A Backend for the Dwingeloo Radio Telescope

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Introduction

The Dwingeloo Radio Telescope is a 25 m parabolic dish for radio astronomy in the Netherlands. The formal opening by H.M. Queen Juliana of the Netherlands was in 1956, and it was at that time the largest fully steerable parabolic dish in the world. For nearly 50 years it served as an astronomical instrument before being eclipsed by newer observatories, and it became disused in the '90s.
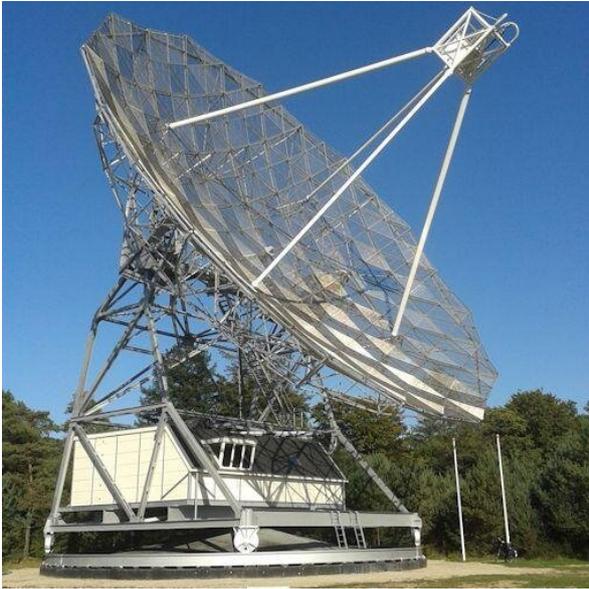
Figure 1: The Dwingeloo Radio Telescope

In 2006 the foundation CAMRAS (C. A. Muller Radio-Astronomie Station), a group of volunteers, started with repairing and restoring the instrument. It received the status of 'National Monument' and a professional restoration of the outside was undertaken. All other parts of the telescope, e.g. receivers, antennas, engines and control system have been built by this group of amateurs.

The Backend

One of the author's contributions has been the design and construction of an FPGA based spectrometer for astronomical observations. It consists of a 10-bit ADC sampling at 70 MS/s and a Xilinx Spartan-3A 1800-DSP FPGA. The digitized, processed data is available on an Ethernet (100 Mb/s or 1 Gb/s) connection. Multiple firmwares have been developed for this platform to support different observational modes.

Figure 2: Backend (top left) with receivers, RAID server and Rubidium clock

In 'pulsar mode', the backend performs a windowed, real-time FFT with 256 bins output. This results in a spectral resolution of 137 kHz, and produces 2136 spectra per second over the Ethernet port. This data can be recorded for post-processing. It can also be de-dispersed in real-time for observation and sonification of strong pulsar signals, which is a great way to demonstrate pulsars to the general public.

In 'line mode', the FFT produces 2048 bins for a resolution of 17 kHz. This mode is used for observations of the 21 cm spectral line. We have performed observations of several galaxies in this mode, including our own Galaxy.

For more advanced post-processing, a 'raw mode' has been introduced where the 700 Mb/s output of the sampler is transmitted over the Ethernet link at 1Gb/s, and stored on a RAID array or fast SSD. This mode allows better spectral filtering such as WOLA or PFB structures, but also allows for use with other types of receivers, such as a software GPS receiver/decoder.

Finally, a recently introduced FPGA personality is the '5M-SDR' firmware. It isolates the central 5 MHz of the passband using a cascaded FIR filter, and sends this data out as an interleaved series of 16-bits integers. This output is directly compatible with GnuRadio. One of the applications is to use GR to receive echoes via the Moon from a beacon located in Belgium (ON0EME). This personality is also used for the SETI activities at CAMRAS, where GR is used to record L-band data with only a single bit resolution.

The functionality of the backend will be illustrated with several astronomical and other results that we have recorded.