Copyright © 1995 IEEE

Reprinted from
IEEE MTT-S International Microwave Symposium 1995

This material is posted here with permission of the IEEE. Such permission of the IEEE does not in any way imply IEEE endorsement of any of Universität Ulm's products or services. Internal or personal use of this material is permitted. However, permission to reprint/republish this material for advertising or promotional purposes or for creating new collective works for resale or redistribution must be obtained from the IEEE by writing to pubs-permissions@ieee.org.

By choosing to view this document, you agree to all provisions of the copyright laws protecting it.

INVESTIGATION OF COUPLING STRUCTURES FOR COPLANAR BANDPASS FILTERS

Wolfgang Menzel, Wolfgang Schwab, Georg Strauss

University of Ulm, Microwave Techniques, D-89069 Ulm, Germany

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

TH
3F

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). ($\epsilon_r=11$, 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. 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). ($\epsilon_r=11$, substrate thickness 0.635 mm).

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). ($\epsilon_{r1}=11$, substrate thickness $h_1=0.635$ mm, $\epsilon_{r2}=2.22$, 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). ($\epsilon_r=11$, substrate thickness $h=0.635$ mm)

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

REFERENCES

- /1/ Schwab, W.; Menzel, W.: On the design of planar microwave components using multilayer structures. *IEEE Trans. on MTT-40* (1992), 67-72.
- /2/ Bögelsack, F.; Wolff, I.: Full-wave analysis of multiport microstrip discontinuities using a superposition principle and mode-matching technique. *Int. Journal of Numerical Modelling. Electronic Networks, Devices and Fields*, J. Wiley & Sons, vol. 3 (1990), 259-268.
- /3/ Williams, D.F.; Schwarz, S.E.: Design and performance of coplanar waveguide bandpass filters. *IEEE Trans. on MTT-31* (1983), 558-566.
- /4/ Everard, J.K.A.; Cheng, K.K.M.: High performance direct coupled bandpass filters on coplanar waveguide. *IEEE Trans. on MTT-41* (1993), 1568-1573.
- /5/ Swanson, D.G.; Forse, R.J.: An HTS end coupled CPW filter at 35 GHz. *IEEE Intern. Microw. Symp. MTT-S 1994*, San Diego, 199-202.
- /6/ Weigel, R. et al.: Narrow-band YBCO superconducting parallel-coupled CPW bandpass filters at 10 GHz. *IEEE Intern. Microw. Symp. MTT-S 1993*, Atlanta, 1285-1288.
- /7/ Schwab, W.; Menzel, W.: Multilayer planar structures and their application to micro- and mm-wave components. *PIERS 1994*, Noordwijk, The Netherlands, Abstract Digest p. 260.
- /8/ Menzel, W. et al.: Compact multilayer filter structures for coplanar MMICs. *IEEE Microw. and Guided Wave Letters*, Dec. 1992, 497-498.