PSEUDO-INTERDIGITAL BANDPASS FILTER WITH TRANSMISSION ZEROS

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ABSTRACT:
A pseudo-interdigital band pass filter using tapped I/O to improve the skirt characteristics is designed and fabricated. In this paper, the method for tuning the frequencies of these transmission zeros is also described. These transmission zeros can be tuned to appear near the passband by both using the technique of the tapped I/O and interstage-coupling. Experimental results of the fabricated filter measured by network analyzer also show a good agreement with the simulation results.

Keywords: Transmission zero, tapped I/O, microstrip filter.

1. INTRODUCTION
A small size and high selectivity microwave bandpass filter is widely used to enhance the performance of RF front end. These requirements are stricter recently because of the rapidly expanding cellular communication systems. The fabricated planar filters using printed-circuit technologies would be preferable whenever they are available and are suitable with their easy integration and lower fabrication costs. In the past, parallel coupled microstrip bandpass filters are popularly used for the most popular communication system due to its advantages, such as planner design, easy to analysis, lower costs and so on. Although parallel coupled microstrip bandpass filters are common elements in many microwave systems, their two disadvantages, large size and slower attenuation rate, are still incongruous with the systems. [1-3].

Conventional microstrip interdigital filter are extremely compact while they require short-circuit connections with via holes, which is not quite compatible with planar fabrication techniques. It is therefore desirable to develop the new microstrip filter. Hong et al.[1] proposed a new type of miniaturized microstrip bandpass filter by using qseudo-interdigital structure without via holes ground. This qseudo-interdigital bandpass filters can have more compact size, and an attenuation pole due to the effect of interstage-coupling, nevertheless, there is still a problem with requiring more resonators to improve skirt characteristics. In a general filter design procedure, greater numbers of the resonators are required to obtain a more rapid attenuation rate outside the passband. However, an increase in the resonator numbers increases not only the insertion loss in the passband but also the filter size.[2] It is therefore desirable to develop another type of microstrip bandpass filters with the qseudo-interdigital which actually meet both requirements of small size and high selectivity.

In this paper, a pseudo-interdigital filter using tapped input/output (I/O) to improve the skirt characteristics is reported and fabricated. These transmission zeros can be created to
appear near the passband by both using the technique of the tapped I/O and interstage-coupling. Experimental results of the fabricated filter measured by network analyzer are well agreed with the simulated predictions. Moreover, it is also more compact than many traditional transmission line filters.

2. DESIGN OF PSEUDO-INTERDIGITAL FILTER

Figure 1 shows the layout of the designed pseudo-interdigital filter with tapped I/O. It is interesting to noted that there is an electrical short circuit at middle position of resonators where the two grounded ends are jointed even without the via hole grounding at the midband frequency.[1] Therefore, there are no much change in the voltage and current distributions in the vicinity of the midband frequency even though the via holes are removed. In addition, the pseudo-interdigital filter can be seen as a combination of the interdigital and the hairpin line resonators. In another side, the structure results the effect of electric coupling and magnetic coupling, and brings the effect of interstage-coupling.[5] From the result of the interstage-coupling effect, the filter configuration of Figure 2 has attenuation poles of finite frequency on the two side of the pass band. The coupling can be even smaller for very small coupling spacing.[1,5] It is important to note that the frequency skirts of passband edge are very sharp. At edges of the passband, these attenuation poles are an inherent characteristic of the interstage-coupling structure and this coupling structure can easily increase the attenuation rate of the frequency skirt. For further improving the passband and rejection, the tapped I/O is used for this pseudo-interdigital bandpass filter.[2-3] Filter with tapped I/O can create two extra transmission zeros in the stopband. This is a very useful feature for many RF transmitters and receives in rejecting image frequencies and enhancing the attenuation characteristics in the stopband of the filter. Besides, the pseudo-interdigital filter with tapped I/O in this letter can also save the first level coupling’s space.

![Figure 1 Layout of the designed pseudo-interdigital bandpass filter having tapped I/O.](image)

3. FABRICATION AND MEASURED RESULTS

A full-wave EM simulator, which is based on the method of moments and proven to be quite accurate in its prediction, was used to simulate the frequency responses of the filter. Figure 2 shows the simulated frequency response of designed pseudo-interdigital bandpass
filter with tapped I/O at center frequency $f_0 = 3.55$ GHz. It can be observed that the passband frequency response is fairly flat and the frequency skirts are sharp. This is attributed to the multipoles in the vicinity of the midband. It can also be seen that there are two transmission zeros at the edges of the passband (Z1, Z2) from interstage-coupling, but their position cannot be easily tuned. Another pair of extra transmission zeros at the stopband (Z0, Z4) from tapered I/O can be easily tuned. By properly adjusting the position of the tapped I/O, the external Q and the extra transmission zeros are well realized in the filter. From the simulated prediction, these transmission zeros are an inherent characteristic of this type of filter due to its interstage-structure and the tapped I/O, and enhance the isolation performance of frequency skirt.

All parallel microstrip lines except for the feeding line have the same width as denoted by $W_1$. As can be seen the whole size of the filter is 22.8 mm by 7.02 mm. The parameters of the filter are shown as follows: $L_1 = 23$ mm, $W_1 = 0.8$ mm, $W_2 = 5.41$ mm, $S_1 = 0.6$ mm, $S_2 = 0.2$ mm, $G = 0.2$ mm, which is optimized by the simulated results for high performance. Here, the input/output 50-$\Omega$ microstrip line is taped to the first and last resonators as the external coupling structure. This filter was then fabricated on the FR4 GD (Glass-Epoxy Double Sided) substrate with a relative dielectric constant of 4.7, a loss tangent of 0.025, and a thickness 0.02 mm, and then measured by an Agilent 8753E Network Analyzer.

Figure 3 shows the measured frequency response of designed pseudo-interdigital bandpass filter having tapped I/O. From properly adjusting the tapped point, the good frequency response at center frequency $f_0 = 3.6$ GHz has insertion loss of 2.7 dB, bandwidth of 0.96 GHz and return losses of 17 dB, respectively. The two extra transmission zeros that are the typical elliptic function response can also clearly be observed by using tapped I/O.[6] The finite transmission zero occurs in the lower side of the stopband are greater than 45 dB at 1.98 GHz and 2.5 GHz while in the higher side of the stopband are greater 45 dB at 5.4 GHz and 33 dB at 6.5 GHz. The performance of cut-off band is more deflexed than parallel coupled microstrip bandpass filter. The systems can provide more high selectivity and more variance for users. The measured response of the filter realized in this section is observed to upper toward higher frequencies than the simulated response, possibly because of deviations in fabricated error and thickness of the substrate. The filter has advantages of compactness and simplicity since it has a size smaller than that of the conventional interdigital bandpass filter and it is also compatible with planar fabrication techniques. In addition, it has been shown that the capability of implementing transmission zeros, the compactness and flexibility in the size, and the simplicity can be simultaneously obtained in the pseudo-interdigital bandpass filter having tapped I/O for further development toward microwave applications.
Figure 2 Simulated frequency response of designed pseudo-interdigital bandpass filter having tapped I/O.

Figure 3 Measured frequency response of designed pseudo-interdigital bandpass filter having tapped I/O.
4. CONCLUSIONS

A technique to design the pseudo-interdigital filter has been presented. The effectiveness of the design has been proven by the experimental and simulated results. The performance of the pseudo-interdigital bandpass filter shows more attractive since the transmission zeros can be adjusted to reject unwanted signals near the passband. Moreover, it is also more compact than many traditional transmission line filters. The filter is also of benefit for monolithic microwave integrated circuit (MMIC) as well as for the growing numbers of microwave superconductive circuits.

REFERENCES