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# A One-to-Two Filter Power Divider Based on LTCC

Yuanyuan LI[1], Xianliang WU, Yunfeng HU, Mengying DONG, Yue MA, Xiaolei GENG and Rongzhen FANG
[a] *Key Laboratory of Intelligent Computing and Signal Processing, Ministry of Education, Anhui University, Hefei 230001, China*

**Abstract.** In order to miniaturize microwave devices in RF systems, a power divider with filtering performance is designed. The filter power divider is based on the LTCC process, and miniaturization is achieved by cascading a bandpass filter and a one-to-two power divider. The band-pass filter adopts a fourth-order comb-line structure, and the one-to-two power divider adopts an LC lumped structure. The size of the one-to-two filter power divider designed is 10mm×4mm×5mm, which is working in 3.3GHz-3.6GHz. The simulation results show that the insertion loss($S_{21}$ and $S_{31}$) are less than or equal to 4 dB, the return loss($S_{11}$) is greater than 15 dB, the isolation($S_{23}$) is greater than 17 dB, and the out-of-band suppression is greater than 18 dB in 3.8-4.3GHz and 22 dB in 0-3.2GHz and 4.3-6GHz.

**Keywords.** Filter power divider, LTCC, cascade

## 1. Introduction

With the continuous development of communication systems, miniaturized and high-performance microwave devices have become the focus of current research in the industry. Filters and power dividers are common microwave passive components, and their performance and size are critical to the overall system. There are usually two design methods. One is to design them separately and then cascade them together. The other is to carry out a comprehensive integrated design to make them have multiple performances such as power distribution, filtering, and frequency selection at the same time.

Xie Hanyu[1] designed a multi-channel filter power divider with a double-layer microstrip structure. The final overall size of the filter power divider is 28mm×30mm. Li Weijin[2] and others designed a filter power divider based on a stepped impedance resonator, the size of which is 22.6mm × 34.2mm. Wang Yujie[3] and others designed a dual-pass band filter power divider using the SIW, the size of which is 18.98mm × 19.05mm. LTCC has the characteristics of high integration and low loss. Dai Yongsheng[4] and others designed an LTCC filter with a center frequency of 60 GHz and a passband of 6 GHz whose overall size is 1.6mm×0.8mm×0.6mm. Fu Jiahui[5] and others designed a 1.27GHz-1.58GHz frequency band, LTCC three-way Wilkinson power divider, its size is 5.3mm×5mm×1.3mm.

Based on the characteristics of LTCC, this paper realizes an LTCC filter power divider by cascading the LTCC filter and the power divider, and its overall size is

[1] Corresponding Author: Yuanyuan Li; E-mail: liyuanyuan_hnxx@163.com.

10mm×4mm×5mm. Finally, the simulation of the filter power divider shows that:in the 3.3GHz-3.6GHz frequency band, the insertion loss($S_{21}$ and $S_{31}$) are less than or equal to 4 dB, the return loss($S_{11}$) is greater than 15.7 dB, the isolation($S_{23}$) is greater than 17.5 dB, and the out-of-band suppression is greater than 18 dB in 3.8-4.3GHz and 22 dB in 0-3.2GHz and 4.3-6GHz, meeting the given index requirements.

## 2. Design principle

The filter power divider designed is formed by cascading a fourth-order comb-line filter and a power divider.

### *2.1. LTCC comb-line filter*

What shown in Figure 1 is the equivalent circuit schematic of the comb-line filter. The serial number N represents the Nth resonator, and the serial number 0 and the serial number N+1 represent the input and output leads respectively. The energy is transferred between the resonators through side coupling. Each resonator is composed of a short-circuit transmission line connected to a lumped ground capacitor, which is equivalent to an LC parallel resonant. The resonant frequency can be tuned by adjusting the size of the transmission line and the size of the ground capacitance.

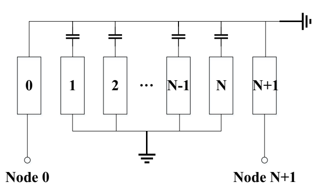


**Figure 1.** Equivalent circuit structure of comb-line filter.

In this paper, the three-layer broadside coupled stripline[6-7] is used as the resonator to design, and its structure is shown in Figure 2. The front end of the stripline in the middle layer is open and the back end is grounded, and the front ends of the upper and lower striplines are grounded and the back end is open, and they are symmetrical with respect to the stripline in the middle layer. The resonator is located in the center between the two ground plates. The distributed inductance of the three-layer broadside coupled stripline resonator is the distributed inductance of the single-layer stripline, and the distributed capacitance is the total capacitance formed by the distributed capacitance of the single-layer stripline and the two coupling capacitors.

The distributed inductance and distributed capacitance per unit length of the three-layer broadside coupled stripline[6] are expressed as:

$$\tilde{L} = \frac{\pi\mu_0}{8\mathrm{arch}(e^{\pi w/2b})} \tag{1}$$

$$\tilde{C} = \frac{8\varepsilon\mathrm{arch}(e^{\pi w/2b})}{\pi} + \frac{2\varepsilon w}{d} \tag{2}$$

The resonant frequency of the three-layer broadside coupled stripline resonator is:

$$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(\tilde{L}l)(\tilde{C}l)}} = \frac{1}{2\pi l\sqrt{\tilde{L}\tilde{C}}} \tag{3}$$

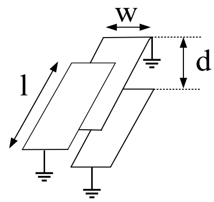


**Figure 2.** Geometry of a three-layer broadside coupled stripline resonator.

### *2.2. Wilkinson power divider*

The Wilkinson power divider has a simple structure. By directly connecting an resistor between the output ports to absorb the reflected energy, the isolation between the ports is increased, and the effect of consuming the reflected power can also ensure the matching between the ports.

The use of quarter-wavelength transmission line in the power divider will make the physical size larger, so this paper uses the equivalent circuit of type $\pi$ [8] to replace the quarter-wavelength transmission line to minimize the size.

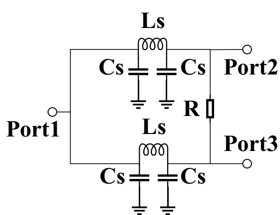


**Figure 3.** Circuit diagram of lumped-element one-to-two-way Wilkinson power divider.

Figure 3 is the circuit diagram of the lumped-element one-to-two-way Wilkinson power divider. The parameters in the figure can be calculated by equations (4)~(6).

$$L_s = \frac{Z_0 \sin\theta}{\omega} \tag{4}$$

$$C_s = \frac{1}{Z_0\omega}\tan\frac{\theta}{2} \tag{5}$$

$$R = 2Z_0 \tag{6}$$

## 3. Models and Simulations

The filter power divider designed in this paper is composed of a LTCC filter and a power divider in cascade. Its indicators are shown in Table 1. In this paper, LTCC multi-layer metallized wiring is used in the design, and silver is used as the wiring conductor. The dielectric constant of the ceramic dielectric used is 5.9 and its tangent loss angle is 0.0005 , and the height between each stripline is 0.1 mm.

**Table 1.** Parameters of filter power divider

| Indicator | Filter | Power divider | Filter power divider |
|---|---|---|---|
| Center frequency | 3.45G | 3.45G | 3.45G |
| Bandwidth | 300MHz | 300MHz | 300MHz |
| Insertion loss | 1dB | 3.5dB | 4.5dB |
| Return loss | 12dB | 15dB | 15dB |
| Isolation | - | 15dB | 15dB |
| Out-of-band suppression | 15dB(0-3.1GHz,3.8-6GHz) | - | 15dB(0-3.1GHz,3.8-6GHz) |

### *3.1. LTCC fourth-order combline filter*

The design steps of the distributed bandpass filter: First, the length, width and layer spacing of the stripline are preliminarily determined through the relationship between the center frequency and the physical quantities related to the stripline**.** Then use HFSS software for 3D modeling and simulation, and determine the bandwidth by optimizing the spacing between the resonators. Finally, between the first and fourth-order resonators, Z shape cross-coupling is added to introduce transmission zeros to enhance out-of-band suppression.

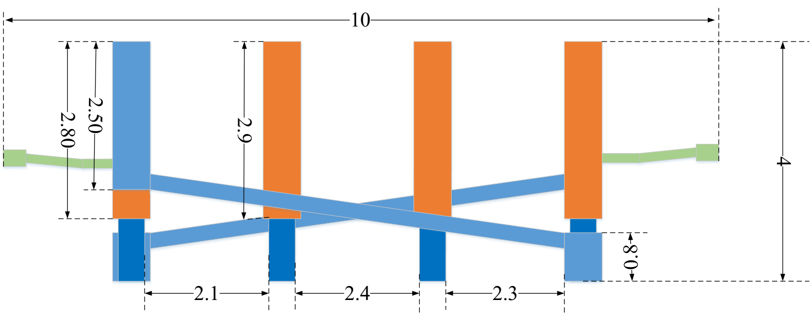


**Figure 4.** Top view of the fourth-order comb-line filter.

The model structure of the fourth-order comb-line filter is shown in Figure 4, and the data units in the figure are all millimeters. The filter size is 10mm×4mm×4.5mm.

In this design, Z shape cross-coupling is inserted above and below the first and fourth resonators[9], and the output signal of the main coupling channel is 180° out of phase with the output signal of the cross-coupling channel[10], so that cancel each other out and introduce transmission zeros near the upper and lower sidebands. Finally, by continuously fine-tuning the parameter variables, the simulation curve of the fourth-order comb-line filter with and without Z shape cross-coupling is finally obtained, which is shown in Figure 5.

From the simulation curve what can be seen is that the out-of-band suppression can be significantly enhanced by introducing transmission zeros through Z shape cross-coupling. In the operating frequency range of 3.3GHz-3.6GHz, the insertion loss($S_{21}$) is less than 0.9dB, the return loss($S_{11}$) is greater than 13dB, the out-of-band suppression is greater than 17dB in 2.8-3.1GHz and 3.8GHz-4.1GHz, and 19dB in 0-2.8GHz and 4.1-6GHz, which meets the given indicators.

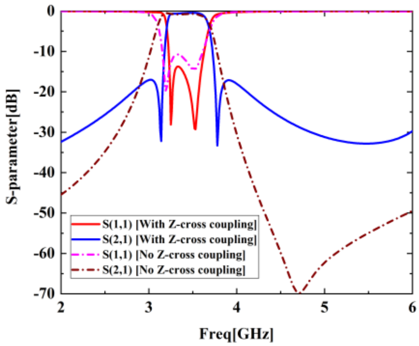


**Figure 5.** S-parameter curve of a fourth-order comb-line filter with and without Z shape cross-coupling.

## *3.2. LTCC Wilkinson Power Divider*

In this section, based on the lumped Wilkinson-type power divider structure mentioned in Chapter 2, through the multi-layer advantage of the LTCC process, an LTCC one-to-two power divider is designed.

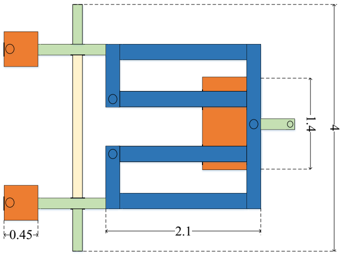


**Figure 6.** Top view of LTCC power divider.

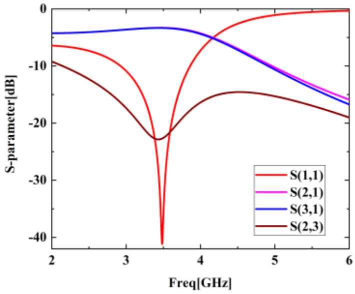


**Figure 7.** S-parameter curve of LTCC power divider.

Build the HFSS model and the model structure of the LTCC power divider is shown in Figure 6. The data units in the figure are all millimeters. The final size of the power divider is 4mm×4mm×0.5mm.

The parameters are continuously optimized, and the final simulation result can be seen in Figure 7. In the 3.3GHz-3.6GHz frequency band, the insertion loss($S_{21}$ and $S_{31}$) are less than 3.45dB, the return loss($S_{11}$) is greater than 17dB, and the isolation($S_{23}$) is greater than 20dB, which meets the design requirements.

### *3.3. LTCC filter power divider*

The LTCC filter power divider adopts the cascade mode. The filter and power divider designed in the first two sections are cascaded. To reduce size, power divider is placed on top of filter and cascaded through metal post. Its structure is shown in Figure 8, whose data units are all millimeters, and the filter size is 10mm×4mm×5mm.

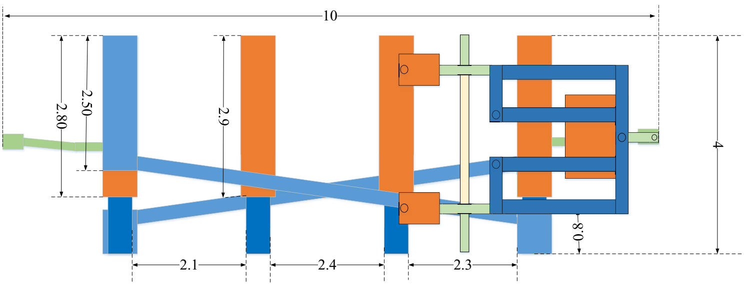


**Figure 8.** Filter power divider model.

By fine-tuning some parameters, the simulation results are presented in Figure 9. What shown in the figure is that in the 3.3GHz-3.6GHz frequency band, the insertion loss($S_{21}$ and $S_{31}$) are less than or equal to 4 dB, the return loss($S_{11}$) is greater than 15.7 dB, the isolation($S_{23}$) is greater than 17.5 dB, and the out-of-band suppression is greater than 18 dB in 3.8-4.3GHz and 22 dB in 0-3.2GHz and 4.3-6GHz, meeting the given index requirements.

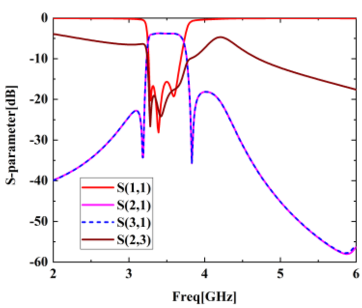


**Figure 9.** S-parameter curve of filter power divider.

### *3.4. Comparison of several filter power dividers*

Table 2 shows the comparison of the filter power dividers designed in this paper with some references. It can be seen from the comparison that the design of the filter power divider using LTCC in this paper can greatly reduce the size and the insertion loss is small.

**Table 2.** Comparison of several filter power dividers

| References | Center frequency | Structure | Insertion loss | Size |
|---|---|---|---|---|
| [1] | 3.98GHz,6.44GHz | Microstrip line | 5dB , 4.8dB | 28mm×30mm |
| [2] | 1.57GHz | Microstrip line | 4.3dB | >22mm×34mm |
| [3] | 7.5GHz,11.7GHz | SIW | 3.811dB, 3.328dB | >18mm×19.mm |
| This work | 3.45GHz | LTCC | 4dB | 10mm×4mm |

## 4. Conclusion

Based on the characteristics of high integration and low loss of LTCC process, this paper designs a power divider with filtering performance.In this design, the working frequency band of the one-to-two filter power divider designed is 3.3GHz-3.6GHz. In order to reduce the overall size, a fourth-order comb-line structure bandpass filter and one-to-two power dividers are cascaded together, resulting in a final size of 10mm×4mm×5mm, and finally meet the performance of insertion loss less than or equal to 4 dB, return loss greater than 15dB, isolation greater than 17dB, and the out-of-band suppression is greater than 18 dB in 3.8-4.3GHz and 22 dB in 0-3.2GHz and 4.3-6GHz.

For further miniaturization, this paper has the following three suggestions: one is to use a ceramic dielectric with a higher dielectric constant, the other is to use an LC lumped structure, and the third is to use a comprehensive integration method to design the filter and power divider together.

## Acknowledgment

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## References

[1] Xie Hanyu, Tao Feng, Huang Qiman, Wu Bian. A double-layer microstrip structure multi-channel filter power divider[C]//. Proceedings of the 2019 National Microwave and Millimeter Wave Conference (Volume 2).[Publisher unknown],2019 :74-77.

[2] Li Weijin, Wei Feng, Wang Xinhuai, Shi Xiaowei. Design of Filter Power Divider Based on Step Impedance Resonator[C]//. Proceedings of the 2015 National Microwave and Millimeter Wave Conference., 2015:1008-1010.

[3] Wang Yujie, Zhou Chunxia, Lin Binbin, Zhao Yanfei, Wu Wen. Design of dual-pass-band filter power divider based on substrate-integrated waveguide[J]. Microwave Journal, 2017,33(S1):148-151.

[4] Y. -s. Dai, H. -h. Yin, H. -t. Sun, Y. Feng, Q. -y. Xie and M. Luo, "A miniaturized millimeter-wave bandpass filter with LTCC technology," 2012 IEEE MTT-S International Microwave Workshop Series on Millimeter Wave Wireless Technology and Applications, 2012, pp. 1-3, doi: 10.1109/IMWS2.2012.6338222.

[5] J. Fu, Z. Wang, B. Lv, Z. Yang and Q. Wu, "A new compact three-way Wilkinson power divider based on LTCC technology," 2015 Asia-Pacific Microwave Conference (APMC), 2015, pp. 1-3, doi: 10.1109/APMC.2015.7411707.

[6] Chang Yumin. Research and design of high-performance miniature filter based on LTCC [D]. Nanjing University of Science and Technology, 2020. DOI: 10.27241/d.cnki.gnjgu.2020.001635.

[7] Zhang Xiangjun, Ma Xiaoping and Lai Qifeng, "Compact multilayer coupled stripline LTCC filter with defected ground structure," 2009 International Conference on Microwave Technology and Computational Electromagnetics (ICMTCE 2009), 2009, pp. 204-206, doi: 10.1049/cp.2009.1300.

[8] Chen Peng. Research on miniaturized power divider and filter based on LTCC technology [D]. University of Electronic Science and Technology of China, 2022. DOI: 10.27005/d.cnki.gdzku.2022.004247.

[9] Li Yongbin, Wang Ziliang, Cheng Kai. Design of tapped comb-line filter based on LTCC process[J]. Research and Progress in Solid State Electronics, 2017,37(01):36-39+44.DOI:10.19623/j.cnki.rpsse.2017.01.008.

[10] Chao Sun, Yongsheng Dai and Bowen Li, "Design of four-order distributed band-pass filter based on LTCC technology," 2016 IEEE MTT-S International Microwave Workshop Series on Advanced Materials and Processes for RF and THz Applications (IMWS-AMP), 2016, pp. 1-3, doi: 10.1109/IMWS-AMP.2016.7588436.