Tracking Artemis II at the UNB Earth Station

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A presentation to the International Repeater Group
at their Annual General Meeting
Doaktown, New Brunswick, May 3, 2026, 2 pm

https://www.ece.unb.ca/petersen/UNB-tracked-Artemis-II.pdf

Land Acknowledgment

Acknowledgements of Funding

- The Canadian Space Agency
- The New Brunswick Innovation Foundation
- The Natural Sciences and Engineering Research Council

Acknowledgements of Support

- Scott Tilley, VE7TIL, Citizen Scientist, tracked Artemis I in 2022.
- We thank for the helpful discussions, regarding mitigating interference:
  - Ron, Owen VE1KO,
  - Don Trynor, VA3XFT, and
  - Greg d'Entremont, VE9GFI.

Image credit UNB if not indicated.

Purpose, Tracking, Not Communicating

- The purpose of the activity was to report to NASA the date, time, and frequency observed.
- This activity involved technical investigations and receiving.
- There was no transmitting.
- short-wave listening (SWLing)
- Artemis II was the name of the mission.
- Orion was the type of spacecraft.
- Integrity was the name of the spacecraft, named by the astronauts.

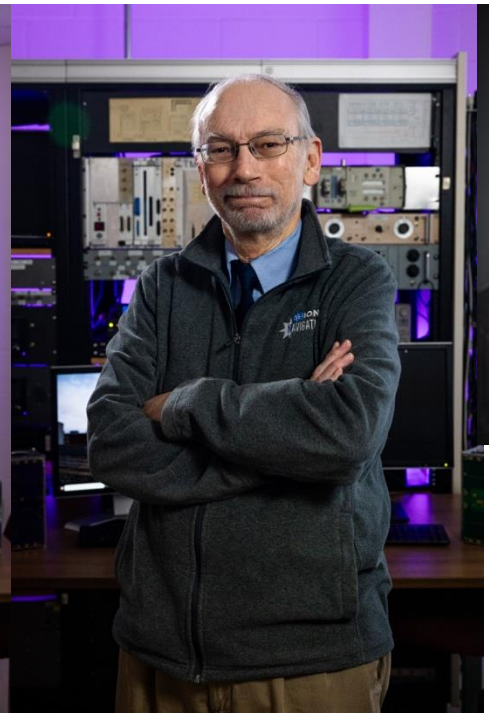
Astronauts

Artemis II NASA astronauts (left to right) Reid Wiseman, Victor Glover, and Christina Koch - and CSA (Canadian Space Agency) astronaut Jeremy Hansen.

Image credit NASA/Frank Michaux: https://www.nasa.gov/image-detail/afs-8-101-1049/

The UNB Artemis II Tracking Team






Left to right: Blake, Chris C, Morgan, Olivia, Megan, Brent, Troy, Richard, Chris R.

Image credits: Anna Mandin, UNB, UNB, UNB

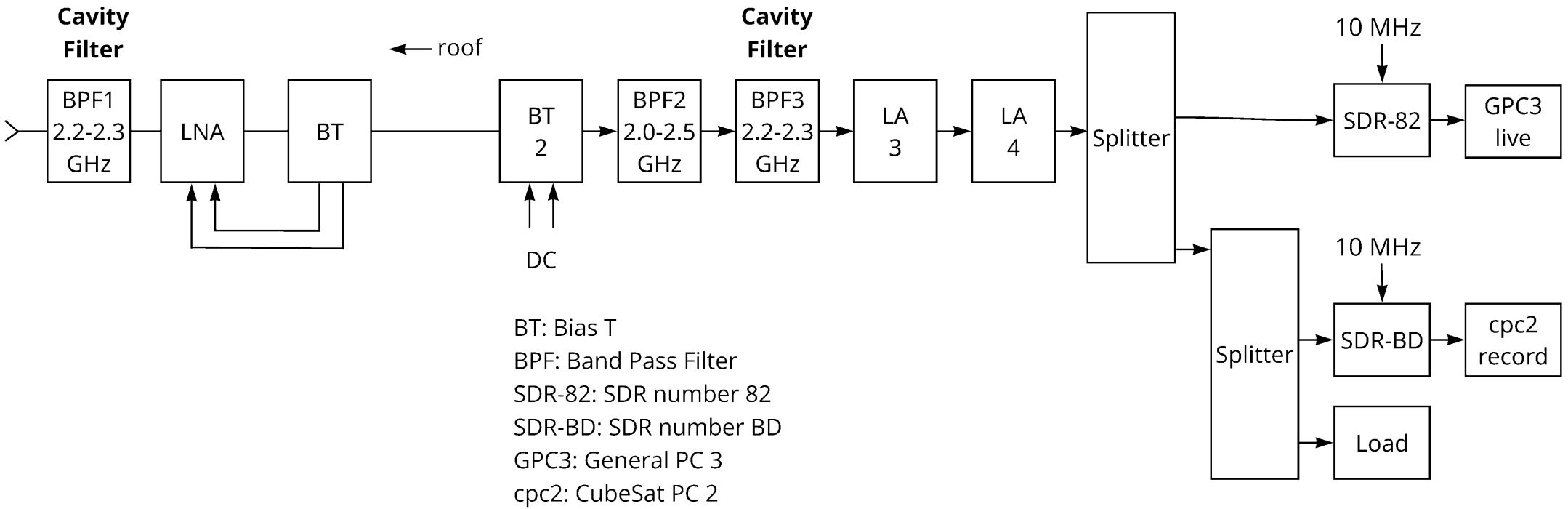
Timeline

- 2018-2024, UNB Earth Station constructed
  - 2024, April, to 2024, September, messages sent to CubeSat VIOLET
- 2025, August, NASA announces a request for input (RFI).
- 2025, October 31, RFI deadline
  - Technical details of the UNB Earth Station were submitted.
  - No funding came from NASA.
- 2026, January 14, NASA notified UNB it was selected, among 34 sites in the world, with UNB being the only Canadian academic institution
- 2026, February 6 and March 6, NASA launch windows, delayed
- 2026, January to March 31, UNB significant preparations, cellular interference, software
- 2026, April 1, launch

UNB Earth Station Images

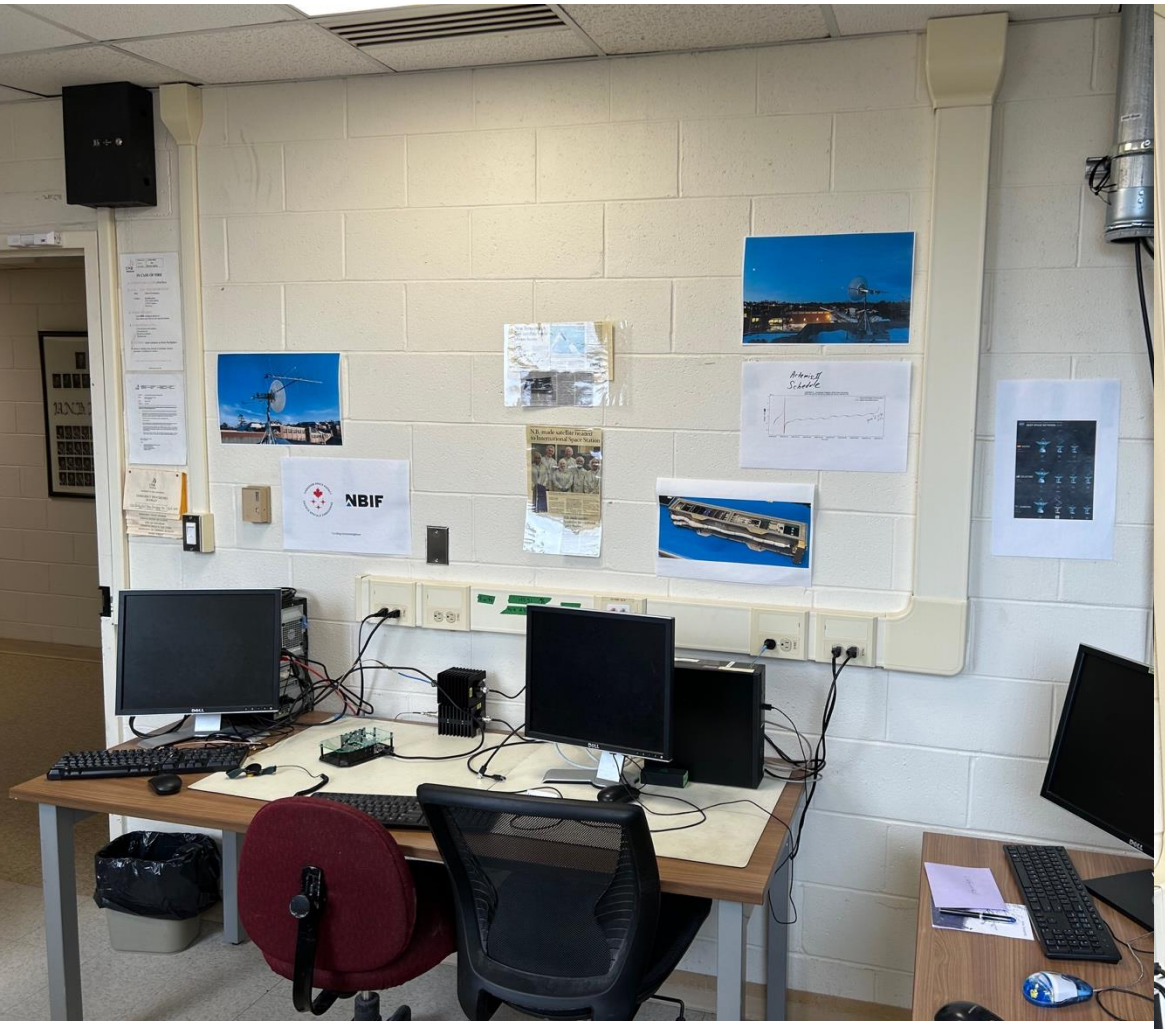
UNB Earth Station Images

System Diagram

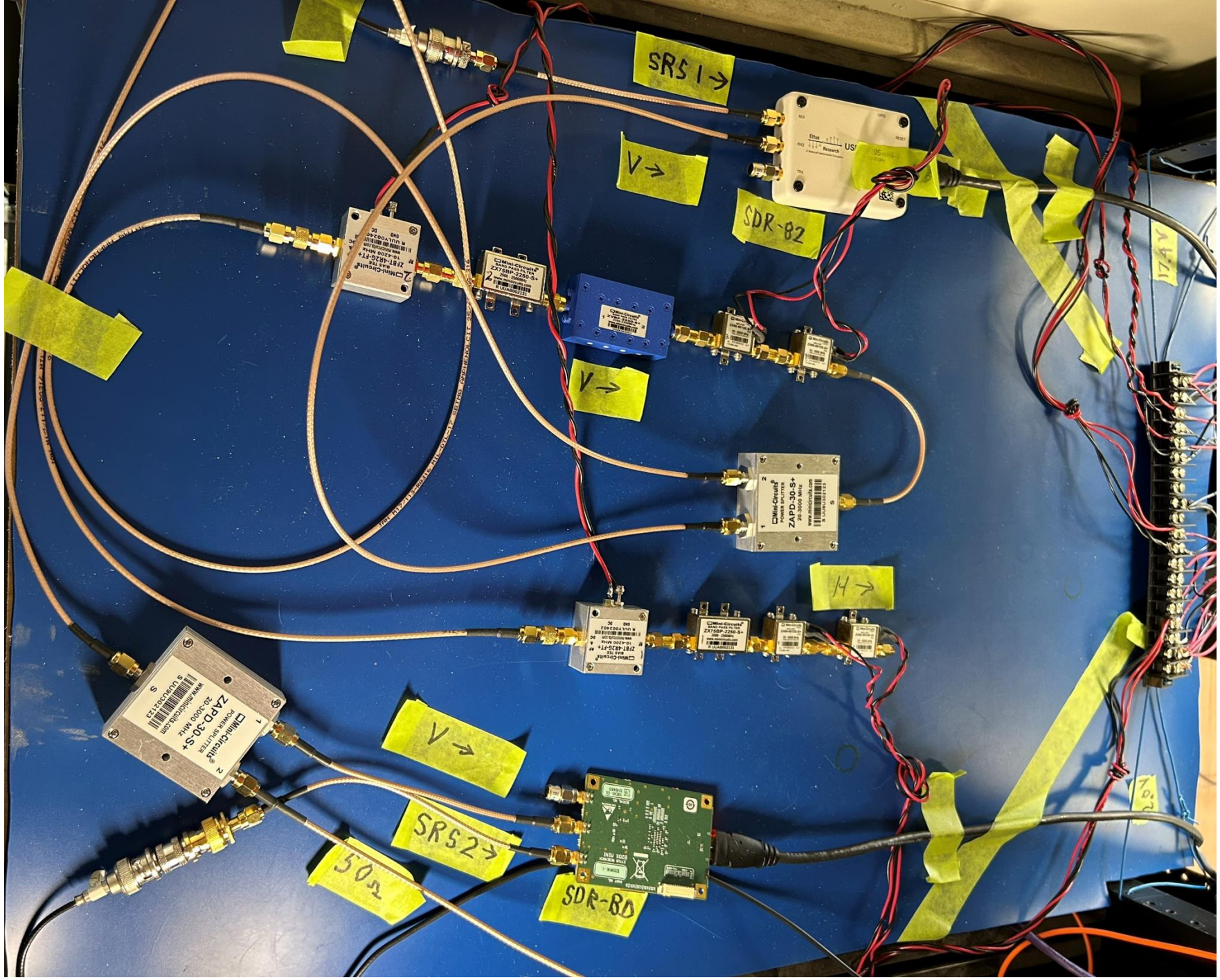


- Vertical polarization, gain, approximately, 30 dB antenna, 30 dB low-noise amplifier (LNA), cable gain -10 dB, two line amplifiers (LA) 30 dB, net 80 dB
- 2216.5 MHz nominal frequency of interest
- Both SDRs (software-defined radio) are an Ettus USRP B205 mini-i.

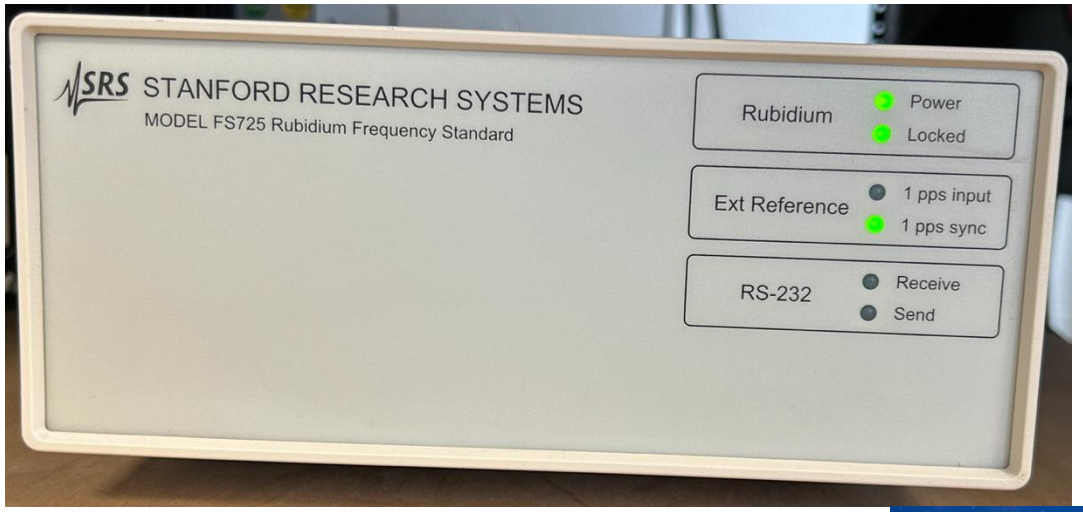
Gillin Hall, Room GE137, The Control Room, The Shack



Radio Shelf

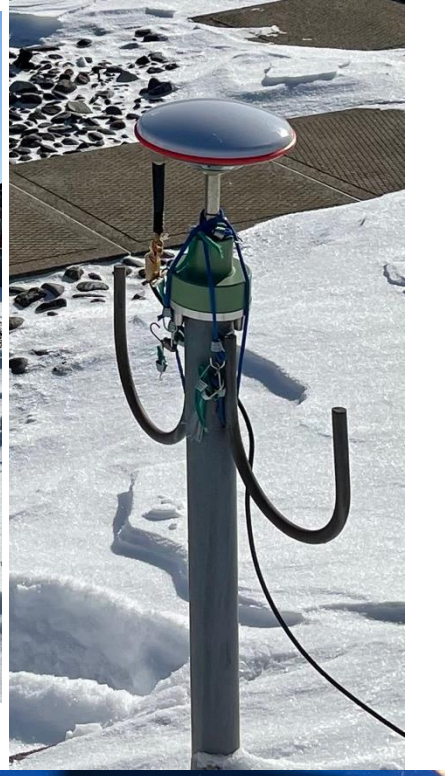

SR5 1→
V→
SDR-82
V→
14→
V→
SR52→
50Ω
SDR-80
ZAPD-30-S+
ZX75BP-2250-S+
ZAPD-30-S+

Time and Frequency Reference



10 MHz outputs from
SRS FS725 to SDRs

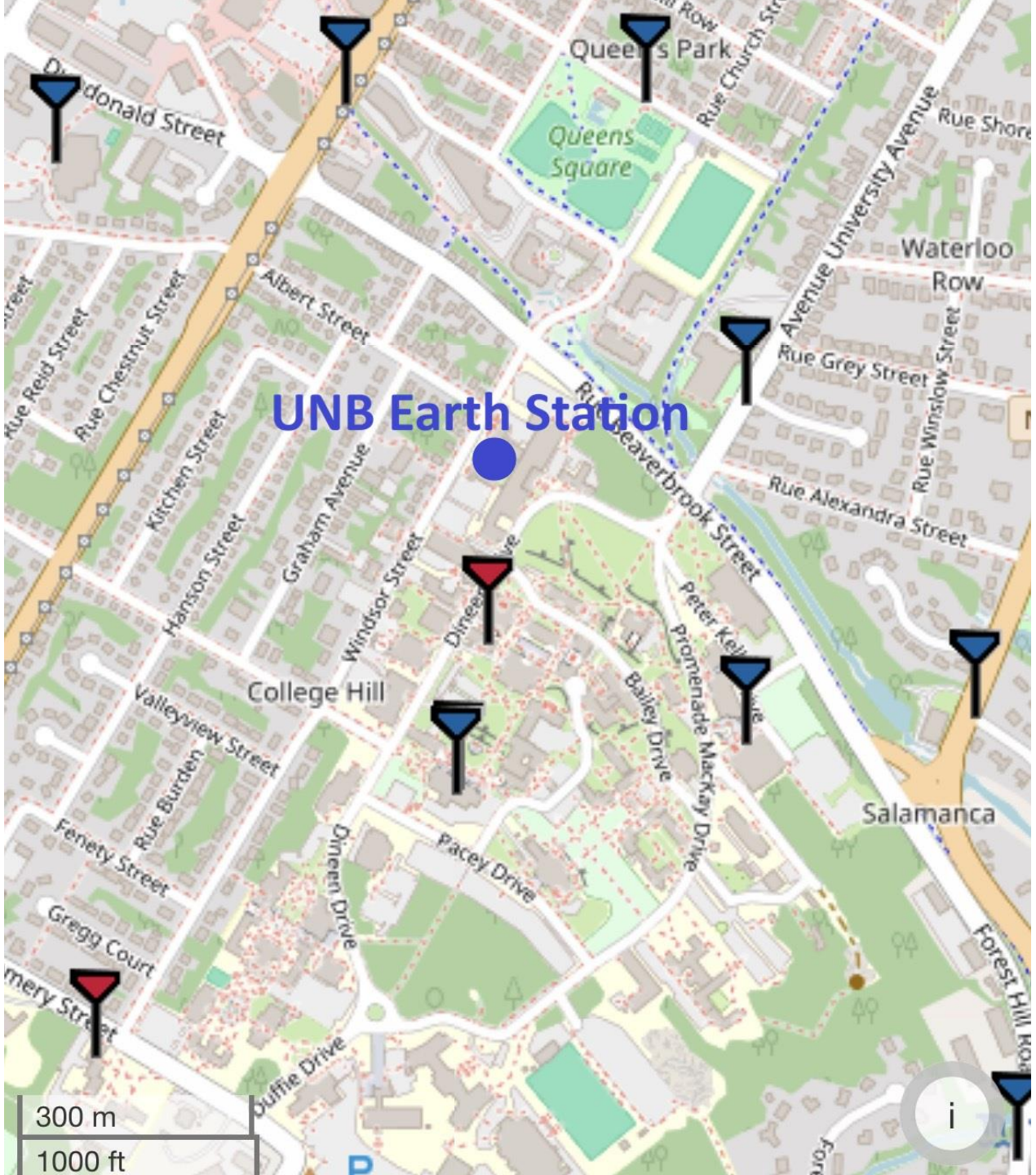
SRS FS725 and
GPS Referenced Clock on an
uninterruptable power supply



GPS antenna on roof of Gillin Hall

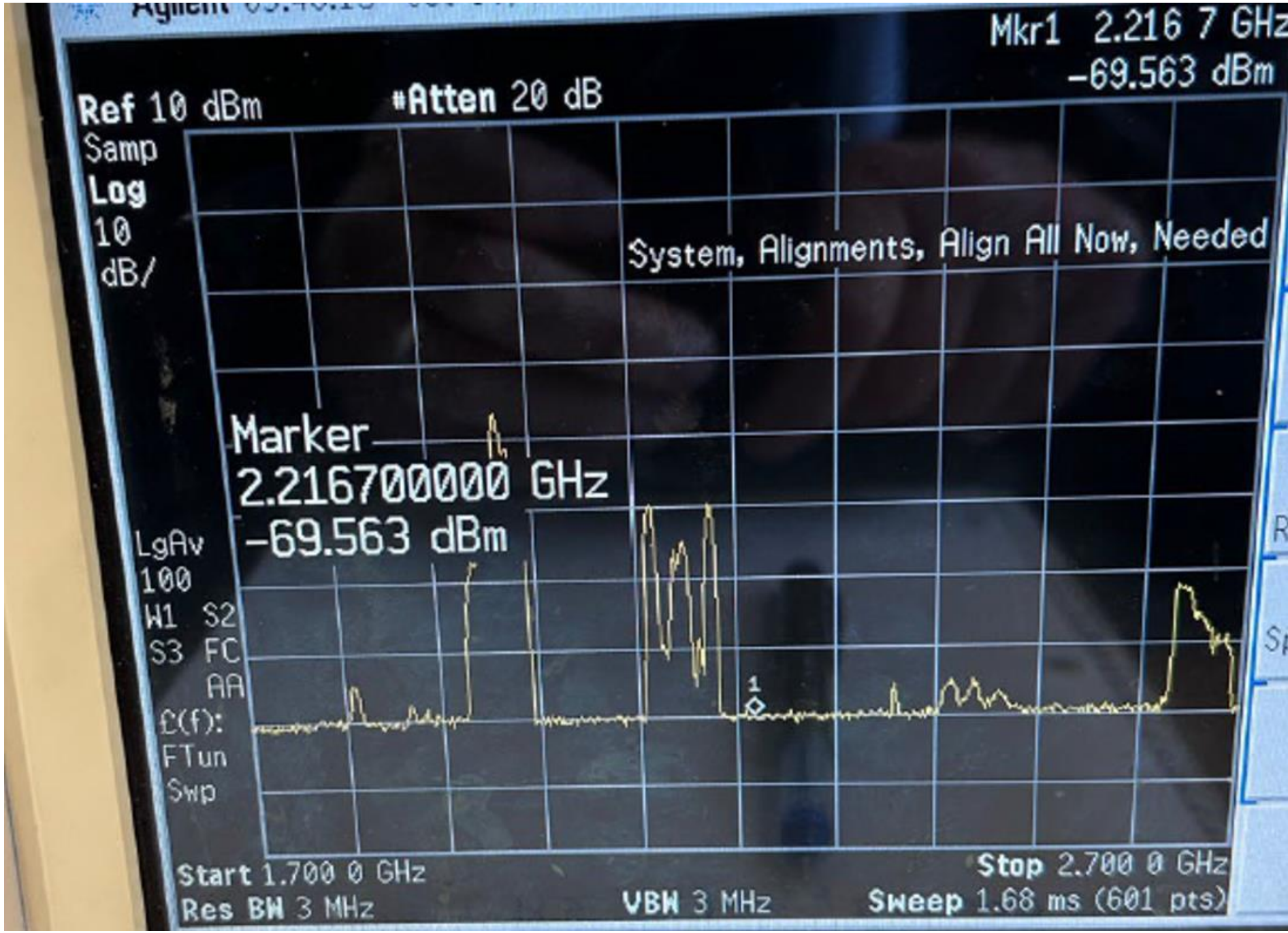
Interference

- Image credit: TowerLocator



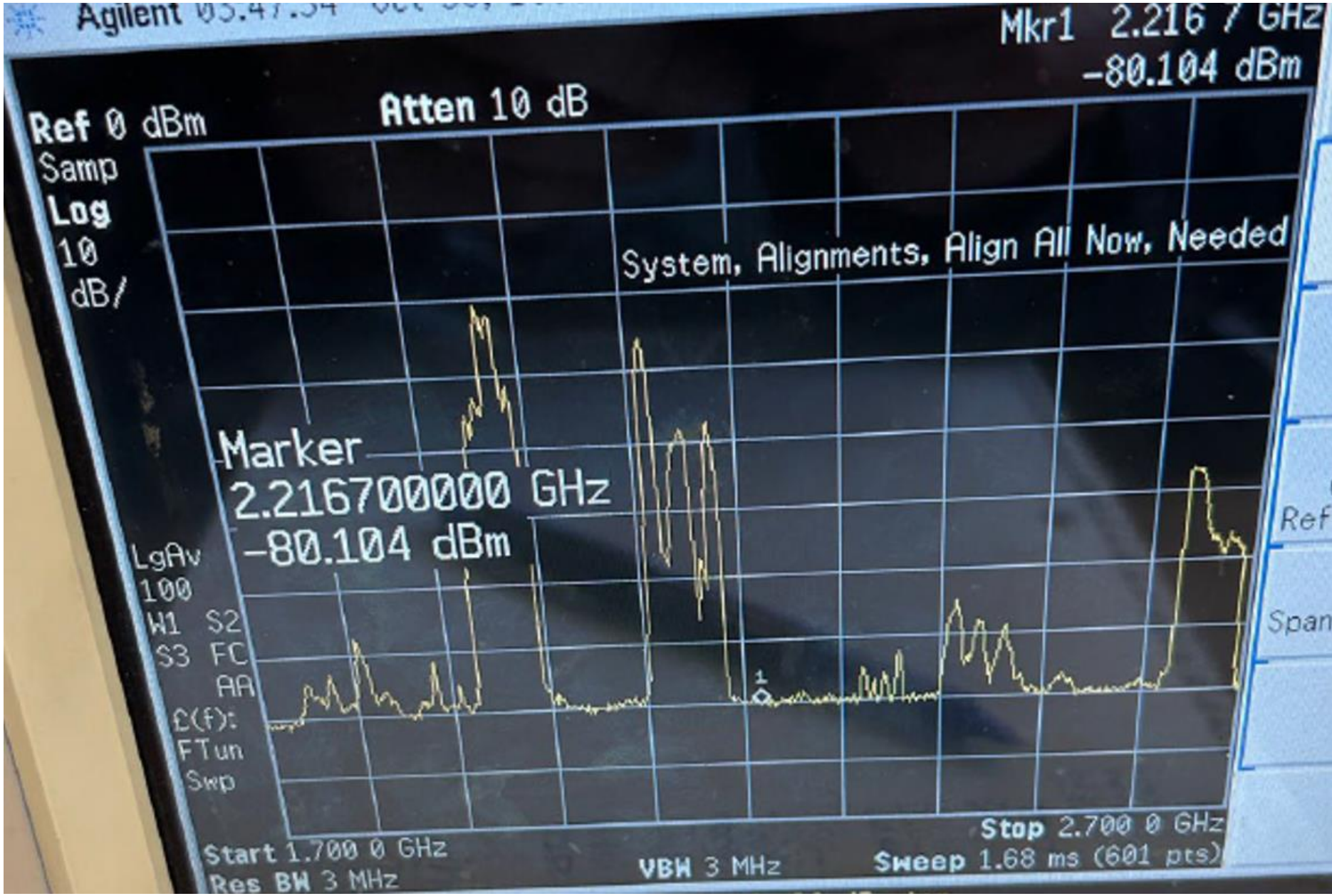
Interference

- LNA and BT on roof, BPF 2.0-2.5 GHz in room
- Elevation 60.0 degrees
- Marker 1 near Artemis II's frequency, 2216.5 MHz
- 2180.0 MHz location of interference



Interference

- Elevation 15.5 degrees
- Marker 1 near Artemis II's frequency, 2216.5 MHz
- 2180.0 MHz location of interference
- LNA compression starting



Interference

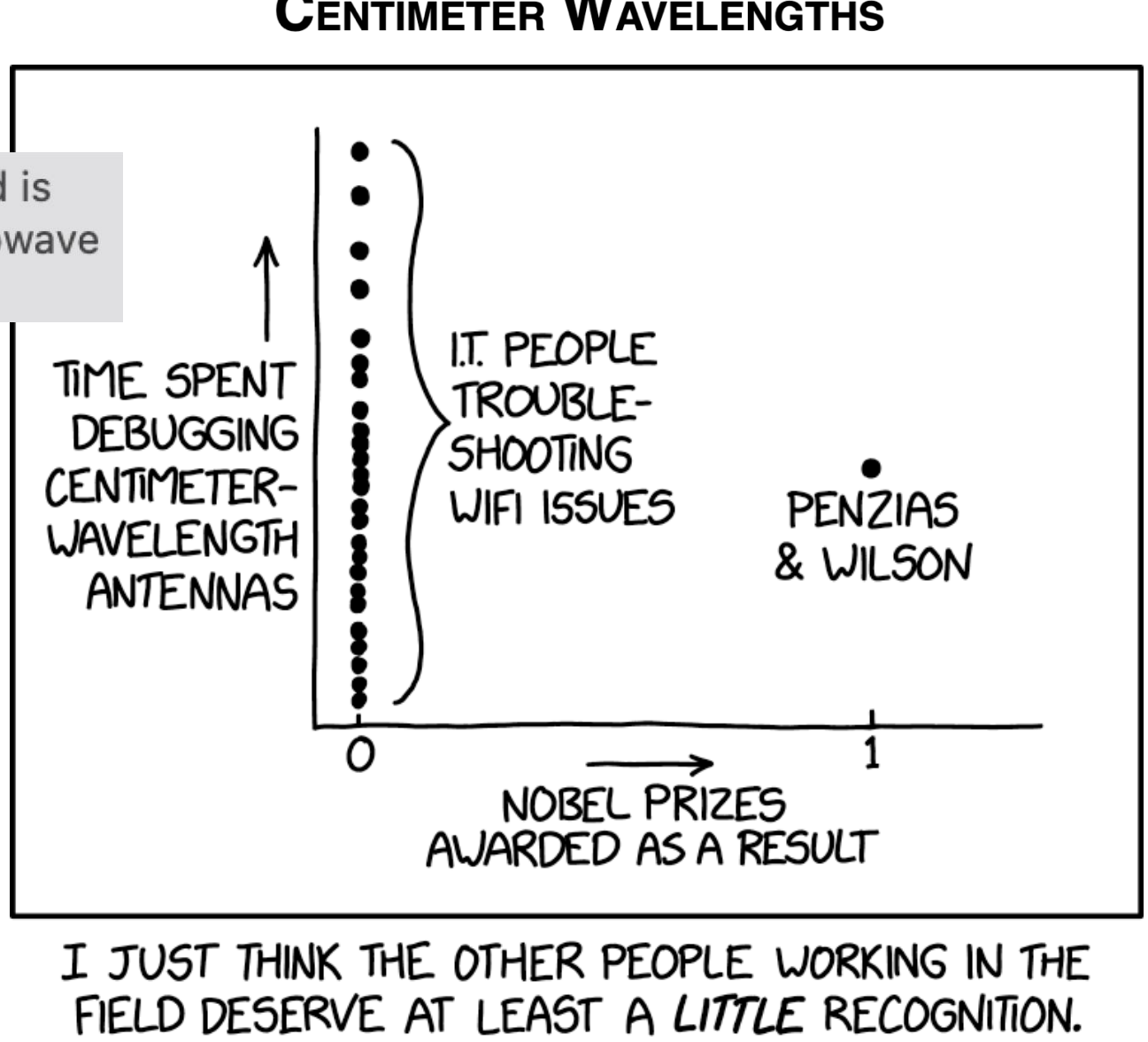
- Elevation 2.0 degrees
- Marker 1 near Artemis II's frequency, 2216.5 MHz
- 2180.0 MHz location of interference
- LNA compression, significant

Interference

- Solution
- S band cavity filters
- 2.2 GHz to 2.3 GHz
- Quantity two
- CDN$1000 each
- One at antenna feedpoint before the low-noise amplifier, stops LNA compression
- One in the shack, stops LA compression
- SDRs would be damaged without the filtering

Humour: xkcd

Yes, the cosmic microwave background is great, but what about the earthly microwave foreground?



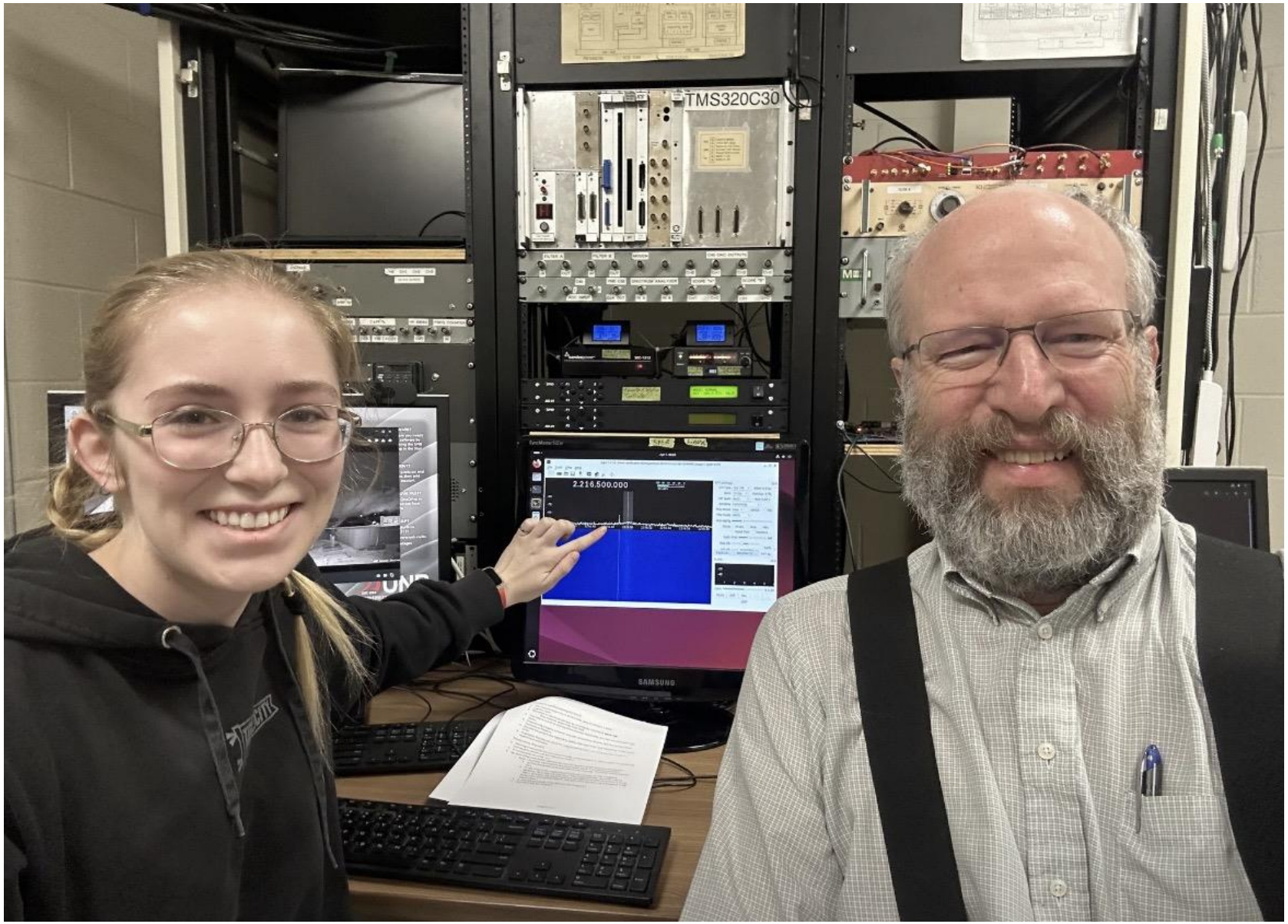
Permanent link to this comic: https://xkcd.com/3224/
Image URL (for hotlinking/embedding):
https://imgs.xkcd.com/comics/centimeter_wavelengths.png
This work is licensed under a Creative Commons Attribution-NonCommercial 2.5 License.
This means you're free to copy and share these comics (but not to sell them).

Operating, Live Display and Recording Signals

- 2026, April 1-2, UTC
  - Tracking was unsuccessful due to software problems and necessary updates.
- 2026, April 3
  - Tracking was unsuccessful due to an internet outage in our lab.
- 2025, April 4
  - Artemis II was finally tracked. The first signal was observed around 08:04 UTC.
- 2026, April 5-10
  - Artemis II was tracked for all of the remaining six days.

First Spotted Artemis II in Live Display

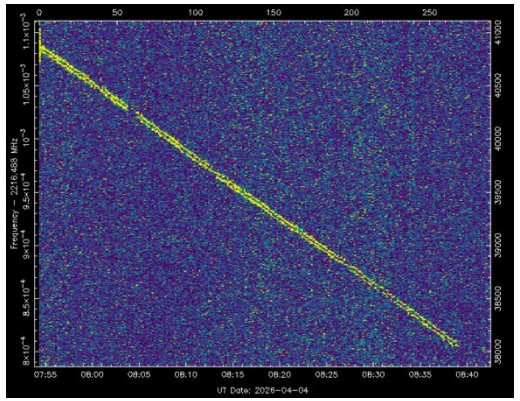
- Software gqrx
- Time
  2026-04-04,
  08:04 UTC



Processing of Recorded Signals

- GNU Radio scripts, from Scott, VE7TIL, recorded the time-domain signal from the SDR.
- Satellite Tracking Radio Frequency (STRF) toolkit
- STRF's rffft converted the time-domain signals to waterfall diagrams with frequency versus time.
- STRF's rfplot was used to display the waterfalls.

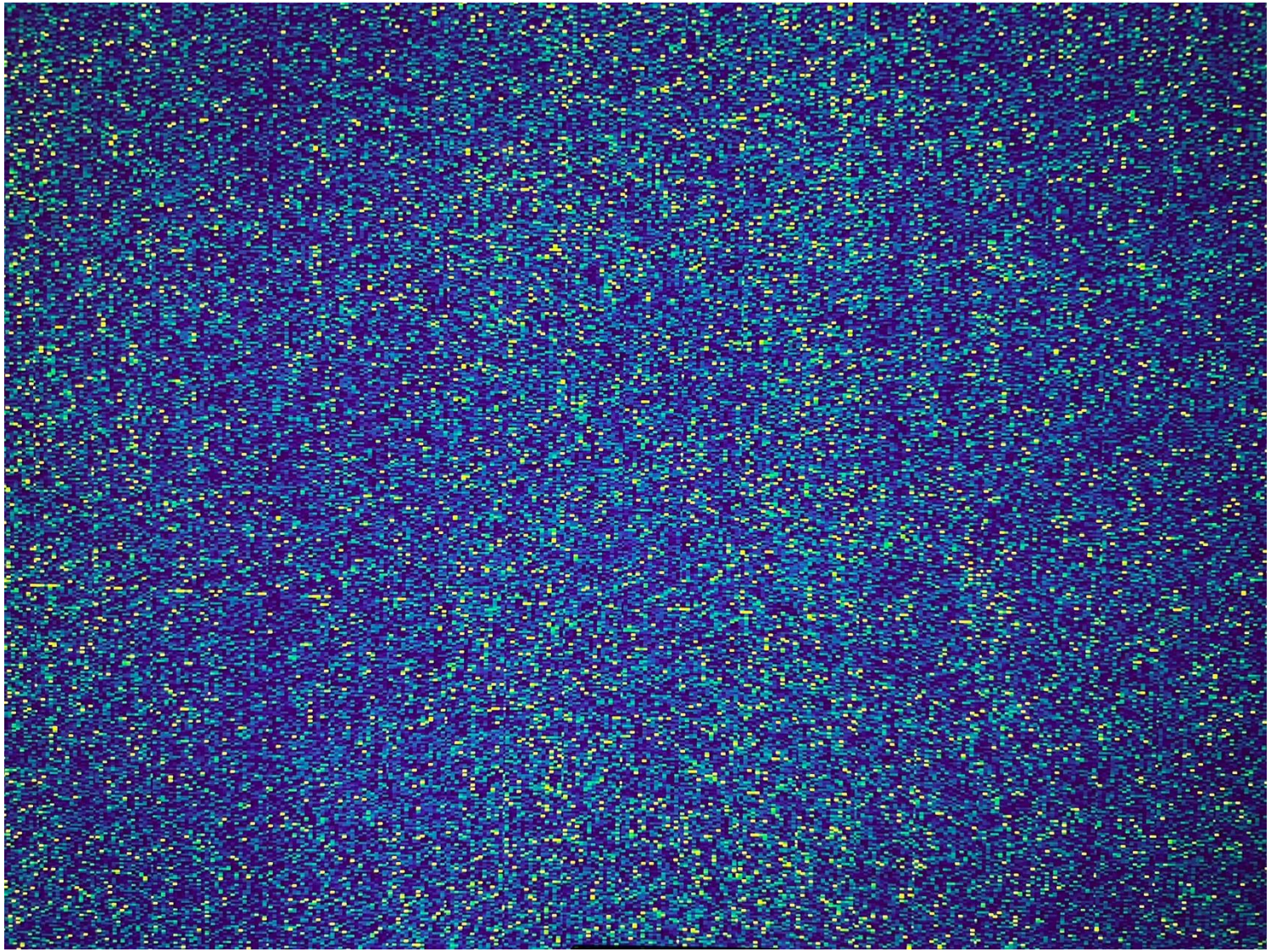
Frequency



Time

Spot Artemis II in the Recorded Signal

Frequency
2216.505 MHz

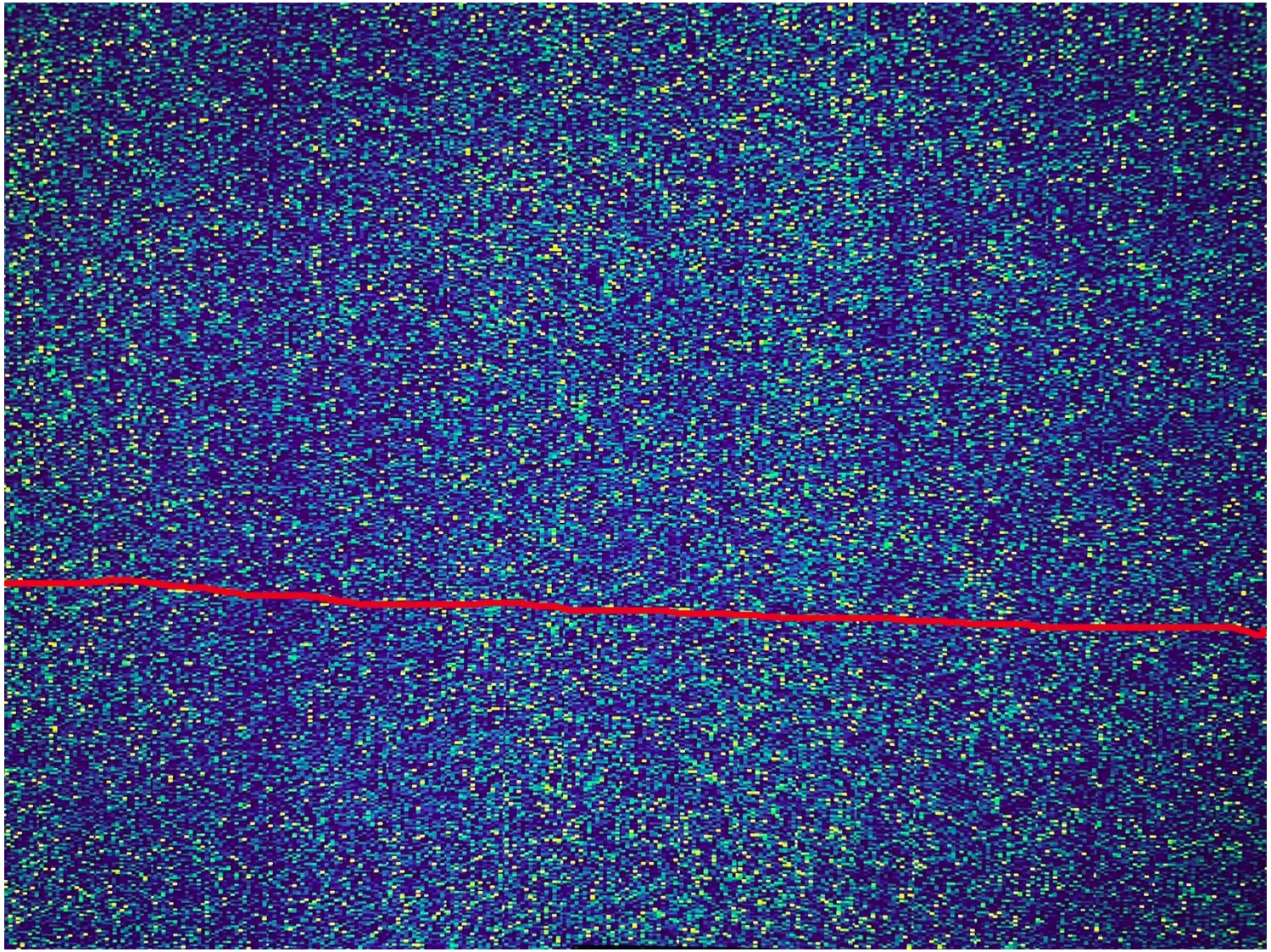


2216.485 MHz

Time, 2026-04-04, 07:54 to 08:54 UTC

Spot Artemis II in the Recorded Signal: Solution

Frequency
2216.505 MHz



2216.485 MHz

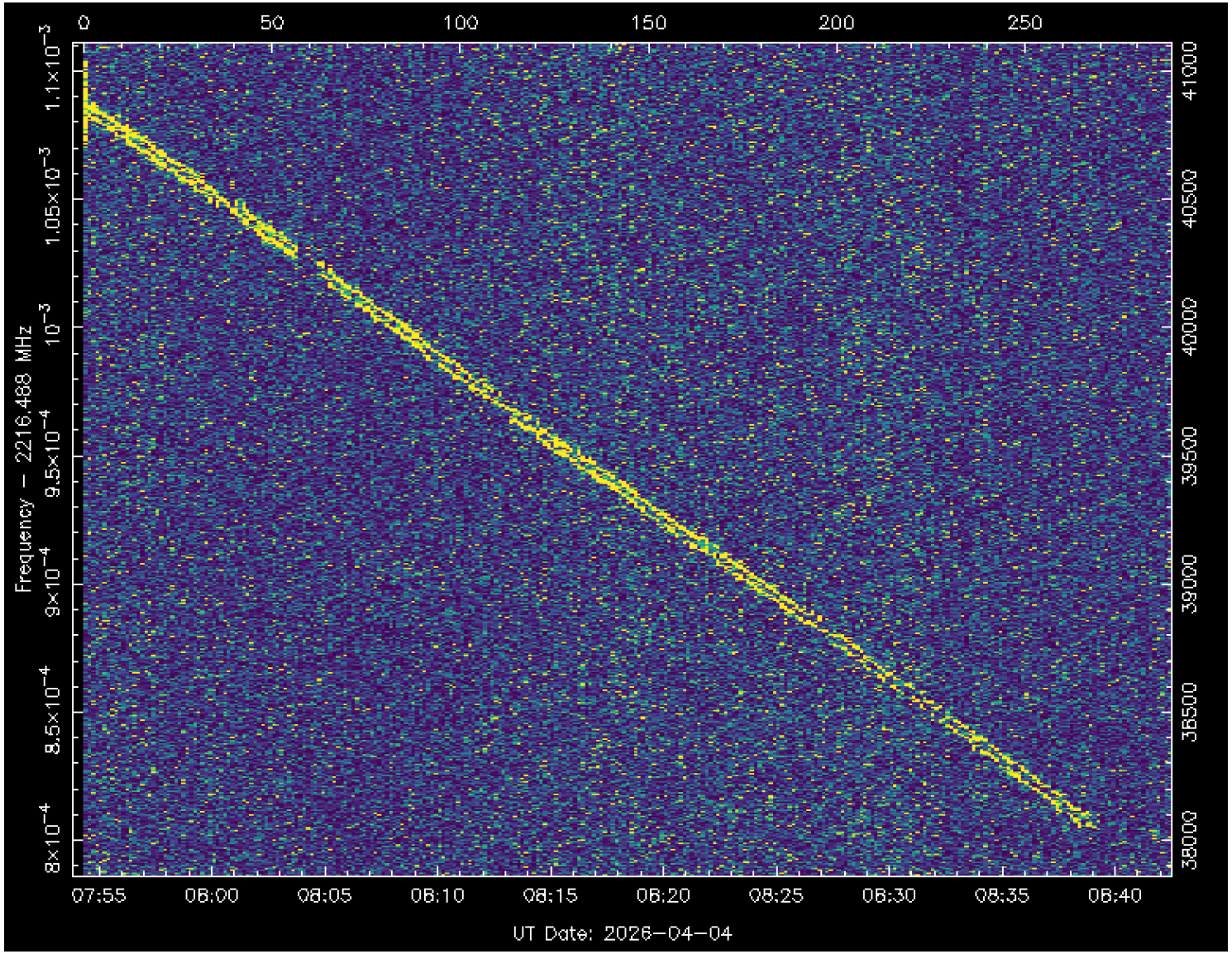
Time, 2026-04-04, 07:54 to 08:54 UTC

Artemis II in the Recorded Signal

Frequency
2216.505 MHz

Megan repointed the dish, 08:04 UTC, to confirm the first signal.

2216.485 MHz



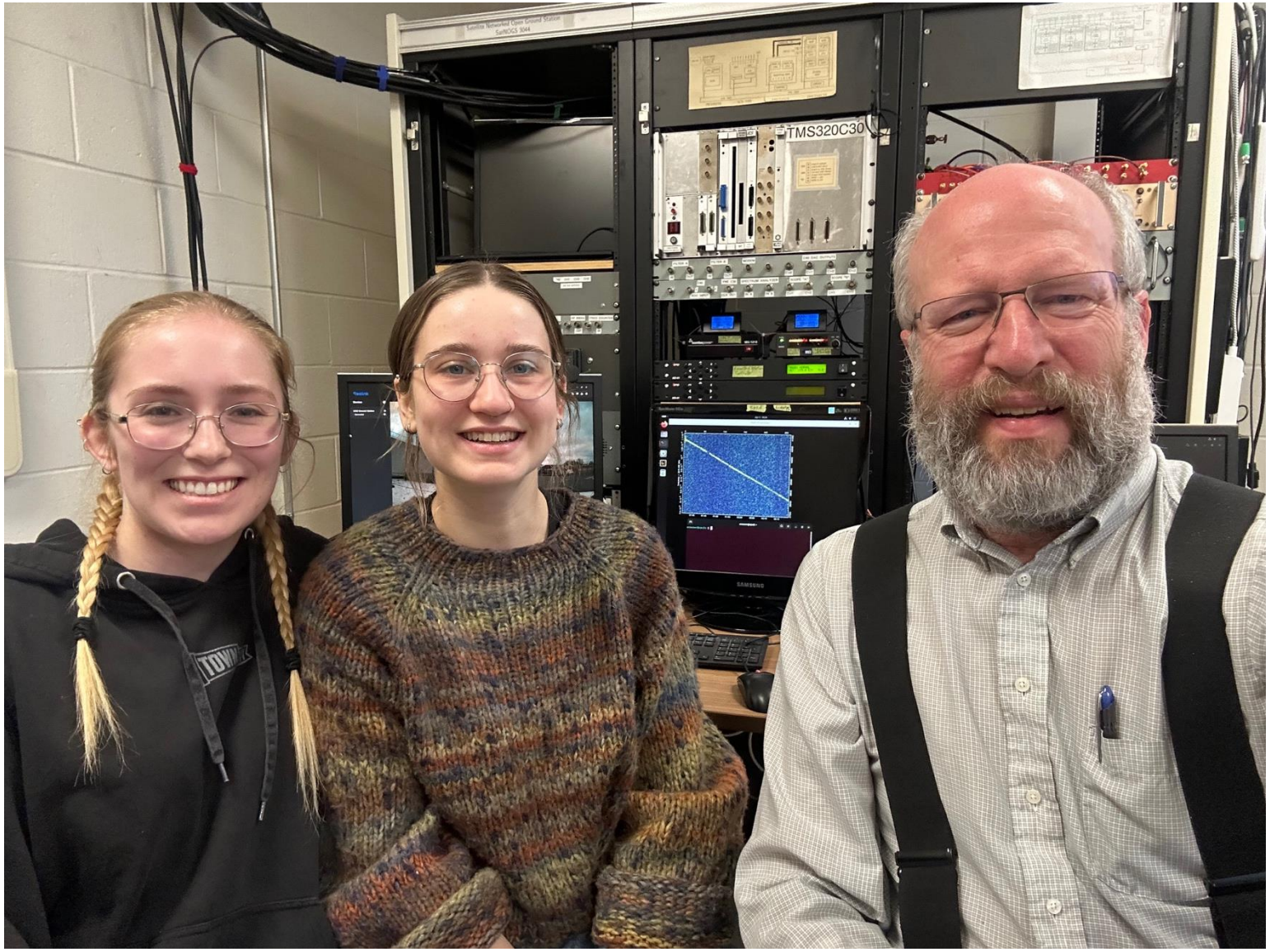
Time, 2026-04-04, 07:54 to 08:54 UTC

Artemis II in the Recorded Signal

Olivia found the transmission change in the recorded data

2026-04-04,

08:39 UTC.



Artemis II's Trajectory provides Relative Velocity with respect to UNB

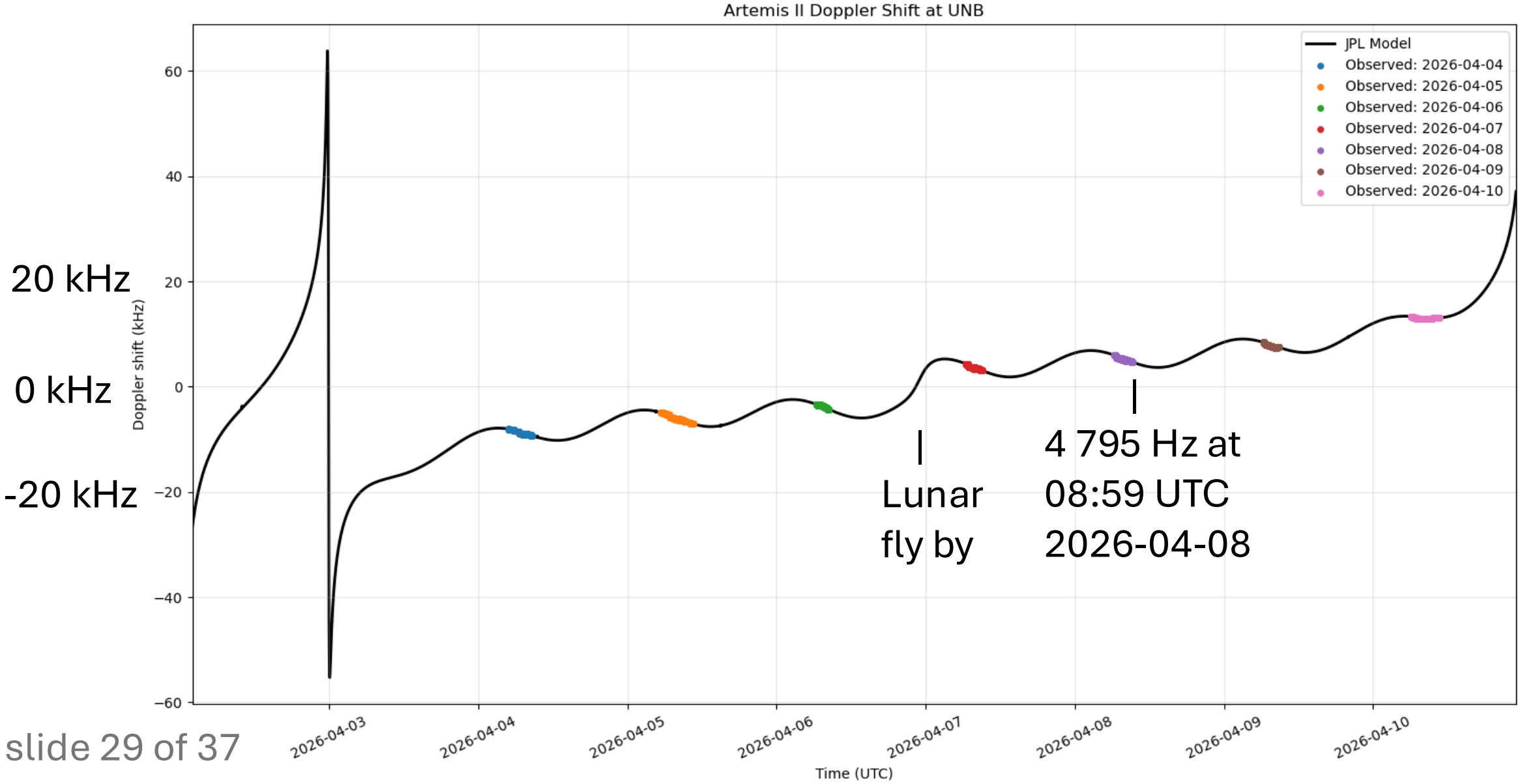
- To help verify our results, we used the online Horizons app from JPL (Jet Propulsion Laboratory) to provide the relative velocity, v, of Artemis II with respect to the UNB Earth Station.

- Image credit NASA: https://www.nasa.gov/wp-content/uploads/2023/03/artemis_2_map_october_2021.jpg

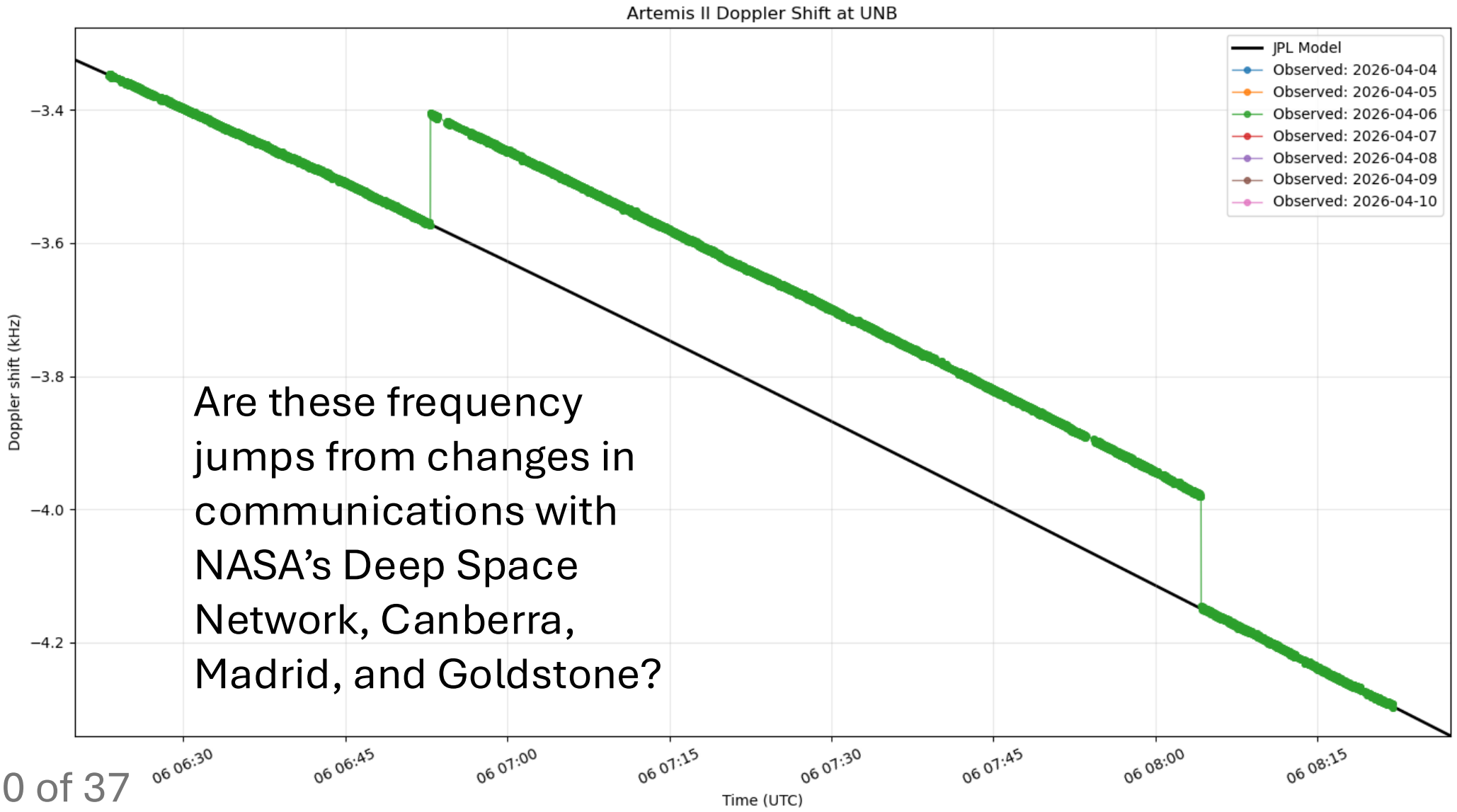
Doppler Shift, f_D

- NASA wanted reports of our actual received frequencies.
- It was easier to compare Doppler shifts to check our data.
- We made an unverified-by-NASA hypothesis of the transmit frequency, f_{Tx}, 2 216 498 103 Hz, being emitted by Artemis II.
- Our estimate of the Doppler shift from measurements was $f_{DM} = f_{Tx} - f_{Rx}$, where f_{Rx} is each received frequency. As an example point, at 2026-04-08, 08:59:59 UTC, the relative velocity, v, of Artemis II toward the UNB Earth Station 648.5 m/s.
- The JPL Model of the Doppler shift was $f_D = f_{Tx}\, v/c$, to give 4 795 Hz, where c is the speed of light.
- Our estimate of the Doppler shift from measurements and the JPL model were compared. Thess estimates for plotting do not account for a further change in frequency caused by the ionosphere.

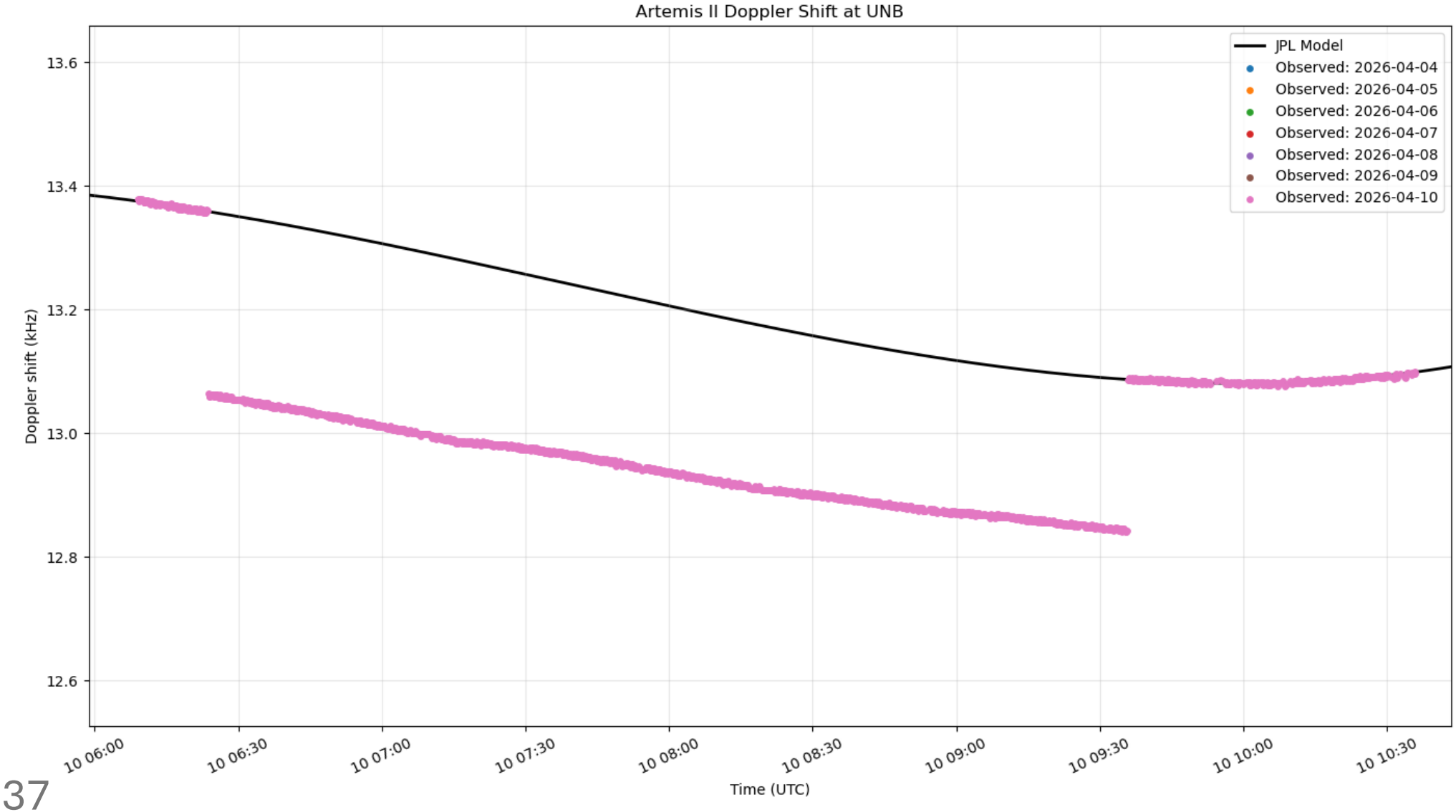
Comparison of Doppler Shifts, Calculated from Observations, to JPL Model



Comparison of Doppler Shifts, Calculated from Observations, to JPL Model

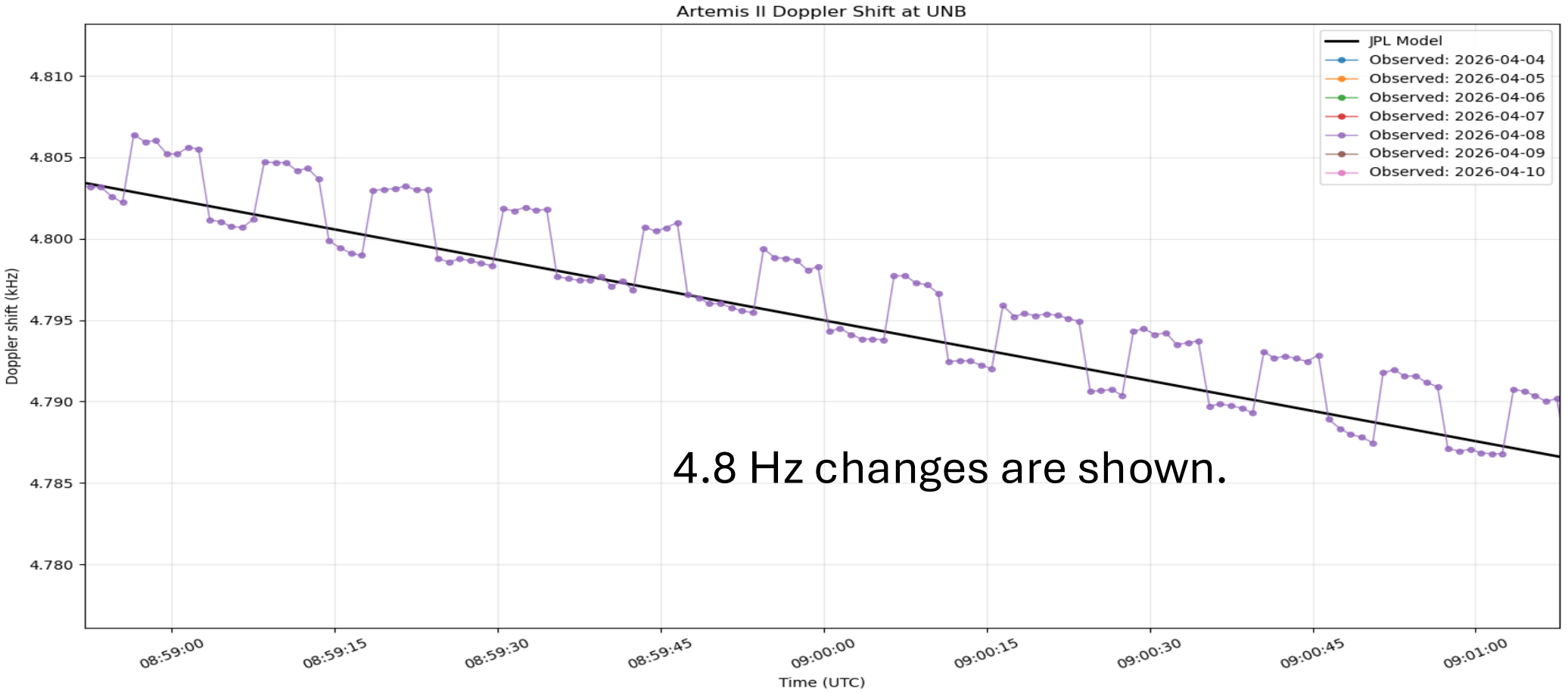


Comparison of Doppler Shifts, Calculated from Observations, to JPL Model



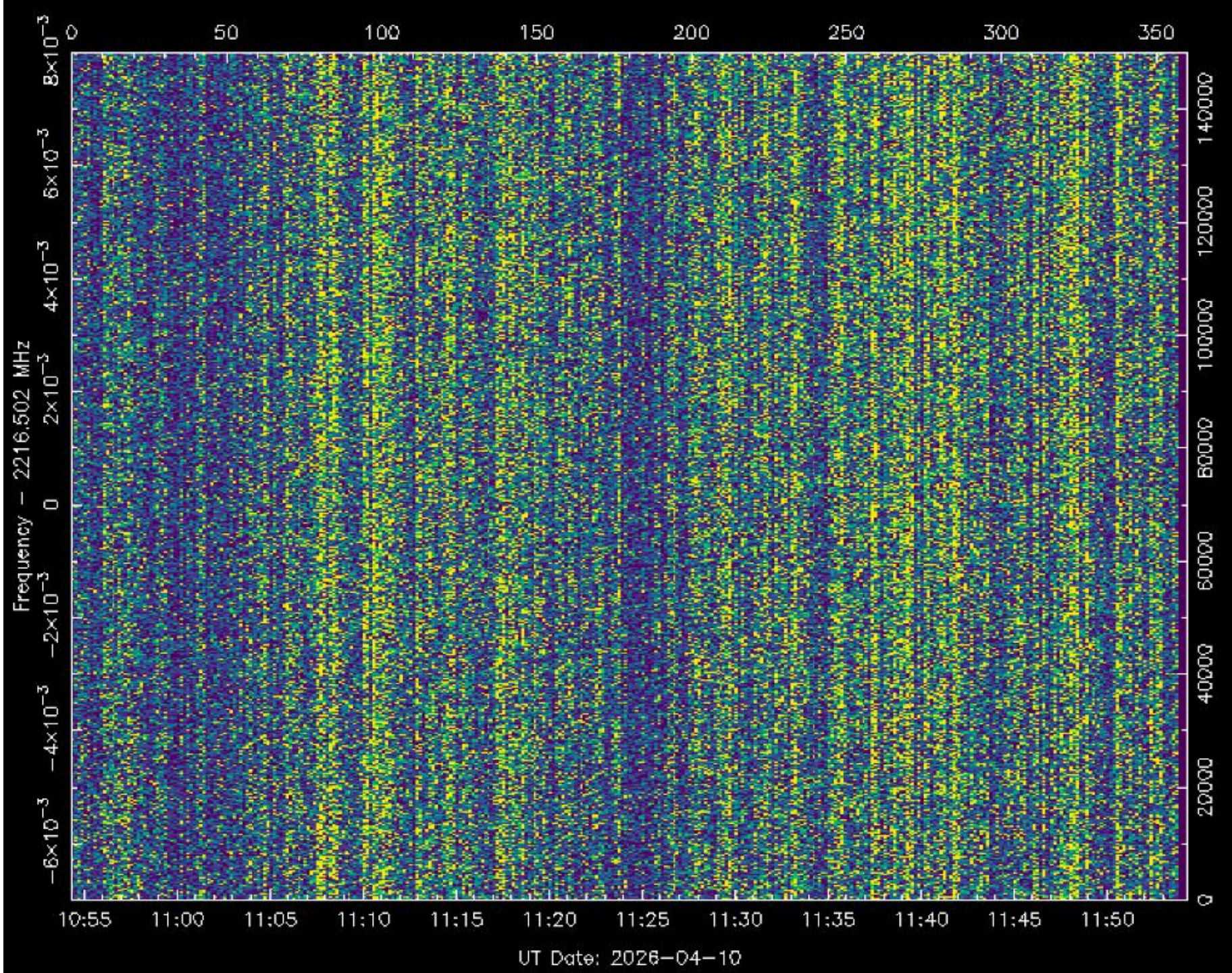
Comparison of Doppler Shifts, SDR Local Oscillator Step Size

- The time and frequency reference is accurate enough to show the effect of the specified 2.4 Hz step size in the local oscillator of the Ettus B205mini-i SDR.



Interference

- Waterfall interference, after filtering, when pointed near the horizon



Team Composition and Teamwork

- Team composition: The teams should have four types of people [Shivani Patel, Small Sat 2018]:
  - Visionary
  - Doer
  - Healer
  - Breaker
- A teamwork analogy is a group of writers for a sitcom where everyone is involved, from junior to senior writers, and from all the interactions of ideas, what comes out is the result from the team, without attributing particular results to particular team members.

One of Files sent to NASA: UNB_Antenna1_20260410.tdm

```
CCSDS_TDM_VERS = 2.0
CREATION_DATE = 2026-112T20:01:32.728Z
ORIGINATOR = UNB
COMMENT The UNB Earth Station is at east longitude 293.35751 E,
COMMENT geodetic latitude 45.94994 N, and a height 0.047 km.
COMMENT This system was updated after RFI-ArtemisII-Tracking-SCaN-2025.
COMMENT The system noise figure is 2.5 dB. G/T is 6.5 dB/K at 2.3 GHz.
COMMENT Only the vertical polarization was used.
COMMENT The time and frequency reference (TFR) is from a Leo Bodnar
COMMENT Precision GPS Reference Clock followed by an SRS FS725 Rubidium
COMMENT Frequency Standard. The software defined radio (SDR) receiver
COMMENT is an Ettus USRP B205mini-i.
COMMENT Our TFR is accurate enough to reveal in the data the effect of
COMMENT the SDR's 2.4 Hz local oscillator step size.
META_START
TIME_SYSTEM = UTC
PARTICIPANT_1 = ORION
PARTICIPANT_2 = 2026-069A
MODE = SEQUENTIAL
PATH = 1,2
INTEGRATION_INTERVAL = 10.0
INTEGRATION_REF = START
TIMETAG_REF = RECEIVE
FREQ_OFFSET = 2217000000.0
START_TIME = 2026-100T06:09:03.024
STOP_TIME = 2026-100T10:35:53.030
TURNAROUND_NUMERATOR = 240
TURNAROUND_DENOMINATOR = 221
META_STOP
DATA_START
RECEIVE_FREQ_2 = 2026-100T06:09:03.024 -488513.111753
RECEIVE_FREQ_2 = 2026-100T06:09:12.960 -488516.467930
RECEIVE_FREQ_2 = 2026-100T06:09:22.982 -488512.940553
...
RECEIVE_FREQ_2 = 2026-100T10:35:53.030 -488793.297449
DATA_STOP
```

TDM: Tracking Data Message

Highlights In The News

- New Brunswick Premier Susan Holt thanked the team, as shown immediately after the story about NASA: https://youtu.be/NsXRwxDg6cU
- PEI Premier Rob Lantz acknowledged Megan MacDonald at 00:08:38 at https://www.youtube.com/watch?v=XHFwbM9tumg
  and is shown on page 261 of the legislature record, Hansard, at: https://docs.assembly.pe.ca/download/dms?objectId=dad2ab92-5f6f-4c09-83ec-4dfd277482c4&fileName=Hansard-8%20April%202026.pdf
- Megan MacDonald represented our team on a Canada-wide CBC Radio program, called As It Happens, around 17:31: https://www.cbc.ca/listen/live-radio/1-2-as-it-happens/clip/16207834-is-right-path-majority-government

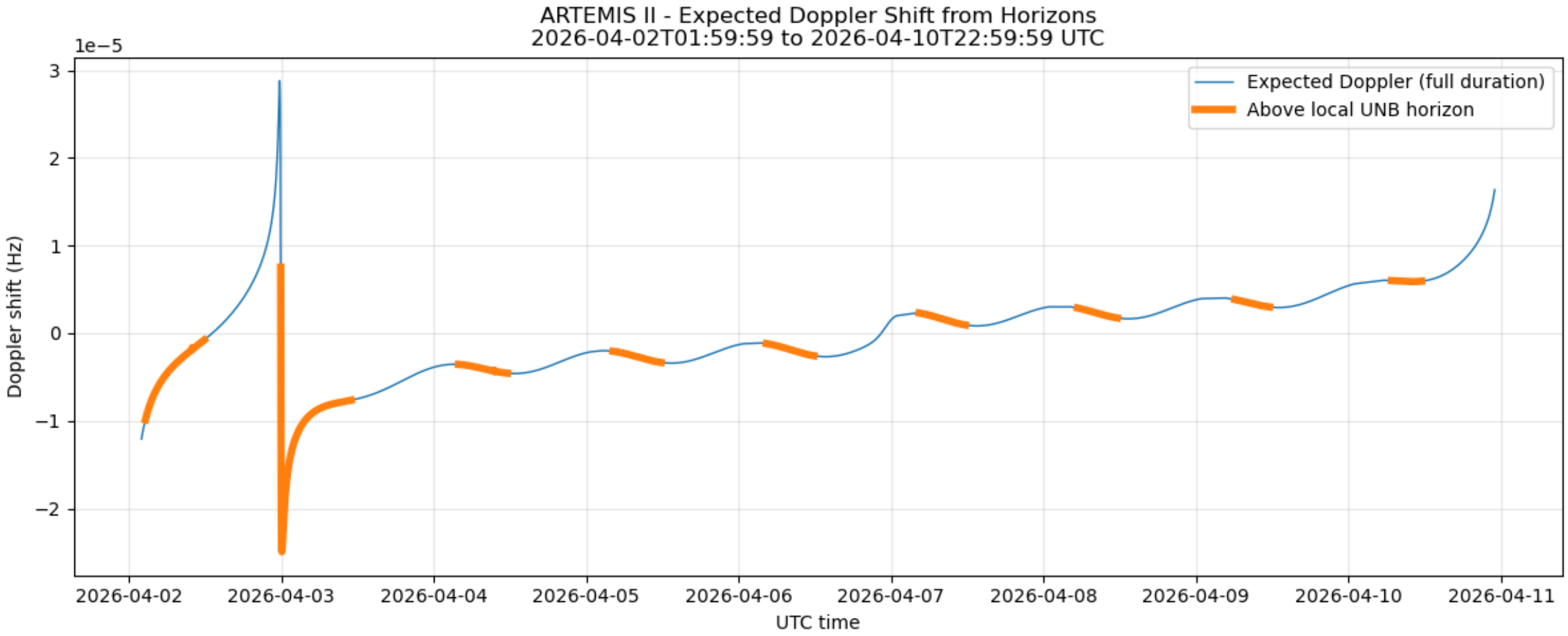
We thank the IRG for the invitation
and
you for attending.

Other Information

Abstract

The team at the University of New Brunswick (UNB) was able to track Artemis II using the UNB Earth Station. This was a response to a request for information from NASA. Local cellular interference was mitigated in order to detect the weak signals. The tracking data of date, time, and frequency was sent to NASA.

Observations Windows, Image Credit: Scott Tilley, VE7TIL



Other News Links

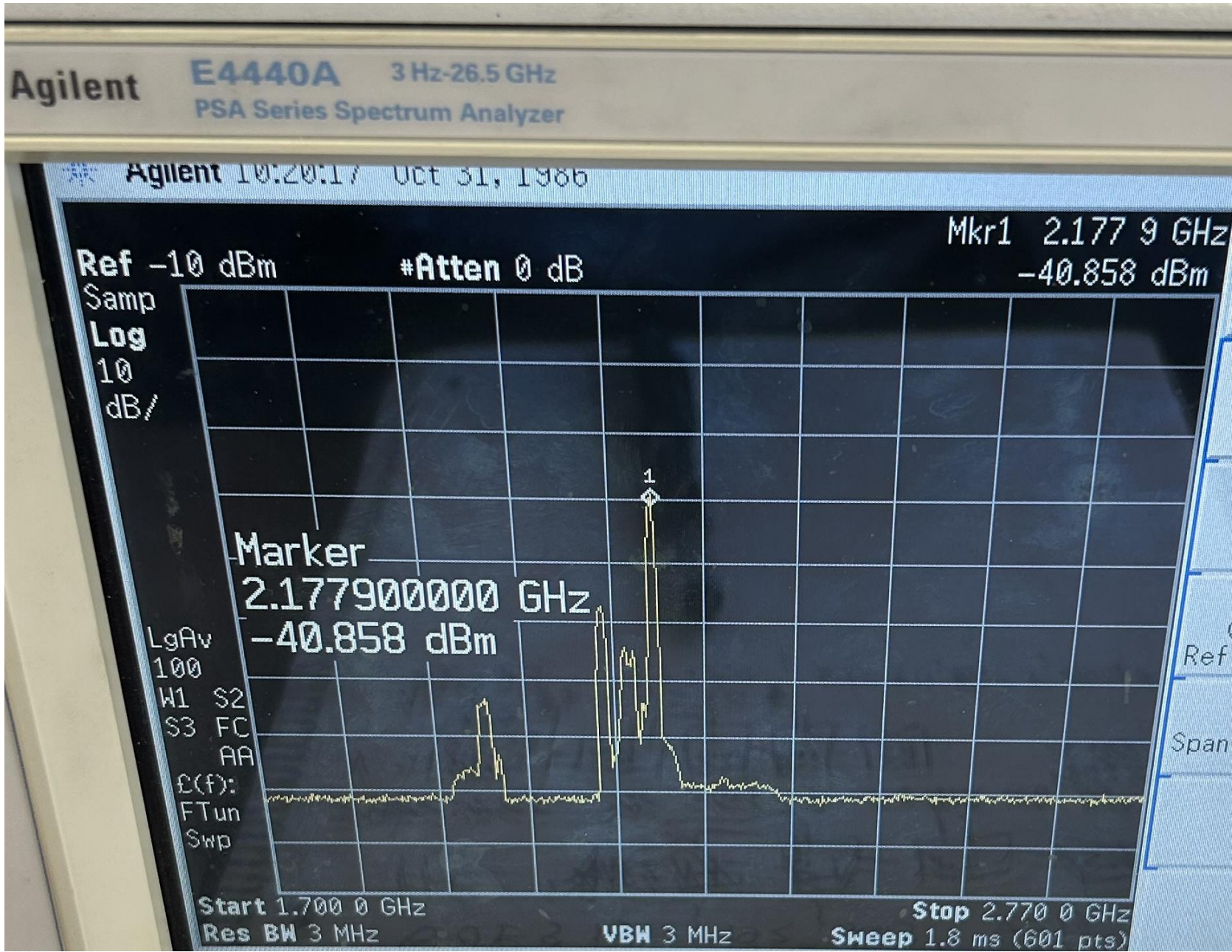
- There was an article in Toronto's Online Globe and Mail on Saturday, April 11, available if one has a subscription: https://www.theglobeandmail.com/canada/science/article-artemis-ii-mission-university-of-new-brunswick-volunteer/
- Megan MacDonald, from PEI, an Islander, represented our team in the PEI CBC News story: https://www.cbc.ca/player/play/video/9.7155284
- Megan MacDonald's tour is shown in this Instagram video: https://www.instagram.com/reel/DXMd_cbjbRE/?igsh=MWJ4MGhjam5yd3lyYw==

Other News Links

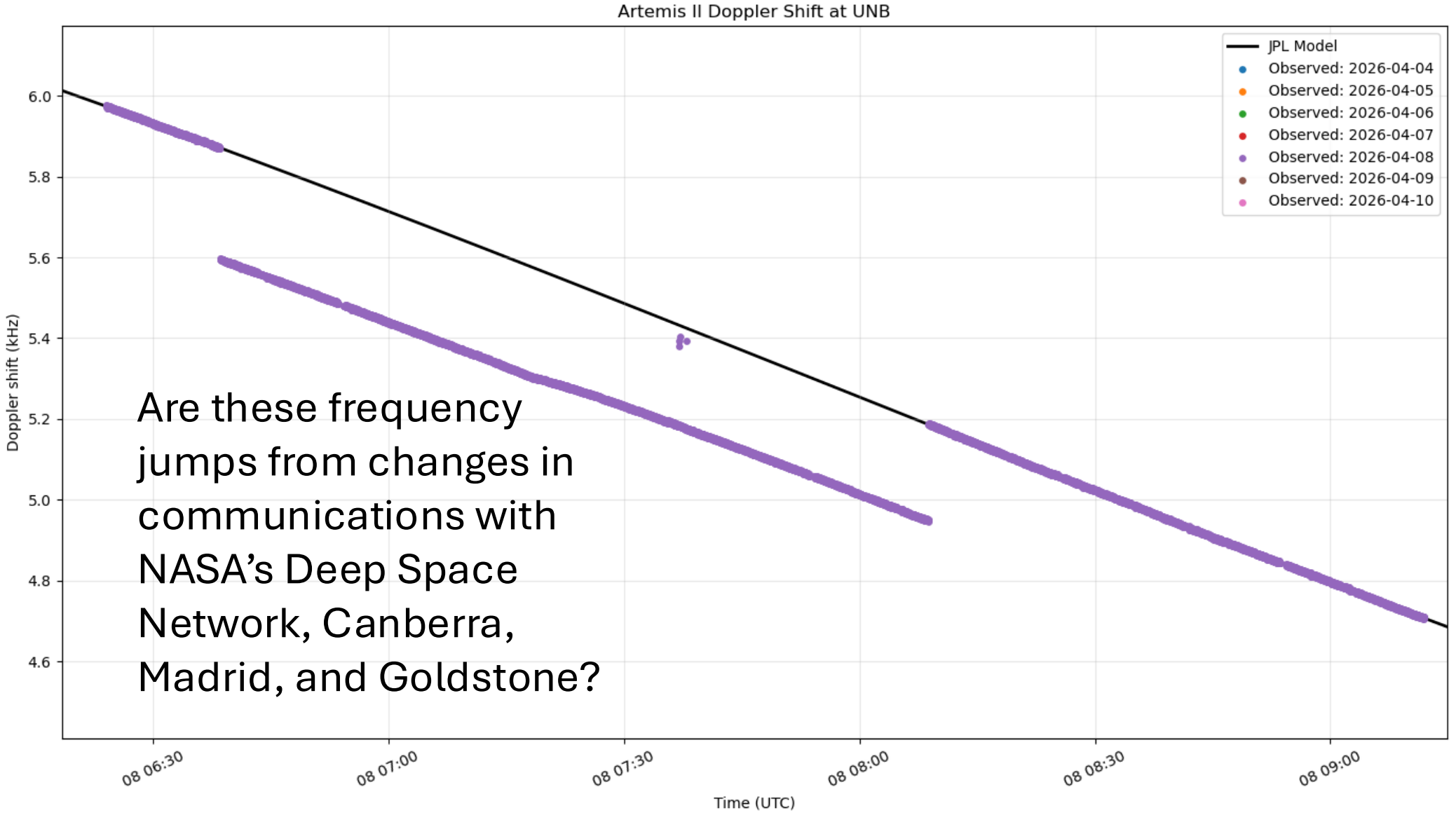
- Brent Petersen represented the team on a local CBC Radio program called Shift NB: https://www.cbc.ca/listen/live-radio/1-83-shift-nb/clip/16207318-tracking-artemis-ii
- UNB News story: https://blogs.unb.ca/newsroom/2026/04/moon-mission.php
- Fredericton CBC TV News story: https://www.cbc.ca/news/canada/new-brunswick/artemis-moon-mission-unb-nb-engineers-brent-petersen-9.7155163
- Global News TV, by Anna Mandin: https://globalnews.ca/news/11755161/university-of-new-brunswick-artemis/

Residual interference

- Residual interference after BPF 2.2-2.3, LNA, and BT on roof, and one BT in control room
- pointed at cell tower on horizon
- 2216.5 MHz nominal frequency of interest
- 2180.0 MHz location of residual interference, even after filtering

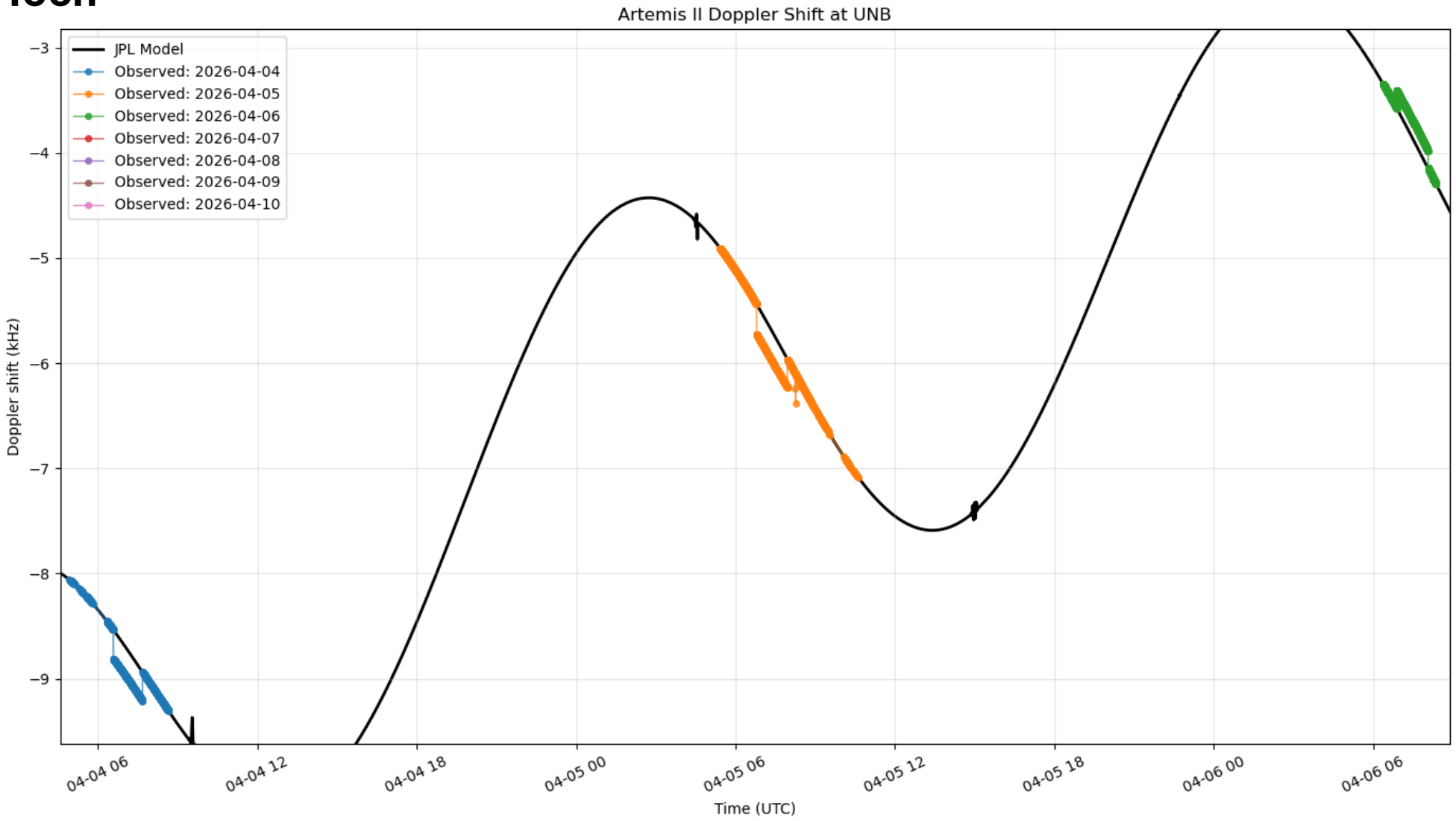


Comparison of Doppler Shifts, Calculated from Observations, to JPL Model

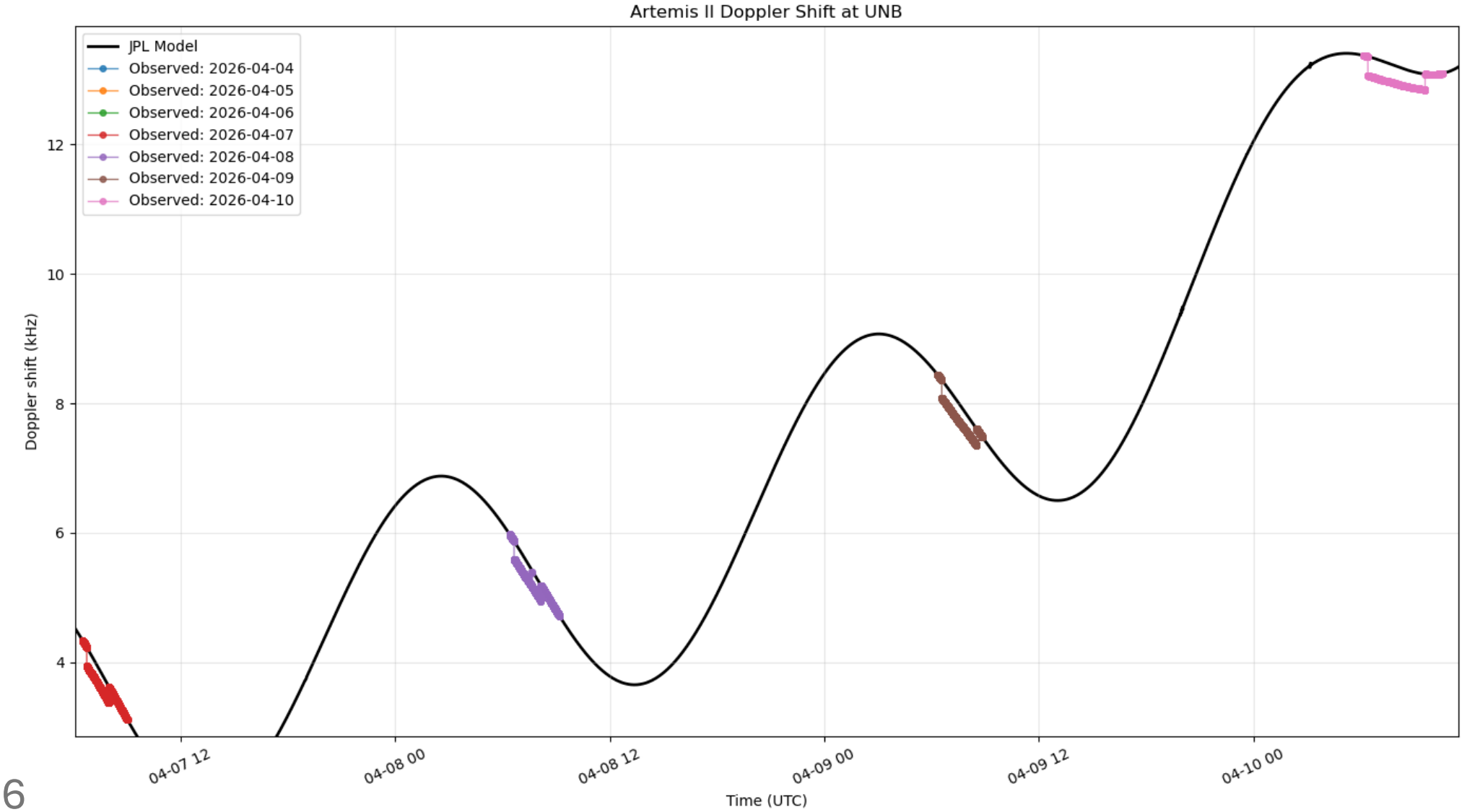


Are these frequency jumps from changes in communications with NASA's Deep Space Network, Canberra, Madrid, and Goldstone?

Comparison of Doppler Shifts, Calculated from Observations, to JPL Model, toward Moon



Comparison of Doppler Shifts, Calculated from Observations, to JPL Model, toward Earth



SRS FS725 Back