Correspondence

A Note on Bolometer Mount Efficiency Measurement Technique by Impedance Method in Japan

As mentioned by Engen in his correspondence,[1] the agreement between the microcalorimetric and impedance determinations of bolometer mount efficiencies was not so good in Japan at the time when the international comparison was performed. It was, however, promptly improved after that international comparison.

The aim of this correspondence is to describe the method adopted for the efficiency determination based on impedance technique, and to present the good agreement between the microcalorimetric and impedance determinations performed at the Electrotechnical Laboratory, Tokyo, Japan.

The discrepancy between the impedance and microcalorimetric determinations of bolometer mount efficiencies was thought to be due to the lack of the accuracy of VSWR measurements of bolometer mounts. While the research for the precise SWR measurement technique was being performed at the Electrotechnical Laboratory, and about one order improvement of accuracy was achieved, using a magic Tee and a sliding short with correction tuners, this technique was employed for the efficiency determination of bolometer mounts based on impedance technique.

Figure 1 shows the diagram of the precise SWR measurement circuit employed for bolometer mount efficiency determinations based on impedance technique. The detector output amplitude of this circuit $|p_4|$ is calculated as follows, neglecting higher order terms of the small quantities

$$|p_4| = \left| \frac{1 + KRe^{j\theta} + aR + s_{34}\dfrac{1}{S_{13}S_{14}}e^{j\theta}}{1 - r_{1i}e^{-j\theta} + r_{2i}R} \cdot S_{13}S_{14}q_g \right|$$

$$K = \frac{S_{23}S_{24}}{S_{13}S_{14}}$$

$$a = s_{22} + Ks_{11} - s_{12}\left(\frac{S_{23}}{S_{13}} + \frac{S_{24}}{S_{14}}\right)$$

$$r_{1i} = s_{11} + (S_{13})^2 \cdot r_g + (S_{14})^2 \cdot r_d$$

$$r_{2i} = s_{22} + (S_{23})^2 \cdot r_g + (S_{24})^2 \cdot r_d$$

where S_{ij} and s_{ij} are the scattering coefficients of the magic Tee, and $|S_{ij}|$ is nearly equal to $1/\sqrt{2}$, $|s_{ij}|$ is nearly equal to 0. r_{1i} and r_{2i} are the small input reflection coefficients of the measurement circuit (in-

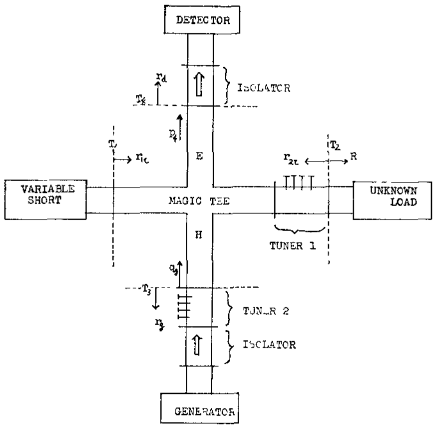

Fig. 1. Diagram of the VSWR measuring circuit.

cluding the generator and detector) seen from the reference plane T_1 and T_2, respectively. θ is twice the variable electrical length of the distance between T_1 and the short-circuited position in the sliding short. R is the reflection coefficient of the unknown load, and r_G and r_d are the reflection coefficients of the generator and detector seen from T_3 and T_4, respectively. q_g is the constant wave amplitude from the equivalent generator.

Therefore, in the ideal case when $|K| = 1$, $a = 0$, $s_{34} = 0$, and $r_{1i} = 0$, the accurate SWR of the unknown load could be obtained by tuning the sliding short for the maximum and minimum output of the detector, and taking their ratio.

$|s_{34}|$ can be approached to zero, by attaching two perfectly matched loads to the reference plane T_1 and T_2, and adjusting the correction tuner 1 for zero output in the detector.

r_{1i} can be approached to zero, after s_{34} being approached to zero, by measuring one of the above perfectly matched load and adjusting the correction tuner 2 for no variation in the detected output as the short-circuited position of the sliding short is moved.

For these two adjustments, the adjustable sliding terminations of Beatty type were used.[2]

The error due to $|K| \neq 1$ and $a \neq 0$ was calculated and evaluated for the magic Tee used. It was 0.2 percent maximum for the measurement of VSWR 1.5, and less for lower VSWR measurements.

Since the VSWRs of the bolometer mounts are less than 1.5 when their dc resistance are adjusted to 150 ohm and 250 ohm for their mount efficiency determinations,[3] the above error is small enough for bolometer mount efficiency determinations based on the impedance technique.

Efficiencies of the standard bolometer mounts ETL-No. 2, No. 4, and No. 6, the same type as those used when the international intercomparison was performed, were determined based on the impedance technique using the precision SWR measurement technique described above, at 9375 Mc/s. Table I shows the results of the determinations comparing with the effective efficiencies determined by the microwave microcalorimeter.[4,5] As seen from Table I, good agreement exists between the impedance and microcalorimetric determinations.[6]

TABLE I

RESULTS OF THE EFFICIENCY DETERMINATION

No. of Bolometer Mount	Efficiencies Determined Based on Impedance Technique	Effective Efficiencies Determined Based on Microcalorimetric Technique
No. 2	January 1961 98.8±1 percent	$99.03^{+0.6}_{-0.3}$ percent
No. 4	January 1961 98.1±1 percent	$98.20^{+0.6}_{-0.3}$ percent
No. 6	January 1961 98.4±1 percent	$98.84^{+0.6}_{-0.3}$ percent

In summary, the bolometer mount efficiency determination technique by impedance method was greatly improved in Japan by January 1961.

Though it was regrettable that the development of the above technique was late to complete for the international intercomparison, this correspondence will show that our technique has arrived in high accuracy soon after the international intercomparison was performed.

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Manuscript received March 1, 1966; revised May 16, 1966.

[1] G. F. Engen, "International intercomparison of standards for microwave power measurement," *IEEE Trans. on Microwave Theory and Techniques (Correspondence)*, vol. MTT-13, pp. 713–715, September 1965.

[2] R. W. Beatty, "An adjustable sliding termination for rectangular waveguide," *IRE Trans. on Microwave Theory and Techniques*, vol. MTT-5, pp. 192–194, July 1957.

[3] R. W. Beatty and F. Reggia, "An improved method of measuring efficiencies of ultra-high frequency and microwave bolometer mounts," *J. Research National Bureau Standards*, vol. 54, pp. 321–327, June 1955.

[4] A. C. Macpherson and D. M. Kerns, "A microwave microcalorimeter," *Rev. Sci. Instr.*, vol. 26, pp. 27–33, January 1955.

[5] S. Omori and K. Sakurai, "A new estimating method of equivalence error in the microwave microcalorimeter," *IRE Trans. on Instrumentation*, vol. I-7, pp. 307–309, December 1958.

[6] T. Tamura and A. Izumi, "Bolometer mount efficiency measurement by impedance method," *Trans. of the 1961 Joint Congress of the Four Electrical Institutes*, Rept. 1182.