REFLECTIVITY STUDIES OF PASSIVE MICROWAVE CALIBRATION TARGETS AND ABSORPTIVE MATERIALS*

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1. ABSTRACT

After an interlude of several years, NIST has recently resumed efforts to develop a primary standard for microwave brightness temperature. The previous work is summarized in [1]. Currently the principal effort [2] is to develop a standard radiometer, traceable to fundamental primary noise standards, but we are also taking steps toward characterizing standard targets. An early step in the characterization of calibration targets is measurement of their reflectivity, and this paper reports initial measurement results for the monostatic reflection coefficient for normal incidence. Such measurements constitute a first step toward measurement of the emissivity of the targets, which also requires full angular information about the scattered and reradiated power (as in [3]). The reflection coefficient at normal incidence is also of interest in its own right, since reflections from the target can have a significant effect on the noise figure of the radiometer if it is not isolated [4].

We measured the reflection coefficient from three different calibration targets at every 0.5 GHz in the range 18 GHz to 26.5 GHz. In addition to the calibration targets, we also measured the reflection coefficient from a flat metal plate, for comparison. Measurements were made for two different ranges of separation distances between antenna and target. The measurements used a pyramidal standard-gain horn connected to a commercial vector network analyzer (VNA). The VNA was calibrated at the input flange to the antenna, and all measured reflection coefficients are with respect to this reference plane. The measurements were performed in the NIST anechoic chamber, which has been well-characterized for use in the 400 MHz to 40 GHz frequency range [5]. The targets were mounted on a precise positioning system that operates over a longitudinal range of approximately 4 meters. The rails and all metallic parts of the cart are covered with rf absorber. The minimum separation distance between antenna and target was dictated by the minimum cart location and the support structure for the target. For the calibration targets, this minimum distance was 36.5 cm; for the metal plate, it was 43.7 cm. The cart position was then scanned from 0 cm to 10 cm and from 225 cm to 235 cm. A photo of the antenna

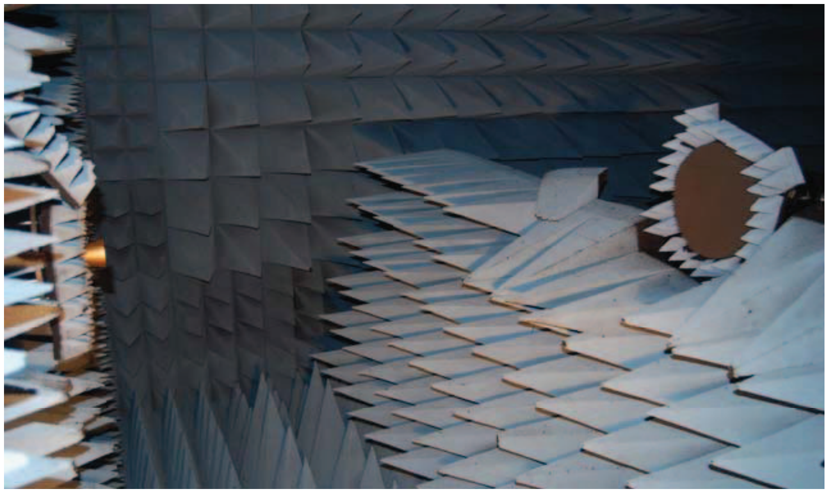
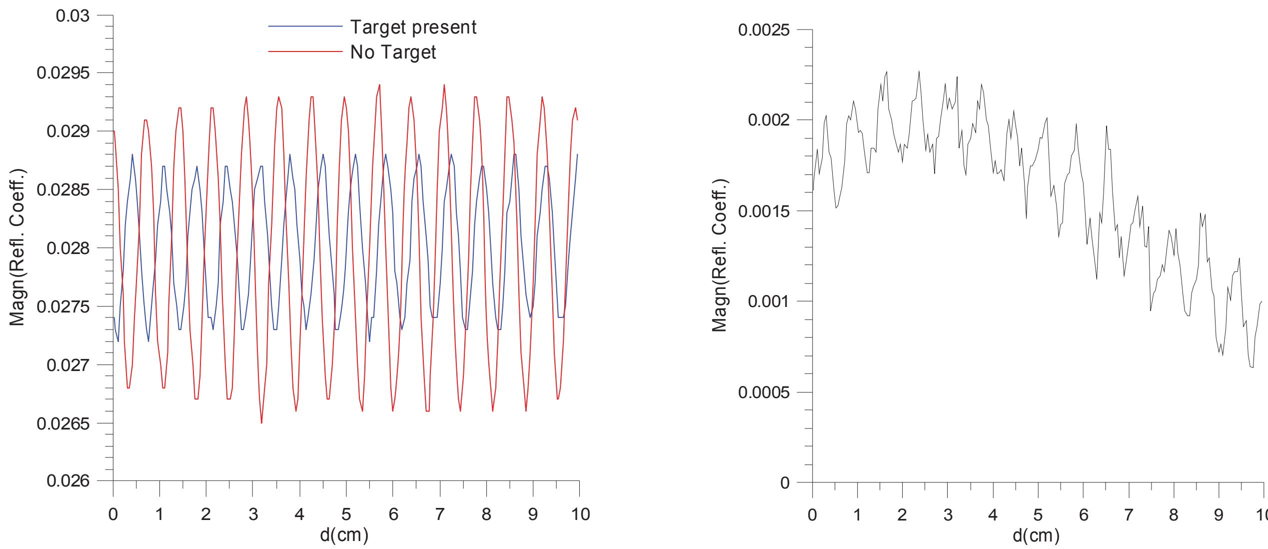


Fig. 1 Measurement setup in anechoic chamber.

and cart, with one of the targets mounted on the cart, is shown in Fig. 1. The three calibration targets were circular discs, two of radius 18.034 cm (7.1 in.), and one of radius 45.72 cm (18 in.), all borrowed from a group at Goddard Space Flight Center. Each target consisted of an iron-loaded epoxy coating on a machined aluminum tetrahedral pyramidal substrate. The two smaller targets differed from each other in the length (and aspect ratio) of the pyramids. Most measurements were performed with the calibration target at ambient temperature (nominally 296.15 K), but for some measurements a heating element was affixed to the back of the target, and the target temperature was raised to approximately 350 K, as measured by platinum resistance thermometers (prt) embedded in the target. (The temperature varied somewhat, depending on prt, target, and time, but it was in the range 349 K to 350 K.)

The calibration target is not the only source of reflections in our measurement setup. Although the anechoic chamber and the cart are designed to minimize any extraneous reflections, they are not perfect, and there will be some small reflections from the cart and the chamber walls. More importantly, the standard-gain antenna is itself a source of reflections, from the junction where waveguide meets flare and from the aperture plane. In order to isolate the reflections due to the target, we measured the reflection coefficient in the absence of any target, for each frequency and separation distance. We then subtracted this "background" reflection coefficient from the reflection coefficient with the target present. All our results are for the magnitude of this complex difference, which is the part of the reflection coefficient due to the target. The background subtraction is critical, because the background is more than an order of magnitude larger than the target contribution. This is illustrated in Fig. 2, which shows results for a representative frequency (22 GHz) and range of separation distances. The distances in the



(a) (b)

Fig. 2(a) Comparison of reflection coefficient with target present and with no target.

Fig. 2(b) Corrected target reflection coefficient.

graphs refer to cart position; the actual separation distance from antenna to target is obtained by adding an additional 36.5 cm. Figure 2(a) plots the magnitude of the uncorrected reflection coefficient with the target absent (background) and with the larger target present (background plus target), and Fig. 2(b) plots the corrected target reflection coefficient (magnitude of the complex difference between target-present and target-absent). Note the different scales in Figs. 2(a) and 2(b). The corrected reflection coefficient lies near or below the VNA manufacturer’s quoted uncertainty for these VNA measurements, which is ± 0.0017. Thus, the results for the corrected reflection coefficient are consistent with zero over much of the range.

Far more data were collected than can reasonably be presented here. Some representative results are shown in Figs. 3 and 4. Figure 3 compares the reflectivity of the larger target for the ambient-temperature and heated cases. Any differences between the two are well below the experimental uncertainty. Figure 4 shows the corrected reflection coefficient from a circular, flat aluminum plate of the same diameter as the larger calibration target. Measurements on the aluminum plate were performed for comparison purposes, and also as exploratory tests on the feasibility of using a reflective metal target as a calibration target for reflectivity measurements. Not surprisingly, the results are two orders of magnitude larger than for the blackbody targets.

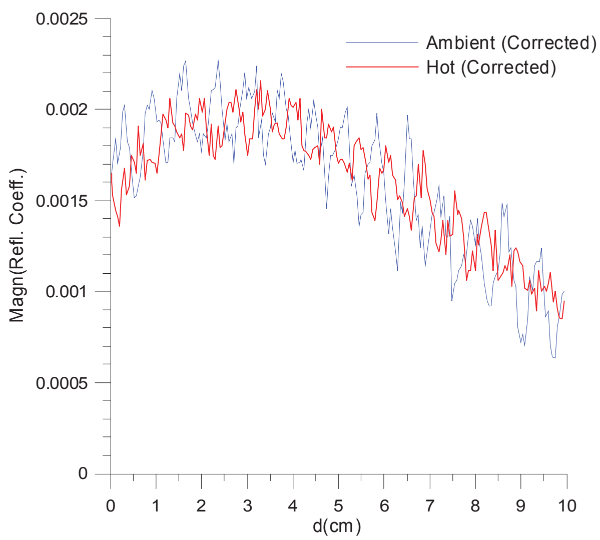


Fig. 3 Comparison of hot and ambient targets.

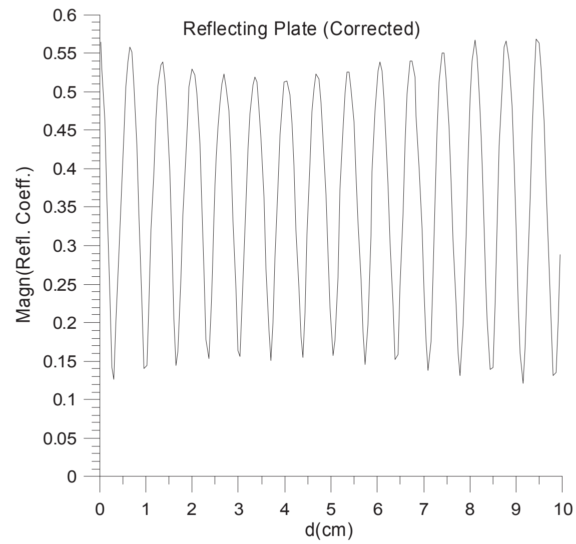


Fig. 4 Results for aluminum plate.

2. REFERENCES

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