Network Coordinator Report

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Abstract

This report summarizes the activities of the IVS Network Coordinator for 2002. It includes an assessment of the network performance in terms of the yield of usable data over a 12 month period. A discussion of a growing problem for geodesy, RFI, is presented. A brief report on the stability of the UTC measurement time-tags based on 18 months of data is presented.

1. Network Performance

The network coordinator maintains a “station performance database”, which contains a wealth of information about station performance and problems. It includes all reports of problems from correlator pre-passes, correlation reports, analysts, and stations as well as a history of inquiries made about resolving problems. It was started in May of 2001 and includes all reports since then. There are no analyst reports except for occasional e-mails about problems processing certain sessions.

It was decided to base assessment of station performance on the correlator reports, since they formed the most reliable, albeit not necessarily the most timely, reports of monitoring station performance. (Within the database, the issue of timely coverage is addressed by the station and correlator pre-pass reports.) The coverage of sessions in the correlator reports is somewhat spotty due to delays in processing sessions and the unevenness of the delays. Last year’s Network Coordinator Report was based on the period of November 2000 to October 2001. This year’s report is based on the period of January 2002 to December 2002. The period of November 2001 to December 2001 has not been covered.

At the time of this writing, for data acquired in 24-hour sessions from January 2002 to December 2002, correlator reports for 161 sessions have been received. Approximately 23 24-hour sessions are not represented either because they have not been processed or the correlation reports were not readily available. The missing sessions include seven JDxxxx, four SYWxxx, two BF071x, two V131xx, E3006-E3008, EURO66, OHIG20-OHIG22, and T2012. There are a total of 991 station days covered in this report, or about six stations per experiment on average.

Any assessment of station performance is somewhat arbitrary, but the following approach was used. For each station in each session an estimate was made of the fraction of data lost. Each station day was then assigned to one of the following categories: (A) No loss (0% lost), (B) Slight Loss (1-6% lost), (C) Moderate Loss (7-20% lost), (D) Severe Loss (21-70% lost), and (F) Failed (71-100% lost). Again these categories are somewhat arbitrary. The divide between slight and moderate loss was set so that loss of one channel (7%) was considered moderate. Consequently, the slight category includes mostly some RFI, and short losses, up to a little less than 90 minutes. The divide between moderate and severe was set so that loss of three channels (21%) would be severe. This also means that the loss of two channels or gaps of up to about 5 hours would be considered moderate. Severe loss includes loss of three channels or more, operation with a warm receiver, long gaps, and other severe problems. Failure includes any cases where the data from the station are not useful for geodesy. The definitions of these categories will probably undergo some refinements in the future. The losses for 2002, 2001, and part of 2000 are given in Table 1.

Table 1. Loss Distribution

	2002	**2001**	**2000 (partial)**
Station Days	**990**	**757**	**382**
Grade (Loss)	**Percentage**	**Percentage**	**Percentage**
A - No Loss (0%)	38	41	51
B - Slight Loss (1-6%)	27	25	18
C - Moderate Loss (7-20%)	21	21	16
D - Severe Loss (21-70%)	9	6	8
F - Failure (71-100%)	6	6	7

For the 2002 period, the integrated data lost correspond to 120.8 station days or about 12.2%. This compares to loss of about 11.6% for 2001. The results from 2002 do not seem out of line with results from previous years. However, there was considerable variation from quarter-to-quarter. Please see Table 2 for a breakdown by quarters for 2002, 2001 and part of 2000. The percentage loss has been declining since the first quarter of 2002, which was particularly poor. Whether the good performance for the last quarter can be maintained will become evident in the future. The good performance in the last quarter of 2002 was somewhat helped by the CONT02 campaign which had a loss of about 7.0%, somewhat better than the average for that quarter, but not significantly so when the few percent of error in these estimates is considered.

The losses per station are given in Table 3 for stations that had more than six sessions in 2002. These results are probably reasonably accurate at the 5-10% level. The results are sorted by increasing percentage of lost data for 2002. Please note that Seshan for 2000 and TIGO for 2000 and 2001 did not have sufficient sessions for the results to be considered meaningful. Please see Table 4 for results for stations that had too few sessions, six or less, for the results to be considered meaningful. This table is sorted first by decreasing number of station days and then by increasing percentage lost.

Table 2. Quarterly Data Lost

Period	**Percentage lost**	**Station Days**
Nov 99-Jan 00 (partial)	6.5	54
Feb 00-Apr 00 (partial)	8.0	61
May 00-Jul 00 (partial)	11.8	87
Aug 00-Oct 00	14.1	180
Nov 00-Jan 01	13.4	167
Feb 01-Apr 01	7.2	173
May 01-Jul 01	12.2	203
Aug 01-Oct 01	13.3	214
Jan 02-Mar 02	18.4	234
Apr 02-Jun 02	11.5	224
Jul 02-Sep 02	12.0	235
Oct 02-Dec 02	8.0	297
(CONT02)	7.0	120

Table 3. 2002 Station Losses

Station	Sessions	% Lost	2001	2000	Problem in 2002
Kokee	99	2.0	1.9%	6.0%	Rat (rodent), RFI, power, overwriting
Wettzell	124	3.5	3.8%	3.6%	lost tapes, missed start, ACU, RFI
Gilcreek	116	4.5	15.8%	13.5%	RX, antenna, rack power module
Westford	82	6.6	7.9%	2.3%	power, RX, RFI, lost disks
Tsukuba	31	8.8	8.2%	2.3%	missed, typhoon, RFI, recorder
Medicina	18	9.2	10.2%	12.8%	RFI, unknown, power, FS
HartRAO	54	11.8	4.1%	6.8%	Dicke switch, antenna, pointing
Seshan	15	11.8	15.8%		recorder, antenna, X roll-off
Onsala	28	12.7	15.9%	3.2%	formatter, clock offset, recorder, ionosphere
Algonquin	78	13.1	17.8%	9.6%	RFI, power, antenna, VLBA4 rack
Ny-Ålesund	105	16.7	8.9%	5.9%	RX warm, antenna, overwriting, FS, missed
TIGO	36	17.5			power, formatter, RX, antenna
Hobart	26	19.6	28.3%	19.2%	RFI, tape tracks, RX
Fortaleza	46	19.9	8.3%	18.1%	RX, antenna, tape drive, clock offsets
Matera	79	30.0	29.4%	5.2%	antenna, RFI

Table 4. 2002 Station Data Loss - small n

Station	Sessions	% Lost	2001	Problem in 2002
Crimea	7	34.0	24.1%	unknown, bad tracks, telescope, pointing?
MV-3	6	12.8	6.1%	VCs, antenna, recorder, RFI
Noto	6	21.6	4.4%	schedule was wrong, signal level/RFI?
Yebes	6	33.4	70.1%	RX, power failure, antenna control
DSS45	6	35.4	7.1%	late, missed, antenna use conflicts?
O'Higgins	5	6.2	79.2%	power failure
DSS65	4	41.8	6.0%	missed, EAC problems, no time on tape
Urumqi	4	53.5	44.1%	pointing, RX?
Parkes	3	11.4		recorder tracks
Yellowknife	3	69.0	41.2%	too cold for cryo, equipment comm. problems
DSS15	2	12.9	28.6%	late start, slewing antenna
Kashima34	1	0.0		None
Syowa	1	25.0	10.0%	missing data in dubbed tapes

There were several problems that contributed to data being lost in 2002. The most significant of these are (not necessarily in order of significance): (1) RFI, (2) general antenna and RX problems, (3) Matera azimuth motor, encoder and RX, (4) track overwriting at many stations but particularly at Ny-Ålesund, and (5) clock offsets, both jumps and incorrectly reported values.

As was explained in the Network Coordinator Report in last year's annual report, these statistics are expressed in terms of equivalent lost observing time at the stations. However since a station appears in more than one baseline, this does not reflect the overall loss in data for the session. The result is that the average percentage loss per station must be multiplied by a factor of two to get the percentage loss per session. This result is an approximation subject to the conditions that: (1) the data distribution by baseline is roughly equal and (2) the losses at different stations are independent. The former assumption is generally reasonable, although the distribution is skewed if some subset of stations in the network is weaker than the others. This is typically the case when TIGO is included. The latter assumption is most accurate when the losses are small. This tends to over-estimate the average loss as the losses become less independent, as they do when they are large. In any event for the overall average data lost per station we see 12.2%, thus the overall average data loss per session is about 24.4%. This is similar to the results from last year.

2. RFI

Although it has not gotten much worse in the last year, Radio Frequency Interference (RFI) continues to be a significant problem. There is concern that more and more of the S-band spectrum will be allocated to commercial applications in the next few years. This may force geodetic operations off this band. Reacting to this challenge will require a significant outlay in research and development and infrastructure in particular for new receivers and most likely new antennas.

RFI is a particular problem at S-band. Direct satellite broadcast of music radio has started in North America. The DARS (Digital Audio Radio Service) band is 2320-2345 MHz. This is particularly a problem for Westford and Algonquin. There continue to be problems with point-to-point communication links in the S-band bandpass for Europe. This is particularly bad at Matera, but other European stations, particularly Medicina, are suffering from S-band RFI as well. A new international cellular telephone standard, IMT-2000, which occupies 2135-2150 MHz is now making an appearance in Japan and impacting Tsukuba and Kashima. At Tsukuba the problem is particularly severe because for some antenna orientations, the S-band front-end is saturating. Since IMT-2000 is an international standard this might also become a problem for other locations.

For the stations that are the most impacted by RFI, Matera, Algonquin, Medicina, Hobart, and Westford, the effects are at the 5-20% data loss. There is evidence of RFI affecting other stations including Kokee, Wettzell, Gilcreek, Tsukuba, and MV-3. The presence of RFI triggers correlator "G" codes which cause scans to be rejected because the fringe amplitudes vary too much between the channels. Ironically because of the way G codes are assigned, stronger scans tend to be deleted preferentially even though weaker scans may be as strongly affected. Unless the scan is strong, it is difficult to determine if a G code is warranted. Some consideration was given to refining the definition of G codes to make them more useful and reduce the data loss. However, this effort was abandoned as impractical. In any event, in the long run, we can expect the RFI situation to get worse.

3. Clock Offsets

One of the goals stated in the IVS Working Group 2 report (included in last year's annual report) is to measure UT1-UTC to an accuracy of about 2-3 μseconds. There was some question whether this is achievable with our current level of clock offset measurement. Any errors in the UTC time-tags of the observations are mapped directly into the estimate of UT1-UTC. The correlators construct the time tags by adding an offset to the measurements made at the stations of

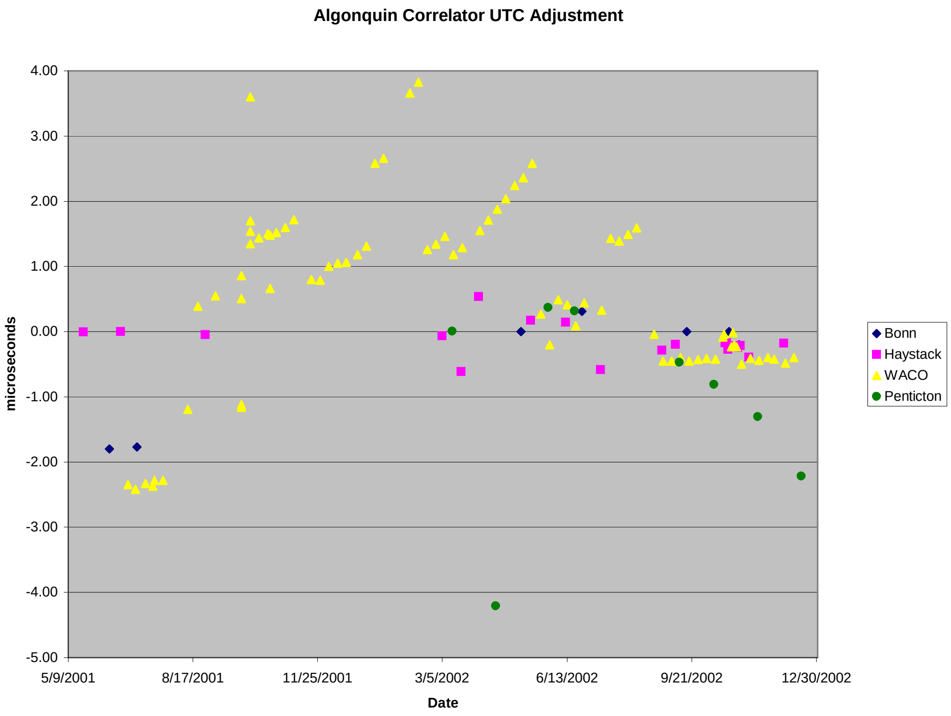

Figure 1. **Algonquin UTC Correlator Adjustment**

the differences between the formatter and UTC as defined by the GPS system. The offset applied by the correlator corresponds roughly to the cable delay between the data recording system in the control room (the "back-end") and the receiver on the telescope (the "front-end"). One would expect that these offsets should be stable to much better than one μsecond, which corresponds to a cable length of about 300 meters. This is much larger than any expected cable variation at the station. After collecting the value of the offset from experiments over an approximately 18 month period a coherent picture is starting to develop. Some problems have come to light at the few μsecond level: (1) different correlators use different offsets for a given station, (2) the offsets for a station at a correlator may vary significantly, sometimes in a noise-like way and sometimes systematically, (3) the Washington correlator has artificially set the offset for Kokee to zero. The latter point is not so significant when examining the evolution of UT1-UTC, but it may cause a few hundred nano-second error in the alignment of the reference frames. A plot of the correlator offsets or "adjustments" to the formatter to GPS differences from Algonquin are shown in Figure 1. The offsets for different correlators are shown with different symbols. Some of the previously mentioned problems are evident here. For the approximately 18 month period that data is available for: (1)

the three correlators have used different offsets for data acquired at about the same time, (2) there are several μsecond trends in the data before summer 2002, and (3) Bonn has been using an offset of zero. The second problem has been resolved. It was caused by using an offset relative to the wrong clock. This problem disappeared after spring 2002, but apparently reappeared for a short time in the summer.

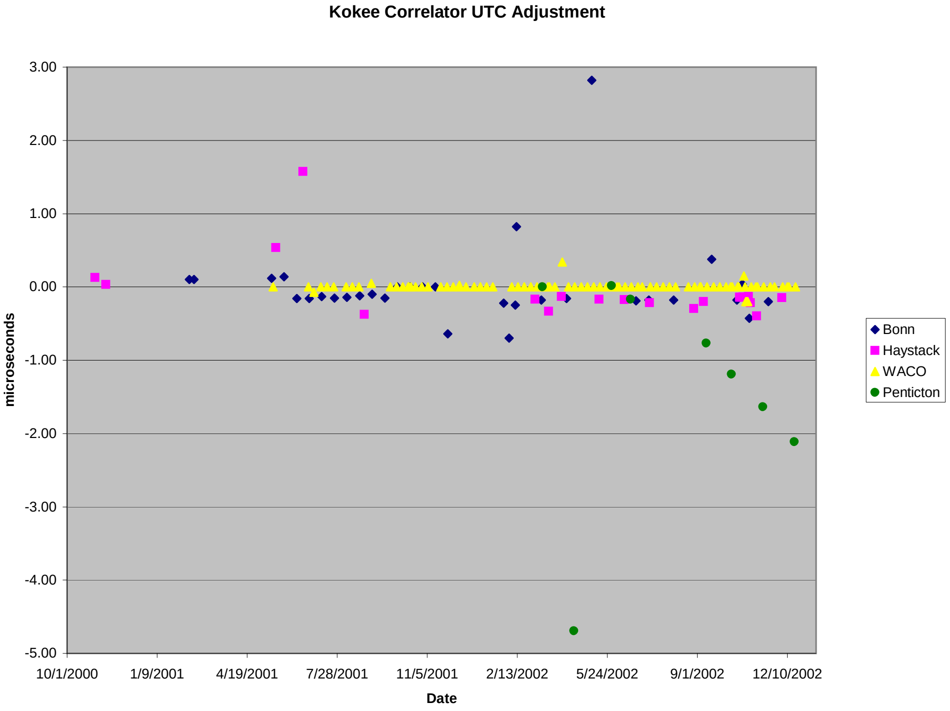

Figure 2. **Kokee UTC Correlator Adjustment**

A more representative plot of the correlator clock adjustments can be seen in the Kokee Correlator UTC Adjustment in Figure 2. In this plot the artificial value of zero used by WACO can be seen. In addition, the scatter at the few tenths of a μsecond level seen in the values used by other correlators can be seen. In general this probably is not a significant effect for reaching the desired accuracy of about 2-3 μseconds. However, some of the excursions for the Bonn correlator are disturbingly large. It is recommended that the correlators use a consistent set of offsets. For example, Kokee's offset can be artificially set to zero and the relative offsets of other stations that observe with Kokee can be determined. Using these stations, offsets for other stations can be determined. While it may be that some stations may have their offsets change over time, it is unlikely that several will change in the same experiment, so it should be possible to keep the noise-level in

UT1-UTC measurements due to the clock offsets at the few tenths of a μsecond level without an extreme amount of effort. This level can improved further by using average clock offsets for entire sessions rather than single measurements.

An interesting feature of Figure 2 is that the correlator offset for Kokee from the Penticton correlator is showing a similar behavior to that of Algonquin's offset at the other correlators before summer of 2002. It could be that this is related to the same problem that was seen at Algonquin before that time. However unlike the older data, since the effect is appearing at both ends of the baseline, it is likely that it is impacting the measurements of UT1-UTC at the level seen on the plot, a couple μseconds. This should be corrected for future sessions. In addition it raises another issue. The data processed by the Penticton correlator is purely S2. The intrinsic delays in the cabling of these systems may be different from those with non-S2 data. Some effort may be needed to find the correct relative offset of the S2 systems relative to the other systems. This may be an issue for comparing K4 data to that from other systems as well. These issues may be at the few tens of nanosecond level, but some care will be needed to make sure they are kept at that level.

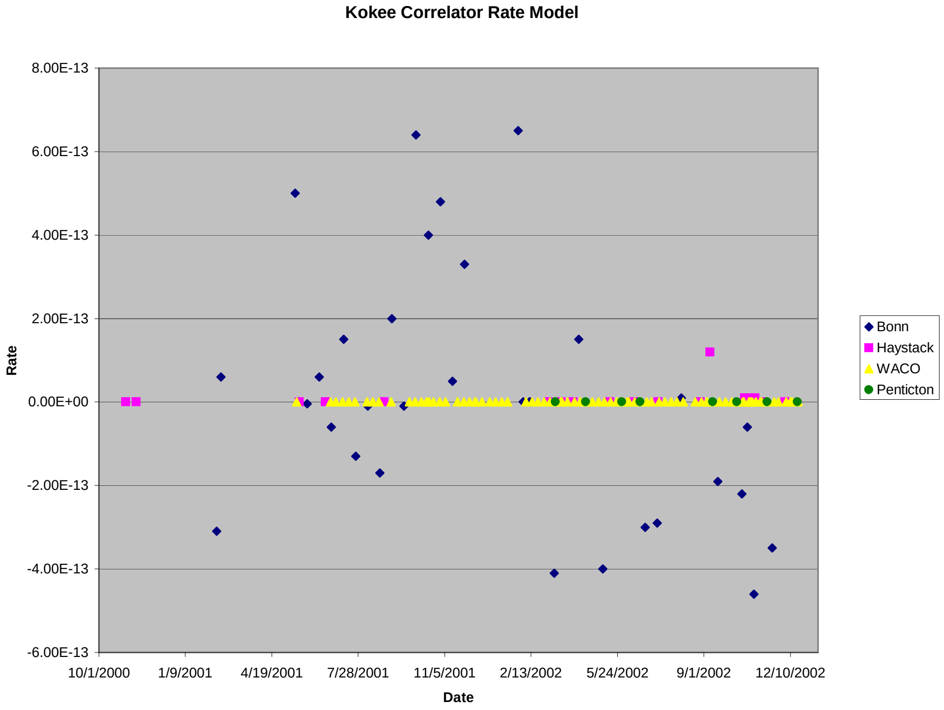

Figure 3. **Kokee Correlator Rate Model**

A further issue is how stable the UT1 rate measurements are. This depends on the accuracy of the correlator models for the Maser rates for the observing stations and the accuracy of the Maser rates themselves. The desired accuracy of the IVS Working Group 2 report was for 0.3-0.5 μseconds/day. This translates into a clock rate of about 3.5e-12 to 5.8e-12. A plot of the Maser rates for Kokee are shown in Figure 3. As can be seen the correlator models show wide variations. Again WACO has artificially set Kokee's rate to zero. Haystack tends to also use a rate close to zero. Although the values used by Bonn can grow as large as one-fifth of the lower limit of the desired accuracy, there is generally no problem at this time. However, a program for establishing a consistent set of clock rates can be carried on simultaneously with one for a consistent set of clock offsets. The result should reduce this problem well below any significant level for some time to come.

A further issue is how close the rates of the underlying Maser are to UTC. The rates for the Masers maintained by NASA are generally kept at the 1e-14 level or better [Private communication from Irv Diegel, Honeywell Technical Services, Inc.]. This should not cause a problem, but when developing a consistent set of Maser rates to be used for correlations care should be taken to make sure that the "zero" rate reference is defined by some station with a Maser that has a rate that is very close to zero. Kokee would seem to be a good choice as long as it is performing at the nominal level.