DESIGN OF PASSIVE COPLANAR FILTERS IN V-BAND

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ABSTRACT

Two passive coplanar filters on GaAs for V-band applications have been designed in parallel. The first one shows a Chebyshev characteristic and utilises coplanar waveguide segments, while the second one is a Cauer filter, where the elements of the prototype filter parameters have directly been transformed into coplanar lumped elements.

INTRODUCTION

Both filters have to fulfil the same specifications. The stop-band range is 48-52 GHz ($|S_{12}|<-25$ dB) and the pass-band 62-66 GHz ($|S_{12}|>-3$ dB). This can be obtained with an order of 11 in the case of the Chebyshev filter and with an order of 6 for the Cauer type. The simulation background for the prediction of the filter response is a very accurate Finite Difference method. A comparison of calculated and measured data will manifest the validity of the models. The great advantage of these investigations is, that a comprehensive CAD tool for filter design is available and that a drastic circuit size reduction can be obtained, if the coplanar lumped elements are utilised (factor: 1:8).

STATE-OF-THE-ART FILTER DESIGN

The design and synthesis of planar filters occupies scientists and engineers since the microstrip technology has been established in the labs around the world. Different methods utilise elementary resonator structures like stubs, edge- and end-coupled lines, ring resonators, active parts for loss compensation and tuning as well as lumped elements (SMD's, planar inductors or MIM capacitors). The most widespread problem is to find accurate models, especially if the desired frequencies are in the GHz bands. This problem

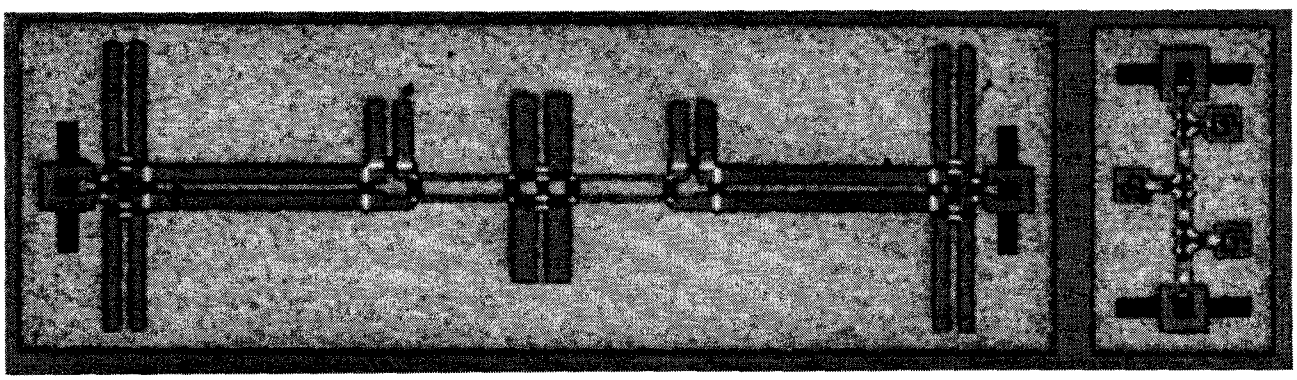

Fig. 1. CPW Chebyshev and Cauer filter on GaAs

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increases, if the circuit designer wants to exploit the advantages of the coplanar technology: low dispersion, compact circuit size, one-side processing, no via holes, etc. The reason is, that for a long time accurate models for the most important elements were not available in commercial CAD tools. Therefore, most publications utilise electromagnetic field solvers or simplified models with empirical equations. Such a proceeding has been extensively used in [9]: equivalent circuit parameters have been extracted from a spectral domain simulation with *em* from Sonnet Software. The filters are build up with coupled line structures and stub resonators in applications up to 24 GHz. Further interesting investigations on coupling structures in multilayer and CPW technology have been published by Menzel et. al. in [10]. Again, spectral domain and the mode matching method have been utilised to predict these compact filters in a frequency range up to 15 GHz. In [8] the authors complain the absence of a coplanar element library. Therefore they used empirical expressions and investigated end-coupled line and ring resonator filters for 23 GHz and 6.3 GHz applications on hybrid technology experimentally. All these examples show clearly, that the design of coplanar filters needs extensive investigations, which oftenley are too expensive for commercial applications.

CPW FILTER DESIGN

In contrast to the given examples, this paper reports on a very conventional method of filter synthesis, which will lead very fast to a sufficient filter characteristic by utilising commercially available design tools. This CAD package is Libra from HP-EEsof extended by a library, which analyses in total 26 coplanar elements using a 2 and 3 dimensional quasi-static Finite Difference formulation. The basic method has been described by Naghed et. al. in [1, 2]. The linked and verified library has been presented in [3] for the first time. With these CPW elements, filters have been analysed by utilising lumped elements up to 25 GHz in [4], multi-coupled asymmetrical lines up to 18 GHz in [5] and even active filters for 2 GHz applications in [6].

The synthesis in this paper starts with the specifications of the prototype filter with a stopband at 48 GHz to 52 GHz and an out-of-band insertion loss of >35dB and a passband between 62 GHz and

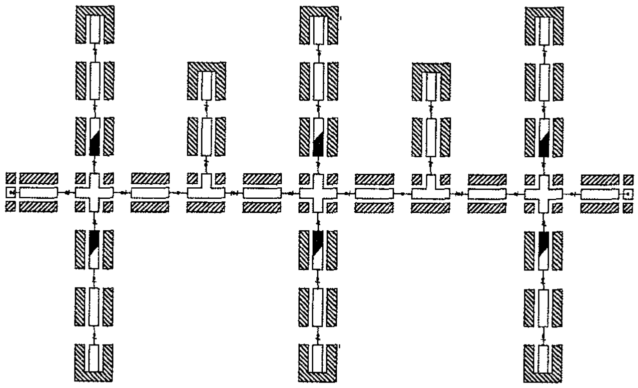

Fig. 2. Schematic circuit of Chebyshev filter, build up with CPW elements

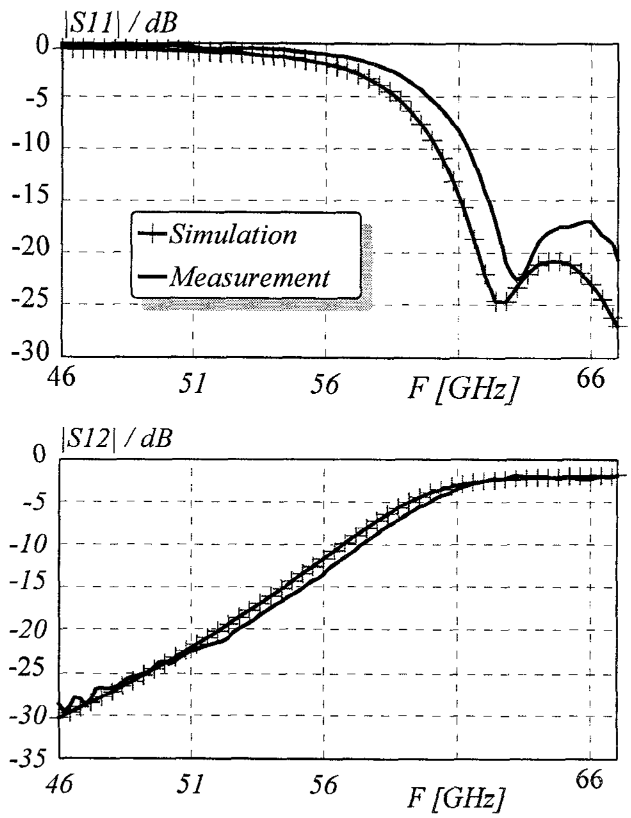

Fig. 3. Measured and simulated Chebyshev filter

66 GHz with an insertion loss of <0.0988 dB. The filter parameters were taken from the tables in [7]. Two filters have been developed in parallel. One, which consists of line-stub elements and another, which utilises lumped elements in the coplanar technique. For the first case, the filter specs can be fulfilled, if a Chebyshev type with the order of n=11 is used. The second prototype filter has been chosen to be a Cauer filter with the order of n=6. In the second step the coefficients of the prototype filters have been transformed into coplanar components. For the Chebyshev type a line filter has been determined, where each line is described by its characteristic impedance and the electrical length. A simple optimisation routine determines the corresponding coplanar lines. The final circuit is built up in the schematic editor of Libra. This is illustrated in figure 2. The filter characteristic changes again, if coplanar T- and cross-junctions will be used instead of ideal nodes. The best performance of the coplanar filter has been achieved after the optimisation of $|S_{12}|_{CPW\text{-}filter}$ to $|S_{12}|_{prototype\text{-}filter}$. It is evident, that the coplanar filter can not reach the same performance as the prototype filter. Nevertheless, the transmission in the passband is better than -3dB and lower than −25dB in the stopband. But more important is the good agreement between the predicted and the measured filter, which is shown in figure 3 for the Chebyshev filter.

If all the design steps have been proceeded, the circuit is ready for the layout synchronisation in the Academy window of Libra. The IMST software supports the GaAs foundry of Daimler Benz in Ulm, where the filters have been fabricated. All relevant foundry parameters like layer numbering, under- and oversize parameters are included into the drawing language (AEL) of Libra. This tool ensures minimum drawing effort during the design-phase of coplanar circuits.

The other filter, which has been fabricated, is the Cauer filter with an order of n=6. In contrast to the Chebyshev filter, the elements of the prototype filter have been directly transformed into coplanar MIM capacitors and spiral inductors. The layout of this structure is illustrated in figure 1, too. The big advantage of this filter is its small size (8 times smaller than the Chebyshev filter) and the enhanced performance (predicted). Nevertheless, the measured filter behaves not as expected. It was found, that the inaccuracy of the simulation was in the model of the spiral inductor. The coplanar inductor model with 1.5 turns is valid up to 40GHz. To overcome this problem, a modified Cauer filter with inductive lines instead of spiral inductors has been designed. The layout is shown in figure 4. The size is slightly greater than that of the first design. The authors expect to demonstrate this filter on the symposium, since the produced wafer will be available in the first quarter of 1996. Therefore, only the simulated characteristic in comparison with the prototype can be presented here (figure 4).

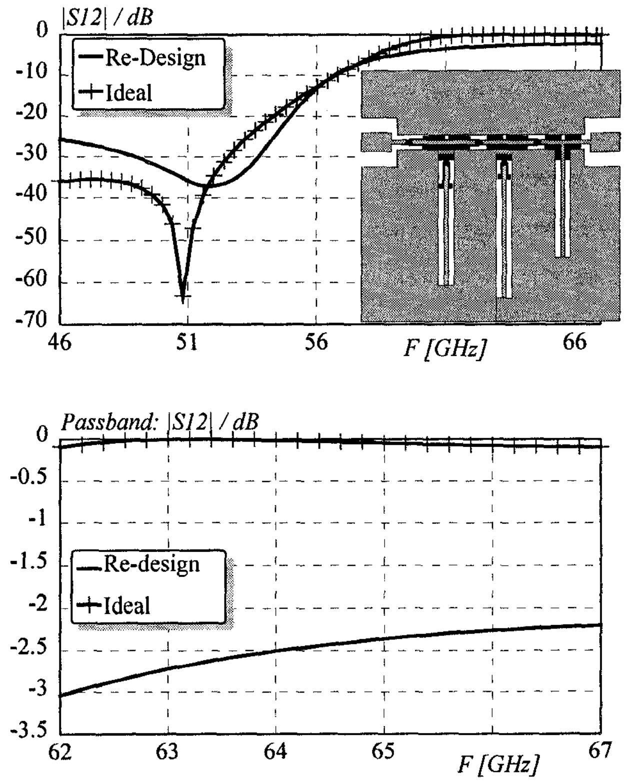

Fig. 4. Predicted characteristic of the redesigned Cauer filter in comparison with the prototype filter

CONCLUSION

A method has been presented, which allows a fast and accurate design of passive filters in coplanar line technology. The parameters for the prototype filters have been taken from standard literature, while the optimization has been made with a common available CAD software. Additional libraries for the analysis and the automatic design synchronization have been integrated into this program to enable the design of coplanar circuits. This has been demonstrated with the examples of two passive coplanar filters.

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