

Understanding Correlator Feedback

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United States Naval Observatory (USNO)
Washington Correlator (WASH)

With thanks to:

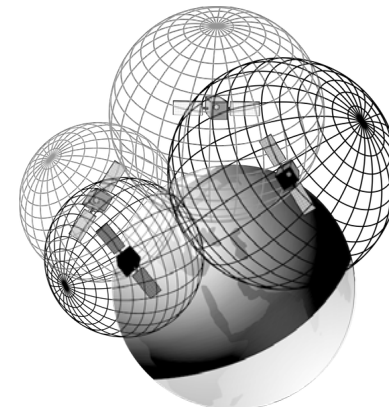
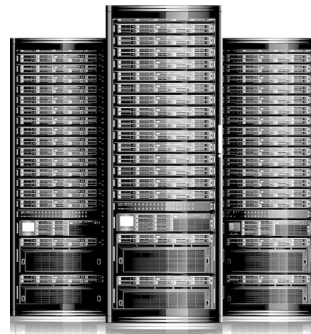
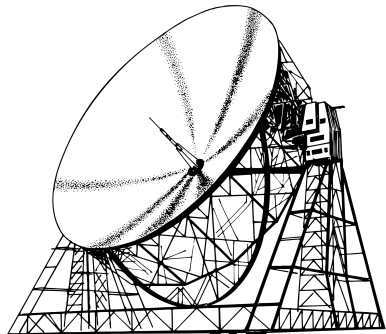
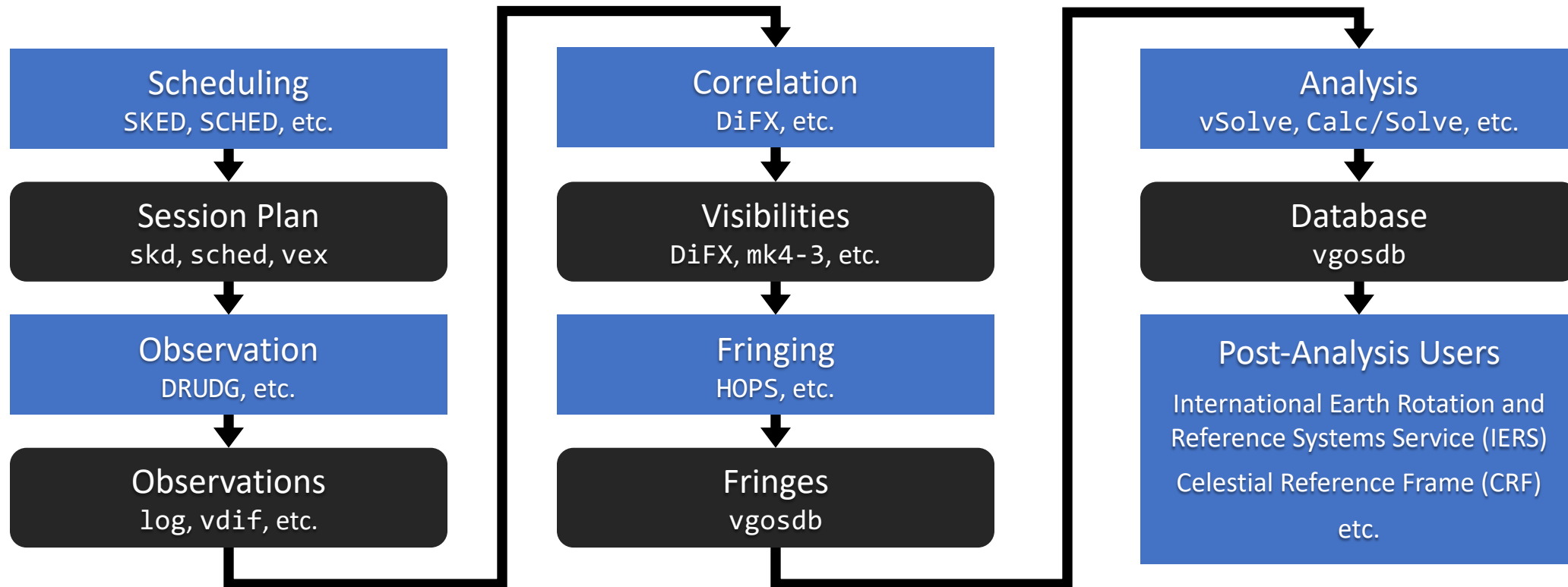
Alessandra Bertarini – Bonn Correlator (BONN)
David Hall – Washington Correlator (WASH)
Mike Titus – Haystack Correlator (HAYS)

About Us: The Washington Correlator

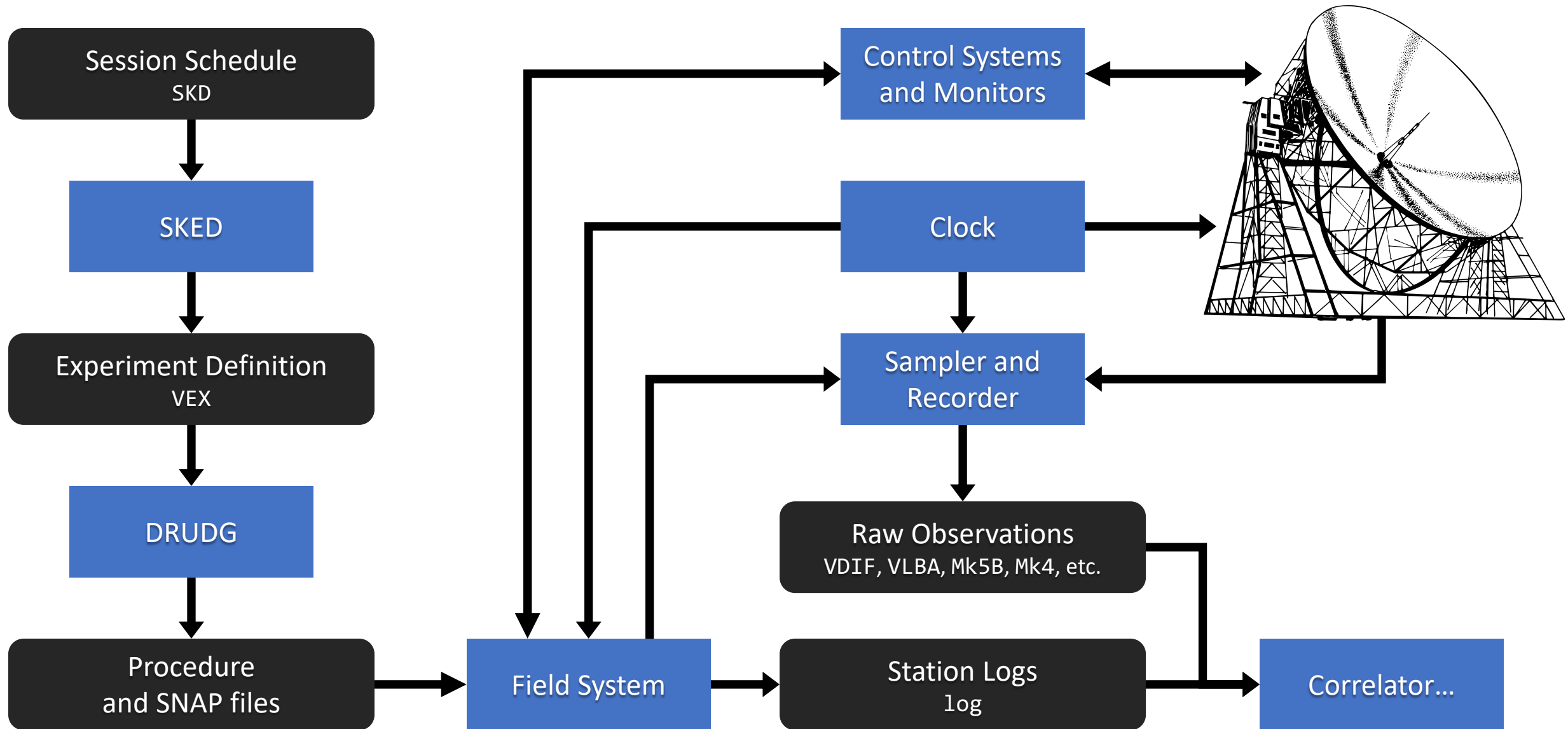
- Transfer
 - 10 Gbps eTransfer
 - Mark5 and Mark6* systems
- Hardware
 - 6.45 TFLOPS (1,792 CPU cores)
 - 1.88 PB storage (923 TB ingest + 961 TB internal)
- Software
 - DiFX, HOPS, nuSolve, SKED, Python3

* Mark6 systems are coming online soon at time of writing

Quick Review: Bird's Eye View



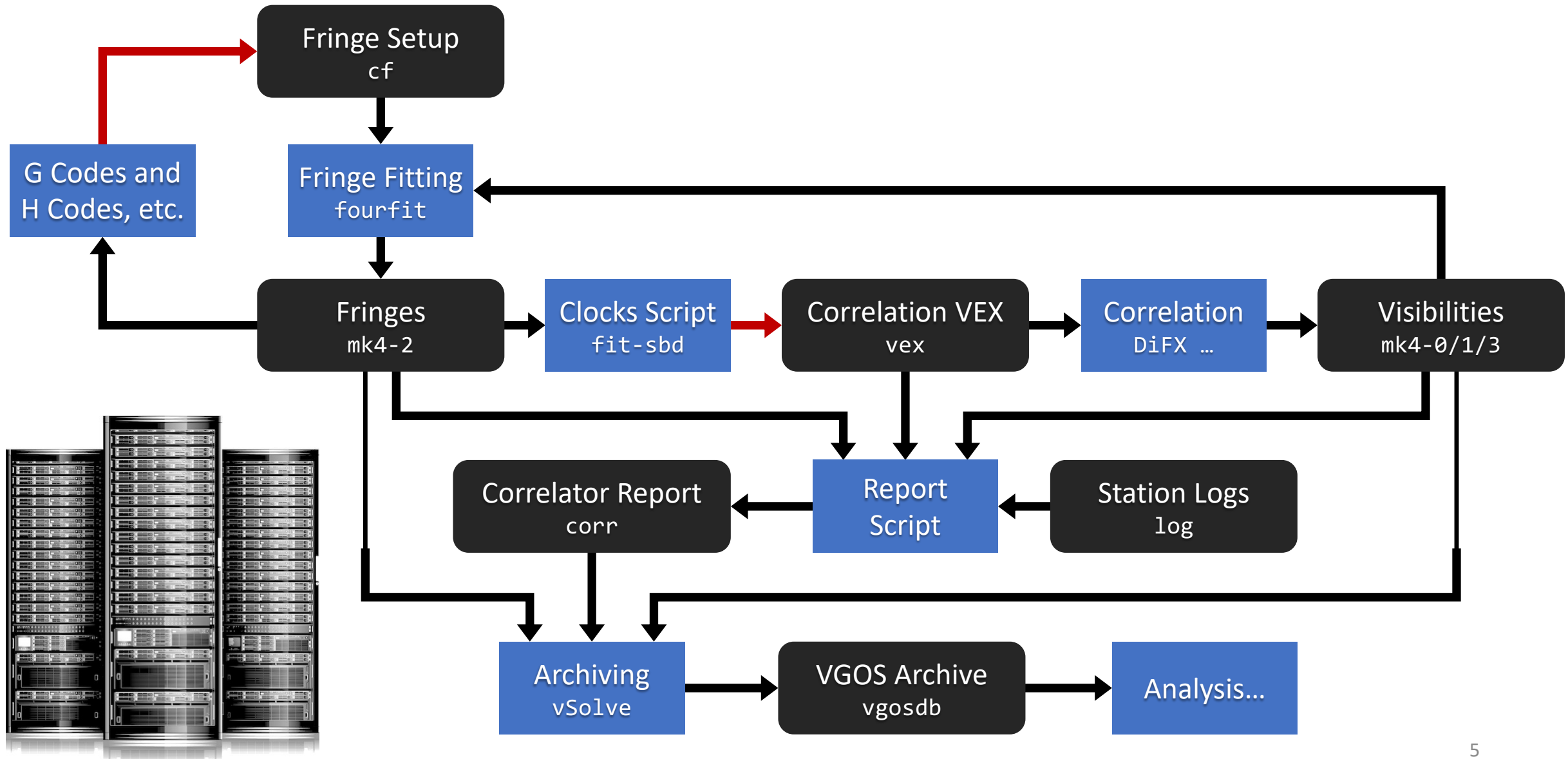
Quick Review: Observation



```
graph TD; A[Session Schedule  
skd, sched] --> B[SKED]; B --> C[Preliminary VEX  
vex]; C --> D[Experiment Setup Scripts]; E[Earth Orientation Parameters (EOP)  
finals.daily] --> D; F[Stations] --> G[Station Logs  
log]; G --> D; D --> H[Correlation VEX  
vex]; H --> I[DiFX Scripts and CALC]; I --> J[DiFX Input Files  
input, calc ...]; J --> K[DiFX]; L[Raw Observations  
vdif, mk5, mk4, etc.] --> K; K --> M[DiFX Visibilities  
difx, mk4-0/1/3]; M --> N[Fringing...]; N --> D; O[Server Racks] --- D;
```

The flowchart illustrates the VLBA DiFX processing pipeline. It begins with a **Session Schedule** (skd, sched) which is processed by **SKED** to produce **Preliminary VEX** (vex). This VEX file is then used in **Experiment Setup Scripts**, which also receives input from **Earth Orientation Parameters (EOP)** (finals.daily) and **Stations** (via **Station Logs** (log)). The **Experiment Setup Scripts** generate **Correlation VEX** (vex), which is then processed by **DiFX Scripts and CALC** to produce **DiFX Input Files** (input, calc ...). These input files are fed into **DiFX**, which also receives **Raw Observations** (vdif, mk5, mk4, etc.) from the **Stations**. The output of **DiFX** is **DiFX Visibilities** (difx, mk4-0/1/3), which are then processed by **Fringing...**. A red arrow indicates a feedback loop from **Fringing...** back to **Experiment Setup Scripts**. An image of server racks is shown next to the **Experiment Setup Scripts** and **Fringing...** boxes.

Quick Review: Fringe Fitting



TLDR: What is correlation?

- Need the **time lag** between signals at different sites:
 - **Cross correlate** signals together to overlay them
 - **Fourier transform** from time to frequency domain
 - It's a **virtual interferometer**
 - Inspect **frequency spectra** to estimate time lag
 - Correct for instrumental effects at each antenna
- Order of operations is flexible:
 - **XF** = (X) **Cross correlate**, then (F) **Fourier transform**
 - **FX** = (F) **Fourier transform**, then (X) **cross correlate** (multiply)

TLDR: What is fringing?

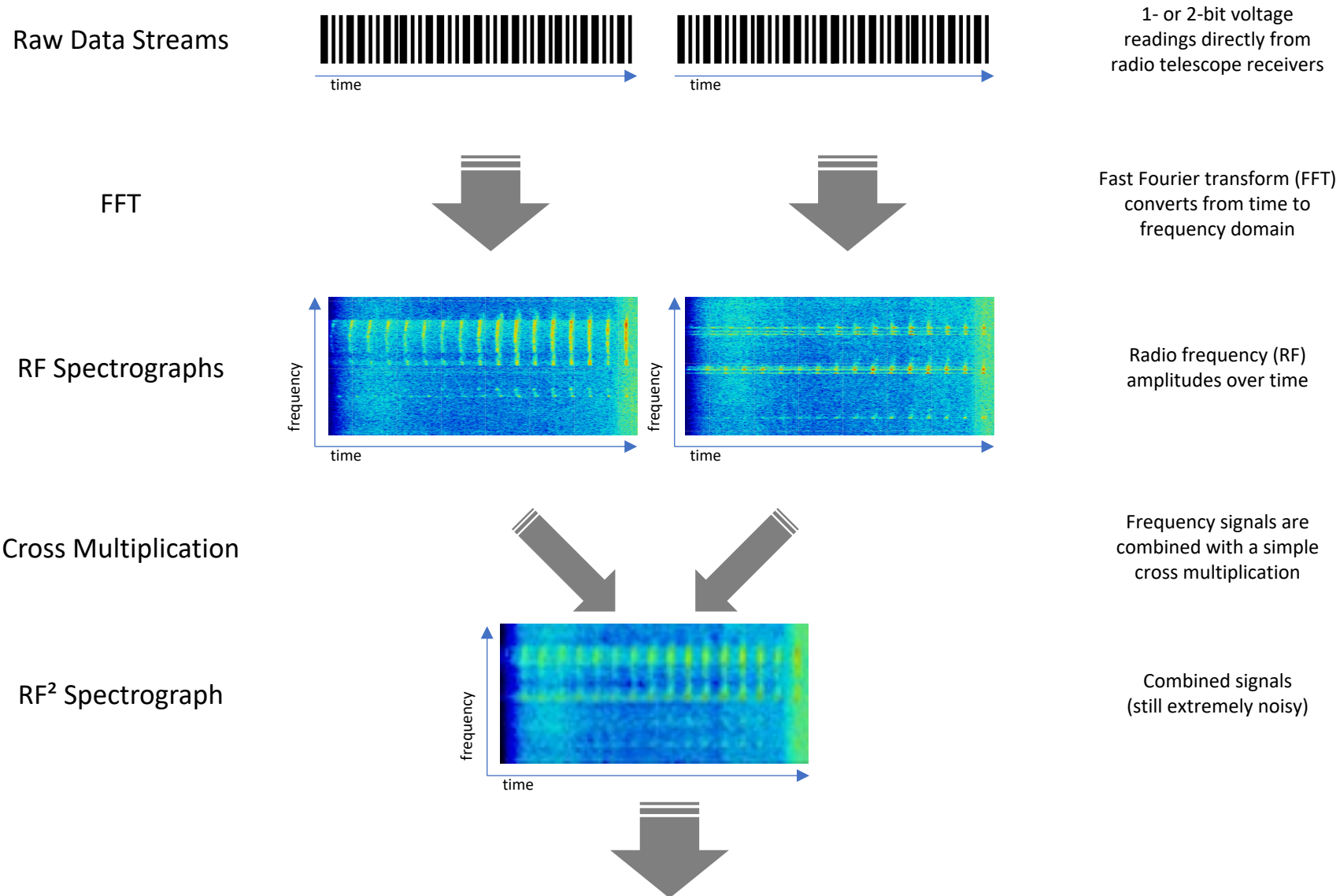
Basic steps:

- Correlator outputs visibilities
- Switch to frequency domain
- Combine channels with **group delay**
- Combine baselines with **closure**

HOPS Software does this fringing

- Haystack Observatory Postprocessing System (HOPS) has a program for **Four**ier transform **fit**ting (fringe fitting) VLBI baseline data called **Fourfit**.

Correlation and Fringing



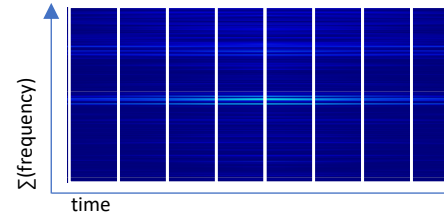
Correlation and Fringing

Integration

Sum over time in chunks to cancel noise with destructive interference

Visibilities

Measure of the contrast of the interference pattern

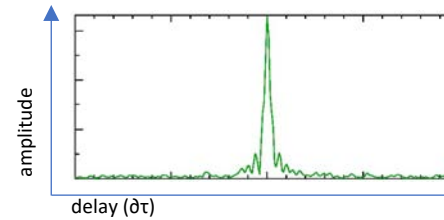


Fringe Finding

Find slope of visibility vs phase (fringe rate) and correct

Single Band Delay

Peaks at the time delay with the greatest common visibility between both telescopes

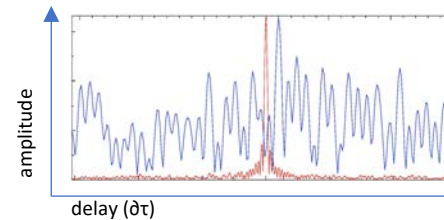


Inverse FFT

Perform inverse fast Fourier transform from frequency to time domain

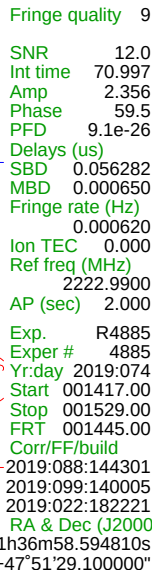
Multiband Delay

Sum of sine waves returned from inverse FFT for each channel (used for closure)

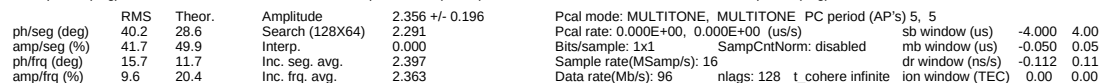


multiband delay (μs)

KOKEE - WETTZELL, fgroup S, pol RR



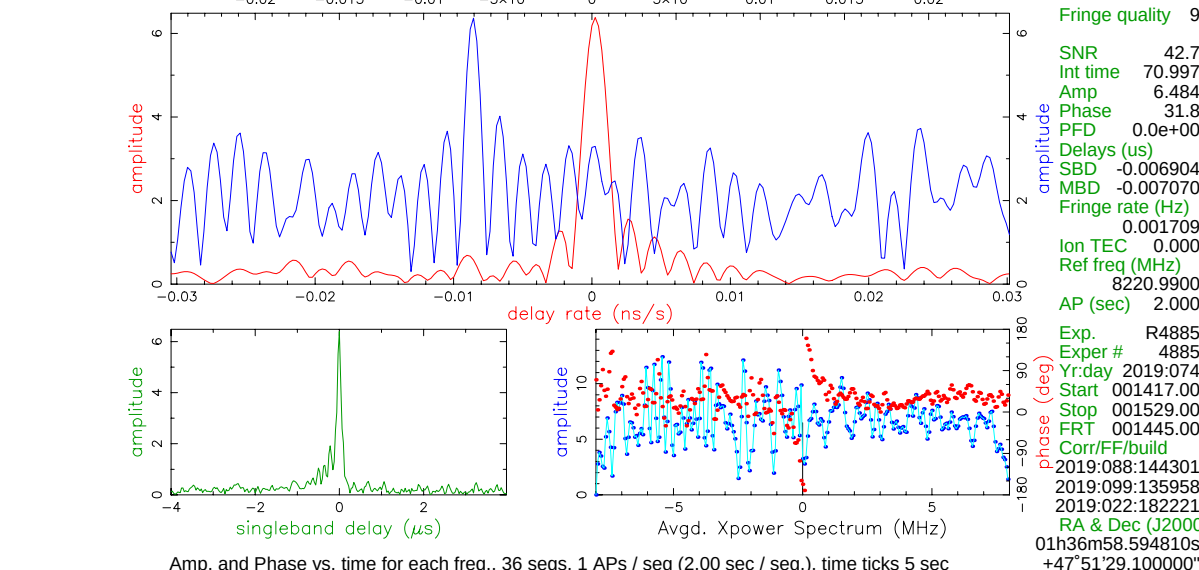
Amp. and Phase vs. time for each freq., 36 segs, 1 APs / seg (2.00 sec / seg.), time ticks 5 sec



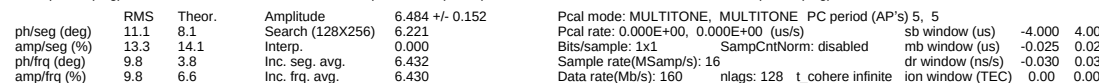
K: az 12.5 el 63.3 pa -162.5 V: az 349.4 el 8.1 pa 10.3 u,v (fr/asec) -71.600 -321.748
Control file: cf 4885 Input file: /isan/data1/correlator/run/rfr4885/Production Pass/1234/074-0014/KV...assocy Output file: Suppressed by test mode

multiband delay (μs)

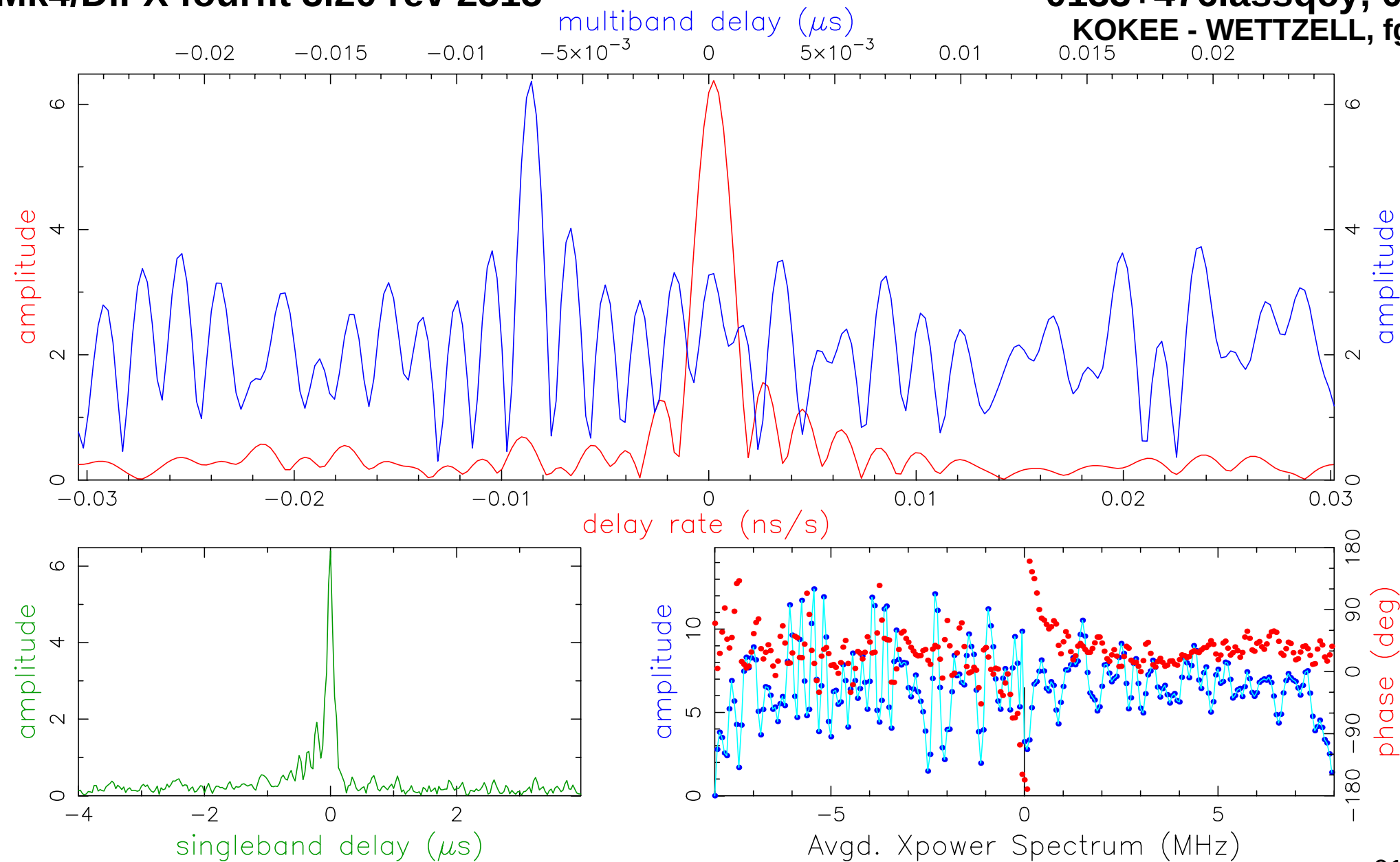
KOKEE - WETTZELL, fgroup X, pol RR



Amp. and Phase vs. time for each freq., 36 segs, 1 APs / seg (2.00 sec / seg.), time ticks 5 sec



K: az 12.5 el 63.3 pa -162.5 V: az 349.4 el 8.1 pa 10.3 u,v (fr/asec) -264.790 -1189.877
Control file: cf 4885 Input file: /isan/data1/correlator/run/rfr4885/Production Pass/1234/074-0014/KV..assqcy Output file: Suppressed by test mode



Fringe quality 9

SNR 42.7

Int time 70.997

Amp 6.484

Phase 31.8

PFD 0.0e+00

Delays (us)

SBD -0.006904

MBD -0.007070

Fringe rate (Hz)

0.001709

Ion TEC 0.000

Ref freq (MHz)

8220.9900

AP (sec) 2.000

Exp. R4885

Exper # 4885

Yr:day 2019:074

Start 001417.00

Stop 001529.00

FRT 001445.00

Corr/FF/build

2019:088:144301

2019:099:135958

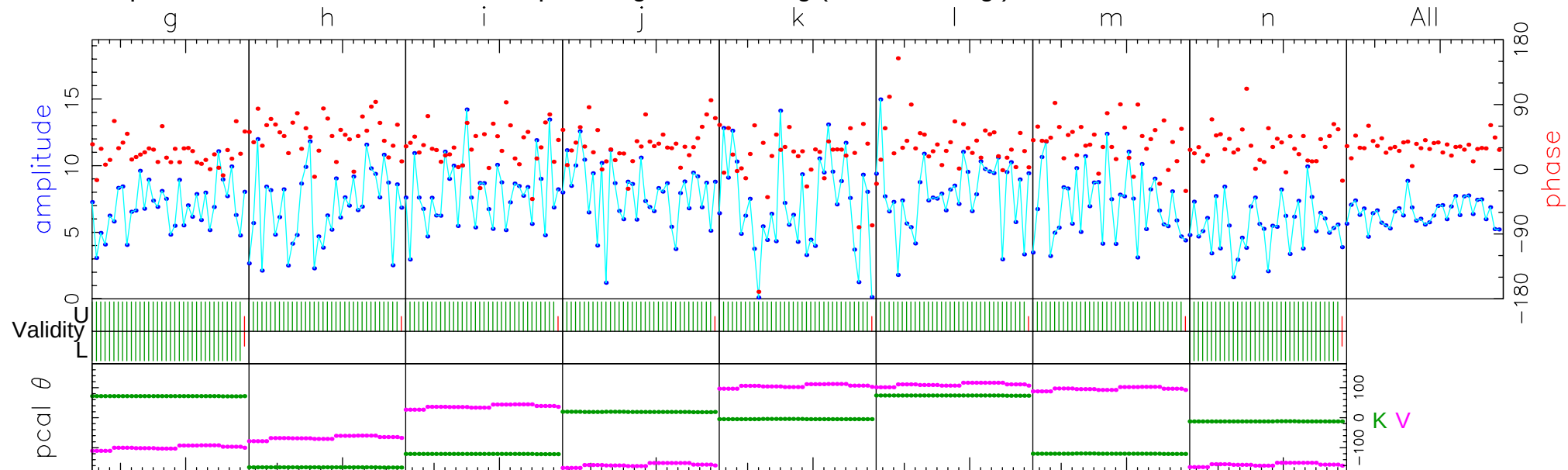
2019:022:182221

RA & Dec (J2000)

01h36m58.594810s

+47°51'29.100000"

Amp. and Phase vs. time for each freq., 36 segs, 1 APs / seg (2.00 sec / seg.), time ticks 5 sec



8212.99	8252.99	8352.99	8512.99	8732.99	8852.99	8912.99	8932.99	Freq (MHz)	All
22.2	51.2	32.3	33.9	24.2	33.1	38.5	30.4	Phase	31.8
6.6	6.4	7.2	7.2	6.5	7.2	6.4	5.2	Ampl.	6.4
129.1	129.3	128.9	128.9	128.2	128.2	128.2	128.3	Sbd box	128.8
U/L 36/36	36/0	36/0	36/0	36/0	36/0	36/0	36/36	APs used	
K -244.2	-233.9	-229.3	-235.1	-243.1	-250.8	-242.1	-251.4	PC R delays (ns)	
V 56.7	57.4	57.8	54.3	75.1	71.7	72.1	68.4	PC R delays (ns)	
K:V 72:-100	-165:-67	-121:37	19:-158	-5:105	74:110	-120:96	-12:-157	PC phase	
K:V 0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0	Manl PC	
K 23	25	24	25	23	20	14	11	PC amp	
V 21	20	23	22	21	23	22	22		
K X06UR,X06LR	X07UR	X08UR	X09UR	X10UR	X11UR	X12UR	X13UR,X13LR	Chan ids	
V X06UR,X06LR	X07UR	X08UR	X09UR	X10UR	X11UR	X12UR	X13UR,X13LR	Tracks	
								Chan ids	

Group delay (usec)(model)	1.60781143456E+04	Apriori delay (usec)	1.60781214154E+04	Resid mbdelay (usec)	-7.06979E-03	+/-	1.3E-05
Sband delay (usec)	1.60781145114E+04	Apriori clock (usec)	-9.6033335E+00	Resid sbdelay (usec)	-6.90400E-03	+/-	1.2E-03
Phase delay (usec)	1.60781214261E+04	Apriori clockrate (us/s)	2.2560000E-07	Resid phdelay (usec)	1.07599E-05	+/-	6.5E-07
Delay rate (us/s)	3.20831462188E-01	Apriori rate (us/s)	3.20831254366E-01	Resid rate (us/s)	2.07822E-07	+/-	2.2E-08
Total phase (deg)	166.7	Apriori accel (us/s/s)	-1.17340437588E-04	Resid phase (deg)	31.8	+/-	1.9

ph/seg (deg)	11.1	RMS	Theor.	Amplitude	6.484 +/- 0.152	Pcal mode: MULTITONE, MULTITONE	PC period (AP's) 5, 5
amp/seg (%)	13.3			Search (128X256)	6.221	Pcal rate: 0.000E+00, 0.000E+00 (us/s)	sb window (us) -4.000 4.000
ph/frq (deg)	9.8			Interp.	0.000	Bits/sample: 1x1	mb window (us) -0.025 0.025
amp/frq (%)	9.8			Inc. seg. avg.	6.432	Sample rate(MSamp/s): 16	dr window (ns/s) -0.030 0.030
				Inc. frq. avg.	6.430	Data rate(Mb/s): 160	nlags: 128 t_cohere infinite ion window (TEC) 0.00 0.00

K: az 12.5 el 63.3 pa -162.5 V: az 349.4 el 8.1 pa 10.3 u,v (fr/asec) -264.790 -1189.877 simultaneous interpolator

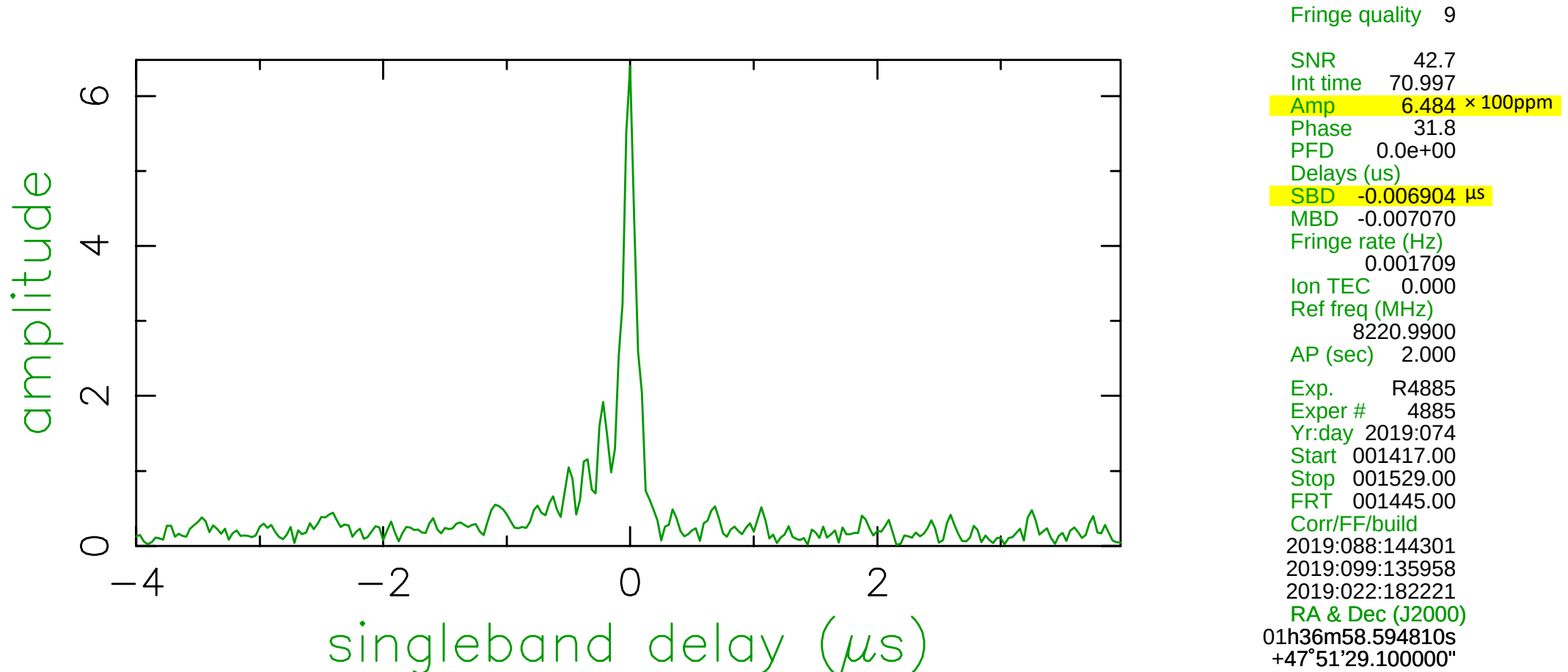
Control file: cf_4885 Input file: /isan/data1/correlator/run/r/r4885/Production_Pass/1234/074-0014//KV..assqcy Output file: Suppressed by test mode

HOPS Fourfit: Single Band Delay (SBD)

- **Clock pass:**
 - relatively few observations
 - measure SBD and SBD rate
 - add SBD correction to **clock offset(s)** and **clock rate(s)**
- Update a priori clock offsets
- **Production Pass:**
 - all observations
 - apparent SBD $\cong 0$ (due to clock pass corrections)

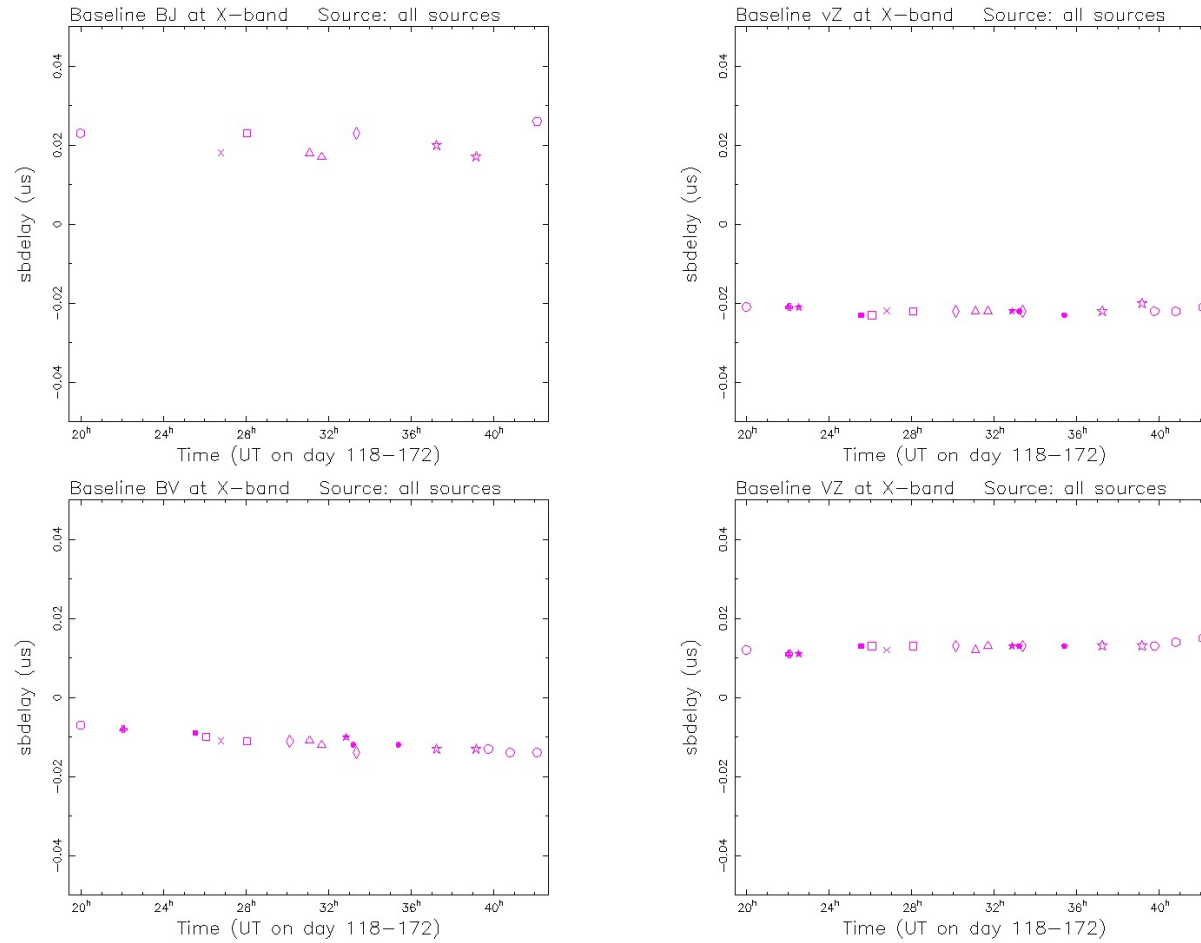
HOPS Fourfit: Single Band Delay (SBD) Cont.

- Clock pass makes apparent **SBD ≤ 20 ns**, and ideally ≤ 10 ns
- Amplitude is typically a few hundred parts per million



HOPS aedit: Plot View

AEDIT plot – Expt 4847, Freq X

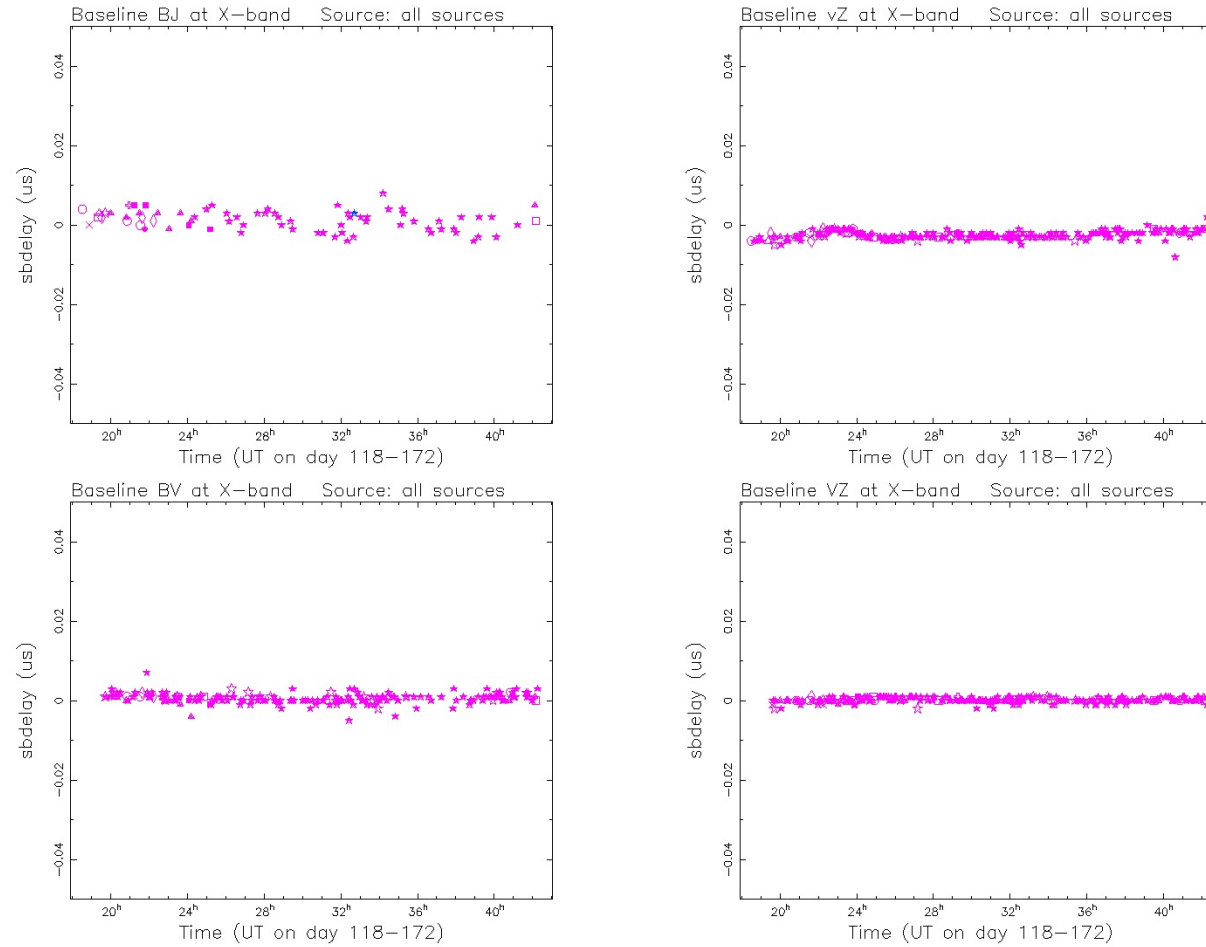


Symbol key: $\circ$ = 1751+288, $\times$ = 0003-066, $\square$ = 0322+222, $\triangle$ = 0458-020, $\diamond$ = 0821+394, $\star$ = 1040+244
 $\blacktriangle$ = 0716+714, $\blacklozenge$ = 0016+731, $\blacksquare$ = 0529+483, $\bullet$ = 1418+546, $\star$ = the rest

Clock pass, before offset and rate corrections

HOPS aedit: Plot View

AEDIT plot – Expt 4847, Freq X



Symbol key: $\circ$ = 1749+096, $\times$ = 1502+036, $\square$ = 1636+473, $\triangle$ = 1409+218, $\diamond$ = 1504+377, $\star$ = 1418+546
 $\blacktriangle$ = 1751+288, $\oplus$ = 2059+034, $\blacksquare$ = 2227-088, $\bullet$ = 2008-159, $\star$ = the rest, $\circ$ = 0149+218

Production pass, after offset and rate corrections

HOPS Fourfit: First Look

Before Configuration:

- Lots of G Codes
(low amp. chan.)
- Lots of H Codes
(low amp. phase)
- Some 0 Codes
(no fringe detected)
- Other quality codes
are spread out.

	A	B	C	D	E	F	G	H	0	1	2	3	4	5	6	7	8	9	*
A:S	-	-	-	-	-	-	<u>18</u>	<u>25</u>	<u>22</u>	-	-	-	-	-	-	1	36	668	770
A:X	-	-	-	-	-	-	<u>8</u>	<u>77</u>	<u>8</u>	-	-	-	-	-	-	3	61	613	770
B:S	-	-	-	-	-	-	<u>263</u>	<u>32</u>	-	-	-	-	-	-	1	17	204	1029	1546
B:X	-	-	-	-	-	-	<u>92</u>	<u>294</u>	<u>4</u>	-	-	-	-	1	1	9	101	1044	1546
J:S	-	-	-	-	-	-	<u>124</u>	<u>44</u>	<u>31</u>	-	-	-	-	-	1	7	85	725	1017
J:X	-	-	-	-	-	-	<u>49</u>	<u>196</u>	<u>18</u>	-	-	-	-	-	-	3	69	682	1017
K:S	-	-	-	-	-	-	<u>68</u>	<u>53</u>	<u>19</u>	-	-	-	-	-	-	7	62	745	954
K:X	-	-	-	-	-	-	<u>16</u>	<u>160</u>	<u>26</u>	-	-	-	-	-	1	15	154	582	954
M:S	-	-	-	-	-	-	<u>1406</u>	<u>319</u>	<u>11</u>	-	-	-	-	-	-	-	-	-	1736
M:X	-	-	-	-	-	-	<u>914</u>	<u>791</u>	<u>31</u>	-	-	-	-	-	-	-	-	-	1736
N:S	-	-	-	-	-	-	<u>234</u>	<u>64</u>	<u>16</u>	-	-	-	-	1	1	52	255	1011	1634
N:X	-	-	-	-	-	-	<u>105</u>	<u>335</u>	<u>8</u>	-	-	-	-	3	1	12	107	1063	1634
S:S	-	-	-	-	-	-	<u>413</u>	<u>71</u>	<u>41</u>	-	-	-	-	1	1	56	307	891	1781
S:X	-	-	-	-	-	-	<u>177</u>	<u>1585</u>	<u>19</u>	-	-	-	-	-	-	-	-	-	1781
V:S	-	-	-	-	-	-	<u>360</u>	<u>37</u>	<u>13</u>	-	-	-	-	-	2	13	123	1283	1831
V:X	-	-	-	-	-	-	<u>206</u>	<u>337</u>	<u>7</u>	-	-	-	-	2	3	32	321	923	1831
v:S	-	-	-	-	-	-	<u>340</u>	<u>66</u>	<u>22</u>	-	-	-	-	-	2	11	172	1254	1867
v:X	-	-	-	-	-	-	<u>160</u>	<u>395</u>	<u>12</u>	-	-	-	-	3	1	21	150	1125	1867
Y:S	-	-	-	-	-	-	<u>19</u>	<u>21</u>	<u>21</u>	-	-	-	-	-	-	4	94	557	716
Y:X	-	-	-	-	-	-	<u>11</u>	<u>66</u>	<u>3</u>	-	-	-	-	1	1	-	41	593	716
Z:S	-	-	-	-	-	-	<u>537</u>	<u>170</u>	<u>30</u>	-	-	-	-	-	4	90	326	595	1752
Z:X	-	-	-	-	-	-	<u>160</u>	<u>354</u>	<u>4</u>	-	-	-	-	2	2	11	130	1089	1752

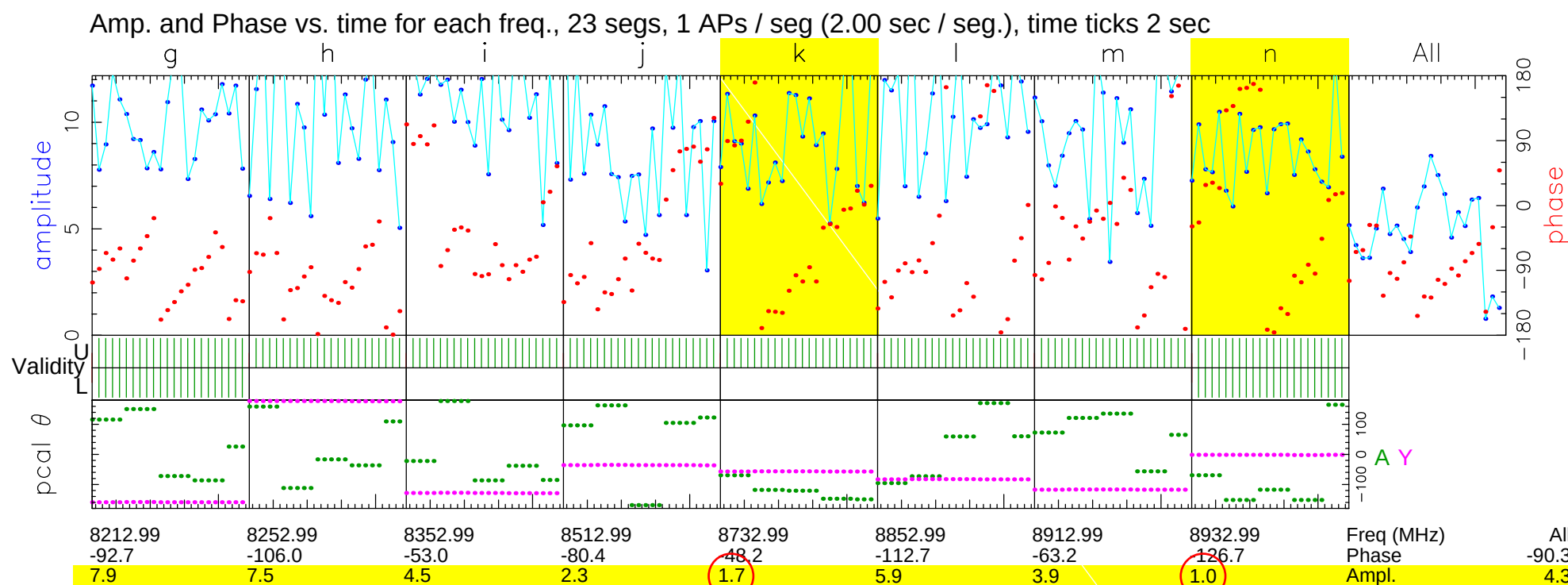
	A	B	C	D	E	F	G	H	0	1	2	3	4	5	6	7	8	9	*
*:S	-	-	-	-	-	-	<u>1891</u>	<u>451</u>	<u>113</u>	-	-	-	-	1	6	129	832	4379	7802
*:X	-	-	-	-	-	-	<u>949</u>	<u>2295</u>	<u>70</u>	-	-	-	-	6	5	53	567	3857	7802
:	-	-	-	-	-	-	<u>2840</u>	<u>2746</u>	<u>183</u>	-	-	-	-	7	11	182	1399	8236	15604

[illegible]

[illegible]

HOPS Fourfit: Weak Channels

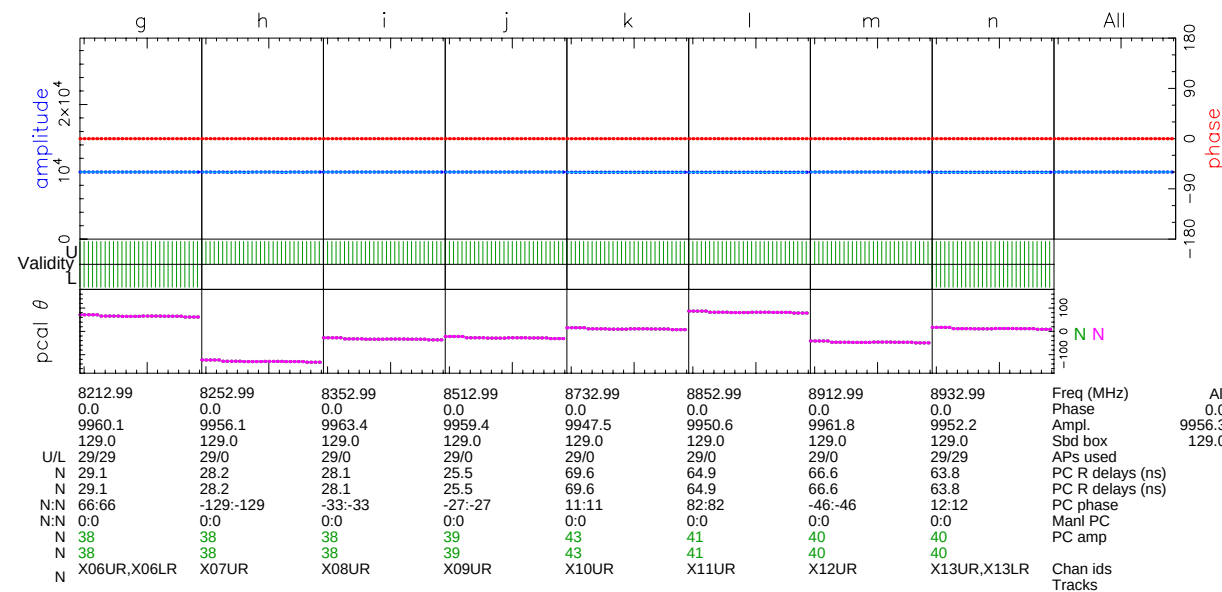
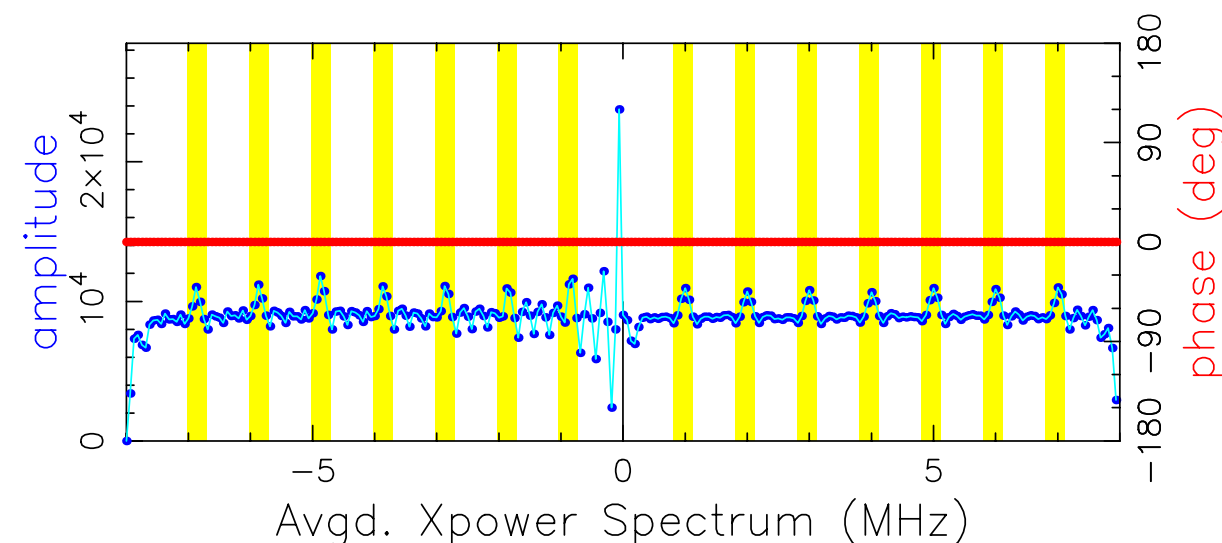
- Radio frequency interference (RFI), and/or signal chain problems can cause low signal to noise (SNR) in one or more channel(s).
- G Code** error (weak channel) happens when: $SNR_{chan} < \frac{SNR_{avg}}{2}$
- Correlator drops channels with excessive G Codes.



Fringe quality 7
Error code G
 SNR 21.3
 Int time 44.988
 Amp 4.063
 Phase -90.3
 PFD 0.0e+00
 Delays (us)
 SBD 0.002248
 MBD 0.023959
 Fringe rate (Hz)
 -0.017503
 Ion TEC 0.000
 Ref freq (MHz)
 8220.9900
 AP (sec) 2.000
 Exp. R4885
 Exper # 4885
 Yr:day 2019:074
 Start 142123.00
 Stop 142209.00
 FRT 142139.00
 Corr/FF/build
 2019:088:174410
 2019:100:162824
 2019:022:182221
RA & Dec (J2000)
 14h27m56.297569s
 -42°06'19.437599"

HOPS Fourfit: Phase Calibration (pcal)

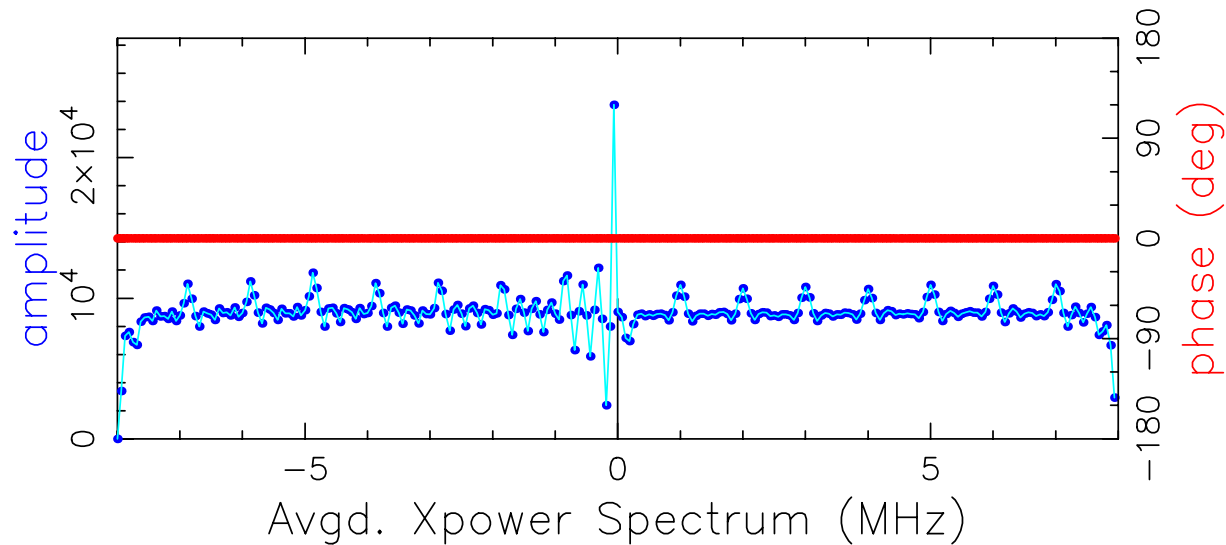
- Injected phase calibration (pcal) tones cause regularly spaced spikes in the apparent power spectrum of autocorrelations.
- Spacing is usually 1 MHz for S/X-band observations.
- Weak tones can be missed.
- Narrow RFI at pcal frequencies may cause spurious detection.
- DiFX extracts all pcal tones, so a few missing tones can be ignored, (e.g. due to RFI).



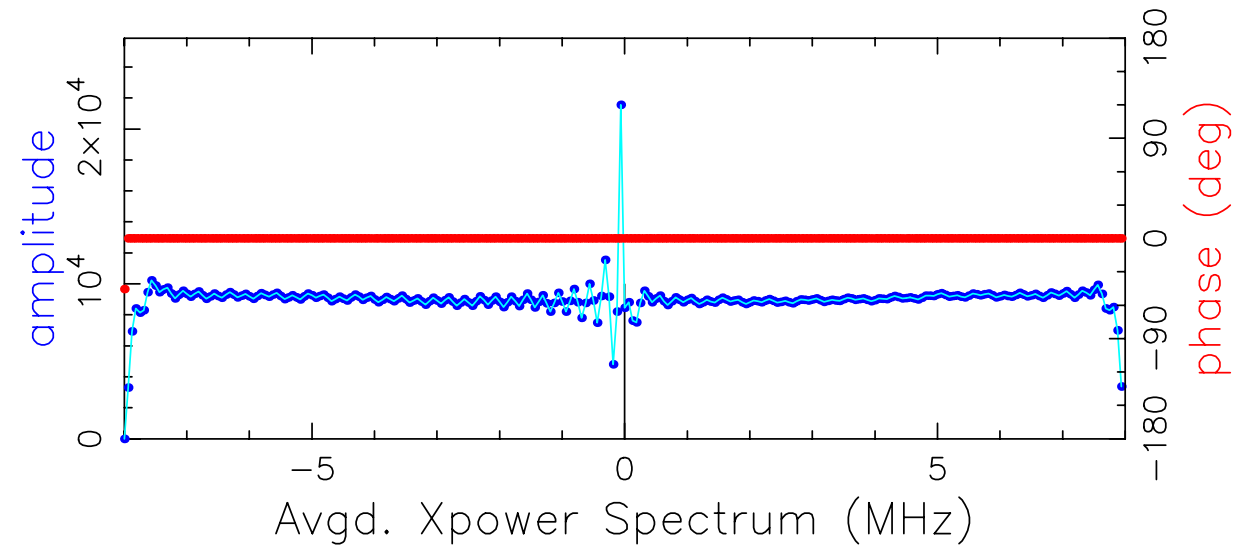
HOPS Fourfit: Phase Calibration (pcal) Cont.

- Here are two example power spectra from autocorrelations with and without good phase calibration tone injection.

sufficient
phase calibration tones

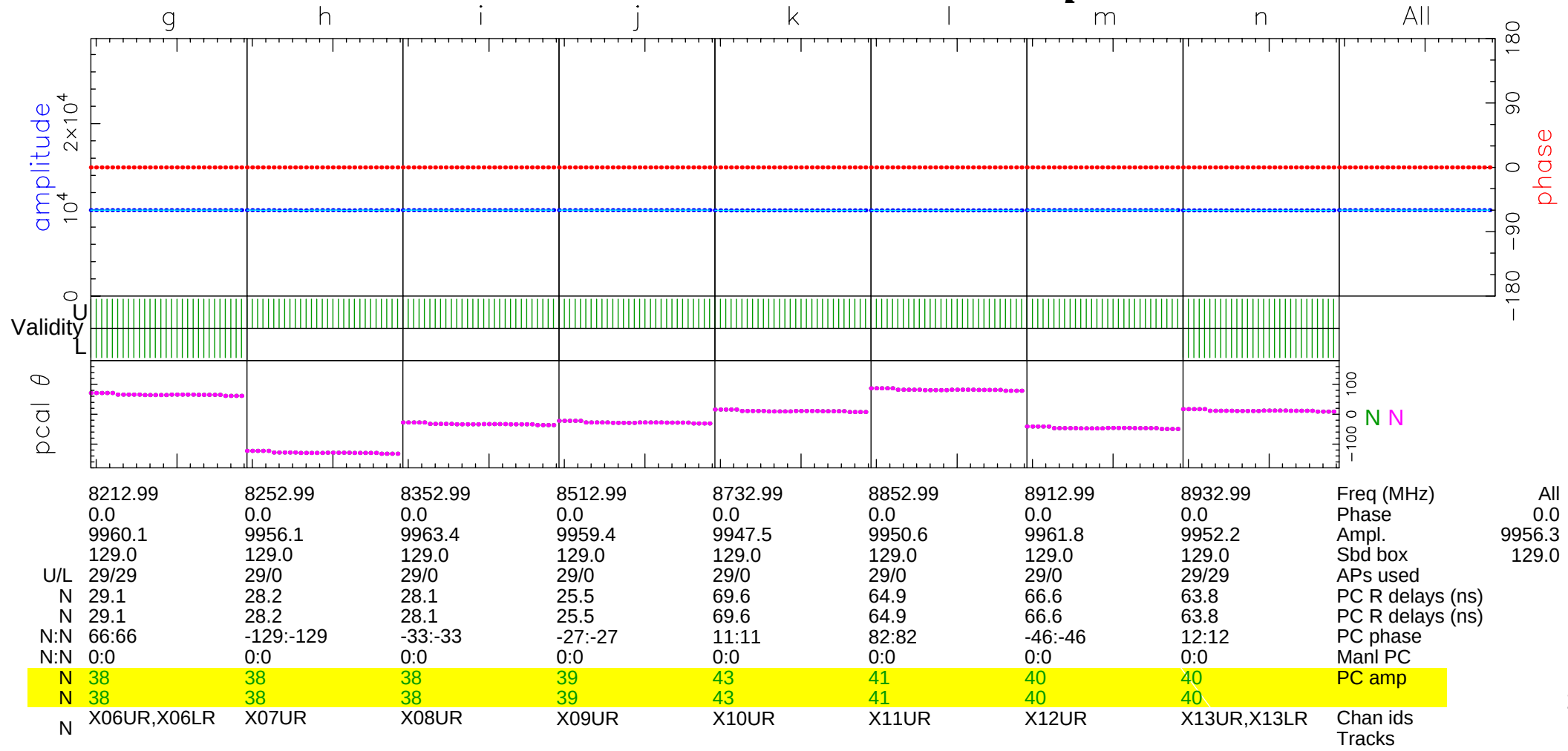


no detectable
phase calibration tones



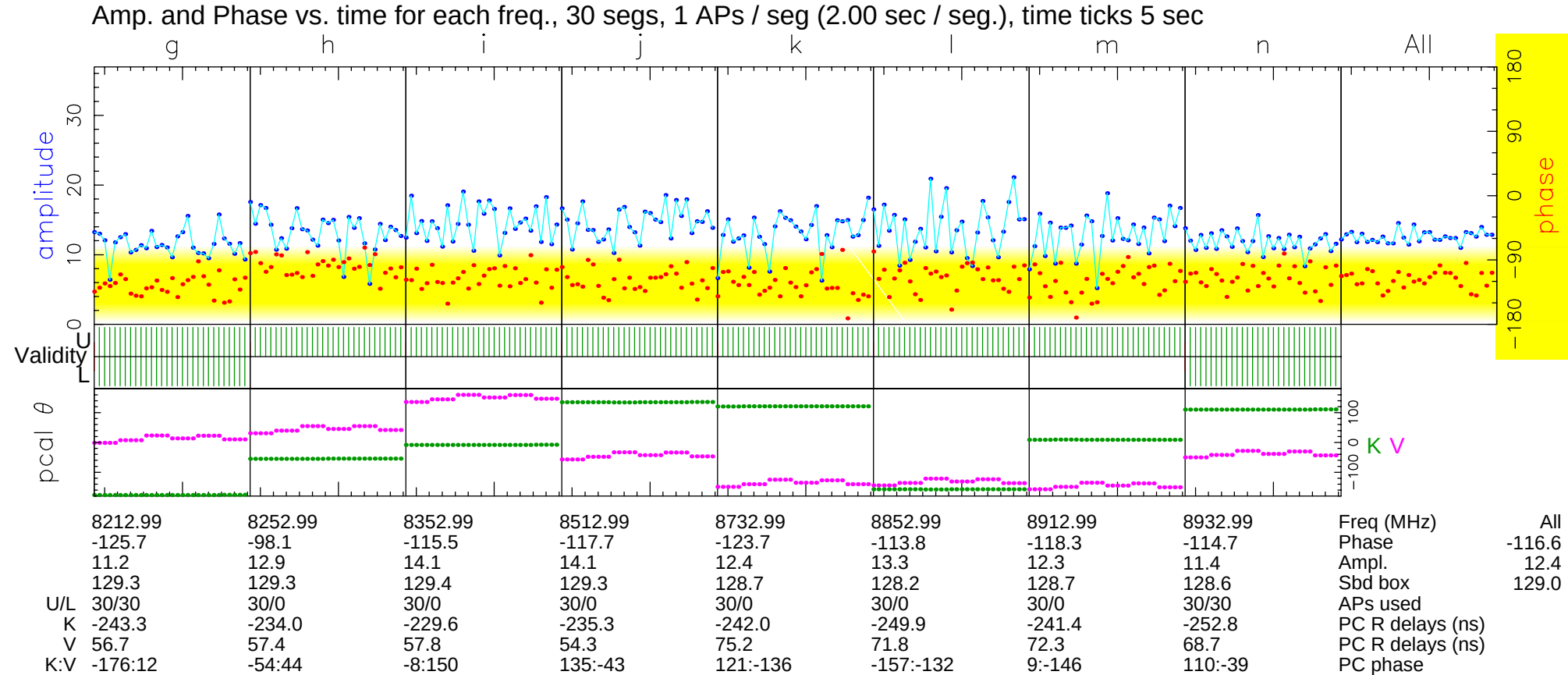
HOPS Fourfit: Phase Calibration (pcal) Cont.

- Phase calibration (PC) amplitude corresponds to pcal SNR.
- H Code** error (no pcal) happens when: $Amp_{pcal} < 500ppm$



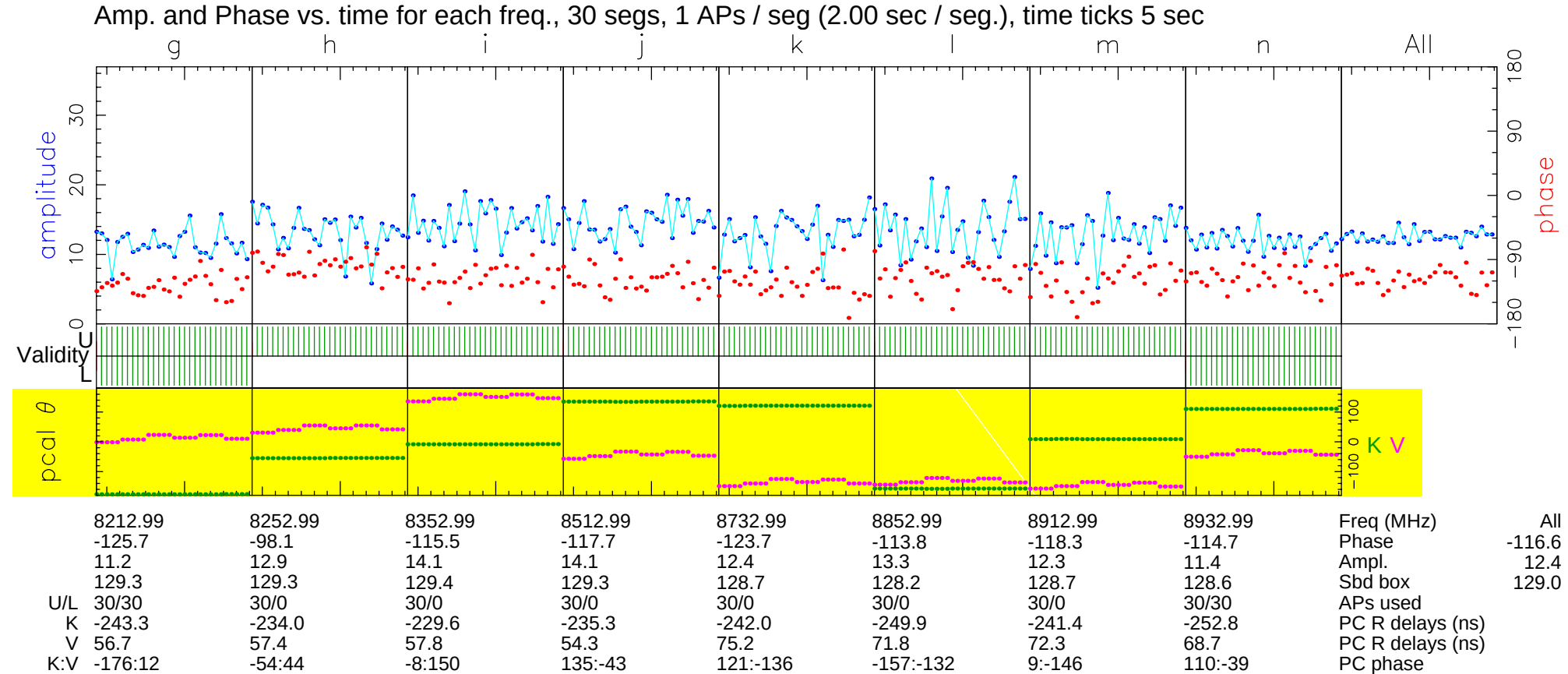
HOPS Fourfit: Phase Calibration (pcal) Cont.

- After fringe fitting and phase calibration, the phases should appear normally distributed around a single mean value.



HOPS Fourfit: Phase Calibration (pcal) Cont.

- Measured pcal phase should be relatively flat within each channel.
- Slopes or curves in the pcal phase within a channel can indicate a drifting or unstable phase calibration.



HOPS Fourfit: Final Look

After Configuration:

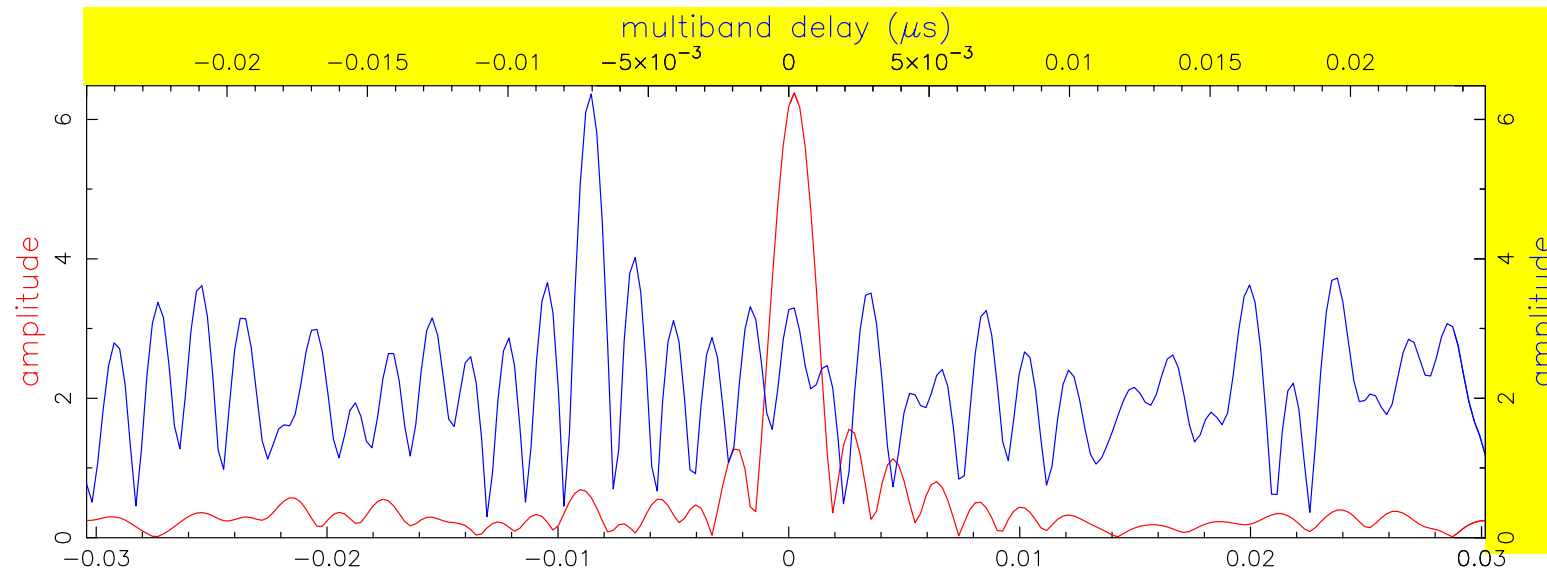
- Fewer G and H Codes
- Fewer 0 Codes
- More 7—9 Codes.
- Goal:
≥ 90% 7—9 Codes

	A	B	C	D	E	F	G	H	0	1	2	3	4	5	6	7	8	9	*
A:S	-	-	-	-	-	-	-	<u>2</u>	<u>21</u>	-	-	-	-	-	-	-	34	713	770
A:X	-	-	-	-	-	-	-	<u>3</u>	<u>5</u>	-	-	-	-	-	-	9	85	668	770
B:S	-	-	-	-	-	-	<u>31</u>	<u>10</u>	-	-	-	-	-	-	-	11	216	1278	1546
B:X	-	-	-	-	-	-	<u>7</u>	<u>3</u>	<u>2</u>	-	-	-	-	2	3	20	156	1353	1546
J:S	-	-	-	-	-	-	<u>2</u>	<u>2</u>	<u>29</u>	-	-	-	-	-	1	4	53	926	1017
J:X	-	-	-	-	-	-	<u>1</u>	<u>5</u>	<u>11</u>	-	-	-	-	-	3	10	117	870	1017
K:S	-	-	-	-	-	-	<u>5</u>	<u>6</u>	<u>18</u>	-	-	-	-	-	-	3	57	865	954
K:X	-	-	-	-	-	-	<u>4</u>	<u>2</u>	<u>16</u>	-	-	-	-	-	2	26	190	714	954
M:S	-	-	-	-	-	-	<u>24</u>	<u>7</u>	<u>8</u>	-	-	-	-	-	2	19	166	1510	1736
M:X	-	-	-	-	-	-	<u>7</u>	<u>3</u>	<u>5</u>	-	-	-	-	13	22	65	432	1189	1736
N:S	-	-	-	-	-	-	<u>17</u>	<u>8</u>	<u>15</u>	-	<u>1</u>	-	-	1	1	23	306	1262	1634
N:X	-	-	-	-	-	-	<u>3</u>	<u>5</u>	<u>4</u>	-	-	-	-	7	4	25	162	1424	1634
S:S	-	-	-	-	-	-	<u>43</u>	-	<u>36</u>	-	<u>1</u>	-	-	1	-	33	298	1369	1781
S:X	-	-	-	-	-	-	<u>39</u>	<u>29</u>	<u>19</u>	-	-	-	-	3	9	80	440	1162	1781
V:S	-	-	-	-	-	-	<u>21</u>	<u>6</u>	<u>13</u>	-	-	-	-	-	2	6	109	1674	1831
V:X	-	-	-	-	-	-	<u>8</u>	<u>2</u>	<u>7</u>	-	-	-	-	7	9	60	578	1160	1831
v:S	-	-	-	-	-	-	<u>26</u>	<u>9</u>	<u>22</u>	-	-	-	-	-	2	7	170	1631	1867
v:X	-	-	-	-	-	-	<u>5</u>	<u>5</u>	<u>12</u>	-	-	-	-	8	12	50	308	1467	1867
Y:S	-	-	-	-	-	-	<u>1</u>	<u>2</u>	<u>21</u>	-	-	-	-	-	-	2	101	589	716
Y:X	-	-	-	-	-	-	-	<u>4</u>	<u>3</u>	-	-	-	-	1	1	4	61	642	716
Z:S	-	-	-	-	-	-	<u>52</u>	<u>34</u>	<u>27</u>	-	-	-	-	-	4	34	306	1295	1752
Z:X	-	-	-	-	-	-	<u>8</u>	<u>3</u>	<u>4</u>	-	-	-	-	3	5	21	221	1487	1752

	A	B	C	D	E	F	G	H	0	1	2	3	4	5	6	7	8	9	*
*:S	-	-	-	-	-	-	<u>111</u>	<u>43</u>	<u>105</u>	-	<u>1</u>	-	-	1	6	71	908	6556	7802
*:X	-	-	-	-	-	-	<u>41</u>	<u>32</u>	<u>44</u>	-	-	-	-	22	35	185	1375	6068	7802
:	-	-	-	-	-	-	<u>152</u>	<u>75</u>	<u>149</u>	-	<u>1</u>	-	-	23	41	256	2283	12624	15604

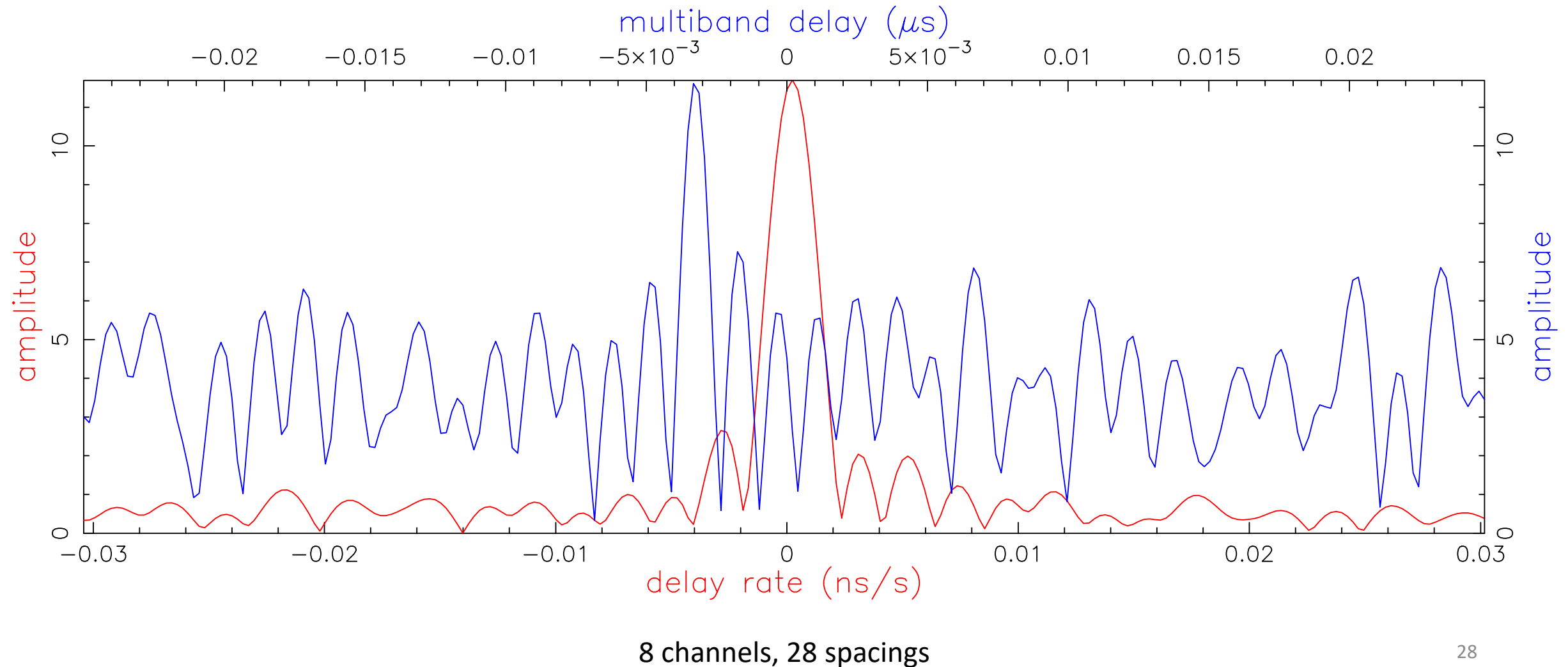
HOPS Fourfit: Multiband Delay

- Each channel only gives a single mean frequency:
We must combine channels to cover the whole band.
- Fourier transforming phase differences between each channel yields a representative sine wave.
- Different spacings produce different sine waves (some redundant).
- The sum of these sine waves is the **multiband delay function**.



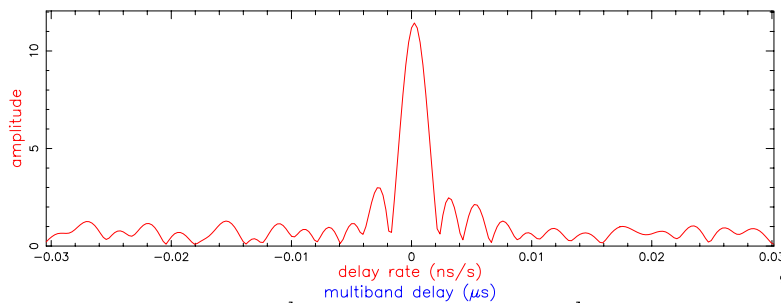
HOPS Fourfit: Multiband Delay Cont.

- Removing channels removes spacings and causes ambiguities.

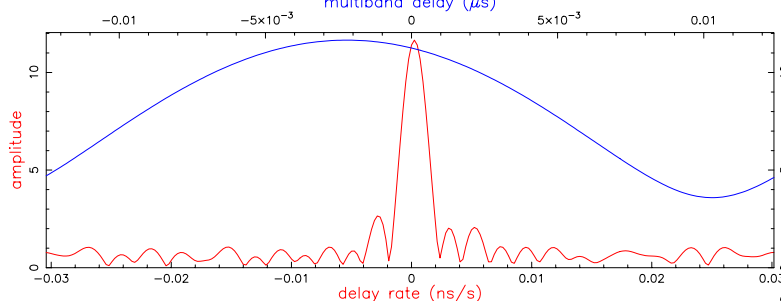


HOPS Fourfit: Multiband Delay Cont.

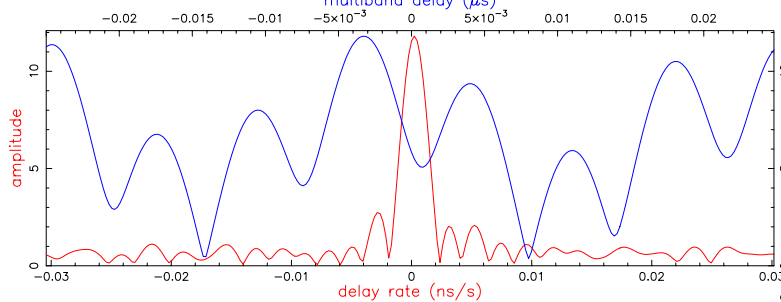
1 channel
0 spacings



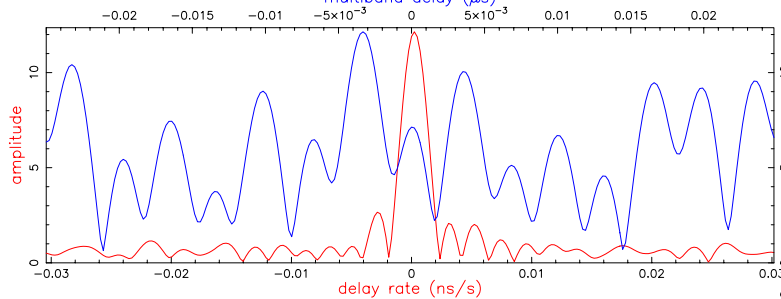
2 channels
1 spacing



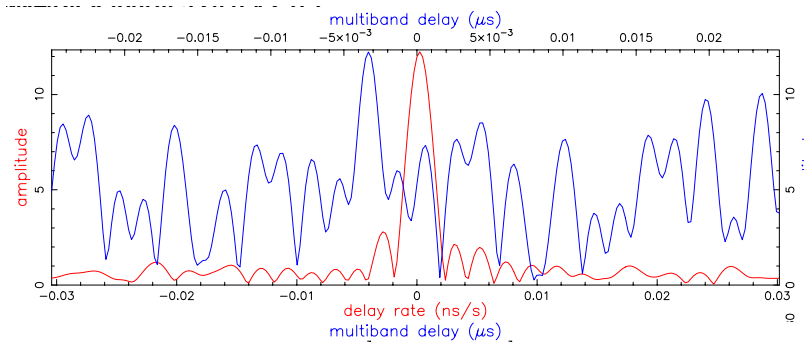
3 channels
3 spacings



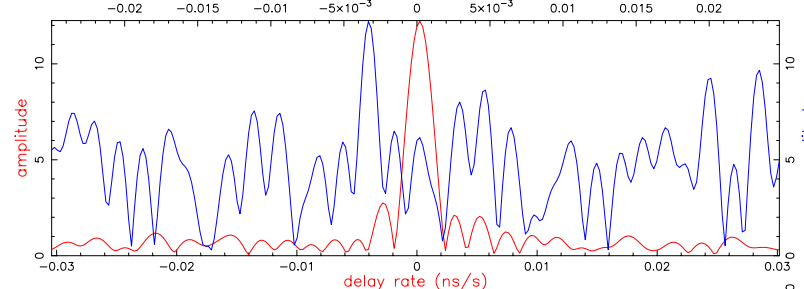
4 channels
6 spacings



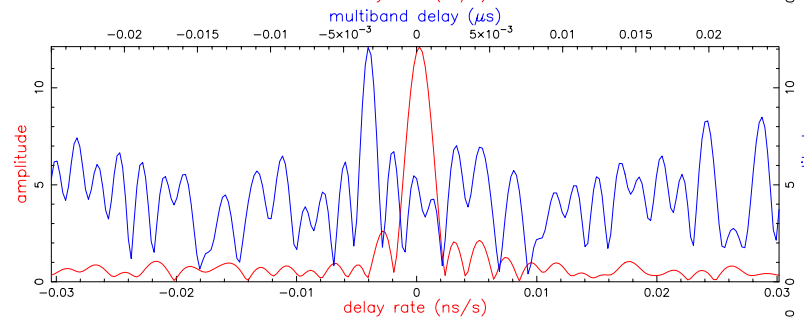
5 channels
10 spacings



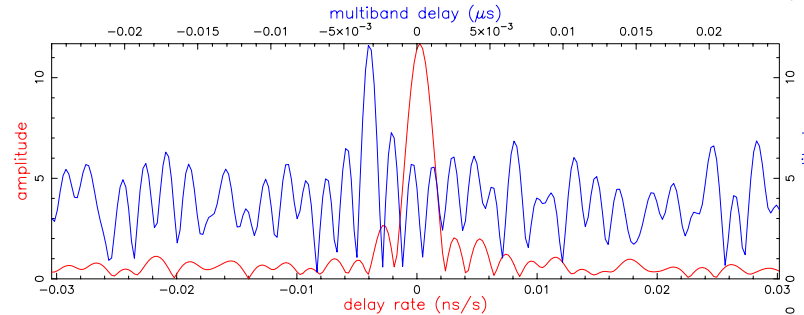
6 channels
15 spacings



7 channels
21 spacings

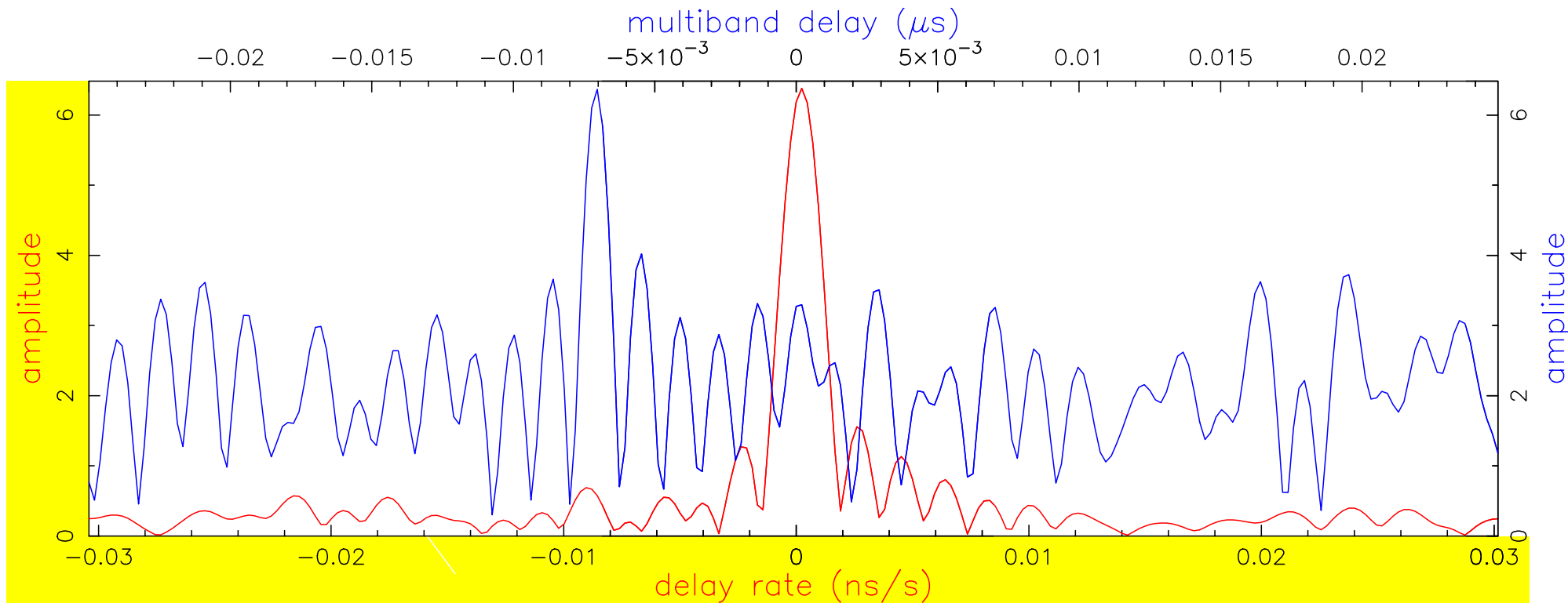


8 channels
28 spacings



HOPS Fourfit: Fringe Rate and Delay Rate

- Fringe Rate (FR): Phase Slope vs Time
- Delay Rate (DR): Phase Slope vs Frequency



Fringe quality 9

SNR 42.7

Int time 70.997

Amp 6.484 $\times 100\text{ppm}$

Phase 31.8

PFD 0.0e+00

Delays (μs)

SBD -0.006904

MBD -0.007070

Fringe rate (Hz)

0.001709

Ion TEC 0.000

Ref freq (MHz)

8220.9900

AP (sec) 2.000

Exp. R4885

Exper # 4885

Yr:day 2019:074

Start 001417.00

Stop 001529.00

FRT 001445.00

Corr/FF/build

2019:088:144301

2019:099:135958

2019:022:182221

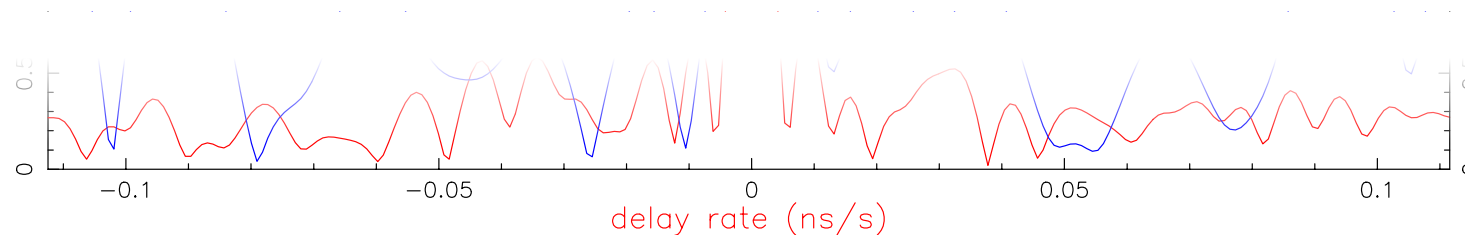
RA & Dec (J2000)

01h36m58.594810s

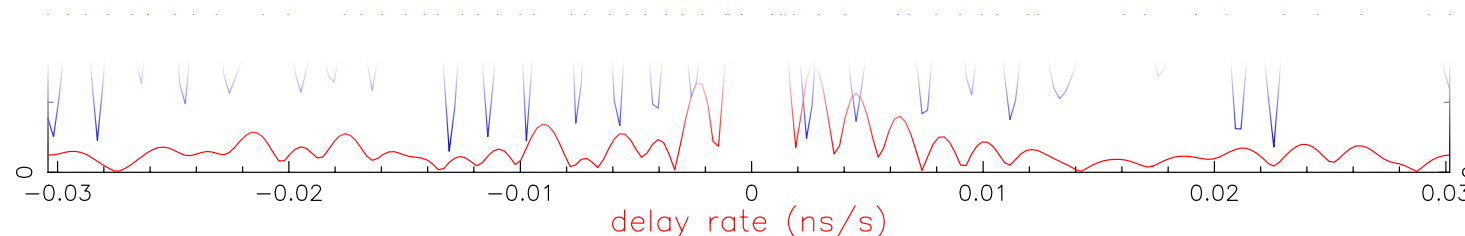
+47°51'29.100000"

HOPS Fourfit: Fringe Rate and Delay Rate Cont.

- Delay Rate (DR) window = $\frac{1}{2 \cdot AP \cdot \nu}$
 - AP = accumulation period
 - ν = reference frequency
- The DR plot axes are confined by the DR window:



- S (1 sec AP, 2.22 GHz): $DRW = 2.25 \times 10^{-10}$



- X (1 sec AP, 8.22 GHz): $DRW = 6.08 \times 10^{-11}$

Fringe quality 9

SNR 42.7

Int time 70.997

Amp 6.484 × 100ppm

Phase 31.8

PFD 0.0e+00

Delays (us)

SBD -0.006904

MBD -0.007070

Fringe rate (Hz)

0.001709

Ion TEC 0.000

Ref freq (MHz)

8220.9900

AP (sec) 2.000

Exp. R4885

Exper # 4885

Yr:day 2019:074

Start 001417.00

Stop 001529.00

FRT 001445.00

Corr/FF/build

2019:088:144301

2019:099:135958

2019:022:182221

RA & Dec (J2000)

01h36m58.594810s

+47°51'29.100000"

TLDR: What can go wrong?

Slow Data Shipping

Effects:

- **preliminary database** followed by **re-release**
 - data aren't used for EOPs (Earth orientation parameters)
- **station dropped** from session
 - **data are lost** (too late to justify disk space)

Solutions:

- ship data ASAP
- always send the **tracking number** to the correlator.
- carefully fill out **customs** declarations / paper work
- use a reputable carrier

TLDR: What can go wrong?

Large Clock Jump

Effects:

- correlator searches for new clock offset
 - $0 \text{ sec} \pm 100 \text{ } \mu\text{s}$, and $\pm 1 \text{ sec} \pm 32 \text{ } \mu\text{s}$
 - very time consuming (man hours and CPU time)
- clock may not be found
 - **data are lost** (no fringes found)

Solutions:

- always upload log file (with GPS)
- inform correlator of likely jumps
 - put jump and jump size in the **ivs-ops mailing list** start or stop message
- **do not unplug** or reseal cables in the signal chain
 - $1 \text{ nm cable shift} \cong 1 \text{ nm observed position shift}$

TLDR: What can go wrong?

Wrong Schedule Used

Effects:

- **data are lost**
(out of network)
- split-release w/
different subnets
 - very occasional
(special circumstances)
 - smaller subnet usually
ignored after analysis

Solutions:

- check for schedule changes as
close to start time as possible
- check **all three** IVS archives:
 - <ftp://cddis.gsfc.nasa.gov/pub/vlbi/ivsdata/aux>
 - <ftp://ivs.bkg.bund.de/pub/vlbi/ivsdata/aux>
 - <ftp://ivsopar.obspm.fr/vlbi/ivsdata/aux>
- FTP timestamps may be wrong!
 - download SKD and compare
SCHEDULE_CREATE_DATE

TLDR: What can go wrong?

Bad Channel / Frequency Setup

Effects:

- correlator searches for channel / frequency setup
 - try other known configurations first
 - searching for unknown configuration is very costly (*rarely done*)
- data are often lost

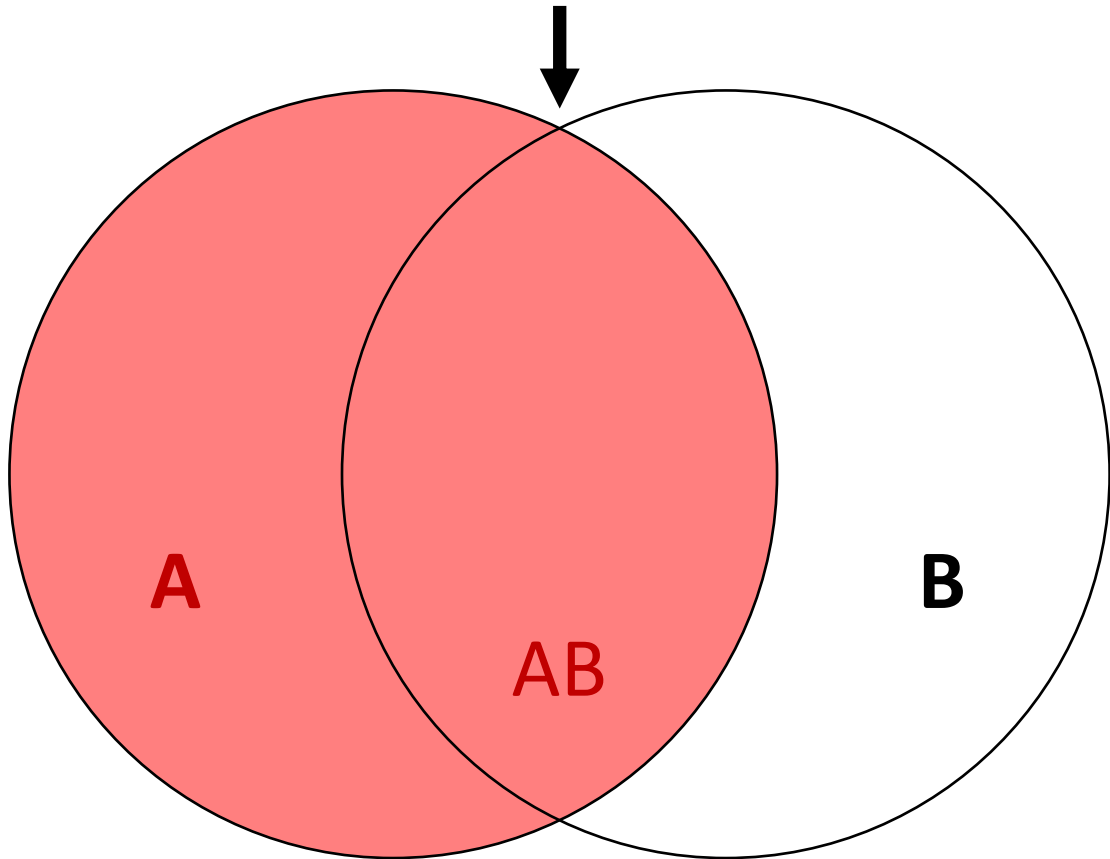
Solutions:

- double-check signal chain and IF/recorder setup before session
- report incorrect channel / freq. setup in SKD or VEX files to IVS
- If something goes wrong:
 - explain *exactly* how channels and frequencies are set up in ivs-ops start or stop message

The Baseline Problem:

We only see 2-station **baselines** and 3-station **closures**.

We can't tell which station
has a problem with only one baseline
(we need to use other information).



Correlator Report:

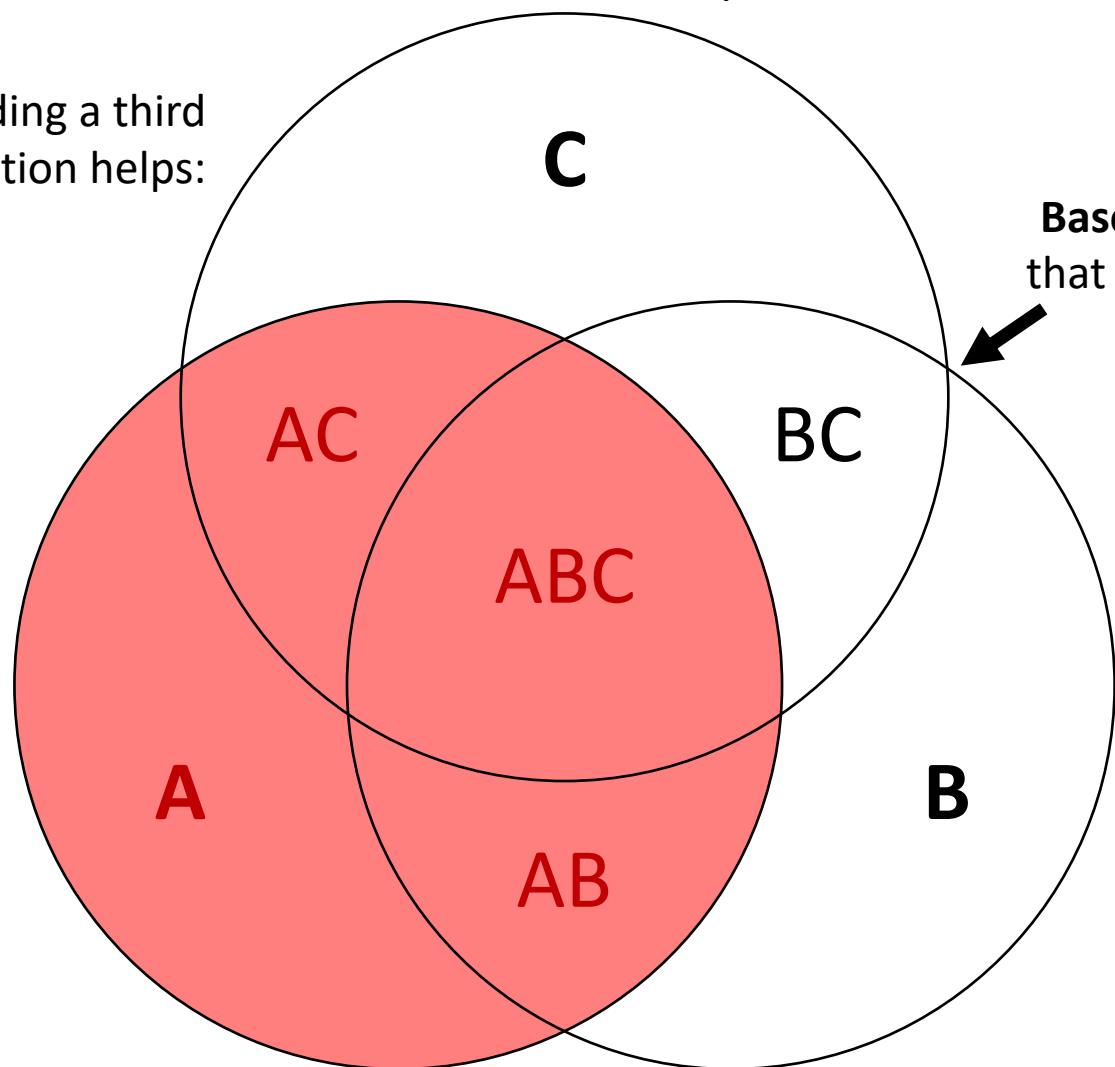
+CORRELATOR_NOTES

Aa-Bb: Removed channel(s) from
fringe fitting: SR1U

The Baseline Problem:

We only see 2-station **baselines** and 3-station **closures**.

Adding a third
station helps:



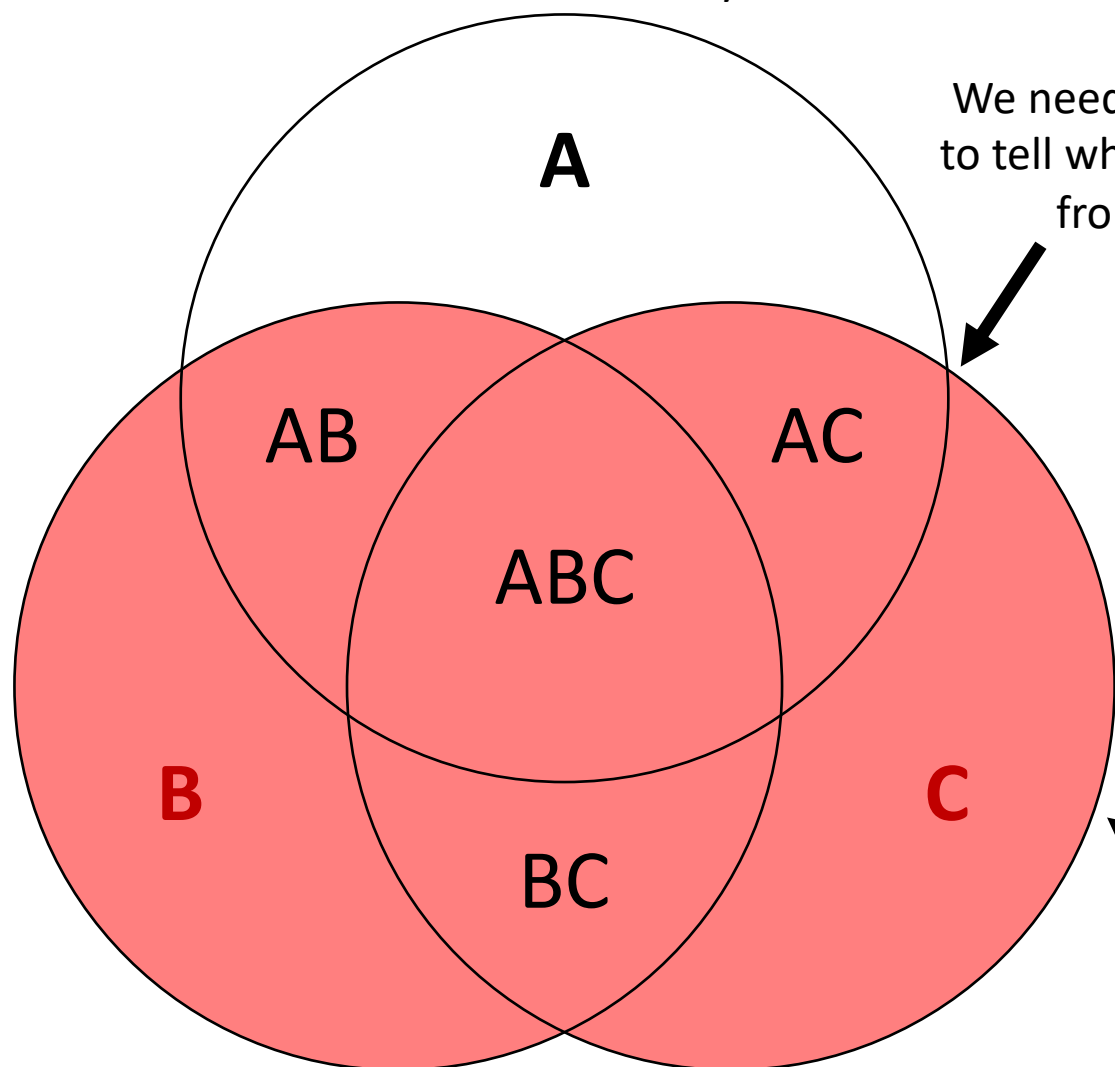
Baseline BC is okay, so we conclude
that **station B** and **station C** are okay.

Correlator Report:

```
+STATION_NOTES  
AAAAAAAA (Aa/A): Removed channel(s) from  
fringe fitting: SR1U
```

The Baseline Problem:

We only see 2-station **baselines** and 3-station **closures**.



We need at least **one okay baseline** to tell which stations have a problem from baseline data alone.

Correlator Report:

+CORRELATOR_NOTES

Aa-Bb-Cc: Removed channel(s) from
fringe fitting: SR1U

What if two stations
have the problem?

TLDR: What else can stations do?

- Double check:
 - **pointing** control
 - **phase cal** injection
 - field system **time sync** (NTP)
 - **channel/frequency** setup
 - **cable cal** and **weather** monitor
- List **missed / problem scans** in **ivs-ops** mailing list stop message.
 - Try to list **why** scans were missed too.
 - The correlator may forward your message in the station notes.

How can we help you?

- We'll notify you if...
 - Missing or problematic data
 - Clock issues (such as 1 second offsets)
- Correlator report!
 - Provides feedback on overall and individual performance (clock/pcal/RFI, etc.)
 - Lets IVS know when a session has been correlated and ready for analysis

Correlator Report

HEADER

- Introductory section identifying:
 - Correlator name
 - VGOS Database name
 - Session name
 - Final/preliminary report

+HEADER

CORREL	WACO
DATABASE	19MAR28XE
SESSNAME	R4887
OBSTIME	2019/03/28 2019/03/29
UTSTART	1830
DURATION	24
DOY	087-088
CORRTIME	2019/04/09 2019/04/10
CORRPASS	1
EXPORT	DONE

Correlator Report

SUMMARY

- Overall fringe quality code summary

CORRELATOR_NOTES

- Overview of issues related to correlation and fringing
- Useful for analysts

+SUMMARY

Qcode	% of Total Scans	% of Correlated Scans
5-9	88%	91%
0	7%	7%
1-4,A-H,N	1%	1%
removed	2%	-

+CORRELATOR_NOTES

The vgosDb for this session is available at
<ftp://rorf.usno.navy.mil/vgosDb/2019/19MAR28XE.tgz>

Correlator Report

STATION_NOTES

- Specific comments related to performance of each participating station in session
- We relay pertinent ops messages
- Check for your station!

+STATION_NOTES

FORTLEZA (Ft/F): AZ encoder failures at 088-0209 -- 088-0214, 088-0342 -- 088-0404, 088-0438 -- 088-0441, and 088-0814 -- 088-1206.

Power failure from 088-0459 -- 088-0810.

Clock break at 088-0814 (-0.117 us).

HART15M (Ht/J): Ok.

ISHIOKA (Is/P): Ok.

KATH12M (Ke/A): No phase cal. Applied manual phase cal.

KOKEE (Kk/K): Ok.

NYALES20 (Ny/N): Ok.

URUMQI (Ur/U): Removed channel(s) from fringe fitting: XR5U, XR6U, XR7U, XR8U/L

WETTZ13N (Wn/v): Ok.

WARK12M (Ww/W): Removed channel(s) from fringe fitting: SR5U, SR6U

No phase cal. Applied manual phase cal.

...

Correlator Report

DROP_CHANNELS

- deleted channels by station

MANUAL_PCAL

- List of stations with manual phase calibrations applied

CHANNELS

- Table of channel labels, BBCs, and sky frequencies

+DROP_CHANNELS

Ur XR5U XR6U XR7U XR8U/L

Ww SR5U SR6U

+MANUAL_PCAL Ke Ww Zc

+CHANNELS

Channels: XR1U = band|polarization|BBC#|sideband

XR1U/L BBC01 8212.99

XR2U BBC02 8252.99

XR3U BBC03 8352.99

XR4U BBC04 8512.99

XR5U BBC05 8732.99

XR6U BBC06 8852.99

XR7U BBC07 8912.99

XR8U/L BBC08 8932.99

SR1U BBC09 2225.99

SR2U BBC10 2245.99

SR3U BBC11 2265.99

SR4U BBC12 2295.99

SR5U BBC13 2345.99

SR6U BBC14 2365.99

Correlator Report

CLOCKS

- Shows the fitted, measured clock values from log files
- Shows clock offsets and drift rates for each station used during correlation
- Reference station and clock breaks

+CLOCKS

Clocks: WACO

Station	fmout-gps [usec]	Used [usec]	Rate [sec/sec]	Comments
Ft	0.326	0.566	-6.135E-15	
Ft	-	0.449	9.107E-14	088-0814
Ht	0.887	3.839	-8.153E-14	Reference
Is	0.604	0.856	-2.006E-14	
Ke	6.184	8.181	-7.523E-13	
Kk	7.132	7.615	-4.039E-13	
Ny	-175.049	-172.740	1.070E-12	
Ur	42.101	44.075	1.437E-12	
Wn	-1.329	1.011	-5.301E-14	
Ww	-37.646	-35.712	-1.397E-12	
Yg	8.290	10.561	5.510E-13	
Zc	-2.887	214.155	-9.936E-14	

Date: 2019/03/28 18:30:00

Correlator Report

QCODES

- Summarizes fringe quality codes on a baseline basis

+QCODES

Qcod	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G	H	N	-	Tot
FJ:S	21	0	0	0	0	0	0	0	7	70	0	0	0	0	0	0	5	2	0	41	146
FJ:X	20	0	0	0	0	0	0	1	17	66	0	0	0	0	0	0	0	1	0	41	146
FP:S	2	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	3	15
FP:X	2	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	3	15
FA:S	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	2
FA:X	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	2
FK:S	8	0	0	0	0	0	1	0	0	19	0	0	0	0	0	0	1	0	0	4	33
FK:X	10	0	0	0	0	0	0	0	1	18	0	0	0	0	0	0	0	0	0	4	33
...																					
UZ:S	6	0	0	0	0	0	0	12	39	136	0	0	0	0	0	0	49	0	3	0	245
UZ:X	24	0	0	0	0	0	0	0	52	166	0	0	0	0	0	0	0	0	3	0	245
vW:S	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
vW:X	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2
vY:S	3	0	0	0	0	0	0	0	9	35	0	0	0	0	0	0	0	0	0	0	47
vY:X	1	0	0	0	0	0	0	1	1	44	0	0	0	0	0	0	0	0	0	0	47
vZ:S	16	0	0	0	0	0	0	7	37	201	0	0	0	0	0	0	20	0	0	0	281
vZ:X	29	0	0	0	0	0	0	0	0	252	0	0	0	0	0	0	0	0	0	0	281
WY:S	2	0	0	0	0	0	0	0	0	189	0	0	0	0	0	0	0	0	0	0	191
WY:X	3	0	0	0	0	0	4	37	60	86	0	0	0	0	0	0	0	1	0	0	191
WZ:S	4	0	0	0	0	0	0	0	5	6	0	0	0	0	0	0	0	0	0	0	15
WZ:X	6	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	15
YZ:S	12	0	0	0	0	0	0	1	6	45	0	0	0	0	0	0	1	0	0	0	65
YZ:X	19	0	0	0	0	0	0	0	2	44	0	0	0	0	0	0	0	0	0	0	65
Tot	881	0	0	0	3	4	29	356	2006	7826	0	0	0	0	0	0	114	9	32	256	11516

Correlator Report

QCODES

- Summarizes fringe quality codes on a baseline basis

+QCODES

Qcod	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G	H	N	-	Tot
FJ:S	21	0	0	0	0	0	0	0	7	70	0	0	0	0	0	0	5	2	0	41	146
FJ:X	20	0	0	0	0	0	0	1	17	66	0	0	0	0	0	0	0	1	0	41	146
...																					
WY:S	2	0	0	0	0	0	0	0	0	189	0	0	0	0	0	0	0	0	0	0	191
WY:X	3	0	0	0	0	0	4	37	60	86	0	0	0	0	0	0	0	1	0	0	191
WZ:S	4	0	0	0	0	0	0	0	5	6	0	0	0	0	0	0	0	0	0	0	15
WZ:X	6	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	15
YZ:S	12	0	0	0	0	0	0	1	6	45	0	0	0	0	0	0	1	0	0	0	65
YZ:X	19	0	0	0	0	0	0	0	2	44	0	0	0	0	0	0	0	0	0	0	65
Tot	881	0	0	0	3	4	29	356	2006	7826	0	0	0	0	0	0	114	9	32	256	11516

QC = 0 Fringes not detected.

= 1-9 Fringes detected, no error condition. Higher #, better quality.

= B Interpolation error in fourfit.

= D No data in one or more frequency channels.

= E Maximum fringe amplitude at edge of SBD, MBD, or rate window.

= F "Fork" problem in processing.

= G Fringe amp in a channel is <.5 times mean amp (only if SNR>20).

= H Low Phase-cal amplitude in one or more channels.

= N No valid correlator data.

Tot Total number of scans in schedule.

Minus Scans in original schedule file for which correlation was not attempted, usually because of known station problems.

Correlator Report

- QC = 0** Fringes not detected.
- = 1-9** Fringes detected, no error condition. Higher #, better quality.
- = B** Interpolation error in fourfit.
- = D** No data in one or more frequency channels.
- = E** Maximum fringe amplitude at edge of SBD, MBD, or rate window.
- = F** "Fork" problem in processing.
- = G** Fringe amp in a channel is $< .5$ times mean amp (only if $\text{SNR} > 20$).
- = H** Low Phase-cal amplitude in one or more channels.
- = N** No valid correlator data.
- Tot** Total number of scans in schedule.
- Minus** Scans in original schedule file for which correlation was not attempted, usually because of known station problems.

Correlator Report

SNR_RATIOS

- Shows measured vs. predicted (by sked) SNR (signal-to-noise) ratios over the course of the session, per baseline, per frequency band
- Shows if your station is as sensitive as sked predicted
 - < 1 = station is less sensitive than expected
 - > 1 = station is more sensitive than expected

+SNR_RATIOS

MEAN RATIOS = Observed SNR / Predicted SNR for exp no. r4884

...by baseline, over all sources:

b1	X	n	S	n
FJ	0.71	85	0.93	84
FP	0.34	10	0.83	10
FA	0.34	1	0.73	1
FK	1.16	19	1.67	21
FN	0.92	34	1.02	34
FU	1.15	20	1.56	20
FW	0.77	16	0.76	18
Fv	0.91	60	0.93	60
FY	0.79	7	0.69	7
FZ	0.30	30	0.54	44
JP	1.04	32	1.03	30
JA	0.96	66	0.96	67
JK	0.00	0	0.00	0
JN	1.15	43	0.95	47
JU	1.46	76	1.58	73
JW	0.86	55	0.79	52
Jv	0.92	115	0.85	114
JY	0.95	96	0.93	100
JZ	0.17	74	0.45	92
PA	0.72	122	0.89	118
PK	1.20	183	1.41	183

...

Correlator Report

FOURFIT_CONTROL_FILE

- These are parameters set during fringe-fitting
- It's how we actually do the post-correlation adjustments:
 - drop channels
 - manual phase cal
 - etc.

+FOURFIT_CONTROL_FILE

** Fourfit control file for r4884*

sb_win -256.0 256.0 **mb_win** -256.0 256.0 **dr_win** -300.e-4 300.e-4

pc_mode multitone

pc_period 5

if **f_group** X **ref_freq** 8220.99

if **f_group** S **ref_freq** 2222.99

...

** Ft / F*

if **station** F

lsb_offset 120.0

...

if **station** U **and** **f_group** X **freqs** g h i j

if **station** W **and** **f_group** S **freqs** a b c d

...

if **station** A **and** **f_group** S

pc_phases abcdef 75.4 106.5 153.6 43.3 130.1 82.6

pc_mode manual

if **station** A **and** **f_group** X

pc_phases ghijklmn -88.5 -74.4 -61.2 1.0 -85.6 -95.0 -135.0 -42.0

pc_mode manual

...

** Matt*

+END

End