The Use of Offset Coupled Microstrip Combline Filters for IF Filters Requiring High Selectivity

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Abstract: IF filtering is crucial to the IMD (Intermodulation Distortion) and noise performance of the entire strip; IF filter should be as sharp as possible. Usually, this amount of rejection is accomplished through high Q-structures such as slabline, cavity or SIW (Substrate Integrated Waveguide), but these types of filters consume more space compared to microstrip filters. Unfortunately microstrip filters suffer from bandwidth enlargement and dispersion. In this paper, a technique to compensate for the bandwidth enlargement while sustaining almost unchanged center frequency loss for microstrip combline filters is proposed.

Keywords: IF Frequency Filtering, Transformer Coupled Combline Filter, Offset Coupled Lines

1. Introduction

Determination of the first IF (Intermediate Frequency) places a key role in the design of the receivers. Due to increasing difficulty to suppress higher spurious modes, there is increasing attention for upconverting in the first IF stage instead of downconverting for the last few years. Especially for wideband systems, the spurious frequencies are pushed beyond the operation limit of the receiver where they can easily be suppressed, for instance with a simple low pass filter.

This is an effective technique as long as there are no spurious causing sources near the IF frequency. Since IF filtering is crucial to the IMD (Intermodulation Distortion) and noise performance of the entire strip, IF filter should be as sharp as possible (about 50dBc compared to the center frequency of the IF filter). As far as current A/D (Analog to Digital) converters are concerned, the LO (Local Oscillator) frequencies for the second IF tends to be about 4%-5% of the edge frequency.

Usually, this amount of rejection is accomplished through high Q-structures such as slabline, cavity or SIW (Substrate Integrated Waveguide), since Q factor of stripline or microstrip structures fail to comply with the above mentioned specifications. Generally, in these types of structures insertion loss and rejection/sharpness specifications tend to work against each other. This situation gets severe as the frequency increases.

2. Designing The IF Filter

In the context of this work an IF filter with 22 GHz center will be designed. Since the system has 500MHz instantaneous bandwidth, the filter would have 2% bandwidth. LO frequency for the proceeding stage is 20.875 GHz. Hence, IF filter must suppress the aforementioned frequency at least

60 dBc in order not to violate the dynamic range of the A/D converter. The IF filter should also suppress all frequencies up to 40 GHz at least 50 dBc.

To satisfy size/cost/simplicity requirements and to avoid box resonances, the filter has to be made as microstrip. For this purpose 10 mil ROGERS 5880 0.5 oz. substrate has been selected. The circuit has been designed using FILPRO [1] and SONNET [2] has been used for the EM simulation. The circuit schematic and layout of the design are shown in Figure 1 and Figure 2, respectively. The circuit shown in Figure 1 is a Transformer Coupled Combline (TCC) filter [3,5]. FILPRO and SONNET results are shown in Figure 3. The circuit has been fabricated and measured. The comparison between the SONNET EM result and fabricated result is shown in Figure 4.

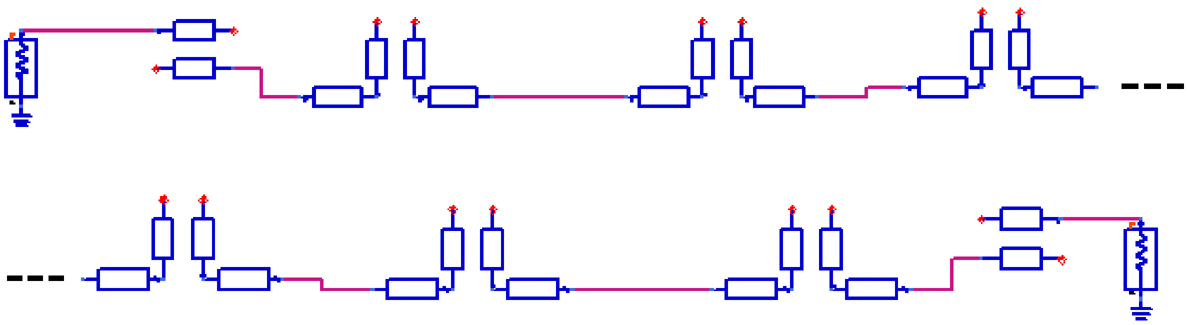

Fig. 1. Schematic of Transformer Coupled Combline (TCC) Filter.

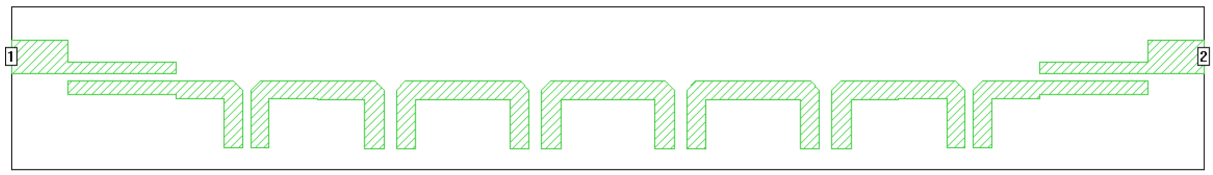

Fig. 2. SONNET Layout of Transformer Coupled Combline (TCC) Filter

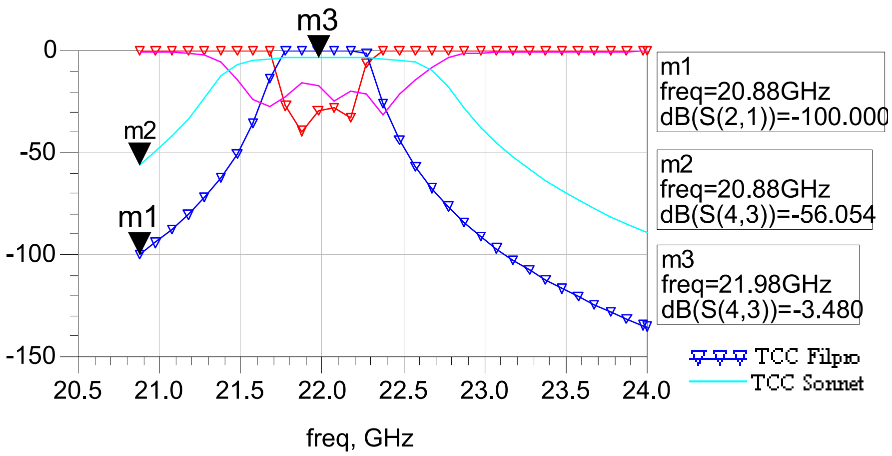

Fig. 3. FILPRO and SONNET EM Responses (S21 & S11).

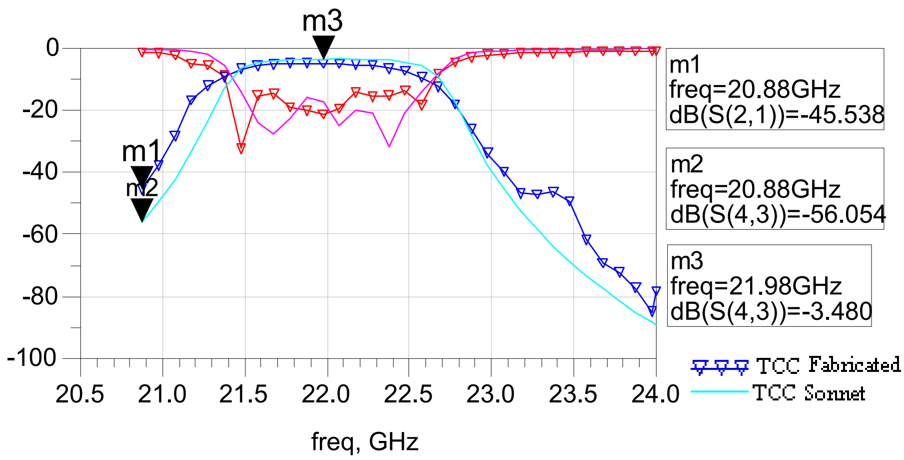

Fig. 4. SONNET EM and Fabricated TCC Filter Responses (S21 & S11).

As seen from the above graphs the measurement results deviate from the theoretical design. The main problem seems to be with the sharpness of the filter due to the bandwidth enlargement. According to SONNET EM simulations, this enlargement is due to the intercoupling between comblines. Hence, the intercoupling between coupled lines should be decreased. Possible remedies may be either designing the filter with a narrower bandwidth or just increasing the spacing between the coupled lines. However both solutions would introduce extra insertion loss to the filter response. Besides, the second method would require extra trial/error and optimization runs for return loss compensation. Both solutions would imply a longer filter in horizontal direction. An alternative method is presented in the next chapter to overcome bandwidth enlargement while sustaining the same level of passband insertion loss.

3. Proposed Filter Topology
(Transformer Coupled Offset Combline-TCOC)

Since increasing the spacing between comblines increases the passband insertion loss, comblines can be changed to offset coupled comblines as shown in Figure 5. The standard combline element of the filter is altered into an offset coupled combline and the new circuit is simulated and optimized using SONNET as shown in Figure 6.

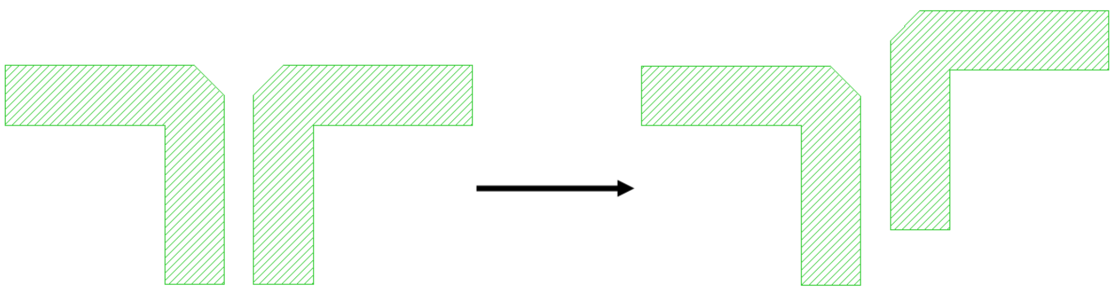

Fig. 5. Change of Standard Combline into Offset Coupled Combline.

When the above figure is studied carefully, it will be noted that there is no change in the spacing between resonators and, no impedance change for any transmission lines, so the changes such as center frequency shift or passband return loss should be accounted for. Therefore the whole circuit in Figure 6 has been re-simulated and tuned using the co-calibrated ports shown in Figure 6.

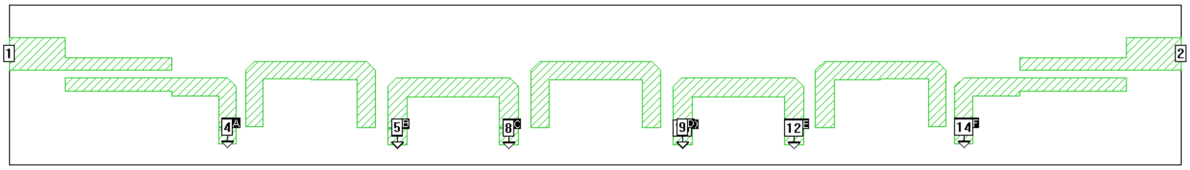

Fig. 6. SONNET Layout of Transformer Coupled Offset Combline (TCOC) Filter.

Figure 7 and Figure 8 show the results of both simulations using classical transformer coupled combline and offset coupled combline. It is readily observed that the proposed topology has a sharper response and better passband return loss performance. Besides there is no significant degradation in center frequency loss. For both cases it is about -4.5 dB.

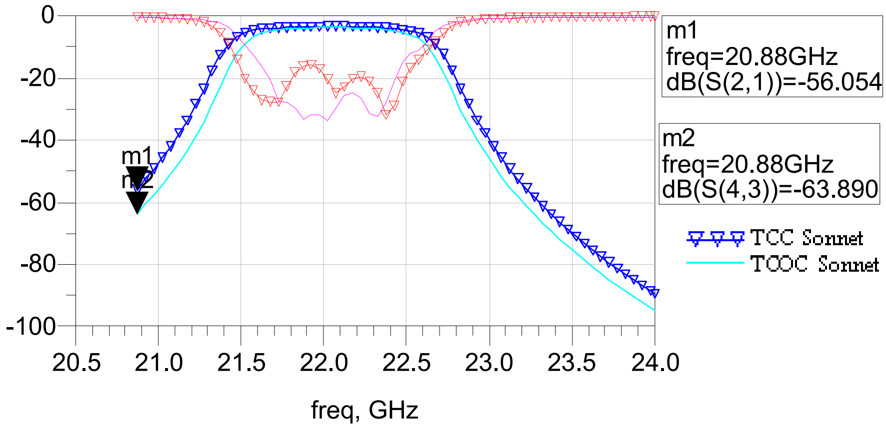

Fig. 7. TCC and TCOC Filters SONNET EM Responses (S21 & S11).

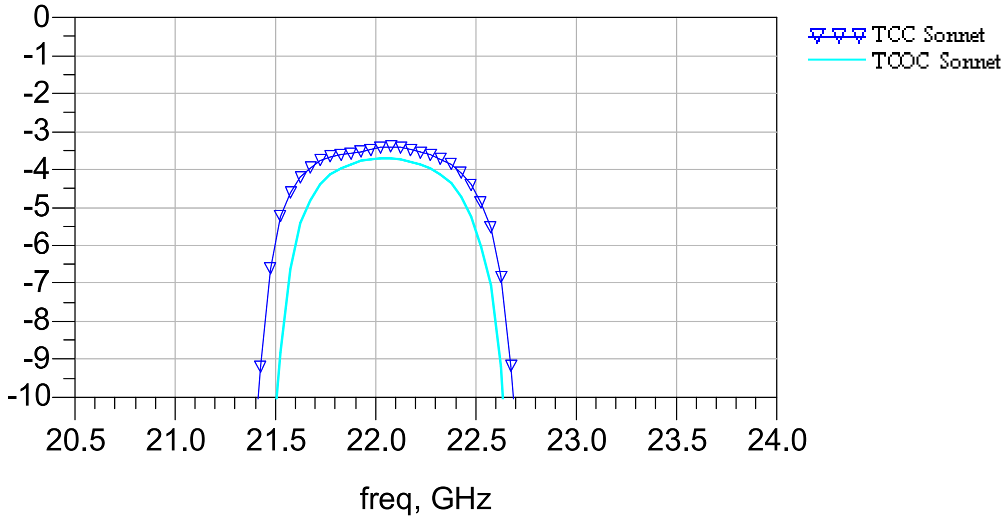

Fig. 8. TCC and TCOC Filters SONNET EM Responses (S21)(1dB Scale).

4. Measurement Results and Conclusion

Both filters were built on 10 mil ROGERS 5880 0.5 oz. substrate. The measurement results are shown in Figure 9. The results agree perfectly with the SONNET EM simulation results. As predicted the filter proposed has higher selectivity than the classical filter and they have the same passband insertion loss about -5.2 dB. The difference between simulated and measured passband loss levels are due the connectors used at that frequency. Both filters have rejection band up to 40 GHz which proves that there is no effect of offset coupling to the rejection at higher frequencies.

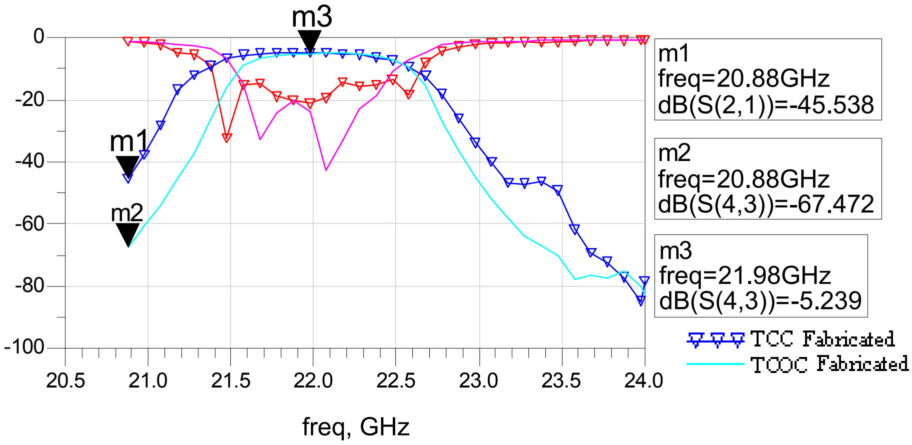

Fig. 9. TCC and TCOC Fabricated Measured Filter Responses (S21 & S11).

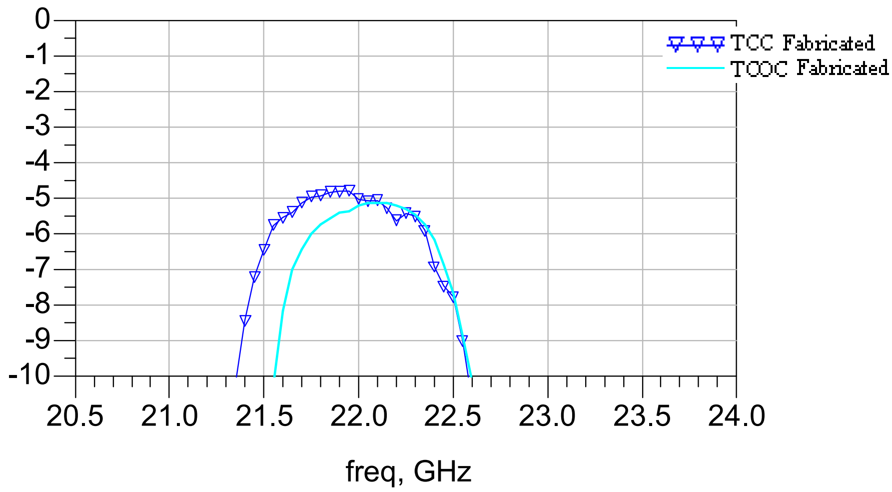

Fig. 10. TCC and TCOC Fabricated Filter Responses (S21)(1dB Scale).

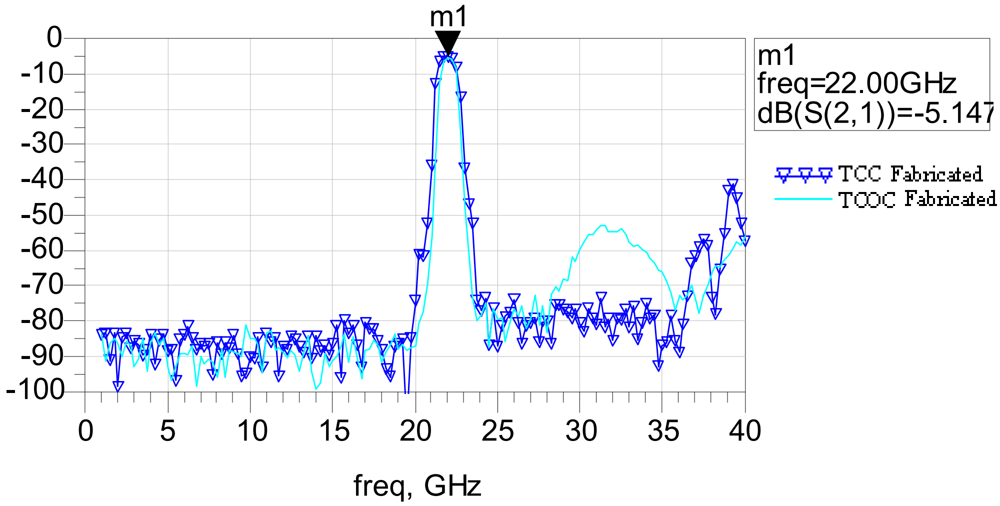

Fig. 11. TCC and TCOC Fabricated Filter Responses (S21)(Up to 40GHz).

References

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