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시컨트 방법을 이용하는 여파기 전달 특성 개선에 관한 연구

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Study on enhancing the filter transfer-function using the Secant method

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Abstract - In this paper, the secant method is adopted to improve a transfer function required by specific filtration properties. It is advantageous over the conventional and widely used 'Template method' in that it enables users to seek the position of a pole which will turn out to meet well the requirements of in-band insertion loss as well as stop-band rejection even after a small number of iterative steps. For validating the proposed method, the transfer function of a 4-pole waveguide filter is targeted.

1. Introduction

To produce a filter with a good performance, each of the procedures from numerical work through physical tuning should be set value on. Among them, before the designing step, the values of electrical sizes are obtained mathematically and/or numerically.

So far, the Template method or its slightly revised version has been widely used among the concerned engineers[1]. It belongs to a group of methods for approximating the amplitudes of filtering characteristics[2]. It is not too difficult to understand and employ on hand in identifying transmission or attenuation functions which will agree with the insertion loss and stop-band rejection.

As a way of improvement, the Secant method is introduced with specific information of zeros and poles for any type of t ransfer function filtering. The Secant method which requires n o derivatives of the function of interest can find the recomme ndable position of a pole within several iteration steps, since t he transfer function used indicates the intervals for good initia l guesses[3]. The specified insertion loss and the out-of-band rejection or skirt-sharpness are targeted in applying the sche me.

In this paper, for the verification of the validity of the propo sed method, the transfer function of a 4-pole waveguide filter for a Ku-band use is investigated[4-5]. The numerical results show the proposed method can be recommended in the numeri cal work in prior to design.

2. Theory

In the Template method application, the concept 'the loss function of a new variable' comes to light. The variable Z is transformed from complex frequency $S(=j\omega)$ via the following form.

$$Z^2 = \frac{\omega^2 - \omega_B^2}{\omega^2 - \omega_A^2} \tag{1}$$

ω_A and ω_B, respectively, stand for the lower and upper edges of a bandwidth. The loss function is represented as

$$L = \left(\frac{Z+\omega_B/\omega_A}{Z-\omega_B/\omega_A}\right)^{\frac{N_Z}{2}} \left(\frac{Z+1}{Z-1}\right)^{\frac{N_{IN}}{2}} \times \prod \left(\frac{Z+Z_i}{Z-Z_i}\right) \tag{2}$$

where N_Z and N_{IN} are the numbers of poles at the origin and infinity, respectively. Z_i is the i-th stop-band pole in the Z-plane. The loss function L is involved this way.

$$A(\omega) = 10\log\left[1 + \frac{\epsilon^2}{4}\left(|L| + \frac{1}{|L|}\right)^2\right] \tag{3}$$

ε is $10^{0.1A_{\max}} - 1$, and $A_{\max}$ the in-band ripple. As is shown, L has no information on the type of transfer function or zeros.

The elliptic-type transfer function is expressed in the equation to come.

$$|T(S)| = -10\log[1 + \epsilon^2 R_n(S, A_{\max}, A_{\min})^2] \tag{4}$$

R_n is an n-th order rational function with elliptic integral parameters, and $A_{\min}$ the attenuation at the offset frequency. Actually, eqn (4) is modified in its pole locations and through the Hurwitz complex-root arrangement, the following is obtained and used for the extraction of the circuit-type parameters.

$$T(\omega) = -10\log[1 + \epsilon^2 \overline{R_n}(\omega, A_{\max}, A_{\min})^2] \tag{5}$$

$\overline{R_n}$ is the pole-modified version of R_n.. Back to the pole-modification or pole-placing, the Secant method is related to the iterative process. The Secant method is easily found in literatures[3]. It is not required to evaluate the derivatives of the object functions in its uses and has similar merits to the Bi-section-&-False-position over non-highly varying intervals, say, being easy to make codes unlike the Golden-section rule. The solutions to be sought by the Secant scheme will be $A_{\max}$ and the skirt-sharpness with $A_{\min}$

3. Numerical Experiments

In the output multiplexer for a Ku-band use, 4-pole channel filters can be used. For one channel with 34MHz wide band centered at 12.33GHz, $A_{\max}$ at zero 0.7458041 and $A_{\min}$ at relative offset value 1.688211 are -0.035dB and below -26dB. $N_z = N_{IN}$=1, i ranges 1 through 2 for eqn (2), and n =4 for eqn (5). The Secant scheme is applied first and then the Template method is mentioned.

When the Secant method applied to the aforementioned specifications, the convergence starts after a few steps as follow. In Figures 1(a) and 1(b), the error curves are getting very small around the 6th step for both cases of insertion loss and stop-band rejection. The truth of the matter is that it can be practically accepted as long as the absolute errors are below 0.5×10^{-2} and 0.5×10^{-1} for insertion loss and stop-band rejection, respectively. At the moment, the searched pole is found to be 1.816259.

The transfer function before and the one after pole-placing with 1.816259 are compared with respect to the insertion-loss. Considering the insertion loss before the modification is almost the same as the specification, Figure 2 shows the relocated pole has no problem in practically meeting the insertion loss. Thinking of the main purpose of pole-placing, the skirt-sharpness has to be enhanced through it. The improper choices of the pole result in wider bandwidths as seen in Figure 3. Though the stop-band is rejected much more with the improper poles, the 1.816259-case well compromises the skirt-sharpness.

4. Conclusion

To improve the skirt-sharpness and the insertion loss properties for a channel filter, the Secant method is proposed . It has been shown that it overcomes the drawbacks of the Template method having been used till now, because it is possible to seek a solution with a small number of iterative steps. The numerical results indicate the validity of the proposed method. To improve the skirt-sharpness and the insertion loss properties for a channel filter, the Secant method is proposed for placing the pole of a transfer function. It has been shown that it overcomes the drawbacks of the Template method having been used till now, because it is possible to seek a solution with a small number of iterative steps and information of the original zeros as well as poles. The numerical results indicate the validity of the proposed method.

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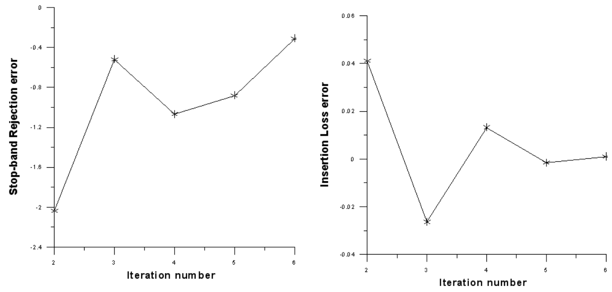
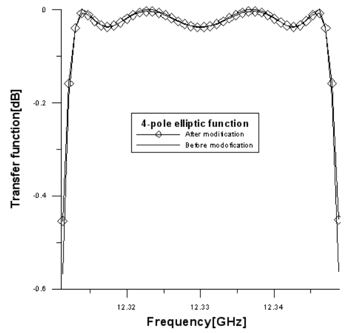
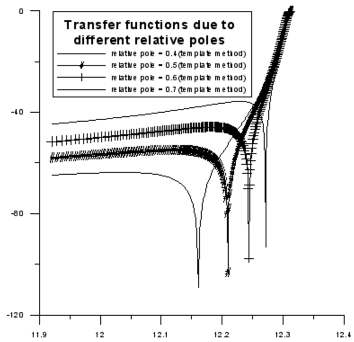


(a) (b)

< Fig. 1 > Insertion loss and Stop-band rejection error



< Fig. 2 > Insertion loss before and after using the method



< Fig. 3 > A variety of cases about the skirt effect