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Near Earth Objects: observations with VIRAC radiotelescopes in VLBI mode

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1. Introduction

Large amount of Near Earth Objects (NEO, including asteorids and space debris, especially near the geostationary orbit, has to be monitored for space mission planning. Almost all sizes of NEO are dangerous to satellites. The small objects with a 1 mm diameter could damage commercial satellite sub-systems, object with a 1 cm diameter could disable satellite systems, while NEO with 10 cm diameters could cause catastrophic break-ups [1].

1.1 VLBI methods

The method of Very Long Baseline Interferometry (VLBI), one of the most powerful instruments used in radio astronomy, allows to get high accuracy determination of coordinates of radios sources. Since 1980-th VLBI method is successfully applied for angular coordinates determination of artificial Earth satellites and interplanetary space stations with the precision 0.01-0.03 arc.sec in single measurements. A promising field in coordinate research proves to be combination of VLBI with range measurements method, such as r-VLBI, laser ranging, telemtric mode and so on.

The rVLBI has been successfully used during the last decades for NEO tracking. By the exploitation of several distant receiver stations of reflected radar signal, the rVLBI has a potential for very high accuracy. Theoretically, rVLBI may even yield all the motion parameters required for a formulation of a Newtonian orbital solution in a single measurement. However, this is not a case yet. One of main limiting factors is the lack of reliable data processing methods and corresponding software.

1.2 Instruments

Since 2011 Ventspils International Radio Astronomy Centre has been involved in the large scale infrastructure project which allowed significant speeding-up of the upgrading activities related to radio telescopes RT-32 and RT-16 as to its fitting with appropriate VLBI receiving and recording equipment. Radio telescopes were instrumented with new state-of-art broadband cryogenic receivers for frequency range of 4.5 – 8.8 GHz developed and installed by company “Tecnologias de

The receiver is formed by a cooled RF subsystem and a room temperature IF subsystem. The RF and IF subsystems are designed to process two C/X band signals (LCP & RCP) in parallel. Normally, during observations, the measured vacuum level in the receivers dewar is from 10^{-6} to 10^{-8} mbar and the temperature inside dewar is at level of 14 K at second stage, 20 K at polarizer and 46 K at the first stage.

Since October 2015 radio telescope RT-32 with new receiver system took part in several successful international VLBI sessions. During preparation for VLBI observations preliminary aperture efficiency, system temperature and beam pattern measurements were carried out to evaluate RT-32 performance after the station’s renovation that besides the receiver also included repairing of the main reflector. Performance parameters were derived with the help of switching noise diode and “on-off” observations of calibration sources with known flux density at various elevations [2].

1.3 Data processing methods

The typical rVLBI (and VLBI) data processing is performed in a few major steps. The first, so called “correlation” step with high computational complexity acts on the raw sampled signals from the pairs of VLBI stations, yielding signal interference functions, so called “fringe

function" (FF) and basic parameters (delays) needed for fringe function construction. The spectral characteristics of FF with the corresponding delays are used in the second step of data processing, which ultimately leads to the measured physical parameters of observed object, such as angular positions, velocities, etc. Due to NEO closeness to the Earth and its fast motion on the sky the standard routines for wave front path corrections in the data processor (correlator) has to be reworked. To achieve that, the existing methods for time and frequency delay compensations are reviewed and additional time-frequency analysis, such as extended short time Fourier transforms, specific data windows and Wavelet analysis are applied to the data for fractional step compensations in the correlation integral constructions.

1.4 Previous knowledge

An international VLBI experiment on radio location of the asteroid 2012 DA14 was organized on 2013 February 15-16, during its flyby close to Earth. The purpose of observations was to investigate and specify orbital parameters of the asteroid, as well as to evaluate its rotation period and other characteristics. The asteroid was irradiated by the 5010.024 MHz frequency signal (radar RT-70, Evpatoria, Ukraine), whereas the echo signals were received by the radio telescopes RT-32 in Irbene (Ventspils, Latvia) and Medicina (Italy) in VLBI regime. A series of observations was implemented for different distances between the Earth and the asteroid (from 30000 km to 250000 km). The reflected signals were successfully received by the both VLBI-stations. Processing of the recorded signals allowed of measuring the Doppler frequency and interference frequency in order to improve the calculation of the radial and angular velocity of the asteroid. Processing and interpretation of the data were performed both in the Radiophysical Research Institute and in the Ventspils International Radio Astronomy Center [1].

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