

BIPM Capacity Building & Knowledge Transfer Programme

2018 BIPM - TÜBİTAK UME Project Placement

REPORT

Project Name	Radio Frequency and Microwave Power Metrology with Primary Level Measurement and Calibration Using Microcalorimeter Microwave Power Standard
Description	The project placement focused on Radio Frequency and Microwave Power standards, measurement techniques and calibration procedures. There was initial introduction to power principles, concepts and measurements. Discussion on the operating principles of devices and circuits like power dividers, attenuators, couplers, converter, sensors and thermistors was provided. Theoretical and Practical learning of both primary and secondary power level measurement systems, calibrations, uncertainty evaluations, traceability chain and inter-laboratory comparisons.
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MOTIVATION & INTRODUCTION

- Kenya Bureau of Standards (KEBS) is the designated national metrology institute whose mandate is the realization, maintenance and dissemination of SI units. KEBS is planning to establish a primary and secondary level radio frequency (RF) and microwave laboratory to serve the metrological needs of the telecommunications industry.
- There is a need for RF and microwave metrological traceability for power measurements and calibrations. KEBS has RF and microwave power sources, meters, sensors, attenuators and a measurement receiver. In order to be in traceability chain, a calibrated RF signal source, power sensors, power meters, attenuators and power splitters are required for secondary level RF power measurements and the Microcalorimeter Microwave Power Standard is required for primary level power measurements.
- The main objectives of the project was to obtain information on the design and development of the microcalorimeter power standard, high frequency power measurement traceability, determining the effective efficiency measurement of power sensors, inter laboratory power measurement comparisons, and lowering power measurement uncertainties.
- The following topics were delivered both by lectures and through practical demonstration during the two month long project;
 - ✓ Power Meter Measurements and Calibration Set Up.
 - ✓ Power Sensor Measurements, S Parameter Measurements and Calibration Set Up.
 - ✓ Power Sensor Calibration Factor and Effective Efficiency Measurements
 - ✓ Microcalorimeter Microwave Power Standard
 - ✓ Inter Laboratory Comparison for Power Standards
- Radio Frequency and Microwave Power metrology is concerned with traceable measurements and calibration of power sources, meters, sensors, splitters, attenuators, amplifiers, terminations, couplers and thermistor reference standards. The establishment of the microcalorimeter technique enables national metrology institutes to realize primary power level measurements at low uncertainties with the determination of effective efficiency as a function of frequency. Effective efficiency is defined as the ratio of the DC substituted power to the total RF Power dissipated in the power sensor (thermistor mount). Effective Efficiency corrects for power absorbed in parts of the mount other than the detection thermistor elements and DC to Microwave power substitution error in the thermistor mount. It is

a correction factor to compensate losses. Thermistor power sensors are then used as reference or transfer power standards to calibrate diode power sensors.

RESEARCH

Measurement and Calibration

Determining the Effective Efficiency of a Thermistor Mount Sensor Using a Microcalorimeter Microwave Power Standard.

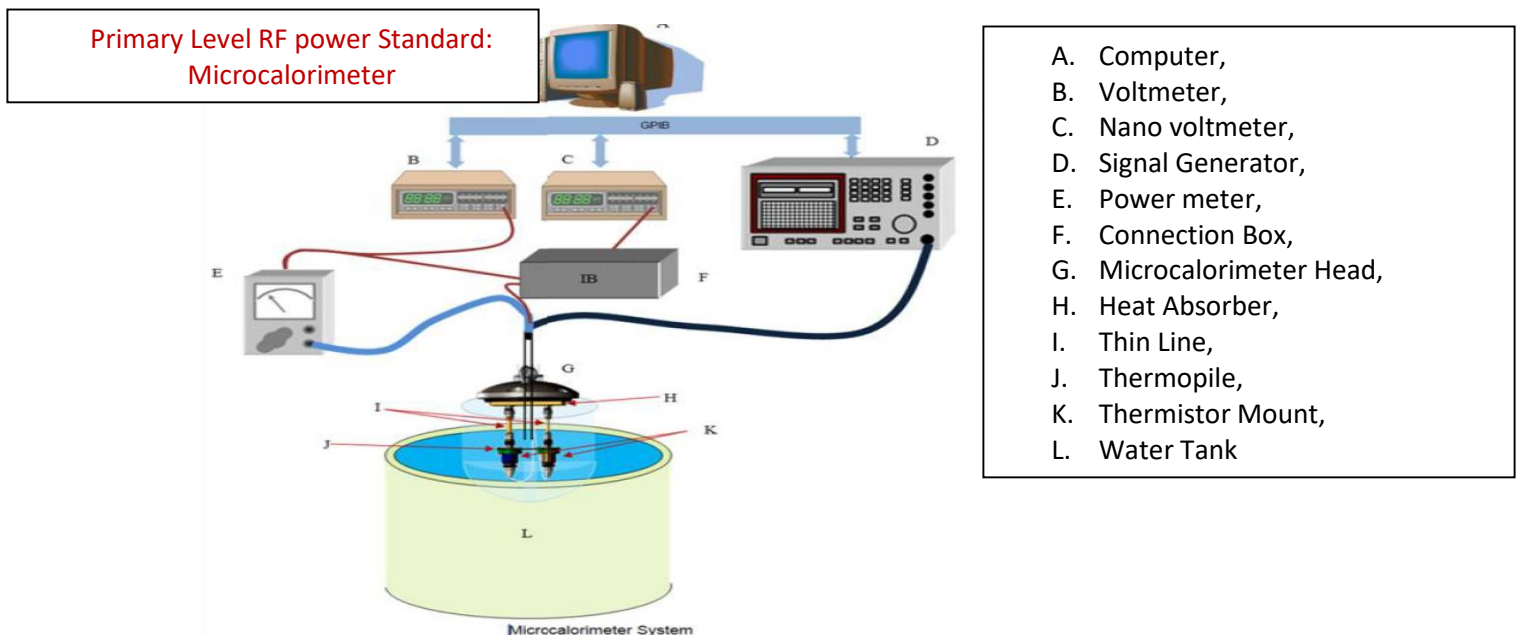
Measurement Standards

Microcalorimeter Head, Thin/Feeding Line, Thermopile, Connection Cables, Signal Generator, Voltmeter, Nano Voltmeter, Wheatstone Bridge, Water Tank and Measurement Software that is internally developed.

Measurement Process

The Microcalorimeter is used simultaneously in conjunction with the Coaxial Reference Standard to measure very small power levels. The level of input power from the signal generator used for the measurement was 10 mW. The coaxial reference standard is referred to as the mount. The main goal is to measure the effective efficiency of the mount. The mount is then dis-mounted and used as a standard in secondary level power meter measurements. The two types of mounts are the bolometer and the thermistor mounts. A thermopile is used to register the amount of heat generated both inside and outside the mount. The ratio of the internal to the external mount power gives the effective efficiency power measurement. The errors associated by the micro calorimeter are quantified and corrected to improve accuracy. (A. Fantom)

Measurement Set Up



Measurement Method

A self-balancing bridge supplies a DC bias so as to maintain the resistance of the bolometer element at a specified value R . Before the commencement of the RF measurement the sensitivity G of the thermopile (Volts/Watt) is determined by noting the rise in the thermopile output voltage when the DC bias power is first applied. When the RF power is switched ON, the power dissipated in the element (RF+ DC) is held constant by the bridge, but power is dissipated additionally in the walls and

elsewhere in the mount, causing an increase in the thermopile voltage. The effective efficiency can be calculated assuming the errors and corrections to be negligible. (A. Fantom)

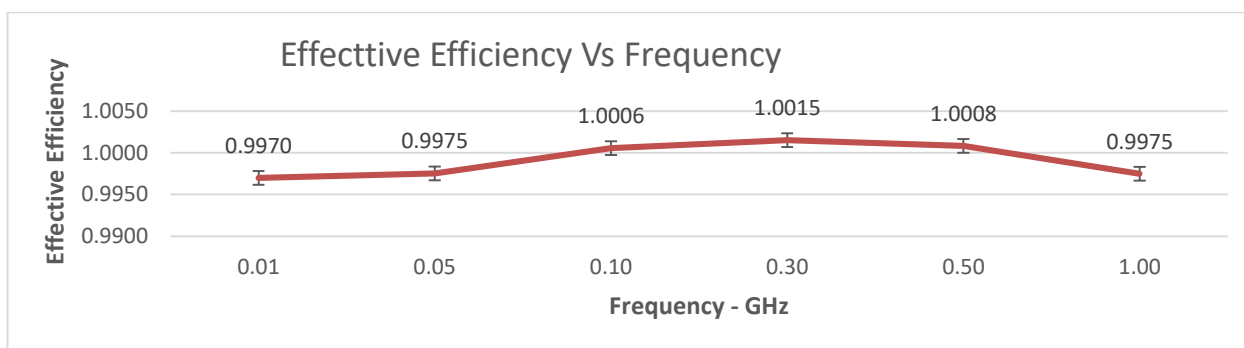
Measurement Errors and Uncertainty

Three main errors are the radio frequency losses in the thermal isolation section, the walls of the reference thermistor mount and the non-linear thermopile response of the microcalorimeter. The uncertainty sources considered are correction factors, repeatability, self-balancing bridge, voltmeter, nano-voltmeter, resistance, thermopile linearity, power level, connectors, signal generator harmonics, thin line and reflection coefficient of the thermistor power reference/transfer standard.

Measurement and Calibration Results

The table shows effective efficient and reflection coefficient with uncertainty. The plot shows the effective efficiency with the uncertainty bars for the frequency range 0.01 GHz to 1.0 GHz. The signal generator power level was 10 mW.

Set Frequency (GHz)	Effective Efficiency (%)	Measurement Uncertainty (%)	Reflection Coefficient	Measurement Uncertainty
0.01	0.9970	± 0.002236	0.0588	± 0.0041
0.05	0.9975	± 0.002237	0.0129	± 0.0040
0.1	1.0006	± 0.002237	0.0086	± 0.0040
0.3	1.0015	± 0.002236	0.0096	± 0.0040
0.5	1.0008	± 0.002235	0.0132	± 0.0040
1.0	0.9975	± 0.002232	0.0230	± 0.0040



Findings on Results

The effective efficiency value is between 0.9974% to 1.0015% and a consistent uncertainty of ± 0.002232 to ± 0.002237 . The reflection coefficient values are in good agreement with manufacturer specifications of 0.273 (0.01 to 0.03 GHz), 0.15 (0.03 to 0.1 GHz) and 0.048 (0.1 to 1 GHz) while the effective efficiency values are within acceptable limits for the thermistor mount.

Conclusions on Results

The automated coaxial microcalorimeter used as the primary level measurement system has confidently provided accurate and reliable results for determining the effective efficiency of the reference thermistor standard at selected frequencies.

Recommendations on Results

Since this is a key technique for the realization and traceability of RF and microwave primary power, the microcalorimeter system requires a maintenance program of comparing current and previous calibration results to provide quality assurance.

Implementation of Results

Microclorimeters are not available commercially and this will need consultancy from leading national metrology institutes like TUBITAK UME who operate and have the experience to design and develop such systems. The end user laboratory must provide specifications for the type of connector, power sensor, input power, frequency band, detection and software needed.

International Aspects of Metrology and Guides to CIPM MRA Participation

There is need for understanding and agreements of international collaboration to enhance the definition and realization of SI units, establishment of measurement standards and their degree of equivalence including laboratory accreditation schemes. The guidelines mentioned on the calibration measurement capabilities, measurement comparisons and quality systems do provide the opportunity for development of national metrology institutes in facilitate improvements to quality of life and increases in international trade.

CONCLUSIONS AND FUTURE WORK

The objectives of the training were all achieved. I learnt about the measurements and calibrations of power sources, meters, sensors, splitters, attenuators, amplifiers, terminations, couplers, thermistor mounts and primary standards. My strategy for KEBS is to write a clear concept paper and road map on the establishment of radio frequency and microwave power metrology.

ACKNOWLEDGEMENTS

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