Impact of Zone Avoidance in reducing satellite downlink signal strength at VLBA station

Aaron Lawson[1], Ylva Pihlstrom[2], Bang Nhan[1],Chris De Pree[1],Frank Schinzel[1]
[1]Spectrum Management Department (SMD),[2]New Mexico Operations (NM Ops)

Date: May 12, 2026
Keys: spectrum management, VLBA, SpaceX, Starlink, RFI

Test Description

In December of 2025, NRAO Spectrum Management was informed by SpaceX that the Fort Davis VLBA station (VLBA-FD) had mistakenly not been receiving any Zone Avoidance (ZA) protection. At the other VLBA sites the ZA protection was used as a basic protection which involved the satellites avoiding directly illuminating the immediate area around the antenna. A subset of seven of the VLBA antennas are equipped with filters that appear to protect from Direct-to-Cell (DtC) downlink transmissions between 1990-1995 MHz. The VLBA-FD is one of the three VLBA stations not equipped with a filter covering the SpaceX's Starlink DtC band. A test was conducted on January 16, 2026 (internal reference test number of ODS-T04-VLBA) which had the same frequency tuning as a previous test, from November 14, 2025 (ODS-T03-VLBA) in the DtC range to look for any signs of data improvement with the addition of active Zone Avoidance. Additionally, a few spectral windows were placed at higher frequencies in the advertised S-band range to look for any decrease in data quality there due to the DtC signal. The setups for both observations can be found below in the Appendix. This memo summarizes the results of the experiment and finds no apparent impact on the S-band observations.

Contents

Changelog

2026.02.12.0 Aaron Lawson et al. — Initial published version.

1 VLBA-FD Zone Avoidance Effectiveness

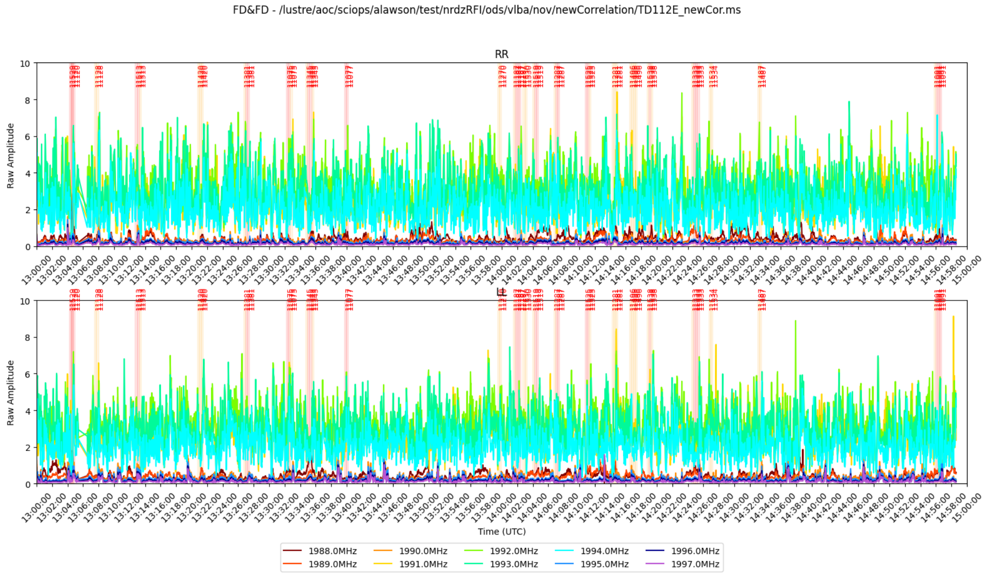


Figure 1: Nov. 14, 2025 data, ZA was not active. Key indicates the 62.5 kHz bandwidth for the associated spectrum. Note that the noise level is significantly higher in the DtC downlink bands than in adjacent bands.

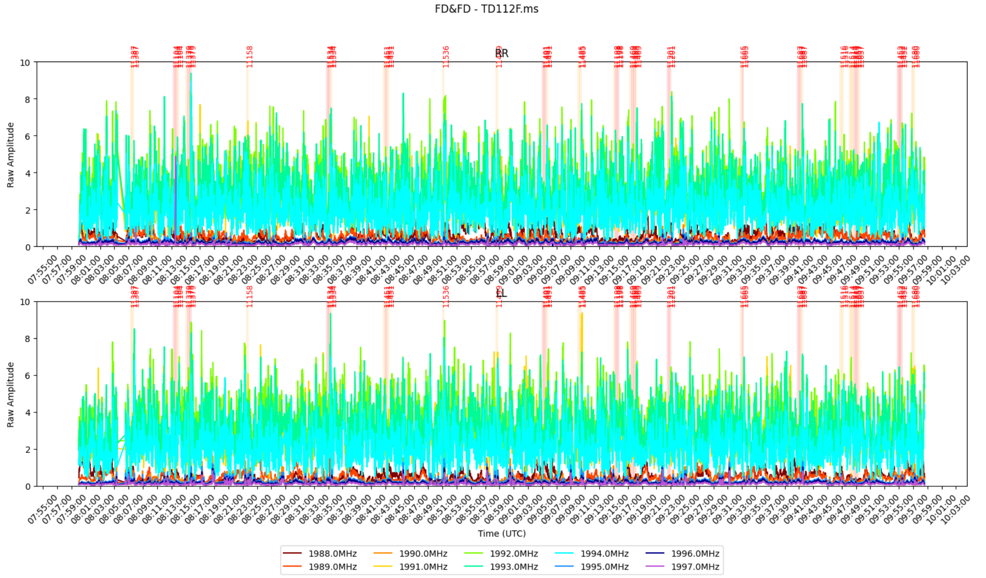


Figure 2: Jan. 16, 2026 data, ZA was active. Key indicates the 62.5 kHz bandwidth for the associated spectrum. Note that the noise level is significantly higher in the DtC downlink bands than in adjacent bands.

Figures 1 and 2 show data from the DtC range (1990-1995 MHz) and surrounding frequencies as observed with the VLBA-FD antenna. Data shown are from real-time autocorrelations collected at this site. Visually there is no obvious improvement. In order to statistically measure any changes between the two observations, the mean, medians, and RMS of the signal were also taken.

In the following tables, red cells represent stronger signals in the January 16 (ZA active) run. Green cells represent weaker signals in the January 16 run. The channel width was 62.5kHz and starts at the listed frequency. Table 1 uses all data shown in Figures 1 and 2. Table 2 uses data from the TBA events, the vertical shaded regions, along with one minute of time before and after the events. Table 3 uses only the data from the TBA events.

Percent Change (worse/better)

Freq (MHz)	LL Mean	RR Mean	LL Median	RR Median	LL RMS	RR RMS
1988	16	47	13	55	24	45
1989	16	60	14	67	21	61
1990	-16	2	-9	11	-16	-4
1991	3	-1	2	-2	5	0
1992	4	0	2	-2	6	1
1993	4	0	3	-2	5	1
1994	2	-3	1	-4	3	-2
1995	-12	14	-8	24	-13	11
1996	-10	23	-6	36	-13	23
1997	-16	18	-8	26	-21	22

Table 1: Percent Change between Nov. 14th and Jan. 16th, $\frac{(\mathrm{Jan}-\mathrm{Nov})\times 100}{\mathrm{Nov}}$, in the autocorrelated left-hand (LL) and right-handed (RR) polarizations. Uses all data sampled over the 2-hour observation, with the DtC channels in bold.

Percent Change (worse/better)

Freq (MHz)	LL Mean	RR Mean	LL Median	RR Median	LL RMS	RR RMS
1988	14	29	10	36	17	26
1989	-5	52	-9	63	-2	48
1990	-17	-4	-13	4	-17	-10
1991	3	-3	2	-5	4	-2
1992	4	-1	3	-4	6	1
1993	5	1	5	-1	7	3
1994	4	-2	3	-5	7	0
1995	-15	6	-13	16	-15	4
1996	-15	14	-12	22	-16	15
1997	-20	10	-14	18	-22	18

Table 2: Percent Change between Nov.14th and Jan. 16th ($((Jan-Nov)/Nov*100)$) in the autocorrelated left-hand (LL) and right-handed (RR) polarizations. Uses 2 minutes of data around the 15s TBA event from the log (1min. - 15s - 1min.), with the DtC channels in bold

Percent Change (worse/better)

Freq (MHz)	LL Mean	RR Mean	LL Median	RR Median	LL RMS	RR RMS
1988	8	22	6	25	8	21
1989	-6	42	-8	44	-6	41
1990	-24	-8	-27	-7	-23	-10
1991	-3	-9	-3	-10	-2	-8
1992	0	-9	-1	-10	1	-8
1993	4	-5	2	-7	5	-4
1994	2	-10	4	-11	3	-10
1995	-19	3	-21	4	-18	5
1996	-18	11	-19	10	-17	17
1997	-23	10	-24	6	-23	22

Table 3: Percent Change between Nov. 14th and Jan. 16th ($(Jan - Nov)/Nov * 100$) in the autocorrelated left-hand (LL) and right-handed (RR) polarizations. Uses only the 15s of data that makes up a TBA event, with the DtC channels in bold.

Tables 1 and 2 show no significant differences between the runs in the DtC band. Table 3 shows some improvement, but only in the Right Polarization (the DtC signal is Left Polarized from the view of the VLBA).

From these results, we conclude there was no significant improvement in data quality (reduction in signal in the downlink channels) at the Fort Davis site when engaging a small zone of avoidance around the telescope site.

2 Effects on S-band

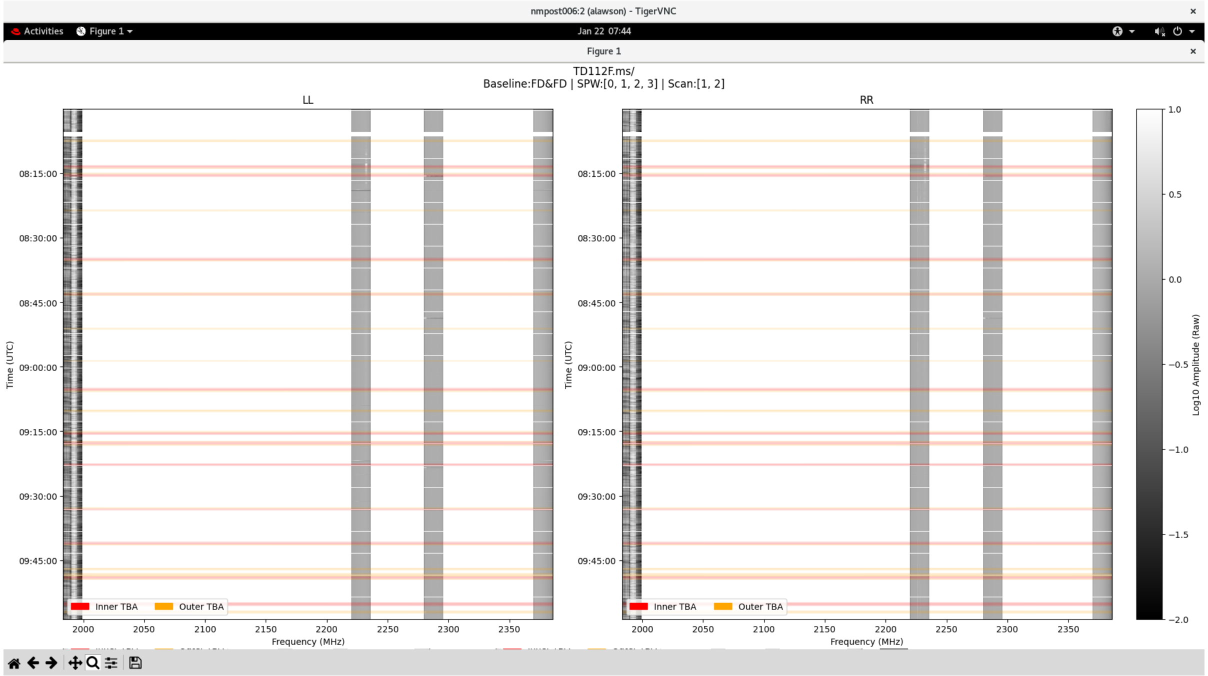


Figure 3: Waterfall plots of FD's autocorrelation data for the observation. The x-axis is shown in frequency space to show the extra spectral windows that were placed in the typical VLBA S-band observation range.

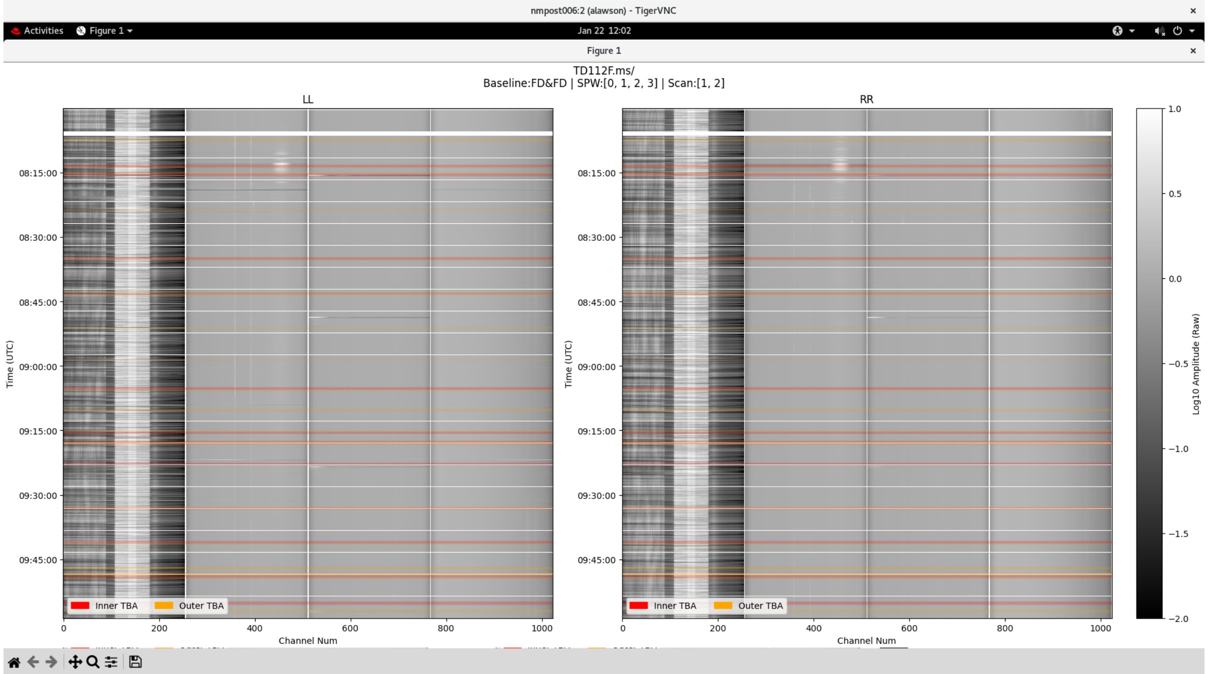


Figure 4: The same waterfall plots as Figure 3, except for the x-axis has been switched to channel index to remove unused space for visual clarity.

The S-band data were inspected with the waterfall plots and most of the typical S-band frequencies studied seemed unaffected by the DtC signal. During the observation, there was a single event that seemed to possibly be related to the Starlink system which is discussed below.

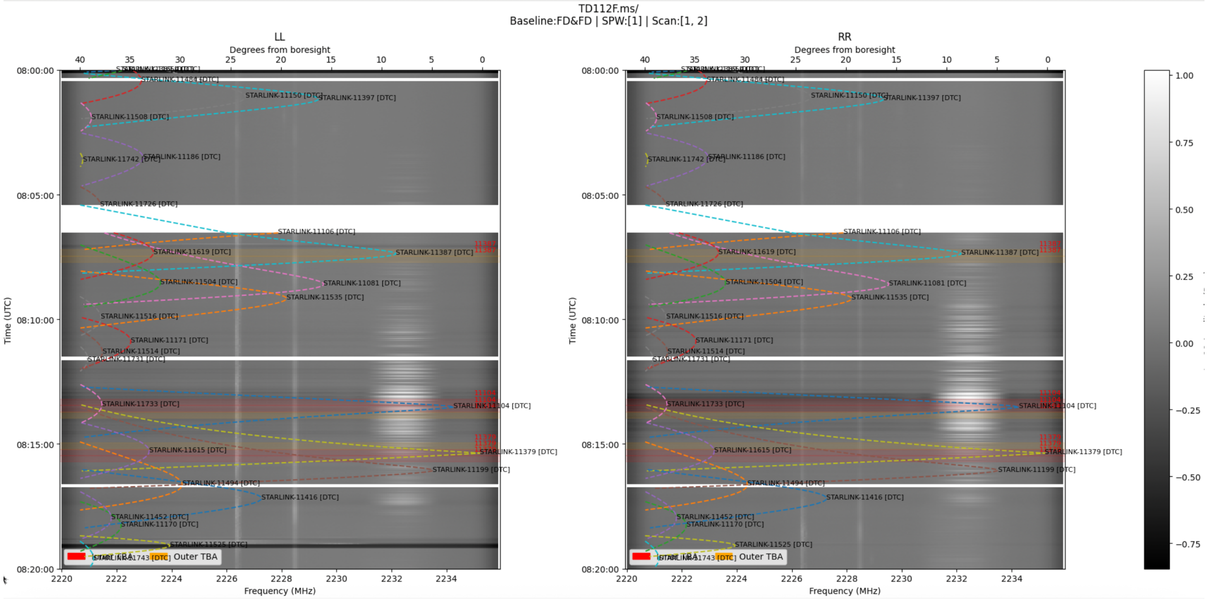


Figure 5: A waterfall plot showing an event that seems to be time coincident with a Starlink satellite (11104) crossing the telescope boresight. Boresight angular separation traces (dashed) are plotted over the data to show how close individual satellites came to the antenna's boresight.

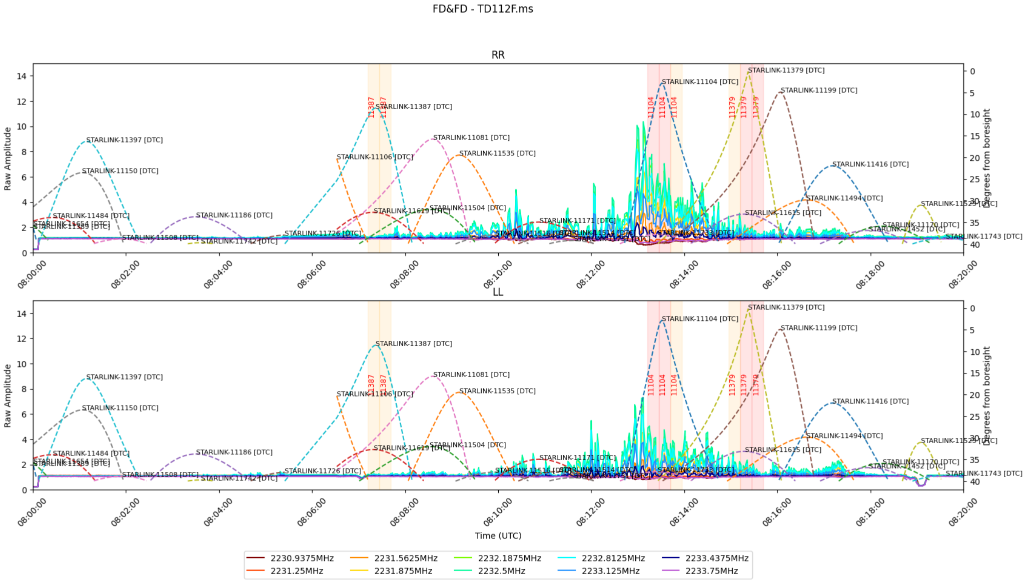


Figure 6: Spectra plot of the same event with a sub-selection of channels from Figure 5. Boresight angular separation traces (dashed) are plotted over the data to show how close individual satellites came to the antenna's boresight.

Figures 5 and 6 show an event near 08:13:30 UTC that is time coincident with Starlink satellite 11104's pass. The blue dashed line indicates that a Starlink satellite did pass very close to the telescope boresight at the time of the signal detected around 2232 MHz. The signal seems to be at a maximum when the satellite is closest to the antenna's boresight. However, due to the signal being measured well before and after the satellite comes close to boresight, it is currently thought that this event is not related to SpaceX satellites even though the peak of the signal is time coincident with satellite 11104's pass. Given the length of the signal's duration it may be more reasonable to conclude the origin of the signal is from a satellite operating at a higher elevation than Starlink's constellation. Conversations with SpaceX engineering staff also support the signal not being related to Starlink satellites.

3 Telescope Boresight Avoidance (TBA) Engaged

During the experiment, TBA was engaged by SpaceX using the mitigation requests (MRs) reported to the NRAO Operational Data Sharing (ODS[1]) API system (Nhan et al., 2025). As illustrated in Figure 7, all satellite passages that were reported by the SpaceX's TBA log are consistent with the angular boresight separation calculated using publicly available Two-Line Elements (TLE) based on the UTC timestamps recorded by the observation, except one satellite (STARLINK-11199, peaked at 08:16 UTC). The angular separation approaches zero when the satellites are passing the boresight of the telescope's main beam.

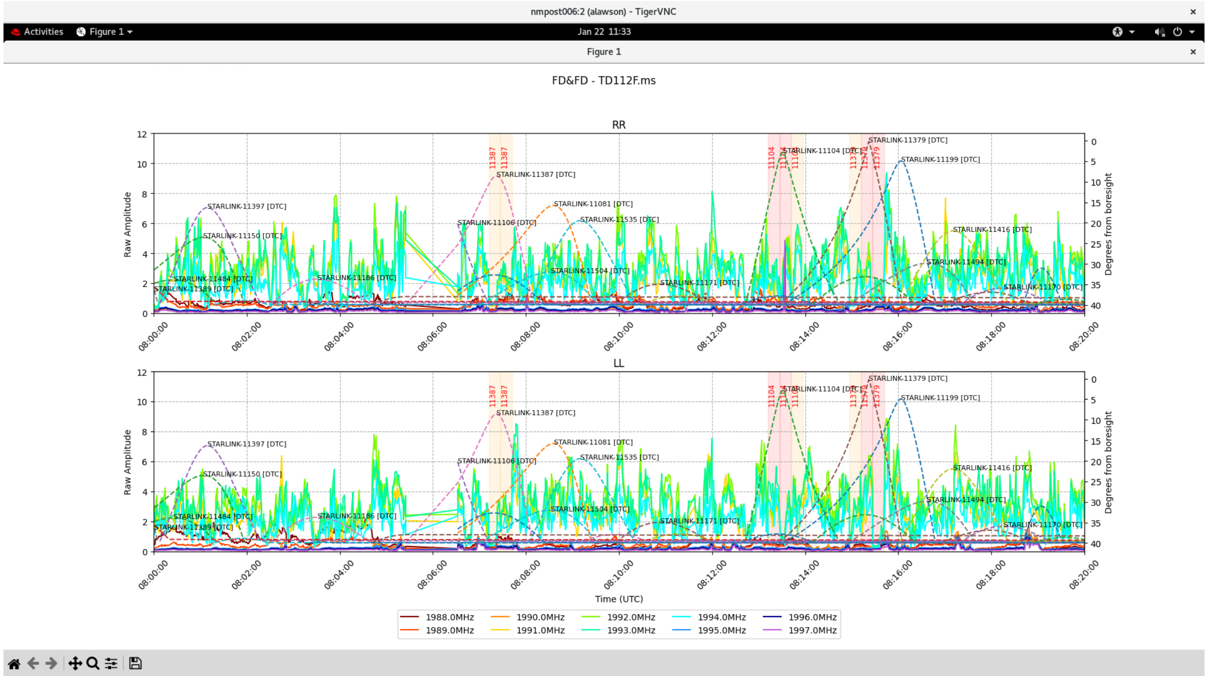


Figure 7: An example of the profile plot for the autocorrelated raw spectra at VLBA-FD as a function of UTC illustrates the TBA being engaged. The VLBA data channels within the DtC bands show the increased signal levels. However, the angular separation between the satellite trajectories and telescope boresight (dashed curve) computed based on publicly available TLE are consistently at a minimum when the TBA is expected to be engaged, based on the provided TBA log files from the satellite operator (shaded orange/outer and red/inner regions). Noting Starlink-11199 does not have a TBA log entry; this is likely because the TBA was within the "inner boresight" region for less than a 15-second increment.

---

[1] https://obs.vla.nrao.edu/ods/

4 Conclusions

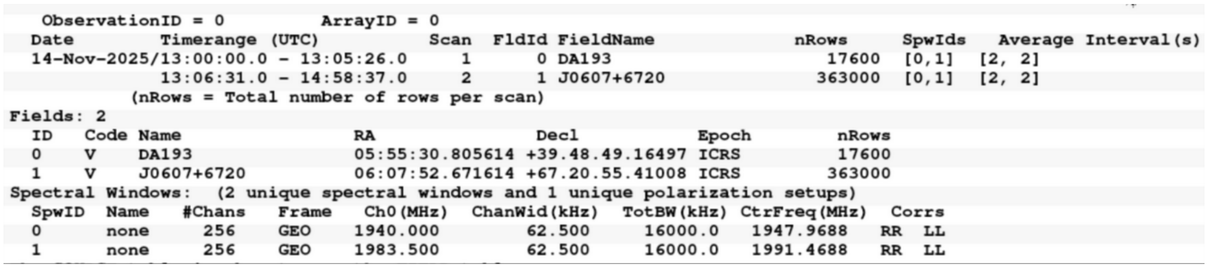
We do not see any significant reduction in signal strength due to the use of Zone Avoidance parameters at the Fort Davis VLBA station. Given these results, we removed Zone Avoidance for the remaining three VLBA stations (PT, FD, MK) and will continue to monitor for degraded data quality.

We do not see a significant impact on data quality in the advertised S-band range due to the DtC signal. A single event of reduced data quality, which also coincided with a TBA event, was present but is thought not to be due to SpaceX's Starlink satellites. We conclude this due to the amount of time the signal is detectable and from discussions with the SpaceX engineering team. NRAO will continue testing and evaluating the performance of the ODS reporting and TBA activation in the coming months.

5 Acknowledgments

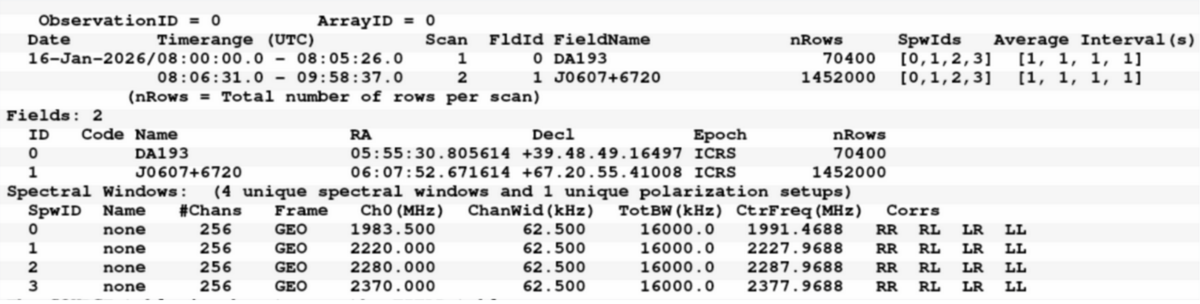
The National Radio Astronomy Observatory (NRAO) and the Green Bank Observatory (GBO) are facilities of the National Science Foundation (NSF) operated under cooperative agreement by Associated Universities, Inc. The ODS system was developed by NRAO with support from the NSF grants: SII NRDZ: Dynamic Protection and Spectrum Monitoring for Radio Observatories (AST-2232159), and SWIFT-SAT: Observational Data Sharing (AST-2332422). The ODS development team consists of Daniel Faes (NMS), Dawn Pattison (SSA), Jack Hill (SIS), Thomas Chamberlin (GBO), Mark Whitehead (DMS), Bang Nhan (SMD), and Randall Arnold (PMD). The authors would like to thank the SpaceX team for their coordination and assistance in reconfiguring the Starlink downlink during this test, particularly Jacob Donenfeld, Matt Iverson, and Christopher Steele.

6 Appendix



```
   ObservationID = 0         ArrayID = 0
  Date        Timerange (UTC)          Scan  FldId FieldName             nRows     SpwIds   Average Interval(s)
  14-Nov-2025/13:00:00.0 - 13:05:26.0     1      0 DA193                    17600  [0,1]  [2, 2]
              13:06:31.0 - 14:58:37.0     2      1 J0607+6720              363000  [0,1]  [2, 2]
           (nRows = Total number of rows per scan)
Fields: 2
  ID   Code Name                RA               Decl           Epoch        nRows
  0    V    DA193               05:55:30.805614 +39.48.49.16497 ICRS         17600
  1    V    J0607+6720          06:07:52.671614 +67.20.55.41008 ICRS        363000
Spectral Windows:  (2 unique spectral windows and 1 unique polarization setups)
  SpwID  Name   #Chans   Frame   Ch0(MHz)  ChanWid(kHz)  TotBW(kHz) CtrFreq(MHz)  Corrs
  0      none     256    GEO    1940.000        62.500     16000.0   1947.9688    RR  LL
  1      none     256    GEO    1983.500        62.500     16000.0   1991.4688    RR  LL
```

Figure 8: The output from the CASA listobs task for the November 14, 2025 (ODS-T03-VLBA) observation. Shows observational metadata including frequency setups, source information, and scan information.



```
   ObservationID = 0         ArrayID = 0
  Date        Timerange (UTC)          Scan  FldId FieldName             nRows     SpwIds   Average Interval(s)
  16-Jan-2026/08:00:00.0 - 08:05:26.0     1      0 DA193                   70400  [0,1,2,3]  [1, 1, 1, 1]
              08:06:31.0 - 09:58:37.0     2      1 J0607+6720            1452000  [0,1,2,3]  [1, 1, 1, 1]
           (nRows = Total number of rows per scan)
Fields: 2
  ID   Code Name                RA               Decl           Epoch        nRows
  0         DA193               05:55:30.805614 +39.48.49.16497 ICRS         70400
  1         J0607+6720          06:07:52.671614 +67.20.55.41008 ICRS       1452000
Spectral Windows:  (4 unique spectral windows and 1 unique polarization setups)
  SpwID  Name   #Chans   Frame   Ch0(MHz)  ChanWid(kHz)  TotBW(kHz)  CtrFreq(MHz)  Corrs
  0      none     256    GEO    1983.500        62.500     16000.0   1991.4688   RR  RL  LR  LL
  1      none     256    GEO    2220.000        62.500     16000.0   2227.9688   RR  RL  LR  LL
  2      none     256    GEO    2280.000        62.500     16000.0   2287.9688   RR  RL  LR  LL
  3      none     256    GEO    2370.000        62.500     16000.0   2377.9688   RR  RL  LR  LL
```

Figure 9: The output from the CASA listobs task for the January 16, 2026 (ODS-T04-VLBA) observation. Shows observational metadata including frequency setups, source information, and scan information.

References

Nhan, Bang D. et al. (2025). “ODS: A Self-Reporting System for Radio Telescopes to Coexist with Adaptive Satellite Constellations”. In: *IEEE Communications Magazine* 63.11, pp. 146–151. DOI: 10.1109/MCOM.001.2500125.