MULTI-SECTION INHOMOGENEOUS COUPLED-LINE FILTERS WITH LARGE MODE-VELOCITY RATIOS†

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ABSTRACT

Design data for single-section inhomogeneous coupled-line filters based on large even/odd mode-velocity ratios has recently been published [1]. The purpose of this paper is to extend those results to multi-section inhomogeneous coupled-line filters with large mode-velocity ratios. Both experimental and theoretical data are presented. The rather complex pole-zero structure of single-section inhomogeneous coupled-line filters permits great flexibility in designing multi-section filters. Very sharp transitions between pass- and stop-bands are possible as well as large stopband to passband width ratios.

INTRODUCTION

Coupled-line structures are utilized extensively as building blocks for filters, directional couplers and other important transmission line devices [2,3]. Odd and even propagation mode components [4] are commonly used in analyzing coupled lines. The phase velocities associated with the odd and even modes are equal for lines in a homogeneous medium but unequal for lines in an inhomogeneous medium. Coupled lines in microstrip [5] and suspended-substrate stripline [6] yield small deviations from equal velocities (velocity ratios typically less than 1.2). Much larger deviations can be obtained with inhomogeneous broadside-coupled strips [7] (velocity ratios of 3.0 and even higher). Velocity ratios of roughly 2 to 1 and higher permit the realization of novel filter properties such as a single inhomogeneous coupled-line filter section with an equiripple, 3-peak stopband and passband response [1].

Design data for single-section inhomogeneous lines has recently been published [1]. The purpose of this paper is to extend those results to multi-section inhomogeneous coupled-line filters with large mode-velocity ratios. The rather complex pole-zero structure of single-section inhomogeneous coupled-line filters permits great flexibility in designing multi-section filters. Very sharp pass-to-stopband transitions are possible as well as large stopband to passband width ratios.

DESIGN TECHNIQUES

Cascade, parallel and combination cascade-parallel realization have been investigated. Two different techniques have been utilized in the design procedure, the first is based on ABCD parameters and data on pole-zero locations of the type given for single-section inhomogeneous coupled-line filters by Allen [1], while the second is based on scattering parameters. Both procedures have been implemented with the aid of a digital computer. Currently, the design is carried out at a remote terminal via an interactive procedure. Included in the computer implementation is a versatile and computationally efficient program for analyzing essentially arbitrary combinations of distributed and/or lumped-constant n-ports (most efficient for $n \leq 4$). This program has enabled the investigation of some unusual combinations of homogeneous with inhomogeneous coupled-line sections that appear promising for such tasks as realizing very broad stop bands with high minimum attenuation with a few simple sections.

EXPERIMENTAL AND CALCULATED RESULTS

Two multi-section inhomogeneous coupled-line filters have been fabricated and tested. Several other filters are currently being fabricated and data on them will be available for the conference paper. The experimental circuits are of the inhomogeneous broadside-coupled strip type [7]. Figure 2 presents experimental and calculated data for a cascade of two inhomogeneous C-sections. The characteristic multi-pole stopband response of this class of inhomogeneous filters [1] is clearly in evidence. Data on filters of several types with 3 and 5 sections will also be available for the conference.

Figure 2 shows calculated response of a pair of 3-section complementary filters with 1db crossover point. The dotted-line response is for a 3-section inhomogeneous comb-line filter, and the solid-line response that of a 3-section inhomogeneous C-section filter. The theoretical minimum attenuation in the stopband of each of these 3-section filters is greater than 100 db. Figure 3 is a cascade of 3 inhomogeneous C-sections to form a low-pass filter. The 0.5 db passband is about 800 MHz wide. The transition from pass to stopband is steep and the minimum stopband attenuation is greater than 40 db from 1 GHz to 5 GHz.

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CONCLUSION

Multi-section inhomogeneous coupled-line filters have been designed, fabricated and tested. The rather complex multi-pole/multi-zero response of single-section inhomogeneous coupled-line filters [1] can be used to considerable advantage in constructing physically simple multi-section filters with excellent characteristics including steep pass-to-stopband transitions and wide stopband to passband ratios. Additional experimental data on 3 and 5 section filters as well as details on the design technique and computer implementation will be presented at the conference.

REFERENCES

1. J. L. Allen, "Inhomogeneous Coupled-Line Filters with Large Mode-Velocity Ratios", IEEE MTT-22 (12), December, 1974.
2. Microwave Filters Using Parallel Coupled Lines, edited by Leo Young, ARTECH House, Inc.
3. Parallel Coupled Lines and Directional Couplers, edited by Leo Young, ARTECH House, Inc.
4. J. Reed and G. J. Wheeler, "A Method of Analysis of Symmetrical Four-Port Networks", I.R.E. MTT-4, pp. 246-252, October, 1956.
5. T. G. Bryant and J. A. Weiss, "Parameters of Microstrip Transmission Lines and of Coupled Pairs of Microstrip Lines", IEEE MTT-16, pp. 1021-1027, December, 1968.
6. H. E. Brenner, "Use a Computer to Design Suspended Substrate IC's", Microwaves, pp. 38-45, September, 1968.
7. J. L. Allen and M. F. Estes, "Broadside-Coupled Strips in a Layered Dielectric", IEEE MTT-19, pp. 662-669, October, 1972.

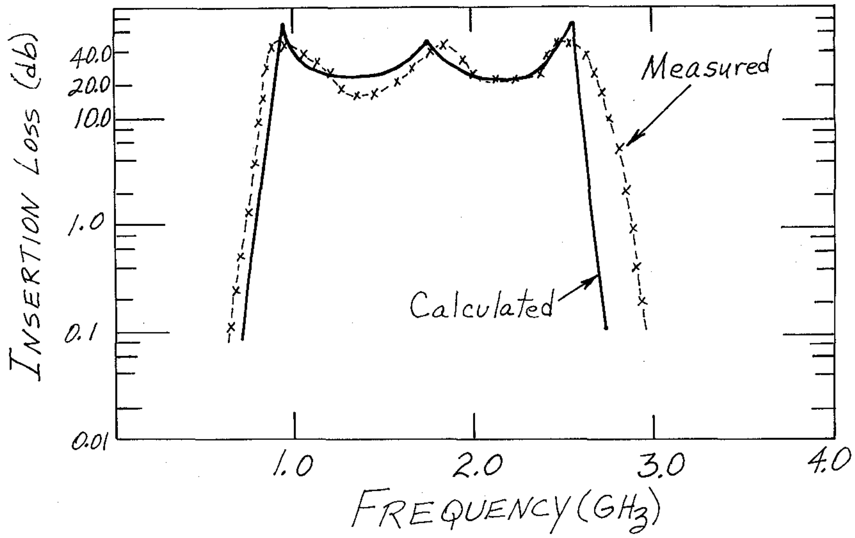

Figure 1. Comparison of measured and theoretical response for 2 cascade inhomogeneous C-sections, each with $v_e = 2.26 \times 10^{10}$ cm/sec, $v_o = 1.13 \times 10^{10}$ cm/sec, $\ell = 3.23$ cm, $Z_{oe} = 94$ ohm $Z_{oo} = 11$ ohm.

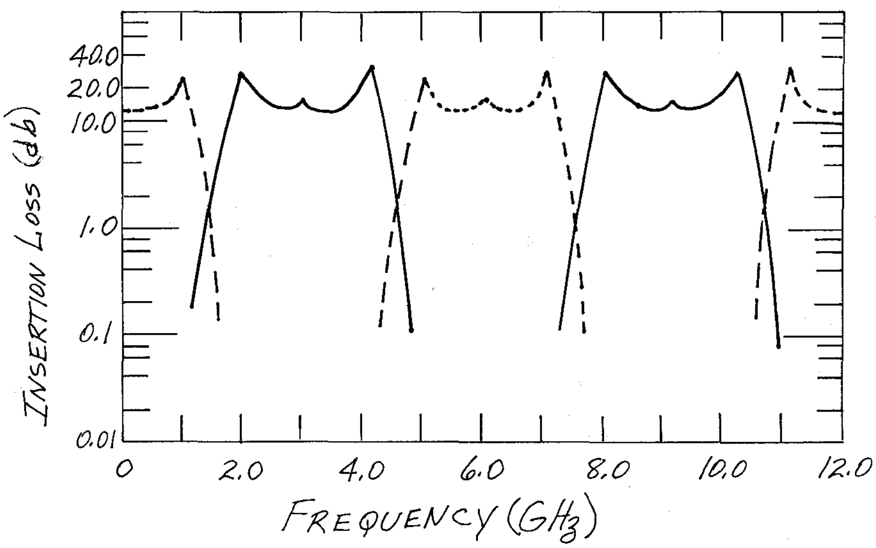

Figure 2. Calculated response of a pair of complementary filters. The dotted-curve response is a 3-section inhomogeneous comb-line filter. The solid-curve response is a 3-section inhomogeneous C-section filter. In each filter $v_{e1} = v_{e2} = v_{e3} =$ 2.26 x 10 cm/sec; $v_{o1} = v_{o2} = v_{o3} =$ 1.13 x 10 cm/sec; $Z_{oe1} = Z_{oe2} = Z_{oe3} = 67.1$ ohm; $Z_{oo1} = Z_{oo2} = Z_{oo3} = 22.4$ ohm; $\ell_1 = \ell_2 = \ell_3 = 1.875$ cm.

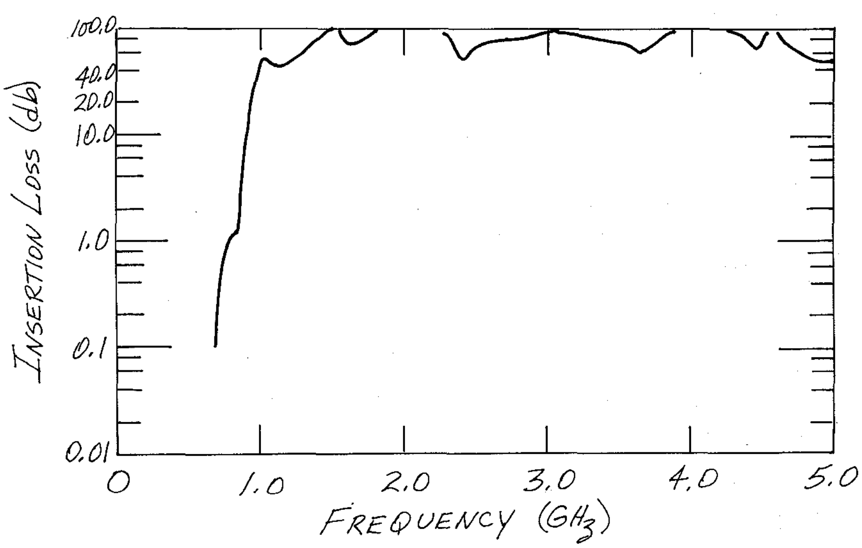

Figure 3. Response of 3-section C-section inhomogeneous coupled line filter. $\ell_1 = \ell_3 = 1.875$ cm, $\ell_2 = 3.75$ cm, $Z_{oe} = 67.1$ ohm in each section, $Z_{oo} = 22.4$ ohm in each section, $v_e = 2.28 \times 10^{10}$ cm/sec, $v_o = 1.14 \times 10^{10}$ cm/sec in each section.