Miniaturized Passive Components in Multilayer Technique for Coplanar mm-wave MMICs

Ch. Warns, W. Menzel

University of Ulm, Microwave Techniques, D-89069 Ulm, Germany
Tel.: +49 (0)731 5026351, Fax.: +49 (0)731 5026359
E-mail: warns@mwt.e-technik.uni-ulm.de

Abstract

Very compact passive circuit elements like highpass, lowpass and bandpass filters in multilayer technique for coplanar MMICs are presented. These are realized in a quasi–lumped fashion using short segments of transmission lines, i.e. elevated coplanar lines of high characteristic impedance and low–impedance thin–film microstrip lines.

Kurzfassung

In Mehrlagentechnik lassen sich sehr kompakte passive Strukturen für koplanare MMICs herstellen, wie z.B. Filter. Der Entwurf erfolgt mit Hilfe hochgelegter Koplanarleitungen hoher Leitungsimpedanz und Dünnfilm–Mikrostreifenleitungen niedriger Leitungsimpedanz in quasi–konzentrierter Bauweise.

1 Introduction

MMICs contain a variety of transmission lines and quasi–lumped elements realized with line segments. In order to make passive structures smaller, a wide range of characteristic impedance values of the transmission lines would be advantageous. However this is difficult to obtain in a coplanar–only design.
Through the use of additional dielectric and conductor layers on top of the coplanar structures such elements can be fabricated, while keeping the advantages of coplanar designs, like less backside processing and no via holes. The realization of coplanar cross and tee structures including underpass connections between both sides of the ground plane is also simplified by this technique.
The substrate used in the examples shown here is high–resistivity silicon, and the metalization is made of evaporated or plated gold. As a dielectric, photosensitive polyimide is used which can be spun on and patterned like a conventional resist [1].

2 Transmission Lines

The cross–sections of the types of lines used in the structures presented here are shown in **Fig.1**.

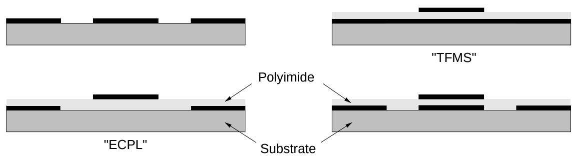

Fig. 1: Cross–sections of coplanar, elevated coplanar (ECPL), thin–film microstrip (TFMS), and broadside coupled coplanar lines

Coplanar transmission lines with elevated center conductor (ECPL) are used for inductive elements where a high characteristic impedance is needed. Low impedance thin–film microstrip lines (TFMS) are used for parallel capacitive elements. Series capacitors in the coplanar line are realized by overlapping center conductors in both metalization layers. The parameters of these line types (ε_{eff}, loss, characteristic impedance) are computed using a mode matching technique [2] which includes losses due to the finite conductivity of the metalization. Typical characteristic impedance values are $2 \ldots 10\,\Omega$ for the TFMS and $100 \ldots 120\,\Omega$ for the ECPL segments [1]. The line parameters as well as S–parameters of discontinuities are imported into a circuit simulator for fast computation and optimization of the designs.

3 Filters

Using very short sections of high– and low–impedance transmission lines, coming close to the size of lumped elements, a variety of filter structures can be realized. Typical line lengths of the quasi–lumped elements in the examples presented here range from 100 µm to 500 µm.
The dark (red) translucent patterns in the pictures **Fig.2**, **Fig.4** and **Fig.6** are the polyimide dielectric structures, through which the substrate and the lower metalization can be seen.

3.1 Highpass Filter

This structure uses series–C and shunt–L elements. Insertion loss is only 0.3 dB at 30 GHz (**Fig.3**). The width of the center conductor in the coplanar tee has been reduced to minimize parasitic parallel capacitances to ground.

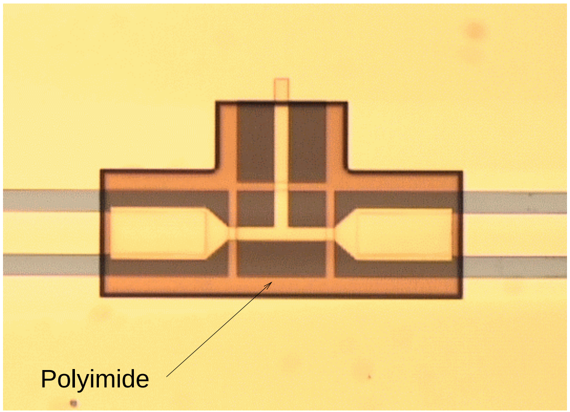

Fig. 2: Layout of third order highpass filter

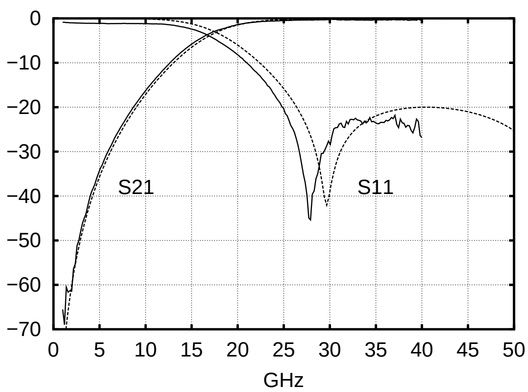

Fig. 3: Third order highpass filter, measured values are shown with solid lines, computed values with dashed lines

3.2 Lowpass Filter

This structure uses alternating shunt–C and series–L elements (stepped impedance design), with a meander layout for reduced length. Insertion loss is about 2.0 dB at 20 GHz (**Fig.5**).

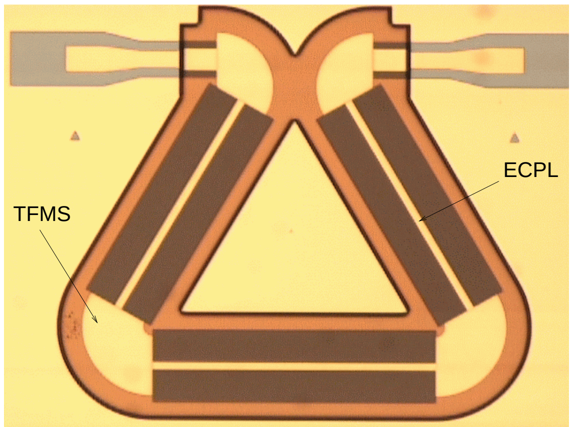

Fig. 4: Meander layout of seventh order lowpass filter

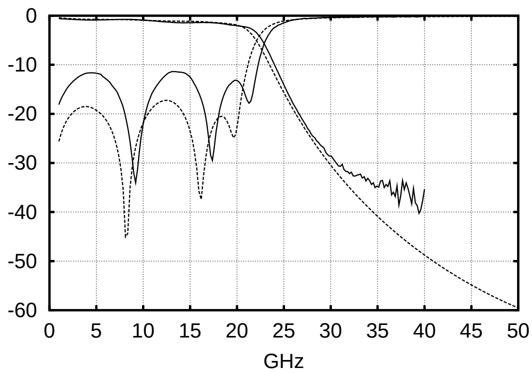

Fig. 5: Lowpass filter of seventh order, measured values are shown with solid lines, computed values with dashed lines

The modelling of the curved TFMS segments is only approximate in the circuit simulator, leading to the difference in the measured vs. computed S–parameters.

3.3 Bandpass Filter

This structure is made of two parallel LC–resonators coupled by series capacitors. The advantages of this structure over $\lambda/2$– or $\lambda/4$– resonator filters are reduced size (450×150 µm for one resonator, compared to a guided wavelength of 4 mm in the coplanar line at 30 GHz) and the absence of higher–order passbands.

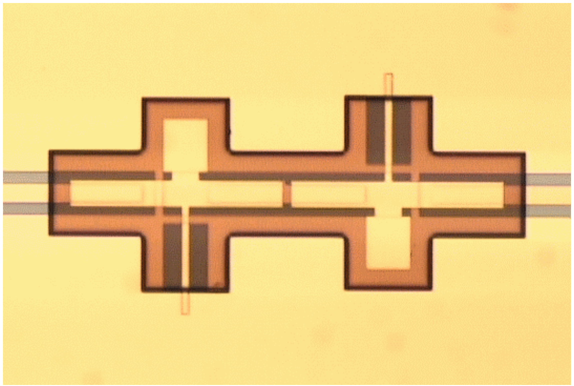

Fig. 6: Bandpass filter using two capacitively coupled LC–resonators

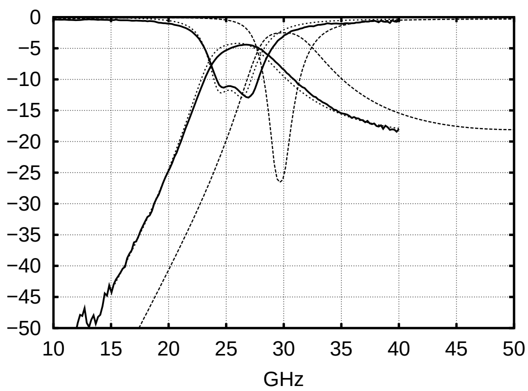

Fig. 7: LC–Bandpass filter with measured (solid line) and simulated characteristics (dashed line: circuit simulator, dotted line: field simulator)

The measured performance of this filter (solid line in **Fig.7**) does not match the expected one (dashed line), because of an unfavorable layout of the parallel capacitors. Ground plane currents provide an additional coupling and a shift in frequency in this structure, which can not be modelled with independent transmission line segments, but only with a field simulator (dotted line in Fig.7). With a better placement of the capacitors, an improvement is expected as shown by the simulation.
For comparison, a bandpass filter with a $\lambda/2$–resonator design has been realized using two end–coupled coplanar resonators overlapping each other and the feedlines (**Fig.8**). The multilayer technique allows for a simple fabrication of this structure, with a required overlapping length of ca. 150 µm, but it is too large for integration in MMICs.

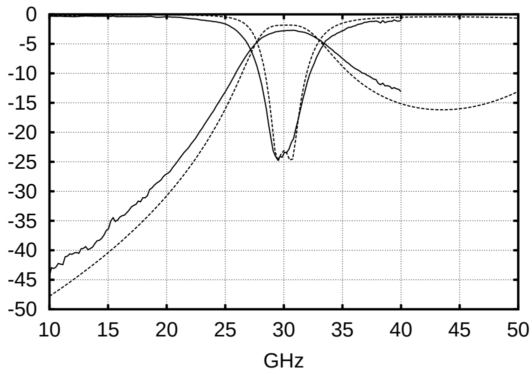

Fig. 8: Bandpass filter with two coupled $\lambda/2$ resonators

4 Conclusion

Additional dielectric and conductor layers on top of a coplanar design allow for a wider range of characteristic impedances of transmission lines, and for easy realization of series and shunt capacitors and inductors, leading to compact quasi–lumped structures. A number of passive structures like filters realized in this technique have been shown, which can be fabricated with about the same processing effort than for a conventional airbridge process.

References

[1] C. Warns, W. Menzel, H. Schumacher, Transmission Lines and Passive Elements for Multilayer Coplanar Circuits on Silicon, IEEE Microwave Theory and Techniques, Vol.46, No.5, p.616 (May 1998)

[2] R. Schmidt, P. Russer, Modelling of Cascaded Coplanar Discontinuities by the Mode–Matching Approach, IEEE Microwave Theory and Techniques, Vol.43 No.12, p.2910 (Dec. 1995)