PRINTED-CIRCUIT REALIZATION OF A TAPPED COMBLINE BANDPASS FILTER

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Abstract

The design of a tapped combline bandpass filter realized by planar or quasi-planar commensurate length transmission lines is presented. The design procedure takes into account the composite effects of multiple quasi-TEM modes, couplings between non-adjacent microstrips, and cover height. An 8-to-12 GHz bandpass prototype is built and tested. Its performance agrees favorably with the theoretical result.

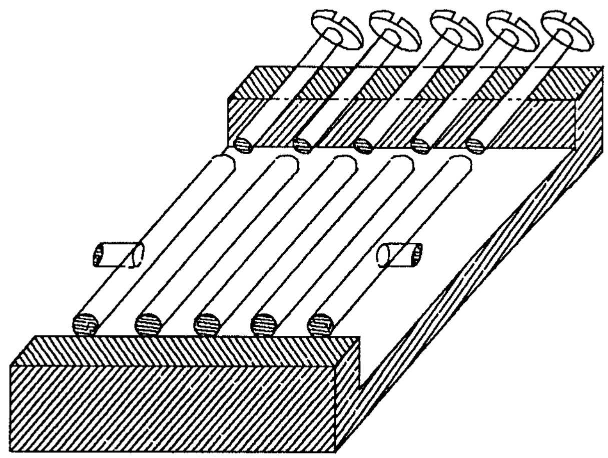

Fig.1 Conventional Tapped Combline Filter (Simplified Drawing)

I. Introduction

Combline filter is one of the widely used bandpass filters employed in many communication systems. It features many useful properties [1] and becomes even more compact and easy to fabricate when using tapped-line arrangement at input/ output [2]. A simplified drawing of Fig.1 shows a variant of combline filter in a tapped fashion. To design the filter shown in Fig.1, one needs to make certain approximations due to the fact that the exact theory of combline filter synthesis only works for commensurate length TEM-mode elements[3]. Here, however, the exact equivalent circuit for the tapped combline [4] and the lumped elements in Fig.1 are not commensurate.

As the frequency of operation increases, say beyond 20 GHz, the conventional combline filter becomes too small to machine it. An alternative filter configuration shown in Fig.2 is the use of microstrip lines integrated on a printed-circuit board. This seems to solve the difficulity since typical photolithography technique can easily handle the tolerance requirement needed for making the filter. However, another problem surfaces. This is the existence of multiple quasi-TEM modes associated with the parallel microstrip lines used in Fig.2. Thus a more elaborate approach to

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tackle this problem is needed.

Section II describes an iterative design procedure to determine the structural parameters of Fig.2. Section III reports the theoretical and measured performances for a particular example.

II. A Synthesis Procedure Based on Field-Theoretic Approach

Planar or quasi-planar microstrip realization of a combline filter can be in the form of Fig.2. Here, the capacitors can be tuning screws, chip or beam-lead capacitors. For a quick turn-around design cycle, a prototype will be presented based on Fig.2 using beam-lead capacitors.

From the exact filter synthesis, the component values corresponding to Fig.1-(a) of [3] are determined. We add one redundent unit element at each end of the two-port equivalent circuit. Then we apply the Norton transformation and Kuroda's identities to obtain the circuit equivalent considering the tapped-line by an approximation that converts the component values at quarter-wave length into those at different electrical lengths restricted by the graph transformation method described in [4]. The approximation changes the prescribed frequency response of the filter slightly.

What follows is the field-theoretic approach which incorporates the work of Itoh [5] based on the quasi-TEM assumption. A variational N by N capacitance matrix is obtained for the N parallel transmission lines. The eigenvalues of the capacitance matrix correspond to N quasi-TEM modes of propagation. Given the target equivalent circuit provided previously, or more precisely the inductance matrix of the equivalent circuit, we optimize an error function in the least-square error sense by adjusting the values of W1, S1, W2, S2,... in Fig.2 until the solutions converge. Notice that many possible solutions exist. We select one with the most relaxed dimensions to work with.

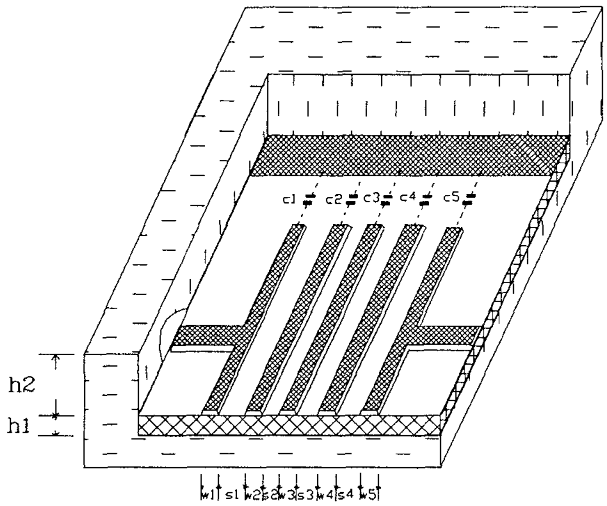

Fig.2 Coplanar Microstrips Combline Filter With Tapped-Lline Input/Output
The electric length of the inductive resonators is 45° at 10 GHz. Duroid 5880 substrate is employed.
unit:mil
h1=10,h2=130,w1=w5=8,w2=w4=16,w3=18,
S1=S4=3,S2=S3=4
unit:pF
c1=c5=0.2002,c2=c4=0.2366,c3=0.2531

III. Prototype Example:Microstrip Realization of a Combline Filter

A five-resonator combline bandpass filter realized by microstrips shown in Fig.2 will be presented. The filter has passband of 8 GHz (f_L) to 12 GHz (f_U) with 0.1dB ripple. A Chebyshev approximate function is employed.

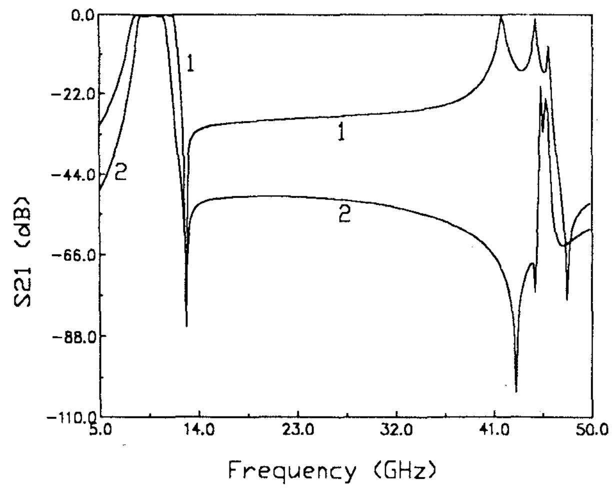

Fig.3 Simulation Results for Two Different Cover Heights. Line 1:h2=130 mils, Line 2:h2=8 mils

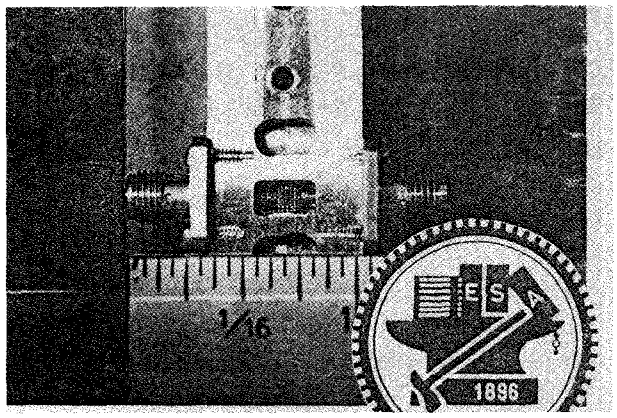

Fig.4 Photograph of the Prototype Combline Filter

(a) Equalization of The Propagation Constants of The Multiple Quasi-TEM Modes Associated With Fig.2

One interesting feature provided by the design procedure is that the filter's stopband performance can be improved if we may equalize the phase velocities of the quasi-TEM modes while keeping the non-adjacent couplings of the microstrips minimal. Fig.3 illustrates the effect of cover height for another set of the optimized structural parameters. As the cover height is reduced from 130 mils to 8 mils, the stopband performance is improved by 20dB compared to the previous case. This can be crucial for certain system application.

(b) Experimental Result

A prototype based on the structural parameters of Fig.2 is built. Fig.4 is the photograph of the filter. Fig.5 compares the

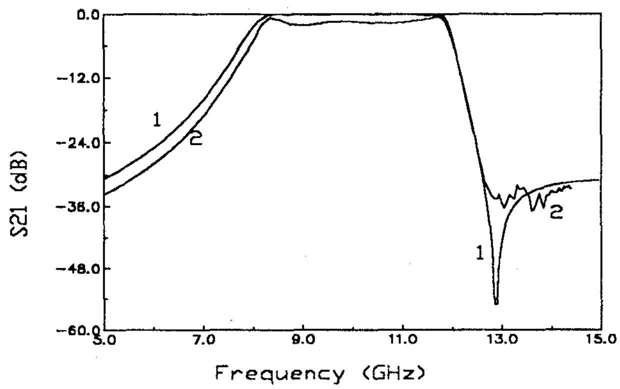

Fig.5 Simulated and Measured Responses
Line 1:Simulated Response
Line 2:Measured Response

measured and theoretical performances. The effects of the launchers of Fig.4 are included in the measured response of Fig.5. Nevertheless the theoretical and measured results agree favorably for both passband and stopband. The prototype seems to experience some losses due to skin-effect associated with the microstrips, dielectric loss tangent, launchers, losses associated with the beam-lead capacitors (SC9100-01 from Alpha)of finite Q. It is not clear where the loss comes from exactly. We expect, however, the loss will be significantly reduced by implementing a printed-circuit combline filter with high-Q MIM(metal-insulator-metal) capacitors.

IV. Conclusion

A design technique for realizing a planar or quasi-planar combline bandpass filter is described. The composite effects of the multiple quasi-TEM modes and non-adjacent couplings are investigated throughly. It is found that the reduction in cover height can equalize the phase velocities of the various quasi-TEM modes and results in performance improvement in the stopband. The amount of improvement can be as high as 20 dB for the particular case under investigation.

References

[1] G. L. Matthaei, "Combline band-pass filters of narrow or moderate bandwidth, " Microwave Journal, Vol.6, pp.82-91, Aug. 1963.
[2] S. Wong, "Microstrip tapped-line filter design, " IEEE Trans. Microwave Theory and Tech., Vol.MTT-27, No.1, pp.44-50, Jan. 1979.
[3] R. J. Wenzel, "Synthesis of combline and capacitively loaded interdigital band-pass filters of arbitrary bandwidth, " IEEE Trans. Microwave Theory and Tech., Vol.MTT-19, No.8, pp.678-686, Aug. 1971.
[4] E. G. Cristal, "Tapped-line coupled transmission lines with applications to interdigital and combline filter, " IEEE Trans. Microwave Theory and Tech., Vol.MTT-23, pp.1007-1012, Dec. 1975.
[5] T. Itoh and A. S. Hebert, "A generalized spectral domain analysis for coupled suspended microstrip lines with tuning septums, "IEEE Trans. Microwave Theory and Tech., Vol.MTT-26, No.10, pp.820-826, Oct. 1978.