Miniaturized Suspended Stripline Filters for Integration into Extended Circuits

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***Abstract* — A novel concept is presented to incorporate suspended stripline filters into extended circuits. To this end, the filters are designed with integrated transitions to microstrip. The necessary channel for suspended stripline is formed by a grove in the carrier plate and a small cap above the filter; the two parts of the channel are connected by rows of vias. Four example filters are presented to prove the concept – a lowpass filter with two transmission zeroes, an extremely broadband highpass filter, and a narrowband as well as an UWB bandpass filter.**

***Index Terms* — Planar transmission lines, microwave integrated circuits, stripline, suspended stripline, stripline filters, planar microwave filters**

I. Introduction

Suspended stripline (SSL) has proven as an interesting medium for all types of filters. An increased cross section is responsible for reduced ohmic and dielectric losses. A shielding channel (Fig. 1 a) prevents radiation, and, if sufficiently small, the excitation of higher order modes. A large portion of the fields in air results in low dispersion of the SSL. Both transmission line filters, e.g. [1 – 4], as well as quasi-lumped filters, e.g. [5], have been realized in this technique. A potential drawback with respect to integration of such filters into larger circuits, however, is a transmission line medium not readily compatible with standard integrated circuits and the necessity of the shielding channel. Therefore, up to now, such filters were mostly realized as discrete components, making a seamless integration into more complex circuits difficult.

II. SSL Filters for Extended Circuits

This contribution shows a way to overcome such difficulties. For an integration into larger circuits, at least the following conditions must be met:

- Small size of the filters
- No special form of the substrate, no cut-outs
- No extended metal mount
- Microstrip connections of the filters to the external circuit (in the case of microstrip circuits)

To this end, quasi-lumped element filters as described in [5] form the basis of this approach. Secondly, as microstrip is the basis of many MICs, these SSL filters include a compact and integrated transition from SSL to microstrip being the basis of many MICs. Consequently, the necessary SSL channel is required only in the area of a filter itself and can be realized, on the one hand, by a grove under the SSL portion of the filter in the carrier block of the circuit, and on the other hand by fixing a small cap on top of the SSL filter (Fig. 1 b). The conductive connection between carrier block and cap is done by rows of vias along the edges of the filter channel [6]. Using substrates like RO4003, such vias can be fabricated easily using conventional printed circuit board (PCB) technology. In this way, no cutting of the substrate to the special form of a SSL filter is necessary.

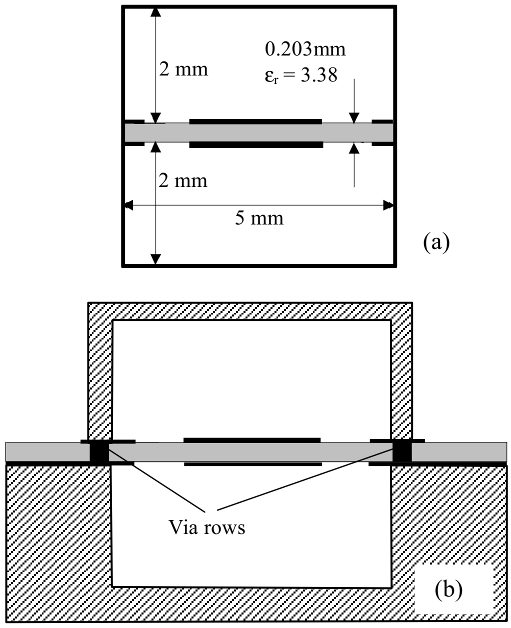

Fig. 1: Cross section of suspended stripline. a) arrangement for full-wave calculation, b) cross section with extended substrate and vias to connect top and bottom portion of the mount.

The design of the filters presented in this work is done as described in detail in [5]. The cross section for the 2½D simulation [7] of the filters is given in Fig. 1a, the cross section for the final realization in Fig. 1b. As the vias need some metal rim around them, small strips of metal are already taken into account in the simulation setup. At the same time, such metal strips reduce the tolerances of the position of the substrate in the mount; if some metallization comes closer to the channel wall, the capacitance is mostly determined by the field towards these strips. A photograph of the test-setup for the filters investigated here is shown in Fig. 2 – the mount itself, the opened mount with a test filter in place, and the closed filter configuration. The mount (top) consists of a carrier with the grove and a cap. In a practical realization, the lengths of grove and cap are adjusted to the actual filter size.

The filters are characterized experimentally using on-wafer probing (with vias to provide ground connections on the top side of the substrate) together with a TRL calibration.

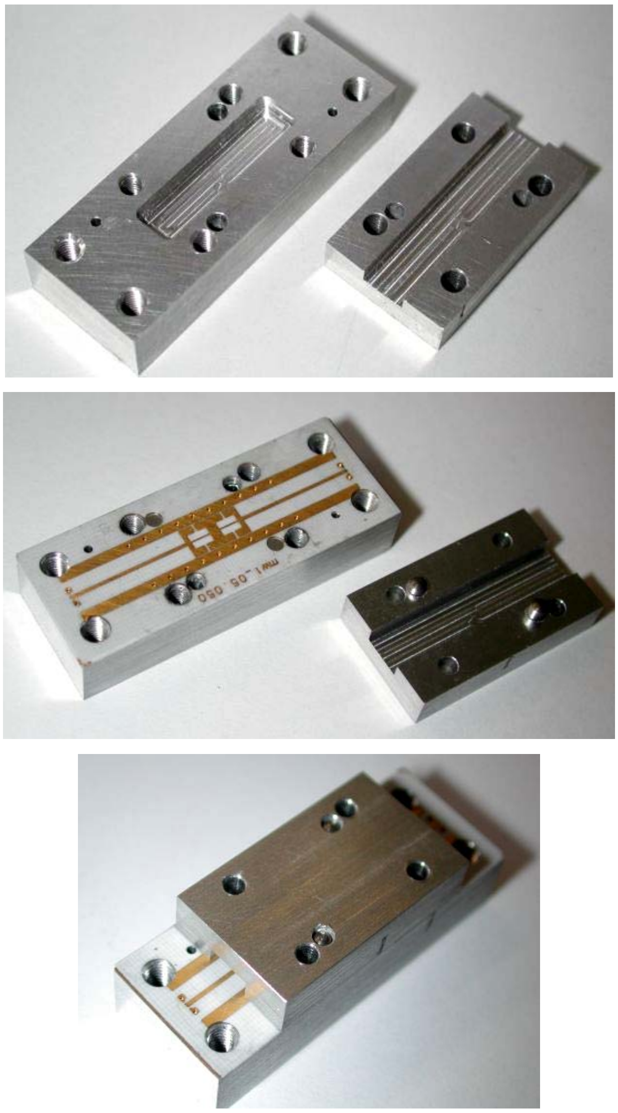

Fig. 2: Photograph of the empty test mount (top) and a lowpass filter on extended substrate in the test mount. Center: opened block with filter, bottom: assembled test setup.

III. FILTER EXAMPLES

The concept as described above was tested at a number of SSL filters; four examples will be shown in the following. The first filter is a five-element lowpass filter. The capacitive elements are reduced in size by placing a ground plane below the respective patches. The patch edges are brought close together, and small metal patches are placed on the backside forming additional coupling capacitances in parallel to the inductive elements (see Fig. 3, top and center), resulting in two transmission zeroes of the lowpass filter [8]. The transmission behavior of this filter is shown in Fig. 3, bottom. This filter is displayed as example filter in the photograph of Fig. 2. Simulation and experiment agree very well; insertion loss is a few tenths of a dB. Filter length is 7.1 mm only, so in a respective circuit, a much shorter grove and cap compared to the test setup can be used.

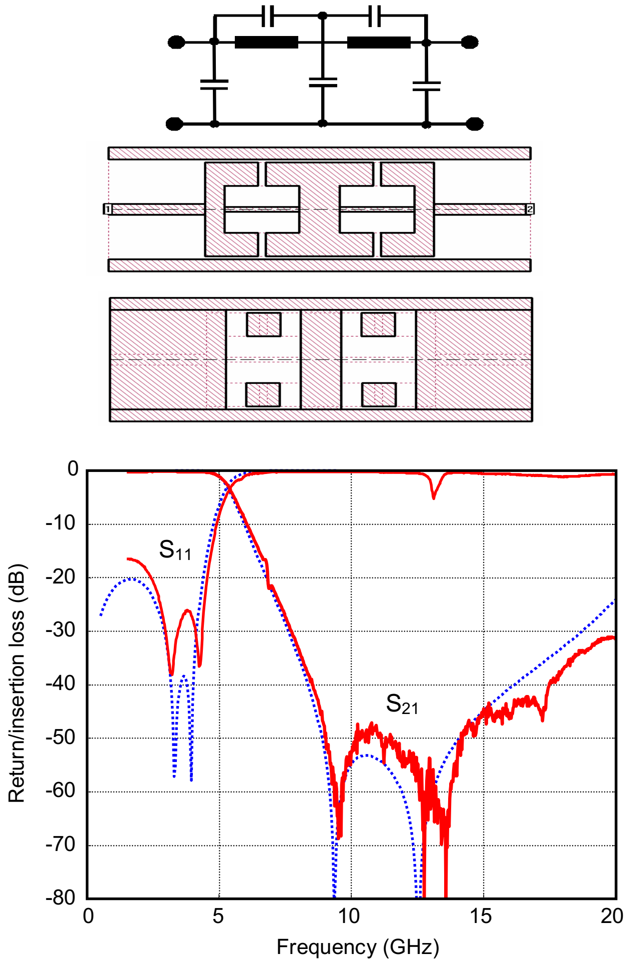

Fig. 3: Equivalent circuit, top and bottom side layout (top and center), and filter characteristics (bottom) of a five element lowpass filter with microstrip input and output lines. Dotted lines: simulation, solid lines: experiment

The second example is a three-resonator bandpass filter. Capacitively coupled shunt resonators consist of a patch and a metal strip to ground (at the side of the channel); some inset increases the inductance. Input and output include transitions to microstrip which, during the design of the filter, have been handled as integral part of the outer inverters. Equivalent circuit and layout of both sides of the substrate, together with simulated and experimental performance are presented in Fig. 4. The length of this filter is 11.4 mm. Passband insertion loss is between 0.4 dB and 0.65 dB.

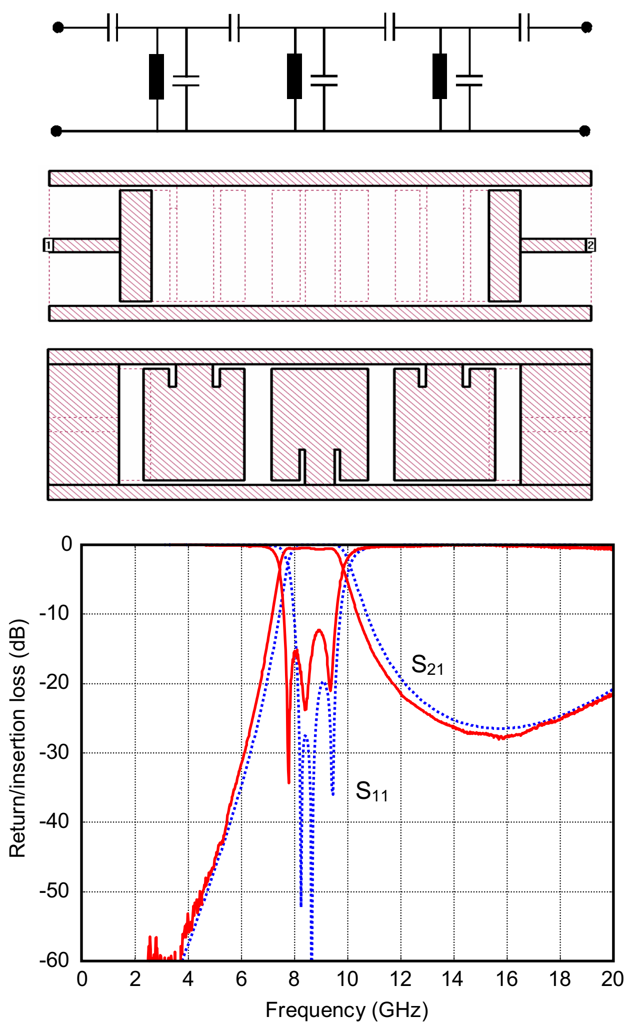

Fig. 4: Equivalent circuit, top and bottom side layout (top and center), and filter characteristics (bottom) of a three-resonator bandpass filter with microstrip input and output lines. Dotted lines: simulation, solid lines: experiment.

Next, a highpass filter with very wide passband from 6 GHz to 20 GHz is presented. By overlapping metallizations, reasonably high coupling capacitances are realized, while the patch capacitances to ground (Fig. 5, top and center), play only a minor role. An approximate equivalent circuit, filter layout and results are displayed in Fig. 5. Filter length is 12.8 mm. Up to 19 GHz, measured return loss is better than -15 dB; insertion loss is a few tenths of a dB.

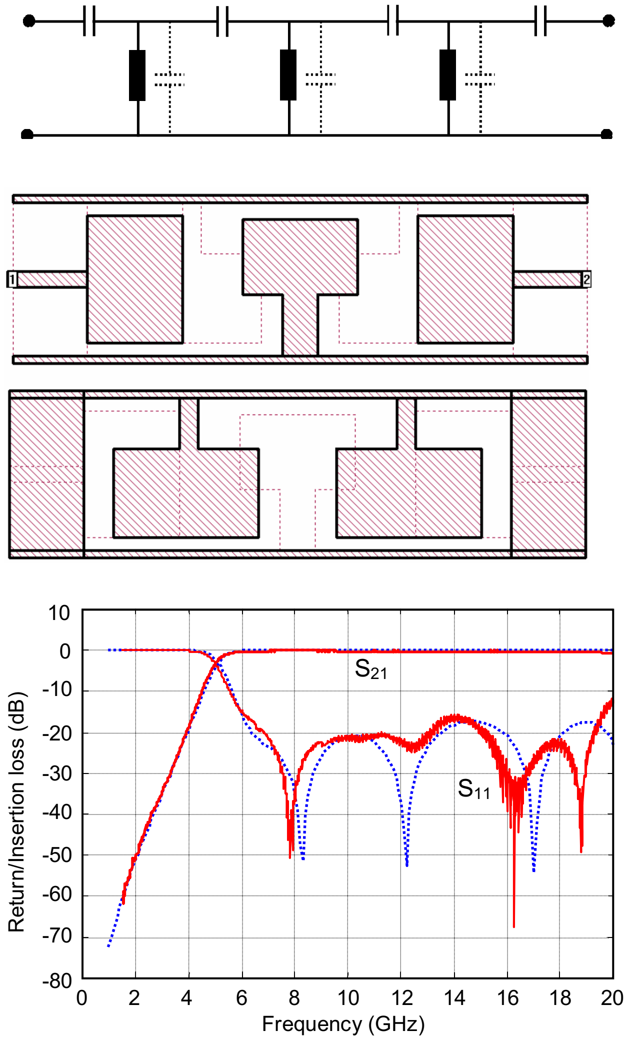

Fig. 5: Equivalent circuit, top and bottom side layout (top and center), and transmission characteristics (bottom) of a five element highpass filter with microstrip input and output lines. Dotted lines: simulation, solid lines: experiment.

Finally, an UWB filter is presented consisting of the combination of a seven-element lowpass filter and a three-element highpass filter. The highpass filter has a similar form like that of the previous example. In addition to such an UWB filter as reported previously [9], this one once again includes transitions to microstrip and thus can easily be integrated into an extended microstrip circuit. A photograph of the filter is shown in Fig. 6; layout of top and bottom side of the substrate as well as return and insertion loss are given in Fig. 7. The length of the filter is 11.6 mm. Passband insertion loss is between 0.2 dB and

0.5 dB. Group delay variation has been measured to maximally 0.15 ns.

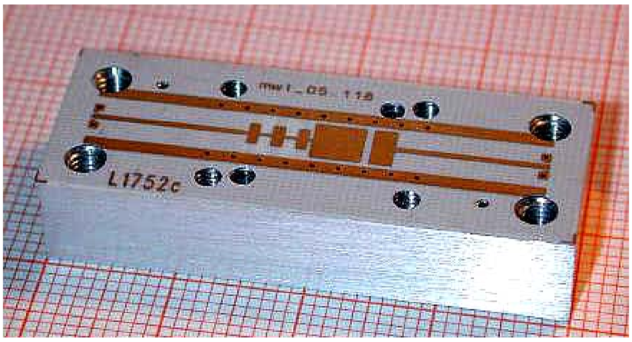

Fig. 6: Photograph of an UWB filter with microstrip input and output lines.

IV. Conclusion

This contribution has demonstrated a method to integrated suspended stripline filters into extended microstrip circuits. In this way, the high degree of integration of microstrip circuits can be combined with the low loss of the SSL filters. Due to the filter realization with quasi-lumped elements, these filters exhibit, at the same time, a reasonably small size. Four different example filters have been presented to prove the concept.

References

[1] J. D. Rhodes: Suspended Substrates provide alternatives to coax. Microwave Syst. News, vol. 9, pp. 134-143, Aug. 1979.

[2] J. D. Rhodes and J. E. Dean: MIC broadband filters and contiguous diplexers. 9th Europ. Microwave Conf. Dig., 1979, pp. 407- 411.

[3] C. I. Mobbs and J. D. Rhodes: A generalized Chebyshev suspended substrate stripline bandpass filter. IEEE Trans. Microwave Theory Tech., vol. MTT-35, pp. 397- 402, May 1983.

[4] J. E. Dean: Suspended substrate stripline filters for ESM applications. IEE Proc., Vol. 132, Pt. F, July 1985, pp. 257 - 266.

[5] W. Menzel, A. Balalem: Quasi-Lumped Suspended Stripline Filters and Diplexers. IEEE Trans. on MTT, vol. MTT-53, Oct. 2005, pp. 3230 - 3237.

[6] G. E. Ponchak, D. Chen, J.-G. Yook, and L. P. B. Katehi: Characterization of Plated Via Hole Fences for Isolation Between Stripline Circuits in LTCC Packages. IEEE MTT-S International Microwave Symposium 1998, Vol. III, pp. 1831-1834.

[7] SONNET, Version 10, Sonnet Software Inc.

[8] W. Menzel, A. Balalem: Compact Suspended Stripline Quasi-Elliptic Low-Pass Filters. German Microwave Conference GeMiC 2005, April 2005, Ulm, Germany, pp. 61 - 64.

[9] W. Menzel, M. S. R. Tito, L. Zhu: Low-Loss Ultra-Wideband (UWB) Filters Using Suspended Stripline. Asia-Pacific Microw. Conf. (APMC), Dec. 2005, Suzhou, China, pp. 2148 - 2151.

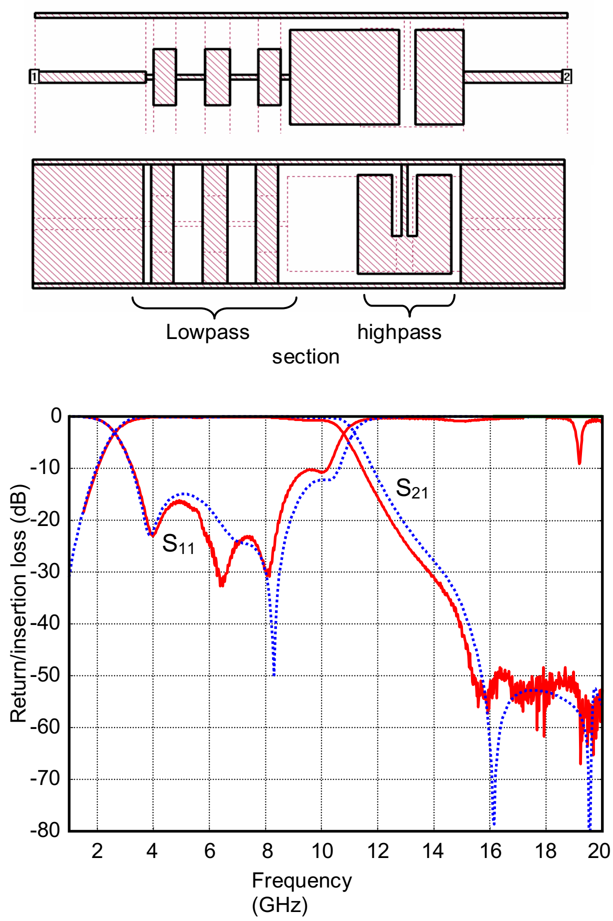

Fig. 7: Top and bottom side layout (top) and filter characteristics (bottom) of a UWB filter with microstrip input and output lines consisting of a combination of lowpass and highpass filters. Dotted lines: simulation, solid lines: experiment.