INVESTIGATION OF COUPLING STRUCTURES FOR COPLANAR BANDPASS FILTERS

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ABSTRACT

Single side metallization is one of the big advantages of coplanar line (CPW) circuits. On the other hand, coupling in one plane only may lead to difficulties designing end or side coupled bandpass filters due to rather weak or multi-mode coupling of the filter resonators. A possible alternative is the introduction of two metallization layers separated by an additional dielectric sheet. In this paper, a number of possible coupling structures for bandpass filters based on standard CPW as well as on multilayer structures are investigated and compared, including some novel coupling arrangements.

INTRODUCTION

Coplanar waveguide has gained wide interest, as it does not require vias and substrate thinning for MMICs. While a number of standard circuit elements can easily be realized in this technique, a severe drawback is given by the rather weak coupling of transmission line segments in one metallization plane only, limiting, for example, the design of bandpass filters with sufficiently large bandwidth or low loss. In this contribution, a detailed investigation is done on coupling elements for coplanar line bandpass filters. This includes standard structures, including a new side coupled arrangement, as well as a number of coupling elements based on multilayer circuits.

Due to the nature of these coupling structures, full-wave methods have to be used for characterization. In this work, spectral domain /1/ and mode matching techniques /2/ were used. Based on these methods, realizable coupling coefficients (s-parameters) of these structures as well as a number of examples for realized filters are given. The filter designs are based on an equivalent circuit of transmission line resonators coupled by shunt inductances or series capacitances. The coupling structure dimensions were chosen to equal the absolute value of the s-parameters of the respective shunt inductance or series capacitance at center frequency of the filter. The transmission line lengths then are corrected for the desired phase angle conditions /1/. All filter results are given without any tuning effort.

STANDARD CPW STRUCTURES

Fig. 1 shows a number of coupling sections using standard coplanar transmission line. Versions a and b provide only a very weak coupling, allowing narrowband filters only with rather high losses, partly due to radiation /3/-/5/. Therefore, some designs have been realized using high temperature superconductors.

An example for a filter based on inductive coupling is given in Fig. 2 a and b. For technologically realizable structures, coupling coefficients of inductive coupling is limited to 6...8 dB (Fig. 2 a). The high electromagnetic fields in the filter resonators, due to the weak coupling, result in high losses and degraded passband edges (Fig. 2 b).

The design of better filters based on side coupling according to Fig. 1 c is possible /6/, although problems in the design result from the excitation of the slot mode in the transition; so basically, the structure of Fig. 1 c has to be dealt with as a fourport.

A new type of coupling is proposed in Fig. 1 d, where, due to the symmetry, the slot mode is not excited. With an overlapping of the lines of $\lambda/4$, higher coupling values can be realized (Fig. 3 a) where the maximum coupling still can be slightly increased. A filter based on such elements was built, and the results are shown in Fig. 3 b.

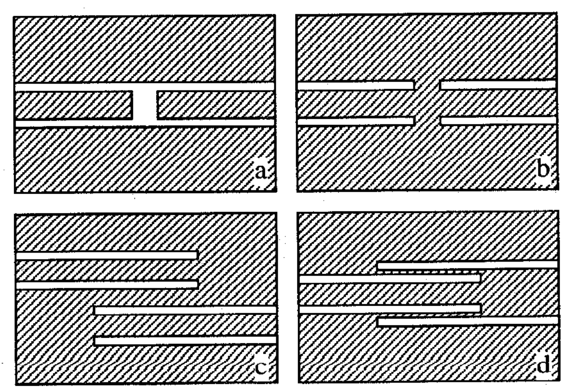

Fig. 1: Metallization pattern of coupling elements in standard CPW technology

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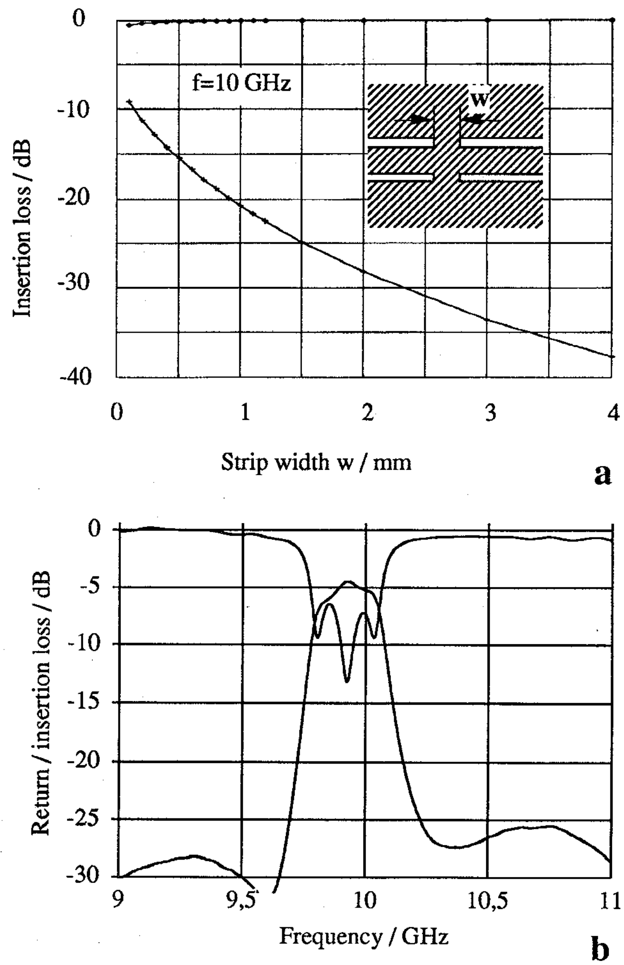

Fig. 2: Insertion loss for inductively coupled CPW lines (Fig. 1 b) as a function of inductive strip width (a) and example for a three resonator filter in this technique (b). (ε_r=11, substrate thickness 0.635 mm).

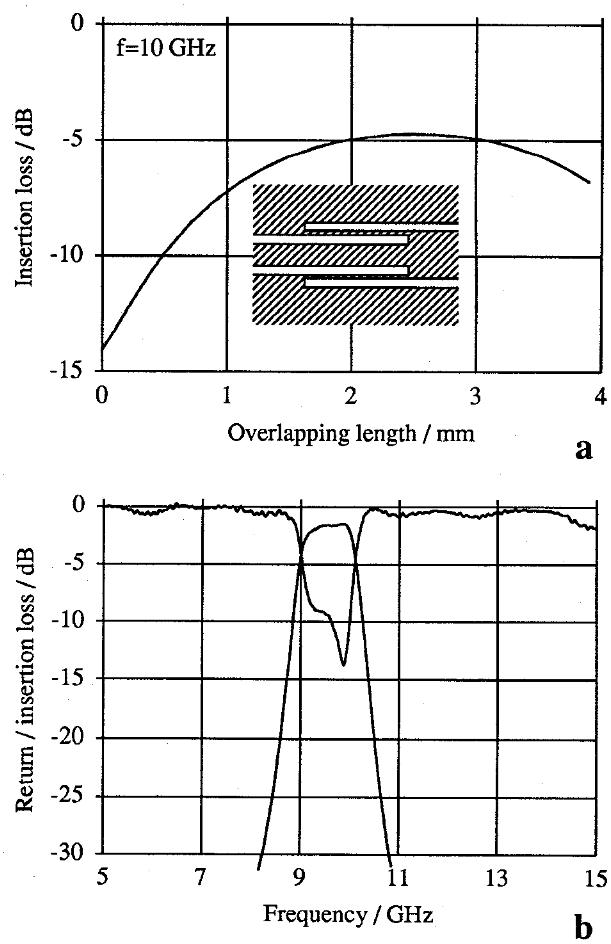

Fig. 3: Insertion loss for symmetrical side coupled CPW lines (Fig. 1 d) as a function of overlapping length (a) and example for a three resonator filter in this technique (b). (ε_r=11, substrate thickness 0.635 mm).

MULTILAYER CPW STRUCTURES

Even stronger coupling can be realized introducing a second layer of dielectric and a second metallization plane (/7/, /8/, Fig. 4 a; the lower substrate can be omitted, too). Broadside coupling as shown in Figs. 4 b-d can achieve very strong coupling, allowing the design of wideband filters. Structures like these may be fabricated by bonding another (thin) substrate onto the base substrate, or by depositing polyimide or silicon nitride on CPW MMICs /8/, or by simply using both sides of a single (hybrid) substrate. Figs. 4 b and c lead to similar results; coupling performance and filter examples are given in Figs. 5 and 6. The transition of Fig. 4 d, on the other hand, has proven to be less suitable for filter applications, as its transmission behaviour is strongly dependent on the overlapping length (Fig. 7) and, consequently, on frequency. Furthermore, the resulting structure for tight coupling can be very long compared to other elements.

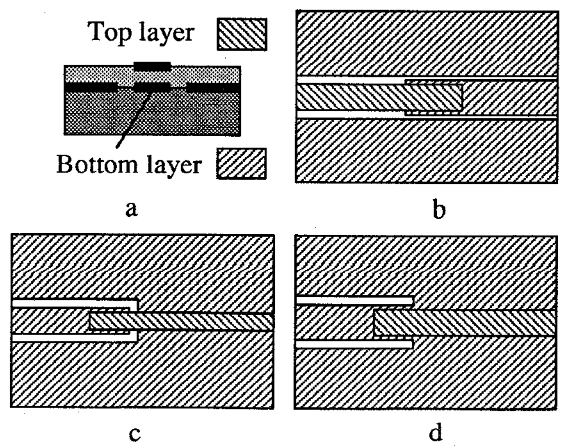

Fig. 4: Cross section (a) and metallization pattern of coupling elements in multilayer CPW technology

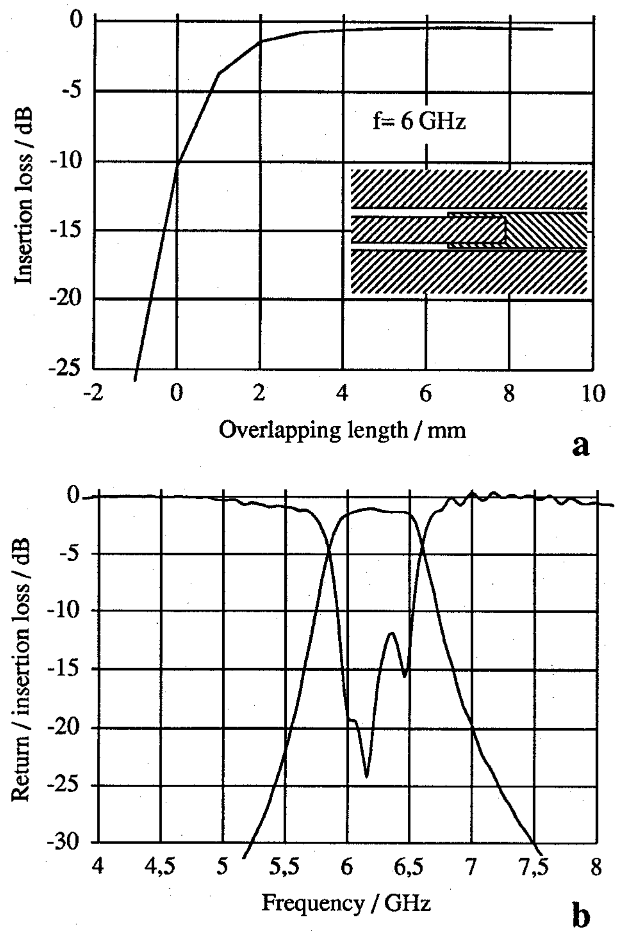

Fig. 5: Insertion loss for double layer broadside coupled CPW lines (Fig. 4 b) as a function of overlapping length (a) and example for a three resonator filter in this technique (b). (ε_{r1}=11, substrate thickness h_1 =0.635 mm, ε_{r2}=2.22, substrate thickness h_2=0.127 mm).

CONCLUSION

A number of coupling structures and filter results for both standard and multilayer coplanar transmission lines have been presented. As most promising structure for standard CPW filters, the symmetrically side coupled CPW has proven. Rather strong coupling for wideband filters, however, probably can only be achieved using multilayer CPW circuits.

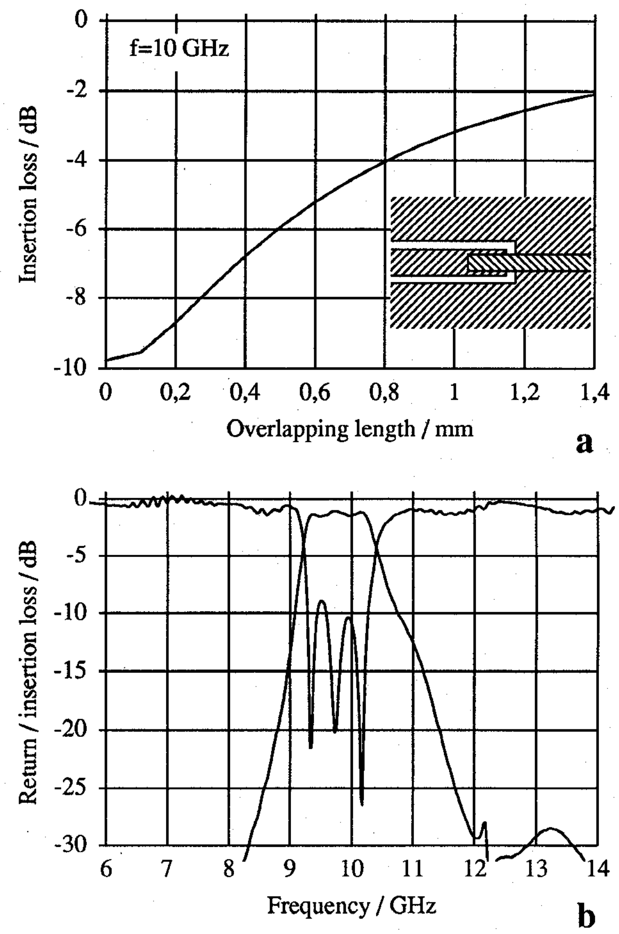

Fig. 6: Insertion loss for a CPW-microstrip transition (Fig. 4 c) as a function of overlapping length (a) and example for a three resonator filter in this technique (b). (ε_r=11, substrate thickness h =0.635 mm)

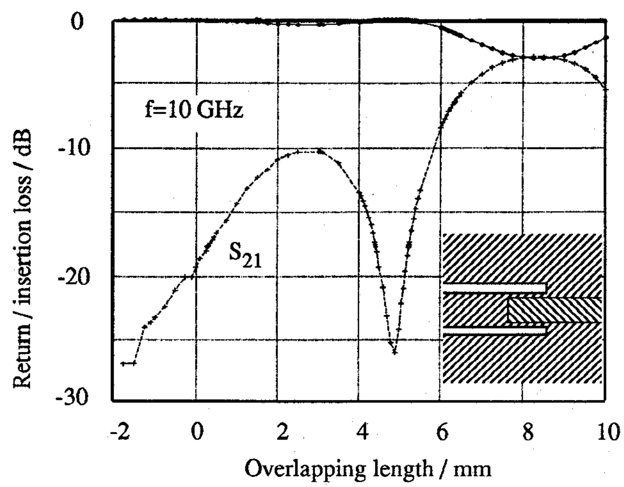

Fig. 7: Insertion loss for a CPW-microstrip transition (Fig. 4 d) as a function of overlapping length (ε_r=11, substrate thickness h =0.635 mm).

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