signal generator was used to measure the bandwidth and also to insure the absence of image response and other spurious responses that might cause erroneous noise figure indications.

An unexpected result of this fine tuning of the system was the realization of noise figures better than that calculated. Additional fine tuning of the input impedance, diode bias, and local oscillator drive gave rise to a measured noise figure of approximately 3 db and a bandwidth of 1–2 megacycles. This condition realized very high conversion gain and was not extremely stable.

There remains now a question of relative merit of the tunnel diode converter vs the tunnel-diode amplifier followed by a standard converter. There is no generalization that can apply. The question must be resolved for each separate application, since each application will have a different set of rules governing stability, gain bandwidth, over-all noise figure and so forth. As has been pointed out,[8] the noise figure of the converter is in general higher than that of the amplifier. As can be seen from (4)–(7), as the gain is made very large the term $(G_g+G_s+G_0)$ becomes very small and the noise-figure equation reduces to that which applies to the one-port negative conductance amplifier. If the high-gain converter is used the system noise figure may approach or surpass that of the system using the negative conductance amplifier, for in the process of converting from signal to IF there is no loss diode mixer involved.

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[8] D. I. Breitzer, "Noise figure of tunnel diode mixer," Proc. IRE, vol 48, pp. 935–936; May, 1960.

Impedance Matching by Charts*

In a previous correspondence, Somlo[1] sought to rectify a misstatement in an article by Hudson,[2] by showing a Smith Chart method of matching impedances. The method entailed finding the correct line length of the right characteristic impedance that would match two arbitrary impedances. The method Somlo shows is substantially that given in various texts,[3,4] although in the texts it is done with rectangular transmission line charts rather than with Smith Charts. Indeed, for this application, the rectangular transmission line chart offers advantage over the Smith Chart. With the rectangular transmission line chart one can find the needed line length directly without having to replot the impedances and draw a second circle, as with the Smith Chart in this application as put forth by Somlo.

The statement of Somlo, "If this circle lies fully within the Smith Chart, the question has a solution, otherwise not,"[1] can be modified. What one can say is that if the circle does not lie fully within the Smith Chart (or fully in the right half plane of a rectangular impedance chart) then the impedances cannot be matched with a single length of line. In this case the thing to do is to place a third impedance on the chart so that circles between it and the first two impedances will lie fully in the domain of positive resistances (right half plane of the rectangular impedance chart or within the Smith Chart). Then the first two impedances can each be matched to the third. This will involve a matching transformer of two sections which for the correct choice of the intermediate impedance will have a wider band than a transformer of one section.[5] Even broader band transformers could be made by increasing the number of intermediate impedances and, hence, the number of matching sections. It is possible that for certain values of mismatched impedance more than one additional intermediate impedance will have to be inserted.

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[1] P. I. Somlo, "A logarithmic transmission line chart" (Correspondence), IRE Trans. on Microwave Theory and Techniques, vol. MTT-8, p. 463; July, 1960.

[2] A. C. Hudson, "A logarithmic transmission line chart," IRE Trans. on Microwave Theory and Techniques, vol. MTT-7, pp. 277–281; April, 1959.

[3] J. C. Slater, "Microwave Transmission," McGraw-Hill Book Co., Inc., New York, N. Y., p. 51; 1942.

[4] W. R. LePage and S. Seeley, "General Network Analysis," McGraw-Hill Book Co., Inc., New York, N. Y., p. 347; 1952.

[5] LePage and Seeley, *op cit.*, pp. 347–348.

Theoretical Evaluation of Resonance Frequencies in a Cylindrical Cavity with Radial Vanes*

When the walls of a cavity resonator are altered from a simple geometrical configuration by a small amount, the effect on the resonance frequencies can be determined by applying perturbation methods involving the use of plausible trial fields.

The case of radial vanes inserted into a cylindrical cavity poses a relatively difficult problem, especially when the vane penetration is large. The calculation of the perturbation usually involves a volume integral over the volume enclosed between the perturbed surface and the unperturbed surface[1] (or a surface integral that reduces to a similar volume integral[2]). The volume thus enclosed, in the case of vanes assumed to be infinitesimally thin, is also infinitesimally small. Since the fields being integrated over the volume are finite, the integral would be infinitesimally small and thus would not represent the effect of the perturbation correctly.

An alternative approach has been worked out and has been tried out in detail for the case of lower-order modes in a shallow cylindrical cavity, perturbed by a pair of radial vanes. Good agreement between calculated and experimental values has been obtained up to changes of 28 per cent between perturbed and unperturbed frequencies.

Basically, the analysis proceeds by first dividing the cavity into different regions by an assumed cylindrical surface, passing through the inner edges of the vanes (Fig. 1). A plausible field distribution at this surface, for the E field, *e.g.*, and a plausible value for the resonance frequency are assumed. The electromagnetic field in two regions on opposite sides of the surface (regions 1 and 2) is built up by appropriately summing up the field distribution associated with the orthogonal modes in a simple cylindrical cavity. (It is to be noted that in these expressions the frequency is also involved.)

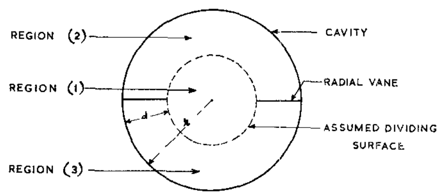

Fig. 1—Diagram showing cross section of the cavity and illustrating the method of analysis.

The Fourier components of the assumed distribution at the dividing surface are used in arriving at the above summation. For region 1 the Fourier components are so chosen that the assumed distribution is obtained for the entire range of azimuthal variation from 0 to 2π. For region 2, a different set of components is chosen so that the assumed distribution is obtained only across region 2, but the E field is zero at the location of the vanes for all the modes. It is to be noted that unlike some of the other perturbation methods, the boundary conditions are satisfied by the trial fields at the perturbed surface also. This makes the method applicable to cases of large vane penetration.

Since the assumed distribution and frequency are only first approximations, the H fields obtained in regions 1 and 2 will not be continuous across the dividing surface. An iterative procedure has been developed by which better approximations to the frequency and the assumed field distribution are obtained in successive alternate steps, while working towards continuity of H field. The matching of fields across the dividing surface need be done in detail only for regions 1 and 2. The matching across region 1 and region 3 follows from symmetry considerations.

In the first step in the iteration, a better approximation to the frequency is obtained

* Received by the PGMTT, October 10, 1960.

[1] J. C. Slater, "Microwave Electronics," D. Van Nostrand Co., Inc., New York, N. Y., p. 81; 1950.

[2] A. D. Berk, "Variational principles for electromagnetic resonators and waveguides," IRE Trans. on Antennas and Propagation, vol. AP-4, pp. 104–111; April, 1956.

TABLE I

TM_{010} Mode	Radius of Cavity = 1.500 inches			
Ratio of vane penetration d to radius of cavity r	Resonance frequency in Mc			Percentage change between perturbed and unperturbed frequency
	Calculated	Observed	Percentage Difference	
0.0	3013	3015	0.07 per cent	0.0 per cent
0.2	3102	3095	0.23 per cent	2.9 per cent
0.4	3338	3337	0.03 per cent	10.8 per cent
0.5	3559	3565	0.17 per cent	18.2 per cent
0.6	3783	3810	0.73 per cent	25.7 per cent

TABLE II

TM_{110} Mode	Radius of Cavity = 1.500 inches			
Ratio of vane penetration d to radius of cavity r	Resonance frequency in Mc			Percentage change between perturbed and unperturbed frequency
	Calculated	Observed	Percentage Difference	
0.0	4800	4790	0.2 per cent	0.0 per cent
0.2	5025	5000	0.5 per cent	4.7 per cent
0.4	5530	5550	0 4 per cent	15.1 per cent
0.5	5765	5870	1.8 per cent	20.0 per cent
0.6	6155	6170	0.2 per cent	28.1 per cent

from an equation arising out of matching the surface integral of the Poynting vector across the dividing surface between regions 1 and 2. Next, a better approximation to the field distribution is obtained by means of a variational principle derived from the requirement of point by point continuity of the H field across the dividing surface. By successive steps, more accurate values of frequency and distribution are thus obtained.

The same process can be carried out by starting with an H field distribution. In this case the correct value of frequency is approached from the other direction (under conditions to be presented in a full paper). Thus, the limits within which the correct frequency lies are ascertained.

Tables I and II give computed and experimental values for frequencies of the TM_{010} and TM_{110} modes, respectively, as perturbed by two radial vanes located diametrically opposite to each other for varying degrees of vane penetration. In the case of TM_{110} mode, the vanes are assumed to be located at the azimuthal angle where the E field is maximum in the undisturbed case. The assumed distribution used two terms of a Fourier series. It is seen that, in practically all cases, the two sets of values agree to within 1 per cent, up to a change of 28 per cent.

The method has also been extended to the case of an interdigital resonator with vanes. It was in relation to the mode control of such a resonator that the problem first arose.[3]

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[3] A. Singh, "Modes and operating voltages of interdigital magnetrons," Proc. IRE, vol. 43, pp. 470–476; April, 1955.