Application

Postgraduate Bursary Programme
Square Kilometre Array Project

i. **Supervisor's Title and Full Name:** Professor Michaël Antonie van Wyk (email: mavanwyk@gmail.com).
ii. **Supervisor's University:** University of the Witwatersrand, School of Electrical and Information Engineering
iii. **Title of Research Project:** Evaluation of Decorrelation Techniques for Direction-of-Arrival Estimation of Coherent Radio-Frequency Sources
iv. **Level of Research Project:** MSc Electrical Engineering
v. **Overview and Aims of the Research Project (300 to 400 words max.)**

Overview:

Radio-astronomy arrays are typically constructed in remote areas in order to minimize the possibility of interference from terrestrial radio frequency sources such as personal wireless devices, broadcast infrastructure and automobiles. Despite this precaution, radio-frequency interference (RFI) remains a significant problem in the radio-astronomy context, and has to be addressed using one or more mitigation techniques [1]. A popular approach towards RFI mitigation, namely adaptive beamforming, relies on a mechanism for accurately estimating the direction of arrival (DOA) of interfering transmissions. Due to the fact that the interferer may transmit in an intermittent and irregular fashion, and move around, DOA estimation must be performed in real time.

A popular approach towards DOA estimation involves the estimation of the spatial covariance matrix of signals arriving at different elements of an antenna array. Using the covariance matrix, a subspace technique such as the multiple signal classification (MUSIC) algorithm or estimation of signal parameters via rotational invariance techniques (ESPRIT) is frequently used to estimate the DOA. These subspace techniques have become popular due to their simplicity, accuracy and robustness; however, they exhibit a severe performance degradation if the interfering signals are coherent – that is, if the phase angles of the signals vary slowly relative to one another. This commonly occurs in multi-path propagation environments, where multiple copies of the interference signal arrive at the antenna array with different path delays.

Several techniques for mitigating source coherence have been developed. These include spatial smoothing and Toeplitz decorrelation techniques [2]. Whereas the working principles behind these algorithms are relatively well understood, their effectiveness depends on how well the measured interference fits the statistical signal model assumed in the derivation of the algorithm. In the case of the Toeplitz decorrelation techniques, the performance impact of model mismatch has not yet been investigated using measured data.

The proposed project is a performance comparison of the spatial smoothing and Toeplitz decorrelation algorithms using signal measurements gathered via an antenna array and software-defined radio (SDR) platform developed by the Defence and Security Cluster of the Council for Scientific and Industrial Research (CSIR). The performance metrics to be considered are the resultant accuracy of DOA estimation using MUSIC and ESPRIT, as well as the computational complexity of the coherence mitigation algorithms. It is anticipated that the outputs of this research will serve to guide the development of a real-time DOA module on the CSIR SDR platform, and eventually on the SKA.

References:

[1] International Telecommunication Union, "Techniques for mitigation of radio frequency interference in radio astronomy", Rep. ITU-R RA. 2126-1, 2013.

[2] C. Hui, H. Benxiong, D. Bin and H. Yaoqin, "A modified Toeplitz algorithm for DOA estimation of coherent signals," in Proc. 2007 IEEE International Symposium on Intelligent Signal Processing and Communication Systems, pp. 80–83, 2007.

Aims of research project:

1. A quantitative evaluation of the resultant DOA estimation accuracy and computational complexity attributed to the spatial smoothing and Toeplitz decorrelation techniques for coherence mitigation. The evaluation is to be based on measurements gathered using the CSIR platform, where DOA estimation is performed using the MUSIC and ESPRIT subspace techniques.
2. A performance comparison of the two coherence mitigation techniques.
3. An evaluation of the feasibility of the two coherence mitigation techniques for the purpose of real-time DOA estimation of RFI sources.

Relation to Priority Areas:

The projects address the following priority areas:

- 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).
- Real-time digital signal processing instrumentation for radio astronomy, specifically using FPGA and GPU platforms.

vi. Work Breakdown Structure

- Year 1 (100 to 200 words max.)

During the first year, the student is expected to (i) conduct a literature survey on DOA and coherence mitigation techniques, (ii) implement the relevant algorithms and simulate an interference scenario using a mathematical software package such as Matlab, as well as (iii) familiarise himself/herself with the CSIR SDR platform. The simulation is to involve synthetically-generated signals.

- Year 2 (100 to 200 words max.)

The student is expected to plan and conduct experimental work to gather relevant and meaningful RF measurements using the CSIR antenna array and SDR platform. The algorithms implemented in the first year are to be