International Comparison of WR15 (50 to 75 GHz) Power Measurements among NIST, NIM, PTB and NMC, A*STAR

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***Abstract* — This paper reports preliminary measurement results of an informal international power comparison in WR15 (50 GHz to 75 GHz) waveguide among NIST, NIM, PTB and NMC, A*STAR. The goal of the comparison was to demonstrate the precision measurement capabilities and validate the equivalence of power measurements in WR15 waveguide at participating laboratories.**

***Index Terms* — Comparison, power measurements, standards, uncertainty, WR15, thermistor sensor**

I. Introduction

We have conducted an informal international comparison of WR15 (50 GHz to 75 GHz) waveguide power measurements among the National Institute of Standards and Technology (NIST) of the USA, the National Institute of Metrology (NIM) of China, the Physikalisch-Technische Bundesanstalt (PTB) of Germany, and the National Metrology Centre (NMC) of the Agency for Science, Technology and Research (A*STAR) of Singapore.

The main motivation of this comparison is a desire to demonstrate the precision measurement capabilities and validate the equivalence of WR15 waveguide power measurements at participating National Metrology Institutes (NMIs) which have made recent changes [1-3]. In addition, to our knowledge, the only previous international comparison with same waveguide size was conducted only at 62 GHz [4].

This comparison was piloted by NIM, China, and performed between May 2014 and December 2015. In this paper, preliminary results of the comparison will be reported and briefly discussed.

II. Traveling Standards

[B]Three traveling standards (all are Hughes 45774H-1100 thermistor power sensors[C]) were provided by the NIM, China. The third one was included only for the last round. They are identified as,

1. NIM-1 with S/N 097,
2. NIM-2 with S/N 461, and
3. NIM-3 with S/N 149 (Measured by NIM and PTB only).

It is also noted that after arrival of NIM-1 and NIM-2 at NIST, their flanges were inspected and some rough spots were sanded using very fine sandpaper.

Table 1. Comparison schedule and measured quantities.

NMIs	Period	η_e	K_c
NIM	May 2014, July 2015	NIM-1, 2, 3	NIM-1, 2
NMC	September 2014		NIM-1, 2
NIST	February 2015	NIM-1, 2	NIM-1, 2
PTB	December 2015	NIM-1, 2, 3	NIM-1, 2, 3

In this comparison, the two measurands, effective efficiency η_e and calibration factor K_c were measured from 50 GHz to 75 GHz in 1 GHz steps. The relationship between the effective efficiency and the calibration factor is given by,

$$K_c = \eta_e(1 - |\Gamma|^2)\,. \quad (1)$$

Here, $|\Gamma|$ is the magnitude of input reflection coefficient of the traveling standards. Table 1 summarizes the comparison schedule and the measured quantities of each NMI.

III. Measurement Systems and Methodologies

NIST, NIM and PTB performed the measurements using their own microcalorimeters, with η_e measured directly and then converted to the calibration factor K_c using $|\Gamma|$.

NMC, A*STAR applied a *direct comparison transfer* technique [3] for measuring the calibration factor K_c only in this comparison. Their waveguide reference standards are Agilent V8486A power sensors which are calibrated and traceable to the microcalorimeter at the National Physical Laboratory of the UK.

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[C] Identification of commercial equipment does not imply endorsement by the authors or their institutions.

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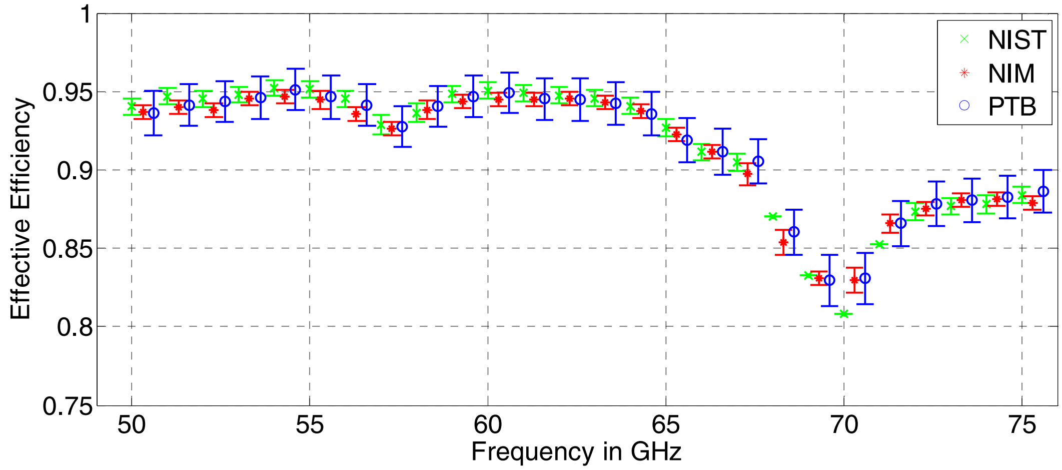

Fig. 1. Preliminary results of η_e for NIM-1. Uncertainty bars are shown for k = 2. Frequency values are shifted for better readability. No uncertainty value provided by NIST for 68, 69, 70 and 71 GHz.

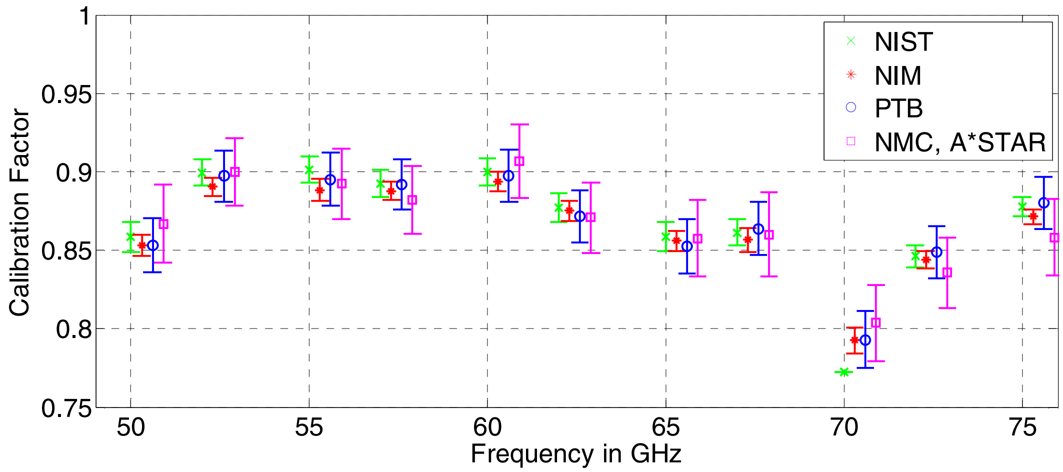

Fig. 2. Preliminary results of K_c for NIM-1. Uncertainty bars are shown for k = 2. Frequency values are shifted for better readability. No uncertainty value provided by NIST for 70 GHz.

In addition to the effective efficiency and calibration factor, the corresponding uncertainties were also given.

IV. Preliminary Results and Analysis

Preliminary results for the traveling standard (NIM-1) at each NMI, together with their expanded uncertainties are shown in Fig.1 and Fig.2. From Fig.1 and Fig.2, it can be observed that generally there are good agreements among the measurement results from each NMI for NIM-1. It is noted that the relative large uncertainty for the calibration factor measured by the NMC, A*STAR is dominated by their reference standards.

However, agreement was not as good for NIM-2 measurements. For NIM-3, there was very good agreement except at two frequencies with large differences. The discrepancies that exist are currently under investigation. More detailed results and analysis for all the traveling standards (NIM-1, NIM-2, and NIM-3) are in process and will be reported later.

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