Examination of a simple pulse blanking technique for RFI mitigation

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Motivation

- ⌧ Radio astronomy observations are complicated by RFI

- ⌧ Traditional instruments are ***not designed*** to cope with this problem.

- ⌧ E.g. Output data already integrated to ***low temporal rate***. Rapid pulsed-interference can not be extracted and suppressed in post-observation process

- ⌧ Can make data recording faster; however, amount of data recorded can be ***excessive***.

- ⌧ ***Real-time*** RFI mitigation is ***desirable:*** remove RFI while keeping manageable output data rate

- ⌧ ***Adaptive*** mitigation algorithm desirable for operation in varying RFI environment.

Outline

Interference Suppressing Microwave Radiometer

Asynchronous Pulse Blanking (APB) Algorithm

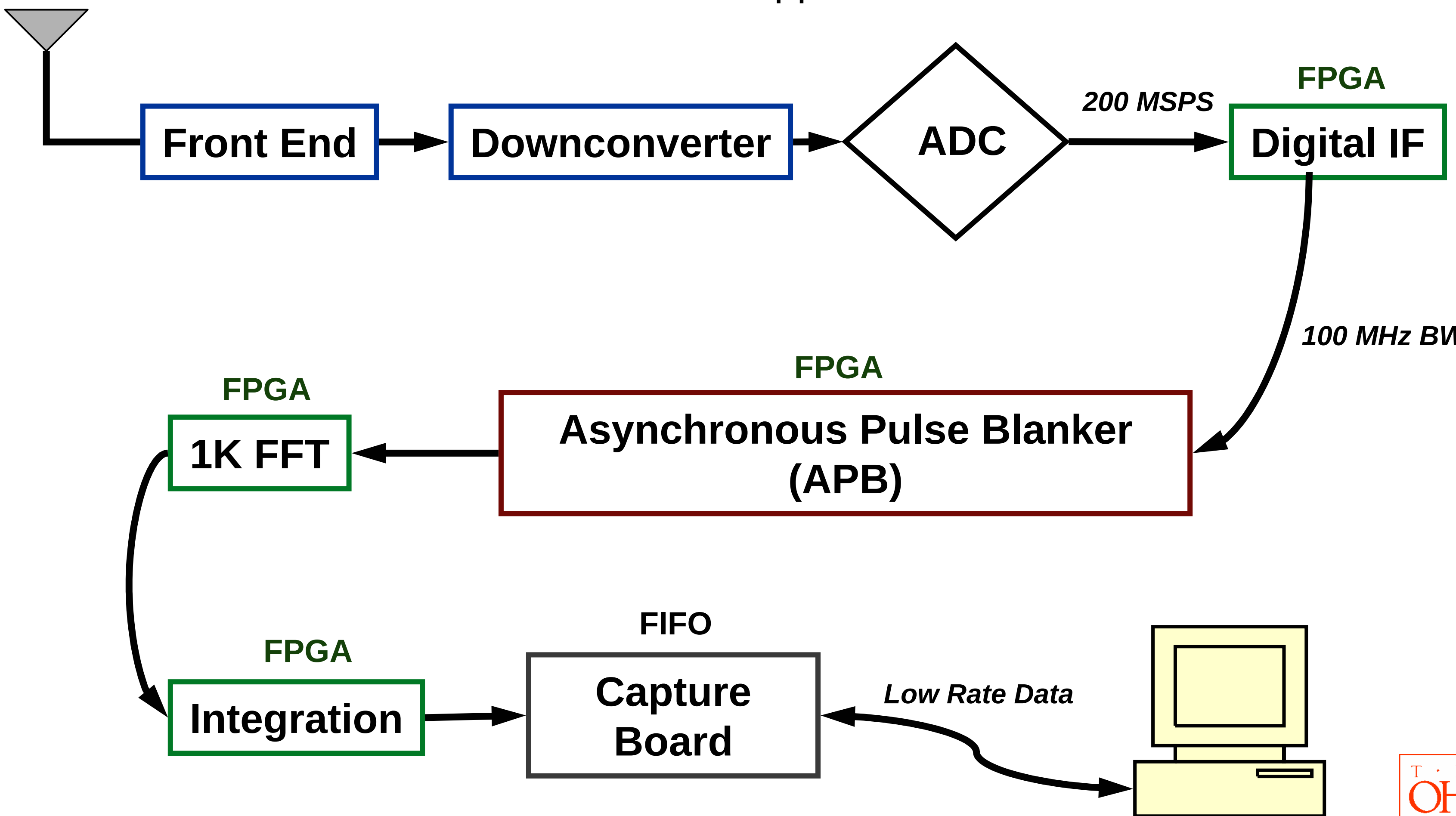
Assessing APB Performance

- ***LISA instrument data set***
- ***Simulations and Results***

Interference Suppressing Microwave Radiometer

Block Diagram

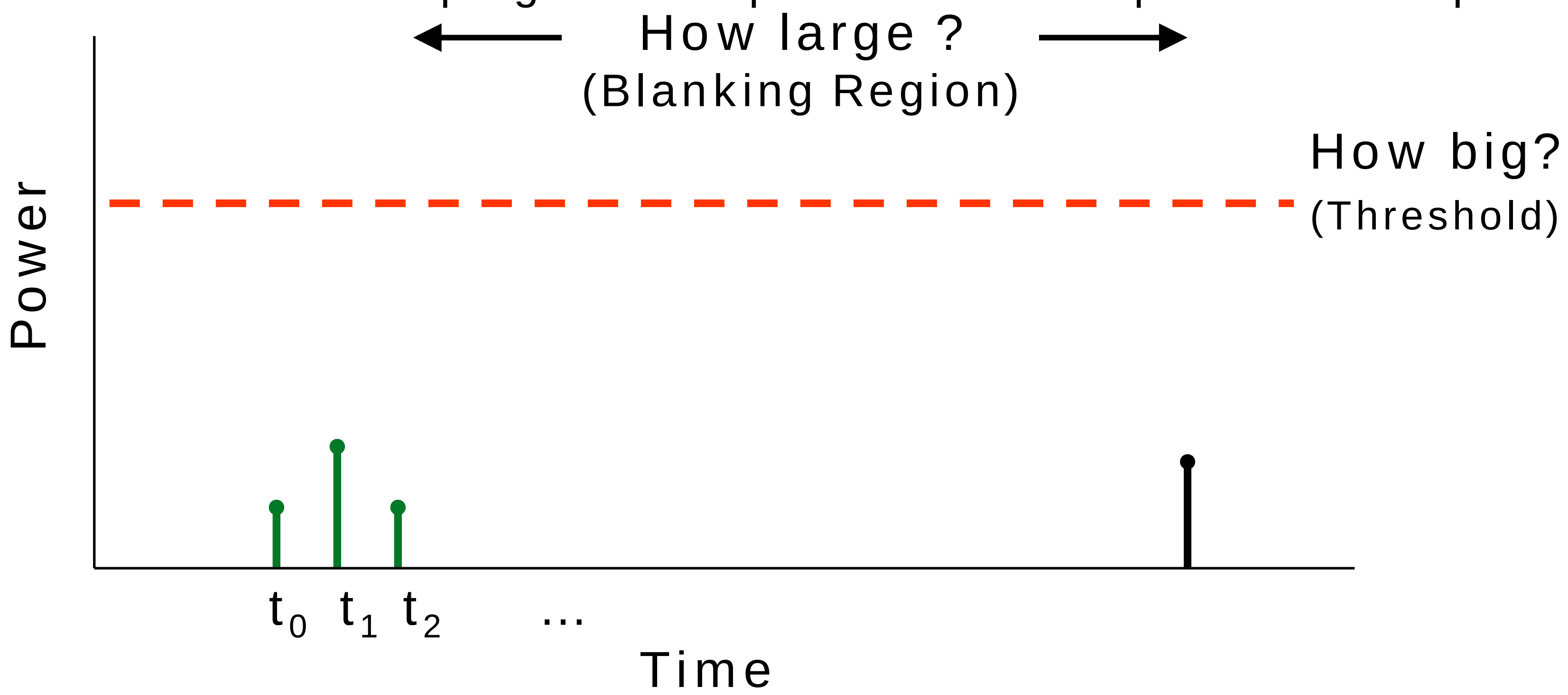
A prototype radiometer has been constructed at OSU under NASA support



APB Algorithm

Basic Idea: Blank samples exceeding a specified threshold

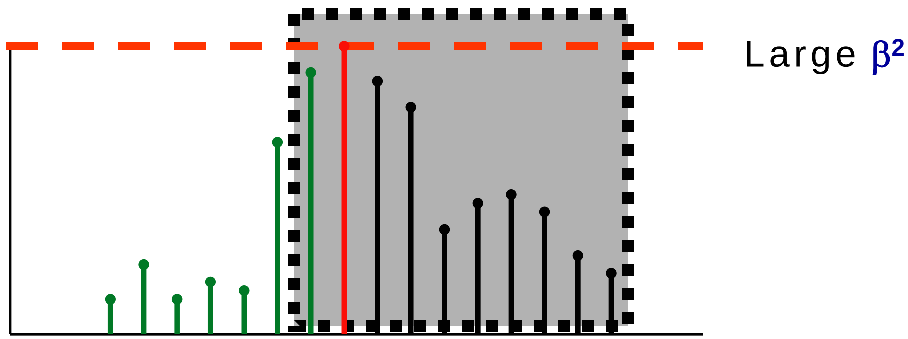
Keep algorithm simple so hardware implementation is possible.

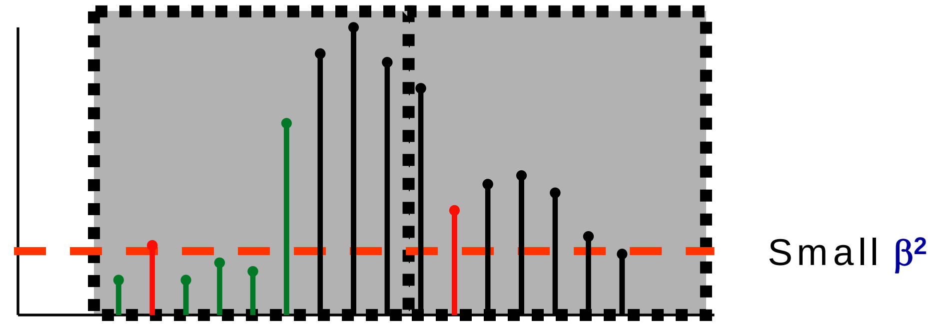


APB Algorithm

Threshold Level:

Defined as **Mean + (β x Standard Deviation)**

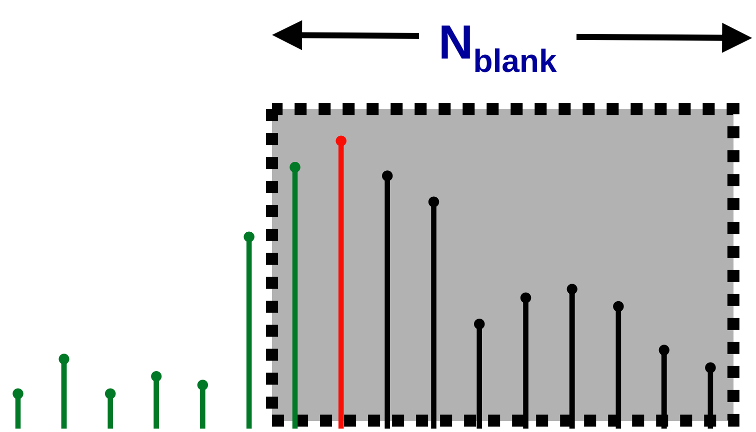




- Large β² reduce the sensitivity of detection.
- Some pulses may be ***missed***.
- Some interference still remains.

- Small β² tends to trigger the ***noise peak.***
- Some desired data is blanked.

Blanking Region:



Assessing APB performance

- Experiments at OSU and the Arecibo observatory with digital radiometer have qualitatively shown ***success*** of APB in removing pulses.

  [Ellingson, S. W., and G. A. Hampson, *RFI and Asynchronous Pulse Blanking in the 1230-1375~MHz Band at Arecibo*, The Ohio State University ElectroScience Laboratory Technical Report 743467-3, Feb 2003a.]

  [Hampson, G. A., J. T. Johnson, and S. W. Ellingson, *Design and demonstration of an interference suppressing microwave radiometer*, IEEE Aerospace Conference 2004, conf. proc., 2004]

- Detailed study of parameter choice was *not* performed; preferable to study in software

- Performance assessing in the *range of RFI* has *not* been studied.

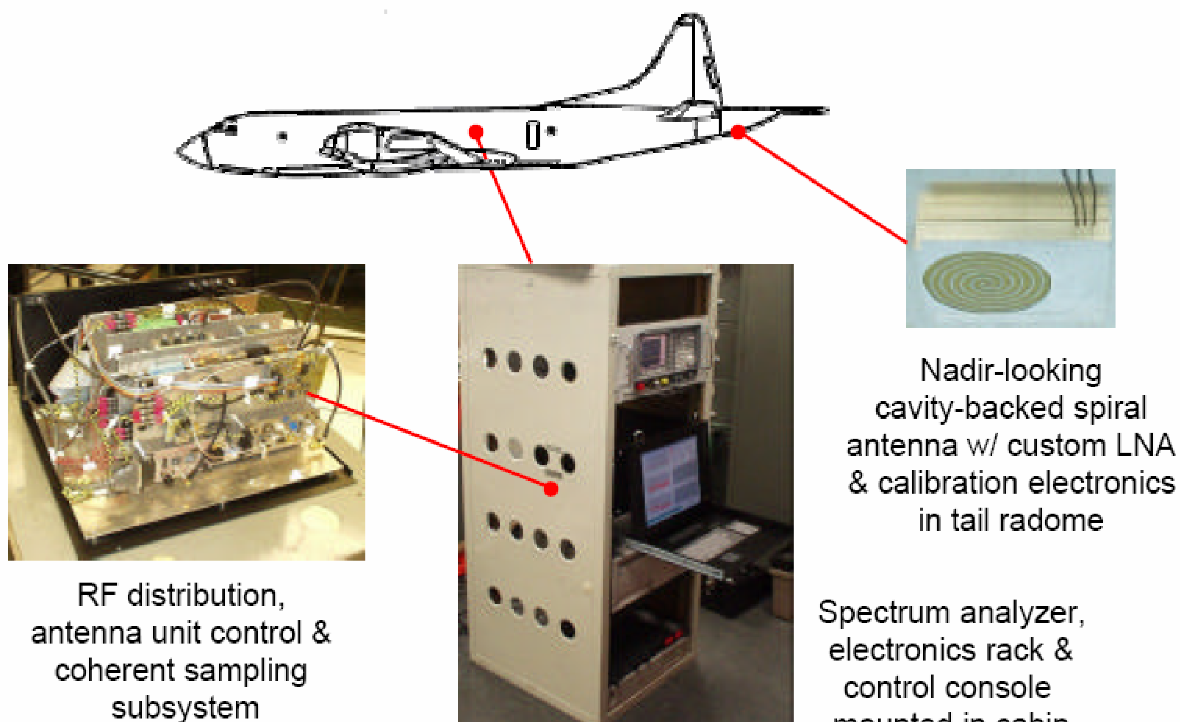
- To address these issues, a *simulation* study has been done using data from LISA instrument

Assessing APB performance

L-Band Interference Surveyor/Analyzer (LISA):

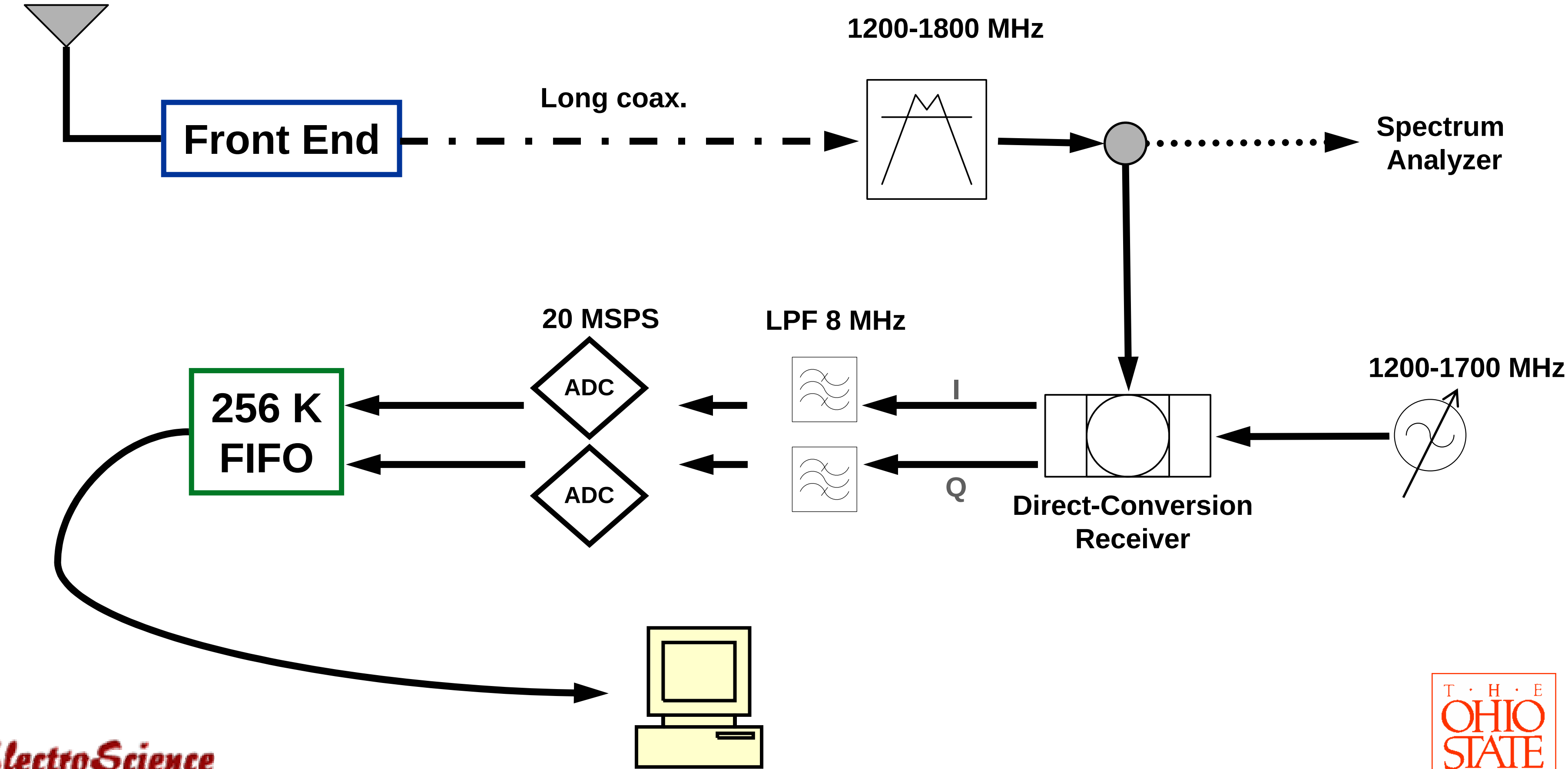
A sensor developed to observe RFI environment.

Deployed in the “Wakasa Bay” remote sensing campaign (Jan-Feb 2003)
flights in US, across pacific and Wakasa bay (Japan)



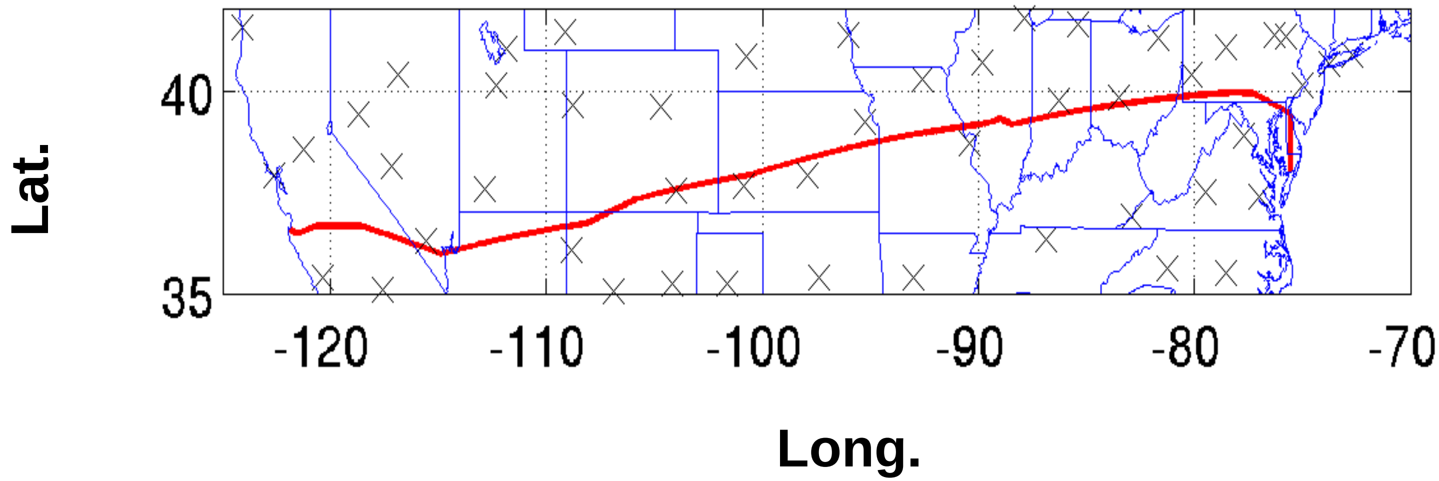
Assessing APB performance

LISA – Block diagram



Assessing APB performance

LISA's Navigation Path: Jan 3, 2003



- Red line represents the navigation path of campaign (VA to CA)
- X-mark shows *known* ARSR station.
- LISA measured 16K captures: 819.2 us sampled every 50 ns.
- For each sweep, ***5*** 16K-samples were sucessively captured wihin 5 seconds
- Capture in same channel is repeated every 15 mins: 145 captures total per channel

Simulations and Results

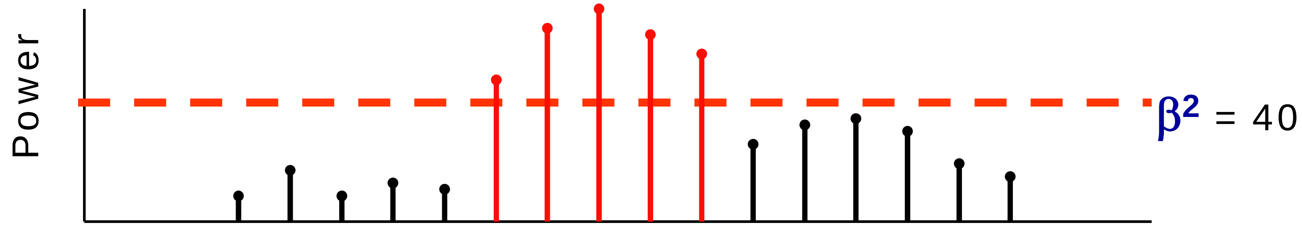
Software study of APB using LISA data set

1. Choosing β^2 and N_{blank}

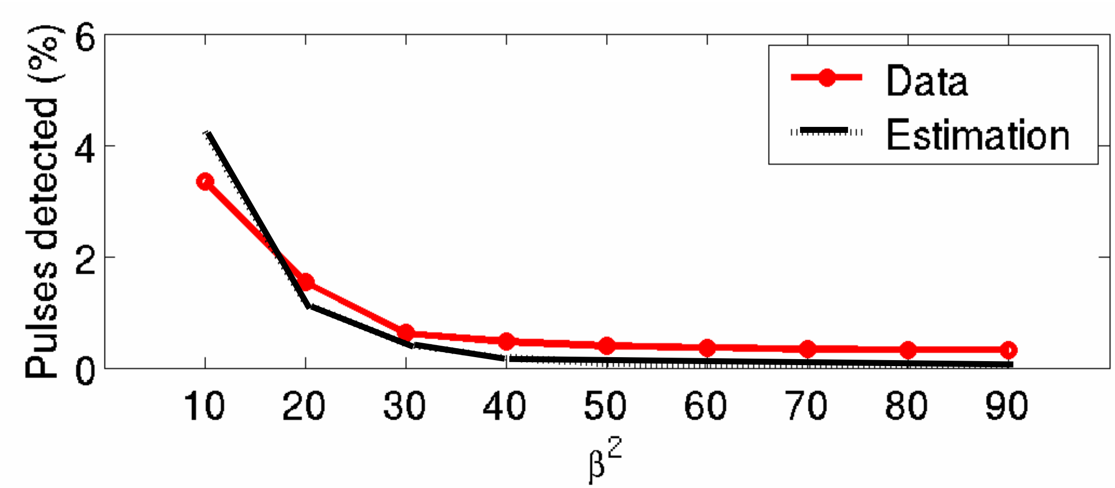
2. Output χ^2 Test

3. Effect of blanking on integrated spectra

Choosing β^2



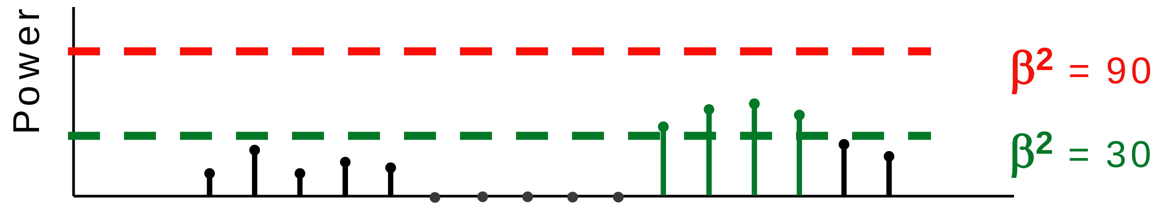
- ***Run*** APB process with given threshold (e.g. β^2 = 40)
- ***Estimate*** amount of samples that can be declared as a pulses.



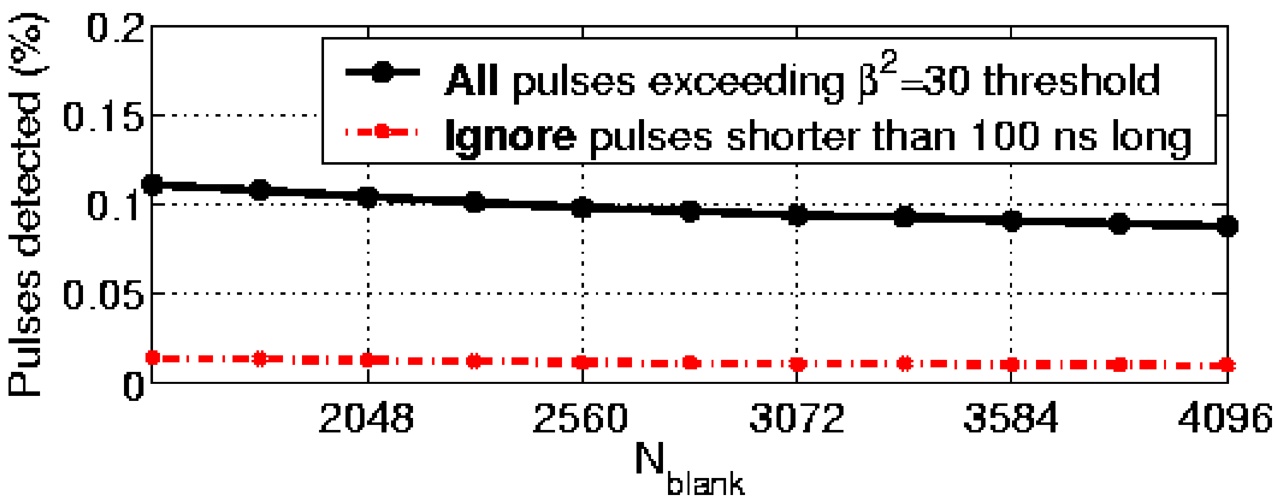
- The estimated % ***steeply increase*** as threshold smaller than 'β^2 = 40' level indicating trigger noise peak

40 < β^2 < 90

Choosing N_{blank}



- With fixed threshold ($\beta^2 = 90$), N_{blank} is ***varied*** for each simulation.
- Reference threshold ($\beta^2 = 30$), used for estimating any pulses left.



N_{blank} is insensitive to % of pulses left

N_{blank} > 1366 samples (68.3 μs)

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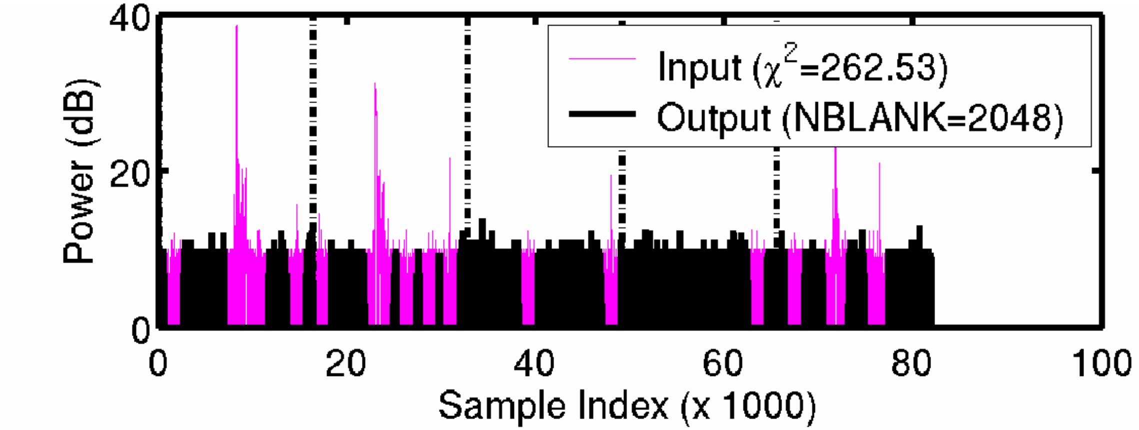
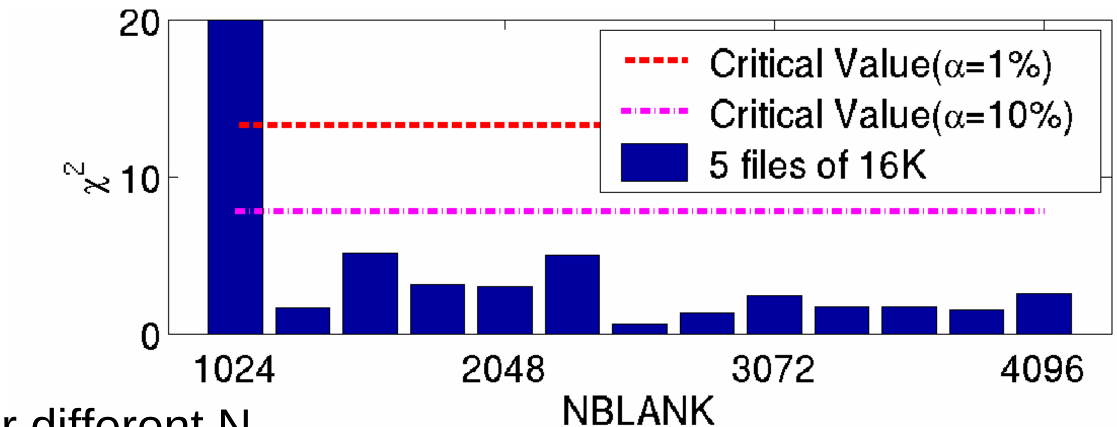
Output χ^2 Test - How Gaussian is the output ?



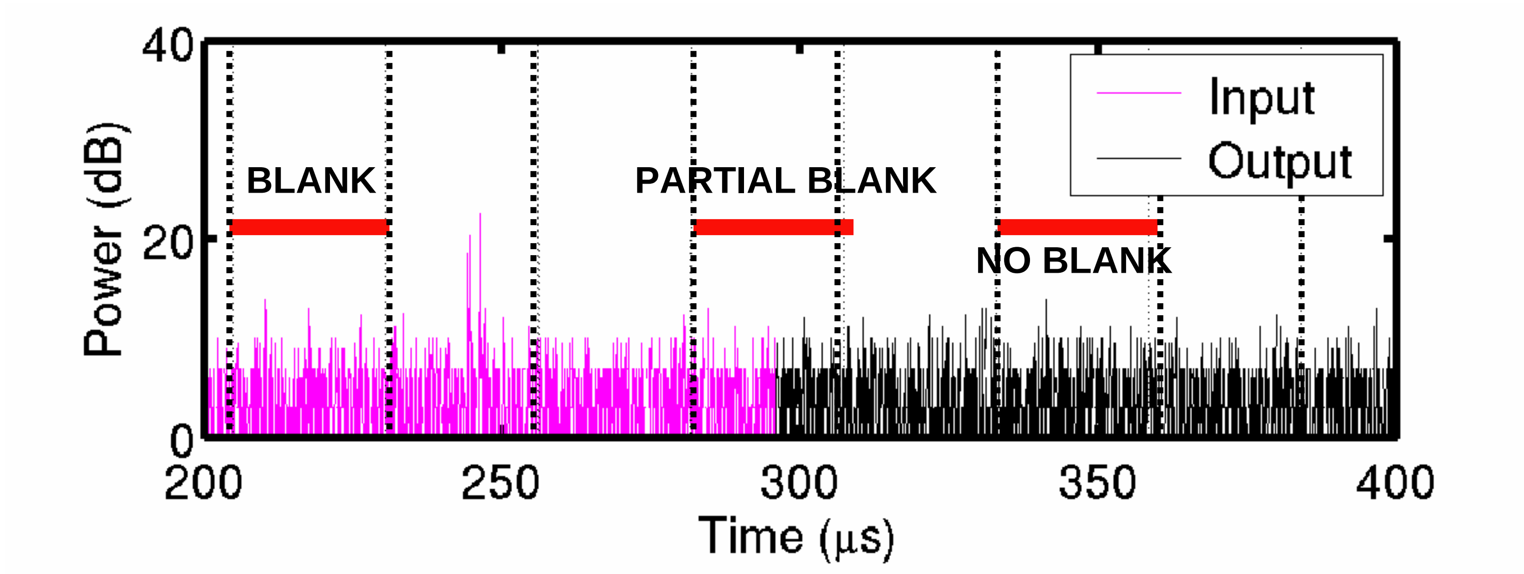
- Five 16K-samples successively captured are tested by ***χ^2*-Test** compared to *gaussian* distribution



-χ^2- value for different N_{blank}

-χ^2 are reduced after blanking (the distribution data tends to become <u>*gaussian*</u>)

Effect of Blanking - Does APB change the desired result?



Split 16K-sample (819.2 μs) into 32 frames of 512-sample

Group them as ***BLANK***, ***PARTIAL BLANK*** and ***NO BLANK "frames"***

FFT each 512-sample; compute spectrum of each frame

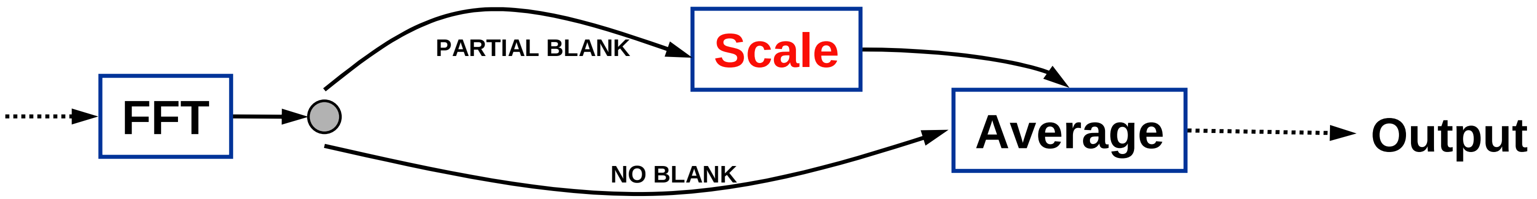
Effect of Blanking - Does APB change the desired result?

Coping with PARTIAL BLANK frames

Instantaneous Scaling: Weigh each frame by N/N_{rem}

N = no. of samples

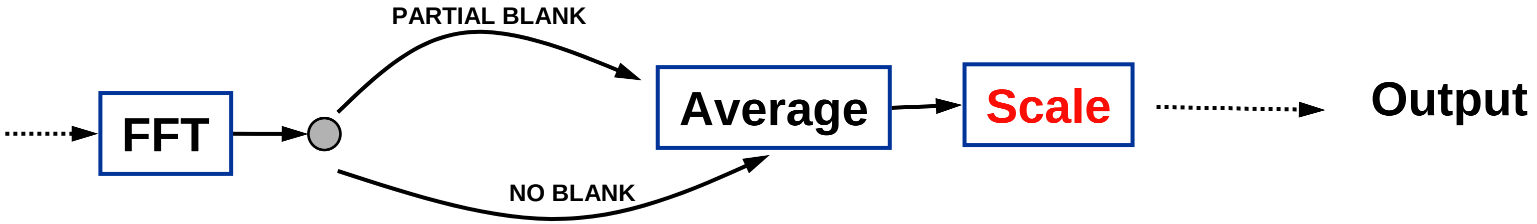
$\mathbf{N_{rem}}$ = no. of ***non-blanked*** samples



Slow Scaling: Weigh total average by $N_{tot}/N_{tot,rem}$

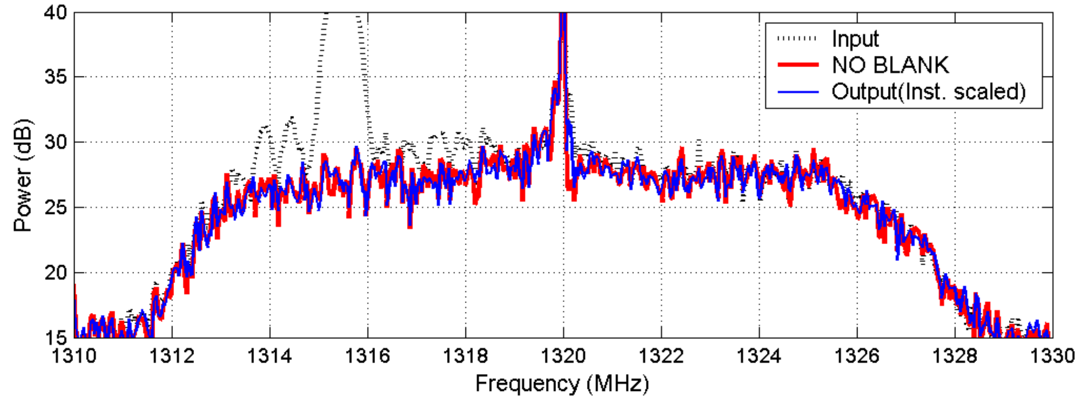
N = ***total*** no. of samples

$\mathbf{N_{tot,\,rem}}$ = ***total*** no. of ***non-blanked*** samples

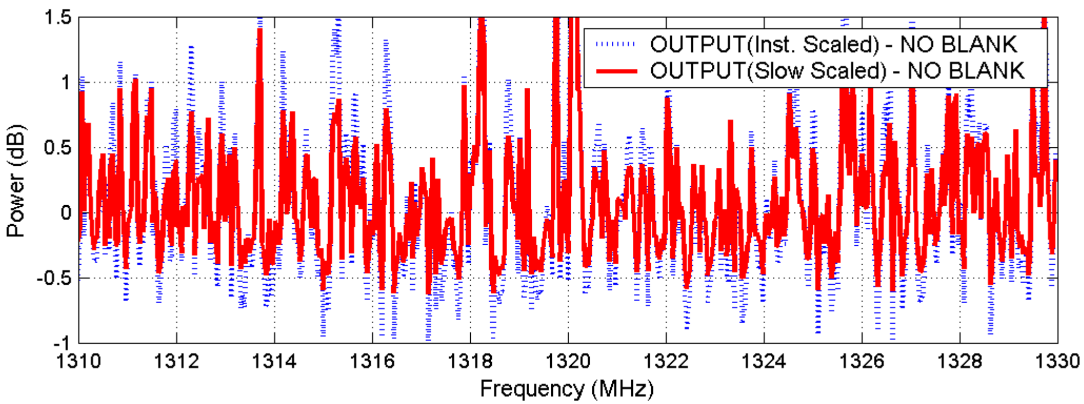


Effect of Blanking - Does APB change the desired result?

Spectral Average



Freq. Spectrum of the desired result (**NO_BLANK**), final **OUTPUT** (NO_BLANK+PARTIAL BLANK) compared to the **INPUT**



The *error* introduced by PARTIAL_BLANK spectrum is relatively ***small***

Conclusion

- APB parameter ranges examined: algorithm seems to be ***fairly robust***, while remaining simple enough to implement in hardware
- The process can ***improve*** the data containing interference and appears to ***perform well*** in varying environments
- Effect on averaged spectra appears small once power is scaled appropriately.