THE TRAVELING WAVE POWER DIVIDER/COMBINER

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SUMMARY

A power divider/combiner circuit designed for application to octave bandwidth microstrip power transistor amplifier is presented.

Circuit characteristics, design and advantages are discussed. Experimental results on a 4-way divider are presented and compared with theory.

INTRODUCTION

Several watts per chip are now currently obtained at X band with power FET's, due to recent improvements in their technology, yet over relatively small bandwidths (20 % typical). Wider bandwidth may be obtained in the near future by the use of internal matching techniques [1]. Nevertheless, the greater the power, the smaller the input impedance and bandwidth. Therefore, large power values (10 watts or more) over octave bandwidth, for ECM applications, require combining techniques.

The divider circuit described here has been designed to achieve this goal.

TRAVELING WAVE DIVIDER/COMBINER

For wide bandwidth, in-phase power dividers derived from the well known Wilkinson circuit are usually chosen when the number of output ports is greater than 2 [2,3,4]. In such circuits, however, if the output ports are connected to unmatched identical loads, power is reflected back to the source. When such a circuit is used to feed transistor amplifiers,resistive input matching circuits are therefore necessary to compensate for the 6 dB/octave gain decrease of the transistor with frequency while maintaining good input matching within all the bandwidth. The transistor input matching circuit is therefore more complicated than it would be if reflected power could be absorbed within the power divider.

Such a result is obtained with the traveling wave divider having the general configuration shown in Fig. 1. N-1 two-way power splitters are cascaded in such a way that each power splitter has one output port which feeds the next splitter. Its second output port is one of the N output ports of the traveling wave divider. Impedance values at the outputs of each power splitter are chosen proportional to the reciprocal of the circulating powers. Therefore, in the absence of reflected waves, the voltages are equal at the outputs of each power splitter. Resistors may then be connected between these outputs without affecting the forward traveling wave propagation. Sections of propagation lines may be inserted between the power splitters to make the phase staggering between output ports different from 0 or π within all the bandwidth. If the traveling wave divider is connected to output loads which are not perfectly matched, reflected waves are generated that are no longer in phase at the output ports of the power splitters. Currents circulate through the resistors. Reflected powers can therefore be absorbed.

FOUR WAY DIVIDER DESIGN

Figure 2 is a photo of a 4 way X-band traveling wave divider/combiner in microstrip configuration. The distance between successive output ports is 3.4 mm. The circuit is fabricated on a 0.25 mm thick alumina substrate. Three thin film resistors are present between adjacent strips to provide reflected powers absorption. Each section of microstrip line is a quarter of a wavelength at a center frequency of 8.5 GHz. The first 2-way power splitter is incorporated in the 3-step input impedance transformer. The theoretical values of quarter wave impedance sections are given in Figure 3. They correspond to microstrip lines of different widths and lengths but special care must be taken to design the transitions between these different lines to obtain the desired power division.

The dimensions of this circuit have been introduced in a computer program which gives the S-matrix and the transmitted and reflected power gains. Variations of the effective dielectric constant of the microstrip with frequency are taken into account. Figures 4 and 5 give the computed S-matrix coefficients. The reflection coefficients are less than 0.06 from 5.4 to 12.4 GHz at port 1 and less than 0.16 from 6 to 11 GHz at ports 2 to 5. Isolation between output ports is better than 17 dB from 6 to 11 GHz and decreases to 13 dB at 12 GHz only between the last two ports.

A dividing + combining structure has also been computed which shows that a phase deviation of 40° in any one of the 4 ways at 12 GHz results in a 0.4 dB transmission loss.

PERFORMANCE

Experimental results are shown on Figures 6 to 8. The divider feeds 4 x 50-ohms microstrips of equal lengths and measurements are made through SMA connectors. Transmitted powers in the 4 ways are found equal within $\pm$ 0.7 dB. The absorption of the reflected waves by the resistors of the divider is made apparent on Figure 7 : when the output ports are shorted, the input return loss remains greater than 10 dB.

The discrepancy with theory in the upper part of the bandwidth is mainly due to the transition between the second and third sections of the input impedance transformer and to the sharp bends at the output ports, which both have been introduced here to minimize transversal dimensions (2.5 mm).

CONCLUSION

Although the 4-way structure described here has not yet been optimized, experimental results confirm the interest presented by this new type of power divider for wide bandwidths integrated power FET combiner amplifiers.

For a large number of outputs, several traveling wave dividers may be fed by a first divider of the same type to maintain acceptable microstrip impedance values, all the output ports remaining in line. Unlike the radial power divider/combiner, power division, amplification and combining can be realized in the same plane. Limits will depend on circuit losses.

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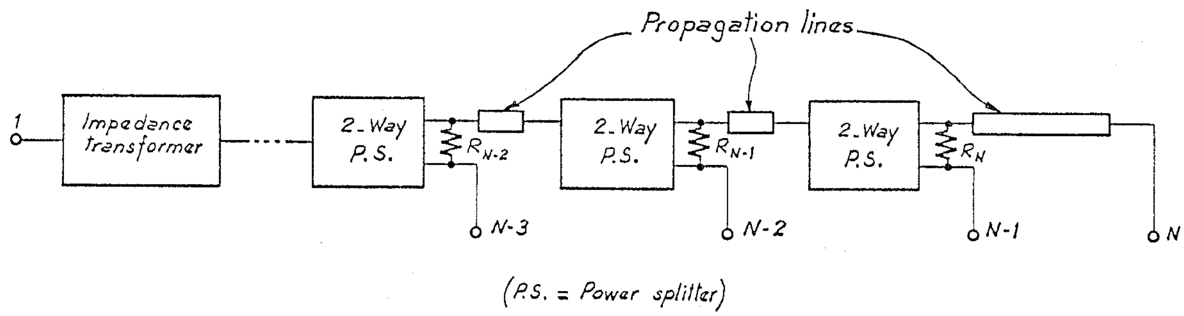

Fig. 1 - Schematic of a Traveling Wave Power Divider

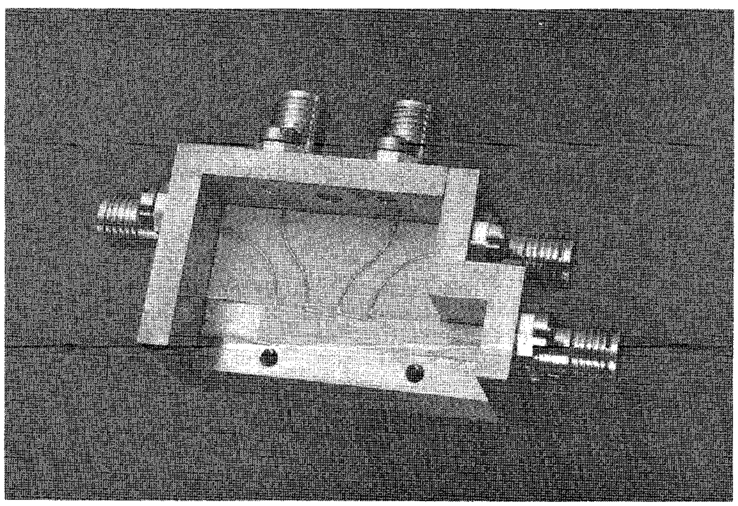

Fig. 2 - 4 - Way Power Divider

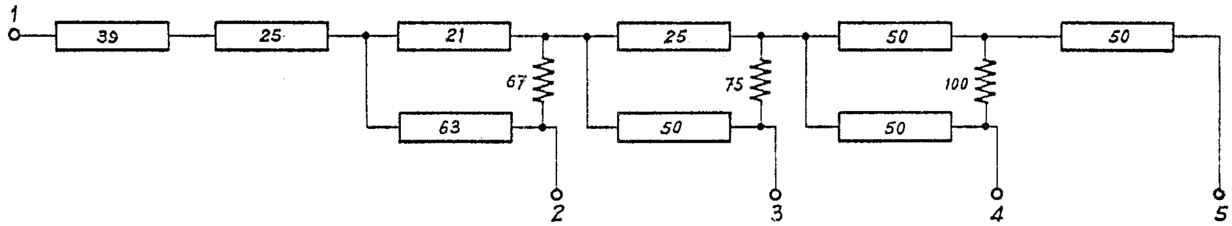

Fig. 3 - Impedance Values for the 4 - way Traveling Wave Divider

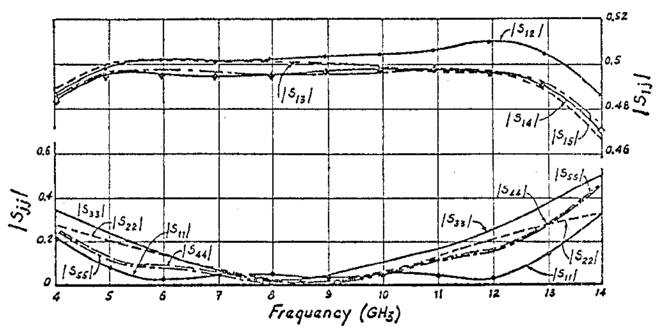

Fig. 4 - Computed S - parameters : transmission and reflection (4 - way TWD)

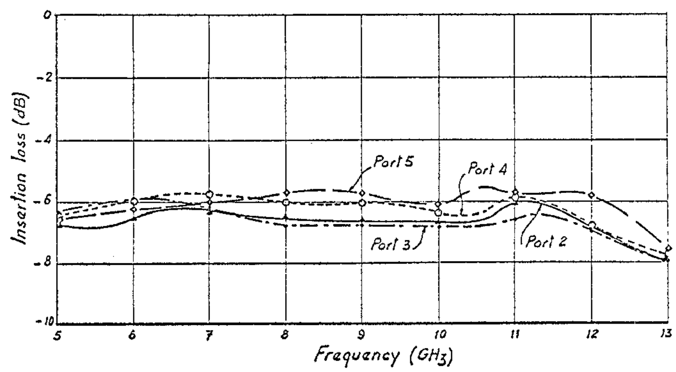

Fig. 6 - Insertion loss between input port and output ports (measured)

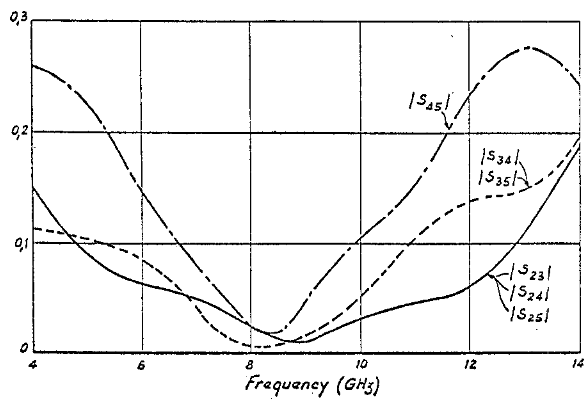

Fig. 5 - Computed S - parameters : isolation between output ports (4-way TWD)

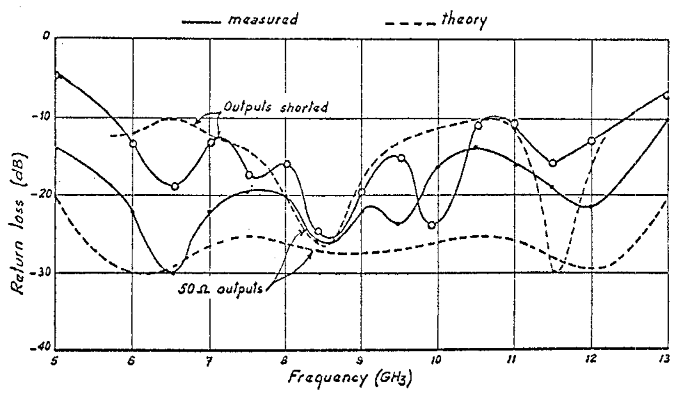

Fig. 7 - Input Return Loss

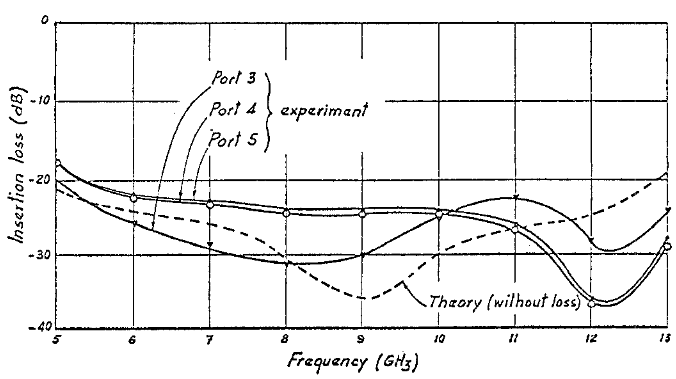

Fig. 8 - Isolation between port 2 and other output ports