Hybrid Resonator Microstrip Line Electrically Tunable Filter

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***Abstract* — A novel hybrid resonator microstrip line electrically tunable filter is presented in this paper. The tunable filter has mixed combline resonators and a hairpin like resonator. With this mixed resonator filter, transmission zeros can be obtained on each side of the passband. This elliptic function filter response is achieved without any non-adjacent coupling. Parascan^{TM} dielectric material varactors are then used at the end of each resonator, so that the filter passband is electrically tunable. A 4-pole design example is provided. The transmission zeros are clearly shown in both simulation and measurement.**

I. Introduction

Wireless communication applications have been boomed in the last decade. Filter products as one of the most important components in the radios have been required to provide better and better performance with smaller and smaller size. Tremendous efforts have been made to develop new type of resonators, new coupling structures and new configurations. One of the techniques to reduce the number of resonators is to add cross couplings between non-adjacent resonators to provide transmission zeros. As a result of these transmission zeros, the filter selectivity is improved. However, in order to achieve these transmission zeros, certain coupling patterns have to be followed. This turns out diminishes the size reduction effort.

Electrically tunable filters use electrically tunable varactors as part of the filter resonators. For most of the tunable filters, it is not desired to make the filter configuration complicated, otherwise it will be hard to tune the filter from one frequency to the other and still to maintain reasonable filter performances. This paper describes a novel hybrid resonator microstrip line tunable filter, which automatically provide elliptic function response without any cross coupling. The tunable filter consists of combline resonators and hairpin [1]-[4] like resonators with loaded varactors.

II. Hybrid resonator filters

Combline filter structure in general is a good candidate for making tunable filters, due to the requirement of the end capacitances on its resonators. A natural replacement of these end capacitances with varactors will make the filter frequency tunable. However, since the whole filter is physically fixed except the end capacitances, filter performance, such as return loss, will degrade when the filter passband frequency is tuned away from the original passband frequency. It is desired not to make the filter coupling structure too complicated and then the filter performance can be kept for a wider frequency tuning range without too much performance degradation. On the other hand, this means, to a degree, not to add any cross couplings, and then it will be almost impossible to achieve any transmission zeros for better filter performance.

Well, it has been well known that combline filter, in general, has a natural transmission zero above its passband [1], where the resonator length meets a quarter wavelength. Even with microstrip line medium, this phenomenon is still true. Fig. 1 provides an example of a 4-pole combline bandpass filter layout with its response. As it can be seen, the filter transmission is skewed by the transmission zero at the high frequency side, which results in the filter selectivity at the high frequency side to be improved and at the low frequency side to be degraded.

For miniaturization, hirepin resonator structure has been widely used in microstrip line filters [2]-[4], especially for HTS (High Temperature Superconductor) [1]. It has been noticed that there is a transmission zero at the low frequency side, which results in the filter selectivity at the low frequency side to be improved and at the high frequency side to be degraded, even though, theoretical analysis shows that the transmission zero should be at the high frequency side [1].

In a tunable filter design for wireless mobile and portable communication applications, small size requirement and not too complicated coupling structure design requirement mean that adding cross coupling to achieve transmission zeros is not a good option. Well, what is going to happen if combline resonators and hirepin resonators are mixed in the microstrip line filter design? Will the transmission zero at high frequency side from combline resonators and the one at the low frequency side from hirepin resonators appear at the same time? This paper provides a positive answer.

Fig. 2 illustrates the principle configuration of the microstrip line hybrid resonator 4-pole bandpass filter. The input and output resonators are typical combline resonators with tapped lines. The second resonator is also a combline resonator. The third resonator is a hirepin like resonator. Instead of having the two ends open, lumped capacitors are added.

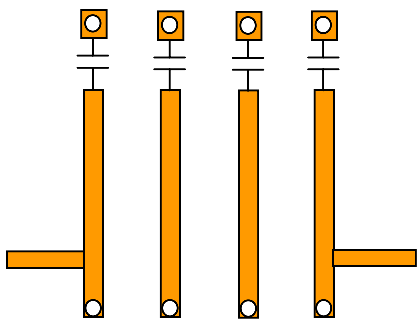

Fig. 1a A 4-pole microstrip combline bandpass filter

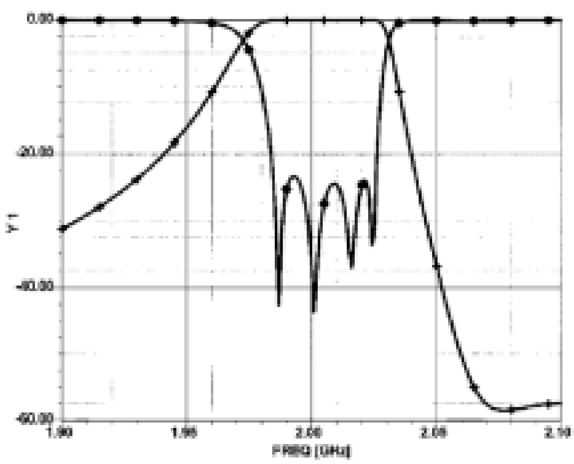

Fig. 1b 4-pole microstrip combline bandpass filter simulated response

III. EXAMPLE

A 4-pole microstrip line hybrid resonator tunable bandpass filter at 2GHz has been designed, built and tested. The microstrip line substrate has 10.2 dielectric constant and 0.025” thickness. As shown in Fig. 3, the combline resonators are grounded at one end through via holes and the other end connected with a varactor. The varactor is then grounded through a DC block capacitor. DC voltage bias is added to the varactors to provide tunability. The hirepin like resonator needs two varactors, but no DC block capacitor. The two end varactors are grounded directly. The DC voltage bias is added to the middle point of the hirepin resonator.

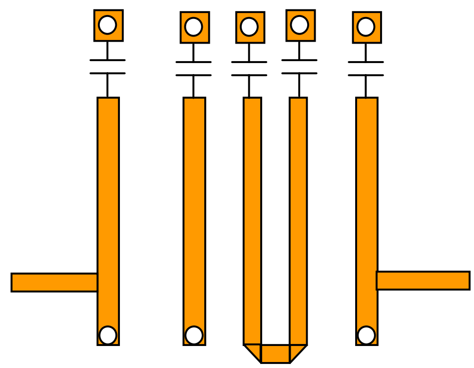

Fig. 2 A 4-pole microstrip line hybrid resonator bandpass filter

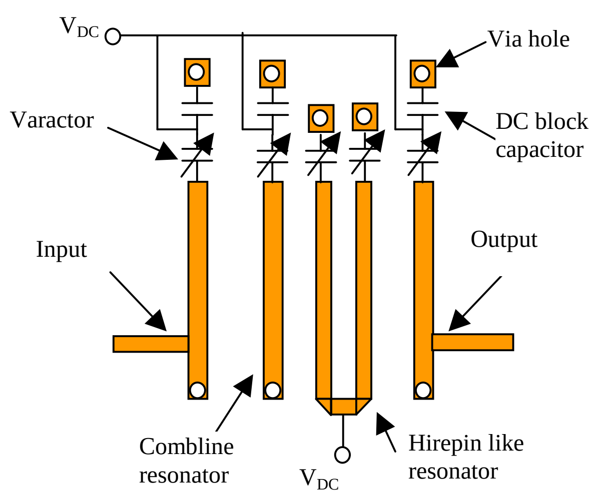

Fig. 3 4-pole microstrip line hybrid resonator tunable bandpass filter layout

Figure 4 shows a simulated filter response at about 2GHz, by using Ansoft Serenade. It is clearly showing that the two transmission zeros, one at each side of the passband, are still there like an elliptic function filter response.

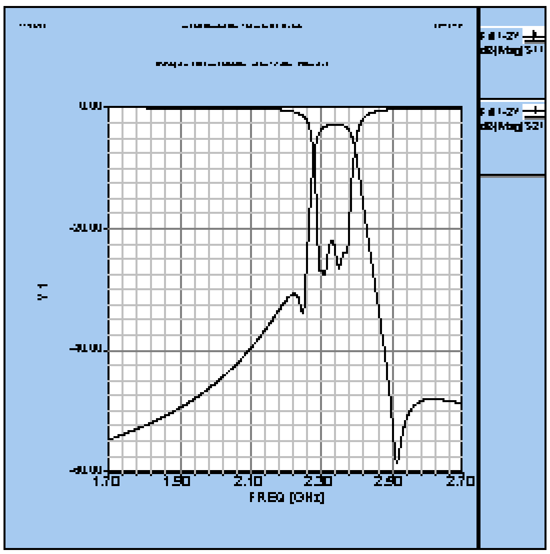

Fig. 4 Simulated 4-pole microstrip line hybrid resonator tunable bandpass filter response

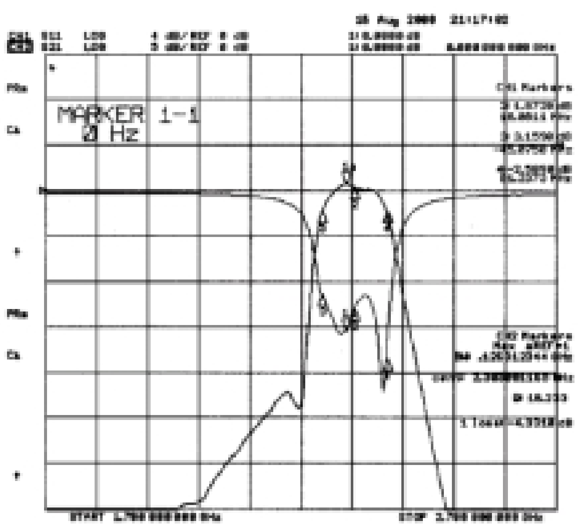

Fig. 5 Measured 4-pole microstrip line hybrid resonator tunable bandpass filter response

The measured filter performance is shown in Fig. 5. As it can be seen, one transmission zero at each side of the filter passband is clearly demonstrated.

Unlike the zeros achieved through cross couplings, the two transmission zeros from this hybrid resonator design are skewed. Discussion is provided in next section.

Figure 6 shows that the filter passband center frequency is tuned from 2.16GHz to 2.36GHz, when the varactors are biased from 0 volt to 200 volts.

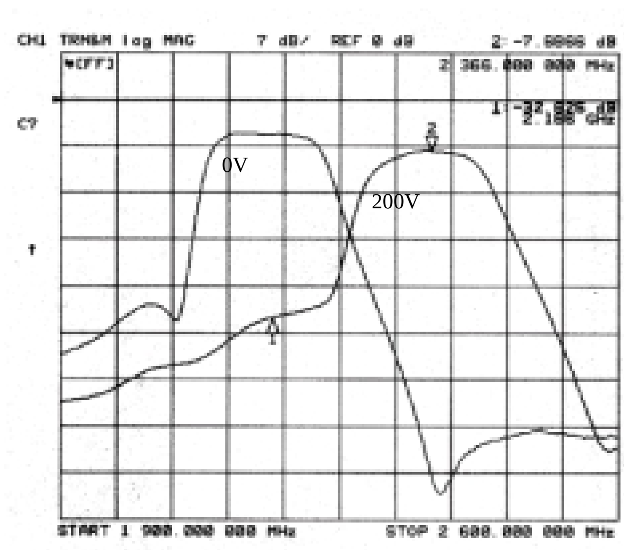

Fig. 4 4-pole microstrip hybrid resonator tunable bandpass filter tuning response when bias is applied

IV. Discussion

For a multi-pole filter, it is desired to have all the varactors biased up together with one voltage source, even though it is theoretically possible to have them biased independently. To achieve this goal, the varactor capacitance values need to be selected the same for all the resonators. By properly adjusting the resonator impedances, this goal can be realized. Hirepin like resonators usually needs to have a high impedance in order to maintain not only the same end capacitance value as the comline resonators, but also the same physical length (not the total resonator transmission line length). The two arms spacing can also help to make the realization more reasonable. However, it should be reserved for the coupling between combline resonator and hirepin like resonator. In this way, the hirepin like resonator behaves almost the same as the combline resonators, during tuning.

The middle point of the hirepin like resonator is basically a short point, due to the symmetry of the resonator. This turns out to be a perfect point to add DC bias line for minimum RF effect.

Coupling between combline resonator and hirepin like resonator is treated the same as between two combline resonators. However, it is noticed that for the same spacing, smaller coupling is obtained comparing with the case where two combline resonators are involved. In order to increase the coupling, higher impedance line on the hirepin resonator is required. To balance up the requirement of the varactor value and the resonator spacing, the space between the two arms of the hirepin like resonator can be the key to achieve the optimized design.

The authors have made effort to control the two transmission zeros in frequency. Theoretically, the high side zero from combline resonators can be adjusted in frequency by varying the resonator electric length. But simulation results do not confirm this clearly. The low side zero from hirepin like resonator is even harder to predict. It has been indicated [1] that this zero is supposed to be at the high side of the passband by the same principle as used in the combline resonator, but due to the unequal even- and odd-mode velocities in microstrip line, the zero shows up actually at the low side of the passband. The authors have tried to adjust the hirepin like resonator spacing to control the zero, but no clear confirmation has been obtained yet. Continuous study is on the way. If any conclusive solutions can be found, it will be reported in the expanded version for December issue of MTT Transactions.

The authors believe that the elliptic function like filter response can be obtained with different combination of combline and hirepin like resonators.

V. Conclusion

A novel microstrip line hybrid resonator bandpass filter configuration is presented. These hybrid resonators consist of combline and hirepin resonators. Elliptic function like filter response is achieved in this configuration without any cross coupling. An example 4-pole tunable filter has been built and tested. The measured results match the simulated response very well. This new filter configuration is very useful for filter miniaturization, and especially for tunable filters in wireless communication applications.

References

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