CAST — Center for Alternative — Synchronization and Timing

Technical Bulletin #008

Summary: Two-way satellite time and frequency transfer (TWSTFT) has been a trusted time transfer and synchronization method for a long time. It provides good timing accuracy, usually 100 ns or less.

Introduction

This technical bulletin is to explain the setup and configuration of two-way satellite time and frequency transfer (TWSTFT) network. Using TWSTFT in your synchronization architecture supports wide area synchronization geo redundancy of your master nodes when fiber optic communications is not available. Within this document we will describe the setup, planning and lessons learned.

Planning

Planning should start well in advance installing and mounting a 2.5 m dish. Calculating the initial dish position [1] allowed the Idaho National Laboratory (INL) team to put the dish on the roof at the approximate azimuth and elevation, thus saving valuable time as shown in Figure 1.

Creating an Oak Ridge National Laboratory (ORNL)/INL topology drawing early in the process allowed INL to set up the rack and connect the receive (RX) and transmit (TX) coaxial cable to and from the antenna. This step reduced the time required in the dish orientation process.

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Figure 1. Aerial image showing initial azimuth and elevation.

Pointing the Dish to the Geostationary Satellite

The 2.4 m offset reflector is designed with a 17.35° elevation offset angle. Therefore, when the reflector aperture is perpendicular to the ground, the antenna elevation angle to the horizontal is 17.35° as shown in Figure 2.

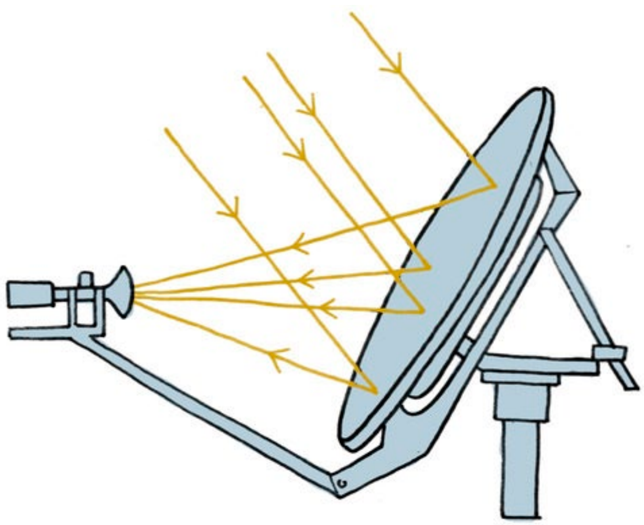

Figure 2. Signal path.

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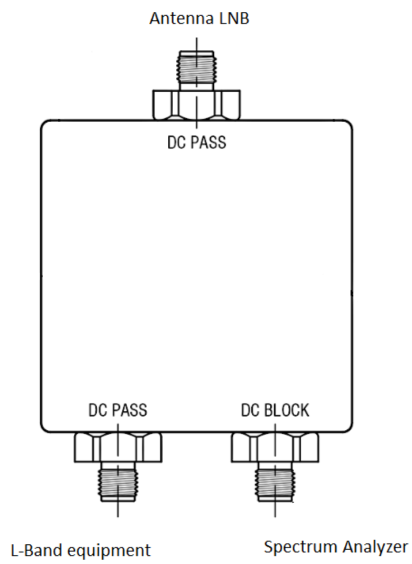

Figure 3. Splitter to connect the spectrum analyzer.

Initial alignment procedure:

1) Place an inclinometer on the reflector.
2) Raise or lower the antenna to find the desired elevation by turning the 1 in. nuts located at the elevation block.
3) After the correct elevation angle is set, rotate the antenna in azimuth by loosening the canister set screws and spinning the entire reflector assembly until the satellite is located. Tighten the canister set screws securely.
4) Peak the antenna signal by adjusting elevation and azimuth until optimal signal is achieved.
5) Adjust feed horn assembly for optimum RX level.
6) Once optimal signal is obtained, tighten all the hardware used for adjustments.

If Satellite is not visible at expected azimuth an elevation, complete a box scan, as illustrated in Figure 4.

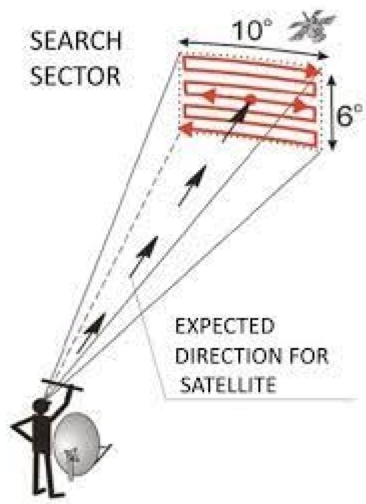

Figure 4. Box scan to search for satellite.

Below is e.g TX, RX, and Telastar info [2]
TX e.g
KU-band: 15,000 MHz
Local oscillator frequency: XX MHz
L-band at the modem: XX MHz

RX e.g
KU-band: 12000 MHz
Local oscillatory frequency: XX MHz
L-band at the modem: XX MHz

Target Eb/N0: 10-17

Telstar 15R
Position: 65° W

e.g, Boulder, CO
Azimuth: 125°
Elevation: 26.27° − 17.35° = 8.92°
Feed horn: −38.49°

Figure 5 shows final orientation azimuth and elevation of the dish.

Figure 5. Final orientation azimuth and elevation for the 2.4 m KU-band dish.

Hardware Setup

The following hardware was used to set up the TWSTFT:

- ATS 6102 L-band ground terminal
  - Receives comms signal from the dish.
- ATS 6502-time transfer modem
  - Enables timing signal to be distributed to multiple sites.
- Global Navigation Satellite System (GNSS) antenna
  - Receives 1 pulse per second (PPS) signal from GNSS
- 5071A cesium clock
  - Provides a stable 10 MHz frequency for timing.
- ATS 6580A TFLEX

    - Ingests 1 PPS from GNSS and the 10 MHz frequency from the cesium clock and distributes it to the grandmaster clock.
- TP4100 time provider (primary time transmitter)
    - Primary timing source.
- TP4100 time provider (secondary time transmitter)
    - Secondary timing source is a backup for redundancy.
- TP4100 time translator (time receiver)
    - Edge timing device. This clock will be the time receiver for the time transmitter at INL over a terrestrial ESNet fiber circuit.

Figure 6 shows the complete wiring diagram and Figure 7 shows the hardware.

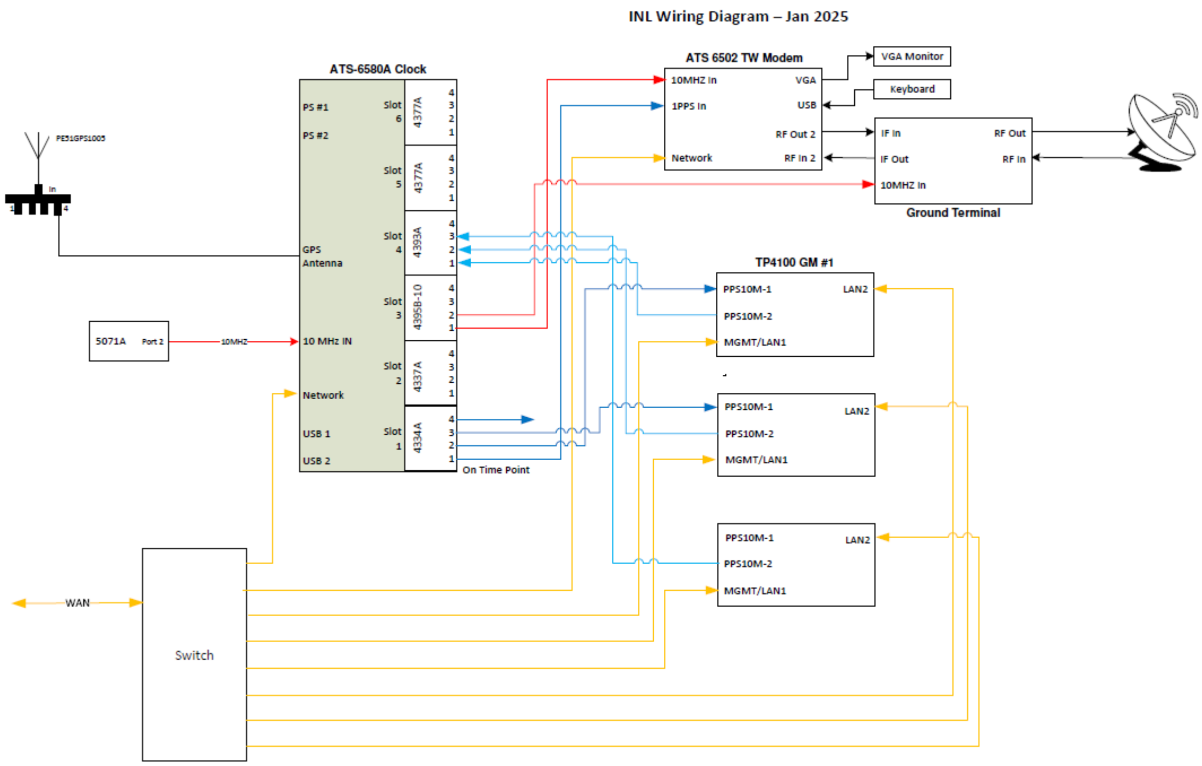

Figure 6. TWSTFT wiring diagram

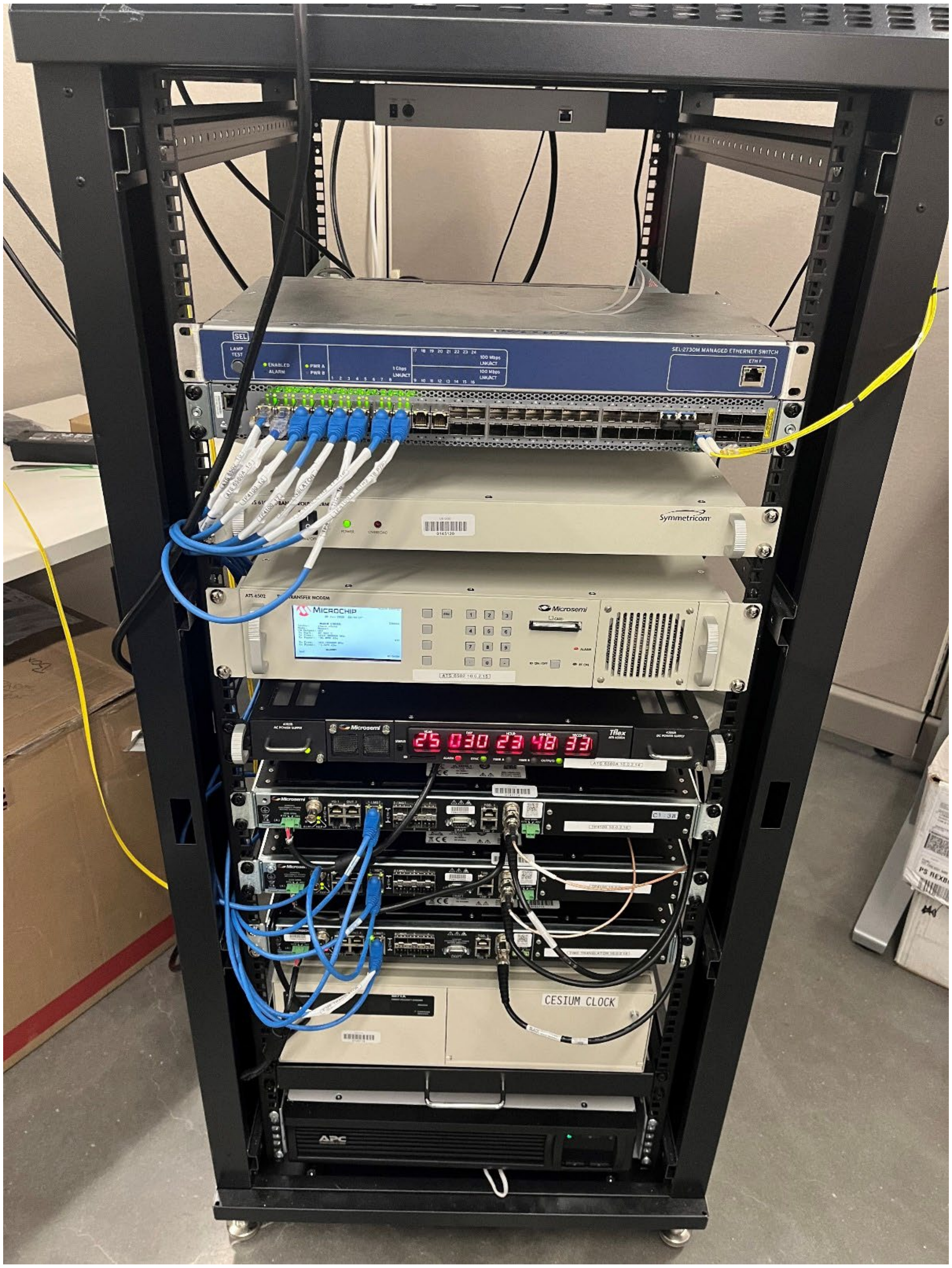

Figure 7. INL rack setup with all necessary hardware.

Hardware Configurations

All hardware was configured on-site to establish the link between ORNL and INL. For future installations, any hardware should be preconfigured and checked before the target date of installation.

Following is a summary of the configurations done at site:

1. Set up the ATS 6580A to use an external reference and monitor the 5071A.
   a. Connected Port 2 On the 5071A to the 10MHz input on the 6580A.
   b. Set the reference type to cesium because the 5071A is unmonitored.

2. Set the 6580A position mode to auto to start an auto survey.
   a. Position was manual and set to other location Restarted the ATS 6580A application.
   b. ATS 6580A started tracking and collecting the Receiver-Independent Exchange Format (RINEX) data

3. Set the ATS 6580A IP address for the LAN and documented the settings.
   a. IP = 11.1.1.11
   b. Class C mask
   c. BC = 11.1.1.12
   d. GW = 255.255.255.X

4. Set Slot 1 4334A to PPS outputs on all four ports.
   a. pps 1 all 1 1 $\times 10^{-4}$

5. Pulled down the RINEX file and post-processed via OPUS.
   a. Fixed the antenna position to the corrected surveyed position.

6. ATS 6580 version 1.2.6 software was updated to version 1.3.5.
   a. Pulled down the default file as a backup after configuration
   b. Disconnected the 4393A card from the 6580A because the TT PPS10M-2 signal output was causing issues
   c. Set up the Time Translator (TT) PPS10M-1 for a 1 PPS output.

7. Changes to the ATS 6502.
   a. Added a 1 PPS, 10 MHz reference cable from the ATS 6580A to the ATS 6502
   b. Set the ATS 6580A IP address for the LAN and documented the settings
      i. IP = 11.1.1.13
      ii. Class C mask
      iii. BC = 11.1.1.14
      iv. GW = 255.255.255.X
   c. Set the 6502 to use the 6580A as the NTP server (TOD source) PPS cable delay of 4 ns
   d. Update the leapsecond file on the 6502 using the leapsecond file from the 6580A

e. Set up TX/RX settings
f. TX PRN and Station ID = XX
g. Set up RX channels for ORNL, National Institute of Standards and Technology (NIST), Microchip-Boulder and loopback from INL
h. Cleaned the air filter
i. Came on the air and adjusted power levels across the network
j. Pulled down the default file from the 6502 after the system configuration was complete
k. Set up a VGA monitor in the rack to allow local operators to monitor the TW links

8. Configured PTP hardware
    a. Management port network settings
        i. GM 1= 11.1.1.11
        ii. GM 2= 11.1.1.11
        iii. TT= 11.1.1.12
        iv. Class C mask
        v. BC = 11.1.1.13
        vi. GW = 255.255.225.X
        vii. Firewall: enabled SSH and HTTPS
    b. Updated GM1 and GM2 from 2.0.5.2 to 2.4.16
    c. Added the NTP/PPS reference licenses to GM1 and GM2
    d. Set up GM1 and GM2
        i. Set up the NTP client to point to the 6580
        ii. Set up PPS10M-1 to use the PPS input as the reference
        iii. Set up PPS10M-2 as a PPS output for measurements and connected these ports to the TIC card on the 6580A
    e. Eth2 on GM1 and GM2 had the 8275.1 (Index 3), clock domain = 25
    f. Eth2 on the TT had 8275.1 (Index 9) using domain 25
    g. Locked the GMS and TT

Verification of TWSTFT Link

To verify the TWSTFT link between ORNL and INL, INL channel 1 was added to the dashboard and plotted against the NIST link. NIST then checked INL PRN50, thereby confirming successful TWSTFT link between ORNL and INL as shown in Figure 8.

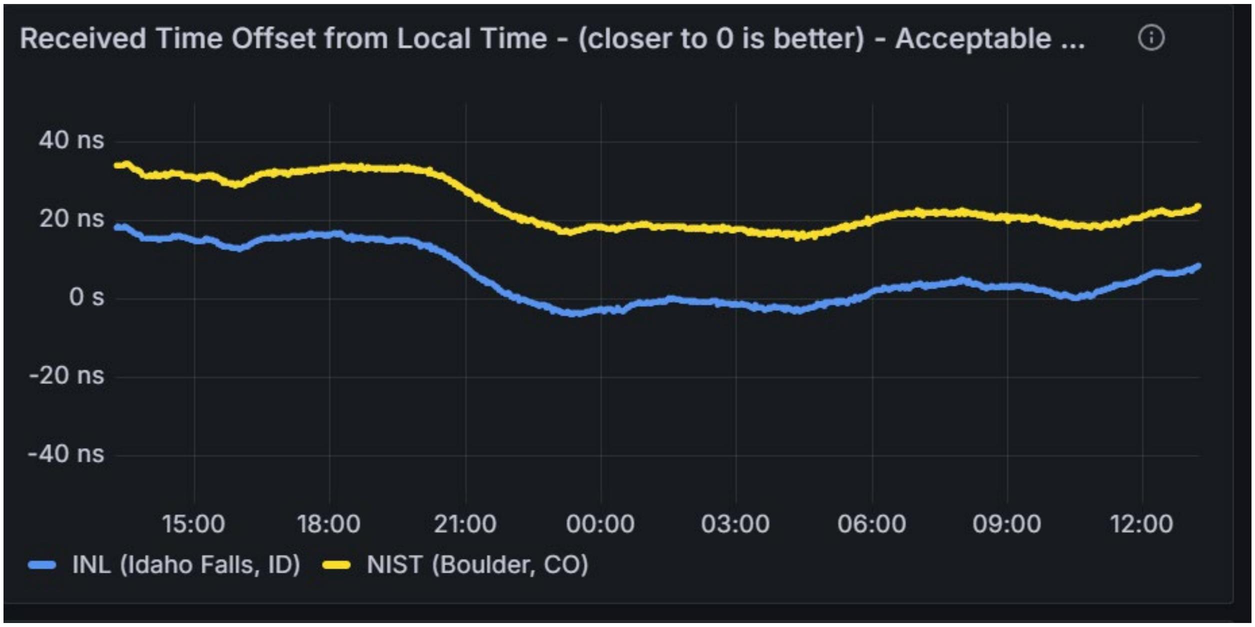

Figure 8. TWSTFT INL time offset compared to NIST.

Conclusion

Setup of TWSTFT requires careful planning and good communication among all team members, from facility manager to engineers. This bulletin provides guidance and lessons learned to help the industry have successful and smooth TWSTFT setup.

References

1- https://www.dishpointer.com/
2- https://in-the-sky.org/spacecraft.php?id=37602

The Center for Alternative Synchronization and Timing (CAST) at Oak Ridge National Laboratory (ORNL) performs research, development, testing, evaluation, and technical assistance to enable resilient timing and synchronization for the power grid. Working closely with power utilities, timing hardware and software vendors, network operators, and federal stakeholders, CAST helps develop and validate alternative timing architectures to augment GPS time. CAST also translates and transfers ORNL's research and development (R&D) advances in secure timing and grid communications to power sector applications, and engages across the broader timing community to develop best practices to ensure the resilience of US critical infrastructure. CAST is sponsored by DOE's Office of Electricity. Visit https://cast.ornl.gov for more information.