International Comparison of Ku-band Standard Gain Horn Characterization

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Abstract— International comparison of antenna measurement results between national measurement laboratories supports interoperability of communication equipment in today's world market. The National Institute of Standards and Technology (NIST) is the pilot National Measurement Institute (NMI) for an international comparison measurement of two Ku-band standard gain horn antennas that involved eleven other NMIs. A variety of measurement techniques such as extrapolation, far field, gain transfer and reciprocity, were used in this international comparison. The individual measurement techniques used by each NMI are indicated and the gain measurement results and associated uncertainties from each NMI are presented in this paper.

Index Terms— antenna gain, fixed frequency gain, international comparison, Ku-band, National Measurement Institute.

I. INTRODUCTION

NIST is the pilot lab for an international comparison of standard antennas for the Consultative Committee for Electricity and Magnetism (CCEM) under the Bureau International des Poids et Mesures (BIPM). The CCEM.RF-K23.F is a key comparison measurement of two Ku-band standard gain horns, serial numbers 3935 and 3936 [1]. It involves 12 NMIs; Australia – National Measurement Institute of Australia (NMIA), China – National Institute of Metrology (NIM), Czech Republic – Czech Metrology Institute (CMI), France – Laboratoire national de métrologie et d'essais (LNE), Japan – National Metrology Institute of Japan (NMIJ), Russia – Russian Scientific Research Institute of Physico-Technical Measurements (VNIIFTRI), South Korea – Korea Research Institute of Standards and Science (KRISS), Sweden – Technical Research Institute of Sweden (SP), Switzerland – Federal Institute of Metrology (METAS), Turkey – The Scientific and Technological Research Council of Turkey (TUBITAK-UME), United Kingdom – National Physical Laboratory (NPL), and United States – National Institute of Standards and Technology (NIST). All of the NMIs performed on-axis gain measurements and uncertainty analyses at 12.4, 15 and 18 GHz on the two traveling standards. The comparison was conducted from 2008 to 2013.

II. MEASUREMENT TECHNIQUES

Several different measurements techniques were used by the NMI's. Table 1 lists the measurement techniques used by each NMI.

TABLE I. NMI MEASUREMENT METHODS

Country	NMI	Measurement Method
Australia	NMIA	3 antenna, extrapolation
China	NIM	3 antenna, 7.07 m
Czech Republic	CMI	3 antenna, 2.4, 3.2, 4 m
France	LNE	reciprocity
Japan	NMIJ	3 antenna, extrapolation
Russia	VNIIFTRI	3 antenna, extrapolation
South Korea	KRISS	3 antenna, extrapolation
Sweden	SP	gain transfer
Switzerland	METAS	3 ant., ANSI C63.5-1998
Turkey	TUBITAK-UME	3 antenna, 9m
United Kingdom	NPL	3 antenna, extrapolation
United States	NIST	3 antenna, extrapolation

III. MEASUREMENT RESULTS

Each NMI performed fixed frequency, on-axis gain measurements at 12.4, 15.0 and 18.0 GHz on the two traveling standards. The measurements were made at the waveguide port of the antennas. Each NMI generated a report of their determined gain values and uncertainties that were sent to NIST to be compiled. The reported uncertainties are based on a standard uncertainty coverage factor of $k=2$. As the pilot lab, NIST performed the measurements at the beginning and end of the measurement campaign and has two reported measurement results, NIST 1st and NIST 2nd.

Averages for the gain and uncertainties reported by the NMIs were calculated as weighted averages of the (linear) gain measured by the participants. The weights were chosen as the inverses of the fractional error in gain as reported by the various laboratories [2]. Theoretical gain values for the traveling standards were also computed using the Naval Research Laboratory model [3].

Graphs of the NMIs reported gain results, weighted-average gains, and calculated gains for s/n 3935 and s/n 3936 are shown in Figure 1 and Figure 2, respectively. For ease in viewing, data reported in all of the graphs in this paper have been plotted nominally with respect to the measurement frequency.

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Fig. 1. On-axis gain results for s/n 3935.

Comparison of the compiled results of the NMI's gain values reveals favorable agreement. All of the NMI's reported gain values agree within their reported uncertainty values except gains measured by SP at 18 GHz for both of the traveling standards.

The NMI's reported gain values were also compared to the weighted average gains. It is interesting to note that the weighted-average gain values for the two antennas are nearly identical as a function of frequency. Here all of the NMI's gain values and uncertainties agree with the weighted gain values and uncertainties except gain measured by SP at 18 GHz for one of the traveling standards.

The calculated gain values were also included in the comparison. Theoretical on-axis gain calculation techniques typically do not account for the throat-to-aperture interaction of standard gain horns that can result in a ~ 0.6 dB peak-to-peak oscillation in the gain curve with respect to frequency. The calculated gains for the traveling standards agree within < 0.06 dB of the weighted average gains. An explanation for this remarkable agreement could be that the measurement frequencies are not at the peak of the oscillations on the gain curve.

IV. CONCLUSION

An international comparison of on-axis gain measurements was conducted for BIPM involving 12 NMIs. As the pilot lab, NIST compiled the results. Most of the reported results from

Fig. 2. On-axis gain results for s/n 3936.

the NMIs agree within their reported uncertainties, the weighted-average gain, and calculated gain, including the two separate measurements performed at NIST. Only one gain measurement at 18 GHz, for both traveling standards, by one NMI, did not agree within the report uncertainty.

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