Quasi-Lumped Suspended Stripline Filters with Adjustable Transmission Zeroes

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Abstract **— Based on quasi-lumped resonators in suspended stripline technique, very compact filters are realized. The resonators consist of patch-like capacitive elements and thin inductive strips, coupled electro-magnetically to the input lines and adjacent resonators. By properly arranging these resonators, transmission zeroes can be produced and shifted easily to frequencies either below or above the passband. A detailed discussion of this effect is given, and three sample filters are presented. At 8.5 GHz, a four resonator filter has a length of 12 mm only. With a bandwidth of 1.3 GHz, minimum insertion loss is 0.7 dB including connecting lines and transitions to the coaxial test system.**

Index Terms **— Stripline, stripline filters, bandpass filters, elliptic filters, quasi-lumped elements.**

I. Introduction

Suspended stripline has proven as a favorable transmission line medium for the realization of low to medium loss printed filter structures, e.g. [1, 2]. Recently, very compact quasi-lumped bandpass filters in this technique have been presented consisting of capacitively coupled shunt resonators [3]. In some respect, these filters resemble interdigital filters, too. The basic cross section of the employed suspended stripling is shown in Fig. 1a, and the layout of a two resonator filter (with slightly modified resonators compared to [3]) is shown in Fig. 1b.

The patch-like structures can be regarded as shunt capacitances, while the thin strips form shunt inductances. The computed insertion loss [4] of this filter is plotted in Fig. 2, showing the typical performance of a two-resonator filter. According to the specific structure of this filter, the isolation above the passband is only moderate. Higher order filters with improved performance have been demonstrated in [3].

Experimenting with this filter, some interesting effects can be observed. Arranging the filter resonators in a "parallel" way (Fig. 3, in contrast to the "antipodal" arrangement as shown in Fig. 1b), an additional transmission zero can be observed. Furthermore, moving the contact points of the inductive strips at the patches from an outer to an inner position, this transmission zero can be shifted from frequencies below the filter passband to frequencies above the passband (Fig. 4). Therefore, such a configuration is capable of providing filter responses with adjustable transmission zeroes, providing completely new design aspects compared to the work as presented in [3].

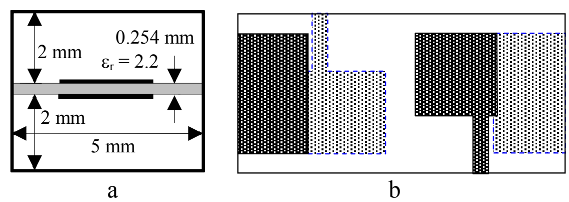

Fig. 1: Cross section of the suspended stripline configuration (a) and principle layout of a two resonator filter (b; dark: front side metallization, light grey: back side).

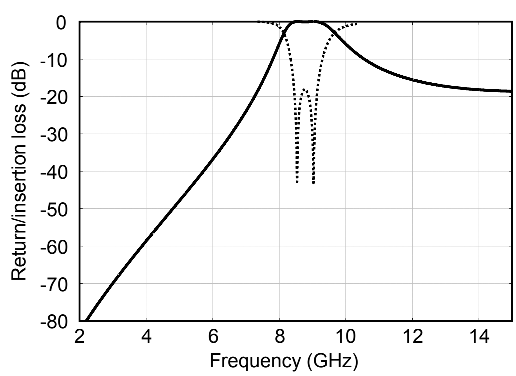

Fig. 2: Computed return and insertion loss of the filter shown in Fig. 1b.

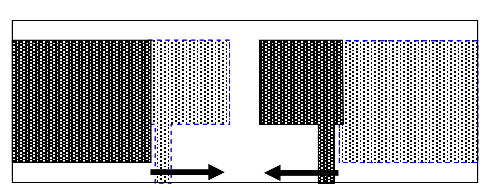

Fig. 3: Principle layout of a modified filter. (Dark grey: front side metallization, light grey: back side metallization)

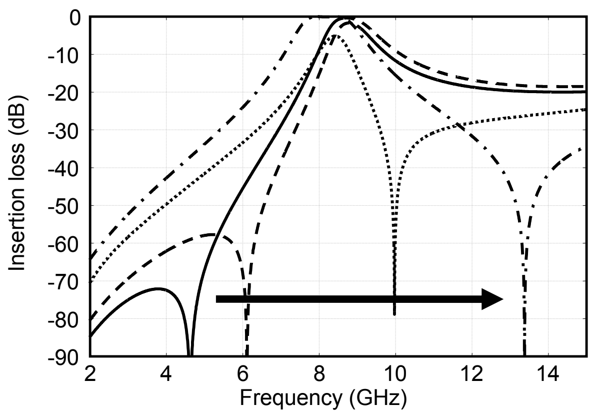

Fig. 4: Theoretical insertion loss curves of the filter as shown in Fig. 3 with different positions of the inductive strips (the frequency of the transmission zero increases moving the contact points from outsides to the center of the filter; see Fig. 3).

II. Investigation of the Nature of the Transmission Zeroes

Investigations of this type of filter were started with an in-depth investigation to explain the nature of the transmission zeroes. In a first step, the current density on the filter metallization was computed at the frequency of the transmission zero for different filter configurations. The current distribution for the filter with the inductive strips at the outer sides of the resonators and excitation of the left port is plotted in Fig. 5. A strong lateral current can be observed at the input strip as well as in the inductive strip of the left-side resonator. This indicates a magnetic coupling in addition to the original capacitive coupling. Casting this into an equivalent circuit, a parallel resonator may be assumed as coupling structure from the input to the resonator as indicated in the inset of Fig. 6. Based on starting values for an equivalent circuit for the complete filter derived from (simplified) full-wave calculations [3], the equivalent circuit was optimized [5] to achieve a similar performance as that calculated on a full-wave basis (in fact, this was done for the improved filter as shown later on in Fig 10). Fig. 6 shows return and insertion loss of the two different approaches. Having in mind that the real filter structure exhibits an even more complex electromagnetic coupling than described by the equivalent circuit, the agreement between the different curves is quite good, giving another confirmation to the explanation of the transmission zero.

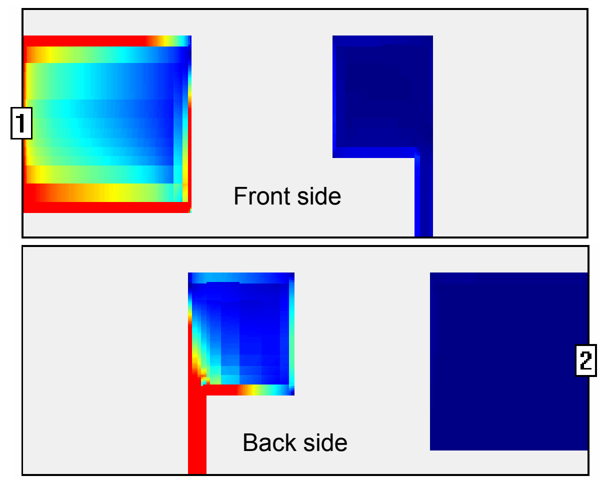

Fig. 5: Current density distribution of a filter with outside position of the inductive strips.

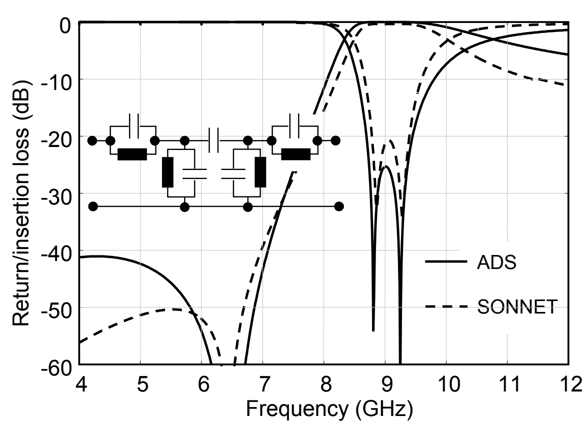

Fig. 6: Equivalent circuit and comparison of full-wave (SONNET) and equivalent circuit based calculations (ADS) of the filter.

An equivalent investigation was done for a filter with the inductive strips in the center of the filter. In this case, at the frequency of the transmission zero, a strong current density concentration is found on the two adjacent inductive strips, indicating, this time, an additional magnetic coupling in the center of the filter (Fig. 7). Thus, an equivalent circuit with coupling via a parallel resonator in the filter center is assumed, giving an even better agreement between the two calculations (Fig. 8).

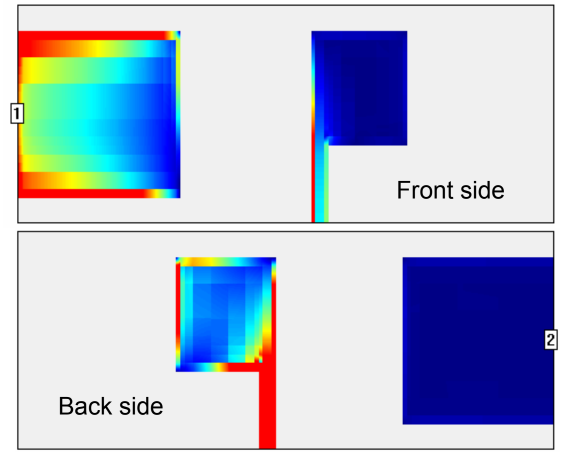

Fig. 7: Current density distribution of a filter with centric positions of the inductive strips.

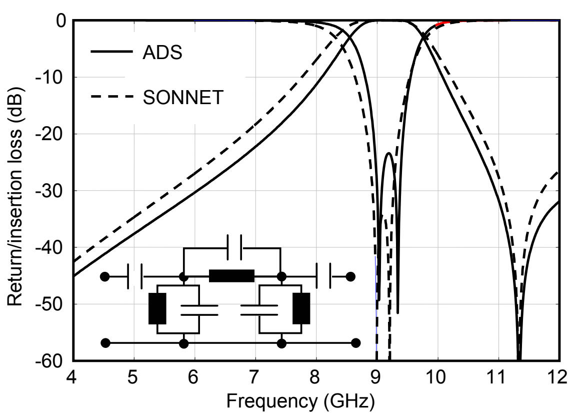

Fig. 8: Equivalent circuit and comparison of full-wave (SONNET) and equivalent circuit based calculations (ADS) of the filter with resonator coupling in the center.

III. Sample Filters

Applying the results of these investigations, a number of filters were optimized for improved passband performance. In a first step, two filters with two resonators, one with a transmission zero below and one above the passband, as well as a four resonator filter were optimized, fabricated and tested. Fig. 9 shows photographs of front and back side of the filters substrates. Theoretical and experimental results of the two resonator filters are presented in Figs. 10 and 11, together with a small 3D sketch of the respective structures. Fig. 10 shows an excellent agreement between theory and experiment. Insertion loss amounts to 0.4 … 0.5 dB, including about 24 mm of connecting lines and the transitions to the coaxial measurement system.

The return loss of the second filter does not show the same good agreement. In this case of a very narrowband filter, however, tolerances are much more critical than in the first case. Here, minimum insertion loss is 0.6 dB.

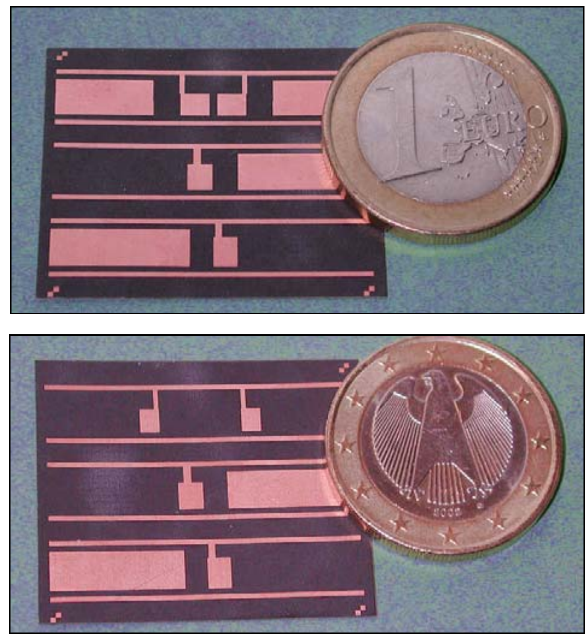

Fig. 9: Photographs of the three sample filter. (Top: front side, bottom: back side).

The structure of the four resonator filter is shown in Fig. 12, calculated and measured results are plotted in Fig. 13. Center frequency of the filter is 8.5 GHz, bandwidth amounts to 1.3 GHz. Once again, an excellent agreement between theory and experiment can be stated. The first transmission zero at about 4.6 GHz is hidden in the noise floor of the measurement. It is due to an additional inductive coupling at input and output (as can be seen from the current density distribution not shown here). The zero at 12.6 GHz is based on the coupling between the two adjacent inductive strips. Surprisingly, another transmission zero shows up around 16 GHz; its nature still has to be checked. Minimum measured passband insertion loss is 0.7 dB, once again including 18 mm of transmission line and the transitions to coaxial line at input and output. With a length of the filter itself of about 12 mm inserted in a channel of 4.25 mm × 5 mm this filter is extremely compact.

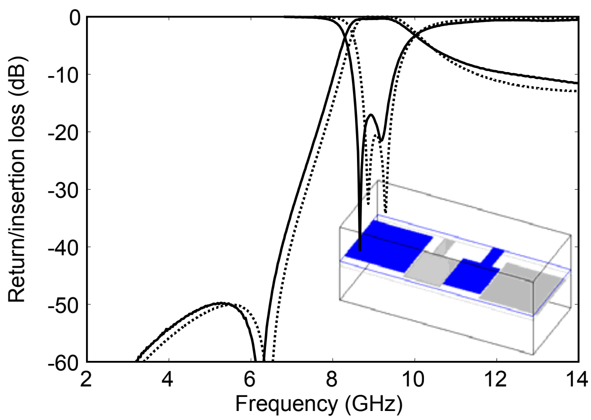

Fig. 10: Theoretical and experimental return and insertion loss of a two resonator filter with resonator coupling at the outer ends. (Dotted lines: theory, solid lines: experiments).

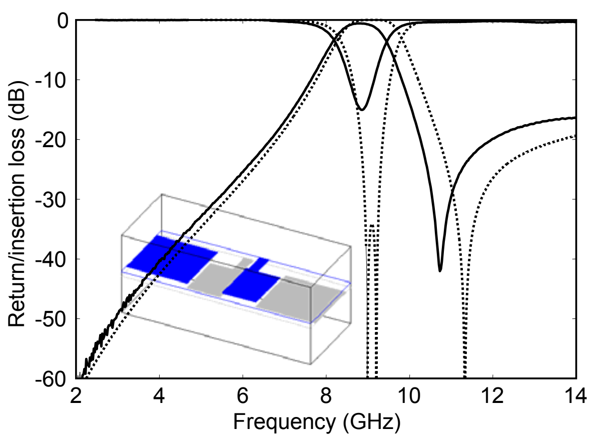

Fig. 11: Theoretical and experimental return and insertion loss of a two resonator filter with resonator coupling in the center. (Dotted lines: theory, solid lines: experiments).

IV. Conclusion

In this contribution, three examples for extremely compact quasi-lumped suspended stripline filters have been presented. Applying a suitable arrangement of the filter resonators, transmission zeroes can be introduced which can be shifted easily to a position below or above the passband just by modifying the position of the inductive strips of the resonators.

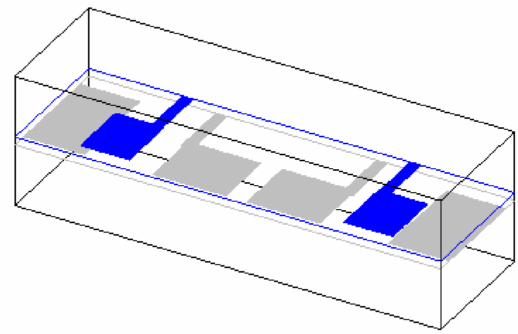

Fig. 12: Basic structure and layout of the four resonator filter.

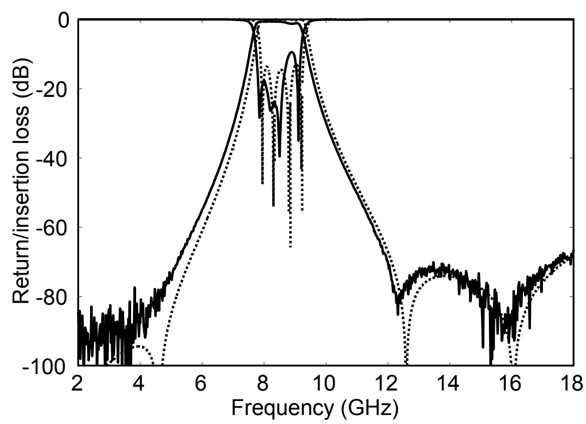

Fig. 13: Theoretical and experimental return and insertion loss of the four resonator filter. (Dotted lines: theory, solid lines: experiments).

References

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