where λ is the free space wavelength. Eq. (2) shows that an increase in the radius of the guide will decrease the characteristic impedance. It is desirable to minimize the change in the impedances at the junction. Therefore, a larger diameter is preferred for matching the circular guide to the rectangular waveguide.

From condition 1) above it it seen that the necessary and sufficient condition for propagation of the dominant TE_{11} mode while suppressing all higher order modes is

$$\frac{\lambda l}{3.41} < a \leq \frac{\lambda h}{2.61}, \qquad (3)$$

where λl is the wavelength at the low end of the band and λh is the wavelength at the high end of the band.

From condition 2) above it is seen that the optimum transformer design occurs at the maximum permissible radius. Thus

$$\frac{\lambda l}{3.41} < a = \frac{\lambda h}{2.61}. \qquad (4)$$

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A Microwave Power Divider*

Recent literature has described the theoretical performance of unmatched power dividers[1,2]

A proposed multilaterally matched power divider for any number n of equal or unequal

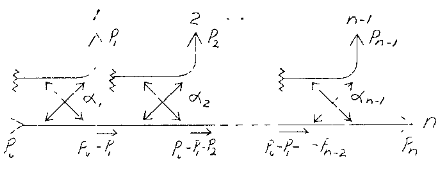

Fig 1—Directional coupler power divider.

outputs, is shown in Fig. 1, where

P_i = input power to the divider
P_k = output power from the kth output port
α_k = power coupling coefficient of the kth coupler =

$$\frac{P_k}{P_i - \sum_{q=1}^{k-1} P_q}.$$

The synthesis of the divider to provide n outputs of prescribed values with a given input is straightforward. The various α's are solved for from the relation

$$\alpha_k = \frac{P_k}{P_i - \sum_{q=1}^{k-1} P_q} \qquad 1 \leq k < n \qquad (1)$$

since

$$P_i = \sum_{q=1}^{n} P_q \qquad (2)$$

from energy considerations, the choice of all P_q, and hence all α_q from $q=1$ to $q=n-1$, quite determines P_n.

The isolation α_{lm} between output ports l and m is

$$\alpha_{lm} = \alpha_l \alpha_m \alpha_D \qquad (3)$$

where all α's are in power ratios and α_D is the directivity of the coupler nearest the input. This is a minimum isolation, since resistive and coupling losses to intervening couplers are neglected.

The divider proposed is 100 per cent efficient; it is matched looking into any port; the isolation between output ports is infinite (assuming perfect directivity); further, there is no theoretical limit to the number of outputs or relative amplitude of outputs that may be obtained consistent with (2).

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[1] E. J. Wilkinson, "An N-way hybrid power divider," IRE Trans. on Microwave Theory and Techniques, vol. MTT-8, pp. 116–118; January, 1960.

[2] H. Kagan, "N-way power divider," IRE Trans. on Microwave Theory and Techniques (Correspondence), vol. MTT-9, pp. 198–199; March, 1961.

On the Efficiency of the Excitation of Surface Waves by Distributed Coupling*

Introduction

The excitation of surface waves on reactive surfaces is accompanied by loss of power which is radiated directly from the region of the feed. Since a surface wave supported by a surface wave line is a (nonhomogeneous) plane wave, it cannot be excited as the only field of a current distribution of finite size and amplitude.

The excitation efficiency is defined as that fraction of the total power transmitted through the exciting aperture, which is contained in the surface wave field. Excitation efficiencies approaching theoretically computed values have been achieved in practice by using horizontal or annular slots, but these apertures usually presented to the primary line highly reflecting loads, and consequent introduction of matching structures made the system rather frequency sensitive.[1]

Several methods have been described for the measurement of the excitation efficiency; most of these depend on some kind of measurement on the reactive surface.[2,3]

The method for the excitation of surface waves which is described in this paper is essentially an application of the theory and technique of directional couplers.[4] In our case, however, it is sought to achieve complete power transfer from the primary line onto the reactive surface waveline. The theoretical treatment will therefore be based on Miller's light coupling theory.[5] The reader is referred to Miller's paper for a complete and systematic analysis of a system of coupled transmission lines. Here we shall summarize, with the aid of Fig. 1, the most important results of this analysis.

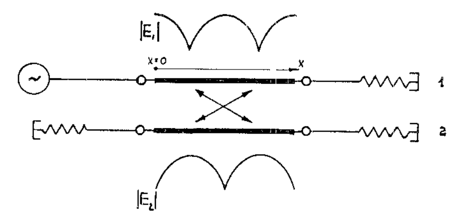

Fig. 1—A system of coupled transmission lines.

1) When two homogeneous transmission lines are coupled along the axis of propagation, power transfer between the lines takes place cyclically.

2) If, and only if, both lines have identical propagation constants, *i.e.*, $\gamma_1 = \gamma_2 (\gamma_n = \alpha_n + j\beta_n)$, complete power transfer is possible, and the minimum length of the coupling aperture necessary is given by $2cx_{\min} = \pi$ where c is the coupling coefficient in nepers per unit length.

Complete power transfer is also possible when $\gamma_1 - \gamma_2 = \alpha_1 - \alpha_2 > 0$, but in this case $x_{\min}$ will be different from the value given above, and generally, in the presence of losses, the term *complete power transfer* will mean only that values of x exist for which no power is present in line 1.

3) When $\gamma_1 \neq \gamma_2$, and in particular when $\beta_1 \neq \beta_2$, only partial power transfer will take place. The maximum possible wave amplitude in line 2 is, in this case, a function of $(\beta_1 - \beta_2)/c$ and is defined as the discrimination function of the coupled system. In this case, again, the point of maximum possible power transfer will differ from the value of x given for $\gamma_1 - \gamma_2 = 0$.

* Received by the PGMTT, August 3, 1961. This note is a sequel to the author's report on "Improvement of the Excitation Efficiency of Surface Waves," M.S. thesis, Technion, Israel Inst. Tech., Haifa, Israel, January, 1960.

[1] Because of the numerous contributions to the subject dealt with in this note the reader is referred to two survey papers which contain exhaustive bibliographies.
a) F. J. Zucker, "The guiding and radiation of surface waves," *Proc. Symp. on Modern Advances in Microwave Techniques*, Polytechnic Institute of Brooklyn, N. Y.; 1954.
b) A. F Harvey, "Periodic and guiding structures at microwave frequencies," IRE Trans. on Microwave Theory and Techniques, vol MTT-8, pp. 30–61; January, 1960.

[2] G. Goubau, "On the excitation of surface waves," Proc. IRE, vol. 40, pp. 865–868; June, 1952.

[3] R. H. DuHamel and J. W. Duncan, "Launching efficiency of wires and slots for a dielectric rod waveguide," IRE Trans. on Microwave Theory and Techniques, vol. MTT-6, pp. 277–284; July, 1958.

[4] R. J. Hanratty, "An end-fire X-band flush antenna based on the branch-waveguide directional coupler," private communication.

[5] S. E. Miller, "Coupled wave theory and waveguide applications," *Bell Sys. Tech. J.*, vol. 33, pp. 661–719; May, 1954.