The Marriage of DiFX and Mark4

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4th DiFX Users Meeting

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Mark4

- in use since 1999
- begat by Mk3A, which was begat by Mk3, which was begat by Mk1, which was begat by VLBI1 – which was a software correlator! (on Goddard's IBM 360/91 it took more than real time to correlate 1 baseline at 360 Kbps)
- the Mark4 consists of
  - correlator hardware for 16 stations (in principle) at 1 Gbps
  - software to control the realtime system
  - experiment preparation and correlation oversight software
  - HOPS post-processing package

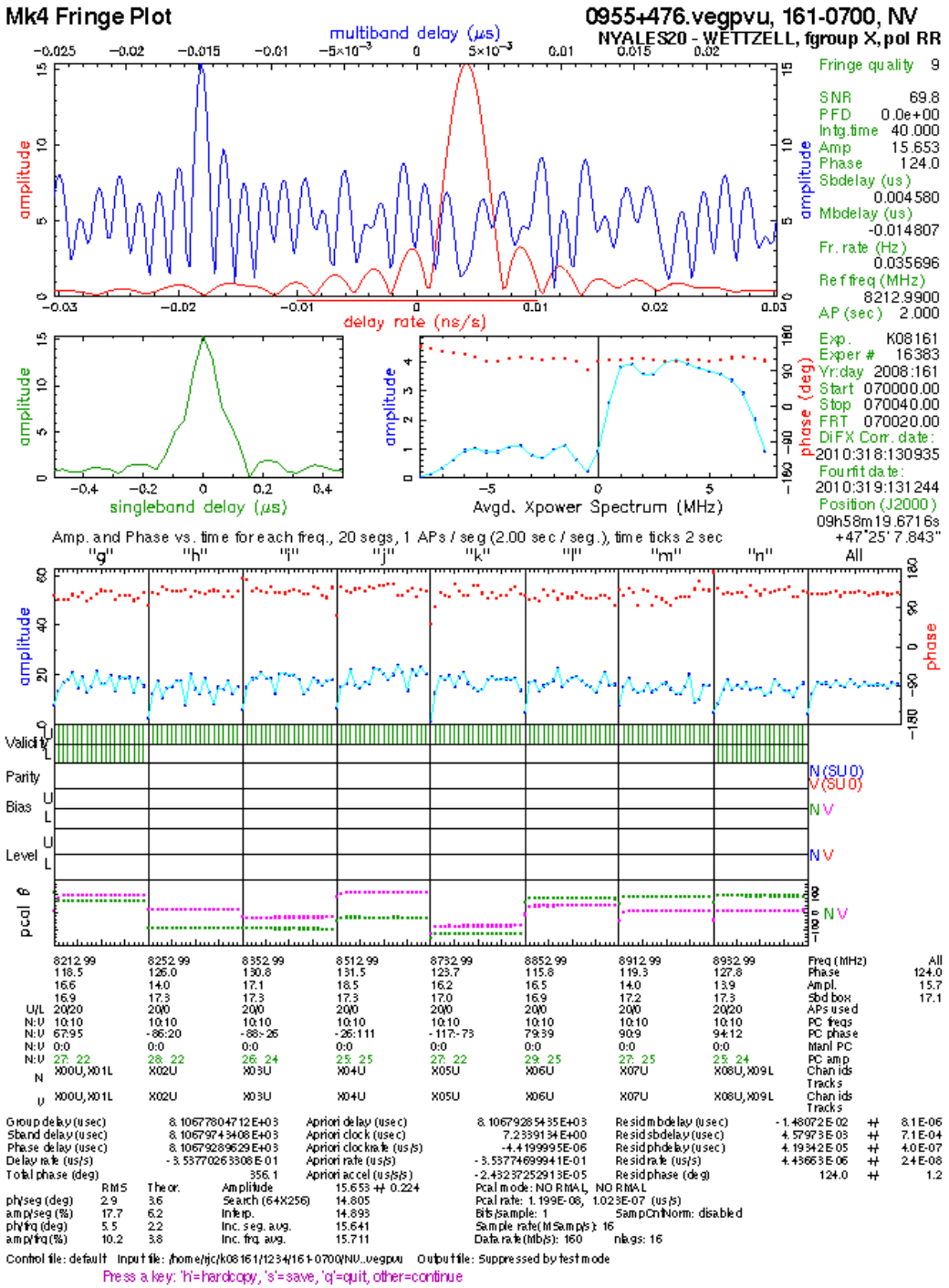
difx2mark4

- pathway from *difx* output into the Mk4 post-processing suite (*fourfit*, *aedit*, *frngex*, *average*, etc.)
- runs in a couple of seconds, converting *difx* output (Swinburne) files to a Mk4 fileset
- converts visibilities and phase cal data
- visibilities are kept in the spectral domain in a new record format, and *not* converted to lag data for *fourfit* input

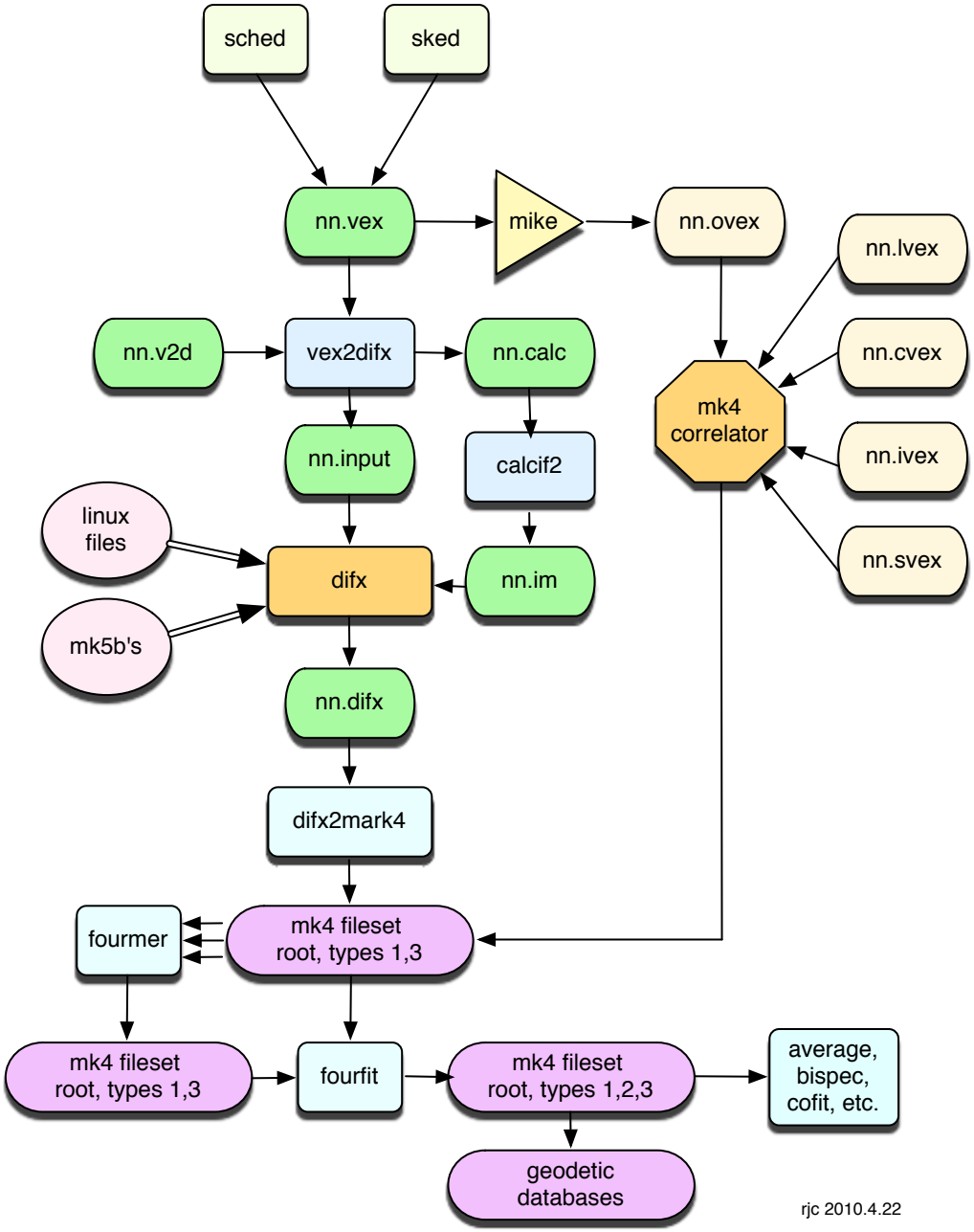
difx2mark4 execution

```
rjc@smm-pc:~/x10110$ difx2mark4 -s 111-0320D x10110_20
Processing scan 111-0320D
output rootfile: ./3C273B.veejbm
Invented new code L for station Gg
number of stations: 2
opened input file x10110_20.difx/DIFX_55307_012000.s0000.b0000
created type 1 output file ./LE..veejbm
created type 1 output file ./LL..veejbm
created type 1 output file ./EE..veejbm
    1824 DiFX visibility records read
       0 DiFX visibility records discarded (slew time)
created type 3 output file ./L..veejbm
created type 3 output file ./E..veejbm
1 of 1 DiFX filesets converted to 1 Mark4 filesets

rjc@smm-pc:~/x10110$ ls
```

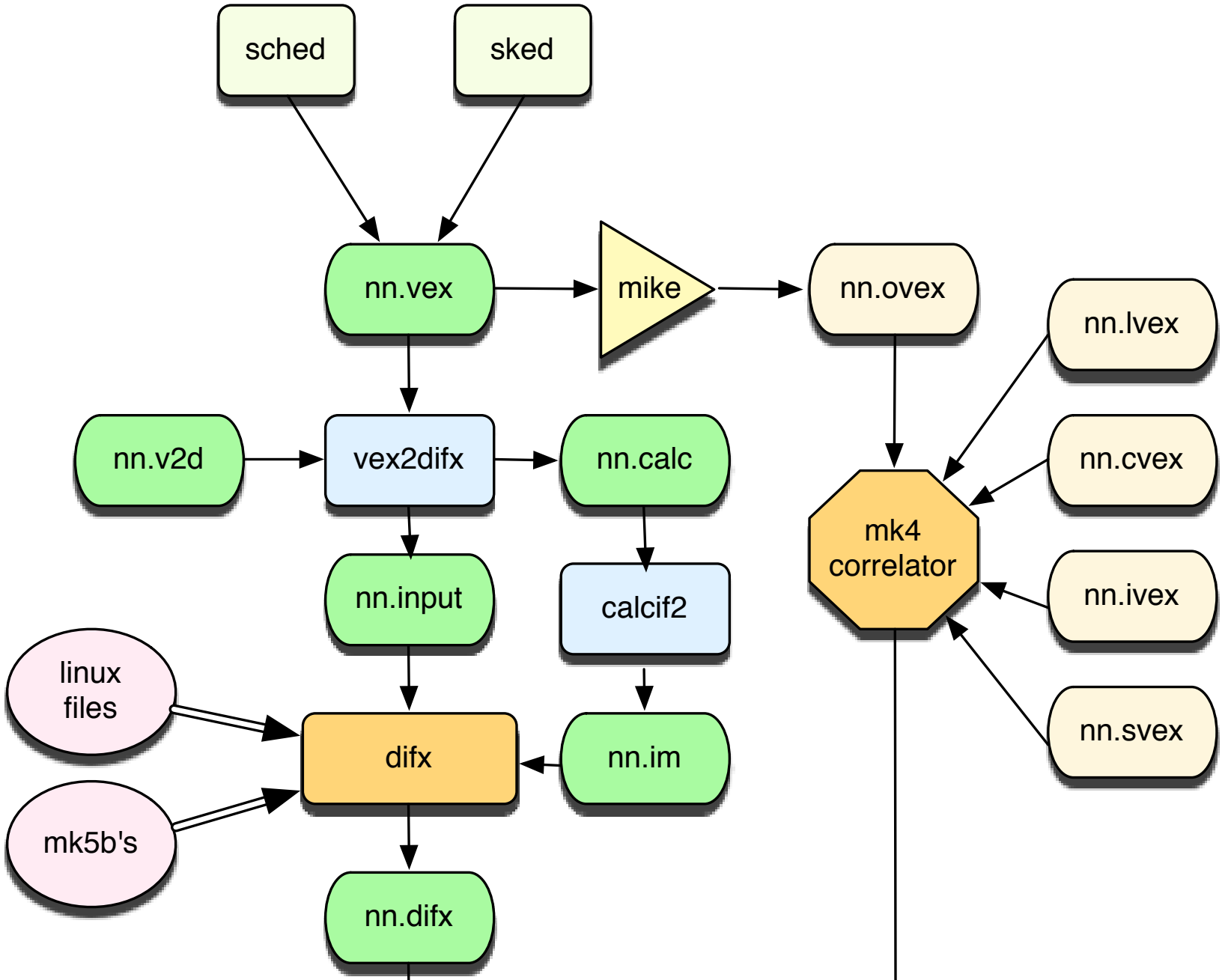

Mk4 Fringe Plot
0955+476.vegpvu, 161-0700, NV
NYALES20 - WETTZELL, fgroup X, pol RR
multiband delay (μs)
amplitude
delay rate (ns/s)
singleband delay (μs)
Avgd. Xpower Spectrum (MHz)
phase (deg)
Fringe quality 9
SNR 69.8
PFD 0.0e+00
Intg.time 40.000
Amp 15.653
Phase 124.0
Sbdelay (us) 0.004580
Mbdelay (us) -0.014807
Fr. rate (Hz) 0.035696
Ref freq (MHz) 8212.9900
AP (sec) 2.000
Exp. K08161
Exper # 16383
Yr:day 2008:161
Start 070000.00
Stop 070040.00
FRT 070020.00
DiFX Corr. date: 2010:318:130935
Fourfit date: 2010:319:131244
Position (J2000) 09h58m19.6716s +47°25' 7.843"
Amp. and Phase vs. time for each freq., 20 segs, 1 APs / seg (2.00 sec / seg.), time ticks 2 sec
"g" "h" "i" "j" "k" "l" "m" "n" All
phase
Validity
Parity
Bias
Level
pcal θ
N(SU0)
V(SU0)
N V
8212.99 8252.99 8352.99 8512.99 8732.99 8852.99 8912.99 8932.99 Freq (MHz) All
118.5 126.0 130.8 131.5 123.7 115.8 119.3 127.8 Phase 124.0
16.6 14.0 17.1 18.5 16.2 16.5 14.0 13.9 Ampl. 15.7
16.9 17.3 17.3 17.3 17.0 16.9 17.2 17.3 Sbd box 17.1
U/L 20/20 20/0 20/0 20/0 20/0 20/0 20/0 20/20 APs used
N:U 10:10 10:10 10:10 10:10 10:10 10:10 10:10 10:10 PC freqs
N:U 67:95 -86:20 -88:-26 -26:111 -117:-73 79:39 90:9 94:12 PC phase
N:U 0:0 0:0 0:0 0:0 0:0 0:0 0:0 0:0 Manl PC
N:U 27: 22 28: 22 26: 24 25: 25 27: 22 29: 25 27: 25 25: 24 PC amp
N X00U,X01L X02U X03U X04U X05U X06U X07U X08U,X09L Chan Ids
Tracks
U X00U,X01L X02U X03U X04U X05U X06U X07U X08U,X09L Chan Ids
Tracks
Group delay (usec) 8.106778047 12E+03 Apriori delay (usec) 8.106792854 35E+03 Residmbdelay (usec) -1.480 72E-02 +/- 8.1E-06
Sbband delay (usec) 8.106797 4408E+03 Apriori clock (usec) 7.233913 4E+00 Residsbdelay (usec) 4.579 73E-03 +/- 7.1E-04
Phase delay (usec) 8.106792896 29E+03 Apriori clockrate (us/s) -4.419 9995E-06 Residphdelay (usec) 4.193 42E-05 +/- 4.0E-07
Delay rate (us/s) -3.537702633 08E-01 Apriori rate (us/s) -3.537746999 41E-01 Residrate (us/s) 4.436 63E-06 +/- 2.4E-08
Total phase (deg) 356.1 Apriori accel (us/s/s) -2.432372529 13E-05 Residphase (deg) 124.0 +/- 1.2
RMS Theor. Amplitude 15.653 +/- 0.224
ph/seg (deg) 2.9 3.6 Search (64X256) 14.805
amp/seg (%) 17.7 6.2 Interp. 14.893
ph/frq (deg) 5.5 2.2 Inc. seg. avg. 15.641
amp/frq (%) 10.2 3.8 Inc. frq. avg. 15.711
Pcal mode: NO RMAL, NO RMAL
Pcal rate: 1.199E-08, 1.023E-07 (us/s)
Bits/sample: 1 SampCntNorm: disabled
Sample rate(MSamp/s): 16
Data rate(Mb/s): 160 nlags: 16
Control file: default Input file: /home/rjc/k08161/1234/161-0700/NU..vegpvu Output file: Suppressed by test mode
Press a key: 'h'=hardcopy, 's'=save, 'q'=quit, other=continue

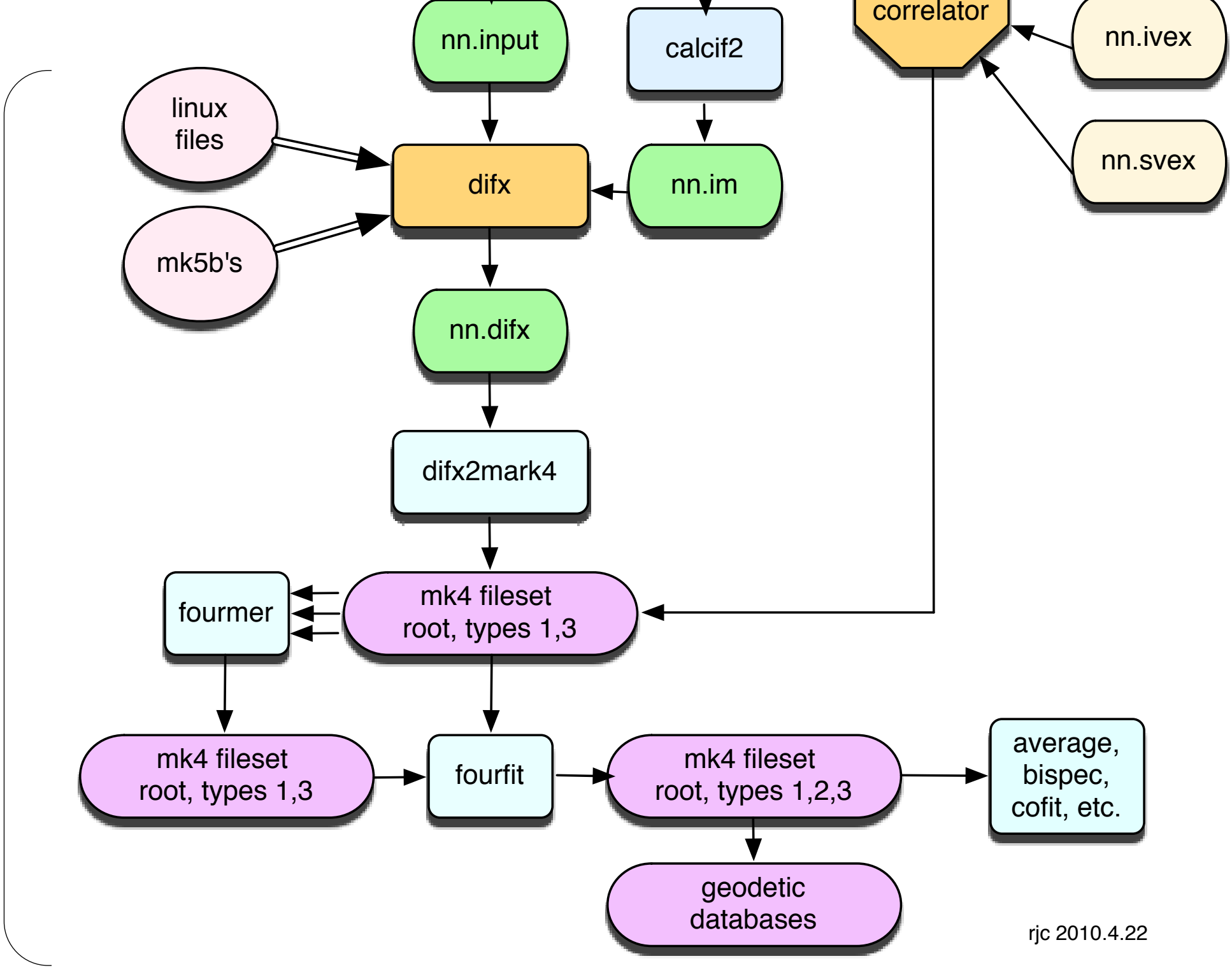
Mark4 & DiFX Integrated Data Flow



rjc 2010.4.22

Mark4 & DiFX Integrated Data Flow




nn.input
calcif2
correlator
nn.ivex
linux files
difx
nn.im
nn.svex
mk5b's
nn.difx
difx2mark4
fourmer
mk4 fileset root, types 1,3
mk4 fileset root, types 1,3
fourfit
mk4 fileset root, types 1,2,3
average, bispec, cofit, etc.
geodetic databases
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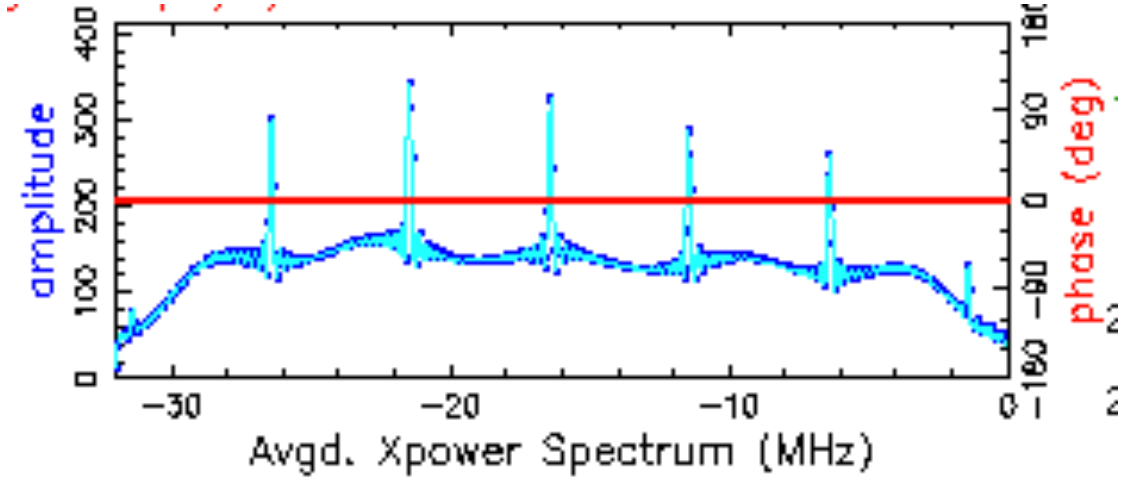
VLBI2010 pcal processing

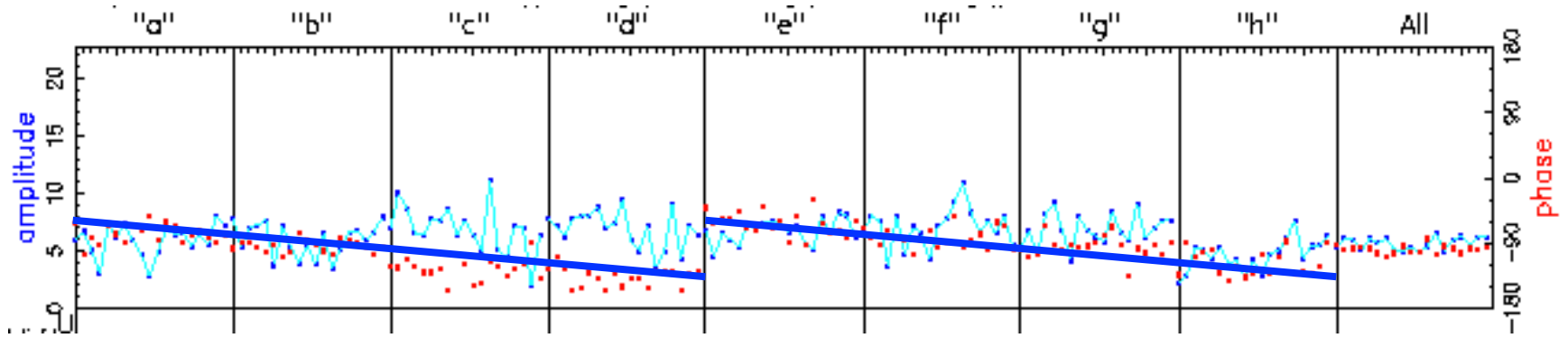
- Unusual characteristics
  - net LSB
  - tone spacing of 5 MHz
  - differing offsets of (0.4, 1.4, 2.4, 3.4, 4.4) MHz
- … flushed out 3 bugs -- found and fixed *



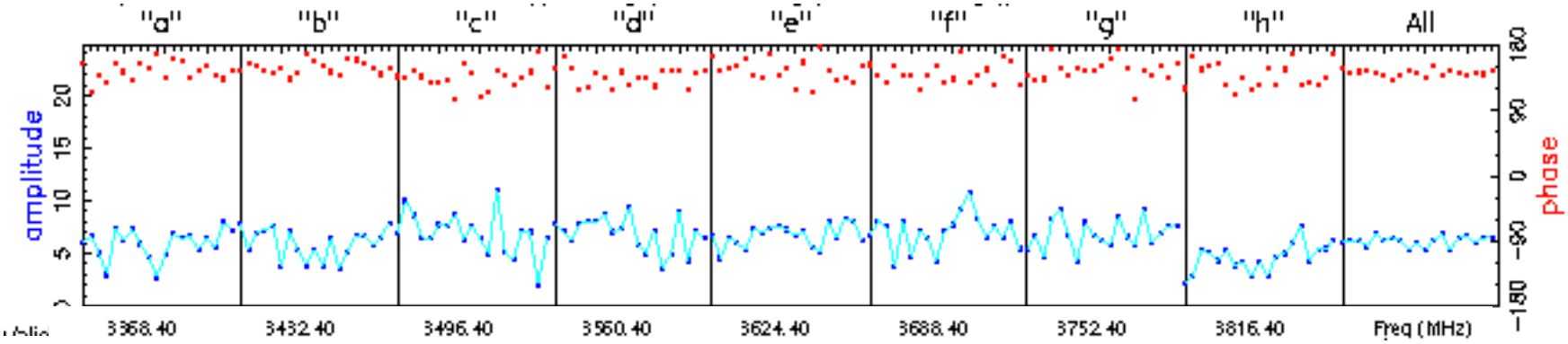
fourfit pcal processing

- traditionally: phase of single tone used to correct whole channel
- drawbacks
  - useful power/information in ignored tones
  - unable to estimate a singleband delay
  - since tones are at different video frequencies, delays cause phase offsets at midband, yielding a sawtooth phase pattern
- new "multitone" mode incorporated
  - uses all tones in band by default
  - individual tones can be masked off
  - FFT of tones yields delay function, whose peak is detected, and used to form coherent weighted sum at midband, the phase of which is used to correct the cross-correlation phase

multitone mode example



phases adjusted by first tone within band (3.4, 2.4, 1.4, 0.4, 4.4, 3.4, 2.4, 1.4 MHz)



phases adjusted using multitone mode (Westford-GGAO baseline)

Amplitude comparisons DiFX vs. Mark4

- (rough) comparisons done with Tsys = 1 in *.input, unity scaling in difx2mark4 and fourfit

expt	ag rate (Gb/s)	s rate (MS/s)	bits/ sample	lags/sp chans	Mk4 amp	DiFX amp	amp ratio
UVLBI	1.92	64	2	32	2.71	2.25	0.83
VLBI2010 LL	4.096	64	2	32	7.24	6.19	0.85
RR	"	"	"	"	6.31	5.65	0.90
geo NV:X	0.160	16	1	32	16.95	15.77	0.93
geo NV:S	0.096	"	"	"	8.47	7.95	0.94

Amplitude comparison notes

- spectral oddities at lower end of LSB
- pcal amplitudes also need reconciliation