Mock Spectrometer Summary

Julia Deneva

November 6, 2009

Parameters and Status

The Mock (aka PDEV) spectrometer has two banks of 7 spectrometer boxes each. When PALFA observes, one bank records high time resolution data for pulsar searching, with one box per ALFA beam. Each of the 7 spectrometer boxes handles two partially overlapping 170 MHz bands: the Low band runs from 1215 to 1385 MHz and the High band runs from 1365 to 1535 MHz. For PALFA observations, we use a sampling time of 65 µs. There is a choice of two data formats: PDEV and PSRFITS and these can be chosen independently for the two spectrometer banks. For pulsar observations, we take data in the PSRFITS format. The Mock spectrometer has been in use for pulsar observations since early 2009, initially in testing sessions only, and later concurrently with the WAPPs during routine PALFA survey observations. If there is a project commensal with PALFA, the second bank of 7 spectrometer boxes records data for the commensal observer, typically at a lower time resolution. Each spectrometer box has its own file server.

Test Observations and Data Reduction

In December 2008 and February 2009 we took test observations of several known pulsars with the Mock spectrometer to evaluate data quality and the types and strength of RFI we can expect. Since Mock data is recorded in the PSRFITS format, pulsar search codes have to either handle that natively or use a conversion tool. For our processing of the test observations, we used psrfit2fil (written by Phil Perillat), which converts from PSRFITS to SIGPROC filterbank format, and the Cornell pulsar search code.

One configuration option we tested was the ADC blanking provided during data-taking. If the ADC blanking is on, once each FFT is computed, it is included in the current accumulation only if less than \( N \) samples in the FFT are clipped. \( N \) is customizable and is typically set to 1. The spectrometer keeps a record of how many FFTs are accumulated for each integrated spectrum that is written to disk so that spectra are scaled appropriately before they are written out. Fig. 1 shows the effect of blanking on bright RFI caused by the FAA radar.

We compared the RFI seen in the Low and High bands of the Mock spectrometer. For the test observations on known pulsars, ALFA beam 0 was aimed at the pulsar and we concentrated on analyzing data from that beam. In general, RFI will vary between the seven ALFA beams within the same observation. Fig. 2 shows dynamic spectra of the Low and High bands of beam 0 for an observation with ADC blanking on. ADC blanking had no effect on the data from the High band during our test observations since there was no strong RFI in that band causing FFTs to be excluded from integrated spectra recorded to disk.

In late 2008 and early 2009 we observed B2016+28, J2229+26, B2127+11, B0301+19, J0051+0423, and J0152+0948. B2016+28 is 1–2 orders of magnitude brighter than the other pulsars and showed
Figure 1: Dynamic spectra of two observations of B2016+28 made without (left) and with (right) ADC blanking. In each plot, the dynamic spectrum is shown in greyscale. Vertical lines around 1330 and 1350 MHz correspond to harmonics of the FAA radar. The top panel shows the average bandpass. The side panel shows a time-varying scale factor which is a measure of total power vs. time, and gives a best fit to the current bandpass shape when multiplied by the average bandpass. Some of the structure in the scale factor is due to pulses from the pulsar. Without blanking (left), radar pulses occurring every 12 s spill over the entire band and give rise to strong spikes in the scale factor. With ADC blanking on (right), the radar pulses are still noticeable in the dynamic spectrum, but their effect on the total power in the band is greatly diminished and pulsar pulses become visible in the dynamic spectrum as faint horizontal lines.
Figure 2: Dynamic spectra of the Low (left) and High (right) bands of a B2016+28 observation made with ADC blanking. In each plot, the dynamic spectrum is shown in greyscale. Vertical lines around 1330 and 1350 MHz correspond to harmonics of the FAA radar. The top panel shows the average bandpass. The side panel shows a time-varying scale factor which is a measure of total power vs. time, and gives a best fit to the current bandpass shape when multiplied by the average bandpass. Some of the structure in the scale factor is due to pulses from the pulsar.
Figure 3: Dynamic spectra of the Low (left) and High (right) bands of a B0301+19 observation made with ADC blanking. In each plot, the dynamic spectrum is shown in greyscale. Vertical lines around 1330 and 1350 MHz correspond to harmonics of the FAA radar. Lines around 1242 and 1257 MHz correspond to aerostat radar frequencies. The top panel shows the average bandpass. The side panel shows a time-varying scale factor which is a measure of total power vs. time, and gives a best fit to the current bandpass shape when multiplied by the average bandpass. In the Low band, sharp drops in the scale factor correspond to blanked aerostat radar pulses. The scale factor in-between the blanked intervals is elevated compared to what happens in the left plot in Fig. 2 because aerostat sub-pulses are present throughout the observation at intervals of 2−3 ms. Outside the blanked main aerostat radar lobe the pulses are not strong enough to cause FFT clipping and therefore blanking has no effect.

up as a candidate in both the Low and High bands after the data was run through the Cornell search pipeline. B0301+19, the second brightest among the test sources, was also found in both bands, although the detection in the Low band was at a harmonic of the pulsar’s actual rotation frequency. The rest of the pulsars were found in search mode only in the High band. B2127+11 is a globular cluster with 8 known pulsars, only 2 of which were bright enough to be detectable within the 300 s observation time, and they were only found in the High band.

B2016+28, J2229+26, and B2127+11 were observed on 15 Dec. 2008 and the dynamic spectra from these observations are very similar to Fig. 1 and Fig. 2, with strong FAA radar RFI in the Low band. B0301+19, J0051+0423, and J0152+0948 were observed on 3 Feb. 2009 and the dynamic spectra from these observations showed strong aerostat pulses with sub-pulses (ipps) at intervals of 2−3 ms present throughout the observations (Fig. 3).

Conclusions and Recommendations
Two things that stand out from the above plots: (1) the RFI situation is and most likely will continue to be very different in the two frequency bands, and (2) where RFI is present, it and its effects on the final data products can be unpredictable. With respect to processing PALFA data in bulk via automated pipelines, we have to make several decisions.

Considering the vastly different RFI conditions in the Low and High bands, should we search each band separately before they are combined and searched again? The overhead of that would be small compared to the time spent dedispersing data. For example, we could produce a dedispersed time series and record candidates for each band, then add the time series for the two bands with an appropriate shift and record candidates for the combined bands. This would be a precaution against missing pulsars that would be found if searching the cleaner High band only, but would be missed if the noisier Low band is added in. Even if RFI excision is applied both in the time-frequency plane before dedispersion and in the power spectrum after the dedispersed time series has been FFT-ed, this may be a good idea since RFI excision is not perfect.

Can we use the two bands for assessing the quality of candidates? For example, if a strong candidate is detected in the Low band but not detected in the cleaner High band, that may be grounds for rejecting the candidate or ranking it lower. On the other hand, that may select against pulsars whose scintillation bandwidth is similar to the 170 MHz width of each band.

Links

Dynamic spectra of test Mock observations:  
http://www2.naic.edu/~palfa/pdev_tests.html

The psrfits2fil tool:  
http://www.naic.edu/~phil/software/pulsars.html

Mock spectrometer info:  
http://www.naic.edu/~phil/pdevall.html

Aerostat radar info compiled by Phil:  
http://www.naic.edu/~phil/rfi/rdr/aerostat/aerostat.html

FAA radar info compiled by Phil:  
http://www.naic.edu/~phil/rfi/rdr/faq/faqadr.html