Broadband miniature quadrature coupler on planar cells

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Abstract

Due to the fact that microwave devices at low frequencies are cumbersome, their designs undergo a miniaturization procedure. This work is aimed at exploring the possibilities of miniaturization of a passive broadband power divider. Through the use of planar cells, it was possible to reduce the area occupied by the divider on the printed circuit board from 3786 mm^2 to 1004.2 mm^2. However, miniaturization reduces bandwidth by 10%.

1 Introduction

Since its inception, planar devices have found wide application in microwave technology, due to their advantages - they are small in size and mass, are cheap to manufacture, technologically advanced and convenient for mass production using integrated technology methods. However, microwave devices have a tight binding of dimensions and operating frequency, the lower the frequency, the greater the area the device occupies on the substrate. This factor is especially important when the device operates in the decimeter wavelength range and lower in frequency. For this reason, it is necessary to find a way to miniaturize such structures, which would significantly reduce the occupied area of the device while maintaining the characteristics in a wide frequency band. In the literature and scientometric databases there are many works on miniaturization of microwave devices [1-12]. This article report the design of a compact broadband directional coupler. Reducing the occupied area of the device is achieved through the use of planar cells having equivalent characteristics with microstrip segments of the transmission line.

2 Layout

Initially, the design of the full-sized design of the coupler is carried out, with the characteristics of which a comparison will be made later. Using the NI-AWR Design Environment program, a coupler was developed, the block diagram of which is shown in Figure 1.

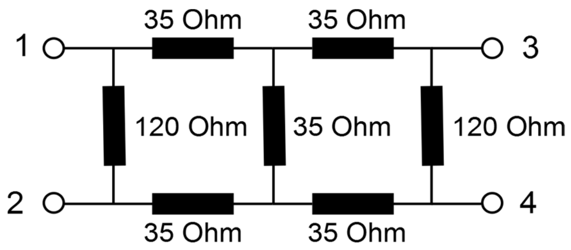

Figure 1. Block diagram of a three-loop coupler.

Such a coupler consists of seven quarter-wave segments tuned to different wave impedances. FR-4 with the following parameters was chosen as the substrate material: ε = 4.4, tanδ = 0.02 and h = 1 mm. The choice of this material is due to the fact that this is one of the cheapest options for microwave substrates. The directional coupler is designed for a center frequency of 1000 MHz (Fig. 2). After calculating the dimensions of the quarter-wave segments, and then combining them into one diagram according to the structural diagram, we found that the area of the full-sized structure is 3786 mm^2.

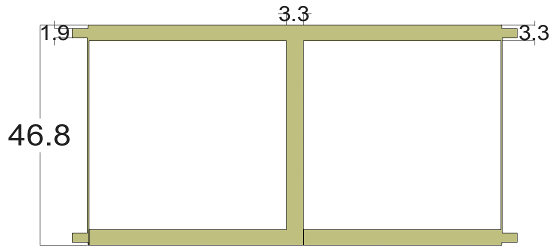

Figure 2. Layout of a standard coupler design.

After electrodynamic analysis of the full-sized design, it was found that the frequency band, according to the isolation level of -20 dB, is 330 MHz. The scattering matrix coefficient S11 has a value below -15 dB in the entire frequency band. There is no imbalance between the transmission coefficients at the central frequency, and the phase difference between the outputs is 90 degrees (Fig. 3, 4).

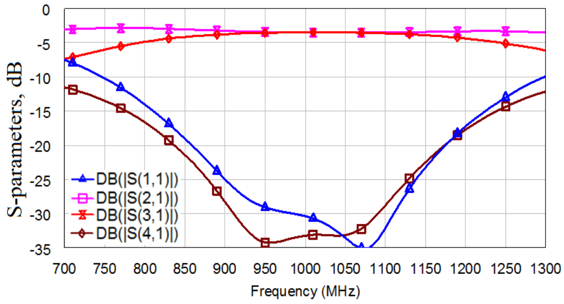

Figure 3. Graph of S-parameters versus frequency.

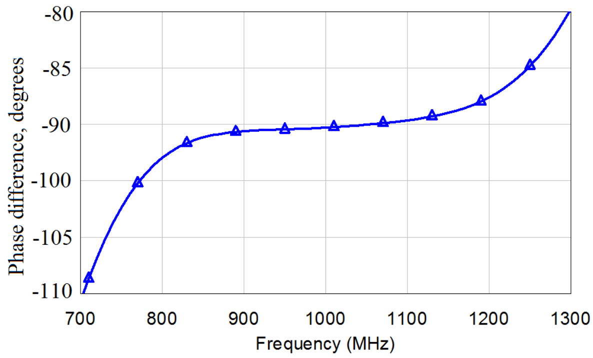

Figure 4. Graphic dependence of phase change on frequency.

It can be seen that the conventional design of the coupler has an area inside the device that is not used in any way. This area can be effectively used in miniaturization. To miniaturize the coupler, it is necessary to synthesize planar cells, and the protruding elements should be located in the internal space of the device. It should be noted that the cells must have a phase of 90 degrees at the center frequency of the device, as well as minimal loss of transmission coefficient at the center frequency. After all the necessary cells have been obtained and installed instead of quarter-wave segments, an electrodynamic analysis of the structure and optimization of the entire device to obtain the best characteristics (if necessary) are performed. The resulting device topology is illustrated in Figure 5, and the frequency characteristics are shown in Figures 6, 7. The area of the resulting structure is 23.3 mm x 43.1 mm = 1004.2 mm^2, which is 73.5% less than the area of a conventional structure.

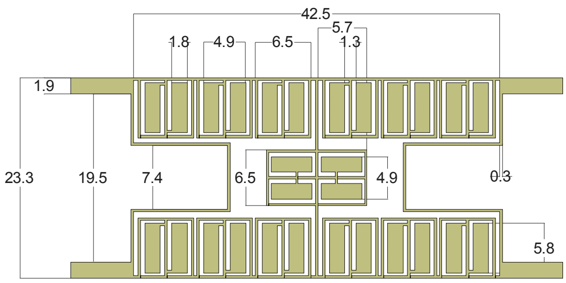

Figure 5. Design of a compact three-loop coupler.

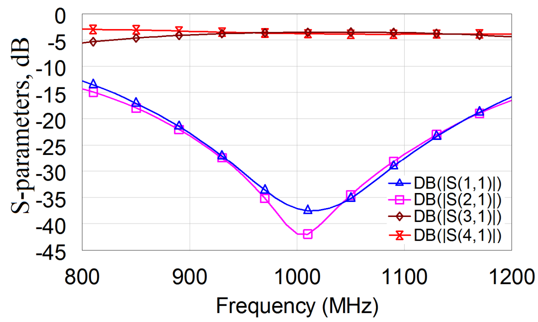

Figure 6. Graph of S-parameters versus frequency.

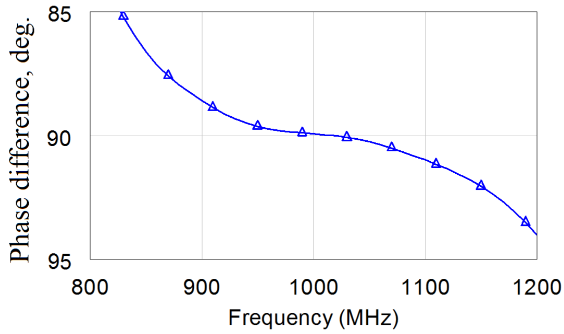

Figure 7. Graphic dependence of phase change on frequency.

After electrodynamic analysis of the full-sized design, it was found that the resulting design works at a center frequency of 1010 MHz and has a working frequency band of 287 MHz. The maximum imbalance between the transmission coefficients does not exceed the value of 0.25 dB. The phase difference between the transmission coefficients is 89 degrees an error of 1.1% is permissible.

3 Parameter Measurement

To analyze the operability of the structure in practice, a model of the proposed coupler was made (Fig. 8). Using the rode & share vector network analyzer, experimental dependencies were obtained, which are illustrated in Fig. 9, 10.

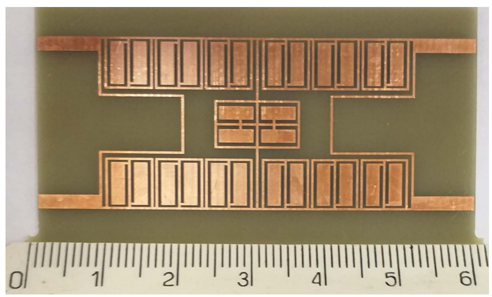

Figure 8. Compact Broadband Power Divider.

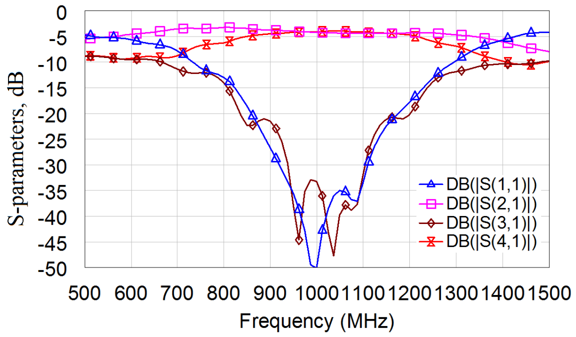

Figure 9. Measured graph of S-parameters versus frequency.

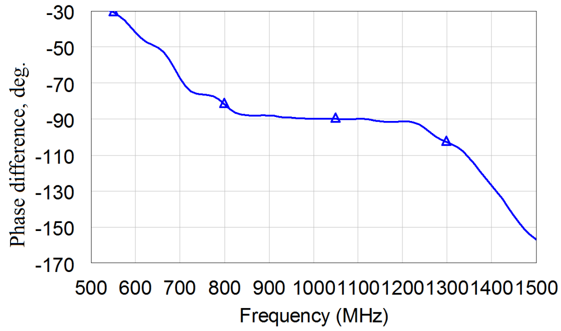

Figure 20. Measured graphic dependence of phase change on frequency.

After electrodynamic analysis of the full-sized design, it was found that the resulting design works at a center frequency of 1016 MHz and has an operating frequency band of 365 MHz. The maximum imbalance between the transmission coefficients does not exceed the value of 2.2 dB. The phase difference between the transmission coefficients is 89.79 degrees. For a detailed comparison, the results are summarized in table 1.

Table 1 Comparison of traditional and compact broadband couplers

Parameters	Proposed	Conventional
Area (mm^2)	1004.2	3786
Relative size	26.5%	100%
Maximum imbalance between transmission coefficients in the frequency band	2.2	1.8
Return loss (dB)	42	30
Isolation (dB)	36	32
Phase difference	89	90
Harmonic Suppression	YES	NO

4 Conclusions

A compact broadband directional coupler with equal division of input power has been developed. At a center frequency of 1 GHz, the coupler has an area of 1004.2 mm2, which is 73.5% less than the area of the full-size structure. However, the compact design has less bandwidth by 5%. The entire tap design process was carried out in the NI-AWR Design Environment. A model of the proposed device was made, which showed high convergence with the design results.

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