South African IEEE Joint AP/MTT/EMC Chapter Conference

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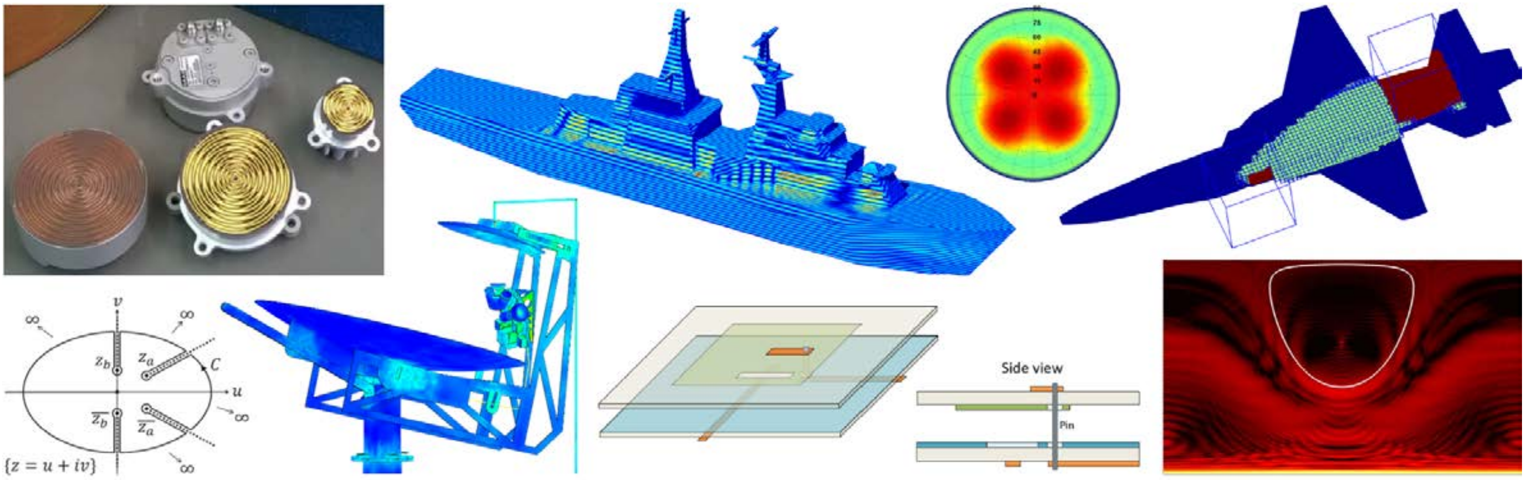

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August 30–31, 2018, Stias Conference Centre, Stellenbosch, South Africa

Conference organizing committee

General Chair: *Prof. Matthys M. Botha, Stellenbosch University*
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Technical Programme Chair (AP/MTT): *Prof. Dirk I.L. de Villiers, Stellenbosch University*
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Technical Programme Chair (EMC): *Dr P. Gideon Wiid, Stellenbosch University*
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Conferencing support services

ConsultUS (Pty) Ltd

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.

Conference website

http://www.ee.sun.ac.za/SAIEEE2018/

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Welcome messages from the Chapter Chair and Conference General Chair

Message from the Chapter Chair

On behalf of the leadership of the IEEE South Africa Joint AP/MTT/EMC Chapter, I wish to welcome you to our 2018 Chapter Conference. This biennial event is undoubtedly the highlight of the Chapter's membership activities.

Apart from the Chapter Conference, the local Chapter also sponsors and hosts technical talks (including distinguished international visitors) throughout the year. In 2017, the Chapter hosted more than 35 events in and around the country, attracting an average of around 15 attendees per event. If news of these activities do not reach you, or do not take place regularly in your area, please engage the Chapter leadership on this. As it is your membership dues that make these events possible, we are always looking to increase the value of these activities by expanding their reach.

Chapter membership (across the three Societies) currently stands at 89 members, of which 25 are Senior Members and 2 are Fellows or Life Fellows. Student membership is still relatively low – given the number of students attending this conference – and, as always, we would like to encourage students to register for membership of the IEEE.

The Chapter leadership currently consists of me, Prof. Riana Geschke (UCT) as Vice Chair for MTT activities, Dr. Gideon Wiid (SU) as Vice Chair for EMC, and Dr. Tinus Stander (UP) as past chair and treasurer. This format ensures both continuity in leadership and representation of all three technical societies in Chapter life. I will be stepping down this year, and we are actively seeking nominations for the role of vice-chair for AP. Please contact any of us if you want to nominate a candidate – self nominations are welcome!

On behalf of the Chapter, I thank the team from the Department of Electrical and Electronic Engineering at Stellenbosch University, for 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 enjoy your stay in Stellenbosch.

Prof. Dirk de Villiers, Stellenbosch University
IEEE South Africa Joint AP/MTT/EMC Chapter Chair

Message from the Conference General Chair

On behalf of the organizing committee, I welcome you to the 2018 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. All oral presentations are by invited speakers. This includes keynote presentations by four leading experts – two international and two South African:

- Dr Goutam Chattopadhyay (NASA-Jet Propulsion Laboratory, California Institute of Technology, USA, see biography here);
- Dr Kris Hatashita (Consultant to the Canadian Department of National Defence, Canada, see biography here);

- Dr Dirk E. Baker (Dirk Baker Consulting, South Africa);
- Prof. PW van der Walt (Stellenbosch University, South Africa).

We gratefully acknowledge these four contributions to the conference. We thank the NASA-Jet Propulsion Laboratory/California Institute of Technology for supporting Dr Chattopadhyay's visit. We thank the IEEE EMC Society for supporting Dr Hatashita's visit through their Distinguished Lecturer programme. Equally, we thank all other local presenters and co-workers, for the value they are adding to this technical community through their contributions.

For the first time this year, the technical programme includes a student poster session which runs concurrently with the banquet reception. We thank the student presenters for their contributions and trust that showcasing their work will stimulate interest and valuable interactions.

The conference would not have been possible without the generous support of its sponsors.

- In alphabetical order, the Tier 1 sponsors are Altair Engineering SA (Pty) Ltd, Concilium Technologies (Pty) Ltd, CST - Computer Simulation Technology, and GEW Technologies. These sponsors provided premium-level support.
- In alphabetical order, the Tier 2 sponsors are FlightScope, Protea Electronics (Pty) Ltd, Qfinsoft (Pty) Ltd, and Tamashi Technology Investments (Pty) Ltd.
- In alphabetical order, the social event sponsors are Altair Engineering SA (Pty) Ltd, EMSS Antennas, and MESA Solutions (Pty) Ltd.
- Great support was received from the IEEE, by way of contributions from the IEEE South Africa Section, the IEEE Antennas & Propagation Society, the IEEE Electromagnetic Compatibility Society, and the IEEE Microwave Theory & Techniques Society.

It is worth pointing out that these sponsors all together, are enabling a large contingent of students to attend, which is critically important for the future. We sincerely thank the sponsors!

Of the 116 conference attendees, 38 are students, 16 are from academia and 62 are from industry. The conference is organized by a team from the Department of Electrical and Electronic Engineering, Stellenbosch University, on behalf of the Chapter. The conference is registered for ECSA CPD points.

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

Prof. Matthys M. Botha, Stellenbosch University
General Chair of the South African IEEE Joint AP/MTT/EMC Chapter Conference, 2018 edition

Sponsors

On behalf of the South African AP/MTT/EMC-community, the Conference Organizing Committee gratefully acknowledges the invaluable support from our sponsors. Tier 1 sponsors provided premium-level support. Tier 2 sponsors provided standard-level support. Social event sponsors provided specific support for the banquet reception and the banquet dinner.

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Conference programme

Programme of the South African IEEE Joint AP/MTT/EMC Chapter Conference 2018, August 30–31, Stias Conference Centre, Stellenbosch, South Africa

Time	Activity	Chair / Presenter	Title / Description
Aug-30	Day 1 of 2		
7:45	Registration + Coffee		
8:45	Opening	**Dirk I. L. de Villiers**, Stellenbosch University	Welcome message from the South African IEEE Joint AP/MTT/EMC Chapter Chair
8:55	Opening	**Albert A. Lysko**, CSIR	IEEE South Africa, and its Joint AP, MTT and EMC Chapter – Opportunities
9:05	Opening	**Matthys M. Botha**, Stellenbosch University	Opening message from the Conference Chair
9:10	Keynote	**Dirk E. Baker**, Dirk Baker Consulting	Half a century of world-class antenna measurement facilities in South Africa
9:40	Session	**Paul S. van der Merwe**	Electromagnetic compatibility and interference
9:40	Presentation	**Pieter H. Pretorius**, TERRATECH	On the earthing of a large telescopic crane
10:00	Presentation	**Paul S. van der Merwe**, MESA Solutions (Pty) Ltd, Willie van der Merwe, juwi Renewable Energies (Pty) Ltd, Pieter Pretorius, TERRATECH	Detailed electromagnetic interference investigation for a large scale PV facility
10:20	Coffee		
11:00	Session	**Brian Woods**	Antennas
11:00	Presentation	**Monique Gerber**, Bennie Jacobs, Johan du Toit, Saab Grintek Defense	Development of a horn antenna array with shaped beamwidths
11:20	Presentation	**Brian Woods**, Magus, Marc Rütschlin, Rodrigo Enjiu, CST Computer Simulation Technology	Developing antenna design concepts – a connected home multimedia device
11:40	Sponsor slot	**Ernst Burger**, Altair Engineering SA (Pty) Ltd	The growing influence of CEM in commercialisation of products
12:00	Keynote	**Goutam Chattopadhyay**, NASA-Jet Propulsion Laboratory, California Institute of Technology	Space science and instruments at NASA
12:30	Lunch		
14:10	Session	**P. Gideon Wiid**	The Square Kilometre Array project
14:10	Presentation	**Robert Lehmensiek**, EMSS Antennas (Pty) Ltd	On the electro-magnetic design of the SKA mid-frequency array's reflector system and its feeds
14:30	Presentation	**George Smit**, Braam Otto, SARAO, Isak Theron, EMSS Antennas	EMI measurements for SKA1 Mid Dish qualification
14:50	Presentation	**Dirk I. L. de Villiers**, Stellenbosch University	The SARChI Chair in antenna systems for the SKA at Stellenbosch University
15:10	Presentation	**P. Gideon Wiid**, Temwani-Joshua Phiri, Stanley O. Kuja, Stellenbosch University	Research on electromagnetic compatibility control for Square Kilometer Array
15:30	Coffee		

16:10	Session	**J. Pieter Jacobs**	Computational electromagnetics and modeling
16:10	Presentation	**Johann van Tonder**, Marianne Bingle, Marlize Schoeman, Altair Development S.A. (Pty) Ltd, Ulrich Jakobus, Altair Engineering GmbH	Recent MLFMM improvements in FEKO
16:30	Presentation	**Matthys M. Botha**, Danie J. Ludick, Keshav Sewraj, Stellenbosch University	Efficient computational methods for large antenna array analysis
16:50	Presentation	**J. Pieter Jacobs**, Warren P. du Plessis, University of Pretoria	Gaussian process modelling of missile RCS magnitude responses involving off-axis angles of incidence
17:10	Sponsor slot	**Arnab Bhattacharya**, CST - Computer Simulation Technology	CST simulation for aerospace applications
17:30	Banquet		The reception starts at 17:30, at the manor house. Join in immediately or during 17:30–19:00. Dinner follows later.
17:30	Poster session	**Dirk I. L. de Villiers**	Student poster session. Posters are displayed at the manor house, as part of the banquet reception.
Aug-31	Day 2 of 2		
9:00	Session	**Tinus Stander**	Measurements and testing
9:00	Presentation	**Gordon Mayhew-Ridgers**, Paul A. van Jaarsveld, Vodacom (Pty) Ltd, Johann W. Odendaal, University of Pretoria	Near-field capabilities for the compact antenna test range at the University of Pretoria
9:20	Presentation	Monique Potgieter, CSIR, **Johann W. Odendaal**, Johan Joubert, University of Pretoria	Bistatic RCS measurements
9:40	Presentation	**Tinus Stander**, University of Pretoria	Recent progress and future challenges in high frequency oscillation-based testing
10:00	Keynote	**PW van der Walt**, Stellenbosch University	Phase noise analysis of multi-loop phase-locked loops with SPICE simulators
10:30	Coffee		
11:10	Session	**Michael R. Inggs**	Radar systems
11:10	Presentation	**Michael R. Inggs**, University of Cape Town	NeXtRAD: A multistatic radar testbed
11:30	Presentation	**Albert A. Lysko**, Francois D. V. Maasdorp, Craig A. Tong, Joshua L. Sendall, CSIR	Dynamic spectrum access/5G and passive radar
11:50	Sponsor slot	**Cornell van Niekerk**, GEW Technologies	GMJ9 multi-role jammer system
12:10	Keynote	**Kris Hatashita**, Consultant to the Canadian Department of National Defence	Electromagnetic environmental effects in the military
12:40	Lunch		
14:10	Session	**Christo A. Nel**	Filters and RF/microwave systems
14:10	Presentation	**Riana Geschke**, University of Cape Town	Aspects of practical design for planar multilayer implementation of multiband filters
14:30	Presentation	**P. Meyer**, Stellenbosch University, R. Maharajah, Newspace	Ku-Band 3D-printed waveguide filters

14:50	Presentation	**Chris Smit**, Kgabo F. Mathapo, Robert J. Anderson, Johann Lochner, Denel Spaceteq, Werner F. Swart, Space Advisory Company	Communications systems of the EO-SAT1 satellite
15:10	Presentation	**Christo A. Nel**, Gert I.P. Veale, Johan L. Wybenga, GEW Technologies	The RFX8000 combined receiver and synthesizer for 20 MHz to 6 GHz operations
15:30	Closing	**Matthys M. Botha**, Stellenbosch University	Closing message from the Conference Chair
15:35	Coffee		
16:00	The end		

Half a century of world-class antenna measurement facilities in South Africa

Dirk E. Baker

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In 1968 the Antenna Group at the National Institute for Defence Research (NIDR) of the Council for Scientific and Industrial Research (CSIR) designed a rectangular anechoic chamber to support antenna development for C-band height finders and X-band monopulse trackers. The absorber material was installed during 1969 and the anechoic chamber was fully operational at the start of 1970. The test equipment comprised a locally manufactured azimuth positioner and the Hewlett Packard HP8410A 110 MHz to 12.4 GHz vector network analyzer (VNA). In 1980 this anechoic chamber was upgraded to cover down to 500 MHz and up to 18 GHz [1]. For almost a decade the NIDR chamber was the only fully-instrumented anechoic chamber in South Africa. In 1979 a second rectangular anechoic chamber was built at NIDR. This anechoic chamber operated from 1 to 40 GHz and was designed specifically for the development of spiral antennas, biconical antennas with slant 45^{o} polarizers, horns and 35 GHz monopulse feeds.

From 1981 to 1996 twelve antenna measurement facilities were established, almost one a year. These antenna measurement facilities ranged from rectangular anechoic chambers, outdoor ground-reflection ranges for physically large antennas, a planar near-field scanner, a compact range and tapered anechoic chambers. In comparison, the period from 2001 to 2013 was relatively quiet with the establishment of only three new facilities. There was a burst of activity from 2014 to 2018 when a spherical near-field scanner, a cylindrical near-field scanner, two rectangular and five tapered anechoic chambers were built. This presentation gives an overview of some of the capabilities (frequency coverage, test zone and antenna sizes, etc.) and evaluated performance of these antenna measurement facilities. There are several EMI/EMC anechoic chambers but their requirements in terms of amplitude and phase quality in the test zone are much less severe than those for antenna measurements. In addition, there are anechoic chambers for medical applications. The EMI/EMC and medical anechoic chambers are not discussed in this presentation.

More than 25 antenna measurement facilities have been designed and built in South Africa from 1968 onwards. Only three have reached the end of their useful lives (30 to 40 years!) and have been decommissioned. Knowledgeable and dedicated users have ensured that the antenna measurement facilities established over the last half century are still operating today. South Africa has a full suite of world-class antenna measurement facilities to support academic institutions and industry.

References

[1] D. E. Baker, "Evaluation and modification of the NIAST microwave anechoic chamber," in *Proc. SAIEE Joint Symp. AP and MTT*, Pretoria, South Africa, 18-21 August 1986, pp. 347-358.

On the earthing of a large telescopic crane

Pieter H. Pretorius

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Lightning damage to a GTK 1100 Telescopic Crane, whilst erecting a wind turbine at a wind farm in the Northern Cape, demanded an investigation into the earthing of the crane. The damage was caused by a 111 kA positive lightning stroke in 2017.

This paper reflects on the earthing requirements as outlined by the crane manufacturer [1] and that actually applied on site. In addition, the lightning performance of the earth electrode is discussed in context of IEC 62305-3 [2] that recommends "*a low earthing resistance (if possible lower than 10 Ω when measured at low frequency)"* to adequately protect against lightning.

The investigation showed that only for soil resistivities approaching 10 Ω.m (and lower), will the electrode resistance, for an electrode as recommended in the operator's manual, meet the required electrode resistance of 10 Ω or less. The soil resistivity at the location where the crane was operated was higher than 559 Ω.m and contributed to the inadequate earthing of the crane that led to the damage.

The paper reflects on the anticipated lightning ground potential rise that presented the conditions for the damage and concludes with recommendations for improved future earthing of the crane.

References

[1] GTK 1100-1, "Operating Instructions", Section 8.5.3.

[2] IEC 62305-3, "Protection Against Lightning, Part 3: Physical Damage to Structures and Life Hazard", 2010.

Detailed electromagnetic interference investigation for a large scale PV facility

Paul S. van der Merwe[1], Willie van der Merwe[2] and Pieter Pretorius[3]

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[2] juwi Renewable Energies (Pty) Ltd, 7 Walter Sisulu Ave, Foreshore, Cape Town, 8001, South Africa, willie.vandermerwe@juwi.co.za
[3] TERRATECH, PO Box 3395, Glenvista, 2058, Johannesburg, South Africa

EMI Emissions From PV Installation

South Africa's greater Karoo region located in the Northern Cape province has the highest direct normal irradiation levels in the country. This makes this area particularly attractive and suitable for the development of large-scale photovoltaic (PV) facilities. However, a considerable portion of this area has been declared as protected under the Astronomy Geographic Advantage (AGA) Act [1]. Under the act, the level of electromagnetic interference (EMI) that may be produced by any new development is subject to compliance to the South African Radio Astronomy Standard (SARAS). This paper describes the process and some of the detailed findings of a compliance investigation that was done for a fix-tilt large-scale PV installation. EMI from conventional electronics, which in most cases complying to commercial standards, were measured as part of a systematic identification process.

Emissions are characterised through both conducted and radiated measurements in time and frequency domains, and finally compared to ensure unique identification of peak levels. This allows the determination of continuous wave (CW) as well as short-duration time varying or transient emissions. The isolated-device identified EMI are used in propagation analysis for estimation of the device impact on both the closest and core-site SKA stations. The process involves the determination of total path-losses between the plant and the SKA telescopes using the Longley-Rice Irregular Terrrain as well as the new Irregular Terrain With Obstruction (ITWOM v3.0) model.

Radiation from the facility generally comes from the inverter station and in particular the electronics within the DC string combiner boxes where micro-controller boards and industrial hardened computers were used. The administration building was also highly contributing to the facility EMI and was dominating the radiated spectrum due to wireless access-points and Ethernet switches for IP-cameras networking. Broad and narrow-band features were measured.

References

[1] Astronomy Geographic Advantage Act, 2007, No. 21 of 2007, Government Gazette, Vol. 516, No. 31157, Cape Town, Republic of South Africa, 17 June 2008.

Development of a horn antenna array with shaped beamwidths

Monique Gerber, Bennie Jacobs and Johan du Toit

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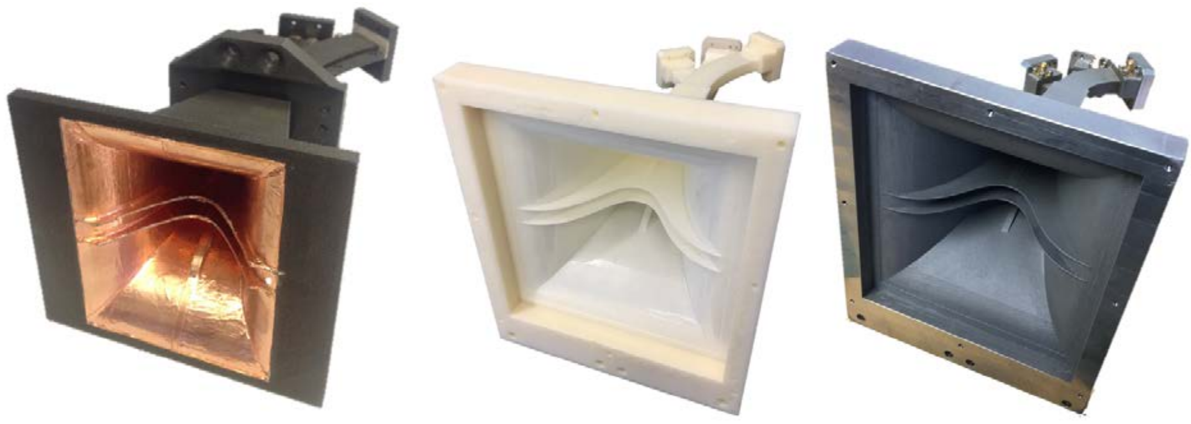
A vertically stacked three element horn antenna array was designed and manufactured. The array had the following requirements:

- Frequency range of 6-18 GHz with WRD 650 waveguide inputs
- Low VSWR
- Maximum gain
- Half power beamwidth in azimuth and elevation not less than 30°
- Slant 45° polarization or preferably Circularly Polarized (CP)

The most difficult requirement to achieve was the beamwidth requirement since the azimuth beamwidth can be controlled by optimizing the sidewall flare angle and shape, albeit with a reduction in gain. The elevation beamwidth is, however, dominated by the array factor. The minimum possible element spacing is around 0.9λ at 18 GHz based on the size of the input waveguides. With this spacing the elevation beamwidth would still be less than the requirement.

The initial design used three identical double ridged horn antennas stacked vertically with minimum spacing. Using FEKO the ridges and sidewalls were optimized for 30° beamwidth in azimuth. This design, however, resulted in overall poor gain especially at the low frequency end where the total aperture is very small. It was therefore concluded that it is not possible to simultaneously achieve the minimum gain requirement at 6 GHz and the maximum elevation beamwidth at 18 GHz with a conventional array of three identical horn antennas.



An unconventional design was thus investigated in which the top and bottom horns also flare in the E-plane, and the center horn is kept as narrow as possible. The photographs above show the prototypes made using Additive Manufacturing (AM) techniques. The presentation will go into detail regarding the process followed to obtain the final design, looking at the different solutions investigated, simulations, measurements as well as challenges encountered and addressed.

Developing antenna design concepts – a connected home multimedia device

Brian Woods[1], Marc Rütschlin[2] and Rodrigo Enjiu[2]

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[2]CST Computer Simulation Technology, Darmstadt, Germany
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Modern 'connected' or 'smart' devices exemplify extremely complex collections of systems – often packaged into impossibly confined spaces and marketed in highly competitive and demanding markets. Delivering a successful product in this market represents a remarkable achievement in which the ability to deal with concurrent complexity and technical risk in many disciplines as effectively as possible is crucial.

For the antenna engineer tasked with the design of antennas for connected devices, modern EM simulation tools provide an excellent platform for design analysis and comparison - but finding, exploring and evaluating candidate solutions remains a time-consuming and error-prone process. In this presentation we will discuss the development of antennas for such a Connected Home Multimedia Device.

Space science and instruments at NASA

Goutam Chattopadhyay

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NASA's Jet Propulsion Laboratory, which completed eighty years of its existence in 2016, builds instruments for NASA missions. Exploring the universe and our own planet Earth from space has been the mission of NASA. Robotics missions such as Voyager, which continues to go beyond our solar system, missions to Mars and other planets, exploring the stars and galaxies for astrophysics missions, exploring and answering the question, "are we alone in this universe?" has been the driving force for NASA scientists for more than six decades.

Fundamental science questions drive the selection of NASA missions. We develop instruments to make measurements that can answer those science questions. In this presentation, we will present an overview of the state of the art instruments that we are currently developing and layout the details of the science questions they will try to answer. Rapid progress in multiple fronts, such as commercial software for component and device modeling, low-loss circuits and interconnect technologies, cell phone technologies, and submicron scale lithographic techniques, is making it possible for us to design and develop smart, low-power yet very powerful instruments that can even fit-in a SmallSat or CubeSat. We will also discuss the challenges of the future generation instruments in addressing the needs for critical scientific applications.

The research described herein was carried out at the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA, under contract with National Aeronautics and Space Administration.

Goutam Chattopadhyay is a Senior Research Scientist at the NASA's Jet Propulsion Laboratory, California Institute of Technology, and a Visiting Associate at the Division of Physics, Mathematics, and Astronomy at the California Institute of Technology, Pasadena, USA. He received the Ph.D. degree in electrical engineering from the California Institute of Technology (Caltech), Pasadena, in 2000. He is a Fellow of IEEE (USA) and IETE (India) and an IEEE Distinguished Lecturer.

His research interests include microwave, millimeter-wave, and terahertz receiver systems and radars, and applications of nanotechnology at terahertz frequencies.

He has more than 300 publications in international journals and conferences and holds more than fifteen patents. He also received more than 35 NASA technical achievement and new technology invention awards. He received the Distinguished Alumni Award from the Indian Institute of Engineering Science and Technology (IIEST), India in 2017. He was the recipient of the best journal paper award in 2013 by IEEE Transactions on Terahertz Science and Technology, best paper award for antenna design and applications at the European Antennas and Propagation conference (EuCAP) in 2017, and IETE Prof. S. N. Mitra Memorial Award in 2014.

On the electro-magnetic design of the SKA mid-frequency array's reflector system and its feeds

Robert Lehmensiek

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The mid-frequency array of the Square Kilometre Array (SKA) radio telescope consists of shaped offset Gregorian reflector antennas each with a set of quasi-octave and wide-band single pixel feeds. The reflector system was optimised by an exhaustive search using realistic feeds [1].

In retrospect, one may ask the question, how close is the performance of this reflector system and its feeds design to the theoretical limit [2, 3]?

This is investigated using a parameterised feed, limited by the spatial constraints on the indexer at the focus of the reflector system, and a parameterised shaped reflector with similar dimensions.

References

[1] R. Lehmensiek, I. P. Theron and D. I. L. de Villiers, "Deriving an optimum mapping function for the SKA shaped offset Gregorian reflectors," *IEEE Trans. Antennas Propag.*, vol. 63, no. 11, pp. 4658-4666, Nov. 2015.

[2] R. Lehmensiek and D. I. L. de Villiers, "Aperture efficiency performance limits of the SKA reflector system," in *Proc. IEEE Int. Symp. AP & USNC/URSI Nat. Radio Sci. Meet.*, San Diego, CA, Jul. 2017, pp. 989-990.

[3] R. Lehmensiek and D. I. L. de Villiers, "On the performance limits of the SKA1-mid reflector system," in *32nd URSI General Assembly and Scientific Symposium (GASS)*, Montreal, QC, Canada, Aug. 2017.

EMI measurements for SKA1 Mid Dish qualification

George Smit[1], Braam Otto[1] and Isak Theron[2]

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[2] EMSS Antennas, Stellenbosch, South Africa
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A number of innovative measurements techniques had to be developed on the MeerKAT and Square Kilometer Array projects in order to demonstrate compliance to the stringent radio astronomy EMI requirements. The techniques and results are presented and include:

- An unique staged approach to quickly demonstrate radiated emissions compliance to the SARAS Spectral Line Threshold using a COTS Real Time Spectrum Analyzer in a reverberation chamber,
- The use of the device under test, a cryogenically cooled Low Noise Amplifier with waveguide antenna that is terminated in a cold load, as the measurement first stage to achieve ultra-sensitive measurements,
- New pulsed RFI investigative measurements on the components of a Dish.

The SARChI Chair in antenna systems for the SKA at Stellenbosch University

Dirk I. L. de Villiers

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Recently, Prof. David Davidson, who held the SARChI Chair in Electromagnetic Systems and EMI Mitigation for SKA, vacated the chair to take up a position in Australia. The author was appointed as the replacement, and the chair renamed to Chair in Antenna Systems for the SKA.

This talk presents an overview of the current and planned research activities within the framework of the research chair – as performed by a large group of academic staff and research students at Stellenbosch University. Given the current state of the SKA development – with the design of the first phase complete – the focus of the research will be on antenna technologies required for future expansion of the telescope. These mainly revolve around wideband reflector antenna feeds, as well as a variety of array antenna technologies.

Specific strategies include developing advanced analysis methods to accurately and quickly model the antenna structures of interest, as well as optimisation strategies specifically tailored to the sensitive receiving systems required in radio telescope applications. Here, collaboration with leading international research groups and astronomy specialists is important to define the realistic response features and design goals of interest.

In addition, continual monitoring of wideband RFI at the telescope site is of critical importance to the long term operational viability of the system. Therefore, continued research into the development of antenna systems for high performance RFI monitoring stations remains of critical interest.

Research on electromagnetic compatibility control for Square Kilometer Array

P. Gideon Wiid, Temwani-Joshua Phiri and Stanley O. Kuja

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The South African Square Kilometer Array (SKA SA) has been incorporated in the South African Radio Astronomy Observatory (SARAO). The MeerKAT telescope of 64 dishes has been constructed and commissioned to do science. The following stage is the SKA1-MID, which will incorporate roughly 130 more dishes in the Northern Karoo site. The site has been proclaimed a radio quiet zone to protect the spectrum in this area [1].

To ensure Electromagnetic Compatibility (EMC) compliance of the installation, conventional test methods are not sufficient. SARAO has adopted a risk-based EMC approach, together with extensive research on land-path-propagation-loss calculation methods, shielding evaluation studies and alternative test methods and instrumentation.

A risk-based approach aids in achieving a cost-effective mitigation plan, where a shield-everything-at -the-highest-level approach is extremely costly. The Karoo environment also allows effective land-path propagation loss, which can be utilised for additional attenuation on top of shielding of interference to the telescopes.

Our research considers alternative electromagnetic full-wave and asymptotic methods which can be used instead of telecommunication path-loss calculations, which do not allow for low height transmitters and short distance propagation [2].

To verify modeling, alternative time-domain instrumentation has already been developed [3]. It is also used together with omni-directional antennas developed at Stellenbosch University for full-time radio frequency interference (RFI) monitoring [4]. Additional high-gain directional antennas are being designed to aid in propagation measurements [5]. Novel unmanned aerial vehicle (UAV) based systems have also been developed to assist in topography and building shielding measurements and RFI heat-mapping, to verify propagation calculations [6].

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Recent MLFMM improvements in FEKO

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The MLFMM in FEKO [1] is continuously being extended and improved to obtain faster solution times using the minimum amount of memory. This paper describes automotive windscreen antenna analysis, requiring the hybridization of the MLFMM based on the surface equivalence principle (SEP), the finite element method (FEM) and windscreen antenna analysis. In addition, the parallel memory efficiency has been improved using MPI3 shared memory arrays for situations when multiple parallel processes run on multiple cores / CPUs of the same node which is part of a distributed memory cluster. The memory footprint on each cluster node is drastically reduced by avoiding data duplication, e.g. geometry, basis function setup, transfer function look-up tables, etc.

The SEP represents homogeneous dielectric regions by modeling their surfaces as mesh triangles applying there equivalent electric and magnetic currents. It is the preferred solution for low contrast homogeneous dielectrics. However, modern antenna modules with multiple dielectrics and fine geometry details will require a fine mesh leading to a dense near field matrix in the MLFMM for this block. For parallel runs, this highly inhomogeneous mesh will degrade the runtime and memory efficiency due to the "load imbalance". Another drawback of the SEP formulation is that the addition theorem used in the MLFMM will become unstable and diverge for high dielectric losses as the number of multipoles is increased.

The FEM, on the other hand, represents dielectric regions as tetrahedral volume elements where each element could have its own dielectric properties. For a hybrid FEM/MLFMM method, the MLFMM is only applied to the boundary elements of the FEM, significantly improving the efficiency of the MLFMM for cases with high levels of geometrical detail and for highly lossy dielectrics.

To combine their advantages, the MLFMM (for metallic parts and dielectrics with SEP) and FEM are now allowed in the same model during windscreen antenna analysis. Examples will be presented to illustrate the advantages of the different techniques, in terms of model complexity, convergence rate of the MLFMM iterative solution, runtime and memory efficiency.

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Efficient computational methods for large antenna array analysis

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This presentation describes computational methods developed at Stellenbosch University, for the efficient analysis of large antenna arrays. The methods involve accelerating the method of moments (MoM), by exploiting a priori knowledge of structural properties. This ongoing work, which is strongly motivated by the Square Kilometre Array project, spans the period from 2014 to the present.

Three approaches are discussed:

1. For identical, disjoint array elements: the solution of the global MoM matrix equation is reduced to solving for the current on each individual array element separately. This is achieved through an assumption of currents on other elements being scaled versions of that on the element under consideration, with assumed, known scaling factors [1]. When the applied excitation is changed, the whole solution must be repeated, as the solution matrices are dependent upon the specific, applied excitation.
2. For non-identical, disjoint array elements: the solution of the global MoM matrix is reduced to a much smaller one, through the use of macro basis functions. These basis functions are constructed dynamically, such that they are tailored to the specific, applied excitation [2]. This approach requires significantly fewer macro basis functions than conventional schemes based upon pre-calculated macro basis functions for general excitation configurations. It does however mean, that when the applied excitation is changed, the whole solution must be repeated.
3. For non-identical, disjoint array elements: the conventional scheme for constructing macro basis functions is revisited. Various alternatives are considered, with regards to larger sub-domains, a new interaction criterion and windowing of sub-solutions. It is found that the required number of macro basis functions needed for a given solution accuracy, can be significantly reduced [3]. Once the reduced global MoM matrix has been established and factorized, it can be re-used to quickly solve for different excitations.

The presentation concludes with aims for future work.

This work is funded in part, by the South African SKA Project (www.ska.ac.za).

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Gaussian process modelling of missile RCS magnitude responses involving off-axis angles of incidence

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Recently, an efficient technique was introduced for the modeling of monostatic radar cross section (RCS) magnitude responses against frequency of hand-held missiles over a wide band [1]. The technique relied on Gaussian process regression and resulted in significant computational savings compared to full-wave frequency-domain simulations using FEKO. RCS responses were limited to the case of on-axis incidence with the missiles viewed from the front.

In the present study, results will be shown demonstrating that the above modeling approach can be extended to good effect to the modeling of RCS magnitude against frequency when the angle of incidence is off-axis. Proposed guidelines for keeping the computational burden to a minimum by restricting the number of training data will be discussed.

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Student poster session

Beswick, Robey	*Stellenbosch University*	Development of MoM tools for MATLAB-based computational electromagnetics
Boning, Pieter	*Stellenbosch University*	Butler Matrix Multiple-Beam Beamforming Network
Burcher-Jones, Jordan	*Stellenbosch University*	Microwave Sterilization of Wet Media
Cerfonteyn, William	*Stellenbosch University*	Designing an antenna for a low-cost water vapour radiometer.
Chose, Matthews	*Stellenbosch University*	Development of a MoM solver for investigating fast antenna array analysis methods
Czech, Daniel	*University of Cape Town*	Time Domain Classification of Transient RFI
De Lange, Lydia	*Stellenbosch University*	Application of Machine Learning for Antenna Array Failure Analysis
Du Toit, Zainodean	*Stellenbosch University*	Ultra Wideband Sinuous Antenna
Gray, Christopher	*Stellenbosch University*	HF Antenna Array Characterisation Using a Multi-Copter Platform
Hunter, Edward	*University of Pretoria*	Millimeter-wave patch arrays with radial feed networks
Johnston, Michael	*Stellenbosch University*	Ultra-wide Balun Design for the Pyramidal Sinuous Antenna
Jordan, Darryn	*University of Cape Town*	MiloSAR: Design and First Results
Kahn, Bradley	*University of Cape Town*	Reconfigurable Computer Interaction for NeXtRAD's Timing Control Unit
Kenned, Raven	*Stellenbosch University*	Noise Optimization for Coupled Antenna Arrays
Klopper, Brandt	*Stellenbosch University*	Antenna Elements for Sparse-Regular Aperture Arrays
Kriel, Scott	*Stellenbosch University*	UAV Measurements of SKAAP Array
Kuja, Stanley	*Stellenbosch University*	Optimised Impulse Radiating Antenna for Time Domain Metrology
Lewis, Simon	*University of Cape Town*	Coherent Multistatic Radar Synchronisation Using a White Rabbit Network

Mokhupuki, Fahmi	*Stellenbosch University*	Surrogate Based Design of Wideband Antennas
Moyce, Shane	*Stellenbosch University*	Hardware requirements of interference suppressing GPS beam formers
Nel, Ben	*Stellenbosch University*	Multilevel Adaptive Cross Approximation Acceleration for Superconducting Circuit Analysis
Nel, Hendrik	*University of Pretoria*	OBIST system for 2.4GHz LNA in 350nm CMOS
Omollo, Nancy	*Stellenbosch University*	Shielding effectiveness evaluation of materials using a reverberation chamber
Phiri, Temwani Joshua	*Stellenbosch University*	Deterministic Topography Modelling and Single Port Antenna Characterisation
Prince, Peter	*University of Pretoria*	The Similarity of Radiation Patterns of a Dual-Band Phased Array
Rolfe, Devon	*Stellenbosch University*	Analysis and Optimisation of Sampling Phase Detectors in PLLs for low phase noise
Sewraj, Keshav	*Stellenbosch University*	Comparison of macro basis function sets for antenna array analysis with the MoM
Smale, Corey	*Stellenbosch University*	Thermal Analysis of a Dense Dipole Array for the SKA Mid-Frequency Aperture Array
Swart, Hein	*Stellenbosch University*	Wideband Axially Symmetric Power Combiners Based on Short Step Filters
Van der Merwe, Bernard	*Stellenbosch University*	Sterilisation of Dry Media through Microwave Radiation
Wilke, Cornelis	*Stellenbosch University*	Beam Shape Calibration for Multi-Beam Radio Astronomical Phased Arrays

Near-field capabilities for the compact antenna test range at the University of Pretoria

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Over the years, the compact antenna test range at the University of Pretoria has proven to be very useful for the evaluation of cellular base-station antennas. However, in terms of antenna size and low-end frequency, the compact range can easily be pushed beyond its limits. In [1] it has been shown how a near-field system can be introduced into the same anechoic chamber, thereby extending the capabilities of the facility significantly. As the authors already had previous experience with the development of a near-field range [2] and much of the available hardware and software could be reused, it was decided to develop a cylindrical near-field range that could be housed within the compact-range chamber. Some of the major challenges included the design and manufacture of a mobile 4.6 m linear scanner that can be carted into and out of the chamber, as well as a deployable wall with microwave absorber to suppress reflections from the compact-range reflector. An open-boundary quad-ridged horn is used as near-field probe. The fully-deployed system in Fig. 1 shows, from the left, the linear scanner (with probe), test antenna and absorber wall, respectively.

In order to verify the capabilities of the new system, the far-field radiation patterns of the 2.0 m base-station antenna in Fig. 1, housing low-band (698–960 MHz) and high-band (1710–2690 MHz) arrays, were measured in both the compact range and the near-field range. This antenna size pushes the boundaries of what can be measured in the compact range with reasonable accuracy. Elevation cuts at 960 MHz for one of the low-band polarisations are shown in Fig. 2, from which it can be seen that the agreement between the far-field (compact range) and near-field results is very encouraging.

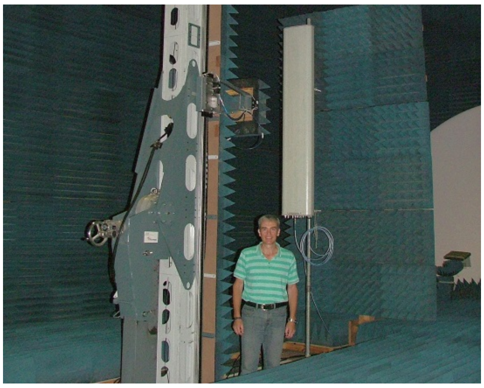

Fig. 1. Near-field range.

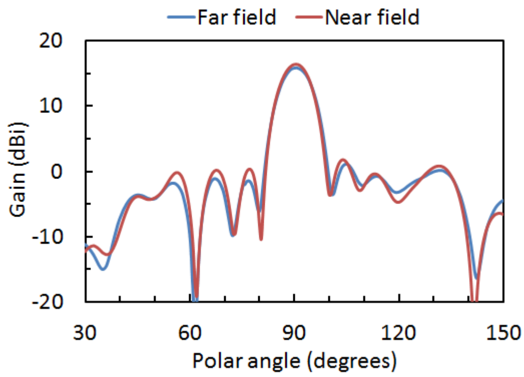

Fig. 2. Measurement results.

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Bistatic RCS measurements

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This presentation will give an overview of recent Bistatic Radar Cross Section (RCS) activities, viz. measurements, simulations and validations preformed at the University of Pretoria [1, 2]. Results comparing simulated bistatic RCS data with measured data for realistic scale models will be presented, to illustrate the performance of bistatic RCS measurements in the compact range.

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Recent progress and future challenges in high frequency oscillation-based testing

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Testing of electronic and microelectronic circuits typically requires the attachment of test equipment to the devices post-production, applying various test stimuli, and monitoring a series of outputs. An alternative to this is oscillation-based testing (OBT) [1]–[4] of the circuit, where an astable feedback loop is applied to the device under test (DUT) and the health of the device determined by monitoring the resulting oscillator's output frequency, as well as output voltage or power. This loop may be established using external testing equipment [1], [5], but if testing is to be applied during the DUT's operational life, this loop must be established in-system as oscillation-based built-in self-testing (OBIST) [3]. Despite the advantages of applying OBT and OBIST to high frequency circuits, very few examples have been published to date [3], [5], [6]. This may be due to the numerous challenges at applying OBT and OBIST at high frequency, which include frequency and power detection errors, lack of broadband characterization techniques, and the substantial impact of OBIST circuitry on the DUT's performance.

This talk presents the principles of OBT and OBIST, and describe notable examples of OBT and OBIST at microwave and mm-wave frequencies from recent literature. It further highlights significant shortcomings in the state-of-the-art, and describe possible approaches to addressing them in future.

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Phase noise analysis of multi-loop phase-locked loops with SPICE simulators

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Introduction

The manual phase noise analysis of multi-loop phase-locked loop can be quite tedious. Apart from calculating a large number of distinct gain functions describing the contributions from various sources of noise, careful track must be kept of correlated and uncorrelated noise that respectively sum like voltage or power.

Accurate phase noise analysis can be performed with Spice simulators that make provision for the thermal noise analysis of circuits, using an analogy where the radians^2/Hz phase noise power spectrum is represented by a volts^2/Hz power spectrum in Spice. In a phase-locked loop, loop phase is converted to voltage by the phase detector and back to phase by the voltage-controlled oscillator. The simulation must therefore harmonize the phase noise representation with the thermal noise voltages produced by resistors in the active loop filter circuit.

Phase Noise Spectrum, converting radians^2/Hz to dBc/Hz

The properties of a typical phase noise spectrum is introduced, with definitions of one-sided and two-sided and single sideband and double sideband spectra. The conversion from spectrum specifications to phase nose spectral density is derived with the aid of small-angle modulation theory. From this the limitations of the technique with respect to allowable observation time is also established.

Phase Noise Models

The creation of Spice phase noise models for oscillators (crystal references as well as voltage-controlled oscillators), phase-frequency detectors, dividers and other loop components from the data sheets of commercially available components, is illustrated with examples.

An example of a multi-loop PLL synthesizer is given, clearly showing how Spice automatically keeps track of correlated and uncorrelated noises. The integral of phase nose is also easily calculated.

Dynamic Performance

The Spice noise models also lend themselves to the dynamic analysis of phase-locked loops, with accurate determination of allowable frequency step size and ramp rates to prevent loss-of-lock.

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NeXtRAD: A multistatic radar testbed

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NeXtRAD is a three node, fully polarimetric, multistatic radar system operating in the X and L Bands. Its design was based on the highly successful NetRAD system that operated in S Band. Both radars are the product of the collaboration between UCT and University College London (UCL), as well as funding agencies.

NeXtRAD has a Command and Control (C&C) system that is integrated to a controller (laptop) at each node (Node Controller). One node is active, producing 1.6 kW at L band, and 450 W at X Band, with antennas with a nominal beamwidth of about 10 degrees in azimuth. The requirements for an experiment (pulse width, waveform, transmit frequencies, PRFs, etc.) are specified in a text file that is distributed together with and Ansible script to the nodes. Transmitted waveforms can be specified from definition files, and can be arbitrary.

Nodes are connected by WiFi (5.3 GHz) for C&C and data exchange. Voice and video communications are also provided, each node having a boresight TV camera. Inter-node distances of tens of km are possible, but for most target scenarios, 10 km and less is common. Each node has its own GPS Disciplined Oscillator, allowing the system to achieve of the order of 3 ns time synchronisation jitter in the common view situation.

Experiments are being carried out on sea clutter in Simon's Bay, using IMT as the active node site. Passive nodes are placed around Simon's Bay. A two-week trial, with participation of UCT, UCL and other agencies is planned for the first two weeks of December, 2018. A recent trial that focussed on measuring system performance with GPS and with White Rabbit to connect the nodes in a quasi bistatic mode was successful and data is being processed.

IMT will probably become the hosts of the facility, and with Eduroam being available, participation from research institutes and Universities is strongly encouraged. A database package has been developed that stores each experiment in a convenient HDF5 file. Future work in the areas of multistatic target signatures of clutter and targets, waveform diversity, comms/radar coexistence is strongly encouraged.

Acknowledgements

The author is grateful for the inputs of my colleagues Profs. Hugh Griffiths, Karl Woodbridge and William Miceli, Drs Palama, Ritchie, Fioranelli and Graham Inggs. The contributions of Stephan Sandenbergh, Craig Tong, Shirley Coetzee, Dane du Plessis, Simon Lewis, Pokai Cheng, Brad Khan, Darryn Jordan and numerous other contributors to NetRAD were critical to our success. Agency funding from the SANDF, NRF, ONR-G, Norwegian Defence Research, IET made it possible, as well as inputs from IMT, Simon's Town (Adrian Stevens and Lance Clayton).

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Dynamic spectrum access/5G and passive radar

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Dynamic Spectrum Access (DSA)/5G developments

The Council for Scientific and Industrial Research (CSIR) continues to work on the dynamic spectrum access and management technologies and support South African regulator, the Independent Communications Authority of South Africa (ICASA), to promote better use of radio frequency spectrum and introduction of novel communication technologies in South Africa [1]. The goal of this work is to lower costs and improve the reach and quality of communication services. The CSIR has:

- demonstrated the feasibility of using the television white space (TVWS) technology in African environments through several large experimental trials executed in collaboration with major international players such as Google and Microsoft, to provide Internet to over 20,000 users;
- developed a TVWS geolocation spectrum database able to apply the transmitter and receiver data to a propagation prediction engine, and to protection criteria, to estimate spectrum availability at a given location. It has been certified for commercial operation in UK by the UK regulator Ofcom, and is available in several African countries including South Africa;
- assisted with establishing a national TVWS regulation for South Africa and beyond.

Presently, the CSIR is working on moving the technology forwards, into 5G. This includes real-time updates and a smart spectrum manager. The talk will overview the developments, and discuss the role of DSA and TVWS in a 5G context.

Passive Radar developments

The CSIR expands the work on passive radar, with a goal of supporting the local passive radar industry, enabling new applications in air traffic management and control (ATM, ATC). Passive radar, also commonly called passive coherent location (PCL), uses a third party transmitter, and can detect non-cooperative targets whilst offering significant savings on the capital and running costs. The removal of the transmitter removes the need for spectrum licensing, reduces power consumption, and adds radio covertness, and portability, when compared to traditional primary surveillance radars. The lower costs can allow for much wider deployments, gap-filling and improved flight safety.

The technology for PCL became cost efficient only recently. The technology is yet to be accepted for commercial ATC applications. It is assumed that the main barrier to this acceptance is the lack of an established track record of performance under varying environmental and flight conditions. The CSIR is establishing a national PCL testbed to obtain such data collected over a long period of time.

The testbed currently has a central node and 6 radar nodes, with 1 more radar node to be operational by April 2019. The radar nodes survey the air traffic around O. R. Tambo airport and send the detections to the central node for storage, fusion and tracking. The talk will summarise details of the current system and results obtained.

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Electromagnetic environmental effects in the military

Kris Hatashita

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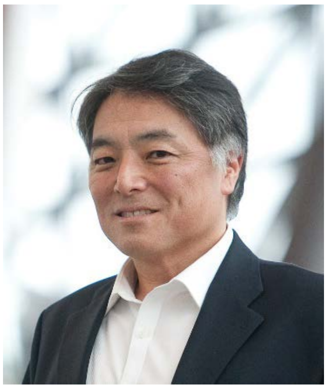
Military electromagnetic compatibility (EMC) is a matter of life and death as modern war-fighters rely on the safe, secure and reliable functioning of their devices. Military EMC includes aspects of electronic interoperability that are seldom or never considered in the commercial realm.

This talk presents technical details of EMC consideration in tactical and strategic military operations. The topics discussed include hazards of electromagnetic radiation to ordnance (HERO), electromagnetic data security (EMSEC), counter improvised explosive device (CIED) EMC issues and includes first-hand experiences of work done in the Afghan theatre.



Kris Hatashita studied physics at the University of Waterloo and has been an EMC professional for thirty years working for industry and government organizations as an EMC subject matter expert. His list of clients includes General Dynamics Canada, The Royal Canadian Mounted Police, Lockheed Martin Canada, The Canadian Parliament and The Communication Security Establishment Canada.

Kris was proclaimed to the IEEE EMC Society Board of Directors in 2014-2015 and was the General Chair of the EMC Symposium in Ottawa in 2016. He was re-elected to the IEEE EMC Society Board in 2017.

Currently, Kris is on the IEEE EMC Society Board of Directors and an IEEE Distinguished Lecturer. He is also a lecturer at the Canadian Forces School of Communication and Electronics at the Canadian Royal Military College in Kingston and a consultant to the Canadian Department of National Defence for the Army Communications Group.

Aspects of practical design for planar multilayer implementation of multiband filters

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This presentation reviews a procedure for fast design convergence for a multiband filter synthesis method [1]. Design choices such as filter topology, substrate loss and layer mapping are reviewed [2], [3].

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Ku-Band 3D-printed waveguide filters

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This paper will discuss the evaluation of a number of Ku-band 3D-printed waveguide filters and resonators which were designed and tested at Stellenbosch University. A wide range of post-printing surface treatments were applied, and the paper presents a detailed comparison of the various structures in terms of dimensional accuracy and electrical performance.

Communications systems of the EO-SAT1 satellite

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The RF communications systems design and EMC compliance programme for the SANSA contracted EO-SAT1 earth observation satellite is presented. The design is presented in line with our RF and EMC Control Plan and the Communication Links Management Plan as required by the System Engineering Management Plan (SEMP).

Topics discussed include:

- Communications systems design; Including:
  - Regulations and Standards applied: ITU-R, CCSDS, ECSS
  - Ground station network architecture: Primary GS at SANSA Hartebeesthoek
  - Using the popular Spaceteq Mission Control System at the ground stations
- Communications systems requirements
  - Two dual redundant command transceivers with omni-directional antennas
  - Dual redundant payload transmitters with body steered high gain antennas
- Telecommand and telemetry systems
  - 10 kbps uplinks
  - 10 to 100 kbps downlinks
  - Dual primary on VHF up- and UHF downlink; in-house development
  - Dual secondary on S-band ITU-R window up- and down; in-house development
- Payload downlink system
  - 110 Mbps Transmitter; in-house development
  - 8-PSK DVB-DSNG
  - X-band ITU-R window
- Communication link budgets
  - Tracks design progress throughout development
  - 3 dB link margins at 5° above horizon
  - 99% TT&C antenna coverage probability
- Antenna systems
  - VHF & UHF: Sumbandila heritage monopoles; tuned on-structure
  - S-Band: wide band PEC antennas; bought-in
  - X-Band high gain rigid horn; in-house development
- EMC compliance
  - Mil-STD-461-F and
  - ECSS-E-ST-20-07C
- Radio frequency license application
  - Spaceteq > SANSA > ICASA > ITU-R
- Conclusion
  - This summary of the EO-SAT1 communication system development records the post SumbandilaSat efforts towards an earth observation satellite for SANSA.

The RFX8000 combined receiver and synthesizer for 20 MHz to 6 GHz operations

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This presentation will detail the development of the RFX8000 receiver in 6U format. The receiver card also contains the synthesizer local oscillators required by the receiver. The design operates from 20 MHz to 6 GHz and has an 80 MHz staring bandwidth.

In direction finder applications, the receivers and the local oscillators used by the receivers are implemented on separate 6U form factor cards. The same local oscillator signals are used by all the receivers allowing a phase coherent receiver system to be constructed. The additional real estate offered by separate receiver and synthesizer cards allows for high performance implementations.

In jammers and interception receivers this approach comes with space penalties that is best avoided. These systems do not require phase coherent receivers, but rather multiple receiver cards with integrated synthesized local oscillators that can be used to increase the total system bandwidth and scanning speed.

The design challenge is how to integrate these two functions onto a single 6U form factor without compromising the performance of the design. The integrated design must still provide low levels of intermodulation distortion (high IM2 and IM3 intercept points), a low noise figure, acceptable phase noise and fast local oscillator tuning speed.

The presentation will explain why these performance figures are important and how they influence the real world performance of the receiver. The RFX8000 performance will be discussed.