COMPACT BANDPASS FILTERS WITH IMPROVED STOP-BAND CHARACTERISTICS USING PLANAR MULTILAYER STRUCTURES

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ABSTRACT

Using multilayer structures, very compact planar bandpass filters can be designed with improved stop-band characteristics taking full advantage of the additional degrees of freedom given by that arrangement.
As examples, a suspended stripline filter with suppression of the first harmonic frequency and a finline filter with improved attenuation close to the pass-band is presented.

1. INTRODUCTION

Planar filters are of great interest for microwave and mm-wave applications, and numerous designs have been presented, e.g. /1/-/3/. Additional degrees of freedom arise using multilayer structures.
In this contribution, a field-theoretical technique based on a spectral domain approach and resonance methods /4/ is used to calculate multilayer discontinuities and to design planar multilayer bandpass filters with improved stop-band characteristics, but maintaining a very compact set-up. Two examples, an X-band suspended stripline filter and a Ka-band finline filter are described.

2. SUSPENDED STRIPLINE FILTER

Suspended stripline is known as a relatively low-loss transmission line medium. The bandpass filter described here is based on the equivalent circuit of capacitively coupled transmission line resonators (Fig. 1). The elements of the filter can be calculated from standard filter designs, e.g. /5/. In this example, the filter is realized using end-coupled suspended stripline resonators on different sides of the substrate. In this way, a wide range of coupling coefficients can be realized suitable even for wide-band filters. The coupling is calculated using the full-wave procedure as described in /4/. The results of a five resonator Chebishev filter are plotted in Fig. 2 without and with slight tuning by screws in the filter mount. The pass-band insertion loss amounts to 0.4 - 0.5 dB.

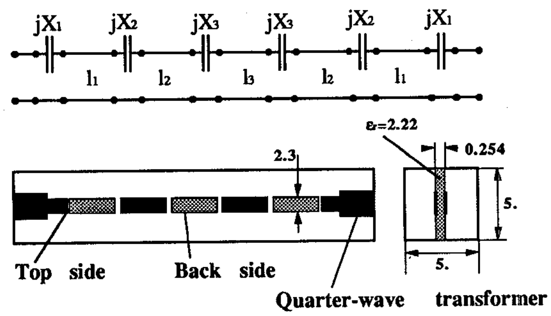

Fig.1: Equivalent circuit and set-up of suspended stripline filter. (All dimensions in mm)

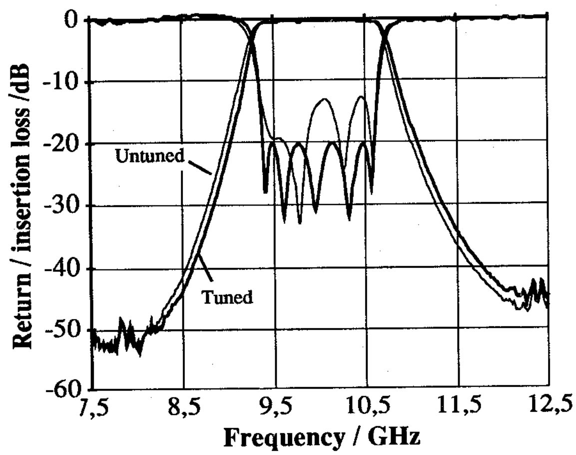

Fig.2: Measured filter characteristics near passband.

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One disadvantage of such end-coupled filters is a further pass-bands already at the first harmonic frequency (Fig. 4, curve a). To overcome this problem, the resonators were modified as shown in Fig. 3. Each resonator now is composed of two parts on different sides of the substrate, overlapping about a quarter wavelength at the center frequency. In this way - together with some matching - the resonator operates well at the desired pass-band frequency, while it has a transmission zero at approximately twice that frequency. Furthermore, the stop-band frequencies of the different resonators can be shifted to some extent against each other to improve the suppression bandwidth at the first harmonic frequency.
The result of a filter designed in such a way is compared with that of a standard design in Fig. 4. At the first harmonic frequency, a rejection of more than 30 dB is achieved. In the desired pass-band, bandwidth is slightly reduced, and insertion loss is increased by only 0.1 dB.

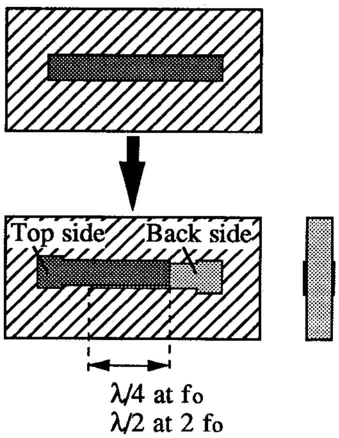

Fig.3: Modified resonator structure

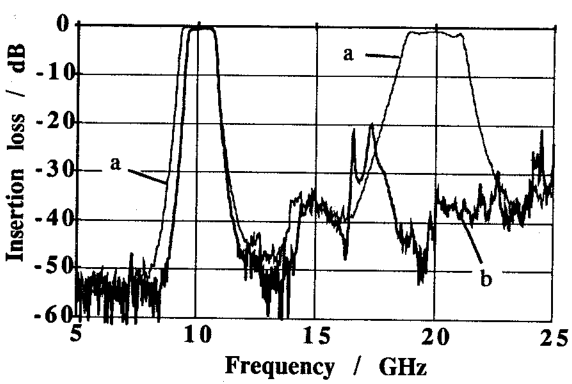

Fig.4: Measured wide band performance of standard (a) and modified (b) suspended substrate filter.

3. FINLINE FILTER

The design of the finline filter is based on the equivalent circuit shown at the top of Fig. 5. In the finline filter set-up, the shunt resonators are realized by microstrip resonators on the opposite side of the substrat (Fig. 5). Starting values for the line lengths of the finline resonators and the required transmission coefficients of the shunt resonators are derived at the centre frequency by standard filter design methods, e.g. /5/. The characteristics of a finline loaded with a shunt resonator, on the other hand, can be calculated according to /4/.

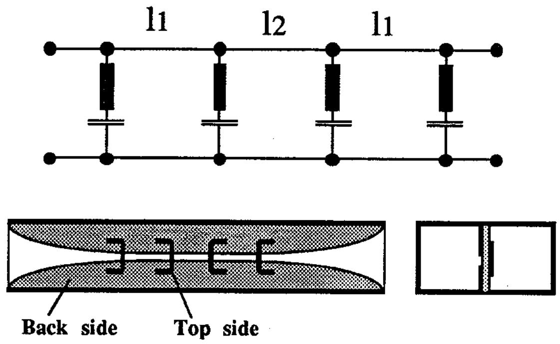

Fig.5: Equivalent circuit and set-up of finline bandpass filter.

In Fig. 6, typical results are plotted as a function of resonator length. Each transmission coefficient value can be obtained with two different microstrip resonator lengths (Fig. 6) with different out-of-band behaviour.
In this way, transmission zeros can be placed near the pass-band, giving an increased steepness at the sides of the filter curve. Additional transmission zeros may be placed further away from the pass-band. Using the exact transmission coefficients of the four shunt resonator arrangements, the filter was redesigned. To avoid coupling of the resonator edges with the waveguide walls (the calculation was done with an increased waveguide height), mitered bends calculated after /6/ were introduced.
The results of such a filter (including some fine tuning) are plotted in Fig. 7. The insertion loss amounts to 2 dB, including 0.5 dB losses due to an excess finline length. At the pass-band edges, an increase of attenuation of up to 20 dB was achieved compared to a standard filter design.

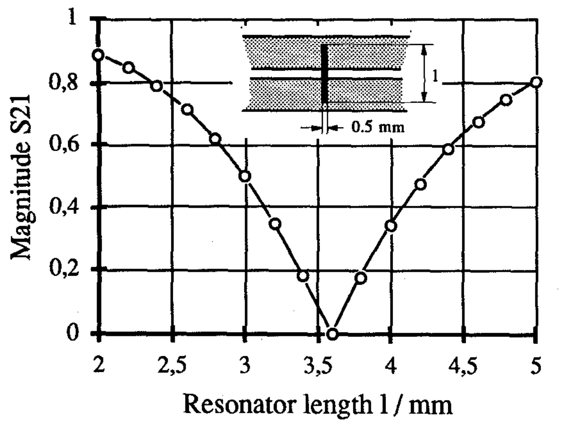

Fig.6: Calculated transmission properties of finline with single resonator. (f=31 GHz, slot width 0.2 mm)

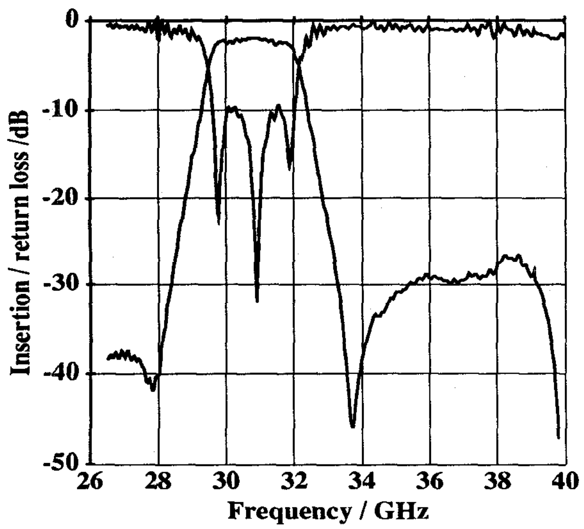

Fig.7: Measured characteristics of finline bandpass filter.

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