COMPARISON OF EXPERIMENTAL TECHNIQUES FOR EVALUATING THE CORRECTION FACTOR OF A RECTANGULAR WAVEGUIDE MICROCALORIMETER

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Abstract

We have evaluated the correction factor of a WR-15 (50 to 75 GHz) rectangular waveguide microcalorimeter with four different techniques. The four methods are in agreement. Our initial uncertainty analysis indicates that the technique with the lowest uncertainty is one that utilized two identical microcalorimeter core sections whose reference planes were connected to each other. This initial uncertainty is smaller than expected, which will require us to re-evaluate uncertainty contributions that were neglected.

Introduction

Microcalorimeters are used as primary standards for microwave power at the National Institute of Standards and Technology (NIST). They are used to measure the effective efficiency of bolometric transfer standards. This is done by measuring temperature differences associated with direct current (DC) power absorption and radio frequency (RF) or microwave power absorption. A key parameter in this measurement is the calorimeter correction factor g which describes the relative response of the microcalorimeter's thermopile to RF and DC power. The thermopile voltage, e is given by:

$$e = k\,(P_{DC} + g\,P_{RF})\,, \qquad (1)$$

where P_{DC} and P_{RF} are the DC and RF powers respectively and k is a proportionality constant. The correction factor has contributions from heat dissipated in different locations and can be expressed as

$$g = aq + br + cs\,, \qquad (2)$$

where q, r, and s are normalized power levels absorbed at the transfer standard termination, transfer standard input section, and microcalorimeter respectively, and a, b, and c are coefficients that describe the relative sensitivity of the thermopile signal to heat dissipated at those same locations. The correction factor is frequently the largest source of error in an effective efficiency measurement, and our motivation for this work was to determine the best technique for evaluating it.

Our measurements were performed with a WR-15 microcalorimeter that will be the United States' national standard for power between 50 GHz and 75 GHz.

Evaluation Techniques

The correction factors for previous rectangular waveguide microcalorimeters at NIST were evaluated using foil shorts placed at the reference plane [1]. Our first technique uses this approach and will be designated FS. The second technique (designated OS) uses an offset short in a manner similar to the FS analysis. We have not performed the type of extensive analysis used with offset shorts in a recent PTB evaluation of a WR-22 microcalorimeter's correction factor [2].

The correction factor of a Type N coaxial microcalorimeter at NIST was evaluated by connecting the reference planes of two microcalorimeters to each other through an adapter [3]. Our third and fourth techniques apply an approach similar to that with the WR15 microcalorimeter. In the third technique (designated 2Ca), a section of straight waveguide that mimics two input sections of a transfer standard is placed between the cores, while in the fourth technique (designated 2Cb), the two microcalorimeter cores are connected directly to each other. The 2Ca technique more closely resembles the coaxial measurement because the adapter in the coaxial case mimics the input section of its transfer standard. We are not aware of any previous work that used a two-calorimeter technique with a rectangular waveguide microcalorimeter.

Developments since previous CPEM

The microcalorimeter design was presented in a previous CPEM summary paper [4]. Between the paper submission and the conference, we improved the geometry of the 2Ca and 2Cb techniques and made measurements with the FS and OS techniques. The new material presented at this conference will be the measurements with the 2Ca and 2Cb techniques, an uncertainty analysis, and a comparison of the four techniques.

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Correction Factor Comparison

A plot of the correction factor, as evaluated by all four measurement techniques, is shown in Fig. 1. The correction factor is approximately 1.01. Representative uncertainty bars for the 2Ca, 2Cb, OS, and FS techniques are shown at 57 GHz, 59 GHz, 61 GHz, and 63 GHz respectively. The different techniques agree within our initial uncertainty limits.

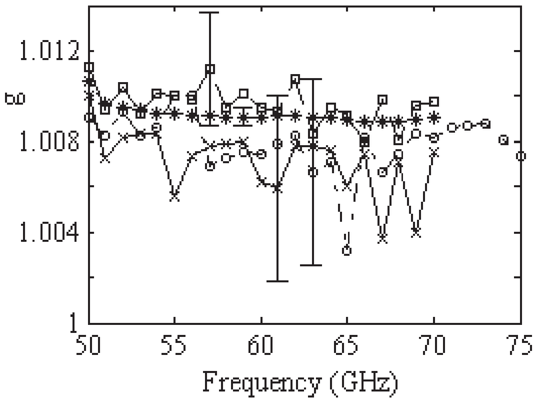

Fig. 1. WR-15 calorimeter correction factor vs. frequency as evaluated by four techniques, 2Ca (squares), 2Cb (*), OS (x), and FS (circles), Error bars are the standard uncertainties from the initial analysis.

Uncertainty

The results of the initial uncertainty analysis are shown in Fig. 2. This analysis included all of the factors that made significant uncertainty contributions in previous WR-42 and 2.4 mm microcalorimeter evaluations. The 2Cb technique has the lowest uncertainty from this analysis. It was several times lower than we expected, and therefore will require us to re-examine contributions from some items that were originally assumed to be negligible. We expect to present the results from our final analysis at the conference.

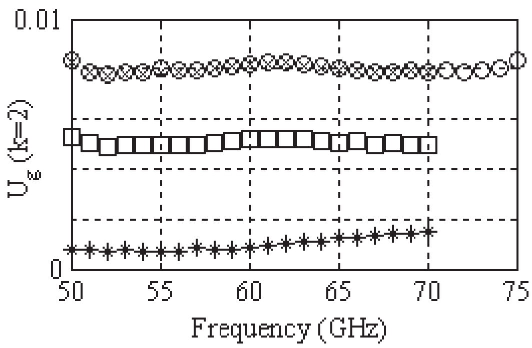

Fig. 2. Expanded (k=2) uncertainty in calorimeter correction factor for four techniques, 2Ca (squares), 2Cb (*), OS (x), and FS (circles). The graph is an initial analysis that will be updated.

The 2Ca and 2Cb techniques differ in how the *br* term in equation (2) is estimated. In the 2Ca technique, it is estimated by assuming that the straight section and the transfer standard behave identically. The straight section's $|S_{21}|$ is needed for the calculation and makes a large contribution to the uncertainty. A comparable term is not present in the 2Cb technique. In that technique, *b* is assumed to be equal to 1. We ignored any uncertainty due to this assumption in the initial analysis, but plan to re-examine that issue.

For the techniques employing shorts (FS and OS), there is RF power dissipated in the shorts that is not present in the microcalorimeter measurement. When evaluating the correction factor, this extra loss must be subtracted out. The uncertainty due to that term is the largest uncertainty in the correction factor evaluation. Since the two-calorimeter techniques (2Ca and 2Cb) have no additional losses, they do not have this uncertainty contribution and therefore have a lower uncertainty.

Conclusions

We have evaluated four techniques for evaluating calorimetric correction factors in rectangular waveguide. Our results show that it is advisable to build two identical microcalorimeters and evaluate their correction factor by measuring the signal with their reference planes connected together.

References

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