Section A: Overview of the Research Project

1. A single-IC 183 GHz water vapour radiometer
2. Engineering
3. Masters

4. Accurate estimation of tropospheric water vapour is imperative to site surveys, observation management, and path length correction in mm-wave radio astronomy. Water vapour radiometer systems are commercially available, but are large and expensive, and require several moving parts. The observation of the 183 GHz water vapour line would benefit significantly from MMIC integration, as this would allow for low-cost manufacturing of an extremely compact device with reduced integration risk. This project will build on previous studies and prototypes with an improved design, implementation, and validation of a working prototype.

5a. Prof Tinus Stander
5b. tinus.stander@up.ac.za
5c. University of Pretoria

Section B: Details of Research Project

1. Scientific merit:

Accurate estimation of tropospheric water vapour is imperative to site surveys, observation management, and path length correction in mm-wave radio astronomy. This may be estimated at 183 or 225 GHz, or with dual-band / spectral methods around 22 and 31 GHz.

Water vapour radiometer systems are commercially available, but are large and expensive (due in large to the extensive reliance on connectorised or waveguide components). In particular, the cost 183 GHz radiometers is compounded significantly by the cost of packaging individual components in a modular system integration. On the other hand, single-IC radiometers at similar frequencies (e.g. airport security scanners at 94 GHz) have proven extremely effective. In addition, it allows for the packaging of an array of radiometers in a single unit, which may pave the way toward tip-curve calibration in post-processing rather than through mechanically steered tipping mirrors. Cross-correlating architectures may also be implemented more readily if multiple radiometers can be packaged as single surface-mount components. Production cost could further be reduced by investigating the use of 3D printed antenna assemblies around mounted-IC receivers, or the use of low-cost CMOS or SiGe BiCMOS processes (as opposed to GaAs or InP) for prototyping.

2. Feasibility:

This project will build on previous student projects, where different radiometer architectures were evaluated and system simulation approaches were established.

The M4 lab at the University of Pretoria has experience in radiometer design, mm-wave design, hybrid integration, and testing of mixed signal and RF circuits and MMIC. The lab is further equipped with all the necessary laboratory facilities for measurement (including anechoic measurements), as well as software for circuit and system modelling.

Potential objectives for this project would be:

Y1: Literature review. Architecture design. Basic total power radiometer circuit design, prototyping and measurement.

Y2: System integration: application of multiple radiometers in an array configuration, design of suitable antenna feed for beam steering. Lab testing. Data processing development and preliminary site characterization.

Y3: Cross-correlating radiometer implementation, prototyping and testing. Updated data processing development and site characterization measurements. Final dissemination.

3. This proposal relates to “Hardware, software and data analytic systems associated with the control and monitoring of radio telescopes”. The prototype developed in this study may be deployed both for surveying potential new mm-wave radio astronomy sites in Africa, and to provide monitoring data at existing centimetric observation sites.

4. A Master’s degree background in high frequency electronics and / or electromagnetics is advisable for this project, with MMIC design experience especially valued. This would include knowledge of basic RF components (transmission lines, filters, couplers, mixers, amplifiers) as well as RF simulation software.

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: 25
- Total international conference papers: 57
- Total patents: 3
- Total citations in Scopus: 207
- h-index in Scopus: 7

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.