Analysis of L-band data from the new GMRT Wideband Backend, or the GWB, in order to test long term amplitude and phase stability.

Report by

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ABSTRACT

We present a series of results from the data analysis performed for data acquired during the two months, August and September 2013 in order to understand the stability of new GMRT backend, i.e., GPU, now called as GMRT Wideband Backend (GWB). This report is organized as follows:

Below we present (i) observing log, (ii) stability results, including self-power amplitude as a function of time, cross-power amplitude as a function of time, phase stability as a function of time and frequency, self-power bandshape stability and cross-power bandshape stability. We support these with appropriate plots made from the data, and finally (iii) we summarize these results, both qualitatively and quantitatively wherever possible in Section 2. We perform this first for the Day-1 (1 Aug 2013) observations (also see Section 1), and with this as our plan, we then summarize only the results for subsequent four observations along with observing logs (Section 2). We give a detailed summary, i.e., (i) a general summary of results along with the comparisons from all the observations in Section 3. Finally, we give a detailed discussion along with lessons learned, detailed comparison of GPU data and GSB data (which are well supported by several plots) and our future plans in Section 4. In Section 5, as mentioned above, we provide all the related plots, i.e. stability results, including self-amplitude as a function of time, cross-amplitude as a function of time, phase stability as a function of time and frequency, self-power bandshape stability and cross-power bandshape stability for all observations as several sub-Sections.

To summarise, it is the first exhaustive summary of the two month long test observations of the new GWB using the new GMRT analog baseband (GAB) system at the L-band. This report gives all details, issues at various levels, and comparison of the new backend with the existing GSB, etc.

1.Data: 1st Aug 2013 (Day-1)

1.1 Observing log

LTAFILE : gputest_gab_01aug2013.lta
Settings:

Observe data 01 AUG 2013
Object 3C147
LO1 1140 MHz
RF 1210 MHz
LO1 < RF (or USB)
No. of Channels 2048
Channel-width 97.66 kHz.
Operator's note: This was continuous track on 3C 147 source.

Note: The two antennas, W01 and W04, which were not working for approximately the first half of the run, they started working after two hours from the start, and were included in the observations.

1.2 Self-power (amplitude) stability

For self amplitude stability the remarks are as follows.
For almost 5 Hrs scan after 3 hours antennas shown few jumps in self but for the first 3 hours all are showing good stability i.e. almost straight line as a function of time.

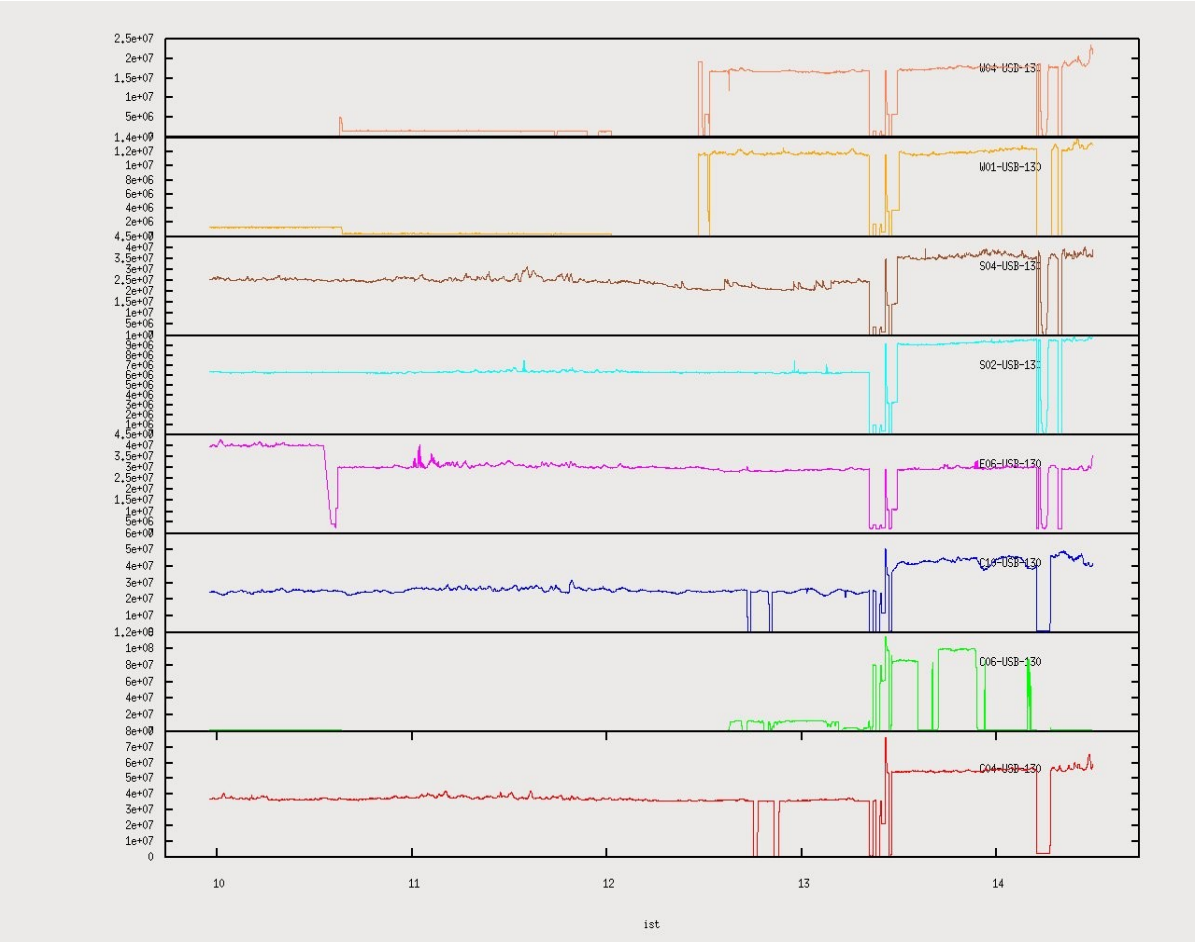

***Fig. 1.1**: Self-power (amplitude) as a function of time. Note the observations were made using the GPU at the L-band on 01 Aug 2013.*

Table 1.1: *Average self-correlation coefficients as a function of time. Note that only the good part of the data was included while determining the average.*

C04	C06	C10	E06	S02	S04	W01	W04
7e+07	1.2e+07	5e+07	6e+07	7e+07	5e+07	1.5e+07	4e+07

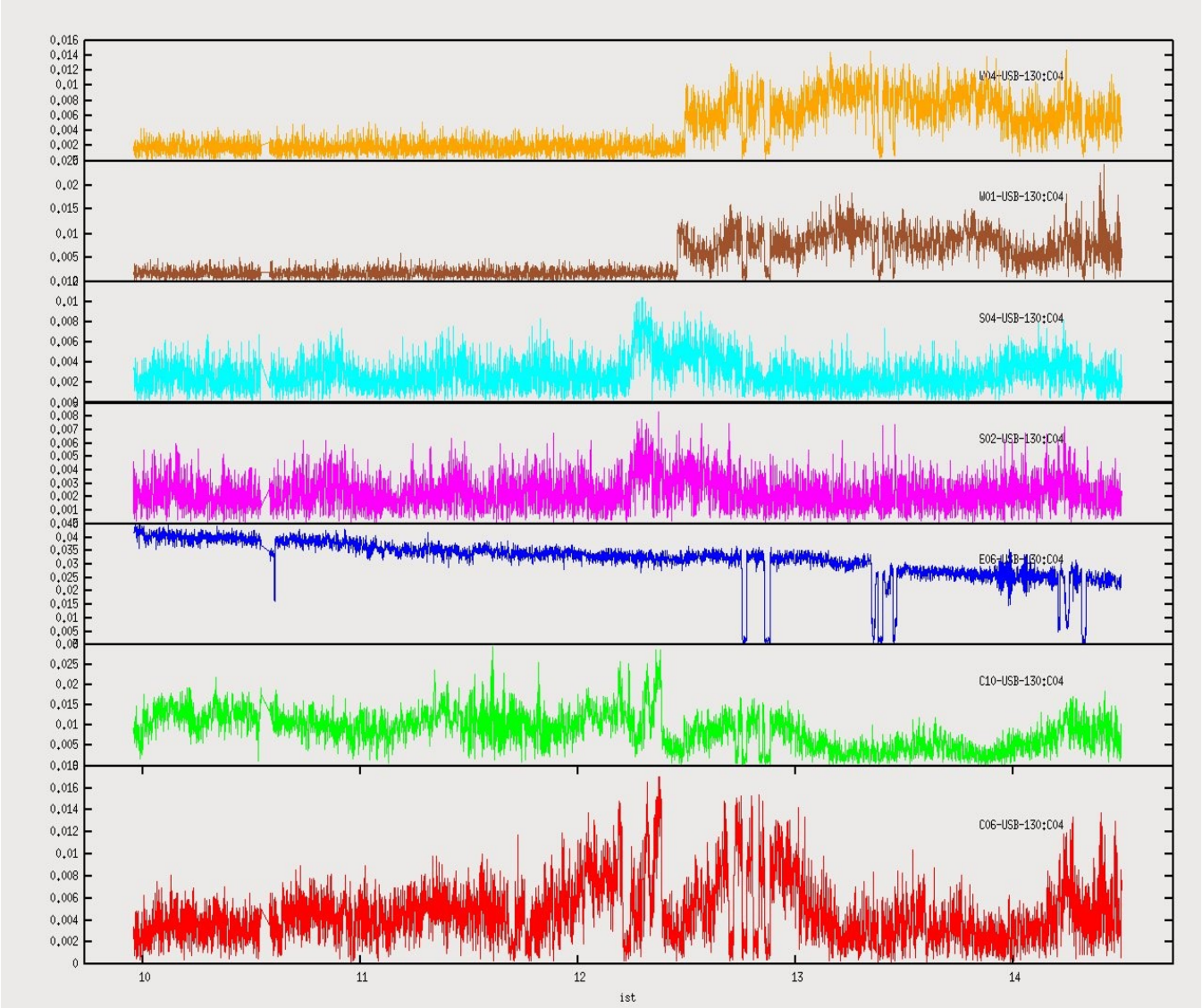

Fig 1.2*: Cross-power (amplitude) as a function of time. Note the reference antenna is C04 and the data is acquired using GPU at the L-band on 01 Aug 2013.*

1.3 Cross-power (amplitude) stability

Here, C04 was chosen as the reference antenna and for all subsequent data analysis (Fig.2). Except antenna E06, all antennas are showing stable power levels. i.e. E06 shows a ramp in cross-correlation coefficients over a five hours run from 0.04 to 0.025 (with a few per cent drop in amplitude).

Table 1.2: *Average cross-correlation coefficients as a function of time. Note the reference antenna is C04. Tables 3.2 and 3.3 shows expected cross-correlation coefficients.*

C04	C06	C10	E06	S02	S04	W01	W04
Ref. Ant	0.004	0.008	0.02	0.003	0.0025	0.006	0.005

1.4 Phase stability as a function of time. Note again, the reference antenna is C04.

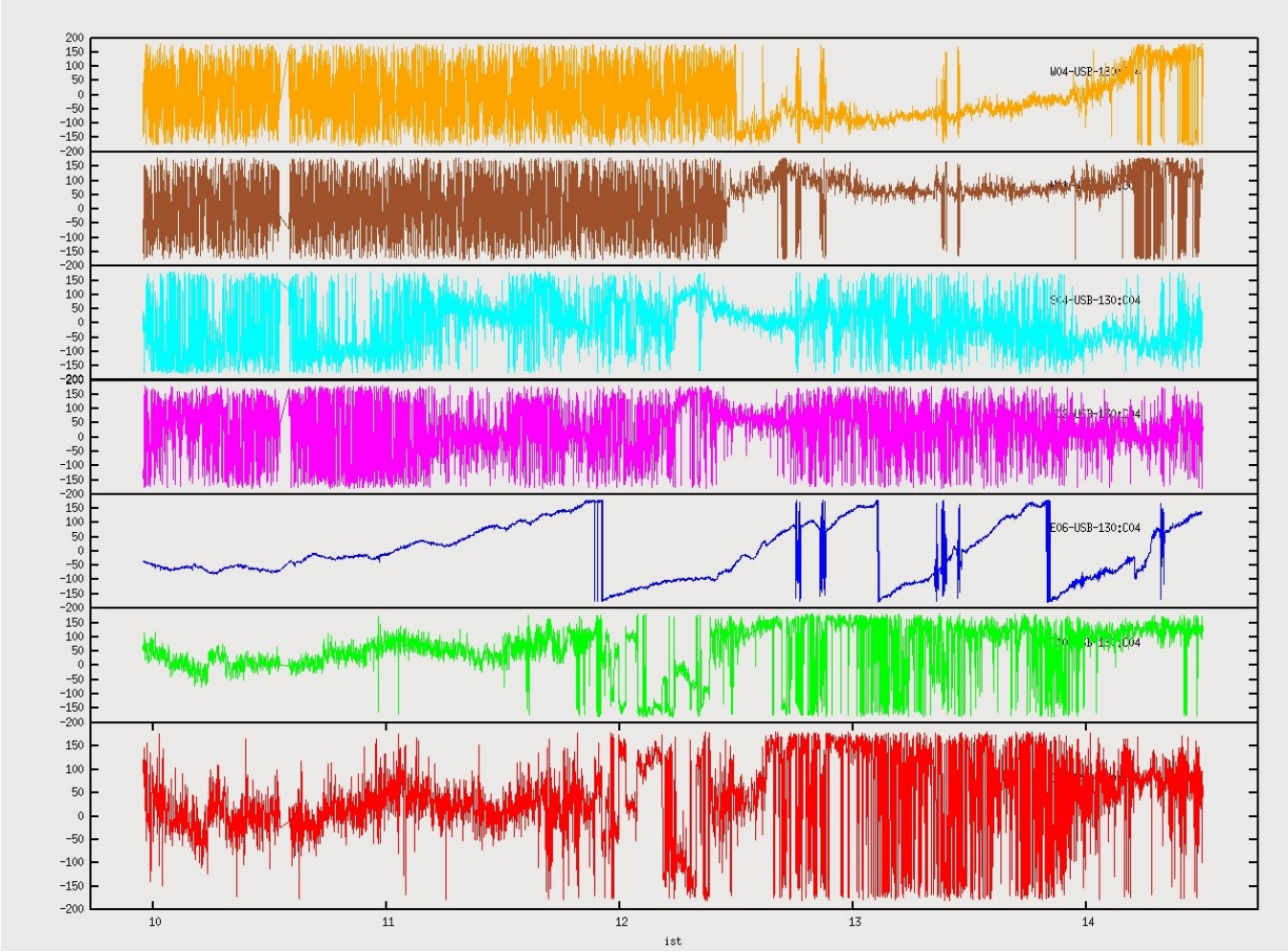

Fig 1.3*: Variation in phase as a function of time. Note the reference antennas is C04 and the data is acquired using GPU at the L-band on 01 Aug 2013.*

Key inferences:

Phase windings over time

C06 and C10 – Reasonably(?) good including some distortions after mid of the observation or that might be the jumps over -180deg to +180deg.

E06 - 4 Winds over 5 hour run.

S02 and S04 - Intermittently good.

W01 and W04 – Started working after 3 hours. But good for next 2 hrs.

1.5 Phase stability as a function of channels, and the reference antennas is C04.

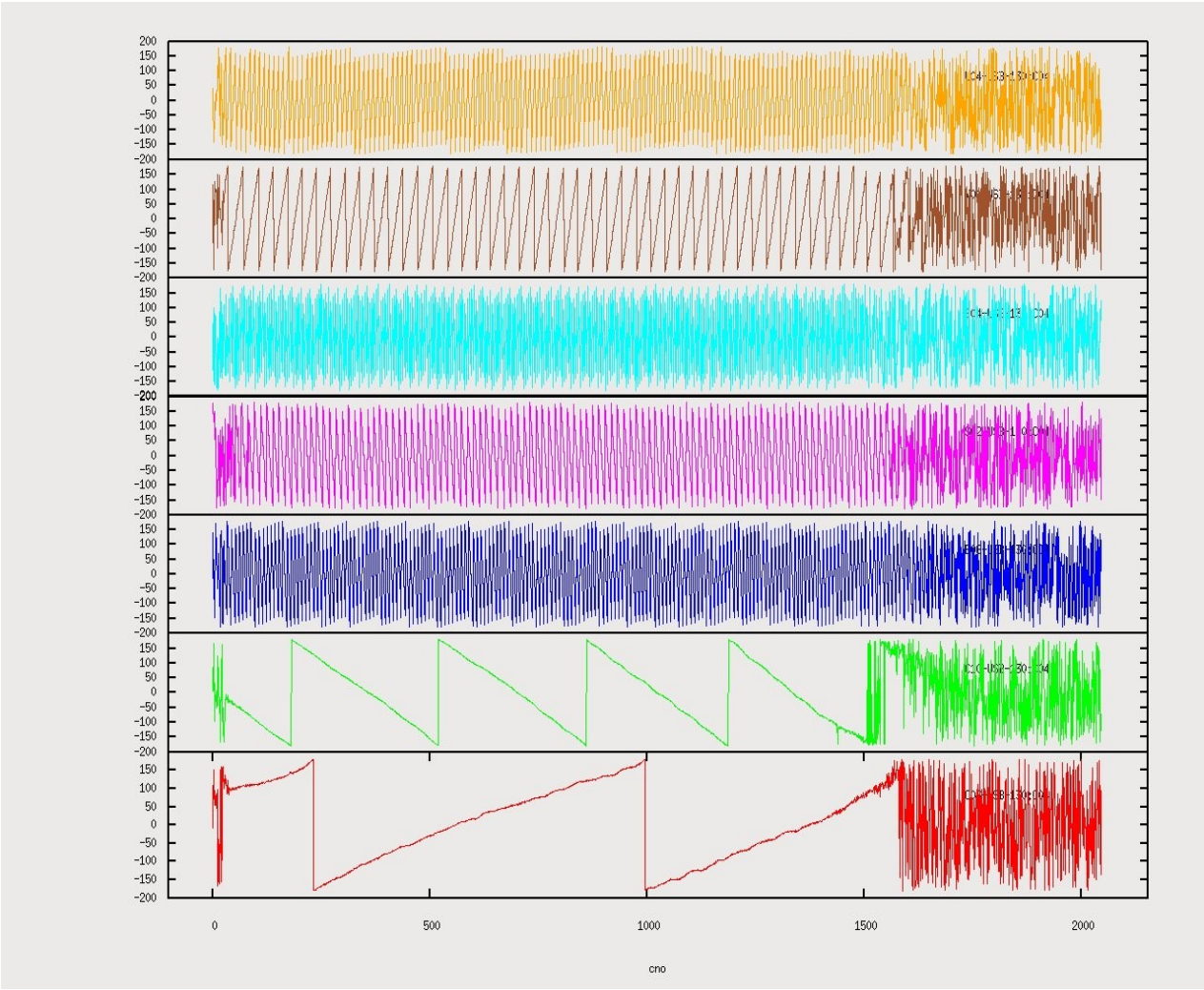

***Fig 1.4**: Variation in phase as a function of channel. Note the reference antenna is C04 and the data is acquired using GPU at the L-band on 01 Aug 2013.*

Key inferences:

C06 - 3 (+ve slope) loops seen over 1500 channels
C10 - 5 (-ve slope) loops seen over 1500 channels
E06 - too many loops seen over 1500 channels
S02 - too many loops seen over 1500 channels
S04 - too many loops seen over 1500 channels
W01 - 45 (+ve slope) loops seen over 1500 channels
W04 - too many loops seen over 1500 channels

1.6 Self-power amplitude (or the self-bandshape) stability

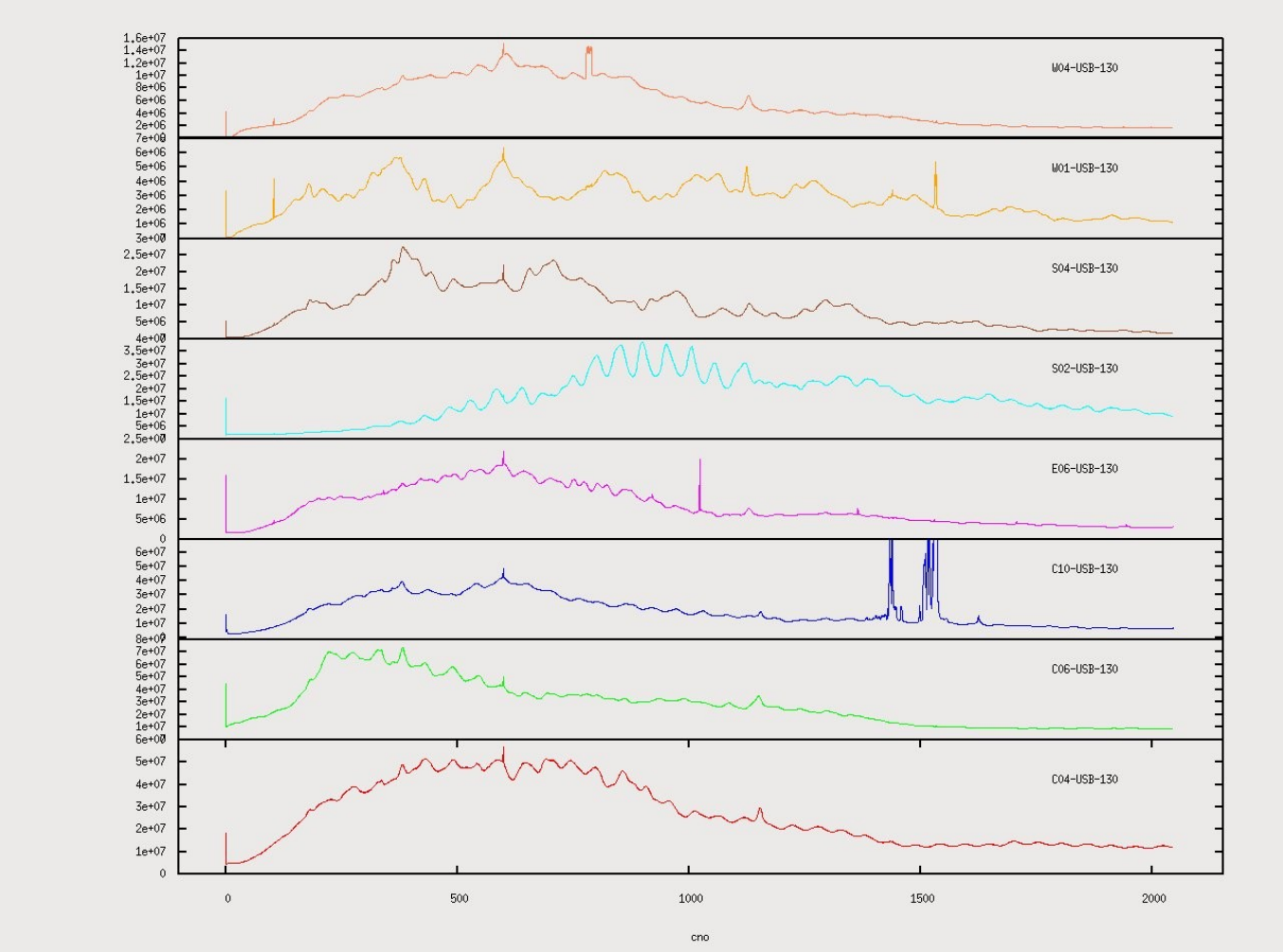

Fig 1.5*: Self-power amplitude as a function of channels, i.e. bandshapes. Note the data was acquired using GPU at the L-Band on 01st Aug 2013.*

1.7 Cross-power amplitude (or the cross-bandshape). Again, note the reference antenna is C04.

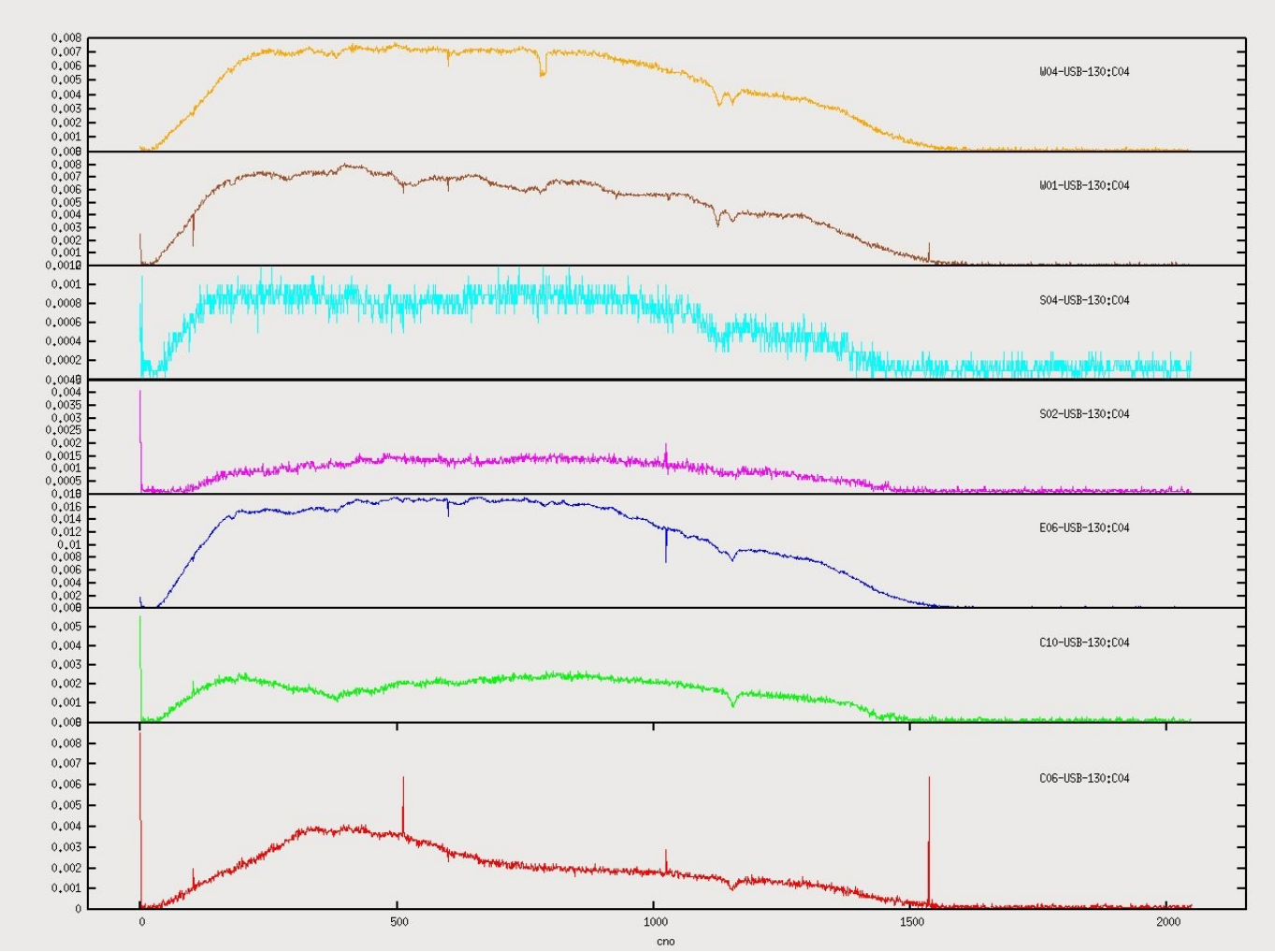

***Fig 1.6**: Cross-power (amplitude) as a function of channels or the cross-power bandshapes. Note the reference antenna is C04 and the data is acquired using GPU at the L-Band on 01st Aug 2013.*

2. Summary of Results for each Observations

2.1 Day-1: 1st Aug 2013

Observing log

LTAFILE: gputest_gab_01aug2013.lta
Settings:
Observe date 01 AUG 2013
Object 3C147
LO1 1140 MHz
RF 1210 MHz
Band = normal (GUI), meaning LO1 < RF (or USB)
No. of Channels 2048
Channel-width 97.66 kHz

Note: W01 and W04 are the two antennas which were not working for first two hours and subsequently they started observing and were included in the observing run.

Self-power (amplitude) stability as a function of time (please see Figure 1.1)

For self amplitude stability the remarks are as follows.
For almost 5 Hrs scan after 3 hours antennas shown few jumps in self but for the first 3 hours all are showing good stability i.e. almost straight line as a function of time.

Cross-power (amplitude) stability as a function of time (please see Figure 1.2)

For this data C04 was reference antenna chosen for data analysis. Except antenna E06, all antennas are showing stable power levels. i.e. E06 shows a ramp in cross-correlation coefficients over a five hours run from 0.04 to 0.025 (with a few percent drop in the amplitude).

Phase stability as a function of time. Note the reference antenna used is C04 (please see Figure 1.3)

Key inferences:
Phase windings over time
C06 and C10 – Reasonably(?) good including some distortions after mid of the observation or that might be the jumps over -180deg to +180deg.
E06 - 4 Winds over 5 hour run.
S02 and S04 - Intermittently good.
W01 and W04 – Started working after 3 hours. But good for next 2 hrs.

Phase stability as a function of Channel. Note the reference antenna is C04 (please see Figure 1.4)

Key inferences:
C06 - 3 (+ve slope) loops seen over 1500 channels
C10 - 5 (-ve slope) loops seen over 1500 channels
E06 - too many loops seen over 1500 channels
S02 - too many loops seen over 1500 channels
S04 - too many loops seen over 1500 channels
W01 - 45 (+ve slope) loops seen over 1500 channels
W04 - too many loops seen over 1500 channels

2.2 Day-2: 08th August 2013

Observation Log
LTAFILE: gputest_08aug2013.lta.2
Settings:
Observe date 08 AUG 2013
Object 3C147
LO1 1420 MHz
RF 1350 MHz
Band = flipped (GUI), meaning LO1 > RF (or USB)
No. of Channels 2048
Channel-width 97.66 kHz

Self-power(amplitude) stability as a function of time (please see Figure 5.2.1)
The session was almost for 6 Hrs. Out of 8 antennas S04 was not tracking but showing stable amplitude but no stable phase. C06 shows oscillations in amplitude over time for all channels. E06 shows few up and downs over time. Rest of the antennas are fine.

Cross-power(amplitude) stability as a function of time (please see Figure 5.2.2)
For this data, C04 was chosen as the reference antenna for all subsequent data analysis (Fig.10). All antennas are showing stable power levels with respect to antenna C04, except a drop in amplitude on all the antennas at around 1600 hrs. This was because antenna C04 showed a drop at this time, which is clearly seen in the self-power as a function of time plot (see Fig. 9).

Phase stability as a function of time. Note the reference antenna used is C04 (please see Figure 5.2.3)
Key inferences:
C06 - Good.
C10 - Good.
E06 - 4.5 Winds over 6 hour run.

S02 - Good.
S04 - Not working.
W01 - Good.
W04 - Almost 2 phase-winds over 6 hour run.

Note: Slight phase variation is observed at around 1600 Hrs because C04 was off from the source just for some time hence phase variation is observed in all antennas.

Phase stability as a function of channel. Note the reference antenna used is C04 (please see Figure 5.2.4)

Key inferences:
C06 - 2 (-ve slope) loops seen over 1500 channels.
C10 - 3 (-ve slope) loops seen over 1500 channels.
E06 - 8 (+ve slope) loops seen over 1500 channels.
S02 - 2 (+ve slope) loops seen over 1500 channels
S04 - Not working.
W01 - 2 (-ve slope) loops seen over 1500 channels.
W04 - 2 (-ve slope) loops seen over 1500 channels.

2.3 Day-3: 16th August 2013

Observation log
LTAFILE : gabtest_1350lo_16aug2013_lsb.lta
Settings:
Observation date 16 AUG 2013
Object 3C147 and 1330+251
LO1 1350 MHz
RF 1280 MHz
Band = flipped (GUI), meaning LO1 > RF (or LSB)
S04 is taken for maintenance
No. of Channels 2048
Channel-width 97.66 KHz.

Note: This observing run used two calibrators, meaning we could quantify if the loss is correlated power was proportional to the ratio of the flux densities of these two calibrators.

Self-power (amplitude) stability as function of time (please see Figure 5.3.1)

Key Inferences:
The observing session was for 5 hours and except few drops in amplitude in self at the beginning for the rest of the time the amplitudes for all antennas were stable up to the end.
S04 is the showing a step at the beginning almost up to 1 hour.

Cross-power (amplitude) stability as a function of time (please see Figure 5.3.2)
Cross bandshapes are taken w.r.t. C04 antenna. The cross bandshapes are also good. As there were 4 sources observed in this observation session.

Phase Stability as a function of time. C04 is taken as reference antenna (please Figure 5.3.3)

Key inferences:
C06 - Good.
C10 - Good.
E06 - Good at beginning then 2 Winds at last 2 hour run.
S02 - Good.
S04 - Previously shown good quality phase then given for maintenance.
W01 - Good.
W04 - At the start it was good then Almost 2 winds at last 3 hour run.

Phase Stability as a function of channel. C04 is taken as reference antenna (please see Figure 5.3.4)

Key inferences:
C06 - Good quality phase over all channels.
C10 - 2 (-ve slope) loops seen over 1500 channels.
E06 - 8 (+ve slope) loops seen over 1500 channels.
S02 - 2 (+ve slope) loops seen over 1500 channels
S04 - 4 (+ve slope) loops seen over 1500 channels.
W01 - 2 (-ve slope) loops seen over 1500 channels.
W04 - 2.5 (-ve slope) loops seen over 1500 channels.

2.4 Day-4: 30th August 2013

Observation Log
LTAFILE : gpu_30aug2013_1350_L.lta.1
Settings:
Observe date 30 AUG 2013
Object 3C48
LO1 1420.0 MHz
RF 1350 MHz
Band = flipped (GUI), meaning LO1 > RF (or LSB)
No. of Channels 2048
Channel-width 97.66 kHz

Self-power (amplitude) stability as a function of time (please see Figure 5.4.1)
This session was having 5.5 hours slot except minute jumps in

amplitude of W04 and S04 was low in counts. Remaining 6 antennas were good.

Cross-power (amplitude) stability as a function of time (please see Figure 5.4.2)

Amplitude stability w.r.t C04 is taken. All the antennas are showing almost stable cross correlation coefficients. W01 shows one small drop between 07:30 Hrs and 08:00 Hrs.

Phase Stability as a function of time. The reference antennas used is C04 (please see Figure 5.4.3)

Key inferences:
C06 - Good.
C10 - Good.
E06 - Reasonably Good.
S02 - Good.
S04 - Good.
W01 - Good.
W04 - Good.

Phase Stability as a function of channel. The reference antenna used is C04 (please see Figure 5.4.4)

Key inferences:
C06 - 3 (-ve slope) loops seen over 1500 channels.
C10 - 4 (-ve slope) loops seen over 1500 channels.
E06 - 20 (+ve slope) loops seen over 1500 channels.
S02 - 5 (+ve slope) loops seen over 1500 channels
S04 - 6 (+ve slope) loops seen over 1500 channels.
W01 - 2 (-ve slope) loops seen over 1500 channels.
W04 - 3.5 (-ve slope) loops seen over 1500 channels.

2.5 Day-5: 25th September 2013

Observation Log

LTAFILE : gputest_25sep2013_1450_200_3c286.lta
Settings:
OBJECTS 3C48,3C147,3C286,0607-0836
LO1 1520 MHz
RF 1450 MHz
Band = flipped (GUI), meaning LO1 > RF (or LSB)
E06 Not working
W01 Self Low.
No. of Channels 2048
Channel-width 97.66 KHz.

Self-power (amplitude) stability as a function of time (Please see Figure 5.5.1)

This slot was one of the biggest slot i.e. 13.5 hours slot.
In this slot multiple sources were observed. Except E06 i.e. non-working antenna and W01 i.e. low self counts remaining 6 antennas were good.

Cross-power (amplitude) stability as a function of time. The reference antenna used is C04 (Please see Figure 5.5.2)

Cross correction coefficient for each source with respect to the C04 antenna were almost in the same range for each antenna except E06 antenna.

Phase Stability as a function of time. The reference antenna used is C04 (please see Figure 5.5.3)

Key inferences:
C06 - Good.
C10 - Good.
E06 - Not working.
S02 - Good.
S04 - Good.
W01 - Good.
W04 - Good.

Phase Stability as a function of channel. The reference antenna used is C04 (please see Figure 5.5.4)

Note this inference us for all calibrators namely, 3C48, 3C286, 3C147, 3C468.1.

Key inferences:
C06 - 1 (+ve slope) loops seen over 1500 channels.
C10 - 1 (+ve slope) loops seen over 1500 channels.
E06 - Not working.
S02 - 2 (-ve slope) loops seen over 1500 channels
S04 - 2 (-ve slope) loops seen over 1500 channels.
W01 - Stable over channel.
W04 - Almost stable.

Instead for one calibrator, 0607-0836, key inferences are:
C06 - 1 (+ve slope) loops seen over 1500 channels.
C10 - 1 (+ve slope) loops seen over 1500 channels.
E06 - Not working.
S02 - Almost stable seen over 1500 channels
S04 - Almost stable seen over 1500 channels.
W01 - 1.5 (-ve slope) rotation over all channel.
W04 - 4 (-ve slope) rotations upto 1500 channels.

3. A Comparison of Results for all Observations

Note that the underlying code of the GPU was changed to obtain reasonable self-power scale. Hence, below we keep two sets of plots, first three days and the remaining two days plots separate to draw inferences.

3.1 Self-correlation coefficient:

Below we look at the behavior of the averaged self-correlation coefficients spread over several days for each broadband antenna.

Table 3.1: *Table showing self-correlation coefficients data for all 5 days at the L-band.*

Antenna	01st Aug 13	08th Aug 13	16th Aug 13	30th Aug 13	25th Sep 13
C04	7e+07	1.2e+07	2.5e+06	200	120
C06	1.2e+07	1.4e+07	2.5e+06	225	120
C10	5e+07	1.0e+07	2.0e+06	300	110
E06	6e+07	1.2e+07	3.0e+06	175	0/N.W.
S02	7e+07	1.5e+07	4.0e+06	175	130
S04	5e+07	1.5e+07	4.0e+06	20	100
W01	1.5e+07	1.0e+07	8.0e+06	150	5
W04	4e+07	1.0e+07	7.0e+06	200	110

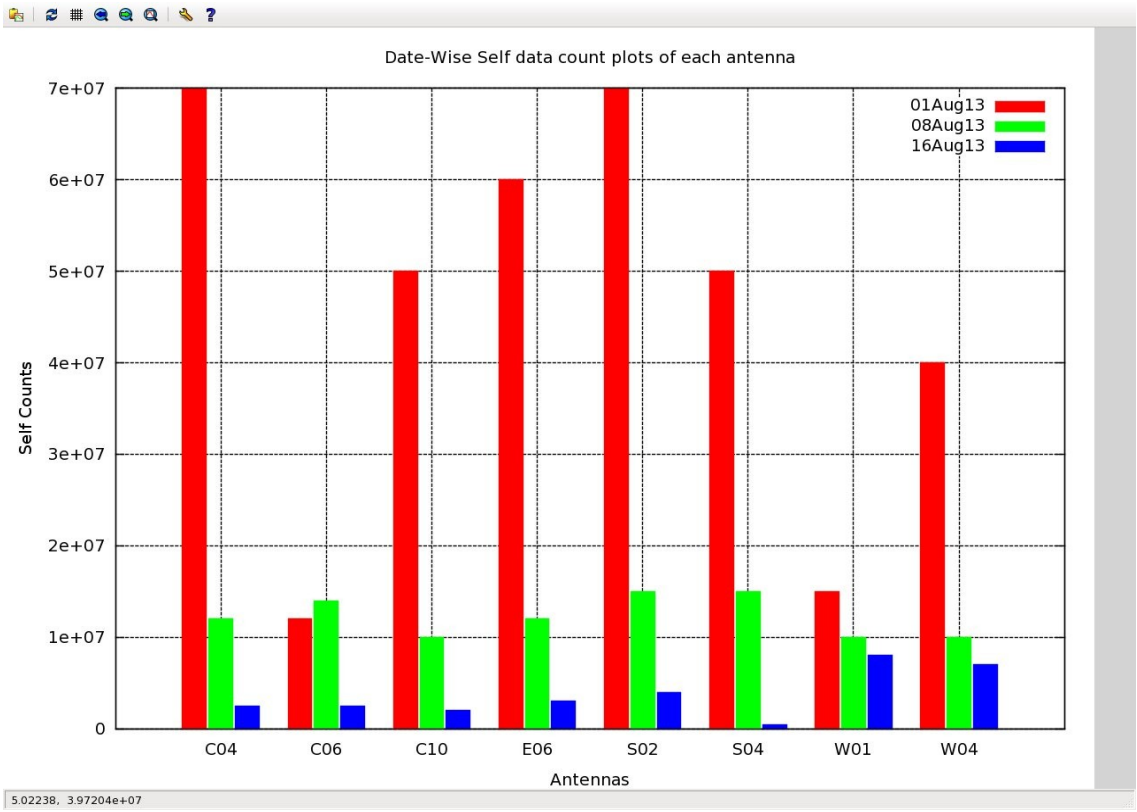

Fig 3.1*: First 3 days of comparison at L-band self-power cross-correlation coefficients.*

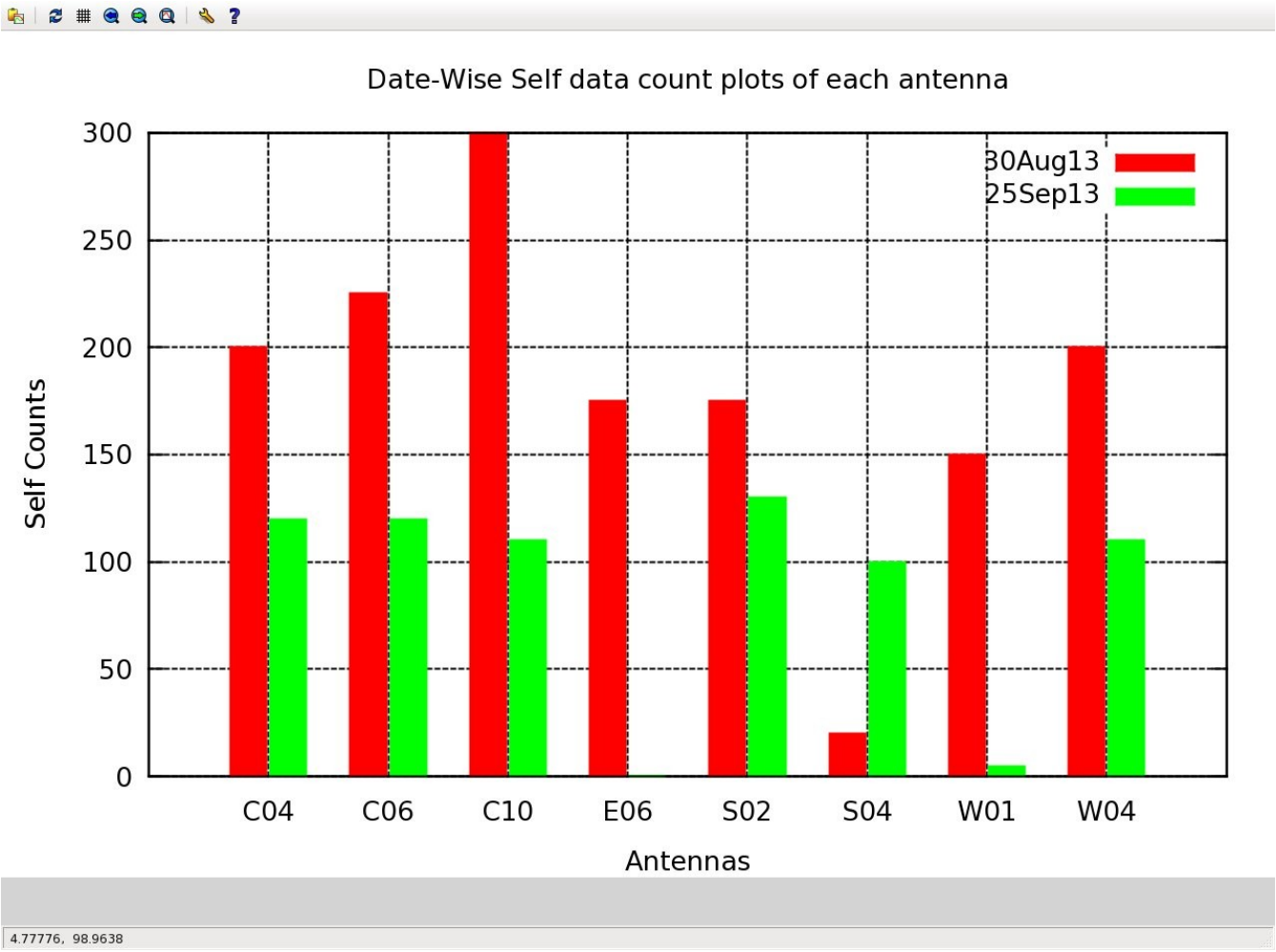

***Fig 3.2**: Rest 2 days L-band self data counts. This is because the scaling of self-counts was changed in the GPU backend.*

3.2 Cross-correlation coefficient:

Below we look at the behavior of the averaged cross-correlation coefficients spread over several days for each broadband antenna.

Table 3.2: *Table showing cross-correlation counts data for 5 days at the L-band. We again choose C04 antenna as the reference. The two values are observed and expected values.*

Antenna	01st Aug 13 Obs./Expt'd	08th Aug 13 Obs./Expt'd	16th Aug 13 Obs./Expt'd	30th Aug 13 Obs./Expt'd	25th Sep 13 Obs./Expt'd
C04	Ref. Ant	Ref. Ant	Ref. Ant	Ref. Ant	Ref. Ant
C06	0.004/0.084	0.008/0.084	0.02/0.084	0.04/0.061	0.045/0.084
C10	0.008/0.084	0.009/0.084	0.01/0.084	0.04/0.061	0.045/0.084
E06	0.02/0.084	0.025/0.084	0.02/0.084	0.025/0.061	N.W./0.084
S02	0.003/0.084	0.007/0.084	0.035/0.084	0.035/0.061	0.05/0.084
S04	0.0025/0.084	0.0015/0.084	0.025/0.084	0.035/0.061	0.05/0.084
W01	0.006/0.084	0.006/0.084	0.035/0.084	0.040/0.061	0.045/0.084
W04	0.005/0.084	0.007/0.084	0.025/0.084	0.035/0.061	0.045/0.084

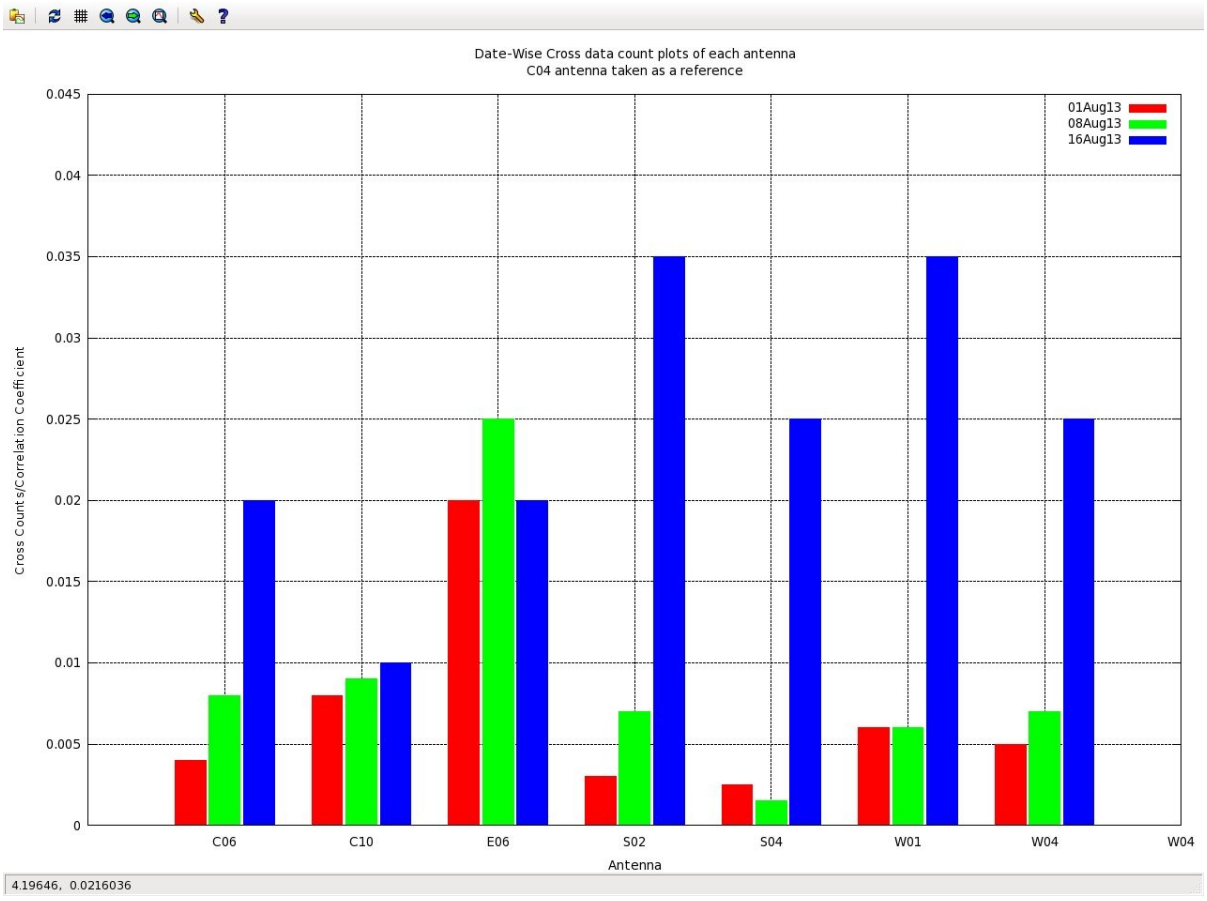

Fig 3.3*: First 3 days L-band Cross count plots. C04 antenna is taken as a reference.*

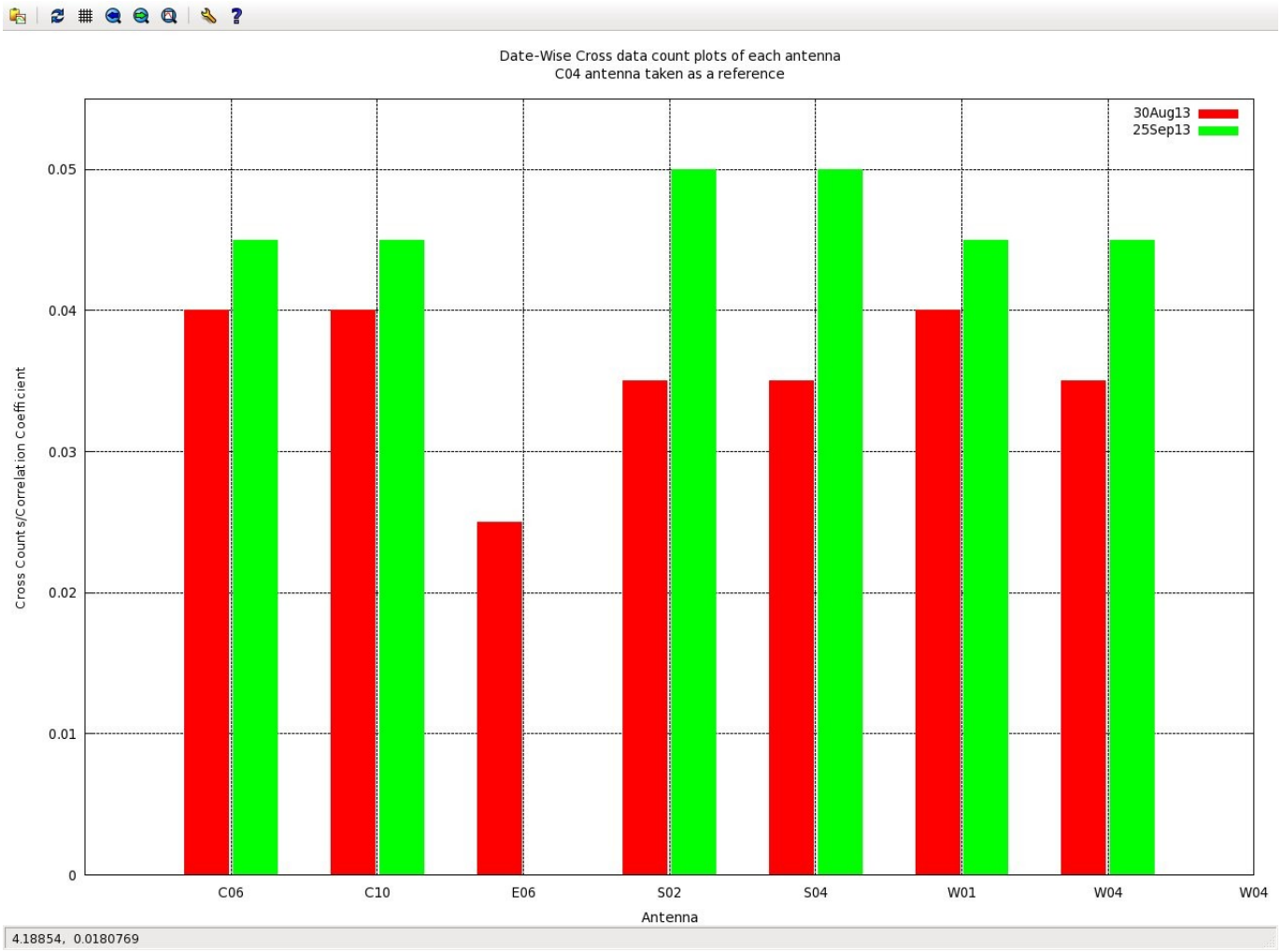

***Fig 3.4**: Rest 2 days L-band Cross counts plots, C04 is taken as a reference. This is again similar to the previous (Fig 3.3) because GPU backend team made changes in the programming code.*

3.3 Cross-correlation coefficient (25 Sep 2013):

Below we look at the behavior of the averaged cross-correlation coefficients for 25 Sep 2013 data for each broadband antenna. C04 antennas is chosen as the reference antenna.

Table 3.3: Averaged cross-correlation coefficients for each source per antenna for 25 Sep 2013 data. Again C04 antenna is taken as the reference. The two values are observed and expected values.

Antenna	3C48 Obs./Expt'd	3C147 Obs./Expt'd	3C286 Obs./Expt'd	0607-0836 Obs./Expt'd
C04	Ref. Ant	Ref. Ant	Ref. Ant	Ref. Ant
C06	0.03/0.061	0.045/0.084	0.03/0.055	0.0025
C10	0.03/0.061	0.045/0.084	0.03/0.055	0.002
E06	Not Working	Not Working	Not Working	Not Working
S02	0.025/0.061	0.05/0.084	0.03/0.055	0.002
S04	0.01/0.061	0.05/0.084	0.03/0.055	0.002
W01	0.02/0.061	0.045/0.084	0.025/0.055	0.002
W04	0.035/0.061	0.045/0.084	0.025/0.055	0.002

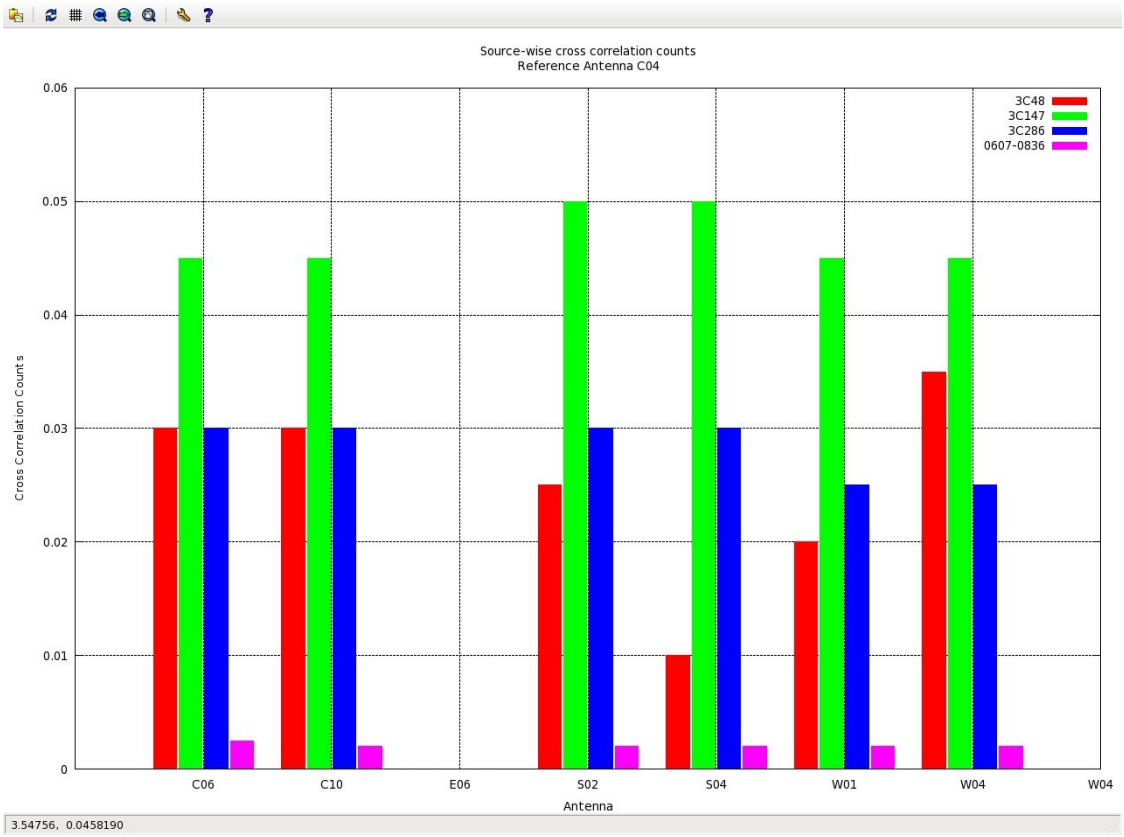

***Fig 3.5**: Averaged cross-correlation coefficients for each source per antenna at the L-band data for the data (shown in Table 3.3) acquired on 25 Sep 2013. Antenna C04 is chosen as the reference.*

4.Discussion and Future Plans

Following these series of tests, we find that there are three key issues, namely, (i) quantifying the deviation of observed cross-correlation coefficient from the expected values, (ii) RFI, and (iii) amplitude and phase variation as a function of (a) time, (b) baseline length and (c) frequency/channel. All these need attention, which we discuss below.

Additionally, we also present our understanding of the GPU from the detailed comparison of it with the data from GSB.

4.1 Quantifying cross-correlation coefficients:

At the start of the tests, e.g., on 8 Aug 2013, cross-correlation coefficients were typically a factor of 20% lower than the expected cross-correlation coefficients (ignore scan-0 and scan-4 where the data was acquired is in error) for all scans. Below in Table 4.1, we also show the expected cross-correlation coefficients for the calibrator targets used in our observations.

***Table 4.1**: Table showing expected cross-correlation coefficients for all the flux calibrators used in our series of observations at the L-band.*

3C147	3C48	3C286
0.084	0.061	0.055

4.2 Radio frequency interference:

The radio frequency interference (RFI) near channel 250 (in 30 Aug 2013 data) looks very intriguing where it appears to change shape from two features for arm antennas to one feature for CSQ antennas. There is another RFI feature in the same data in the channel range 1000-1100 and the cross-power amplitude plots for scans 0, 3, 7, in fact all scans show it moving in frequency. Self-power bandshape plot for E06 and S04 antennas show a strong line at around channel 1100, and the cross-power amplitude plots of these two antennas also show this RFI.

4.3 Amplitude and phase stability:

During the first two tests (data from 8 and 30 Aug 2013), the self-correlation amplitudes, cross-correlation amplitudes and phases with both, time and frequency looked to be behaving fairly decently. This was a good sign stating that the basic performance and stability of the entire chain from RF to GPU correlator worked well.

GPU L-Band Analysis Summary

We have generated several series of plots and also have tabulated them wheresoever possible for comparisons. Below we gives details of these data and plots.

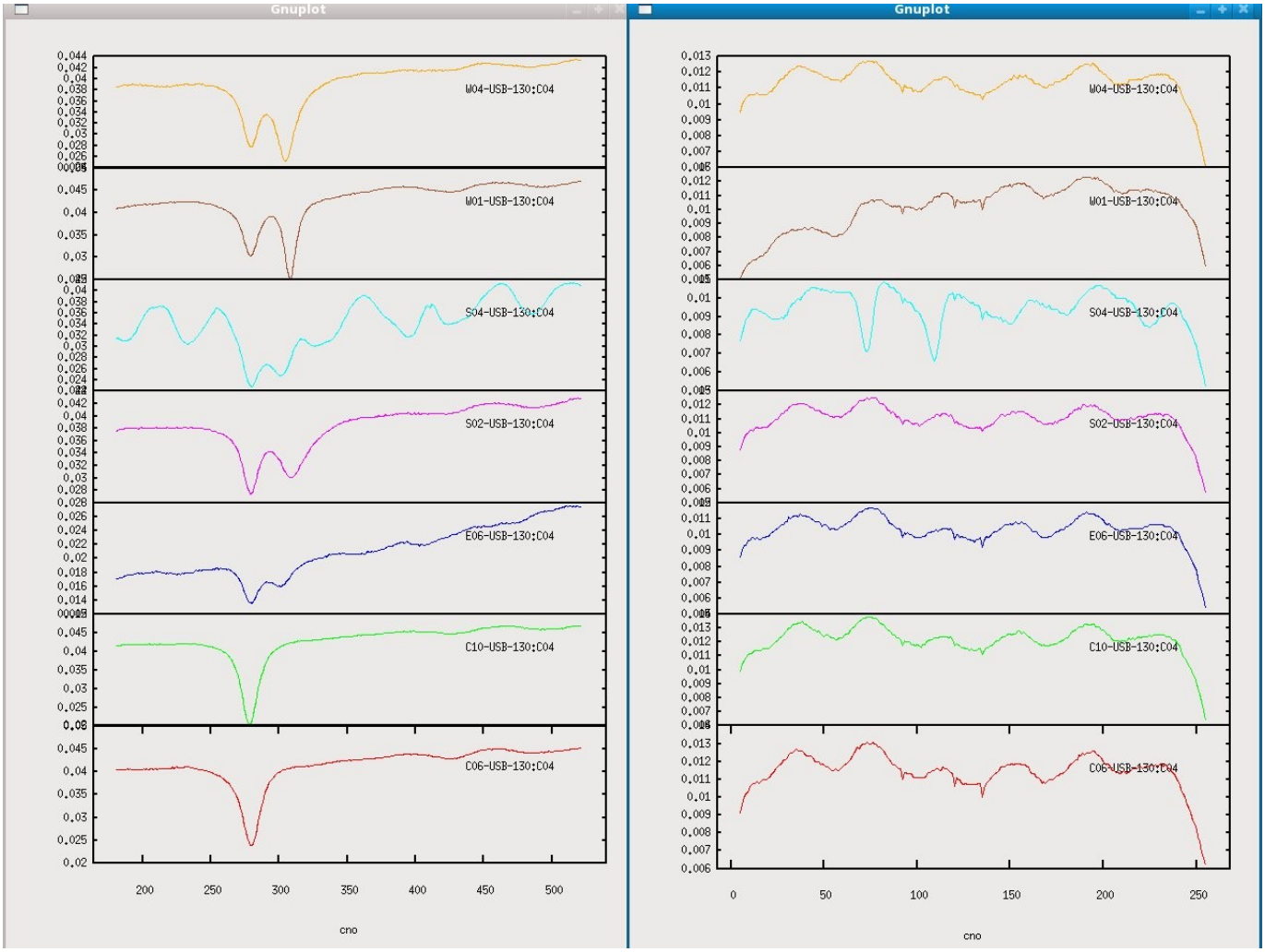

Fig 4.1*: Cross-power amplitude as a function of channel/frequency. The first channel corresponds to 1299 MHz and the last channel corresponds to 1332 MHz in both panels, and we use data from one good scan (no. 7). Note that the left panel is for data from GPU and the right panel is for data from GSB, and as always, we again use antenna C04 as the reference.*

4.3.1 Cross-power amplitude stability as a function of channel:

Several Figures (Figures: 1.7, 5.1.7, 5.2.7, 5.3.7, 5.4.7, 5.5.7) were generated in order to understand the stability of cross-power amplitude as a function of channels or the cross-power bandshapes.

4.3.2 Self-power amplitude stability as a function of channel:

Several Figures (Figures: 1.6, 5.1.6, 5.2.6, 5.3.6, 5.4.6, 5.5.6) were

generated in order to understand the stability of self-power amplitude as a function of channels or the self-power bandshapes.

4.3.3 Cross-power amplitude stability as a function of time:

Several Figures (Cross-correlation: Figures 1.2, 5.1.2, 5.2.2, 5.3.2, 5.4.2, 5.5.2) and Tables (Cross-correlation: Tables 1.2, 5.1.2, 5.2.2, 5.3.2, 5.4.2, 5.5.2) were generated in order to understand the stability of cross-power as a function of time.

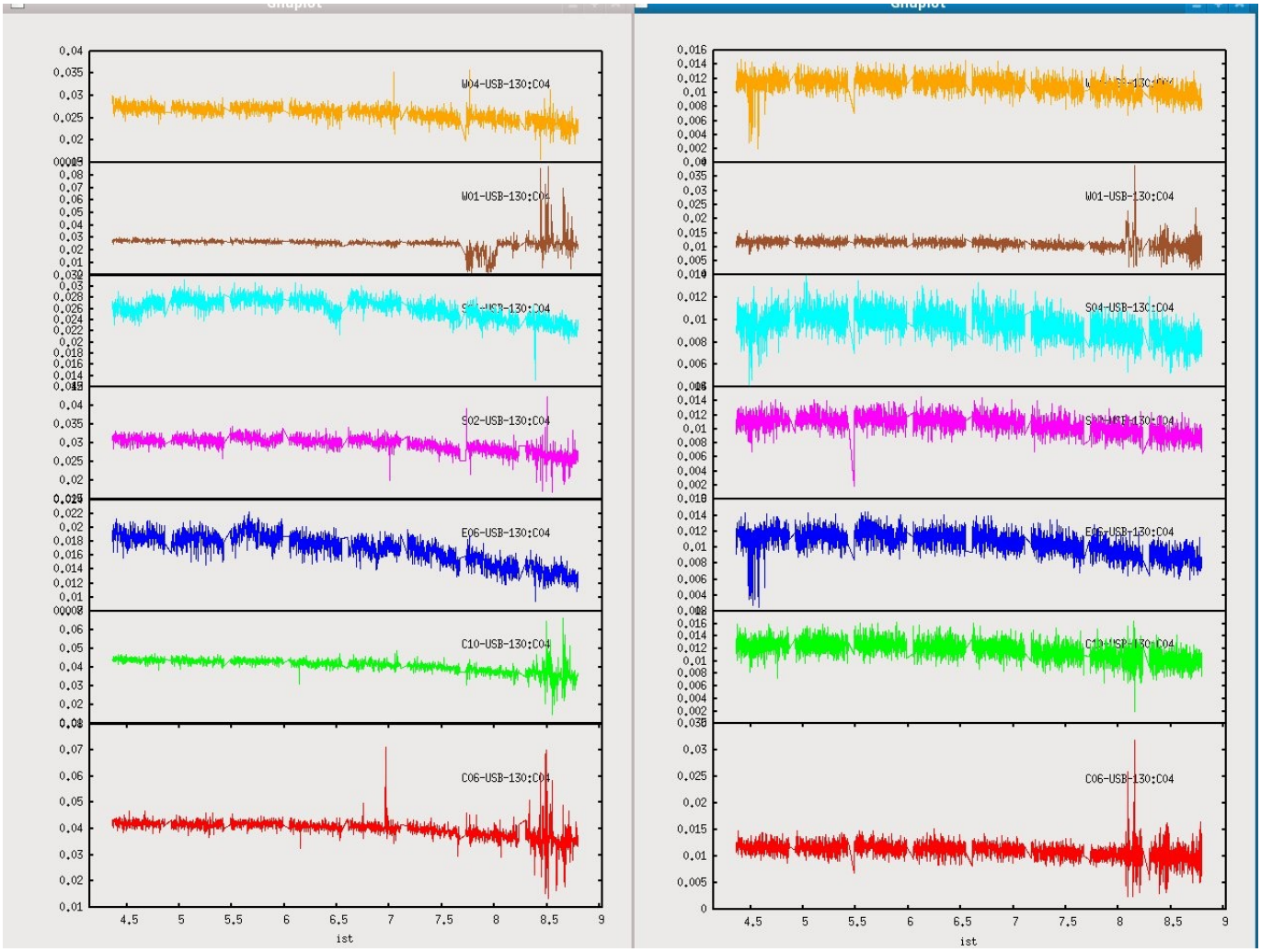

***Fig 4.2**: Cross-power amplitude as a function of time at 1320 MHz. Note that the left panel is for data from GPU and the right panel is for data from GSB, and as always, we again use antenna C04 as the reference.*

4.3.4 Self-power amplitude stability as a function of time:

Several Figures (Self-correlation: Figures 1.1, 5.1.1, 5.2.1, 5.3.1, 5.4.1, 5.5.1) and Tables (Self-correlation: Tables 1.1, 5.1.1, 5.2.1, 5.3.1, 5.4.1, 5.5.1) were generated in order to understand the stability of self-power as a function of time.

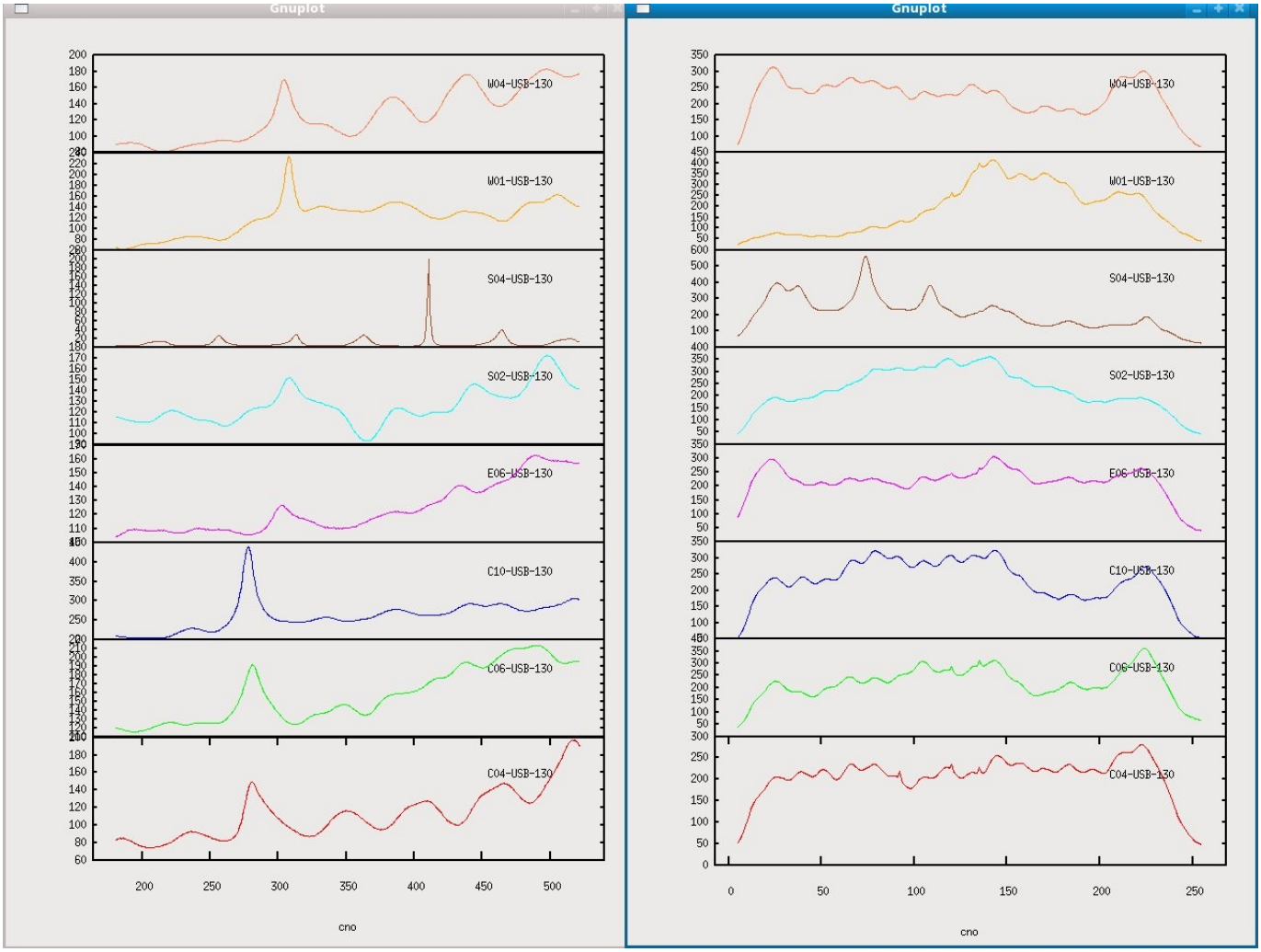

***Fig 4.3**: Self-power amplitude as a function of channel/frequency. The first channel corresponds to 1299 MHz and the last channel corresponds to 1332 MHz in both panels, and we use data from one good scan (no. 7). Note that the left panel is for data from GPU and the right panel is for data from GSB.*

4.3.5 Phase stability as a function of time:

Again several Figures (Figures: 1.3, 5.1.3, 5.2.3, 5.3.3, 5.4.3, 5.5.3) were generated in order to understand the stability of phase as a function of time. We also quantify phase-wraps seen as a function of time and as a function of baselines lengths in corresponding Sections (Sections: 1.4, 5.1.4, 5.2.4., 5.3.4, 5.4.4, 5.5.4, respectively).

To summarize briefly, with C04 as reference antenna, (30 Aug 2013) data clearly shows that the phase is quite stable with time on short baselines (e.g. C6, C10), e.g., very flat or constant phase with time and the low rms levels as one move to a stronger calibrator, etc. Whereas, as one goes to longer baselines, one can see increasing phase variations with time, with some of the worst being for C04 with W04

and E06. More importantly, when one is on a weaker calibrator, the phase of C04 with W04 and E06 shows a ramp with time and this ramp is faster for E06 than for W04, and much shallow for W01.

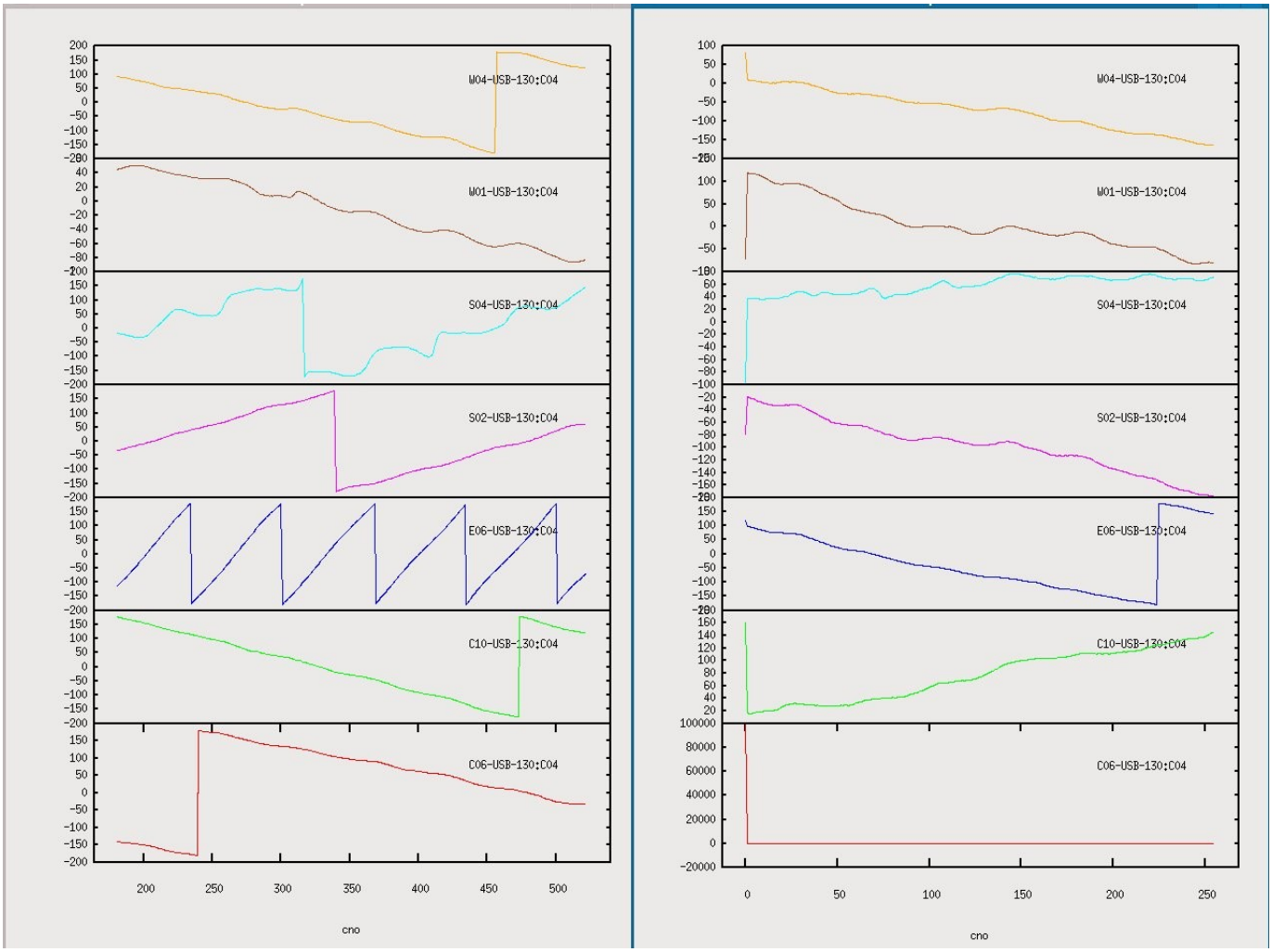

***Fig 4.4**: Phase as a function of channel/frequency. The first channel corresponds to 1299 MHz and the last channel corresponds to 1332 MHz in both panels and we use data from one good scan (no. 7). Note that the left panel is for data from GPU and the right panel is for data from GSB, and as always, we again use antenna C04 as the reference.*

4.3.6 Phase stability as a function channel:

Finally, regarding the phase stability as a function of channels, once again several Figures (Figures: 1.4, 5.1.4, 5.2.4, 5.3.4, 5.4.4, 5.5.4) were generated in order to understand the stability of phase as a function of time. We also quantify phase-wraps seen as a function of time and as a function of baselines lengths in corresponding Sections (Sections: 1.5, 5.1.5, 5.2.5., 5.3.5, 5.4.5, 5.5.5, respectively).

A comparison of phase as a function of time between GPU and GSB shows clear evidence for extra phase variation on long time scales in GPU.

This is clearly a (East-West) baseline length dependent) and has obvious symptoms of a time error in the GPU correlator. This seems to have been fixed and quick test data showed expected behaviour. There appears to be an evidence of a ~15 deg phase-jump in the phase as a function of time plot for the C04-C10 baseline. This is seen at IST of ~8.4 hrs in the GPU data, which is absent in the GSB data. Correspondingly, there is a glitch in the cross-power amplitude for many baselines of the GPU and not in the GSB data. This is the kind of problem that may occur if there is a loss of synchronizing signal in the integer and fractional delay updates.

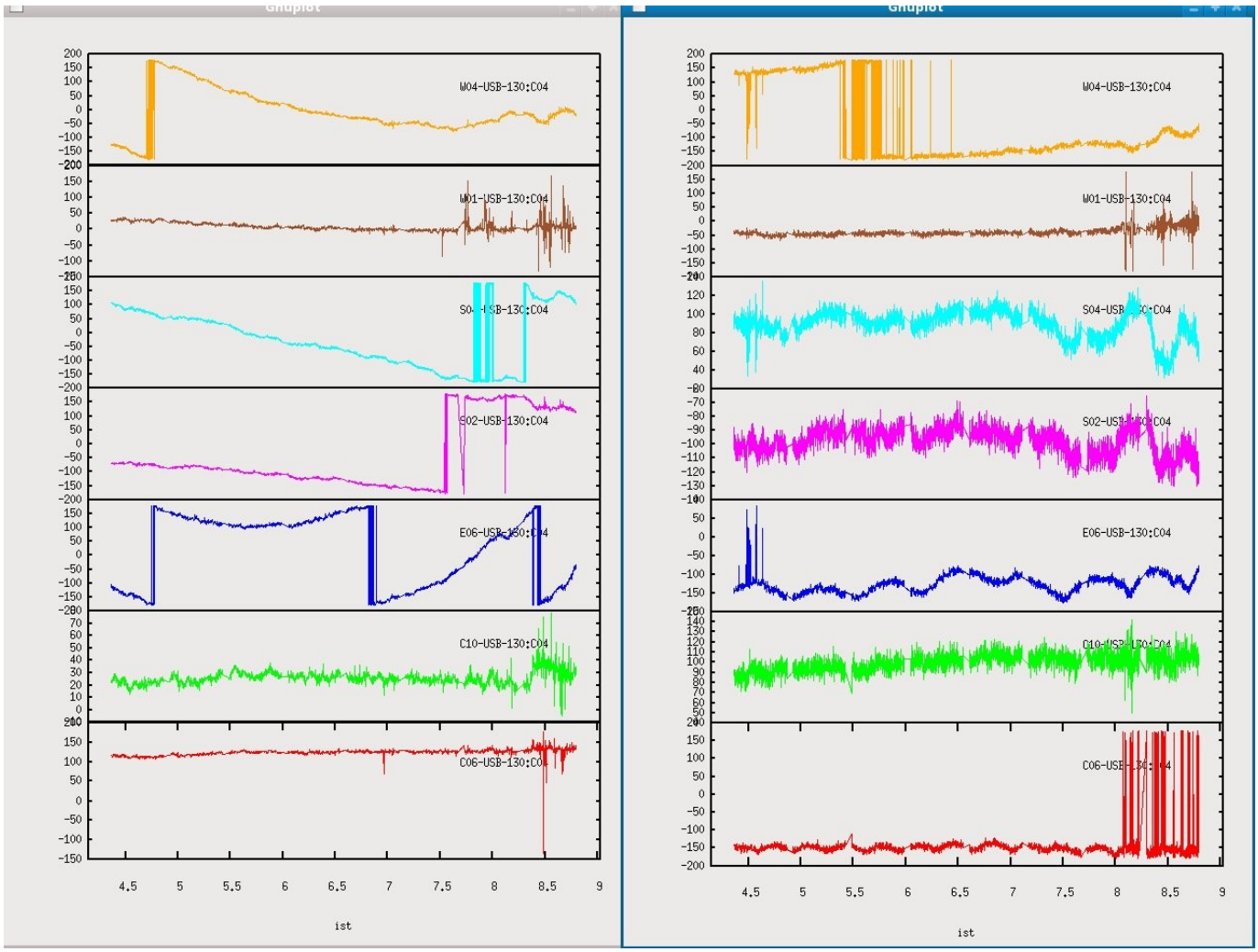

***Fig 4.5**: Phase as a function of time at 1320 MHz in both panels. Note that the left panel is for data from GPU and the right panel is for data from GSB, and as always, we again use antenna C04 as the reference.*

4.4 Comparison of GPU data with the GSB data:

This comparison was made in a systematic manner on 30 Aug 2013. Several plots (Figures 4.1, 4.2., 4.3, 4.4 and 4.5) showing cross-

power as a function of channel/frequency, cross-power as a function of time at 1320 MHz, self-power as a function of channel/frequency, phase as a function of channel/frequency and phase as a function of time at 1320 MHz, respectively. The two panels in these series of plots show results from GPU data (left panel) and GSB data (right panel).

Since, the two panels in the plots show identical frequency coverage, it is therefore clear that the RFI seen in the GPU data (at around channel 250) is not seen at the corresponding frequency in the GSB data. Meaning, this RFI feature is something internal to the new, broadband signal path.

4.5 Other (minor/major) issues which were fixed:

4.5.1 lta-file header:

Issues in the header of the lta-file were found, e.g., issue with an arbitrary date being displayed by tax (an offline observatory data analysis package), which was fixed and made available on node51 machine. Presently, since the new GMRT Analog Baseband (GAB) is being developed and put in place, it has made a lot of old strings in the header of the lta-file redundant. For example, in 8 Aug 2013 observation, RF = 1350 MHz, which corresponds to channel zero and we expect the frequency to decrease as channel no. Increases, i.e., channel 2047 = 1150 MHz. But the presence of LO1 = 1420 MHz adds to the confusion. In short, there is a conflict in understanding RF/LO values given by ONLINE by the GPU-GUI and TPA by the GPU correlator.

An additional check was performed by converting the lta-file to FITS and loaded into AIPS. A few more new issues along with the above were seen, e.g., some header strings had a conflict while running some of the AIPS tasks. Many of these have been addressed.

We need to discuss these issues and agree upon which informations to be made available in the header of the lta-file, and perform tests, acquire and analyse it using AIPS/casapy and fix this issue.

4.5.2 Disk space on node51:

node51 is the key machine for running GPU, acquiring data, etc., but it has finite disk space. A long term solution needs to be discussed.

4.5.3 Antennas with low input powers, poor band-shapes, oscillations, etc.:

Here many problems were found, which were followed by respective team members, and fixed. Of these some are discussed below:

- Several antennas showed low levels of powers or poor cross-power bandshapes; e.g., E06 showed a clear evidence for a problem in its cross- and self-bandshapes and baselines involving it gave very low cross-correlation coefficients as compared to other baselines (30 Aug 2013 data). These were reported to appropriate personnel, followed and fixed.

- Again E06 antenna and S04 antenna as well showed bad self-power bandshapes and this is also reflected in the cross-power amplitude plots for these antennas (as compared to the remaining five antennas, which show relatively good responses). In addition, it appears that S04 shows oscillations. This was followed by the FE and OF teams and has been tracked-down.

- During the first two round of tests, antennas usually showed signatures of small amount of ripples. The cross amplitude-power as a function of channel for rest 5 antennas (excluding E06 and S04) is fairly decent, showing very little evidence of such ripples. However, the phase as a function of channel does show evidence for a very low levels of ripples superimposed on top of the ramps.

- Occasionally large differences in the cross-correlation amplitude power was seen for GPU as compared to the GSB, which are about three times larger for GPU than for GSB. These were probably due to choice of the C04 as the reference antenna. On replacing C04 with C06 as the reference antenna, things looked reasonable. This was again followed by the operations group and fixed.

- Finally, for some antennas, e.g., again E06 and S04, and also W01 show low-counts in the 130-channel polarisation. This too was brought to the notice of the operations group and hopefully it has been fixed.

4.5.4 diffstop and phase-wrap issues, etc.

Phase-wraps issue being the serious one and there was one thought that a time error of ~1.7 sec is present the code and it is this time error which is the root cause of this. A series of tests were performed, i.e., run offline package, “diffstop” for correcting the residual errors in phases, which arise due to the error in time. We produced plot of phase as a function of 'time' (single clean channel centered at centre) after the time error has been incorporated. Input from this exercise, i.e., correction to time obtained along with the modification in the code to add “dut”. With this new code, a test was performed and a new fixed delay table was generated, which is now being used. Hopefully, with this fix, phase-wraps issue would come to an end.

4.5.5 Documentation and related SOPs:

Several series of mails/documents were exchanged, which eventually were compiled and made into SOPs, e.g., (i) SOP for running the GPU, (ii) SOP for running the new GMRT analog baseband (GAB), (iii) SOP for converting raw GPU data format into AIPS compatible FITS data format, etc.

4.6 Future plans:

4.6.1 Radio frequency interference:

- Occasionally RFI appears to change shape from two features for arm antennas to one feature for central-square antennas, e.g., this was reported in data 8 Aug 2013 data, it would be good to report what does the self show for these antennas at the same timestamp.

- RFI feature in the cross-power amplitude plots in almost all scans show it to be moving in frequency (seen in 30 Aug 2013 data), it would be useful to track and quantify this feature in order to see what can be learned about this RFI.

- Again, in the 30 Aug 2013 data, presence of RFI seen in the GPU data (at around channel 250) was not seen at the corresponding frequency in the GSB data. Meaning, this RFI feature is something internal to the new, broadband signal path. This should be followed-up.

4.6.2 Antennas with low input powers, poor band-shapes, oscillations, etc.

As stated above, during the first two round of tests, antennas usually showed signatures of small amount of ripples. Subsequently this improved and the cross amp-power as a function of channel for as many as five antennas (excluding E06 and S04) showed very little evidence of such ripples. However, the phase as a function of channel does show evidence for a very low levels of ripples superimposed on top of the ramps. A closer look at these ripples, depending on the choice of antennas, suggest that these could be anywhere between a few percent and 30% levels. These will need to be understood better.

4.6.3 diffstop and phase-wrap issues, etc.

Phase-wraps issue being the serious one has hopefully been fixed with this new fix, including modification the code and from the backend team. Our one of the key goal in the forthcoming tests to check this,

including (i) phase as a function of time still shows phase-wraps for baselines and (ii) the plot should some weird behaviour. Also, if things do not behave as expected, a comparison of the GPU data with the GSB data should show visible differences. If so, then there is a more worrisome, subtle/difficult problem, which requires some careful checking to try and localise the root cause of the problem.

An evidence of a ~15 deg phase-jump in the phase as a function of time plot for the C04-C10 baseline at ~8.4 hrs timestamp in the GPU data acquired on 30 Aug 2013, which is absent in the corresponding GSB data. Possibly, this is due to the loss of synchronizing signal in the integer and fractional delay updates. Backend team members have been informed, hopefully they have tracked this, modified the code and have fixed the same.

4.6.4 Miscellaneous: presentation re. issues, etc.

The variation of cross-power amplitude with time for the 30 Aug 2013 data seems to have similar shape for both GPU and GSB (except for some small differences) e.g. the fractional drop in amplitude from the beginning to the end is about 25% and is the same in both backends. Here, it would help if we could aim for having the integration time such that the integration-time times the bandwidth is about the same for both backends; thereby we have similar S/N quantities for a faithful comparison.

4.7 Summary:

Following these series of tests, below we give salient features of the new backend, GWB.

1. Phase and cross-/self-amplitude variation as a function of time and channel behave fairly decently. Meaning, the basic performance and stability of the entire chain from RF to the backend is working well.

2. Observed cross-correlation coefficients typically are lower by a factor of 20% than the expected values.

3. RFI is an issue, we have listed it at several places whenever found. During the next series of tests, we would continue to monitor and coordinate with the respective team members.

4. Phase-wraps seen as a function of time is a concern and we have quantified, amount of wraps both as a function of time and baseline-lengths whensoever possible. It is possible that it was due to an error in the code, i.e., “dut”. Hopefully, this issue has now been fixed.

5. The contents of the header lta-file, its conversion to FITS format and the compatibility with AIPS or casapy is not fully debugged. Subsequent tests (after discussions within the group), e.g., imaging an extended source using upcoming 16-antenna system should address this.

6. Initially, there were antennas with low input powers, poor band-shapes, oscillations, etc. These were constantly followed with other (FE and OF) team members and many such issues on various antennas have been fixed. Soon we would move from 8-antenna system to the 16-antenna system, hopefully there would be a relative large no. of antennas which would stabilize in the longer run for more tests by several users.

7. Due to testing of this backend, several SOPs and the related documentation, and mapping of cables with respective GAB/panel were put in place. This documentation would be helpful for the new GMRT users to perform and plan more new tests/observations.

5. Data from all 5 Days

5.1 Day-1 (1st August 2013)

5.1.1 Observing log

LTAFILE:gputest_gab_01aug2013.lta
Settings:

Observe data 01 AUG 2013
Object 3C147
LO1 1140 MHz
RF 1210 MHz
LO1 < RF (or USB)
No. of Channels 2048
Channel-width 97.66 kHz.
Operator's note: This was continuous track on 3C147 source.

Note: The two antennas, W01 and W04, which were not working for approximately the first half of the run, they started working after two hours from the start, and were included in the observations.

5.1.2 Self-power (amplitude) stability

For self amplitude stability the remarks are as follows.
For almost 5 Hrs scan after 3 hours antennas shown few jumps in self but for the first 3 hours all are showing good stability i.e. almost straight line as a function of time.

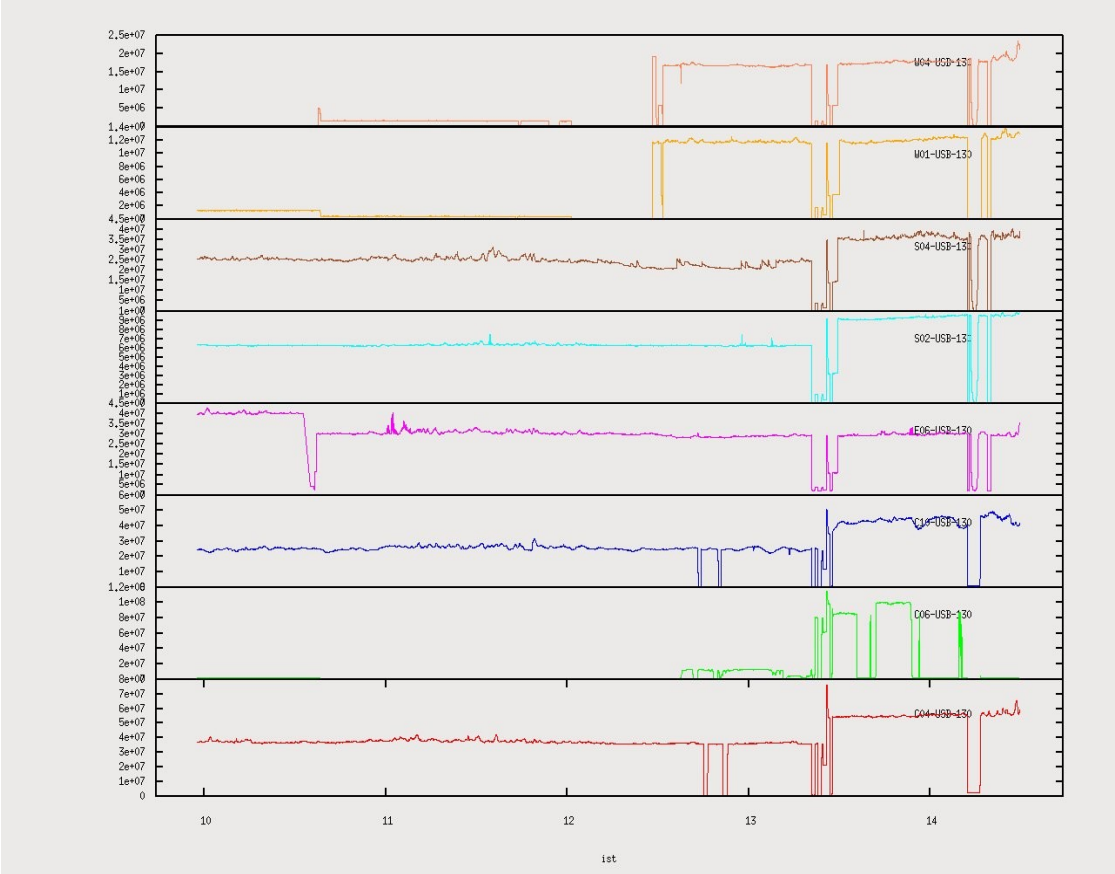

***Fig. 5.1.1**: Self-power (amplitude) as a function of time. Note the observations were made using the GPU at the L-band on 01 Aug 2013.*

Table 5.1.1: *Average self-correlation coefficients as a function of time. Note that only the good part of the data was included while determining the average.*

C04	C06	C10	E06	S02	S04	W01	W04
7e+07	1.2e+07	5e+07	6e+07	7e+07	5e+07	1.5e+07	4e+07

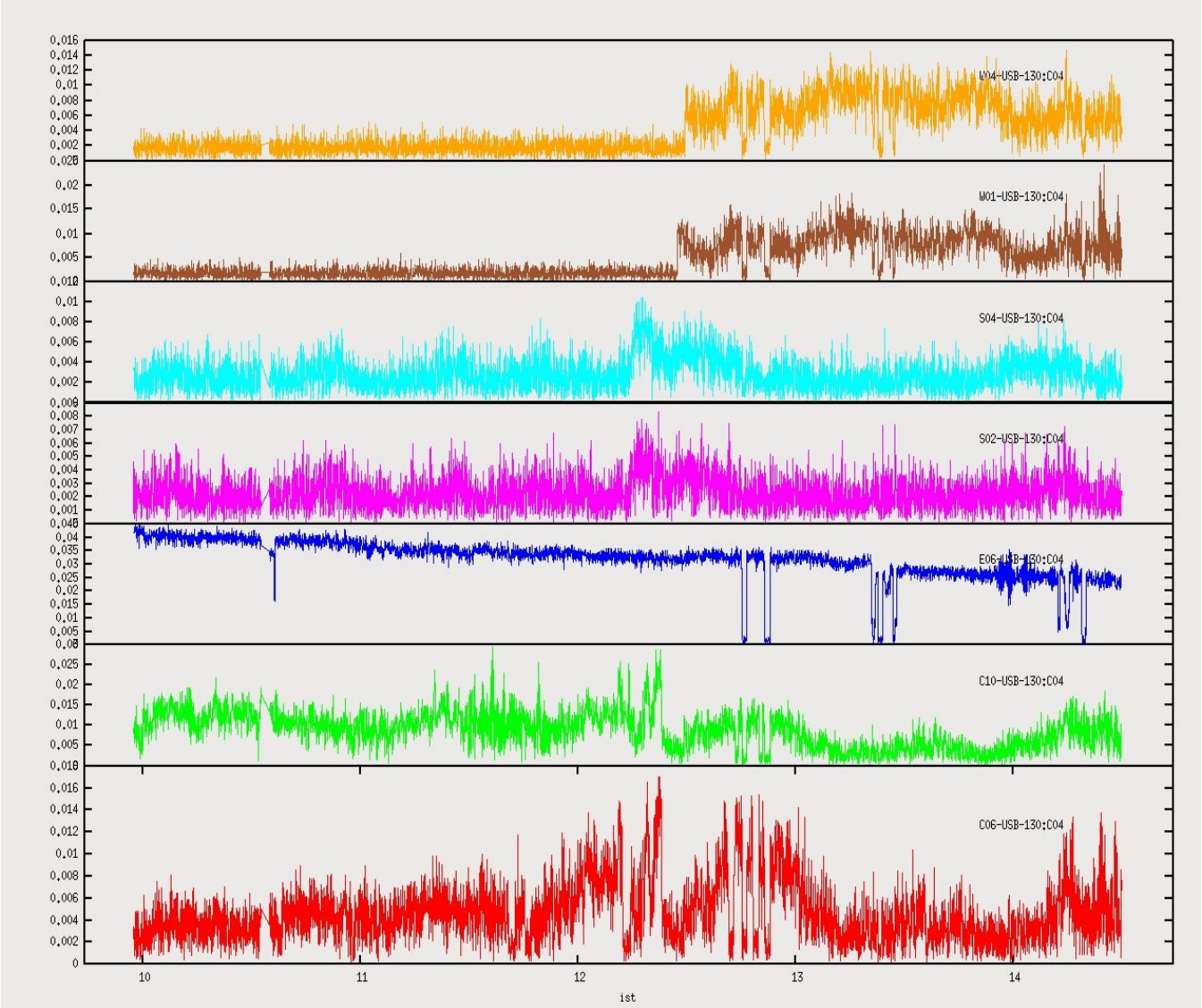

Fig 5.1.2*: Cross-power (amplitude) as a function of time. Note the reference antenna is C04 and the data is acquired using GPU at the L-band on 01 Aug 2013.*

5.1.3 Cross-power (amplitude) stability

Here, C04 was chosen as the reference antenna and for all subsequent data analyses (Fig.2). Except antenna E06, all antennas are showing stable power levels. i.e. E06 shows a ramp in cross-correlation coefficients over a five hours run from 0.04 to 0.025 (with a few per cent drop in amplitude).

Table 5.1.2: *Average cross-correlation coefficients as a function of time. Note the reference antenna is C04. Tables 3.2 and 3.3 shows expected cross-correlation coefficients.*

C04	C06	C10	E06	S02	S04	W01	W04
Ref. Ant	0.004	0.008	0.02	0.003	0.0025	0.006	0.005

5.1.4 Phase stability as a function of time. Note again, the reference antenna is C04.

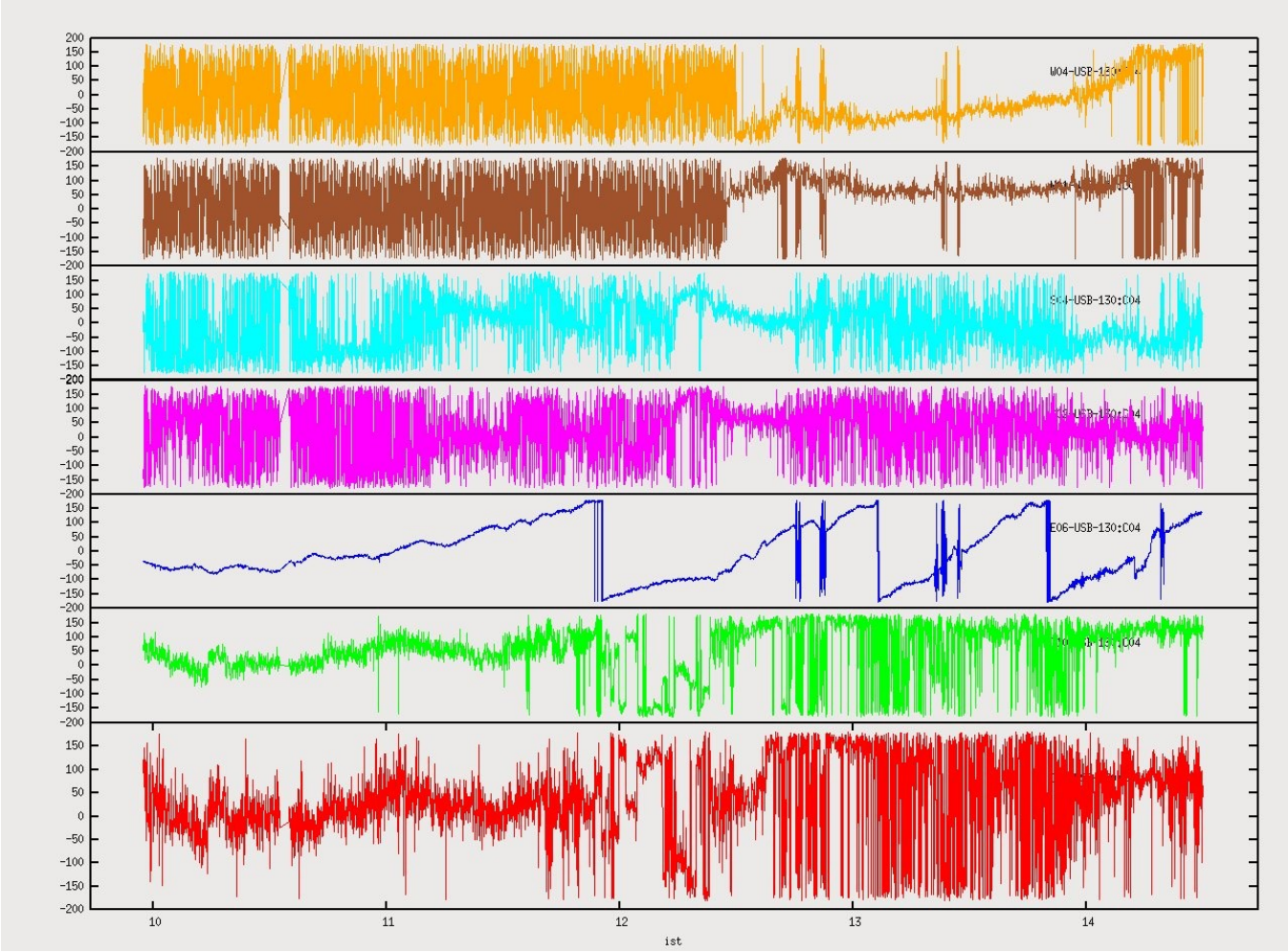

Fig 5.1.3*: Variation in phase as a function of time. Note the reference antennas is C04 and the data is acquired using GPU at the L-band on 01 Aug 2013.*

Key inferences:

Phase windings over time

C06 and C10 – Reasonably(?) good including some distortions after mid of the observation or that might be the jumps over -180deg to +180deg.

E06 - 4 Winds over 5 hour run.

S02 and S04 - Intermittently good.

W01 and W04 – Started working after 3 hours. But good for next 2 hrs.

5.1.5 Phase stability as a function of channels, and the reference antennas is C04.

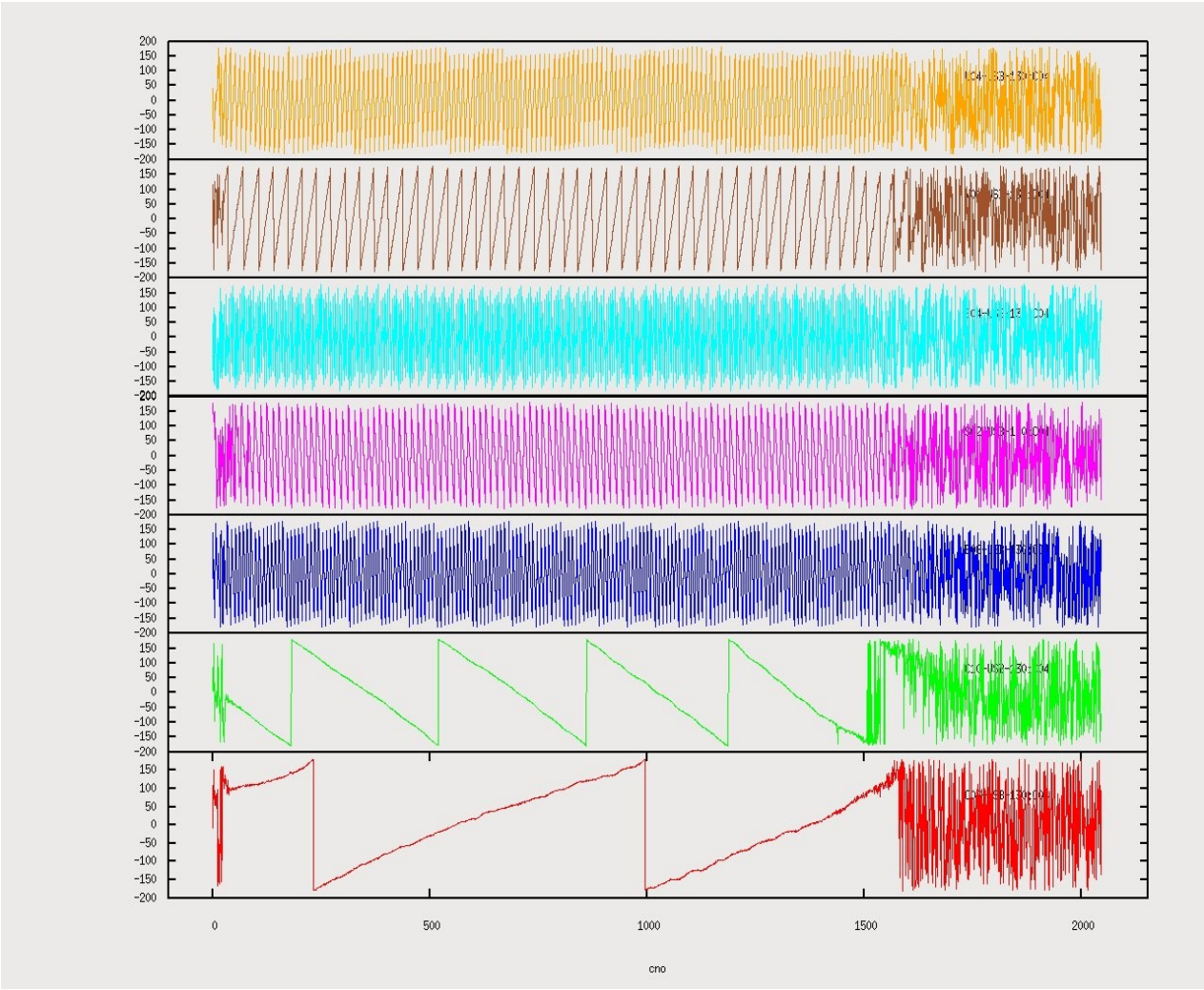

***Fig 5.1.4**: Variation in phase as a function of channel. Note the reference antenna is C04 and the data is acquired using GPU at the L-band on 01 Aug 2013.*

Key inferences:

C06 - 3 +ve sloped loops seen upto 1500 channels
C10 - 5 -ve sloped loops seen over 1500 channels
E06 - too many loops seen over 1500 channels
S02 - too many loops seen over 1500 channels
S04 - too many loops seen over 1500 channels
W01 - 45 +ve sloped loops seen over 1500 channels
W04 - too many loops seen over 1500 channels

5.1.6 Self-power amplitude (or the self-bandshape) stability

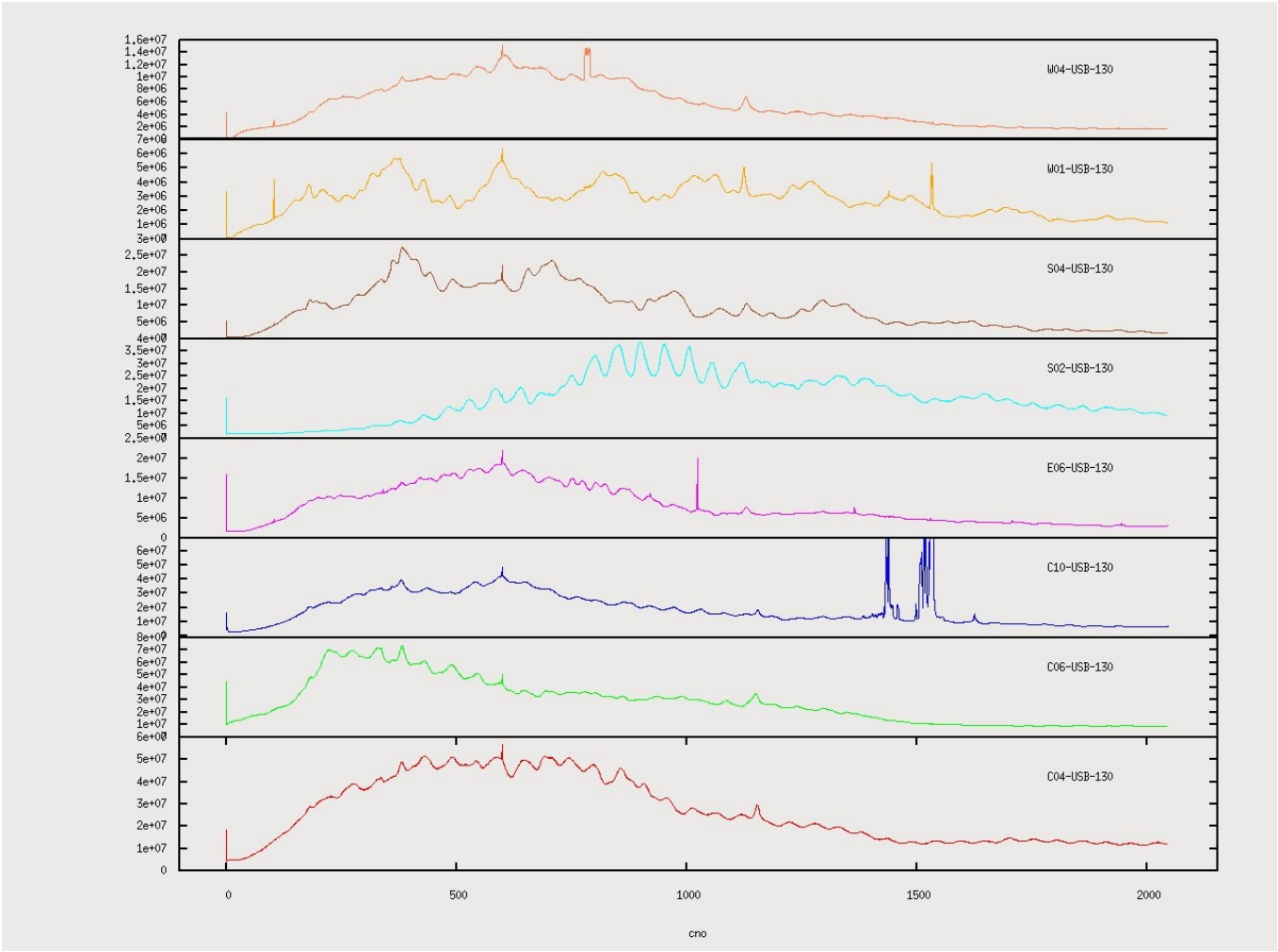

Fig 5.1.5*: Self-power amplitude as a function of channels, i.e. bandshapes. Note the data was acquired using GPU at the L-Band on 01st Aug 2013.*

5.1.7 Cross-power amplitude (or the cross-bandshape). Again, note the reference antenna is C04.

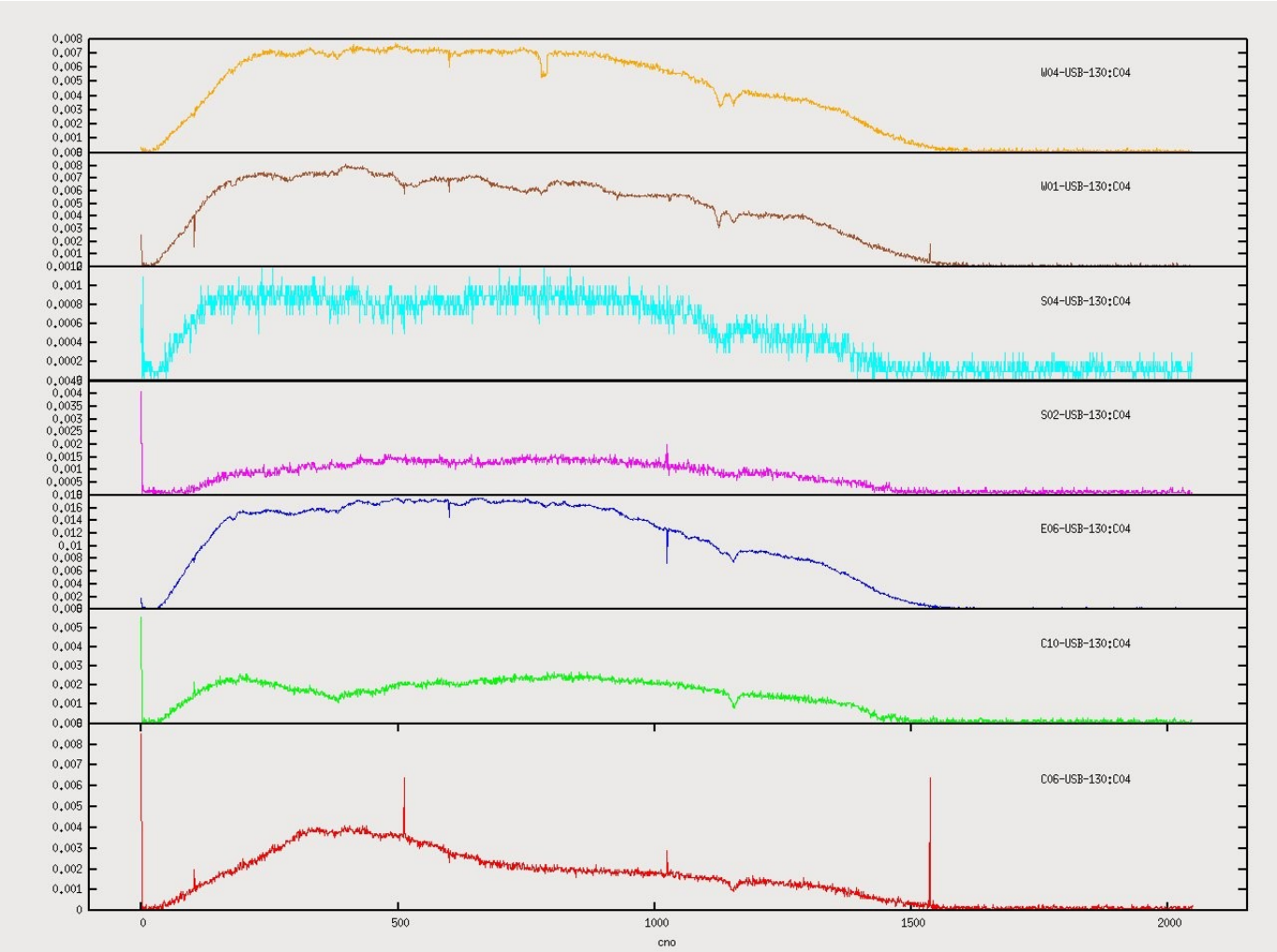

***Fig 5.1.6**: Cross-power (amplitude) as a function of channels or the cross-power bandshapes. Note the reference antenna is C04 and the data is acquired using GPU at the L-Band on 01st Aug 2013.*

5.2 Day-2 (8th August 2013)

5.2.1 Observation log

LTAFILE: gputest_08aug2013.lta.2
Settings:

Observe date 08 AUG 2013
Object 3C147
LO1 1420 MHz
RF 1350 MHz
LO1 > RF (or USB)
No. of Channels 2048
RF 1350 MHz
LO1 > RF (or USB)
No. of Channels 2048
Channel-width 97.66 kHz

Operator's note: This was a continuous track on 3C 147 source.

5.2.2 Self-power (amplitude) stability

For self amplitude stabilities the remarks are as follows:
The session was almost for 6 Hrs. Out of 8 antennas S04 was not tracking but showing stable ampliutude but no stable phase. C06 shows oscillations in ampliutude over time for all channels. E06 shows few up and downs over time. Rest of the antennas are fine.

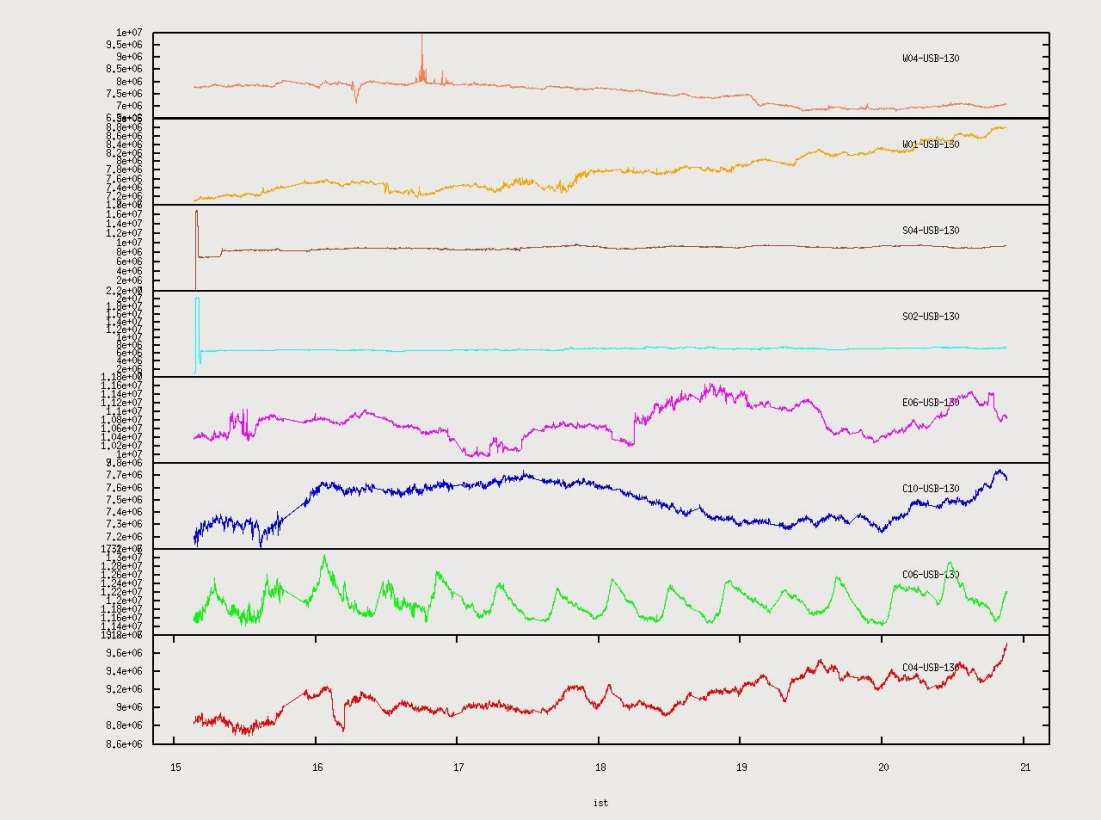

***Fig 5.2.1**: Self-power(amplitude) as a function of time. Note the observation were made using the GPU at the L-band on 8th Aug 2013.*

Note :S04 antenna was not tracking so it is not showing any phase stability.

Table 5.2.1: *Average self-correlation coefficients as a function of time. Note that only the good part of the data was included while determining the average.*

C04	C06	C10	E06	S02	S04	W01	W04
1.2e+07	1.4e+07	1.0e+07	1.2e+07	1.5e+07	1.5e+07	1.0e+07	1.0e+07

5.2.3 Cross-power (amplitude) stability

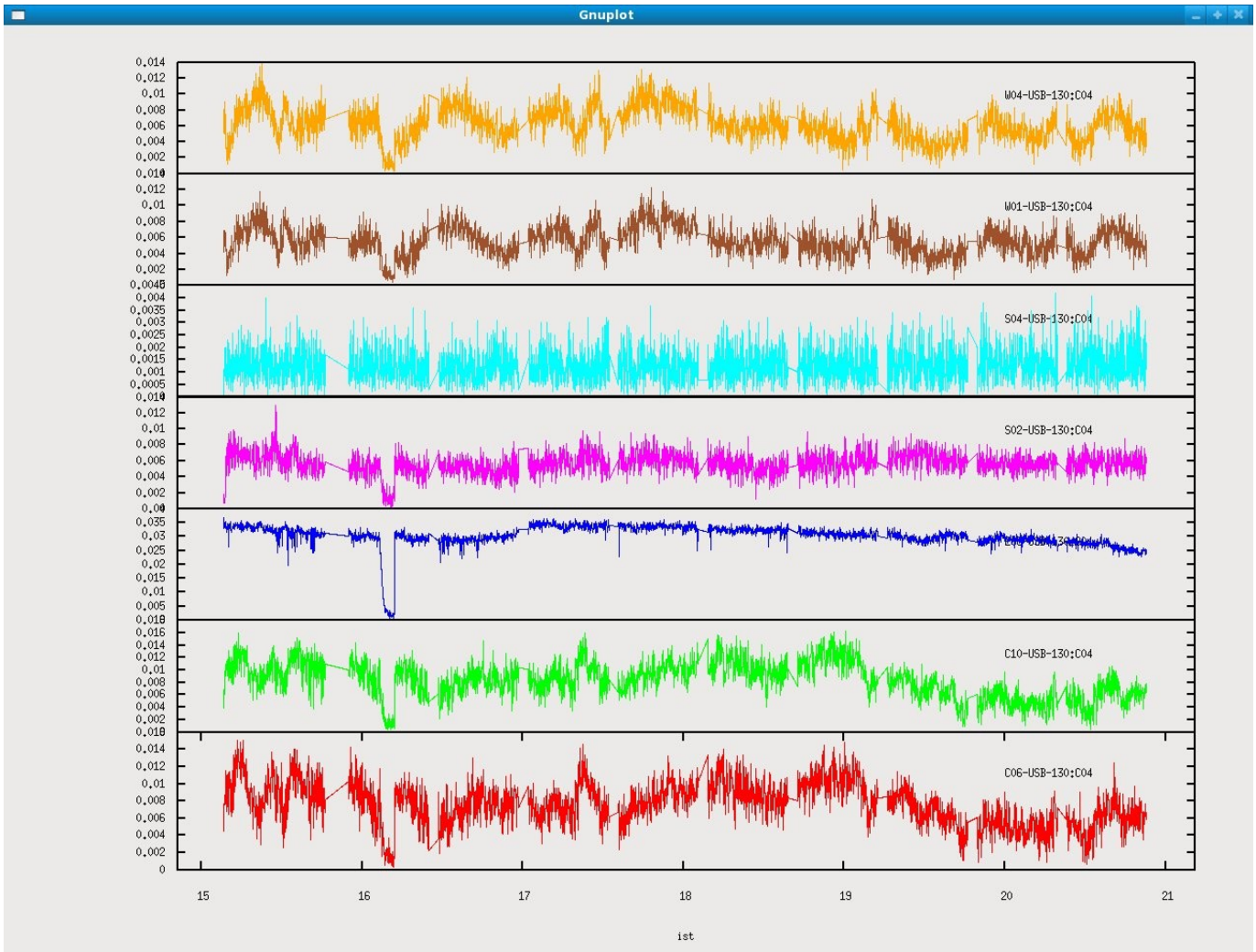

Fig 5.2.2: *Cross-power (amplitude)as a function of time. Note the reference antenna is C04 and the data is acquired using GPU at the L-band on 08th Aug 2013.*

All antennas are showing stable power levels w.r.t. C04.except one amplitude drop on all the antennas at around 1600Hrs because C04 was having drop at that time in the self see Fig. 4.2.2).

Table 5.2.2: *Average cross-correlation coefficients as a function of time. Note that only the good part of the data was included while determining the average. Tables 3.2 and 3.3 shows expected cross-correlation coefficients.*

C04	C06	C10	E06	S02	S04	W01	W04
Ref. Ant	0.008	0.009	0.025	0.007	0.0015 Not tracking	0.006	0.007

5.2.4 Phase stability as a function of time. Note again, the reference antenna is C04.

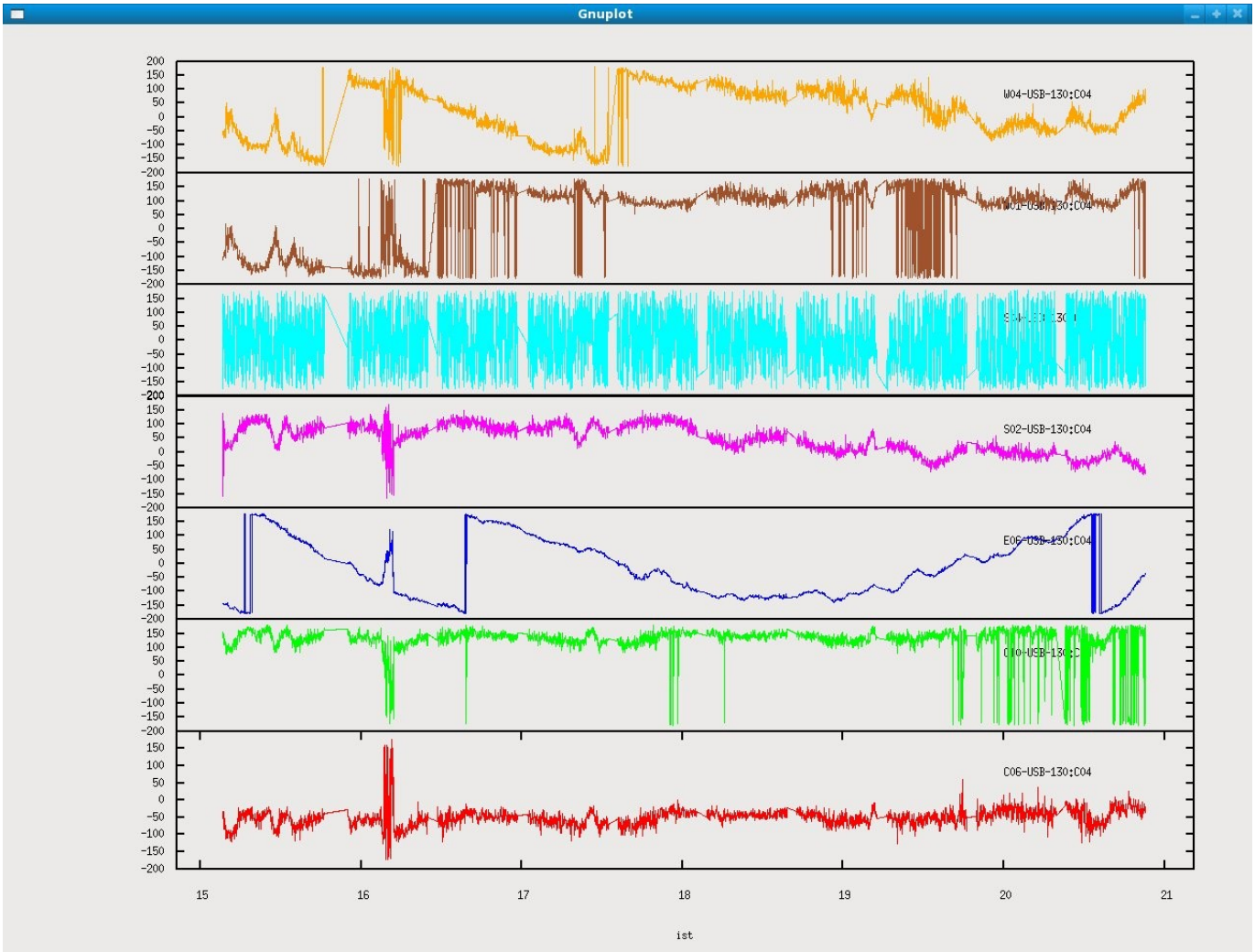

Fig 5.2.3*: Variation in phase as a function of time. Note the reference antenna is C04 and the data acquired using GPU at the L-band on 08th Aug 2013.*

Key inferences:
C06 - Good.
C10 - Good.
E06 - 4.5 Winds over 6 hour run.
S02 - Good.

GPU L-Band Analysis Summary

S04 - Not working.
W01 - Good.
W04 - Almost 2 winds over 6 hour run.

Note: Slight phase variation is observed at around 1600 Hrs because C04 was off from the source just for some time hence phase variation is observed in all antennas.

5.2.5 Phase stability as a function of channels, and the reference antenna is C04.

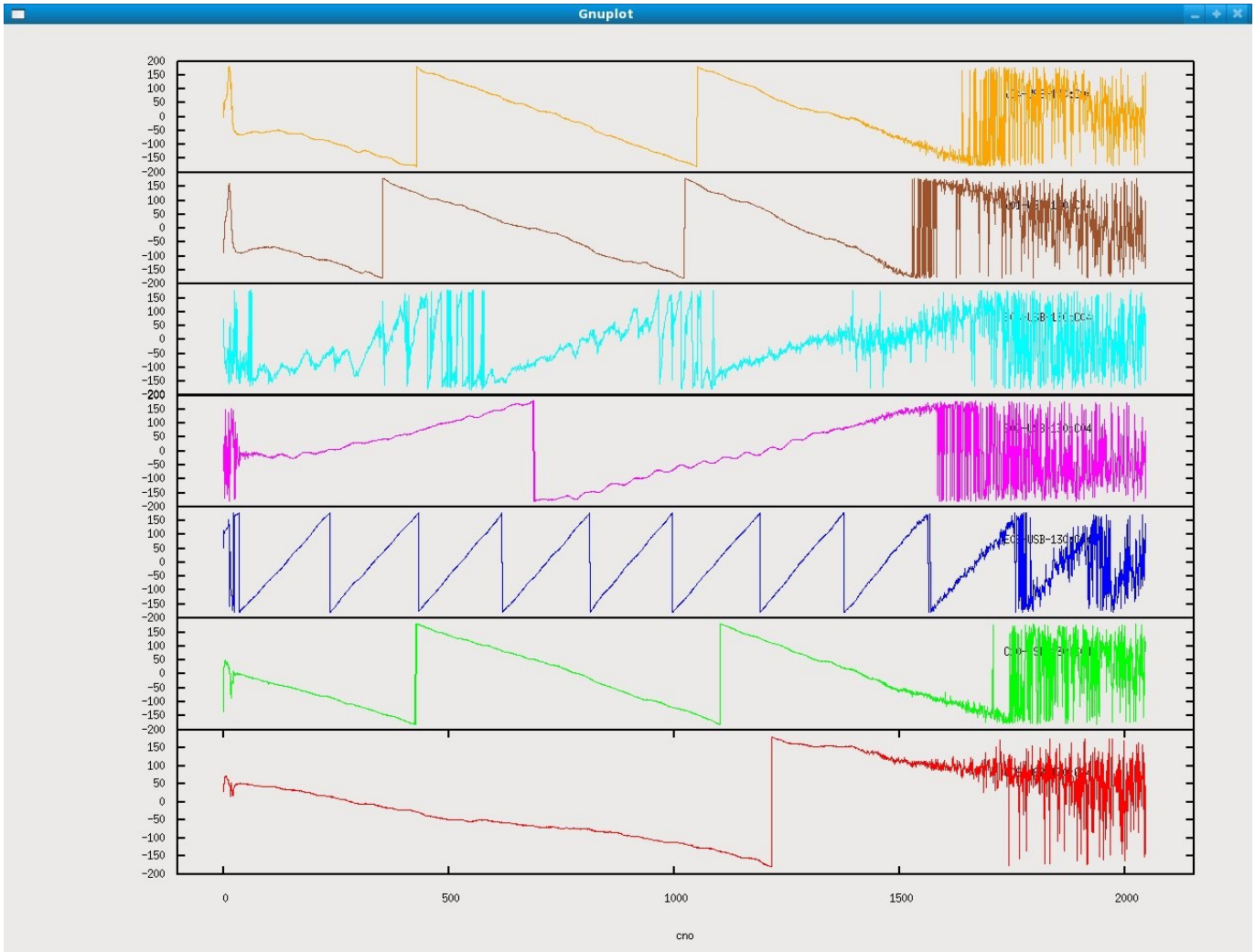

***Fig 5.2.4**: Variation in phase as a function of channel. Note the reference antenna is C04 and the data acquired using GPU at the L-band on 08th Aug 2013.*

Key inferences:
C06 - 2 (-ve slope loops seen over 1500 channels.
C10 - 3 (-ve slope) loops seen over 1500 channels.
E06 - 8 (+ve slope) loops seen over 1500 channels.
S02 - 2 (+ve slope) loops seen over 1500 channels
S04 - Not working.

GPU L-Band Analysis Summary

W01 - 2 (-ve slope) loops seen over 1500 channels.
W04 - 2 (-ve slope) loops seen over 1500 channels.

5.2.6 Self-power amplitudes(or the self-bandshapes) stability

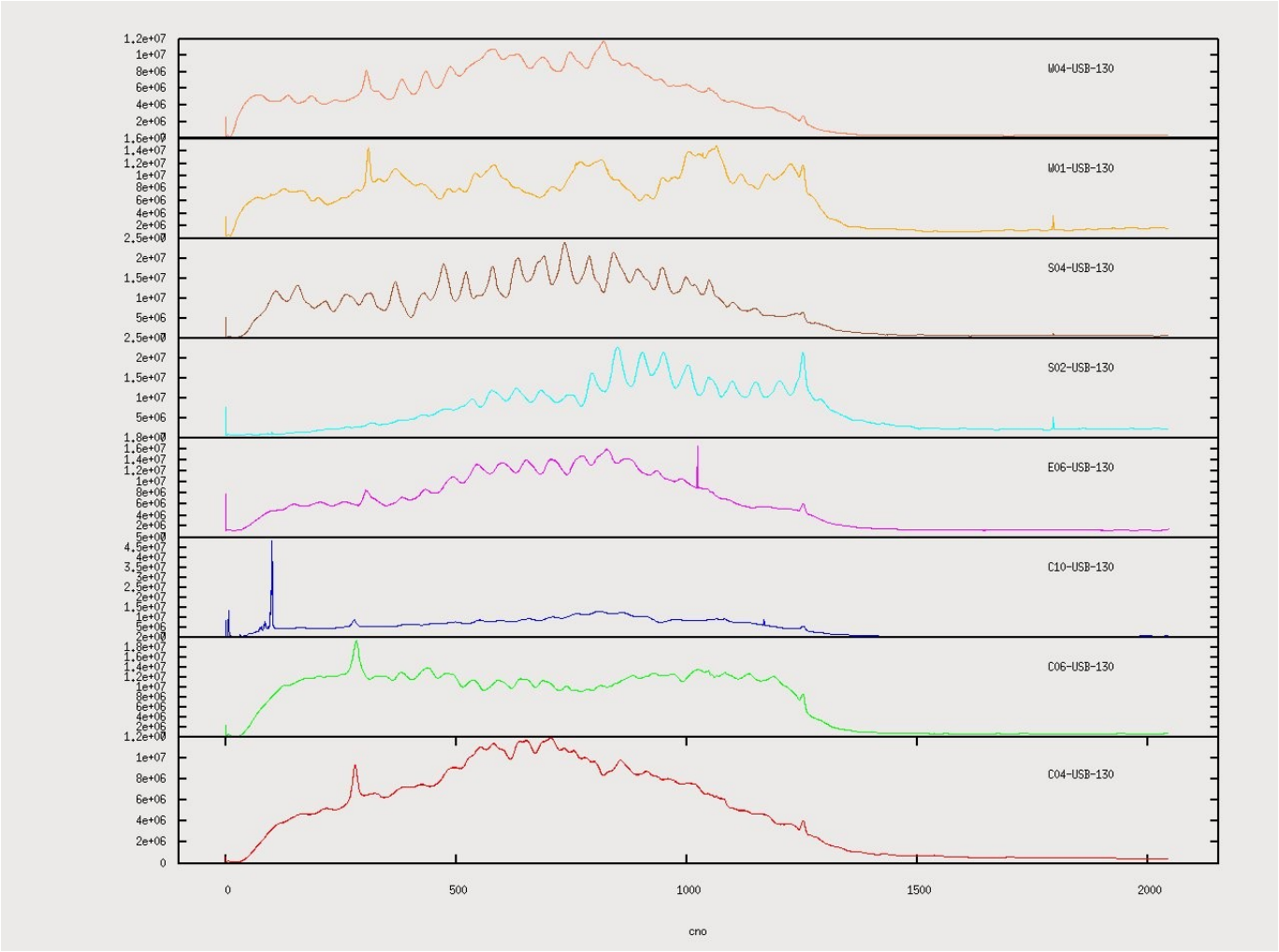

Fig 5.2.5*: Self-power amplitude as a function of channels, i.e. bandshapes. Note the data was acquired using GPU at the L-Band on 08th Aug 2013.*

5.2.7 Cross-power amplitude (or the cross-bandshapes). Again note the reference antenna is C04.

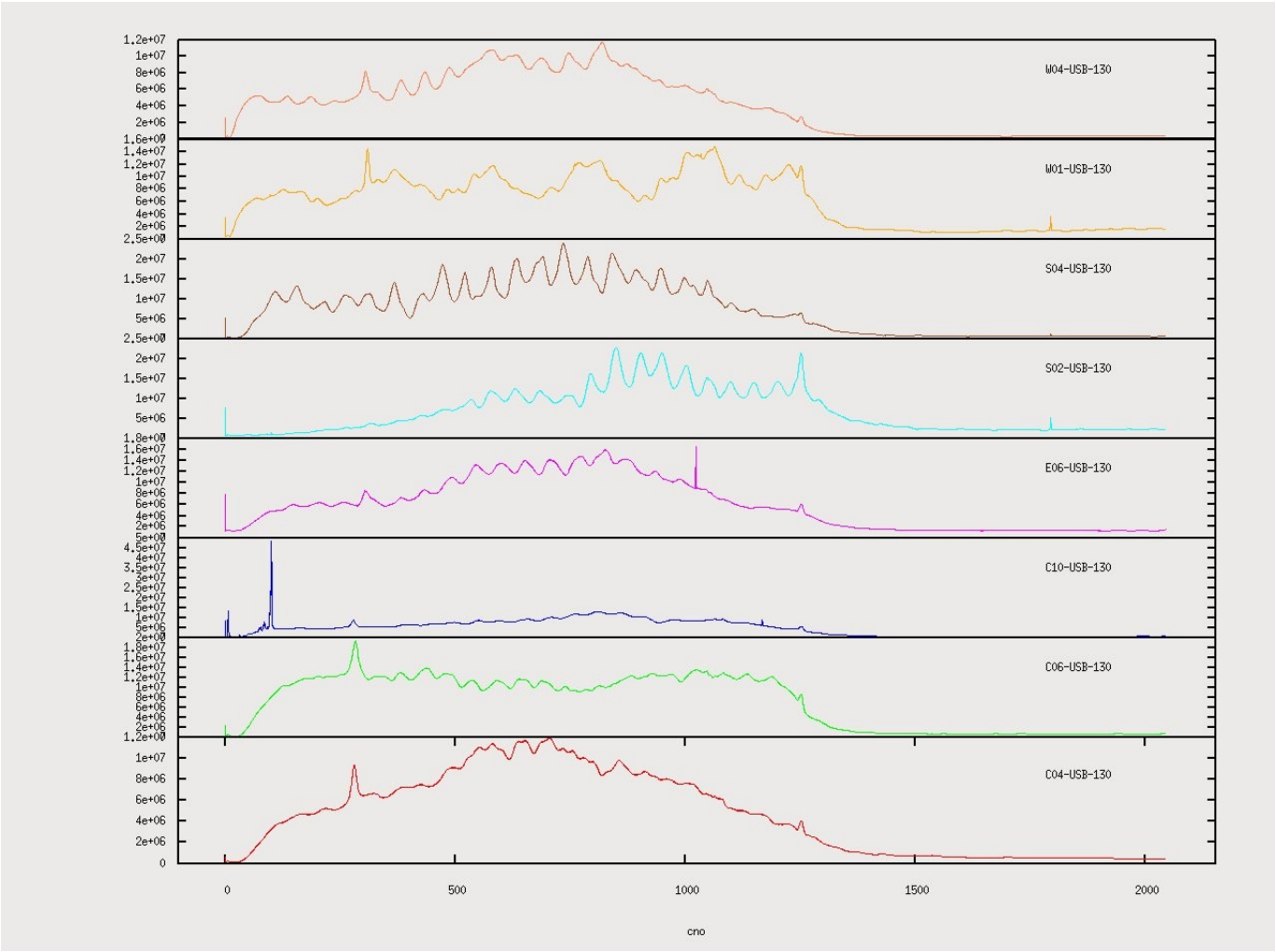

***Fig 5.2.6**: Cross-power (amplitude) as a function of channels or the cross-power bandshapes. Note the reference antenna is C04 and the data is acquired using GPU at the L-Band on 08th Aug 2013.*

5.3 Day-3 (16th August 2013)

5.3.1 Observation log

LTAFILE : gabtest_1350lo_16aug2013_lsb.lta

Settings:
Object 3C147 and 1330+251
LO1 1350 MHz
RF 1280 MHz
Band = flipped (GUI), meaning LO1 > RF (or LSB)
S04 is taken for maintenance
No. of Channels 2048
Channel-width 97.66 Khz.

Operator's note: There are a total of scans spread over ~5 hrs. which are listed below.

```
  0 3C147       05h43m39.54 +49d51'27.28" 15:47:58
  1 1330+251    13h31m16.28 +25d04'59.21" 17:04:15
  2 3C147       05h43m39.54 +49d51'27.28" 17:53:35
  3 1330+251    13h31m16.28 +25d04'59.21" 18:40:20
  4 1330+251    13h31m16.28 +25d04'59.21" 19:38:10
  5 3C286       13h31m46.01 +30d26'21.34" 19:49:55
```

Note: This observing run used two calibrators, meaning we could quantify if the loss is correlated power was proportional to the ratio of the flux densities of these two calibrators.

5.3.2 Self-power(amplitude) Stability

For self amplitude stability the remarks are as follows:
The observing session was for 5 hours and except few drops in amplitude in self at the beginning for the rest of the time the amplitudes for all antennas were stable up to the end.
S04 is the showing a step at the beginning almost up to 1 hour.

Table 5.3.1: *Average self-correlation coefficients as a function of time. Note that only the good part of the data was included while determining the average.*

C04	C06	C10	E06	S02	S04	W01	W04
2.5e+06	2.5e+06	2.0e+06	3.0e+06	4.0e+06	4.0e+05	8.0e+06	7.0e+06

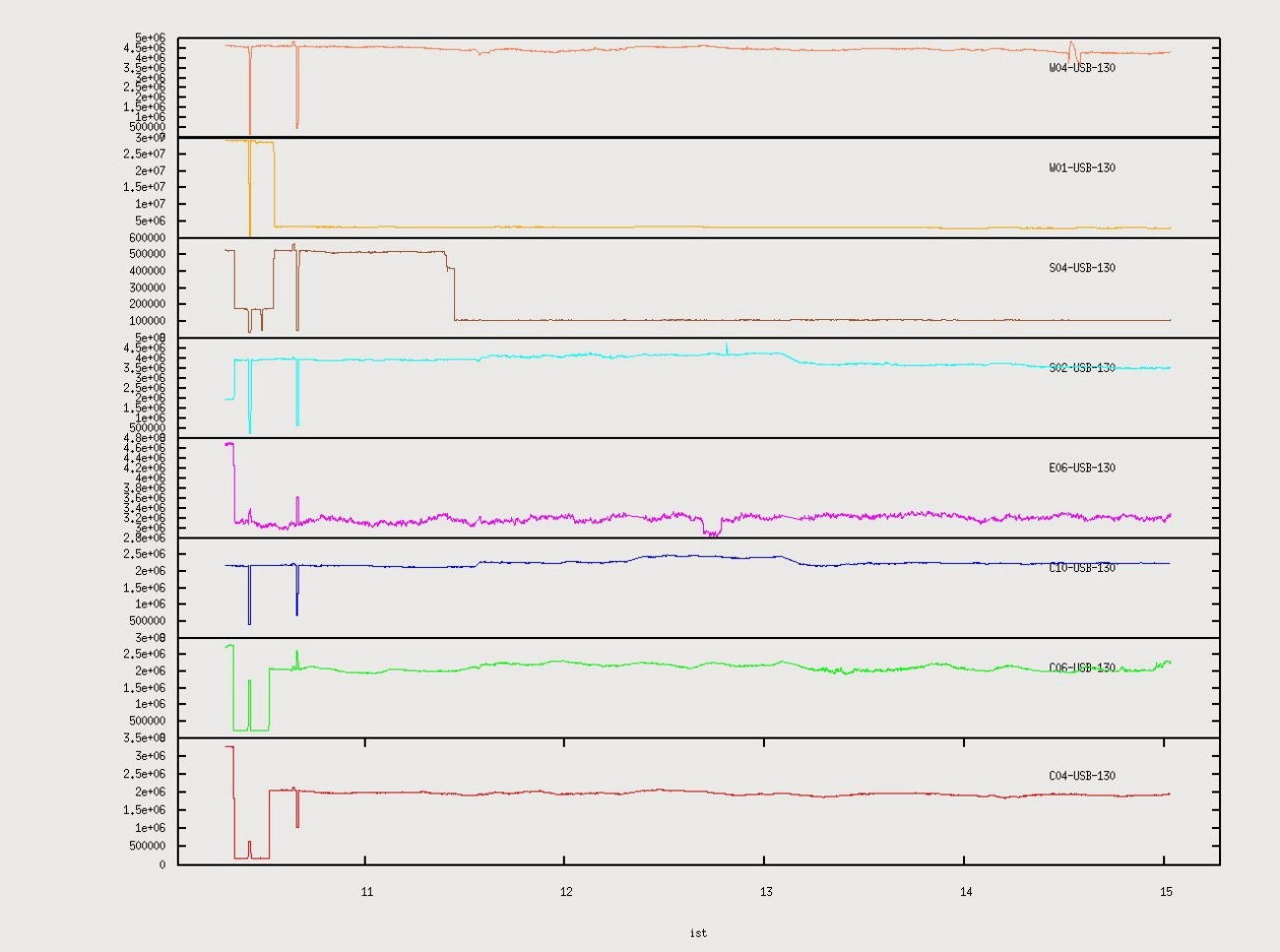

Fig 5.3.1*: Self-power (amplitude) as a function of time. Note the observations were made using the GPU at the L-band on 16th Aug 2013.*

5.3.3 Cross-power(amplitude) Stability

Cross bandshapes are taken w.r.t. C04 antenna. The cross bandshapes are also good. As there were 4 sources observed in this observation session.

Table 5.3.2: *Average cross-correlation coefficients as a function of time. Note that only the good part of the data was included while determining the average. Tables 3.2 and 3.3 shows expected cross-correlation coefficients.*

C04	C06	C10	E06	S02	S04	W01	W04
Ref	0.02	0.01	0.02	0.035	0.025	0.035	0.025

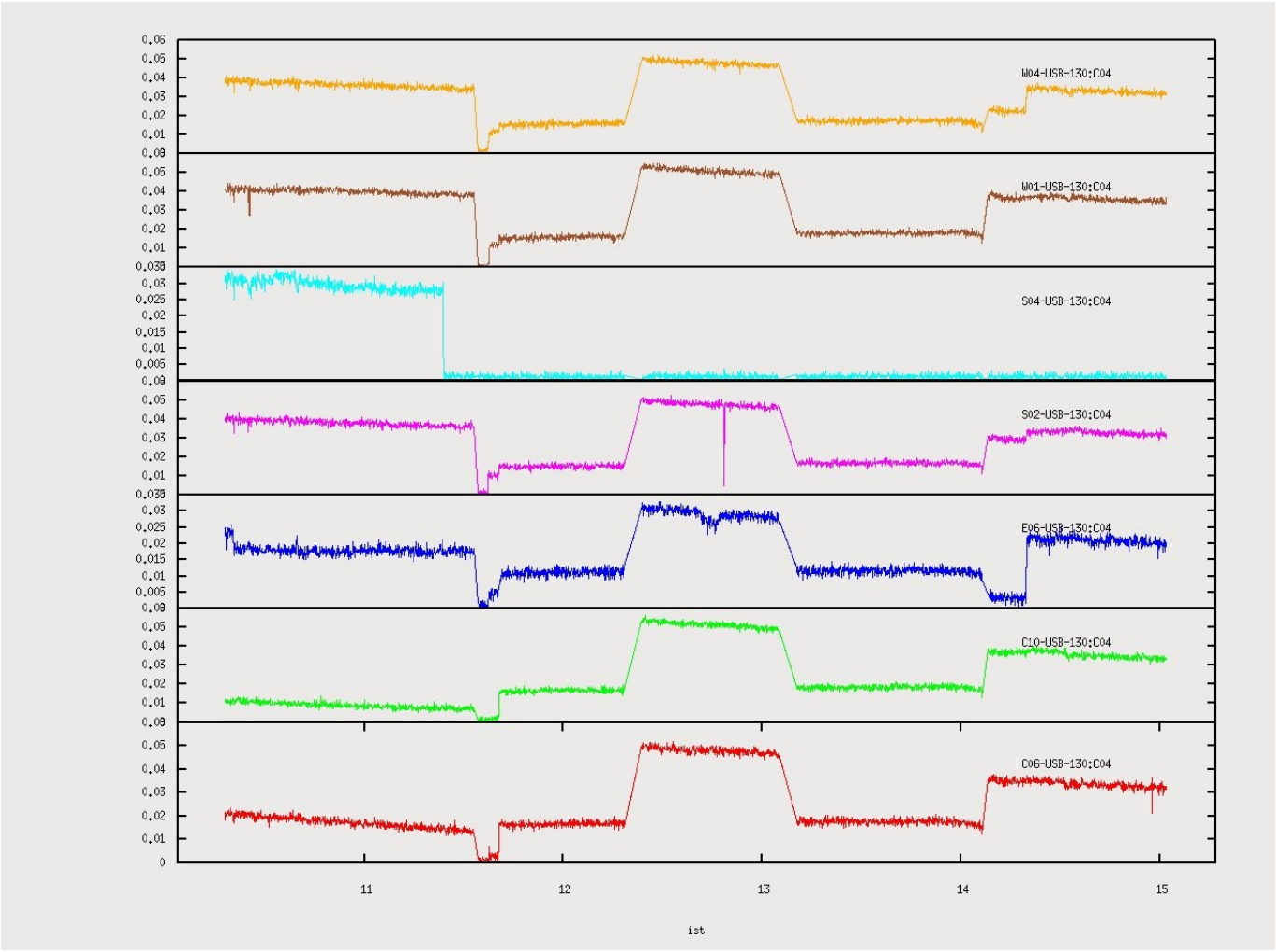

***Fig 5.3.2**: Cross-power (amplitude)as a function of time. Note the reference antenna is C04 and the data is acquired using GPU at the L-band on 16^{h} Aug 2013.*

5.3.4 Phase stability as a function of time. Note again, the reference antenna is C04.

Key inferences:
C06 - Good.
C10 - Good.
E06 - Good at beginning then 2 Winds at last 2 hour run.
S02 - Good.
S04 - Previously shown good quality phase then given for maintenance.
W01 - Good.
W04 - At the start it was good then Almost 2 winds at last 3 hour run.

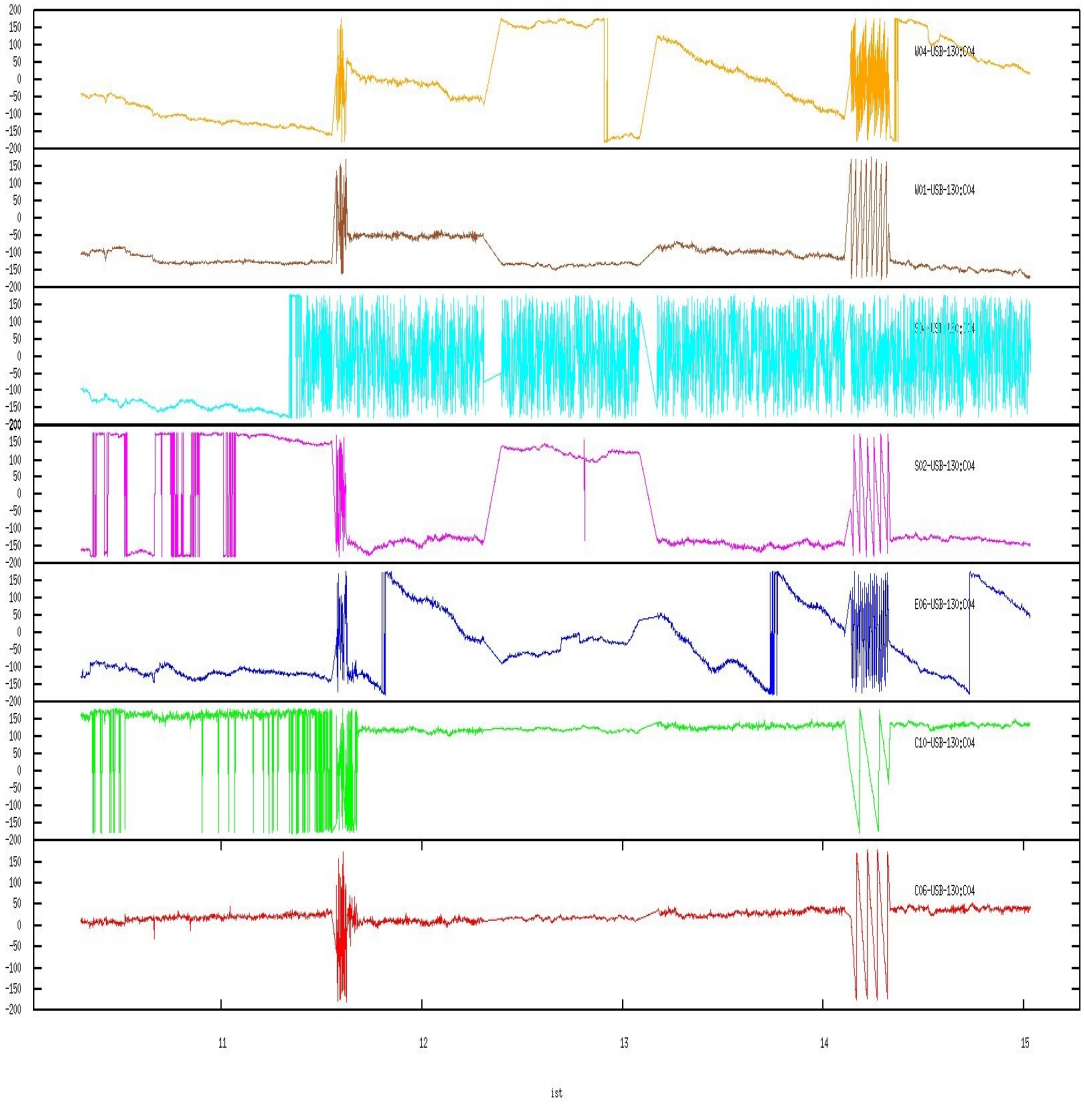

Fig 5.3.3*: Variation in phase as a function of time. Note the reference antenna is C04 and the data acquired using GPU at the L-band on 16th Aug 2013.*

5.3.5 Phase stability as a function of channels, and the reference antenna is C04.

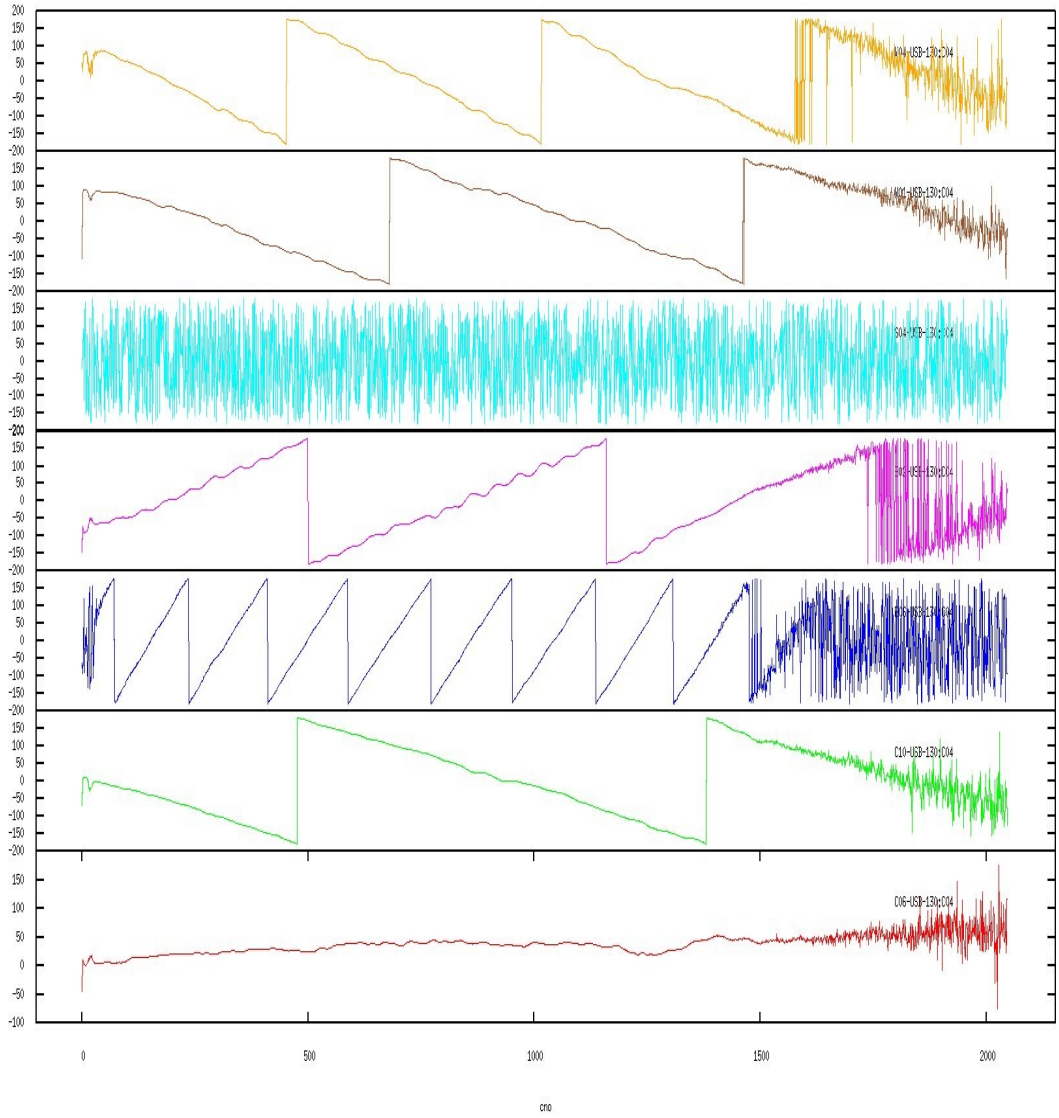

Fig 5.3.4*: Variation in phase as a function of channel. Note the reference antenna is C04 and the data acquired using GPU at the L-band on 16th Aug 2013.*

Key inferences:

C06 - Good quality phase over all channels.
C10 - 2 (-ve slope) loops seen over 1500 channels.
E06 - 8 (+ve slope) loops seen over 1500 channels.
S02 - 2 (+ve slope) loops seen over 1500 channels
S04 - 4 (+ve slope) loops seen over 1500 channels.
W01 - 2 (-ve slope) loops seen over 1500 channels.
W04 - 2.5 (-ve slope) loops seen over 1500 channels.

5.3.6 Self-power amplitude (or the self-bandshape) stability

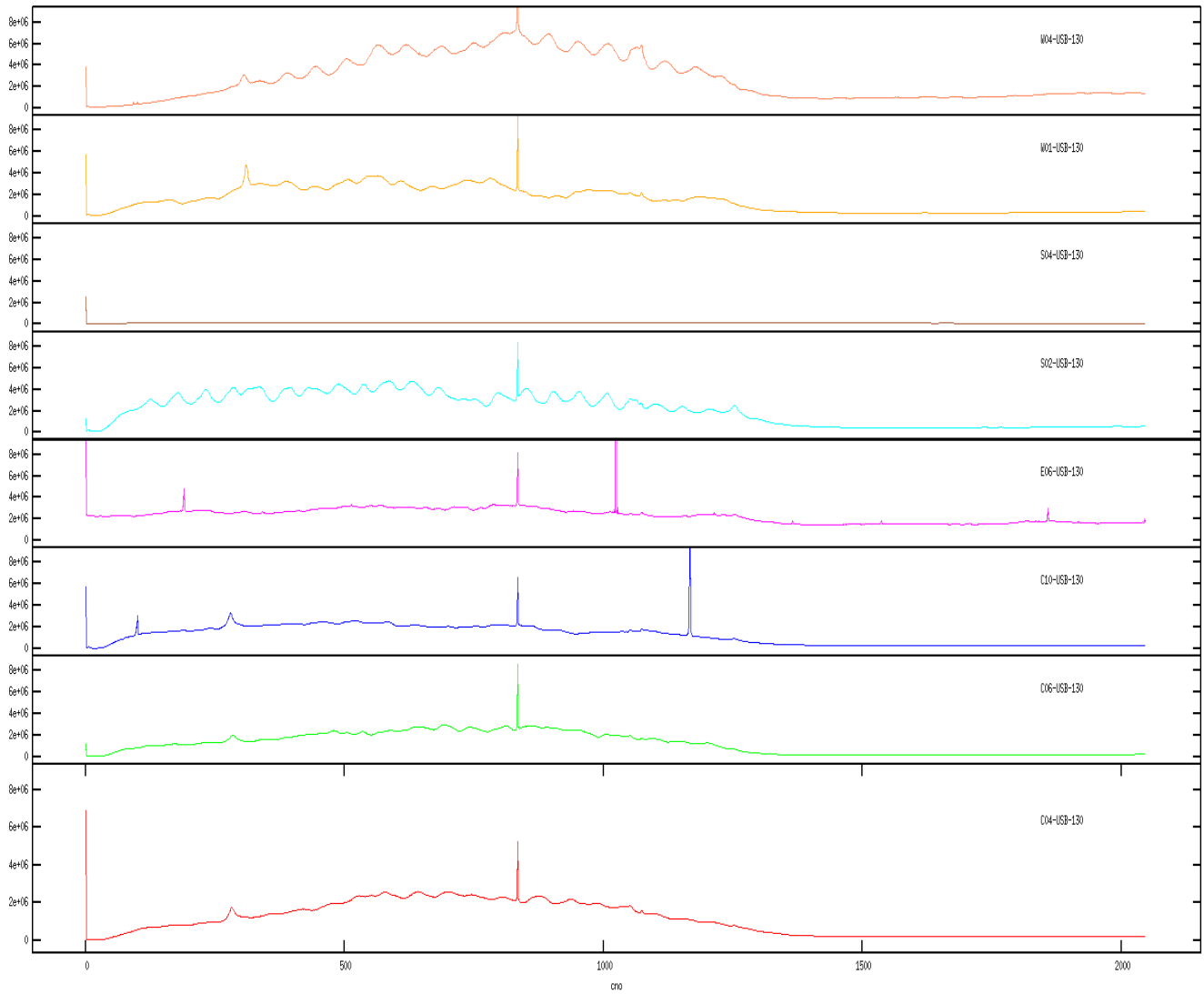

***Fig 5.3.5**: Self-power amplitude as a function of channels, i.e. bandshapes. Note the data was acquired using GPU at the L-Band on 16th Aug 2013.*

5.3.7 Cross-power amplitude (or the cross-bandshape). Again, note the reference is C04.

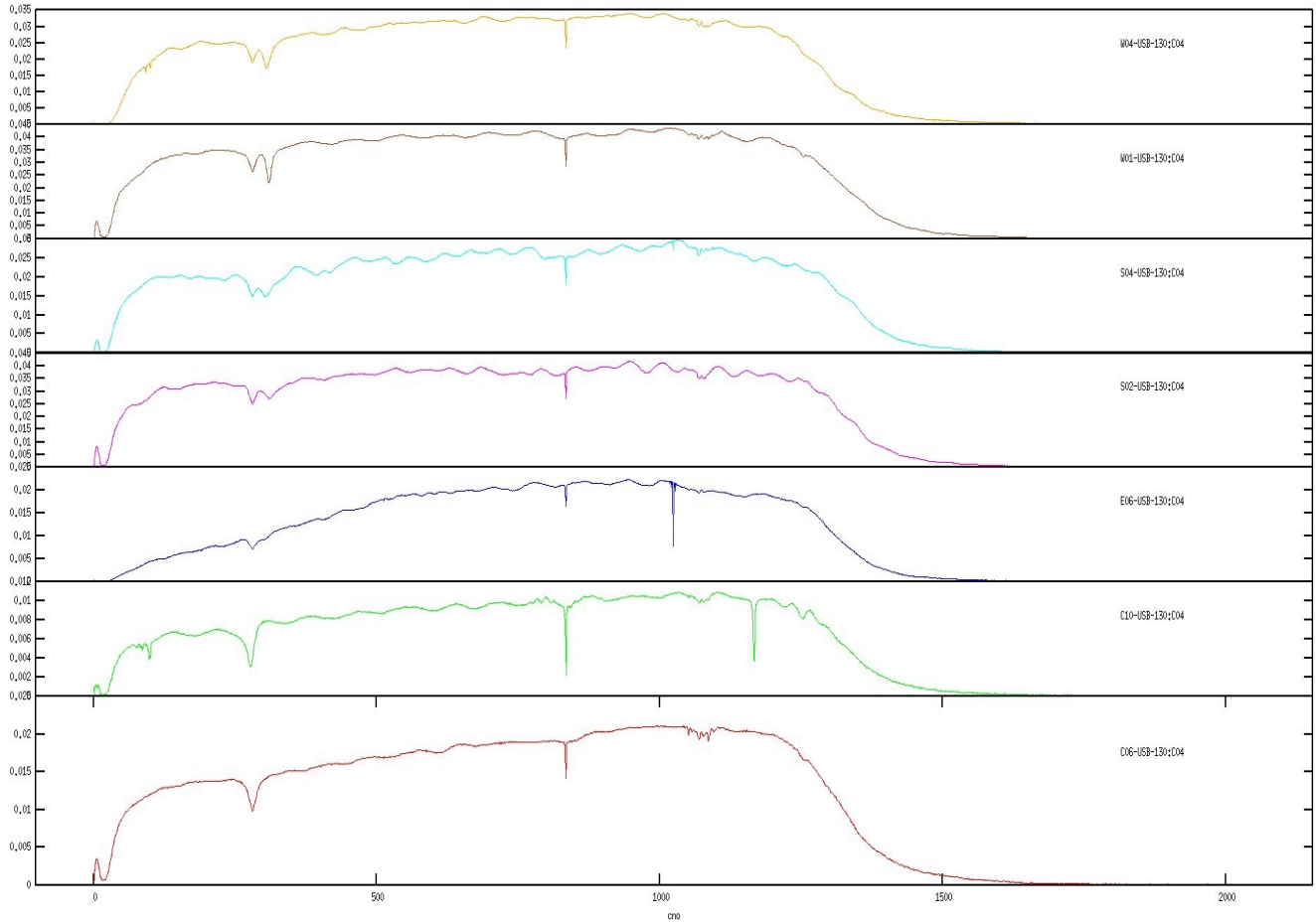

Fig 5.3.6*: Cross-power (amplitude) as a function of channels or the cross-power bandshapes. Note the reference antenna is C04 and the data is acquired using GPU at the L-Band on 16th Aug 2013.*

5.4 Day-4 (30th August 2013)

5.4.1 Observation Log

LTAFILE : gpu_30aug2013_1350_L.lta.1
Settings:
Observe date 30 AUG 2013
Object 3C48
LO1 1420.0 MHz
RF 1350 MHz
Band = flipped (GUI), meaning LO1 > RF (or LSB)
No. of Channels 2048
Channel-width 97.66 kHz.

Operator's note: this run was a continuous track on 3C48.

5.4.2 Self-power(amplitude) Stability

This session was having 5.5 hours slot except minute jumps in amplitude of W04 and S04 was low in counts. Remaining 6 antennas were good.

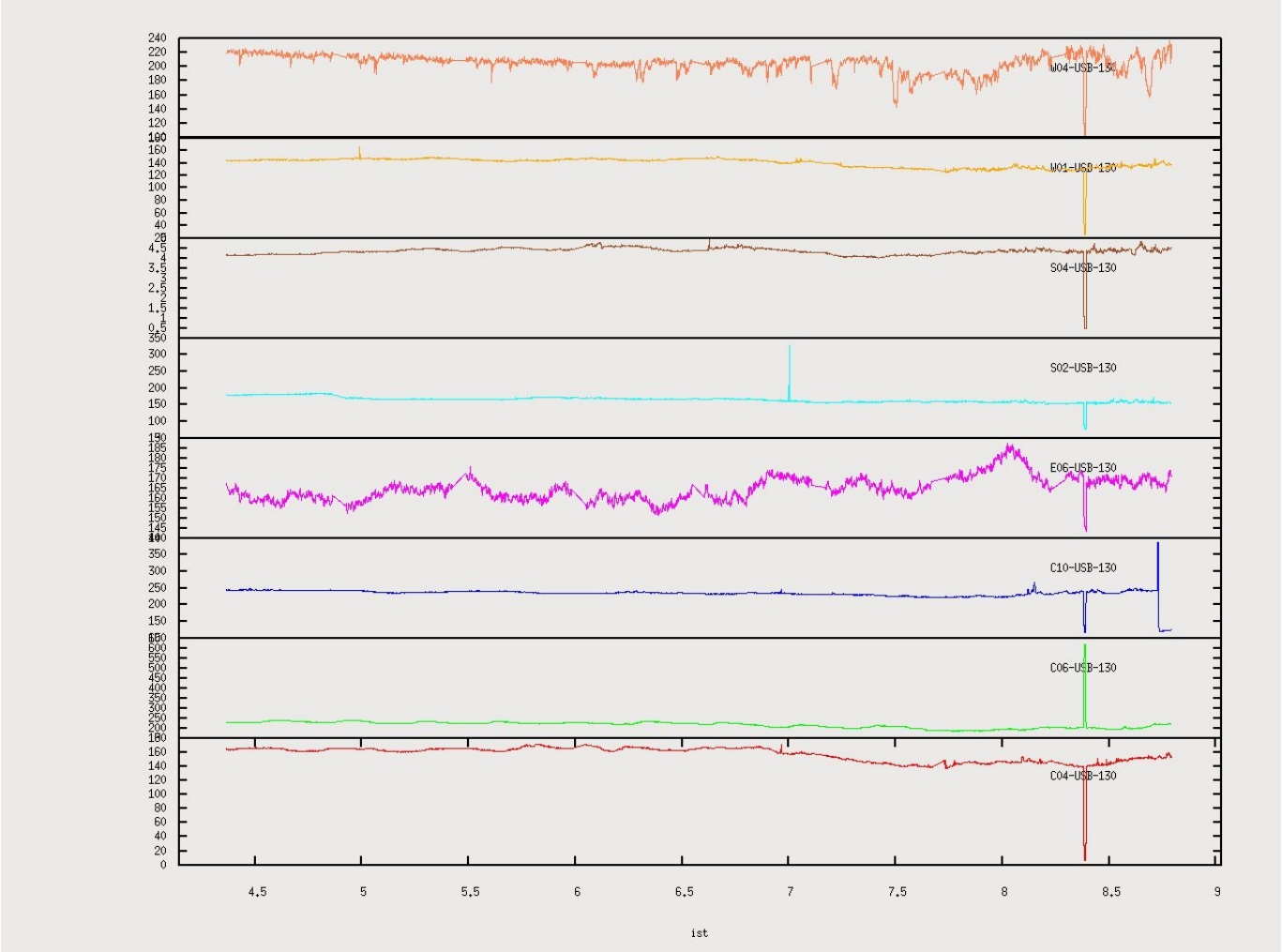

***Fig 5.4.1**: Self-power(amplitude) as a function of time. Note the observation were made using the GPU at the L-band on 30th Aug 2013.*

Table 5.4.1: *Averaged self-correlation coefficients as a function of time. Note that only the good part of the data was included while determining the average.*

C04	C06	C10	E06	S02	S04	W01	W04
200	225	300	175	175	20	150	200

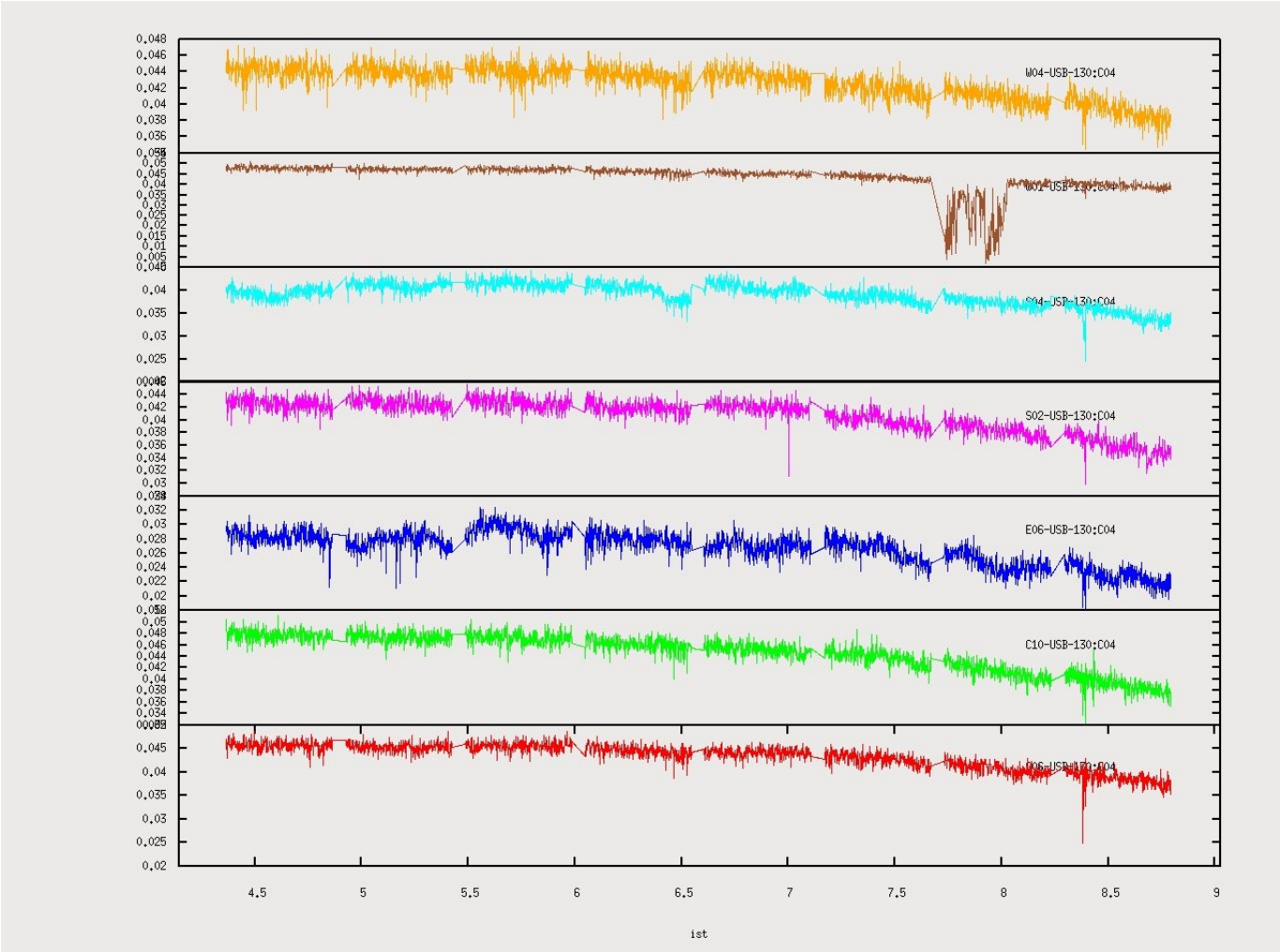

Fig 5.4.2*: Cross-power (amplitude) as a function of time. Note the reference antenna is C04 and the data is acquired using GPU at the L-band on 30th Aug 2013.*

5.4.3 Cross-power(amplitude) Stability

Amplitude stability w.r.t C04 is taken. All the antennas are showing almost stable cross correlation coefficients. W01 shows one small drop between 07:30 Hrs and 08:00 Hrs.

Table 5.4.2: *Average cross-correlation coefficients as a function of time. Note the reference antenna is C04. Tables 3.2 and 3.3 shows expected cross-correlation coefficients.*

C04	C06	C10	E06	S02	S04	W01	W04
Ref.	0.04	0.04	0.025	0.035	0.035	0.040	0.035

5.4.4 Phase Stability as a function of time; the reference antennas is C04.

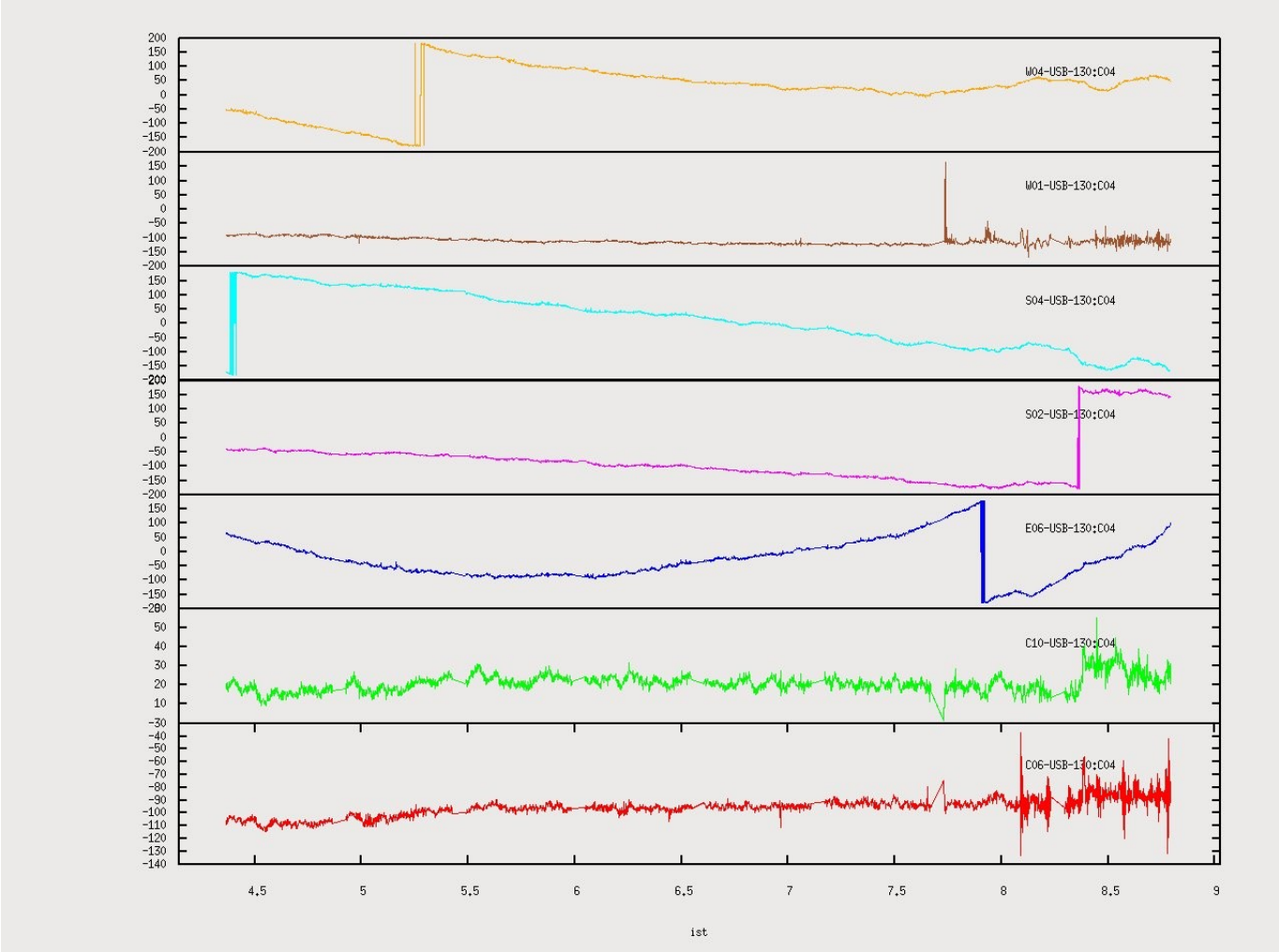

***Fig 5.4.3**: Variation in phase as a function of time. Note the reference antennas is C04 and the data is acquired using GPU at the L-band on 30th Aug 2013.*

Key inferences:
C06 - Good.
C10 - Good.
E06 - Reasonably Good.
S02 - Good.
S04 - Good.
W01 - Good.
W04 - Good.

5.4.5 Phase Stability as a function of channel; the reference antenna is C04.

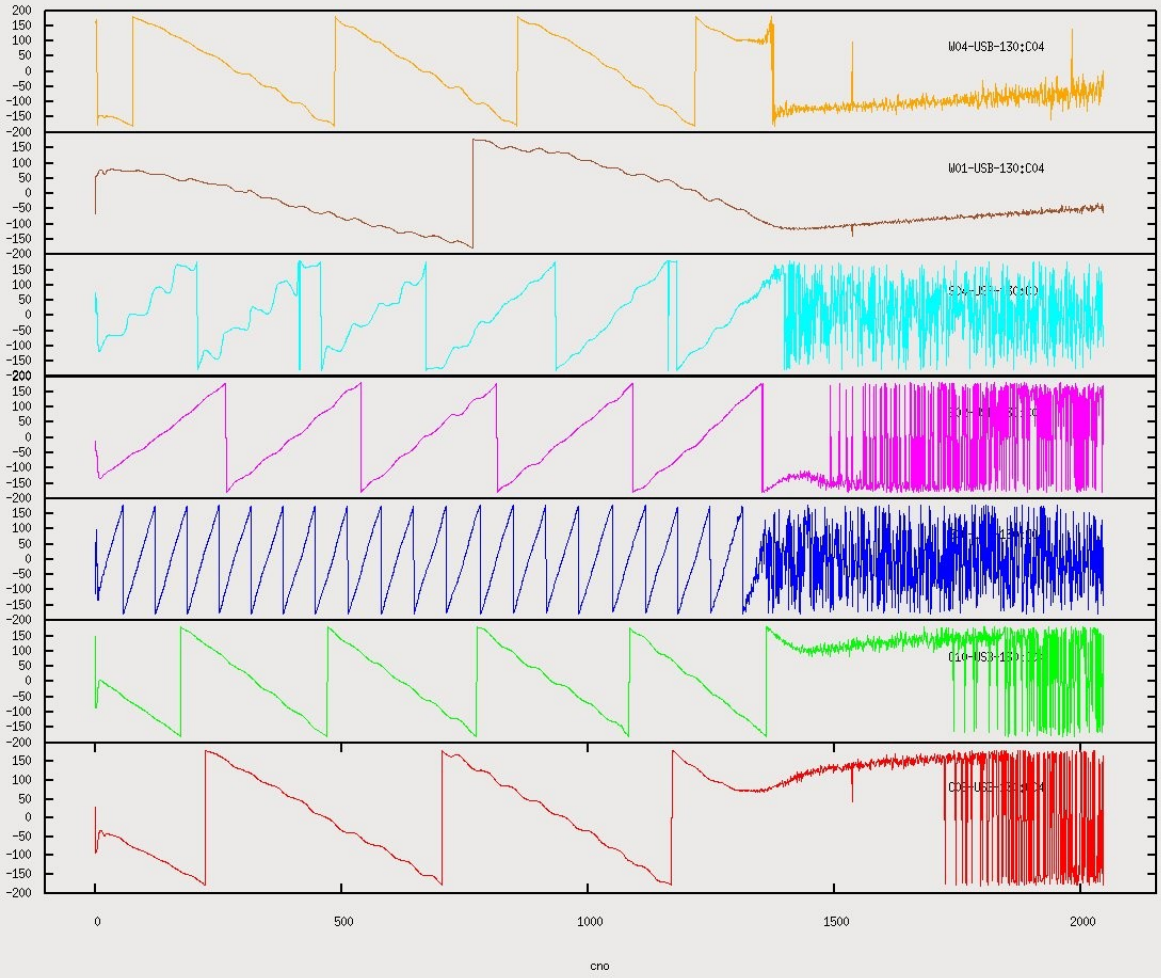

Fig 5.4.4: *Variation in phase as a function of channel. Note the reference antenna is C04 and the data is acquired using GPU at the L-band on 30th Aug 2013.*

Key inferences:

C06 - 3 -ve sloped loops seen over 1500 channels.
C10 - 4 -ve sloped loops seen over 1500 channels.
E06 - 20 +ve sloped loops seen over 1500 channels.
S02 - 5 +ve sloped loops seen over 1500 channels
S04 - 6 +ve sloped loops seen over 1500 channels.
W01 - 2 -ve sloped loops seen over 1500 channels.
W04 - 3.5 -ve sloped loops seen over 1500 channels.

5.4.6 Self-power amplitude (or the self-bandshape) stability

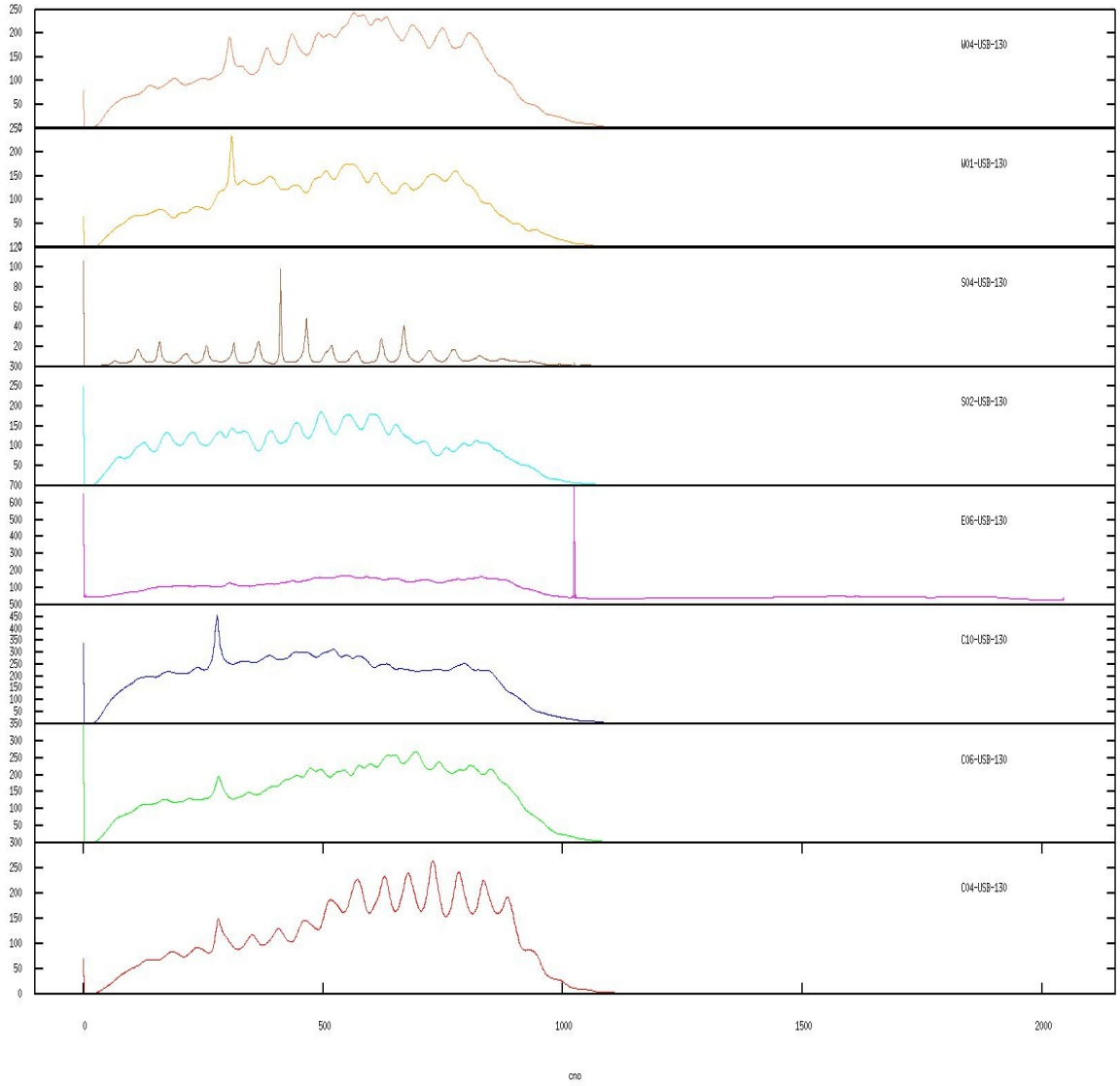

Fig 5.4.5*: Self-power amplitude as a function of channels, i.e. bandshapes. Note the data was acquired using GPU at the L-Band on 30th Aug 2013.*

5.4.7 Cross-power amplitude (or the cross-bandshape). Again, note the reference antenna is C04.

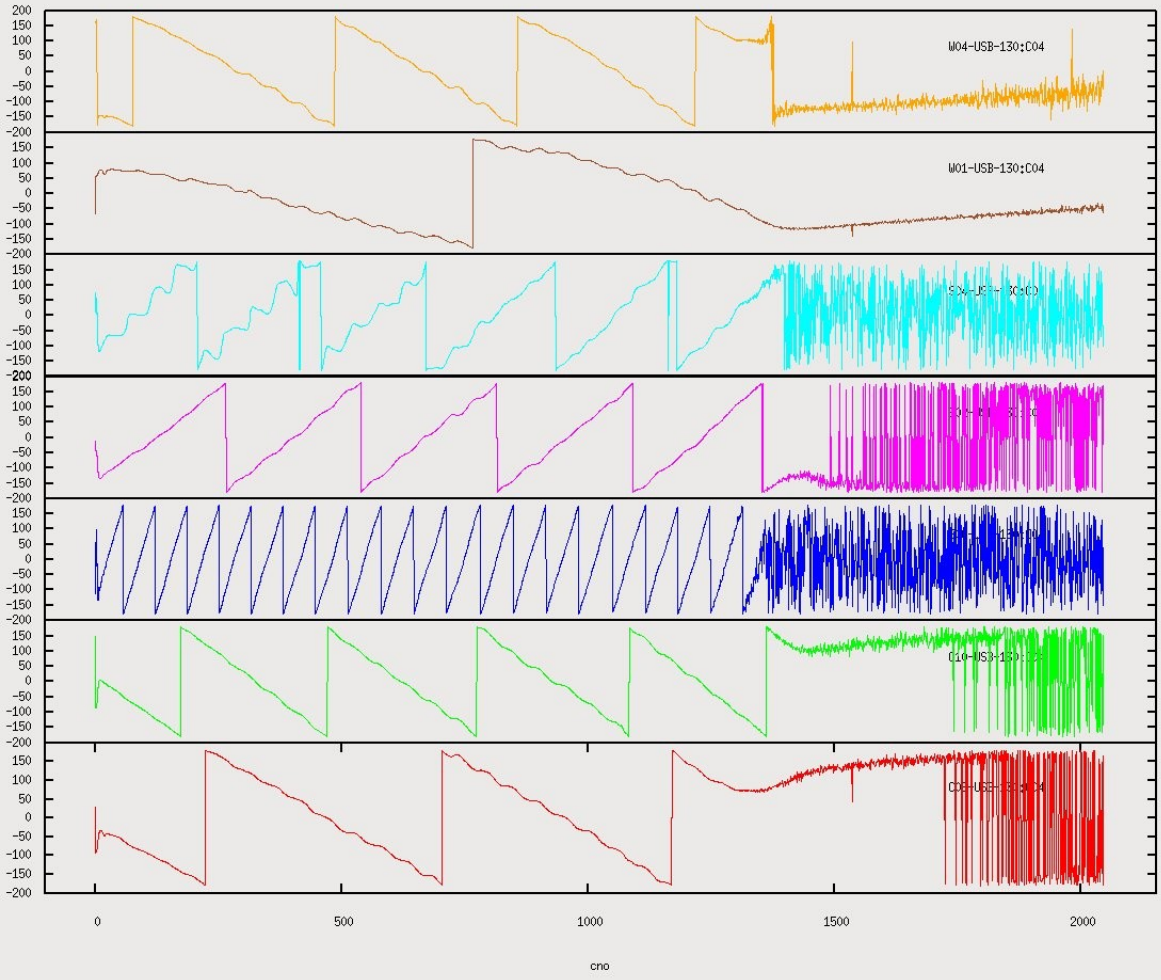

***Fig 5.4.6**: Cross-power (amplitude) as a function of channels or the cross-power bandshapes. Not ethe reference antenna is C04 and the data is acquired using GPU at the L-Band on 30th Aug 2013.*

5.5 Day-5 (25th September 2013)

5.5.1 Observation Log

LTAFILE : gputest_25sep2013_1450_200_3c286.lta
Settings:
Objects 3C48, 3C147, 3C286, 0607-0836
LO1 1520 MHz
RF 1450 MHz
Band = flipped (GUI), meaning LO1 > RF (or LSB)
E06 Not working
W01 Self Low.
No. of Channels 2048
Channel-width 97.66 KHz.

Operator's note: There are a total of 20 scans spread over ~12 hrs, which are listed below.

```
  0 3C286       13h31m46.31 +30d26'19.32" 23:56:31
  1 3C468.1     23h51m35.61 +64d44'53.25" 00:45:57
  2 3C48        01h38m28.51 +33d13'45.48" 01:59:33
  3 3C48        01h38m28.52 +33d13'45.53" 06:44:47
  4 3C147       05h43m40.06 +49d51'27.44" 07:16:06
  5 0607-0836   06h08m06.36 -08d36'12.24" 07:24:22
  6 3C147       05h43m40.06 +49d51'27.44" 07:48:05
  7 0607-0836   06h08m06.36 -08d36'12.24" 07:56:22
  8 3C147       05h43m40.06 +49d51'27.44" 08:20:18
  9 0607-0836   06h08m06.36 -08d36'12.24" 08:28:48
 10 3C147       05h43m40.06 +49d51'27.44" 08:52:51
 11 0607-0836   06h08m06.36 -08d36'12.24" 09:01:28
 12 3C147       05h43m40.06 +49d51'27.44" 09:25:57
 13 0607-0836   06h08m06.36 -08d36'12.24" 09:35:01
 14 3C147       05h43m40.06 +49d51'27.44" 10:00:04
 15 0607-0836   06h08m06.36 -08d36'12.24" 10:09:42
 16 3C147       05h43m40.06 +49d51'27.44" 10:35:45
 17 0607-0836   06h08m06.36 -08d36'12.24" 10:46:16
 18 3C147       05h43m40.06 +49d51'27.44" 11:13:27
 19 0607-0836   06h08m06.36 -08d36'12.24" 11:24:58
 20 3C147       05h43m40.06 +49d51'27.44" 11:53:16
```

5.5.2 Self-power(amplitude) Stability

This slot was one of the biggest slot i.e. 13.5 hours slot.
In this slot multiple sources were observed. Except E06 i.e. non-working antenna and W01 i.e. low self counts remaining 6 antennas were good.

Table 5.5.1: *Average self-correlation coefficients as a function of time. Note that only the good part of the data was included while determining the average.*

C04	C06	C10	E06	S02	S04	W01	W04
120	120	110	Not Working	130	100	5	110

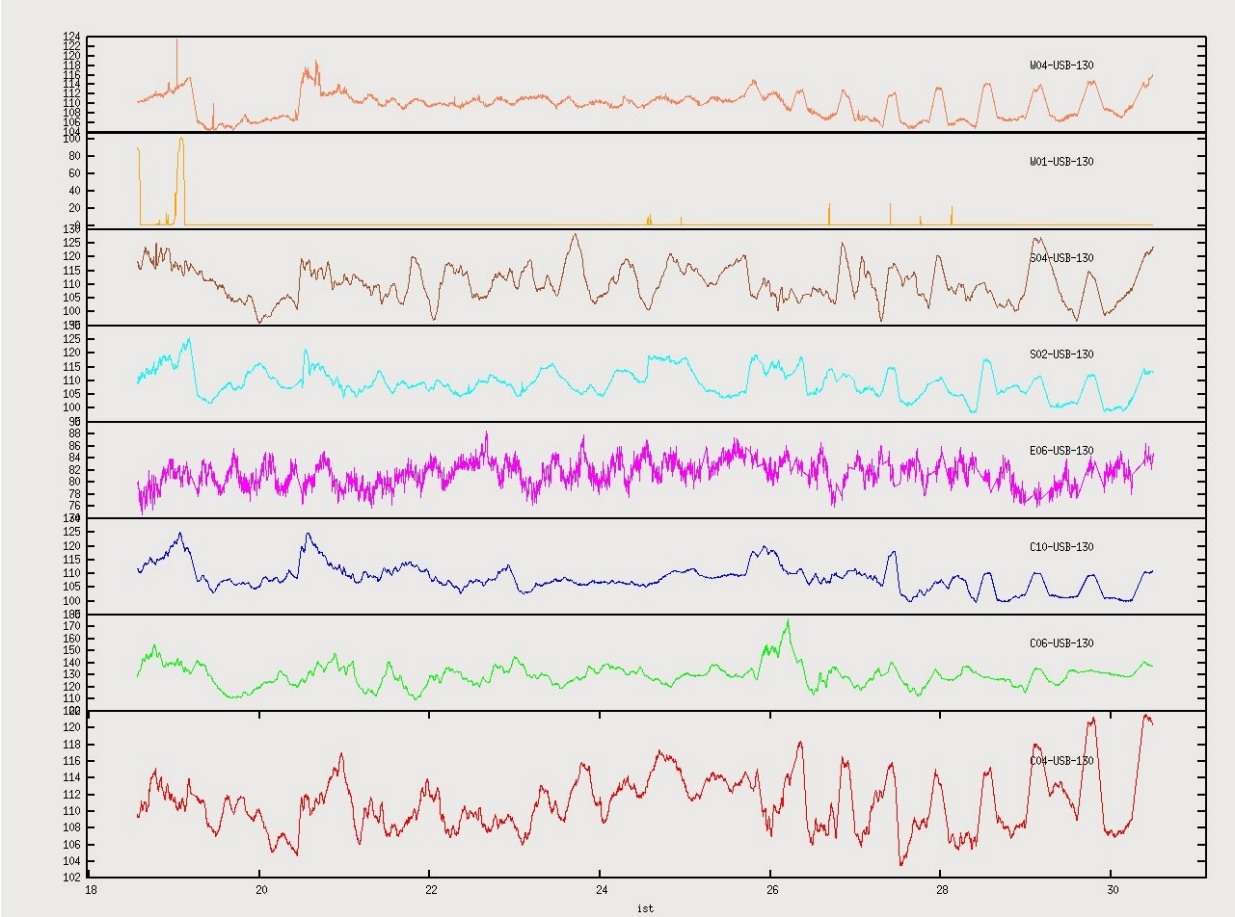

Fig. 5.5.1*: Self-power (amplitude) as a function of time. Note the observations were made using the GPU at the L-band on 25th Sep 2013.*

5.5.3 Cross-power(amplitude) Stability

Cross correction coefficient for each source with respect to the C04 antenna were almost in the same range for each antenna except E06 antenna. (See Fig. 5.5.2)

Table 5.5.2: *Table showing average cross-correlation coefficients as a function of time for each calibrator source. Note reference antenna is C04. Tables 3.2 and 3.3 expected cross-correlation coefficients.*

Antenna	3C48	3C147	3C286	0607-0836
C04	Ref. Ant	Ref. Ant	Ref. Ant	Ref. Ant
C06	0.03	0.045	0.03	0.0025
C10	0.03	0.045	0.03	0.002
E06	Not Working	Not Working	Not Working	Not Working
S02	0.025	0.05	0.03	0.002
S04	0.01	0.05	0.03	0.002
W01	0.02	0.045	0.025	0.002
W04	0.035	0.045	0.025	0.002

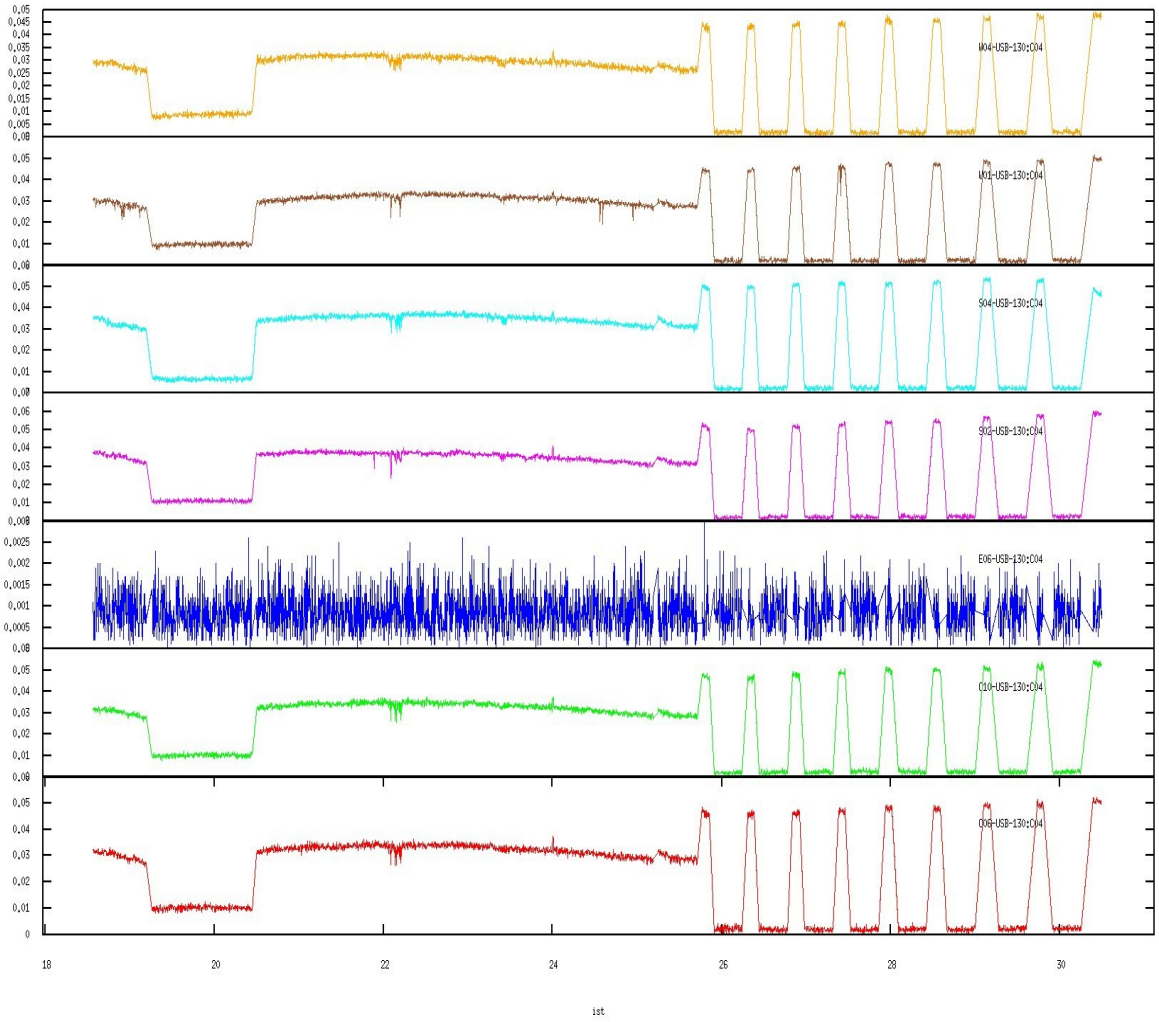

***Fig 5.5.2**: Cross-power (amplitude) as a function of time. Note the reference antenna is C04 and the data is acquired using GPU at the L-band on 25th Sep 2013.*

5.5.4 Phase Stability as a function of time; again the reference antenna is C04.

Key inferences:

C06 - Good.
C10 - Good.
E06 - Not working.
S02 - Good.
S04 - Good.
W01 - Good.
W04 - Good.

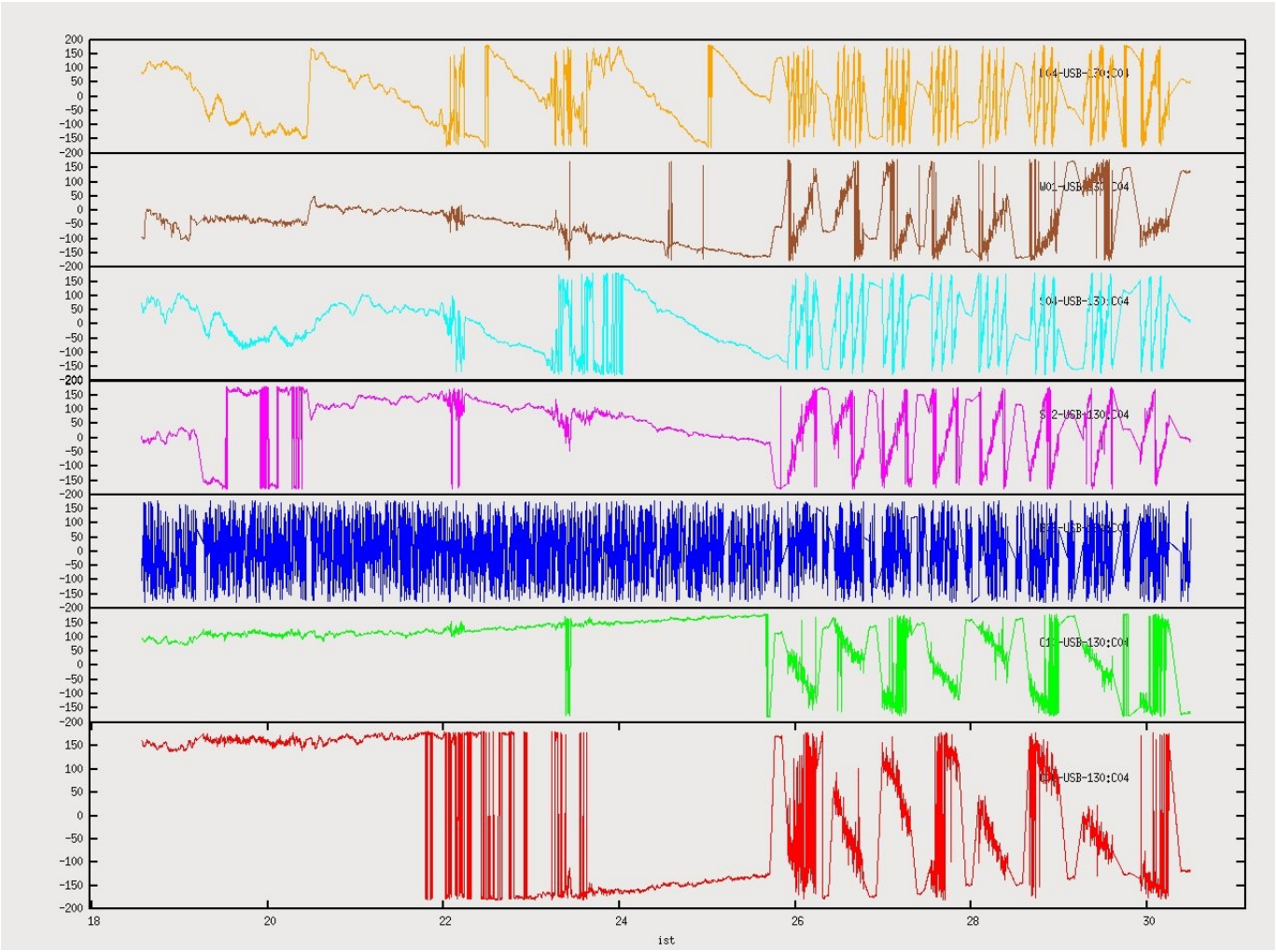

Fig 5.5.3*: Variation in phase as a function of time. Note the reference antennas is C04 and the data isacquired using GPU at the L-band on 25th Sep 2013.*

5.5.5 Phase Stability over channel. Note that reference antenna is C04.

Note this inference is for all calibrators namely, 3C48, 3C286, 3C147, 3C468.1.

Key inferences:
C06 - 1 +ve sloped loops seen over 1500 channels.
C10 - 1 +ve sloped loops seen over 1500 channels.
E06 - Not working.
S02 - 2 -ve sloped loops seen over 1500 channels
S04 - 2 -ve sloped loops seen over 1500 channels.
W01 - Stable over channel.
W04 - Almost stable.

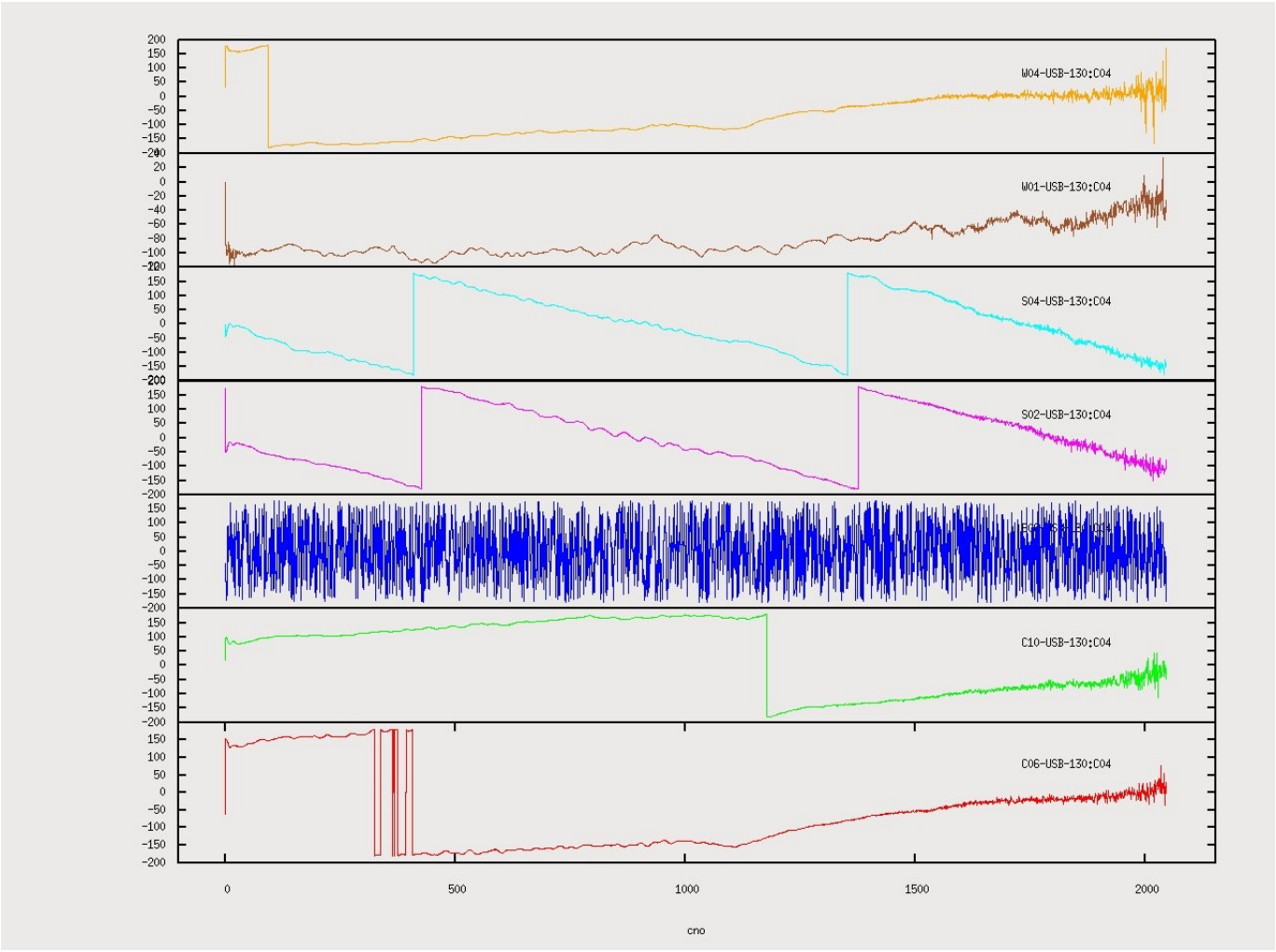

Fig 5.5.4*: Variation in phase as a function of channel. Note the reference antenna is C04 and the data is acquired using GPU at the L-band on 25th Sep 2013.*

Instead for one calibrator, 0607-0836, key inferences are:
C06 - 1 (+ve slope) loops seen over 1500 channels.
C10 - 1 (+ve slope) loops seen over 1500 channels.
E06 - Not working.
S02 - Almost stable seen over 1500 channels
S04 - Almost stable seen over 1500 channels.
W01 - 1.5 (-ve slopes) rotation over all channel.
W04 - 4 (-ve slopes) loops over 1500 channels.

5.5.6 Self-power amplitude (or the self-bandshape) stability

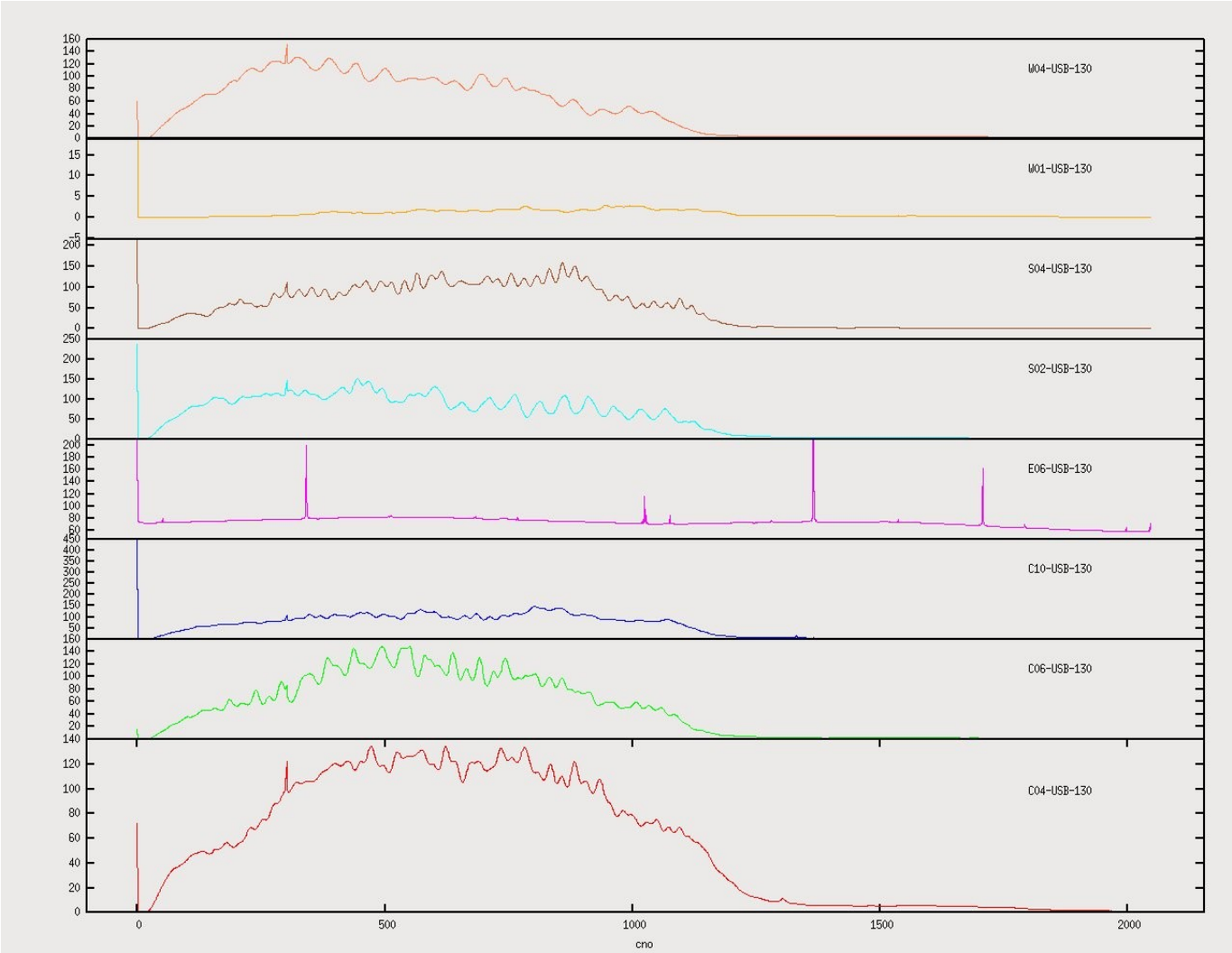

Fig 5.5.5*: Self-power amplitude as a function of channels, i.e. self-power bandshapes. Note the data was acquired using GPU at the L-Band on 25th Sep 2013.*

5.5.7 Cross-power amplitude (or the cross-bandshape). Again, note the reference antenna is C04.

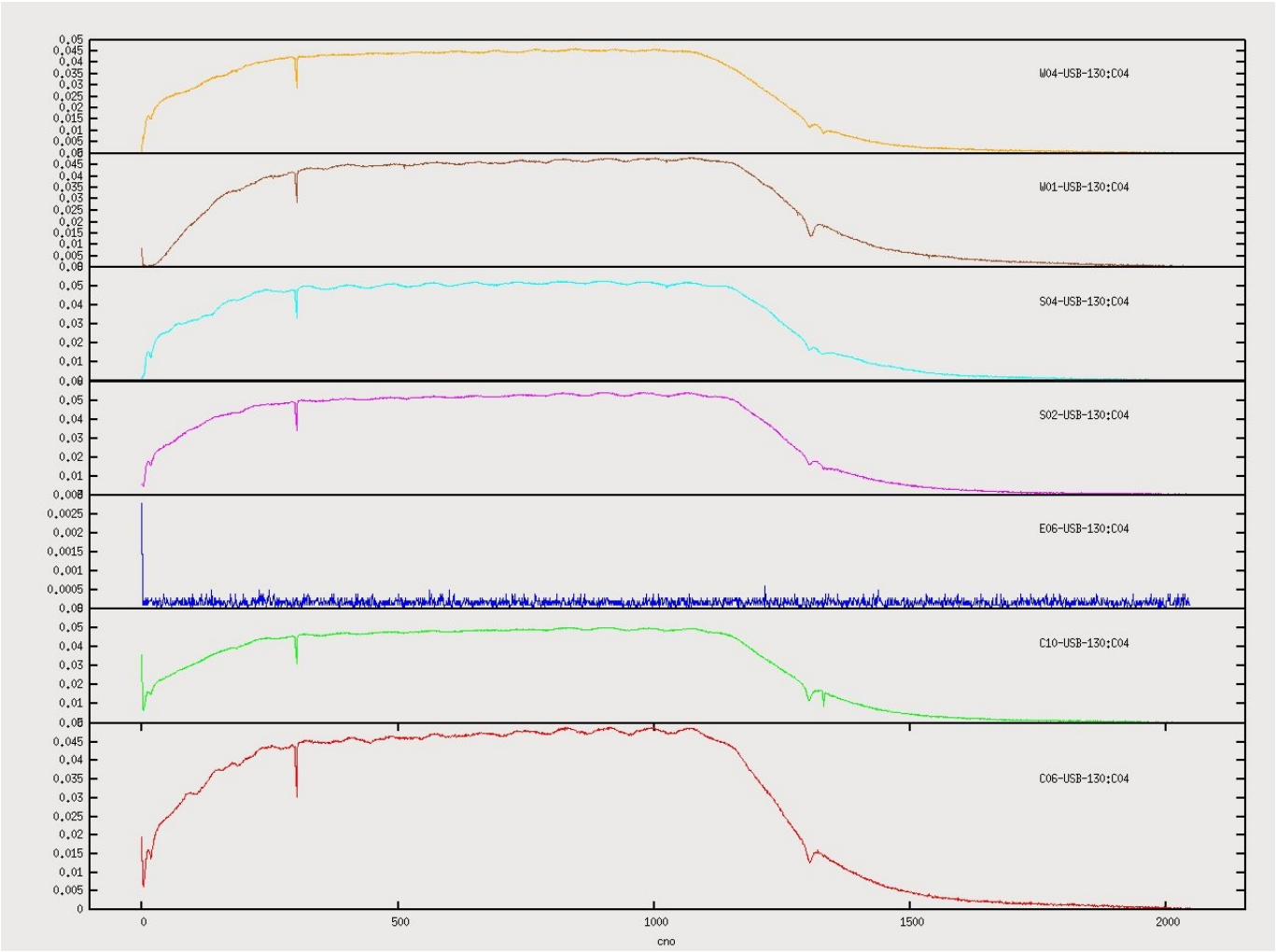

***Fig 5.5.6**: Cross-power (amplitude) as a function of channels or the cross-power bandshapes. Note the reference antenna is C04 and the data is acquired using GPU at the L-Band on 25th Sep 2013.*