NARROW BANDWIDTH ELLIPTIC-FUNCTION FILTERS

by

I. Rubinstein, R. L. Sleven, and A. F. Hinte

AIRBORNE INSTRUMENTS LABORATORY
A DIVISION OF CUTLER-HAMMER, INC.
Deer Park, New York 11729

Although wide bandwidth microwave elliptic-function filters have previously been reported (references 1, 2, 3, and 4), this paper describes a circuit which provides, for the first time, a narrow bandwidth elliptic-function response at microwave frequencies. It is for narrow bandwidth applications (from 5 percent to a fraction of a percent) that the elliptic-function filter offers its most important advantages over other filter types--lower loss and greater selectivity. These features are verified by theoretical analysis and experimental data on a 1-percent bandwidth S-band stripline filter. The design of the filter, which is based upon the low-pass prototype, is simple to obtain with the relationships presented in this paper, and the elliptic-function response is readily realizable in printed or other TEM transmission lines. A waveguide elliptic-function filter is also discussed, but experimental verification of this has not yet been attempted.

The first step in the elliptic-function filter design is to determine the appropriate normalized low-pass prototype circuit (reference 5) and convert this to an unnormalized bandpass circuit at the desired microwave center frequency. The necessary formulas are presented to obtain the microwave element values or resonator slope parameters. Figure 1 shows the equivalent circuit of an N = 5 elliptic-function bandpass filter.

The lumped element filter consists of both series- and parallel-connected resonant circuits. However, for narrow bandwidth transmission line applications, the resonant circuits must be all parallel-connected for TEM line and series-connected for waveguide. This paper shows that this can be accomplished with impedance inverter networks, and presents the necessary design equations. Figure 2 shows the inverter networks in a stripline N = 5 elliptic-function filter. The impedance ratio of the various circuits is only about 3 to 1, with the nominal impedance level set by the input and output coupling capacitors.

Although this stripline circuit is apparently the microwave equivalent of the lumped constant-bandpass circuit, there is a serious problem associated with the notch pairs (reference 6). Each notch pair has resonators tuned above and below f_o, and there should be no line-length separating the resonators, and no stray coupling between them. It was hoped that by locating each of the resonators of a notch pair on opposite sides of the line (as shown in Figure 2) this would be accomplished. In practice, however, interaction between resonators could not be eliminated. Similar problems have also been observed at low frequencies with lumped components, and the solution there was an isolating network given by Geffe (reference 7). Applying this solution to the stripline problem, the resulting successful N = 5 elliptic-function filter is shown in Figure 3. The measured and calculated responses shown in Figure 4 are in very close agreement. The actual stripline circuit was printed on Rexolite dielectric, with a 1/4-inch ground-plane spacing (Figure 5). The unloaded Q was only 500, thereby explaining the high midband loss and absence of stopband ripple normally associated with elliptic-function filters. The calculated response is obtained from a computer program which takes into account the effects of dissipation.

For the same rejection bandwidth, the equal-element filter, which has the lowest loss of the conventional type (ladder network low-pass prototype), would have 1-db additional midband loss and a shape factor (53 to 3 db) of 3.1, as compared to 2.4 for the elliptic-function filter. Pseudo-exact Chebyshev and Butterworth filters (reference 8) would have about the same characteristics as the equal-element filter, and an exact Chebyshev filter with the same shape factor as the elliptic-function filter could not be realized because the Q_u of 500 is less than Q_{MIN} for the 1-percent bandwidth.

The measured data for the N = 3 filter (Figure 6) was obtained with a high Q transmission line (air supported stripline with 3/4-inch ground-plane spacing) and illustrates the stopband ripple obtained with low-loss elliptic-function filters.

Although experimental data are shown for stripline circuits only, this technique can be adapted for the realization of the narrowband elliptic-function filter using waveguide or helical line. The methods of such realization are discussed in the paper.

In summary, this paper describes a stripline circuit for the realization of the first narrow bandwidth microwave elliptic-function filter. The superiority of the elliptic-function response, with respect to shape factor and loss, is verified both theoretically and experimentally.

The authors wish to express their appreciation to A. Anselmo, P. Dammers, D. Levinson, and J. Taub for their assistance on this program. This work was sponsored by Rome Air Development Center, Rome, New York.

REFERENCES

1. M. C. Horton and R. J. Wenzel, "Realization of Microwave Filters with Equal Ripple in Both Pass and Stop Bands," presented at the International Symposium on Generalized Networks, Polytechnic Institute of Brooklyn, Brooklyn, New York, April 1966.

2. R. Levy and I. Whiteley, "Synthesis of Distributed Elliptic-Function Filters from Lumped-Constant Prototypes," IEEE Transactions on Microwave Theory.

3. M. C. Horton and R. J. Wenzel, "The Digital Elliptic-Filter - A Compact Sharp-Cutoff Design for Wide Bandstop or Bandpass Requirements," IEEE Transactions on Microwave Theory and Techniques, Vol MTT-15, p 307-314, May 1967.

4. J. D. Rhodes, "The Stepped Digital Elliptic Filter," to be published in the IEEE Transactions on Microwave Theory and Techniques.

5. R. Saal, "Der Entworf von Filtern mit Hilfe Des Kataloges Normieter Tiefpasse," (The Design of Filters Using the Catalogue of Normalized Low-Pass Filters), Telefunken, G.M.B.H., Backnang/Wurttemberg, Western Germany, 1961.

6. R. Sall and E. Ulbrich, "On the Design of Filters by Synthesis," IRE Transactions on Circuit Theory, Vol CT-5, p 284-326, December 1958.

7. P. Geffe, "Simplified Modern Filter Design," John Rider Publishers, Inc., New York, 1963.

8. R. L. Sleven, "Pseudo-Exact Bandpass Filter Design," Microwaves, Vol 7, p 38-47, August 1968.

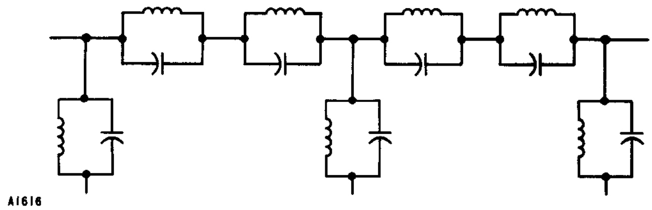


Figure 1. Lumped Element Elliptic-Function Filter

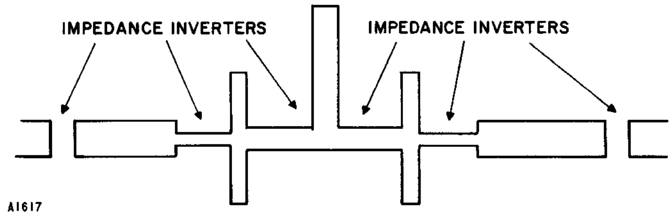


Figure 2. N = 5 Stripline Elliptic-Function Filter With Interacting Notch Pairs

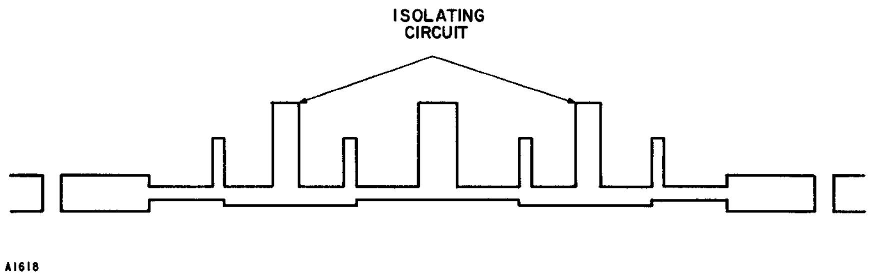
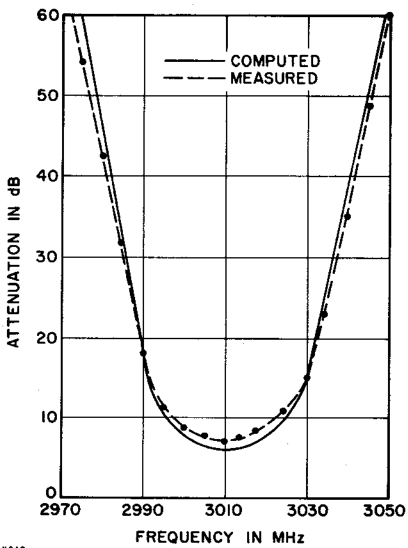
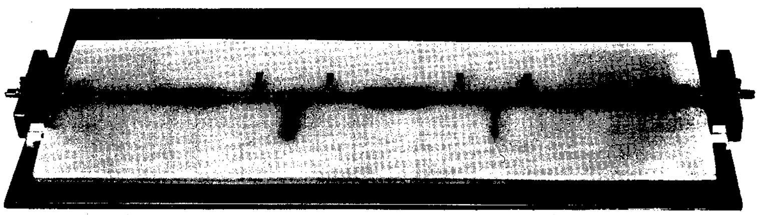


Figure 3. N = 5 Stripline Elliptic-Function Filter With Isolated Notch Pairs



4313

Figure 4. N = 5 Stripline Elliptic-Function Response (Q_u = 500)



A1620

Figure 5. **Stripline Elliptic-Function Filter**

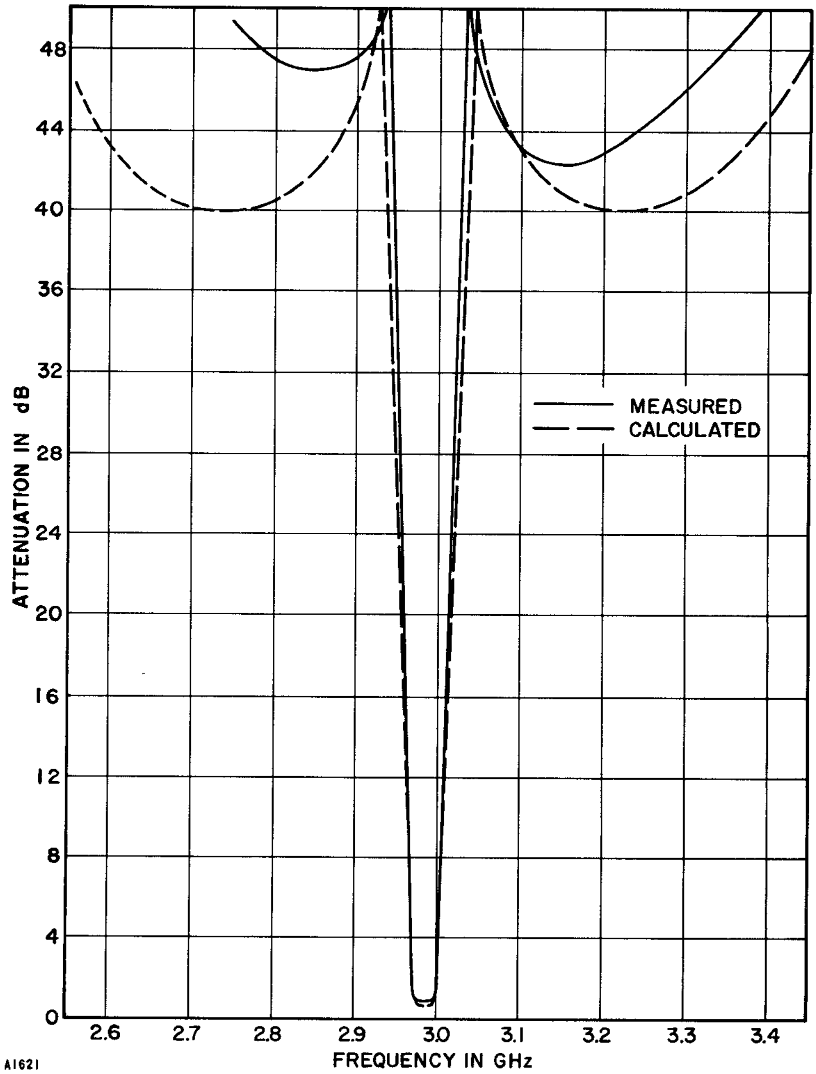


Figure 6. N = 3 Solid Strip Elliptic-Function Filter Response (Q_u = 2700)