The GAVRT Back-End Sub-System: an FPGA based instrument capable of processing radio astronomy signals with extremely large instantaneous bandwidth

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As the bandwidth of radio astronomy receivers continues to grow, it is important that the capabilities of the digital back-end keep pace to take full advantage of the instrument. Such wideband systems present a number of challenges. First, gigahertz bandwidths imply multi-gigasamples per second of data which must be reduced to a usable product. Any continuous 1 GHz band in the centimeter-wave regime will almost certainly contain RFI. In the range below 5 GHz, RFI dominates the spectrum.

The Goldstone Apple Valley Radio Telescope (GAVRT) is one such wideband system. The receiver is able to down convert four 2 GHz bands which may be independently tuned. This provides a total of 8 GHz in each of two polarizations. We describe here the strategy taken to process this vast amount of instantaneous bandwidth.

The GAVRT Back-End Sub-System is built upon the CASPER hardware and software platform from the Berkeley Wireless Research Center. The current hardware is mature and stable, and the software libraries allow for rapid instrument development after an initial learning curve. FPGA based systems are inherently reconfigurable, thus enabling a broad range of observation modes. For example, in spectral line observations, high spectral resolution is more important than total bandwidth. In this case, a coarse polyphase filter bank (PFB) divides up the band into sub-bands. Then a much finer PFB can be used to analyze the sub-band of interest at the desired spectral resolution. The PFB should provide sufficient rejection of the remaining RFI present at the Goldstone site.

In another mode, the full incoming data rate is stored in a circular buffer until a trigger signal is received, at which point the data is written to a cluster of computers for processing or written to disk. This will provide a relatively high duty cycle which should, for example, enable the capture of a high percentage of giant pulses from a pulsar. Incoherent dedispersion can easily be implemented in the FPGAs to provide a more sensitive trigger. For pulsar timing observations, the system will be well suited to operating in a similar fashion to current pulsar machines, wherein the RF band is broken into sub-bands a few megahertz wide which are then sent to a cluster of computers which perform coherent dedispersion and folding. Initial tests by other members of the pulsar community have demonstrated that modern programmable graphics cards are very efficient at coherent dedispersion. We are investigating this technology as a way to reduce the number of nodes needed in the accompanying computer cluster.