International Core Journal of Engineering Volume 6 Issue 1, 2020
ISSN: 2414-1895 DOI: 10.6919/ICJE.202001_6(1).0042

A Compact Filter Using CPW-Stripline Transition Structures

Zhiyue Zhang [a], Wusheng Ji [b], Wei Dai [c]

School of Electronic Engineering, Tianjin University of Technology and Education, Tianjin 300222, China.

[a] 15502253873@163.com, [b] wshji1326@sohu.com, [c] 13820554343@163.com

Abstract

A compact bandpass filter （BPF） is proposed using two coplanar waveguide (CPW)-stripline transition structures. The top layer of the CPW-stripline transition structure is a CPW with petal shape at the short-circuit end, and the bottom layer of the CPW-stripline transition structure is a stripline with petal shape at the open end. The input signal is electromagnetically coupled transition from CPW to the stripline. The simulation of HFSS software shows that the passband range of the filter is 3.93-6.83GHz, the center frequency of the passband is 5.38GHz, the fractional bandwidth (FBW) is 53.9%, the S11 is better than -12.5dB and the S21 is 0.7dB in the passband. This filter contains the second passband of 4.8GHz-5.0GHz in the low frequency band of 5G communication in china, and has application prospects in 5G communication.

Keywords

Bandpass filter, compact, CPW-stripline transition structure.

1. Introduction

With the rapid development of mobile communication and the high integration of microwave circuits, filters as the key components of communication systems are also required to develop in the direction of high performance and miniaturization. In order to reduce the size of the filter, multilayer technologies such as low temperature co-fired ceramics (LTCC) and multilayer printed circuit boards (PCBs) have received extensive attention [1, 2].

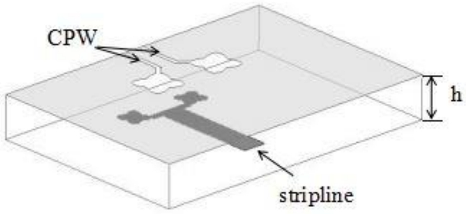
There are two major techniques to realize the interconnection or transition between circuits in different layers. One is by physical contact and the other is by electromagnetic coupling.The physical contact between different layers of the filter is generally achieved through Via-holes, bonding wires, etc, which increases the complexity of fabrication. Methods for achieving electromagnetic coupling include broadside coupling, transition structures, etc. The coupling between the top layer and the bottom layer of the broadside coupling structure is achieved by the method of slotting the mid-layer. A transmission line such as a CPW, a microstrip line or a slot line is formed on both sides of the same dielectric substrate to form a transition structure, and the coupling between them can constitute a filter, a directional coupler, eac. [3-5] proposed a single-band BPF applied microstrip-CPW broadside-coupled structure. In [6], the microstrip-slotline transition structure was applied to produce an ultra-wideband filter, but the out-of-band suppression of the filter was poor. [7] proposed a broadband transition structure of a microstrip-CPW applied microstrip and CPW transmission line . However, S21 in the transition structure has ripples, and S11 is poor. In [8], an ultra-wideband (UWB) filter is realized by applying the transition structure of the microstrip-CPW. [9] realize an UWB filter applied to a back-to-back microstrip-CPW transition structure , but the S-parameter of the filter is poor. In [10], the open-ended terminal is a fan-shaped microstrip line, and the short-circuit terminal is a radial CPW, which forms a microstrip-CPW transition structure that can be used to generate UWB filters. [11] proposed a single-passband filter with 5 transmission pole applied CPW-stripline transition

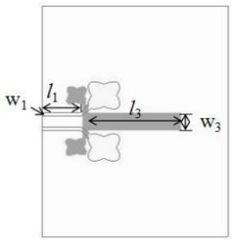
ISSN: 2414-1895 DOI: 10.6919/ICJE.202001_6(1).0042

structure that short-circuit terminal of the CPW and the open-circuit terminal of the stripline are both traditional rectangular shapes, and [11] suppresses the spurious harmonics used Via-holes, which makes the fabrication of the filter more complicated. A compact BPF proposed in this paper. Based on [10, 11], a compact band-pass filter is realized by using the CPW-stripline transition structure which the short-circuit terminal of the CPW is a petal shaped slot and the open-circuit terminal of the stripline is a petal shaped stripline. The filter does not need to achieve the suppression the spurious harmonics by Via-holes, so the fabrication is simple.

2. Filter theory and design

All of the conductors of the CPW transmission line are located on the same surface of the dielectric substrate, facilitating integration with active or passive lumped parameter components and support the transmission of quasi-TEM modes. Stripline is a relatively common type of planar transmission line that can be used to make microwave passive components. CPW and stripline are fabricated in different layers of the dielectric substrate to create a CPW-stripline transition structure. The transition structure terminal in this design is a petal shaped structure. The petal shaped structure is formed by the intersection of two ellipses at 60 degrees. The short semi-axis of the ellipse corresponding to the petal shaped slot of the short-circuited terminal of the CPW is r_1, and the long semi-axis is r_2; the short semi-axis of the ellipse corresponding to the petal shaped stripline of the open-circuited terminal of the stripline is r_3, and the long semi-axis is r_4. The two short-circuited petal shaped slots of the CPW are identical in size and structurally symmetrical; the two petal shaped open-circuited ends of the stripline are identical in size and structurally symmetrical. Figure. 1 shows the side view and top view of the whole structure. Where in (a) is a side view of the transitional structure, (b) is a top view of the transitional structure, and (c) is a structural diagram of the petal shaped slot line short-circuit terminal and the petal shaped stripline open-line terminal.





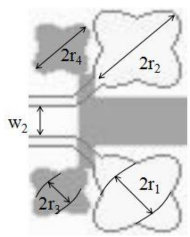


Figure 1. The proposed transitional structure. (a) side view of the whole structure. (b) Top view of the transitional structure. (c) the structural diagram of the petal shaped slot line short-circuit terminal and the petal shaped stripline open-line terminal.

Figure. 1 show the transition structure: the top layer is a CPW with two petal shaped short-circuit terminal slot lines; the bottom layer is a strip line, and the open-circuit end is two petal shaped open-circuit striplines. The short-circuited terminal slot line of the CPW can be electromagnetically coupled to the open-end terminal petal shaped stripline of the steipline to realize electromagnetic coupling between different layers, thereby forming a transition structure and realized signals are transmitted in different layers.

The CPW short-circuit line adopts a 1/4λ slot line, and the stripline open-circuit line uses a 1/4λ stripline. The short-circuit line at 1/4λ can be equivalent to a capacitor and an inductor in parallel. The open-circuit line at 1/4λ can be equivalent to a capacitor and an inductor in series.Figure. 2 shows the equivalent circuit of the transition structure. The parallel connection of L_{p1} and C_{p1} is the equivalent circuit of the CPW short-circuit line, and the series connection of L_{s2} and C_{s2} is the equivalent circuit with the stripline open-circuit line.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202001_6(1).0042

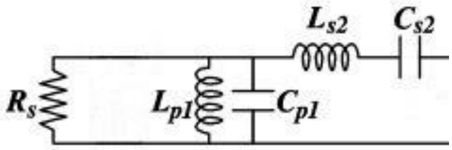


Figure 2. The equivalent circuit of the transition structure.

In this paper, two CPW-stripline transition structures are used to realize a compact BPF structure. Figure.3 is a circuit diagram of the filter. The circuit is a multilayer structure with three-layer dielectric substrate and four-layer metal. The first and fourth layers are CPW structures, and the structure and size of the two layers of CPW are the same; the second and third layers are stripline structures with the same structure and size. The first layer and the second layer of metal constitute a CPW-stripline transition structure, and the third layer and the fourth layer of metal constitute a CPW-stripline transition structure, the two transition structures are of the same size and structurally symmetric . The input port is connected to the CPW of top-layer, the output port is connected to the CPW of bottom layer, and the signal is transmitted to the bottom CPW from the CPW of top layer through the dielectric substrate, thereby realizing the transmission of signals at different layers, and a compact BPF is generated.

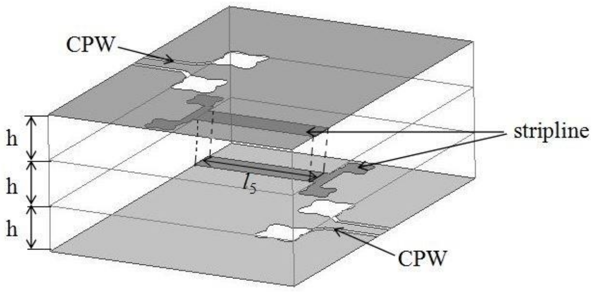


Figure 3. Circuit diagram of the filter.

The equivalent circuit of the filter can be obtained as shown in Figure. 4 through the analysis of the equivalent circuit of the transition structure. Where T_1 and T_2 respectively represent the equivalent circuits of the two transition structures of the filter circuit. The return loss S_{11} of the input port and the insertion loss S_{21} of the output port can be calculated by the following formula:

$$S_{11} = \frac{1-C^2(1+\sin^2(\beta_{ef}l))}{\left[\sqrt{1-C^2}\cos(\beta_{ef}l)+j\sin(\beta_{ef}l)\right]^2} \tag{1}$$

$$S_{21} = \frac{j2C\sqrt{1-C^2}\sin(\beta_{ef}l)}{\left[\sqrt{1-C^2}\cos(\beta_{ef}l)+j\sin(\beta_{ef}l)\right]^2} \tag{2}$$

Where C is the coupling strength and β_{ef} is the effective phase constant. The S parameter of the filter can be obtained by the above formula.

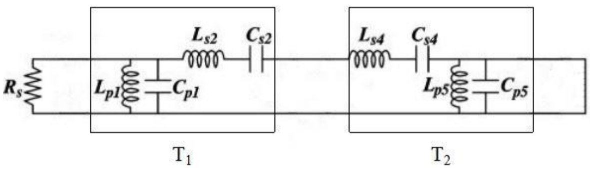


Figure 4. Equivalent circuit of the filter

ISSN: 2414-1895 DOI: 10.6919/ICJE.202001_6(1).0042

3. Simulation Optimization of Filter

3.1 Impact of w_1 on S parameters

Figure.5 shown the filter S parameters corresponding to different w_1,w_1 is the width of the top CPW slot line. It can be seen from the figure ,as w_1 increases, S_{11} curve moves up and S_{11} becomes worse.And as w_1 increases, the frequency point of high-resistance band generates a transmission zero shifts to the high end of the frequency, and the stop band on the passband becomes not steep, the roll-off degree of the stop band deteriorates. It can be seen that the value of w_1 has an influence on the filter S parameter, and the S parameter can be adjusted by adjusting w_1.

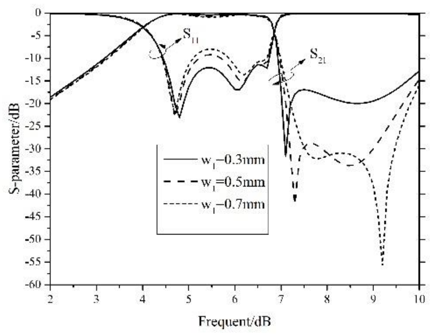


Figure 5. S parameters corresponding to different w_1.

3.2 Impact of w_2 on S parameters

During the filter design process, changes in circuit parameters affect the performance of the filter, and w_2 is the width of the CPW conductor. Figure. 6 shows the filter S parameters corresponding to different w_2. As can be seen from Figure. 6, as w_2 increases, the transmission pole of S_{11} decreases, and S_{11} deteriorates; as w_2 increases, the frequency at which the transmission zero occurs is shifted to the lower end of the frequency, and the FBW of the filter is narrowed. Therefore, it can be seen that changing the value of w_2 has an effect on the filter S parameter. When designing the filter, the S parameter of the filter can be improved by adjusting w_2.

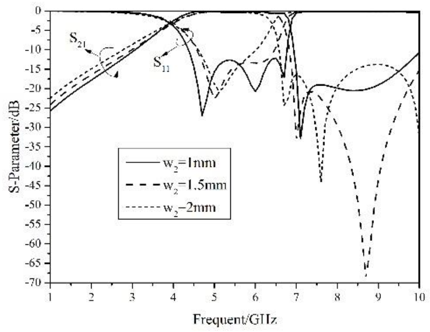


Figure 6. S parameter corresponding to different w_2.

3.3 Impact of w_3 on S parameters

Figure. 7 shows the filter S parameters corresponding to different w_3. w_3 is the width of the 1/4λ stripline with the petal shaped open terminal, and the S parameter of the filter can be improved by adjusting w_3.It can be seen from Figure. 7 that in the passband of the filter, when w_3=1.2mm, S_{11} contains two transmission poles, and in the frequency band of 5.1GHz-5.7GHz, S_{11} is above -10dB; When w_3=1.6mm ,S_{11} contains three transmission poles, S_{11} is below -12dB in the passband; when w_3=2mm, S_{11} contains three transmission poles, and in the 6.4GHz-6.7GHz frequency band, S_{11} is above -10d . In the upper stop band of the filter, as the w_3 increases, the upper stop band S_{21} moves up, and S_{21} becomes worse. From the above analysis, the optimal value of w_3 is w_3 = 1.6 mm.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202001_6(1).0042

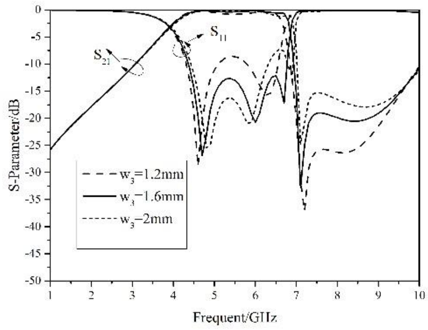


Figure 7. S parameters corresponding to different w_3.

3.4 Impact of l_3 on S parameters

Figure. 8 shows the S parameters corresponding to different l_3. l_3 is the length of the 1/4λ stripline with the petal shape terminal, and the S parameter of the filter can be adjusted by adjusting the length l_3. It can be seen from Figure. 8 that when l_3=7mm, S_{11} has three transmission poles in the passband, and the value of S_{11} is optimal; when l_3=6mm, the transmission poles of S_{11} becomes two and the value of S_{11} becomes worse; when l_3 =8mm, the transmission poles of S_{11} is three, but the value of S_{11} is deteriorated. In the upper stop band of the filter, as the l_3 increases, the frequency at which the transmission zero occurs is shifted to the lower end of the frequency, the bandwidth of the filter is narrowed, and the S_{21} of the upper stop band becomes worse . From the above analysis, the optimal value of l_3 is 7mm.

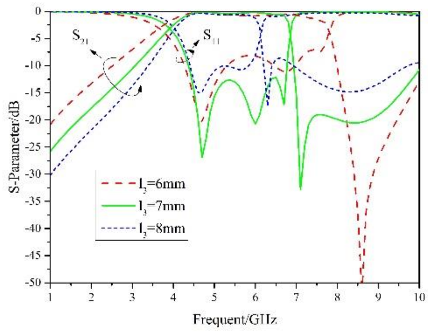


Figure 8. S parameters corresponding to different l_3.

3.5 Impact of l5 on S parameters

Figure. 9 is the S parameter corresponding to different l_5. l_5 is the length of the overlapping part of the second and third layers stripline with the petal shape open-circuit terminal in the vertical direction. The S parameter of the filter can be adjusted by adjusting l_5. It can be seen from Figure. 9 that when l_5=6mm, S_{11} has three transmission poles in the passband of the filter, and the value of S_{11} is optimal, and as l_5 increased or decreased, S_{11} is worse; As l_5 increases,the frequency at which the transmission zero is generated moves to the up end of the frequency in the upper stop band of the filter , the bandwidth of the filter becomes wider, and the S_{21} of the upper stop band becomes better. From the above analysis, the optimal value of l_5 is 6 mm.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202001_6(1).0042

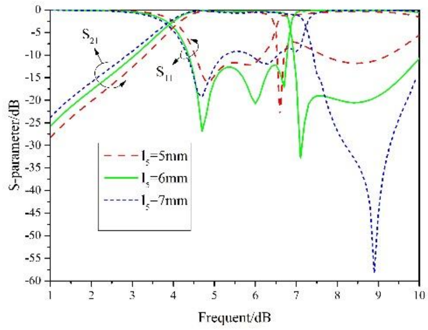


Figure 9. S parameters corresponding to different l_5.

3.6 Design parameters of filter

In this paper, a three-layer dielectric structure and a four-layer metal multilayer structure are used to realize a compact filter with a CPW-stripline transition structure. The dielectric material of the dielectric structure is RO4003C, the dielectric constant is εr=3.55, the loss tangent is tanσ=0.0029, and the thickness of the dielectric structure is h=0.203 mm. The width of the CPW rectangular slot is w_1=0.3mm, the length l_1=3mm, w_2=1mm, and the CPW petal shaped short-circuit terminal is obtained by overlapping the two elliptical slots of the same size by 60 degrees, and the short semi-axis of the elliptical slot is r_1=1.5mm, long semi-axis r_2=3mm, the width of the second and third-layer stripe strips is w_3=1.6mm, the length is l_3=7mm, the length of the rectangular stripline of the two and three-layer stripline in the vertical direction overlapping part is l_5 = 6 mm. The stripline petal shaped open-circuit terminal is obtained by overlapping the two elliptical stripline of the same size by 60 degrees, the short semi-axis of the ellipse is r_3=1mm, and the long semi-axis is r_4=2mm. The overall circuit size of the filter is: 20mm ×14mm × 0.609mm.

4. Conclusion

A new compact BPF that includes a CPW-stripline transition structure is proposed in this paper. The multi-layer structure is applied to realize the compact of the filter. The transition structure of the filter is relatively novel, and the open-circuit end of the stripline is a petal shaped stripline; the short-circuit end of the CPW is a petal shaped slot. In this paper, the filter passband contains three transmission poles, the upper stopband contains a transmission zero , and the upper sideband has a good roll-off degree. The bandwidth of the filter can be adjusted by adjusting w_2, l_3 and l_5; the S parameters of the filter can be adjusted by adjusting w_1, w_2, w_3, l_3 and l_5. The passband of the filter in this paper contains the second passband of 4.8GHz-5.0GHz in the low frequency band of 5G communication in China, which has application prospects in 5G communication. However, there are still some shortcomings in the filter. For example, the lower sideband of the passband is not very good. In the future, the roll-off degree of the lower sideband will be improved by cascading.

Acknowledgements

This work is supposed by the Natural Science Foundation of Tianjin, China (18JCYBJC16400), Graduate Innovation Foundation of Tianjin University of Technology and Education in 2020, China (YC20-3).

References

[1] J.K. Xiao.Research on Performance of Novel Microwave Resonators and Filters in Modern Wireless Communication Systems [M]. Shanghai： Shanghai University Press, 2010.

[2] S.Zhang.Research on Structure and Performance of Miniature Planar Microwave Filter[M].Shanghai： Shanghai University Press, 2010.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202001_6(1).0042

[3] C.H. Wang, P.H. Deng, C.H. Chen : Coplanar-Waveguide-Fed Microstrip Bandpass Filters With Capacitively Broadside-Coupled Structures for Multiple Spurious Suppression[J],IEEE Transactions on Microwave Theory and Techniques, Vol.55(2007) No.4,p.768-775.

[4] Bowen Liu, Yingzeng, Yi Yang, et al. UWB bandpass filter with notched band using broadside-coupled microstrip-coplanar waveguide structure[C]// IEEE International Conference on Microwave Technology & Computational Electromagnetics. IEEE, 2011.

[5] A. Abbosh, M. Bialkowski, S. Ibrahim: Ultra-wideband bandpass filters using broadside-coupled microstrip-coplanar waveguide [J], IETMICROWAVES ANTENNAS & PROPAGATION, Vol. 5 (2011) No.7,p.764-0.

[6] R.Li: Ultra-wideband (UWB) bandpass filters with hybrid microstrip/slotline structures[J],IEEE Microwave & Wireless Components Letters, Vol.17(2007) No.11,p.778-780.

[7] L. Zhu, W. Menzel: Broad-band microstrip-to-CPW transition via frequency-dependent electromagnetic coupling [J], IEEE Transactions on Microwave Theory and Techniques, Vol. 52(2004) No.5,p. 1517-1522.

[8] H. Wang, L. Zhu,W. Menzel: Ultra-wideband bandpass filter with hybrid microstrip/CPW structure [J], IEEE Microwave and Wireless Components Letters, Vol.15(2005) No.12,p.844-846.

[9] H. Wang, L. Zhu: Ultra-wideband bandpass filter using back-to-back microstrip-to-CPW transition structure [J], Electronics Letters, Vol. 41(2005) No.24, p. 1337.

[10] T.H. Lin: Via-free broadband microstrip to CPW transition [J], Electronics Letters, Vol. 37 (2001) No.15, p.960.

[11] G. S. Huang ,Y. S. Lin ,C. H. Wang , et al: A Novel Transition-Included Multilayer Filter [J], IEEE Transactions on Microwave Theory & Techniques, Vol.57(2009)No.4 ,p.807-814.