Unifying Tsys, IF, and VSOP Recording across the EVN

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This document raises three issues which can cause confusion and operational trouble at EVN stations if not dealt with in an uniform way. We will need correct system temperature estimates in the same format regardless of the data acquisition rack type. The different inherent limitations of MarkIII/IV and VLBA rack IF connections will become more acute as dual polarization experiments are becoming more common. Finally, a simple wiring change is described which would alleviate the need to move VLBA rack sampler cables from MarkIII position to VLBA position for VSOP mode support.

Contents

1 Tsys measurements

In the following we are presenting several individual implementation details of Tsys measurements which—when realized in an uniform way—can ease the post-processing step of VLBI data considerably. The suggestions are presented in rough priority order. It is implicitly assumed that there is a remotely-controllable noise diode/tube available in the receiver(s).

1.1 Ensuring "onsource" status before start of scans

The most prevalent reason for wrong Tsys estimates being present in ANCAL files is that the "preob" Tsys before each scan was measured wildly off-source. This often results in the need for manual editing and copying the “postob” after each scan values to replace the plain wrong Tsys values in the ANCAL file.

At present, the only widely accepted way to ensure the on-source status is to make sure that all scheduling packages have a correct estimate of the slewing speed of each antenna. This means that the VLBI friends would have to know the right contact persons to whom they need to announce any changes in their antenna performance.

It is not a practical idea to force the FS to wait until the antenna has reached the source, since this would result in a different tape start times for each individual antenna. Also, a few reference-mapping applications have deliberately started recording when the majority of antennas have reached the source—there is no point in waiting for the slowest one while the majority subnet can already produce good data. However, in these cases start-of-the-scan Tsys figures of all slow antennas will be wrong.

1.2 Ensuring correct “tpzero” measurements

Currently the FS uses the 60dB (MarkIII/IV) or 20dB (VLBA) attenuators to present a “zero” IF level to all VCs/BBCs and uses that as the zero level of total power indicators (“tpzero”). 60dB is probably quite safe in this sense, but 20dB is not enough to prevent a strong source from “coming thru” with enough level to distort the final Tsys readings, calculated using an artificially high estimate of the internal “tpzero” noise level. This results in too optimistic Tsys figures.

There are (at least) two possible solutions to this problem which plagues in practice VLBA data acquisition racks only. The first is to adjust the formulae used in the FS to compensate for the amount of attenuation instead of assuming a terminated IF input. The second one is to use an unused BBC IF input such as input D as “tpzero” reference level. By using the “bbcnn” command to switch the IF input from the normal input channel to an “empty” channel before measuring “tpzero” an accurate value can be obtained. However, this practice will conflict with the needs of dual polarization setups, as will be seen in section 2.

1.3 Providing similar log lines using MkIII, VLBA, and MkIV racks

There is a fundamental difference between MarkIII/IV VCs and VLBA BBCs, namely MarkIII/IV VCs only have a single one total power indicator whereas VLBA BBCs have two. BBCs can measure total power of both USB and LSB simultaneously but VCs have to be separately switched from USB to LSB and vice versa. Furthermore, the integration period of the TPI of MarkIII/IV VCs is fixed at one second which means one has to wait for at least two seconds after switching the TPI source from USB to LSB or vice versa before reading out the TPI value.

To get a similar set of log lines and Tsys figures of both upper and lower sidebands, we propose that the following strategy be adopted for measuring any “tpi”, “tpical”, and “tpzero” value, regardless of the rack type:

1. All TPIs of VCs are kept at the USB setting.
2. The TPI values of all VCs/BBCs *USB channels only* are read in.
3. All TPIs of VCs are switched over to the LSB setting.

4. A two-second delay.
5. The TPI values of all VCs/BBCs *LSB channels only* are read in.
6. All TPIs of VCs are switched back to the USB setting.
7. A two-second delay (unless this is the last in a series of measurements).

The net result would be that the “tsysn” lines in the logs would be in a similar format regardless of the rack type. This would make it easier to generate the ANCAL file automatically using the “LOG2ANCAL” / “CAP” package. Also, this would introduce Tsys of LSBs using MarkIII/IV video converters—these are not usually measured at the moment.

1.4 Providing Tsys figures of appropriate IF channels of a given mode

To further ease the interpretation of “tsysn” lines in the “CAP” package it would be beneficial to agree on the order of VC/BBC numbers in which the TPI readouts will appear in the log. There are a few possible alternatives:

1. “drudg” will be modified to emit the procedures for measuring Tsys and it will include only those VC/BBC channels which are actually being used in the current mode. This would happen much in the same way “drudg” currently emits mode-specific setup SNAP procedures in the schedule procedure file.
2. We will always include all 14 converters in the “tpxxxx” log lines. This introduces the problem that if an unnecessary VC/BBC is missing or malfunctioning, we will not get the log line at all. This is probably an oversight in the implementation of “tpxxxx” commands in the FS and can be rectified.
3. We will use fixed sets of all BBCs (Mark III mode A), odd-numbered BBCs (Mark III modes B, C, and E), and/or first eight BBCs (all VLBA and most MarkIV modes). SNAP procedures for a limited number of cases can be “prepackaged” and selected either manually or by “drudg” into the “.prc” schedule procedure file.

1.5 Estimating Tsys during scans

Practice has shown that most VLBI receivers feature relatively stable gain, i.e. the gain does not change considerably during the timescales of the order of minutes, the duration of most scans/passes. The same holds for noise diodes and this would allow us to estimate changes in Tsys even during the scans although we cannot fire up the noise diode.

We can linearly interpolate the values of “tpical-tpi” and “tpzero” in between the start and the end of a given scan. During the scan we can measure additional “tpi” values at regular intervals and these will enable us to calculate more accurate estimates for during-the-scan Tsys values. This approach requires that VLBA BBC automatic gain control is disabled and set to manual at the start of each scan, in conjunction with measuring the start-of-scan Tsys value. It is important to let AGC to adjust gain levels just before measuring start-of-scan Tsys, at a time when the antenna is already on source. It needs to be estimated if disabling AGC during one scan will affect 2-bit sampling too much.

Measuring “tpi” at regular intervals during the scan can be performed in (at least) the following ways:

1. Using the so-called “time-scheduled” SNAP commands. Unfortunately in the current implementation of FS any absolute timed wait will prevent any time-scheduled commands from being executed, i.e for instance every typical wait in a schedule will prevent any timed commands from executing while the FS is waiting for the absolute wait to expire.
2. Using SNAP procedures with a calculated number of “tpi” commands and short waits. There is a danger of accidentally inserting too long a procedure after the “midob” of a short scan, unless the extra “tpi” commands are inserted automatically by for example “drudg”.

1.6 Enabling 80Hz continuous Tsys with VLBA BBCs

The method presented in previous section 1.5 can be useful in getting pseudo-continuous Tsys estimates regardless of data acquisition rack type. The VLBA BBCs, however, are capable of supporting true continuous Tsys measurements with their 80Hz synchronized on-off total power indicators.

Enabling continuous 80Hz Tsys using VLBA BBCs requires the following:

1. A low-level noise diode in the receiver(s), controllable by a 80Hz 5MHz/1pps synchronized signal.
2. A device which can generate the synchronization signal. Some (but not all) VLBA racks feature a timing module which is primary used to ensure correct phase difference of 5MHz and 1pps but which can also generate synchronized 80Hz. This signal has to be routed from the rack to the receiver, however.
3. Adjustments to the FS “bbcnn” SNAP command so it can read out the on and off TPI MCB registers. In principle this can be done with hexadecimal “mcb=” commands for testing purposes. Integration of the values is performed independently by BBC firmware.
4. The same kind of support for performing periodic SNAP commands as what is required for Tsys estimates during scans. (See previous section 1.5.)

2 IF connections

Dual polarization (and possibly multi-frequency) observations are becoming more common in EVN sessions. The limitations MarkIII/IV racks and VLBA rack impose on multiple IF connections are slightly different.

A MarkIII/IV rack accept a maximum of two IFs. Any individual VC can be manually “patched” to select either of these. (There is an additional restriction that the patch panel IF output connectors for both IFs have been divided into two groups, “low” and “high” band, i.e. depending on the IF patch panel connector, a given VC can be set to “low” or “high” frequencies only.)

VLBA racks have four IF input connectors. In the original 8 BBC configuration all eight BBCs have access to all four IFs and the selection can be performed remotely from within the FS. However, most EVN stations which have VLBA racks have the so-called “geodetic VLBA” variation of the rack with 14 slots for fourteen

BBCs required by MarkIII mode A support. In these racks the original BBCs 1–8 have access to IF channels A and C and the "extra" BBCs 9–14 can use only B and D. BBCs 1 and 2 are a special case, since they can access all four IFs. (Please see the diagram attached as appendix to this document.)

There are many conflicting requirements for IF connections using a geodetic VLBA rack:

1. MarkIII mode A requires the use of external power splitters to get a single IF to all fourteen converters, for example LCP to IFs A and B and RCP to IFs C and D. Dual polarization (or dual frequency) needs two power splitters and it uses all four IF inputs.
2. Using up all four IF inputs prevents "tpzero" measurements using a terminated IF input as reference zero level.
3. Measuring dual polarization in a VLBA/MarkIV mode using BBCs 1–8 only can be done using IF channels A and C much in the same way as with MarkIII/IV racks.
4. MarkIII modes B, C, and E can be recorded in dual-pol either:
   (a) With the two-power-splitter setup used for MarkIII mode A. This allows using the same VC/BBC numbers as with MarkIII/IV.
   (b) Or alternatively, BBCs 1–7 can be used with formatter "trackform" set to route BBCs 1–7 as MarkIII VCs 1, 3, 5, 7, 9, 11, and 13. In this case IF inputs A and C can be used in the same way as with any VLBA/MarkIV mode.
5. Using more than two IFs in a VLBA-compatible mode is in the general case impossible with geodetic rack wiring, since IF channels B and D go to BBCs 9–14 which do not have magnitude bit samplers connected. One-bit modes could be emulated if BBC numbers 9–14 are acceptable for third and fourth IF.

In summary, the IF flexibility offered by MarkIII/IV and VLBA racks is different:

- MarkIII/IV has only two IFs, but any VC can select either of them. This selection is manual, however, and changing the patch panel should be avoided.
- VLBA has four IFs, but permanent wiring limits that a given BBC can only select between two alternatives. This selection can be performed remotely from within the FS.

Since the usefulness of more than two IF inputs in geodetic VLBA racks is limited (see above), we could decide to always use power splitters to connect IF number 1 to A and B and IF 2 to B and D. This will however preclude the use of an "empty" IF input as "tpzero" reference level and makes the need for a formula adjustment in FS more acute. (See section 1.2.) The net result would be that any BBC in a geodetic VLBA rack could choose between two IF inputs, much in the same way as in MarkII/IV racks.

There is still the final problem of manual patching of MarkIII/IV racks. We do not have sufficient experience with MarkIII to be able to suggest a set of suitable standard patching schemes. Obviously it needs to be made clear to the proposers what kind of IF patching will be available.

3 Recording the VSOP mode regardless of VLBA sampler cable positions

Together with modifying the IF input connectors, the designers of the “geodetic” VLBA rack had to find a way to connect the extra BBCs to the 32 available bit stream input channels of the VLBA formatter. In the original VLBA design one sampler box takes the 8 USB/LSB “video” channels of 4 BBCs and samples each with two bits, resulting in 16 bit streams which are routed to the formatter in a 40-way ribbon cable as differential ECL levels (two wires, a twisted pair per each bit stream). Two sampler boxes together take care of all 8 BBCs and use all 32 available formatter inputs.

The sampler boxes of a geodetic VLBA rack have six additional sign bit samplers each: one for USB/LSB of BBCs 9–14. Since there is no place for these bit streams in the original VLBA sampler output connectors, an alternative “MarkIII” output connector was added to both sampler boxes. These connector carry only outputs of sign bit samplers and use 28 of the available 32 bit stream inputs of the VLBA formatter.

The FS currently supports the use of either kind of sampler output connectors. However, every time one has to switch from VLBA configuration to MarkIII and vice versa, the following happens:

1. The field system must be stopped.
2. The connectors must be moved to other positions. The formatter clock will stop while the cables are disconnected since 1pps is being input using this route.
3. A control file of the FS (‘/usr2/control/equip.ctl’) must be edited to reflect the change of rack type (‘vlba’/‘vlbag’).
4. FS needs to be restarted.
5. The formatter clock has to be set with ‘sy=fmset’.
6. FS time has to be updated with ‘sy=run setcl’.

Additionally, regular ribbon cable connectors are not rated for more than tens, perhaps a few hundreds of insertions.

These cable swaps can be avoided if:

1. Magnitude bit streams of two additional BBCs are made available in the “MarkIII” compatible sampler output connectors. These additional wires have been indicated with dashed lines in the diagram in appendix. We have to use BBC05 instead of the “natural” BBC02, since there are only two vacant outputs in each sampler box and BBC01 and BBC02 share the same box.
2. The FS is updated to know about this new “rack type”.
3. The VSOP schedules will start to use BBC05 instead of BBC02, or at least tolerate stations which substitute all references to BBC02 with BBC05 on their own.
4. Alternatively the problem will eventually go away when there is no demand for MarkIII mode A. MarkIII modes B, C, and E, all VLBA modes, and all MarkIV modes possible for a VLBA rack can

be recorded using only BBCs 1–8. For astronomy purposes, a number of VLBA/MarkIV modes offer improved bandwidth, better tape usage, and faster correlation than MarkIII mode A, and still use only eight or fewer BBCs.

4 Suggestions for action items

1. Establish a way to convey antenna slewing speeds back to all scheduling software being used for astronomy and geodesy scheduling.
2. Investigate if it will be possible to correct the formulae of "tpzero" in the FS.
3. All friends: modify the station-specific Tsys SNAP procedures to result in two log lines, one for USB only and the other for LSB only.
4. Investigate if it will be possible to have "drudg" generate the Tsys procedures.
5. Determine the best way to implement "tpi" (and other SNAP) commands occurring at regular intervals during scans.
6. Document available MarkIII/IV patch alternatives (or perhaps only one) and their limitations ("low/high" band). Make this available to the proposers and scheduling software.
7. Decide whether to add extra wires to VLBA samplers or to start developing standard procedures for running MarkIII modes B, C, and E with standard 8 BBC VLBA configuration.