RECTANGULAR, COAXIAL-LINE, SPLIT-TEE POWER DIVIDERS

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ABSTRACT

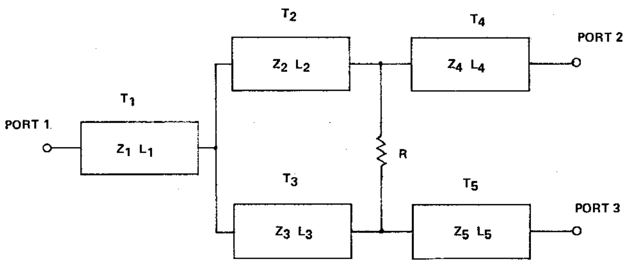
This paper describes a family of high power, low VSWR, S-band split-tee power dividers with coupling values from 3 dB to 5 dB. The power dividers use rectangular coaxial transmission line and employ a unique self-compensated isolation resistor.

## Introduction

A family of moderately high power, split-tee power dividers operating at S-band has been designed and constructed using rectangular coaxial transmission line. The dividers were designed with coupling values which vary from 3 dB to nearly 5 dB (unbalance ratios from 0 dB to 3 dB). They have a VSWR less than 1.20:1 over a 17 percent frequency band and an output port isolation of more than 22 dB over that same frequency band. Power levels of the order of 10 kW peak and 10 W average necessitate an isolation resistor of fairly substantial physical size. Such an isolation resistor has parasitic reactances associated with it which degrade the performance of the split-tee power divider unless these reactances are properly compensated. The subject of this paper is the characterization of the parasitic reactances and the methods of compensation.

## Power Divider Structure

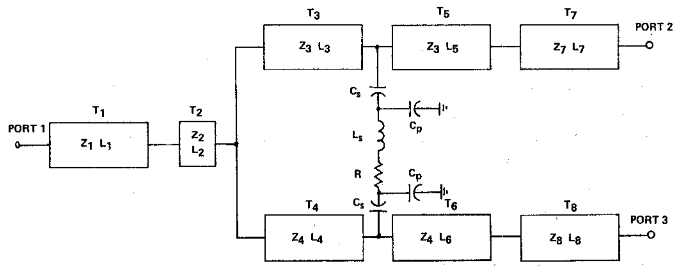
The split-tee power divider circuit described here uses two transformation stages at the input and one at the output. Figure 1 shows the ideal split-tee divider circuit. Basic design equations are given by Parad and Moynahan.[1] The circuit has been implemented in rectangular coaxial transmission line for two principal reasons. First, a coaxial structure is capable of supporting greater power levels than printed lines, notably stripline. Second, both the inner and outer conductors of the rectangular coaxial line structure can be precisely, accurately, and repeatably machined using numerically controlled milling techniques.




1. Circuit Model of Ideal Split-Tee Power Divider

The isolation resistor capable of dissipating the required power consists of a block of berylia (BeO) in the shape of an inverted "U" with a multilayer thick-film resistance coating and integral series thick-film capacitors. BeO is used as the substrate to conduct the dissipated power to the outer conductor which serves as a heat sink. The multilayer thick-film resistive material is capable of handling both the peak and average power without either breakdown or deterioration. Finally, the integral series capacitors serve to resonate the distributed inductance of the resistor and thus insure good output port isolation. The equivalent circuit of the non-ideal split-tee power divider including the resistor and its integral thick-film capacitors is shown in Figure 2. The capacitance to ground, $C_p$, is due to the resistor body and is tuned out by the short length of low impedance transmission line $T_2$. $T_5$ and $T_6$ are included in the model since the resistor body has been located entirely to the left of the junction between T2 and T4 in Figure 1.

The use of the integral series capacitors is important for two reasons. First, the compensating element (the capacitor) is located in close proximity to the element it is compensating (the parasitic inductance), thereby minimizing the



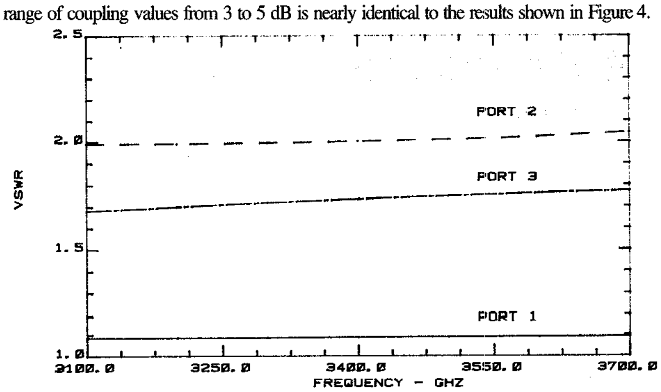

2. Circuit Model of Actual Split-Tee Power Divider

number of energy storage components and thus maximizing the bandwidth. Second, techniques which modify the lengths and impedances of the transmission lines to compensate for the inductance require modification of the resistance value of the resistor to obtain adequate isolation. Since the modified resistance is a function of the coupling value, different resistors are required for each of the couplers in a network of such couplers. This in turn complicates the assembly of such a network. Using the integral capacitor results in a range of resistances which vary by only 2.5 percent and therefore are nominally a single value.

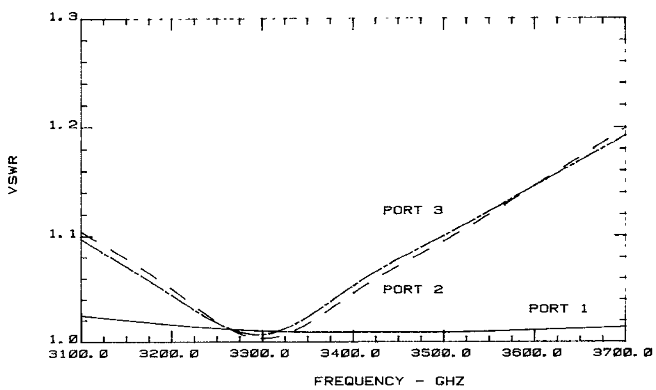
## Power Divider Design

The family of power dividers was designed with the aid of a network optimization computer program. The equivalent circuit of the resistor was obtained by modeling the power divider circuit and analytically duplicating the data measured with an uncompensated resistor. The optimization program was then used to "trim" the transmission line dimensions and values of the compensating elements. The ideal transmission line impedances and lengths were used as initial values for the optimization. The initial values of the compensating capacitances were calculated using conventional network analysis techniques to resonate them against the parasitic inductance. The value of the resistance R was modified by the optimization since the combination of $L_s$, $C_s$ and $C_p$ act as an impedance transformer.

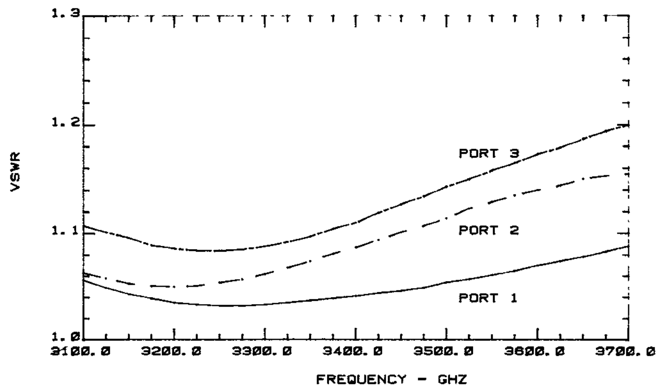
Figure 3 shows the computed VSWR at each of the three ports for an uncompensated 3.5 dB split-tee power divider. The corresponding calculated performance of the compensated divider is shown in Figure 4. The improvement is readily apparent. The predicted performance of the compensated design over the range of coupling values from 3 to 5 dB is nearly identical to the results shown in Figure 4.




3. Calculated VSWR at Each Port of Uncompensated 3.5 dB Split-tee Power Divider



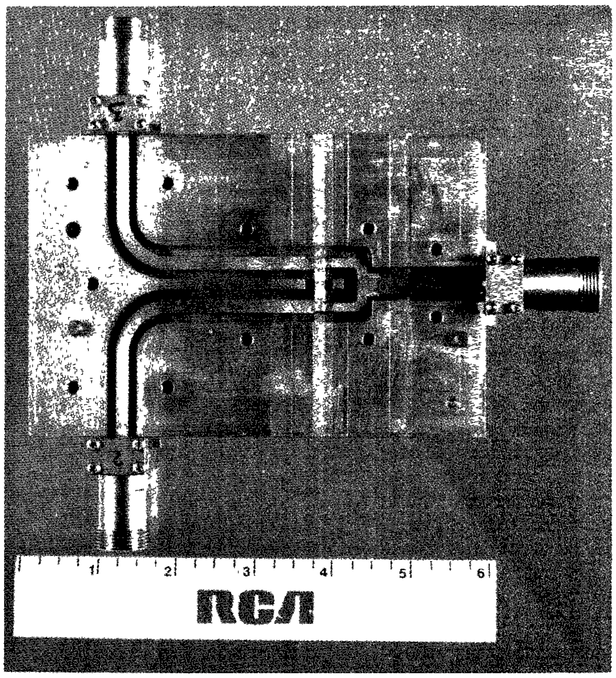

4. Calculated VSWR at Each Port of Compensated 3.5 dB Split-Tee Power Divider



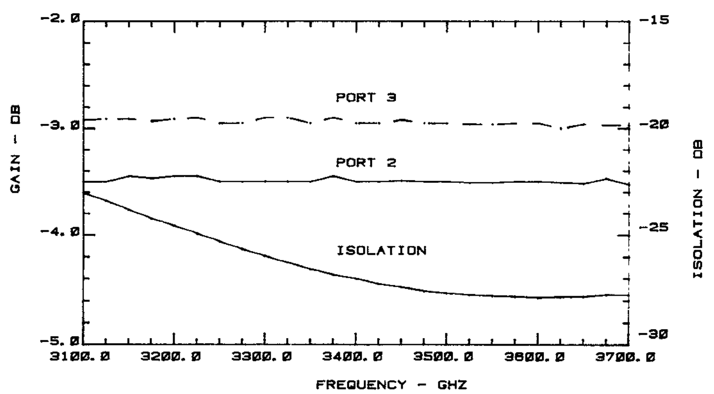

6. Measured VSWR at Each Port of Compensated 3.5 dB Split-Tee Power Divider

## Discussion of Results

Split-tee power dividers with coupling values of 3.0, 3.5, and 4.7 dB were constructed to verify the predicted performance. A photograph of the 3.0 dB coupler is shown in Figure 5. Figure 6 shows measured VSWR at each of the three ports over a frequency band from 3.1 to 3.7 GHz for the 3.5 dB power divider. The VSWR at Port 1 remains below 1.09. At Ports 2 and 3 the VSWR is less than 1.20 over the band. The insertion loss from Port 1 to Ports 2 and 3 is shown in Figure 7 as is the isolation between Ports 2 and 3. The coupling to Ports 2 and 3 are flat with frequency and the ratio of the two coupling values is extremely close to the desired value The isolation remains below 22 dB as expected from the computations. Results for the 3 dB and 4.7 dB couplers are similar to that shown in Figures 6 and 7 except for the coupling values.




5. 3.0 dB Split-tee Power Divider Breadboard Model




7 Measured Coupling and Isolation of 3.5 dB Split-Tee Power Divider

## Conclusions

Low VSWR, high isolation split-tee power dividers have been designed and constructed to operate at moderately high power levels at S-band with a range of coupling values from 3 to 5 dB. They use rectangular coaxial transmission line and unique integral thick-film matching elements on the isolation resistor. A network of such power dividers can be accurately and repeatably fabricated using numerically controlled machining techniques. In addition, the compensation techniques insures that only a single resistor design is required for the entire range of coupling values rather than necessitating a different resistor value for each different coupler

## References

1. Parad, L. I., and R. L. Moynahan, "Split-Tee Power Divider", IEEE Trans. MTT, Vol. MTT-13, No. 1, January 1965, pp. 91-95.