V-4 MICROSTRIP HYBRID COUPLERS AND THIER INTEGRATION INTO BALANCED MIXERS AT X AND K-BANDS

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A number of 3 db couplers have been designed for microstrip transmission lines utilizing materials with dielectric constants between 9 and 11 for integration with other microstrip elements to form balanced mixers, power dividers, phase shifters, etc. Two- and three-arm branch-line couplers and the T.E.M. back coupler have been developed on alumina, gallium arsenide and sapphire between 8-18 GHz/s.

For initial evaluation, the couplers were fabricated on small area substrates and housed in metal boxes to minimize the possibility of mode conversion and loss by radiation. Microstrip line lengths external to the couplers were quite small and measured loss values were primarily due to path lengths within the coupler. Measurements were made with coaxial equipment after matching the junction discontinuity that normally occurs between coaxial and microstrip lines.

A microstrip standing wave indicator was used to evaluate the coaxial-to-microstrip discontinuity, RF admittance of Schottky barrier mixer diodes and an admittance transforming network. An X-band integrated dual balanced mixer with preamplifier was designed and evaluated.

As an example, performance data for a two-arm branch-line coupler on alumina at X-band is given in Fig. 1.

The differential coupling or power split characteristic between output arms of this unit is sensitive to the ratio of branch line impedances being approximately .2 db for a 1.02 ratio. Maintaining the same impedance values in this design for operation at 18 GHz/s required an empirical approach to obtain the required coupling value. Here the aspect ratio (line length to width) is so distorted that it is perhaps unrealistic to assume these lines to be of uniform impedance. Figure 2 shows a branch line coupler of this form centered at 19 GHz/s. Experimentally, the coupling was adjusted to 3 db by introducing capacitive discontinuities midway on opposite branch arms. The following measurements were recorded:

Center Frequency	18 GHz/s
Bandwidth	2 GHz/s
Differential Coupling	± 0.2 db
Decoupling	20 db (20 db max) at center frequency
VSWR	1.3:1
Loss at center frequency	0.3-0.4 db
Substrate	30 mil alumina (AL 995)

Three-arm branch-line couplers with improved bandwidth have been designed at 11 and 13.5 GHz/s. Due to increased path lengths, insertion loss values are higher.

The T.E.M. back coupler is attractive for a wider band application. The form employing side coupling between conductors requires a gap separation in the vicinity of 0.002". Because the finite conductor thickness is the same order of magnitude, the realization of this gap by photoetching techniques is difficult. The Approach taken here was to scribe the gap with a diamond chisel.

The surface finish of alumina ceramic, even when lapped to a 1- to 2- micron finish is still unacceptable as a substrate. The remaining voids have diameters comparable to the required gap size. They are then random discontinuities in the coupling region.

For this reason, single-crystal sapphire was selected. Sapphire has a mirror-like surface when polished. The dielectric constant is similar to alumina when the C axis lies in the plane of the substrate. Progress to date with this coupler is shown by the differential coupling characteristic, Fig. 3. The VSWR's are of the order 1.2:1 and the decoupled arm minus 20 db over the useful operating band. Dissipation loss was calculated to be 0.4 db.

Figure 4 shows five different couplers on 30-mil substrates.

The microstrip line shown in Fig. 5 fits a standard carriage with probe to form a standing wave indicator suitable for X-band measurements. It was used initially for evaluating coax microstrip junction discontinuities and to determine self impedance relative to 50-ohm teflon loaded coaxial line. The three connectors shown in this figure were used to displace a load (also shown) by $\lambda/6$ increments. The admittance plots on a Smith chart referenced to the junction are points on a circle.

The RF admittances of Schottky barrier mixer diodes were measured with this line. The diodes were mounted to minimize admittance transformation due to parasitics effects at these frequencies (principally the series inductance of the bonding lead).

An integrated X-band module is shown in Fig. 6. It employs two-arm branch line couplers for the two balanced mixers (for signal and AFC in a radar system). Diodes are matched with sections formed from shunt capacitances produced by open circuit stubs, series bonding-lead inductances and diode junction and parasitic capacitances.

A two-way power splitter feeds the local oscillator power to the mixers. The load terminating the fourth arm of this unit provides the power splitter with 20 db of isolation between mixer terminals. This load is a thin chromium film deposited on a 2-mil ceramic wafer. The noise figure of the receiver was 7.5 db at 9.375 GHz/s.

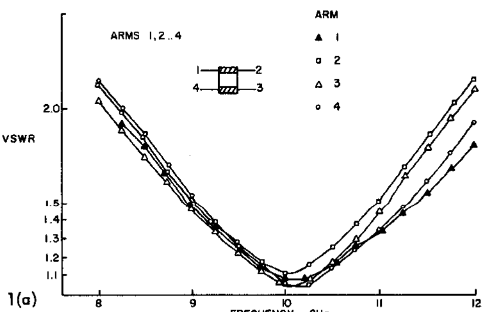

FIG. 1 - X-Band Branch Line Coupler Characteristics

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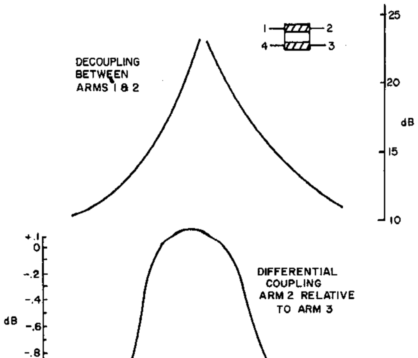

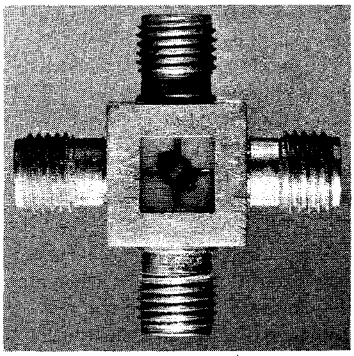

FIG. 2 - Branch Line Coupler at 18 GHz

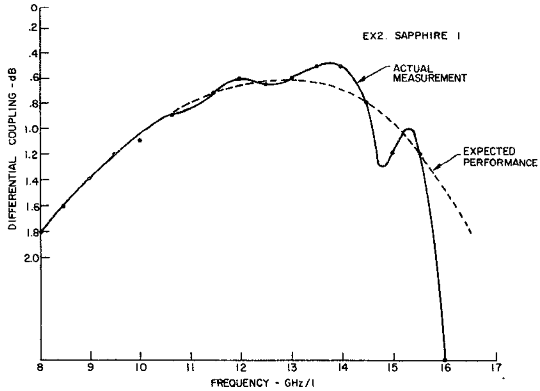

FIG. 3 - Coupling Characteristic of a TEM Back Coupler

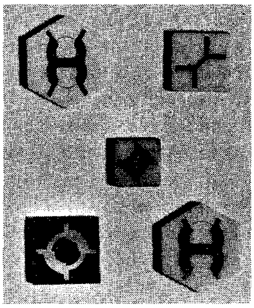

FIG. 4 - Branch Line Couplers on Different Substrates

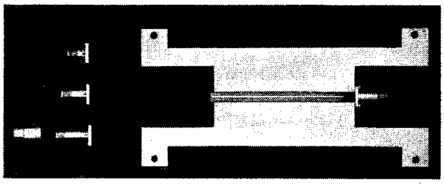

FIG. 5 - Microstripline for Standing-Wave Indicator

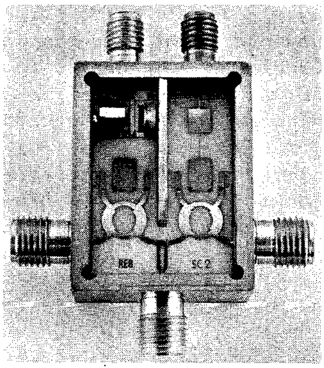

FIG. 6 - X-Band Dual Balanced Mixer with Preamplifier