Quasi-lumped suspended stripline bandstop filters

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Possibilities are investigated for realising compact, quasi-lumped bandstop filters using a suspended stripline transmission-line configuration. Different approaches are considered, and two test filters have been designed, optimised and evaluated experimentally. Good results have been achieved with a chain configuration of four serial shunt resonators and with a novel approach using a hybrid resonator structure.

Introduction: Suspended stripline (SSL) has proven to be an excellent transmission-line system for realising different types of filters, e.g. [1–4]. Compared to microstrip or coplanar line, its larger cross-section results in considerable ohmic and dielectric losses. Furthermore, no radiation occurs owing to the shielding (mount) of the SSL. The possibility of using both sides of the realtively thin substrate gives an increased flexibility in circuit design not as easily available in other planar lines.

A considerable size reduction of SSL filters can be achieved using a quasi-lumped element approach based on very short very low impedance lines for capacitances and very short high impedance lines for inductances as described for different types of filters in [4]. While lowpass, highpass or bandpass filters have been described frequently, only little work is known about bandstop filters [5, 6]. Therefore, this Letter describes novel approaches to realising bandstop filters in an SSL configuration based on general ideas and concepts of [4], but not yet included in previous publications.

Circuit elements for SSL bandstop filters: The general structure of suspended stripline consists of a thin substrate suspended in the centre of a metal channel (Fig. 1). The channel as used throughout this work is typically 5 mm wide, and typically 2 mm of air is provided above and below the substrate. For simplicity of simulation purposes, the channel has a rectangular cross-section as shown in Fig. 1*a*; in the experimental setup, the channel has small grooves at the sides to hold the substrate (Fig. 1*b*). With these small mount dimensions, filters can be easily realised in the 3–15 GHz frequency range. Owing to the small cross-section, effects of metal waveguide modes occur in this configuration above 20 GHz only. For filters at lower or higher frequencies, the structures as demonstrated here can be scaled in size.

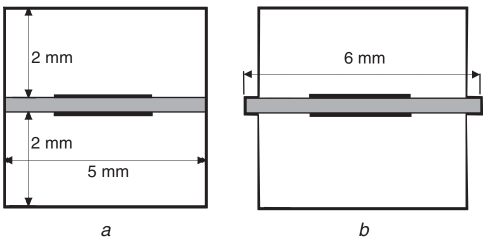

Fig. 1 *Ideal and practical cross-section of suspended stripline as used in these investigations*
a Ideal
b Practical

The general ideas, circuit elements, and the principal design approach for the bandstop filters described here are equivalent to those in [4]. Typical elements required for bandstop filters are parallel resonators connected in series to a transmission-line and series resonators connected to ground. In SSL, these elements can be realised with structures as shown in Figs. 2*a* and *b*; metal parts on opposite sides of the substrate are equivalent to capacitors, narrow lines or an inset in line form inductances. As a first step, a standard filter design is done with ideal capacitors and inductors. A precomputed database for SSL elements is then used to transfer the ideal elements into the respective SSL geometry, followed by a further optimisation step. SSL elements and filter structures are computed and optimised using a commercial simulator [7]. All filters presented in the following have 50 Ω ports and are placed in a mount of 30 mm length. Input and output lines are soldered to SMA connectors. Experimental results are given with respect to the coaxial ports, including the losses of transmission-line lengths between filter and ports and the transitions from SSL to the coaxial measurement system.

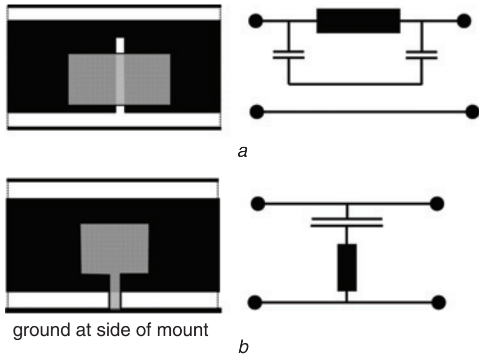

Fig. 2 *View of sections of SSL substrate and respective circuit elements for bandstop filters*
a Parallel resonator in series configuration
b Series resonator in shunt configuration
Light grey and black areas are metallisation structures on back- and front-side of substrate, respectively

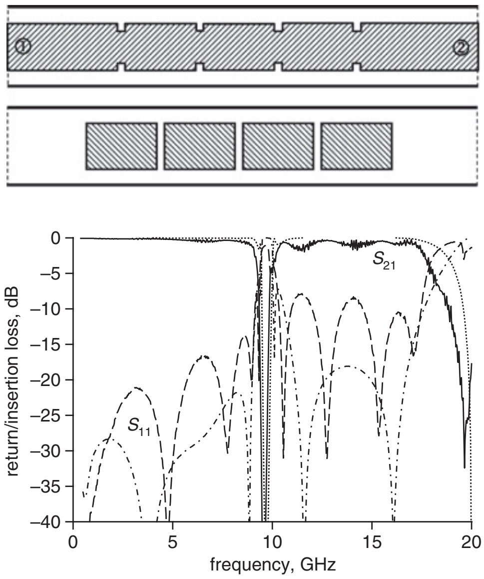

Fig. 3 *Layout (top and bottom side of substrate (top)) and simulated and measured return and insertion loss of chain-type filter (bottom)*
Solid and dashed lines: experiment results; dotted and dash-dotted lines: simulation. Substrate thickness 0.254 mm, $\varepsilon_r = 10.8$

Filter with chain-connected shunt resonators: A bandstop filter with narrow stopband and wide upper passband could be realised using a number of series-connected shunt resonators similar to Fig. 2*a*, separated by sections of transmission lines, as shown in the layout of Fig. 3 (top). In this way, the series resonators to ground with their unfavourable element values can be avoided. This filter approach can be designed for a very narrow and deep stopband, as shown in Fig. 3 (bottom). The upper passband is quite wide, and only the return loss in this frequency range still needs some improvement; possibly, some problem soldering the SMA connectors to the substrate occurred.

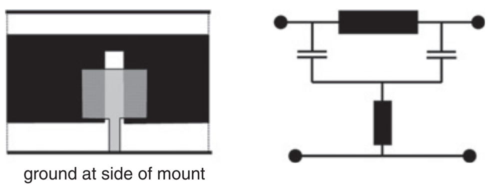

Fig. 4 *Substrate section and equivalent circuit of arrangement with combined shunt and series resonators*
Light grey and black areas are metallisation structures on back- and front-side of substrate, respectively

Filter with combined resonator elements: Looking at the resonator structures in Fig. 2, the idea came up to combine the two resonators as shown in Fig. 4, which illustrates the combined layout structure and the resulting equivalent circuit. Accordingly, this structure itself is already a bandstop filter of second order. In a test filter, two of these novel elements were combined, resulting in the layout as given in Fig. 5. The two patch-strip resonators are arranged in point symmetry. Together with some modification of the patch shape (to bring the resonators closer together) a very small filter size is achieved in this way. In addition, a fine tuning during the optimisation process is possible just modifying the cutout area of the patches. A photograph of this filter with opened mount is shown in Fig. 6.

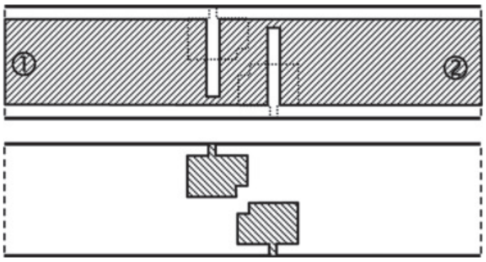

Fig. 5 *Layout on top and bottom side of substrate for novel filter with combined resonators*

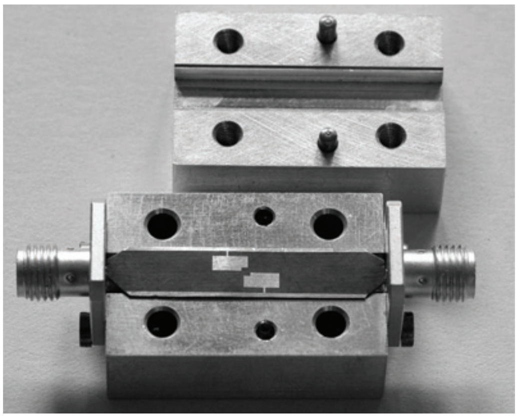

Fig. 6 *Photograph of novel filter with opened mount*

Originally, the passband attenuation was designed for more than 30 dB. Owing to an additional inductance of the thin strips to ground caused by the clamping area for the substrate [4, 8], only a 17 dB passband attenuation resulted experimentally (Fig. 7, solid lines). To check this, a modified configuration was simulated approximating the clamping area using a wider waveguide channel and reducing its width by inserting edge vias at the appropriate positions according to Fig. 2*b*. The resulting return and insertion loss curves are included in Fig. 7 as dotted lines, showing a reasonably good agreement with measurement. A redesign of the filter with improved stopband rejection therefore is possible.

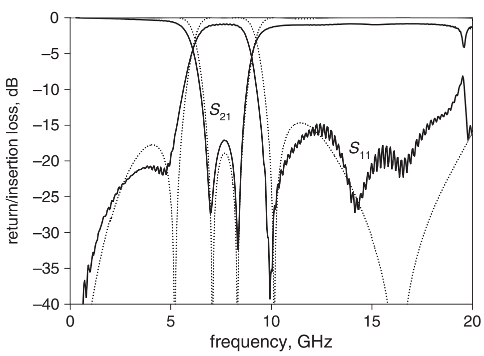

Fig. 7 *Simulated and measured return and insertion loss of filter with combined resonators*

Solid lines: experiment; dotted lines: simulation including actual influence of clamping region. Substrate thickness 0.254 mm, $\varepsilon_r = 2.22$

Conclusions: Different approaches have been shown for SSL bandstop filters, including an arrangement of parallel resonators in a chain configuration, and a filter with a novel structure of combined series and shunt resonators. Both filters give good results, the first one with a narrow, the second one with a wide stopband. A satisfactory agreement between simulation and experiment can be found.

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