Report to the 30th meeting of the CCEM about

NIS Activities in the Field of Electricity and Magnetism

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1. NIS History, Mission and Structure

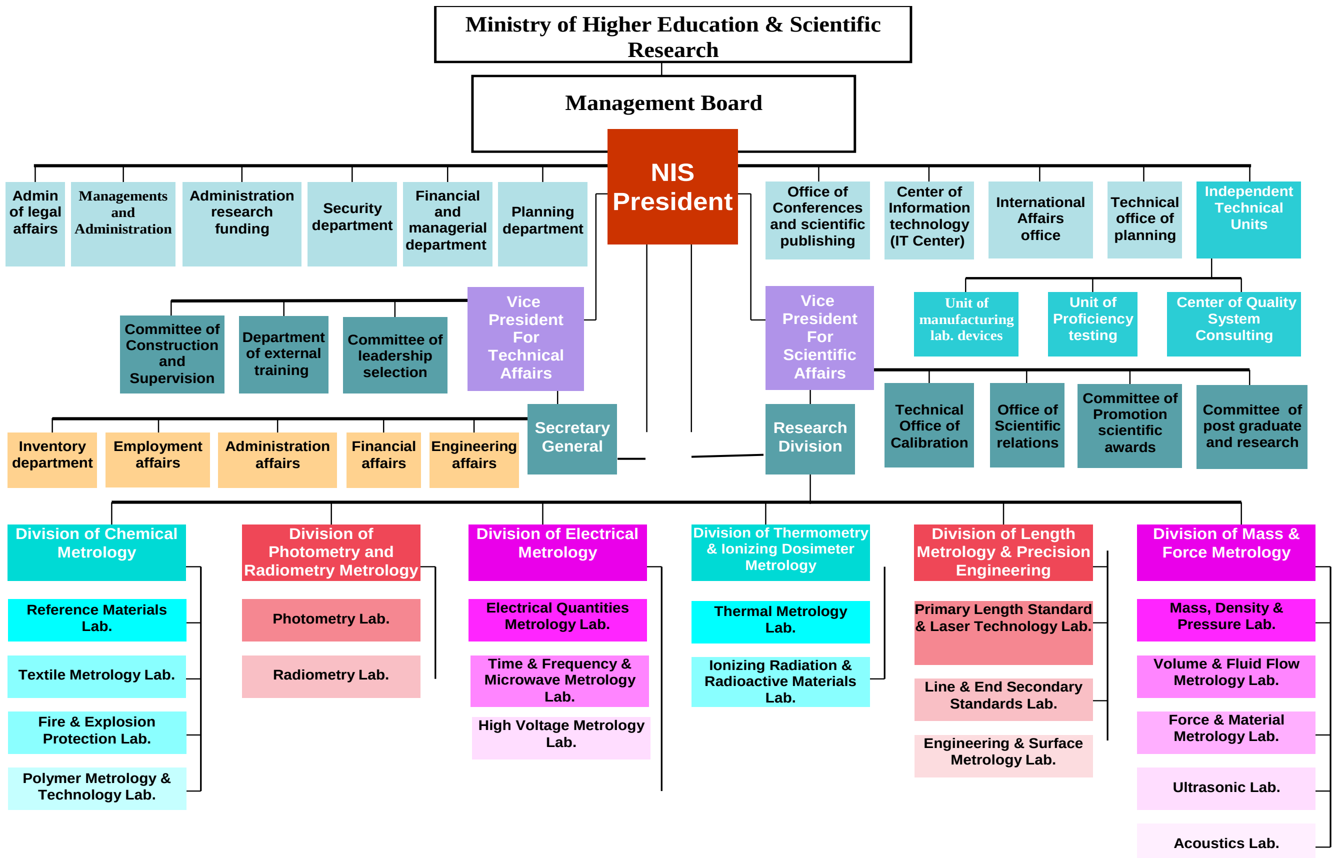
In 1962, Egypt joined the meter convention and became a member of the Bureau International des Poids et Measures, BIPM. The National Institute of Standards (NIS) was established in 1963 as one of the Egyptian research institutes. NIS as the Egyptian national metrology institute is an old member of the BIPM and currently an active member in the regional metrology organization AFRIMETS. Due to the affiliation of NIS to the Ministry of Higher Education & Scientific Research, NIS is interested in scientific research in all of its activities.

The general tasks of NIS are to realize, maintain and develop the Egyptian national standards of the basic and derived units. NIS provides the industrial and governmental as well as private organizations with traceability of their measurements to the national and international standards. NIS is also responsible for operating the National Measurement System.

1.1 Main NIS Responsibilities & Objectives

- **Realization and dissemination of SI Units.**
- **Maintaining the Egyptian National Measurement Standards.**
- **NIS represents Egypt in the international and regional metrology organizations such as AFRIMET and BIPM.**
- **Offering Tractability of Measurement to the SI Units.**
- **Operate the national laboratory of professionally test**
- **Provide calibration services to end user in the area that, are not available in the industrial laboratory.**
- **Training courses in measurement technologies and related subjects, consultancies and courses. These activities are all end user oriented and run on economic basis.**
- **To share and organize the international, regional and national metrology programs, quality and accreditation activities.**
- **Conduct Research & Development in Metrology and Advanced Measurement Technology.**

1.2 General NIS Structure and Electricity & Magnetism Manpower



NIS has a division dedicated for electrical metrology consists of three laboratories with well-qualified staff members with PhDs and MScs. The main staff of the Electricity and Magnetism (EM) laboratories is as follows:

Laboratory Name	Staff
Electrical Quantities	4 Professor emeritus 1 Ph.D. (Professor) 3 Ph.D. (Associate Professor) 3 Ph.D. students 1 M.SC. student 1 Engineer 2 Technicians
High Voltage	2 Professor emeritus 1 Ph.D. students 4 Engineers 1 Technician
Microwave	1 Ph.D. 1 Ph.D. student

2. Activities and Capabilities of NIS in the Field of Electricity and Magnetism

In the following sections a brief description of NIS activities and capabilities in the field of electricity and magnetism are introduced. More technical information and detailed data are demonstrated in a supplementary presentation entitled "NIS Activities in the Field of Electricity and Magnetism", which will be presented on Friday 24 March 2017, as part of the agenda point "review of membership and observer ship" during the CCEM meeting.

2.1 Electrical Quantities Laboratory

The department is responsible for maintaining and disseminating the national electrical standards for the quantities of DC voltage and current, resistance, capacitance, inductance and AC/DC transfer. Also, the activities of the information technology laboratory are related to this department. Calibration of the standards and electrical equipments of scientific and industrial laboratories are performed. Scientific research is carried out to improve the calibration measurement capabilities of the department. The following activities are performed:

1. **Maintenance and dissemination of the national electrical standards for DC voltage, resistance, capacitance, inductance and AC/DC transfer, through the traceability to the SI units.**
2. **Improving and establishing the quality of the primary, secondary and reference standards by continuous highly accurate internal calibrations.**
3. **Establishment and development of the measurement standards and methods to realize and maintain the highest levels of accuracy due to many scientific researches.**
4. **Verifying degree of equivalence of measurements within the department with other national laboratories through international comparisons.**
5. **Calibration of all related standards and instruments such as voltage and current sources, multi-meters, meggers , testers, RCL meters, and ….etc.**
6. **Giving consultation and training for all purposes related to accurate electrical measurements for industry in Egypt, Middle East region and African countries.**
7. **Many activities related to the information technology field.**

2.2 High Voltage Laboratory

High Voltage lab can achieve traceability to SI Unit for measuring and sourcing AC & DC high voltage and high current instruments. This lab can achieve traceability to SI unit for measuring and sourcing power and energy instruments based on the primary standard of electrical power and energy at NIS. Also, HV lab can perform

tests that are related to these activities according to international standards. In addition to that, scientific research is carried out to improve the calibration measurement capabilities of the laboratory. The following activities are performed:

1. **Calibration of AC H.V. measuring & sourcing instruments more than 1 kV up to 400 kVAC and 200 kVDC.**
2. **Calibration of AC current measuring & sourcing instruments more than 20 A up to 5000 AAC and 2000 ADC.**
3. **Calibration of partial discharge calibrators up to 2000 pC.**
4. **Calibration of transformer oil testers up to 60 kV.**
5. **Calibration of transformers turns ratio meters.**
6. **Calibration of MEGGERS more than 100 MΩ up to 611 GΩ, with DC voltage source up to 5 kVDC.**
7. **Calibration of electrical safety testers.**
8. **Safety tests for electrical household appliances.**
9. **Testing of withstand and breakdown voltage for all types of insulators.**
10. **Calibration of power and energy measuring and sourcing instruments.**
11. **Performing the TYPE TEST for all kinds of energy meters.**
12. **Testing of phase sequence indicators**
13. **Calibration of power, current, and voltage transducers.**

2.3 Microwave Laboratory

This lab is responsible for realizing, maintaining, and developing the national primary standard of high frequency (HF) power for Egypt using Microcalorimeter in the frequency range 10 MHz-18 GHz. Participation in the International Inter-comparisons. Conducting research for enhancing the accuracy and uncertainty of measurements in the microwave metrology. Providing traceability to SI for Electromagnetic Compatibility (EMC) measurements. The following activities are performed:

1. **Participation in the international comparisons for radio frequencies.**
2. **Calibration of microwave power sensors, signal generators, and cable & antenna analyzers, …etc.**
3. **Circuit characterization (measurement of scattering parameters and attenuation coefficient) in the frequency range 10 MHz - 40 GHz.**
4. **Measuring the harmonic content and distortion of signals in the frequency range of 9 kHz - 30 GHz.**
5. **Providing training, and Consultations.**

2.4 List of the Main NIS Comparisons in the field of EM:

1. **DC voltage sources: BIPM.EM-K11.a (Comparison of 1.018 V DC Voltage References).**
2. **DC voltage sources: BIPM.EM-K11.b (Comparison of 10 V DC Voltage References).**
3. **DC current sources: EUROMET.EM-S24 (Comparison of ultra-low DC current sources).**
4. **DC resistance standards and sources: EURAMET- EM-k2.1 (Comparison of Resistance Standards at 10 MΩ and 1 GΩ), Values: (100 kΩ to 1 MΩ) and (10 MΩ to 100 MΩ).**
5. **Capacitance: BIPM.EM-K14.a (Bi-Lateral Comparison of 10 pF Standards).**
6. **Capacitance: BIPM.EM-K14.b (Bi-Lateral Comparison of 100 pF Standards).**
7. **AC/DC current transfer difference: SIM.EM-K12 (Inter-Comparison of AC-DC current transfer standards), Values (10 mA, 5 A) @ Frequencies (10 Hz, 55 Hz, 1 kHz, and 10 kHz).**
8. **AC/DC current transfer difference: EURAMET.EM-K12 (Inter-Comparison of AC-DC current transfer standards), Values (10 mA, 5 A) @ Frequencies (10 Hz, 55 Hz, 1 kHz, and 10 kHz).**
9. **Digital Multi-meter Comparison: P1-APMP.EM-S8 (Digital Multi-meter Comparison).**
10. **Radio Frequencies: AFRIMETS.EM.RF-S1 (Attenuation and reflection for coaxial), the technical protocol of this comparison has been prepared, and it is already registered in the KCDB.**

2.5 Published and Some of the Submitted CMCs:

Calibration and Measurement Capabilities

Electricity and Magnetism, Egypt, NIS (National Institute for Standards)

KCDB

Calibration or Measurement Service			Measurand Level or Range			Measurement Conditions/Independent Variable		Expanded Uncertainty							
Quantity	Instrument or Artifact	Instrument Type or Method	Minimum value	Maximum value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	Uncertainty Matrix	Comments	NMI Service Identifier
DC resistance standards and sources: intermediate values	Fixed resistor	Potentiometric ratio bridge, 1:1 ratio	1E+05	1E+06	Ω	Applied voltage	10 V	4 to 41	μΩ/Ω	2	95%	Yes	Matrix 1	Approved on 15 July 2014	1
						Temperature	20 °C to 30 °C								
DC resistance standards and sources: high values	Fixed resistor	Potentiometric ratio bridge, 1:1 ratio	1E+07	1E+08	Ω	Applied voltage	20 V	94 to 760	μΩ/Ω	2	95%	Yes	Matrix 1	Approved on 15 July 2014	2
						Temperature	20 °C to 30 °C								

In last October, the following CMCs and others were submitted to the AFRIMET TCEM chair for intra-RMO review:

Calibration or Measurement Service			Measurand Level or Range			Measurement Conditions/Independent Variable		Expanded Uncertainty					Reference Standard used in calibration	
Quantity	Instrument or Artifact	Method of Measurement	Min value	Max value	Units	Parameter	Specification	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	Standard	Source of traceability
DC voltage sources: single values	DC solid state voltage standard	Direct Comparison with primary standard (JVS)	1.018	10	V	Temperature	23 ± 2°C	0.03 to 0.2	µV/V	2	95%	yes	JVS	NIS
DC current sources: low values	Standard Capacitor , Voltage Source , High Resistance Standard	Current Generator: current generated by charging or discharging a gas-filled capacitor With Software Controlled for Nonlinearity Compensation	-1E-13	1E-10	A	Ambient temperature	23 ºC to 24 ºC	4.4E-16 to 3.4E-14	A	2	95%	NO	10 µF to 1 nF), -1V to (-10V), 100MΩ	NPL, BIPM
						Ambient humidity	45 % to 50 %							
Capacitance : low-loss capacitors	Fused Silica Capacitors	Direct method	10	100	pF	Fixed Capacitance	10 pF, 100 pF	0.63 to 0.70	µF/F	2	95%	Yes	10 pF and 100 pF Standard Capacitors	BIPM
						Frequency	1000 Hz, 1592 Hz							
AC/DC current transfer difference	AC/DC transfer standard plus shunt	Comparsion with another AC/DC transfer standard	10 mA	5A		Frequency	10 Hz, 55 Hz, 1 kHz, 10 kHz	2.7 to 17.3	µA/A	2	95%	yes	10 mA, 5 A AC/DC Transfer Standard	PTB

3. Planned AFRIMETS Comparisons

Year	Identifier	Description	Participants	Pilot	Status
2015	AFRIMETS.EM-S1	DC resistance at 1 Ω, 10 Ω, 100 Ω , 1 kΩ and 10 kΩ	NMISA, LPEE/LNM, DEF-NAT, KEBS, NIS, SIRDC-NMI, UNBS, ZABS	NMISA	Ongoing
2017	AFRIMETS.RF-S?	RF attenuation	NMISA, NIS, DEF-NAT	NMISA	Planned
2018	AFRIMETS.EM-K?	DC voltage at 1,018 V and 10 V reference	NMISA, LPEE/LNM, DEF-NAT, KEBS, NIS	NIS	Planned
2019	AFRIMETS.EM-S?	Digital Multimeter, ACV: 200 mV, 200 V @ 40 Hz and 1 kHz. ACI: 100 mA, 1 A @ 40 Hz and 1 kHz. DCI: 10 mA and 1 A. DCV:100 V and 1000 V	NMISA, LPEE/LNM, DEF-NAT, KEBS, NIS	DEF-NAT	Planned
2020	AFRIMETS.EM-K?	AC Power and energy	NMISA, LPEE/LNM, DEF-NAT, KEBS, NIS	NIS	Planned
2021	AFRIMETS.EM-S?	AC-DC transfer	NMISA, DEF-NAT, NIS	NMISA	Planned

4. Research and Development Activities of NIS in the EM fields

In the remaining part of this report, research activities in each filed of the electricity and magnetism at NIS are presented.

4.1 DC Voltage and Current

4.1.1 S. S. Solve, R. Chayramy , M. Stock , Hala M. Abdel Mageed , Omar M. Aladdin and M. Helmy A. Raouf "Bilateral Comparison of 1 V and 10 V Standards between the NIS (Egypt) and the BIPM", August to September 2014", (part of the ongoing BIPM key comparison BIPM.EM-K11.a and b), Metrologia, Vol. 52, 2015,Tech. Suppl., 01011.

As part of the ongoing BIPM key comparison BIPM.EM-K11.a and b, a comparison of the 1 V and 10 V voltage reference standards of the BIPM and the National Institute of Standards (NIS), Giza, Egypt, was carried out from August to September 2014. Two BIPM Zener diode-based travelling standards (Fluke 732B), BIPM_B (ZB) and BIPM_C (ZC), were transported as hand luggage on board an airplane to NIS and back to BIPM. At NIS, the reference standard for DC voltage is a Josephson Voltage Standard. The output EMF (Electromotive Force) of each travelling standard was measured by direct comparison with the primary standard. At the BIPM, the travelling standards were calibrated, before and after the measurements at NIS, with the Josephson Voltage Standard. The comparison result shows that the voltage standards maintained by NIS and the BIPM were equivalent, within their stated standard uncertainties, on the mean date of the comparison.

4.1.2 Hala M Abdel Mageed, "A New Automatic System for Calibrating the Solid State DC Voltage Reference Standard at NIS, Egypt," MAPAN, Vol. 26, No. 4, pp. 329-337, Dec. 2011.

A new automatic system for calibrating the solid-state DC voltage reference standards (Zener Diode reference standards) has been established at National Institute of Standards (NIS), Egypt to disseminate the unit of volt in the country. Besides, this system has been implemented as a coherent structure that, from the national DC voltage reference standards, can disseminate the traceability of all the instruments under calibration. The system consists of a set of programmable instruments and proper software. Design and the implementation of the system software have been discussed in details. The system validation has been carried out for the measurement repeatability and the results compatibility in both automatic and manual modes.

4.1.3 Ahmed Hussien Ali, M.Sc. thesis, "Establishing and Confirming a National Standard System for Generating DC Current in the Femto Ampere Range"

A new automated very low D.C current source was implemented for generating D.C current in the ranges of pico and femto ampere. This new improved low current source is based on the idea of applying a linear voltage ramp to a differentiator reference standard capacitor. Faithfully, this new system enhanced the very low-current calibrations capabilities of Egypt and the Arabian/African region. To get full confidence in this work, NIS participated in EUROMET.EM-S24: "Comparison of small current sources". The nominal values of the eight measuring points of that comparison were +100 fA, -100 fA, +1 pA, -1 pA, +10 pA, -10 pA, + 100 pA, and -100 pA ranges.

4.1.4 Some of the Key Publications

1. S. S. Solve, R. Chayramy , M. Stock , Hala M. Abdel Mageed , Omar M. Aladdin and M. Helmy A. Raouf "Bilateral Comparison of 1 V and 10 V Standards between the NIS (Egypt) and the BIPM", August to September 2014", (part of the ongoing BIPM key comparison BIPM.EM-K11.a and b), Metrologia, Vol. 52, 2015,Tech. Suppl., 01011.
2. Hala M Abdel Mageed, "A New Automatic System for Calibrating the Solid State DC Voltage Reference Standard at NIS, Egypt," MAPAN, Vol. 26, No. 4, pp. 329-337, Dec. 2011.
3. Abla H. Abd El Rahman. "Towards A New Highly Improved Voltage Transfer Standard ", AUEJ., Fac. Eng., Al Azhar Univ., Vol.5, No. 3, July 2002,pp.41.
4. Abla H. Abd El Rahman," Evaluation Of The Performance Of The Zener Diode Reference As A Transport Standard of Voltage at The National Institute For Standards" J.Eng. And Appl. Sci., Fac. Eng. Cairo Univ., Cairo, Egypt, Vol.48 No.2,Apr.2001,pp 247-261.
5. Abla H. Abd El Rahman, " an Improved Technique For Calibrating Zener Diode Reference Standards " J. Eng. Appl. Sci., Fac. Eng. Cairo Univ. , Cairo, Egypt Vol. 40 No. 6, Dec. 1993.
6. Abla H. Abd El Rahman et al., "A New Method for Calibration of D.C. Potentiometers", Egyp. Soc.Eng., Vol. 30 No.2 pp.18-25., 1991.

4.2 Resistance

4.2.1 N. N. Tadros, Rasha S. M. Ali, "Automated Accurate High Value Resistances Measurements in the Range from 100 kΩ to 100 MΩ at NIS ", Measurement 45, PP.988-992, 2012.

This paper describes the procedures made at National Institute of Standards (NIS), Egypt to establish accurate resistance measurements for high value resistance standards in the range from 100 kΩ to 100 MΩ, which are done automatically. Guarded Hamon transfer standards have been used at NIS for scaling to high resistance levels up to 100 MΩ. The used method at NIS for the high resistance measurements, above 100 kΩ, is the DMM-based method, which works automatically. The scaling process from the NIS 10 kΩ resistance standard up to 100 MΩ value is made using two Hamon transfer standards. The automatic measurement improved the quality of the calibration of high value resistance; eliminating the noise due to the operator and errors that result from transcribing data.

4.2.2 N. N. Tadros, Rasha S. M. Ali, "Improved System for the Automatic Calibration of Standard Resistors in the Meg-ohm Range", Measurement 46, PP. 2077-2081, 2013.

An automated measuring system is developed for improving the calibration of high value standard resistors in the meg-ohm range at the National Institute of Standards (NIS), Egypt. This system is suitable for the calibration of the standard resistances from 100 kΩ to 100 MΩ using the DMM-based method by the substitution technique. The unknown resistor and the standard resistor are indirectly compared in the same position using a dummy resistor as a short–term reference standard. The system operation is automatically controlled by using a LabVIEW program which is especially developed for this purpose. The performance of this system is evaluated by comparing the measurement results obtained from this technique with those obtained by the direct comparison DMM-based method. It is found that the span of the expanded uncertainty of measurement with this method is from 4.1 μΩ/Ω to 27 μΩ/Ω, whereas its span is from 40 μΩ/Ω to 110 μΩ/Ω for the direct comparison method.

4.2.3 M. Helmy A. Raouf, "Design, Implementation, and Characterization of a New Resistance Box Fabricated with Fifteen Outputs Decades", Measurement, Vol. 101, PP. 206 – 210, April 2017.

A new automated Resistance Box (RB) has been presented that mainly consists of three decades. They have the same design, but each has four different internal resistive elements. Each decade generates 15 different output resistance values; therefore, it is more economical and practical compared to the other usual decades, which produce only 10 values by using 10 internal resistive elements per decade. 4096 resistance values can be obtained by the all possible combinations of the new RB decades. Design, fabrication process, and characterization of the new RB are demonstrated in detail including its main specifications and advantages. 4096 resistance steps could be obtained by all possible combinations, but 1666 of them are different from each other. The minimum number of the used resistive elements leads to minimum power losses, cost, and maintenance effort with better electrical properties and performance. The relative deviation of output resistance steps from their rated values is less than or equal ±50 ppm, whereas the relative uncertainty because of the summation effect is less than or equal ± 6.0 ppm. The huge number of the output resistance steps enables the new resistance box to be used dependably for manual and fully automated calibrations of the resistance meters and their linearity checking.

4.2.4 Some of the Key Publications and Patents

1. **M. Helmy A. Raouf, "Decade Resistance Formed by Minimum Number of Elements", Ministry of Higher Education and Scientific Research, Patent Office, Cert. No. 24567, October 2009.**
2. **M. Helmy A. Raouf, "Automated Decade Resistance of Fifteen Output Values", Ministry of Higher Education and Scientific Research, Patent Office, Cert. No. 26493, December 2013.**
3. **N. N.Tadros, Rasha S. M. Ali, "Automated Accurate High Value Resistances Measurements in the Range from 100 kΩ to 100 MΩ at NIS ", Measurement 45, PP.988-992, 2012.**
4. **N. N.Tadros, Rasha S.M. Ali, "Improved System for the Automatic Calibration of Standard Resistors in the Meg-ohm Range", Measurement 46, PP. 2077-2081, 2013.**
5. **M. Helmy A. Raouf, "Design, Implementation, and Characterization of a New Resistance Box Fabricated with Fifteen Outputs Decades", Measurement, Vol. 101, PP. 206 – 210, April 2017.**
6. **Beat Jeckelmann, Hani Saad Abdel Aziz, Nadia Nassif Tadros, Andrey Tenev, "RMO Key Comparison EURAMET.EM-K2.1 Comparison of Resistance Standards at 10 MΩ and 1 GΩ Final Report", BIPM KEY Comparison Data Base , February 2013,and Metrologia 2013 ,50, Tech. Suppl., 01001.**
7. **Rasha S.M. Ali, and M. Helmy A. Raouf, "Current Dependence Coefficient Determination for Different DC Standard Resistors Measurements Based on V-I Method", Journal of Measurement Science and Instrumentation, Vol. 7, No. 4, PP. 332-335, December 2016.**
8. **M. Helmy A. Raouf, Rasha S.M. Ali, and M.S. Gadelrab, "Construction and Remote Calibration for an Automated Resistance Measuring System", MAPAN-Journal of Metrology Society of India, Vol. 26, No. 2, PP. 125 – 131, June 2011.**
9. **M. Helmy A. Raouf, "Manual / Automated Decade Resistance Using Micro - Controller Technique", The International Journal of Metrology, Cal Lab Journal, Vol. 17, No. 2, PP. 28-34, June 2010.**
10. **M. Helmy A. Raouf, "Fabrication of a New Decade Resistance Using Parallel Port Technique", The International Journal of Metrology, Cal Lab Journal, Vol. 15, No. 4, PP. 26-31, December 2009.**

11. M. Helmy A. Raouf, "Theory for Accurate Calibrations of Decade Resistance Boxes", Journal of Al-Azhar University Engineering Sector, JAUES, Vol. 3, No. 6, PP. 96-101, January 2008.
12. N. N. Tadros. "Investigation into The Effect of Loading on the NIS Primary Group of Standard Resistors". Conference Proceedings of 1998 IEEE Instrumentation and Measurement Technology Conference, IMTC /98, May 18-21, 1998, ST .Paul Minnesota, USA, Vol.2, PP 1286-1288.
13. N. N. Tadros. "Application of the 10 kΩ Standard Resistor as a Reference for Resistance Scaling". Conference Proceedings of 1994 IEEE Instrumentation and Measurement Technology Conference, IMTC /94, May 10-12, 1994, Hamamatsu Japan, Vol.2 PP 353-356.
14. N. N. Tadros. "A Measuring System for the Improved Accuracy of one-Ohm Standard Resistance Measurement". Jl Egyptian Society of Engineers, Vol.29, No 4, 1990, PP 30-33.
15. Abla H. Abd El Rahman, "Determination of the Resistance Scale Accuracy in A.R.E" J.Egyp Soc. Eng.,Vol I.,No.3 pp.59-66.,1972.

4.3 Low Frequency Impedance

4.3.1 M. Helmy A. Raouf et al., "Measurement of Capacitance and Resistance Using Two Perfectly Synchronized Voltage Sources", Measurement, Vol. 60, PP. 174 – 177, January 2015.

A programmable bridge has been constructed by using two arbitrary waveform generators and DVM as a null-detector for capacitance and resistance measurements. Methodology of this bridge has been introduced demonstrating the best way to get accurate ratio measurements up to the accuracy level of 10^{-5}. Our bridge has been used, through this research, to get resistance to resistance and capacitance to resistance ratios at different frequencies. It has been used to measure resistance to resistance ratio (R-R) as well as capacitance to resistance ratio (C-R), at 1592 Hz. A reasonable agreement between the resistance ratio measurements has been noticed through the performed comparisons with the currently used IVD bridge at 1 kHz. The relative bridge asymmetry error is in the order of 10^{-7} with high quality measured standards. Measurements repeatability using this reliable bridge is less than 2.6 ppm on the average, while the evaluated expanded uncertainty is less than 11 ppm, for both in – phase and quadrature – phase measurements.

4.3.2 M. Helmy A. Raouf, and Rasha S. M. Ali, "Study the Performance of the AC/DC Resistors During Their DC and AC Measurements", MAPAN-Journal of Metrology Society of India, Vol. 31, No. 3, PP. 219 – 224, September 2016.

Some of traceability chains for the ac resistance measurements are based on ac/dc resistors. Performance of two types of them with different values has been investigated for their optimum utilization. Tinsley and Cambridge ac/dc resistors have been measured as dc resistors using different measurement methods and as ac resistors at various frequencies. DC direct method using digital reference multimeter is more accurate for the resistance values 1 Ω, 10 Ω, 100 Ω, and 1 kΩ. While the results obtained for the values 10 kΩ and 100 kΩ are very near by using the dc direct and ratio techniques. The 100 mΩ resistor could be measured very precisely using DCCB than V-I method. The resistors frequency dependence has been obtained and illustrated using R_s and R_p functions of an accurate LCR meter.

4.3.3 M. Helmy A. Raouf, "Fully Automated Capacitance Measurement System Using New Precise Capacitance Box", IEEE Conference on Precision Electromagnetic Measurements, (CPEM 2016 Digest), PP. 390-391, Ottawa, Canada, 10-15 July 2016.

A new accurate capacitance box has been demonstrated to be used for calibration of capacitance measurement devices. The introduced capacitance box has been established by twelve capacitors connected to their corresponding twelve reed relays and controlled by only one micro-controller. 1666 different capacitance values, with minimum number of internal capacitive elements, could be produced by this new capacitance box compared to 1111 steps that are produced by the ordinary corresponding box. The presented capacitance box has relative accuracy in the range from $\pm 5\times10^{-5}$ to $\pm 5\times10^{-4}$. A fully accurate automated capacitance measurement system has been constructed and used for the first time at NIS, Egypt, by using the new fabricated capacitance box and completely controlled by a specially designed LabVIEW program. Full specifications of this capacitance box will be presented in details, through an extended paper, including its voltage and frequency dependence, long-term stability and uncertainty calculations.

4.3.4 Some of the Key Publications and Patents

1. **M. Helmy A. Raouf, "Decade Capacitance Formed by Minimum Number of Elements", Ministry of Higher Education and Scientific Research, Patent Office, Cert. No. 24446, July 2009.**
2. **M. Helmy A. Raouf, "Automated Decade Capacitance of Fifteen Output Values", Ministry of Higher Education and Scientific Research, Patent Office, Cert. No. 26040, December 2012.**
3. **M. Helmy A. Raouf, "Decade Inductance Formed by Minimum Number of Elements", Ministry of Higher Education and Scientific Research, Patent Office, Cert. No. 24447, July 2009.**
4. **M. Helmy A. Raouf, "Automated Decade Inductance of Fifteen Output Values", Ministry of Higher Education and Scientific Research, Patent Office, Cert. No. 26576, March 2014.**
5. **M. Helmy A. Raouf et al., "Measurement of Capacitance and Resistance Using Two Perfectly Synchronized Voltage Sources", Measurement, Vol. 60, PP. 174 – 177, January 2015.**
6. **M. Helmy A. Raouf, and Rasha S. M. Ali, "Study the Performance of the AC/DC Resistors During Their DC and AC Measurements", MAPAN-Journal of Metrology Society of India, Vol. 31, No. 3, PP. 219 – 224, September 2016.**
7. **M. Helmy A. Raouf,"Manual/Automated Capacitance Box Using Micro - Controller Technique", MAPAN-Journal of Metrology Society of India, Vol. 26, No. 2, PP. 105 – 113, June 2011.**
8. **M. Helmy A. Raouf, A. Eliwa Gad, S. Soliman, and M. A. Elwany, "Electrical Characterization of a New Established Inductance Box Using an Automated Measurement System", International Journal of Engineering and Applied Sciences, IJEAS, Vol. 2, No. 8, PP. 83-86, Aug. 2015.**
9. **M. Helmy A. Raouf, "Manual / Automated Inductance Box Using Micro - Controller Technique", Journal of Al-Azhar University Engineering Sector, JAUES, Vol. 5, No. 3, PP. 114-124, December 2010.**
10. **M. Helmy A. Raouf, "Fully Automated Capacitance Measurement System Using New Precise Capacitance Box", IEEE Conference on Precision Electromagnetic Measurements, (CPEM 2016 Digest), PP. 390-391, Ottawa, Canada, 10-15 July 2016.**
11. **M. Helmy A. Raouf, "Design of a Universal Circuit for Generation of Impedance Standards", IEEE Conference on Precision Electromagnetic Measurements, (CPEM 2014 Digest), PP. 94-95, Rio de Janeiro, Brazil, 24-29 August 2014.**
12. **M. Helmy A. Raouf, Kyu-Tae Kim, Dan Bee Kim, and Mun-Seog Kim, "A Simple Double-Balance Impedance Bridge for Routine Calibrations", IEEE Conference on Precision Electromagnetic Measurements (CPEM 2012 Digest), PP. 716-717, Gaylord National Resort, Washington DC, USA, 1-6 July 2012.**

4.4 AC/DC Voltage and Current

4.4.1 Rasha S. M. Ali, "New internal multi-range resistors for ac voltage calibration by using TVC", Measurement Science and Technology Journal, Vol. 26, No. 10, Oct. 2015.

Accurate calibration of ac voltages up to 1000 V by using thermal converters requires range resistors connected in series with the converter. In this work, multi-range internal range resistors are designed and implemented at NIS to cover the ac voltage ranges from 10 V to 750 V. Six range resistors are mounted in series with a single-junction thermo-element in the same box to provide a new thermal voltage converter (TVC). The advantage of the internal range resistors combined with the thermo-element is the removal of the contact resistance between the range resistor connector and the thermo-element connector. It also protects the connector from wear due to repeat connection cycles. The implementation of multi-range internal range resistors limits the number of TEs and reduces the cost. The required range resistor is selected by using a 6-pin selector switch. The new TVC ranges are automatically calibrated against other standard TVCs at different frequencies by using a LabVIEW program to determine their ac-dc transfer difference at each range. It is found that the frequency dependence of the new TVC by using the new internal range resistors is good especially at the frequencies up to 20 kHz for higher ac voltages due to smaller distributed capacitances and inductances.

4.4.2 Rasha S.M. Ali, and M. Helmy A. Raouf, "Improved Automated System for AC Voltage Calibrations Using Extending Range Resistors", MAPAN-Journal of Metrology Society of India, Vol. 32, No. 1, PP. 39 – 42, March 2017.

In this work, some improvements are presented to the previously introduced automated multi-range multipliers system. In this old system, these multipliers; range resistors are selected automatically by using electronic relays controlled by a micro-controller that connects the suitable multiplier to the thermal voltage converter to calibrate the required ac voltage. The modifications done on the old system are mainly in used resistors and connectors. The ac-dc transfer differences for the improved and the old multipliers systems combined with the same thermal converter are determined automatically against another standard thermal voltage converter. The obtained ac-dc differences results and their repeatability; Type A for both systems are compared to evaluate the performance of the new one. The improved system achieves relatively very small ac-dc differences in the 200 V range at the various frequencies. The results show that the improved system is more precise and reliable than the old one in ac voltage calibrations especially in the high voltage and frequency ranges. This improvement is occurred because of the frequency effect compensation due to reducing the reactance of the new system structure.

4.4.3 Hala A. Mageed, Rasha S. M. Ali, N. N. Tadros, M. M. Halawa, "Italy-Egypt Inter-laboratory Comparison for Precise Generating Low-Level ac Voltage" , MAPAN-Journal of Metrology Society of India, Vol. 29, No. 3, pp. 175-181, Sept.2014.

The paper describes an interlaboratory comparison program between the National Institute of Standards (NIS), Egypt and the Istituto Nazionale di Ricerca Metrological (I.N.Ri.M.), Italy for measuring low ac voltages. The aim of this program is to demonstrate the technical competence of both institutes. The interlaboratory comparison has been carried out under the framework of the executive program of scientific and technological cooperation between Italy and Egypt. A Fluke model 792A has been used as a travelling standard, which was calibrated against the reference standard of NIS and I.N.Ri.M. at 10, 20, 50, 100 and 200 mV at 40 Hz, 1 kHz, 10 kHz and 20 kHz. The standards of

the two institutes, NIS and I.N.Ri.M., have been used to calibrate the traveling standard at 10, 20, 50, 100 and 200 mV at frequencies of 40 Hz, 1 kHz, 10 kHz and 20 kHz. The ac–dc transfer difference results of the traveling standard are evaluated then compared at the intended frequencies. The comparison results and the efficiency test En values show a good agreement between the NIS and the I.N.Ri.M. systems in assigning ac–dc transfer difference for the ranges 200, 100 and 50 mV at 40 Hz, 1 kHz, 10 kHz and 20 kHz. However, there is disagreement between the results of 20 and the 10 mV at 10 and 20 kHz, due to the inductive errors in the NIS radial resistors, which has a great effect on the higher frequencies. So, in the near future a corrective action will be taken for NIS µPots at the high frequencies to overcome this effect of high inductance. Such as using resistors independent of frequency and have lower skin effect. Furthermore, the output connector should be connected to the circular resistors with a precise mounting that assures the almost perfect coaxial distribution of the input current.

4.4.4 Some of the Key Publications

1. **Rasha S. M. Ali, "New internal multi-range resistors for ac voltage calibration by using TVC", Measurement Science and Technology Journal, Vol. 26, No. 10, Oct. 2015.**
2. **Rasha S.M. Ali, and M. Helmy A. Raouf, "Improved Automated System for AC Voltage Calibrations Using Extending Range Resistors", MAPAN-Journal of Metrology Society of India, Vol. 32, No. 1, PP. 39 – 42, March 2017.**
3. **Mamdouh Halawa, A. Hassan, El-Sayed Shehab, El-Sayed Refai, "Integrated Calibration System for Accurate AC Current Measurements up to 100 kHz", MAPAN- Journal Metrology Society of India, July 2012.**
4. **Hala A. Mageed, Rasha S. M. Ali, N. N. Tadros, Mamdouh M. Halawa, "Italy-Egypt Inter-laboratory Comparison for Precise Generating Low-Level ac Voltage" , MAPAN-Journal of Metrology Society of India, Vol. 29, No. 3, pp. 175-181, Sept.2014.**
5. **Mamdouh Halawa and M. Rahal "A Step-Down Technique to Calibrate AC Current down to 10 µA Using a Precision 10 mA Current Shunt", MAPAN, Journal Metrology Society of India, Sept. 2012.**
6. **Rasha S.M. Ali, and M. Helmy A. Raouf, "Establishment of Automated Multi-Range Multipliers Combined with TVC", Journal of Measurement Science and Instrumentation, Vol. 2, No. 3, PP. 297-299, September 2011.**
7. **H. A. Mageed, A. Zobaa, M. Helmy A. Raouf, A. Hosni, and M. A. Aziz, "An Improved Design of a Fully Automated Multiple Output Micropotentiometer", Energy and Power Engineering Journal, Vol. 2, No. 2, PP. 103 – 110, May 2010.**
8. **H. A. Mageed, A. Zobaa, M. Helmy A. Raouf, A. Hosni, and M. A. Aziz, "Temperature Effects on the Electrical Performance of Large Area Multicrystalline Silicon Solar Cells Using the Current Shunt Measuring Technique ", Engineering Journal, Vol. 2, No.11, PP. 888–894, November 2010.**
9. **Rasha S. M. Ali, "Comparison between Two Different Designs in the AC Voltage Measurement" Measurement, Vol. 44, Issue 9, pp. 1539-1542, November 2011.**
10. **H. A. Mageed, A. Zobaa, A. Ghitas, M. Helmy A. Raouf, M.Sabry, A. Hosni, and M. A. Aziz, "Electrical Performance Study of a Large Area Multicrystalline Silicon Solar Cell Using a Current Shunt and a Micropotentiometer", Engineering Journal, Vol. 2, No. 4, PP. 263 – 269, April 2010.**
11. **CPEM2014: Lucas Di Lillo, Thomas Lipe, Sara Campos, Alfredo Spaggiari, Peter Filipsky, Renata Vasconcellos, Mamdouh Halawa "SIM.EM-K12 AC-DC Current Transfer Difference" Aug. 2014.**

12. **Rasha S. M. Ali, “The Effect of Changing the Applied Sequence Using the TVC on the Accuracy of the AC Signal Calibration”, Sensors and Transducers, Vol. 153, Issue 6, PP. 155-160, June 2013.**
13. **Rasha S. M. Ali, “AC Current automatic calibration using two different TCC designs”, Journal of Measurement Science and Instrumentation, Vol. 4, No. 3, PP. 205-209, September 2013.**
14. **Rasha S. M. Ali, "Automatic Determination of the Thin-Film Multijunction Thermal Voltage Converter Parameters ", CMEM Conference, Spain, 2-4 July 2013.**
15. **Mamdouh Halawa and Shereen M. El-Metwally, "Investigation of Two Different Techniques for Accurate Measurements of Sinusoidal Signals", International Journal of Engineering and Technology (IJET), Vol 5 No 1 Feb-Mar 2013.**
16. **Rasha S. M. Ali, Hala A. Mageed , N. N. Tadros "Automated Multimeter Method for the Scaling of low AC Voltage from 200 mV to 2 mV" , Energy and power Engineering (EPE) Journal, 2013, 5,129-134.**
17. **Mamdouh Halawa, “Implementation and Verification of Building-up AC-DC Current Transfer up to10A”, "IJEET", International Journal of Electrical Engineering & Technology, Vol. 3, No. 2. July 2012.**
18. **Mamdouh Halawa, “Achievement of AC Voltage Traceability and Associated Uncertainty of NIS, Egypt through Capabilities of NIST, USA”, ISDE, USA, Innovative Systems Design and Engineerin, Vol. 3, No. 6, July 2012.**
19. **Rasha Sayed, Mamdouh M. Halawa, Mohamed Abd-latif Badr, Ibrahim Saad, "Automatic calibration and Confirmation of Modified Designs Thermal Voltage Converters", Second Arabic Conference for the Measurement and Calibration, Damascus, Syria, 3-5 November 2009.**
20. **Mamdouh Halawa and Najat Al-Rashed, “Performance of the Single Junction Thermal Voltage Converter at 1 MHz via Equivalent Circuit Simulation” Journal of Cal. Lab. USA Sep. 2009.**
21. **M. A. Badr, Ibrahim M. H. Saad, Mamdouh M. Halawa, and Rasha S. Attiya, "Characterization and Electric Simulation of Modified Designs for the Thermal Voltage Converters", Al-Azhar Univ. Eng. Journal (AUEJ), Vol. 5, Oct. 2008.**
22. **Ara Haroutunian1, Mamdouh Halawa, A. Hassan, R. Attyia and H. A. Mageed “Comparison Of The Technical Performance For Different Designs Of Single Junction Thermal Converters” CPEM-2008 Boulder, USA, June 2008.**
23. **Mamdouh Halawa and Ahmed Husien, “Improvement and Confirmation of a New Automatic System for AC-DC Calibration at NIS, Egypt” Symposium of Metrology, Mexico, Oct. 2006.**
24. **Mamdouh Halawa and I. Sad, “A New Thermal Current Converter for Accurate AC Current Measurements at NIS, Egypt,” Al-Azhar Univ. Eng. Journal (AUEJ), Vol. 6, Jan. 2003.**
25. **Mamdouh Halawa and Abla Hosni, “Influence of Accuracy of the DC Side on the AC-DC Differences of Micropotentiometers,” Ain Shams Univ. Eng. Journal, Dec. 2002.**
26. **Mamdouh Halawa, Abdel-Latif Badr and I. Sad, “An International Comparison of AC Voltage and Current between IEN, Italy and NIS, Egypt,” Al-Azhar Univ. Eng. Journal (AUEJ), Vol. 5, N. 4, Oct. 2002.**

4.5 High Voltage, Power & Energy

4.5.1 This Lab has Primary Standard of Power & Energy Measurements (2100B) which is designed to generate voltages up to 600 V and currents to 100 A at any power factor. This device can calibrate power meters, energy meters, power transducers and all VA measurements. Recently in 2017, the Lab Staff had a training for two weeks on the operation and the Uncertainty Calculations of this device by the TÜBİTAK UME, Turkey. EU funded twinning project.

4.5.2 Hala M Abdel Mageed, Ali M El-Rifaie, Omar M Aladdin, "Traceability of DC high voltage measurements using the Josephson voltage standard", Measurement, Vol. 58, pp. 269-273, Dec. 2014.

This paper introduces a new methodology for obtaining high voltage DC measurements traceability to the International System of Units at NIS. The traceability has been achieved via the NIS automated 10 V DC Josephson Voltage Standard (JVS). A 100 kV DC voltage divider with a nominal voltage ratio of 10,000:1 is being used with its display in parallel with a high sensitive digital voltmeter. The traceability has been realized by calibrating this digital voltmeter via the JVS system and then it has been used to calibrate the divider display readings. Moreover, the divider ratio has been accurately calibrated using a traceable calibrator source on its high voltage side and the calibrated digital voltmeter on its low voltage side. Accurate and traceable high voltage values have been obtained associated with their expanded uncertainties. Enhanced uncertainty results have been attained using this calibration methodology. The expanded uncertainty has a maximum value of 0.06% for the low range measurements (1–10 kV), while it decreases to about 0.05% for the high range measurements (20–100 kV).

4.5.3 Ali M El-Rifaie, Hala M Abdel Mageed, and Omar M Aladdin, "Enhancement of AC high voltage measurements' uncertainty using a high voltage divider calibration method", International Journal of Metrology and Quality Engineering, Vol. 6, No.2, 2015.

A high voltage divider calibration technique has been used to enhance the uncertainty of high voltage AC measurements up to 100 kV at NIS. Traceability of the AC high voltage measurements to SI units has been obtained as well. The KVM100 divider and display have been automatically calibrated using specially constructed LabVIEW programs. Applying the actual turn's ratio, the actual values of the Phenix-KVM100 readings as well as calibration uncertainties have been automatically calculated and stored in the prepared excel sheets. The relative expanded uncertainties for the voltage ranges do not exceed 0.05% of their values. These relative expanded uncertainties have been decreased to 0.01% at the higher ranges. Improved uncertainty results have been attained using this automatic calibration methodology.

4.5.4 Key Publications

1. **Hala M Abdel Mageed, Ali M El-Rifaie, and Omar M Aladdin, "Traceability of DC high voltage measurements using the Josephson voltage standard", Measurement, Vol. 58, pp. 269-273, Dec. 2014.**
2. **Ali M El-Rifaie, Hala M Abdel Mageed, and Omar M Aladdin, "Enhancement of AC high voltage measurements' uncertainty using a high voltage divider calibration method", International Journal of Metrology and Quality Engineering, Vol. 6, No.2, 2015.**
3. **Ali M El-Rifaie, Hala M Abdel Mageed, and Omar M Aladdin, "Traceability of AC High Voltage Measurements up to 100 kV at NIS," Recent Advances in Civil Engineering and Mechanics, WSEAS Congress, pp.272-275, Oct. 2015.**

4.6 RF & Microwave

4.6.1 The primary standard is realized by a type-N twin-load coaxial microcalorimeter setup, which is being operated in the frequency range 10 MHz to 18 GHz and power range 1 mw to 10 mw. Microcalorimeter, which is used for effective efficiency measurement of thermistor mounts, is the primary level measurement system of the microwave power measurements. At these measurements, in addition to the power measurement from a power meter using a thermistor mount, temperature change due to the power loss of a thermistor mount is measured as voltage. Effective efficiency is calculated from these two measurements. The expanded uncertainty of the measured effective efficiency using this setup is 2.9 mW/W.

4.6.2 Yaser S. E. Abdo, and Murat Celep, "New Effective Coaxial Twin-Load Microcalorimeter System", Conference on Precision Electromagnetic Measurements, CPEM, July 2016.

This paper describes a new coaxial twin-load microcalorimeter, which was designed and fabricated to be installed at the national metrology institute of Egypt (NIS). Each component of the microcalorimeter measurement setup was measured and characterized separately to ensure its performance. The effective efficiency of a type-N thermistor mount at different frequency points was measured using the designed microcalorimeter setup. A comparison between these measured values and the corresponding effective efficiency measured by the microcalorimeter setup of the national metrology institute of Turkey (TÜBİTAK UME) was done to validate the accuracy of the new setup.

4.6.3 International Project, EMPIR -15RPT01 (RFMicrowave): "Development of RF and microwave metrology capability", which is funded by the European Union's Horizon 2020 research and innovation programme. The overall objective of this project is to improve the European measurement and research capability for RF&MW metrology and to establish a basis for future cooperation between European NMIs. This will enable less developed European NMIs to build necessary research capacity, as well as improving their calibration and measurement capabilities (CMCs) and reducing the increasing technological gap between NMIs.

4.6.4 Key Publications

1. **Yaser S. E. Abdo, and Murat Celep, "New Effective Coaxial Twin-Load Microcalorimeter System", Conference on Precision Electromagnetic Measurements, CPEM, July 2016.**
2. **D. A. Abd El-Aziz, T. G. Abouelnaga, E. A. Abdallah, M. El-Said, Yaser S. E. Abdo, "Analysis and Design of UHF Bow-Tie RFID Tag Antenna Input Impedance", Open Journal of Antennas and Propagation, vol. 4, pp. 85-107, 2016.**
3. **Yaser S. E. Abdo, M. R. Chaharmir, J. Shaker, Y.M.M. Antar, "Detailed Study of Millimeter Wave EBG Guide: Broadbanding Techniques, Modal Structure, and Crosstalk Behavior", Progress in Electromagnetics Research B, vol. 50, pp.141-156, 2013.**
4. **Yaser S.E., Ahmed M. Attiya, "Modified Two-Probe Approach for Amplitude Only Near-Field Measurements", Microwave and Optical Technology Letters (Wiley InterScience), vol. 41, no.4, pp.270-273, May 2004.**

5. List of Common Publications

1. Tamer Abd Elrehim, and M. Helmy A. Raouf, "Simulated System for Sensitive Laser Ultrasonic Detection by CFP Based on Power Amplification Using Laser Injection Locking", Optics and Lasers in Engineering, Vol. 53, PP. 6 – 11, February 2014.
2. Tamer Abd Elrehim, and M. Helmy A. Raouf, "Detection of Ultrasonic Signal Using Polarized Homodyne Interferometer with Avalanche Detector and Electrical Filter", MAPAN-Journal of Metrology Society of India, Vol. 29, No. 1, PP. 1 – 8, March 2014.
3. Mamdouh Halawa, "Confirmation of the Electrical Measurements Capabilities of the National Institute for Standards (NIS), Egypt'', CPEM-2006 Torino, Italy, July 2006.
4. Shady HE Abdel Aleem, Ahmed F Zobaa, Hala M Abdel Mageed, "Assessment of energy credits for the enhancement of the Egyptian Green Pyramid Rating System," Energy Policy, Vol. 87, pp. ,407-416, Dec. 2015.
5. M. Helmy A. Raouf, Ahmed khalil, and A. B. Kotb, "Required Capacitance for Wind-Driven and Constant Voltage Self-Excited Reluctance Generator", International Journal of Scientific & Engineering Research, Vol. 7, No. 10, PP. 1604 – 1609, October 2016.
6. H. A. Mageed, Ali El Rifaie, "Electrical Quantities in Terms of the International System of Units," World Congress on Engineering 2013 (WCE2013) ,"The 2013 International Conference of Information Engineering", London, UK., 3-5 July, 2013
7. H. A. Mageed, Ali El Rifaie, "Automatic Calibration System for Electrical Sourcing and Measuring Instruments," International Conference on Environment and Electrical Engineering 2013, Wroclaw, Poland, 2-4 May, 2013
8. Mamdouh Halawa, "Estimation of Electrical Characteristics in Equivalent Circuit Model of Non-ideal Potential Transformer", ISDE, USA, Innovative Systems Design and Engineering, Vol. 3, No. 7, Sept. 2012 .
9. N. N. Tadros, "First Egyptian Resistance and Voltage Round Robin Interlaboratory Comparison ".Conference Proceedings of NCSL 2000 International Workshop and Symposium, NCSL 2000, July 16-20, 2000, Toronto – Canada.
10. N. N. Tadros, "Second Egyptian Round Robin Interlaboratory comparison for Electrical Measurements". Conference Proceedings of 2003 Congrès International De Metrologie, October 20-23, 2003, Toulon –France.
11. N. N. Tadros, "International Comparison of Electric Measurands". Physikalisch Technische Bundeesanstalt PTB-Bericht E-60, June 1998, PP 1-30.