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High Performance Parallel Coupled Microstrip Filters

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ABSTRACT

A new construction technique allows microstrip parallel coupled filters to have greater passband symmetry and largely removes the parasitic passband at twice the center frequency. This technique brings microstrip filters closer to stripline filter performance. Advanced computer aided design tools and a high precision thin film process make these filters predictable and repeatable.

INTRODUCTION

Parallel coupled microstrip filters are easily designed and implemented. Both approximate and exact realizations are available [1],[2]. These filters work well for bandwidths between 5% and 50%. There are two problems with these filters when implemented in microstrip: asymmetric response, and a parasitic passband at twice the center frequency (Figure 1). The latter effect is due to the unequal even and odd mode phase velocities in coupled microstrips. Often this poor high end rejection forces the designer to use a low pass filter after the bandpass filter.

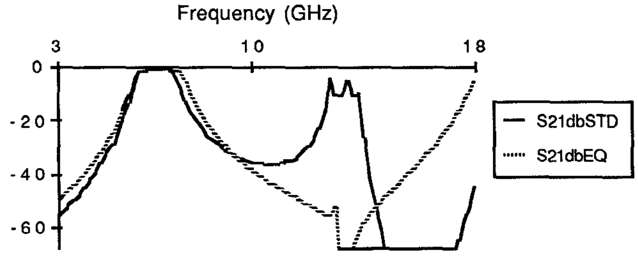

Figure 1. Comparison of standard and equalized microstrip parallel coupled filters.

Since the length of each coupled section in a parallel coupled filter is the same for both even and odd modes, the unequal phase velocities of these modes create different half wavelength frequencies for these modes. Homogeneous mediums would allow the half wavelength frequencies to coincide and so create a response zero at this frequency. This lack of cancellation in microstrip causes a second passband around twice the filter center frequency and also reduces the stopband attenuation (Figure 1).

THEORY

There are two basic methods of reducing the parasitic passband: equalizing the phase velocities, and providing different lengths for the even and odd modes. Equalizing the phase velocities may be done by suspending the substrate [3], opening a slot in the ground plane, or providing an overlay[4]. However, all of these add cost to the original filter. Providing different lengths for even and odd modes has been done in suspended substrate to enhance the passband symmetry, but in this case the parasitic passband was only narrowed and not attenuated [5]. Since in suspended substrate the even mode often has a higher phase velocity than the odd mode, the even mode (resonator) lengths were extended inbetween the coupling regions[5].

Microstrip has an even mode phase velocity lower than the odd mode, and so the odd mode length should be extended. Because the even and odd modes are required to cancel, accurate modeling is a must in this situation. This need for accuracy precluded the use of wiggly line techniques. Approximate designs will only narrow the parasitic band, and in reality perfect cancellation will not occur because of dispersion. The key is to get the cancellation so close that the finite Q of the medium virtually eliminates the parasitic response. A great deal of time has been spent on

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accurate computer modeling of parallel coupled lines. The starting point was the Kirschning-Jansen equations for coupled lines. Analytical expressions for thickness and loss were then pieced together from many different papers, experiments, and lecture notes. The loss evaluation was critical to estimating rejection of the parasitic passband.

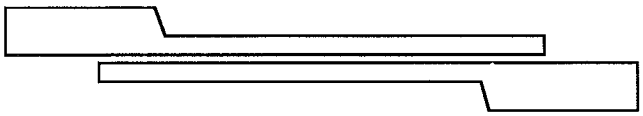

Figure 2. Layout for overcoupled resonators (extended odd mode).

The filters described in this report extended the odd mode phase length by allowing the coupled lines to overlap lines outside the resonator proper (Figure 2). It can be seen in Figure 2 that the coupling gap of the resonator has been extended out onto the 50Ω lines. The even mode length has been set by the distance between the 50Ω lines. In other words, the reference plane for the even mode has been moved into the resonator. This configuration makes the odd mode length longer than the even mode and thus compensates for the phase velocity difference between modes. This new resonator structure has extended the odd mode length while maintaining the even mode length.

In order to design filters with this resonator, we must be able to calculate the lengths of the overcoupled region and the total resonator. Since a microstrip coupled line pair has a zero in its response when the equation below is satisfied, the total resonator length must be chosen to place this zero at twice the desired center frequency.

$$\frac{Z_{oe}}{Z_{oo}} = \frac{\sin \beta_e l}{\sin \beta_o l}$$

The resonators are then overlapped so the phase shift of each resonator is -90° at the filter center frequency. This ensures proper operation of the filter. The overlapping may be calculated as a movement in the reference planes, or as a negative line length put before and after the resonator. This line of negative length should have an impedance equal to the even mode impedance.

This procedure will increase the bandwidth of the filter because the coupling of each resonator is increased. The bandwidth increase is related to the even and odd mode phase velocity difference. On 15 mil thick alumina this bandwidth increase is approximately 30%. A software implementation of this design procedure should iterate on each resonator until the desired coupling is obtained.

EXPERIMENT

Figure 3 shows the calculated (a) and measured (b) responses of 3rd order filters using this equalized design technique. No optimizing was done during the design process. Figure 4 shows the results of tuning the equalized filter with two small pieces of alumina placed at the ends of each input resonator. Note that another 10 db of rejection can be obtained. The effects of a cover on the filter were negligible. This filter is not particularly sensitive to process variations, a 2db delta in the parasitic passband was seen across the lot.

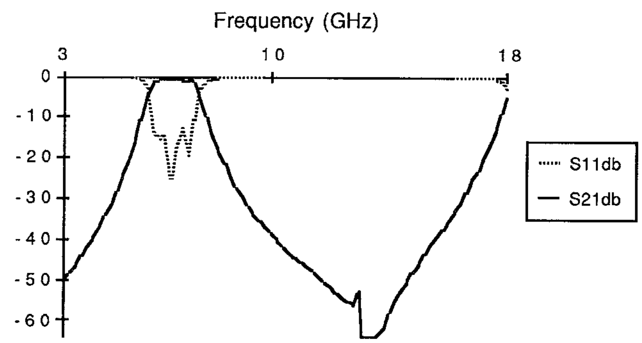

Figure 3a. Predicted response of equalized parallel coupled filter.

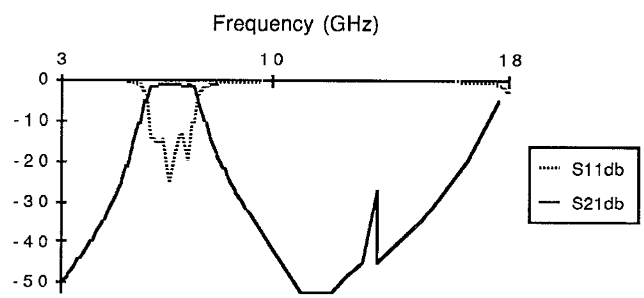

Figure 3b. Measured response of equalized parallel coupled filter.

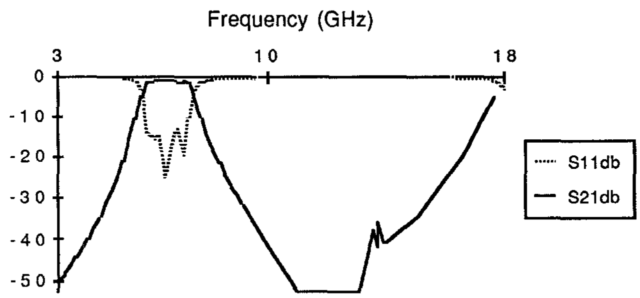

Figure 4. Tuned equalized parallel coupled filter.

A scale drawing of this filter is shown in Figure 5. The filter of Figure 5 has 15 mil wide lines on the input and output. The substrate was 15 mil thick alumina. Notice how the overlapped regions are angled to preserve the line widths and gaps. As can be seen from comparing the predicted and measured responses, further effort is needed on the modeling of the overcoupled line section and possibly the dispersion of coupled microstrips.

CONCLUSIONS

The efficient and cost effective construction of high performance filters is vital to the production of subassemblies. The filter described in the paper significantly improves the performance of previous microstrip parallel coupled filter structures. The use of this structure can remove the need for low pass filters following a bandpass filter because of its greater stopband rejection. The improvement in filter symmetry allows for reduced order in some situations. This filter requires accurate design tools and a precision thin film process, but requires no more space, cost, or tuning than ordinary parallel coupled filters.

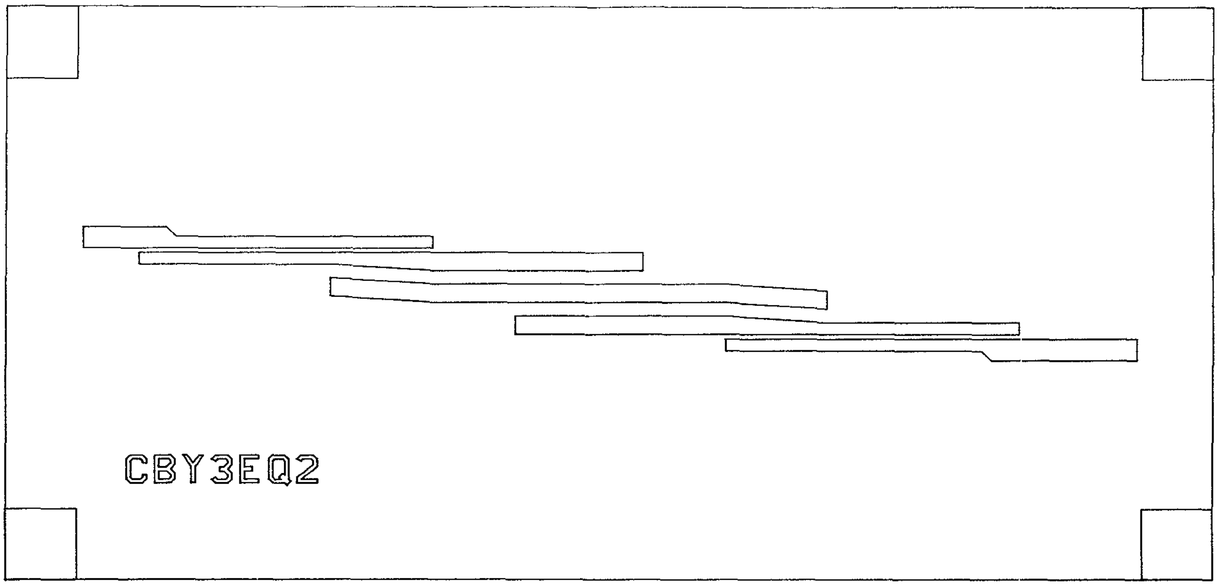

Figure 5. 3rd order filter layout on 15 mil alumina.

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