fluctuations [1, 2].

2. THE SYSTEM FOR RECEIVING 1.6 GHz SIGNALS

In 2012, the RT-32 radio telescope at the Ventspils International Radioastronomy Centre (VIRAC), Irbene, was involved in the VLBI experiments dedicated to the ionospheric observations based on transradiating the ionosphere with the signals from navigational satellites. Therefore, it was necessary to equip the RT-32 VLBI station with a signal receiving system meeting the VLBI requirements and taking into account the specifics of the radiation emitted by navigation satellites. Navstar GPS satellites emit signals on the 1575.42 MHz frequency with a bandwidth of 20 MHz. Each of the GLONASS satellites emits in a specified 10 MHz bandwidth between 1598 and 1605 MHz. In each case the right circular polarization and 60–65 W transmitting power were used [4].

At the same time, it is appropriate to use the receiving equipment available at RT-32 (VIRAC) for reception of the signal characterizing the power spectrum and for further data processing. Thus, the aim of this research was to assemble – using off-the-shelf components – a universal radio receiver for a frequency range from 1500 to 1700 MHz which would be configured for the existing receiving system of RT-32. It was also necessary to introduce two operational modes: for a 2 MHz bandwidth in the case of data registration with TN-16, and a 8 MHz one – in the case of DBBC and Mark5b. A block diagram of the experimental setup is shown in Fig. 1.

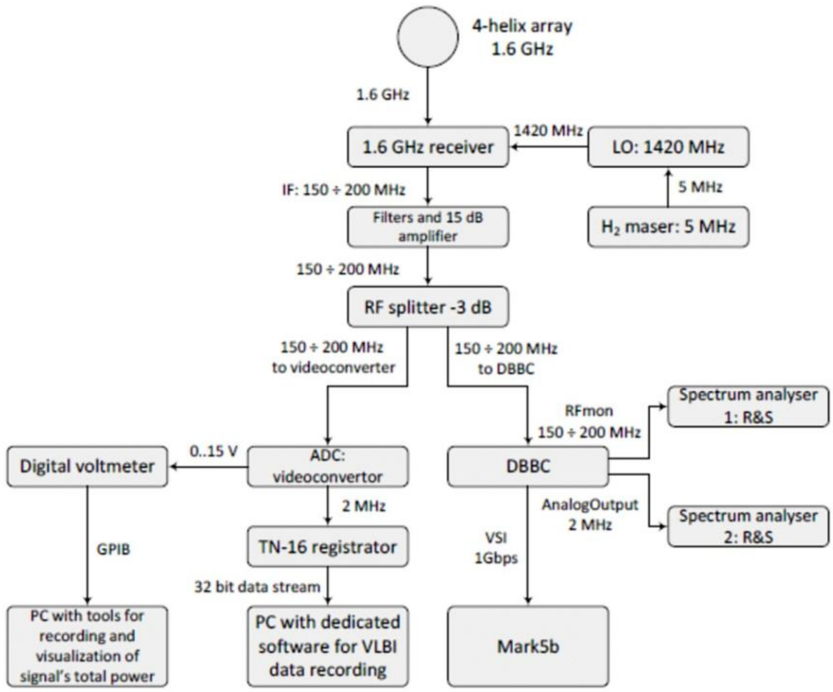

Fig. 1. Block diagram of the RT-32 receiving and recording system for ionosphere studies on 1.6 GHz frequency.

In order to fully utilize the aperture of the secondary reflector (21° for RT-32), the equipment room on the antenna surface was equipped with a quadruple helix antenna array consisting of five-turn right-hand axial mode elements. According to [5], the axial mode helical antennas with a gain of 5 dB were set for the central frequency of the range (i.e. 1.6 GHz), phased and impedance-matched with a 50 Ω feed line using the impedance lowering strip technique. The standing wave ratio of 1.5 was achieved. The assembled antenna array is shown in Fig. 2.

The receiver was built on the standard superheterodyne principle, where a highly stable Rohde&Schwarz generator synchronized with the hydrogen maser frequency standard was used as heterodyne. The system's special feature lies in its being modular, consisting of HF blocks (*Mini Circuits* Ltd.). The system's components have stable characteristics and are suitable for the given application.

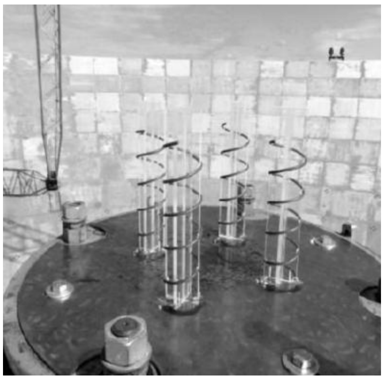

Fig.2. Four-helix antenna array for receiving right-hand circularly polarized radiation on 1.6 GHz.

A block diagram of the receiver is shown in Fig. 3. The input has a remotely controlled ZFSWHA-1-20+ (1) antenna switch for switching to a left-hand circular polarization of antenna in the case of its positioning in the primary focus of RT-32. The signal is then sent to a low-noise preamplifier ZEL-1217LN (2) with a gain of 20 dB in the 1.2–1.7 GHz band and a noise figure of 1 dB. After being amplified, the signal is transferred via voltage-controlled attenuator ZX73-2500+ (3) to VBFZ-1690+ band pass filter (4), allowing the signals in the 1.4-1.8 GHz range to be fed to ZX05-C24+ RF mixer (5). As a result of multiplying the signal with the 1420 MHz output from the Rohde&Shwarz generator synchronized with a hydrogen maser, a differential intermediate frequency (IF) signal is formed. This is then filtered in the range of 130–190 MHz using SHP-150+ and SLP-200+ filters (7), and amplified with low-noise amplifier ZX60-33LN+ (8). Next, the intermediate frequency signal is transmitted to the input connector of video-converter and ZX47-50+ total power meter (9). All the units are powered by stabilized voltage ±15 V and +5 V from a linear power supply.

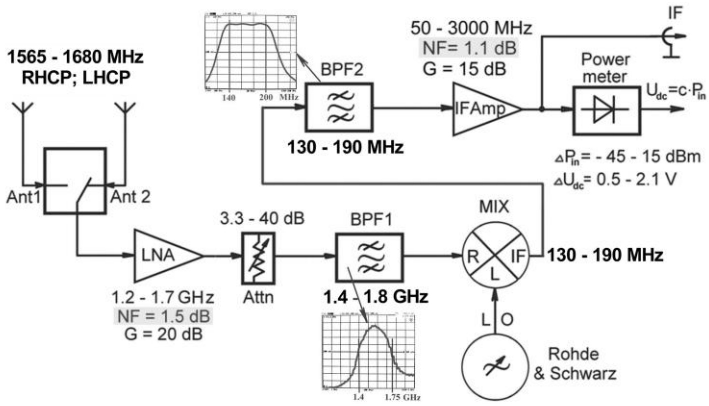

Fig. 3. Block diagram of the 1.6 GHz receiver.

3. RESULTS

The spectrum of the IF signal originating from Navstar GPS and received by the aforementioned system is exemplified in Fig. 4.

The directivity pattern for the RT-32 stationary antenna on 1.6 GHz was measured using the signals from the Navstar 29601 satellite during its passing through the pattern (Fig. 5). According to the calculations, the beam width at the given frequency for both the azimuth and the elevation is 20 min of arc.

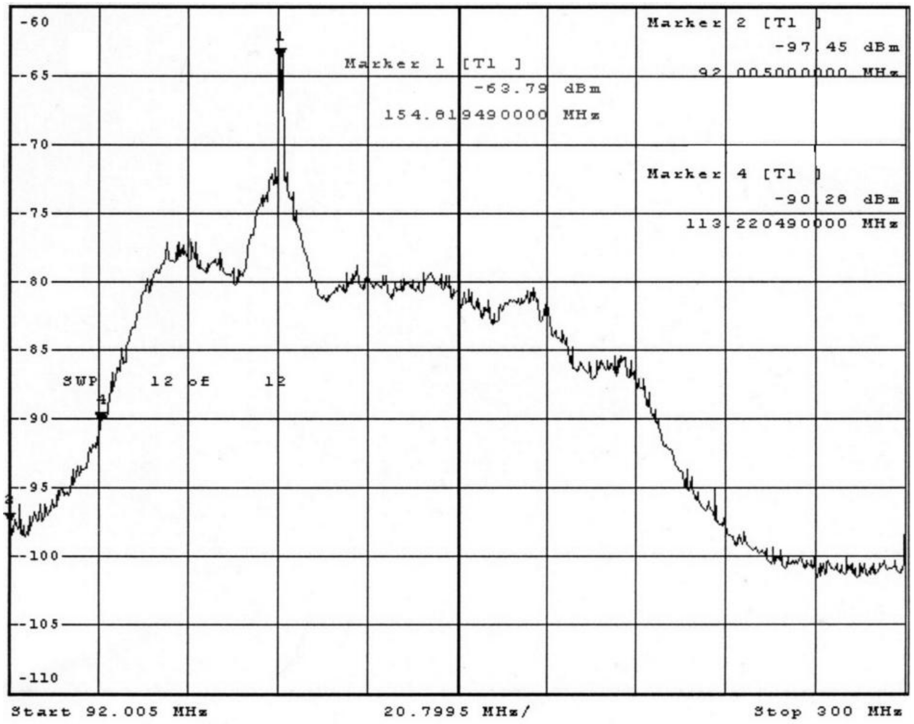

Fig. 4. Spectrum of the intermediate frequency signal originating from Navstar GPS.

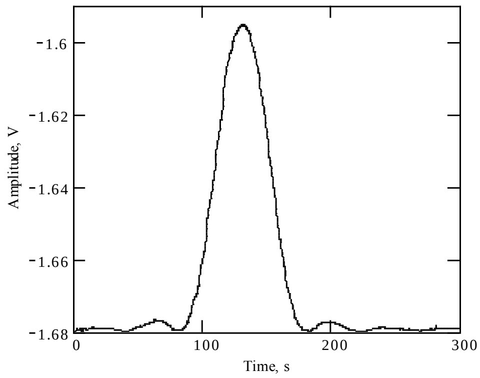

Fig. 5. Navstar 29601 signal during its passing through the directivity pattern of RT-32 stationary antenna.

4. CONCLUSIONS

The high power of Navstar GPS and GLONASS signals allows building a low-cost receiver system from off-the-shelf components and its integration into an existing recording system used for VLBI observations. The implemented receiver system of RT-32 radio telescope (Irbene) was used in 2012 for the ionosphere studies in VLBI mode as part of the multi-element interferometer consisting – apart from the RT-32 – of RT-14 & RT-1 (Staraja Pustin, Nizhny Novgorod) and RT-2

(State University of Nizhny Novgorod, horn antenna with a 20 cm aperture) [6]. The interferometric echoes in a baseline including the RT-32 antenna have been registered from all observed satellites, which gives proof to the efficiency of the implemented receiver system.

ACKNOWLEDGEMENT

This research is supported by the European Social Fund's Project "Receiving, transmitting and processing technologies of signals related to artificial Earth satellites" (2009/0231/1DP/1.1.1.2.0/09/APIA/VIAA/151).

Authors would like to thank K. Laizans for personal contribution to the development and calibration of the helix antenna array.

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UZTVEROŠĀ SISTĒMA JONOSFĒRAS PĒTĪŠANAI

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K o p s a v i l k u m s

Irbenes radioteleskops RT-32 ir iekļāvies jonosfēras īpašību pētīšanas eksperimentos VLBI režīmā, jonosfēras apgabalu caurstarošanai, izmantojot navigācijas sistēmu Navstar GPS un GLONASS satelītu signālus. Irbenes VLBI mezgls aprīkots ar modulāru 1,6 GHz diapazona uztveršanas sistēmu, kas uzbūvēta no *Mini Circuits Ltd* rūpnieciski ražotiem augstfrekvences blokiem un RT-32 sekundārajā fokusā izvietota četru spirālveida antenu režģa. Izveidotais uztveršanas komplekss ir veiksmīgi izmantots daudzelemetu interferometra eksperimentos, kuros iegūta pārliecinoša interferometriskā reakcija no visiem novērotajiem satelītiem.