Adaptive Filters Revisited: RFI Mitigation in Pulsar Observations

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The Motivation:
Parkes 50cm Observing Band

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The adaptive filter is well suited to this problem

- It filters the IF – compatible with the downstream processing.
- We know the location of the RFI – a good reference copy is available.
- The RFI is strong.
- Can be implemented in real-time (on-line) hardware.
- The post-correlation alternative is very expensive.
Power spectra

Top: input IF
Bottom: filtered IF
Filter attributes

INR = Interference/RXnoise ratio (reference IF)

In the signal IF, RFI power is replaced by:

RXnoise, magnitude = RFI power / (1 + INR)

RFI power reduced to RFI power / (1 + INR)^2
The filter will adapt automatically if the conditions change – to delay/phase/amplitude changes between signal and reference channels.

- Filter fairly neutral to fluctuations in RFI power if common to both signal and reference. (If the RFI transmitter modulates the power level). True for large INR; sampling bits.

- The filter cuts out if there is no RFI common to signal and reference.
Current status

- Software implementation of the filter.
- Baseband data (CPSR2) (1 Gbyte files)
  + Software filter to produce a new CPSR2 data file for de-dispersing/folding.
- We have started to quantify the RFI impact on the pulsar observations and timing.
- We continue to investigate the practical (observational) problems with RFI mitigation.
Field Trials

- 64 MHz bandwidth centred on 675 MHz
- Dual polarisation
- 2-bit sampling
- Pulsar J0437-4715 (5.7 msec period)

- Filter works as predicted – RFI reduced by expected amount
- Filter is linear – the pulse characteristics unaffected
Power spectra

Top: input IF
Bottom: filtered IF
Folded data - filtered
Problems

- Low INR – multipathing?
  - Try bigger antenna (3m on tower)
  - Try spatial diversity (two reference antennas)
  - Try decoding the digital TV signal (this strategy worked on glonass)

- Multipathing
  - Sets lower limit on the update time in the filter
Filter performance over 15 secs – multipathing affects relative amplitudes and phase. Filter updated every 3 ms.
Sampling issues

- S/N degradation at the initial sampling
- Non-stationarity
- S/N degradation at the resampling stage
- Dynamic range limitations
Problems (2)

- Resampling noise: 2-bit into filter; floating operations within the filter; 2-bit out for the down-stream processing.

- 2-bit sampling. Will be an issue when higher dynamic range is required. Current system has attenuation in the 10 to 1% range.
Conclusions

- The adaptive filter works well for pulsar observations.
- We plan to start the hardware (FPGA) implementation.
- Maintaining a large INR is clearly a challenge, and is perhaps the main limiting factor.
Project plans

- Develop a hardware filter (FPGA) installed in the IF chain in front of the on-line processor (CPSR at Parkes).

- Improve our understanding of RFI mitigation problems.
The software filter is slow - after some effort, it now takes 10 minutes to process 15 sec of data.

The processing was much improved with the (Intel) IPP library.