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Real-time RFI mitigation for the beamformer mode of the upgraded GMRT

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1. Extended Abstract

The continual increase in sensitivity of radio telescopes (due to improvements in collecting area, improved receivers and increased bandwidth), coupled with the ever growing use of the radio spectrum for man made activities, pose significant challenges for RFI mitigation in radio astronomy. The challenge is often more severe for low frequency radio telescopes like the Giant Metrewave Radio Telescope (GMRT) which works in the centimetre to metre wavelength regimes. In some situations, to be most effective, the mitigation has to be carried out in real-time, which significantly increases the challenge.

The upgraded Giant Metrewave Radio Telescope (uGMRT) that is getting ready for release to the global user community, offers near seamless frequency coverage in the 100 to 1500 MHz frequency range, with an instantaneous bandwidth of upto 400 MHz. This makes the telescope more sensitive -- to astronomical signals as well as radio frequency interference. In addition to spectral line RFI from various transmitters, a good fraction of the RFI seen by the GMRT is short duration and bursty in time, and is best removed by working on the data at high time resolutions, necessitating a real-time implementation. Furthermore, for routine studies of pulsars with the beamformer mode of this multi-element array telescope, it is preferable to collapse the data in time and frequency (after correction for dispersion) before recording to disk, in which case the RFI needs to be removed at appropriate resolutions in time and frequency.

We have developed a RFI mitigation tool for the beamformer mode of the GMRT, that (i) efficiently detects and filters RFI in time and frequency domains (ii) does the operation in real-time, at nyquist rate (iii) generates statistics on the raw data as well as the filtered data, which can be used to judge the quality of the filtering done. We use an approach where the goal is to get to the statistics of the data before it was corrupted by outliers. Then that information is used to detect and eliminate RFI. The tool provides multiple algorithms to calculate statistical estimates, including standard ones like Median Absolute Deviation (MAD). To overcome the limitations of MAD under conditions of very strong and persistent RFI, we have developed a new method that extracts information about the distribution of the intensity signal by estimating the histogram. The binning of histogram is done optimally using an adaptive approach. We describe this technique in detail, and show that it outperforms MAD, both in accuracy and reliability of the filtering, as well as in computational expense. These techniques are first applied on the time series looking for impulsive bursts of RFI, and then the bandshape, cleaned of impulsive RFI, is looked at for spectral lines. We then track the time-frequency points flagged by the scheme, as we generate dedispersed and folded profiles for pulsars from the beamformer data. We present sample results from application of this tool for improving the quality of pulsar data obtained with the GMRT. These results include cases where RFI filtering improves the signal to noise of the folded pulse by an order of magnitude. We also see the quality of noise as measured by various parameters like the ration of mean to rms of the signal and Anderson–Darling test statistic improving dramatically after filtering.

The tool is implemented in c++ and runs on any general multi-core CPU. It is able to filter RFI, dedisperse the data, fold and dump the time series and folded profiles to disk in real time, for up to 2048 channels across 200 to 400 MHz bandwidths and time resolution of 20 microseconds, utilizing six threads of the CPU. The performance scales almost linearly with the number of processing cores used; the user can decide that number at run-time, providing both flexibility and optimal utilization of resources.

We describe the distribution of tasks among threads that enables real-time processing with such efficiency and flexibility. The tool is now in regular use at the observatory and will be an integral part of the suite of RFI mitigation schemes for the uGMRT. It is flexible enough that it can easily be adapted to similar time-frequency data from any other radio telescope. We also discuss possible future improvements in the scope and capability of this RFI mitigation tool.