Precise Time and frequency dissemination to Indian Deep Space Network from NavIC PTF

Aakanksha Avnish Bhardwajan*, Anu Arora, Suresh Dakkumalla, Farhana Ahmed and T Subramanya Ganesh
ISRO Telemetry Tracking and Command Network, Peenya, Bangalore-560058

Abstract

ISTRAC's Indian Deep Space Network (IDSN) provides telemetry, tracking and command services for inter-planetary missions. IDSN requires a precise reference with frequency stabilities of that of atomic clocks in order to make precise measurements.
An elaborate dissemination network was designed and realized to provide precise time and frequency to IDSN, co-located with NavIC Precise Timing Facility (PTF), via copper RF cables. The design ensures that there are no single point failures. This paper dwells on the challenges in realization of the dissemination network and the finally realized architecture of the network.

1 Introduction

ISRO operates a wide network of ground stations which provide Telemetry, Tracking and command services for earth observation satellites. Additionally, Indian Deep Space Network (IDSN) consists of a 32-m diameter and an 18-m antenna, which create a two-way communication link that guides and controls ISRO's inter-planetary probes (such as Chandrayan-1, Mars Orbiter Mission and the most recent, Chandrayan-2), and receives the images and scientific information from these missions. These ground stations require precise time and frequency signals for making precise range measurements to the spacecraft.
Precise Timing Facility, located at the control center of Navigation with Indian Constellation (NavIC), generates precise time and frequency using an ensemble of atomic clocks. This time is traceable to UTC (NPLI) on Indian Standard Time with an accuracy of 40 ns (2σ). Accurate and stable outputs of NavIC PTF satisfy the timekeeping requirements of IDSN. A copper RF cable based dissemination network was planned to provide time and frequency signals from NavIC PTF to IDSN since the phase noise performance required cannot be achieved through satellite based time transfer. [1]

2 Requirements of IDSN

IDSN requires precise and accurate time and frequency signals as reference input to their ranging modems. The requirements are tabulated in Table 1.

Table 1. Requirements of IDSN

Signal Type	Specifications
5/10/100 MHz	ADEV @1s: <=5e-12 Amplitude: 0±3 dBm
IRIG-B 120	1 kHz AM; 6 Vp-p
1 Pulse per second	TTL Level, Delay compensated at the user site
Network Timing Protocol (NTP)	Accuracy of ±100 ms

The design of the network was carried out keeping in view the above requirements.

3 Challenges in the design of time and frequency dissemination network

Since IDSN and NavIC PTF are co-located, at first, an optical fiber based solution was considered [2]. Optical fibers with the necessary end equipments consisting of source and terminators were deployed. However, due to the lower phase noise specifications of the source and terminator devices, the signal received at the IDSN site was degraded in short term frequency stability. Figure 1 and 2 depict the Frequency stability of Active Hydrogen Maser (AHM) received through copper and optical fiber links, respectively.

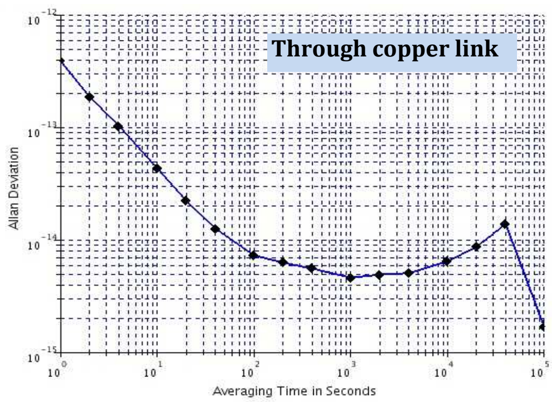

Figure 1. Stability of Maser signal received through copper link; ADEV at 1 second is 7e-13

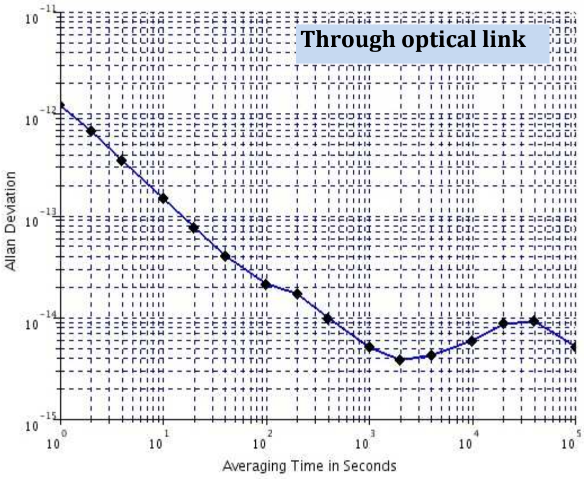

Figure 2. Stability of Maser signal received through optical fiber link; ADEV at 1 second is 8e-12

Hence, a copper RF cable-based solution was considered for the dissemination network. However, this solution too had its own share of challenges, namely the following:

a. There was a ground potential difference between the PTF site and the IDSN site. This made the copper links and the associated equipment in the chain vulnerable to lightening effects. This was resolved by including Baluns in the chain.

b. The distance between the two sites was almost 500 meters and hence, it was essential to ensure that signal reaching IDSN has sufficient power level. This requirement was sufficed by selecting very low loss RF cables with not more than 1 dB/100 m.

c. Because of the long distances involved, it was essential to calibrate the network and adjust the 1 PPS received at the end site. All the cables and the equipment involved were precisely calibrated using Time Interval counter before the installation. This delay was compensated at the end site using a 1-PPS regenerator.

4 Architecture of the dissemination network

The architecture of the time and frequency dissemination was designed to cater to all the requirements tabulated in Table 1 and considering the challenges in the implementation as described in section above. Apart from these design considerations, one of the most important design aspects was to ensure there are no single point failures. The signal flow was designed in such a way that there was no loss of frequency or time to the IDSN even in case of failure of one chain of timescales at the PTF. Figure 3 depicts the final architecture of the network.

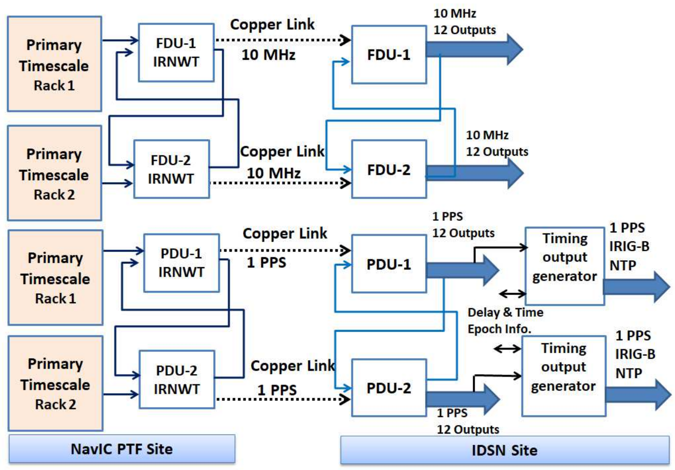

Figure 3. Architecture of Time and frequency dissemination network

As can be seen from Figure 3, adequate redundancy has been built into the architecture at each site.

5 Performance of the realized network

The performance of the network was assessed in terms of the frequency stability and the phase noise of the frequency signal received at IDSN. Figure 4 below shows the phase noise of 10 MHz signal at 18 m diameter IDSN terminal. The phase noise at 1 Hz offset is recorded as -120 dBc/Hz.

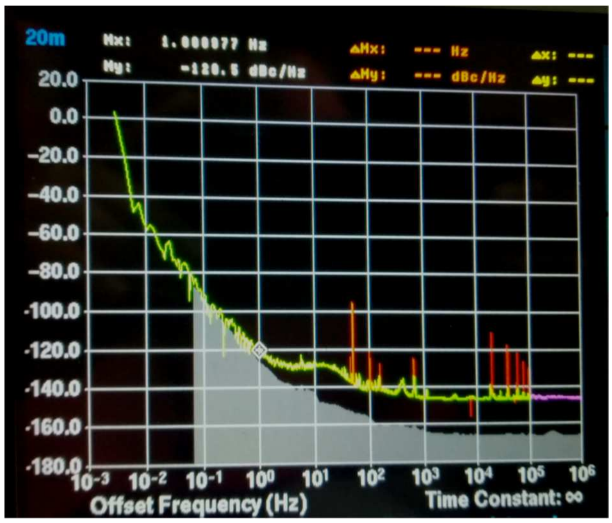

Figure 4. Phase noise of 10 MHz signal at IDSN

The frequency stability of 10 MHz is tabulated in Table 2 below.

Table 2. Frequency stability of 10 MHz signal observed at IDSN

Averaging Time (s)	Allan Deviation of 10 MHz signal
1	8e-13
10	4e-13
100	2e-13
1000	3e-14
10000	4e-15

6 References

1 Matsakis, Demetrios N., Senior, Ken, Breakiron, Lee A., "Analysis Noise, Short-Baseline Time Transfer, and Along-Baseline GPS Carrier-Phase Frequency Scale," Proceedings of the 31st Annual Precise Time and Time Interval Systems and Applications Meeting, Dana Point, California, December 1999, pp. 491-504

2 Per Olof Hedekvist and Sven-Christian Ebenhag (2012). Time and Frequency Transfer in Optical Fibers, Recent Progress in Optical Fiber Research, Dr Moh. Yasin (Ed.), ISBN: 978-953-307-823-6, InTech, Available from: http://www.intechopen.com/books/recent-progress-in-optical-fiber-research/time-and-frequency-transferin-optical-fibers