Section A: Overview of the Research Project

1. A broadband X-band radio astronomy receiver
2. Engineering
3. PhD

4. There are a wide range of X-band (8 – 12 GHz) sources of interest in radio astronomy, which had led to the development of several X-band receivers at the SARAO station at Hartebeesthoek. Unifying multiple receivers into a single, broadband receiver will free up space in the receiver cabin of the 26m dish on site, and will be supported well by the recent availability of broadband back-ends and front-end components. This project will develop such a receiver, with emphasis on novel approaches to compact RF packaging (even IC integration of some sections) and low-noise front-end Dicke switching.

5a. Prof Tinus Stander
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5c. University of Pretoria

Section B: Details of Research Project

1. Scientific merit:

The 8 – 16 GHz spectrum contains numerous spectral lines of interest to radio astronomy, including methanol (12.178 GHz) and formaldehyde (14.488 GHz). In addition, it is an important band for VLBI, as well as for geodetic observations and geodetic VLBI. The traditional approach to receiver design has been narrowband, single-purpose instruments; a design choice motivated in part by limited capacity in data processing. This has left many observatories, including the SARAO station at HartRAO, with receiver cabins containing numerous receivers for co-located narrow bands.

However, with increased computational capacity available in the digital back-end, modern receivers are predominantly designed for wider bands, thereby serving multiple observational purposes. In terms of architecture and integration, there are many approaches to follow. In state-of-the-art lithography nodes, it is a simple matter to integrate full receivers (even full systems) on a single MMIC, but this approach has not seen much application in radio astronomy. The suitable application of monolithic integration, and hybrid modularized / connectorized co-design, with appropriate approach to use of available cooling stages, would seem to be an open-ended research question at X-band.

Another interesting question to consider is mitigating the effect of front-end Dicke switches (used for calibration) in these receivers. In some works, it was found that that the TSYS penalty incurred through the front-end switch exceeds that expected by simply considering switch loss, which would imply the presence of excess noise generation in the switch. In other works, the functions of switching and low-noise amplification have been combined into single circuits, though the obvious question of gain mismatch was not addressed. There are, therefore, many open research questions in the field of broadband, switched, low-noise receiver front-ends.

This project will develop a concept broadband receiver, covering the X- and Ku-bands, as a step toward replacing several legacy receivers currently operating on the 26m dish at HartRAO. This will include studies into suitable receiver architectures, approaches to switching calibration and cooling, selection of suitable semiconductor processes and devices, integration media, appropriate use of available cooling stages, and IF output.

2. Feasibility:

The M4 lab at the University of Pretoria has significant experience in RF system and MMIC design. The lab is further equipped with all the necessary laboratory facilities for measurement, as well as software for circuit and system modelling. Semiconductor prototyping is also in place, with access to various suitable foundries and processes. Although cryo-coolers are available on campus, it is anticipated that most of these measurements will be taken at HartRAO, about an hour's drive from Hatfield campus.

Potential objectives for this project would be:

Y1: Literature review. System architecture design and simulation. Detail component design using discrete semiconductors.

Y2: Design of low-noise switching stage. Integration and evaluation of uncooled broadband RF front-end.

Y3: Monolithic design stages and prototyping. Integration and evaluation of final prototype. Dissemination. Conclude study.

3. The project relates to "Radio astronomy antennas and receiver systems (including digitisation) associated with supported and hosted instruments.". The proposed techniques, if successful, will lead to the availability of new receivers to an SARAO station.

4. The preferred candidate would have a postgraduate background in high frequency electronics and / or electromagnetics. Prior knowledge of microelectronic design would will be beneficial.

Section C: CV of primary supervisor

Prof Tinus Stander, *Pr.Eng, PhD(Eng)(SU), SMIEEE*

Education

- **PhD, Electronic Engineering**
  Stellenbosch University, South Africa, 2009.
- **B.Eng, Electrical and Electronic Engineering with Computer Science**
  Stellenbosch University, South Africa, 2005

Awards, Distinctions and Fellowships

- Coimbra Staff Exchange Fellowship (2014)
- Erasmus Mundus EUROSA III scholarship (2013)
- Awarded NRF C-rating (2020)
- Awarded SANRAL B-category researcher rating (2020)
- IEEE MTTSAT Challenge Phase 2 participant (2020)

Leadership positions

- Vice-Chair: SA IEEE APS/MTTS/EMC Chapter (2019 – 2021)
- Project Leader, SANRAL Research Project 1.2a, “Sensors”.
- Co-PI, SA-Mexico Bilateral Programme on Water Vapour Radiometry (2018 – 2021)
- Advisor to VIP team, “Reliable Systems”

Professional Activities

- Registered as Professional Engineer with the Engineering Council of South Africa
- Consultant to South African National Roads Agency (SANRAL), leader of Project 1.2s: “Sensors”
- Scientific advisor to Multifractal Semiconductors (Pty) Ltd.
- Senior member of the IEEE (2005 – present)

Employment History

- **Associate Professor**
  Department of Electrical, Electronic and Computer Engineering, University of Pretoria, South Africa, January 2020 – present.
- **Senior Lecturer**
  Department of Electrical, Electronic and Computer Engineering, University of Pretoria, South Africa, January 2013 – December 2019.
- **Radio frequency and microwave engineer**, Denel Dynamics, Centurion, South Africa, 2010 – 2012

Teaching Activities

- Postgraduate Communications Electronics EMK732, UP, 2017 – current.
- Electronic engineering design ELO320, UP, 2014-current.
- Advanced Electronics ENE410, UP, 2014-current.
- Digital Electronics ERS 220, UP, 2013.
- Postgraduate Analogue Electronic Design EME 732, UP, 2013-2014.
- Analogue Electronics ENE310, UP, 2013.
- Microwave Filters for RADAR, UCT, 2013.
- Microwave Engineering EMW040, CPUT, 2008.

Research Interests

- mm-Wave microelectronics for terrestrial communications.
- Built-in self-testing of RF and mm-wave electronics
- mm-Wave radiometry for radio astronomy
- mm-Wave remote sensing for transportation applications
- Additive manufacturing for microwave and mm-wave components and packaging.

Research Activities

Completed Postgraduate Supervision

- M.Eng (Electronic and Microelectronic Engineering): 6
- PhD (Electronic Engineering): 6

Current Student Supervision

Supervisor or co-supervisor to 6 postgraduate students (M.Eng and PhD)

Current Research Grants

- NRF Competitive Support for Rated Researchers (2022 – 2024)
- Eskom Tertiary Education Support Programme on mm-Wave terrestrial communications (2014 – current)

Current Facilities Management

- mm-Wave coaxial and waveguide lab
- mm-Wave microelectronic wafer probe lab
- mm-Wave anechoic chamber
- Class 6 cleanroom

Publication Metrics

- Total journal papers: 22
- Total international conference papers: 46
- Total patents: 3
- Total citations in Scopus: 144
- h-index in Scopus: 6

Top Publications

1. J. J. P. Venter, T. Stander and P. Ferrari, “X-band Reflection-Type Phase Shifters Using Coupled Line Couplers on Single Layer RF PCB”, IEEE Microwave and Wireless Components, Vol. 28, no. 9, pp. 807 – 809, 2018.
2. P. J. Osuch, T. Stander, “A Millimeter-Wave Second-Order All-Pass Delay Network in BiCMOS”, IEEE Microwave and Wireless Components Letters, Vol. 28, no. 10, pp. 912 – 914, 2018.
3. J. B. Cloete, T. Stander, D. N. Wilke, “Parametric Circuit Fault Diagnosis Through Oscillation-Based Testing in Analogue Circuits: Statistical and Deep Learning Approaches”, IEEE Acccess, Vol. 10, pp. 15671 - 15680
4. N. Singh, T. Stander, “E-band Active Q-enhanced pseudo-combline E-band resonator 130nm SiGe BiCMOS”, Journal of Infrared, Millimeter, and Terahertz Waves, Vol. 39, No. 10, pp 949–953, 2018.
5. F. Sagouo Minko, T. Stander, “Effect of TID Electron Radiation on SiGe BiCMOS LNAs at V-band”, Microelectronics Reliability, Vol. 112, e113750, 2020.
6. J. J. P. Venter, T. Stander, “Phase Shifters with Multiple Independently Controllable Bands Utilizing Frequency-Selective Variable Gain Networks”, IET Microwaves, Antennas and Propagation, Vol. 15, no. 2, pp. 143-153, 2021.
7. H. P. Nel, T. Stander, F. C. Dualibe, “Built-In Oscillation-Based Self-Testing of a 2.4 GHz LNA in 0.35μm CMOS”, Proc. IEEE ICECS 2018, pp. 837 – 840.
8. P. J. Osuch, T. Stander, “High-Q second-order all-pass delay network in CMOS”, IET Circuits, Devices and Systems, Vol. 13, no. 2, pp. 153 – 162, 2019.
9. J. J. P. Venter, R. Maharaj, T. Stander, “Additive Manufacturing of Interdigital Filters with Arbitrary Line Cross Section”, IEEE Transactions on Components, Packaging and Manufacturing Technology, Vol. 10, no. 4, pp. 686–693, 2020.
10. F. Sagouo Minko, T. Stander, “A comparison of three-dimensional electromagnetic and RC parasitic extraction analysis of mm-wave on-chip passives in SiGe BiCMOS low-noise amplifiers”, International Journal of RF and Microwave Computer-Aided Engineering, vol. 30, no. 2, e22019, 2020.