URSI GASS 2023, Sapporo, Japan, 19 – 26 August 2023

Towards Transient Radio Interference Detection Using MeerKAT's D-Engine

Z. Mohamed-Fakier*(1)(2), Dr. S. Paine(2) and Dr. S. Winberg(2)
(1) South African Radio Astronomy Observatory, Cape Town, South Africa; e-mail: zfakier@sarao.ac.za
(2) Radar Remote Sensing Research Group, University of Cape Town, Cape Town, South Africa; email: stephen.paine@uct.ac.za; simon.winberg@uct.ac.za

With the rapid advances in hardware radio astronomy observatories have become increasingly sensitive. While the increased sensitivity is welcomed, it also leads to significant problems related to terrestrial radio frequency interference (RFI). In particular, transient RFI has become more relevant with time domain astronomical sciences such as pulsar and fast radio burst (FRB) studies as unlike narrowband, continuous RFI, there are fewer regulations and transient RFI is generally unintentional [1].

The MeerKAT antenna array in South Africa [3] is being commissioned by the South African Radio Astronomy Observatory (SARAO) with the goal of being incorporated into the larger Square Kilometre Array (SKA). Due to the sensitivity of the system, a particular emphasis has been placed on RFI detection and mitigation throughout the system, including the use of fixed RFI monitoring stations that are independent of the array itself. These stations house the Real Time Analyser (RTA) system that makes use of the Reconfigurable Open Architecture Computing Hardware (ROACH2) FPGA platform. While the flexibility and power of the ROACH2 platform has numerous benefits, there are complications with stand-alone RFI monitoring stations. Such as the requirement for stringent shielding with regular testing and maintenance to ensure no additional RFI is emitted from the system itself. In addition to this, the current system uses a linear buffer scheme which means a transient could be missed during the buffer read out period.

To overcome the limitations of a separate on-site RFI detection system, automatic RFI detection within the main array digitisation stage is proposed. This approach has a number of advantages such as earlier RFI detection and therefore improved RFI mitigation, leading to improved resource management throughout the entire signal chain. Another advantage of the proposed approach is clear when used in conjunction with direction finding algorithms to pinpoint RFI sources.

This work describes the foundations of a transient RFI detection design using MeerKAT's D-Engine [5]. The D-Engine is part of the digitiser system located at the feed of the MeerKAT antennas [4]. The firmware, broken into two subsystems, has been designed using the Collaboration for Astronomy Signal Processing and Electronics Research (CASPER) toolflow [6] [2]. The fist subsystem is an impulse detector consisting of a moving average filter based on sum of absolutes calculations, thresholding based on a runtime programmable setpoint and latching logic for indicating when a detection occurs [2]. The second subsystem is responsible for data capture, where 8-bit ADC data is stored in a circular buffer. Once a potential RFI event has been detected, the data within the circular buffer is written into BRAM and the trigger point address is recorded.

This work outlines the initial step in creating an automated on-board transient RFI detection system. With the planned upgrade of the MeerKAT D-Engines [7], the next phase of this project is to leverage the additional FPGA resources to evaluate the performance of the proposed design on real hardware before finally using the captured data to train an appropriate classification algorithm.

References

[1] D. Czech, "Time Domain Classification of Transient RFI," PhD. dissertation, University of Cape Town, Feb. 2019. [Online]. Available: https://open.uct.ac.za/handle/11427/30071.

[2] J. Gowans, "Design and Implementation of an RFI Direction Finding System for SKA Applications," M.S. Thesis, University of Cape Town, Oct. 2020. [Online]. Available: https://open.uct.ac.za/handle/11427/33701.

[3] J. L. Jonas, "MeerKAT," 2019 URSI Asia-Pacific Radio Science Conference (AP-RASC), New Delhi, India, 2019, pp. 1-1, doi: 10.23919/URSIAP-RASC.2019.8738534.

[4] R. Siebrits et al., "Dissemination of Reference Signals for a Next Generation Radio Telescope," 2018 IEEE International Frequency Control Symposium (IFCS), Olympic Valley, CA, USA, 2018, pp. 1-6, doi: 10.1109/FCS.2018.8597492.

[5] A. van der Byl et al., "MeerKAT correlator-beamformer: a real-time processing back-end for astronomical observations," Journal of Astronomical Telescopes, Instruments and Systems, vol. 8, no. 1, Nov. 2021. Accessed: Feb. 6 2023. doi: 10.1117/1.JATIS.8.1.011006. [Online]. Available: https://doi.org/10.1117/1.JATIS.8.1.011006.

[6] X. Duan et al., "Implementation of CASPAR Firmware Interface on PYNQ-Z2," 2022 IEEE 9th International Symposium on Microwave, Antenna, Propagation and EMC Technologies for Wireless Communications (MAPE), Chengdu, China, 2022, pp. 53-57, doi: 10.1109/MAPE53743.2022.9935197.

[7] S. Malan, *MK+ Design Document*, rev. A, South African Radio Astronomy Observatory, Cape Town, South Africa, 2020.