GRADIENT RAZOR SEARCH METHOD FOR OPTIMIZATION

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Summary

A new and more efficient strategy based on the idea of the razor search method is presented. The adjoint network method of evaluating partial derivatives is incorporated. It is applied to the optimization of a seven section filter with frequency variable terminations.

Introduction

The razor search method of Bandler and Macdonald[1], which has been used to optimize microwave networks by computer[2], was developed to minimize the maximum deviation of some network response from an ideal response specification.

The gradient razor search method presented in this paper follows the same basic philosophy as the previous one. Several innovations are, however, exploited in this paper resulting in considerably greater efficiency in addition to a simpler strategy. The adjoint network method for evaluating gradient vectors of responses of networks containing uniformly distributed elements[3] is now incorporated.

The New Strategy

Beginning with the maximum deviation of the network response from the specified response at the starting point a search in the negative gradient direction is initiated to find the minimum. It is then assumed that a point near a path of discontinuous derivatives has been reached. These arise when the objective function jumps from one response ripple extremum to another. A simple method of obtaining the downhill direction of discontinuous derivatives by solving as many linear equations as there are ripples currently being considered is employed, and a further search for a minimum is conducted as before. This type of process is repeated with as many ripples as necessary until a minimax solution is reached to some desired accuracy. The required response gradients are evaluated using the results of one network analysis by the adjoint network method.

Example

The new razor search method was applied to the optimization of the transmission-line filter shown in Figure 1. This problem was previously considered by Carlin and Gupta[4]. The frequency variation of the terminations is like that of rectangular waveguides operating in the H_{10} mode with cut-off frequency 2.077 GHz. A passband insertion loss of 0.4 dB over 2.16 to 3 GHz and an edge to the useful band of 5 GHz was called for.

Figure 2 shows the response of Carlin and Gupta which was used as an initial design. The other responses in Figure 2 are a least 10th optimum obtained by Bandler and Seviora[3] and a minimax optimum obtained by the present authors using the gradient razor search method. In both cases only the passband was optimized keeping the section lengths fixed. In the minimax case quadratic interpolation was used to locate the ripple extrema. The equal-ripple response has a maximum passband insertion loss of .086 dB. Table 1 shows the appropriate parameter values.

Figure 3 shows the results of applying the gradient razor search method to producing an optimum in the filtering sense. Thus, it was desired to meet the 0.4 dB passband insertion loss while maximizing the stopband insertion loss at 5 GHz. The objective function formulation follows Bandler[5]. Here, 22 frequencies in the passband were used. Table 1 shows the resulting parameter values (they were not constrained).

Conclusions

The improved razor search method employing gradient information has been programmed and successfully applied to microwave transformer and filter design problems. Typically, a few minutes on the CDC 6400 are required to optimize a seven parameter design.

References

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[4]H.J. Carlin and O.P. Gupta, "Computer design of filters with lumped-distributed elements or frequency variable terminations", IEEE Trans. Microwave Theory and Techniques, vol. MTT-17, pp. 598-604, August 1969.

[5]J.W. Bandler, "Optimization methods for computer-aided design", IEEE Trans. Microwave Theory and Techniques, vol. MTT-17, pp. 533-552, August 1969.

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TABLE 1

Parameters (normalized)	Carlin and Gupta	Minimax Design (Figure 2)	Minimax Design (Figure 3)
Z_1	1476.5	1305.2	3069.4
Z_2	733.6	607.8	2856.4
Z_3	1963.6	1323.3	25871.2
Z_4	461.8	362.7	10573.3
Z_5	1963.6	1323.2	25874.0
Z_6	733.6	607.9	2856.7
Z_7	1476.5	1305.2	3069.8

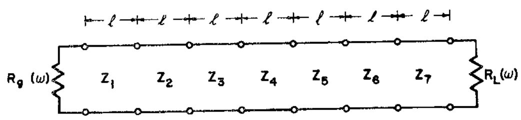

Figure 1. Cascaded transmission-line filter operating between

$$R_g(\omega) = R_L(\omega) = 377/\sqrt{1-(f_c/f)^2}$$

where

f_c = 2.077 GHz. ℓ = 1.5 cm.

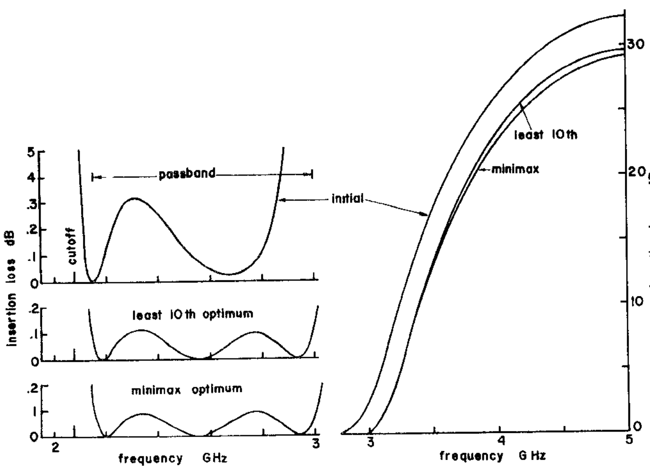

Figure 2. The response of Carlin and Gupta[4] is the initial one. The least 10th response was obtained by Bandler and Seviora[3]. The minimax response was produced by the gradient razor search method.

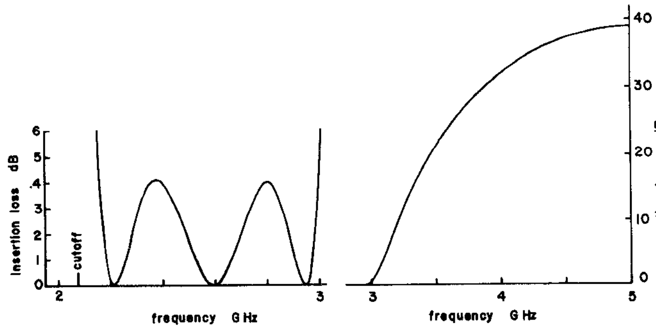

Figure 3. Response of the minimax design with 0.4 dB passband insertion loss produced by the gradient razor search method.

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