# NARROWBAND CONTIGUOUS MULTIPLEXING FILTERS WITH ARBITRARY AMPLITUDE AND DELAY RESPONSE

R. J. Wenzel and W. G. Erlinger
Wenzel/Erlinger Associates
Woodland Hills, California 91364

Abstract

The solution to the design problem for narrowband contiguous multiplexing filters with channels having arbitrary amplitude and delay response is presented. The resulting networks use singly terminated component filters that may be substantially different in type of response and in relative complexity. The design procedure is described and illustrated with a contiguous triplexer example.

Doubly terminated bandpass filters can be designed to provide arbitrary amplitude and delay response characteristics. A solution to the general narrowband approximation problem has been presented (1), restricted closed form approximating functions have been given (2), and suitable network realizations have been described in detail (3) - (4). Multiplexing filters with guard-bands between channels can be effectively designed by starting with such doubly terminated filters, and combining them to form a common junction device. Slight modification of the doubly terminated component filter element values is usually required; however, with appropriate guard-bands, little design difficulty is encountered. When the channels become contiguous, the design problem is best solved by the use of singly terminated component filters. This paper describes the general solution to the contiguous multiplexer problem using component filters with arbitrary amplitude and delay response.

As with doubly terminated designs, arbitrary amplitude and delay characteristics in multiplexer component filters are achieved by the use of multiple resonator structures with additional couplings between non-adjacent resonators. These multiple couplings can produce transmission zeros at both real and complex frequencies. Real frequency transmission zeros produce elliptic-type stopband performance, while complex transmission zeros primarily affect the passband delay response. The general design guidelines for the design of contiguous bandpass filters with arbitrary transmission zeros are identical to those for more conventional designs (5) - (6). Good performance is achieved if the filters are designed using the following general criteria:

(1) Component filters should be designed on a singly terminated basis.

(2) Crossover should occur where the real part of the appropriate input immittance (impedance for a series connection and admittance for a parallel connection) is 0.5 on a normalized one ohm basis. This corresponds to the 3 dB point on a power transmission plot.

(3) The slopes of the real part of the input immittances of the component filters at the crossover frequencies should be equal in magnitude and opposite in sign.

(4) The prototype ripple value r (in dB) for the singly terminated component filters is approximately $r = 10 \log_{10} V$, where V is the desired VSWR of the contiguous multiplexer.

The approximation problem for arbitrary amplitude and delay response is solved using the transformed variable approach (7) - (8). The use of a transformed variable both improves numerical accuracy and significantly simplifies solution of the equal ripple approximation problem. Synthesis of singly terminated prototype networks is more complicated than synthesis for the doubly terminated case. Singly terminated prototype filters are not symmetric, and cannot be synthesized with the even mode network approach used to simplify the doubly terminated filter synthesis. Also, the exact time delay response of the contiguous multiplexer cannot be determined until the multiplexer design has been completed, although quite accurate initial estimates can be obtained. Exact delay response can only be obtained by analysis after forming the common junction and determining the element values of the required annulling network.

An efficient computerized synthesis procedure for contiguous multiplexers has been developed. Practical design criteria have been found that provide excellent estimates of initial transmission zero placement and multiplexer delay response. In the computerized design process, each channel of the multiplexer is designed on a singly terminated basis to satisfy the four criteria given above. Transmission zero locations are modified until satisfactory amplitude and delay response is achieved. Complete multiplexer performance including the effects of dissipation is then determined by use of an analysis program that automatically computes the elements of the required annulling network.

For narrow-band multiplexers with equal bandwidth channels of identical electrical characteristics, the same singly terminated prototype design can be used for all channels by simply choosing the proper 3-dB bandwidth. Note however, that the general procedure does not require the channel bandwidths to be equal, or the component filters to be of equal complexity, or to even have similar types of response. Thus the channels may have Chebyshev type, elliptic-function type, or linear-phase types of transmission response, or any desired combination of response types. As long as the four basic criteria (1) - (4) described above are satisfied, a suitable multiplexer network can be synthesized.

The theoretical amplitude response of a

narrowband contiguous triplexing multiplexer design obtained using the above techniques and computerized procedure is shown in Figure 1. A different type of component filter has been chosen for each channel to demonstrate the wide variety of design possibilities, and the ability to combine filters with substantially different response characteristics. The channel (1) filter is an N = 10 resonator design with a real transmission zero for amplitude selectivity, and complex zeros of transmission to provide very flat delay and amplitude response. It requires four cross-couplings of both positive and negative sign. The channel (2) filter is an N = 6 resonator elliptic function design using two cross-couplings. The channel (3) filter is an N = 10 resonator design with one cross-coupling for delay compensation. The normalized time delay response of each channel and a comparison of loss and loss variation is shown in Figure 2. The computed common junction VSWR is less than 1.1:1 across the complete multiplexer band including the cross-over regions. The multiplexer equivalent circuit for a series junction is shown in Figure 3, and a coaxial comb-line realization of the series common junction is sketched in Figure 4. Other channel arrangements and physical realizations are possible.

## References


(1) R. J. Wenzel, "Solving the Approximation Problem for Narrowband Bandpass Filters with Equal-Ripple Passband Response and Arbitrary Phase Response," Paper presented at the 1975 IEEE-MTT-S International Microwave Symposium, Palo Alto, California, May 12-14, 1975. 1975 Symposium Digest, p. 50.

(2) J. D. Rhodes, "A Lowpass Prototype Network for Microwave Linear Phase Filters," IEEE Trans. on MTT, pp. 290-300, June, 1970.

(3) J. D. Rhodes, "The Generalized Interdigital Linear Phase Filter," IEEE Trans. on MTT, pp. 300-306, June, 1970.

(4) A. E. Atia and A. E. Williams, "Non-Minimum-Phase Optimum Amplitude Bandpass Filters," IEEE Trans. on MTT, pp. 425-431, April, 1974.

(5) R. J. Wenzel, "Wideband High-Selectivity Diplexers Utilizing Digital-Elliptic Filters," IEEE Trans. on MTT, pp. 669-680, December, 1967.

(6) R. J. Wenzel, "Some General Properties of Commensurate Linelength Complementary and Pseudo-Complementary Microwave Filters," IEEE Trans. on MTT, pp. 191-192, March, 1968.

(7) J. A. C. Bingham, "A New Method of Solving the Accuracy Problems in Filter Design," IEEE Trans. on C. T., September, 1964.

(8) H. J. Orchard and G. C. Temes, "Filter Design Using Transformed Variables," IEEE Trans. on C. T., pp. 385-408, December, 1968.


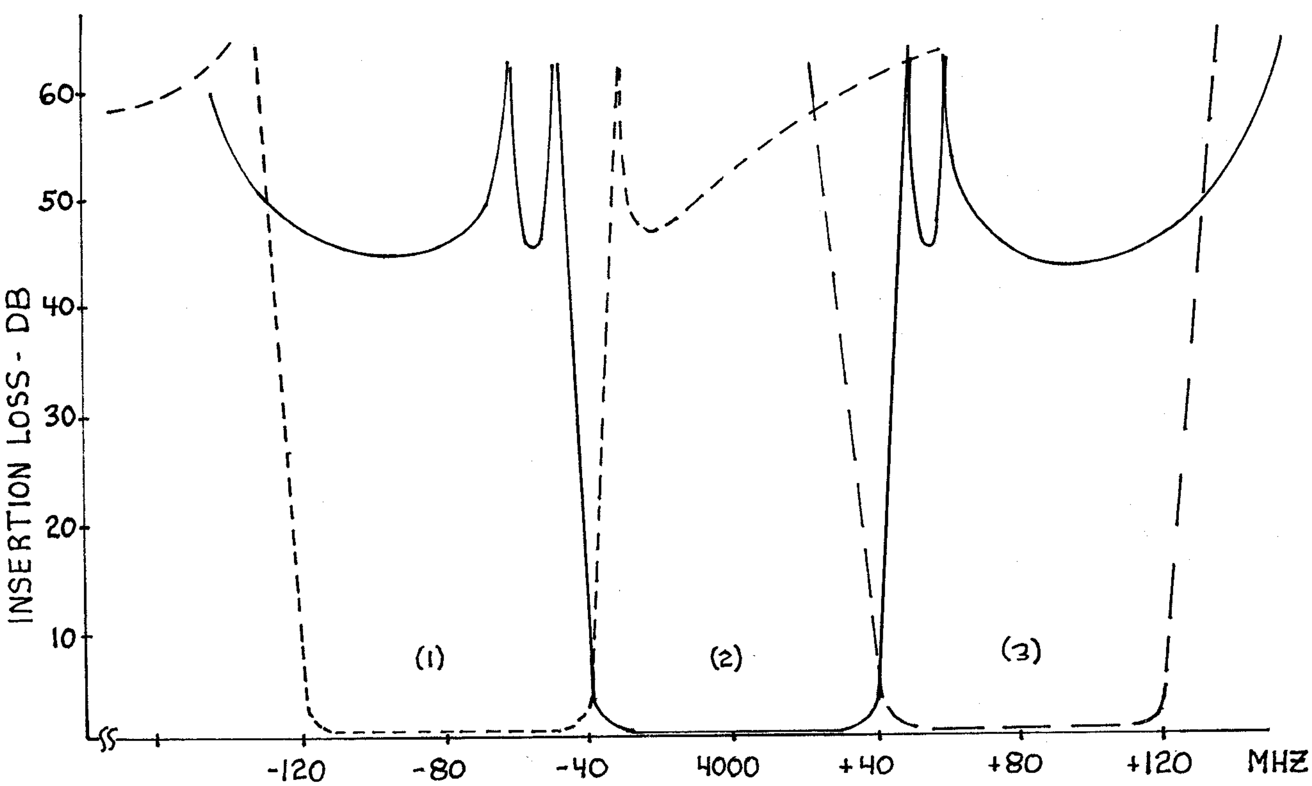


Figure 1. Amplitude response of contiguous triplexer using filters of differing types.

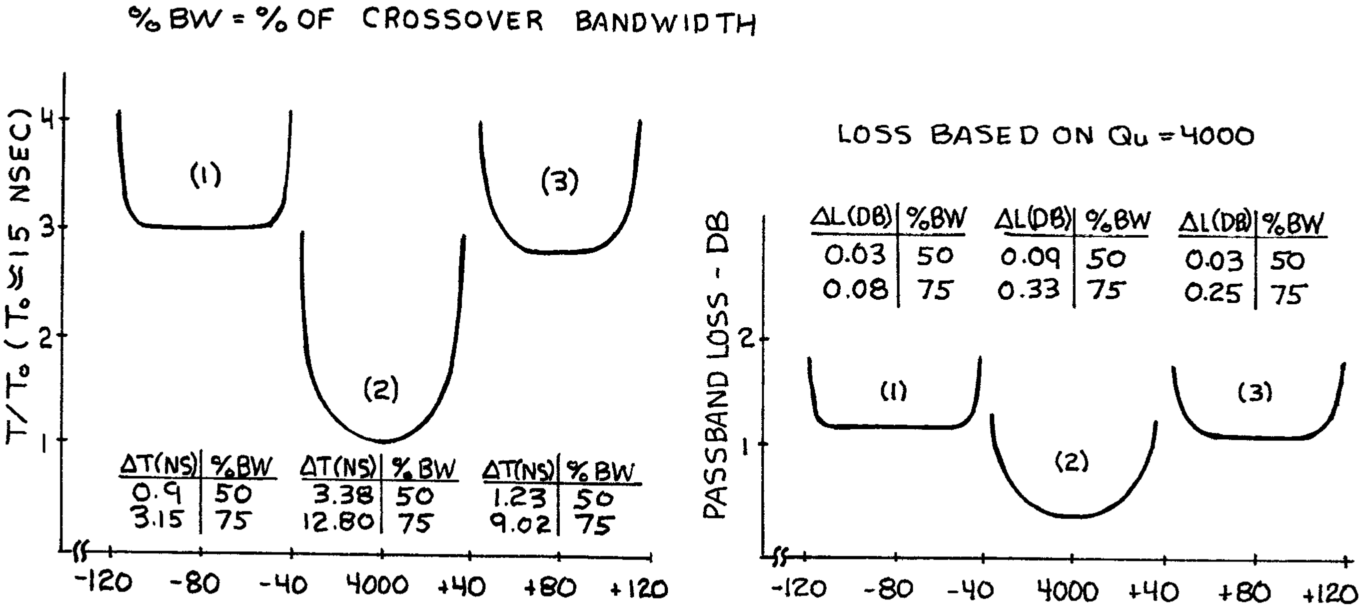


Figure 2. Computed time delay and dissipation loss of contiguous triplexer design.

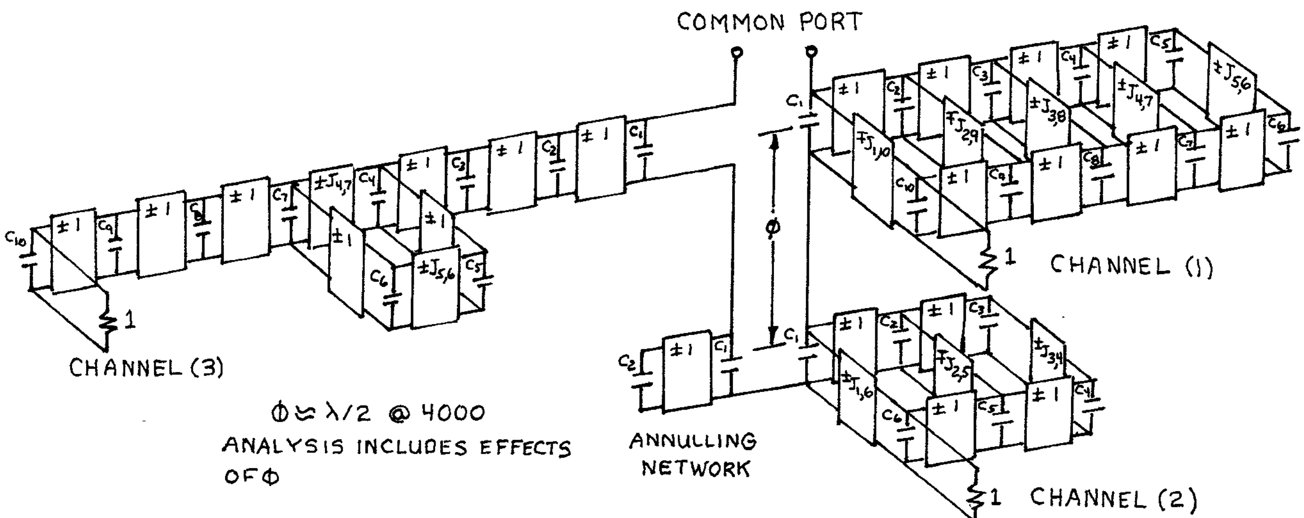


Figure 3. Series junction equivalent circuit of contiguous triplexer.

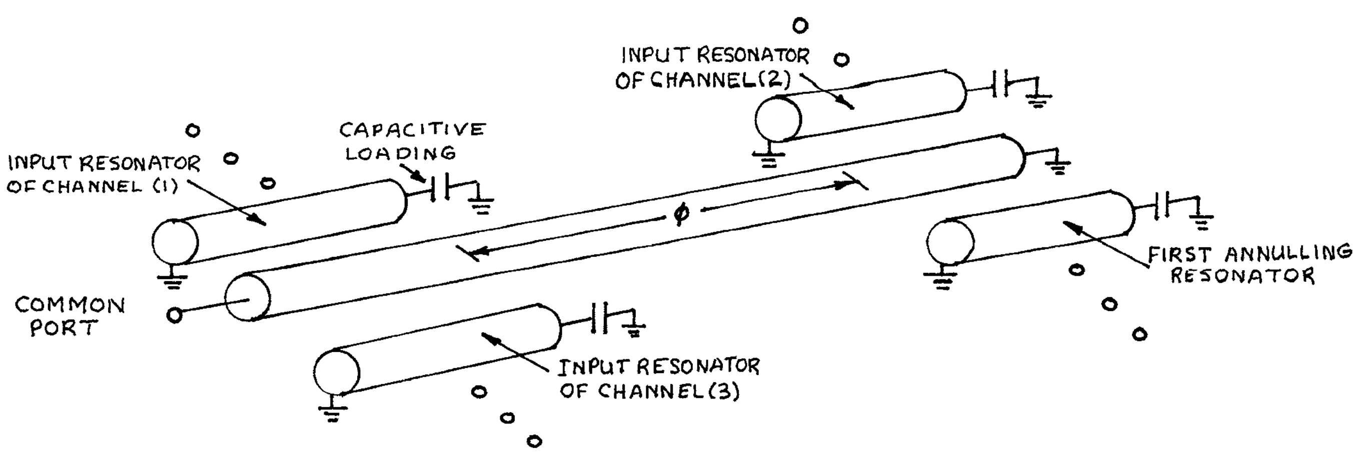


Figure 4. Conceptual sketch of common junction for a comb-line realization of a contiguous triplexer.