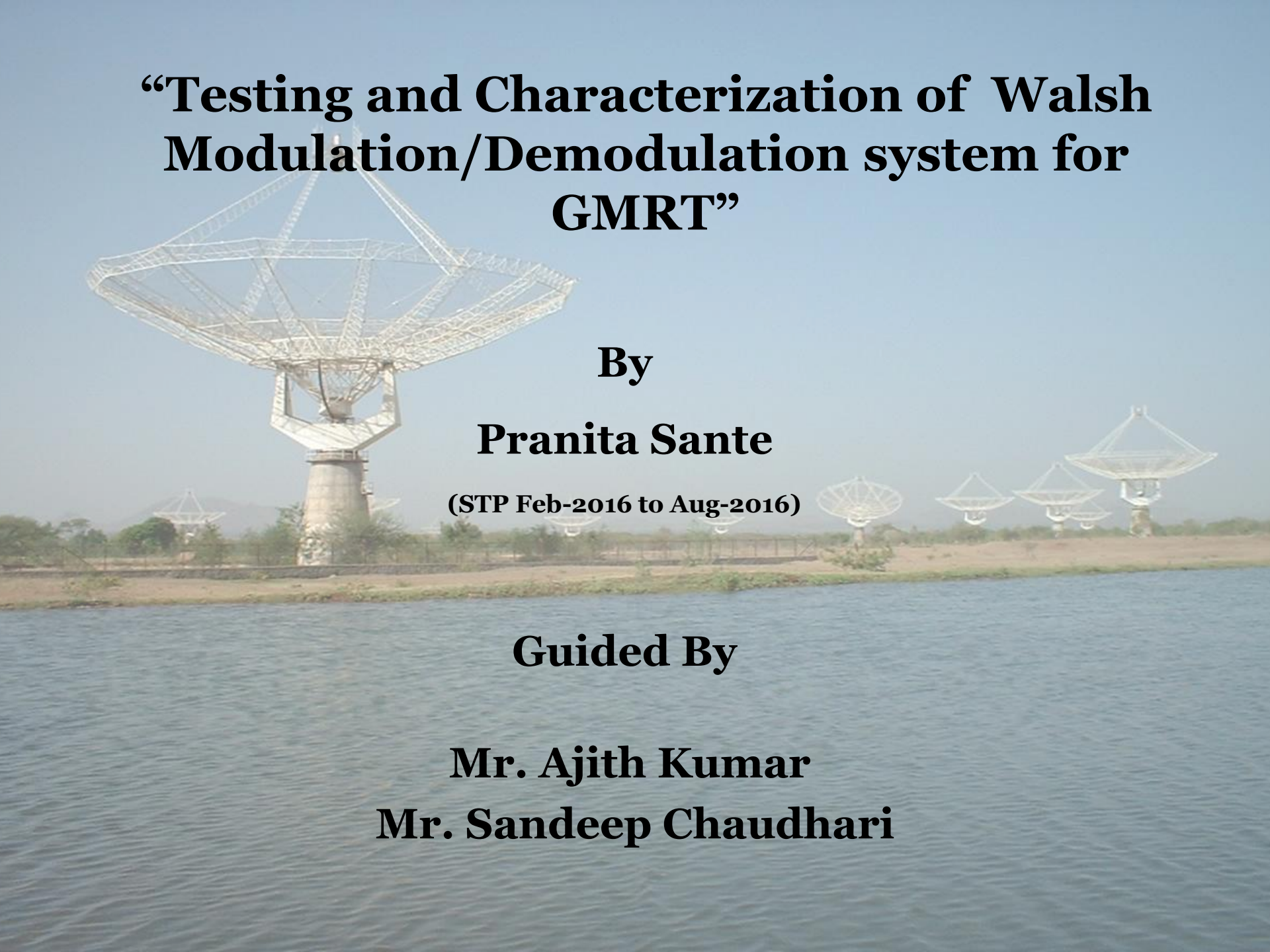

“Testing and Characterization of Walsh Modulation/Demodulation system for GMRT”

By

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(STP Feb-2016 to Aug-2016)

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Introduction

In GMRT there are 30 antennas with dual polarization channels from each antenna providing 60 RF signals.

Signals from one antenna could leak into another antenna at various points along the signal flow chain. This is normally referred to as cross-talk. This would cause a spurious correlation between the baseband signals from these two antennas.

The effect of leakage can be minimized by switching the phase of the RF signal of each antenna by a pattern that is ortho-normal to the pattern used for all other antennas.

At the correlator the exact reverse phase switching is done for each anteena so that the original phase is recovered just before the cross correlation is done such a scheme would greatly reduce the cross talk at all points between the RF amplifier and base band,

.

My Work

- Understanding walsh modulation demodulation system of GMRT
- Lab testing for walsh system.
- Testing and debugging the walsh scheme.
- Carrying out antenna testing.

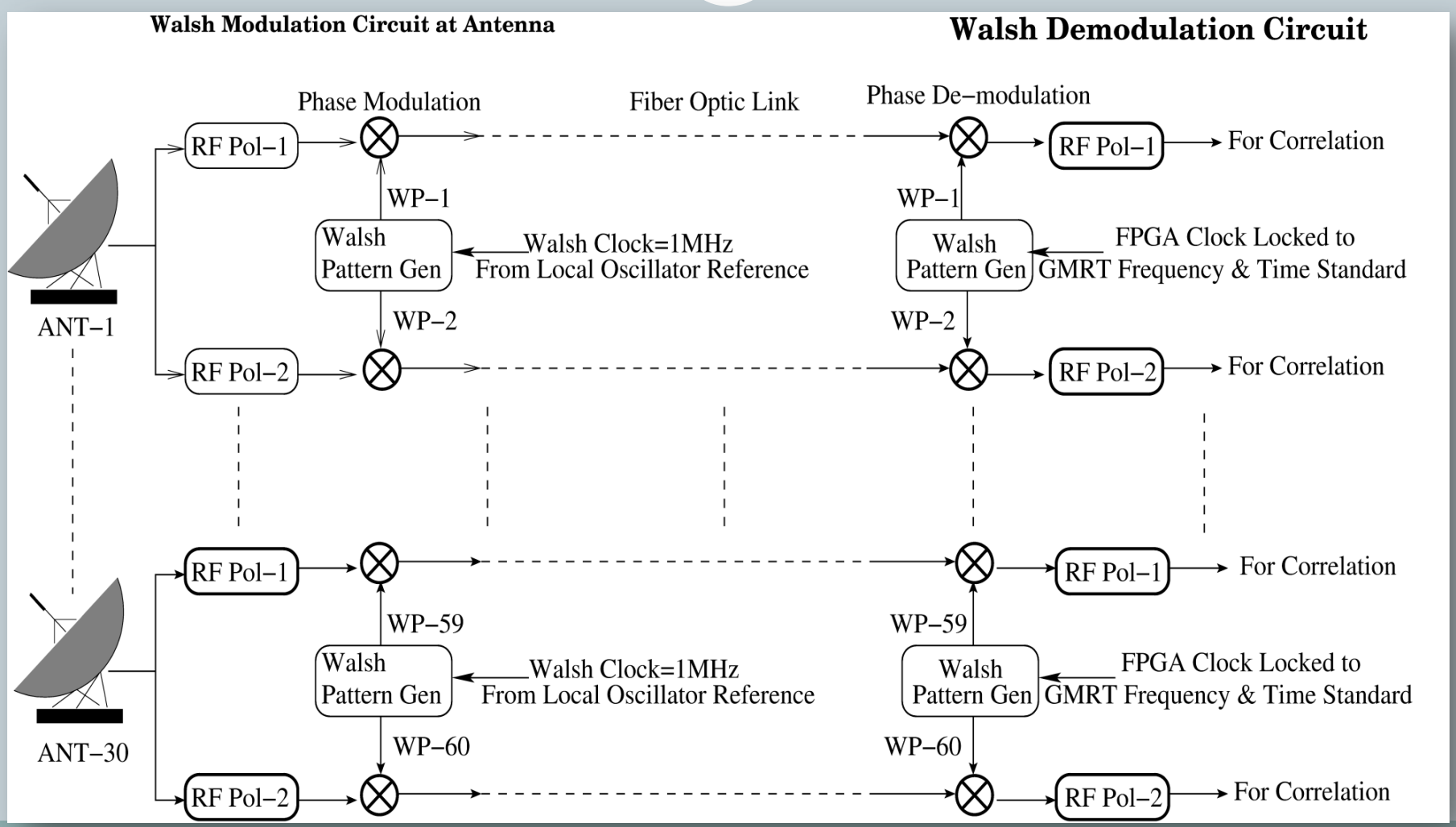
Overview of the Presentation

- Introduction to walsh scheme
- Proposed Walsh scheme for GMRT
- GMRT Walsh Modulator-Demodulator facilities
- Delay Hunting Algorithm
- Characterization of walsh system in Lab
  - ✓ Cross talk reduction test – with sine wave
  - ✓ Correlation loss test – with noise & with sine wave
- Modification : Basic Walsh for delay hunting
- Modified Delay Hunting Test
- Debugging
  - ✓ Walsh channel swap test
  - ✓ Debugging Delay Hunting Failure reasons
- Antenna testing

Introduction to Walsh scheme

- Walsh patterns are a series of square waves & these walsh functions satisfy certain orthonormal relations.
- For modulation purpose these walsh patterns are generated using CPLD based Walsh card circuit in D-49 PIU at antenna base.
- Each walsh card generates 64 Cal patterns and each pattern is of 128 bit.
- For each GMRT antenna will have unique walsh pattern for it's two polarizations. Hence for GMRT total 60 Walsh patterns are required.
- FPGA based Walsh demodulation is implemented in ROACH board where digitization occurs.
- Digital backend generates the identical Walsh pattern which is used for demodulation after the digitization stage

Proposed Walsh Scheme for GMRT



GMRT Walsh Modulator-Demodulator facilities

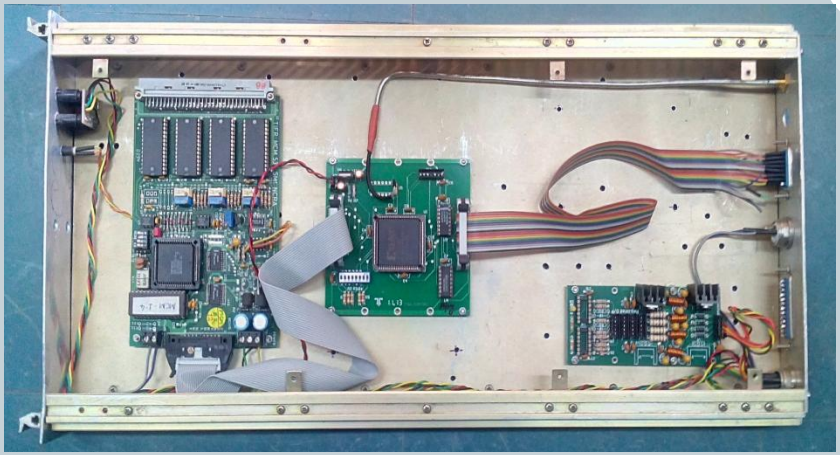


Fig.1 MCM - 4 CPLD based Walsh PIU

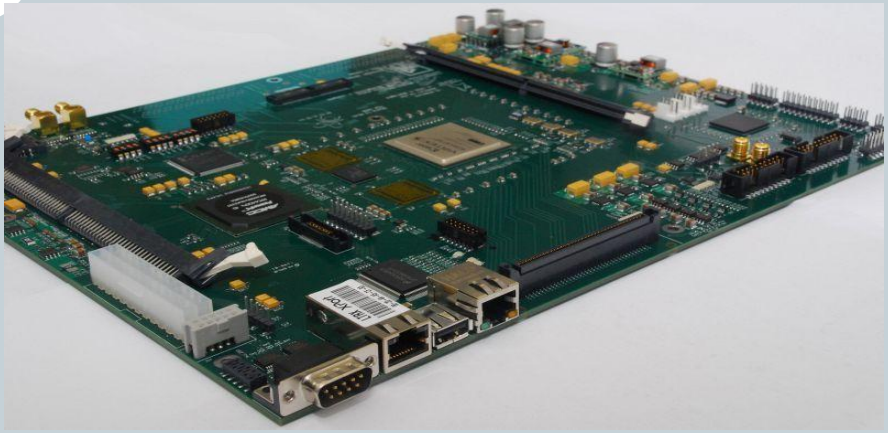
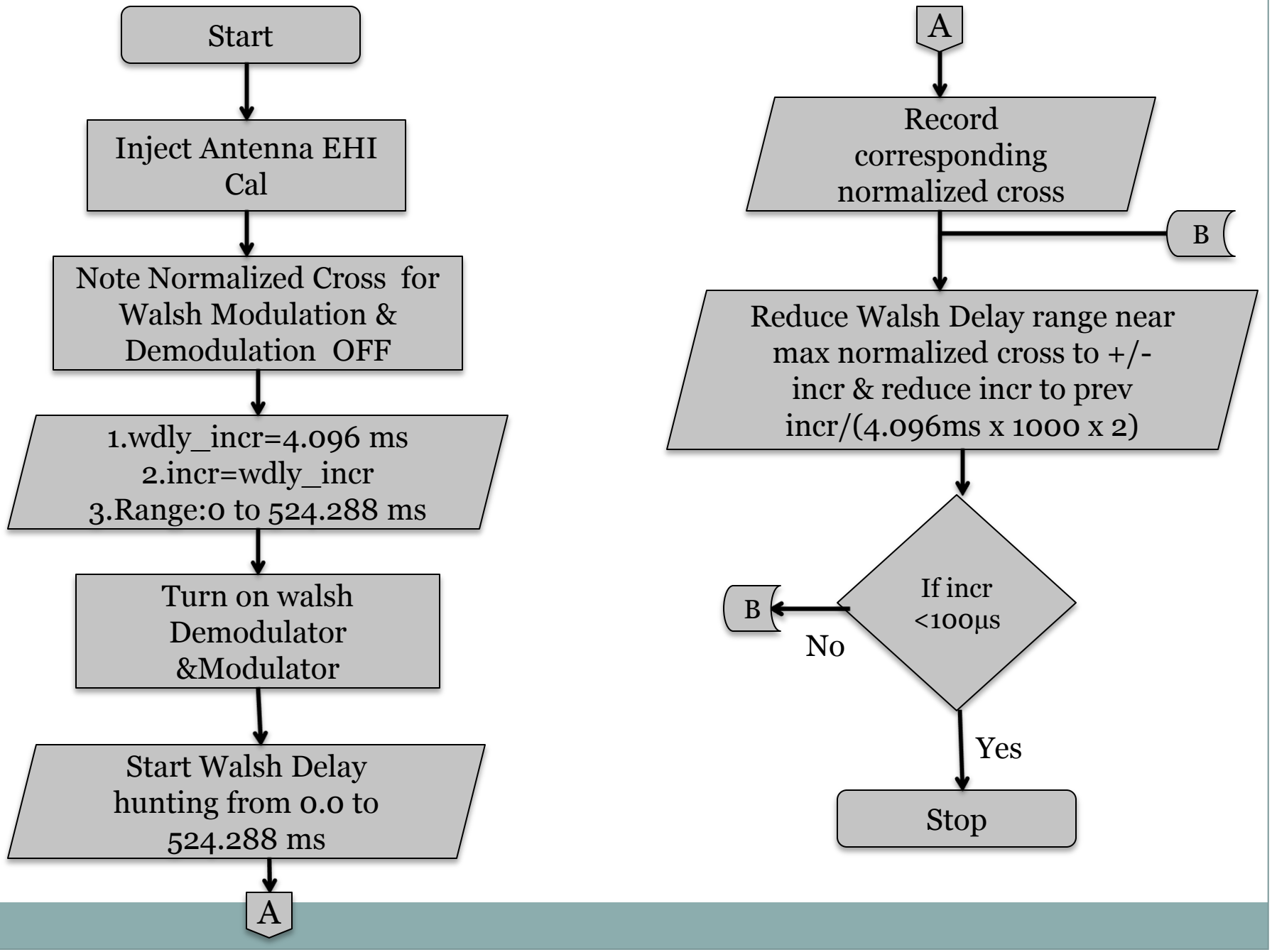


Fig.2 ROACH board

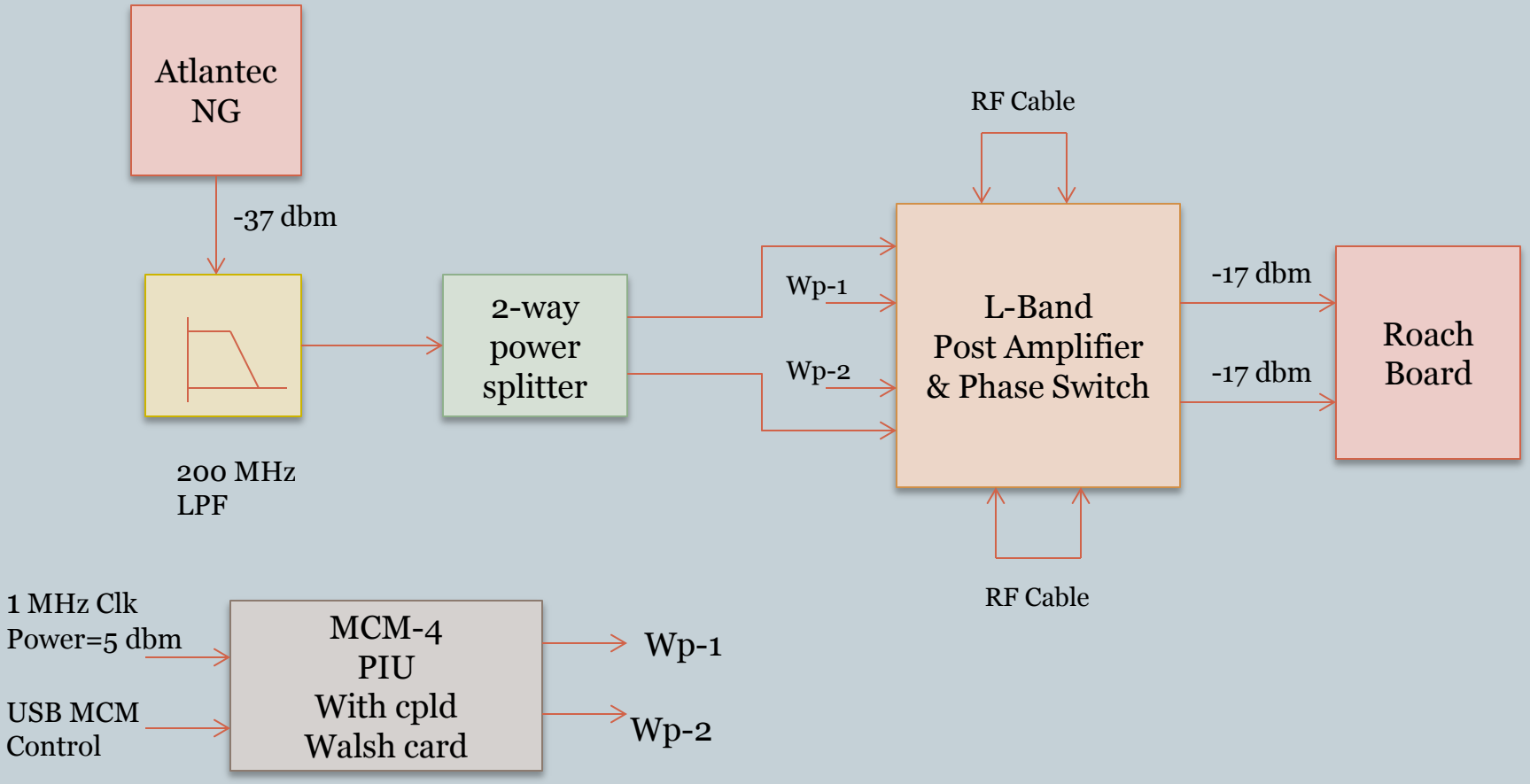
- **Walsh facilities at Modulator & Demodulator side**
  - Enable wp-1 on ch-1 only
  - Enable wp-1 on ch-1 and wp-2 on ch-2
  - Enable wp-2 on ch-1 and ch-2
  - Enable wp-2 on ch-2 only
  - Enable wp-1 on ch-1 and ch-2
- **Antenna selection facility**
  - We can select any antenna 0 to 29 from modulator & demodulator side.
- **Walsh demodulator implemented on ROACH board POCKET CORRELATOR having Delay adjustment facility.**

Understanding of Delay Hunting Algorithm

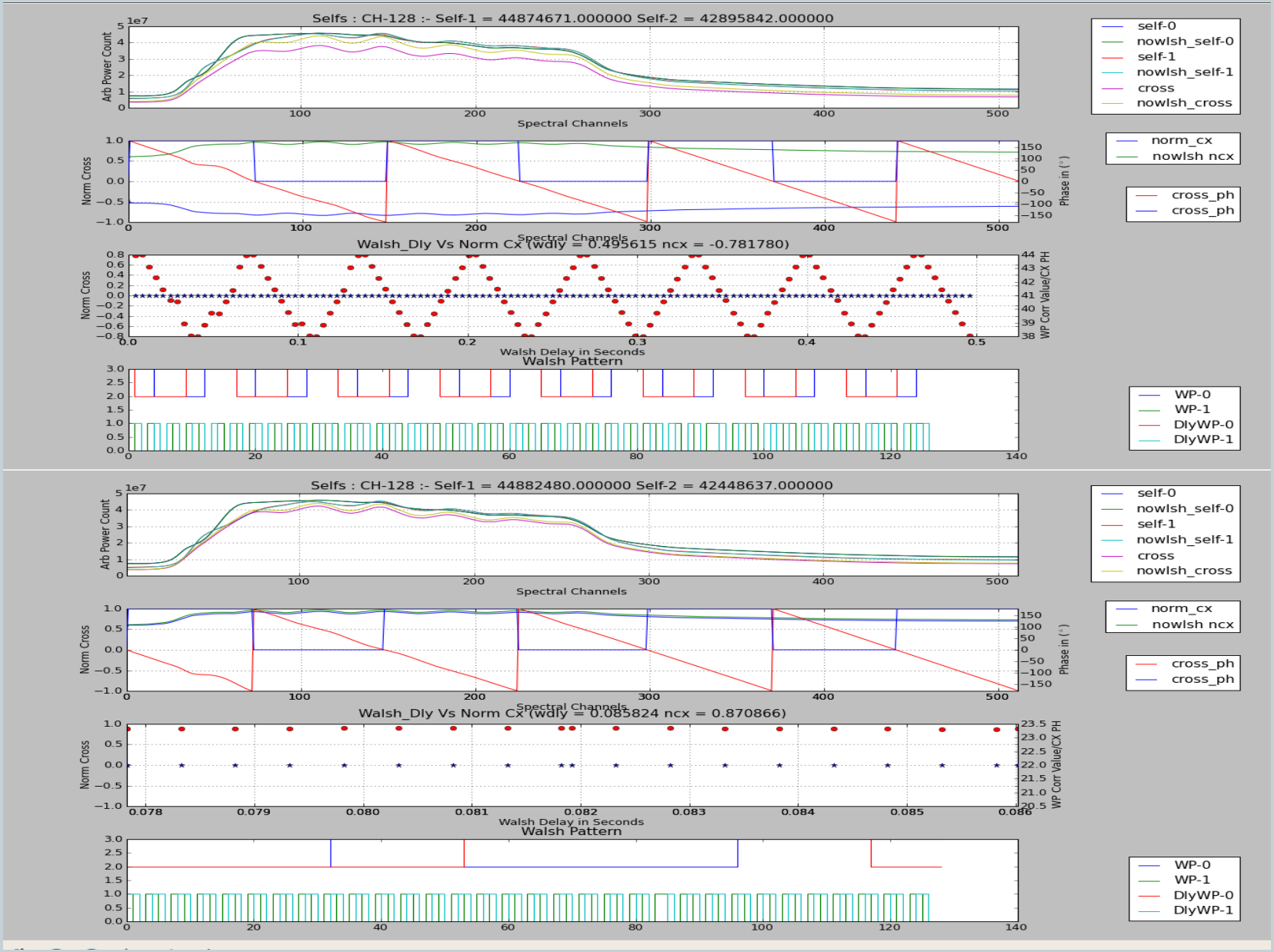
- It is very important to match and align the modulating and demodulating patterns, else this can lead to loss of coherence of the desired signal.
- Delay hunting algorithm is used to find Walsh delay between modulator patterns at antenna and demodulator patterns at central electronics building (CEB) in order to maximize cross correlation.
- Since the delay is different for each antenna and also can change with time and with the exact configuration of the receiver chain, the value has to be determined for exact alignment.


Start
Inject Antenna EHI Cal
Note Normalized Cross for Walsh Modulation & Demodulation OFF
1.wdly_incr=4.096 ms
2.incr=wdly_incr
3.Range:0 to 524.288 ms
Turn on walsh Demodulator &Modulator
Start Walsh Delay hunting from 0.0 to 524.288 ms
A
A
Record corresponding normalized cross
B
Reduce Walsh Delay range near max normalized cross to +/- incr & reduce incr to prev incr/(4.096ms x 1000 x 2)
If incr <100µs
B
No
Yes
Stop

Delay Hunting Test Setup



Delay Hunting Plots



Characterization of walsh system in Lab

- **Characterization of walsh system using following test**

- Effect of Walsh on Cross Talk Rejection
- Correlation loss test

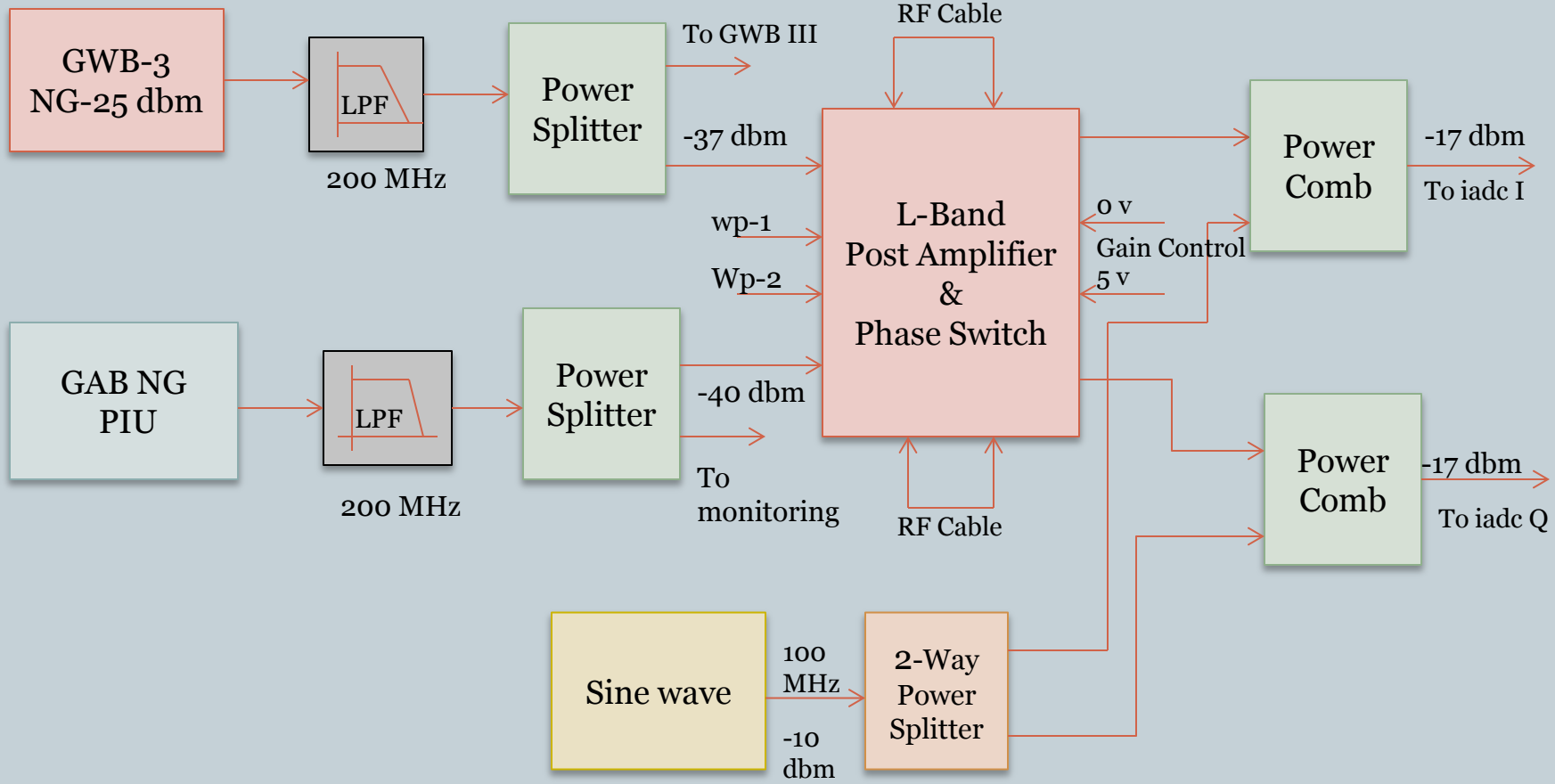
Walsh System Characterization : Effect of Walsh on Cross Talk Rejection

- This test was intended to study the effect of Walsh on cross talk in the receiver chain of antenna to verify that it cancels out cross-talk in a receiver chain.

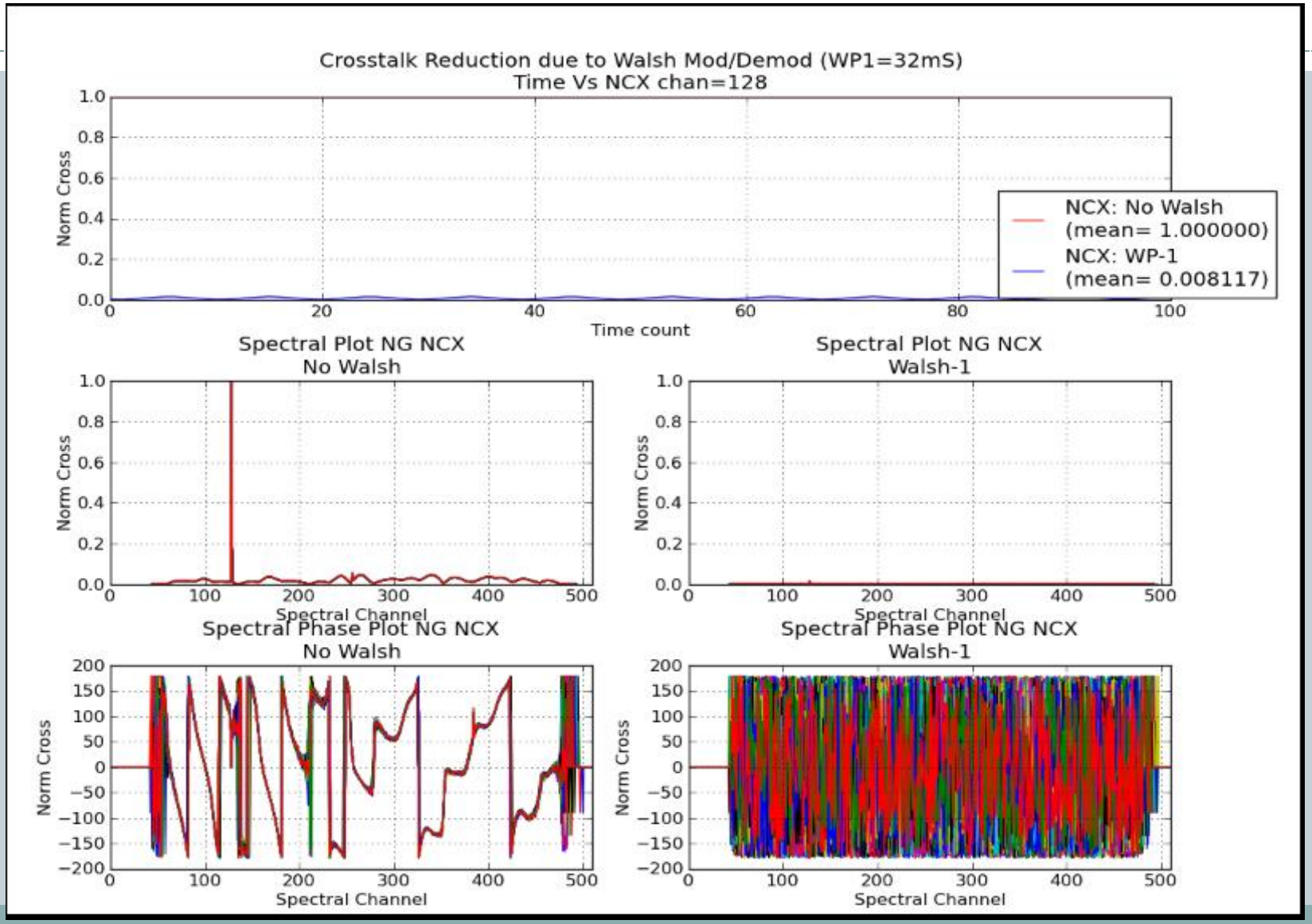
- We use sine wave of (100 MHz) as cross talk after modulation block.

a) without Walsh modulation
b) with Walsh modulation : Walsh Pattern – 1
c) with Walsh modulation : Walsh Pattern – 2
d) with Walsh modulation : Both Walsh Patterns

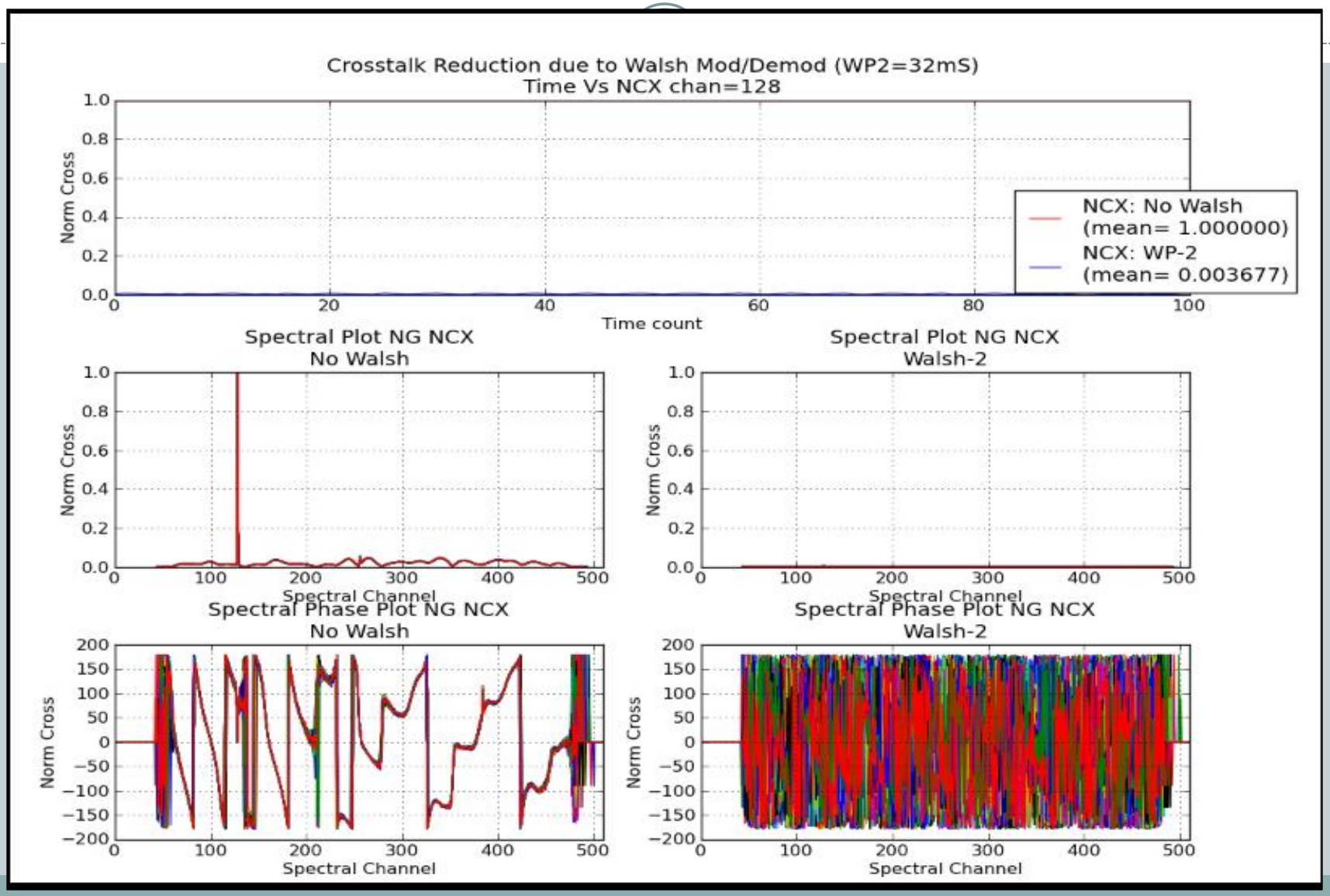
Test Setup for cross talk reduction



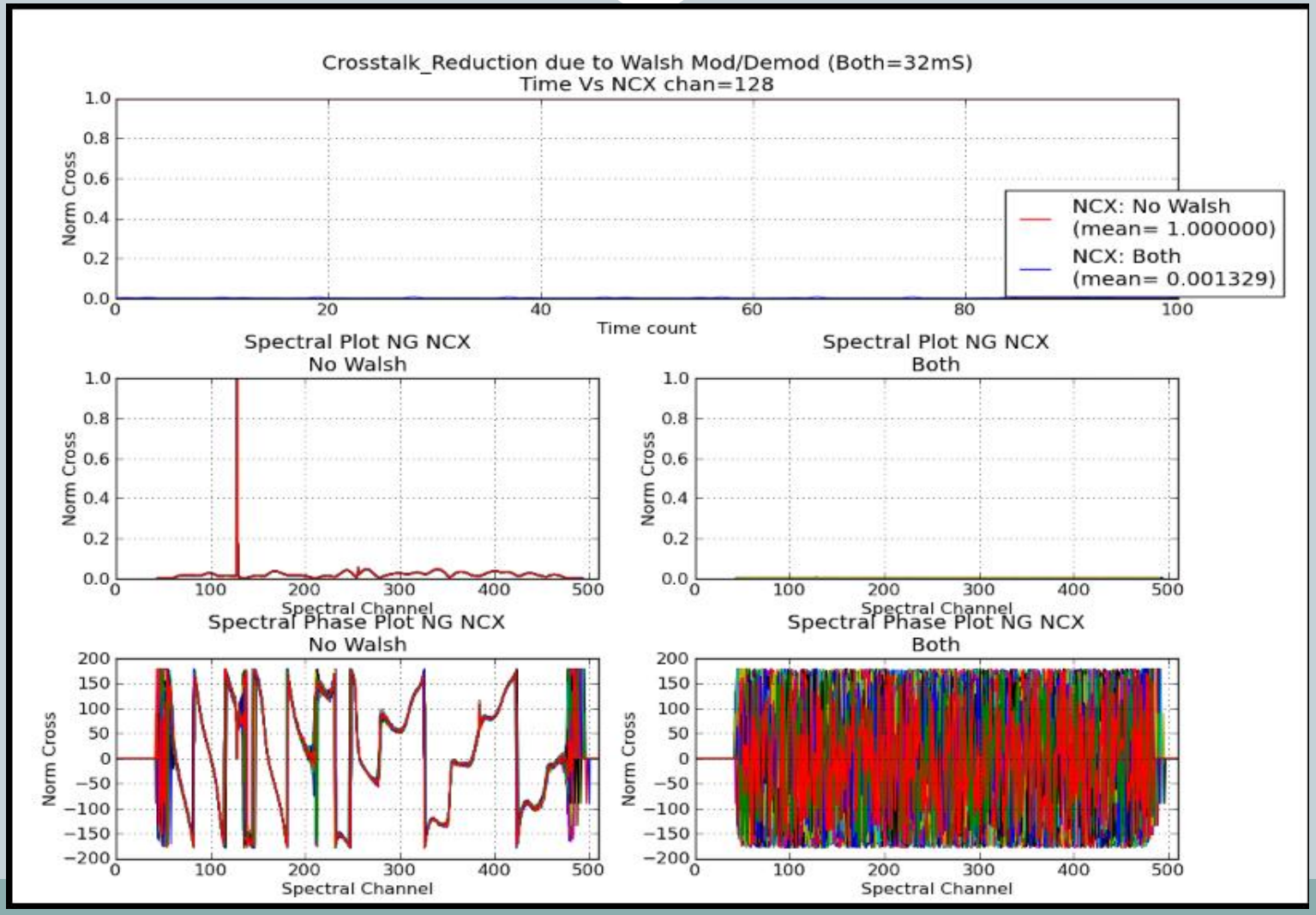
Cross talk reduction due to modulation of wp-1 on ch-1 only



Cross talk reduction due to modulation of wp-2 on ch-2 only



Loss of correlation due to modulation of wp-1 on ch-1 and wp-2 on ch-2



Test Results

1) wp1 = No walsh Ncx – wp1 Ncx
= 1 – 0.008117
= 0.991883
= (99.1883 %)

2) wp2 = No walsh Ncx – wp2 Ncx
= 1 – 0.003677
= 0.996323
= (99.6323 %)

3) Both wp = No walsh Ncx – Both wp Ncx
= 1 – 0.001329
= 0.998671
= (99.8671 %)

The above results shows that there is (~ 99 %) rejection in cross talk due to walsh modulation / demodulation .

Walsh System Characterization :Correlation loss test with Noise Source

In Lab This test is intended to check correlation loss due to walsh modulation/demodulation, test was done using three noise generators (NG) .NG-3 injected as a common noise before L-Band PA &PS along with NG-1 & NG2. Recorded normalized cross for following conditions,

a) Without Walsh.

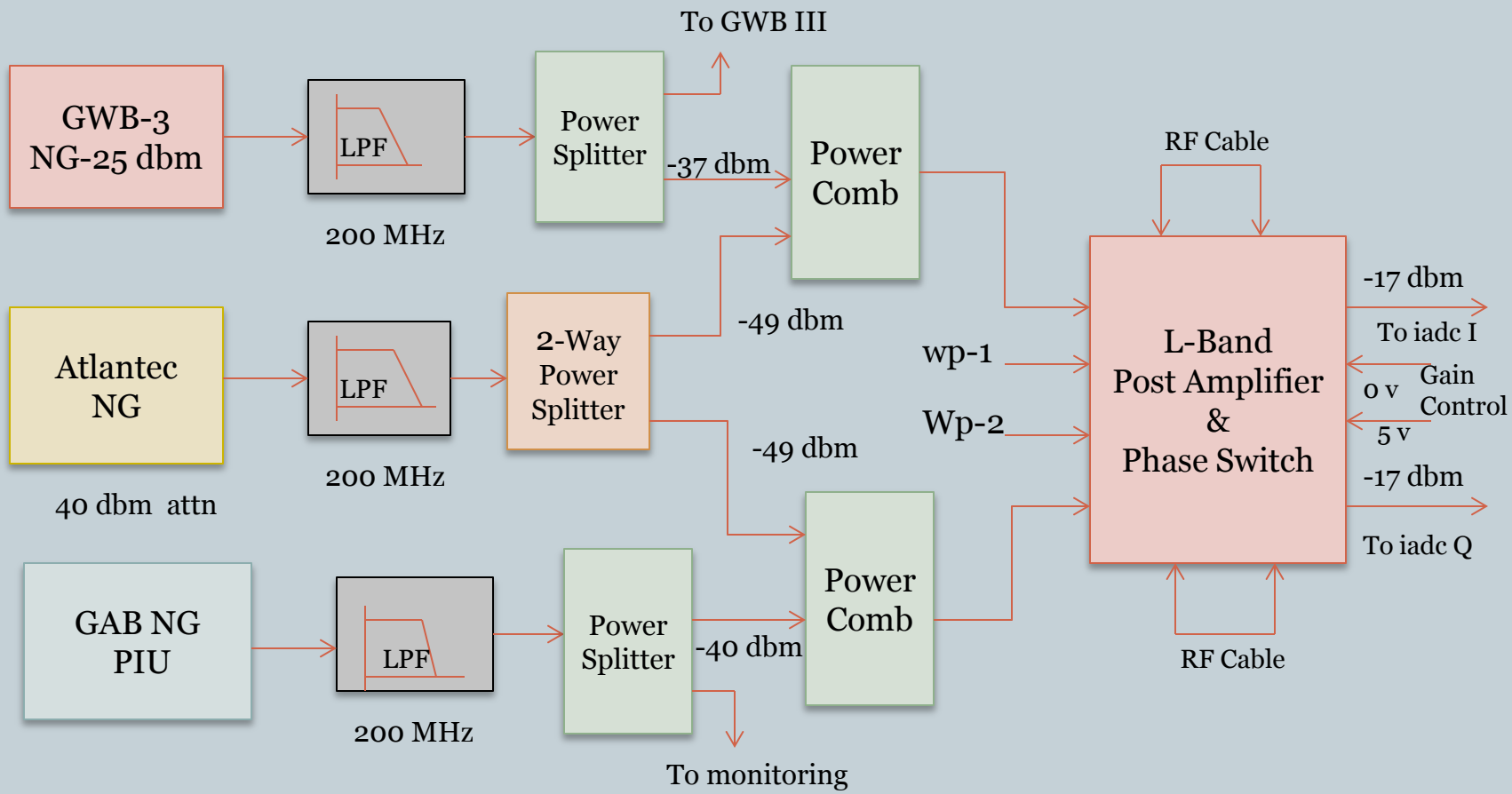
b) With Walsh Pattern-1 mod-demod.

c) With Walsh pattern-2 mod-demod.

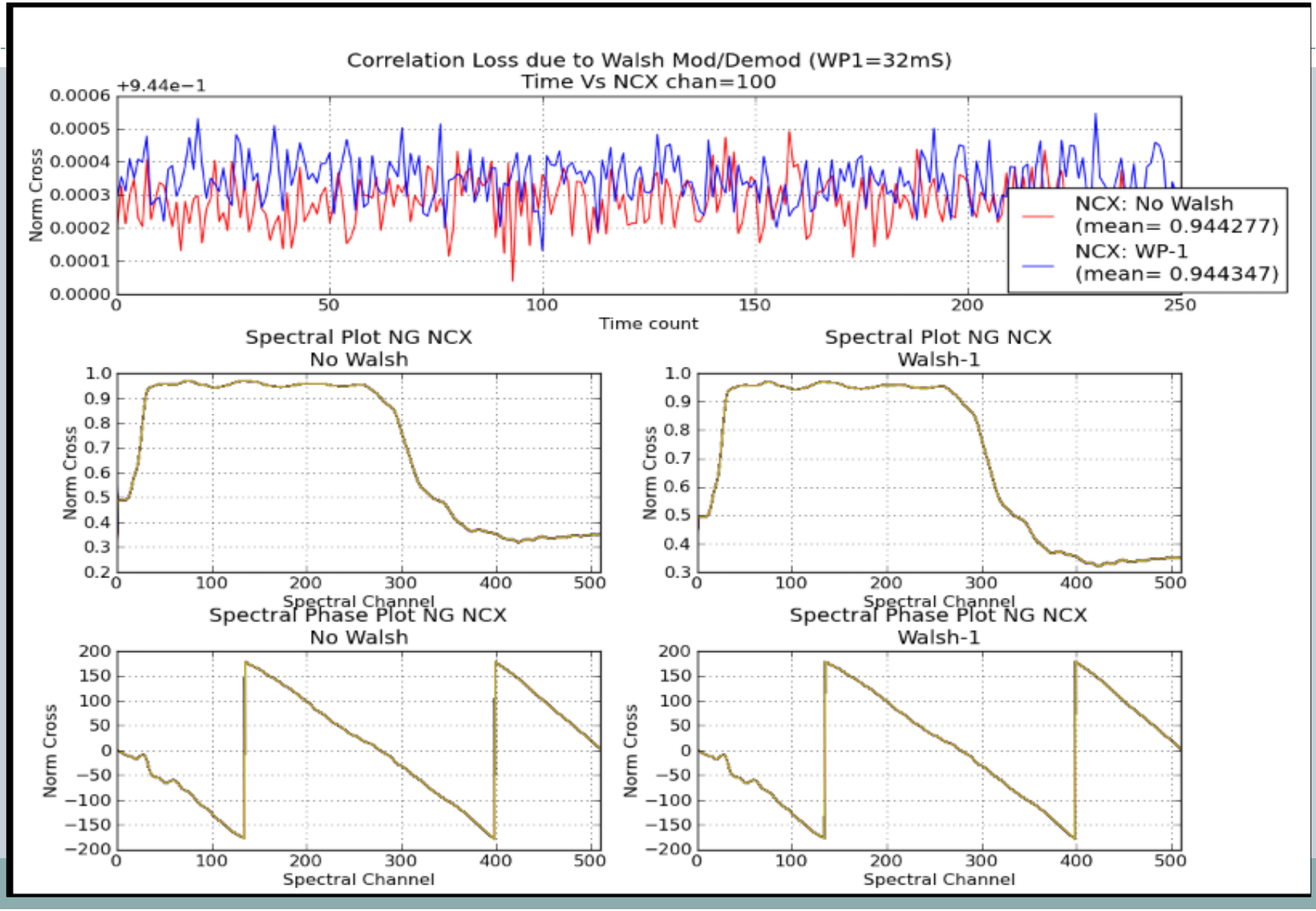
d) With both Walsh patterns mod-demod.

Test Setup

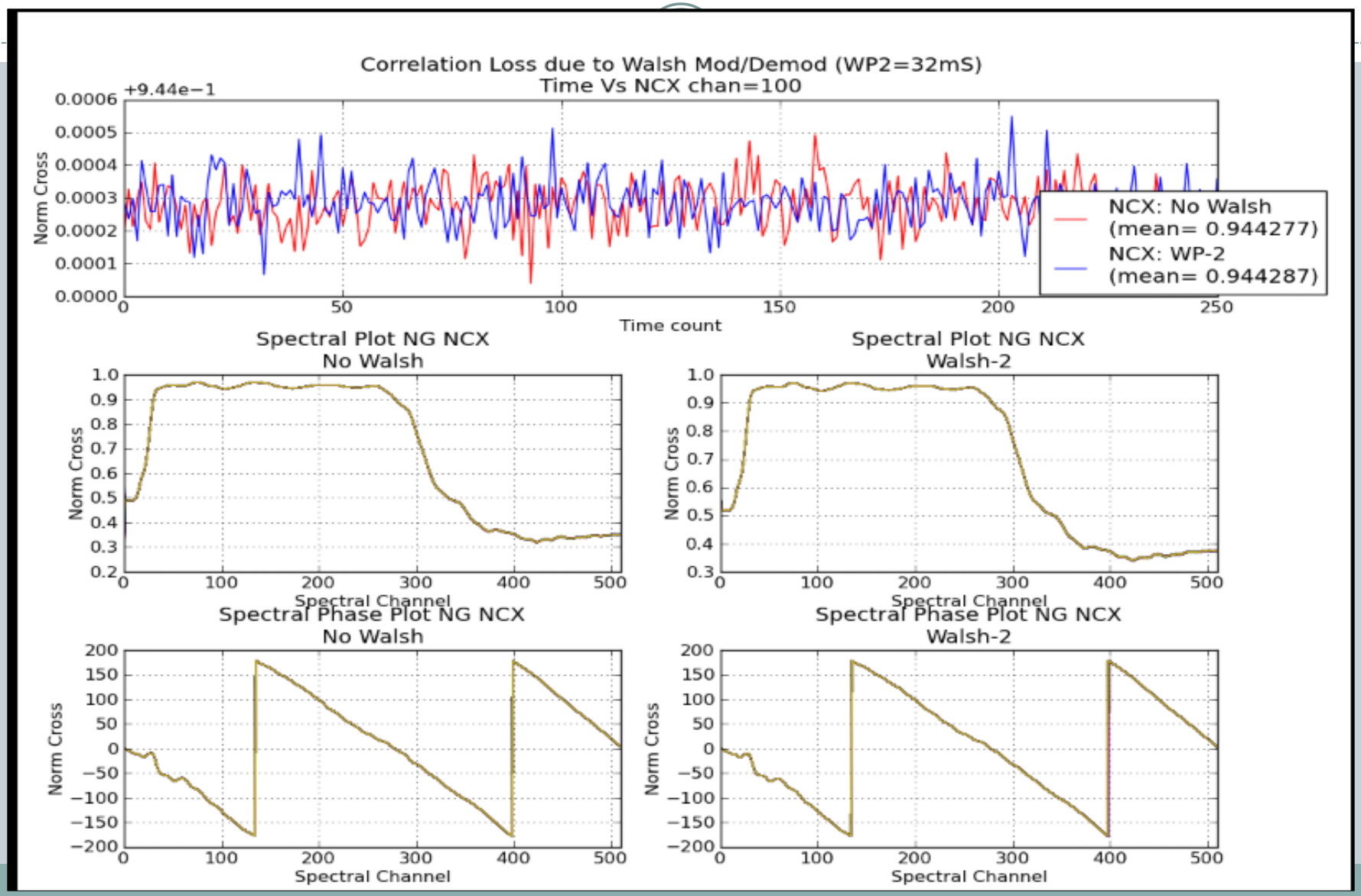
Common Noise (NG3) Injection Before Walsh Modulation



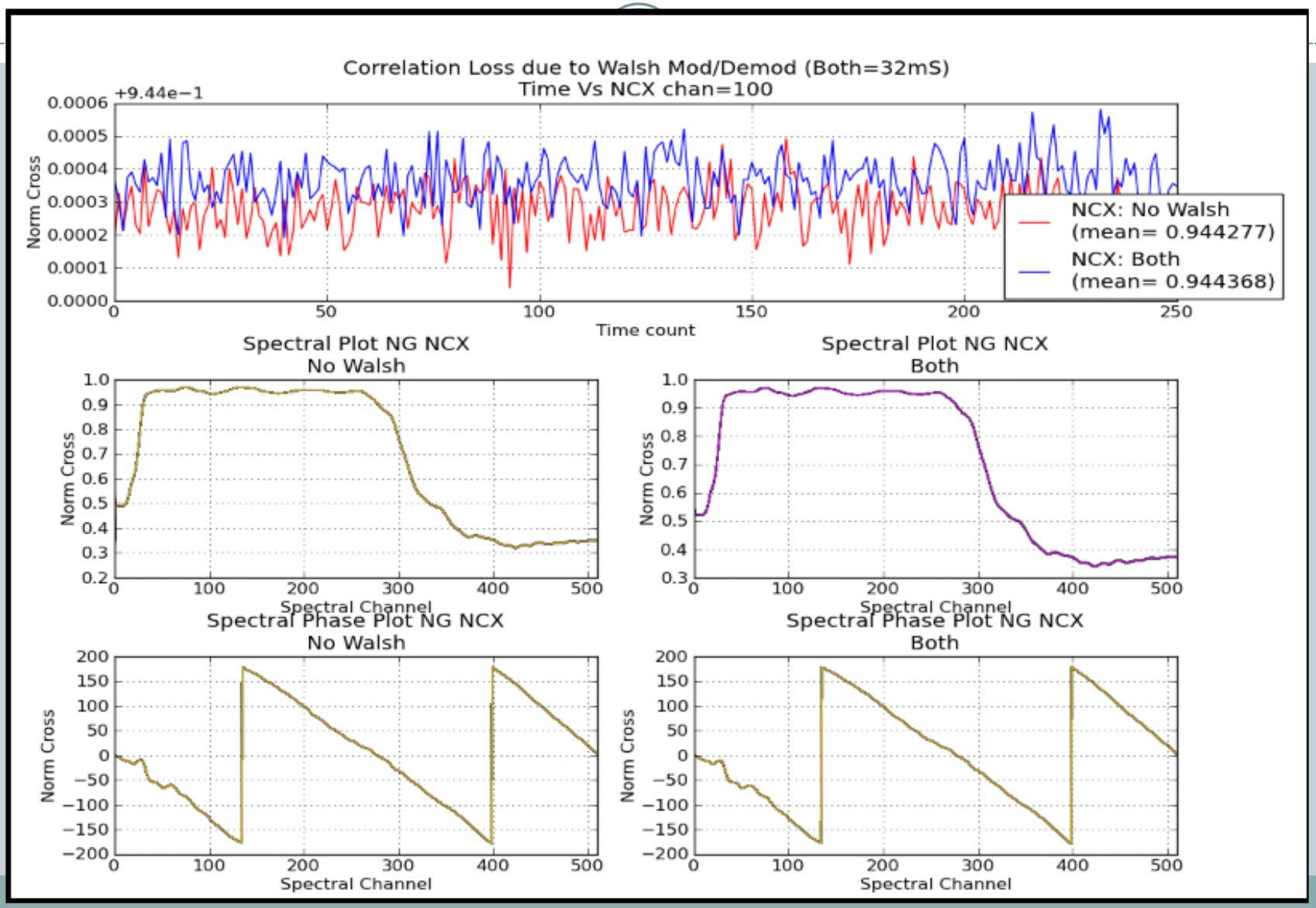
Effect of walsh on correlation: modulation of wp-1 on ch-1 only



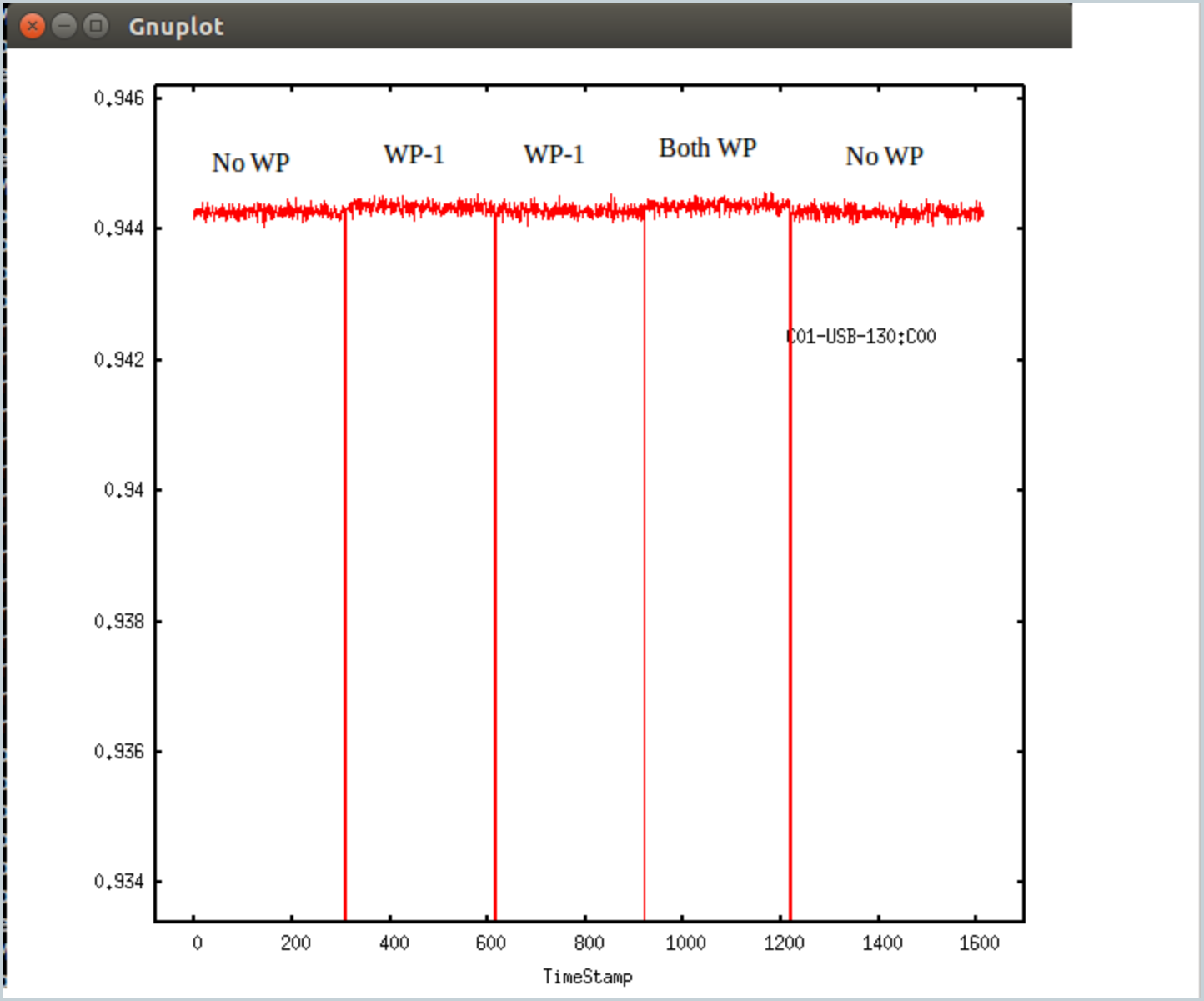
Effect of walsh on correlation: modulation of wp-2 on ch-2 only



Effect of walsh on correlation :modulation of wp-1 on ch-1 and wp-2 on ch-2



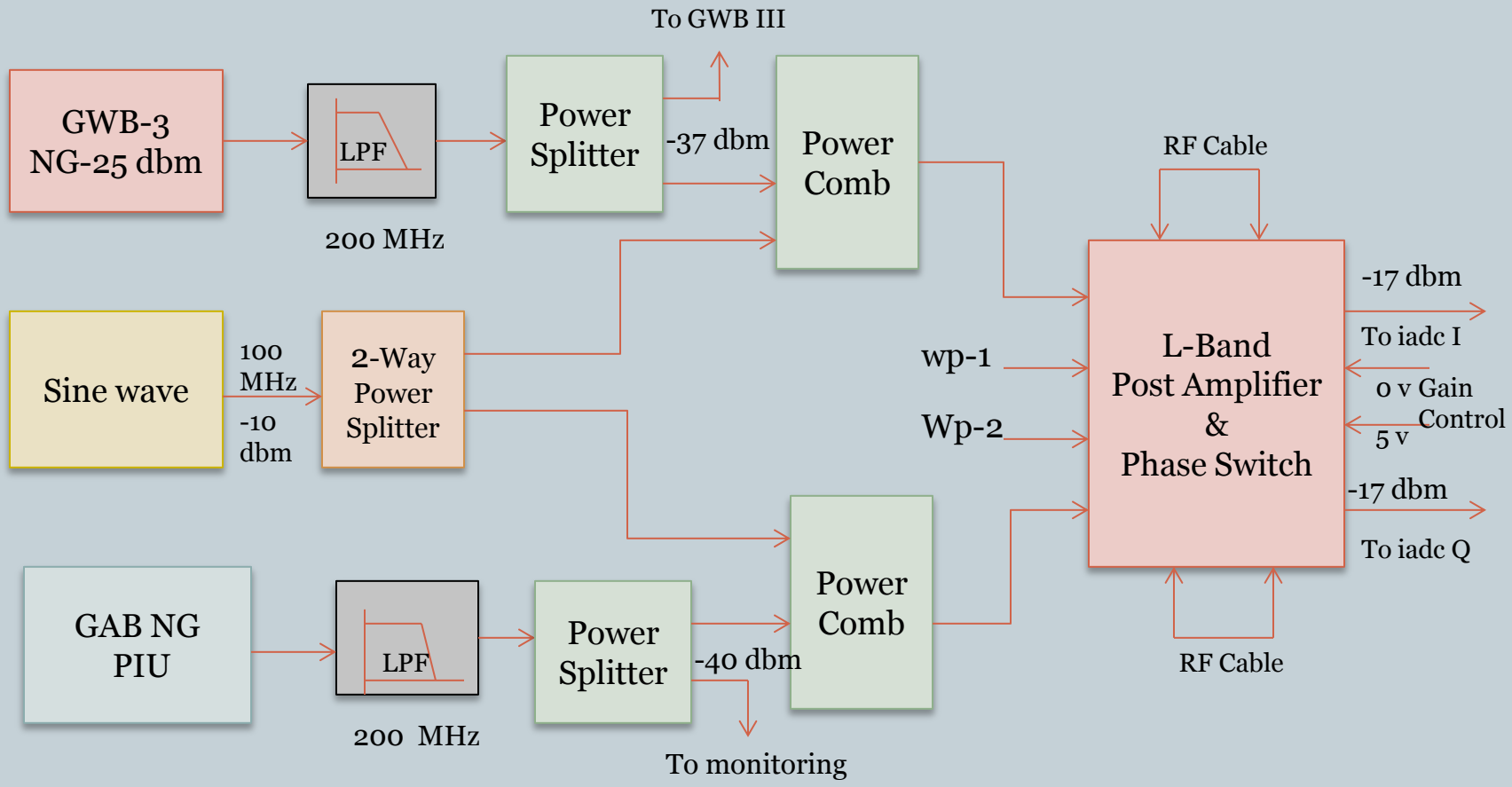
Recorded file to check the normalized cross value for different walsh conditions:



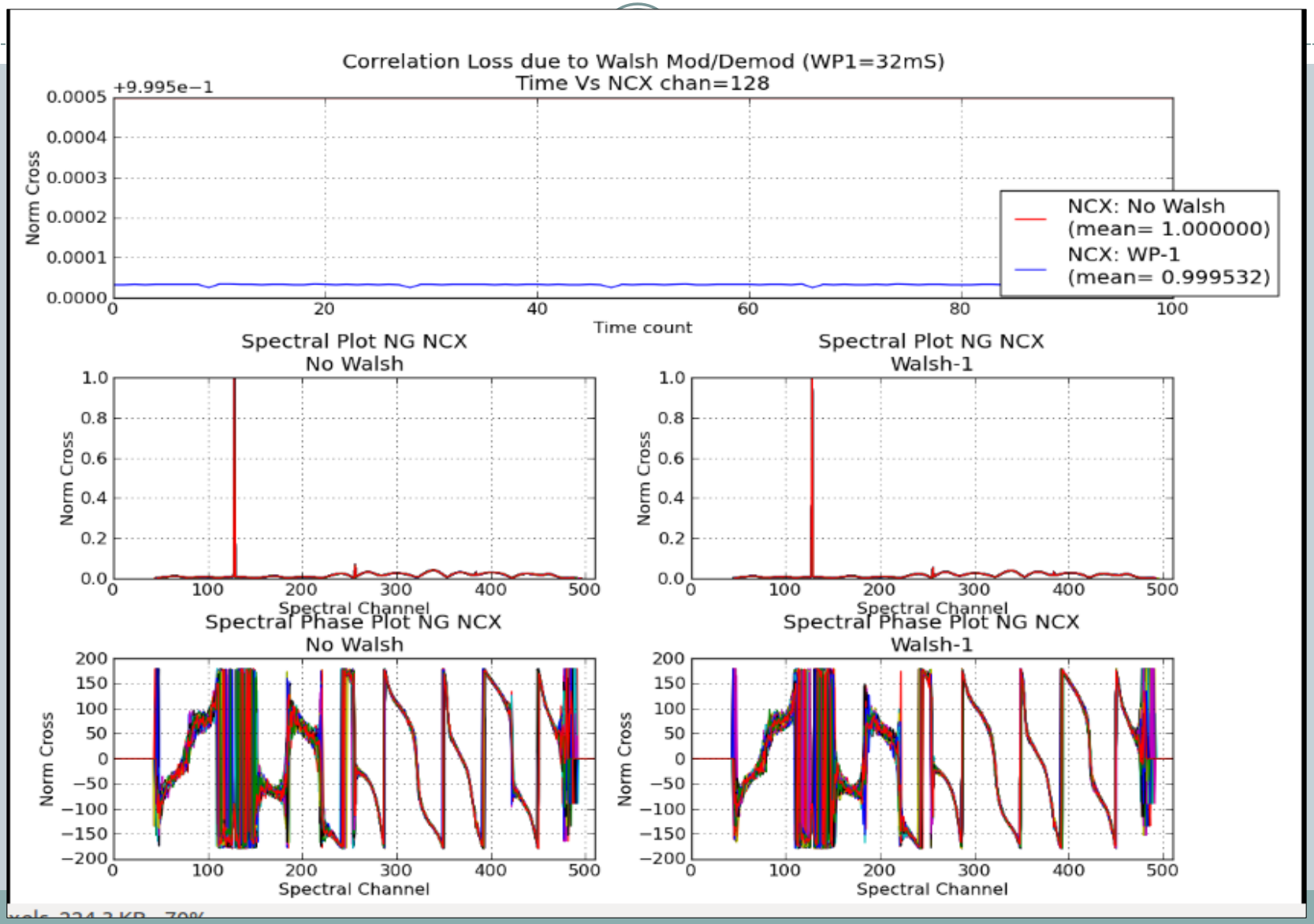
Effect of walsh on correlation in case of NG3 noise for the following conditions are :

- No walsh = (0%)
- walsh pattern-1 mod/demodulation = (~ 0)
- walsh pattern-2 mod/demodulation = (~0)
- Both walsh pattern mod/demodulation = (~0)

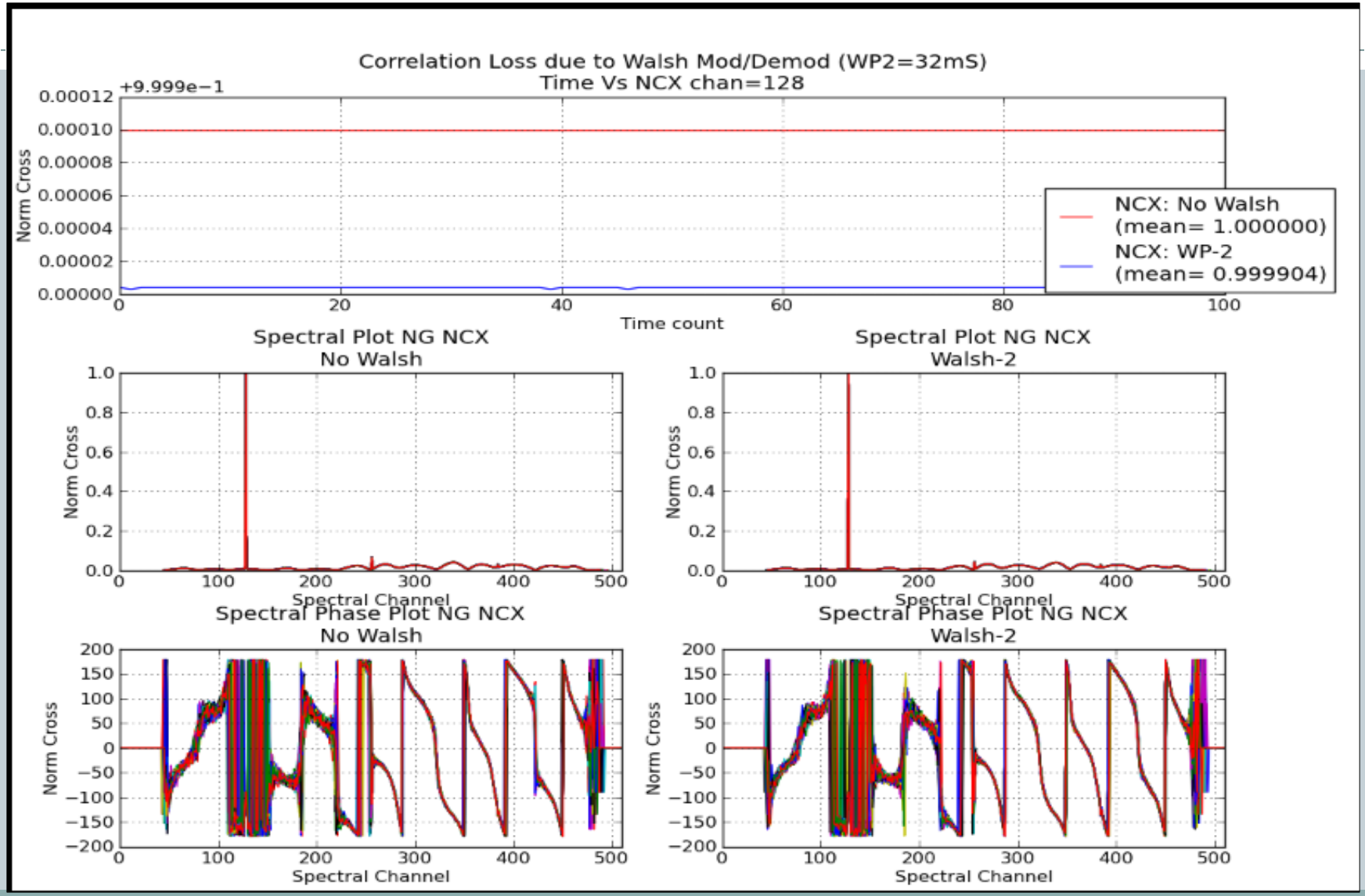
Walsh System Characterization :Correlation loss test with Sine Wave



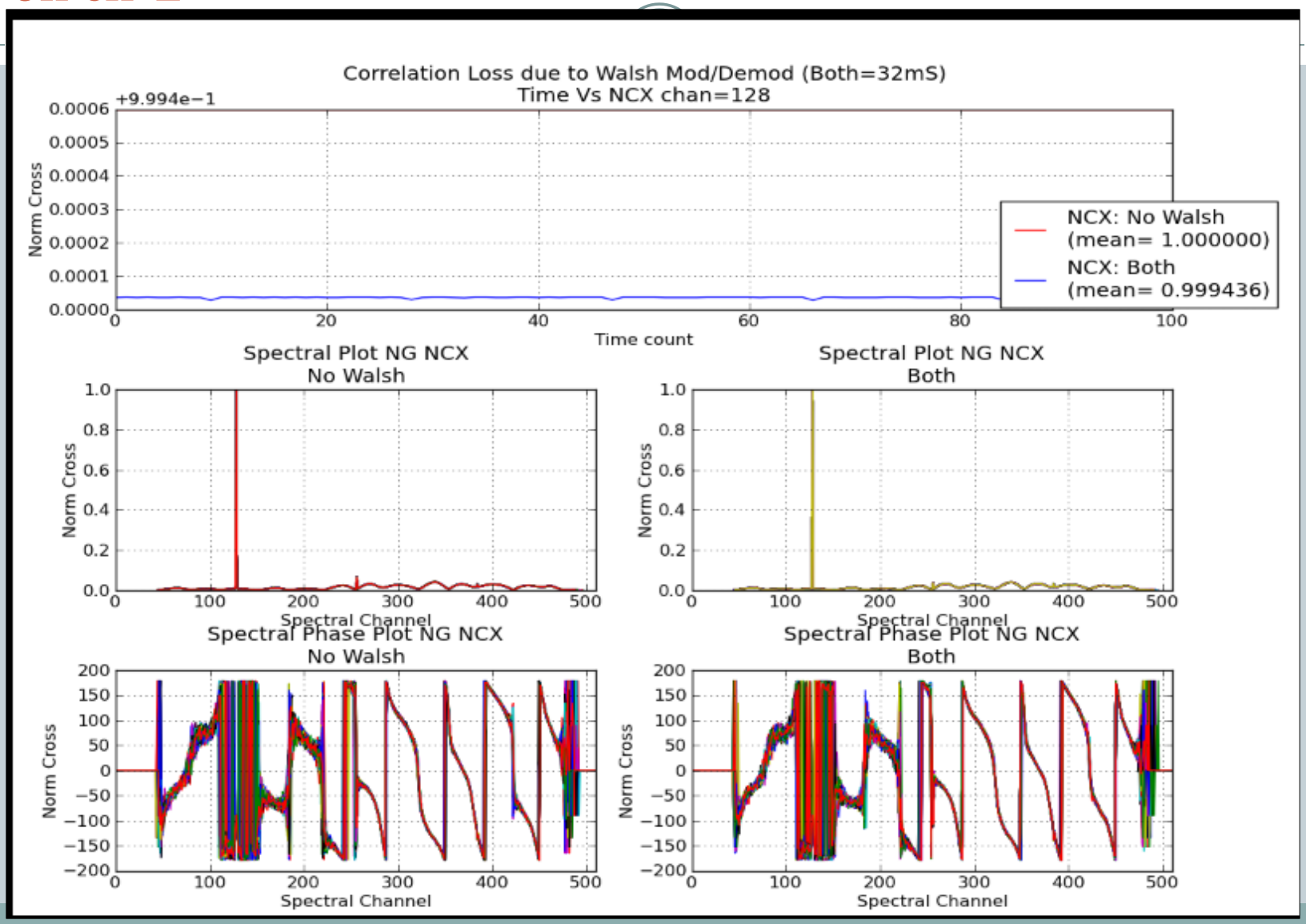
Loss of correlation due to modulation of wp-1 on ch-1 only



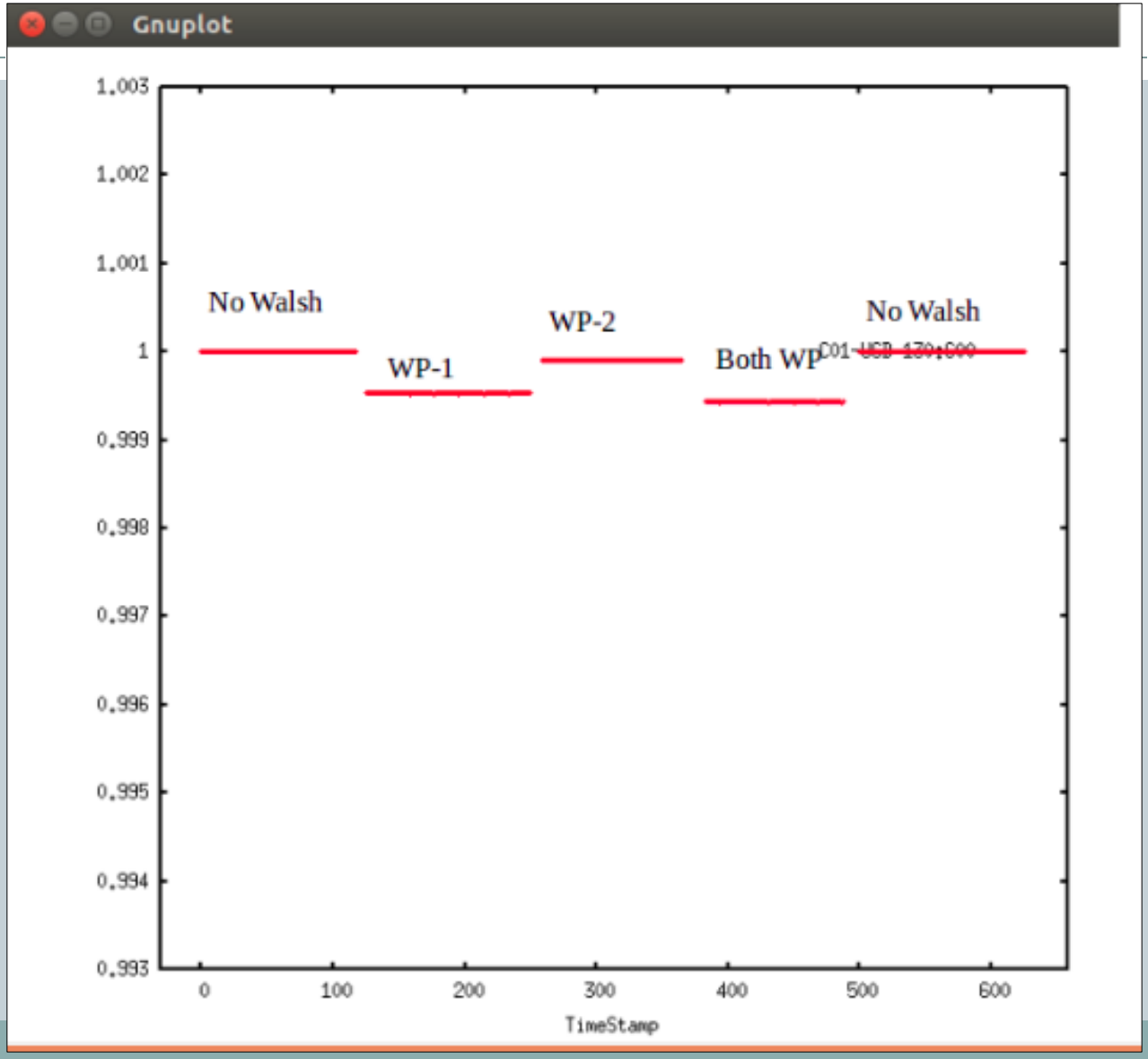
Loss of correlation due to modulation of wp-2 on ch-2 only



Loss of correlation due to modulation of wp-1 on ch-1 and wp-2 on ch-2



Analysis of data for correlation loss Test



Loss of correlation in case of constant wave for the following conditions are :

No walsh = (0%)

walsh pattern-1 mod/demodulation = (~ 0.0468 %)

walsh pattern-2 mod/demodulation = (~ 0.0096 %)

Both walsh pattern mod/demodulation = (~ 0.0564 %)

Modification in Delay Hunting Scheme: Basic Walsh Pattern

- What is basic walsh pattern?
  - Basic walsh pattern is of 50% duty cycle having time period of 524.288 ms.
- Need of basic walsh pattern?
  - Need of basic walsh pattern is to simplify the delay hunting .
- Modifications from modulator-demodulator side :
  - Additional facility of generation of basic walsh pattern on pol-1 and pol-2 from both sides (CPLD and FPGA).

Delay Hunting Scheme with basic Walsh Testing & Debugging

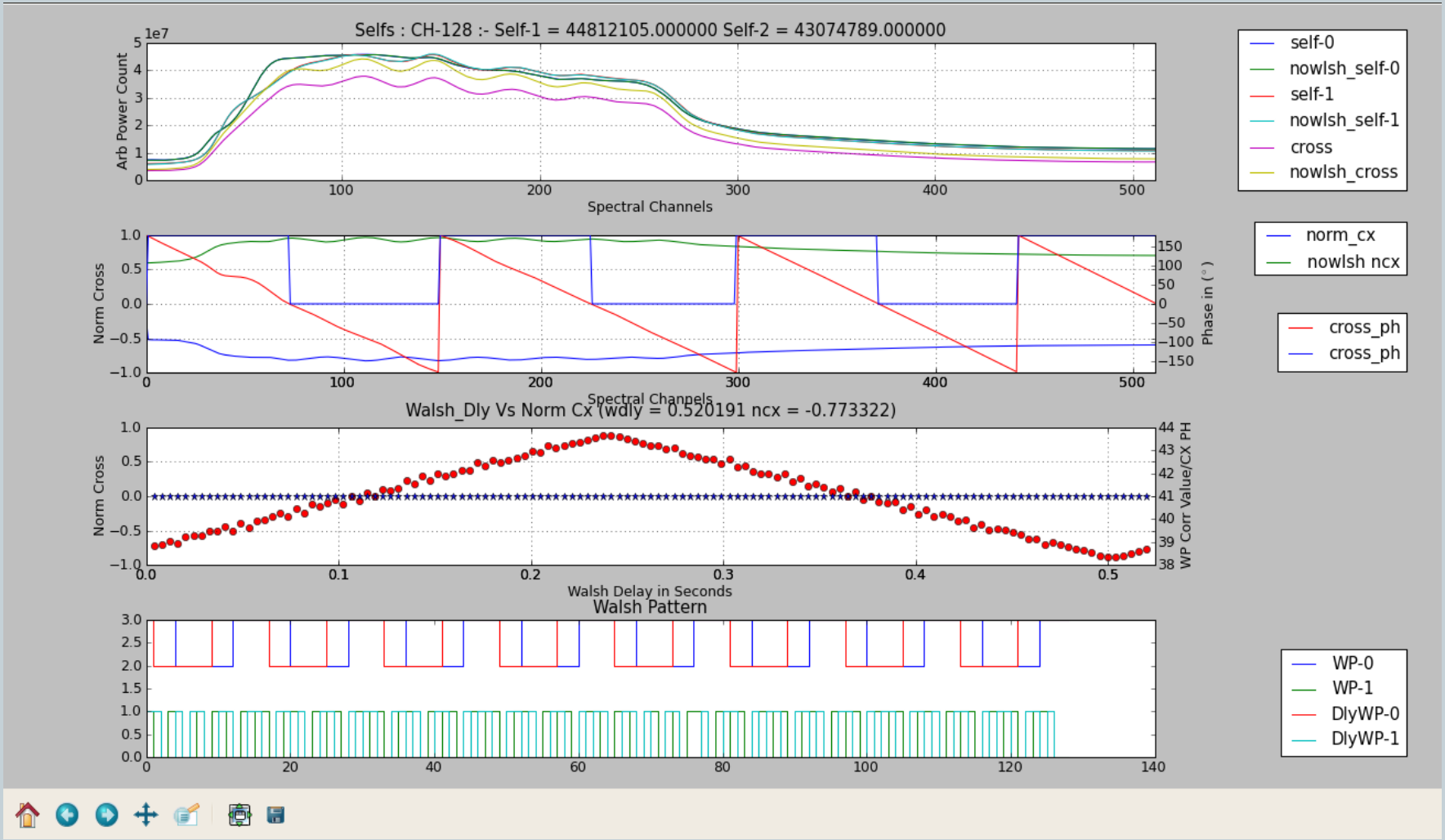
- Previously the delay hunting test for antenna was carried out with antenna patterns,i.e adjusting delay between two patterns with there respective antenna patterns to get the maximum cross correlation.

- In that case delay value for that particular antenna was not applicable to the remaining antenna patterns, hence we go for basic walsh pattern.

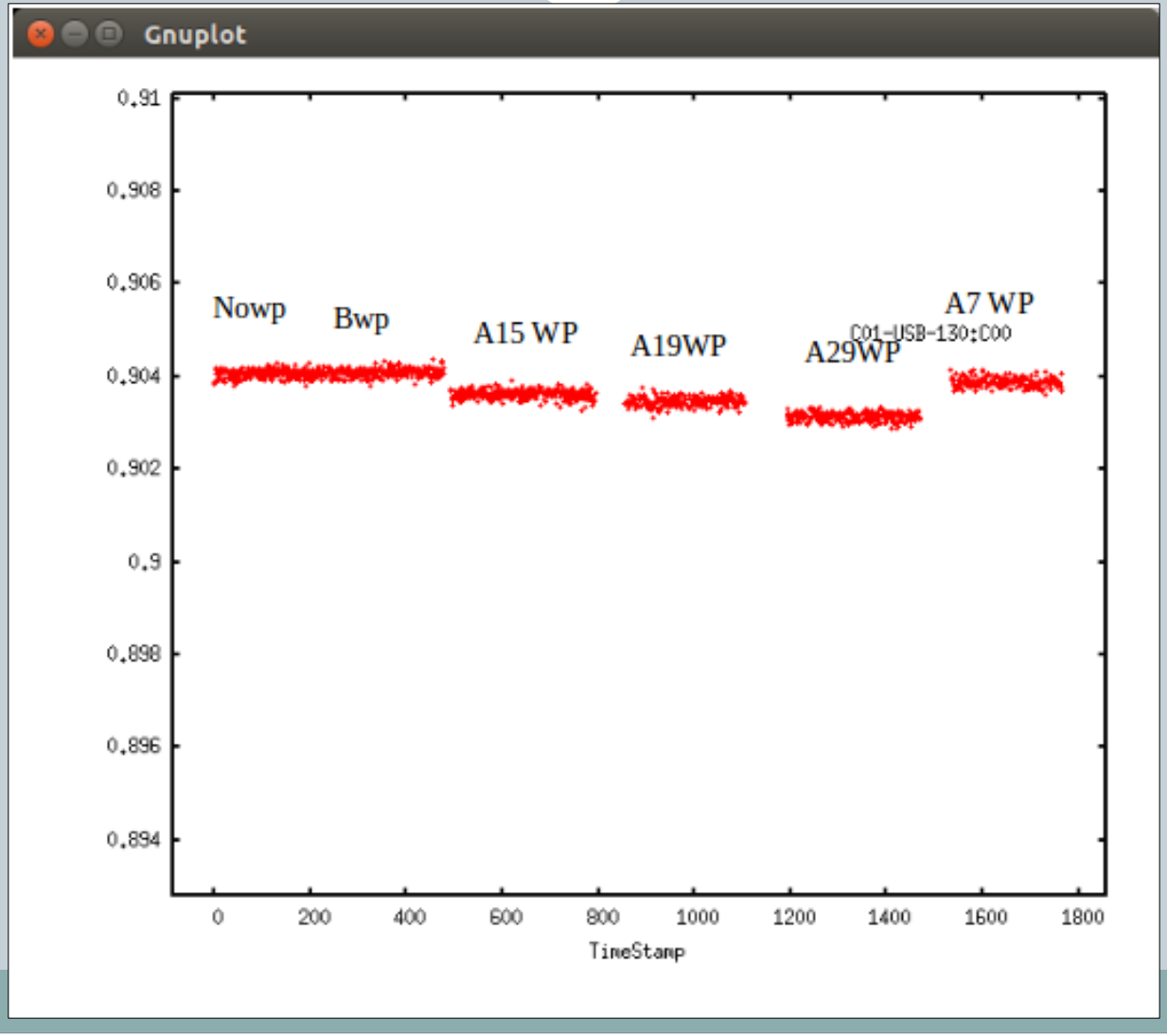
- After delay hunt with basic walsh pattern we get only one maxima. While with other patterns we get multiple maximas.

Test Results

Single maxima after delay hunt with basic walsh pattern.



After delay hunt with basic pattern there is no need to find delay every time for other antenna patterns, the same delay will be applicable to rest of the patterns.

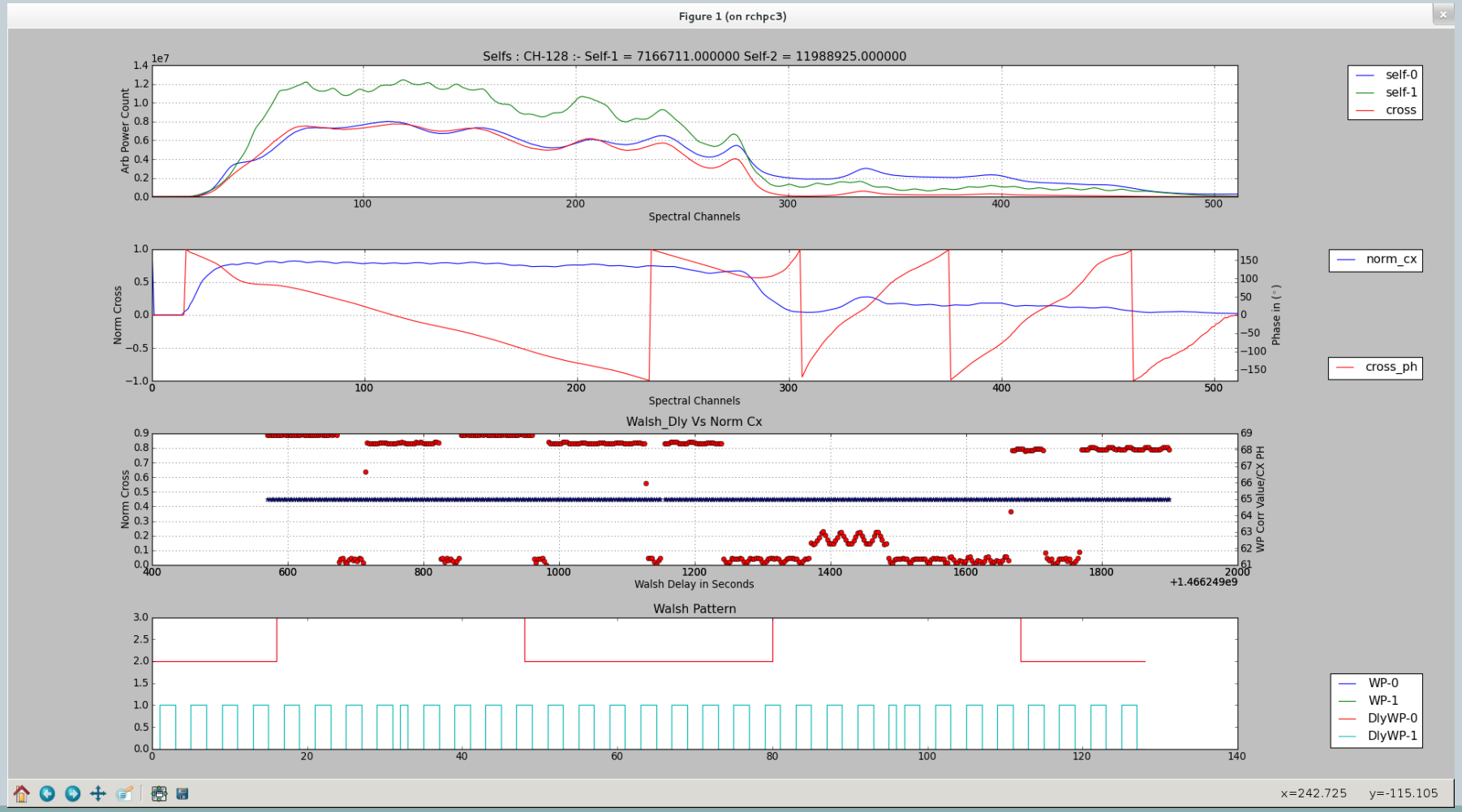


Debugging

- Delay hunting failure sometimes.

Noise Level (Attenuation)	Walsh Pattern	Pol	CH	No Walsh Ncx	After DH Ncx		Difference
10+0	wp1	Pol0	75	0.983677	0.9838		-0.000123
	wp2	pol1	75	0.983757	0.983		0.000757
10+2	wp1	pol0	200	0.952746	0.9529		-0.000154
	wp2	pol1	200	0.952752	0.6378	x	0.314952
20+2	wp1	pol0	100	0.830036	0.8301		-0.000064
	wp2	pol1	100	0.82979	0.5785	x	0.25129
20+5	wp1	pol0	100	0.710728	0.7108		-0.000072
	wp2	pol1	100	0.710327	0.66	x	0.050327
20+7	wp1	pol0	100	0.607154	0.6074		-0.000246
	wp2	pol1	100	0.60739	0.6074		-0.00001
30+9	wp1	pol0	100	0.090744	0.0896	x	0.001144
	wp2	pol1	100	0.191269	0.0579	x	0.133369

After switching from basic pattern to Antenna pattern normalized cross value goes to zero.



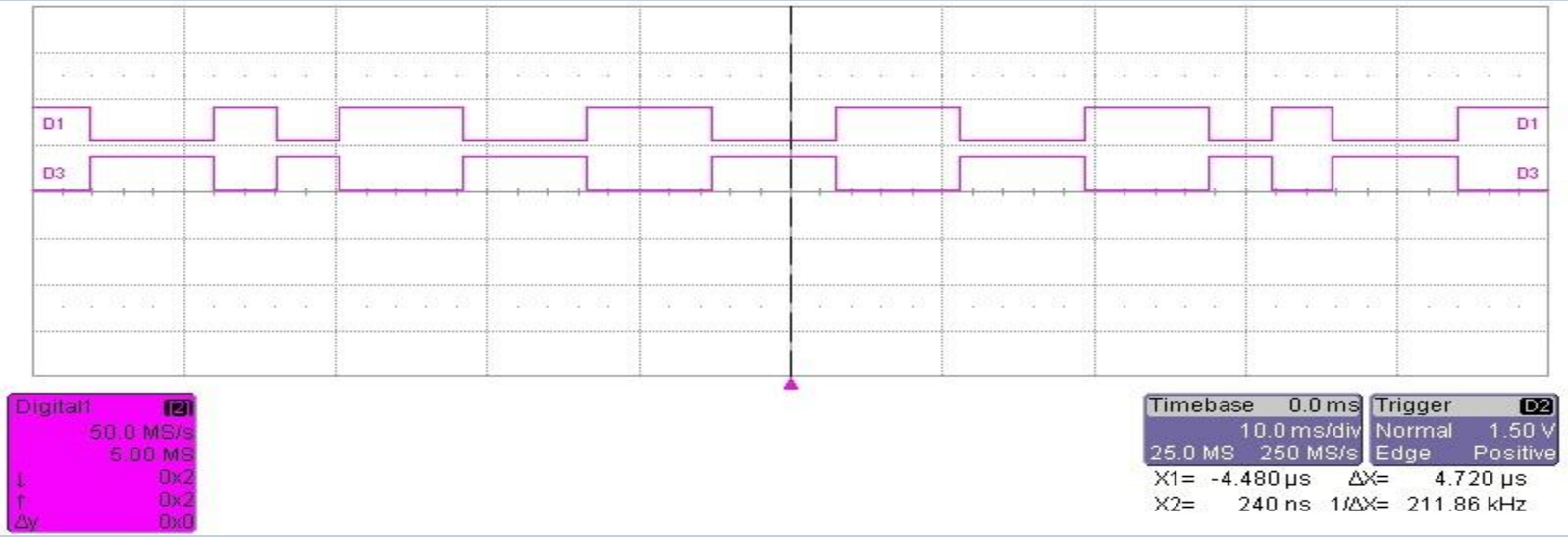
Debugging Delay Hunting Failure reasons

I. At demodulator side walsh patterns are delayed by 4.096 ms, that delay is corrected by modifying the FPGA design.

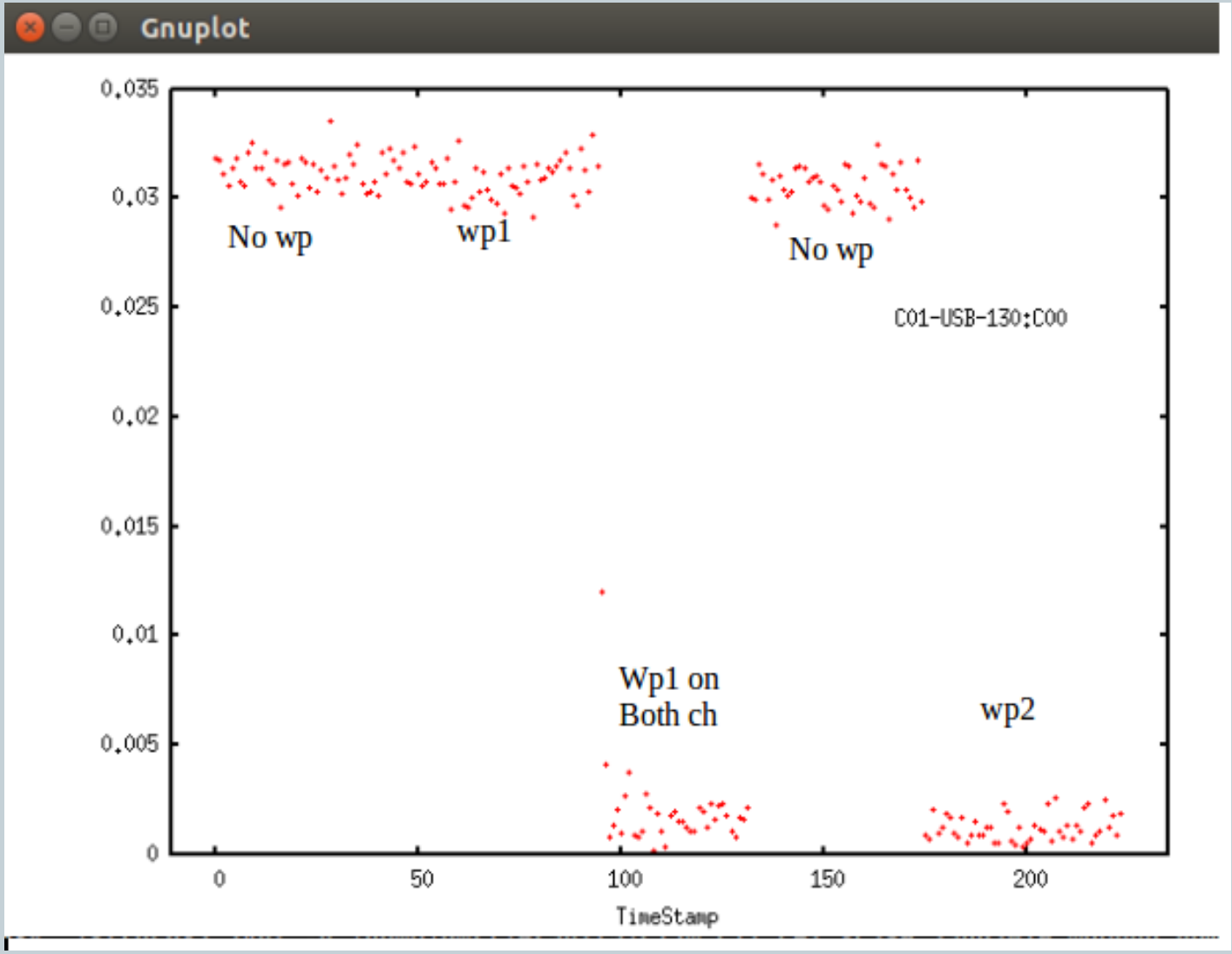
II. The walsh pattern generated from FPGA side are inverted with respect to CPLD side walsh patterns.

D1 is the CPLD side walsh pattern.

D3 is the FPGA side walsh pattern.



Debugging C12 Antenna walsh Channel swap test

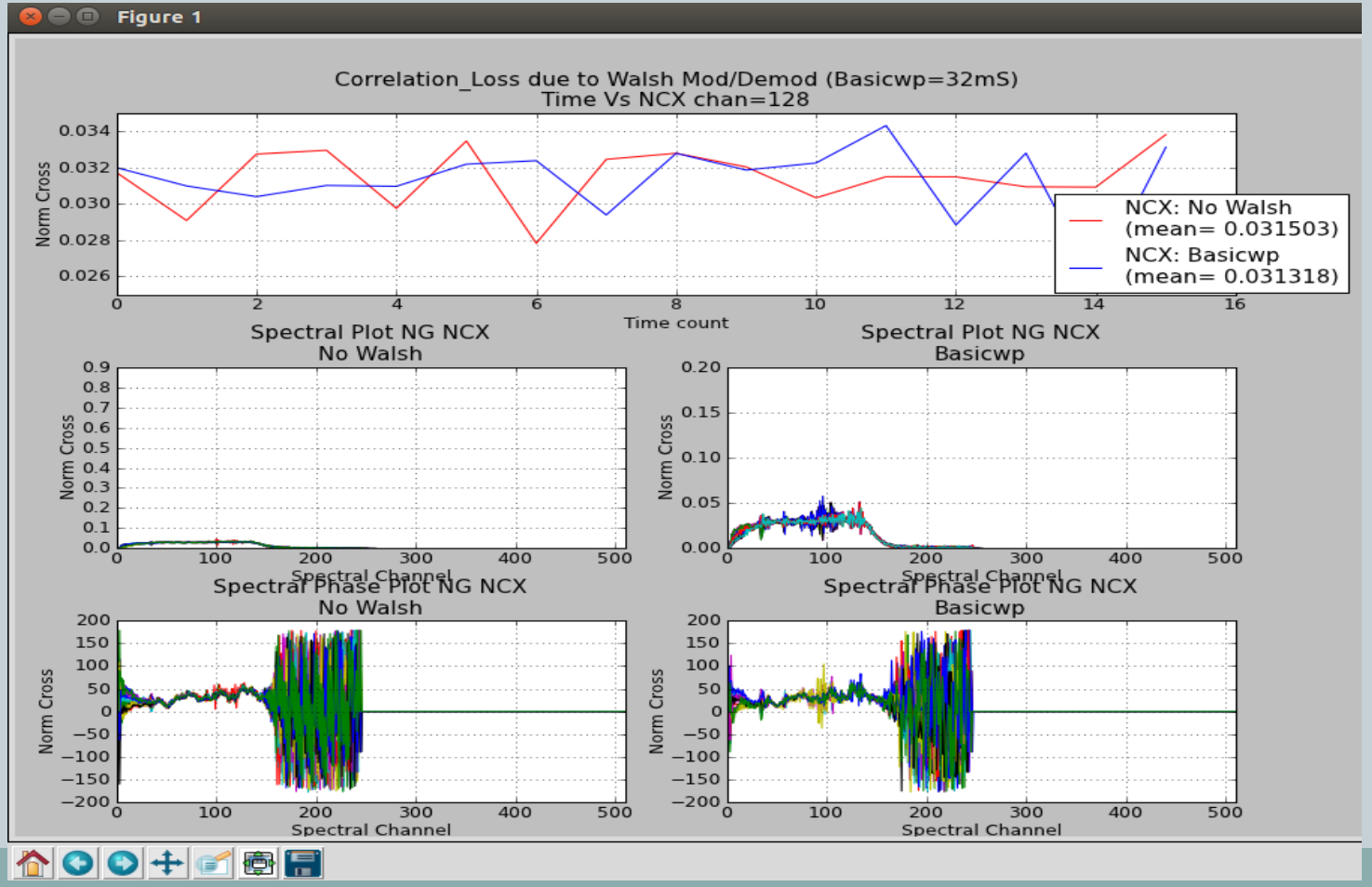


Antenna testing

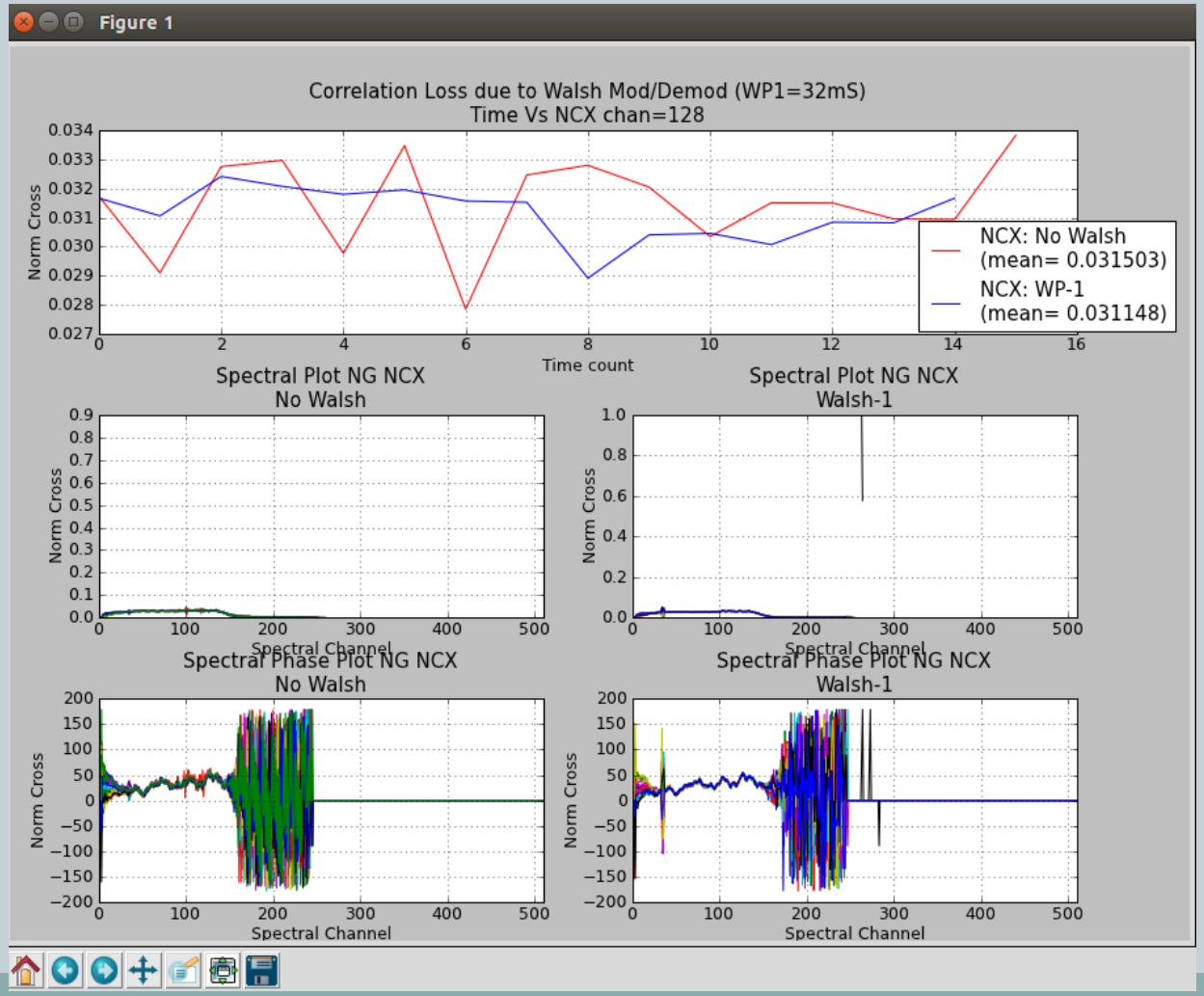
- Actual implementation of walsh scheme on central square antennas i.e. C11 & C12
- Only the C12 antenna having walsh functionality.
- We use only ch-1 of both the antennas.
- Adjusting the delay for ch-1/path-1 of C12 antenna using basic walsh pattern .
- Finding the loss of correlation by modulating/demodulating the single channel .

Results of Antenna Testing

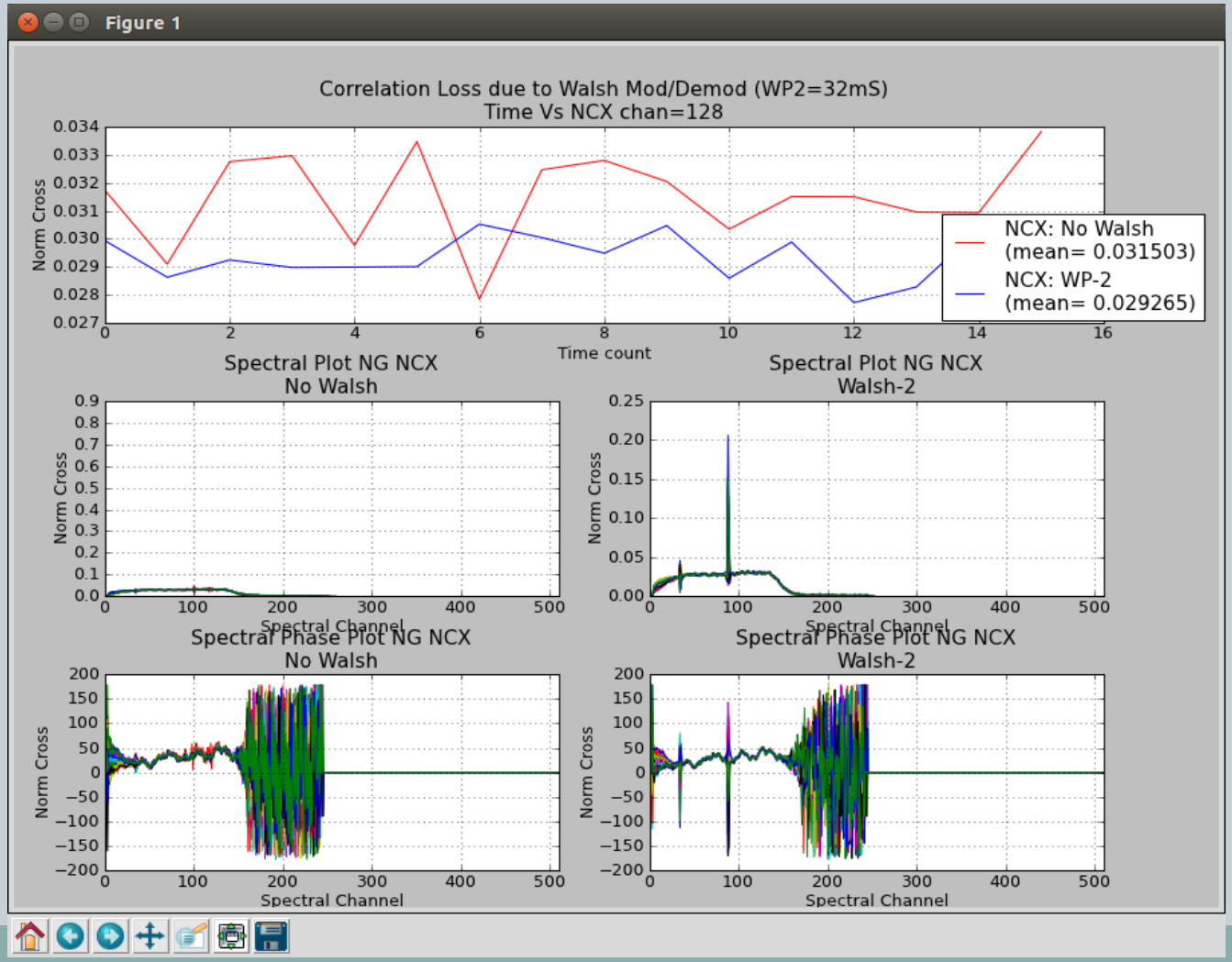
Correlation loss due to Basic wp



Correlation loss due to wp-1



Correlation loss due to wp-2



Loss of correlation for following condition:

- No walsh = (0%)
- Basic walsh pattern mod/demod = (~ 0.58%)
- walsh pattern-1 mod/demod = (~ 1.12 %)
- walsh pattern-2 mod/demod = (~ 7.10 %)

Conclusion & Future Scope

- Lab testing of the scheme shows encouraging results and required repeated testing with GMRT antennas.
- The scheme then may be expanded to 30 antennas of GMRT.
- Walsh delay hunting algorithm need to be suitably modified to work with GWB system.

Thank you