Quasi-Lumped—Open-Loop Suspended Stripline Bandpass Filters

Atallah Balalem[1], Wolfgang Menzel[2], and Abbas Omar[1]

[1]Chair of Microwave and Communications Engineering, University of Magdeburg, Magdeburg, D-39016, Germany, E-Mails: balalem@iest.et.uni-magdeburg.de, a.omar@ieee.org

[2]Microwave Techniques, University of Ulm, D-89069 Ulm, Germany, E-Mail: wolfgang.menzel@ieee.org

***Abstract* —In this paper, a combined quasi-lumped-open-loop resonator (QL-OLR) is introduced and applied for filter design. The resonator can have single and dual-band behavior. Two bandpass filters as well as two dual-band bandpass filters have been designed, fabricated, and tested, that consist of two resonators each. The bandpass filters show the behavior of four return loss poles (fourth order filter), and by slitting these resonators a dual-band bandpass filter can be achieved (each band has two return loss poles). Transmission zeroes can be easily introduced into the filter response as well by utilizing the properties of both quasi-lumped and open-loop resonators.**

***Index Terms* — Filters, bandpass filters, dual-band filters, dual-band resonators, suspended stripline filters.**

I. Introduction

The increasing potential of the modern wireless communication and radar applications in today's technology has boosted the demand for microwave filters. However, most of the classical filters are designed as cascaded resonators coupled to each other either by pure inductive or pure capacitive coupling. Each resonator is usually responsible for one return-loss pole, while transmission can be achieved by linking the resonators via mixed coupling [1]. Dual-mode filters are a good example for multi- resonance structures that use dual-mode resonators. E.g., a second order bandpass filter can be achieved using a single dual-mode resonator, furthermore transmission zeros can be easily introduced, (see e.g. [2], [3]). However, these kind of resonators are mostly used for narrow-band filters.

In this paper, a combination of a suspended stripline quasi-lumped resonator (QLR) and an open-loop resonator (OLR) is proposed. Both of the resonators are combined in one QL-OLR resonator, which has two return-loss poles in its pass-band. In other words using one QL-OLR resonator coupled to the I/O ports, a second order bandpass filter can be achieved, and by splitting the resonances of the QL-OLR, a dual-band bandpass filter can be achieved.

Suspended stripline (SSL) quasi-lumped resonators have been introduced in [4]. Different filter types including broadband bandpass filters and high-pass filters have been achieved using SSL quasi-lumped resonators in [5].

OLRs have been proposed first for cross-coupled filters in [6], some size reduction, and resonance-frequency control for this resonator has already been done e.g. [7].

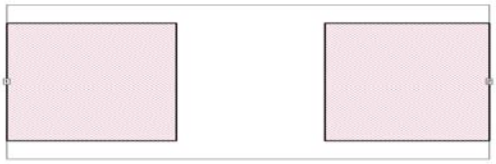
The filters proposed in this paper have been fabricated on an RT-Duroid 5880 substrate, with a thickness of 0.254 mm and dielectric constant of 2.2. The dual-mode bandpass filters have been implemented in a mount that has a height of 2 mm over the substrate and 2mm below it, and mount width of 5 mm, wile the dual-band bandpass filters have been implemented in a mount that has a height of 2.373 mm over the substrate and 2.373 mm below it and a width of 10 mm width.

II. Design Method

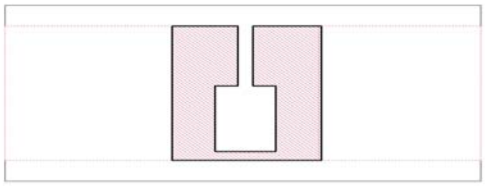
Compactly combining two resonators requires that they have nearly the same size and share the same resonance frequency. Moreover the resonance frequency of both resonators should be easily controlled. Therefore the SSL- QL resonator has been chosen to be combined with an open-loop one.

Based on that, two different bandpass filters are designed. The first filter consists of one QL resonator coupled to the I/O ports capacitively. The second filter is based on an OLR. Fig. 1 (a) shows the I/O ports at the topside of the substrate. Fig. 1 (b) shows the OLR on the backside of the same substrate, Fig. 1 (c) the SSL-QL parallel resonator on the backside of the substrate as well.

Having fixed the resonance frequency and the size of both resonators, both resonators can be combined in one QL-OLR. This can be done by adding the inductive narrow strip of the QL resonator to the OLR. By this arrangement, a new resonator with the behavior of both resonators can be achieved. Fig. 2 (a) shows a 3D sketch for the single QL-OLR filter, Fig. 2 (b) the return and the insertion loss of the single QL-OLR filter. A transmission zero is observed at 15.5 GHz, this occurs due to the slot parallel to the narrow stripline at the other side of the resonator.



(a)



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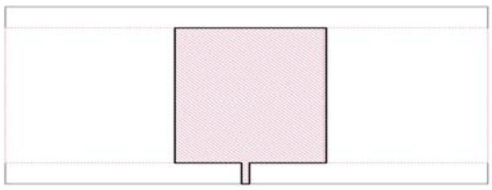
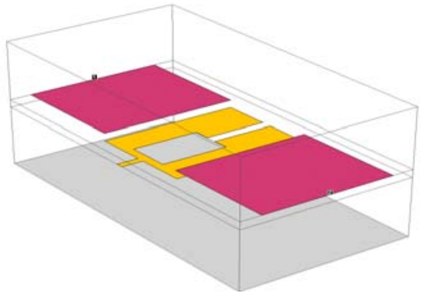


(c)

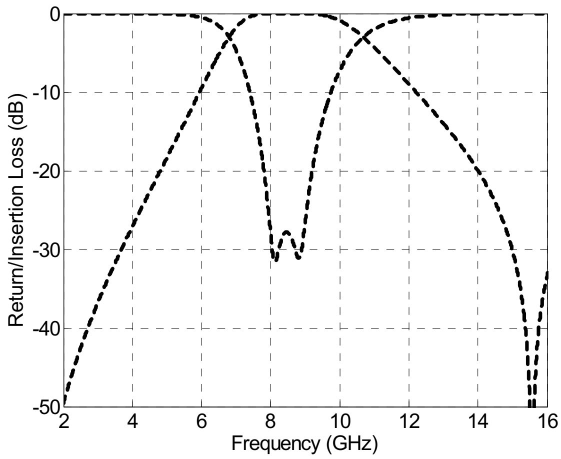
Fig. 1. (a) 50 ohm SSL transmission lines, (b) open-loop resonator on the backside of the substrate, and (c) parallel quasi-lumped resonator on the backside of the substrate.

III. Fourth Order Bandpass Filter

The same principle has been extended to the design of a fourth order bandpass filter. Two coupled QL-OLR have been implemented on the backside of the substrate. Each of these resonators is coupled to the neighboring port, which is implemented on the topside of the substrate. The parallel inductive strips are located on different sides of the substrate to avoid any inductive coupling between both resonators (see [5], [8]). The filter has been simulated using a commercial MoM simulator [9]. Fig. 3 shows a 3D sketch of the fourth order bandpass filter structure. Fig. 4 shows the simulated return and insertion losses of the filter. The four return-loss poles can be observed clearly. In addition a transmission zero occurs at about 14 GHz. This occurs due to the slot that is in parallel to the narrow stripline at the other side of the resonator. The filter has a bandwidth of about 2 GHz, an center frequency of 10.8 GHz.



(a)



(b)

Fig. 2. (a) 3D sketch for the one QL-OPR filter, (b) return and insertion loss of the filter.

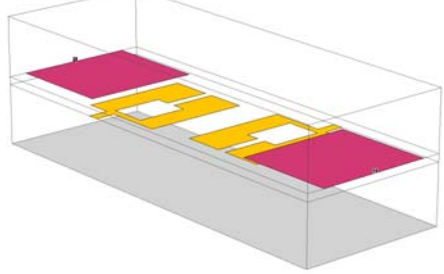


Fig. 3. Structure of the fourth order bandpass filters.

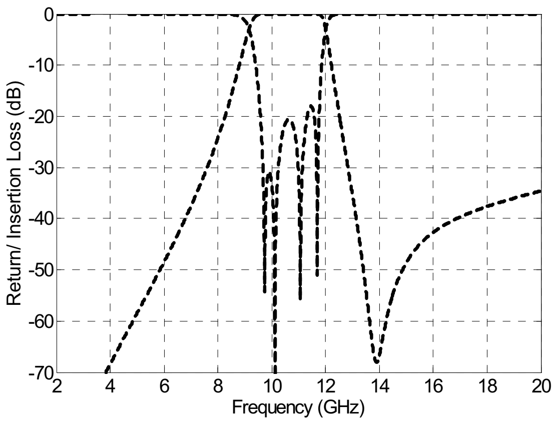


Fig. 4. Simulated return and insertion loss of the forth order bandpass filter.

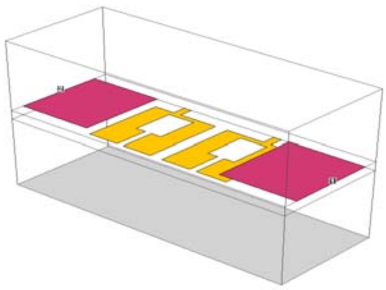


Fig. 5. Fourth order bandpass filter structure.

Fig. 6. Photograph of fourth order bandpass filter structure.

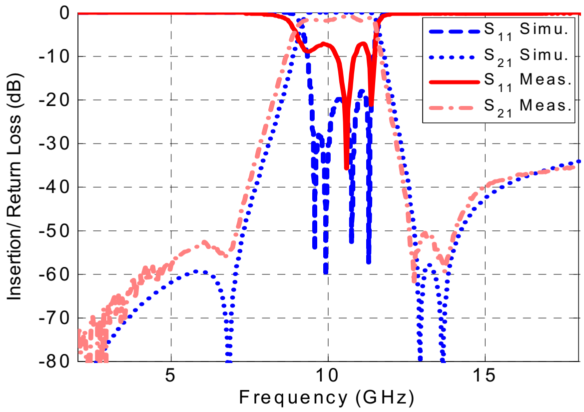


Fig. 7. Measured and simulated return and insertion losses of the fourth order bandpass filter.

ORDER BANDPASS FILTER

As it has been already demonstrated in [5], [8], locating the parallel inductive strips of two resonators on the same side of the substrate, introduces an inductive coupling in parallel to the original capacitive coupling. This causes an additional transmission zero. The same principle has been transferred to our design. An additional transmission zero has been introduced bellow the pass-band. The transmission zero which was introduced in the last structure is splitted now into two zeroes. Fig. 5 shows the simulated filter structure, while Fig. 6 shows a photograph of the measured structure, Fig. 7 the simulated and the measured return and insertion losses of this filter. The general behavior of the insertion loss is well met. A slight frequency shift is due to the increased resonator inductance caused by a grove in the mount clamping the substrate. The maximum return loss is about 7.5 dB. This is probably due to fabrication errors, combined with the relatively high sensitivity of this type of filter. Insertion loss is smaller than 1.8 dB where most of this is caused by the problem in the return loss.

V. DUAL-BAND BANDPASS FILTER

Another application for such kind of resonators is a dual-band bandpass filter. The dual-band bandpass filter can be easily achieved by splitting the resonance frequencies of the QL-OLR into two bands. In other words, by designing two bandpass filters, each operates at a different frequency band. The first one is built by using QL resonators, at the lower frequency band. While the other one is built using OLRs. The frequency band for the latter filter is chosen to be higher than that of the former one. Both filters share the same dimensions and the same resonator size. The two filters can therefore be combined as was discussed before.

With this configuration, a dual-band bandpass filter

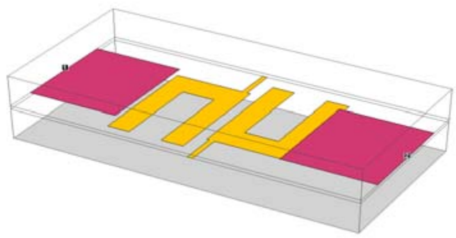


Fig. 8. 3D sketch of a dual-band bandpass filter structure.

has been designed using this kind of resonators. The filter has center frequencies of 3.8GHz and 8.85GHz, with bandwidths of 200MHz and 300 MHz, respectively. The length of filter is 9.65 mm. Fig. 8 shows the 3D sketch of the two QL-OLR filter structure. Since the filter has been designed using two QL-OLRs, each band of the filter contains two return loss-poles. The stop-band attenuation between the two pass-bands, however, So transmission zeroes were needed between the pass-bands.

To improve the attenuation between the pass-bands, a transmission zero can be introduced there by applying additional inductive coupling between the resonators. This can be easily done by flipping one resonator by 180°. By this arrangement the parallel inductive strips are located on one side (see sec. IV). A transmission zero is introduced at about 5.5 GHz. Measured and simulated return and insertion losses are shown in Fig. 9. An excellent agreement between the experimental and the theoretical results has been achieved.

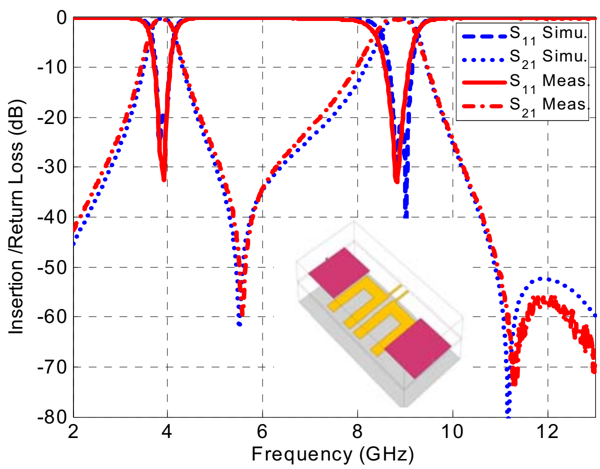


Fig. 9. Simulated and measured insertion and return loss of the dual-band bandpass filter with additional transmission zero, together with 3D sketch of the filter structure.

VI. Conclusion

A quasi-lumped—open-loop resonator (QL-OLR) has been introduced and applied to filter design. Very compact bandpass filters and dual-band bandpass filters have been designed fabricated and tested. Transmission zeroes have been introduced to the filter response by applying additional inductive coupling between the resonators. The QL-OLR has shown to be an excellent resonator for filter applications especially for dual-band bandpass filters. A good agreement between measured and simulated results has been achieved.

Acknowledgement

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