**DSES Detects Tianwen-2 from Nearly 40 Million Kilometers Away**

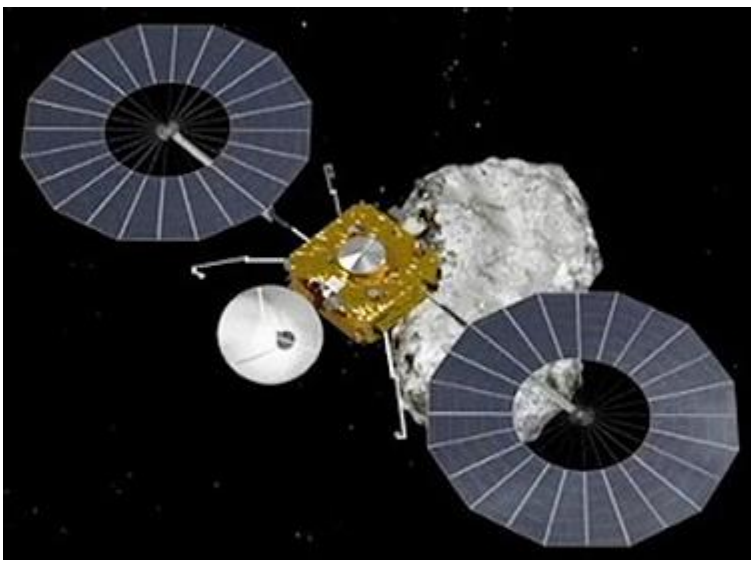
We are excited to share some great news.

On **June 6, 2026, at approximately 02:00 UTC**, the Deep Space Exploration Society successfully detected its first deep-space signals in the **8.4 GHz X-band**, despite significant logistical challenges and difficult weather conditions.

The signals were positively identified as transmissions from China's **Tianwen-2 spacecraft**.

**What is TIANWEN-2?**

*Tianwen-2 is China's ambitious deep-space asteroid sample-return and comet exploration mission. Launched on a Long March 3B rocket from the Xichang Satellite Launch Center, the spacecraft is currently on an extended 10-year journey to collect samples from the near-Earth asteroid Kamoʻoalewa and study the main-belt comet 311P/PANSTARRS.*



The Tianwen-2 spacecraft transmits its primary telemetry signal on an X-band frequency centered near **8428.19 MHz**, using **PCM/PSK/PM modulation**, a data rate of **16,384 baud**, and a **65,536 Hz subcarrier**.

**The Tracking Challenge**

One of the main challenges we encountered was obtaining accurate ephemeris data for tracking the spacecraft.

Because Tianwen-2 is a Chinese mission, spacecraft ephemeris data were not publicly available through the NASA JPL Horizons system. Reports from other observing stations suggested using the ephemeris data for the asteroid Kamoʻoalewa itself, since Tianwen-2 was approaching its target.

We would once again like to thank **Daniel Estévez, EA4GPZ**, for his detailed technical report and the information he made publicly available. His work was extremely helpful in supporting our detection effort.

**DSES Receiving System**

For the initial detection, we used **SatDump**, running directly on the DSES DCPM computer located near the antenna feed.

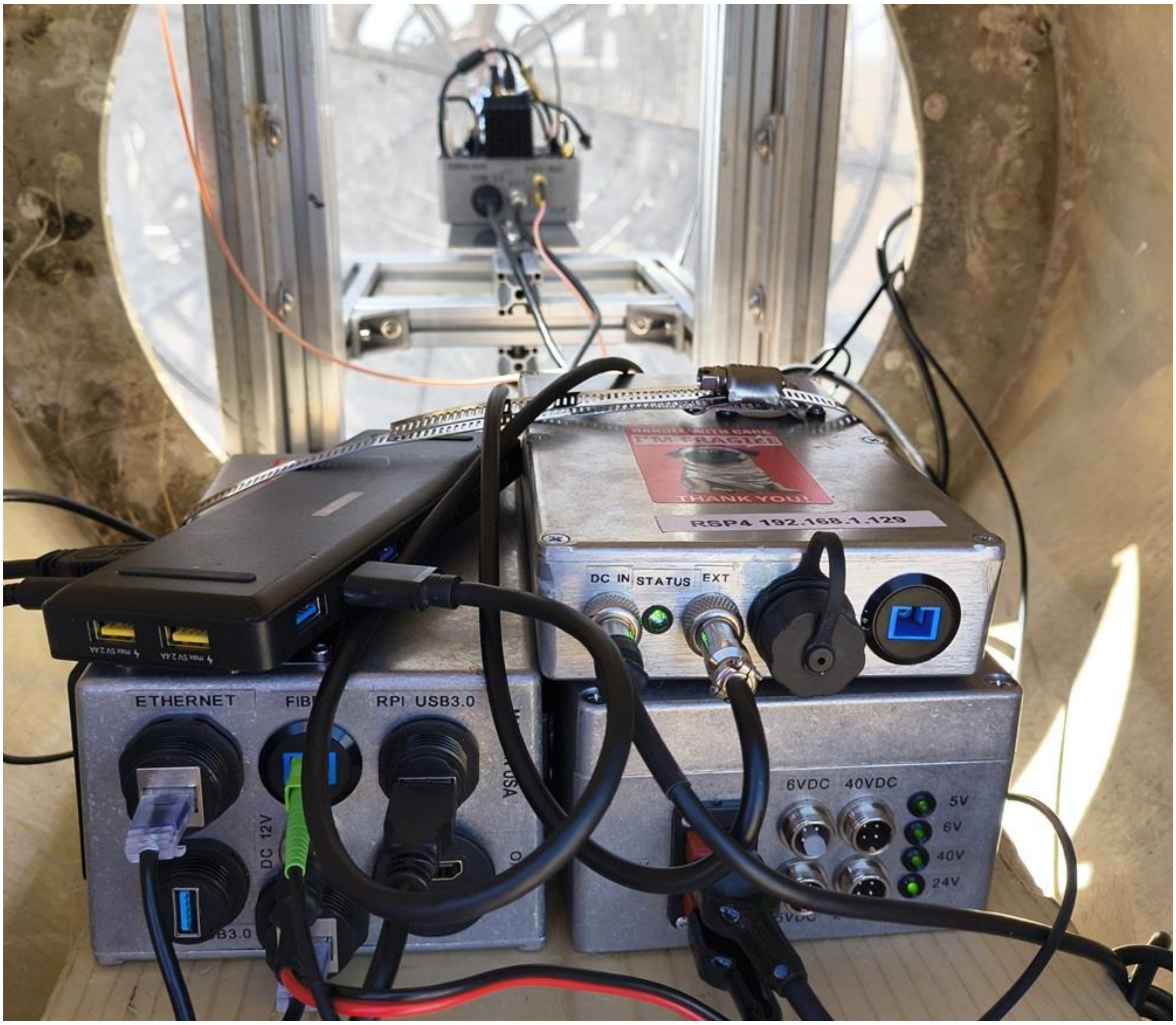
The receiving system consisted of:

- CPL septum feed, using LHCP
- Down East Microwave downconverter with a **7968 MHz local oscillator**
- Approximately **460 MHz intermediate frequency**
- AirSpy R2 SDR connected through USB 2.0
- DSES DCPM computer running Debian Linux
- SatDump graphical user interface
- Custom DSES Python-based deep-space detection software

Although most deep-space probes transmit signals intended for RHCP reception, the LHCP feed port was used during this observation.

The feed was installed on Friday using a custom-made mounting assembly fabricated by **Roger, W3MIX**. We sincerely appreciate his contribution.

The receiving equipment was installed inside the antenna hub. The complete system was controlled and monitored remotely through the DSES fiber-optic network.




**Where Was Tianwen-2?**

At the time of our observation, Tianwen-2 was in close proximity to the asteroid Kamoʻoalewa following its interplanetary cruise from Earth.

The spacecraft was approximately **0.26 astronomical units from Earth**, corresponding to roughly:

- **24.2 million miles**
- **38.9 million kilometers**

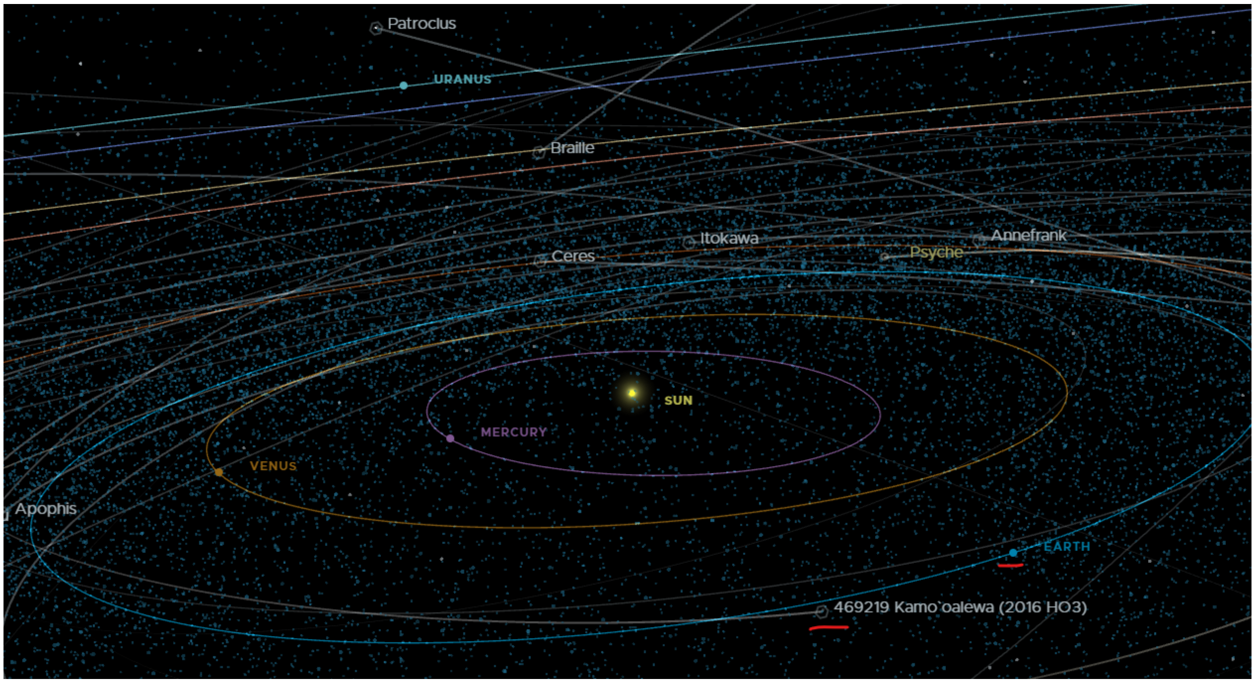
In other words, Tianwen-2 was nearly **40 million kilometers away** when its signal was detected at DSES.

**What Is Kamoʻoalewa?**

**Kamoʻoalewa** is a small near-Earth asteroid that acts as a **"quasi-satellite" of Earth**, meaning it orbits the Sun but stays very close to our planet. Discovered in 2016 by telescopes in Hawaii, this space rock is roughly the size of a Ferris wheel, measuring between 130 and 330 feet across. It spins very fast, completing a full turn every 28 minutes

For anyone interested in exploring asteroids and their trajectories, we strongly recommend visiting NASA's **Eyes on Asteroids** interactive website:

https://eyes.nasa.gov/apps/asteroids/#/home




**The Tianwen-2 Signal**

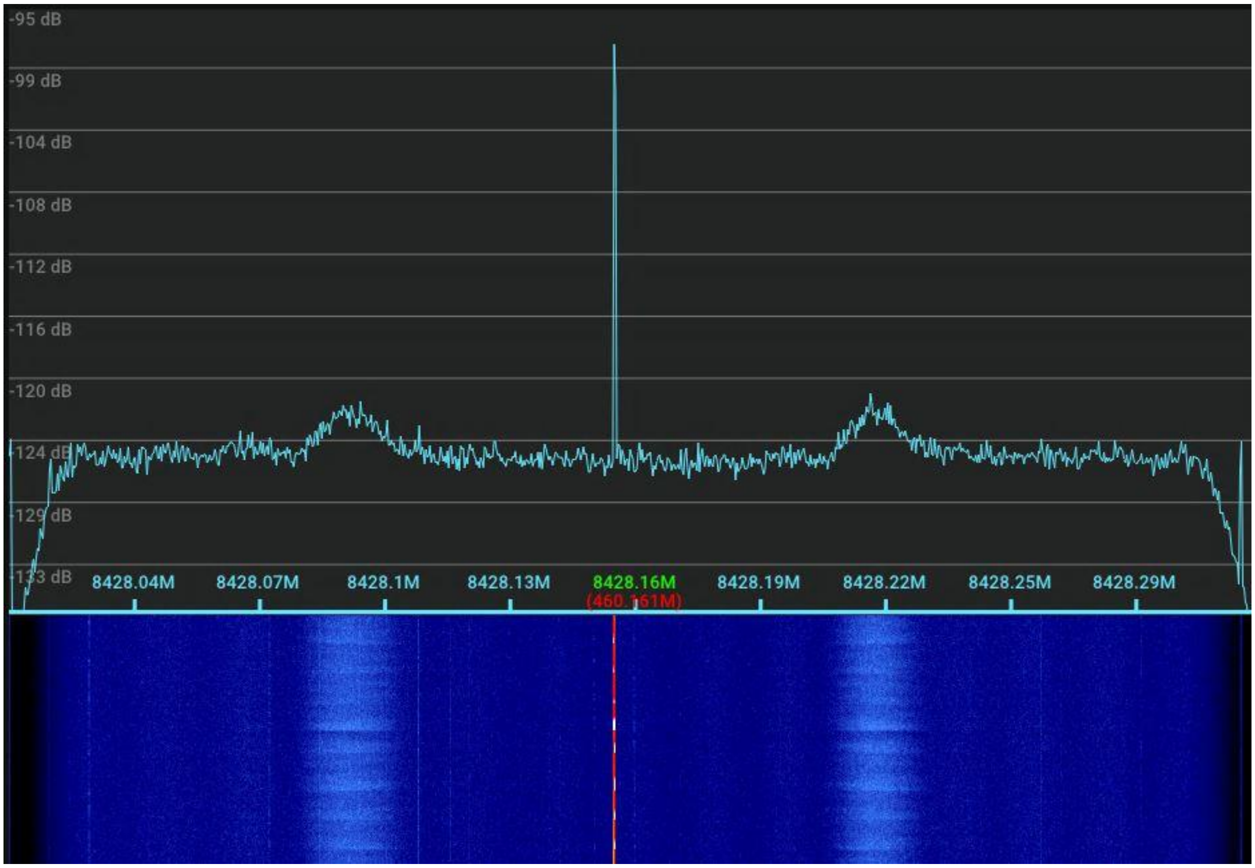
Despite the spacecraft's enormous distance from Earth, the received signal was clearly visible in the SatDump spectrum display.

During the observation, we recorded a maximum signal-to-noise ratio of approximately **30 dB above the displayed noise floor**.

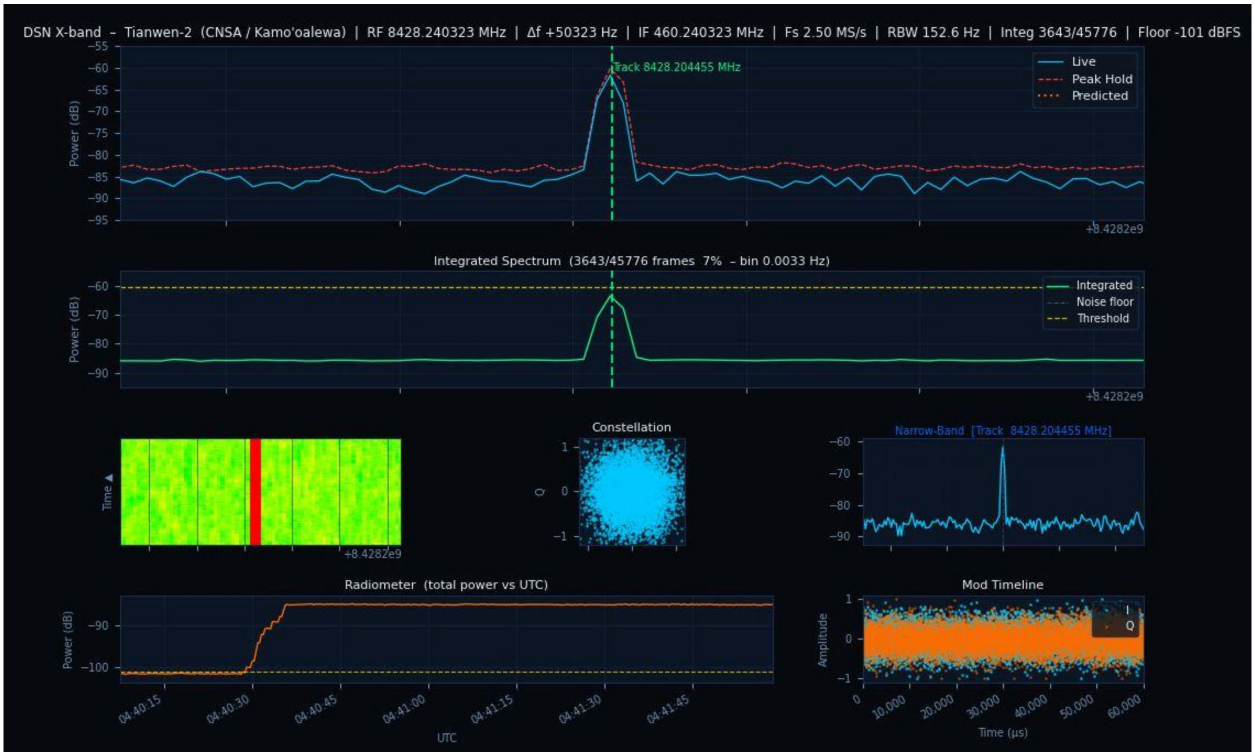
The signal was independently observed using three different software platforms:

- SatDump
- DSES custom DSN Detection software
- GQRX

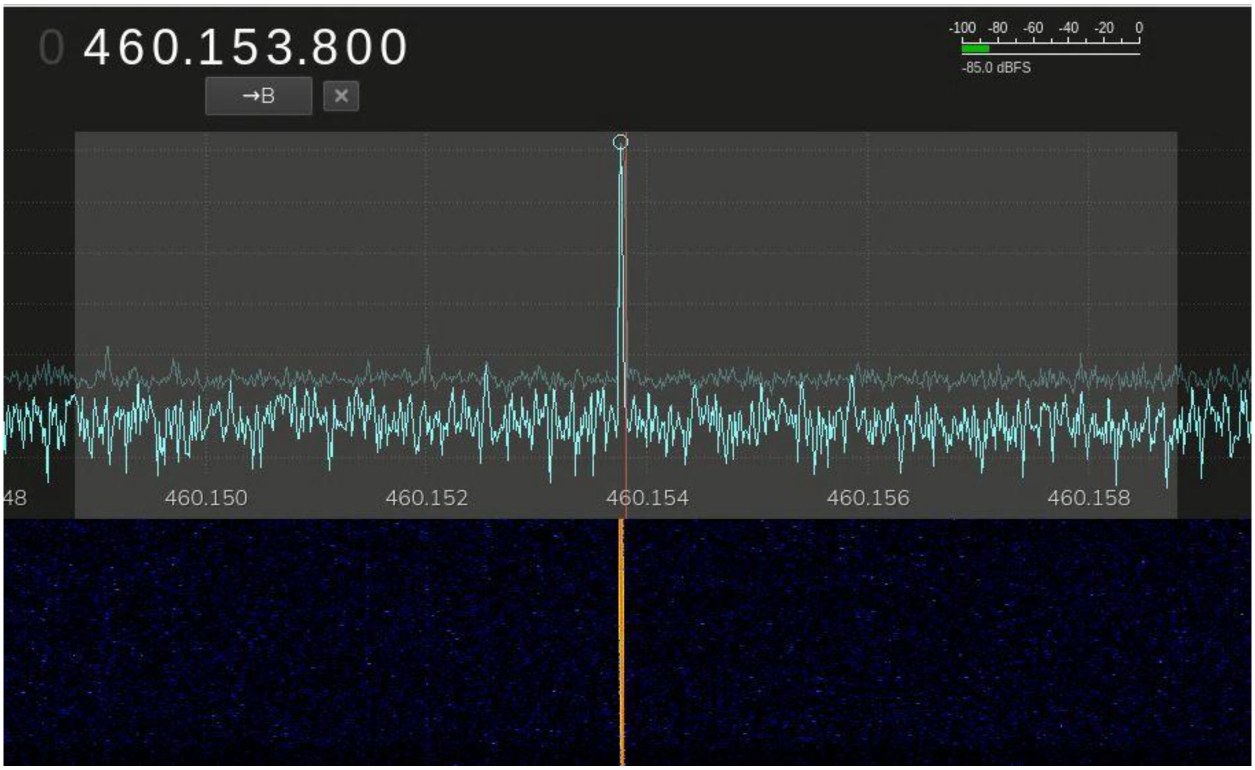
The consistent appearance of the signal across multiple receiving and analysis applications provided additional confidence in the observation.




Here is the screenshot from DSES DSN Detection software.




The same signal observed using the GQRX software.




Now let's talk about the numbers.

# Observation Report

## Tianwen-2 (CNSA / Kamo'oalewa)

2026-06-06 04:08:32 UTC

| Field | Value |
|---|---|
| Observer | Alex K6VHF / Deep Space Exploration Society |
| Observatory | K0PRT |
| Location | Lat 38.38086°N Lon -103.156369°E Elev 1341.0 m |
| UTC Offset | -06:00 |
| Report Generated | 2026-06-06 04:08:32 UTC |
| Target Probe | Tianwen-2 (CNSA / Kamo'oalewa) |
| Nominal RF | 8428.190000 MHz |
| LO Frequency | 7968.000 MHz |
| IF Center | 460.240 MHz |
| SDR Sample Rate | 1.00 MS/s |
| FFT Size | 131,072 |

## 2 Live Ephemeris (JPL Horizons)

| Parameter | Value |
|---|---|
| RA (J2000) | 11 20 09.12 |
| Dec (J2000) | +07 08 47.8 |
| Azimuth | 242.3 deg |
| Elevation | 40.4 deg |
| Horizon status | ABOVE HORIZON (El 40.4 deg) |
| Constellation | Crt |
| Range | 0.0368 AU (0.005B km) |
| Radial velocity | -2.374 km/s (approaching) |
| Doppler shift | -66752.2 Hz (-66.7522 kHz) |
| RF observed | 8428.123248 MHz |
| Rise time | 18:51 UTC |
| Transit time | 01:14 UTC |
| Set time | 07:37 UTC |
| Data source | JPL Horizons API (qty 2: RA/Dec qty 19: range+rv) |

## 4 Receiver & Observation Settings

| Parameter | Value |
|---|---|
| SDR Device | AirSpy |
| LO Frequency | 7968.000 MHz |
| IF Center | 460.240 MHz |
| Sample Rate | 1.00 MS/s |
| FFT Size | 131,072 |
| FFT Bin Width | 7.63 Hz |

## 7 Spectrum & Signal Plots

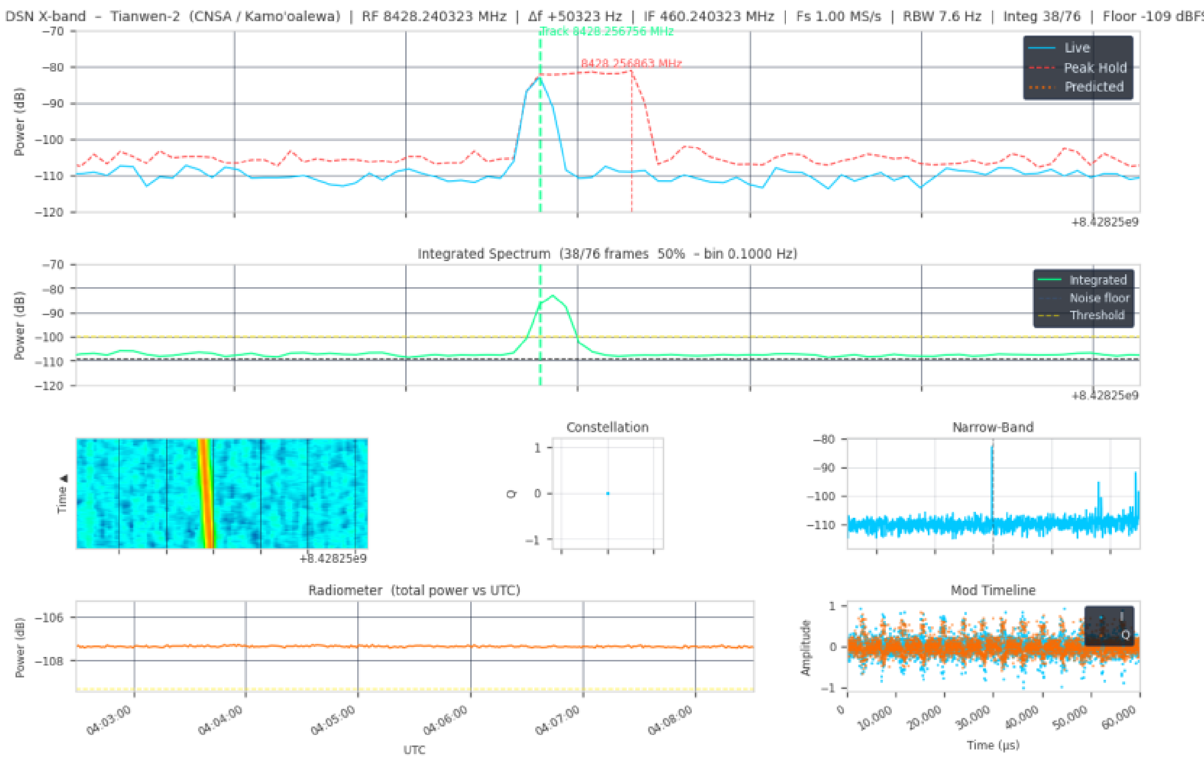



Figure 1 – Live Spectrum & Integrated Spectrum (2026-06-06 04:08:32 UTC)

### A Historic Achievement for DSES

We are extremely pleased with the results of this observation. The test also helped us identify several areas where the receiving system can be improved and upgraded for future deep-space observations.

This historic first detection of an operational deep-space spacecraft in the **8.4 GHz X-band** demonstrated DSES's ability to receive and analyze signals originating from tens of millions of kilometers away.

This achievement would not have been possible without the dedication, technical knowledge, and hard work of everyone who contributed to the effort.

**Second DSN probe detection on 8.4GHz**

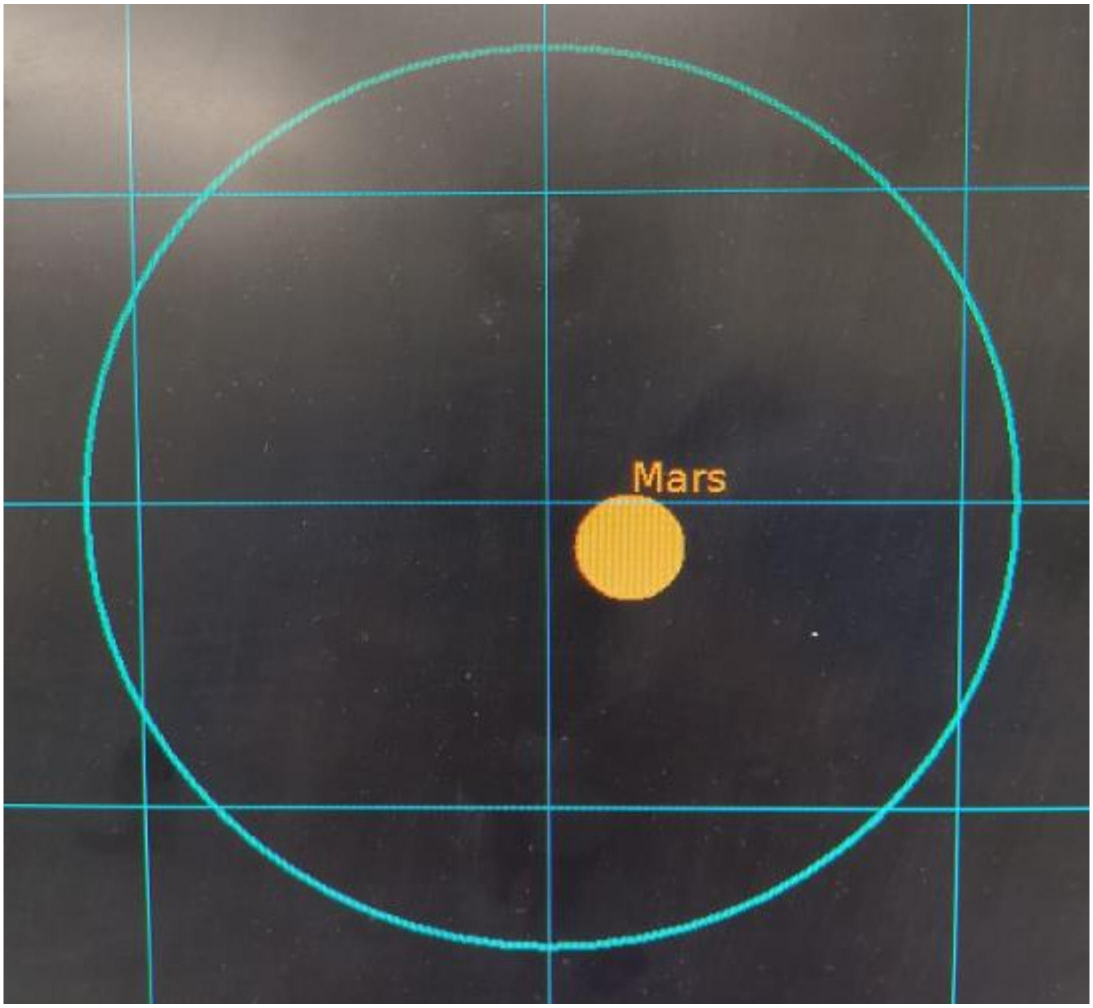
On 6/7/26 we were able to detect another DSN probe.

This time it was the Mars Reconnaissance Orbiter (MRO) about **323 million kilometers (200 million miles)** away from Earth.

The signal was easily detectable and observed on the screen. The maximum SNR was about 10dB.

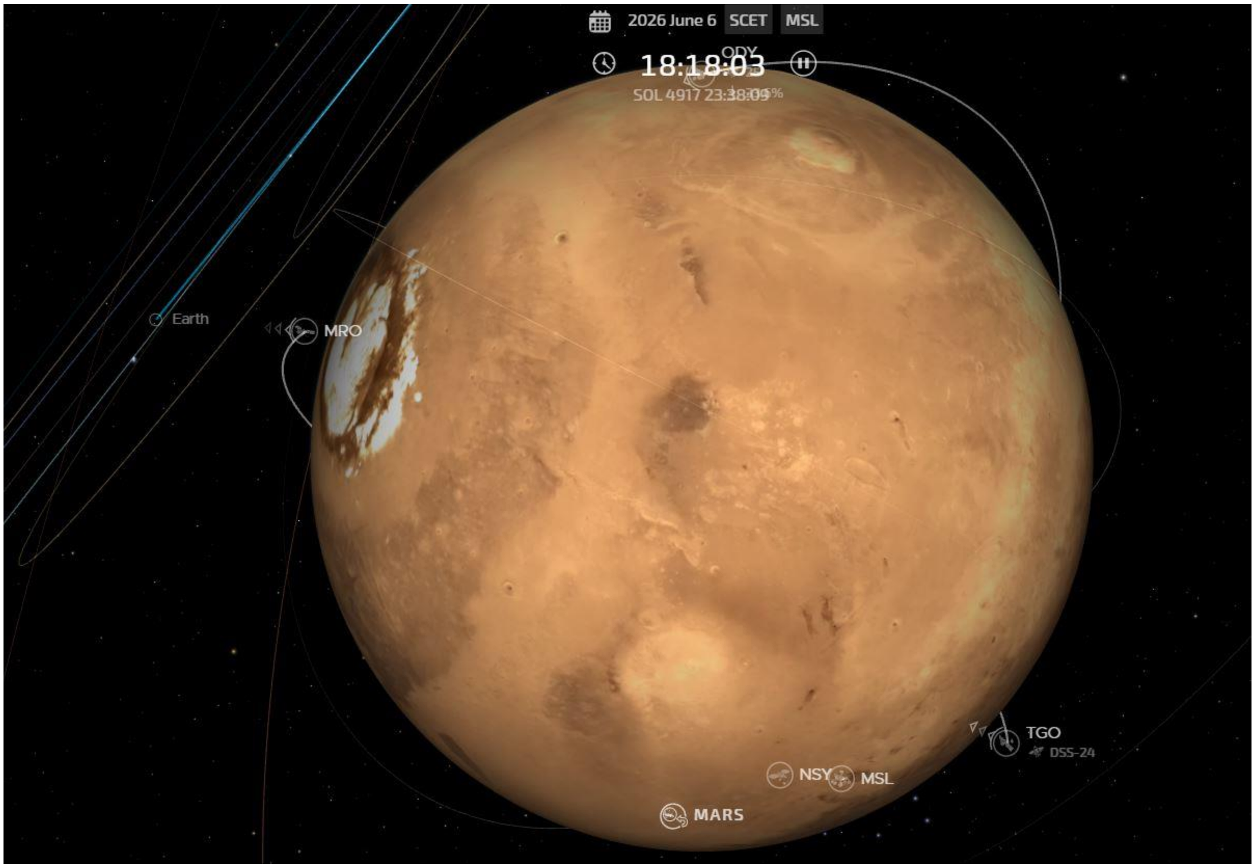
As with TIANWEN-2 probe tracking and detection we used JPL Horizons website for accurate ephemeris data.

This was the antenna position at the time of NASA MRO detection.

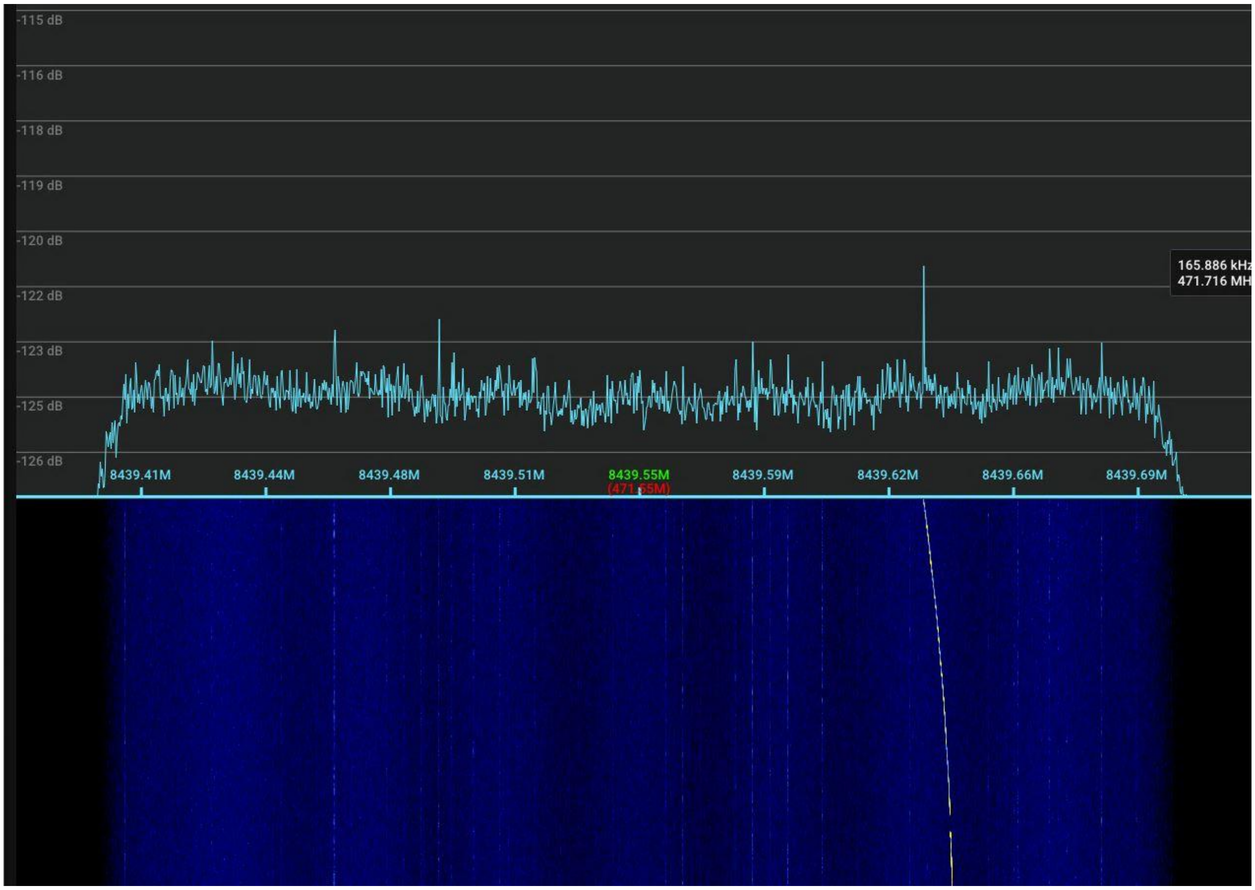


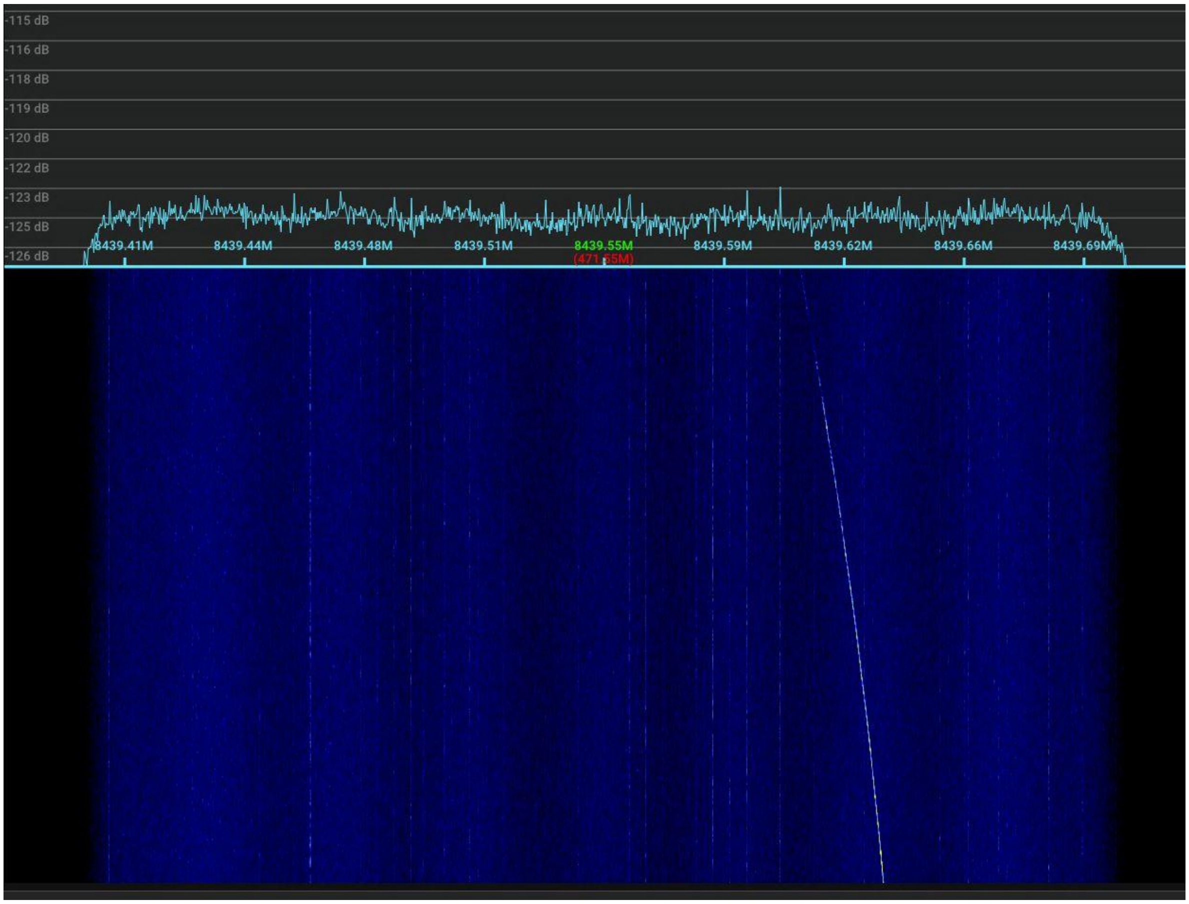

We also used a NASA Mars Relay Network Website to identify the MRO position relative to Earth.

Link https://science.nasa.gov/mars/mars-relay-network/




Here is the observer signal from MRO, We could easily see the Doppler and frequency was shifting from + and - when probe was flying towards or away from Earth orbiting the Mars.


-115 dB
-116 dB
-118 dB
-119 dB
-120 dB
-122 dB
-123 dB
-125 dB
-126 dB
165.886 kHz
471.716 MH
8439.41M
8439.44M
8439.48M
8439.51M
8439.55M
8439.59M
8439.62M
8439.66M
8439.69M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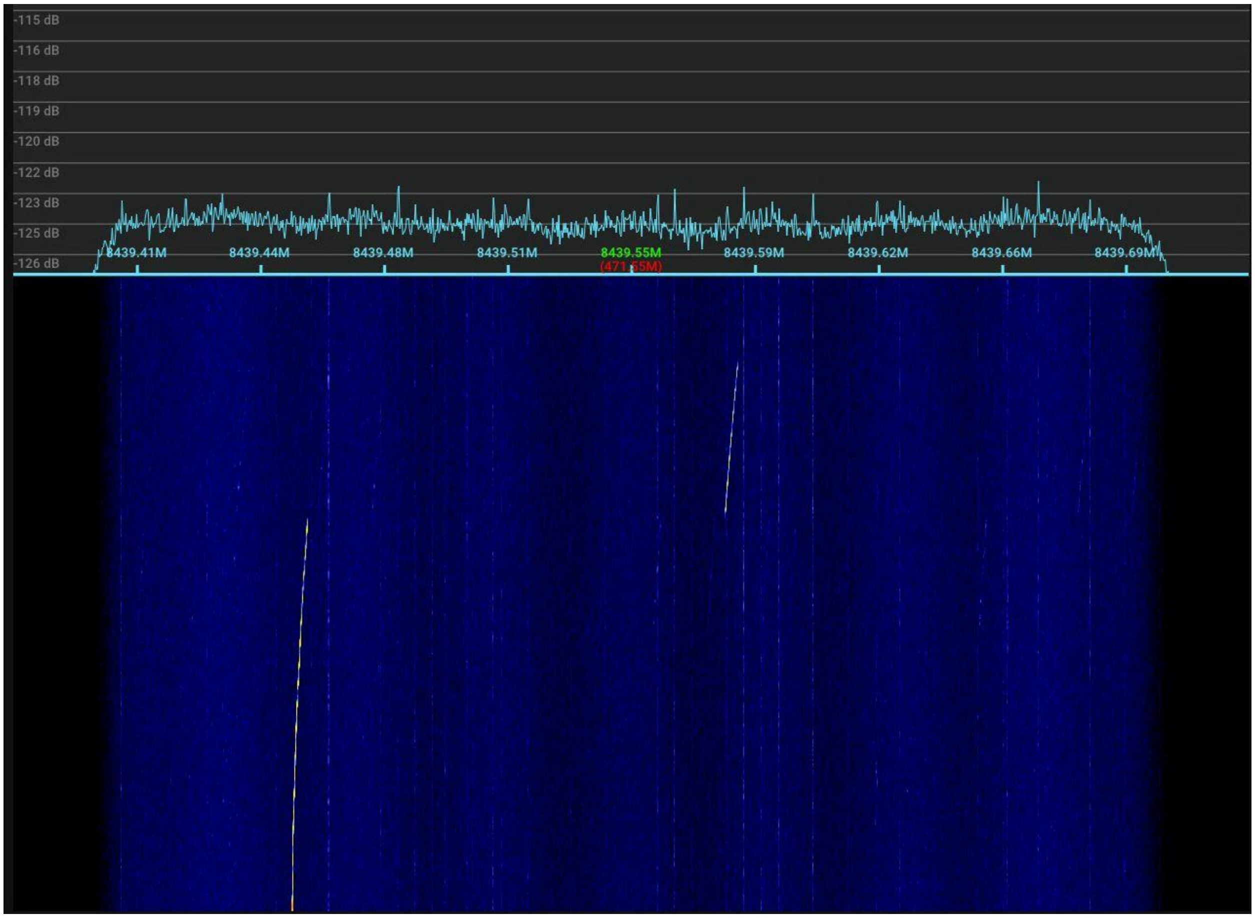


**Preliminary Assessment of the DSES 8.4 GHz Receiving System**

After a thorough analysis of the received 8.4 GHz data and measured signal levels, we concluded that the current system appears to have an estimated 12–20 dB gain deficit.

The observed signal-to-noise ratios were compared with detailed link-budget calculations and with previous observations reported by other ground stations. Based on this analysis, the system in its present configuration is not expected to provide sufficient sensitivity for reliable detection of the Voyager 1 and Voyager 2 spacecraft.

The most likely causes of the reduced system performance are:

- Antenna pointing error
- Feed position or focus error
- Lower-than-expected illumination efficiency
- A combination of these factors

Pointing Error

At 8.4 GHz, the approximate half-power beamwidth of an 18.2 m dish is:

$$\theta_{3dB} \approx \frac{70\lambda}{D} \approx \frac{70(0.0355)}{18.2} \approx 0.137^\circ$$

This corresponds to approximately 8 arcminutes.

Because the beam is extremely narrow, even a relatively small pointing error can produce a significant reduction in received signal strength. A pointing error near 0.15° could result in several decibels of loss, while an error of approximately 0.25–0.30° could potentially account for more than 10 dB of signal loss.

A detailed pointing calibration and raster scan should therefore be performed using a stable and well-characterized radio source.

Feed Focus Error

The feed may not currently be positioned at the optimum focal point of the reflector.

This should be re-evaluated using the remotely controlled Z-axis feed-positioning system while monitoring a stable received signal. The feed should be moved incrementally along the Z-axis, and the received signal level should be recorded at each position to identify the true peak.

This test would determine whether an incorrect feed position is contributing to the observed gain deficit.

Illumination Efficiency

The feed currently installed on the antenna was donated to DSES, and several of its important design characteristics are unknown. These include:

- The reflector (f/D) ratio for which the feed was designed
- The feed radiation pattern
- Edge-taper characteristics
- Spillover performance
- Expected antenna gain and system (G/T)

The DSES 18.2 m dish has an approximate (f/D) ratio of 0.43. If the feed was designed for a substantially different reflector geometry, it may not illuminate the dish efficiently.

The current feed may require additional optimization, such as a flare, choke ring, or other modifications to improve edge taper, reduce spillover, and provide better illumination of the reflector.

<u>Preliminary Conclusion</u>

The observed 12–20 dB sensitivity deficit may be caused by one dominant problem or by a combination of pointing, focus, and illumination-efficiency errors.

Until the actual source of the gain deficit is identified and corrected, the existing 8.4 GHz receiving system should be considered suitable primarily for demonstration and system-development purposes, rather than for dependable scientific observations or extremely weak-signal spacecraft detection.

Alex K6VHF

DSES Senior Space Scientist