Examination of a simple pulse blanking technique for RFI mitigation

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RFI2004 Workshop, Penticton, BC, Canada
Jul 16, 2004
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

Front End → Downconverter → ADC → Digital IF

200 MSPS

FPGA

100 MHz BW

Asynchronous Pulse Blanker (APB)

Capture Board

Low Rate Data

FPGA

1K FFT

Integration

Low Rate Data

FPGA

FPGA

FPGA

FPGA

100 MHz BW
**APB Algorithm**

**Basic Idea:** Blank samples exceeding a specified threshold

Keep algorithm simple so hardware implementation is possible.

How large?  (Blanking Region)

How big?  (Threshold)

Diagram showing samples at time points $t_0$, $t_1$, $t_2$, etc., with power levels indicated.
**APB Algorithm**

**Threshold Level:** Defined as \( \text{Mean} + (\beta \times \text{Standard Deviation}) \)

- Large \( \beta^2 \) reduce the sensitivity of detection.
- Some pulses may be **missed**.
- Some interference still remains.

- Small \( \beta^2 \) 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.
  


- 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 successively captured within 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** $\beta^2$ and $N_{\text{blank}}$

2. Output $\chi^2$ Test

3. **Effect** of blanking on integrated spectra
Choosing $\beta^2$

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

- The estimated % ***steeply increase*** as threshold smaller than ‘$\beta^2 = 40$’ level indicating trigger noise peak

$$40 < \beta^2 < 90$$
Choosing $N_{\text{blank}}$

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

$N_{\text{blank}}$ is insensitive to % of pulses left

$N_{\text{blank}} > 1366$ samples (68.3 µs)
**Output $\chi^2$ Test - How Gaussian is the output?**

- Five 16K-samples successively captured are tested by $\chi^2$-Test compared to *gaussian* distribution.

- $\chi^2$- value for different $N_{\text{blank}}$

- $\chi^2$ are reduced after blanking (the distribution data tends to become *gaussian*).
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 $N/N_{\text{rem}}$

$$N = \text{no. of samples}$$

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

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

$$N = \text{total no. of samples}$$

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