Asia Pacific Metrology Programme

20th APMP TCEM 2017 Meeting and Workshops

Nov 24 – Nov 29, 2017

New Delhi, India

TCEM 2017 Calendar

Asia Pacific Metrology Programme

- **Day 0:** Friday Nov. 24, 2017

  NPLI Electrotechnical Workshop

  - "Advances in Electrical and Electromagnetic Metrology"

- **Day 1**: Saturday Nov. 25, 2017

  TCEM Workshops

  - WS1: The New SI and Quantum Standards
  - WS2: Metrology for Industry
  - Workshop Dinner

- **Day 2:** Sunday Nov. 26, 2017

  Possible city tour - tba

- **Day 3**: Monday Nov. 26, 2017

  TCEM 2017 Meeting

  - Laboratory Report Posters during breaks

- **Day 4**: Tuesday Nov. 28, 2017

  TCEM Workshop

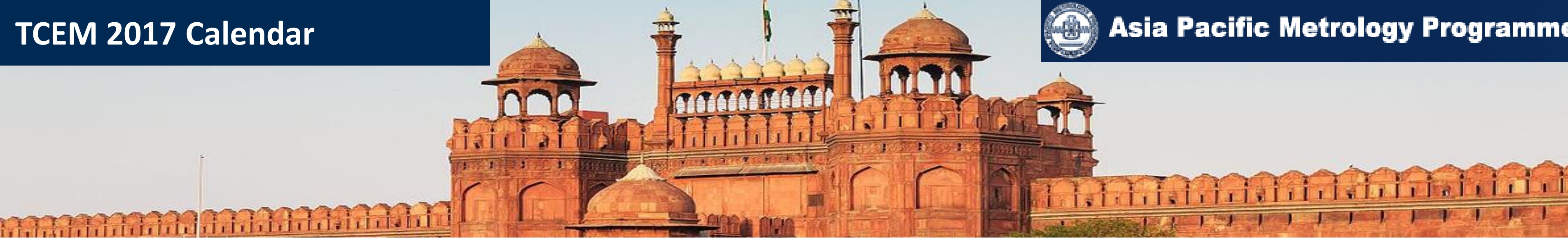
  - WS3: RF Workshop

- **Day 5**: Wednesday Nov. 29, 2017

  Symposium & Optional City Tour

TCEM 2017 Calendar

Asia Pacific Metrology Programme



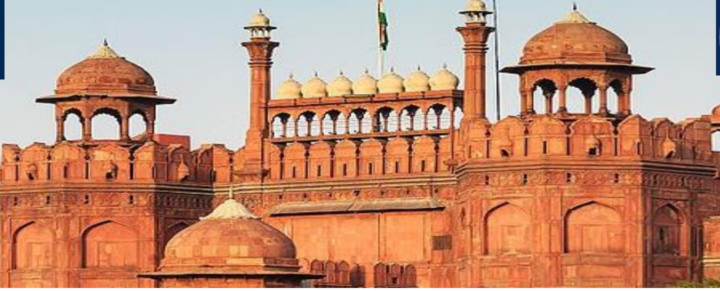
Nov. 24 (Fri)	Nov. 25 (Sat)	Nov. 26 (Sun)	Nov. 27 (Mon)	Nov. 28 (Tues)	Nov. 29 (Wed)
Electro-Technical Workshop, hosted by CSIR-NPL	WS1: DC and Quantum Standards (See the program)	Possible City Tour (tba)	TCEM Meeting with poster session of laboratory reports (see Agenda – coming)	WS3: High Frequency Metrology (See the program)	Symposium Location: CSIR-NPL Auditorium, NPL Campus
Lunch	Lunch		Lunch	Lunch	Lunch
Electro-Technical Workshop, hosted by CSIR-NPL	WS2: Metrology for Industry (See the program)	tba	TCEM with poster session of laboratory reports		Optional City Tour
		Welcome Reception?? (Not sure at this stage)	TCEM Dinner		

Time	TITLE	SPEAKER
	Chair: Dr Nobuhisa Kaneko	
09:30-09:40	Opening and Introductions	TCEM Chair
09:40-10:00	Arbitrary waveform generation of current with GaAs single-electron pump	Dr Nobu-hisa Kaneko (NMIJ)
10:00-10:20	QHR System Verification using the enhanced performance of the DC current comparator based on AccuBridge® Technology	Mr Duane Brown (Measurements International)
10:20-10:30	Measurement of Harmonic Phase Angles Traceable to a Josephson Waveform Synthesiser	Dr Ilya Budovsky (NMIA)
10:30-10:50	Break	
10:50-11:10	Voltage Divider Technology- Past, Present and Next Generation	Mr Richard Timmons (Guildline)
11:10-11:40	µ0 and the SI	Dr Murray Early (MSL)
11:40-12:00	Towards the representation of 'Ampere' using quantum phenomena: World Scenario and developments at NPLI	Dr R P Aloysius (NPLI)
13:00-14:00	Lunch	All

WS2: Metrology for Industry

Asia Pacific Metrology Programme

Time	TITLE	SPEAKER
	Chair: Dr Murray Early	
14:00-14:20	Use of the Binary Voltage Divider for Traceably Verifying DC Voltage Linearity on 8.5 Digit Calibrators and DMMs	Mr Duane Brown (Measurements International)
14:20-14:40	Electrical Power and Energy Standards at NMIA	Dr Ilya Budovsky (NMIA)
14:40-15:00	The New Calculable Capacitor and AC Impedance Chain at NIM	Dr Yan YANG (NIM)
15:00-15:20	DC Current Comparator History and Applications	Mr Richard Timmons (Guildline)
15:30-16:00	Break	
16:00-16:20	Application of digital techniques in calibration of Low Frequency impedance measurements	Priyanka Jain (CSIR-NPL)
16:20-16:40	Electrical & Electronics Metrology at NPLI: For Industries	Saood Ahmad (CSIR-NPL)
16:40-17:00	Metrological Traceability of Impedance Standards up to 250 MHz at CSIR-NPL	Satish (CSIR-NPL)
17:00-17:20	Electrical Conductivity Measurement of Metal Plate using van der Pauw Method	Dr Sung Jung Joo (KRISS)
	Close	



Title & Speaker	Abstract
Arbitrary waveform generation of current with single-electron pump Nobu-hisa Kaneko (NMIJ)	Generation of electric current based on a single-electron pumps is one of the promising candidates for direct primary representation of the revised SI ampere. In contrast to dc current generation with which the uncertainty is as low as sub-ppm level had already been demonstrated, generation of finite-frequency current based on a single-electron pump is still challenging. Here we have demonstrated arbitrary waveform generation of current at a sub MHz frequency range using a GaAs-based single-electron pump. In our experiment, the pump operation is digitally controlled to generate a density-modulated single-electron stream, by which arbitrary waveforms of current including sinusoidal, square, and triangular waves have been generated. Our result can open new avenues for precision measurement of electric impedance and current noise as well as demonstration of a quantum metrology triangle experiment at a finite frequency range.
QHR System Verification using the enhanced performance of the DC current comparator based on AccuBridge® Technology Duane Brown (Measurements International)	The Quantum Hall effect (QHE) or primary resistance standard provides a universal representation of the unit of resistance which depends on the elementary charge *e* and the Planck constant *h*. The quantum resistance standard can be reproduced with a relatively low uncertainty using the traditional gallium arsenide (GaAs) silicon sample. If the measurements on a QHE are implemented according to specific technical guidelines and the sample is at a temperature of 1.2 K in an 8-tesla magnetic field, uncertainties as low as few parts in 10^{-9} can be achieved. Quantum Hall resistors (QHRs) have a defined value RK of 25,812.807 Ω on step I = 1, with appropriate sub-multiples of this value on other steps. Such resistors are used as representations of the ohm in national laboratories of many countries, where it is common practice to compare these primary resistance standards on a regular basis with a set of thermally stabilized wire resistors. These Quantum Hall resistance measurements are typically carried out using either resistance ratio bridges equipped with the cryogenic current comparator bridge (CCCB) or the room temperature direct current comparator (DCC) where the performance of each relies on the magnetic flux sensitivity. Binary wound current comparators are used in both, which makes them easy to calibrate. Calibrations of wire resistors in terms of the QHE can also be carried out with similarly low uncertainties. Nevertheless, there are difficulties associated with implementing a CCCB, amongst these the necessity to cool the coil with liquid helium. Over the last five years the DCC bridge, which is another application of the same connection technique as the CCCB, provides an effective solution for measuring the QHR with a relative ratio uncertainty below two parts in 10^{-8}. However, the DCC ratio bridge development has been hindered by this inherent ratio error of the direct current comparator. This paper describes the improvement introduced in the DCC technology and the latest results of GaAs sample verification. Moreover, a QHR vs QHR comparison is shown to emphasize the development done to the cryogenics system.

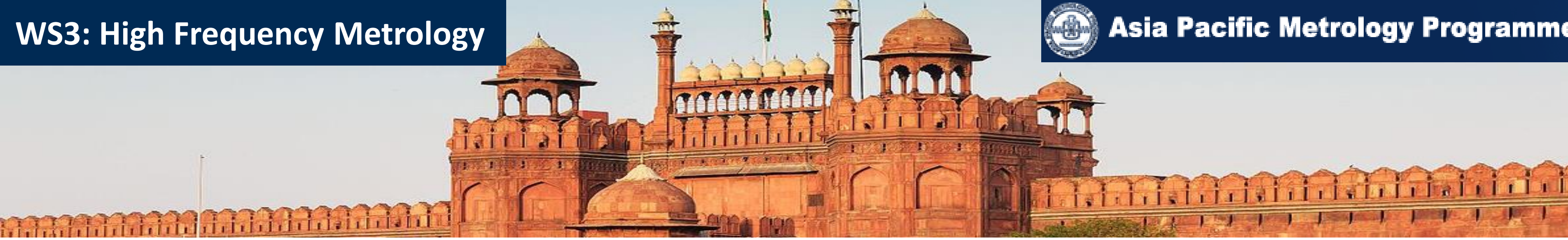
Title & Speaker	Abstract
Measurement of Harmonic Phase Angles Traceable to a Josephson Waveform Synthesiser Ilya Budovsky (NMIA)	A new harmonic phase standard based on an Arbitrary Josephson Waveform Synthesiser has been developed to provide traceability to power analysers used to measure voltage and current harmonics in the electrical power lines. The new standard will support electricity distribution companies and manufacturers of power analysers and help meet the requirements of the IEC 61000 series of standards on low-frequency electromagnetic compatibility. The preliminary uncertainties are 0.001 degrees for harmonics up to the 9th and 0.005 degrees for harmonics up to the 39th. The new standard will also be an ultimate source of traceability for the amplitude of harmonics.
Voltage Divider Technology- Past, Present and Next Generation Richard Timmons (Guildline)	Voltage dividers are commonly used with Voltage References, typically 10 V or 1 V, to calibrate voltage references, voltage meters, and voltage sources. One application is to divide down the reference voltage to create very accurate lower voltages (e.g. from 1 V to 1 mV via 1:10, 1:100 and 1:1000 ratios). Another use of voltage dividers is to allow comparison from a secondary voltage source to a Voltage Reference by reducing the secondary's voltage level to that of the Voltage Reference. This presentation will show the progression of voltage dividers from the early 1950's through the variations available today. Different designs will be presented for voltage dividers, along with a description of manufacturing issues and operational challenges. For example, today the lowest uncertainty voltage dividers require a lengthy calibration process before use and typically can meet their best uncertainties for only an 8-hour operational period. The calibration process is either 100% manual, or requires very expensive and complex standards as well as time-consuming and complicated procedures. Newly developed patent pending technologies and designs that overcome many of the issues that have plagued operators using precise voltage dividers for the last 60 years will also be presented.
μ_0 and the SI Murray Early (MSL)	

Title & Speaker	Abstract
Towards the representation of 'Ampere' using quantum phenomena: World Scenario and developments at NPLI R P Aloysius (NPLI)	'Ampere' is the only SI unit among the electrical quantities, still not realised using a physical principle or based a fundamental constant. The existing definition of 'ampere' based on the Ampere's force law between two parallel current carrying conductors of infinite length, is too difficult to realise and the associated uncertainty is relatively high. As the voltage and resistance standard were realised from quantum phenomena such as Josephson effect and quantum hall effect, the metrological community started a practical realisation of 'ampere' through Ohm's law (I= V/R). As a consequence, the 'ampere' has lost the true sense being an SI unit. So, the metrological community started research on developing a quantum based current standard which allows one to count the number of electrons passing through some nanostructures. This development was augmented by the simultaneous development in nanofabrication technologies started in 1990s. The present talk is focussed on a review of quantum current standard developments on different NMIs, and the research initiated by NPLI towards this direction. In NPLI we started programmes for the realisation of 'ampere' using quantum phase slip(QPS) phenomena in superconducting nanowire, also started development of single electron tunnelling based on a semiconductor quantum dot. As these devices are capable of generating extremely small currents of the order of 100 pA, the associated measurement challenges are also dealt with.
Use of the Binary Voltage Divider for Traceably Verifying DC Voltage Linearity on 8.5 Digit Calibrators and DMMs Duane Brown (Measurements International)	This paper reviews the difficulties and limitations of verifying the performance and linearity of the DCV function on high performance calibrators and voltmeters. The general recommended metrology guidelines, such as the EURAMET cg-15, recommend verifying for performance and linearity at 5 different points within the instrument's setting for higher performance instrumentation. Usually they are at 10%, 30% 50%, 70% and 90% of a given operating range. Plus several additional points are used for verifying reverse or negative polarity voltage operating performance. With existing dividers verification can readily be done at decade points using 10:1 and 100:1 dividers and 10 volt reference standards. However, verification of non-decade ratios is not readily possible (for example the desired 10%, 30%, 50%, 70% and 90% of scale operating points.). Traditional metrology instrumentation with variable ratio capabilities, such as Kelvin-Varley dividers, fall short in satisfying the uncertainty requirements needed for these high performance instruments. As a solution the OEM manufactures of calibrators and voltmeters recommend techniques using built in internal instrument checks (problematic to traditional metrology philosophy). Alternatively, they use external measurement techniques with very high performance techniques, such as Josephson junction voltage systems, or highly characterized standards for comparison measurements. The OEM's laboratories can readily utilize such techniques due to the speciality of their work. However, these techniques are not practical nor easily done in other labs which must support traceability not only of such special instruments but are also required to support a wider metrology

Title & Speaker	Abstract
Electrical Power and Energy Standards at NMIA Ilya Budovsky (NMIA)	The paper presents a range of standards developed at the National Measurement Institute Australia to provide traceability to electrical power and related quantities. These include thermal, sampling and quantum measurement standards for different application as well as NMIA's unique 1000V Inductive Voltage Dividers with uncertainties of 1×10^{-10} and computer-controlled precision current transformers for currents up to 200 A.
The New Calculable Capacitor and AC Impedance Chain at NIM Yan YANG (NIM)	The new NIM's calculable capacitor was established at the end of 2013, and it initially linked the capacitance unit to the SI unit of length with the relative standard uncertainty of 2.0×10^{-8}. Since 2014, many improvements have been achieved. A two terminal-pair capacitance bridge, a four terminal capacitance bridge and a four terminal pair quadrature bridge were also established to build NIM's ac impedance measuring chain.
DC Current Comparator History and Applications Richard Timmons (Guildline)	
Electrical Conductivity Measurement of Metal Plate using van der Pauw Method Sung Jung Joo (KRISS)	In Korea, many industries related to electrical conductivity such as material development of metal alloy, purity and quality. Generally, conductivity meter based on eddy current used in industry can easily provide conductivity information for metal from 0.5 to 65 MS/m. In KRISS, the Centre for Electromagnetic Metrology is providing calibration/testing service responding to the demand of industry. We measure the conductivity of standard metals using van der Pauw method and evaluated its uncertainty. Additionally, because the resistivity of metal change with temperature, we calculated the temperature coefficient (α) by a typical linear approximation and evaluated its uncertainty.
tba	

WS3: High Frequency Metrology

Asia Pacific Metrology Programme



Time	TITLE	SPEAKER
	Chair: Dr No-Weon KANG	
09:30-09:40	Opening	TCEM Chair
09:40-10:00	WR-6 Microcalorimeter: Traceable Power Measurements in D-band (110 to 170GHz)	Dr Xiaohia Cui (NIM)
10:00-10:20	RF power research in KRISS	Dr Jae-yong Kown (KRISS)
10:20-10:30	Precision and Reproducible On-Wafer Measurement at Millimeter-wave and THz frequency	Dr Anton Widarta (NMIJ)
10:30-10:50	Catching up with RF Metrology	Dr Blair Hall (MSL)
10:50-11:10	Break	
11:10-11:40	Error Models in Testing of Balanced Twisted-pair Cabling with Portable VNA	Dr Meng Yusong (NMC)
11:40-12:00	(TBD) India RF metrology	NPLI (TBD)
12:00-12:20	Photonics-based Electric and Magnetic Field Sensor Research at KRISS	Dr Dongjoon Lee (KRISS)
12:20-12:40		
12:40-13:00		
13:00-14:00	Lunch	

Title & Speaker	Abstract
WR-6 Microcalorimeter: Traceable Power Measurements in D-band (110 to 170GHz) Xiaohia Cui (NIM)	RF power measurement requirements from industry have exceeded 100GHz, in China, the power sensor has reached 325GHz, and many devices such as frequency doubler, amplifier, detector, etc., the frequency range have reached 500GHz. National Institute of Metrology of China (NIM) has developed a wr6 micro calorimeter and metrology level power sensor, can provide traceable power measurements from 110 to 170GHz. The principle and measurements of the wr6 power sensor and microcalorimeter will be reported in this workshop.
RF power research in KRISS Jae-Yong Kown (KRISS)	This talk starts from brief history of RF power research in KRISS, and then describes recent research activities on primary standards system for millimeter-wave power. The basic design scheme of the primary standards and their basic performance will be presented. The feasibility of a new type of wide band reference standards for W-/D-band waveguide calorimeters will be discussed.
Precision and Reproducible On-Wafer Measurement at Millimeter-wave and THz frequency Anton Widarta (NMIJ)	Probe-tip positioning on a on-wafer probe station has a major contribution to the accuracy of on-wafer microwave and millimeter wave calibration and measurements. It is recognized that the probe positioning reproducibility with conventional visual techniques is strongly influenced by the type of probe used as well as the experience and skills of the operator. At NMIJ/AIST, an automatic non-visual probe positioning system using a coordinate mapping algorithm has been developed and mounted on the on-wafer probe station. From the initial experimental results, the uncertainty caused by probe-tip positioning errors could be significantly reduced, and no longer as a major source of uncertainty
Catching up with RF Metrology Murray Early (for Blair Hall) (MSL)	RF & Microwave metrology has made striking progress in recent decades. Commercial off-the-shelf VNA technology outpaced and out-performed the bespoke impedance measurement set-ups developed by NMIs in the twentieth century. So, these days, a well-equipped NMI will use essentially the equipment available to a well-resourced commercial calibration laboratory. International comparisons that ran during the first decade of the new millennium showed that the RF community was struggling to adapt to the change in technology and to produce consistent uncertainty budgets for VNA measurement systems! However, in this decade, the RF community has responded by developing tools and guidance that will harmonise reporting and provide valuable assistance for commercial calibration laboratories as well.

WS3 Abstracts

Title & Speaker	Abstract
Error Models in Testing of Balanced Twisted-pair Cabling with Portable VNA Meng Yusong (NMC)	Driving by quick development of emerging technologies such as internet of thing (IOT) and automotive industry, quality assurance for balanced twisted-pair cabling and installation has drawn great attention by the industry. In the talk, some recent works on development of measurement error models in testing of balanced twisted-pair copper cabling will be presented. The dissemination of conventional metrological traceability in VNA measurements will be discussed, with some future works.
?? tba (NPLI)	
Photonics-based Electric and Magnetic Field Sensor Research at KRISS D J Lee (KRISS)	The Center for Electromagnetic Metrology at KRISS has conducted research in microwave photonics for the last eight years. The capability to measure microwave can be significantly enhanced when it is assisted with photonic technology. We have employed optical crystals - associated with laser systems - to overcome several challenges in relation to electromagnetic measurements. The crystals were utilized to build EO/MO (electrooptic/magnetooptic) probes to measure challenging electric/magnetic fields. The recent progress to significantly enhance the sensor capability based on integrated optics is to be discussed.