NVS-01 signal and clock analysis

by Peter Steigenberger, Jean-Marie Sleewaegen, Oliver Montenbruck

NVS-01 is the first 2nd-generation satellite of the Indian Navigation Satellite System (IRNSS) also known as NavIC (Navigation with Indian Constellation). It was launched into geostationary orbit on May 20, 2023. The satellite is placed at 129.6° eastern longitude and will finally replace IRNSS-1G launched in April 2016

Whereas the 1st-generation satellites transmit navigation signals in the L5- and S-band, NVS-01 is the first IRNSS satellite also transmitting in the L1-band. The 1547.42 MHz frequency is also used by other satellite navigation systems, including GPS, Galileo, and BeiDou-3. However, a different modulation is used, namely a Synthesized Binary Offset Carrier (SBOC) signal. The IRNSS L1 SBOC signal has data and pilot components with and without navigation data. Data and pilot signals consist of BOC(1,1) and BOC(6,1) components with sub-frequencies of 1.023 and 6.138 MHz. A quadrature multiplexing is applied for the data and pilot components with a power sharing of 41.82 and 58.18 %. The IRNSS L1 signal has a different structure of the navigation message compared to the legacy L5- and S-band signals. The new L1 navigation message uses an advanced frame structure and forward error correction inherited from the CNAV-2 message of the GPS/QZSS L1C signal as well as a similar orbit model. Amongst others, it provides inter-signal corrections for the L1 data and pilot signals w.r.t. the S band signal for single-frequency L1 band users.

NVS-01 started signal transmission on June 17, 2023, with the pseudo-random noise (PRN) code I10. L1 and L5 signals of NVS-01 were tracked by a Septentrio PolaRx5 receiver located in Tokyo, Japan, with a prototype firmware that is capable of tracking the L1 pilot signal. Figure 1 shows the multipath linear combination of the L1 and L5 pilot signals of NVS-01. Whereas the short-term variations are smaller for L1 compared to L5, the overall RMS is 18 cm for both signals.

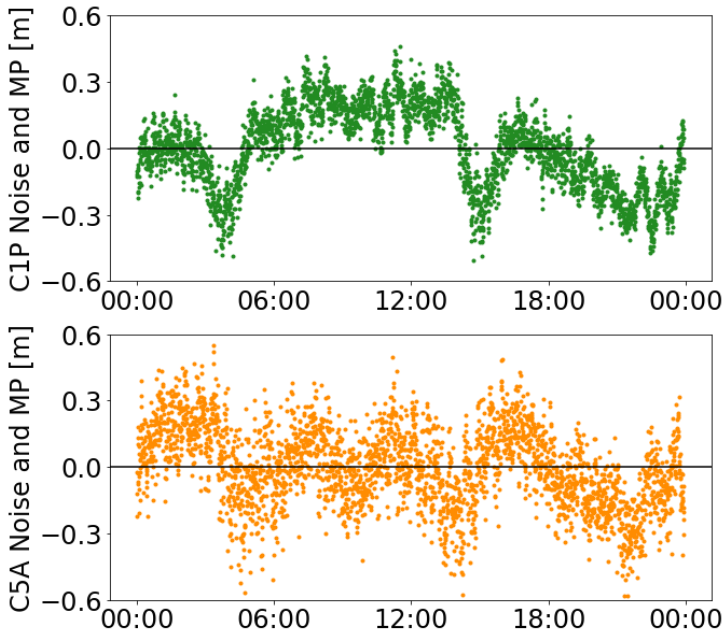

Figure 1: Noise- and multipath linear combination for the L1 and L5 pilot signals of NVS-01 received on 26 June 2023.

Whereas the Rubidium clocks of IRNSS-1 were provided by Spectratime, NVS-01 is the first satellite operating a new type of Rubidium atomic frequency standard (RAFS) developed in India. The short-term performance of GNSS satellite clocks can be evaluated with the one-way carrier phase method. The receiver is connected to a highly stable external clock, e.g., a Hydrogen maser. Thus, the receiver clock error is negligible. Measurement biases as well as the delays of ionosphere and troposphere on short time scales are removed by fitting a 4th-order polynomial. If no external clock is available, like for the station in Tokyo, the precise clock information can be transferred from another station by a reference satellite jointly tracked by both receivers.

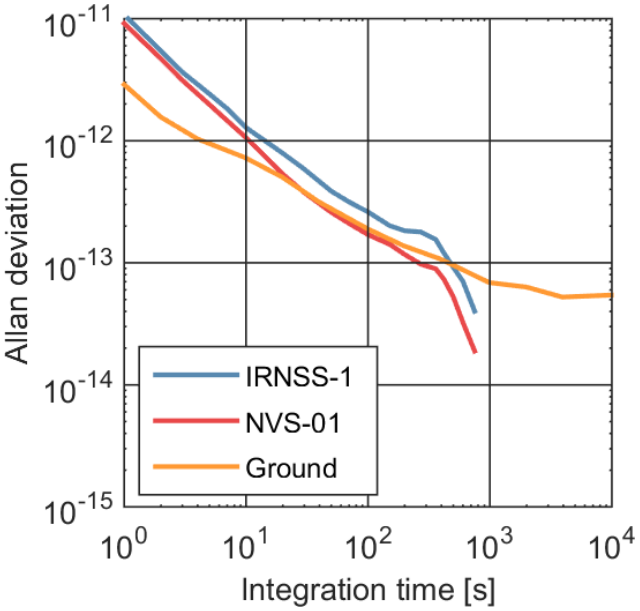

Figure 2: IRNSS clock performance obtained from three-way carrier phase analysis as well as ground tests.

The Allan deviation based on this three-way carrier phase (TWCP) analysis is shown in Fig. 2. The hydrogen maser of the IGS station USUD in Usuda, Japan, is used as reference clock. At short integration times up to 20 s, the Allan deviation computed from the TWCP analysis is dominated by the GNSS measurement noise hiding the true clock performance. Above 20 s, the TWCP demonstrates that the NVS-01 RAFS stability meets the performance of the ground tests and even exceeds them for longer integration times. At all integration times, the new RAFS outperforms the 1st generation IRNSS clocks.

Manufacturers

GNSS data used in this article were collected with a Septentrio (www.septentrio.com) PolaRx5 receiver.

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Further Reading

Bandi TN, Arora R (2019) Indigenous Atomic Clock and Monitoring Unit for NavIC. ICG-14, https://www.unoosa.org/documents/pdf/icg/2019/icg14/WGD/icg14_wgd_09.pdf

ISRO (2022) NavIC Signal in Space ICD for Standard Positioning Service in L1 Frequency, Version 1.0. U.R. RAO Satellite Centre, Indian Space Research Organization, Bangalore, https://www.isro.gov.in/media_isro/pdf/SateliteNavigation/Draft_NavIC_SPS_ICD_L1_Oct_2022.pdf

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