A miniaturized filtering power divider with wide stopband

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***Abstract* - This paper presents a miniaturized power divider integrated with wide-stopband bandpass responses. Two *K*-inverters with bandpass functions are utilized to replace the two quarter-wavelength transmission lines in the conventional Wilkinson power divider. The *K*-inverter consists of transmission lines and capacitors which can reduce the occupied area and suppress the high-order harmonics. Theoretical analysis is carried out and design equations are derived. For demonstration, a filtering power divider operating at 470 MHz is implemented with the wide stopband up to 4 GHz. The circuit size is 0.033 λg × 0.044 λg, featuring compact size.**

***Index Terms* —Power divider, bandpass filter, integration, compact size, wide stopband.**

I. INTRODUCTION

Power dividers and bandpass filters (BPFs) are indispensable building blocks in many RF front-ends. These two components occupy a considerable area, especially at low frequency region. Thus, it is beneficial to integrate them for size reduction.

There are three typical methods for integration of power dividers and bandpass filters. The first technique is to cascade the filtering circuit with power dividers. The filtering structure is cascaded with the T-junction [1] or directly embedded in the power divider [2], resulting in dual functions of power dividing and filtering. The second one is to replace the quarter-wavelength transformers in Wilkinson power dividers with BPFs [3]-[5]. Besides the two methods, the filtering and power splitting circuits can be merged together to obtain dual functions [6] & [7].

In this paper, a novel method for designing compact filtering power divider with wide stopband is proposed. The proposed power divider consists of two *K*-inverters, which can also function as the filtering network. By adopting the *K*-inverters structures, a compact size and harmonic suppression can be implemented simultaneously. The main features of the proposed filtering power divider include: 1) compact size; 2) wide stopband; 3) dual functions;

II. THEORY OF THE FILTERING POWER DIVIDER

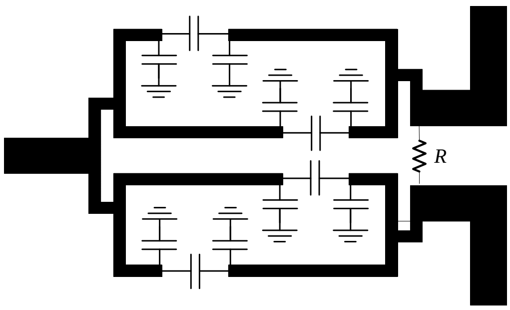


Fig. 1. Configuration of filtering power divider.

A. Configuration

Fig. 1 shows the configuration of the proposed filtering power divider. It consists of two coupling structures which have four transmission lines with the length of l_1 and l_2 and six capacitors. The coupling structures can function as two *K*-inverters to replace the two λ/4-lines in the conventional power divider [5].

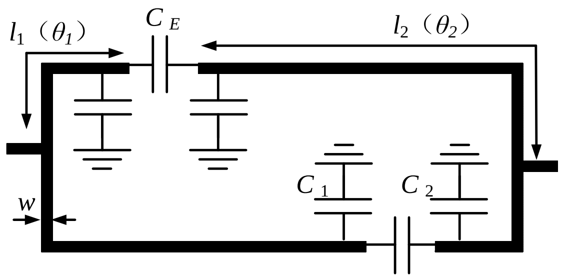


Fig. 2. Configuration of *coupling structure*.

B. Analysis of coupling structure

Besides the *K*-inverter, the coupling structure can also function as a filtering network. As shown in Fig. 2, two transmission lines (l_1, l_2) and two capacitors (C_1 and C_2) form a resonator. It can be considered as two resonators coupled with each other through the two capacitors C_E. The fundamental resonant frequency f_0 can be determined by

$$2\pi f_0(l_1+l_2)\sqrt{\varepsilon_e}/c+\tan^{-1}(2\pi f_0 C_1 Z)+\tan^{-1}(2\pi f_0 C_2 Z)=\pi \quad (1)$$

where ε_e is the effective dielectric constant. While the second harmonic f_h can be determined based on (2),

$$2\pi f_h(l_1+l_2)\sqrt{\varepsilon_e}/c+\tan^{-1}(2\pi f_h C_1 Z)+\tan^{-1}(2\pi f_h C_2 Z)=2\pi \tag{2}$$

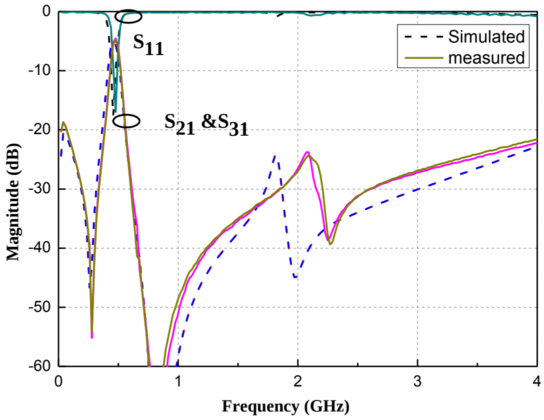
It can be seen that f_h can be extended to higher frequency by adopting the capacitors. Therefore, the K-inverter can be designed for wide stopband and compact size.

III. CIRCUIT IMPLEMENTATION

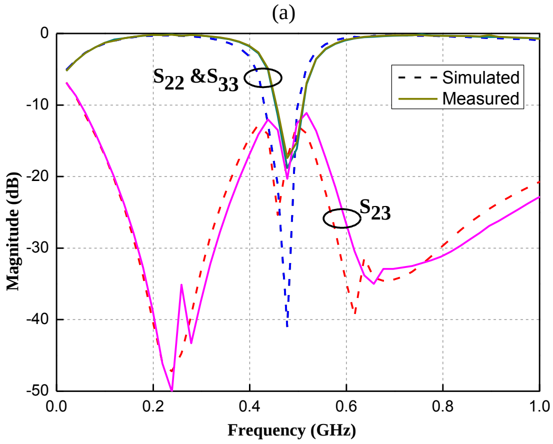
A. *Circuit Design*

As shown in Fig. 1, the proposed power divider consists of two coupling structures. The design procedure is summarized as follows: Firstly, with a given operating frequency and the second harmonic, choose the proper values for C_1, C_2 and (l_1+l_2) based on (1) and (2) such that it could obtain the minimum size of the coupling structure. Then, design the two coupling structures matched to 70.7 Ω. The output port of this circuit is 50 Ω which is identical to a conventional power divider.

B. *Experimental Results*



(a)



(b)

Fig. 3 Simulated and measured results. (a) S_{11}, S_{21} and S_{31}. (b) S_{22}, S_{33} and S_{23}

For demonstration, a filtering power divider with wide stopband operating at 470 MHz is implemented. In this design, the substrate has the relative dielectric constant of 3.38, the thickness of 0.81 mm and the loss tangent of 0.0027. The parameters in Fig. 2 are obtained as follows: L_1=4.5 mm, L_2=12 mm, w=0.3 mm, C_1=8.2 pF, C_2=39 pF, C_E=5 pF, R=100 Ω. The size of this circuit is 0.033 λg × 0.044 λg, where λg is the guided wavelength at the center frequency of passband. As can be seen, the size is greatly reduced.

Fig.3 shows the simulated and measured results of the power divider. The center frequency is located at 470 MHz and the fractional bandwith is 14%. Two transmission zeros are generated close to the passband edges. Within the passband, the power is equally split with the S_{21} and S_{31} of -4.4 and -4.5 dB. The insertion loss is around 1.5 dB, which is caused by the parasitic resistances of the capacitors. As the design combines filtering and power splitting functionalities, it is equivalent to the cascaded filer and Wilkinson power divider and therefore the insertion loss is higher than the power dividers without bandpass characteristics. The stopband is extended to 4 GHz (8th harmonic) with more than 20 dB rejection level. Fig. 3 (b) shows the simulated and measured isolation between ports 2 and 3, which is more than 15 dB at the center frequency.

IV. CONCLUSION

This paper demonstrated a novel Wilkinson power divider, in which two K structures are used to realize compact size and filtering responses simultaneously. The proposed power divider has capabilities of equal power division and the extra filtering function with wide stopband. The design formula was given and verified by a demonstration dual-function device. This work is useful in the implementation of compact filtering power divider.

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