Coherent On-line Baseband Receiver for Astronomy

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Abstract. Coherent On-line baseband receiver for astronomy (COBRA) is a new digital receiver for pulsar observations being commissioned at Jodrell Bank Observatory. It consists of 16 bandpass samplers and a Beowulf cluster of 91 dual-processor nodes based on 1.13 GHz Pentium III processors connected by Scalable Coherent Interface (SCI). It is capable of processing 80 Mhz bandwidth on-line. The pulsar signal is processed digitally in software to remove the effect of dispersion in the interstellar medium using the technique of coherent dedispersion. The resulting high time resolution profiles are useful in a variety of applications for pulsar research.

The radio emission from pulsars is dispersed by the electrons in the interstellar medium (ISM). Consequently, their pulsed signal arrives at progressively later time with decreasing frequency of observation. This smears the pulse and limits the achievable time resolution of the integrated profile for a given observational bandwidth. High time resolution data are desirable in many pulsar studies such as high precision timing, pulse emission and polarization studies of pulsars. High precision timing leads to well constrained timing solutions which are useful for precision astrometry (Freire et al. 2001), studies in gravitational physics (van Straten et al. 2001; Bailes, this proceedings) and estimation of binary parameters (Nice, this proceedings). Such data are also useful in identifying profile components and estimating component location, widths and separations (Lyne & Manchester 1988) and in constraining the geometry and physics of pulsar emission (Rankin 1983 , Lyne & Manchester 1988, Weisberg, this proceedings).

The inter-stellar medium acts as a unity gain phase delay filter and the form of this filter function can be specified if the dispersion measure (DM) of the pulsar is known. The dispersion smear due to ISM can be eliminated by using an inverse filter function. This technique is called coherent dedispersion (Hankin & Rickett 1975). Coherent Online Baseband Receiver for Astronomy (COBRA) is a new instrument for pulsar research at Jodrell Bank Observatory implementing the coherent dedispersion technique with software. In this approach, the spectrum of the digitized time series is obtained using Fast Fourier Transform in West (FFTW) algorithm. This spectrum is then multiplied by the frequency domain representation of the inverse filter. The filtered time series is then recovered by taking an inverse transform. Applying only the first transform provides a software filterbank.
COBRA consists of 16 5-MHz sampler boards carrying out complex base-band sampling followed by a similar number of 20 Mbytes/sec data acquisition boards. As the radio frequency interference (RFI) has increased substantially in the past few years at the observatory, we have used 8-bit sampling as opposed to 2-bit sampling in other similar receivers. Thus, we have sufficient dynamic range to use RFI excision techniques. The digitized data is processed by a distributed processing code based on Message Passing Interface (MPI) on a dedicated Beowulf cluster having 182 Pentium III 1.133 GHz processors with Linux operating system. The interprocessor communication is based on Scalable Coherent Interface (SCI) supporting MPI. The code implements logical separation between data acquisition, communications and processing functions and a variety of functions such as coherent dedispersion and filterbanking can be carried out with plug in modules. In this sense, our implementation provides a flexible, upgradeable and obsolescence free solution.

We have also developed a benchmark code, which was run on different commercially available processor architecture to determine the required number of processors. This code implements tests which measure the computational efficiency as a function of length of FFT and compute-to-observe ratio as a function DM. The code will prove useful for designing future systems with more advanced processor architecture.

Ten sampler boards have been produced and tested in house and a 20 MHz receiver has been tested with 30 m telescope at the observatory. A 5 MHz system has been in operation with the smaller 13 m telescope for over three months. We have used the latter telescope to compare the timing accuracies of the new system with a traditional 32 channel filterbank system. The timing residuals obtained with COBRA were consistent with the filterbank and much smaller error bars were obtained as expected.

A 50 MHz system is expected to be in regular use with Lovell telescope at the observatory by the end of year. We plan to extend the bandwidth of the receiver in a scaled fashion to 160 MHz by next year. This will require the addition of a front end FFT processor on the sampler board for which provision has already been made. We also intend to incorporate RFI rejection techniques in the software to improve the data quality further. Thus, COBRA promises to be a unique instrument for high precision pulsar timing.

References