Section A: Overview of the Research Project Proposal

1. Doctoral
2. Engineering
3. Single-chip receivers for MFAA
4. The SKA Mid-Frequency Aperture Array (MFAA) will make use of aperture array antennas in the 500 – 1500 MHz range. Each of these antennas would need a low noise, but uncooled receiver. Monolithic integration of such a receiver would allow for low-cost mass-production, but there are several shortcomings to the state-of-the-art that need to be addressed first. The co-integration of the low-noise amplifier (LNA) and the analogue-to-digital converter (ADC) poses two significant problems: one relating to dynamic impedance and optimal power transfer to the ADC, the other being switching noise leaking into the LNA input. There are methods that may be adopted to mitigate both problems (SOI integration, dynamic impedance matching), but have not been applied in this context. Furthermore, there is the issue of power consumption; this may be addressed by adopting an advanced CMOS node with moderate-inversion design using the gm/ID technique, although this has never been attempted for RF LNAs.

Section B: Supervisor(s) Details

1. Primary supervisor's details

a. Dr Tinus Stander
b. University of Pretoria
c. tinus.stander@up.ac.za
d. Supervision of postgraduate students
i. Doctoral Students:

Name of student	Nationality	Date started Doctoral Degree (Month and Year)	Date completed / will complete Doctoral Degree (Month and Year)	Title of Research Project / Thesis	Co-Supervisor (if relevant)
Piotr Osuch (Also supervised for M.Eng)	RSA	01/2016	07/2018	Synthesis and monolithic integration of in-system analogue data pre-processing networks	
Flavien Sagouo Minko	Cameroon	01/2014	12/2018 (part-time)	Broadband, radiation hardened mm-wave components for space-based Sun observation instruments	
Brilliant Habeenzu	Zambia	02/2015	12/2018 (part-time)	Radiation degradation characterization and modelling in mm-Wave microelectronics	
Titus Oyedokun	Nigeria	01/2014	08/2018	Planar Groove Gap Waveguide	Prof. RH Geschke (primary, UCT)
Hannes Venter (Also supervised for M.Eng)	RSA	06/2018	12/2020	Dispersive and multi-band phase shifters	

ii. Masters Students

Name of student	Nationality	Date started Doctoral Degree (Month and Year)	Date completed / will complete Doctoral Degree (Month and Year)	Title of Research Project / Thesis	Co-Supervisor (if relevant)
Nishant Singh	India	01/2015	05/2017	Active Q-Enhanced Tunable High-Q On-Chip E-band Resonators and Pseudo-Combline Coupled Resonator Filters in 130nm SiGe BiCMOS	
Vishal Bhana	RSA	01/2013	11/2017 (part-time)	A Slow-Wave CMOS Delay Line Filter for mm-Wave Applications	Prof. S. Sinha (UP)
Shaunel Walker	RSA	01/2016	12/2018	Low cost RF PCB integrated front-ends for mm-wave water vapour radiometry	Mr AC de Villiers (TUT)
Edward Hunter	RSA	01/2017	12/2018	Radially distributed mm-wave array antennas	Prof. DIL de Villers (SU)
Anthony Gaskell	RSA	01/2016	12/2018 (part-time)	Resonant tunnelling diode based analogue to digital converters	Prof. WE Meyer (UP)
James Smith	RSA	01/2014	12/2018 (part-time)	A substrate integrated waveguide amplifier matching scheme	

2. Co-supervisor / Research Supervisor’s details (if relevant): N/A

Section C: Full Research Project Proposal

Maximum of three A4 pages, written for a professional who is not necessarily an expert in the relevant subfield

1. Scientific merit:

The SKA Mid-Frequency Aperture Array (MFAA) will make use of aperture array antennas in the 500 – 1500 MHz range. Each of these antennas would need a low noise, but uncooled receiver. Monolithic integration of such a receiver would allow for low-cost mass-production, but there are several shortcomings to the state-of-the-art that need to be addressed first.

The co-integration of the low-noise amplifier (LNA) and the analogue-to-digital converter (ADC) poses two significant problems: one relating to dynamic impedance and optimal power transfer to the ADC, the other being switching noise leaking into the LNA input.

For noise leakage, there are several mitigating options. The one is to adopt bulk CMOS integration with deep-trench isolation, effectively building barriers in the bulk substrate. The other would be silicon-on-insulator (SOI) integration, where the devices are explicitly isolated. Both would have to be characterized experimentally before a final choice is made, to see whether the increased SOI production cost is justified by the improved isolation.

As for optimal matching, it may be necessary to revisit the type of digitizer used on-chip; specifically, to consider whether voltage-mode or current-mode ADCs are best suited to high-speed digitization from a CMOS LNA. It would also be necessary to evaluate the optimal driving impedance of the ADC and optimal load impedance of the LNA dynamically, with dynamic impedance matching.

Finally, it may be of interest to investigate low-power options for biasing. This may be addressed by adopting an advanced CMOS node with moderate-inversion design using the gm/ID technique, although this has never been attempted for RF LNAs.

2. Feasibility:

The M4 lab at the University of Pretoria has significant experience in RF CMOS design. The lab is further equipped with all the necessary laboratory facilities for measurement (including wafer-probed microelectronic measurements), as well as software for circuit and system modelling. Semiconductor prototyping is also in place, with access to various suitable foundries and processes.

Potential objectives for this project would be:

Y1: Literature review. Training in microelectronic design. Design experiments for noise coupling tests. Simulate. Prototype, measure coupling.

Y2: Investigate dynamic impedance matching between RF sources and ADCs, as well as different CMOS ADC options. Initial circuit design, simulation, prototyping, measurement.

Y3: Iterate design of LNA, this time using moderate inversion (using the gm/ID technique). Evaluate power consumption in simulation. Prototype, measure.

3. This project relates to Priority Area 3: Radio Astronomy antennas and receivers. Successful single-chip MFAA receiver integration could potentially reduce the MFAA's production cost significantly.

4. The preferred candidate would have, if not a postgraduate, than at least a firm undergraduate background in high frequency electronics and / or electromagnetics. Prior knowledge of microelectronic design is not required (this will be acquired through formal training in Year 1) but will be beneficial.

Section D: Signatures

1. Signed: T. Stander ______________________ Date: 31 August 2018

1. Radio Pulsar and Fast-Transient science, instrumentation and data analysis (including real-time RFI detection).

3. Radio Astronomy antennas and receivers.

5. Instrumentation and systems for Radio Frequency Interference (RFI) detection and data analysis/archival/interrogation/visualization.

8. Interferometric Data Processing and Analysis, including calibration and imaging.

9. VLBI science, instrumentation, observations and data processing (astronomy, astrometry and geodesy applications).

12. Predictive maintenance and scheduling using sensor data analytics, machine learning and system modelling.