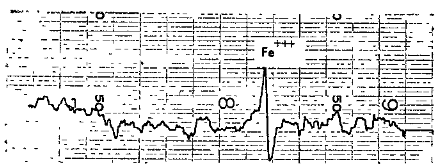
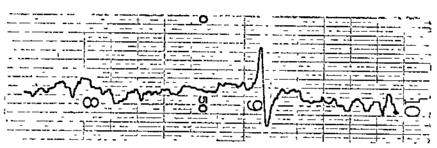
magnet field modulation system together with a coherent detection system provides an output suitable for displaying the derivative of the absorption characteristic on a strip chart recorder.

In order to operate within a sensitivity region where predetection amplification would show advantages a crystal of "pure" sapphire was used for the sample. These crystals have unavoidable traces of iron (Fe^{3+}) and serve well for spectrographic performance checks. A typical trace obtained without the klystron amplifier showing the absorption characteristic of iron in sapphire is shown in the upper trace (a) of Fig. 3. This was obtained with about 10 mw of 9355-Mc microwave input power to the sample cavity. The second trace (b) was obtained with the klystron predetection amplifier, while employing only 10 μw input power to the sample cavity, the power incident on the crystal detector being constant.



(a)



(b)

Fig. 3—Microwave spectrographic responses. 9355 Mc, $\theta = 90°$. (a) Without predetection amplifier ($P_0 = 10^{-2}$ watts). (b) With predetection amplifier ($P_0 = 10^{-5}$ watts).

Here the second trace shows about the same signal-to-noise ratio indicating that the limiting noise of the system is not the klystron amplifier which now allows the system to operate with powers incident on the sample cavity of approximately 1/1000 of that for the straight detection. The increased sensitivity and simplicity of the klystron amplifier should make a very useful addition to simple microwave spectrometers where there is a need to operate at low microwave power levels.

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Correction to "In-Line Waveguide Calorimeter for High-Power Measurements"—Accounting for Transverse Waveguide Wall Currents*

In a recent paper[1] an analysis of calorimeter error due to standing waves in the measured section of waveguide appeared in (11)–(13) and Fig. 3. This analysis was based on the most pessimistic case of a standing-wave of waveguide dissipated power proportional to the square of the transverse H field. Engen[2] has pointed out that the resulting error expression thus obtained is applicable to a TEM wave problem; the actual waveguide calorimeter error will be smaller due to the effects of transverse waveguide wall currents. In the following an expression for the ratio of longitudinal to transverse dissipated power for the TE_{01} mode is developed and a resulting correction to the original error expression (14) is given.

The power dissipated in the walls of a rectangular waveguide is proportional to the integrated H squared fields:

$$P \propto \int_0^b (H_yH_y^* + H_zH_z^*)_{x=0}\,dy + \int_0^a (H_xH_x^* + H_zH_z^*)_{y=0}\,dx$$

where the subscript notation follows present convention. Performing this integration using the customary expressions[3] for the H components of the TE_{01} mode of propagation results in

$$P \propto (4a^3/\lambda_g^2) + (a + 2b)$$

where $4a^3/\lambda_g^2$ represents the power loss due to longitudinal wall currents and $(a+2b)$ represents the power loss due to transverse wall currents. The ratio of these two quantities can be written

$$P_{\text{long}}/P_{\text{trans}} = (\lambda_c/\lambda_g)^2(1 + 2b/a)^{-1}$$

where λ_c is the cutoff wavelength and λ_g is the waveguide wavelength.

The general effect of standing waves is covered in the original paper.[1] This effect is modified by the presence of both longitudinal and transverse dissipated powers whose undulating components are spatially out of phase by π radians. Thus if the magnitudes of the powers are equal, the power dissipation in the waveguide is uniform with longitudinal position. In any event, if there exists a standing wave of H fields in the waveguide, the amplitude of the standing wave of power dissipated in the walls F is given by the absolute value of the ratio of the difference to the sum of the longitudinal and transverse dissipated powers:

$$F = \left|\frac{P_{\text{long}} - P_{\text{trans}}}{P_{\text{long}} + P_{\text{trans}}}\right| = \left|\frac{\left(\frac{\lambda_c}{\lambda_g}\right)^2 - (1 + 2b/a)}{\left(\frac{\lambda_c}{\lambda_g}\right)^2 + (1 + 2b/a)}\right|$$

where the scaling factors involving the physical characteristics and reflection coefficient for the particular situation are omitted for the sake of clarity. The quantity F is easily evaluated, for the ratio b/a is fixed for any given waveguide geometry and the ratio λ_c/λ_g is known or easily computed for most commonly used waveguides.

Eq. (11),[1] giving the distribution of dissipated power in a waveguide as a function of longitudinal position x, the load reflection coefficient Γ and the power P_0 dissipated when $\Gamma = 0$ is now modified to read

$$P = P_0\left[1 + F\frac{2\Gamma}{1 + \Gamma^2}\cos\frac{4\pi(x - \phi)}{\lambda_g}\right]. \quad (11)$$

Thus (14),[1] expressing the maximum of the absolute value of the error of calorimeter indication due to nonzero reflection coefficient, becomes

$$|\epsilon| \leq F\left(\frac{\sin L}{L}\right)^2 \frac{2|\Gamma|}{1 + |\Gamma|^2}. \quad (14)$$

It should be noted that F in the revised Eq. (14), above, is frequency dependent, so the ordinate of the error plot of Fig 3[1] is simply multiplied by a constant dependent on frequency. In S-Band waveguide, for example, this term ranges from 0.68 to 0 to 0.35 as the operating frequency is increased from the lower to the upper limit of operation of the waveguide. The revised error is now seen to be zero when $(\lambda_c/\lambda_g)^2 = (1 + 2b/a)$ as well as when the normalized length $L = n\pi$ corresponding to the total calorimeter length being an integral multiple of waveguide wavelengths. For a fixed length of calorimeter the error can then be zero at two or more frequencies over the operating band of the waveguide used; several error zeros may be possible for the waveguide wavelength being a submultiple of or equal to the total calorimeter length while one zero is possible when the term F goes to zero This suggests a method of broad-banding the calorimeter in that it is possible to choose a distribution of error zeros due to the above causes such that the error over any given frequency band is minimized. The calorimeter waveguide dimensions could be so chosen or its length and operating frequency so fixed that the error could be made negligible over an appreciable portion of a waveguide band.

The foregoing analysis was greatly facilitated through the suggestions of Tor Schaug-Pettersen.

Two errors appear elsewhere in the paper: the left-hand side of (13) should read "$\theta(0, \infty)$" and the caption of Fig. 5 should read "Experimental calorimeters."

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Additional Comment on Fabry-Perot Type Resonators*

In a recent paper on Fabry-Perot type resonators,[1] Culshaw makes reference to a note of mine[2] to the effect that one of the rather lengthy formulas (5) in my paper is incorrect. I should like to point out the errors as they appeared in our internal research report:

1) A "$\frac{nb\lambda}{\gamma}$" should have been a "$\frac{nb\lambda}{8}$."

2) A "$\frac{\pi}{b\lambda}$" should have been a "$\frac{2\pi}{b\lambda}$."

These are, however, typographical errors, as can be seen from the fact that the final numerical values and graphs given by Culshaw reproduce mine down to the fourth decimal place.

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* Received November 11, 1962, revised manuscript received December 12, 1962.

[1] W. Culshaw, "Further considerations on Fabry-Perot type resonators," IRE Trans. on Microwave Theory and Techniques, vol. MTT-10, pp. 331–339; September, 1962.

[2] C. L. Tang, "On Diffraction Losses in Laser Interferometers," Raytheon Research Div., Waltham, Mass., Tech. Memo T-320, October 23, 1961.

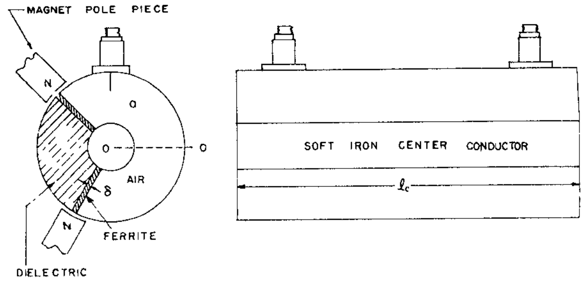

Fig. 1—Experimental cavity showing the arrangement of the dielectric and ferrite materials. Type M-063 ferrite manufactured by Motorola Solid State Electronics Department was used inside the cavity along with Stycast Hi-K dielectric material ($K_e=15$) manufactured by Emerson Cuming, Inc.

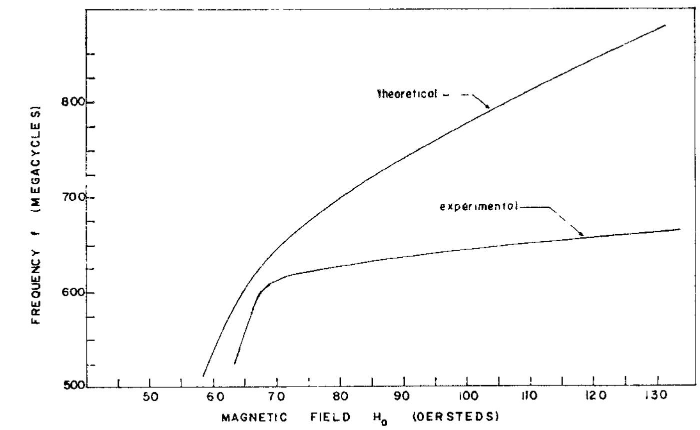

Fig. 2—Tuning curves for experimental and theoretical results.

$\beta=\pi/l_e$ radians/cm.
$\delta=0.382$ cm
$a=1.75$ cm
$c=1.35$ cm

$l_c=7.62$ cm
$K_d=15$
$K_f=13$

A Ferrite-Tuned Coaxial Cavity*

This communication presents a calculation of the electromagnetic wave propagation constant β in a coaxial cavity partially loaded with ferrite and dielectric materials. The cavity was designed to operate around 600 Mc. The advantage of using a coaxial cavity compared to a rectangular cavity at 600 Mc is the fact that a coaxial cavity is much smaller than a rectangular cavity. Electronically tuned cavities have been built utilizing ferrite materials in the X-band frequency range.[1] However, until recently no ferrite materials have been produced that could be used feasibly in the UHF frequency range. Tuning cavities with ferrites has certain advantages that some other electronically tuned cavities do not have with regard to power relations. For example, cavities have been built that are electronically tuned with the use of varactor diodes.[2] These types of cavities cannot tolerate medium power levels, whereas, ferrite materials can withstand higher powers.

An experimental cavity was constructed and it is shown in Fig. 1. The outer conductor was constructed from a brass pipe with a $1\frac{1}{4}$-inch inside diameter. The inner conductor was constructed from a soft iron rod. The reasons for using the iron center conductor was so that the applied magnetic field would be more uniform in the ferrite and the applied magnetic field would be perpendicular to both the inner and outer conductors. The propagation constant β has been derived previously for the loaded waveguide and the loaded coaxial line.[3] The results were given in a slightly different form than those which are presented below.

$$\begin{aligned}(F^2\beta^2 + k_m{}^2\rho^2) &\cosh K_a a \sin k_m\delta \\ &+ \beta F K_a \sinh K_a a \sin k_m\delta \\ &- K_a\rho k_m \sinh K_a a \cos k_m\delta \\ &+ k_d K_a \sinh K_a a \sin k_m\delta \tan k_d c \\ &+ k_d K_m \rho \cosh K_a a \cos k_m\delta \tan k_d c \\ &+ k_d\beta F \cosh K_a a \sin k_m\delta \tan k_d c = 0\end{aligned}$$

where $F=-j\rho/\theta$. (See Button[3] for the definition of other symbols.)

This equation may be written symbolically as

$$F(f_0, H) = 0$$

where f_0 is the resonant frequency of the cavity and H is the applied static magnetic field. Hence, one could obtain the resonant frequency by knowing the magnetic field.

The IBM-650 digital computer was programmed to solve this equation for our case. Fig. 2 shows the results obtained by computation and by experiment.

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Some Remarks Concerning "Conditions for Maximum Power Transfer"*

In these Transactions Shulman[1] studied the conditions for maximum power transfer.

It should be noted that in the *Comptes rendus de l'Academie des Sciences* (Paris, France, vol. 252, pp. 689–691; January 30, 1961) we studied this problem in the general case on the Smith Diagram. The method de-

* Received December 3, 1962.

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