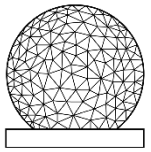

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Phase cal and sampler delay
(dealing with phases, not amplitudes)

Phase calibration

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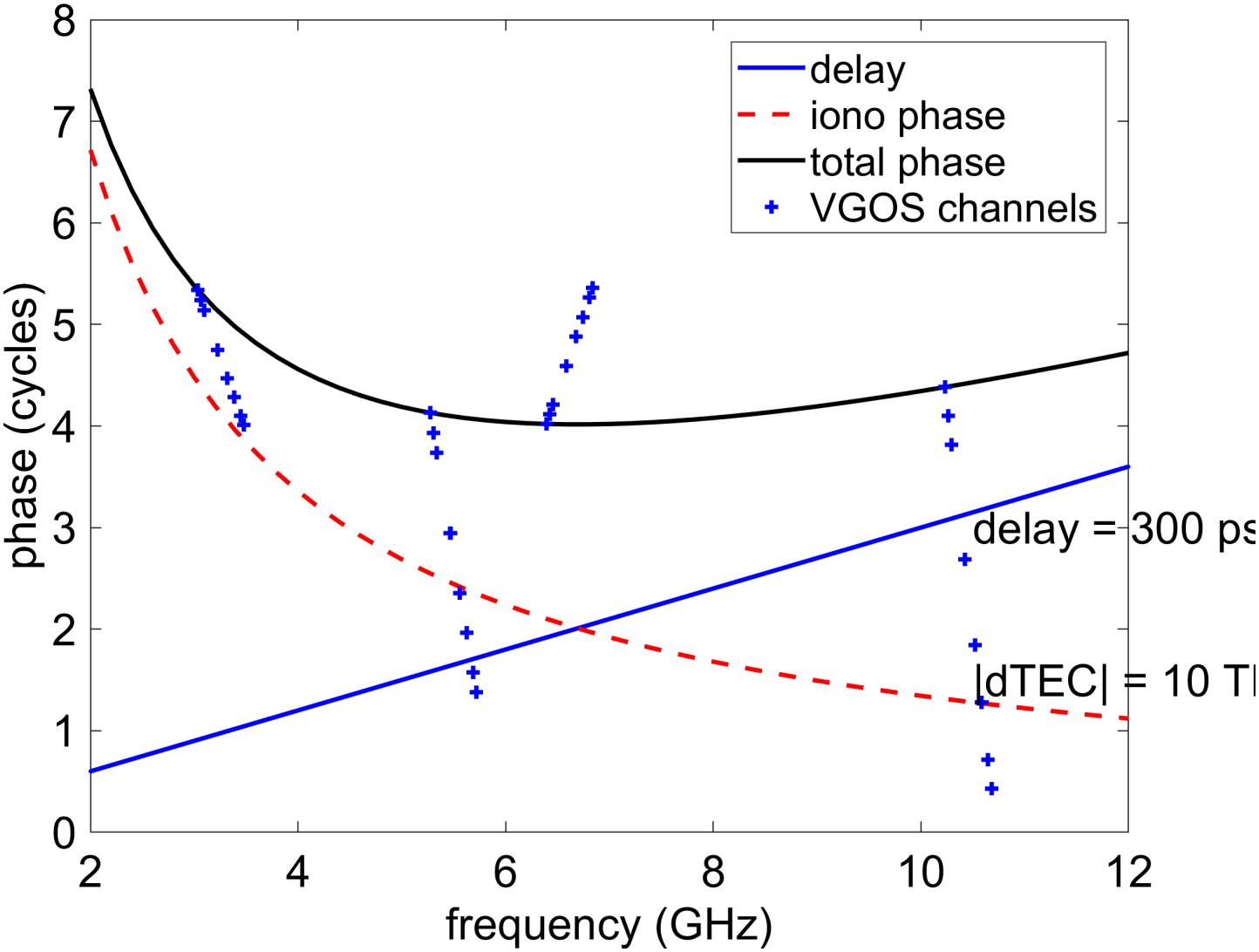
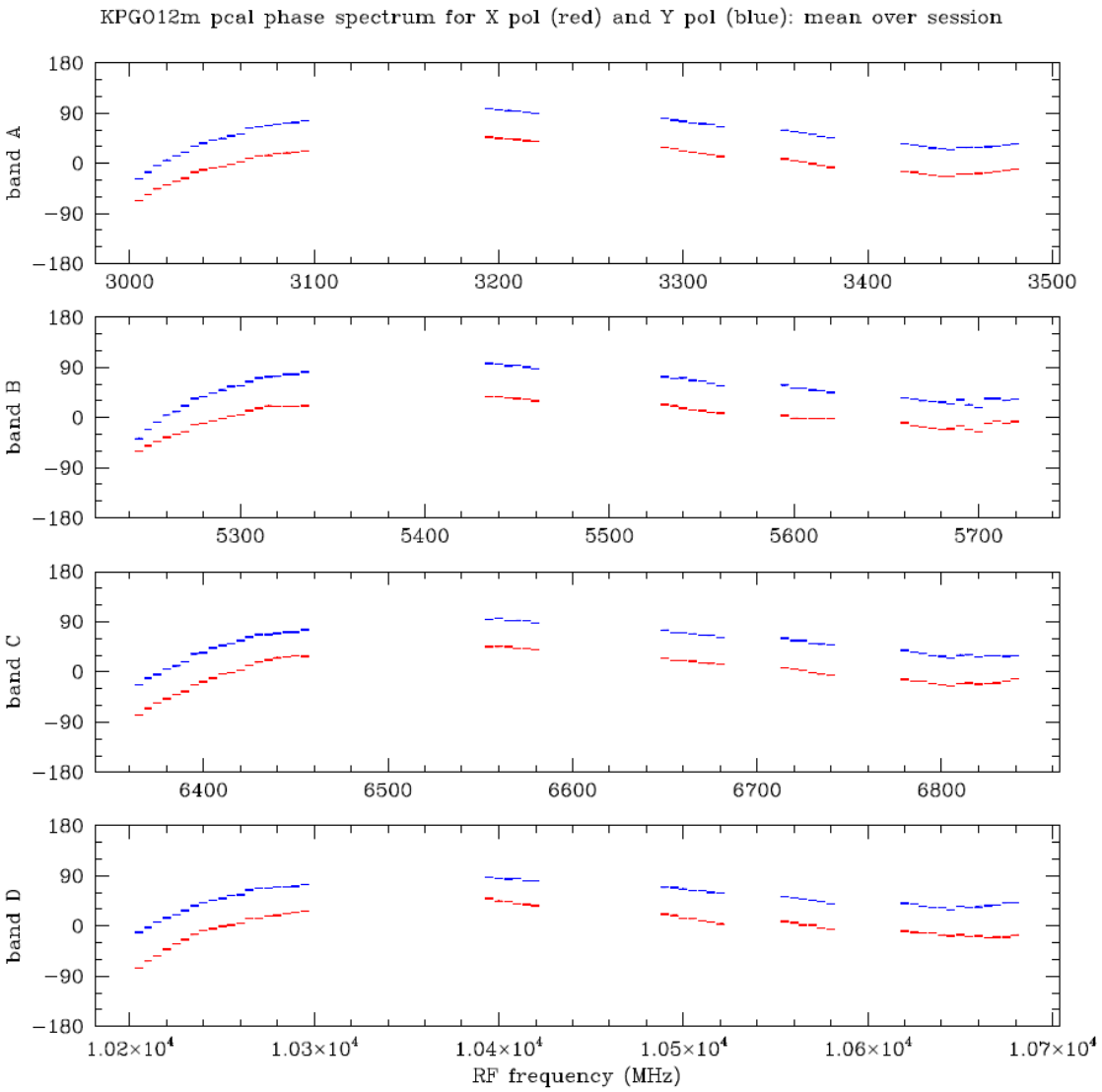
- Phase cal
  - Corrects for delay and phase differences among the bands and between polarizations.
  - Why needed?
    - Phases among bands and channels must line up to coherently add them together.
  - Delay and phase errors caused by what?
    - Cables: different lengths and types
    - Delays and phase shifts in the equipment, e.g., amplifiers, filters, and frequency converters

Broadband phase and delay



Phase cal phase



Broadband phase and delay

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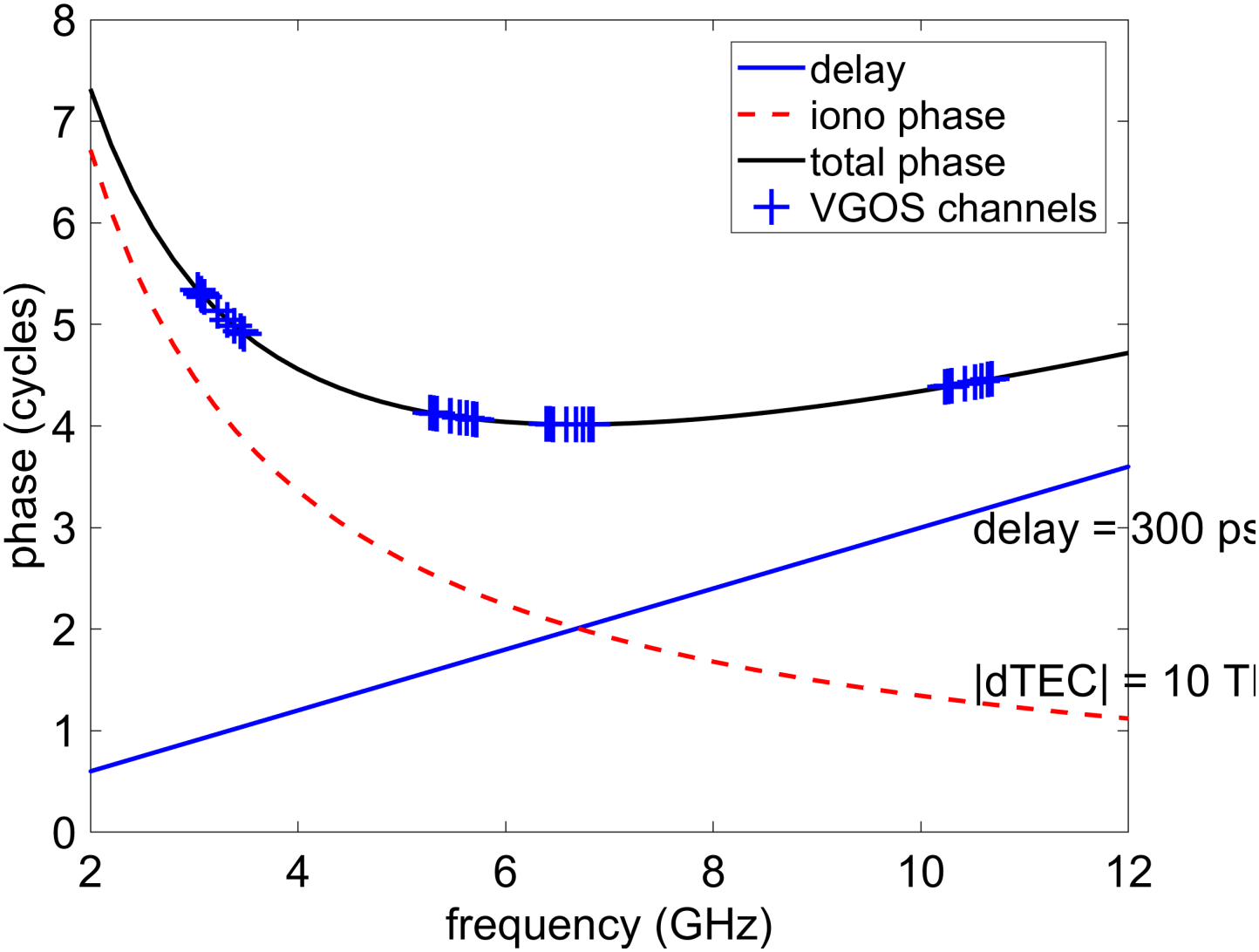
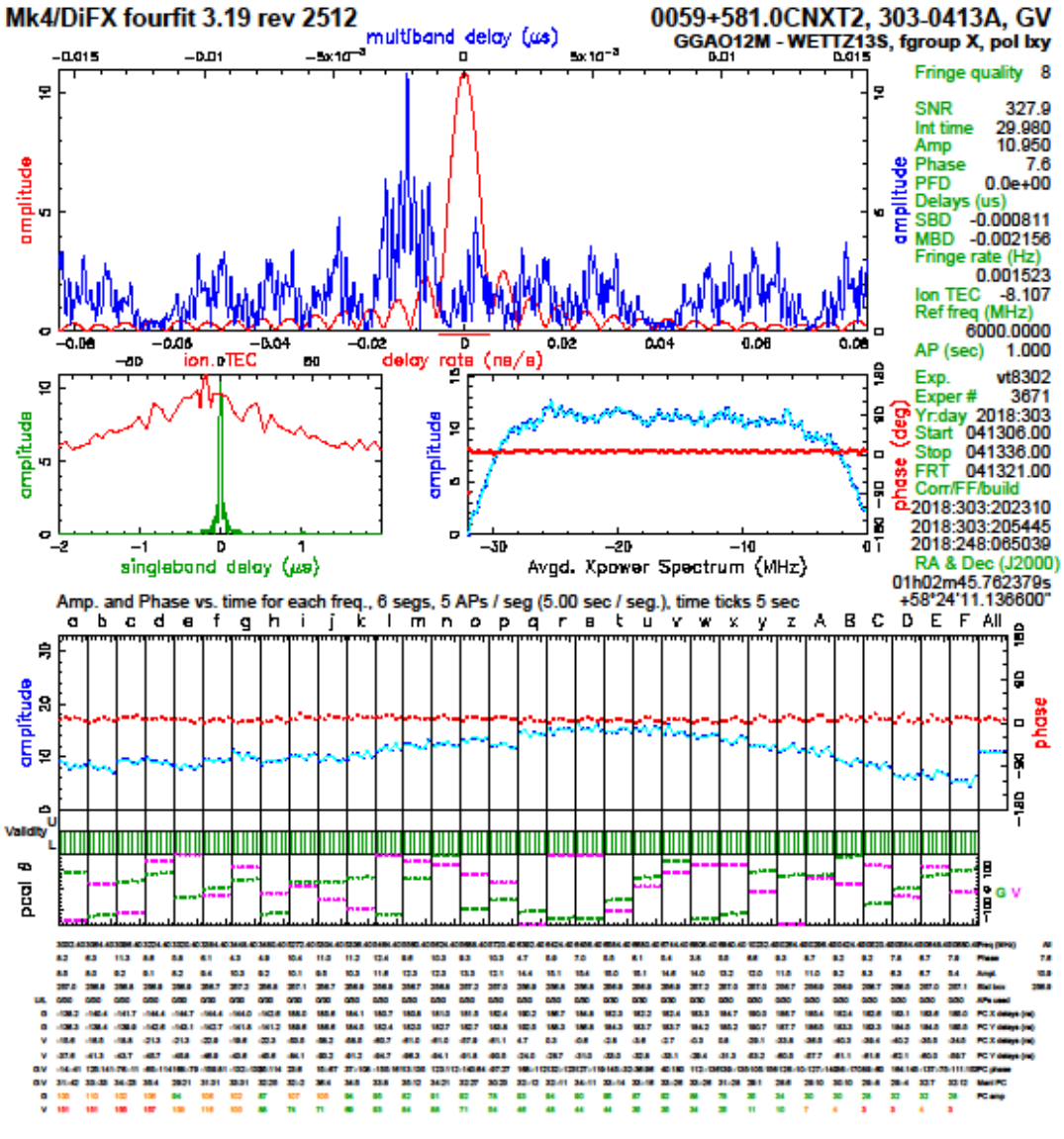
corre





Group delay (usec)(sbd)	7.41285560863E+03	Apriori delay (usec)	7.41285776456E+03	Resid mbdelay (usec)	-2.15593E-03	+/-	5.3E-07
Sband delay (usec)	7.41285695366E+03	Apriori clock (usec)	7.02308356E+01	Resid sbdelay (usec)	-8.11000E-04	+/-	5.3E-05
Phase delay (usec)	7.41285776810E+03	Apriori clockrate (us/s)	7.1299997E-07	Resid phdelay (usec)	3.53764E-06	+/-	1.6E-07
Delay rate (us/s)	4.27024920040E-01	Apriori rate (us/s)	4.27024666206E-01	Resid rate (us/s)	2.53833E-07	+/-	9.3E-09
Total phase (deg)	219.1	Apriori accel (us/s/s)	-5.12539364074E-05	Resid phase (deg)	7.6	+/-	1.2

	RMS	Theor.						
			Amplitude	10.950 +/- 0.033	Pcal mode: MULTITONE, MULTITONE PC period (AP's) 1, 1	dTEC +/-	0.013	
ph/seg (deg)	2.5	0.4	Search (64X1024)	10.754	Pcal rate: 0.000E+00, 0.000E+00 (us/s)	sb window (us)	-1.000	1.000
amp/seg (%)	0.6	0.7	Interp.	0.000	Bits/sample: 2x2 SampCntNorm: disabled	mb window (us)	-0.016	0.016
ph/frq (deg)	2.4	1.0	Inc. seg. avg.	10.952	Sample rate(MSamp/s): 64	dr window (ns/s)	-0.005	0.005
amp/frq (%)	25.1	1.7	Inc. frq. avg.	10.949	Data rate(Mb/s): 8192 nlags: 256 t_cohere infinite	ion window (TEC)	-88.00	88.00

G: az 346.9 el 69.7 pa 160.4 V: az 320.0 el 36.5 pa 53.8 u,v (fr/asec) -328.614 -497.269 simultaneous interpolator

Control file: cf_3664_GIEHSVY_pstokes.mod Input file: /data-sc03/mike/vt8302/3671/303-0413/GV..0CNXT2 Output file: Suppressed by test mode
Samplers: abcdefgh ijklmnop qrstuvwx yzABCDEF

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Phase cal delay

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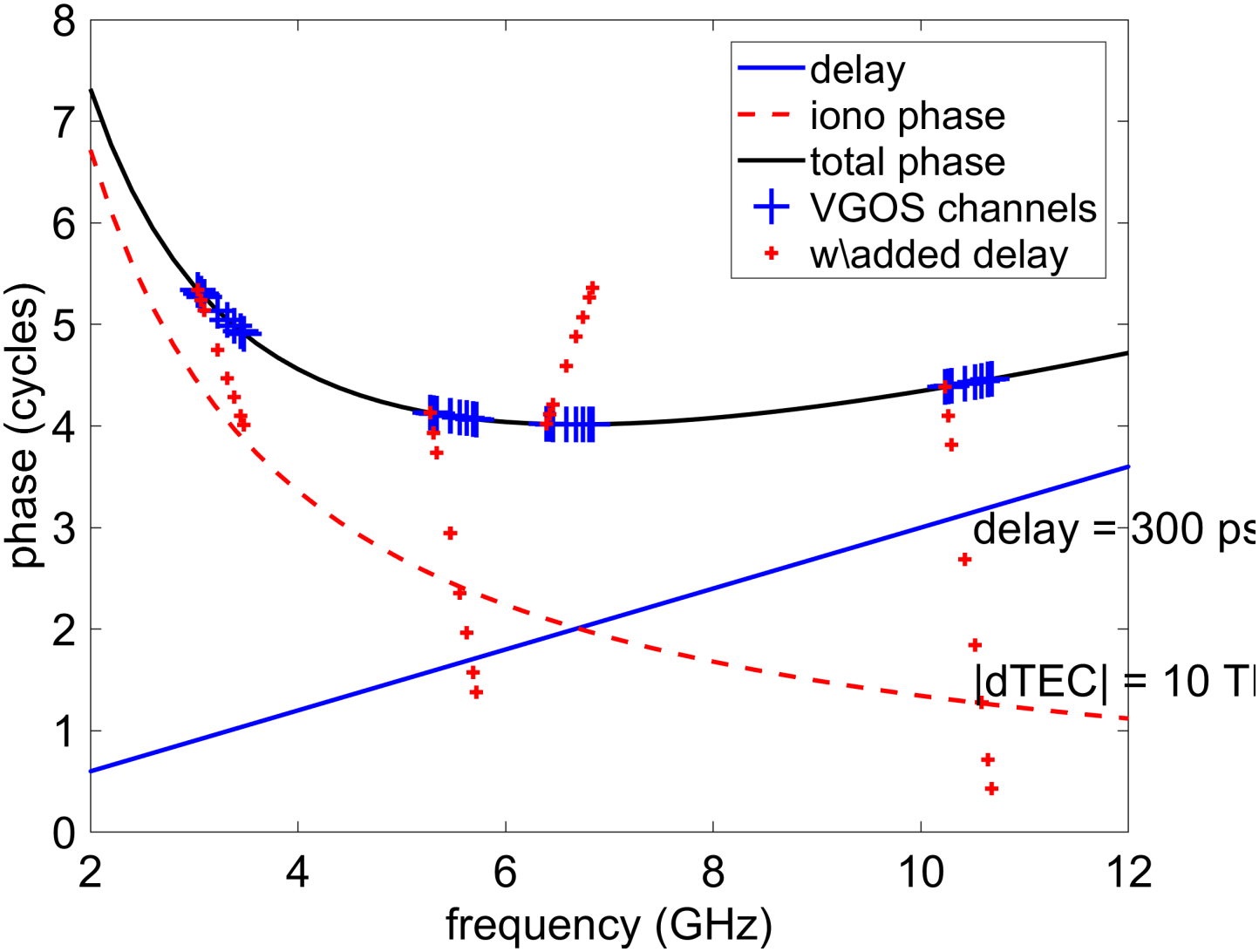
- Correct the delay error in *fourfit* by using multitone phase cal delay.
  - *haystack.mit.edu/tech/vlbi/hops/multitone_phasecal.pdf (Roger Cappallo)*
- This should also remove most channel-to-channel phase variations, but doesn't.
  - Causes unknown (RFI? phase cal reflections?)
  - so use 'manual' phase corrections (*ffres2pcp.py*).
- Doesn't correct delays in front of phase cal injection, but these are common to all bands.

Broadband phase and delay

MIT HAYSTACK OBSERVATORY



phase cal amps and phases

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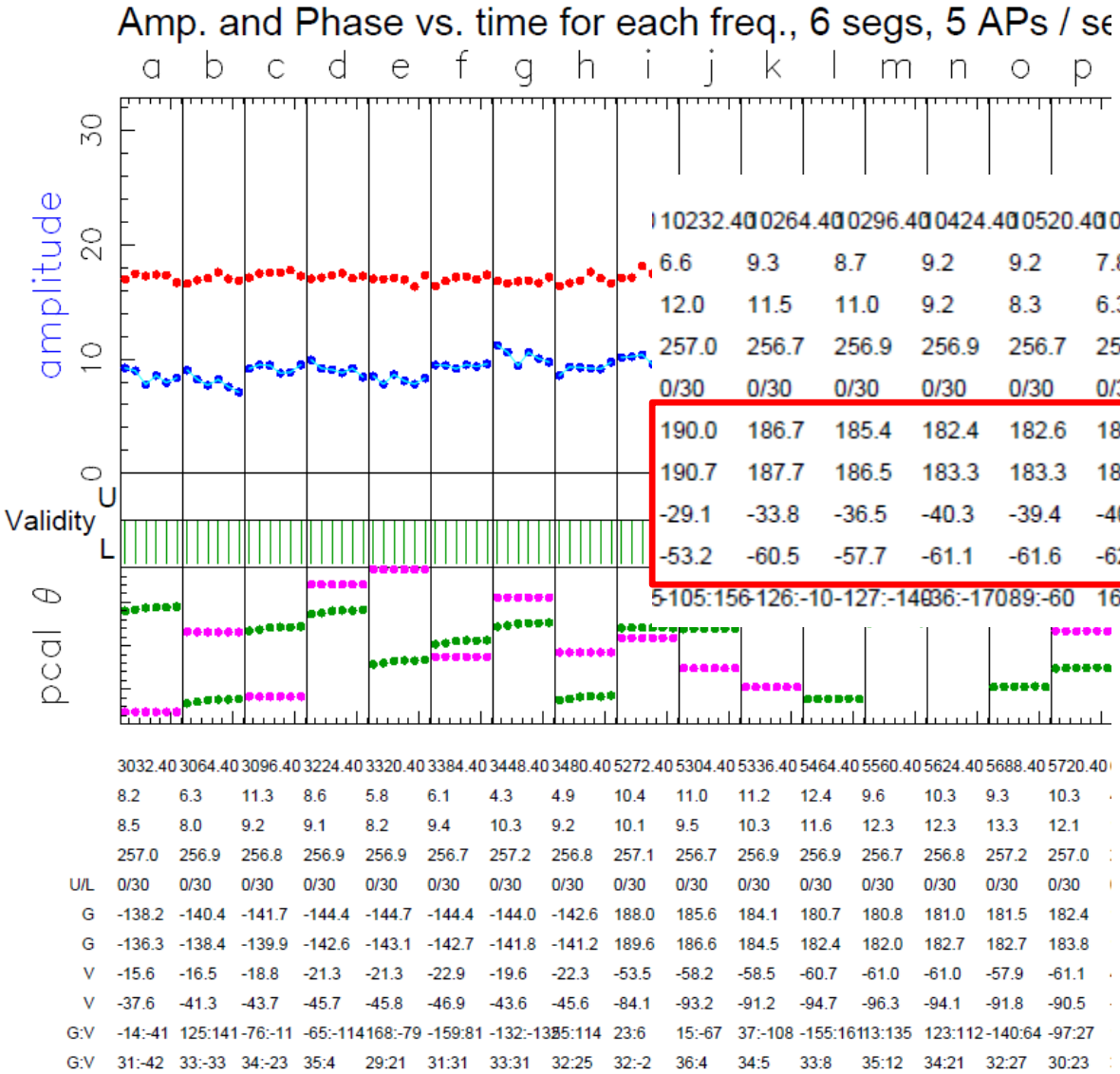

	10232.40	10264.40	10296.40	10424.40	10520.40	10584.40	10648.40	10680.40	Freq (MHz)	All
	6.6	9.3	8.7	9.2	9.2	7.8	6.7	7.9	Phase	7.6
	12.0	11.5	11.0	9.2	8.3	6.3	6.7	5.4	Ampl.	10.9
	257.0	256.7	256.9	256.9	256.7	256.5	257.0	257.1	Sbd box	256.9
	0/30	0/30	0/30	0/30	0/30	0/30	0/30	0/30	APs used	
	190.0	186.7	185.4	182.4	182.6	183.1	183.6	185.0	PC X delays (ns)	
	190.7	187.7	186.5	183.3	183.3	184.5	184.5	185.5	PC Y delays (ns)	
	-29.1	-33.8	-36.5	-40.3	-39.4	-40.2	-35.5	-34.5	PC X delays (ns)	
	-53.2	-60.5	-57.7	-61.1	-61.6	-62.1	-60.0	-59.7	PC Y delays (ns)	
	5-105:156	-126:-10	-127:-148	36:-170	89:-60	164:145	-137:-75	-111:153	PC phase	

	3032.40	3064.40	3096.40	3224.40	3320.40	3384.40	3448.40	3480.40	5272.40	5304.40	5336.40	5464.40	5560.40	5624.40	5688.40	5720.40
	8.2	6.3	11.3	8.6	5.8	6.1	4.3	4.9	10.4	11.0	11.2	12.4	9.6	10.3	9.3	10.3
	8.5	8.0	9.2	9.1	8.2	9.4	10.3	9.2	10.1	9.5	10.3	11.6	12.3	12.3	13.3	12.1
	257.0	256.9	256.8	256.9	256.9	256.7	257.2	256.8	257.1	256.7	256.9	256.9	256.7	256.8	257.2	257.0
U/L	0/30	0/30	0/30	0/30	0/30	0/30	0/30	0/30	0/30	0/30	0/30	0/30	0/30	0/30	0/30	0/30
G	-138.2	-140.4	-141.7	-144.4	-144.7	-144.4	-144.0	-142.6	188.0	185.6	184.1	180.7	180.8	181.0	181.5	182.4
G	-136.3	-138.4	-139.9	-142.6	-143.1	-142.7	-141.8	-141.2	189.6	186.6	184.5	182.4	182.0	182.7	182.7	183.8
V	-15.6	-16.5	-18.8	-21.3	-21.3	-22.9	-19.6	-22.3	-53.5	-58.2	-58.5	-60.7	-61.0	-61.0	-57.9	-61.1
V	-37.6	-41.3	-43.7	-45.7	-45.8	-46.9	-43.6	-45.6	-84.1	-93.2	-91.2	-94.7	-96.3	-94.1	-91.8	-90.5
G:V	-14:-41	125:141	-76:-11	-65:-114	168:-79	-159:81	-132:-135	85:114	23:6	15:-67	37:-108	-155:161	113:135	123:112	-140:64	-97:27
G:V	31:-42	33:-33	34:-23	35:4	29:21	31:31	33:31	32:25	32:-2	36:4	34:5	33:8	35:12	34:21	32:27	30:23

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Very large band delay difference

- What can cause an apparent very large single-band delay difference (200 ns)?
  - Different cable type, especially from the antenna to the control room
    - By design: coax for low-band, optical fiber for high-band (GGAO12M, KOKEE12M, MCD12M)
    - By change: cable type replaced because of bad connector

      – may affect only one band-polarization

Phase cal delay

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- Phase cal tone spacing is 5 MHz across the entire VGOS range
- Results in ambiguity of N*200 nanoseconds for each band
- On *fourfit* plot looks like a change in single-band delay value but all other values (amp, phase, mbd delay) stay the same
- No detection in that band-polarization when the clock for the other bands is used

Samplers keyword

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- Group all of the channels of one band together for common effects, e.g.

  samplers 4 abcdefgh ijklmnop qrstuvwx yzABCDEF

- Set the center of the range for the phase cal delay for each of the four bands (nanoseconds)

```
if station G
  sampler_delay_x  -140  180  180  180
  sampler_delay_y  -140  180  180  180
if station V
  sampler_delay_x    20   20   20   20
  sampler_delay_y    20   20   20   20
```

Sampler delay

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sampler delay = apriori phase cal delay

NOT a specific assigned value

fourfit adjusts the phase cal delay to the ambiguity nearest the sampler delay

Phase cal delay

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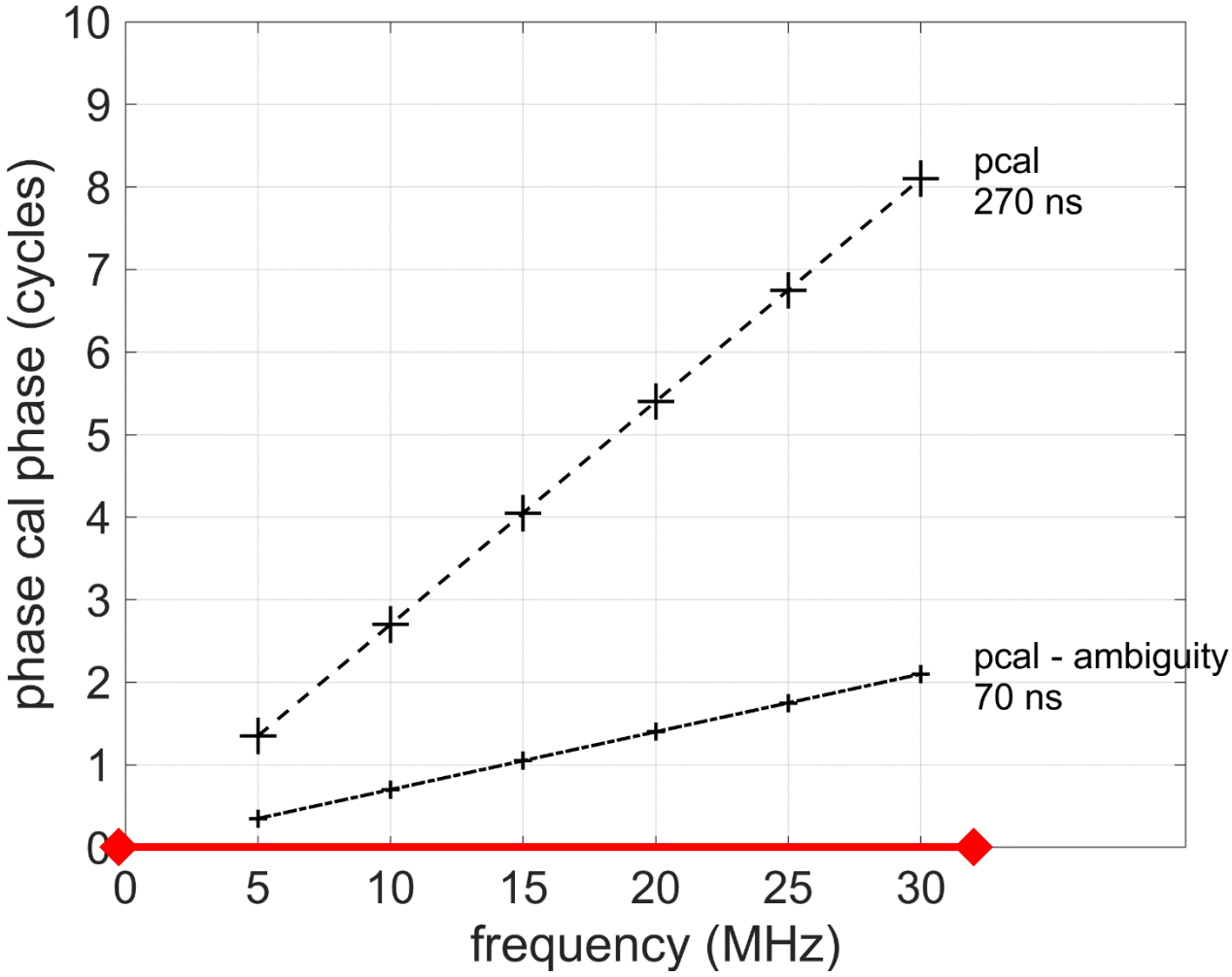

Sampler delay as 'apriori' delay

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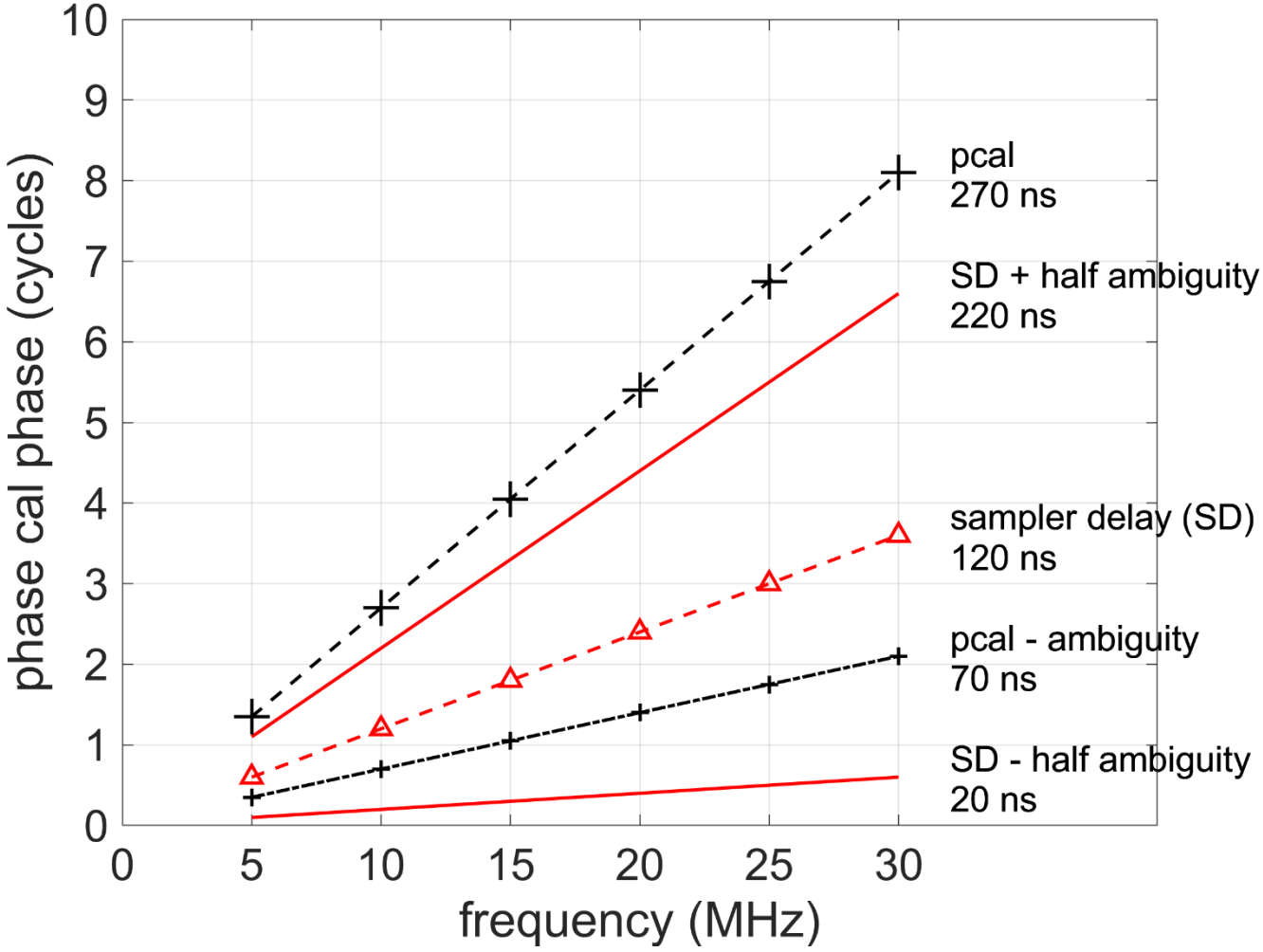

Sampler delay
Bands ABCD

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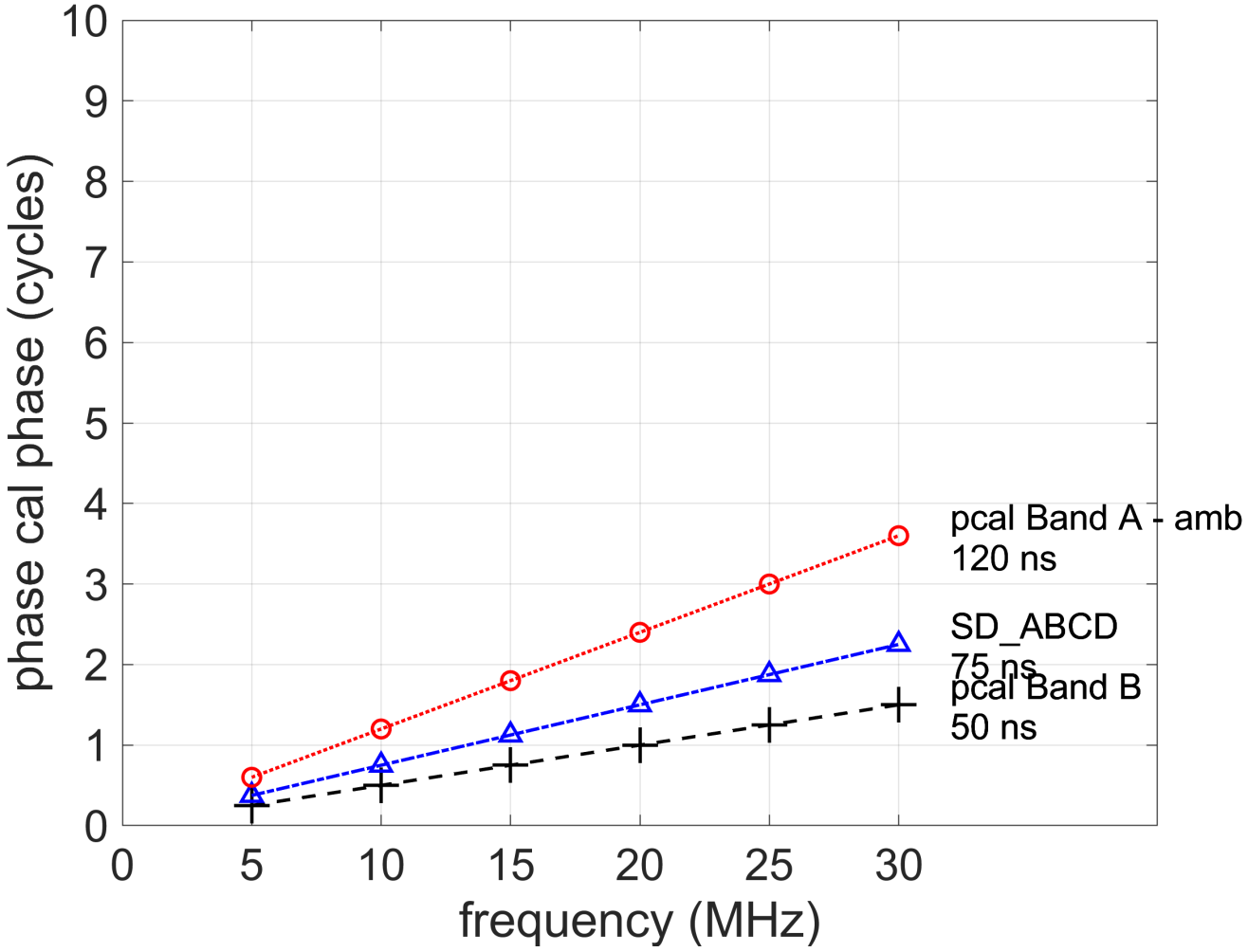

Sampler delays
Band A & Bands BCD

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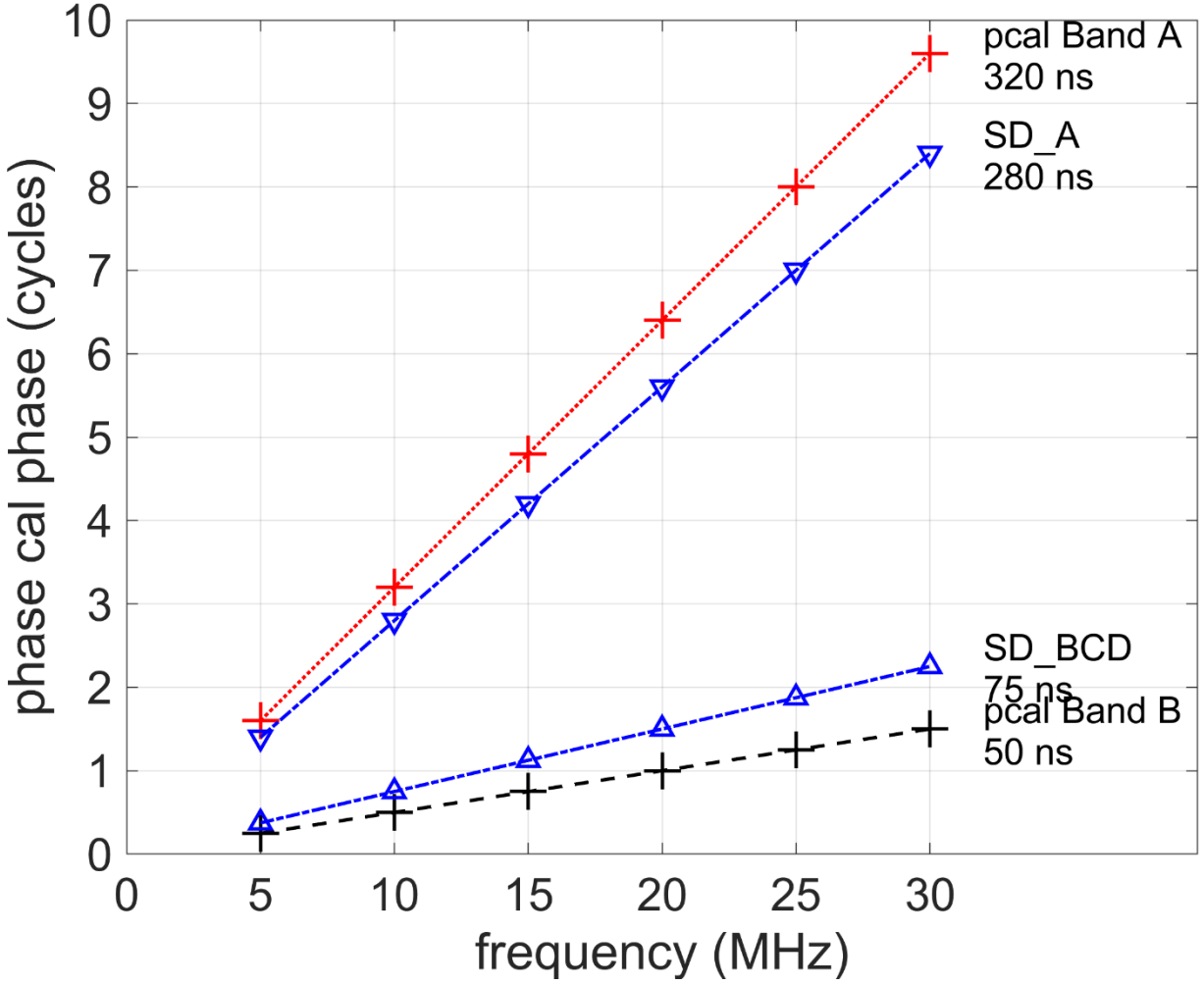

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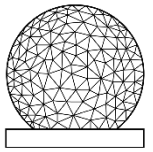
Detection of incorrect sampler delay

- Typically the single-band delay for one or both polarizations of a band will differ by close to 200 ns from the other bands when correlated with the same clock.
- If all four bands are *fourfit'd* together, then one band will not have a detection.
- The fix:
  - Set the sampler delay for that band to the average PC X delay or PC Y delay for that band



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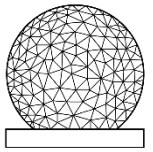
How is the sampler delay related to the clock offset?

- If the sampler_delay values are changed by 200 ns for all bands, the residual SBD will change by (+/-)200 ns.
- If the clock offset is then adjusted by (-/+)200 ns, the residual SBD will return to original value.

- Next is how to set sampler_delays and clock for a new station (slides courtesy Brian Corey)

VGOS clock setting procedure



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- Procedure differs from S/X due to use of PC delay in *fourfit* to correct for differences in station delays among bands.
- To minimize errors in data sample time tags (and in estimated UT1), PC delay ambiguity should be zero: -100 ns ≤ PC delay ≤ +100 ns

  → Set SD in range -100 ns ≤ SD ≤ +100 ns
- This will ensure time tag error under 100 ns.

VGOS clock setting procedure
(new or old station)

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1. With sampler_delays (SDs) set to zero (new station) or prior values (old), correlate against a station of known SDs and peculiar offset.
2. For a station with <~ 100 ns spread in single-band delays among bands, set SD for each band/pol'n to mean of channel PC delays (all in range -100 ns ≤ SD ≤ +100 ns).
3. Re-correlate against station of known properties.
4. Adjust peculiar offset to give residual SBD = 0.
5. Should get |resSBD| < few ns in all bands.

VGOS clock setting procedure

(new station)

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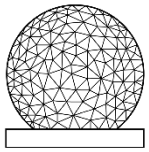
- Special cases:
  1. Some PC delays near +100 ns, others -100 ns
     - Solution: Set all SDs near one or the other,

       e.g., sampler_delay_x 90 105 98 99,

       not sampler_delay_x 90 -95 98 98
  2. >100 ns singleband delay diff between band A & bands B-D (e.g., GGAO12M and KPGO12M)
     - Solution: Choose SD ambiguities so that $-100 \text{ ns} \leq \frac{1}{2}(PCD_A + PCD_{BCD}) \leq +100 \text{ ns}$ and resSBD is ~same across all bands.



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