

Section A: Overview of the Research Project

1. Title of the research project

Frequency-selective surfaces for RFI mitigation in radio telescope feeds

2. Broad area of research

Engineering

3. Academic level of research project

Doctoral

5. Primary supervisor's details

a. Heinrich Edgar Arnold Laue

b. heinrich.laue@up.ac.za

c. University of Pretoria

4. Co-supervisor's details

a. Tinus Stander

c. University of Pretoria

5. Abstract of research project

Radio-frequency interference (RFI) from man-made sources is a major challenge in radio astronomy systems, whether inside or outside of the frequency band of the receiver. Some RFI effects can be mitigated after digitisation, but there is great potential benefit in filtering unwanted signals before the receiver. Frequency-selective surfaces (FSS) that filter specific frequencies could be retrofitted to existing telescope feed antennas and could be customised to the RFI environment at a specific site. The aim of this research project is to perform a comprehensive investigation into the application of static and/or reconfigurable FSSs to radio astronomy antennas.

Section B: Details of Research Project

1. Scientific/Engineering merit

The presence of strong in-band or out-of-band RFI can be a severe challenge in radio astronomy systems. Many existing techniques aim to deal with RFI after digitisation; however, strong interfering signals risk saturating the receiver, and reducing the receiver gain means utilising less of the available dynamic range for the signal of interest. In addition, strong out-of-band RFI can induce unwanted non-linear behaviour in various parts of the receiver. There is, therefore, an incentive to develop frequency-filtering antennas that are able to suppress RFI in passive radio-frequency (RF) hardware before reaching the receiver.

In-band notch filters could be designed based on the requirements of a specific installation to suppress known sources of RFI that would otherwise make it difficult or impossible to perform astronomical observations in a given geographical location. Bandpass filters can also be designed to suppress out-of-band RFI.

Whereas classic filtennas typically place RF filters after the antenna aperture, frequency-selective surfaces can be placed in front of an existing antenna, allowing frequency-selective behaviour to be introduced with minimal installation time and/or cost and without requiring the existing antenna to be redesigned. Using additive manufacturing techniques would further reduce the cost and enable the rapid development of FSSs based on site-specific RFI conditions. Furthermore, using reconfigurable (programmable) FSSs would potentially allow a single FSS to be designed that can be digitally reconfigured to suppress varying and site-specific RFI.

This project will contribute to the following SARA0 priority areas:

Area 1: Antenna, receiver, (analogue and digital) signal processing, data analysis and data recording systems associated with radio telescopes and geodesy instruments supported and hosted by SARA0.

Area 3: Hardware and data analysis systems for detecting, monitoring and locating sources of Radio Frequency Interference (RFI).

This project focuses on both priority areas 1 and 3 by addressing the issue of RFI in the feed design itself.

2. Feasibility

Bandpass FSSs have been successfully designed for L-band conical horn feeds, specifically for 21 cm hydrogen line observations, demonstrating the feasibility of the concept for out-of-band RFI suppression in horn feeds for radio telescopes. Reconfigurable FSSs have been demonstrated in principle. The additive manufacturing or printing of dichroic materials is also an interesting possibility.

3. Skills development

The student who undertakes this study will develop advanced skills in the understanding of RFI, FSSs, and feed antennas for radio astronomy instruments. The study of feed antennas and FSSs will provide the student with background that is applicable to a wide range of engineering problems related to radio astronomy applications.

4. Availability of data/equipment/facilities

The labs at the University of Pretoria (UP) are equipped with the software and infrastructure required for the in-house design, manufacturing, and characterisation of antennas and RF components based on conventional printed circuit board (PCB) and additive manufacturing techniques. The PCB manufacturing facility at CEFIM allows high-prec-

sion, multi-layer RF PCBs to be manufactured in-house, and the Nano-Micro Manufacturing Facility at CEFIM includes aerosol-printing, inkjet-printing, and screen-printing capabilities. The Compact Antenna Test Range at UP is able to characterise antennas, and the RF labs at CEFIM are equipped with measurement equipment suitable for developmental testing. Electromagnetic simulation software is also available.

5. Milestones and timeframes

The proposed milestones for this project include:

Year 1: Literature review and a preliminary investigation into potential applications of FSSs to radio astronomy feeds, leading to the publication of a conference article.

Year 2: Design, simulation, implementation and characterisation of a single FSS for radio astronomy feeds, leading to a journal article.

Year 3: Design, simulation, and implementation of a reconfigurable and/or additively manufactured FSS, leading to a journal article.

6. Required qualifications, academic abilities, skills and/or experience

Bachelor's and master's degrees in electronic engineering are required, including extensive knowledge of electromagnetic theory and experience in the use of electromagnetic simulation software. Experience in antenna design would be beneficial. Candidates with an undergraduate degree in the natural sciences, e.g. physics, are not eligible.

Bibliography

S. Chatterjee, Y. Gupta, S. K. Ghosh, and S. Bhattacharyya, "RFI Mitigation of Radio Astronomical Receiver Using a Low-Profile Metasurface-Loaded Antenna," *IEEE Transactions on Electromagnetic Compatibility*, vol. 66, no. 1, pp. 108–117, Feb. 2023.

W.-J. Liao, Y.-F. Chen, C.-L. Liao, and Y.-C. Hou, "Reconfigurable Frequency Selective Surfaces With Complementary Reflection and Transmission Responses Using Duality Theorem-Based Elements," *IEEE Transactions on Antennas and Propagation*, vol. 70, no. 10, pp. 9406–9414, Oct. 2022.

Section C: CVs of Primary Supervisor and Co-supervisor

Heinrich Edgar Arnold Laue

PhD Pr Eng MIEEE | NRF Y1-rated researcher | heinrich.laue@up.ac.za | +27 12 420 2177

Education

Doctor of Philosophy (Engineering)	2020
<i>Design of compressive antenna arrays</i>	<i>University of Pretoria, South Africa</i>
Bachelor of Engineer Honours (Electronic Engineering)	2015
With distinction (89.8%)	<i>University of Pretoria, South Africa</i>
Bachelor of Engineering (Electronic Engineering)	2011-2014
With distinction (79.5%)	<i>University of Pretoria, South Africa</i>

Work Experience

Department of Electrical, Electronic and Computer Engineering, University of Pretoria

<i>Senior Lecturer</i>	May 2023-present
PCB manufacturing facility manager, CEFIM	2023-present
EJJ 210 Professional and Technical Communication	2022-present
ELO/EWE/ERD 320 210 Electronic/Electrical/Computer Engineering Design	2023-present
<i>Contract Lecturer (remote)</i>	Feb.-Jun. 2022; Feb.-Apr. 2023
Namibia Water Corporation Ltd	Feb. 2019-Apr. 2023
<i>Electronic Engineer in Training, Communications sub-division</i>	
University of Pretoria, South Africa	2015-2018
<i>Assistant Lecturer (part-time)</i>	

Supervision

Successfully completed	<i>University of Pretoria, South Africa</i>
Bachelor of Engineering Honours (2)	
Current postgraduate students	<i>University of Pretoria, South Africa</i>
Bachelor of Engineering Honours (1), Master of Engineering (6)	

Volunteer Experience

IEEE AFRICON 2023 Chair, Track 3	2023
IEEE South AP/MTT/EMC Joint Chapter officer: Students & Young Professionals	Jul. 2022-present
IEEE Antennas & Propagation Society Young Professional Ambassador	2022

Professional Memberships

Professional Engineer: Engineering Council of Namibia	PE2107006
Professional Engineer: Engineering Council of South Africa	202101846

Top Publications

orcid.org/0000-0002-5706-1539	Scopus h-index: 5
H. E. A. Laue and T. Stander, "24/31 GHz dual-band phased array for water vapour radiometry", <i>2026 National Radio Science Meeting</i> , Boulder, CO, USA, 6-9 Jan. 2026, paper 1133.	
H. E. A. Laue and W. P. du Plessis, "Design and analysis of a proof-of-concept chequered-network compressive array," in <i>IEEE Transactions on Antennas and Propagation</i> , vol. 70, no. 9, pp. 7546-7555, Sep. 2022.	
H. E. A. Laue and W. P. du Plessis, "A checkered network for implementing arbitrary overlapped feed networks," in <i>IEEE Transactions on Microwave Theory and Techniques</i> , vol. 67, no. 11, pp. 4632-4640, Nov. 2019.	
H. E. A. Laue and W. P. du Plessis, "Numerical optimization of compressive array feed networks," in <i>IEEE Transactions on Antennas and Propagation</i> , vol. 66, no. 7, pp. 3432-3440, Jul. 2018.	
H. E. A. Laue, "Demystifying compressive sensing [Lecture notes]," in <i>IEEE Signal Processing Magazine</i> , vol. 34, no. 4, pp. 171-176, Jul. 2017.	
H. E. A. Laue and W. P. du Plessis, "A coherence-based algorithm for optimizing rank-1 Grassmannian codebooks," in <i>IEEE Signal Processing Letters</i> , vol. 24, no. 6, pp. 823-827, Jun. 2017.	
A. E. Raju, H. E. A. Laue and T. Joubert, "Microfabrication of an e-QR code sensor display on a flexible substrate," <i>MDPI Engineering Proceedings</i> , vol. 109, no. 16, Sep. 2025.	
L. Hurter, H. E. A. Laue and J. Schoeman, "Addressing manufacturing and cost challenges toward solving low-cost in situ digital holographic microscopy problems", <i>MDPI Engineering Proceedings</i> , vol. 109, no. 14, Sep. 2025.	

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
- **M.Eng (Engineering Management)**
University of Pretoria, South Africa, 2024 (current)

Short Courses and Certifications

- **Programme in Project Management**
University of Pretoria, South Africa, 2023.

Awards, Distinctions and Fellowships

- Erasmus Mundus EUROSIA III scholarship (2013)
- Awarded NRF C-rating (2020)
- Awarded SANRAL B-category researcher rating (2020)
- IEEE MTTSAT Challenge Phase 2 participant (2020)
- Oppenheimer Memorial Trust Sabbatical Funding (2024)

Leadership positions

- Vice-Chair: SAIEEE APS/MTTS/EMC Chapter (2019 – 2022)
- Project Leader, SANRAL Research Project 1.2a, "Sensors".
- Co-PI, SA-Mexico Bilateral Programme on Water Vapour Radiometry (2018 – 2021)

Professional Activities

- Registered as Professional Engineer with the Engineering Council of South Africa
- Scientific advisor to Multifractal Semiconductors (Pty) Ltd.
- Senior member of the IEEE (2005 – present)
- Journal Reviewer: IEEE T-MTT, IET MAP, IET CDS, IEEE MWTL,

Employment History

- **Professor**
Department of Electrical, Electronic and Computer Engineering, University of Pretoria, South Africa, January 2023 – present.
Responsible for conducting and supervising novel academic research, and supporting research activities by securing research grants, as well as establishing and maintaining relevant research facilities. Responsible for undergraduate and postgraduate teaching, including curriculum development and assessment.
Responsible for community engagement through professional society volunteering and consultation to industry.
 - Previously Senior Lecturer (2013 – 2019) and Associate Professor (2020 – 2022).
- **Radio frequency and microwave engineer**, Denel Dynamics, Centurion, South Africa, 2010 – 2012
Responsible for RF component designs: requirements analysis, conceptualization, implementation, testing and reporting. Designs included communication systems, filters, and EMC measurement equipment.

Teaching Activities

- Postgraduate Wireless Electronics EMK732, UP, 2017 – current.
- Electronic engineering design EPR320, 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

- 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): 10
- PhD (Electronic Engineering): 6

Current Student Supervision

Supervisor or co-supervisor to 15 postgraduate students (M.Eng and PhD) and 2 postdoctoral fellows

Current Research Grants

- NRF National Equipment Programme (2023-2028) "sub-THz Measurement Facility" (R15,000,000)
- NRF National Equipment Programme (2022-2027) "Advanced microfabrication and integration facility" (R12,428,000)
- SARAO Research Group Grant "Wide-Band, High-Frequency Receivers and Data Recording Systems" (R3,800,000)
- Member of AtLAST2 consortium

Current Facilities Management Responsibilities

- mm-Wave microelectronic wafer probe lab
- mm-Wave anechoic chamber
- Class 6 cleanroom
- Microelectronics packaging line
- PCB patterning and assembly line

Active Research Collaborations

- TU Eindhoven, Fraunhofer FHR, IMT Atlantique, Kutleng Engineering Technologies
"Materials characterization and design paradigms for 3D printed dielectric parts"
- National Autonomous University of Mexico, INAOE Mexico, Radboud University, University of Namibia
"Radio astronomy site characterization through water vapour radiometry"
- Saab South Africa
"Resilience and built-in self-testing of wideband GaN LNAs"
- SARAO, University of Groningen, Radboud University
"Multi-band receivers for the African Millimeter Telescope (AMT)"
- University of Sao Paulo, Brazil
"Hybrid packaging of mm-wave circuits on nanowire substrates"

Publication Metrics

- Total journal papers: 30
- Total international conference papers: 61
- Total patents: 3
- Total citations in Scopus: 293
- h-index in Scopus: 8

26 February 2026

CONFIRMATION OF RESOURCES FOR SARAO-FUNDED M AND PHD STUDIES

We hereby confirm the confirmation of the following software, equipment, and data at the Carl and Emily Fuchs Institute for Microelectronics, in support of our proposed M.Eng and PhD topics:

Software:

EM simulation software (CST Microwave Studio, Ansys HFSS, Altair FEKO)
Circuit and system simulation software (Cadence AWR, Cadence IC design suite)
AMD Vivado™ Design Suite: Enterprise Edition

Digital hardware and development boards:

Xilinx ZYNQ Ultrascale+ RFSoc FPGA development board
RealDigital RFSoc 4x2 Xilinx Ultrascale+ FPGA development board
Digilent Eclipse Z7 Xilinx FPGA development board

Manufacturing and assembly equipment:

3D printers (FormLabs Form3, Intamsys Funmat HT, Creality Halot Mage S)
PCB / planar substrate patterning (LPKF ProtoLaser U4, ProtoMat S64, MultiPress S4, Contac S4 copper plating bath)
F&S BondTec 53XX semi-automatic wirebonder
Tresky T-5100 manual die bonder

RF metrology equipment:

Anritsu ME7838G VNA (220 GHz)
Harmonic mixers and noise sources up to 220 GHz
Anritsu ME7828A VNA (110 GHz)
R&S FSW50 signal analyser (with noise figure and phase noise measurement)
Cascade Microtech PM300 wafer probe station, with probes and positioners
Compact antenna test range (CATR), for antenna measurements up to 40 GHz
Millimetre-wave anechoic chamber for antenna measurements > 50 GHz

Kind regards



Tinus Stander
Professor



Johan Schoeman
Senior Lecturer



Heinrich Laue
Senior Lecturer



Archibald Rohde
Lecturer