South African IEEE Joint AP/MTT/EMC Chapter Conference, 2024 Edition

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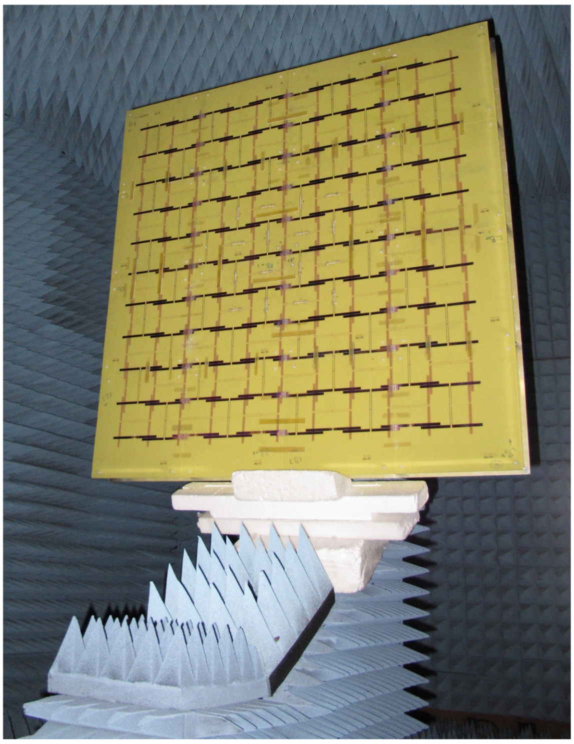

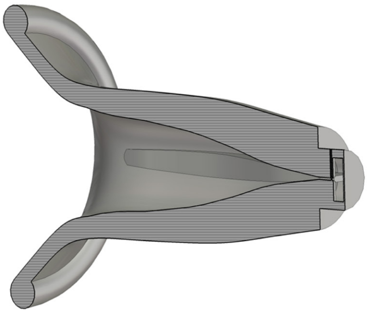

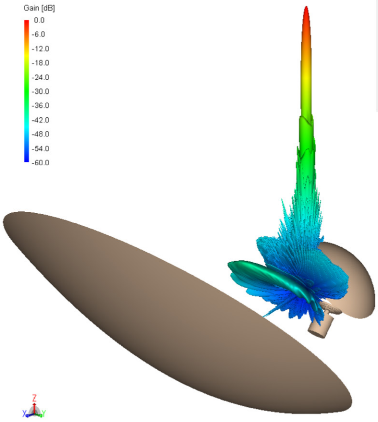

Book of Abstracts

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August 1–2, 2024, Stias Conference Centre, Stellenbosch, South Africa

Conference organising committee

General Chairs: *Prof. Matthys M. Botha, Stellenbosch University*
mmbotha@sun.ac.za
Prof. Dirk I.L. de Villiers, Stellenbosch University
ddv@sun.ac.za
Technical Programme Chair (AP): *Dr Werner Steyn, Stellenbosch University*
wiidg@sun.ac.za
Technical Programme Chair (MTT): *Prof. Tinus Stander, University of Pretoria*
tinus.stander@up.ac.za
Technical Programme Chair (EMC): *Dr P. Gideon Wiid, University of Cape Town*
gideon.wiid@uct.ac.za

Conferencing support services

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Venue address

Stias Conference Centre, 10 Marais Street, Stellenbosch, South Africa

Exhibition

An industry exhibition forms part of the conference, where all Tier 1 and Tier 2 industry sponsors are represented.

Banquet

The banquet takes place on August 1, 18:30 for 19:00 until late, at De Warenmarkt Restaurant, Corner of Van Riebeeck and Ryneveld streets, which is within walking distance from the conference centre.

Conference website

http://www.ee.sun.ac.za/SAIEEE2024/

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Welcome messages from the Chapter Chair and Conference General Chairs

Message from the Chapter Chair

On behalf of the leadership of the IEEE South Africa Joint AP/MTT/EMC Chapter, I welcome you to our 2024 Chapter Conference. This biennial conference is the flagship event of the Chapter's membership activities. I am glad to have the conference taking place again this year, after the last edition took place back in 2018. Unfortunately, in 2020 the conference was called off due to the pandemic. In September 2022, the well-known International Conference on Electromagnetics in Advanced Applications (ICEAA) took place in Cape Town, which featured a full-day session consisting of 21 talks by presenters from across the country, entitled "Antennas, Microwaves and EMC in South Africa," which replaced the 2022 edition of the Chapter Conference.

Apart from the Chapter Conference, the local Chapter also sponsors and hosts technical talks by local experts and distinguished international visitors, throughout the year. If news of these activities does not reach you, or if activities do not take place in your area, please engage the Chapter leadership on this. We are always looking to increase the value of these activities by expanding their reach.

The current leadership team of the Chapter is as follows:

- Matthys M. Botha, Stellenbosch University, Chair;
- P. Gideon Wiid, University of Cape Town, Past Chair;
- Danie J. Ludick, IXUS Software Suite, Secretary;
- Heinrich Laue, University of Pretoria, Coordinator for Students and Young Professionals.

On behalf of the Chapter, I thank all those involved in organizing this year's conference. I trust that you will make the most of this opportunity to engage with the rest of the community; and that you enjoy your visit to Stellenbosch.

Prof. Matthys M. Botha, Stellenbosch University
IEEE South Africa Joint AP/MTT/EMC Chapter Chair

Message from the Conference General Chairs

On behalf of the organizing committee, we welcome you to the 2024 edition of the biennial conference of the South African IEEE Joint Chapter on Antennas and Propagation (AP), Microwave Theory and Techniques (MTT) and Electromagnetic Compatibility (EMC). The conference brings together engineers and researchers from South African industry and academia who work in these fields.

The technical programme runs over two full days. Presentations are by invited speakers as well as by speakers who made their own submissions, with the former making up a large majority. The programme includes four keynote presentations – two international and two South African:

- Prof. Nuno Borges Carvalho, Universidade de Aveiro, Portugal;
- Prof. Johannes H. Cloete, Emeritus Professor, Stellenbosch University, South Africa;
- Prof. Atif Shamim, King Abdullah University of Science and Technology, Saudi Arabia;
- Prof. PW van der Walt, Emeritus Professor, Stellenbosch University, South Africa.

We gratefully acknowledge these four contributions to the conference.

Profs Borges Carvalho and Shamim are part of an IEEE delegation to promote IEEE membership and societal activities in Africa. We thank the IEEE and its relevant societies for supporting their visit. The delegation and their roles within the IEEE are as follows:

- Prof. Maurizio Bozzi, President of the IEEE MTT Society;
- Dr Goutam Chattopadhyay, President Elect of the IEEE MTT Society;
- Prof. Nuno Borges Carvalho, Past President of the IEEE MTT Society;
- Dr Samir El-Ghazaly, Past President of the IEEE MTT Society;
- Prof. Atif Shamim, Vice Chair, Member and Geographic Activities (MGA) Committee of the IEEE AP Society;
- Prof. Qammer H. Abbasi, Vice Chair, Young Professionals (YP) Committee of the IEEE AP Society;
- Prof. Riadh Abdelfattah, Member, Administrative Committee of the IEEE GRSS (Geoscience and Remote Sensing Society).

We are fortunate to have this delegation of senior societal administrative committee members in attendance, and we encourage all delegates to make them feel most welcome and to engage with them.

Equally, we thank all local presenters for their contributions, as well as all attending delegates for the value they are adding to this technical community through their participation.

The technical programme includes a student poster session at the end of Day 1. We thank the student presenters for their contributions and trust that showcasing their work will stimulate interest and valuable interactions. Canapes and drinks will be served during the poster session, as appetisers for the extensive banquet to follow afterwards. The banquet takes place at *De Warenmarkt Restaurant*, corner of Van Riebeeck and Ryneveld streets, starting at 18:30 and running until late.

The conference would not have been possible without the generous support of its sponsors, which are listed in the next section. All Tier 1 and 2 sponsors are participating in the industrial exhibition at the conference, with some also presenting short workshops in parallel with the poster session. The Tier 1 sponsors are lending premium-level support, and thus have presentation slots scheduled ahead of coffee breaks/lunches. Altogether, the sponsors are enabling a large contingent of students to attend, which is critically important for the future. We sincerely thank the sponsors!

Of the 100 conference attendees, 21 are students, 19 are from academia and 60 are from industry.

The conference is organized by a team from Stellenbosch University, the University of Cape Town and the University of Pretoria, on behalf of the Chapter.

We trust that you will find the conference interesting, constructive and enjoyable.

Prof. Matthys M. Botha, Stellenbosch University
Prof. Dirk I. L. de Villiers, Stellenbosch University
General Chairs of the South African IEEE Joint AP/MTT/EMC Chapter Conference, 2024 Edition

Sponsors

On behalf of the South African AP/MTT/EMC-community, the Conference Organising Committee gratefully acknowledges the invaluable support from our sponsors.

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Conference Programme

South African IEEE Joint AP/MTT/EMC Chapter Conference, Stellenbosch, August 1-2, 2024		
Programme Day 1 of 2		
Time	Activity	Chair / Speaker
08:00	Registration & Coffee	
08:55	Conference Opening and Notices	Matthys M. Botha, *Stellenbosch University*
	Opening Session: Day 1	Dirk De Villiers, *Stellenbosch University*
09:10	Keynote: Net ZERO Radio Communications Use of SWIPT for IoT Applications	Nuno Borges Carvalho, *Universidade de Aveiro, Portugal*
09:40	Keynote: Invention of the Microstrip Patch Antenna in South Africa 52 Years Ago in 1972	Johannes H. Cloete, *Emeritus Professor, Stellenbosch University*
10:10	Coffee Break	
	Session: Systems and Receivers	Tinus Stander, *University of Pretoria*
10:50	Design and Challenges Faced by the CW Radar System Used to Power Inrange Golf	Ockert Jacobs, *Alphawave Golf*
11:10	The Design Challenges in SATCOM Systems - Positioning for Future Aeronautical Applications	Willem Koen, *Thales*
11:30	SDR vs RFSoC Type Transceivers. How do Modern Integrated Transceivers Compare to Classical Receiver Architectures?	Christo Nel, *Hensoldt GEW*
11:50	Direct RF Frequency Digitisers for Radio Astronomy Applications	Sias Malan, *South African Radio Astronomy Observatory*
12:10	Sponsor Talk: How to Address mm-wave Signal Detection and Characterization	Ferdinand Gerhardus, *Tamashi / Anritsu*
12:25	Lunch	
	Session: Electromagnetic Compatibility	P. Gideon Wiid, *University of Cape Town*
13:50	On the Importance of an EMC Management Plan in Electric Utility Projects	Pieter Pretorius, *TERRATECH*
14:10	Managing Radio Frequency Devices in the Danger Area of Explosives Manufacturing Plants	Callie Fouche, *ITC Services*
14:30	Less Snakes, More Ladders, and a Weighted Dice: Improving the Odds Through Diagnostic Pre-Compliance Testing	Kurt M. Coetzer & Joely A. Andriambeloson, *MESA Solutions (Pty) Ltd*
14:50	Electromagnetic Interference from an HVDC / HVAC Cable Crossing to a Submarine Pipeline with Focus on Diver Safety	Pieter Pretorius, *TERRATECH*
15:10	Sponsor Talk	Qfinsoft / Ansys
15:25	Coffee Break	

	Session: Modelling	Leanne Johnson, *Stellenbosch University*
16:00	Yield Optimization of a 38-Variable Passive Diplexer Structure Using NLPLS-based PCE	Leanne Johnson, *Stellenbosch University*
16:20	Developments in MoM Formulations for Analysis of Antenna Arrays and Wires	Matthys M. Botha, *Stellenbosch University*
16:40	**Student Poster Session and Sponsor Workshops** * Qfinsoft / Ansys * Tamashi / Anritsu: *PhaseLync vs Historical Antenna System Setups - New Technology Allows for Better Performance at Lower Cost*, Ferdinand Gerhardus	
18:30	Banquet, 18:30 for 19:00, Until Late, at ***De Warenmarkt Restaurant***, Corner of Van Riebeeck and Ryneveld Streets	

South African IEEE Joint AP/MTT/EMC Chapter Conference, Stellenbosch, August 1-2, 2024		
Programme Day 2 of 2		
Time	Activity	Chair / Speaker
8:15	Registration & Coffee	
	Opening Session: Day 2	Tinus Stander, *University of Pretoria*
9:00	IEEE Society Presentations	Society Representatives
9:30	Keynote: Flexible, Wearable, Disposable Wireless Communication and Sensing Systems Through Additive Manufacturing	Atif Shamim, *King Abdullah University of Science and Technology, Saudi Arabia*
10:00	Keynote: Transfer Function Design for SMC Filters on Printed Circuit Boards	PW van der Walt, *Emeritus Professor, Stellenbosch University*
10:30	Sponsor Talk	EMSS Antennas
10:45	Coffee Break	
	Session: Synthesis and Manufacture of Microwave Devices	Werner Steyn, *Stellenbosch University*
11:20	Filter Arrays for 100GHz Systems	Petrie Meyer, *Stellenbosch University*
11:40	Ultrawideband Miniaturized Klopfenstein Impedance Transformer	Joseph Pembamoto, *Poynting Antenna (Pty) Ltd*
12:00	Advanced Microfabrication at the Carl and Emily Fuchs Institute for Microelectronics	Heinrich Laue, *University of Pretoria*
12:20	Sponsor Talk	Hensoldt
12:35	Lunch	
	Session: Antennas I	Jacki Gilmore, *Stellenbosch University*
13:50	Phaseless Near-Field Measurements of Active 5G Antennas	Paul van Jaarsveld, *Vodacom (Pty) Ltd*
14:10	Evaluation of GNSS Anti-Jamming Antennas with Controlled Radiation Patterns	Vian Reynders, *Saab Grintek Defence*
14:30	Active Integrated Array Design Philosophies and Measurement Approaches	Jacki Gilmore, *Stellenbosch University*
14:50	Assembly and Measurement of a Wideband Feed for the Ghana Radio Telescope	Michael Johnston, *South African Radio Astronomy Observatory*
15:10	Coffee break	
	Session: Antennas II	Arnold de Beer, *University of Johannesburg*
15:30	Extending the Bandwidth of Double Ridge Guide Horn (DRGH) Antennas	Bennie Jacobs, *University of Pretoria & Saab Grintek Defence*
15:50	Electrically Small Antenna for Terrestrial Wildlife Tracking	Arnold de Beer, *University of Johannesburg*
16:10	Comparison of Measurement Facilities for Cellular Base-Station Antennas	Gordon Mayhew-Ridgers, *Vodacom (Pty) Ltd*
16:30	Conference Closing	Organising Committee

Keynote 1

Net ZERO Radio Communications
Use of SWIPT for IoT applications

Nuno Borges Carvalho

Departamento de Electrónica, Telecomunicações e Informática, Instituto de Telecomunicações,
Universidade de Aveiro, Portugal
nbcarvalho@ua.pt

Energy is central to all our activities, especially now, as electricity is needed for basic human survival. Nevertheless, the resources are limited. On certain occasions, we need to rely on the opportunity to have specific energy availability and energy on demand so that sensors, emergency communications, and ICT will continue to operate even if the energy grid is not there.

This talk will discuss the electricity generation problem and how to cope with the huge demand for ICT (Information Communication Technologies) technologies. We will address new paradigms for radio communications and alternatives to make energy available when needed and where needed. It is expected that Net Zero Radio alternatives will be available on the market in the future. Exploration of SWIPT – Simultaneous Wireless Information and Power Transmission alternatives will be explored, as well as some examples of bateryless sensors will be presented.

Keynote 2

Invention of the Microstrip Patch Antenna in South Africa 52 Years Ago in 1972

Johannes Hendrik Cloete

Emeritus Professor, Department of Electrical and Electronic Engineering, Stellenbosch University,
South Africa,
jhcloete@sun.ac.za

Abstract

The microstrip patch antenna [1]-[4], in its various guises (square, rectangular, circular, elliptical, triangular, etc.), is truly ubiquitous. It is cheap to manufacture, flush mountable on planar and curved surfaces, and thus ideal for aerodynamic and stealth applications. It is readily integrated with receiver and transmitter electronics and makes an excellent array element. It is found worldwide in wireless networks, satellite systems (uplink and downlink), radars, missiles, and satellites and is indispensable in IoT devices. Its invention was the birth of a new technology—and 1000s of papers.

Although the germ of the microstrip antenna concept dates back to Deschamps' and Sichak's 1953 paper (classified at the time) [4, p. 7-2], credit for the invention of practical wrap-around and patch microstrip antennas is usually given to Munson for his work in the early 1970s [5]-[7].

However, in this paper it will be shown that the microstrip patch antenna was independently invented at the National Institute for Defence Research, CSIR, South Africa by Bob van der Neut in 1972 [8]. It will also be shown how the patch was used to realise a 3x24 element electronically scanned C-band cylindrical array with PIN diode switches [9]. At the time security considerations prevented the work from being published in the open literature.

References

[1] K.R. Carver and J.W. Mink, "Microstrip Antenna Technology," *IEEE Trans. Antennas Propag.*, vol. AP-29, pp. 2-24, January 1981.

[2] J.R. James and P.S. Hall, *Handbook of Microstrip Antennas, Vols. 1 and 2*, Peter Peregrinus Ltd. on behalf of the IEE, 1989.

[3] D.M. Pozar and D.H. Schaubert (Eds.), *Microstrip Antennas. The Analysis and Design of Microstrip Antennas and Arrays*, IEEE Press, 1995.

[4] D.R. Jackson, *Microstrip Antennas,* in J.L. Volakis (Ed.), Antenna Engineering Handbook, 4th Ed., McGraw-Hill, 2007.

[5] R.E. Munson, "Microstrip Phased Array Antennas," *Proc. Twenty-Second Symp. USAF Antenna and Development Program*, October 1972.

[6] R.E. Munson, "Single Slot Cavity Antenna Assembly," US Patent 3713162, 23 January 1973.

[7] R.E. Munson, "Conformal Microstrip Antennas and Microstrip Phased Arrays," *IEEE Trans. Antennas Propag.,* vol. AP-22, pp. 74-78, January 1974.

[8] C.A. van der Neut, "Change of Approach to the Antenna Problem," Memorandum, National Institute for Defence Research, CSIR, Pretoria, 9 October 1972, SECRET.

[9] C.A. van der Neut, "Development of a C-band Wrap-Around Directional Microstrip Antenna Array," Report No. R&D 75/21, National Institute for Defence Research, CSIR, Pretoria, April 1975, RESTRICTED.

Design and challenges faced by the CW Radar system used to power Inrange Golf

Ockert B. Jacobs[1]

[1] Alphawave Golf, Tracking Systems, Stellenbosch, Republic of South Africa
ojacobs@inrangegolf.com

Inrange is a product that aims to provide golfers with an engaging and entertaining experience when visiting a driving range. This is enabled by the radar systems developed for Inrange that aims to track every golf ball hit at the driving range. The tracked shot data is then used in to help track a user's progress or compete in games. The goal behind this is to help users improve but also to enable a more entertaining and engaging experience at ranges where it is installed

Accurately tracking a large number of balls across the range and reporting the results to users with low latency in diverse environments is a challenging and interesting problem.

This talk will provide some details regarding the X-band radar hardware and system designed to achieve this. Some of the challenges experienced in the process of the development, operation and wider roll-out of the system will also be discussed.

The design challenges in SATCOM systems - positioning for future aeronautical applications

Willem Koen, David Howie, Jason Bonarius and Alex Vermeulen

Thales, Engineering Department, Cape Town, South Africa
willem.koen@cobham.com

Connectivity and data are key elements for every individual and organisation in making an efficient contribution to business and social environments. These elements also apply when travelling in the sky by aircraft. The demand for connectivity presents an exciting future for connected aircraft, but at the same time it also presents design challenges in an environment where the demand for secure data, spectrum availability, reliable communication networks and environmental friendly product solutions are ever increasing.

A very relevant program in aerospace, initiated by EASA, is Iris. Iris is making aircraft flights greener and more efficient, providing a safe and secure text-based data link between pilots and air traffic control networks using satellite technology. Satellite communication systems such as Iris are among the essential enablers supporting next generation air traffic management systems in Europe and will help relieve pressure on the aviation sector's congested radio frequency communication channels.

L-band satellite communication systems are well positioned to deliver on the Iris expectations. The objective of this industrial paper is to present the future applications of these satellite communication systems and products. It will explain some of the design challenges faced and how innovative product and system designs address these. The rollout of many 5G terrestrial networks have increased the challenges in the design of robust linear receivers at L-band where these networks co-exist with satellite systems. This requires careful consideration in the design of sensitive satellite products on both a product and system level.

SDR vs RFSoC type transceivers. How do modern integrated transceivers compare to classical receiver architectures?

Christo Nel[1], Johan Wybenga[1]

[1] GEW Technologies trading as Hensoldt GEW, Pretoria, South Africa
Christoa.nel@hensoldt.net

The heterodyne receiver as a SDR has been the most common wideband architecture for decades. However recent advances in ADC sampling rates, the incorporation of embedded digital signal processing and the improvement of matched channels on chip, has seen a whole new field of receiver possibilities. These highly integrated RF on chip transceivers promise impressive specifications in extremely small packages. Apart from the basic difference between superheterodyne, direct conversion and direct sampling receivers, this paper will look at the practical and performance differences between the GEW technologies RF8000 (classical SDR) and GRX7 (ADRV9009) receivers.

Direct RF frequency Digitisers for Radio Astronomy applications

Sias Malan[1] and Henno Kriel[1]

[1] South African Radio Astronomy Observatory (SARAO), Cape Town, South Africa,
sias@sarao.ac.za

Radio astronomy digitisers are required to provide wide instantaneous bandwidths due to the wide spectral content of the sources typically observed by radio astronomers. To achieve these bandwidths, digitisers are required to digitize RF signals at giga-sample per second rates [1]. RF signals are either directly digitized after first low noise amplification, or downconverted to an intermediate frequency. For direct digitized architectures the signal is sampled either in the first or second Nyquist zone. Downconverted signal are downconverted to an intermediate frequency (IF) which falls in the second Nyquist zone. Both of these architectures result in the signal entering the analog to digital converter (ADC) to be at RF frequencies reaching C-band. Additionally, Radio Frequency Interference (RFI) requires that high dynamic range is available to ensure that the sensitive radio astronomy signal is received without being degraded by non-linear behavior of the digitiser.

The combination of these requirements leads to digitiser architectures requiring gigabit per second sample rates and a high number of sampling bits. In this talk, we will present digitizer architectures which has been deployed on the MeerKAT telescope to address these design challenges.

References

[1] A. Pellegrini et al., "MID-Radio Telescope, Single Pixel Feed Packages for the Square Kilometer Array: An Overview," in IEEE Journal of Microwaves, vol. 1, no. 1, pp. 428-437, Jan. 2021[2]

On the Importance of an EMC Management Plan in Electric Utility Projects

Pieter H Pretorius

TERRATECH, South Africa
office@terratechnology.co.za

Experience has shown that EMC Management is generally overlooked from a planning perspective in typical projects focusing on, for example, high voltage substations and large utility scale photovoltaic (PV) plant in South Africa. The motivation for EMC Management and its associated planning early in the project phases stems from the fact that retrofitting for EMC requirements on an existing plant is practically challenging and can be rather costly. The particulars related to an EMC Management Plant are covered in this presentation and cover the following:

- First of all, what an EMC Management Plan entails;
- Secondly, why is it necessary to have an EMC Management Plan prepared;
- Further, the Project Phases covered by an EMC Management Plan and
- How the EMC Management Plan interfaces with earthing and lightning protection of the project.

Awareness about an EMC Management Plan will not only be useful to the design engineer of electric utility plant, but also to the design team in general, as will be pointed out.

Managing Radio Frequency Devices in the Danger Area of Explosives Manufacturing Plants

Callie Fouche

ITC Services, Pretoria, South Africa
callie@itc-services.com

The use of radio frequency devices in the danger zone of explosives manufacturing plants, in South Africa, is prohibited by the Explosives Regulations R109 (Occupational Health and Safety Act 1993 section 43). The revised radio frequency regulations to be published in 2024 only allow the use of radio frequency devices in the danger area based on a risk assessment by an approved inspection authority and authorization by the explosives manager.

The management of RF devices, based on the risk assessment method, has a three-step approach:

- Assessments of RF devices.
  Evaluate the effective radiated power and operating frequency.

- Assess the impact on current processes, production line equipment and products.
  Determine the exclusion zones where the devices will not be allowed.

- Submission of the assessment results to the Department of Employment and Labour.
  Concludes the legal requirement to receive a permit.

The assessment methodology, including the determination of exclusion zones, is unpacked in the presentation.

Less Snakes, More Ladders, and a Weighted Dice: Improving the Odds Through Diagnostic Pre-Compliance Testing

Kurt M. Coetzer[1], Joely A. Andriambeloson[1], Casey J. Bryant[1], and Howard C. Reader[1]

[1] MESA Solutions (Pty) Ltd, Stellenbosch, South Africa
info@mesasolutions.co.za

MESA is becoming increasingly interested in pre-compliance and good diagnostic measurements for clients. This is in the field of electromagnetic compatibility (EMC) and certification. In general, EMC does not just relate to the legal standards, but also forms a part of ensuring overall system integrity.

A simple illustration of this is a well-designed electronic system which interferes with itself. A recent national EMC user group initiative has prompted us to write a little more technically about this topic.

Real-Time Spectrum Analysis

Traditional spectrum analyzers (SAs) employ a swept-tuned methodology – i.e. they sweep through the frequency band of interest. These devices can cover a wide frequency range in a single sweep. However, when operating at one spectral point, they do not capture what is going on elsewhere – making it difficult to characterize quick events fully. This is irrespective of the repetition of these events. Real-time spectrum analyzers (RTSAs), by contrast, continuously observe narrow portions of the frequency spectrum. This improves the probability of capturing short transient bursts, albeit over a limited band. Where emissions are repetitive, multiple real-time captures can be stitched together to form a single, wideband characterization.

Chargers – do you have the power?

Battery-powered SAs are an invaluable tool for in-field assessments of conducted and radiated emissions. Their greatest strength is their portability – there is no need to be tethered to a wall outlet. At some point, however, these batteries need to be charged, presenting a metrology problem. The chargers, generally simple alternating current (ac) to direct current (DC) switched-mode power supplies, are often produced by a third party. As a result, there is less of an opportunity for a careful integration with the analyzer. Most desktop SAs have metallic enclosures, filtered power connections, and dedicated earth terminals. Battery-powered SAs do not. Understanding the implications of introducing a noise source – the charger – into the measurement environment becomes important to prevent diagnostic red herrings.

(EMC) Electromagnetic…Coffee?

Cable layout can make or break an EMC problem. This not only goes for the Device-Under-Test (DUT), but the measurement setup as well. A simple experiment demonstrates this by observing the common-mode current on the power cables of a DUT with a battery powered SA. A recent experience with a coffee machine in a nearby, but separate, building illustrates this. It created a pulse which then coupled into the test setup and was observed by the analyzer. The analyzer signal and charger connections were then adjusted, and a reduction in coffee-induced crosstalk was observed.

These points will be presented as a demonstration of improving the EMC odds, and link to a MESA EMC cabinet, a reverberation chamber at Houwteq, and diagnostics.

Electromagnetic Interference from an HVDC / HVAC Cable Crossing to a Submarine Pipeline with Focus on Diver Safety

Pieter H Pretorius[1], Jurjen P Couperus Cabadag[2] and Peet J Schutte[3]

[1] TERRATECH, South Africa
office@terratechnology.co.za

[2] DNV, Germany
Jurjen.Couperus.Cabadag@dnv.com

[3] DNV, Netherlands
Peet.Schutte@dnv.com

Abstract

With the expansion of offshore submarine cables, it is guaranteed that other infrastructure, such as, telecommunication cables, other power cables and pipelines will need to be crossed at some point. Very little has been published on the anticipated electromagnetic interference of HVDC / HVAC cable crossings of pipelines, particularly in the context of diver safety. This paper reflects on the anticipated electromagnetic interference of a planned power cable / pipeline crossing to ensure the safe and efficient operation of the pipeline in relation to its proximity to the power cables. The objectives with the study were to assess the risk of electromagnetic interference from the power cables with the pipeline and, mainly, at the crossing points. Details pertaining to the full assessment, criteria and twenty-six assessed risks associated with potential electromagnetic interference are addressed in [1]. A summary of the risk, in the context of a diver only, is covered in this presentation. The assessment criteria for the diver were sourced from [2]. The following conclusions were drawn:

- Apart from two electromagnetic risks addressed in the Cable Crossing / Pipeline study, all risks were tolerable risks. No intolerable risks were identified from the electromagnetic study. Risk No 1 (induced voltage on the pipeline due to an HVAC 50 Hz fault on the cable near the crossing) and Risk No 2 (induced voltage on the pipeline due to an HVDC 0,1 Hz fault on the cable near the crossing) fall in the "as low as reasonably practicable" (ALARP) region and are dependent on: i) The actual fault current and ii) The maintenance procedure to be used on the pipeline. It is expected that these risks will be reduced as a result of the fault current having a tendency to pass through the sea water rather than the person doing maintenance. The reason is because of the lower resistivity of the sea water compared to that of the human body [3, 4]. Further, the risk can be reduced by personal protection equipment (PPE). The latter forms part of future investigations.
- The relatively low levels of electromagnetic coupling to the pipeline can be assigned to the following: i) The relatively low, steady state, ripple current (63 A) at 550 Hz in the HVDC case, presented a relatively low magnetic field for coupling to the pipeline; ii) Despite a higher, steady state, current (1270 A) at 50 Hz in the HVAC case, the trefoil arrangement of the cable presented a relatively low magnetic field for coupling to the pipeline; iii) The relatively low resistivity associated with the sea water and the sea bed; iv) The fact that the pipeline is in essence "earthed" to the sea bed (and the sea water) via sacrificial anodes that are in direct contact with the pipeline, the sea water and the sea bed.
- The electromagnetic studies and assessments were performed at a conservative cable-to-pipeline separation distance of 0,3 m and for a crossing angle of 66 degrees. It is to be expected that the electromagnetic coupling, specifically from an inductive perspective, will be lower with increasing separation distance between the power cables and the pipeline as well as at lower crossing angles.

This paper offers insights into electromagnetic interference associated with submarine cable and pipeline crossings, particularly in the context of divers performing work / maintenance on the pipeline. These are viewed as important and supportive to the crossing design engineer.

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Yield optimization of a 38-variable passive diplexer structure using NLPLS-based PCE

Leanne Johnson, Dieter Klink, Werner Steyn, Petrie Meyer

Department of Electrical and Electronic Engineering, Stellenbosch University, South Africa,
ljohnson@sun.ac.za, wernersteyn@sun.ac.za, pmeyer@sun.ac.za, dklink@emss.co.za

Yield optimization can be a crucial step in the high-volume microwave and antenna design, however this process can be a very expensive process, as a multitude of full-wave electromagnetic analyses are required for statistical analysis. Such optimization however becomes an option if the statistical analysis can be performed in a very efficient manner. Recently, a Non-Linear Partial-Least-Squares-based Polynomial Chaos Expansion (NLPLS-based PCE) approach was successfully proposed. In this paper, the yield of a 38-variable passive diplexer structure is optimized using gradient-based techniques and random walk optimization techniques which utilizes the ability of NLPLS-based PCE to efficiently construct high-dimensional surrogate models. The yield for the initial nominal design is estimated as 57.28 % for the first specification (S_1) and 80.40 % for the second specification (S_2). The first specification, S_1, is a reflection coefficient lower than -23 dB for 1.15 GHz $\leq f_1 \leq$ 1.3 GHz and S_2 is a reflection coefficient lower than -23 dB for 1.55 GHz $\leq f_1 \leq$ 1.65 GHz. It is shown that the yield is successfully improved when NLPLS-based PCE is combined with these optimization techniques.

Developments in MoM formulations for analysis of antenna arrays and wires

Matthys M. Botha[1], Keshav Sewraj[2], Pierre I. Cilliers[1], André S. Conradie[1],
William R. Dommisse[1] and Thomas Rylander[3]

[1] Department of Electrical and Electronic Engineering, Stellenbosch University, South Africa,
mmbotha@sun.ac.za
[2] Department of Emerging Technologies, Université des Mascareignes, Rose-Hill, Mauritius,
ksewraj@udm.ac.mu
[3] Department of Electrical Engineering, Chalmers University of Technology, Göteborg, Sweden,
rylander@chalmers.se

The method of moments (MoM) is widely used for electromagnetic scattering and radiation analysis. For electrically large and/or multiscale structures, the degrees of freedom can become very large, and system conditioning may deteriorate. Consequently, computational costs become very high. Increasingly challenging applications which fall into this category, may benefit from specialised formulations to enable higher solver efficiencies, such that accurate solutions can be obtained quickly and reliably. Recent work at Stellenbosch University on computational methods for high-frequency electromagnetic analysis, includes development of efficient methods for two application domains, namely large-scale antenna arrays and complex wire structures. Various foundational method, such as low-rank factorisation, macro basis functions, etc., are combined towards constructing the new solver formulations. The presentation gives an overview of this ongoing work, which is applicable to, e.g., the design of radio astronomy antenna arrays and the assessment of electromagnetic interference.

Student poster session

Allen, Gary	*Stellenbosch University*	Antenna Modeling for the REACH 21-cm Experiments
Conradie, André	*Stellenbosch University*	Fast Localised-Solution Methods for Full-Wave Analysis of Large Antenna Arrays
Crews, Madison	*Stellenbosch University*	Design of a Feed Antenna for the HIRAX Telescope
Dommisse, William	*Stellenbosch University*	Accurate and Efficient Modelling of Wires with Macro Basis Functions
Fourie, Jack	*Stellenbosch University*	W-Band Array Element Folded Filter in Gap Waveguide
Keatimilwe, Amantle	*University of Pretoria*	Microwave Filters
Lötter, Aidan	*Stellenbosch University*	Towards Implementation of Tri-ridged Orthomode Transducer
Luvhengo, Fhatuwani	*University of Pretoria*	An AI Classifier for a 60 GHz LNA with Oscillation-Based Testing
Manas, Sean	*Stellenbosch University*	Over-The-Air Measurements inside a Reverberation Chamber
Mohamed-fakier, Zubair	*University of Cape Town*	Transient Detection Using MeerKATs D-Engine
Neate, Reuben	*University of Pretoria*	Progress Towards a Low-Cost Planar Water Vapour Radiometer
Nfanyana, Ketshabile	*Stellenbosch University*	Swarm Intelligence Yield Optimisation of Microwave Devices
Pieterse, Carla	*Stellenbosch University*	The Effects of Directivity Uncertainty Within a Global 21cm Experiment
Rohde, Archibald	*University of Pretoria*	Microwave Characterisation Methods for 3D-Printed Materials
Van Eeden, Christiaan	*University of Pretoria*	An Instantaneous Frequency Measurement Receiver for Radio-frequency Interference Detection
Watts, Steven	*Stellenbosch University*	Machine Learning-Enabled Design of Microwave Components for astronomy applications

Flexible, Wearable, Disposable Wireless Communication and Sensing Systems Through Additive Manufacturing

Atif Shamim

King Abdullah University of Science and Technology (KAUST)
atif.shamim@kaust.edu.sa

With the advent of wearable sensors and internet of things (IoT), there is a new focus on electronics which can be bent so that they can be worn or mounted on non-planar objects. Due to large volume (billions of devices), there is a requirement that the cost is extremely low, to the extent that they become disposable. The flexible and low-cost aspects can be addressed through additive manufacturing technologies such as inkjet and screen printing. This talk introduces additive manufacturing as an emerging technique to realize low cost, flexible and wearable wireless communication and sensing systems. The ability to print electronics on unconventional mediums such as plastics, papers, and textiles has opened up a plethora of new applications. In this talk, various innovative antenna and sensor designs will be shown which have been realized through additive manufacturing. A multilayer process will be presented where dielectrics are also printed in addition to the metallic parts, thus demonstrating fully printed components. Many new functional inks and their use in tunable and reconfigurable components will be shown. In the end, many system level examples of wireless sensing applications will be shown. The promising results of these designs indicate that the day when electronics can be printed like newspapers and magazines through roll-to-roll printing is not far away.

Transfer Function Design for SMC Filters on Printed Circuit Boards

Pieter W. van der Walt[1]

[1] Department of Electrical and Electronic Engineering, Stellenbosch University, South Africa,
pwvanderwalt@gmail.com

Abstract

Low-Pass and band-pass filters are frequently implemented on printed circuit boards with miniature surface mount inductors and capacitors. The inductors especially tend to be quite lossy. The component losses cause a deterioration of the pass and stop band responses especially near the edges of these bands. While techniques like predistortion can improve the response at the edge of the pass band, improvement of the stop band edge of, for example, elliptic function filters, requires a redesign of the transfer function.

The paper will discuss the requirements for suitable transfer functions for filters with transmission zeros at finite frequencies and revisit a powerful approximation technique for deriving suitable transfer functions. After synthesizing a suitable filter as a cascade of Darlington A, B and C sections, a simple approach to the several further network transformations that are usually required to find implementable band-pass filters will be presented.

The paper will give examples of high-performance filters that were successfully implemented on printed circuit boards with surface mount components.

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Filter Arrays for 100GHz Systems

Petrie Meyer[1], Jack D Fourie, Leanne Bodenstein[1]

[1] Department of Electrical and Electronic Engineering, Stellenbosch University, South Africa,
pmeyer@sun.ac.za

This paper will describe various filter array options developed as part of the ENTRY100GHz project, which aimed at designing a high-bandwidth 100GHz radio. Two technologies were investigated, namely a Gap-Waveguide filter array feeding slotted waveguide antenna arrays, and a Ridge-Waveguide filter array feeding a Vivaldi antenna array. In both cases, the yield of the filters was a very important design parameter, and yield estimation using PCE will be discussed briefly. Finally, the manufacture of these filters calls for very high accuracy, and different manufacturing approaches will be discussed.

Ultrawideband Miniaturized Klopfenstein Impedance Transformer

Joseph K. Pembamoto[1], Dr. Derek Nitch[2], Prof. Alan Clark

[1] Poynting Antenna (Pty)Ltd, Research and Development, Tshwane, South Africa,
joseph.pembamoto@poynting.co.za
[2] Poynting Antenna (Pty)Ltd, Research and Development, Tshwane, South Africa,
derek.nitch@poynting.co.za
[3] School of Electrical and Information Engineering, University of the Witwatersrand, Johannesburg.
alan.clark@wits.ac.za

Traditionally, an impedance transformer is a passive device that is used in matching a device of one impedance to another device which has a different impedance [1]. A Klopfenstein impedance transformer is a typical example of an impedance transformer [2]. For acceptable performance the length of the impedance transformer is typically defined to be a quarter wavelength at the lowest frequency [1]. With the rise of miniaturized antennas, there is also a need for the use of miniature feeding networks. To help achieve this, a novel miniaturize impedance transformer is proposed in which the length has been reduced by 68% compared to a traditional Klopfenstein quarter-wave impedance transformer and has a 16:1 bandwidth where the reflection coefficient is less than -15dB.

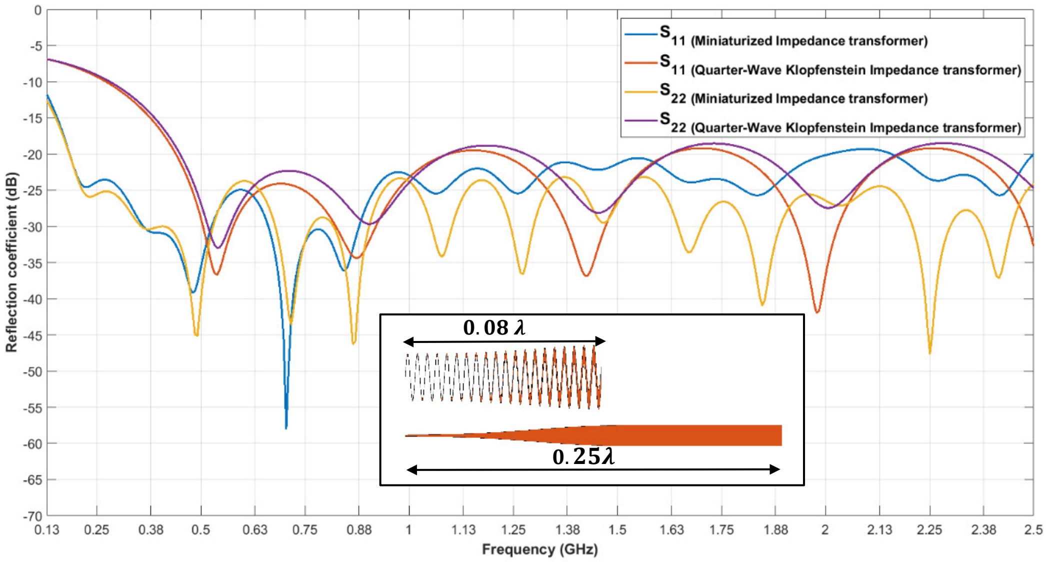

Figure 1: Reflection coefficient vs. frequency for proposed 0.08λ miniaturized impedance transformer and traditional 0.25λ Klopfenstein impedance transformer

By adding a modulating function to the Klopfenstein profile, results in a miniaturized impedance transformer which has comparable performance to a traditional transformer.

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Advanced microfabrication at the Carl and Emily Fuchs Institute for Microelectronics

Heinrich E. A. Laue[1], Trudi-Heleen Joubert[1], Tinus Stander,[1] Johan Schoeman[1] and
Kim L. R. Williamson[1]

[1] Department of Electrical, Electronic and Computer Engineering, University of Pretoria, South Africa,
heinrich.laue@up.ac.za

The recently commissioned Advanced Hybrid Microelectronics Packaging Facility at the Carl and Emily Fuchs Institute for Microelectronics (CEFIM) at the University of Pretoria enables the fabrication of patterned electronic circuits on a variety of media, the direct integration of integrated circuit (IC) dies onto such circuits, and their visual inspection down to micron level.

The new patterning capabilities include an LPKF ProtoLaser U4, capable of patterning planar media with features down to 20 µm. This is augmented by a milling station for 2.5D patterning, galvanic through-hole copper plating bath, multilayer PCB lamination press, programmable reflow oven and microscoped manual pick-and-place station. For die bonding and packaging, the new facility includes an F&S Bondtec 53xxBDA station for deep-access, 2-axis automated ball and wedge bonding, as well as a Tresky T-5100 for epoxy, thermocompression and thermosonic flip-chip bonding. Finally, the facility is now augmented with an Olympus DSX1000 digital microscope for 2D visual inspection and 3D image processing (including profiling) down to micron level.

Combined with the existing printed electronics, microelectronics and mm-wave labs at CEFIM, the new facility enables the rapid prototyping of advanced electronic and microelectronic circuits on a variety of media for a variety of applications including microwave and mm-wave systems.

This talk provides an overview of the facility and discusses the results of some initial experiments that demonstrate its versatility. Some of the more unusual materials and methods include the patterning and laser cutting of alumina substrates, laser cutting of polyimide film (Kapton) for flexible printed electronics applications, and laser cutting of apertures in PCB substrates for lensless camera systems.

Phaseless near-field measurements of active 5G antennas

Paul A. van Jaarsveld and Gordon Mayhew-Ridgers

Vodacom (Pty) Ltd., Midrand, South Africa
paul.vanjaarsveld@vodacom.co.za

The introduction of 5G standards brought with it massive MIMO (mMIMO) antenna arrays. As it is possible with mMIMO arrays to generate beams that point in arbitrary directions, it is required to characterize the three-dimensional beamforming capability of the antenna. This is typically measured with near-field scanning techniques that require the amplitude and phase of the electric field to be known. It complicates matters that access to a reference signal is mostly not available. Novel ways are therefore required to recover the phase information from the near-field scan data. Various options have been developed to derive these phase values [1]. This paper aims to describe an alternative method. The complexity of pattern measurements on active mMIMO antennas is that the signal being measured is most often not a standard continuous wave (CW) signal, but a modulated 5G signal that cannot be processed by a standard vector network analyzer (VNA). Fortunately, most of the major 5G equipment suppliers do conform to the requirement to produce a static radiation pattern with a 3GPP test model (TM) signal. As such, a known signal can at least be produced.

The proposed method is to utilize a software-defined radio (SDR) with at least two coherent receiver chains. It is used to sample a portion of the TM signal radiated by the antenna under test (AUT) on one of the SDR receive paths, and, simultaneously, also sample a stable reference copy of the same signal during the near-field scanning procedure on the other path. The latter is typically obtained from a suitably placed reference antenna close to the AUT. Both receive paths are analyzed and decoded to produce demodulated orthogonal frequency-division multiplexed (OFDM) frame structures. The pair of demodulated signals is then mapped to a specific 5G TM reference signal grid and then compared at the specific physical channel allocations. This contribution proposes at least one method to recover the phase of 5G modulated signals and describes test and verification measurements. Figure 1 shows the phase comparison of measured antenna patterns via the standard far-field VNA method (CW) and the SDR method (5G modulated signal).

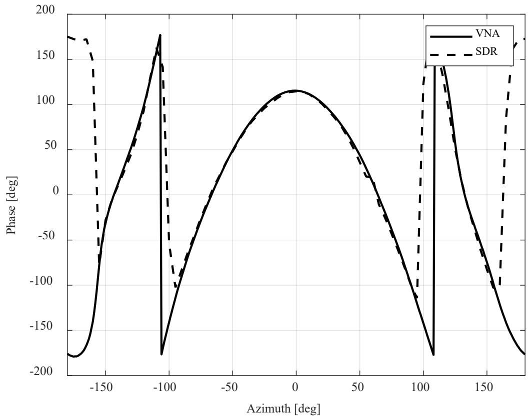

Figure 1. Phase comparison of measured antenna patterns.

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Evaluation of GNSS anti-jamming antennas with controlled radiation patterns

Vian Reynders[1]

[1] Saab Grintek Defence, Antenna Development Department, Centurion, South-Africa
vian.reynders@za.saabgroup.com

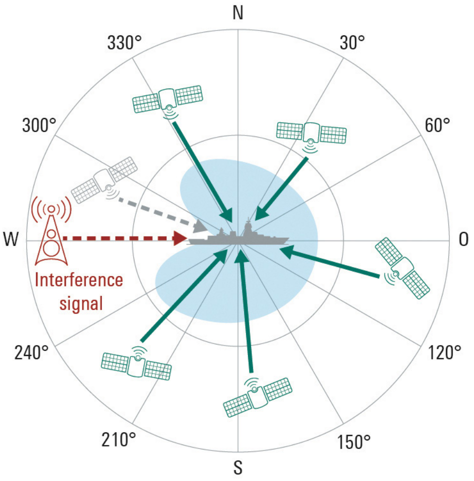
Global Navigation Satellite System (GNSS) is a critical technology that allows users to determine their precise location, velocity, and time anywhere on Earth or in its vicinity. GNSS systems are essential for a wide range of applications, from simple navigation for individuals to complex positioning and timing requirements for military applications.

Because of the low broadcasting power and long transmission distances, the GNSS signal is easily jammed by unintentional or intentional Radio Frequency Interference (RFI). To mitigate these challenges, advanced signal processing techniques and improved hardware are continually developed.

Jamming can be done by means of emitting a signal in the specified frequency band larger than that of the satellites, effectively saturating the GNSS receiver with noise and stopping it from acquiring an accurate position, or by spoofing. Spoofing is done by simulating a wrong set of coordinates to the GNSS receiver, confusing the receiver to where it is

Anti-Jamming can be implemented on multiple levels; at antenna, in receiver and/or in software. At SGD Antennas, we focused on the antenna level, and more specifically Controlled Radiation Pattern Antenna (CRPA). CRPA and null steering anti-jam GNSS systems consist of a small array of antennas. The individual elements in the array are amplified or attenuated together with an applicable phase shift to steer the main radiation beam. This technique can also be used to create a radiation pattern null to a direction when an attempted jam is picked up, thus significantly suppressing the jamming signal, as illustrated in the figure below.

Two CRPA anti-jam antennas were evaluated as potential solutions for our anti-jam requirement, and the test setups and results will be presented during the conference. We found that the CRPA anti-jam GNSS antennas worked very well as we were not able to jam them in a lab environment.



Active Integrated Array Design Philosophies and Measurement Approaches

Jacki Gilmore[1], Sean Manas[1] and Lanche L. Grootboom[2]

[1] Department of Electrical and Electronic Engineering, Stellenbosch University, South Africa,
jackivdm@sun.ac.za

Abstract

Ultra-low-noise applications like radio astronomy necessitate ever-closer integration of the low-noise amplifier (LNA) with the antenna, which is often located in an array. This close integration poses several design and measurement challenges are discussed in this presentation.

The traditional approach to receiver design is to design and test the antenna and the LNA separately, with both specified to a constant real impedance (often 50 Ω) over the entire bandwidth. However, low-noise and low-power transistors used for LNA design often have high optimum source impedances. The matching network required to match the input of the transistor to 50 Ω, therefore, adds significant loss to the system.

The design objective of active, integrated receivers is to eliminate the loss introduced by the matching network by prioritising noise performance [1]. The LNA and antenna are co-designed for optimal noise match—ideally without the need for a matching network between the antenna element and the first amplification transistor. Additionally, the distance between the antenna and the LNA is minimised to avoid unnecessary transmission line losses. Several design philosophies exist to implement this objective and address the design challenges [2].

The resulting product is a one-port device that is no longer reciprocal. The only measurable port is the output of the LNA, which makes characterising the device for power transfer, gain, and noise performance difficult. Several approaches have been developed to address these difficulties [3] and [4].

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Assembly and Measurement of a Wideband Feed for the Ghana Radio Telescope

Michael Johnston[1] and Sias Malan[1]

[1] South African Radio Astronomy Observatory, Cape Town, South Africa
mjohnston@sarao.ac.za

The Ghana Radio Telescope is a Cassegrain shaped dual-reflector system forming part of the African Very Long Baseline Interferometry (VLBI) Network (AVN). The telescope supports VLBI and methanol line operations at 5 and 6.7 GHz respectively. The current receiver signal chain consists of Intermediate Circular Orbit (ICO) satellite system waveguide components, low-noise amplifiers (LNAs), as well as diode noise modules. Furthermore, the necessary inclusion of waveguide couplers, orthomode transducers (OMTs) and band-pass filters results in a complicated and bulky receiver architechure which is susceptible to increased system noise temperature.

The design of a wideband feed for integration with a South African Radio Astronomy Observatory (SARAO) receiving system on the Ghana Telescope was presented in [1]. The aim was to reduce the complexity of the feed system and to provide large instantaneous bandwidths for improved continuity of multiple spectral line observations. The feed consists of a wideband OMT and hybrid couplers covering the entire band between 5 and 6.7 GHz i.e. 40% bandwidth.

We provide updates to the previously designed wideband feed and present measured results for comparison to simulated predictions. Recommendations based on the manufacturing and assembly process are also discussed.

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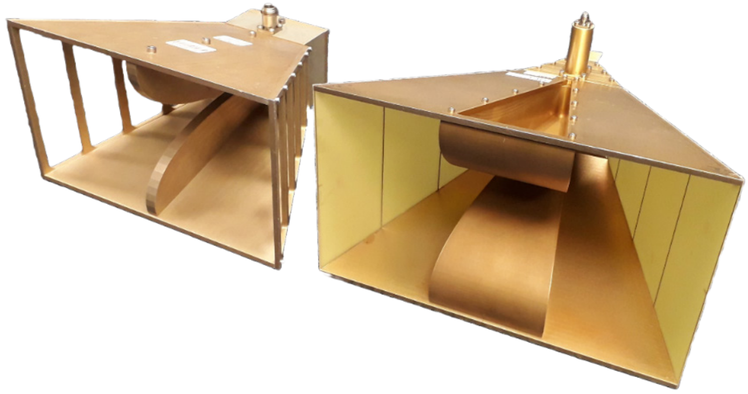
Extending the bandwidth of Double Ridge Guide Horn (DRGH) antennas

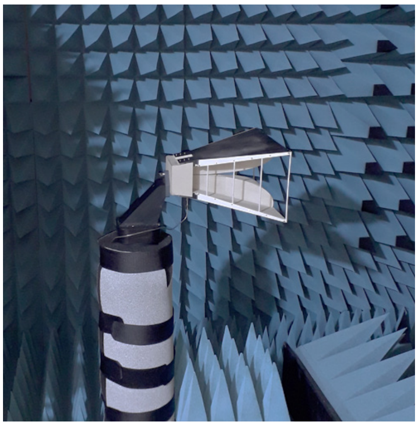
Bennie Jacobs[1,2], Wimpie Odendaal[1] and Johan Joubert[1]

[1] Department of Electrical and Electronic Engineering, University of Pretoria, South-Africa,
bennie.jacobs@za.saabgroup.com
[2] Saab Grintek Defence, Antenna Development Department, Centurion, South-Africa

Abstract

The explosive growth in bandwidth requirements on antennas and antenna systems, driven by various industries, also drives the need for the ever-increasing bandwidth of antennas used for testing. The DRGH antenna finds widespread use in antenna measurement and ElectroMagnetic Compatibility/Interference (EMC/I) testing. An example of a DRGH used extensively for testing is the 1-18 GHz DRGH antenna [1]. A study using the ElectroMagnetic (EM) simulation package FEKO from Altair was performed to determine the factors that limit the bandwidth of these antennas. The design changes that resulted from this study were implemented in several prototype antennas used for verification [2,3], see photos below. It was found that it is possible to design DRGH antennas with bandwidth ratios of 100:1 and possibly beyond. It is believed that at higher frequencies, the limit will be the manufacturing tolerances and technology, and at lower frequencies, the maximum permissible size of the antenna.





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Electrically Small Antenna for Terrestrial Wildlife Tracking

Arnold de Beer

Department of Electrical and Electronic Engineering, University of Johannesburg, South Africa
asdebeer@uj.ac.za

This presentation describes the trade-offs in an electrically small antenna, used for terrestrial wildlife tracking. In contrast to satellite trackers, this tracker (also called a "tag") does not fit onto a collar that goes around the neck of the animal but is attached to the ear. This is much less invasive. If the tag is light enough (which implies a small size), the animal is not aware of it. This ensures that the animal does not try to get rid of it. Ear tags result in longer operational lifespans while sending positional data to a central server.

Ear tags are currently being rolled out in the Kruger National Park (KNP), South Africa. It utilizes the Sigfox® network in the ISM band at 868 MHz. The main design parameters of a tag are the mass of the device (typically less than 30 g) and its range (in excess of 100 km – line of sight). Of concern is the number of towers/base stations in the KNP. Not only are they unsightly but they incur capital and maintenance costs. A tag must be under a weight limit, with its range at a maximum to minimize towers/base stations.

The range of a tag is directly related to the efficiency and gain of its antenna. Because of the tag's footprint (typically 20 mm X 40 mm), the size of the antenna is severely limited. With the free space quarter wavelength around 85 mm and an area of only 10 mm X 20 mm available on the PCB, the antenna is electrically small. Because of its allowable size, there is a limit on the maximum gain achievable, especially since the antenna should be omnidirectional.

An added complexity to the antenna's performance is its proximity to the animal ear. The ear is a dielectric in the near field of the antenna. The dielectric effect is variable as the tag can change position on the ear. This complicates the implementation of a compensating network as the resonance of the antenna shifts. The solution of using a broadband compensating network is dealt with in the presentation.

This presentation introduces an electrically small antenna for a tag that terrestrially tracks wildlife. The choice of topology incorporating variable resonance for maximum gain is investigated. It also looks at the trade-off between the antenna choice and the demands of the compensating network - given the change in the dielectric on the animal ear.

Comparison of measurement facilities for cellular base-station antennas

Gordon Mayhew-Ridgers and Paul A. van Jaarsveld

Vodacom (Pty) Ltd., Midrand, South Africa, gordon.mayhew-ridgers@vodacom.co.za

Abstract

It was previously shown how upgrades to the compact antenna test range at the University of Pretoria enabled near-field antenna measurements, both for cylindrical [1] and spherical [2] scanning configurations. The cylindrical near-field scanner, in particular, has proven to be very successful for the evaluation of cellular base-station antennas. A measurement campaign was recently undertaken with two major antenna suppliers (referred to here as Suppliers A and B for the sake of anonymity) to compare the alignment of results from this custom-developed system to those from their respective facilities. These facilities both feature spherical near-field antenna test ranges, the one with multiple measurement probes and the other with a single measurement probe.

The antenna gain was of special interest as it is often one of the most difficult parameters to determine accurately. Both suppliers make use of reference antennas to determine the gain of the antenna under test (AUT) via the gain-transfer method. These reference antennas were specifically designed to have a similar form factor than the AUT. As the accuracy of the reference gain values directly impacts the accuracy of the measured AUT gain values, much effort went into the independent verification of the supplier-provided reference gain values. This resulted in the development of a new three-antenna technique for cylindrical near-field scanning, which is to some extent based on the technique in [3] for spherical near-field scanning. Using the reference antennas, the gain values of more complex AUTs from both suppliers, each featuring four low-band and eight high-band ports, were subsequently measured. Table 1 shows the difference in gain when comparing the measured gain values to those from each supplier. Here, the gain difference is expressed as the root-mean-square value over frequency for all antenna ports in the relevant frequency band. As can be seen, these results show that good agreement could be obtained between an in-house developed facility and those from two major antenna suppliers.

Table 1. Difference in antenna gain when compared to the results from two suppliers.

	Low band (698–960 MHz)	High band (1427–2690 MHz)
Supplier A	0.28 dB	0.24 dB
Supplier B	0.19 dB	0.25 dB

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