2018 RFM

2018 IEEE International RF and Microwave Conference

17th to 19th December 2018

PARKROYAL HOTEL, PENANG, MALAYSIA

PROGRAM BOOK

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WELCOME MESSAGE

WELCOME TO 2018 IEEE INTERNATIONAL RF AND MICROWAVE CONFERENCE

'Selamat Datang'

The IEEE International RF and Microwave Conference returns to the north of Malaysia after taking place in Kuala Lumpur, Shah Alam, Seremban and Kuching from 2004 through 2015. The conference makes it return to Penang after last visiting this beautiful island five years ago.

As many long-time RFM attendees know, the symposium is one of the more successful series of IEEE conferences in Malaysia. RFM was initiated by IEEE Antennas and Propagation/Microwave Theory and Techniques/Electromagnetic Compatibility (AP/MTT/EMC) Joint Chapter of Malaysia in 2004. The conference has since then grown in popularity, and has become an important event in the calendar of the microwave fraternity in the region. RFM 2018 offers many opportunities to network with colleagues from various disciplines and provides an excellent platform to explore new ideas by teaming with new partners from many fields. The conference covers key areas related to microwaves and RF, including the evolving fields of materials, enabling technologies, device design, and applications of these technologies to cover the whole spectrum of life in the 21st century, including commercial, medical, aerospace and military. The research findings reported at the conference range from characterization of new materials, application of micro- and nanomaterial systems, to new ideas related to the Internet of Things, Industry 4.0, and the use of data in product design, fabrication, maintenance and system management.

This year, a total of 146 papers were received, and from these 113 were accepted. This represents an acceptance ratio of 77 %. Of the papers accepted, 82% are from the Asia Pacific region, 15% are from Europe/Middle East/Africa, and the remaining 2% are from US/Canada. The reviewing committee consisted of 241 reviewers from more than 30 countries. A total of 608 reviews were carried out, with the number of reviewers per paper averaging to 3. As in the past meetings, this year we are proud to bring several renowned speakers for the Keynote Session. They are: Prof. Tian-Hong Loh of the UK National Physical Laboratory who will deliver a talk titled 'Research Trends in Antennas and Testbeds for 5G and Beyond', Prof. Naoki Shinohara of Kyoto University ('Current Research and Development of Wireless Power Transfer via Radio Waves and the Application') and Dr. Mohanraj Soundara Pandian of SilTerra Malaysia Sdn. Bhd. (SilTerra's Monolithically Integrated RFMEMs Platform for Active Circuits and Passive Components').

In order to encourage more participation from the industry, and to add value to the conference, this year we introduced two new sessions namely the Industrial Session and Women in Microwaves. In the Industrial Session we have speakers from the industry who will present latest developments in wireless technology and state-of-the-art advances in test and measurement capabilities. The special session of Women in Microwaves is supported by MTT-S and co-organized by Women in Engineering Society. In addition to these, participants will also be able to enjoy product demos offered at some of the booths at the Exhibition. The industry have also shown tremendous support to our effort by sponsoring this event. For this I would like to take this opportunity to express our sincere gratitude to the sponsors Pico Technology, Anritsu, RF Station, Rohde & Schwarz, SilTerra and Altair. I should also mention the Penang Convention & Exhibition Bureau who have kindly provided assistance to us, both material and in kind.

Penang offers so much to the visitor – it is the nation's premier tourism state. Penang is the second smallest state in Malaysia but it has the highest population density in the country. It's capital Georgetown is the second largest city of the nation, and is also home to a UNESCO World Heritage Site. Known as the 'Pearl of the Orient', its culture is a reflection of the diverse cosmopolitan society which is unique to Malaysia – many of these are manifested in the varied architecture, cuisine and festivals offered by Penang. The island is connected to the mainland by two bridges – one of the bridge spans 24 km and is currently the longest bridge in South East Asia. Penang is also known as The Silicon Valley of the east owing to its high-technology manufacturing activities - it is home to several multi-nationals related to semiconductor and rf industries such as Intel, Motorola, Keysight Technologies, Bosch, Plexus and Mini Circuits. These economic and cultural factors are key to a successful meeting, and we hope that participants will have a fruitful conference, and enjoy their stay here.

I wish you an enjoyable and successful visit to Penang!

Zaiki Awang,
General Chair

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LIST OF EXHIBITORS:

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B1: RF Station Sdn. Bhd.

B2: Universities (Reserve)

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B4: Anritsu Pte. Ltd.

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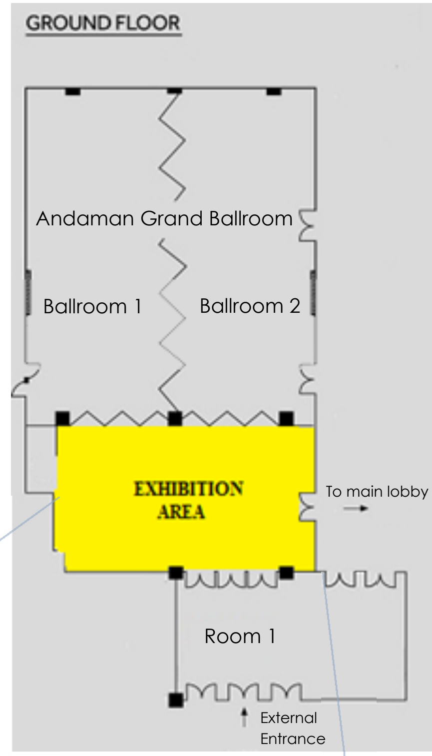
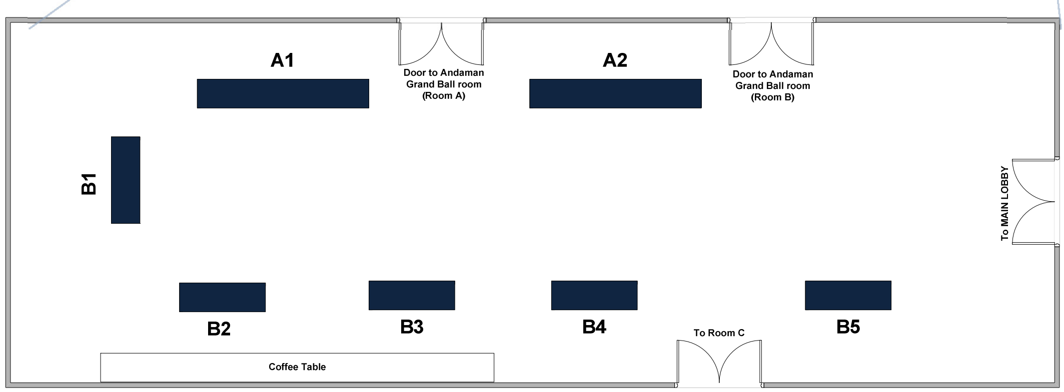


EXHIBITION LAYOUT:



TECHNICAL PROGRAM OVERVIEW

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<tr><th>Time</th><th>Ballroom 1</th><th>Ballroom 2</th><th>Room 1</th></tr>
<tr><td colspan="4">Monday, 17th December 2018</td></tr>
<tr><td>01:00 pm-02:00 pm</td><td colspan="3">REG1: Registration for Full Conference (In Front of Andaman Grand Ballroom)</td></tr>
<tr><td>02:00 pm-03:30 pm</td><td colspan="3">TT1: Tutorial 1 - Antenna Measurement Techniques and Their Limitations for 5G (Room 1)</td></tr>
<tr><td>03:30 pm-04:00 pm</td><td colspan="3">TB: Tea Break</td></tr>
<tr><td>04:00 pm-05:30 pm</td><td colspan="3">TT2: Tutorial 2 - An Overview of 5G Filtering - Challenges and Opportunities ((Room 1))</td></tr>
<tr><td colspan="4">Tuesday, 18th December 2018</td></tr>
<tr><td>08:00 am-09:00 am</td><td colspan="3">REG2: Registration for Normal Conference (In Front of Andaman Grand Ballroom)</td></tr>
<tr><td>09:00 am-09:20 am</td><td colspan="3">WM: Welcoming Address (Andaman Grand Ballroom)</td></tr>
<tr><td>09:20 am-10:20 am</td><td colspan="3">KEY1: Keynote 1 (Tian Hong Loh) - Research trends in antennas and testbeds for 5G and beyond (Andaman Grand Ballroom)</td></tr>
<tr><td>10:20 am-11:20 am</td><td colspan="3">KEY2: Keynote 2 (Mohan Raj Saundara Pandian) - SilTerra's monolithically Integrated RFMEMS platform for active circuits and passive components (Andaman Grand Ballroom)</td></tr>
<tr><td>11:20 am-12:20 pm</td><td colspan="3">KEY3: Keynote 3 (Naoki Shinohara) - Current Research and Development of Wireless Power Transfer via Radio Waves and the Application (Andaman Grand Ballroom)</td></tr>
<tr><td>12:30 pm-02:00 pm</td><td colspan="3">LB1: Lunch Break 1</td></tr>
<tr><td>02:00 pm-05:40 pm</td><td>A1: 5G / Millimeter wave Antenna and MIMO Technologies</td><td>B1: RF/Microwave/Terahertz Circuit and System</td><td>C1: Emerging Technologies and Applications</td></tr>
<tr><td>07:50 pm-10:30 pm</td><td colspan="3">DN: RFM 2018 DINNER</td></tr>
<tr><td colspan="4">Wednesday, 19th December 2018</td></tr>
<tr><td>08:00 am-01:00 pm</td><td rowspan="2">A2: Antenna and Advance Materials</td><td rowspan="2">B2: Measurement, Sensors & Electromagnetic Modeling</td><td>C2: Industry Special Session</td></tr>
<tr><td>10:20 am-01:00 pm</td><td>D2: Computational Methods for Radar Technologies and Satellite Applications</td></tr>
<tr><td>01:00 pm-02:00 pm</td><td colspan="3">LB2: Lunch Break 2 & Registration for WIM Special Session</td></tr>
<tr><td>02:00 pm-05:40 pm</td><td rowspan="2">A3: Low Profile and Antennas Arrays</td><td rowspan="2">B3: Antenna, Dielectric Resonators and Coupling Structures</td><td>C3: Women in Microwaves Special Session</td></tr>
<tr><td>04:00 pm-05:40 pm</td><td>D3: Passive Devices and Filter Design</td></tr>
<tr><td>05:40 pm-06:30 pm</td><td colspan="3">Event End</td></tr>
</table>

KEYNOTE SPEAKERS

Venue: Andaman Grand Ballroom
18th December 2018, 09:20 – 10:20

Keynote 1:

Tian Hong Loh

UK National Physical Laboratory, United Kingdom

Research Trends in Antennas and Testbeds for 5G and Beyond

Abstract: The next generation (5G) communications won't just deliver a much faster connection and higher data capacity. They also promise to deliver low energy consumption and seamless connectivity between billions of people and trillions of devices. The definition of 5G is in progress and it is anticipated that both sub-6GHz and millimetre wave (mm-wave) spectrum bands will be considered in support of significantly increased user density. Standards bodies and worldwide research communities are facing the challenge of diverse 5G technological requirements. A raft of new technologies have emerged in the arena of modern device, antenna and system design. The advancement in these areas enable new applications been constantly developed where complex performance are often required. Design, test and measurement methods to underpin all aspects from signals, devices to systems is essential as these ultimately affect the coverage and reliability of the network radio links. In particular, testing at mm-wave bands presents challenges over antenna and propagation characterisation due to their higher losses at these frequencies. The National Physical Laboratory (NPL) is the UK's National Measurement Institute and is a world leading centre of excellence in developing and applying the most accurate measurement standards, science and technology. This talk presents recent research trends in 5G antennas and testbeds and some highlights on NPL's capabilities on 5G and emerging wireless technologies developed under several UK and EU programmes. The topics to cover include 5G antenna designs, multiple-input-multiple-output over-the-air (MIMO-OTA), sub-6GHz & mm-wave MIMO/massive-MIMO testbeds, smart antenna & mm-wave hybrid beamforming phased array testbeds, etc. This talk will covers also an overview of NPL as well as research and development for electromagnetic technologies and measurement capabilities at NPL.

Biography: Tian Hong Loh received the PhD degree in engineering from the University of Warwick, UK in 2005. He has been with the UK National Physical Laboratory (NPL) since 2005 as a Higher Research Scientist (2005 – 2009) and Senior Research Scientist (2009 – 2017). He is currently a Principal Research Scientist at NPL. He leads work at NPL on a wide range of applied and computational electromagnetic metrology research areas to support the telecommunications industry. He has authored and co-authored over hundred refereed publications and holds five patents. His research interests include 5G communications, MIMO, smart antennas, small antennas, metamaterials, body-centric communications, WSN, EMC, and computational electromagnetics. He is currently visiting professor at Surrey University, visiting industrial fellow at Cambridge University, UK representative of URSI Commission A (Electromagnetic Metrology), project coordinator of an EU H2020 co-funded project on 'Metrology for 5G Communications', and senior member of the IEEE. He is an associate editor of IET Communications Journal and was the TPC chair of 2017 IEEE International Workshop on Electromagnetics. He also has acted on the session chair and technical programme committee for several international conferences, and as technical reviewer for several international journals on these subjects.

Venue: Andaman Grand Ballroom
18th December 2018, 10:20 – 11:20

Keynote 2:

Mohanraj Soundara Pandian

SilTerra Malaysia Sdn. Bhd., Malaysia

SilTerra's monolithically Integrated RFMEMS platform for active circuits and passive components

Abstract: The exponential increase in the number of wireless devices as well as the limited wireless spectrum, pose significant challenges in the design of future wireless communication systems. Adaptive and reconfigurable radios that can change their frequency and mode of operation based on the unused/available wireless spectrum have been proposed to address such challenges. Frequency Agile RF circuits play a key role in realization of such radios.

Biography: Mohan Raj is Deputy Director of MEMS & Sensors BU at SilTerra Malaysia Sdn. Bhd., he is responsible for MEMS foundry service and MEMS integrated solutions for the emerging markets using Radio-Frequency, Acoustic, Ultrasonic, Optical, and Bio-MEMS devices. He has 20 years of experience in the development of silicon-based process technologies for MEMS, TSV and Packaging. He started his career in 1998 as Process Engineer at SPEL Semiconductor Limited, India. In the year 2001 he moved to Singapore as an Engineering Associate for MEMS research, the focus was on process module and integration at A*STAR Institute of Microelectronics, Singapore. Prior to joining SilTerra Malaysia Sdn. Bhd., he was Senior Research Engineer and his areas of expertise include MEMS fabrication for Optical, Radio-Frequency & Bio-MEMS devices and TSV process modules. He has authored and co-authored more than 30 research publications in journals and conferences, 2 US Patents in the field of TSV, and Optical MEMS. Mohanraj received his Bachelors of Engineering (B.E) in Mechanical Engineering from Thiagarajar College of Engineering, Madurai, India. Master of Science (M.Sc) in Material Science and Engineering & Doctor of Philosophy (Ph.D.) in Mechanical Engineering-Applied Mechanics division from National University of Singapore, Singapore, respectively.

Venue: Andaman Grand Ballroom
18th December 2018, 11:20 – 12:20

Keynote 3:

Naoki Shinohara

Kyoto University, Japan

Current Research and Development of Wireless Power Transfer via Radio Waves and the Application

Abstract: Theory, technologies, applications, and current R&D status of the wireless power transfer (WPT) will be presented. The talk will cover both the far-field WPT via radio waves, especially beam-type and ubiquitous-type WPT, and energy harvesting from broadcasting waves. The research of the WPT was started from the far-field WPT via radio waves, in particular the microwaves in 1960s. In recent years this became a hot topic again due to the rapid growth of wireless devices. Theory and technologies of antenna and circuits will be presented in case of beam-type and ubiquitous-type WPT. The industrial applications and current R&D status of the WPT via radio waves will be also presented.

Biography: Naoki Shinohara **r**eceived the B.E. degree in electronic engineering, the M.E. and Ph.D (Eng.) degrees in electrical engineering from Kyoto University, Japan, in 1991, 1993 and 1996, respectively. He was a research associate in the Radio Atmospheric Science Center, Kyoto University from 1996. He was a research associate of the Radio Science Center for Space and Atmosphere, Kyoto University by recognizing the Radio Atmospheric Science Center from 2000, and there he was an associate professor since 2001. he was an associate professor in Research Institute for Sustainable Humanosphere, Kyoto University by recognizing the Radio Science Center for Space and Atmosphere since 2004. From 2010, he has been a professor in Research Institute for Sustainable Humanosphere, Kyoto University. He has been engaged in research on Solar Power Station/Satellite and Microwave Power Transmission system. He is IEEE MTT-S Technical Committee 26 (Wireless Power Transfer and Conversion) vice chair, IEEE MTT-S Kansai Chapter TPC member, IEEE Wireless Power Transfer Conference advisory committee member, URSI Commission D vice chair, international journal of Wireless Power Transfer (Cambridge Press) executive editor, technical committee member and 1st chair of IEICE Wireless Power Transfer, Japan Society of Electromagnetic Wave Energy Applications president, Space Solar Power Systems Society board member, Wireless Power Transfer Consortium for Practical Applications (WiPoT) chair, and Wireless Power Management Consortium (WPMc) chair.

Venue: Ballroom 1
19th December 2018, 16:00 – 16:20

Speaker 11:

Evizal Abdul Kadir
Universitas Islam Riau, Indonesia

Reconfigurable MIMO Antenna for Wireless Communication Based on Arduino Microcontroller

Wireless communication is common use on devices to send or exchange information such computer peripheral, mobile device, home appliances, etc. Every device embedded with wireless module and contribute electromagnetic, thus high possibility of occurring interference. One of method how to control interference is by controlling signal to transmit as well as power, thus in this research designed reconfigurable MIMO antenna to control antenna radiation pattern to reduce interference issue in wireless communication. The antenna designed in 2.4 GHz band because most and common use of devices peripheral using unlicensed band as well as for Wireless Fidelity (Wi-Fi). The designed antenna is 4×4 MIMO which operate at 2.4 and 2.6 GHz for Wireless Local Area Network (WLAN) and Long Term Evolution (LTE). The system radiation pattern is configured using an Arduino Microcontroller to driven PIN diode to switch he beam. Simulations and measurements are in good agreement with the configuration of the single antenna and 2×2 and 4×4 MIMO. The antenna is operational between 2.387 and 2.628 GHz, whereas the simulated and measured reflection coefficients are obtaining at least -24.3 dB. The MIMO antenna designed to improve data communication, especially in mobile communication systems.

Wednesday, December 19, 14:00 - 17:40
A3: Low Profile and Antennas Arrays
Venue: Ballroom 1
Chairs: Evizal Abdul Kadir (Universitas Islam Riau, Indonesia), Eng Hock Lim (Faculty of Engineering and Science, UTAR, Malaysia)

14:00 - 14:20	**Compact Z-Slotted Patch Antenna for UHF Metal-Mountable Tag (Invited)** Yaw Hua Niew, Eng Hock Lim, Kim Yee Lee and Fwee Leong Bong and Boon Kuan Chung (UTAR, Malaysia)
14:20 - 14:40	**Radiated Electromagnetic Bad Gap Antenna for ISM Band in Medical Application** Ida Maria Mohd Yusoff (Politeknik Sultan Salahuddin Abdul Aziz Shah, Malaysia); Norhana Mat Salleh (Universiti Teknologi MARA, Malaysia); Ahmad Azlan Ab Aziz (Politeknik Sultan Salahuddin Abdul Aziz Shah, Malaysia); Robiatun Adayiah Awang, Mohd Tarmizi Ali Ali (Universiti Teknologi Mara, Malaysia)
14:40 - 15:00	**Advances in Passive UHF RFID Tag Antenna Designs for Challenging Environment Surfaces** Jun Ouyang, Abubakar Sharif, and Yi Yan (University of Electronic Science and Technology of China, P.R. China)
15:00 - 15:20	**An Electrically Small Multiband Antenna for USB Dongle Antenna Application** Muhsin Ali (Comsats University, Abbottabad, Pakistan); Azremi Abdullah Al-Hadi (University Malaysia Perlis, Malaysia); Jalil Kazim (Comsats University, Abbottabad, Pakistan); Rizwan Khan (Universiti Malaysia Perlis, Malaysia); Owais Owais (CIIT, Pakistan); Ping Jack Soh (Universiti Malaysia Perlis (UNIMAP) & Katholieke Universiteit Leuven, Malaysia)
15:20 - 15:40	**Electronically Scanned Phased Array Antenna Design and Implementation** Hazem Banna (Higher Institute of Engineering and Technology, New Damietta, Egypt); Khaled Hassab-Allah and Ahmed Abd-Allatif (Akhbar Alyoum Academy, Egypt)

16:00 - 16:20	**Reconfigurable MIMO Antenna for Wireless Communication Based on Arduino Microcontroller (Invited)** Evizal Abdul Kadir (UIR, Indonesia); Sharul Kamal A. Rahim (UTM, Malaysia); Sri Listia Rosa (Universitas Islam Riau, Indonesia); Hitoshi Irie (Chiba University, Japan); Yudhi Arta (UIR, Indonesia)
16:20 - 16:40	**A Balanced Feed Triple Frequency Patch Loaded Printed Dipole Antenna for WiMAX/WLAN Applications** Sayan Sarkar, Amartya Banerjee and Bhaskar Gupta (Jadavpur University, India)
16:40 - 17:00	**Comparison Between 2 3D-Printed 2X2 Horn Antenna Arrays at 12.5GHz with Different Feeding Structures** Maha El Feshawy (German University in Cairo - Home, Egypt); Hany F Hammad (German University Cairo, Egypt)
17:00 - 17:20	**Multiple Bands of Antenna Design Based on Slits Configuration** Fwen Hoon Wee and Siti Zuraidah Ibrahim, Muzammil Jusoh (Universiti Malaysia Perlis, Malaysia); Been Seok Yew (Universiti Sultan Zainal Abidin & Faculty of Innovative Design and Technology (FRIT), Malaysia); Lee Yeng Seng (University Malaysia Perlis, Malaysia)
17:20 - 17:40	**Small-Size Modified Meander Line Antenna for Dual-Band (433.92MHz and 2.45GHz) Operation** Sung Woo Choi, Sheikh Faisal Ahmad, Ick Chang Choi, Hyun Deok Kim (Kyungpook National University, Korea)

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Ali, Mohd Tarmizi
Ali, Mohd Tarmizi Ali
Ali, Muhsin
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Amin Nordin, Muhammad
Amiri, Nasrin
Amiruddin, Mohd Fadzil
Ansarudin, Farizah
Ansarudin, Farizah
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Arai, Hiroyuki
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Asan, Noor Badariah
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Shafiq
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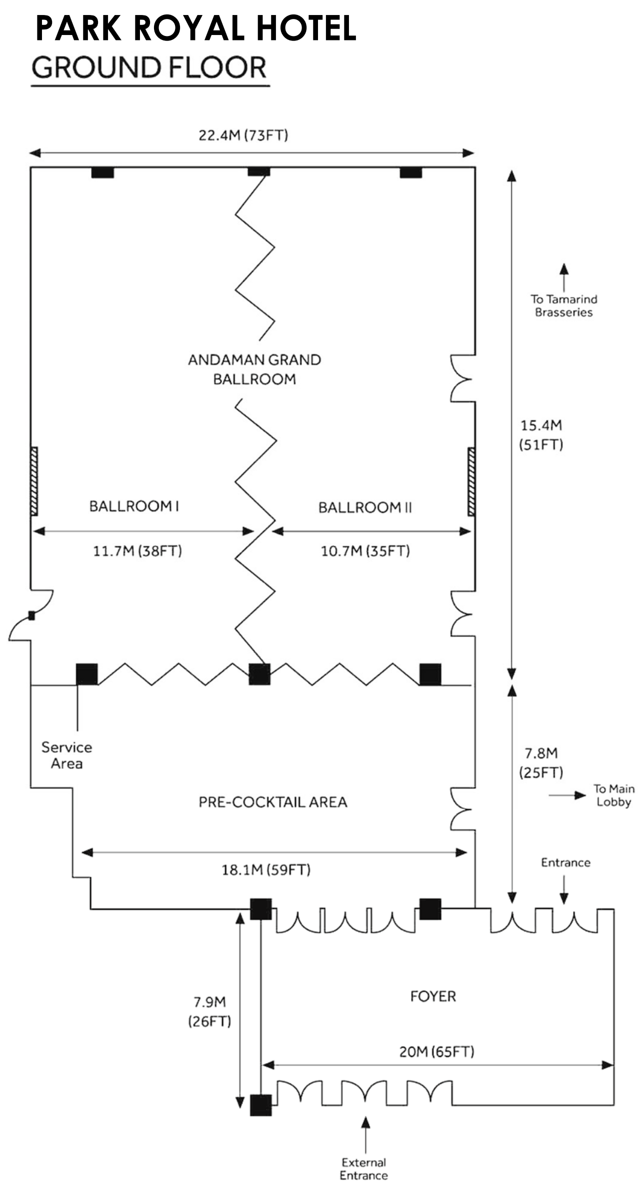
He, Songbai

FLOOR PLAN


PARK ROYAL HOTEL
GROUND FLOOR
22.4M (73FT)
To Tamarind Brasseries
ANDAMAN GRAND BALLROOM
15.4M (51FT)
BALLROOM I
BALLROOM II
11.7M (38FT)
10.7M (35FT)
Service Area
7.8M (25FT)
To Main Lobby
PRE-COCKTAIL AREA
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26 September 2018

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JI. Kaharuddin Nasution,
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Indonesia

Dear Dr Evizal ;

Invitation as an Invited Speaker to 2018 IEEE International RF and Microwave Conference (RFM 2018)

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An official confirmation letter will be sent to you once we have received your acceptance in return mail. We look forward to hearing from you soon.

Yours sincerely,

Prof. Zaiki Awang
General Chair
RFM2018

Reconfigurable MIMO Antenna for Wireless Communication Based on Arduino Microcontroller

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***Abstract* — Wireless communication is common use on devices to send or exchange information such computer peripheral, mobile device, home appliances, etc. Every device embedded with wireless module and contribute electromagnetic, thus high possibility of occurring interference. One of method how to control interference is by controlling signal to transmit as well as power, thus in this research designed reconfigurable MIMO antenna to control antenna radiation pattern to reduce interference issue in wireless communication. The antenna designed in 2.4 GHz band because most and common use of devices peripheral using unlicensed band as well as for Wireless Fidelity (Wi-Fi). The designed antenna is 4×4 MIMO which operate at 2.4 and 2.6 GHz for Wireless Local Area Network (WLAN) and Long Term Evolution (LTE). The system radiation pattern is configured using an Arduino Microcontroller to driven PIN diode to switch he beam. Simulations and measurements are in good agreement with the configuration of the single antenna and 2×2 and 4×4 MIMO. The antenna is operational between 2.387 and 2.628 GHz, whereas the simulated and measured reflection coefficients are obtaining at least -24.3 dB. The MIMO antenna designed to improve data communication, especially in mobile communication systems.**

Index Terms — Antenna, MIMO, Reconfigurable, Arduino Microcontroller, Wireless Communication

I. INTRODUCTION

The application of reconfigurable antenna for communication system very useful to suppressing interference issues that currently facing. Signal strength and data throughput can be further improved by implementing a reconfigurable system using MIMO antenna for Wireless Communication System (WCS) front end. A means for such improvement is dynamically changing the characteristics of antenna radiation. The change can be accomplished in line with the user's preferences, such as mobility, data usage, and method used to access WCS. Hence, the introduction of the MIMO antenna system based on a reconfigurable front end considerably enhances the data capacity and directivity of WCSs. Research on MIMO antenna based on frequency configurability for mobile devices has been conducted in [1]-[3]. Research on frequency re-configurability have been carried out to control or steer radiation patterns for MIMO antenna designs. Furthermore, in these proposed frequency configurations, the design is mostly for switching the antenna beam. MIMO antennas which are reconfigurable in terms of polarization and radiation are proposed in [4]-[6]. Designs, such as used slot, array, or butler matrix, are utilized to control radiation pattern and polarization. In these designs, only the receiver side controls the radiation of the antenna beam. References [7]-[8] present the use of dielectric resonators as MIMO antennas for LTE bands. However, the design covers a single frequency band at 700 MHz.

Proposes of reconfigurable MIMO antenna for a wireless transceiver system, the system is designed to operate at 2.4 and 2.6 GHz. A single element antenna can be configured to form a single 4 × 4 MIMO antenna, either as two 2 × 2 antennas or a single 4 × 4 array. The microstrip line on the reverse side of the patch layer is fed coaxially and fitted with PIN diodes to enable switching via a microcontroller module. To optimize space, an air gap is introduced between the ground and radiating elements to produce a high gain antenna. This technique can control the transmitter antenna radiation pattern for efficiency and reduce interference. Adaptive radiation pattern can be achieved by controlling the antenna configuration using either a 4×4 or two 2×2 MIMO antennas. Alternatively, single antenna that combines all elements can be used to obtain high gain with a narrow beam radiation pattern.

II. RECONFIGURABLE ANTENNA DESIGN

In the proposed design, individual antennas are cascaded to form the MIMO antenna system. The antenna is implemented using a low-cost FR-4 board with a relative permittivity of εr=4.7, h=1.6 mm (and height), tan δ =0.019 (loss tangent). The single element and 2×2 MIMO antenna are designed based on the procedures described in [9] and [10] which result in the optimized structure illustrated in Figure 1(a) presents the location of the radiating elements. Meanwhile, Figure 1(b) shows the bottom antenna layer comprising transmission lines. 6 PIN diodes are employed to connect or disconnect these lines by on/off the DC power for each PIN diode with a microcontroller unit.

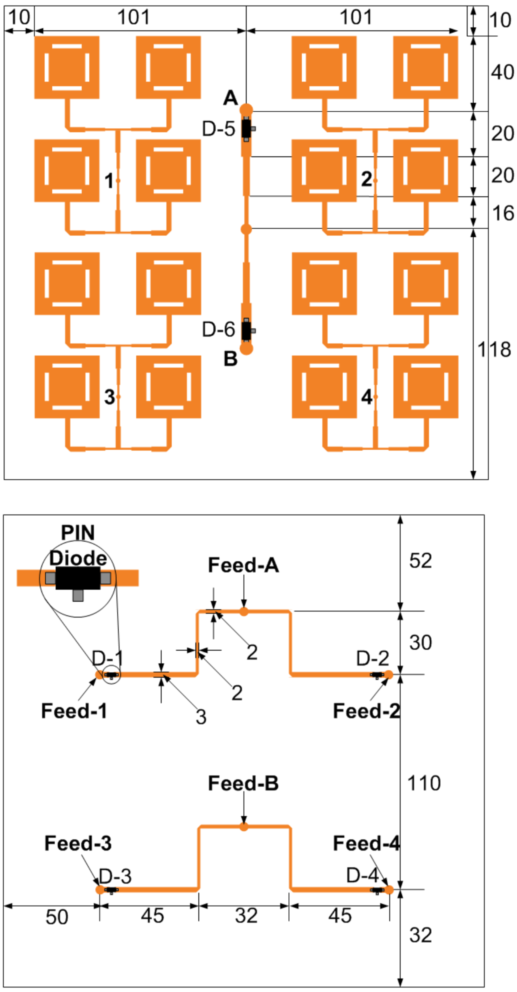


Fig. 1. Design of the 4×4 MIMO antenna (a) Top and (b) bottom views

The antenna elements are arranged and fed using a corporate feeding scheme. PIN diodes are used to connect the desired antenna feed to the main transmission line as shown in Figure 2. Each set element of the MIMO antenna has a transmission line that connects or disconnects other element. Figure 2 presents a side view of the proposed MIMO antenna system. An aluminum plane placed 10 mm from the FR4 layer is used as aground plane. The top layer consists of patch elements, whereas the bottom layer contains the transmission lines. SMA connectors are used to feed the MIMO antenna ports.

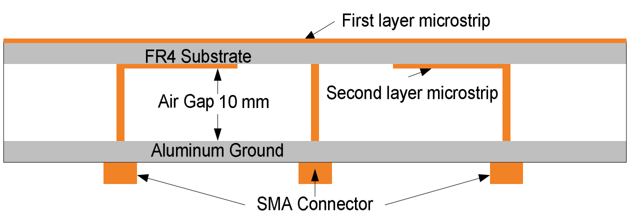


Fig. 2. Side view of the proposed antenna system

Arduino microcontroller were used for switching system of MIMO antenna, while radio transceiver received from user (client) signal, in this case Radio Signal Strength Indicator (RSSI) used as parameter to determine distance of user connected to base station. Once RSSI value received then analyze by controller to drive of antenna configuration. The MIMO antenna configurations currently only 2x2 or 4x4, else another configuration which is single antenna with fully high gain. Figure 3 shows a block diagram of MIMO antenna system connected to Arduino microcontroller to drive the PIN diodes.

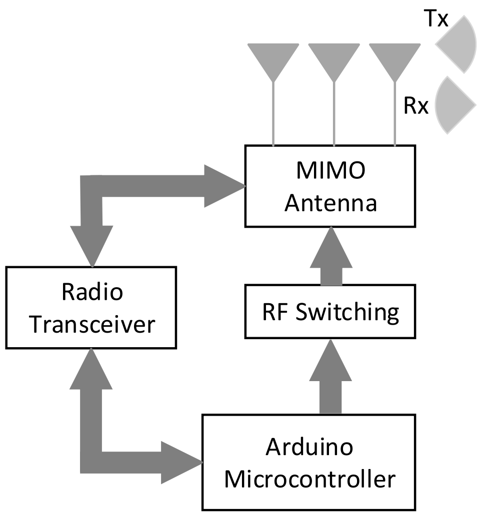


Fig. 3. Block diagram of microcontroller to drive MIMO antenna switching.

This designed antenna used PIN diode to switch the configuration of MIMO antenna, every port of the antenna connected to a diode to on/off the feeding line. Table 1 shows the operating of PIN diode to the antenna configuration, 6 sets of PIN diode used to cover all the 4x4 MIMO antenna:

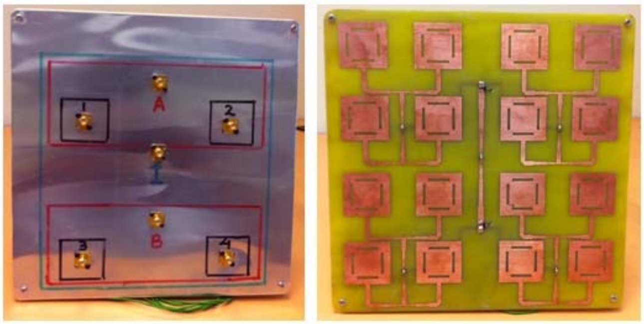
TABLE I

PIN DIODE SETTINGS FOR THE THREE ANTENNA CONFIGURATIONS

CONFIGURATION	DIODE					
	D-1	D-2	D-3	D-4	D-5	D-6
MIMO 4 × 4	Off	Off	Off	Off	Off	Off
MIMO 2× 2	On	On	On	On	Off	Off
Single Antenna	On	On	On	On	On	On

III. RESULTS AND DISCUSSION

The MIMO antenna system is fabricated and integrated with a microcontroller to enable reconfiguration, figure 4 shows the system prototype. Antenna performance is first evaluated using a vector network analyzer and radiation pattern measurement system in an anechoic chamber. To properly evaluate the antenna reflection coefficient, radiation pattern, and antenna gain, each port is evaluated individually, whereas the rest is terminated.



(a) (b)

Fig. 4. Prototype of the MIMO antenna system (a) Top and (b) bottom views

The single MIMO antenna evaluated indicated a satisfactory agreement between simulation and measurement. The measured reflection coefficient of this antenna indicated operation from 2.387 GHz to 2.628 GHz for WLAN and LTE bands (see Figure 5). Simulations produced a minimum S11 of -27.8 dB at 2.45 GHz, whereas an optimal S11 of-24.3 dB is measured at a slightly higher frequency of 2.5 GHz.

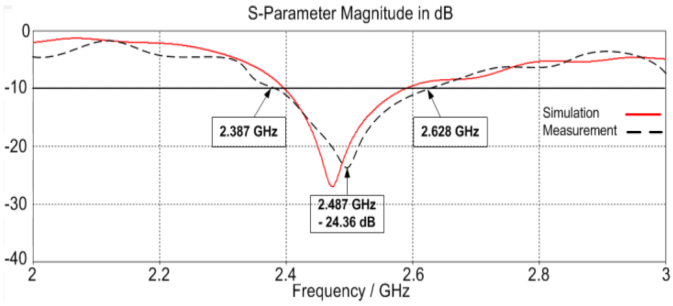


Fig.5. Simulated and measured reflection coefficients of the single MIMO antenna

Figure 6 assesses and summarizes isolation between the antenna ports, indicating a maximum isolation of approximately 15 dB.

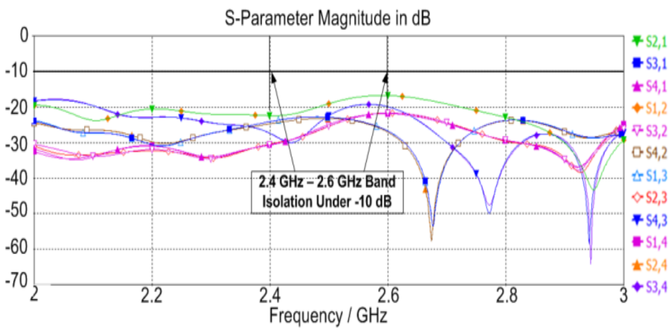
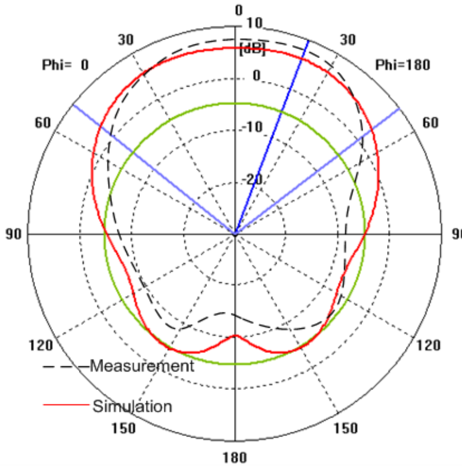
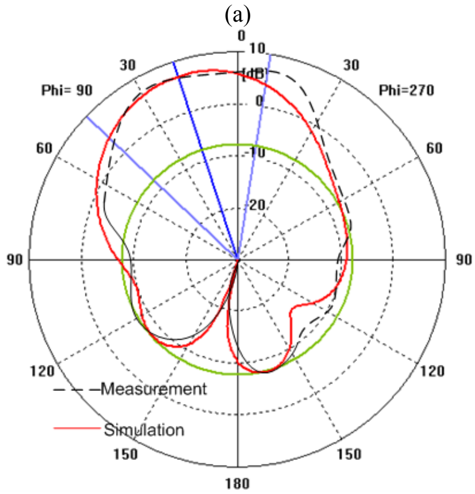


Fig.6. Isolation between different ports of the MIMO antenna

The radiation pattern of the first configuration using the 4×4 MIMO antenna is simulated and measured at 2.5 GHz, as shown in Figure 7, which indicates good agreement with both of results. A directional forward beam is generated for the E- and H-planes with minimal side lobes.



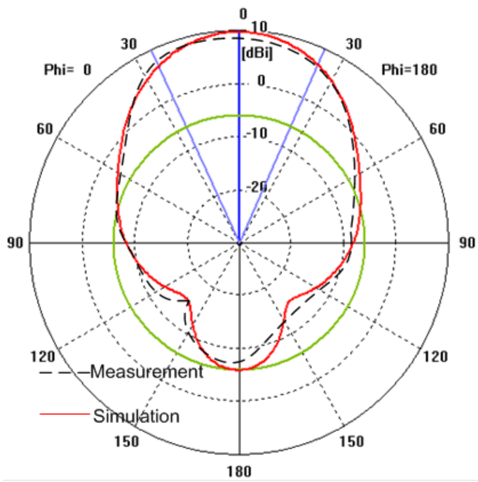
(a)



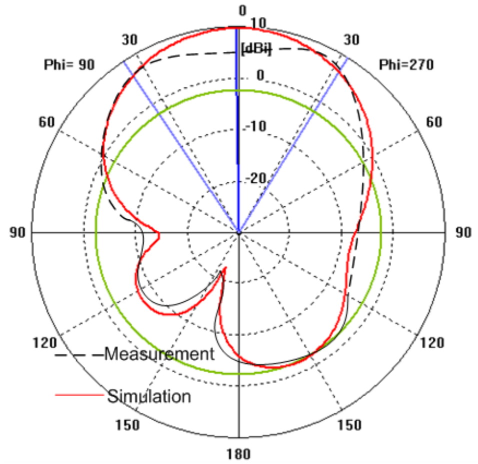
(b)

Fig.7. Radiation pattern of the 4x4 MIMO antenna
(a) E- and (b) H-fields

Similar to the previous structure, the radiation pattern of the 2×2 MIMO is evaluated separately at 2.5 GHz and summarized in Figure 8. Note that the same forward radiation is exhibited with a beam width narrower compared to that of the previous single antenna due to additional array elements. The simulated and measured results are in agreement with slightly minor lobe disagreements.



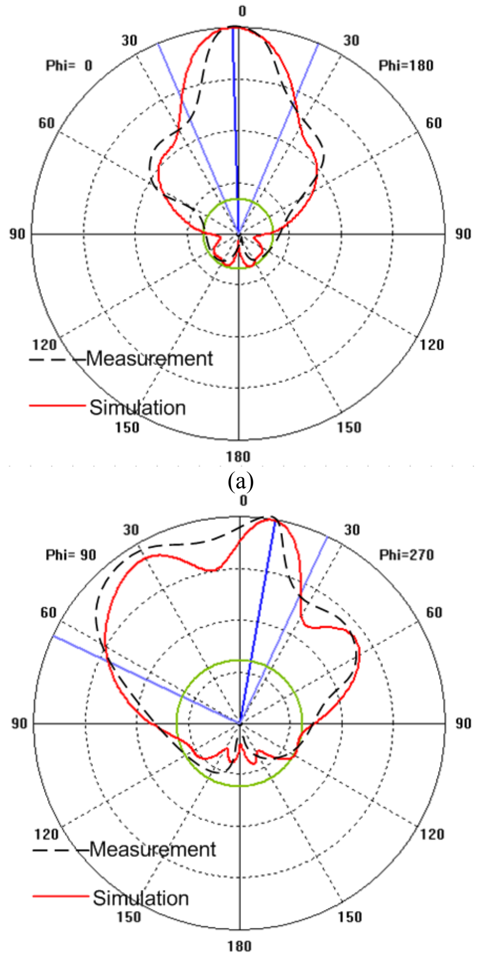
(a)



(b)

Fig.8. Radiation pattern of the dual 2x2 MIMO antenna (a) E- and (b) H-fields

The third antenna operating as a single, high gain 4 × 4 array is evaluated by activating all PIN diodes to enable each element's connection to the transmission line. The radiation pattern of this antenna is measured at 2.5 GHz, Figure 9 shows that the beam direction is narrower compared with that of the previous single and dual MIMO antennas.



(a)

(b)

Fig.9. Radiation pattern of single antenna (a) E- and (b) H-fields

IV. Conclusion

A reconfigurable MIMO antenna system for wireless communications with Arduino microcontroller designed which consisting of rectangular slotted microstrip antenna elements. They form an array antenna which can either be configured as a single, 2×2, or 4×4 MIMO antenna system. They can also be used as a conventional high gain directional array. Pattern configurability is achieved by switching the six PIN diodes in the microstrip transmission line. Measurements confirmed that the antenna is operational from 2.387 GHz to 2.628 GHz, which agree well with simulations with optimal reflection coefficients of -27.8 dB at 2.4 GHz and -24.3 dB at 2.6 GHz. MIMO antenna configurations produced narrow beam forward radiation patterns in E- and H-planes.

Acknowledgement

We would like to express our gratitude to the KEMENRISTEKDIKTI of Indonesia for fund this project as well as Universitas Islam Riau, Universiti Teknologi Malaysia, and Chiba University, Japan for give facilities.

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