Section A: Overview of the Research Project

1. Title of the research project

Filtering antennas for RFI mitigation in radio astronomy receivers

2. Broad area of research

Engineering

3. Academic level of research project

Doctoral

4. 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 in the antenna itself using so-called filtennas that combine the functions of antennas and filters. The aim of this research project is to perform a comprehensive investigation into the application of filtennas to radio astronomy receivers, including feeds for dish radio telescopes or aperture arrays such as the mid-frequency aperture array (MFAA).

5. Primary supervisor's details

a. Heinrich Edgar Arnold Laue

b. heinrich.laue@up.ac.za

c. University of Pretoria

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, fixed sources of RFI that would otherwise make it difficult or impossible to perform astronomical observations in a given geographical location. Filtering structures could potentially be retrofitted to standard antennas (e.g. horn feeds), so that only the filtering structure needs to be customised for a particular installation. Passband filters can also be designed to suppress out-of-band RFI, in which case the filtenna design can be standardised across multiple installations.

The successful design and implementation of filtennas for radio astronomy receivers will demonstrate their potential to maintain sensitivity in the presence of known RFI sources.

2. Feasibility

Passband filtennas 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. Vivaldi filtennas have been designed successfully for other applications, but have not yet been applied to aperture arrays for radio astronomy.

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, potentially, additive manufacturing techniques. The newly-installed PCB manufacturing facility at CEFIM allows high-precision, multi-layer RF PCBs to be manufactured in-house, and the Nano-Micro Manufacturing Facility at the CEFIM includes inkjet- 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.

Proposed objectives for this project include:

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

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

Year 3: Integration and evaluation of filtennas with real-world radio astronomy receivers, leading to a journal article.

3. Contribution to SARAO research priority areas

Area 1: Antennas for radio telescopes and geodesy instruments supported and hosted by SARAO, and

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 antenna design itself.

4. 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.

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 Trans. Electromagn. Compat.*, vol. 66, no. 1, pp. 108–117, Feb. 2023.

C. X. Mao, Y. Zhang, X. Y. Zhang, P. Xiao, Y. Wang, and S. Gao, "Filtering Antennas: Design Methods and Recent Developments," *IEEE Microw. Mag.*, vol. 22, no. 11, pp. 52–63, Nov. 2021.

Section C: CV of the Primary Supervisor

Heinrich Edgar Arnold Laue

Ph.D. Pr. Eng. (ECN) Pr. Eng. (ECSA) MIEEE
Senior Lecturer
Department of Electrical, Electronic and Computer Engineering, University of Pretoria
heinrich.laue@up.ac.za | +27 12 420 2177

Education

Doctor of Philosophy (Engineering) 2020
Design of compressive antenna arrays *University of Pretoria, South Africa*
Bachelor of Engineer Honours (Electronic Engineering) 2016
With distinction (89.8%) *University of Pretoria, South Africa*
Bachelor of Engineering (Electronic Engineering) 2015
With distinction (79.5%) *University of Pretoria, South Africa*

Work Experience

University of Pretoria, South Africa
Senior Lecturer May 2023-present
Contract Lecturer (remote) Feb.-Jun. 2022; Feb.-Apr. 2023
Research, supervision, teaching, lab management, general administration

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*

Namibia Water Corporation Ltd Feb. 2019-Apr. 2023
Electronic Engineer in Training *Communications sub-division*
Telemetry and communications-network design, assembly, installation, commissioning, and maintenance; procurement; SCADA design, server maintenance and support to operational staff

University of Pretoria, South Africa 2015-2018
Assistant Lecturer (part-time)

Mentorship

Supervision of final-year project students *University of Pretoria, South Africa*

Keegan O'Reilly	Visual coffee roast development analyser	2023
Joshua Travern	Acoustic camera	2023
Tinosimuka Ndava	Multi-beam antenna array	2023
Mu'Azzam Omar	Reconfigurable intelligent radio-frequency surface	2023

Informal workplace mentorship
Candidate engineers and technicians at NamWater 2021-2022

Volunteer Experience

IEEE AFRICON 2023 2023
Chair, Track 3—Wireless Communication Systems, Antennas, Microwave Systems and Propagation Models

IEEE South Africa Antennas & Propagation/Microwave Theory & Technology/Electromagnetic Compatibility (AP/MTT/EMC) Joint Chapter Jul. 2022-present
Chapter officer: Students & Young Professionals

IEEE Antennas & Propagation Society Young Professional Ambassador 2022
Presented multiple talks at various international chapters/sections

Professional Memberships

Engineering Council of Namibia
Professional Engineer PE2107006

Engineering Council of South Africa
Professional Engineer 202101846

Institute of Electrical and Electronics Engineers (IEEE)
Member 2021-; student member 2016-2020 93936730

Personal Information

Date of birth
4 November 1991

Citizenship
Namibian

Languages
Afrikaans (native), English (proficient)

Publications

webofscience.com/wos/author/record/2183563 Scopus h-index: 5
orcid.org/0000-0002-5706-1539

Peer-reviewed journal publications

[1] H. E. A. Laue and W. P. du Plessis, "Design and analysis of a proof-of-concept chequered-network compressive array," in *IEEE Transactions on Antennas and Propagation*, vol. 70, no. 9, pp. 7546-7555, Sep. 2022.

[2] H. E. A. Laue and W. P. du Plessis, "A checkered network for implementing arbitrary overlapped feed networks," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 67, no. 11, pp. 4632-4640, Nov. 2019 (with code).

[3] H. E. A. Laue and W. P. du Plessis, "Numerical optimization of compressive array feed networks," in *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 7, pp. 3432-3440, Jul. 2018 (with code).

[4] H. E. A. Laue, "Demystifying compressive sensing [Lecture notes]," in *IEEE Signal Processing Magazine*, vol. 34, no. 4, pp. 171-176, Jul. 2017.

[5] H. E. A. Laue and W. P. du Plessis, "A coherence-based algorithm for optimizing rank-1 Grassmannian codebooks," in *IEEE Signal Processing Letters*, vol. 24, no. 6, pp. 823-827, Jun. 2017 (with code).

Peer-reviewed conference publications

[6] H. E. A. Laue and W. P. du Plessis, "Compressive direction-finding antenna array," in *IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications (APWC)*, Cairns, QLD, Australia, 19–23 Sep. 2016, pp. 158-161.

Other conference publications/presentations

[7] H. E. A. Laue and W. P. du Plessis, "Chequered-network compressive arrays: overview and future directions," in *International Conference on Electromagnetics in Advanced Applications (ICEAA)*, Cape Town, South Africa, 5–9 Sep. 2022, p. 64.

Popular articles

[8] H. E. A. Laue, "Innovation, a skewed balance between old and new—lessons from my journey to compressive antenna arrays" in *IEEE Antennas and Propagation Magazine*, vol. 65, no. 3, pp. 102-106, June 2023.

[9] "A new direction," in *Science Today* insert in Mail & Guardian, 2016. Available: https://sciencetoday.co.za/2016/11/14/a-new-direction/