DESIGN OF HAIRPIN-LINE AND HYBRID HAIRPIN-PARALLEL-COUPLED-LINE FILTERS*

E.G. Cristal** and S. Frankel†

Hairpin-line filters are compact structures particularly suited for microstrip and TEM printed circuit realizations. Two types of hairpin-line filters are described in this paper. They are shown in Figs. 1(a) and (b). The image impedance and propagation constant for the infinite periodic hairpin-line has been given previously.[1] Equivalent circuits for several periodically-terminated lines, including the hairpin line were discussed by one of the authors at the recently-concluded IEEE sixth region conference.[2] However, for finite length hairpin-line filters, neither exact or approximate design equations, nor equivalent circuits have been reported. The exact equivalent circuits for the filters of Figs. 1(a) and (b) have been rigorously derived and are presented in Figs. 2(a) and (b), respectively, for the most important case in which coupling beyond nearest neighbors is negligible. These circuits are topological, but not exact, duals of the well-known interdigital and half-wave parallel-coupled-line filters. Consequently, the exact design tables[2] and approximate design equations[4,5] may be used in designing hairpin-line filters.

Conceptually, hairpin-line filters may be obtained by folding the resonators of parallel-coupled half-wave open-circuited resonator filters. Consequently, a large number of hybrid physical realizations are possible by folding some resonators but not others. In all cases the same design equations may be used.

Inductance matrix transformations (analogous to capacitance matrix transformations) may be utilized to achieve electrically equivalent but dimensionally varied designs, or to obtain impedance transformations internally or at the input and output ports. However, for hairpin-line and hybrid hairpin-parallel-coupled-line filters the inductance transformations must be performed on paired-rows and paired-columns, in distinction to conventional capacitance, matrix transformations. For example, Fig. 3 illustrates a permissible inductance transformation for hairpin-line and hybrid hairpin-parallel-coupled-line filters. Physical realizability requires that $Z_{ii} - Z_{i,i+1} - Z_{i,i+1} \geq 0$.

An experimental filter was constructed on 0.025-inch thick alumina. The design was based on a 4-resonator, 0.1 dB Chebyshev ripple prototype, and utilized approximate design equations.[5] The nominal bandwidth was 5 percent. In order to avoid complications that might arise from having differing even-mode and odd-mode phase velocities, a ground plane was placed at 0.025 inch above the substrate. This had the effect of equalizing the phase velocities.* A photograph of the filter is shown in Fig. 4. The computed (for an assumed unloaded resonator Q of 90) and the measured attenuation responses are shown in Fig. 5. The measured VSWR was less than 1.35 in the passband.

References

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2. S. Frankel, "Equivalent Circuits for TEM Structures with Periodic Terminations," Proc. 1971 IEEE Region 6 Conference, Woodlake Inn, Sacramento (May 11-13, 1971).

3. R.J. Wenzel, M.C. Horton, "Exact Design Techniques for Microwave Filters," Final Report, Contract DA28-043-AMC-00399(E), Bendix Research Laboratories, Southfield, Michigan (February 1-April 30, 1965).

4. G.L. Matthaei, L. Young, E.M.T. Jones, Design of Microwave Filters, Impedance-Matching Networks, and Coupling Structures, McGraw-Hill, New York, 1964.

5. E.G. Cristal, "New Design Equations for a Class of Microwave Filters," scheduled for publication in the IEEE Trans. on Microwave Theory and Techniques.

6. A. Podell, "A High Directivity Microstrip Coupler Technique," G-MTT 1970 International Symposium Digest, pp. 33-36, May 11-14, 1970.

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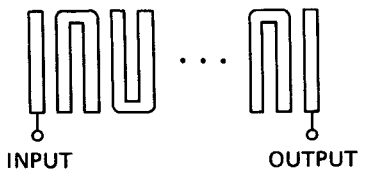
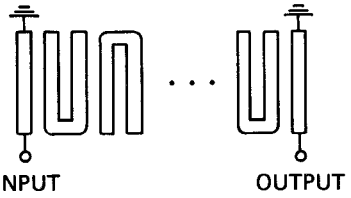
**Stanford Research Institute, Menlo Park, California 94025.

†Technical Consultant, P.O. Box 126, Menlo Park California 94025.

*An alternative technique would have been to use Podell's wiggly line method.[6]



a) TYPE A



b) TYPE B

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FIGURE 1 HAIRPIN-LINE FILTERS

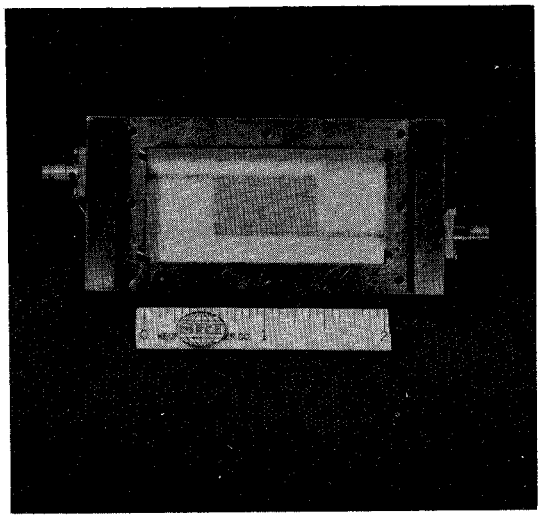
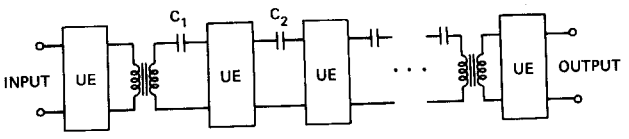
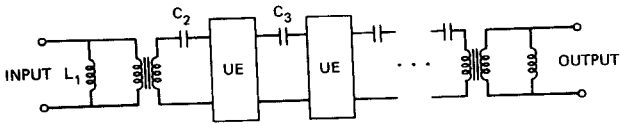


Figure 4 Photograph of Trial Hairpin-Line Filter



a) EQUIVALENT CIRCUIT FOR HAIRPIN-LINE FILTER OF FIGURE 1 (a)



b) EQUIVALENT CIRCUIT FOR HAIRPIN-LINE FILTER OF FIGURE 1 (b)

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FIGURE 2 EQUIVALENT CIRCUITS FOR HAIRPIN-LINE FILTERS

[C_1 = Open-circuited transmission line
L_1 = Short-circuited transmission line
UE = Unit element]

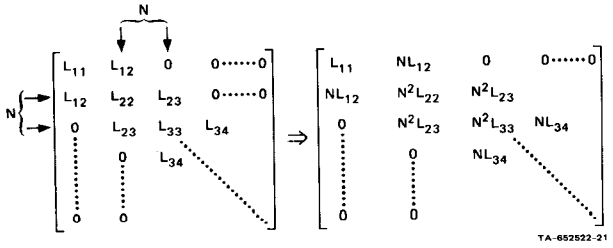

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FIGURE 3 EXAMPLE OF INDUCTANCE TRANSFORMATION FOR HAIRPIN, PARALLEL-COUPLED-LINE, OR HYBRID HAIRPIN-PARALLEL-COUPLED-LINE FILTERS

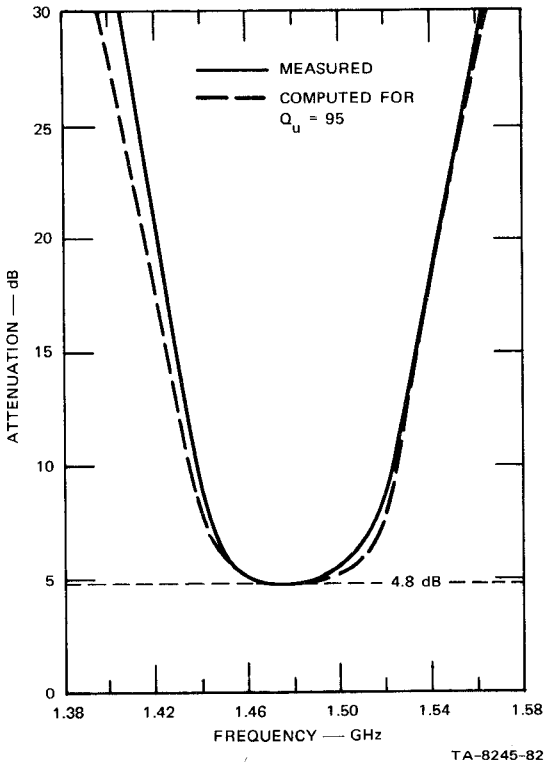

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Figure 5 Measured and Computed Attenuation Responses for Trial Hairpin-Line Filter

Notes