



**Report on Electricity and Magnetism Metrology Activities at the National Metrology Centre (NMC), Singapore**  
For the 30<sup>th</sup> meeting of CCEM (2017)

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This report highlights key activities in the field of electricity and magnetism at the National Metrology Centre, Singapore, since the 29<sup>th</sup> meeting of the CCEM.

### **Electrical DC and Low Frequency Laboratory**

- *Resistance*

The laboratory is in the process of re-establishing the quantized Hall resistance (QHR) standard and cryogenic current comparator (CCC) resistance bridge to realize the unit of ohm. The CCC resistance bridge is based on NPL (UK)'s dual SQUID detectors design for both the current and voltage balance. Work is currently on evaluating the system performance and improving its immunity to interference from the surrounding. The laboratory will be optimising its resistance scaling arrangement based on the re-established reference resistance and to seek comparisons to validate the QHR system performance.

- *AC-DC Transfer and AC Quantities*

The laboratory has completed piloting the second loop of APMP key comparison of AC-DC current transfer standards (APMP-EM K12) using 10 mA PMJTC and 5 A coaxial current shunt. Draft A of the comparison report is currently in progress.

The laboratory is working with government agencies and industry to support energy efficiency related electrical measurements and knowledge transfer for green building energy efficiency measurement and verification and smart grid condition monitoring applications.

- *Electrical Characterisation of Devices and Materials*

The laboratory has set up measurement system for electrical characterisation of MEMS and semiconductor devices. The system is capable of performing DC parametric and high frequency spectrum impedance measurements. The measurement capabilities are available to semiconductor and electronics industry, as well as research institutes to cater their needs in precision small signal and impedance spectroscopy characterisation measurements for devices and materials from DC to 3 GHz. Work is currently on determining the residual parameters of capacitance standards to extrapolate the maintained 1 kHz reference capacitance values to high frequency to provide the traceability of measurement for the impedance spectroscopy measurement system.

The laboratory is also working on developing new measurement capability to support industry and research institutes on characterisation of electrical strength, dielectric permittivity, and loss angle of materials. The work is a follow up development of an NMC led A\*STAR collaboration aerospace project to develop high temperature dielectric material for encapsulating high voltage power semiconductor devices. The laboratory is to start another aerospace project on the medium voltage power distribution system on board airplanes.

The laboratory has established a new characterisation service to evaluate low energy high voltage impulses from conducted energy devices such as stun guns to support the government regulatory agency. Such devices are hazardous or fatal and are regulated under the national Firearm Act.

- *Proficiency Test*

A proficiency test (PT) on digital multimeter DC parameters was conducted as part of NMC's on-going Measurement Assurance Programme for the industry in 2016. The PT adopted DC parameters and test values of the APMP-EM-S8 Supplementary Comparison on DMM.

### **RF and Microwave Laboratory**

Under A\*STAR's Technology for Enterprise Capability Upgrading (T-UP) scheme that directly assists small and medium enterprise (SME) innovate and develop new capabilities and knowledge to increase their productivity and competitiveness, Dr Meng Yusong, Scientist from the RF and Microwave Laboratory was attached to a local SME company to help the development of a high speed portable network analyser. A measurement method using mixed-mode S-parameters was developed to achieve the metrological traceability to SI units and allowed the company to obtain an ETL certification with Level V accuracy specifications up to 1000 MHz. The attachment also helped the company to propose revisions to current cabling standard of Telecommunications Industry Association (TIA) such as measurement error models. The work also enabled the company to produce the first instrument in the world capable of certifying 40 Gbps Ethernet copper cabling systems.

### **Comparisons:**

- APMP-EM K12: APMP Key Comparison on AC-DC current transfer standards. In progress since February 2014. Measurement completed February 2016 (NMC Pilot Lab).
- APMP.EM-S12: Supplementary Comparison on Standards for DCV, ACV, DCI, ACI, R meters. Measurement completed September 2016.
- APMP.EM-K3: Key Comparison on 10 mH Inductance. Schedule to be confirmed.
- APMP.EM-S10: Supplementary Comparison on 100 mH. Schedule to be confirmed.
- APMP.EM-K1.1: Key Comparison on DC resistance; 1  $\Omega$  and 10 k $\Omega$ . Schedule to be confirmed.
- APMP.EM.RF-S5.CL: Characteristic Impedance of precision air-dielectric coaxial lines. Measurement completed February 2015.
- CIPM Key Comparison CCEM.RF- K26 Attenuation at 18 GHz, 26.5 GHz and 40 GHz using a step attenuator. Measurement completed March 2016.

### **Training Courses, Seminars and Talks**

<b>Date</b>	<b>Courses, Seminars and Talks</b>
3-4 Mar 2015	High Voltage Measurement and Testing Techniques
18 May and 28 Sep 2015	Power Measurement module for Measurement & Verification of Central Chilled-Water Plant Efficiency
8-9 Oct 2015	Estimation of Uncertainty in Electrical Measurement
25-26 Nov 2015	Measurement Using Data Logger
20-21 Jan 2016	Power Measurement for Energy Efficiency Monitoring

25-28 April 2016	Training in RF and Microwave Metrology (Measurement of power and signal parameters)
5-6 May 2016	Course on Digital Multimeters and their Calibration
10 May 2016	Basic RF Metrology: Fundamentals and Uncertainty
25 Jul and 1 Nov 2016	Course on Power Measurement module for Measurement & Verification of Central Chilled-Water Plant Efficiency
24 Aug 2016	Industry Talk on Calibration and Testing of Phasor Measurement Unit to meet IEEE standard
25 Aug 2016	Course on High Voltage Generation and Stun Device Tests
2 Sep 2016	Course on Uncertainty Evaluation in Electrical Measurement
20 Oct 2016	Course on Measurement Using Data Logger

### **Participation in International Meetings/Activities**

<b>Date</b>	<b>Event</b>
2-6 Feb 2015	Dr Jing Tao conducted peer review of NRC
9-13 Mar 2015	Dr Jing Tao attended CCEM and its working groups meetings
26-29 May 2015	Dr Meng Yusong attended 2015 Asia-Pacific International Symposium on Electromagnetic Compatibility
1-3 July 2015	Dr Meng Yusong attended 2015 IEEE 4th Asia-Pacific Conference on Antennas and Propagation
29 Oct 2015	Regional Workshop on Measurement Challenges in Renewable Energy and Climate Science (RECS)
1 Nov 2015	APMP Focus Group for Energy Efficiency (EEFG) meeting
2-3 Nov 2015	APMP TCEM meeting and Workshop
18 to 21 May 2016	Dr Meng Yusong attended 2016 Asia-Pacific International Symposium on Electromagnetic Compatibility
13 to 17 June 2016	Dr Meng Yusong attached to GE's Jack Welch Technology Centre in Bangalore, India
10 to 15 July 2016	Dr Meng Yusong attended 2016 Conference on Precision Electromagnetic Measurements (CPEM 2016)
10 July 2016	Dr Meng Yusong attended Informal Meeting of the APMP TCEM before CPEM2016
10 July 2016	Dr Meng Yusong attended CCEM Working Group of Regional Metrology Organisations (WG-RMO) before CPEM2016
14-15 Nov 2016	APMP TCEM meeting and Workshop
7-9 Dec 2016	Dr Shan Yueyan conducted peer review of NIMT on RF area

### **Conference Papers / Technical Publications**

Y. H. Lee and Y. S. Meng, Key considerations in the modeling of tropical maritime microwave attenuations, *International Journal of Antennas and Propagation*, vol. 2015, Article ID 246793, 7 pages, 2015.

Y. S. Meng and Y. Shan, Measurement and calibration of a high-sensitivity microwave power sensor with an attenuator, *Radioengineering*, vol. 23, no. 4, pp. 1055-1060, Dec. 2014

Y. H. Lee, F. Dong, and Y. S. Meng, Near sea-surface mobile radiowave propagation at 5 GHz: measurements and modeling, *Radioengineering*, vol. 23, no. 3, pp. 824-830, Sep. 2014

S. Cui and Y. S. Meng, Equivalent input noise measurement and its associated measurement uncertainties for MEMS microphones, *2015 XXI IMEKO World Congress "Measurement in Research and Industry"*, Prague, Czech Republic, Aug.-Sep. 2015

F. Yuan, Y. H. Lee, Y. S. Meng, and J. T. Ong, Detection of cloud vertical structure using water vapor pressure in tropical region, *2015 IEEE International Geoscience and Remote Sensing Symposium*, Milan, Italy, Jul. 2015.

- F. Yuan, Y. H. Lee, Y. S. Meng, and S. Winkler, Impact of cloud effective temperature on cloud attenuation in tropical region, *2015 IEEE 4th Asia-Pacific Conference on Antennas and Propagation (APCAP)*, Bali Island, Indonesia, Jun.-Jul. 2015, pp. 464-465
- A. C. Patel, Y. S. Meng, H. N. Pandya, and Y. Shan, Measurements of transverse conversion loss for evaluating EM immunity of twisted-pair cable, *2015 Asia-Pacific Symposium on Electromagnetic Compatibility (APEMC 2015)*, Taipei, Taiwan, May 2015, pp. 30-32
- Y. S. Meng, Y. Shan, H. Neo, Z. Liu, Z. Yuan, and Y. Guo, Experimental evaluation of writing process induced EMI/EMC in magnetic recording system, *2015 Asia-Pacific Symposium on Electromagnetic Compatibility (APEMC 2015)*, Taipei, Taiwan, May 2015, pp. 510-512.
- F. Yuan, Y. H. Lee, and Y. S. Meng, Comparison of cloud models for propagation studies in Ka-band satellite applications, *19th International Symposium on Antennas and Propagation*, Kaohsiung, Taiwan, Dec. 2014, pp. 383-384.
- X. Cui, Y. S. Meng, Y. Shan, W. Yuan, C. Ma, and Y. Li, Evaluation and validation of a national WR-15 (50 to 75 GHz) power measurement system, *2014 84th ARFTG Microwave Measurement Conference (ARFTG) Digest*, Boulder, CO, USA, Dec. 2014.
- F. Yuan, Y. H. Lee, Y. S. Meng, and J. T. Ong, Water vapor pressure model for cloud vertical structure detection in tropical region, *IEEE Transactions on Geoscience and Remote Sensing*, vol. 54, no. 10, pp. 5875-5883, Oct. 2016.
- X. Cui, Y. S. Meng, Y. Li, Y. Zhang, and Y. Shan, An improved design and simplified evaluation technique for waveguide microcalorimeter, *IEEE Transactions on Instrumentation and Measurement*, vol. 65, no. 6, pp. 1450-1455, June 2016.
- X. Cui, Y. S. Meng, Y. Shan, and Y. Li, Microwave power measurements: standards and transfer techniques, *New Trends and Developments in Metrology*, Chapter 1, pp. 3-20, InTech, DOI: 10.5772/60442, Jul. 2016
- X. Cui, W. Yuan, Y. Li, C. Jia, and Y. S. Meng, Development of a national WR-10 (75 to 110 GHz) microcalorimeter, *2016 URSI Asia-Pacific Radio Science Conference (URSI AP-RASC 2016)*, Seoul, South Korea, Aug. 2016, pp. 478-480.
- X. Cui, Y. S. Meng, R. Judaschke, J. Ruehaak, T. P. Crowley, and R. A. Ginley, International comparison of WR15 (50 to 75 GHz) power measurements among NIST, NIM, PTB and NMC, A\*STAR, *2016 Conference on Precision Electromagnetic Measurements (CPEM 2016) Digest*, Ottawa, Canada, July 2016.
- X. Cui, Y. S. Meng, Y. Li, W. Yuan, C. Ma, and Y. Shan, Comparative modeling of thermal isolation section in a rectangular waveguide microcalorimeter, *2016 Conference on Precision Electromagnetic Measurements (CPEM 2016) Digest*, Ottawa, Canada, July 2016.
- W. Yuan, X. Cui, Y. Li, C. Ma, and Y. S. Meng, Uncertainty analysis and evaluation of a WR-28 (26.5 to 40 GHz) millimeter-wave power standard, *2016 Conference on Precision Electromagnetic Measurements (CPEM 2016) Digest*, Ottawa, Canada, July 2016.
- Y. S. Meng, J. Luo, Y. Shan, and Y. Lu, Investigation of peak envelope power measurements and uncertainties, *2016 Conference on Precision Electromagnetic Measurements (CPEM 2016) Digest*, Ottawa, Canada, July 2016.
- Y. S. Meng, S. C. K. Ko, Y. Shan, A. Y. K. Yan, and H. Neo, Bilateral comparison of RF power measurements with 2.4 mm connectors between SCL and NMC, A\*STAR, *2016 Conference on Precision Electromagnetic Measurements (CPEM 2016) Digest*, Ottawa, Canada, July 2016.
- S. Manandhar, F. Yuan, Y. H. Lee, and Y. S. Meng, Weather radar to detect and differentiate clouds from rain events, *2016 USNC-URSI Radio Science Meeting (Joint with AP-S Symposium)*, Fajardo, Puerto Rico, Jun.-Jul. 2016, pp. 103-104.
- F. Yuan, Y. W. Lek, Y. H. Lee, and Y. S. Meng, Correlation between cloud optical thickness and solar radiation, *2016 USNC-URSI Radio Science Meeting (Joint with AP-S Symposium)*, Fajardo, Puerto Rico, Jun.-Jul. 2016, pp. 105-106.
- F. Yuan, Y. H. Lee, and Y. S. Meng, Investigation of cloud attenuation on Ka-band satellite beacon signal in tropical region, *2016 IEEE International Symposium on Antennas and Propagation*, Fajardo, Puerto Rico, Jun.-Jul. 2016, pp. 1255-1256.
- Y. S. Meng, J. Luo, Y. Lu, Y. Shan and Y. H. Lee, Peak envelope power measurements for mobile communications: A preliminary study, *2016 Asia-Pacific International Symposium on Electromagnetic Compatibility (APEMC 2016)*, Shenzhen, China, May 2016, pp. 363-365.