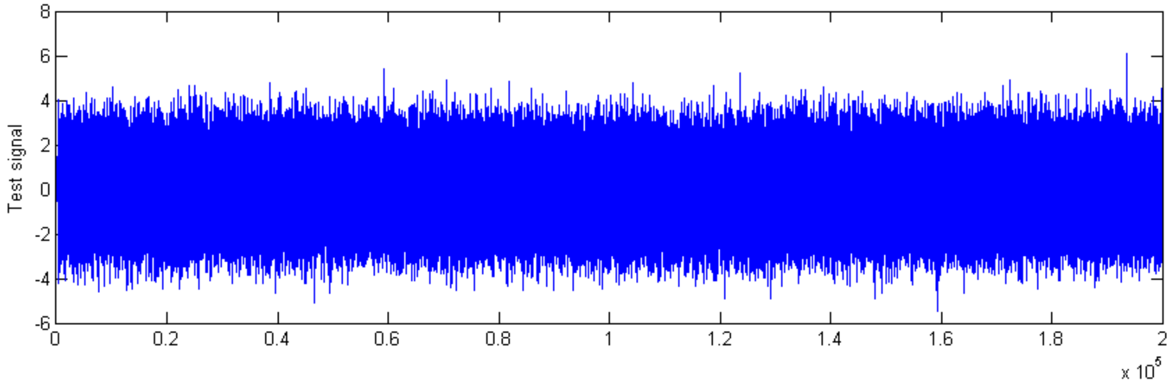
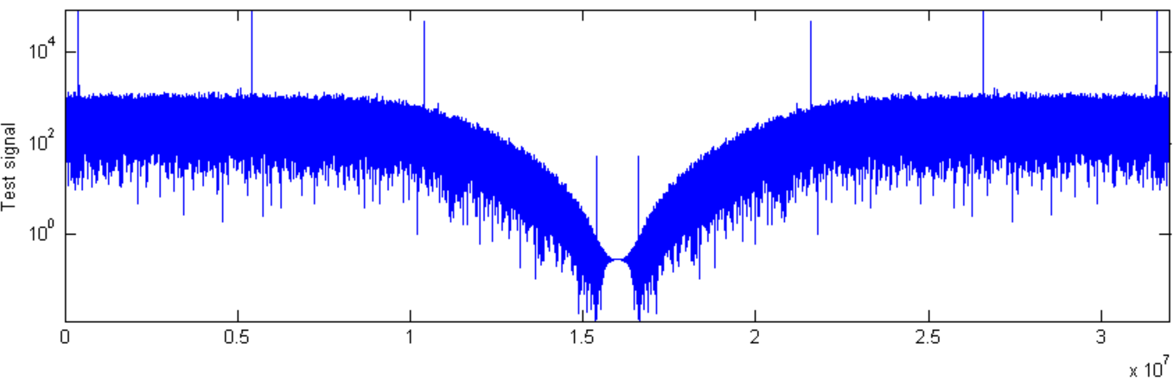
Phase Cal Extraction

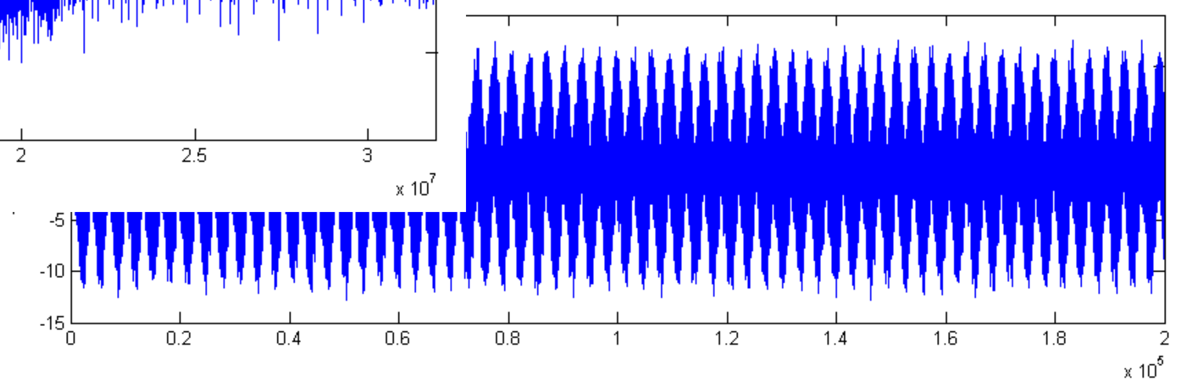
- Haystack has misused MarkIV correlator chips to do phase cal extract (convolution with precomputed long tone vectors), but much less flexibly, nobody really used it – and besides who uses hardware correlators for VLBI nowadays anyway ;-)
- Enter Pogrebenko-Wagner method
- Devised by Sergei Pogrebenko ~1993, a classic ;)
- See EVN Memos #2, #8
- Implemented augmented refined 2008 by Jan Wagner, used in ESA ExoMars and several others, see presentations 2008-2009 (radionet or so)



Just making a test signal, 5 MHz RF PCal spacing and 400kHz offset of the first PCal in the baseband, a little bit of lowpass filtering applied ...

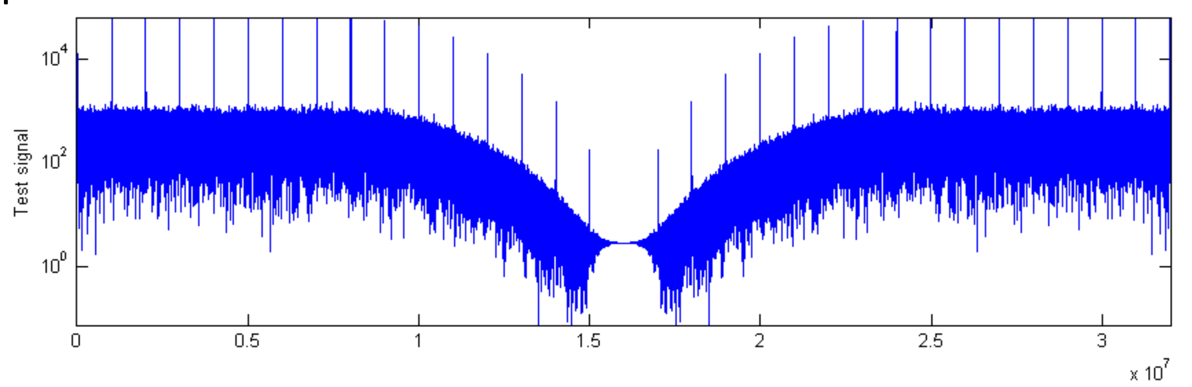
[a sloppy ‘buttord(0.65, 0.80, 6, 20)’ so we have interesting phase shift at upper tones]

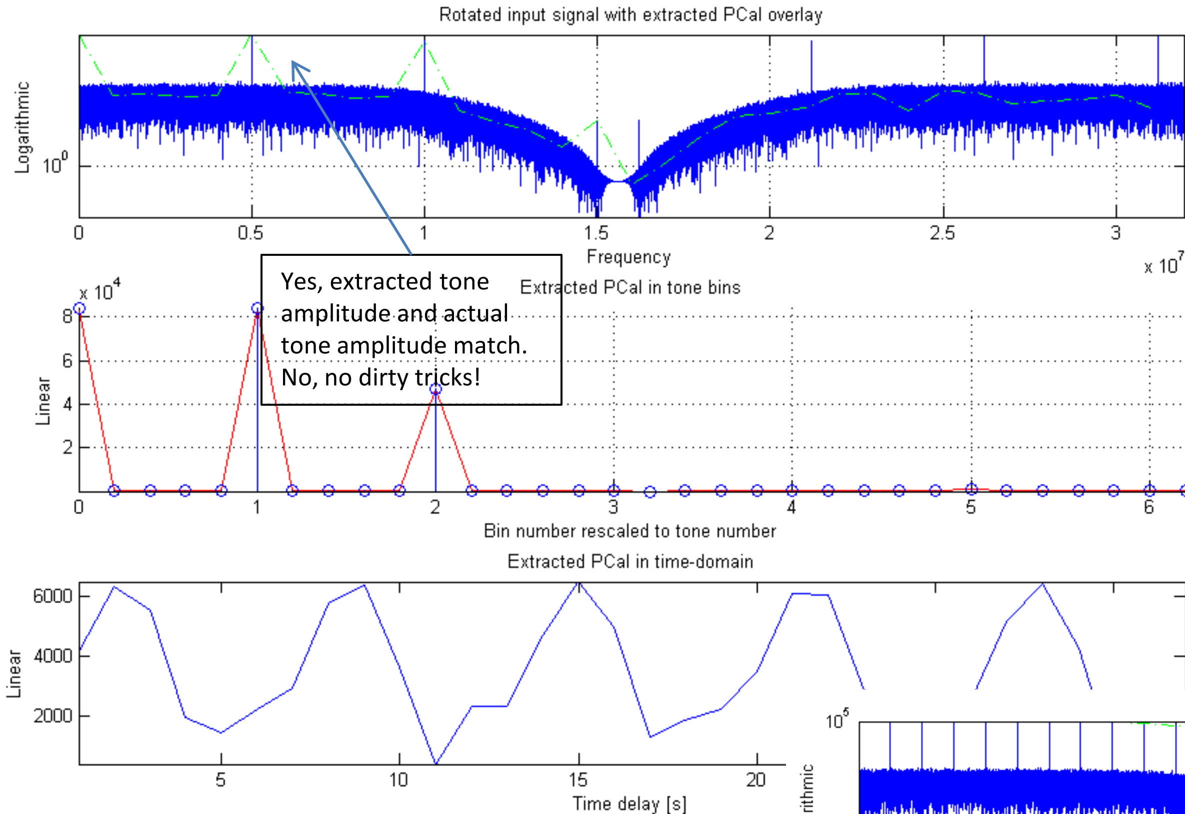




... and another test signal much more typical in geodetic VLBI, with VLBA/NRAO/Haystack style 1 MHz RF Pcal spacing and 10kHz offset.

Sure 0 Hz offset is also common. But let‘s excercise a bit.





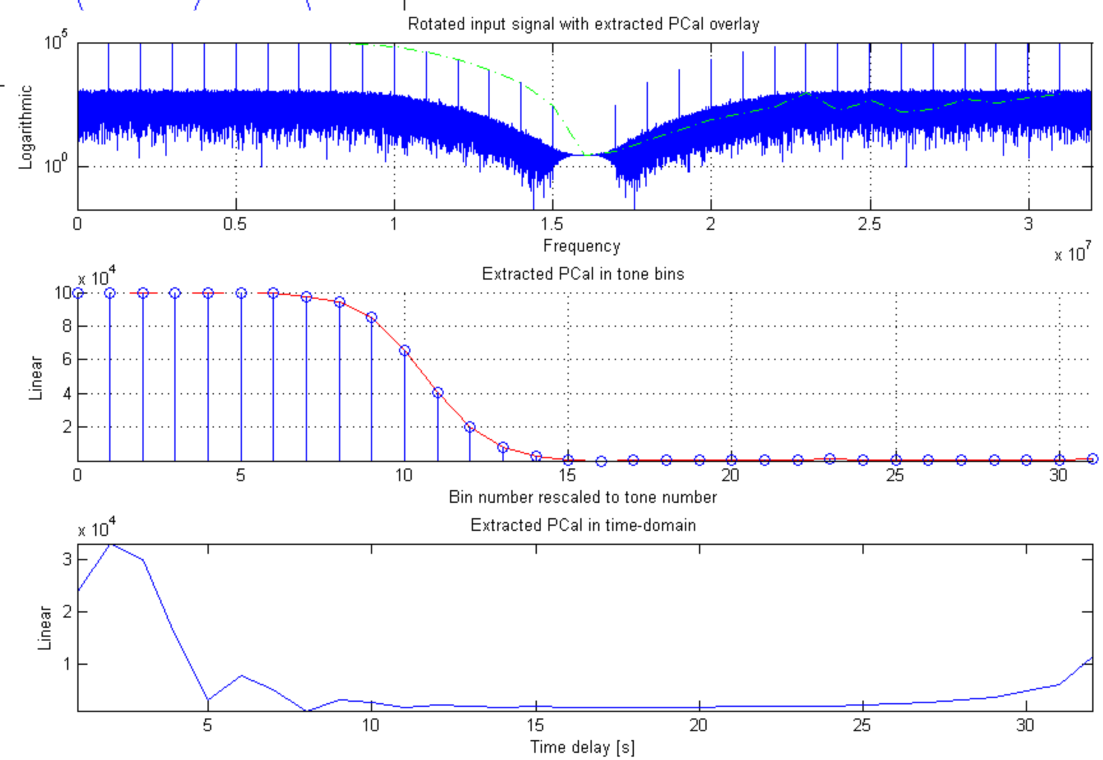
Offset was 400kHz or 80 samples at 32Ms/s. So we compute a tiny 80-sample vector, unit circle, -400kHz.

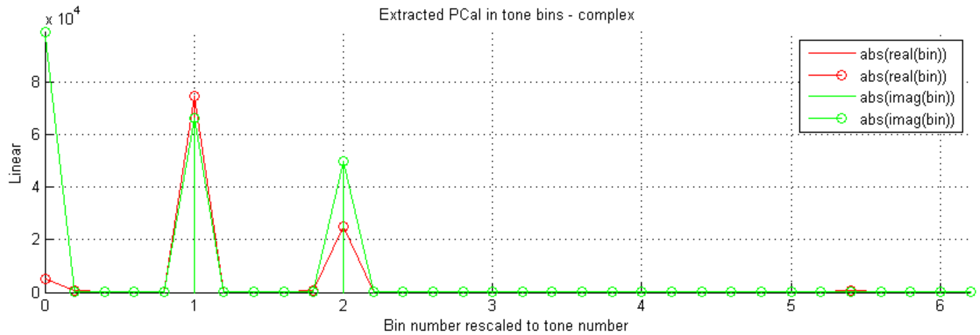
Rotate input signal with 80 samples from cache. Binning for PCal, shortest nonfractional period of 5MHz@32Ms/s is 32 bins = fs/GCD(fs,fspacing). Done! Overlaid plot on the left!

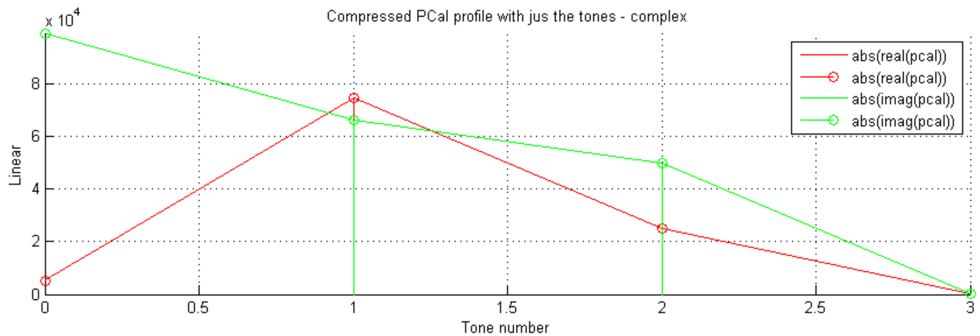
Now do the same with the other test signal, counter-rotate by 10kHz i.e. 3200 cache values (GCD again).

Then bin for PCal, 32 bins here too.

Sure: if offset were 0 Hz, or certain lucky special cases, we can go straight to binning!



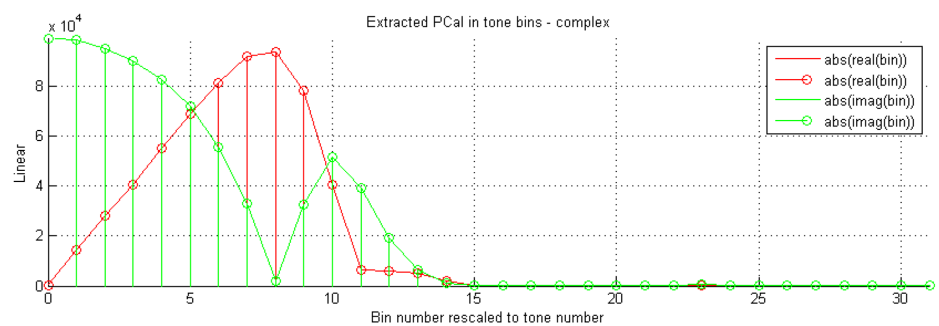




Same frequency-domain plot as earlier, just showing both Re and Im magnitudes now.

As you see, sometimes some of the left frequency bins (before Nyquist) are not occupied. Like in the 5MHz spacing and 32Ms/s case.

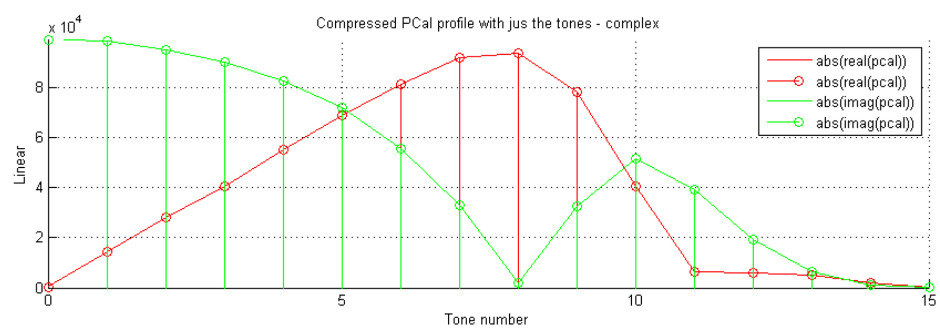
We are interested only tone bins.



So we copy bin all bins with tones into a „denser“ PCal output result.

The bins to copy are found at indices
n*(Nbins*fs/fspacing) ; n=0..Ntones-1

Similar could be done in time-domain but the vectors get rather long.



So how much arithmetics do we need?

When baseband offset is zero:
- one ACC accumulate per input sample : 1 FLOP

When baseband offset is non-zero:
- two MAC multiply-accumulates per input sample : 4 FLOP aka 2 MACOPS

And how about memory and buffers?

When baseband offset is zero:
- typically 32 float bins or less : 8 SSE2 registers
- memory fetches : 1 sample

When baseband offset is non-zero:
- typically 32 complex bins or less : 16 SSE2 registers
- typically 3200 complex values for precomputed rotation, 25.6kB in L1 cache
- memory fetches : 1 sample, 2 floats from precomputed complex

Special case where non-zero baseband offsets can be processed faster than above?

When Nbins=fs/GCD(fs,fspacing) or smaller divides the Npre=fs/GCD(fs,foffset)

- here we can use Npre-bin binning : 1 FLOP, no SSE2 registers, 12.8kB L1 cache
- last we may perform actual rotation and final large Npre-bin FFT

That‘s it!

All tones at once, all phases at once, filter shape reconstructed, delay calculated, etc etc.

Some special cases may be implemented as a balance between SSE/MMX register use and cache use. Like omit the „live“ rotation in some cases.

Way too many slides again... ;)