



Report on Electricity and Magnetism Metrology Activities at the National Metrology Centre (NMC), A*STAR, Singapore

For the 29th Meeting of the CCEM

Contacts:

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This report summarized key activities in the field of electricity and magnetism at the National Metrology Centre, Singapore, since the 28th meeting of the CCEM.

Electrical Laboratory

- *Peer Reviews*

The Laboratory has completed peer reviews for the DC and low frequency areas led by Singapore Accreditation Council (SAC) for compliance to the CIPM MRA implementation requirements:

Areas	Assessors	Date
DC and Impedance Quantities	Dr. Tae-Kyu <u>Kim</u> (KRIS, Korea) Mr. Kolin <u>Low</u> (SAC Lead Assessor)	12-14 Nov 2014
AC Quantities	Dr. ZHANG Jiangtao (NIM, China) Mr. Jason <u>Tan</u> (SAC Lead Assessor)	26-28 Nov 2014
High Voltage Quantities	Dr. Yi <u>Li</u> (NMIA) Mr. Kolin <u>Low</u> (SAC Lead Assessor)	1-2 Dec 2014

- *DC Voltage*

The Laboratory is working on improving the low voltage measurement stability of Josephson voltage systems for calibration of low voltage meters. Investigation on the sources of interference is currently being carried out to locate the cause of the instability.

- *Resistance and Impedance*

The Laboratory will be replacing the ageing quantized Hall resistance (QHR) standard system and CCC resistance bridge. New system is expected to be established in 2015 and the Laboratory will be seeking resistance and QHR on-site comparisons to validate the system performance.

Work has been initiated to extend the frequency range of impedance standards to provide traceability of measurement for a capability building project on electrical characterization of MEMS/NEMS devices, which requires traceable high frequency impedance measurements up to 200 MHz.

- *AC-DC Transfer and Power*

The Laboratory has completed piloting of the first loop of the APMP key comparison of AC/DC current transfer standards (APMP-EM k12) and is working on second loop of the comparison scheduled to start in March 2015.

New capabilities and services are under development to support the calibration and measurement needs from government and industry's energy efficiency measurement and verification requirements from green building and utilities sectors.

- *Electrical Characterisation of Devices and Materials*

The Laboratory is in the process of developing capabilities in electrical characterisation of MEMS/NEMS devices from DC to 3 GHz. Measurement systems capable of conducting DC parametric, high frequency impedance, network and spectrum measurements will be established to support the semiconductor and electronics industry, and research institutes' needs in precision small signal characterisation measurements.

The Laboratory is leading an A*STAR research institutes collaboration project team on high temperature dielectric material for encapsulating high voltage power semiconductor devices for aerospace applications. The Laboratory developed measurement and testing methods and setup to evaluate and verify the performance of the newly developed

dielectric material. Laboratory has also completed a project on evaluation of charging characteristics of non-conductive materials for use in marine off-shore platforms environment where discharges could act as an ignition source for an explosive gas/air or vapour/air mixture.

RF and Microwave Laboratory

- The Laboratory has completed a A*STAR Science and Engineering Council funded project to establish millimeter and submillimeter wave measurement systems and standards for microwave power, scattering parameters, and attenuation for frequency range up to 500 GHz.
- The Laboratory has developed attenuation measurement systems using the audio frequency substitution method. The newly developed attenuation measurement system covering frequency range from 40 GHz to 500 GHz.
- The Laboratory has developed a series of power sensor calibration systems for coaxial connections from 100 kHz to 50 GHz and rectangular waveguide WR15 and WR10 from 50 GHz to 110 GHz to provide traceable calibration services with low measurement uncertainties.
- Scattering parameters measurement systems using vector network analysers for coaxial connections at frequency from 5 Hz to 110 GHz, and waveguide connections at frequency from 50 GHz to 110 GHz have been established and measurement service is now available to the industry. The Laboratory has participated in a National Physical Laboratory coordinated international comparison in 3.5mm microwave airline measurement with phase. The Laboratory has piloted a bilateral comparison with INRIM for scattering parameters with high frequency waveguide connections, WR15 and WR10.
- The Laboratory has completed a preliminary bilateral comparison of Diameter Measurements of Precision Coaxial Air Lines for Scattering Parameter Measurement Traceability with KRISS.
- The Laboratory has completed a bilateral comparison on RF-DC voltage standard between NMC and NRC for frequency up to 1 GHz.
- The Laboratory has initiated various measurement technology and standards related projects with the industry including the metrological development and assurance of portable vector network analyser for testing of high-speed network cabling, the measurement of nano-material shielding effectiveness, and the experimental evaluation of meteorological influence (e.g., rain and cloud) on Ka-band satellite signal propagation and attenuation in tropical region.

Key and Supplementary Comparisons

- APMP-EM K12: APMP Key Comparison on AC-DC current transfer standards. Completed Loop 1 in November 2014. Second loop to start in March 2014
- APMP-EM-S8: Supplementary Comparison on DMM. Completed measurement in November 2014.
- APMP-EM-S12: Supplementary Comparison on Standards for DCV, ACV, DCI, ACI, R meters. Scheduled to start in 2015.
- APMP-EM-RF-K8-CL: APMP Key Comparison "Power in 50 Ω coaxial line, frequency: 10 MHz to 18 GHz" piloted by NMIJ. Completed measurement in 2013.
- CCEM-RF-K5c-CL: CCEM Key Comparison of Reflection coefficient /S parameters in PC-3.5mm connector, piloted by NMIJ. Completed measurement in 2013
- APMP-EM-RF-S5-CL: Characteristic impedance of precision air-dielectric coaxial lines 7 mm, 2.4 mm 1.85 mm all in 2 different lengths, piloted by NMIJ. Completed measurement in 2014
- 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

Proficiency Test

Proficiency tests (PT) on digital multimeter parameters based on APMP-EM-S8 and microwave power have been conducted by as part of NMC's Measurement Assurance Programme for the industry as well as supporting the Singapore accreditation scheme.

Publications

- [1] "Measurement uncertainty of complex-valued microwave quantities", Y. S. Meng and Y. Shan, Progress In Electromagnetics Research, Vol. 136, pp.421-433, 2013, (Journal).
- [2] "Direct comparison transfer of microwave power sensor calibration with an adapter: modeling and evaluation", Q. Zhang , Y. S. Meng, Y. Shan and Z. Lin, Progress In Electromagnetics Research Letters, Vol. 38, pp. 25-34, 2013, (Journal).
- [3] "Comparative evaluation of uncertainty transformation for measuring complex-valued quantities", Y. S. Meng and Y. Shan, Progress In Electromagnetics Research Letters, Vol. 39, pp. 141-149, 2013, (Journal).
- [4] "Choose the right instrument for M&V measurements", S. W. Chua, BCA-IFMA FM conference on Improving Productivity and Sustainability in Facilities Management, (Conference).
- [5] "Generic model and case studies of microwave power sensor calibration using direct comparison transfer", Y. Shan, Y. S. Meng, and Z. Lin, IEEE Transactions on Instrumentation and Measurement, Vol.62, No. 6, pp.1834-1839, June 2013, (Journal).
- [6] "Stand-off distances for non-line-of-sight maritime mobile applications in 5 GHz band", Y. H. Lee, F. Dong, and Y. S. Meng, Progress In Electromagnetics Research B, Vol. 54, pp. 321-336, 2013, (Journal).
- [7] "EMI shielding effectiveness of CNTS composites", P. Li, A. S. Low, Y. Shan, G. Ong, and X. Yin, International Conference on Process Equipment, Mechatronics Engineering and Material Science (PEME 2013) Wuhan , China, June 2013, (Conference)
- [8] "Carbon nanotube composites for electromagnetic radiation protection", P. Li, Y. Shan, J. Lin, A. S. Low, X. Yin, G. C. Ong, 7th International Conference on Materials for Advanced Technologies (ICMAT2013), Symposium W: Advanced Structural and Functional Materials for Protection, 30 June to 5 July, 2013, Singapore, (Conference).
- [9] "Impact of sapling movements on VHF and UHF radio-wave propagations", Y. H. Lee and Y. S. Meng, IEEE International Symposium on Antennas and Propagation and USNC-URSI National Radio Science Meeting, Orlando, Florida, USA, Jul. 2013, (Conference).
- [10] "Evaluation of a Calorimetric Thermal Voltage Converter for RF-DC Difference Up to 1 GHz", Yueyan SHAN, Yu Song MENG, and Piotr S. Filipski IEEE transactions on Instrumentation and Measurement, VOL.63, NO.2, pp.. 467-472, Feb 2014, (Journal).
- [11] "Comparison of S-Parameter measurements at millimeter wavelengths between INRIM and NMC", Marco Sellone, Luca OBERTO, Yueyan SHAN, Yu Song MENG, Luciano Brunetti, and Noshewan Shoaib, IEEE Transactions On Instrumentation And Measurement, Vol. 63, No. 7, July 2014, pp.1810-1817, (Journal).
- [12] "Microwave Power Sensor Calibration Using Direct Comparison Technique with Different Adaptors", Tie Qiu, Zhiping Lin, Yueyan Shan, Yu Song Meng, IEEE Ninth International Conference on Intelligent Sensors, Sensor Networks and Information Processing (IEEE ISSNIP2014), 21-24 Apr 2014, Singapore, (Conference).
- [13] "Comparison of radio-sounding profiles for cloud attenuation analysis in the tropical region", Feng Yuan, Yee Hui Lee and Yu Song Meng, IEEE International Symposium on Antennas and Propagation and USNC-URSI National Radio Science Meeting, Memphis, Tennessee, USA, July 2014, (Conference).
- [14] "Cloud attenuation on Ka-band satellite link in the tropical region: preliminary results and analysis", Yee Hui Lee, Vidhya Natarajan, Yu Song Meng, Jun Xiang Yeo, and Jin Teong Ong, IEEE International Symposium on Antennas and Propagation and USNC-URSI National Radio Science Meeting, Memphis, Tennessee, USA, July 2014, (Conference).
- [15] "Error Model for Insertion Loss Measurement in Testing of Balanced Twisted-Pair Cabling: A Complete Expression and Its Simplification", Yu Song Meng, Arvind C Patel, Yueyan Shan, and Harshang N Pandya, XXXIst URSI General Assembly and Scientific Symposium (31st URSI GASS) and workshops, 16-23 Aug 2014, Beijing, China, (Conference).
- [16] "Performance Evaluation of a Handheld Network Analyzer for Testing of Balanced Twisted-Pair Copper Cabling", Yu Song Meng, Arvind C Patel, Yueyan Shan, Harshang N Pandya, and Youbo Wang, Conference on Precision Electromagnetic Measurements (CPEM2014), 24-29 Aug, 2014, Rio De Janeiro, Brazil, (Conference).
- [17] "Phase Comparison between NMC and INRIM on Scattering Parameter Measurements with WR15 and WR10 Connections", M. Sellone, N. Shoaib, L. Oberto, L. Brunetti, Yueyan Shan and Yu Song Meng, Conference on Precision Electromagnetic Measurements (CPEM2014), 24-29 Aug, 2014, Rio De Janeiro, Brazil, (Conference).

- [18] "Linearity Analysis of a Calorimetric Thermal Voltage Converter for RF–DC Transfer Difference Up to 1 GHz", Yueyan Shan, Yu Song Meng, and Piotr S. Filipski, Conference on Precision Electromagnetic Measurements (CPEM2014), 24-29 Aug, 2014, Rio De Janeiro, Brazil, (Conference).
- [19] "Practical Evaluation of Phase Uncertainty in Scattering Parameter Measurements", Yu Song Meng and Yueyan Shan, Conference on Precision Electromagnetic Measurements (CPEM2014), 24-29 Aug, 2014, Rio De Janeiro, Brazil, (Conference).
- [20] "Evaluation of Coaxial Air-Lines as Impedance Standards at NMC, A*STAR", Yu Song Meng, Yueyan Shan, and Jin-Seob Kang, Conference on Precision Electromagnetic Measurements (CPEM2014), 24-29 Aug, 2014, Rio De Janeiro, Brazil, (Conference).
- [21] "Interpolating AC-DC Transfer Differences for an AC-DC Voltage Transfer Standard", Jing Tao, Justin Sim, Conference on Precision Electromagnetic Measurements (CPEM), 24-29 August 2014, Rio De Janeiro, Brazil, (Conference).
- [22] "Evaluation and validation of a national WR-15 (50 to 75 GHz) power measurement system, X. Cui, Y. S. Meng, Y. Shan, W. Yuan, C. Ma, and Y. Li, 84th ARFTG Microwave Measurement Conference (ARFTG), Boulder, CO, USA, Dec. 2014, (Conference).
- [23] "Comparison of cloud models for propagation studies in Ka-band satellite applications", F. Yuan, Y. H. Lee, and Y. S. Meng, 19th International Symposium on Antennas and Propagation, Kaohsiung, Taiwan, Dec. 2014, pp. 383-384, (Conference).
- [24] "Near sea-surface mobile radiowave propagation at 5 GHz: measurements and modeling", Y. H. Lee, F. Dong, and Y. S. Meng, Radioengineering, vol. 23, no. 3, pp. 824-830, Sep. 2014, (Journal).
- [25] "Measurement and calibration of a high-sensitivity microwave power sensor with an attenuator", Y. S. Meng and Y. Shan, Radioengineering, vol. 23, no. 4, pp. 1055-1060, Dec. 2014, (Journal).
- [26] "Error analysis and uncertainty estimation for a millimeter-wave phase-shift measurement system at 325GHz", T. Y. Wu, Y Lu, Measurement, vol 59, pp198-204, Jan 2015, (Journal)