CAD AND ELECTRICAL PERFORMANCE OF NEW COMPACT POWER DIVIDER SUITABLE FOR USE IN M(H)MICS

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ABSTRACT

This paper presents a class of new compact power dividers suitable for use in microwave and millimeter-wave integrated circuits (ICs). Compared to the classical structure, the new topology of the power divider is made with a sinusoidally taped circuit shape attached with multiple output ports that are co-linearly located along one plane. The phase and magnitude balance of a signal for the output ports are achieved with diffractive hole(s) etched in the middle of the circuit contour. An efficient field-theoretical CAD procedure is applied to accurate design of this irregularly shaped circuit with a mixed waveguide model and boundary integral method. Electrical performance of the power divider shows a good agreement with theoretical prediction.

I. INTRODUCTION

Multiple-port power divider/combiner networks are essential elements in the design of transistor-based high power amplifier. A number of researchers have studied the feasibility and electrical performance of planar integrated N-way power divider without resorting to resistive elements [1-2].

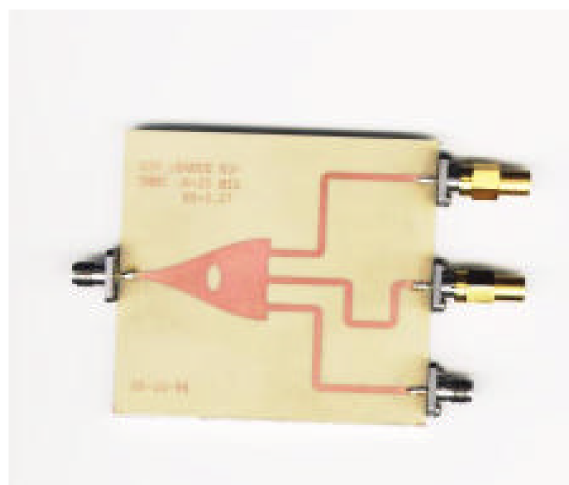

Fig. 1. A three way new compact power divider.

Generally speaking, these structures have the output ports located along a curved wide side (arc) to ensure equalized phase of the power dividing if the divided signal magnitudes are not the primary concern in the consideration of signal balance at the output ports. Although acceptable results have been demonstrated with such

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structures, the problem of realizing co-linearity makes it difficult to design the phase-balanced topology for an amplifier, which is a critical issue at high frequencies. In order to solve these problems, a new power divider was proposed in [3] which consists of co-linear output ports located along a wide plane. The phase equalization is achieved through the use of three-holes compact geometry. However, few details have been given in connection with design and electrical performance of this power divider.

In this paper, complete analysis and CAD of an improved power divider are presented. The improved topology uses a sinusoidal taped circuit contour of which one side is attached with a number of co-linear output ports. Experimental samples with three-way power dividing are made with and without etched hole compensation. The electrical performance of this new circuit is examined in detail with theoretical prediction and measurement results.

A mixed waveguide model and boundary integral method is used to model the frequency response of the new multiple-port structure considering effects of the curved shape of the structure and etched hole [4].

II. CAD OF THE PROPOSED SINUSOIDAL DIVIDER

The objective of our work is to model and design a compact three-way balanced power divider suitable for use in the fabrication of M(H)MICs-based power amplifier. Considering the fact that irregular circuit contour of the power divider including compensation hole is involved, the design may become highly complicated and multiple geometrical variables of the circuit should be considered. In our work, several dividers are designed in the Ku-band operating at 14.5 Ghz over a bandwidth of 500 MHz. In this design scheme, certain restrictions are applied to the divider. The use of surface-mounted amplifier cells requires a 5 mm spacing between two adjacent ports to accommodate the amplifier cell. To achieve a simultaneous phase and amplitude equalization of the output signals, the sector angle of the divider has to be limited within 50 degrees.

To highlight the technical merits of the proposed structure sketched in Fig. 1, a sectorial co-linear divider is first considered in which the output ports are evenly spaced and located along the straight wide side of the structure attached with three 50 Ohms impedance lines. Obviously, the phase imbalance judging from the output ports will appear if no compensation measure is taken. In view of the requirement of power dividing performance, the tape transition from the input to the multiple output ports should be designed as smoothly as possible. In this case, the shape of the taper section can be transformed in the sinusoidal form and also arc bends are made between the adjacent ports such that any abrupt discontinuities can be effectively eliminated. The impedance matching from the input to the outputs can also be improved.

As the output ports are co-linearly located, the electrical path from the input to the outputs is different from one to another. It is evident that the physical distance from the input to the middle output port is shortest and therefore the phase and magnitude imbalance is inevitable. In order to equalize or synchronize the output ports, a hole is introduced and etched around the center part of the structure. This design strategy is based on the fact that the hole will create a built-in signal diffraction and can be used to compensate the electrical paths through the back-and-forth multiple reflections and transmissions. The resulting signal division at the output ports can be equalized if an appropriate design of the compensation hole is made. Therefore, the design of such a

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hole is a critical issue in the realization of a compact sinusoidal power divider. In addition to the equalization of the signal path and balance of the signal division, the hole should be made such that the input and output matching is guaranteed simultaneously. In any case, the hole should be long enough to delay the signal transmission from the input to the middle output port and narrow enough to avoid potential interactions with the other ports. An ellipsoidal form of the hole seems to be the optimal solution which is able to satisfy simultaneously these conditions.

A number of design iterations are therefore necessary to adjust the divider dimensions and the hole position as well as it size to optimize the electrical performance of the power divider. Fig. 1 shows the optimal design layout for a three-way balanced power divider.

II. CAD OF THE PROPOSED SINUSOIDAL DIVIDER

The divider was fabricated on the standard TMM3 substrate (Trade Mark of Rogers Corporation) with εr = 3.27 and the substrate thickness H = 25 mil. Fig. 2 and Fig. 3 show frequency-dependent electrical performance of signal transmission and return loss predicted by the field-theoretical based CAD tool and the experimental sample sketched in Fig. 1. It is found that the design predictions are in good agreement with the measurement results even though a small frequency shift of the designated center frequency is observed between them. Fig. 2 indicates clearly that an excellent return loss performance can be achieved at the center frequency and 5% effective bandwidth can easily be realized (with reference to S_{11} below -15 dB). Nevertheless, the transmission characteristics suggest that the loss of the divider be important (approximately 1.6 dB at 14.5 Ghz). Hence, the combining efficiency of this structure may not be adequate. The loss is essentially caused by the mismatch at the output ports with the discontinuities along the wide end of the structure. Fig. 4 shows that perfect and simultaneous equalization of phase and magnitude of the three output ports can be made at the shifted center frequency (f = 14.25 Ghz). The effect of the hole etched inside the structure is highlighted in Fig. 4 showed that the hole can effectively compensate the phase and magnitude imbalance for the frequency band of interest. It can be seen that the difference between the two cases are significant. It also indicates that the hole compensation has to be considered in the high frequency range.

CONCLUSION

This paper presents a new improved power divider having a sinusoidal contour of the taper section and ellipsoidal hole. The hole is introduced to compensate the imbalance of the phase and magnitude appearing at the output ports. New design strategy is presented with a field-theoretical based CAD tool considering port-to-port and port-to-hole interactions. It is found through the design prediction and experimental results that the compact divider can be effectively made with an excellent input match performance and an effective 5% bandwidth is obtained. The good agreement between the theory and experiments suggests that such a multiple-port power divider be optimally designed. It is also observed that the use of the hole is a critical issue in the design of this divider which yields a significant impact on its electrical performance.

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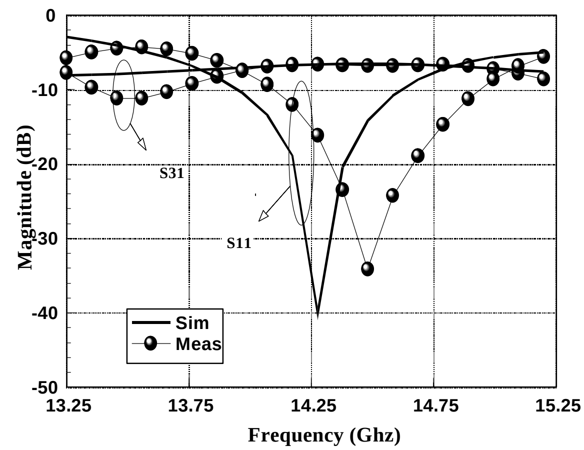

Fig. 2. Comparison of the return loss and transmission characteristics between the predicted and measured results for Ku-band experimental sample.

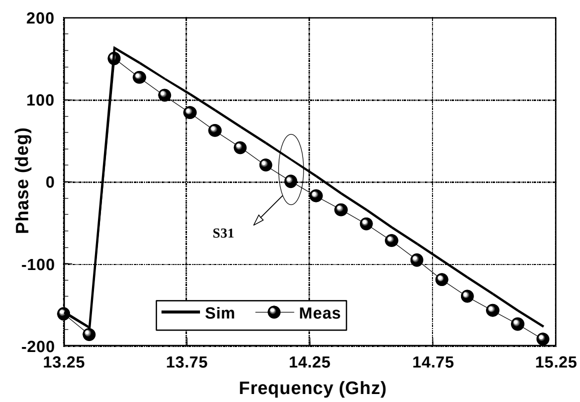

Fig. 3. Comparison of the phase balance characteristics between the predicted and measured results for a Ku-band experimental sample.

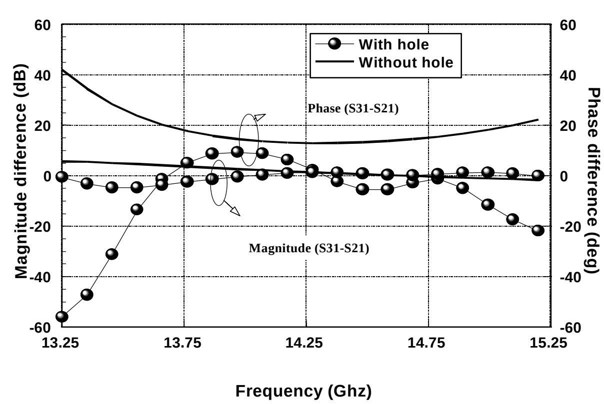

Fig. 4. Frequency response of the power divider with and without hole compensation.

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