Laboratory Report
Of
National Physical Laboratory
(NPL), India

33rd CCEM Meeting
(08-09 March 2023)

CSIR-NPL measures electrical quantities that are accurate, reliable and traceable to the SI units. The National standards are realized, established, maintained, upgraded and disseminated to support industry, govt. sector, research and academia. Electrical and Electronics Metrology major activities are based on the research and indigenous development of quantum standards of electrical and electronic parameters. These include LF & HF Voltage, Current and Microwave Metrology parameters, Electromagnetic metrology (free space electric and magnetic field measurements), DC parameters such as voltage, current and resistance; low frequency and high frequency impedance related quantities such as capacitance, inductance and AC resistance; AC/DC high voltage and high current; AC power & energy; and quantum hall resistance (QHR). Work is in progress for quantum current (QC) and quantum nano-photonics (QN). To maintain the international traceability, a number of international & bilateral intercomparisons under the umbrella of BIPM and APMP have been carried out. We are disseminating measurement traceability in the above-mentioned parameters along with the other derived parameters and their measurement capabilities.

I. Electrical and Electronic Metrology

1. Established Precision power calibration system (PPCS) for ac power & energy with uncertainty: 10 to 30 ppm, 40 to 400Hz, 01V to 480V, 1mA to 100A, 1.0 to 0.0(lag/lead).
2. Established high stability automatic calibration bench (50ppm stability) with reference power comparator COM-5003 (ZERA, Germany) with uncertainty:50ppm , 40Hz to 70Hz, 01V to 640V/1mA to 160A , 1.0 to 0.0 (lag/lead) for apex level calibration and testing for ac power & energy parameters.

3. Up-gradation of Cross-Calculable Capacitance Standards
4. Automation for the calibration facilities at LF, HF Impedance and DC Standards.
5. Design and Development of high frequency capacitance and inductance standards
6. Upgraded AC High Voltage (HV) capability of capacitance and tan delta, measuring facility for calibration of Standard HV Capacitors, HV Transformers, AC HV Dividers / kV Meters, AC HV Sources, etc. up to 200 kV.
7. In house traceability of NPLI's attenuation standard i.e. 30 MHz WBCO, against the CMC of 1 kHz IF substitution measurement traceable against IVD has been established.
8. Free space measurement facility for E-field strength and related parameters (Antenna Factor, Gain, radiated power density) at NPLI, using completely indigenous instrumentation including GTEM, E-Field sensors and antennas up to 40 GHz.
9. Established Shielding effectiveness measurements traceable to attenuation measurements based on IEEE standard 299-2006.
10. Established AC Magnetic Field Measurement Facility from 10 mGauss to 2000 Gauss at 50 Hz, its extension to 100 kHz range is in progress using Helmholtz coil and GTEM.
11. To make microwave measurement traceable to universal constants (SI traceability) microwave section has formulated the unique concept of Double Electromagnetically Induced Transparency (DEIT) and Double Autler-Towens Splitting (DATS) and NPLI is at the verge of establishing SI traceable microwave measurements. This particular work has been recognized by two prestigious Young Scientist Awards by URSI.
12. Primary Standards of Microwave Power has been re-established with the improvement in measurement uncertainty. 50 GHz "2.4mm Coaxial Microcalorimeter" uncertainty has been improved from ±1.9 % in 2015-16 to ±0.5% in 2021-22 and 18 GHz "N type Coaxial Microcalorimeter" uncertainty has been improved from ±1.0 % in 2015-16 to ±0.72% in 2021-22.
13. Organized an E-Workshop on "**Role of Traceable PMU in Smart Grids**" on March 29, 2022 to propagate the message that CSIR-NPL (NMI-India) has established a PMU-CAL System to calibrate PMU as per IEEE standard.
14. A **news article** on "*Calibrated Phasor Measurement Unit as metrological tool for real time monitoring of Indian Smart Grid*" has been published in **APMP Newsletter,** page 17, issue 46, Feb 2022.

15. Providing national traceability to Indian Power Grid by calibrating their PMU-CAL System, hence supporting the power industries in the country.
16. Providing national traceability in the above parameters through apex level calibration to Strategic sectors, STQC labs, regional laboratories and the other user organizations including SARC countries.

II. CIPM Related

1. CMC on E-Field Measurements, Antenna Factor, Antenna Gain and probe calibration based on TEM Cell (indigenously developed) validated against commercial GTEM Measurements.
2. Attenuation Measurement upgraded to 40 GHz based on the participation in CCEM.RF-K26 and traceable to national standards
3. Impedance measurement upgraded to 67 GHz based on the airline based measurement system and participation in APMP.EM.RF-S5.CL.
4. Dielectric Measurements for Liquid up to 20 GHz calibrated the indigenously designed probe against water, Methanol and Ethanol and validated on commercial system.
5. Dielectric Measurements in waveguide system is for X band, Ku Band and Ka Band proposed for review against indigenously designed waveguide system with VNA and perform the measurements against standard sample of Teflon.
6. AC Magnetic Field Measurement at 50 Hz from 10 mG (1 μT) to 2000 Gauss against Helmholtz coil and validated against theoretical values.
7. Apart of above 10 other CMC of DC magnetic field is still pending even after peer review.
8. Under Electrical metrology, NPL (NMI-India) has given onsite training to NML-BSTI (NMI Bangladesh), from 18th -22nd Sept 2022 on the establishment of their AC Voltage and Current Calibration Facility.
9. Upgradation of CMC for Microwave Power from 18 GHZ up to 50 GHz, measuring effective efficiency of a thermocouple power sensor using coaxial microcalorimeter in the upcoming technical peer review of various electrical and electronic parameters in next financial year (2023-24).
10. The revised Intercomparison report of APMP.EM-S8 has been submitted to the Chairman, WGLF in Feb 2023.

III. Intercomparisons

a) High frequency capacitance standards of 1pF – 1nF in the range of 10 kHz – 10 MHz is in-progress, other Participating labs are NIM China and Thailand.

b) **APMP.EM.RF-S5.CL** Characteristic Impedance of precision air-dielectric coaxial lines (Data Submitted)

c) **Bilateral/Multilateral Projects:** Bilateral with LNE France on Vector SAR Measurements.

d) **APMP.EM.RF-K8.CL:** Microwave power, Measuring calibration factor of power sensors from 10 MHz to 18 GHz piloted by NMI-Japan

e) **APMP.EM-S8** A supplementary comparison (APMP.EM-S8) of DC voltage, DC current, DC resistance, AC voltage and AC current has been carried out by NPL India among seventeen national metrology laboratories with the travelling standards 6½ digit multimeters (Fluke model 8846A) for the nominal values of the measured parameters for establishing the degrees of equivalence among the participating NMIs.

f) BIPM key comparison of 1 ohm and 10 k ohm resistance standards has been successfully completed and results sent to BIPM, France.

g) Review of Inter-comparison of Zener reference voltage standard (1 V and 10 V) with respect to primary Programmable Josephson Voltage Standard

IV. Cooperation to strengthen Quality Infrastructure

Joined IEC commissions

1. Expert Member-**IEC TC 106WG9**-Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure.
2. Expert Member-**IEC TC 106WG8**-Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure

V. Future Plans

1. Atomization of Phasor Measurement Unit Calibration (PMU-CAL) system for establishing its traceability from the respective primary standards of AC Voltage & Current, DC Voltage & Current, QHR for resistance and Time and Frequency standards of CSIR-NPL.
2. Comparisons under discussion for Calibration factor in coaxial 7 mm transmission line for Coaxial Thermistor mount (Microcalorimeter System, 7mm up to 18 GHz), NIM China and NMC Singapore are the Pilot Laboratory.
3. To Establish Vector SAR Measurements for upcoming wireless communication challenges.
4. To Establish Quantum Magnetic and E-Field Measurement SI traceable System based on LASER atom interactions. Following Measurement will be traceable against universal plank constant
   a. E- Field
   b. Radiated Power Density

c. Microwave Power

d. Antenna Pattern

e. Microwave Mixers

f. Antenna Gain

g. Antenna Factor

5. Establishment of dielectric constant, loss tangent, resistivity and conductivity measurement for liquid and solid samples up to 30 MHz
6. Establishment of DC high voltage measurement facility up to 300 kV
7. Establishment of AC Ultra High Voltage Laboratory (50m x 35m x 35m)
8. High Voltage Measurement up to 800 kV
9. High Current Measurement up to 20 kA
10. Electric Field Measurement 100 – 300 kV/m
11. Partial Discharge Measurement up to 500 kV
12. Impulse High Voltage Measurement up to 1500 kV
13. Upgradation of the Cryogenic Current Comparator (CCC) bridge
14. **Establishment of National EMI/EMC measurements facility up to 40GHz**
    a. Radio interference (Established)
    b. Electrostatic Discharge (ESD) (Established)
    c. Conducted and Radiated Disturbances (Established)
    d. Damped Oscillatory Waves (Proposed)
    e. Surge Immunity Test (Proposed)
    f. Harmonics and flickers (Under Process)
15. **Establishment of Testing Facilities for Smart Energy Meters**
    a. DLMS compliance test (Data communication capability)
    b. Load switching test
    c. Resistance to heat and fire test
    d. Penetration of dust and water test
    e. Short time over current (2000A) test
    f. Impulse voltage test (15kV)
    g. Integrated Tamper test system etc.

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