# Broadband multilayer in-phase power divider

K. Song, Y. Fan and X. Zhou

A new broadband in-phase power divider based on multilayer technology is presented. A simple design procedure is developed for the proposed multilayer power divider. An S-band four-way multilayer power divider was designed and measured. The simulated results are compared with the measured data, and good agreement is reported. The measured 15 dB return loss bandwidth is demonstrated to be about 72%, and its phase difference between the output signals is less than 3°.

*Introduction:* Broadband microwave power dividers are a very important category of passive microwave circuits. Indeed, these components are often used in microwave systems to combine or divide RF signals, and they are commonly used in many applications, such as antennas feeds, power amplifiers, mixers and so on. With the development of mobile communication systems, the miniaturisation of the communication system is urgently needed. Multilayer integration technologies, such as low-temperature co-fired ceramics (LTCC) and laminated multi-chip modules (LMCM), are extremely advantageous to reduce the size of microwave devices. These new technologies can also be used to miniaturise the microwave power divider. The Wilkinson divider is most widely used in microwave communication systems [1]. It offers equal-phase characteristics at each of its output ports. However, in its original configuration, the Wilkinson power divider has a narrow bandwidth, which makes it inconvenient for broadband applications. Several modifications have been proposed to either enhance its performance or reduce its size [2–7]. Recently, parallel strip-lines have been used with a modified configuration of the Wilkinson power divider [8, 9]. The measured performance of the developed devices shows broadband performance.

In this Letter, a compact multilayer broadband microwave power divider using a broadside slot-coupling configuration is presented and investigated. The ports of the power divider are distributed among different layers, which make the presented divider compatible with the modern multilayer technology. A broadband four-way in-phase power divider operating over the entire S-band has been designed and tested. The results show that the measured values are in agreement with the simulated values. The power divider presented can find important applications in the design of power-combining amplifiers and multi-port networks.

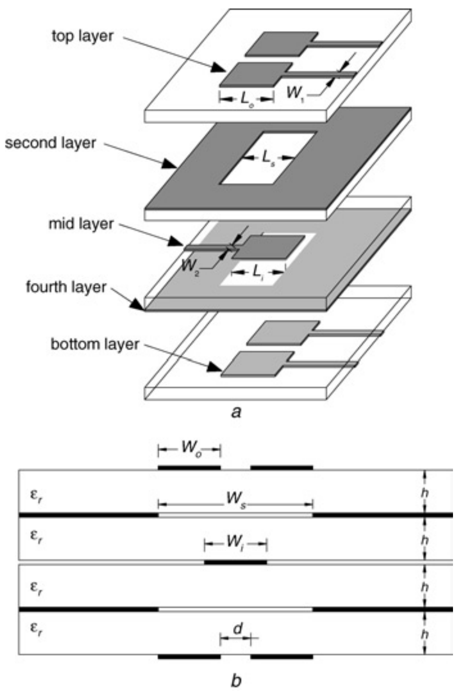


**Fig. 1** *Configuration of multilayer power divider*

*a* Perspective view
*b* Section view

*Design:* The configuration of a multilayer power divider is shown in Fig. 1. It is a four-way power divider, and consists of five conductor layers interleaved by four dielectrics. The input port is at the mid layer of the structure, while the four output ports are located at the top and bottom layers. The second and fourth layers of the structure are the ground plane, which also includes the coupling slot. The microstrip coupled patches and the slots are of rectangular shape. The RF signal is input from the input port at the mid layer, and divided equally into four output ports located at the top and bottom layers because of the symmetry of the multilayer power divider. The four output signals are equal in amplitude and in phase.

For the rectangular-shaped microstrip and slot of the power divider proposed, the analysis and design procedure is similar to the one described in [10], and the odd and even modes of propagation have been taken into account. The rectangular microstrip width at the mid layer and the top layer are $W_i$ and $W_o$, respectively. The rectangular microstrip length at the mid layer and the top layer are $L_i$ and $L_o$, while the rectangular coupling-slot width and length are denoted by $W_s$ and $L_s$. For a simple design procedure, the rectangular microstrip width at the top layer $W_i$ can be obtained according to the literature [10], and let $W_o = W_i \simeq W_s/2$. The rectangular microstrip length of the top layer $L_o$ is chosen to be about one-quarter of the effective wavelength at the design central frequency (here, the design central frequency is about 7 GHz), and $L_i = L_s = L_o$. The width of the microstrip-line output ports (at the top layer and bottom layer) and the stripline input port (at the mid layer) are $W_1$ and $W_2$, respectively, which can be decided according to the characteristic impedance of the ports (here, the characteristic impedance is equal to 50 Ω). Owing to the symmetry of the multilayer power divider, the parameters of the bottom layer and the fourth layer are the same as those of the top layer and the second layer, respectively.

Since there are various interactions among the parameters involved in the proposed design procedure, a rigorous analysis is necessary for the optimisation of the multilayer power divider parameters. The initial dimensions of the power divider are obtained according to the simple design procedure proposed above, and commercial computer software Ansoft-HFSS is used to design and optimise the proposed power divider. The parameters of the power divider have been adjusted for receiving broadband characteristics at the desired frequency range.

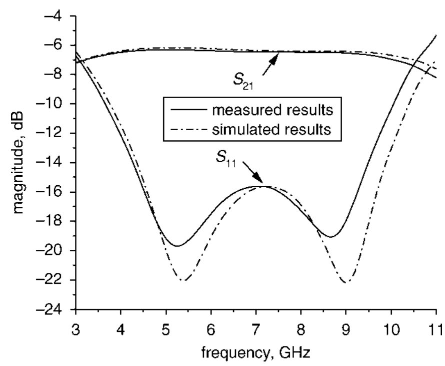


**Fig. 2** *Measured and simulated S-parameters*

*Results:* To validate our analysis and design procedure for the multilayer power divider, a proposed broadband four-way power divider based on multilayer techniques was fabricated and measured. A Rogers RO4350 board (with $h = 0.508$ mm, a relative permittivity of 3.48, and a loss tangent of 0.004) was selected for the power divider development. Using the proposed simple design method with the help of the optimisation capability of the software Ansoft-HFSS, the dimensions of the multilayer power divider were found to be (see Fig. 1): $W_1 =$ 1 mm, $W_2 = 0.6$ mm, $W_i = 3.6$ mm, $W_o = 3.9$ mm, $W_s = 9.4$ mm, $L_i =$ 6.9 mm, $L_o = 6.25$ mm, $L_s = 7$ mm, and $d = 0.7$ mm.

The simulated and measured return loss and insertion loss are shown in Fig. 2. The measured and simulated 15 dB return loss bandwidths were all found to be approximately 5 GHz (72%). The bandwidth around which the minimum insertion loss increases by 0.5 dB was found to be about 6 GHz (93%) experimentally. The shift of the operation frequency in the measured response was due to the imprecision in assembly. Nevertheless, the overall measured response shows good agreement with the simulated results. In addition, the isolations between the output ports of the four-way power divider have also been measured (see Fig. 3). The isolations are as low as 10 dB at the entire design frequency range. Concerning the phase performance of the power divider, the measured results shown in Fig. 4 indicate that the proposed device is an in-phase power divider, where the four output signals are in phase with less than 3° phase difference.

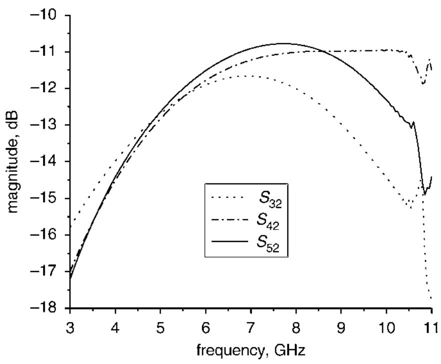


**Fig. 3** *Measured isolation between output ports*

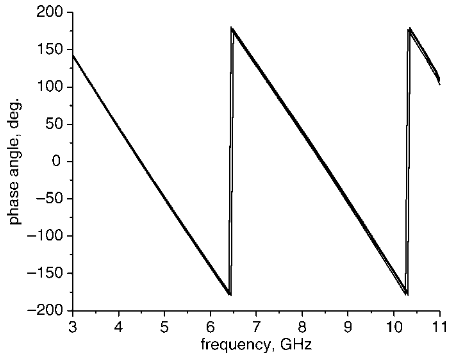


**Fig. 4** *Measured phase of output signals*

*Conclusions:* A compact broadband multilayer in-phase power divider has been presented. A broadside coupling via a multilayer microstrip/slot configuration has been used in this power divider. A simple design method with the help of the software Ansoft-HFSS has been applied to design and analyse the multilayer power divider proposed. A four-way multilayer power divider operating over the entire S-band has been designed, built and tested. The simulated and measured results of the developed device have shown a 15 dB return loss bandwidths of about 5 GHz (72%) and less than 3° phase difference between the output signals. This new configuration of multilayer power divider is compact and easy to fabricate using LTCC technologies.


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