N-Terminal Power Divider*

Recently Wilkinson[1] has described an N-way hybrid power divider which decouples the outputs. This device can be arrived at by observing that its scattering matrix is

$$S = \frac{j}{\sqrt{n}} \left(\begin{array}{c|ccccccc} 0 & 1 & 1 & 1 & 1 & \cdot & \cdot & \cdots \\ \hline 1 & & & & & & & \\ 1 & & & & & & & \\ 1 & & & & & & & \\ 1 & & & & 0 & & & \\ \cdot & & & & & & & \\ \cdot & & & & & & & \\ \vdots & & & & & & & \end{array} \right).$$

Then

$$S^2 = \frac{1}{n} \left(\begin{array}{c|cccccc} n & & & 0 & & & \\ \hline & 1 & 1 & 1 & 1 & 1 & 1 \\ & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 \\ & - & - & - & - & - & - \\ & - & - & - & - & - & - \end{array} \right)$$

and

$$S^3 = \frac{-j}{n\sqrt{n}} \left(\begin{array}{c|cccccc} 0 & n & n & n & n & \cdot & \cdot \\ \hline n & & & & & & \\ n & & & & & & \\ n & & & 0 & & & \\ n & & & & & & \\ \cdot & & & & & & \\ \cdot & & & & & & \\ \cdot & & & & & & \end{array} \right) = -S.$$

Then

$$\begin{aligned} y &= (1 - S)(1 + S)^{-} \\ &= (1 - S)^2(1 - S^2)^{-1} \\ &= (1 - 2S + S^2)S(S - S^3)^{-1} = -S \\ &\qquad\qquad\qquad \text{(See below}^2\text{)} \\ &= -S^2S^{-1} = (S - S^2 + S^3)S^{-1} \\ &= 1 - S + S^2 \end{aligned}$$

$$Y = \left(\begin{array}{c|ccccc} 0 & \frac{-j}{\sqrt{n}} & \frac{-j}{\sqrt{n}} & \frac{-j}{\sqrt{n}} & \cdots & \\ \hline \frac{-j}{\sqrt{n}} & \frac{n-1}{n} & \frac{-1}{n} & \frac{-1}{n} & \cdot\,\cdot & \\ \frac{-j}{\sqrt{n}} & \frac{-1}{n} & \frac{n-1}{n} & \frac{-1}{n} & & \\ \frac{-j}{\sqrt{n}} & \frac{-1}{n} & \frac{-1}{n} & \frac{n-1}{n} & & \\ \cdot & \cdot & \cdot & \cdot & & \\ \cdot & \cdot & \cdot & \cdot & & \end{array} \right).$$

This represents $n(3\lambda/4)$ transmission lines of characteristic admittance $\sqrt{(n/n)}\,Y_0$, each terminated in a pure conductance of value $(n-1)/n$ and coupled to the output of every other line by transfer admittance (conductance) of $1/n$ in units of Y_0, when all outputs except the one considered are short circuited. It is not hard to see that the termination shown in Fig. 1 satisfies this requirement. Moving the reference of S by $\lambda/2$, lines in Y become $\lambda/4$ lines and the final network is (Fig. 2).

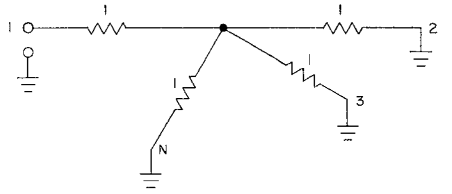

Fig. 1.

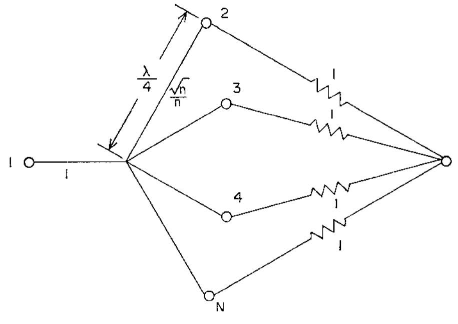

Fig. 2.

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10-DB X_L Cross Guide Coupler*

Two interesting points were noted while working with half-height cross guide couplers. The first was that if the same size coupling holes were used as in the full size waveguide, coupling was increased approximately 3 db. The second, and more important, was that the value of coupling was much more constant over a given frequency band, with essentially no change in directivity.

With this information, a standard 15±1 db coupler in WR 112 waveguide was taken, and step transitions of various heights were designed to insert into the coupling area. By inserting steps to reduce the waveguide to a half-height size, the 3-db increase in coupling was noted and the coupling flattened out to 12±0.5 db over the desired 7.5 to 8.5 kMc frequency range. By using only one step, coupling was increased to 13±0.5 over the same frequency band.

The need of a 10-db cross guide coupler resulted in Fig. 1.

Coupling, previous to inserting the steps, was 13.8 db to 15.8 db over the 7.5- to 8.5-kMc range with greater than 20-db directivity. After inserting the steps, coupling varied from 9.9 db to 10.2 db over the same frequency range with greater than 20-db directivity. A maximum VSWR of 1.13 was obtained in the secondary arm.

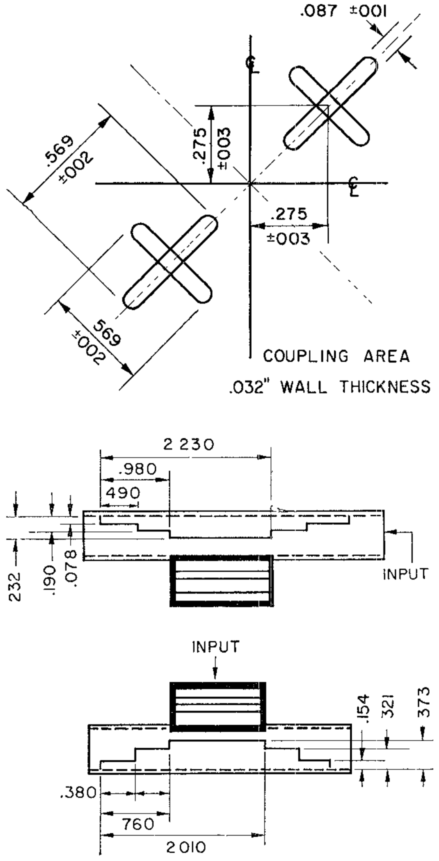

Fig. 1.

Electrically, a good coupler is needed to start with since a change in VSWR due to the step causes a decrease in directivity. Also a smaller step in the primary arm is desirable both for input VSWR and higher power requirements. Mechanically the steps should be brazed in place since a loose step causes large variations in coupling.

Cross guide couplers with greater coupling have been built at the expense of directivity which drops down to 15 db or lower.

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Design Note on an L-Band Strip-Line Circulator*

The technique of using magnetized yttrium-iron-garnet slabs in dielectrically-loaded strip transmission line as the nonreciprocal elements in a UHF and low-

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* Received by the PGMTT, July 20, 1961.

[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] $Y = -S$ does not lead to a realizable microwave network.

* Received by the PGMTT, May 10, 1961.

* Received by the PGMTT, July 7, 1961.