Impact of Operations on Data Analysis

May 2019 TOW

WEH/BEC/RAS/MAT/AEN/AB/MP/MB

Peculiar Offsets

- Roughly speaking, they represent the signal path delay from the antenna to the sampler at each station
  - They are "Peculiar" (unique) for each station
  - They are "Offsets" because they are added to the stations' `fmout-gps` values to get the final (`Used`) correlation clocks.
  - They are necessary because the VLBI data has to be related to the VLBI reference point, not the time-tags of the recording, i.e., we want the time-tags to be for the VLBI reference point.
- Any errors in the "Peculiar Offsets" (or the `fmout-gps` data) directly affect our estimates of UT1, one of our most important products.
  - A +1μs error in the time-tags makes a -1 μs error in UT1
  - So it is very important that we get it right!
- For more details, see the **Why is my Offset so Peculiar?** article
  - In April 2019 IVS Newsletter:
    - https://ivscc.gsfc.nasa.gov/publications/newsletter/issue53.pdf

Peculiar Offsets – What to report

- Please report to the correlators any change in signal path from the antenna to the formatter, for example:
  - IF cables
  - Change of formatter
  - Electronics inserted into the data path
    - e.g., adding FiLa10G to path to Mark 5B recorder
- Also any change in:
  - GPS receiver or its setup or cabling
  - `fmout-gps` counter, cabling, or setup (triggering)

fmout-gps

- Offset of the recorded time tags from UTC
- Critical for finding fringes
- `Labeling`
  - `fmout-gps` if formatter leads GPS: `fmout` should start counter
  - `gps-fmout` if GPS leads formatter: GPS should start counter
- Stable triggering
- Good cables/connectors
- Correct impedance termination
- Do not use processing of 1 Hz measurements
  - e.g., No "1-x" to correct for wrong label
- Do not use averaging
- For more details, see **Got "fmout-gps" right?** article
  - In April 2017 IVS Newsletter:
    - https://ivscc.gsfc.nasa.gov/publications/newsletter/issue47.pdf

Mark 5 Issues To Be Aware Of

- Follow module check-out instructions (from pre-check class) before using
  - Verifies module is in working order
  - Verifies electronic VSN in module is correct
- Write SDK version on module field label, e.g.:
  - SDK 8.2
- Contact IVS and EVN before upgrading SDK version

NTP

- Strongly recommend that the FS PC runs on NTP
  - See `/usr2/fs/misc/ntp.txt` for set-up recommendations
- Use up to 10 stratum 1 servers
  - Some local: TAC, CNS Clock II, Symmetricom
  - Some remote
  - NTP likes to have at least three servers available
  - Use `iburst minpoll 4` server options
- Set `time.ctl` to use `computer` model
- Do not start FS operations until NTP is sync'd
- Place `check_ntp` procedure in `station` library
  - Use manually at any time
  - Call `check_ntp` at end of `initi`
  - Call `check_ntp` at start of `exper_initi`

check_ntp

- Procedure contents

```
sy=popen 'uptime 2>&1' -n uptime &
sy=popen 'ntpq -np 2>&1|grep -v "^[- x]" 2>&1' -n ntpq &
```

- Output example

```
ntpq/==============================================================================
ntpq/+192.5.41.209    .PTP.            1 u    4 1024  367   89.534    0.267  14.599
ntpq/+18.26.4.105     .CDMA.           1 u   36 1024  377   25.581    0.561   0.209
ntpq/+192.12.19.20    .GPS.            1 u 1009 1024  377   65.842    0.159   0.192
ntpq/+164.67.62.194   .GPS.            1 u  690 1024  377   65.516    0.242   2.145
ntpq/+204.123.2.72    .GPS.            1 u 1003 1024  377   72.726    0.174   0.207
ntpq/*128.227.205.3   .GPS.            1 u  217 1024  377   29.554    0.030   0.267
ntpq/+128.59.0.245    .GPS.            1 u  145 1024  377    9.523    0.409  25.274
uptime/ 17:35:21 up 10 days,  2:42, 14 users,  load average: 0.03, 0.05, 0.00
```

- `ntpq` output
  - To be sync'd, one server must have `*` in the first column after `/`
  - Next to last column is offset in milliseconds, Should be small, less than ±100
- `uptime` output
  - Just a record of how long since boot, to help troubleshoot

Formatter Clock Jumps

- The DiFX correlators can apparently handle arbitrary clock offsets
- Generally it is not necessary (and not desirable) to correct clock jumps unless the jump is large, greater than:
  - ±500 milliseconds for fmout-gps (or gps-fmout)
  - ±5 seconds for setcl/time.
- Mark 5B `syncerr_gt_3` does not mean a re-sync is needed if `fmout-gps` is stable
- This do not mean we want arbitrary clock offsets
  - Start experiments with correct time in the formatter and a small offset (microsecond level)
  - If the offset is not stable at the microsecond level, some other corrective action is needed
  - Fix small jumps after experiments

Other Issues

- Performing the pre-checks from the class is strongly recommended
  - Really helps increase the likelihood of success
- Send logs as soon as you have completed post-checks/experiment
  - Especially important for Intensive experiments
  - Consider using `push_log` SNAP procedure to automate pushing logs
    - See FS change item #12 in FS 9.13 update notes.
- Be sure to send stop message for e-transfers when completed.
- Please be pro-active in troubleshooting your station, look for potential problems:
  - Plot ancillary data with `plotlog` for every experiment
    - Examine plots for problems, jumps, noisy data, etc.
  - Examine IVS experiment web pages for plots, correlator, and analysis reports
  - IVS can provide assistance in troubleshooting problems

Missed Experiments

- If you don’t observe send e-mail message to ivs-ops
- Important so that correlators don’t delay correlation waiting for data that will never arrive.
- See included DRAFT (but final) message on policy included in this section
- Bottom line: send message to ivs-ops

PLEASE Inform Coordinating Center about Changes in Station Status

- Typical Problems
  - Increased SEFDs, e.g., warm receiver
  - Antenna slewing problems
  - Staffing Problems
  - Station not operational, i.e., “down” or unreliable
  - Observing conflicts
  - Insufficient media
  - Any other issues that impact station performance or experiments that can be supported
- Report expected duration
  - One day, One week …
  - If expected duration is unknown any estimate is helpful, particularly a minimum duration
- Send messages to ivs-urgent@lists.nasa.gov
- This information will help the coordinating center determine how to handle the situation and get the best data possible.
- Please also tell us when a situation is resolved and other good news too!

Four primary ways for Coordinating Center to deal with station problems

- Change Master Schedule
  - Mostly for observing conflicts and extended periods when a station may be “down”
- Modify scheduling parameters
  - Used for problems that limit station performance, e.g., warm receiver, antenna slewing degraded, temporarily or permanently
- Change scheduling status to “Tag-along”
  - Works well for temporary situations that <u>may</u> prevent observing or make station unreliable
  - Allows a station to contribute to network if it can observe, but limits bad consequences if it is unable to observe
- Help organize repair and troubleshooting

When to re-cool

- Generally we prefer you **NOT** stop the schedule to re-cool, except in some specific circumstances:
  - There is not enough time after this experiment and before the next to re-cool
  - The experiment requires the highest sensitivity and is useless without a cool receiver, you will receive special instructions for the experiment in this case
  - You have personnel or equipment constraints that will not allow re-cooling after the session and before the next
  - Other situations as appropriate

Extra Cable delay

- If you leave the cable extender for the cable measurement in the line by accident, don't take it out once the experiment has started unless you believe there is something wrong with the extender.
- Likewise do not make the cable measurement during the experiment. If you forget to make it beforehand, please wait until the end.
- Phase meter must be in the middle half of the range

Missing channels

- Each lost channel reduces data yield by about 7%
- In addition it can compromise the delay resolution function, please see the accompanying write-up by Axel Nothnagel
- Order to drop to channels if not enough VCs/BBCs
  - Stations should follow the same order to minimize impact
  - Sequences with 8 BBCs (RDV) should always have enough working converters.
  - 14 BBC/VC sequences: drop order is 6, 11, 7, 2, 5
    - That is: one bad converter, drop #6, two then drop #6 and #11, and so on

Mark IV VC power levels

- Set attenuators for minimum power level above 0.1 volts in all recorded channels (USB &LSB as appropriate) at zenith in clear weather
- If this approach is used, it should not be necessary (hopefully) to change levels during an experiment because of rain or other events
  - please don't change the level if possible, it can causes problems for correlator diagnostics if you do
- See e-mail included in the notes for more details
- `ifadjust` command can be used for this if there is not too much RFI. It is worth a try anyway:
  - Point to zenith in clear weather
  - Set frequencies etc with mode set-up command
  - then try `ifadjust`

More Information in Notebook

- Background information the effect of increased SNR
- Memo on the effect of a losing a ”track” (channel)
- IVS messages sent about:
  - Reporting missed experiments
  - Setting Mark III/IV power levels
  - Channel drop order
- After the meeting, the questions from the feedback session and the responses will be added.

Sensitivity Effects, Background

- Geodetic Precision is roughly proportional to observation sigma σ
- $\sigma \propto \frac{1}{SNR} \propto \sqrt{\frac{SEFD_1 SEFD_2}{T_{\text{int}}}} \Big/ S_c$
  - σ is the precision of the observation (sigma) or how good a measurement we are making (the smaller the better)
  - *SNR* is the signal-to-noise ratio, or how much stronger the signal is than the noise (the larger the better)
  - $SEFD_1$ is SEFD at antenna 1 (the smaller the better)
  - $SEFD_2$ is SEFD at antenna 2 (the smaller the better)
  - T_{int} is the integration (recording time) of observation (the larger the better)
  - S_c is the correlated source flux (the larger the better)
  - Note:
    - Observation sigma σ is inversely proportional to *SNR*
    - Observation sigma σ is proportional to square root of product of SEFDs
    - Observation sigma σ is inversely proportional to square root of T_{int}, recording time
    - For example: warm receiver with SEFD 3 times normal is the same as observing 1/3 of the time

Sensitivity Effects, Impacts

- Geodetic Precision and a Warm Receiver
  - If one station's receiver is warm, that station's SEFD might typically go up by a factor of three. Then the average sigma would go up a factor of $\sqrt{3}$ or about 1.7, a station position estimate that would have been precise to about 5 mm would instead be precise to about 8.5 mm.
  - Warm receiver with SEFD 3 times normal is the same as observing 1/3 of the time
  - Target (minimum) SNR values are typically 20 at X-band, there are no fringes of SNR falls below about 7. With an SEFD 3 times normal, the target SNR becomes 11, not fatal and many observations exceed the target.
  - A warm receiver at one station usually will not destroy an experiment as is, but it may prevent fringes to a high SEFD station if it was scheduled with a lower SNR target. For example, baselines to O'Higgins are typically scheduled with a target of 15. If Hobart warms-up the SNR is reduced below 9 and the Hobart-O'Higgins baseline will be marginal at best.

- Other effects that increase SEFD
  - Pointing off by one half of a full-width-half-maximum (FWHM) drops the response of the antenna by a factor of two and so doubles the SEFD and the sigma is increased by $\sqrt{2}$
  - If the focus is off, the same rule applies, if the response is down half, the SEFD is doubled and the sigma is increased by $\sqrt{2}$
  - Poor image rejection:
    - Front-end, doubles the noise level in all channels, so increases sigma by $\sqrt{2}$ (also does bad things to phase-cal: adds spurious signals)
    - VC/BBC, doubles the noise level in that channel, so increases the sigma by about a small amount, but also adds spurious signals

- Missing channels
  - Each lost channel reduces data yield by about 7%
  - In addition, it can compromise the delay resolution function, please see the accompanying write-up by Axel Nothnagel
  - See recommended drop order above

- Phase-cal
  - Should be about 1% in power
  - Too strong reduces sensitivity and produces spurious signals
  - Phase-cal too weak spurious signals can be a problem

On the Effects of Missing Tracks

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1 Introduction

In recent VLBI sessions of the Europe series we suffered a considerable loss of data and, even more importantly, a loss of data quality from radio frequency interference (RFI), formatter failures, and data recording deficits. In this paper we try to summarize the basics of bandwidth synthesis with special emphasis on the effects of missing data channels. It should be understood that each channel scheduled to be observed is necessary for achieving the good data quality which we aim at. In this paper frequencies and bandwidths are used according to the current Mark III (narrow band) setup. All explanations apply to the wide band case (720 MHz and 125 MHz) in the same way.

The Signal-to-Noise-Ratio (SNR) of an interferometer, defined as the inverse of the standard deviation of fringe phase in radians, is given by

$$SNR = \eta \sqrt{\frac{A_1 A_2 2BT}{T_{s1} T_{s2}}} \cdot \frac{F}{2k} \tag{1}$$

where k = Boltzmann's Constant, F = correlated flux density of the source in units of watts per steradian of the emitting region per m^2 of antenna collecting area per Hertz of observing bandwidth, T_{si} = system temperature at station i, A_i = effective area of antenna i, B = total recorded bandwidth, T = total integration time (2BT is the total number of bits at the Nyquist rate), η = loss factor to account for clipping and signal losses (Clark et al., 1985).

The accuracy of a group delay σ_τ determined from a cross-correlated stream of bits representing the coherent signal of a radio source received by two telescopes may be deduced from the SNR as

$$\sigma_\tau = \frac{1}{2\pi \;\; SNR \;\; \Delta f_{rms}} \tag{2}$$

with Δf_{rms} = root-mean-squared spanned bandwidth or rms frequency deviation about the mean of the observing frequencies.

$$\Delta f_{rms} = \sqrt{\sum_{i=1}^{n} \frac{\omega_i^2}{n} - \left(\sum_{i=1}^{n} \frac{\omega_i}{n} \right)^2} \tag{3}$$

where ω_i are the individual center frequencies and n is the number of channels. Combining (1) and (2) leads to

$$\sigma_\tau = \frac{2k}{F} \cdot \sqrt{\frac{T_{s1} T_{s2}}{A_1 A_2 2BT}} \cdot \frac{1}{2\pi \eta \Delta f_{rms}} \tag{4}$$

Under the assumption that we cannot increase the effective aperture of the telescopes with economical costs and that the noise of the receivers is at their lower limits we may only use an increased recording bandwidth to improve the accuray of the delay determination.

2 The Single-Channel Case

In order to understand the basics of and the necessity for bandwidth synthesis we should first look at the single band delay determination. Consider that we have recorded a single channel of a certain bandwidth B with a rectangular bandpass. After cross-correlating two coherent signals of the same source the cross correlation function would become

$$R_{xy}(\tau) = 2\,cos\,[\theta + \omega^0(\tau) + \pi\,B\,\tau]\frac{sin\,\pi\,B\,\tau}{\pi\,B\,\tau} \tag{5}$$

with θ being the local oscillator phase difference, ω^0 the local oscillator frequency and τ the group delay (Rogers, 1970).

The envelope function of this cross-correlation function has the form of a so-called sinc-function ((sin x)/x) which would be equivalent to a Fourier transform of the bandpass from the frequency domain into the lag domain. The sinc-function has a delay width of approximately

$$\Delta_\tau = \frac{1}{B} \tag{6}$$

with B being the bandwidth of the bandpass. The delay width is important since it determines, at least in part, the inherent accuracy of the delay determination, i.e the sharper the peak, the more accurate the determination of the location of the maximum on the τ axis (Fig. 1). From (6) and Figure 1 it can easily be deduced that we could improve the delay accuracy just by increasing the bandwidth (e.g. Beyer, 1985). This, however, has its limitations since it requires coherence across the whole band and an enormous, ever increasing, recording capacity.

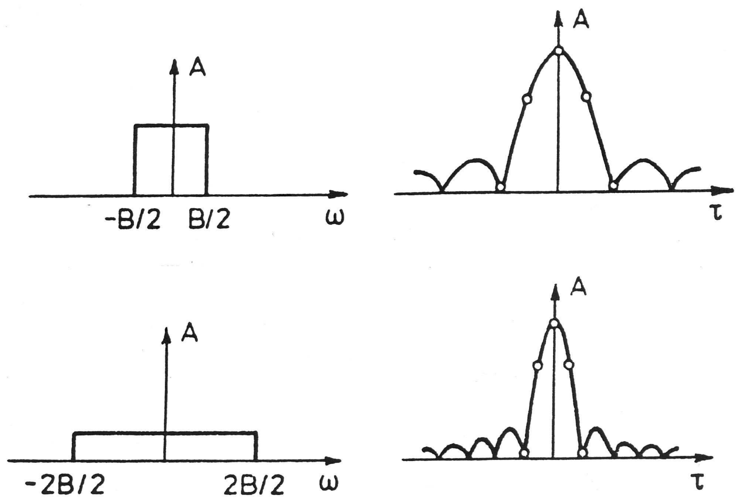

Figure 1: Fourier transform from frequency domain into lag domain with bandwidth B and 2B (Beyer, 1985)

3 Bandwidth Synthesis

In order to improve the delay determination under economic restrictions, Rogers (1970) "solved the problem in a rather ingenious way" - as Whitney (1974) wrote - by developing the bandwidth synthesis method.

Similar to antenna aperture synthesis where a number of small telescopes synthesize the aperture of a much larger telescope (e.g. VLA or Westerbork Synthesis Radio Telescope) a wide frequency band is sampled using a number of narrow bands, in the case of Mark III/IV/V of 2 to 16 MHz bandwidth. This is achieved by placing two channels at the extreme frequencies defining the total spanned bandwidth, 720 MHz at X band and 125 MHz at S band. In addition, a number of intermediate frequency channels are introduced in between according to a certain scheme which is discussed later. Using only these narrow bands the whole bandwidth (between the first and the last frequency) is synthesised and the accuracy of the delay determination is improved.

In order to describe the frequency band - time lag (delay) relationship Rogers (1970) defined a complex delay function for an ideal situation

$$D(\tau) = \int_0^\infty S_{xy}(\omega) e^{-i\omega\tau} e^{-i\omega^0\tau} \frac{d\omega}{2\pi} \tag{7}$$

with $S_{xy}(\omega)$ being the cross-spectral function, ω the radio frequency and ω_0 the local oscillator frequency. The envelope or magnitude of this function is called the delay resolution function (DRF).

The delay resolution function of any synthesis frequency setup has an envelope which represents the Fourier transformed of the channel bandwidth similar to Fig. 1a with a main peak at 0 delay and first nulls at plus and minus 1/B. In the case of Mark III with 2 MHz channel bandwidths (Fig. 2) the envelope has a base width of about -500 nsec to +500 nsec (from $(2MHz)^{-1}$). Underneath this envelope there are distinguished peaks with sharp edges. The lower dashed line represents the level of the sidelobes if the total bandwidth would be synthesised perfectly.

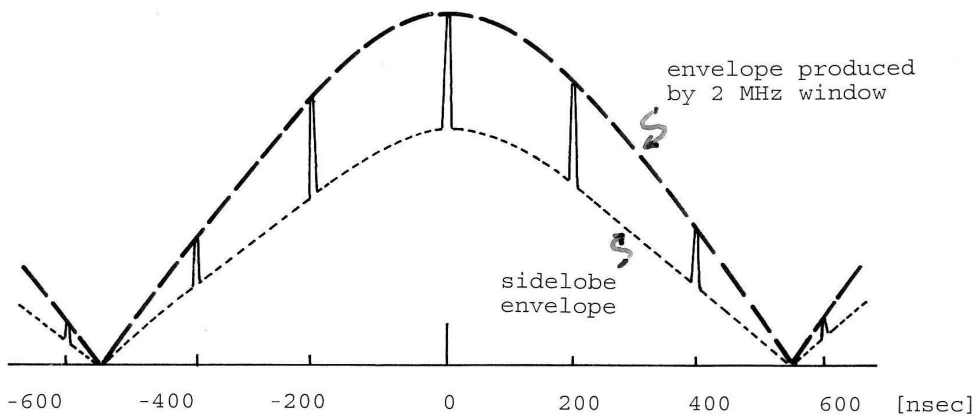

Figure 2: Semi-complete delay resolution function with envelope of 2 MHz channel bandwidth with main lobe, ambiguous peaks and envelope of sidelobes.

Now, let's turn to the criteria of how and where to place the intermediate channels. If we would use only the two bands at the lower and upper edge of the current Mark III S band bandpass spanning about 85 MHz there would be peaks underneath the envelope every $(85MHz)^{-1}$ or about 12 nsec. This of course would be an ambiguity spacing too narrow to be solved in the analysis. One way to overcome this problem is the introduction of one or more frequency channels in between.

The basis for the selection of the band separations is the fact that the sharp peaks in Figure 2 are spaced 1/S where S is the greatest common denominator of all n(n- 1)/2 frequency differences of n frequency bands used to synthesise the total bandwidth (currently 5 MHz at S band and 10 MHz at X band). 1/S is the so-called ambiguity spacing. If, for example, one introduces another band at ω_1 + 5 MHz the smallest common denominator of all frequency differences would be 5 MHz. The resulting ambiguity spacing is then

$(5MHz)^{-1}$ or 200 nsec as it is in the current Mark III standard S band setup. However, there is a large number of sidelobes within one ambiguity spacing almost as high as the main peak (Fig. 3).

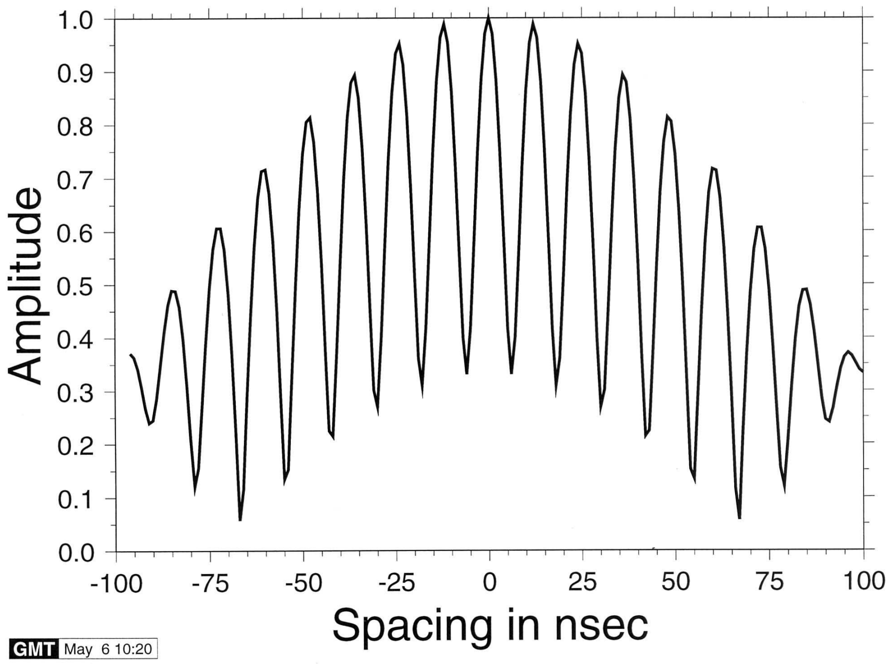

Figure 3: Central part of the delay resolution function for a 0, 5, 85 MHz frequency setup. N.B.: This is only the portion between -100 and +100 nsec of Figure 2.

If we consider that the delay resolution function represents the ideal situation it is quite understandable that the fringe fitting process which uses a "maximum likelyhood method" (Rogers, 1970) may select the wrong peak in the case of bandpass irregularities and/or a high noise level. Therefore, more frequency channels are introduced between the two bandpass edges which serve the purpose of reducing the level of the sidelobes to a level which is uncritical for the fringe fitting process. In addition, more channels increase the signal-to-noise-ratio (SNR) by providing more bits to be correlated and subsequently more reliable cross-correlation coefficients.

The frequency channel separation is selected for an optimal suppression of the sidelobes with an optimal ambiguity spacing. The initial selection of the channel separation was done using an algorithm which is based on the Golomb ruler theory (Taylor and Golomb, 1985). A Golomb ruler describes the separation of elements (e.g. frequency bands or antenna separation in an array) on the basis of non-redundant difference sequences, i.e. integer sequences which have the property that the difference of each pair of integers is distinct from the difference of each other pair (Robertson, 1991). However, in practice technical limitations like harmonic interference and limited bandwidth require a certain compromise. Therefore, 0, 1, 4, 10, 21, 29, 34, 36 times 10 MHz are used to span the 360 MHz bandwidth of Mark III X band observations and 0, 2, 5, 11, 16, 17 times 5 MHz synthesise 85 MHz of S band. The central parts of the resulting delay resolution functions within the limits of plus/minus one and a half ambiguity spacings are shown in Figures 4 and 5. It is immediately obvious that with only 6 channels at S band the suppression of the sidelobes is less successful than with 8 channels at X band. In addition, more channels at X band produce a higher SNR according to formula (1).

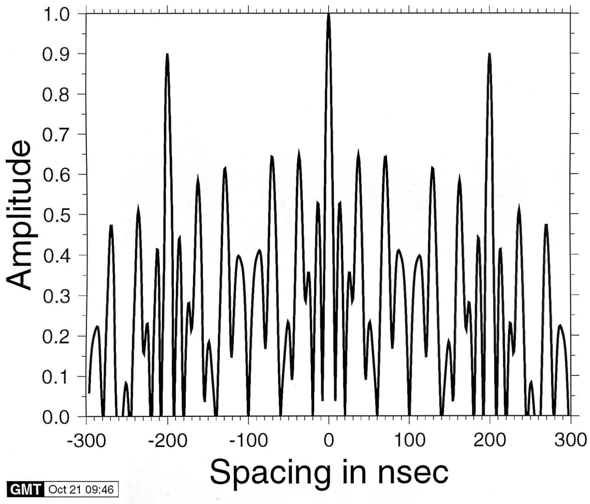

Figure 4: Central part of delay resolution function with 8 channels at X band.

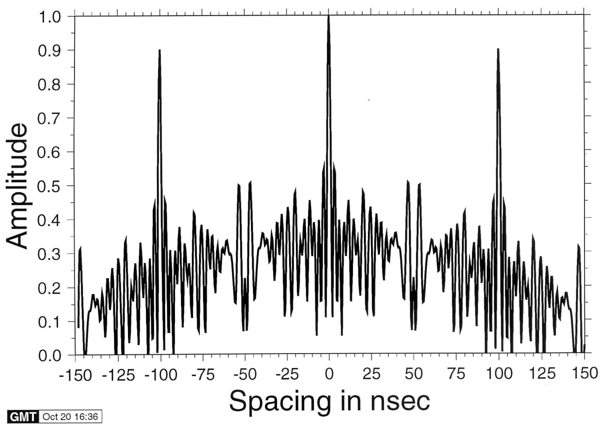

Figure 5: Central part of delay resolution function with 6 channels at S band.

4 Effects of Missing tracks

As we have seen in the previous section tracks are introduced in between the two extreme channels for an increase in SNR and for the suppression of sidelobes in the delay resolution function. Since each channel scheduled to be observed has its specific "purpose" the loss of a channel due to radio frequency interference, formatter failure, or recording deficits not only reduces the SNR by $1/\sqrt{(n-1)/n}$ but also distorts the delay resolution function. Figure 6 shows the central part DRF (just one ambiguity spacing of it) of the undisturbed (no RFI) Matera S band channels in the Europe-3/97 session (channels 2 and 6 are missing due to RFI). It is obvious that the sidelobes within the ambiguity spacing may easily be detected as the main lobe in case of low SNR or bandpass irregularities. In the data analysis of the resulting group delays, for example with OCCAM or Calc/Solve, the deficit becomes even more obvious. Fig. 7 shows the delay residuals on the Matera - Yebes baseline where abnormally large deviations from the expected level of a few tens of picoseconds are easily discernable. The reason for this is that for a number of scans the fringe fitting process (FRNGE or fourfit) has indeed chosen the wrong peak generating pseudo- ambiguity levels of odd

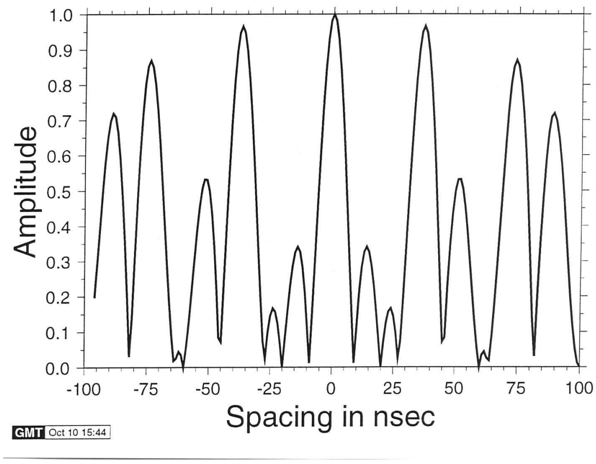

Figure 6: Central part of Delay Resolution Function of Matera using only S band tracks 1, 3, 4, and 5.

separations.

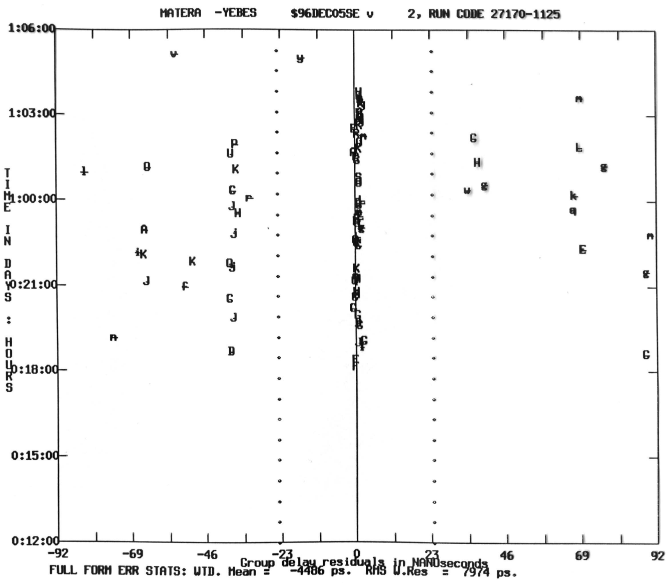

Figure 7: Delay fit residuals on the baseline Matera - Yebes with pseudo-ambiguities caused by missing tracks.

Generally, these observations have to be discarded since their separation from the main lobe may only be computed with low accuracy. However, the author has devised a routine which forces the fringe fitting process to home in on the correct peak. The procedure uses initial Solve delay residuals and converts them into FRNGE/fourfit multiband residual delays (correlator model residuals) and subsequently into search windows of about 10 nsec. With these search windows the fringe fitting process is repeated with a high success rate. However, all scans with missing tracks suffer from a reduced SNR which lead to reduced data quality. Although this software is now available it should not become a routine requirement to use it.

5 Conclusion

The ensemble of frequency channels in the geodetic VLBI Mark III setup serves the purpose of providing sufficient SNR and delay resolution with low sidelobes. Missing tracks reduce the SNR and require an iterative method to narrow the fringe fitting search window, a procedure which is rather laborious and non-routine. The staff at the observing stations and at the correlators should, therefore, take utmost care that all channels are recorded and processed properly.

References

Beyer, W.; Laufzeitschätzung in digitalen Korrelationsinterferometern unter besonderer Betrachtung des MK-II-Systems des Max-Planck-Instituts für Radioastronomie; Mitteilungen aus den Geodätischen Instituten der Rheinischen-Friedrich-Wilhelms-Universität Bonn, No. 68; Bonn, 1985

Clark, T.A. et al.; Precision Geodesy Using the Mark III Very Long Baseline Interferometer System; IEEE Trans. on Geoscience and Remote Sensing, Vol. GE-23, No. 4, p. 438; July 1985

Robertson, D.S.; Geophysical Applications of Very Long Baseline Interferometry; Reviews of Modern Physics, 63, 4, p.899-918, 1991

Rogers, A.E.E; Very Long Baseline Interferometry with Large Effective Bandwidth; Radio Science, Vol. 5, p. 1239 - 1247; 1970

Taylor, H., S.W. Golomb; Rulers, Part I: CSI Technical Report 85-05-01, Communication Science Institute, Univ. Southern California, Los Angeles, CA.; 1985

Whitney, A.R.; Precision Geodesy and Astrometry via Very Long Baseline Interferometry; PhD thesis, Massachusetts Institute of Technology, Cambridge, 1974

Subject: DRAFT Messages for missed experiments
Date: Mon, 06 Apr 2009 17:37:29 -0400
From: Ed Himwich <Ed.Himwich@nasa.gov>
To: ivs-stations@ivscc.gsfc.nasa.gov

To: IVS Network Stations

From: Ed Himwich, IVS Network Coordinator

Re: E-mail messages for missed experiments

We would like to request that all stations send a message to the IVS OPS mail list to report anytime they miss an experiment that is shown for their station in the master schedule. This may seen unimportant since there is no data to send to the correlator. However, if the correlator does not know that a station failed to observe, correlation may be delayed unnecessarily to wait for data that will not arrive. Suggestions for the message contents are given below.

Please send the message no later than the nominal end time of the experiment (it could be sent before) or as soon as practical afterwards. The message should be sent to the IVS OPS mail list: "ivs-ops@ivscc.gsfc.nasa.gov". The subject line should include the experiment code, name of the station, and appropriate text such as "Did not observe" or "Will not observe", e.g.:

  R1369, Fairbanks, Did not observe

To assist with message identification, please follow the pattern of the above example if possible. It would be helpful if the body of the message contains at least a short, but longer is better if practical, explanation of the reason the experiment was missed.

Please note that including the experiment code in the subject line will not only identify the experiment affected to the recipients but will also allow the ivscc mail system to route a copy of the message to experiment e-mail archive. The archive is available on the experiment web page which can be accessed from the HTML master files which are available through links at:

 http://ivscc.gsfc.nasa.gov/program/master.html

The experiment e-mail archive is where all message relating to the experiment are collected and is where the correlators look for "Did not observe" and other messages, including "Ready"/"Start"/"Stop", that contain information they need to process the data.

Subject: Mark III/IV VC Levels
Date: Fri, 02 Mar 2001 10:00:12 -0500
From: Ed Himwich <weh@ivscc.gsfc.nasa.gov>
Reply-To: weh@ivscc.gsfc.nasa.gov
To: pcfs@ivscc.gsfc.nasa.gov, EVNtech <evntech@jb.man.ac.uk>

To: Mark III and Mark IV Stations

From: Ed Himwich and Brian Corey

Re: Mark III/IV VC Levels

March 2, 2001

Introduction

This information is only relevant for stations with Mark III or IV Video Converters. It does not apply to stations with VLBA racks or VLBA racks modified for Mark IV by adding a Mark IV formatter (so-called VLBA4 systems). The remainder of this memo consists of two sections. The first titled "Operational Procedures" outlines important rules for working with Mark III and IV VCs. This section is somewhat simplified to give a clear set of guidelines for setting levels. The second section is titled "Discussion" and covers more of the details.

Operational Procedures

1. Always adjust the signal levels with the VC 10 dB pads in the signal path.

2. The power level in each video sideband that is being recorded should be greater than 0.1 volts on the front panel, but as low as possible above 0.1 volts. Please set the IF attenuators to the maximum value that keeps the levels above 0.1 volts for all sidebands that are being recorded (note: some modes record both sidebands in some or all VCs). This level should be set during dry weather with the antenna at zenith or wherever the system temperature is a minimum.

3. Please avoid changing IF attenuator settings during experiments. If all levels are set as low as possible, but above 0.1 volts, there should be no need to change them under normal conditions, including rain. If it was not possible to set the levels in dry weather before the experiment, it may be necessary to reduce the attenuation when the weather clears.

Discussion

As a rule, the IF levels for the Mark III and IV VCs should always be set with the 10 dB pad in the VCs switched in. With the pads in, the minimum front panel power level in the sidebands that are being recorded should be 0.1 volts. The values should be less than 0.5 volts if possible and in no case should be above 2.0 volts.

You can also adjust the levels using the TPI measurements from the VCs in the FS. A front panel sideband power reading of 1 volt should correspond to about 32768 counts. Therefore 0.1 volts is about 3300 counts. You should correct for the TPZERO (no signal) level of the converter. For example if the zero level is 600 counts, then the specification of 0.1 volts on the front panel would be the same as 3300+600=3900 counts. Please note that the front panel may have a zero offset that should be corrected for if you are using the front panel to determine the level. The next version of the FS will include a new command, ifadjust, which will use the VC TPI counts to automatically determine the best attenuator levels.

The specification of 0.1 volts minimum level is necessary to overcome the intrinsic noise in VCs. (In addition for Mark IV VCs the level must be above 0.1 volts to make sure that there is sufficient input power for the AGC circuit to work properly.) The power levels should also be as low as possible, but above 0.1, in order to give as much dynamic range for Tsys measurements as possible. You will also want to make sure that the levels are low enough so that when the noise diode is turned on, the TPI measurements do not saturate under normal conditions. If you are unable to balance all of these conditions, please contact us.

Ideally the front panel levels should be as low as possible above 0.1 volts, during normal measurements, through varying ground pick-up and weather. Please note it is very undesirable to change the attenuator settings during an experiment since this will change the delay through the system. This should not be necessary and will cause some correlator diagnostics to be difficult to use (and therefore more difficult for the correlator to give you useful feedback). In the worst case, if there is a problem with your station's phase-cal and it is necessary to use manual phase-cal at the correlator, it will introduce a clock jump, which will significantly degrade the geodetic solution. In particular, this means you should not change the levels at X-band when it starts to rain. Ideally, your attenuator settings should be adjusted for dry weather and left in that state. The signal level will increase during wet weather, but there should be enough dynamic range to prevent VC overflows. You also shouldn't change the IF attenuators for low-elevation observations. However, if the TPI overflows for low elevation observation you should probably inform us so that the elevation mask for your station can be adjusted in SKED.

Ideally, the signal levels of the IFs coming into the rack should be such that, when the VC sideband levels are set as specified above, the IF attenuators are in the range of 10-43 dB. If more than 43 dB of attenuation are required, the error in Tsys due to the measurement of TPZERO will start to exceed 1%. On the other hand, if the attenuators are less than 10 dB the signal is weak enough that there is concern about spurious signals in the rack interfering with the phase-cal in IF. This is reduced as the power level is increased. So the best compromise is when the signal is strong enough that correct attenuator settings are relatively high, but below 43 dB. It is relatively easy to get the attenuators settings down to this level if they are too high by adding attenuators before the rack. On the other hand, increasing the settings requires adding amplification external to the rack.

There are some problems with the linearity of the output of the power detectors in the VCs. This issue is still being investigated. The nonlinearities cause fractional errors in Tsys measurements of a few percent when TPICAL is about 20,000 counts, and the error varies roughly quadratically with power level. If high accuracy Tsys measurements are needed, the value of TPICAL should be kept as low as possible consistent with the minimum 3300 count level above the TPZERO level for normal operations. Of course there are other calibration errors that can affect Tsys results at the 10% level as well.

Please note that the TPZERO reading for each sideband in each VC should be about 300-1000 counts. If it is more than 2000 counts it should certainly be fixed.

An additional point is that in the absence of significant RFI and bandpass problems, the power for the two sidebands should be within 1 dB. If it isn't, the VC should be fixed.

Subject: Dropping Channels Gracefully for Geodesy
Date: Wed, 03 Sep 2008 14:05:12 -0400
From: Ed Himwich <Ed.Himwich@nasa.gov>
To: ivs-stations@ivscc.gsfc.nasa.gov
CC: pcfs@ivscc.gsfc.nasa.gov, Brian Corey <bec@haystack.mit.edu>

To: Stations Observing in Geodetic VLBI Experiments

From: Ed Himwich and Brian Corey

Re: Dropping Channels Gracefully

Ideally, all stations should have a full complement of working BBCs (or VCs, both hereafter referred to as "BBCs"). However, we recognize that there may be occasions when this is not possible. For many years we have had a standing recommendation that, for experiments that require 14 BBCs, a station with a single bad BBC should put it in position #6, i.e., BBC #6 should be "dropped". If a second BBC is bad, BBC #11 should be dropped. We hoped that the bad BBCs would be repaired rapidly so that a full complement would soon be available again. The point of these recommendations, originally developed by Dave Shaffer in the 1980s, is two-fold: (1) to have the least impact on the delay resolution function, in terms of both preventing the wrong peak from being picked in fringing and losing the least amount of observation precision, and (2) to avoid having different stations, operating independently, drop different BBCs, thereby causing even more data loss between them.

Due to the aging of equipment and the difficulty of obtaining repairs, there are times now when stations may have more than two BBCs that are not working and/or they may not be being repaired in a timely fashion. Consequently, Brian, with contributions from Alessandra Bertarini, has put together recommendations for which BBCs to drop when missing up to four. We are not planing to make a recommendation for going beyond dropping four BBCs for experiments that require 14 due to the rapid reduction in performance that occurs. Please note that the recommendations apply to all experiments requiring 14 BBCs. Although the recommendations are not optimal for all frequency sequences currently in use, they are nearly so. Very little improvement would be achieved by varying the recommendations for different experiments. Having to keep track of which BBCs should be dropped in which experiments would reduce the utility of the recommendations beyond what is justified, given the small improvement that would result. If a new frequency sequence is developed that requires a different drop order, the recommendation will be revised; for the foreseeable future however this is not a concern.

For now, there are only two qualification to the experiment independence of the recommendations: (1) for the infrequent experiments that require only eight BBCs (RDVs primarily), stations should physically re-arrange the BBCs if necessary in order to have a full complement of BBCs, and (2) if a station knows that one or more channels are persistently lost to RFI or some other problem, they should try to use the bad BBCs in those positions first before applying the drop order. The second qualification has reduced importance compared to general recommendations; if applied it may lead to varying the drop order depending on the experiment. The following final paragraph of this message states the new recommendations independent of such complications.

For experiments requiring 14 BBCs, when a station does not have enough working BBCs (or VCs) to form a full set, we recommend the following order for dropping BBCS: 6, 11, 7, and finally 2. In other words: if a station has a single bad BBC, they should place it in position 6; when there are two bad BBCs, they should go in positions 6 and 11, and so on. The order of dropping BBCs is independent of the frequency sequence for experiments using 14 BBCs.