Section A: Overview of the Research Project

1. Title of the research project

Impact of Harmonics in radio astronomy

2. Broad area of research (Engineering or Science)

Science and Engineering

3. Academic level of research project (Masters or Doctoral)

Masters

4. Abstract of research project

Radio frequency interference (RFI) has plagued radio astronomy since its inception, and will likely only get worse by the time the Square Kilometre Array (SKA) comes up. RFI can be either internal, man-made i.e. generated by instruments; or external i.e. originating from intentional or unintentional radio emission generated by man. A radio signal received by an antenna consists of a summation of signal from sources in the sky with RFI and thermal noise.

Traditional interferometric workflows attempt to detect and excise the effects of RFI in the correlator output products. We know have the technical capability to explore an alternative approach, that is, to capture and store raw voltage streams and analyze them for RFI harmonics. This project therefore consists of understanding the physics behind harmonic production, simulating them and creating a database of known harmonics which can be used to excise RFI from astronomical data.

5. Primary supervisor's details:

Prof Oleg Smirnov
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6. Research supervisor's details (if relevant)

Dr Nadeem Oozeer,
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Data Scientist
SARAO/Rhodes University

Section B: Details of Research Project

1. Scientific/Engineering merit: describe the objectives of the research project, placing them in the context of the current key questions and understanding of the field.

Data from the MeerKAT digitiser is sent to the correlator beam former. These are further piped into ingest at 0.5s dump period which then average the data to produce the L0 data stream with a time resolution of 2s, 4s, or 8s. The ingest step's output is an averaged outlier excised dataset with relevant meta-data stored in telstate, which is called the visibility sample. To better understand RFI, having a high time resolution is essential. However, storageat higher time resolution has not been feasible, so regular interferometric workflows attempt to detect and excise RFI in the visibility products of the correlator.

With the Breakthrough Listen engine now providing the ability to capture the raw voltage streams from the antenn digitizers, we have the opportunity to detect and analyze RFI harmonics “at the source”. RFI harmonics will undoubtedly continue to become more of a concern as more equipment that produces them is added to the SKA site. But if adequately considered during the initial design of the system, harmonics can be managed and their detrimental effects avoided.

The objective of the project is to use data science tools to analyse the raw per-antenna voltage streams (at high time resolution) as measured by MeerKAT. We will provide a database of potential harmonics with their potential sources at various MeerKAT operating frequencies. This will allow us to understand the impact of these RFI due to harmonics on radio astronomy data. Using a similar framework as the KATHPRFI (see Shilangu et al 2022, https://arxiv.org/pdf/2211.08879.pdf), we will provide the statistics of how much of such harmonics have been picked up by MeerKAT and show their evolution around the MeerKAT site.

2. Feasibility:

Data is already available for this research work and some preliminary analysis has already been carried out. Further data collection will be done using the raw voltage capture machine of the Breakthrough Listen project. Compute resources at SARAO (science cluster) and Rhodes (RATT cluster) are also in place for this project.

3. Link the proposed project to one or more of the SARAO research priority areas for 2023 (refer to Section 5 of the Application Guide), and explain in some detail how the proposed research will contribute to the priority area(s).

This project aligns with the following priority areas of SARAO:

- Science
- Hardware and data analysis systems for detecting, monitoring and identifying Radio Frequency Interference (RFI), including the use of telescope data (e.g. using MeerKAT visibilities to locate RFI sources).

4. If relevant, describe any particular qualifications, academic abilities, skills and/or experience that a student should have in order to successfully deliver on the objectives of the research proposed.

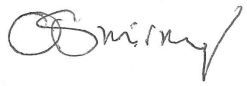
Compulsory skills

- Physics/Engineering/Mathematics (BSc Hons level),
- Python programming - intermediate level

The following skill will be advantageous:

- Background of radio astronomy
- Signal processing,
- Data science

Supervisor



Oleg Smirnov 22 February 2023