Compact-Size Coplanar Waveguide Bandpass Filter

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***Abstract*—A compact-size coplanar waveguide (CPW) bandpass filter (BPF) is proposed. In this study, we use the bended stub with novel folded skill to improve the three parallel coupled-lines structure of BPF for $N = 1$. It gets the sharp transition band (TB) and reduces the dimension of the circuit by 66.67% at 2.45 GHz. Its center frequency can be shifted easily by adjusting the interfaces of SS and S'S' simultaneously. It is very useful for applications in the wireless communication systems.**

***Index Terms*—BPF, compact-size, CPW structure, three parallel coupled-lines structure.**

I. Introduction

THE two parallel coupled-lines microstrip filter has been found as one of the most common microwave filters in many practical wireless systems for several years [1]. This kind of filter must increase its orders to produce the sharper transition band (TB). Therefore, one predicts the filter would occupy more dimension and achieve more insertion loss (IL) of the circuit. The other kind of filter decreases the gap of the coupling stage to improve the IL, but the general chemical etching process limits the minimum size of the gap. In order to increase the coupling to achieve the low IL, the three parallel coupled-lines structure was considered, as shown in Fig. 1. However, it still occupies more circuit dimension when we want to make the TB sharper. Recently, there are some methods proposed to reduce the size of the filter and to improve the TB [2], [3]. Y. K. Kuo considered the bended and folded skills to reduce the size of the filter and achieve better stopband rejection [2]. However, the response in the lower TB is not sharp enough. In [3], the performance of miniaturized CPW bandpass filters (BPFs) with high temperature superconducting (HTS) films has been studied, which revealed the sharp TB and no limited conductor loss. However, the fabricated process is more expensive. Up to now, BPFs with low cost, small size, and lightweight characteristics are the fundamental requirement for the components of communication systems. Therefore, in this paper, we proposed a compact-size CPW bandpass filter, as shown in Fig. 2, with the sharp TB. Its center frequency can be shifted easily by adjusting the interfaces of SS and S'S' simultaneously, as shown in Fig. 3. This filter is not only fabricated on the FR4 substrate easily, but also has a very small circuit size $(1.5 \times 1.4\ \text{cm}^2)$ at 2.45 GHz. There are good agreements between the measured and simulated results.

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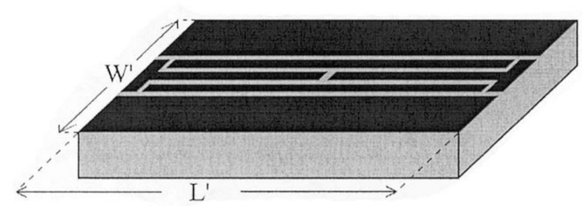

Fig. 1. The three parallel coupled-lines CPW bandpass filter for $N = 1$.

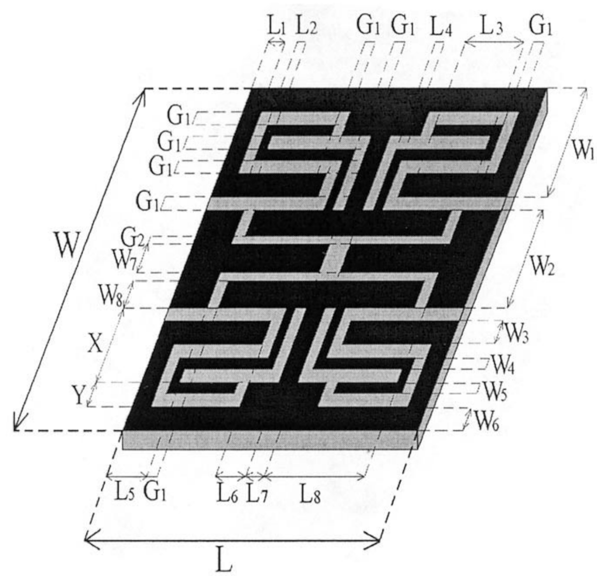

Fig. 2. The compact-size CPW bandpass filter circuit structure.

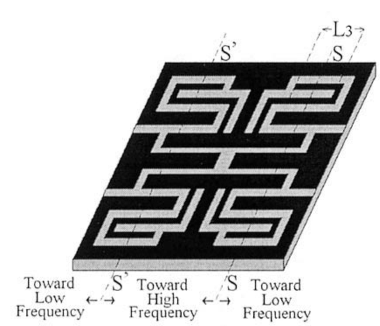

Fig. 3. The diagram of the adjustable interface for different frequency.

II. Design Description

A capacitor loaded CPW resonator has been reported [4], its signal strip was slotted to increase the load effect, which reduces the size of conventional $\lambda/2$ CPW end- coupled filter. In this study, we apply the concept of the shunt open-end stub and the short-end stub into the three couple-lines in order to increase its

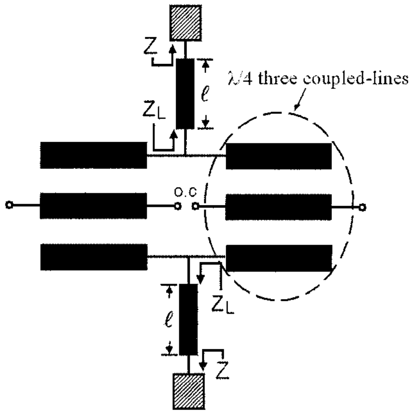

Fig. 4. Three coupled-lines with load effect.

load effect, as shown in Fig. 4. The corresponding impedance Z_L is given by

$$Z_L = Z_o \frac{Z + jZ_o \tan\beta\ell}{Z_o + jZ \tan\beta\ell} \quad \text{for lossless line}$$

where Z_o and β are the characteristic impedance and phase constant of this stub, respectively. If the stub is open-end or short-end, the impedance $Z = \infty$ or 0, respectively. The shunt inductor forms a high pass response to make lower TB sharper [5], the shunt capacitor also forms a low pass response to make upper TB sharper. Furthermore, the CPW folded open stub is usually utilized not only to reduce the circuit dimension, but also to improve the shape factor [6], [7]. The bended CPW open stub technique can reduce the radiation loss by the parasitic coupled slot line mode [8]. By combining the novel folded skill [6] and above techniques together, it not only reduces the radiation loss, but also makes an easy way for circuit design. The compact-size CPW bandpass filter, as shown in Fig. 2 has the following dimensions: $L_1 = L_7 = 1$ mm, $L_2 = L_4 = 0.5$ mm, $L_3 = 3$ mm, $L_5 = 2$ mm, $L_6 = 1.5$ mm, $L_8 = 5$ mm, $W_1 = 4.5$ mm, $W_2 = 4$ mm, $W_3 = W_6 = W_7 = 1$ mm, $W_4 = W_5 = 0.5$ mm, $W_8 = 1.25$ mm, $G_1 = 0.5$ mm, $G_2 = 0.25$ mm. If we want to make the upper TB sharper, we increase L_3 under the condition of $L_8 = \text{constant}$. If we want to make the lower TB sharper, we increase X under the condition of $X + Y = \text{constant}$. In this study, all the simulated S-parameters of the circuits are accomplished by using the full-wave Sonnet *em* simulator.

III. Simulated and Measured Results

The experimental compact-size CPW bandpass filter has been designed and tested. All the implemented circuits in this paper are fabricated on the FR4 substrate ($\epsilon_r = 4.7$, $\tan\delta = 0.022$, $\text{thickness} = 0.8$ mm, $\text{metal thickness} = 0.02$ mm). The simulated and measured results are shown in Fig. 5. It reveals both upper and lower sharp TB. As we increase the load effect to produce the slow wave effect, the circuit size is reduced strongly from 4.5×1.4 cm^2 to 1.5×1.4 cm^2. According to above descriptions, it is very convenient to design a filter at the different frequencies by adjusting the interfaces of SS and S'S' simultaneously, as shown in Fig. 3 (The SS and S'S' are symmetrical

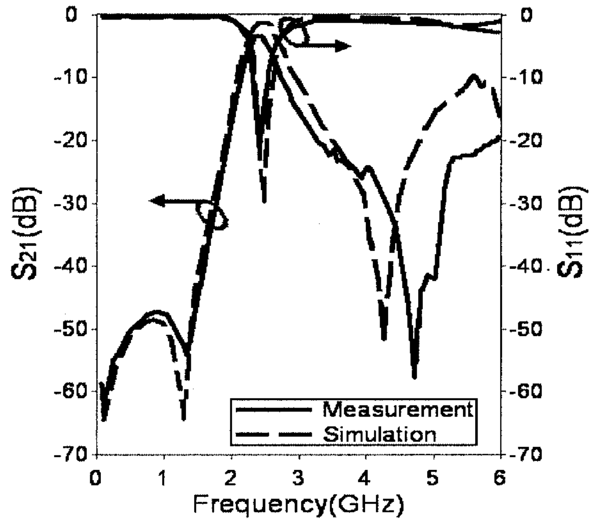

Fig. 5. Simulated and measured response of the compact-size CPW bandpass filter.

TABLE I
THE COMPARED RESULTS OF THE DIFFERENT FREQUENCIES BETWEEN THE THREE PARALLEL COUPLED-LINE FOR $N = 1$ AND COMPACT-SIZE CPW BANDPASS FILTERS

	Three coupled-line L'×W' (cm²)	Compact-size L×W (cm²)	Reduced factor (%)
2.45GHz	4.5×1.4	1.5×1.4	66.67
1.8GHz	5.9×1.4	2.0×1.4	66.10
900MHz	10.95×1.4	4.0×1.4	63.47

and limited by L_3). Therefore, we can easily design 900 MHz and 1.8 GHz BPF by using this method respectively. The results of those compact-size BPFs and the three parallel coupled-lines BPFs for $N = 1$ are shown in Table I. The reduced factor keeps above 60% in all three different frequencies.

IV. Conclusion

We have proposed a novel compact-size BPF using the bended stub with a novel folded skill. This BPF gets sharper TB and reduces more dimension of the circuit at 2.45 GHz than the conventional three parallel coupled-lines BPF. Its center frequency can be shifted easily. The advantage of the proposed BPF is the reduced factor keeping above 60% for 900 MHz, 1.8 GHz, and 2.45 GHz. This compact-size filter has good performance, low cost, and is believed to be quite useful for MICs and MMICs applications.

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