A WIDEBAND STRIPLINE MATCHED POWER DIVIDER

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Introduction. In many microwave systems, a signal must be split into two equal-amplitude in-phase signals by a power divider. The power divider must be matched at the input to achieve complete power transfer and should, in most applications, be matched at the two output ports to avoid interaction between the power divider and mismatched networks connected to the outputs.

It is well known that a lossless three-port network cannot be matched at all ports and thus cannot perform the function described above. Three-port networks with internal resistors can be built which operate from dc well into the microwave region. These networks perform the desired function but have a 3-dB insertion loss.

A lossless four-port hybrid junction, or "magic tee," can be used as a matched power divider if the difference port is terminated. An octave bandwidth coaxial line power divider of this type has been reported[1] which has the difference port internally terminated. A multi-octave stripline hybrid has also been reported[2] but the device is rather large and must use overlapped center conductor geometries to obtain the tight coupling required in the design. The former unit is physically symmetric with respect to the two output ports, and thus achieves excellent phase and amplitude balance. The latter unit lacks this symmetry; the output unbalance depends on the exact design parameters and is typically 0.5 dB and/or 5 degrees.

This paper describes a stripline power divider which has both physical symmetry and multi-octave coverage. It utilizes simple single-layer construction to obtain excellent performance over wide bandwidths. Output unbalance is less than 0.1 dB and isolation is greater than 20 dB over a 12:1 bandwidth.

Theory of Operation. The internal configuration of the stripline power divider is shown in Figure 1. The center conductor of the input line is bifurcated forming two parallel closely-spaced conductors. These conductors are gradually widened and separated and finally turned at right angles to form the two output lines. A resistive card is placed across the conductors near the input end of the structure.

The operation of the power divider is most easily discussed in terms of even- and odd-normal modes of propagation on the center conductor pair. The input line is connected in parallel to the two lines. Thus an input signal is fed onto the two lines in the even mode. This mode on the parallel line system results in signals which are in-phase on the two output lines. In contrast, an odd mode on the parallel line system would result in out-of-phase signals on the two output lines.

Complete power transfer will occur only if the 50-ohm input port is matched to the two 50-ohm output ports. This is achieved by varying the even-mode impedance along the parallel conductor pair to provide matching between a 50-ohm level at the output and a 100-ohm level at the input. At the input end of the parallel conductor pair the lines are connected in parallel to present a 50-ohm impedance level at the input port. The even-mode impedance variation chosen to provide the required 2:1 impedance transformation was a Klopfenstein taper.[3] The particular taper used was 5 inches long in polyolefin dielectric (ε = 2.32) and provided a theoretical maximum VSWR of 1.07:1 at frequencies above 800 MHz.

To this point there has been no restriction placed on the odd-mode impedance of the parallel line structure. We must now consider the output port match and isolation between the outputs. It can be shown that the input impedance at either output port is given by

$$Z_{in} = \quad (Z_{oe})_{in} \, (Z_{oo})_{in}$$

where $(Z_{oe})_{in}$ and $(Z_{oo})_{in}$ are even- and odd-mode input impedances at the output end of the structure. A more useful statement of this relationship is:

$$\Gamma_{IN} = 1/2 \, (\Gamma_e + \Gamma_o) \ ,$$

where Γ_e and Γ_o are reflection coefficients for the even and odd mode, respectively. It can also be shown that the isolation is given by

$$T = 1/2 \, (\Gamma_e - \Gamma_o) \ .$$

As discussed above, the even-mode reflection coefficient is about 0.035 (VSWR = 1.07) maximum. Since the output port match and isolation depend on the sum and difference, respectively, of the two normal-mode reflection coefficients, the best overall results will be obtained by minimizing the odd-mode reflection coefficient. This was accomplished by maintaining a uniform odd-mode impedance of 50 ohms and terminating the mode in a low-reflection tapered load.

The odd-mode terminattion is made by placing a resistive film between the two conductors. The odd-mode field is of maximum intensity in the plane of the film whereas the even-mode field in this region is theoretically zero. The correct dimensions and resistivity of the load were determined experimentally. It was found that a resistivity of 150 ohms/square provided the best compromise for low VSWR and high attenuation of the odd mode. For highest odd-mode attenuation, the termination should be as long as possible. It was found, however, that if the resistive material extended all the way to the output end of the structure, some attenuation also occurred in the even mode. A reasonable compromise was obtained with a three-inch long termination.

Performance Characteristics. The characteristics of the completed power divider are shown in Figure 2. Isolation between outputs is greater than 20 dB from 1 to 12.4 GHz and is generally better at the higher frequencies. Insertion loss gradually increases from 0.1 dB at 1 GHz to 0.75 dB at 12 GHz. Output unbalance is at most 0.1 dB. The VSWR of all ports is less than 1.25 throughout the 1 to 12 GHz band.

Conclusion. A design concept for realization of a semi-infinite bandwidth matched power divider has been discussed. A simple, compact stripline device has been built which demonstrates that this concept can be used to achieve excellent performance characteristics throughout a bandwidth of at least 12:1.

References. [1]S. David, "A Wideband Coaxial-Line Power Divider," IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-15, April 1967, pp. 270-1.

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[3]R. W. Klopfenstein, "A Transmission Line Taper of Improved Design," Proceedings of the IRE, Vol. 44, January 1956, pp. 31-5.

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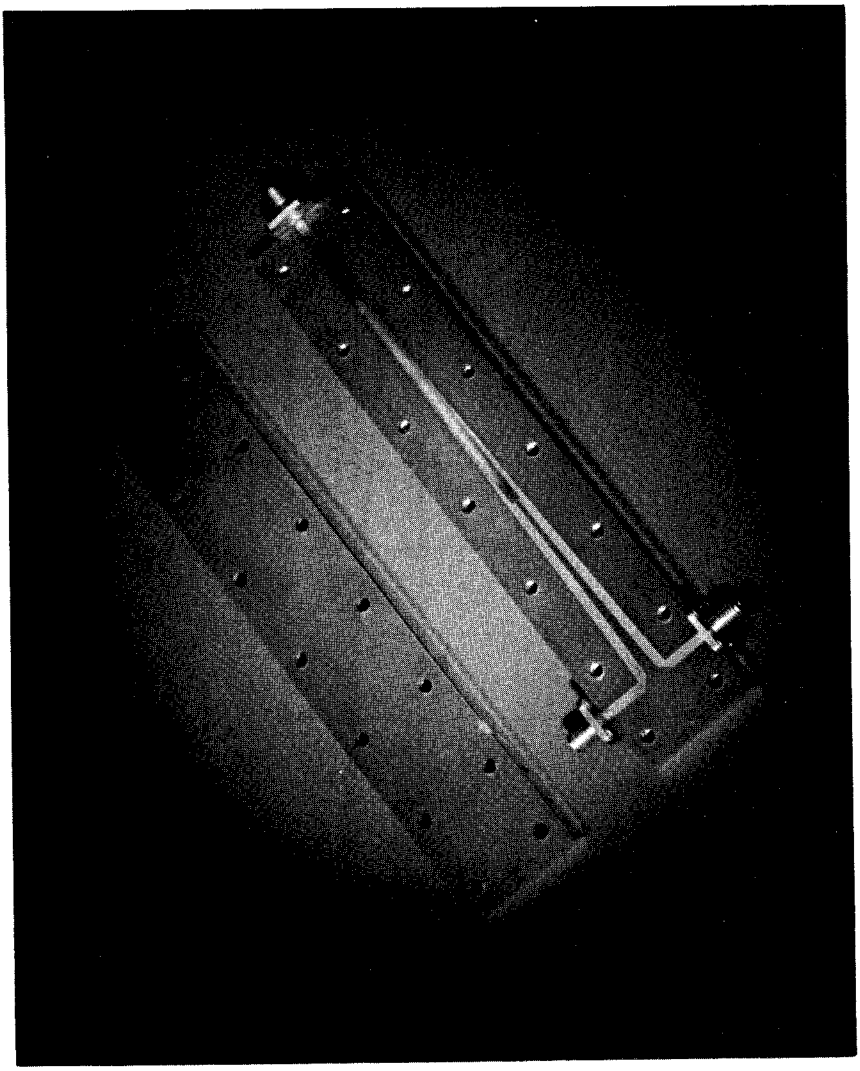

Figure 1 - Wideband Power Divider

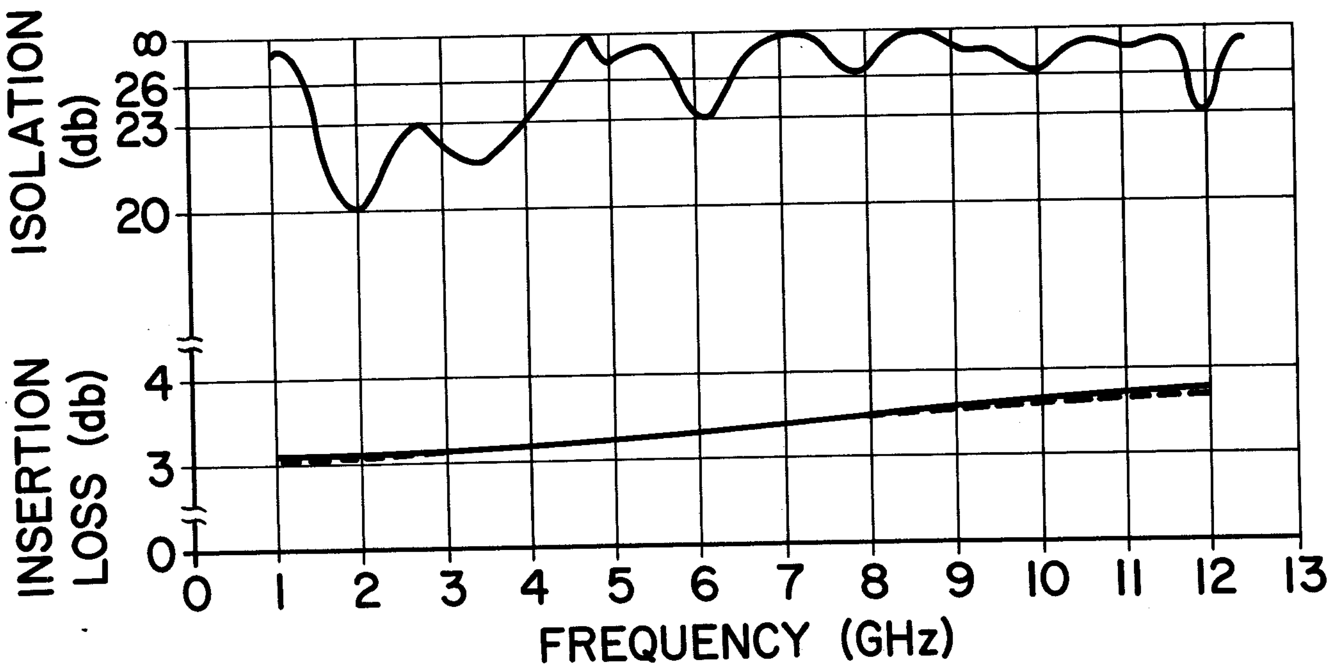

Figure 2 - Performance Characteristics of the Wideband Power Divider