TABLE I

Original coordinate system	New coordinate system
$\nabla \times E = -\dfrac{\partial B}{\partial t}$	$\nabla' \times E' = -\dfrac{\partial B'}{\partial t}.$
$\nabla \times H = j + \dfrac{\partial D}{\partial t}$	$\nabla' \times H'^* = j' + \dfrac{\partial D'}{\partial t}$
$\nabla \cdot B = 0$	$\nabla' \cdot B' = 0$
$\nabla \cdot D = \rho$	$\nabla' \cdot D' = \rho'$
$B = MH$	$B' = (\lambda_{\alpha\alpha})H'$
$D = \epsilon E$	$D' = \epsilon E'^*$

Transformation equations

$$B' = PB$$
$$H' = PH$$
$$E' = -jP^* E$$
$$D' = jPD$$
$$j' = jPj$$
$$\nabla' = P^*\nabla$$
$$\rho' = -j\rho$$

$$P = \begin{bmatrix} j\dfrac{\sin\phi}{\sqrt{2}} & -j\dfrac{\cos\phi}{\sqrt{2}} & \dfrac{1}{\sqrt{2}} \\ -j\dfrac{\sin\phi}{\sqrt{2}} & j\dfrac{\cos\phi}{\sqrt{2}} & \dfrac{1}{\sqrt{2}} \\ \cos\phi & \sin\phi & 0 \end{bmatrix}. \qquad (11)$$

We can now transform the entire set of Maxwell's equations to the new coordinate system which, we hope, will be simpler to work with. Table I shows the results.

It is indeed the case that the Maxwell equations—including the relations between the magnetic induction and magnetic intensity, and electric displacement and electric intensity—are much simpler in the primed than in the unprimed form. It may be an advantage in a particular problem involving arbitrary angle of magnetization of a ferrite to work in the primed system as far as possible before switching back to the original one.

GEORGE TYRAS
Boeing Airplane Co.
Pilotless Aircraft Div.
Seattle, Wash.

Resistive-Film Calorimeters for Microwave Power Measurement*

Two papers[1,2] published recently in these TRANSACTIONS have described calorimetric techniques for the measurement of microwave power at the milliwatt level which are free from the limitations inherent in existing methods using resistance-type milliwattmeters.

As the authors point out, the development of improved techniques is especially important at frequencies of the order of 10^4 mc and above. Somewhat similar work has recently been carried out in the United Kingdom at the Radio Research Station, Slough, and this note summarizes the essential features of the techniques used.

A 3-cm band calorimeter[3] in the form of a differential air thermometer has been developed for the power range 10–100 mw. This consists of two identical tapered resistive films located inside thin glass cells which are connected by a capillary tube containing a movable liquid index. One film absorbs the input microwave power and the other serves as a control against variations in ambient temperature. A measurement is made in terms of the equivalent dc power by a null technique. The input voltage standing-wave ratio (VSWR) is less than 1.15 over the band 8800–10,000 mc.

Comparison experiments have shown that the error limit is not more than ±2 per cent. The instrument is extremely compact, and could be adapted for use at other frequencies.

Sucher and Carlin suggest that the substitution error in their calorimeters would be reduced to a minimum by using a transverse film as the absorbing load. This technique has in fact been used by the author for the measurement of power flow in rectangular waveguides, preliminary details being published in 1956.[4] A thin mica strip sputtered with platinum is located in the transverse plane, and with the optimum value of film resistivity an input VSWR of 1.1 or less can be obtained over the band 8500–10,000 mc, if the film is followed by a movable plunger. The input power can be determined in a dc calibration by utilizing the change of resistance produced in the platinum film, or, more conveniently, by observations of the temperature rise indicated by a thermocouple attached to the film. The wires of the thermocouple are parallel to the broad face of the waveguide. A detailed comparison[5] at 9200 mc, against reference standards operating at higher power levels has already confirmed that the technique affords a simple yet accurate method of power measurement in the range 1–100 mw.

Recent experiments (details of which are shortly to be published) have shown that this type of film bolometer can still be used at frequencies as low as 3000 mc. Furthermore, if a stable multirange dc amplifier is connected to the thermojunction, powers in range 100 μw–100 mw can be measured in a single instrument. Using this arrangement, the time constant of the 3-cm band model is not more than 5 seconds, compared with 2.6 minutes for the calorimeter described by James and Sweet.[2] The error limit is approximately ±2 per cent at 100 mw and ±5 per cent at 100 μw. Measurements at the latter level are at present limited in their accuracy as a result of random fluctuations in ambient temperature and amplifier gain. At a frequency of 10,000 mc, these fluctuations result in output variations equivalent to a power of about 3 μw. This "noise level" could probably be reduced by isolating the absorbing load in the manner described by James and Sweet.[2]

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J. A. LANE
Dept. Sci. Indust. Res., Radio Res. Station
Ditton Park, Slough, Bucks, England

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[1] M. Sucher and H. J. Carlin, "Broad-band calorimeters for the measurement of low and medium level microwave power. I. Analysis and design," IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-6, pp. 188–194; April, 1958.

[2] A. V. James and L. O. Sweet, "Broad-band calorimeters for the measurement of low and medium level microwave power. II. Construction and performance," IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-6, pp. 195–202; April, 1958.

[3] A. C. Gordon-Smith, "A milliwattmeter for centimetre wavelengths," *Proc. IEE*, vol. 102, pp. 685–686; September, 1955.

[4] J. A. Lane, "A film radiometer for centimetre wavelengths," *Nature*, vol. 177, p. 392; February, 1956.

[5] J. A. Lane, "Transverse film bolometers for the measurement of power in rectangular waveguides," *Proc. IEE*, vol. 105, pp. 77–80; January, 1958.