On the Processing of Log Files for Monitoring Antenna Health

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Abstract To improve the quality of geodetic results, we have developed an infrastructure for timely processing of telemetry from IVS observing stations. We check every three hours for new log files with telemetry from both VLBI observing sessions and single dish experiments and automatically process them. The telemetry data we use are the system temperature, phase calibration phases and amplitudes, system equivalent flux density, and differences between formatter clock and GPS clock. For the system temperature and phase calibration, processing includes filtering outliers and computing averages and standard deviations of the scatter in each scan. Cleaned and post-processed telemetry is archived. Our process detects abnormalities, such as anomalously high system temperature, unstable phase calibration phases, jumps in the GPS and formatter clock differences, and others. With our procedure, the latency of detection of station abnormalities is reduced to less than six hours. Early detection of abnormalities reduces the amount of affected data because station personnel get early alerts. We discuss our experience of running this system since 2022.

Keywords Telemetry, Tsys, GPS Clock Offset, Single Dish Experiment

1 Introduction

Very Long Baseline Interferometry (VLBI) observations are carried out by two or more radio telescopes simultaneously observing the same extragalactic sources. VLBI stations are operated by software. Most geodetic VLBI stations are running the VLBI Field System (FS) package [1]. The VLBI Field System executes two command files, collectively called schedules, that code commands for antenna slewing, setting VLBI hardware, and making inquiries of sensors. Raw data from sensors, as well as some derived quantities from sensor reading, are recorded in the FS log files. The telemetry includes:

- meteorological sensors, which are limited to temperature, humidity, and air pressure sensors;
- total power integrated units (*TPI*);
- system temperature sensors (*Tsys*);
- phase calibration sensors (*PCal*);
- system equivalent flux density (*SEFD*); and
- difference between GPS and formatted time (*FMTGPS*).

FS log files from IVS stations during VLBI experiments are archived by the Crustal Dynamics Data Information System (CDDIS), and they are publicly available at https://cddis.nasa.gov/archive/vlbi/ivsdata/aux. The use of VLBI Field System logs for data analysis is complicated because their format is inconsistent and undocumented. To overcome this difficulty, we convert original full FS log files into a standardized format. The conversion is done using the utility Log2ant, developed by Sergei Bolotin. Log2ant is distributed with the software package nuSolve [2]. It processes all flavors of FS log files and writes them in a standardized antcal format. This format is convenient for further analysis. Specifications of the antcal format are available in the docs repository of the latest release of nuSolve [2].

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We have developed the Antenna Telemetry Processing (ATP) toolkit for processing telemetry in antcal format. Processing entails averaging the telemetry data over each scan. This filters out any short lived disturbances and reduces the noise from the data. The output of this processing can be used in data analysis, source imaging, and system health diagnostics. In this paper we discuss how we developed the ATP toolkit and how it has been used to assess the functionality of antennas at VLBI sites.

2 Reduced Data File

The telemetry provided by the FS has a varying sampling rate. Depending on the hardware, the sampling rate may be one second. These sampling rates are useful for detecting abrupt jumps in the telemetry, e.g., short-lived spikes in system temperature (*Tsys*). However, a 1-s sampling rate is excessive for most scientific analyses and calibration. For further processing, it is convenient to have the telemetry averaged over a scan interval. Therefore, the ATP toolkit cleans the telemetry for outliers, then it computes the scan time averages and their standard deviations. In the case of phase calibration data (*PCal*), before the averaging, the phase group delays are computed, and phase ambiguities are resolved. The output of this process is written to a reduced data file in the same standardized format that we call antcal version 2. Each version of antcal formatted files has a provenance section that holds details about the origin of the data and the history of modifications. A flow chart of the processing of antenna telemetry from FS log files is detailed in Figure 1

It was customary in the past to process VLBI logs after all data had reached a correlator, which could be weeks or months after observing. Therefore, this resulted in data failures being noticed and reported after a large delay. We download FS logs from CDDIS and initiate the processing pipeline by a cron job every three hours. Therefore, within six hours of a log file's availability we can begin to assess the quality of the data from a given observation session. If any failures are discovered in the telemetry data, we are able to provide feedback to the station operators by the next business day. This automation reduced delays from weeks and months to less than one day.

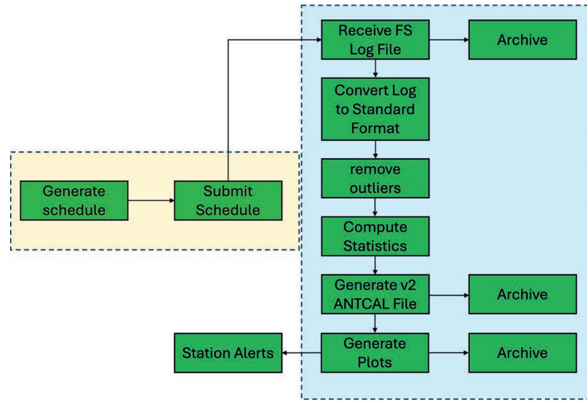

Fig. 1 Flow chart for processing antenna telemetry from FS logs. The shaded blocks indicate processes that are automated, with the yellow shade representing only the single-dish experiment (SDE) automation and blue indicating automation for all logs.

2.1 Telemetry Visualization

We have also developed capabilities to visualize the data. The ATP toolkit allows one to plot the telemetry data as functions of any available variable using either the original (version 1) or the reduced (version 2) telemetry file; e.g., *Tsys* is given as a function of frequency, time, elevation, and azimuth, and, therefore, it can be plotted in any of those modes or in a combination of the modes. To illustrate this, Figure 2 shows the average *Tsys* in K at V-polarization, at a frequency of 10,696.4 MHz, as a function of elevation at the Goddard Geophysical and Astronomical Observatory (GGAO) 12-m antenna, GGAO12M, on 16 November 2023 from VLBI Global Observing System (VGOS) experiment vr2304. The contribution of the emission of the atmosphere grows with a decrease in elevation, raising the antenna system temperature, as shown in Figure 2. When the elevation is too low, an antenna may pick up emission from the ground either directly or by sidelobes.

3 Study Cases

Regularly monitoring telemetry data is essential for the assesment of station hardware and diagnosing malfunctions. In addition to processing telemetry from regular VLBI experiments, in 2022 we launched a program of single dish experiments (SDE) that are exe-

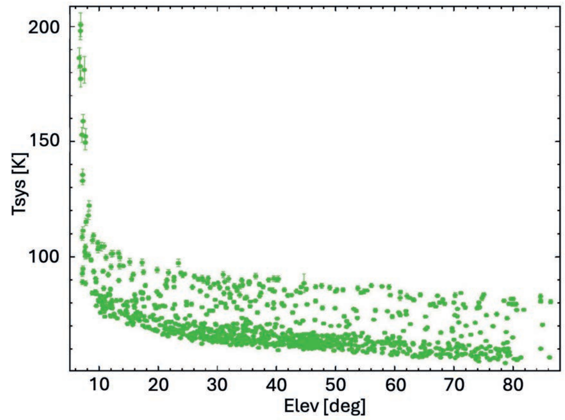

Fig. 2 Average V pol *Tsys* observations in K at GGAO12M observed at $10,696.4$ MHz frequency on 16 November 2023. The abscissae show Elevation in degrees, and the ordinates are average scan *Tsys* values in K. The error bars of each point show the σ of each scan.

cuted at each station independently. Unlike VLBI experiments, for SDEs we do not record voltage from the receivers. We process FS log files only. We ran SDEs of several types: (a) stow-in, when the antenna is set to a parked position throughout the duration of the experiment; (b) tipping curve, when the antenna only moves in the elevation direction; and (c) az-el, when the antenna moves in both azimuth and elevation. This section gives examples of cases where ATP was used for the purposes of isolating radio frequency interference (RFI) and outliers in clock differences.

3.1 RFI Monitoring

Large radio antennas are very sensitive and highly susceptible to any incoming radio signals. A strong artificial signal raises the antenna system temperature, thus reducing sensitivity. Depending on the power of the radio frequency interference (RFI), the signal-to-noise ratio (SNR) of the interferometric response can be reduced. Strong RFI can reduce the SNR below the antenna receiver's detection level or even damage the low noise amplifier. To monitor for RFI we use the time series of the *Tsys* data. VGOS specifications require $Tsys < 50$ K. Therefore, ATP uses that as the threshold to check if a given observation is potentially affected by the RFI. ATP scans the spectrum for any outliers (Figure 3), and if any are identified, we can zoom into each of them as a function of time (Figure 4) to identify when the interference occured, as well as the direction from which the interference came. In this particular case, the RFI source was identified as a nearby cellphone tower that transmits daily at midnight UTC, near Kokee Park Geophysical Observatory (KPGO).

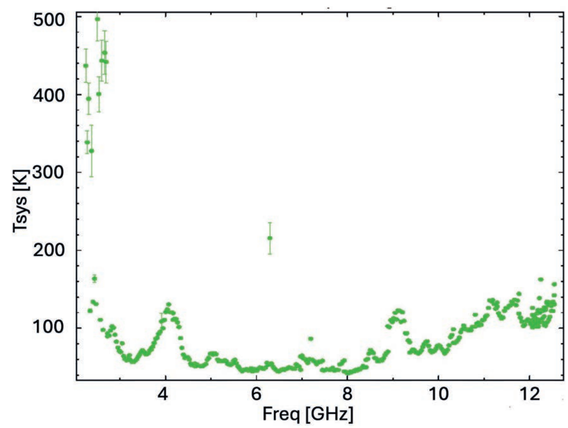

Fig. 3 Average H pol *Tsys* observations in K at the Kokee Park Geophysical Observatory (KPGO) 12-m antenna KOKEE12M observed through the weekend of 18 May 2024, as part of SDE k2x068. The abscissae show frequency in GHz, and the ordinates are average scan *Tsys* values in K. The error bars of each point show the standard deviation (σ) of each scan. There is a clear saturation between 2–3 GHz that warrants further investigation.

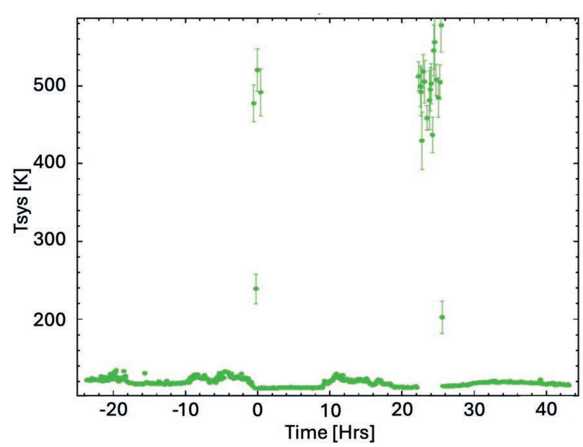

Fig. 4 Average H pol *Tsys* observations in K at KOKEE12M observed at $2,568.4$ MHz through the weekend of 18 May 2024. The abscissae show *time* in hours from midnight UTC, and the ordinates are average scan *Tsys* values in K. The error bars of each point show the standard deviation (σ) of each scan.

3.2 Antenna Clock Offset

The VLBI data acquisition terminal performs synchronization of the so-called formatter time, maintained by the local hydrogen maser, against the GPS time from the GNSS receiver. This terminal may have more than one board and therefore several formatter time implementations. The difference in formatter time implemented by different boards should be small. ATP allows us to visualize these differences and to compute statistics. See an example of anomalously large offsets in formatter minus GPS time differences among three boards in Figure 5. There are four plots representing clock sensor boards, two of which are overlaid, as we would expect. The rest of the boards are offset up to 150 ns.

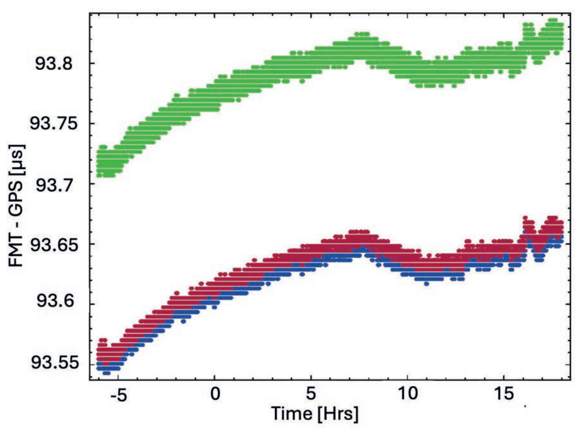

Fig. 5 Formatter minus GPS clock differences in µs from VGOS experiment vo3327 at YEBES on 23 November 2023.

4 Outcome and Future Work

We have developed an automated toolkit for the automatic processing of VLBI log files. The system sets alerts when it detects abnormalities. We have processed logs from CDDIS dating back to 2020. To supplement the assessment of VLBI data, we run weekend-long single-dish experiments (SDEs) at NASA sites GGAO, MGO, and KPGO. This allows us to store telemetry data that would have otherwise been lost when antennas are idle.

In the future, we will propagate the computation of atmospheric brightness from NASA numerical weather models to the reduced data files and also back date our log analysis to files from 2010 to 2020.

Acknowledgements

The authors would like to acknowledge and thank the station operators at the NASA sites for their weekly support ensuring that the SDEs are run and sent back to us for analysis in a timely manner every week. At GGAO, we are supported by K. Pazamickas, J. Redmond, and S. Gilliams; at MGO, we have E. Terrazas and R. Spencer; and at KPGO, we are supported by C. Coughlin and K. Imai. The authors also wish to thank Dr. Sergei Bolotin, for his assistance and timely responses to our requests related to the Log2ant utility.

References

1. Himwich, E. (2024). “VLBI Field System,” NVI, Inc. GitHub repository, accessed 2 May 2024, https://github.com/nvi-inc/fs
2. Bolotin, S. (2023). “nuSolve: Geodetic VLBI data analysis software,” Source Forge Repository, accessed 2 May 2024, https://sourceforge.net/projects/nusolve/
3. Gipson, J. (2018). “SKED VLBI Scheduling Software,” Goddard Space Flight Center, Web document https://ivscc.gsfc.nasa.gov/IVS_AC/sked_cat/SkedManual_v2018October12.pdf
4. Petrov, L. (2023). “Program SUR_SKED for scheduling VLBI observations,” Astrogeo Center, accessed May 2 2024, http://astrogeo.org/sur_sked/
5. Schartner, M., Böhm, J. (2019). “VieSched++: a new VLBI scheduling software for geodesy and astrometry,” Publications of the Astronomical Society of the Pacific, vol. 131(1002), pp. 1–12, doi:10.1088/1538-3873/ab1820