COMPARISON OF MICROWAVE BLACK-BODY TARGET RADIOMETRIC MEASUREMENTS*

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1. ABSTRACT

Accurate characterization of the brightness temperature (T_B) of black-body targets used for calibrating microwave remote-sensing radiometers includes many inputs: antenna pattern and loss, target temperature, target emissivity, mechanical alignment, and radiometric T_B measurements calibrated against physical standards. Here we describe measurements made using several black-body targets with two different antennas within the WR-42 (18 – 26.5 GHz) waveguide band. Uncertainty estimates are also calculated for the retrieved target T_B measurements.

2. INTRODUCTION

Many realizations of microwave brightness-temperature standards exist in the form of heated or cooled calibration targets, but none is maintained as a national standard by a National Measurement Institute (NMI). This is in contrast to the visible and infrared (IR) portions of the spectrum, in which radiance standards exist—and have proven very useful [1]. There are many reasons to want a national microwave brightness-temperature standard based on fundamental physical quantities. It would provide a constant reference for comparison of different instruments over years or decades. Such a stable, accessible reference would benefit programs such as the National Polar-orbiting Operational Environmental Satellite System (NPOESS), which plans to launch multiple copies of the same instruments, as well as studies of long-term phenomena, such as climate monitoring.

As part of NIST's ongoing development work on brightness-temperature standards, we have measured combinations of three different-geometry black-body targets used for calibration and test purposes by NASA Goddard Space Flight Center, with two different antennas, along with our WR-42 radiometer over the 18 – 26.5 GHz frequency range.

3. METHODOLOGY

The measurement methodology used is similar to that described in [2]. All measurements were performed in an anechoic chamber with floor, ceiling, and walls covered with pyramidal carbon-loaded foam absorber. The chamber's reflection coefficient was measured across the WR-42 band with a vector network analyzer (VNA) to confirm that the background reflections are suitably low enough. Two antennas were characterized; the first is a WR-42 standard-gain horn with half-power beam width of approximately thirteen degrees and the second is a conical horn with half-power beam width of approximately eight degrees. Each antenna was first measured on a near-field range at 0.5 degree increments in azimuth and elevation to obtain the near-field and, by transformation, the far-field antenna patterns. The ohmic loss was estimated using calculations based on the antenna's geometry and metal resistivity of the antenna bore.

In the work of [2] we found that one potential source of error in our target T_B measurements is the alignment between the antenna axis and the target. Previously, this alignment was performed using a laser beam aimed along the edge of the antenna. The alignment accuracy of this arrangement wasn't established then, but current estimates are that it could've introduced errors on the order of a degree between the antenna axis and the target center. Recently, we've constructed a rigid frame for mounting the antenna in a manner that allows sighting directly through the antenna bore with an optical theodolite. The target being measured is mounted on a six-axis micropositioner. The target is fitted with a temporary cross-hair "bull's eye" to allow antenna-target alignment. A post-check of the alignment over the entire longitudinal range of the positioner (about 4.5 meters) confirmed that the alignment accuracy is now better than 2 arc-sec, or approximately 2 mm lateral misalignment at 4.5 m range.

Another potential source of error in our previous work was that the η, or fraction of the antenna pattern subtended by the target, was calculated from the far-field antenna pattern, with no correction made for near-field effects [3]. In the present work, we compared our results with and without using a near-field correction.

Three targets were measured with each antenna. The targets each consist of iron-loaded epoxy coating upon a machined aluminum tetrahedral pyramidal substrate with backside heating element and embedded thermometers for temperature control and target monitoring. Two targets were approximately 200 mm in diameter with 3 cm periodic spacing between pyramids. These two targets differ in that one has pyramids of 3 cm height with flat valleys between the bases from the machining process, while the other has pyramids of 5 cm height with sharp valleys at the bases.

We also monitored the background (chamber) temperature during operation. Depending on the target being tested, foam absorber was used to surround the circular target face to reduce unwanted reflections from the backing plate or the positioner. Each target was measured at multiple ranges, from approximately 0.5 m up to 4.5 m between antenna and target, while heated to around 340 K as well as at ambient temperature as a check.

The NIST WR-42 noise-temperature radiometer [2] was used for all T_B measurements. After calibrating the radiometer system, the reflection coefficient and microwave noise temperature of the entire DUT forward of the measurement plane (comprising the waveguide feed, antenna, and chamber with target) is measured. The target brightness temperature is then deembedded and associated uncertainty calculations made.

4. RESULTS

A representative radiometric measurement of one of the three black-body targets with a standard-gain horn attached to the WR-42 waveguide radiometer is shown in Figure 1, with η calculated using a near-field antenna pattern correction. The measured brightness temperature was then compared to the brightness temperature computed from the target physical temperature and approximate emissivity of the target. The final paper will show measurements of all the various antenna-target combinations. The uncertainties associated with the measured and predicted target brightness temperatures are observed to depend on the target size and range, along with the antenna pattern correction used. Areas of potential improvement will be discussed.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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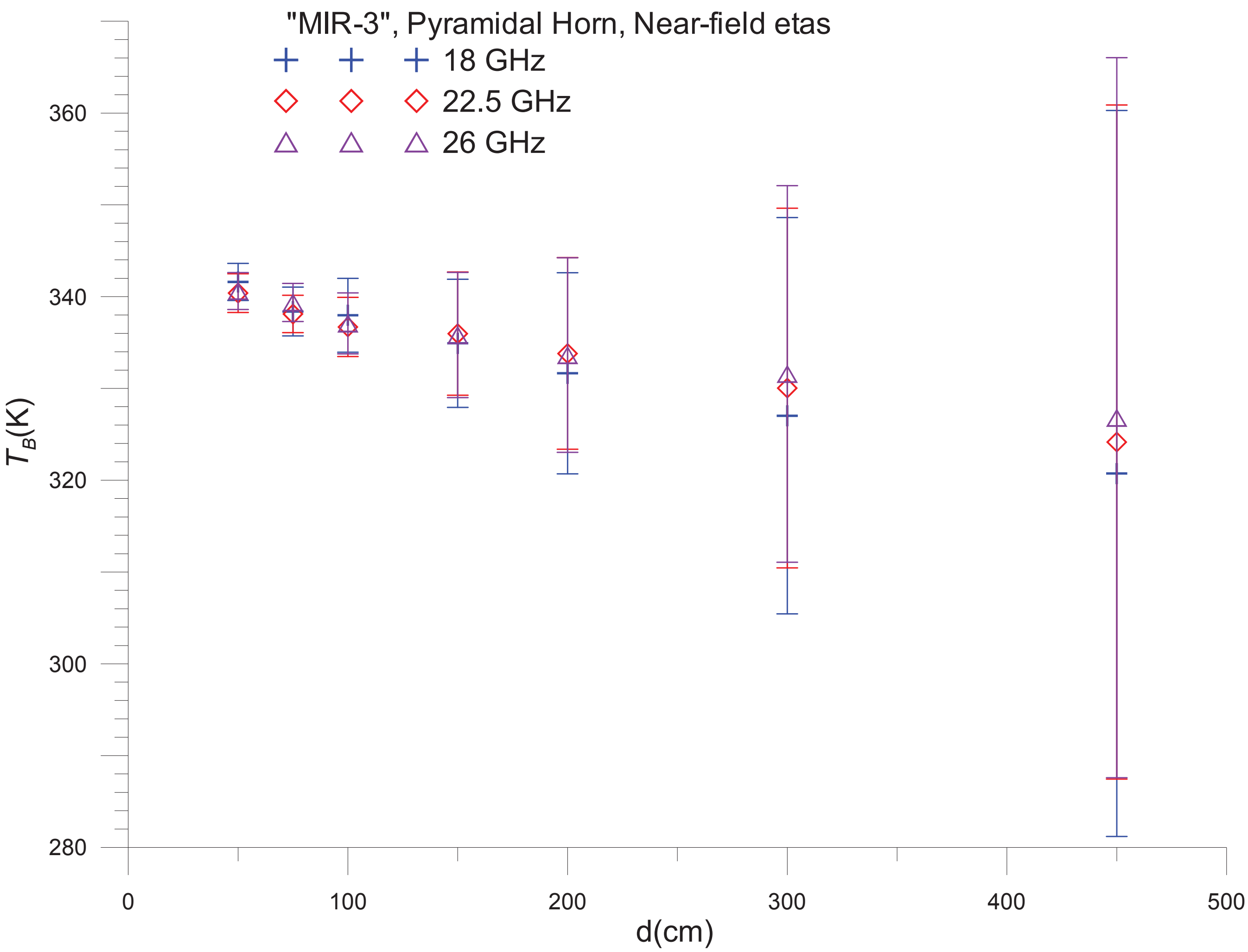

Figure 1. Measured and predicted target temperature vs. distance