TAPPED-LINE COUPLED-TRANSMISSION-LINES WITH APPLICATIONS TO COMBLINE AND INTERDIGITAL FILTERS

by

Edward G. Cristal
Hewlett-Packard Laboratories

ABSTRACT

Exact, general, open-wire-line equivalent circuits for tapped-line combline and interdigital arrays are derived using a combination of graph-transformations and induction. A significant feature of the equivalent circuits is that they do not require commensurate length sections. The equivalent circuit for tapped-line interdigital arrays is utilized to develop new design equations for tapped-line interdigital filters. Computed responses for five and twenty percent bandwidth designs show considerably improved VSWR's compared to designs based on previous procedures.

SUMMARY

In the physical realization of narrow and moderate bandwidth combline and interdigital filters, the conventional input and output transformer couplings are often replaced with direct, tapped connections, as shown in Figures 1(a) and 1(b). This method was first described in the literature by Dishal (1) for small percentage bandwidth interdigital filters and recently by Cohn (2) for combline filters. Dishal's procedure is straight-forward, and can be applied to both interdigital and combline filters. However, analysis of the resulting designs is approximate since the open-wire-line equivalent circuits for tapped-line coupled-transmission-lines have not been previously published. Consequently, strict computer aided optimization is not possible and final design refinements must be done experimentally.

In this paper exact, general, open-wire-line equivalent circuits for combline and interdigital arrays are developed using a combination of graph-transformations(3) and induction. The graph transformation method of analysis consists of representing a coupled-line array of commensurate-length lines by an equivalent open-wire-line circuit having no coupled lines. The open-wire-line circuit, called the network graph, is in one-to-one correspondence with the coupled-line array. Next, transformations are performed on the graph to reduce the open-wire-line equivalent circuit to a simpler or more useful form. The graph-transformation process is suggested in Figure 2 for the two coupled-line combline case with the tap located 1/3 distance from the ground connection. In Figure 2, inductor symbols and straight bold lines represent short-circuited transmission lines and transmission lines, respectively, all of length L_T. Figure 2(a) depicts the geometry; Figure 2(b), the network graph; Figure 2(c) the network graph after several graph transformations, and Figure 2(d) the network graph in final form. When the tap is positioned $2L_T$ from the short circuit, the equivalent circuit is identical to Figure 2(d), but with L_T and $2L_T$ interchanged. If L_T were made L/N, analogous results would be obtained. Hence, by induction, the exact, general, open-wire-line equivalent circuit for the combline case for arbitrary lengths L_T is given in Figure 3. Notice that the equivalent circuit contains transmission lines of lengths, L, L-L_T and L_T, where the lengths L_T and L need not be commensurate. Generalization to the multi-line array is straight-forward.

Several cases can easily be examined to test the consistency of the equivalent circuit of Figure 3 in limiting cases: [1] for L_T = L, Figure 3 yields the conventional combline circuit; [2] for y_{12} = 0, Figure 3 yields the correct equivalent circuit of a single tapped line; [3] for Port 3 open, Figure 3 yields the conventional combline circuit. By the same procedures, the equivalent circuit for the tapped-line interdigital coupled pair was derived and is given in Figure 4. Again, generalization to the multi-line array is easily accomplished.

The exact equivalent circuits can be used to derive improved design equations for tapped-line combline and interdigital filters. For illustrative purposes the interdigital filter case is briefly described, and computed results of two design examples are presented.

The basic design approach in this paper was first to design a conventional filter [4]; next, replace the conventional input and output couplings by the tapped-line circuits; and last determine parameters that would make the tapped-line circuit and conventional coupling circuit equivalent. Of course, the latter is not possible over a band of frequencies, since the conventional coupling circuit consists of commensurate lines, whereas the tapped-line circuit does not. However, reasonably good results are achieved for narrow to moderate bandwidth filters.

Five resonator, 0.1-dB ripple, interdigital filters of five and twenty percent bandwidths were designed by Dishal's method and by the new procedures of this paper.

Parameter values from the conventional coupling sections [4] are used with three universal design charts to determine all parameters of the tapped-line coupling circuit, and the lumped capacitor necessary to bring the coupling section to resonance. Figures 5 and 6 compare computed VSWR data for the five and twenty percent bandwidth filters, respectively. In the case of the five percent bandwidth filter designed with the new procedures, the VSWR is virtually within the specifications. In the twenty percent bandwidth case, there is substantial improvement in the VSWR although it does not yet meet specifications.

These data are for designs prior to any optimization. In view of the fact that the VSWR's nearly meet specifications, one might expect computer optimization to quickly yield an acceptable design.

CONCLUSIONS

General equivalent circuits for tapped-line combline and interdigital arrays were presented. The tapped-line interdigital equivalent circuit was utilized to derive improved design equations for tapped-line interdigital filters of narrow to moderate bandwidth.

REFERENCES

(1) M. Dishal, "*A Simple Design Procedure for Small Percentage Bandwidth Round-Rod Interdigital Filters,*" IEEE Trans. on Microwave Theory and Techniques, MTT-13, pps. 696-698, September, 1965.

(2) S.B. Cohn, "*Generalized Design of Bandpass and Other Filters by Computer Optimization,*" Digest of Technical Papers of the 1974 IEEE International Microwave Symposium, pps. 272-273, (IEEE Catalog No. 74CH0838-3MTT).

(3) R. Sato, E.G. Cristal, "*Simplified Analysis of Coupled Transmission-Line Networks,*" IEEE Trans. on Microwave Theory and Techniques, MTT-18, pps. 122-131, March 1970.

(4) E.G. Cristal, "*New Design Equations for a Class of Microwave Filters,*" IEEE Trans. on Microwave Theory and Techniques, MTT-19, pps. 486-490, May 1971.

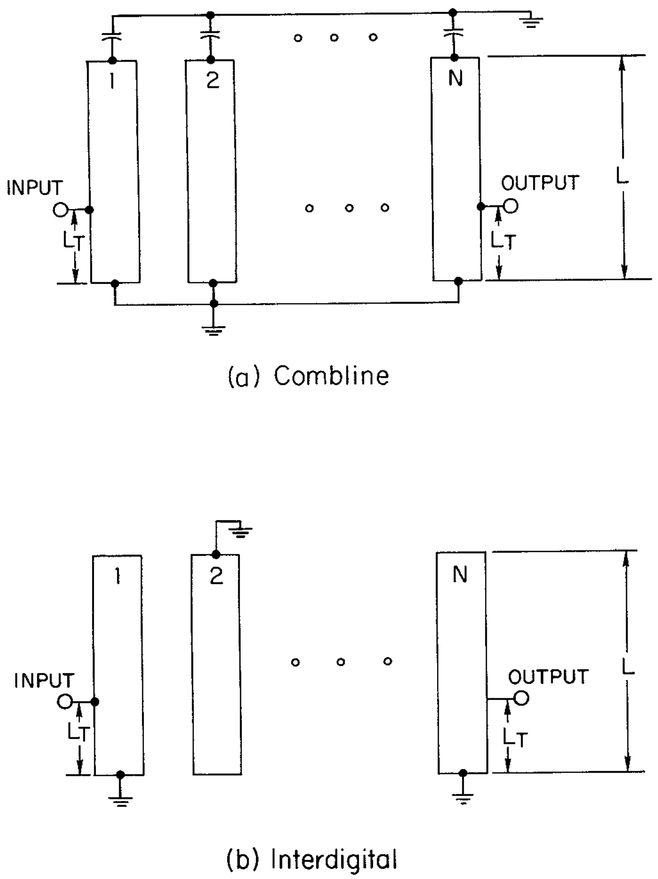

Figure 1. Combline and Interdigital Filters having Tapped-Line Input and Output Couplings.

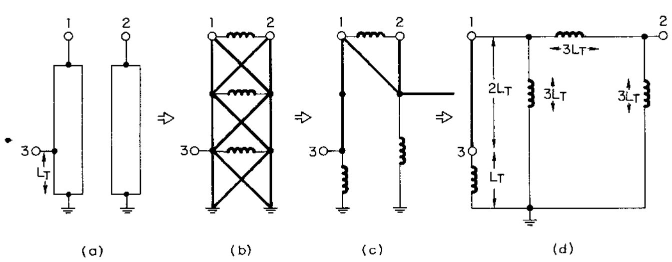

Figure 2. Illustration of the Technique Used to Derive the Equivalent Circuit for the Tapped-Line Combline Geometry.

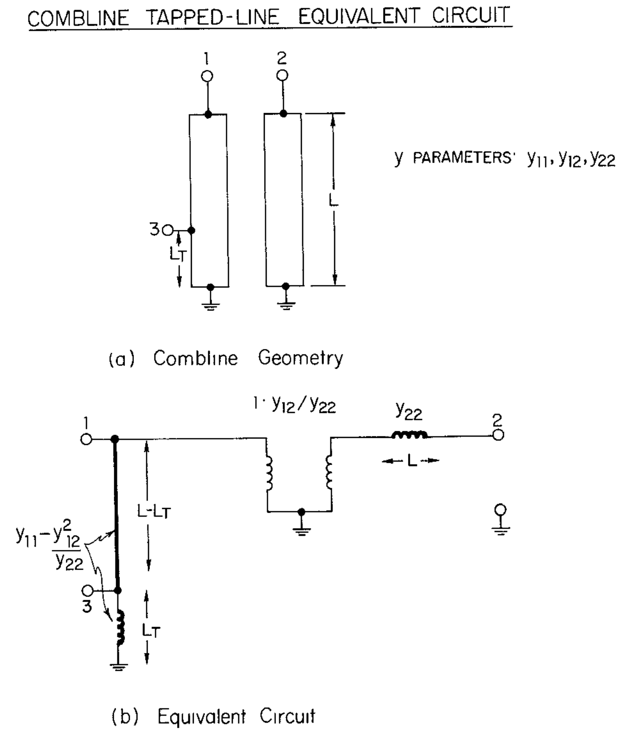

Figure 3. Open-Wire-Line Equivalent Circuit for Tapped-Line Combline Geometry.

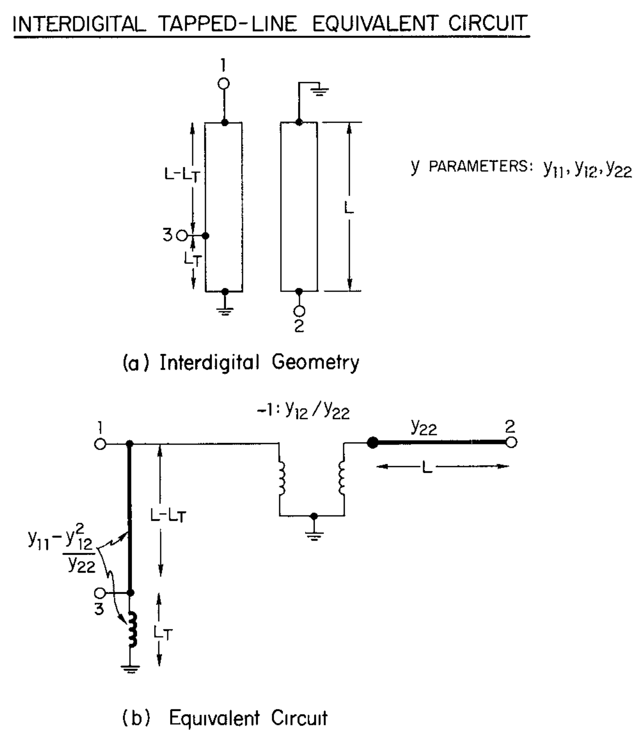

Figure 4. Open-Wire-Line Equivalent Circuit for Tapped-Line Inter-Digital Geometry.

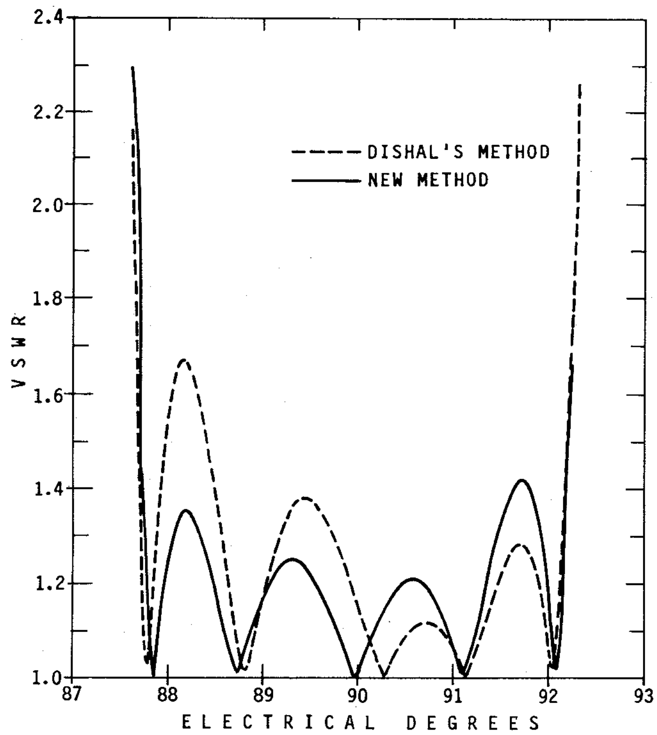

Figure 5. Computed VSWR's for Example Five Percent Bandwidth Tapped-Line Interdigital Filters.

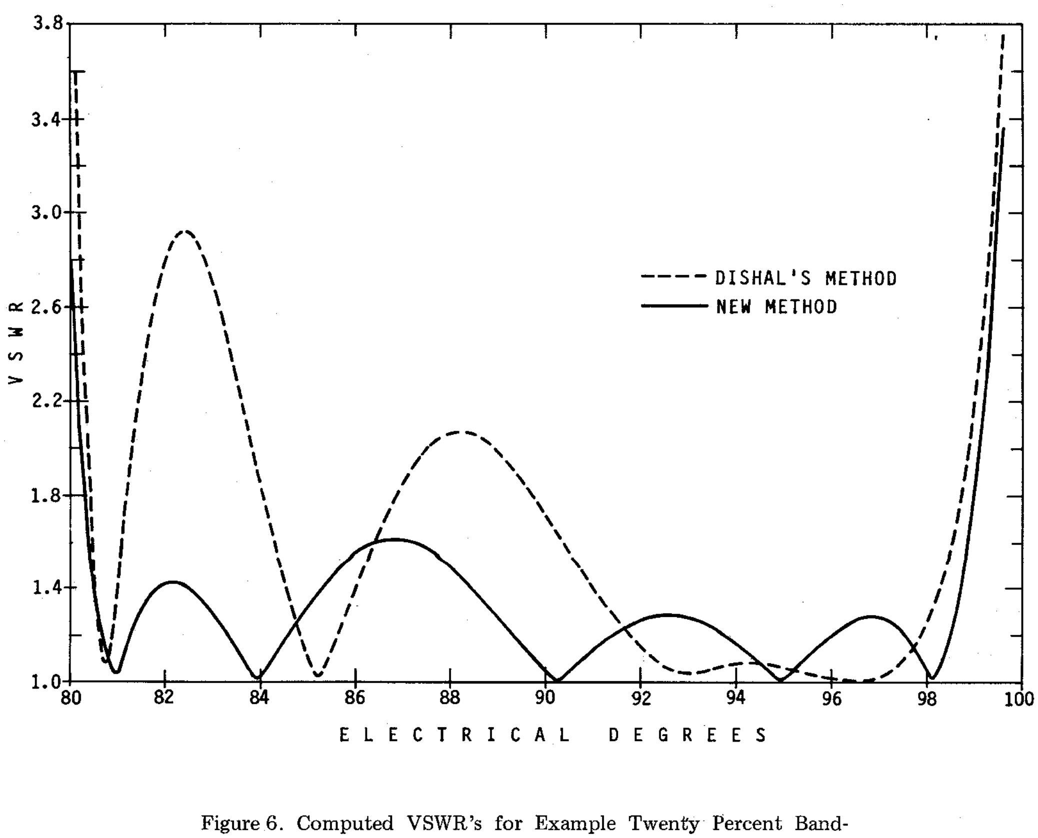

Figure 6. Computed VSWR's for Example Twenty Percent Bandwidth Tapped-Line Interdigital Filters.