A 2-18 GHz 180 DEGREE PHASE SPLITTER NETWORK

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ABSTRACT

A 2-18 GHz phase splitter network has been designed and developed to provide two outputs 180° out-of-phase, with a low insertion loss.

The network consists of an active 2-20 GHz in-phase power divider, implemented in MMIC, the two outputs of which feed band pass filter networks, which have identical amplitude response but are 180° out-of-phase. The filter network has been modified in a novel fashion to make it MMIC compatible. The network has applications in double balanced mixers, class AB power amplifiers, push-pull amplifiers, etc.

INTRODUCTION

A 2-18 GHz phase splitter network has been designed and developed to provide two outputs 180° out-of-phase with a low insertion loss. The network consists of an active 2-20 GHz in-phase power divider, implemented in MMIC, the two outputs of which feed bandpass filter networks which have identical amplitude response, but are 180 out-of-phase. The filter network has been modified in a novel fashion to make it MMIC compatible. The network has applications in a variety of components which will be detailed later. The active power splitter has compression points in the +15 dBm range and has an excellent phase tracking performance. The phase shifting filter networks have insertion loss in the region of 0.5 dB in mid-band.

The development of 180° networks has been a continuous challenge for the microwave industry. The available components satisfying this requirement have a large size and high insertion loss. The present network can replace many existing components. A block diagram of the network is shown in Figure 1. It consists of an active power divider and two filter networks. The design and performance of these components is detailed below.

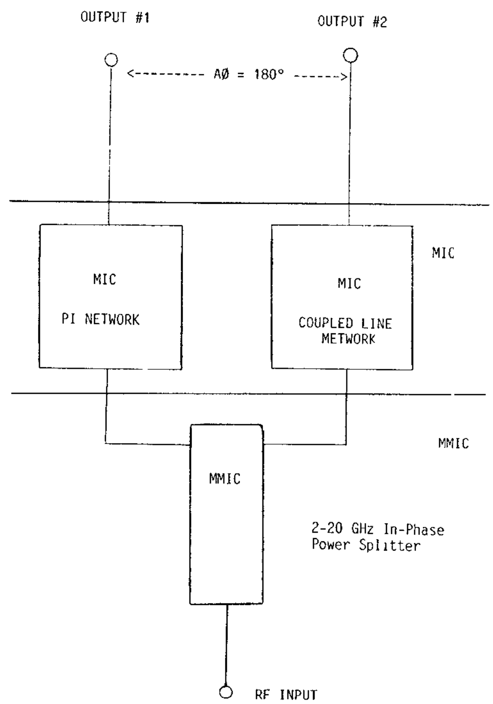

Figure 1

WIDEBAND ACTIVE POWER SPLITTER

The in-phase power divider is comprised of two single stage, four section, distributed amplifiers that share a single input transmission line structure. Identical distributed amplifiers are used in both arms. The excellent phase and amplitude performance obtained stems from this topological symmetry. The FET cell within each section is actually a cascode chosen to increase isolation. The cascode also extends bandwidth due to low drain line loading. Resistances in series with the second gate of each cascode provide stability. The schematic of the circuit is shown in Figure 2. The simulation is detailed in Figure 3.

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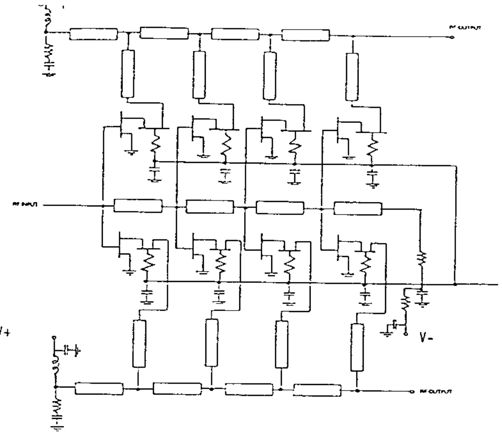


Figure 2 Distributed In-Phase Power Splitter Schematic

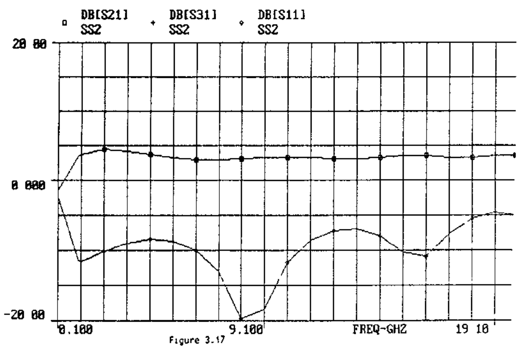


Figure 3 Power split and Return Loss of Power Splitter

A distributed power divider of this type has twice the number of the FET's, with their associated gate to source capacitances, as does a conventional single output distributed amplifier. For this reason the determination of individual gate width requires a trade off between desired output power level and cutoff frequency. For this design, 150 micron width by 0.5 micron length FET's were chosen. On-chip bias is included in this design. The drain lines use square spiral inductors; and a series RC network reduces the effect of the inductors self resonance.

A large resistance is used to bias the gate transmission line. The second gate of each cascode is connected through the stabilizing network to be joined into a bypassed common second gate line. This second gate line is brought to a bonding pad. A series diode network sets this voltage everywhere to a predetermined voltage.

In order to facilitate testing and integration, all dc connections should be located in a single area, preferably along one edge of the die. This was accomplished by the routing of several lines across and around the chip in order to reach the central bias bonding location as shown in the die photo. It was decided that any needed crossovers involving RF lines over bias lines would, if possible, be executed so that the gate/input RF line was the only RF line intersected. Thus, any perturbations in the response introduced by these crossover parasitics would be equally and identically translated to the output structures and thereby preserve the amplitude and phase match.

Measured chip performance is shown in Figures 4 and 5. The forward gains are from unity to +3 dB midband gain with better than $\pm$ 1.5 dB gain flatness from 2 to 18 GHz. The amplitude match from output port to output port is better than .6 dB over the band and the phase match is better than five degrees throughout. The circuit return losses, as well as the input/output and output/output reverse isolations are quite good.

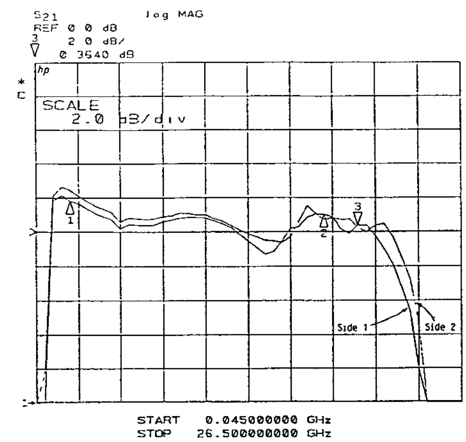


Figure 4 Output Amplitude Tracking

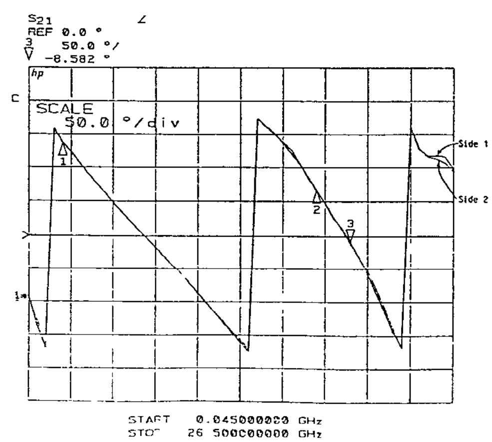


Figure 5 Transmission Phase

PHASE SHIFTING NETWORK

The basic building block for the wideband BALUN is shown. The BALUN consists of a network of shorted coupled lines and a simple Pi network of transmission lines, as shown in Figure 6[1].

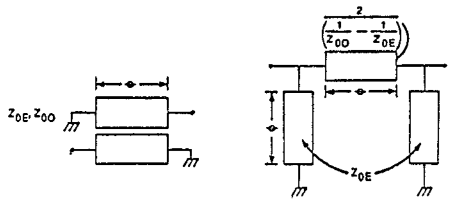


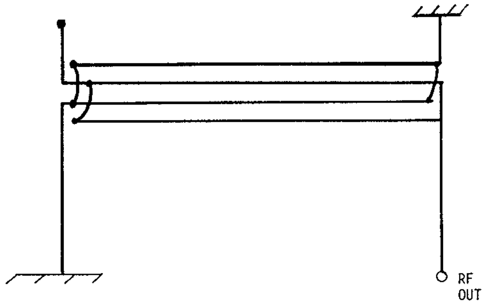
Figure 6

The two networks are exactly equivalent for all frequencies except that the transmission phase difference between the two circuits is exactly 180° out-of-phase. These networks are best described by their ABCD matrices [2].

$$\begin{bmatrix} A & B \\ & pi \\ C & D \end{bmatrix} = \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix} \bullet \begin{bmatrix} A & B \\ & coupled \\ C & D \end{bmatrix}$$

The Pi network of transmission lines is equivalent to the shorted coupled section preceded by an ideal phase-reversing transformer. This result is independent of the electrical length of the two networks and thus independent of frequency. The two networks behave identically as bandpass filters.

In order to obtain wideband performance, the shorted coupled line network was designed as a multisection Lange coupler. The dimensions of the coupler were obtained from an in-house program and optimized on Touchstone. The dimensions of this section are shown in Figure 7. The simulated performance is detailed in Figure 10.



ON GALLIUM ARSENIDE
ER = 13
W = 1 mil
S = 0.7 mil
L = 90 mil
LANG COUPLER WITH SHORTED ENDS
N = 4

Figure 7

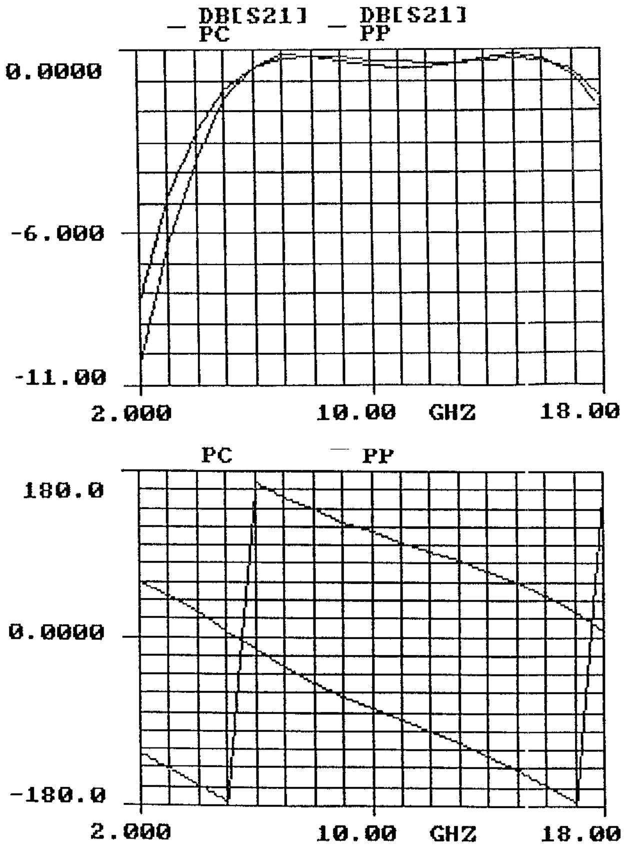
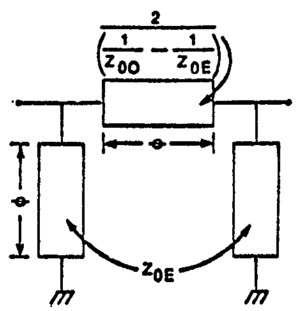


Figure 10

For the Pi network the dimensions, shown in Figure 8, were obtained for optimum performance. As shown, the network consists of three quarter wavelength sections, centered at 14 GHz. The physical format of this circuit, as shown, is not implementable in MMIC form, due to its large area. A novel feature of this circuit was introduced by using a coupled Pi network. This is shown in Figure 9. Again Touchstone was used to optimize the performance as shown in Figure 10. Figure 11 shows the network as fabricated on alumina, 10 mil thick.



ON GALLIUM ARSENIDE
SHORTED LINES W = 2 mil L = 90 mil
SERIES LINE W = 10 mil L = 90 mil

Figure 8

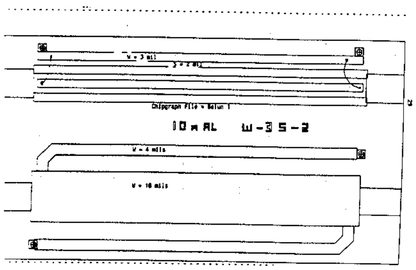


Figure 9

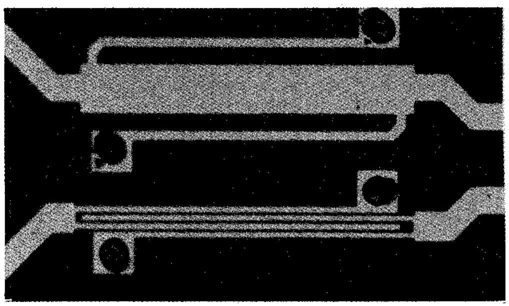


Figure 11 Filter Networks on 10 Mil Alumina

MEASUREMENTS

The assembled phase splitting network consisting of an active wideband power splitter and filter network is shown in Figure 12. The filter networks were connected to the output of the divider. The measured amplitude and phase responses are shown in Figure 13 and the return loss in Figure 14.

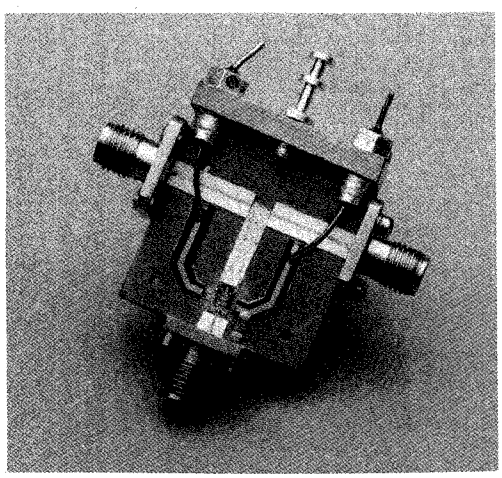


Figure 12 Active Divider with Passive Phase Splitters

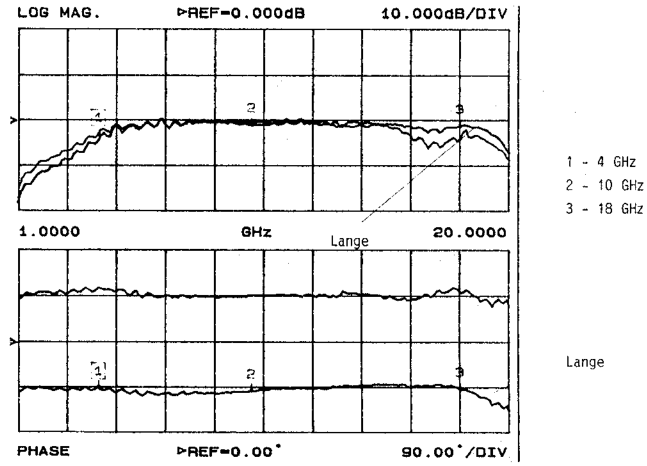


Figure 13

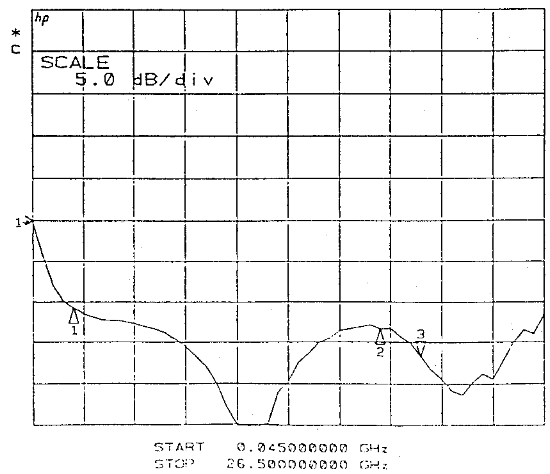


Figure 14 Return Loss of Power Splitter Plus BALUN

The circuit provides excellent phase response from 2 GHz to 18 GHz. However, the amplitude response is good from 4 GHz to 18 GHz. Amplitude tracking was measured to be within $\pm$ 1 dB and phase to be within $\pm$ 7 dB.

CONCLUSION

A 180° phase splitting network has been described with excellent performance. It has applications in numerous components, such as planar BALUNs for double balanced mixers, push-pull amplifiers, sampling phase detectors, etc.

REFERENCES

[1] Matthei, Young and Jones, Microwave-Filters, Impedance Matching Networks and Coupling Structures, McGraw Hill, New York, pp. 219-230.

[2] D.C. Boive, et al, "A 4 to 18 GHz Phase Shifter," MTT-1985, p. 601.