

# A New Feed Line of Parallel-Coupled Bandpass Filters With Out-Stopband Rejection

Yu-Cheng Sun and Ching-Wen Tang

Department of Electrical Engineering, National Chung Cheng University, 168, Sec.1, Ta-Hsyeh rd., Ming-Hsiung Township, Chiayi, Taiwan, ROC  
xander90131013@gmail.com

**Abstract** —A new design of feed lines, called ‘U Corner’, is proposed in order to improve the rejected bandwidth of a compact microstrip filter topology. The first spurious resonance frequency can be conveniently suppressed by the use of two identical U corners at the input and output of the filter. After the derivation of design rules, a two-pole filter based on Parallel-Coupled Filter was designed for a proof-of-concept. The working frequency was chosen equal to 1 GHz with a 21.4 % fractional bandwidth. Measurements and simulations are in very good agreement. A wide stopband up to more than six times the working frequency was achieved. The insertion and return losses in the passband are 1.2 dB and 16 dB respectively.

**Index Terms** —Microstrip bandpass filter, parallel-coupled line.

## I. INTRODUCTION

Parallel-coupled bandpass filters have been widely used for their simplicity [1]. However, in microstrip technology [2], [3], this topology suffers from a fundamental limitation due to the difference of velocities of even and odd modes, leading to spurious resonances [4]. A lot of structures allow improving the bandwidth rejection but many of them need an important work of modeling. For example, in [5].

In this paper, the high rejection bandwidth can be further improved thanks to an efficient optimization of the feed lines by using a ‘‘U-corner’’ topology. Without modifying the in band filtering characteristics, the rejection bandwidth can be enlarged up to more than eight times the working frequency. This out-of-band improvement is achieved without deterioration of the filter surface area by only adjusting the U-corner structure. A detailed design methodology is described. It is also explained how the three coupled lines feeding network contributes to the rejection band improvement by generating its proper transmission zero. For a proof-of concept, two similar three-pole bandpass filters with non-optimized and optimized U corners are compared to demonstrate the efficiency of the proposed concept.

It is simple to design the transmission zero points in outer-stopband with new feed line and make good use in stopband rejection for band pass filter.

## II. DETAILED TEXT FORMATTING

### A. U-corner design for transmission zero

In order to improve coupling of this filter, three-couple microstrip line is used for this filter, then two feed line was need to feed the three-couple microstrip line of th bandpass filter as show in Fig. 1. The design of these feed lines, called U corner, can be conveniently optimized to improve the bandwidth rejection by adding transmission zeros in the rejection band. The design and optimization of this U-corner topology is detailed below.

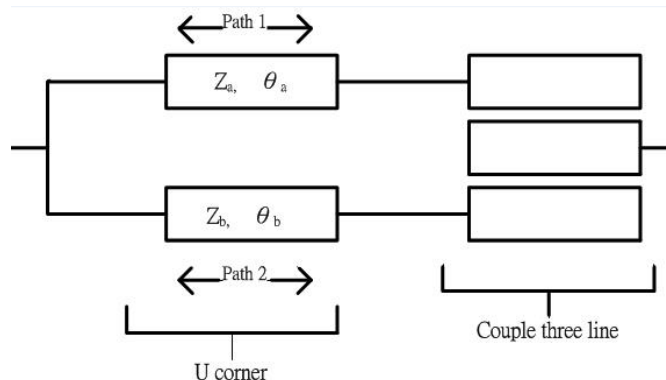


Fig. 1 Schematic circuit of the feed lines.

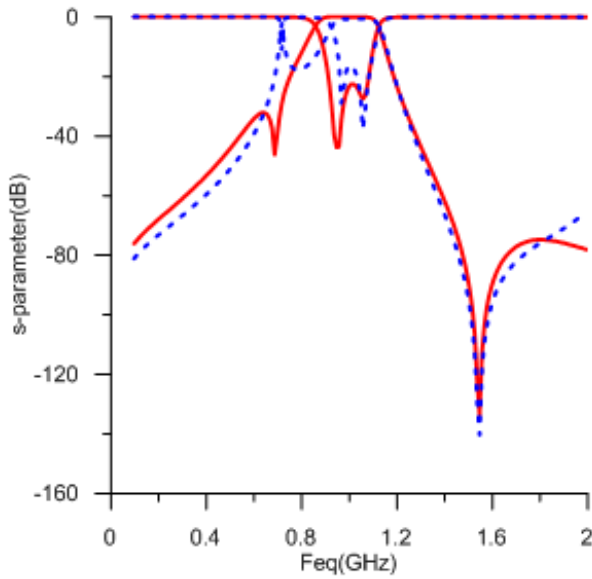
Consider a bandpass filter operating at 1 GHz and having a 17% fractional bandwidth. The filter with U corners is symmetrical since both paths 1 and 2 have equal electrical length and equal characteristic impedance. The simulate result is shown in Fig. 2(a) and Fig. 2(b). It compares (a) the narrow-band and (b) large-band S parameters of the filters with non-optimized U corners (dashed line) and with optimized U corners (red line).

Let consider the first two transmission zeros, occurring near 3.13 GHz respectively. The first transmission zero (at 3.13 GHz) appears when the signals from both U-corner paths are in opposite phase (see Fig. 3) with the same magnitude

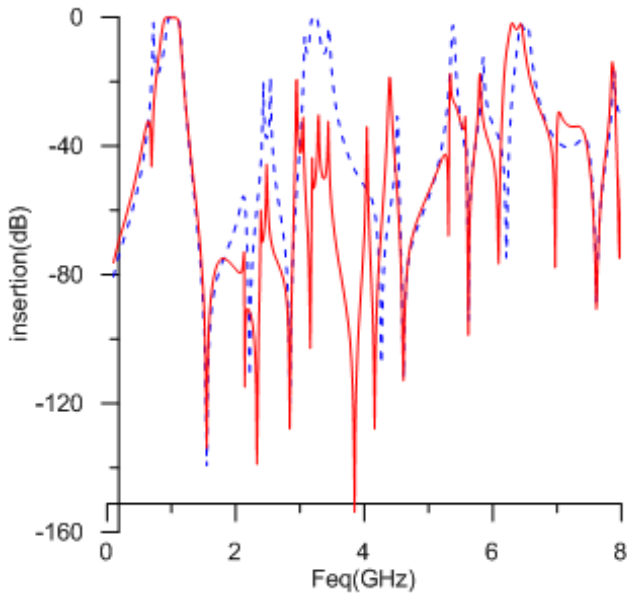
$$\theta_a - \theta_b = (2k + 1)\pi, k \in N$$

Thus, for these particular frequencies, the output of the U-corner is virtually short circuited, and prevents the transmission of the signal to the three-coupled microstrip

lines.



(a)



(b)

Fig. 2 Comparison of (a) the narrow-band and (b) large-band S parameters of the PC-SLR filters with non-optimized U corners (blue line) and with optimized U corners (red line).

### B. The behavior of the Parallel-coupled three conductor line fed by the U-corner: transmission zero in the passband

As shown in Fig. 4, for the optimized filter, a transmission zero appears very close to the passband. This interesting transmission zero can be explained by examining the behavior of the parallel-coupled three conductor line fed by the U corner, but any design rules were carried out. The circuit shown in Fig. 4 is used to derive the design rules for this transmission zero placement.

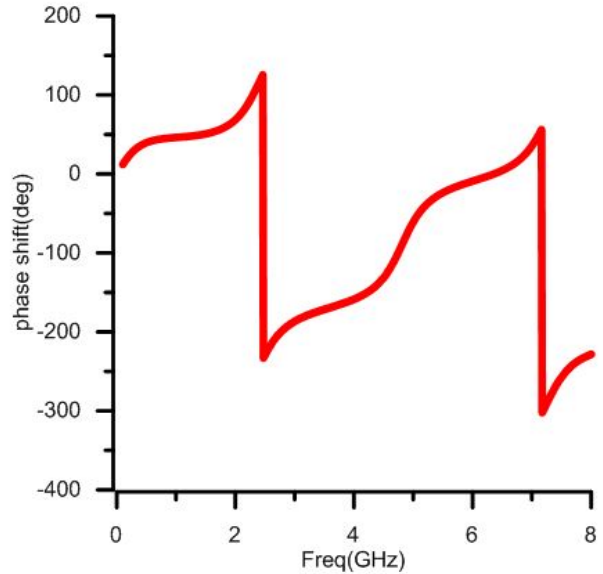


Fig. 3 Phase difference of two signal path.

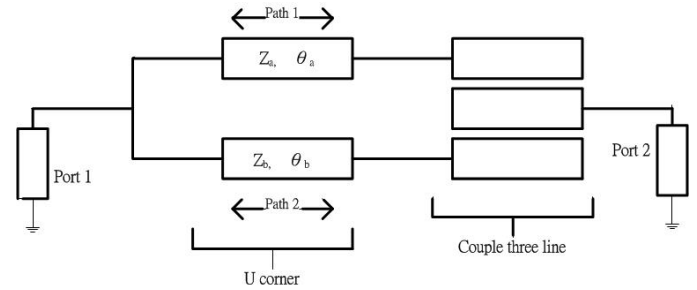


Fig. 4 gives the insertion loss S21 (dashed line), considering the circuit in Fig. 8. For comparison, the simulated response of a parallel-coupled three line without U corner (i.e.  $\theta_a = \theta_b$ ) is also plotted in the same graph (solid line).

## III. RESULTS

For a proof-of-concept, three-pole filters with optimized U corners were fabricated, it increase the rejection bandwidth and create a transmission zero near the passband. The center frequency and the fractional bandwidth were chosen as 1 GHz and 21 %, respectively. The filters were designed with Agilent ADSTM and fabricated on a RT 5880 substrate (dielectric constant  $\epsilon_r = 3.55$ , dielectric loss tangent  $tg = 0.0024$ , substrate thickness  $h = 803 \mu\text{m}$ , copper thickness  $t = 17 \mu\text{m}$ ). Fig. 5 shows the photography of the fabricated filters. Their dimensions are about  $100 \text{ mm} \times 50 \text{ mm}$ .

Fig. 6 gives the simulation and measurement responses of the filter without optimized U corner. Simulation and measurement results are in good agreement. We note a first spurious frequency located at 5 GHz, i.e. five times the center frequency. Detailed data shows that the in-band minimum insertion loss is lower than 1.2 dB while the return loss is better than 18 dB. The 3-dB bandwidth is 21 %, as expected of one of the rare instances when the double

column format requirement can be violated.

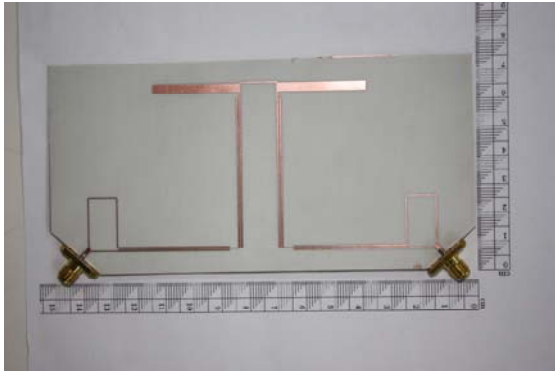
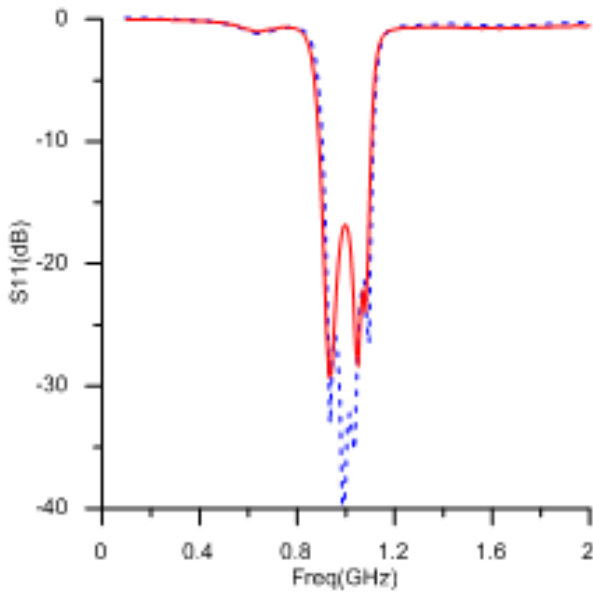
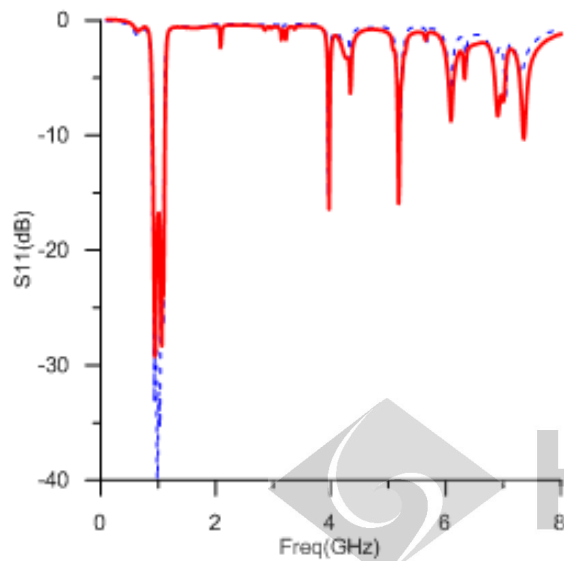


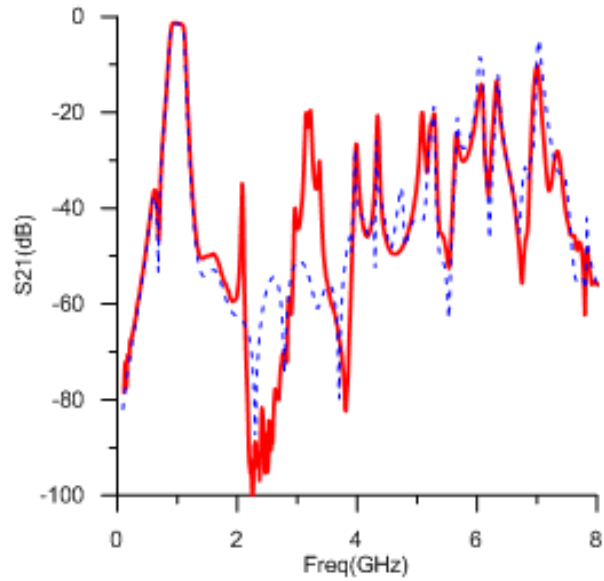
Fig. 5 Photograph of the measured 3rd order filter



(a)



(b)



(c)

Fig. 6 S-parameters of the filter with optimized U corners: EM simulations (blue dashed line) and measurement (red solid line) results. (a) Narrow band of  $S_{11}$ . (b) Wide band of  $S_{11}$ . (c) Wide band of  $S_{21}$ .

#### IV. CONCLUSION

An optimized parallel-coupled stub-loaded-resonator filter showing a very wide rejection band has been demonstrated thanks to transmission zeros generated by a specific feeding network called U corner. The U-corner design rules were carefully derived and a prototype filter working at 1 GHz was carried out for a proof-of-concept. A wide stopband filter was achieved for good performance, as detailed data shows that the in-band minimum insertion loss is lower than 1.2 dB while the return loss is better than 16 dB. The 3-dB bandwidth is 21 %. Finally, it can be noted that the flexibility of the U-corner structure could also be used to place the transmission zeros in order to reject specific frequencies.

#### ACKNOWLEDGMENT

This work was supported in part through grants from the National Chung Cheng University.

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