6차 단일종단 이중모드 타원응답 필터의 회로망 파라미터 추출에 관한 연구

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Network Parameters of 6-Pole Dual-Mode Singly Terminated Elliptic Function Filter

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ABSTRACT

An output multiplexer of manifold type is widely used in a recent satellite transponder for its mass and volume reduction. For correct operation, the filters of such a multiplexer must be singly terminated. In this paper, a simple synthesis method of a 6-pole dual-mode singly-terminated filter is described. From the transfer function of the filter, network parameters such as in/output terminations and coupling coefficients are obtained easily without complicated matrix algebra such as orthogonal projection and similarity transformation. Two different-structure filters are taken into consideration and the network parameters of each filter have been extracted from the same transfer function. It is shown that the responses of two filters are same to each other since their network parameters are obtained from the same transfer function. The method described in this paper can be applied to the other degree singly terminated filter.

Key Words : Singly Terminated Filter, Network Parameters, Dual-Mode

I. Introduction

Generally, in satellite communications, amplified channel signals are transmitted to the ground station after they are recombined by output multiplexer in satellite transponder. Due to its small volume and less mass, manifold type is widely adopted in designing output multiplexer[1]-[3]. One of the most important conditions that need to be met for correct operation of such a multiplexer is that the filters must be singly terminated[4]. Only when filters are singly terminated does the necessary mutual cancellation of input susceptances tack place. Furthermore, dual-mode technique[5] is widely adopted in channel filters of output multiplexer for mass and volume reduction.

Fig. 1 shows the process of microwave filter development. When the transfer function is obtained by determining the pole and zero locations based on the given specifications, the network parameters such as in/output terminations and coupling coefficients must be extracted for the determination of filter's physical dimension. Methods for obtaining the transfer function of the filter from pole and zero loactions are well described in [6] and [7].

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논문번호 : 020514 - 1204, 접수일자 : 2002년 12월 4일

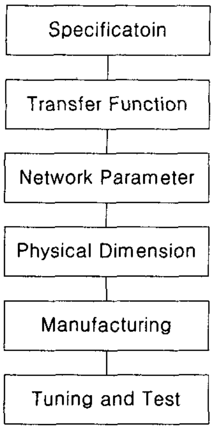


Fig 1. Development process of the microwave filter.

Chen has described the technique for extracting the network parameter of a singly terminated pseudo-elliptic function filter[8]. Since Chen's method is somewhat difficult and needs complicated algebra such as orthogonal projection and similarity transformation, this paper focuses on the simple method to extract the network parameters of the singly terminated filter from its transfer function. Although only the 6-pole singly terminated filter is dealt with in this paper, the network parameter of the other degree order filter can also be obtained with the method described in this paper.

II. Theory

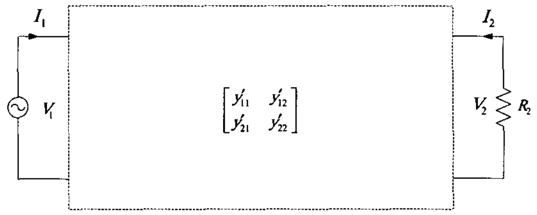
Fig. 2 shows the equivalent network for a singly terminated filter. The transfer function, *t(s)*, for a elliptic function filter is of the form

$$t(s)=\frac{1}{\varepsilon}\frac{P(s)}{A(s)+sB(s)} \tag{1}$$

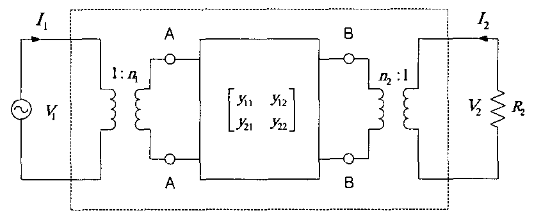
where $s=j\omega$. If the filter is connected to the load with unit resistance, the transfer admittance can be represented as follows:

$$Y'_{21}=\frac{1}{\varepsilon}\frac{jP(s)}{A(s)+sB(s)} \tag{2}$$

The factor j is introduced in (2), since the input voltage and output current in an LC circuit must be 90° out of phase[8][9].



(a) Unnormalized scheme



(b) Normalized scheme

Fig. 2. Equivalent network for a singly terminated filter.

The transfer admittance is also be related to the short-circuit parameters by

$$Y'_{21}=\frac{y'_{21}}{1+y'_{22}} \tag{3}$$

therefore, the short-circuit parameters can be derived as follows:

$$y'_{21}=\frac{jP(s)/\varepsilon}{A(s)} \tag{4-a}$$

$$y'_{22}=\frac{sB(s)}{A(s)} \tag{4-b}$$

An n-pole synchronously tuned filter may be represented by a lumped circuit, as shown in Fig. 3[8]. From Fig. 3, the voltage-current relationship can be written as

$$\begin{bmatrix} V_1 \\ 0 \\ \vdots \\ 0 \\ V_n \end{bmatrix} = Z\cdot\begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_{n-1} \\ I_n \end{bmatrix} \tag{5}$$

where

$$Z(s) = s \cdot U_n + j \cdot M \qquad (6)$$

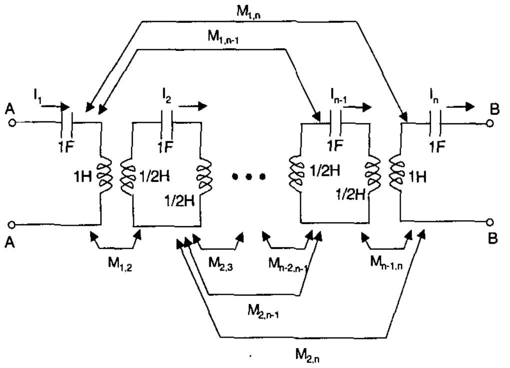


Fig. 3. Equivalent circuit with LC elements for n-pole synchronously tuned filter.

In the above equation, U_n and M are n-th degree unit diagonal matrix and n×n coupling matrix, respectively. Furthermore, the relationship between the impedance matrix, $Z(s)$, and normalized short-circuit admittances are as follows[8]:

$$y_{11} = (Z^{-1})_{11} \qquad (7\text{-a})$$

$$y_{21} = (Z^{-1})_{n1} \qquad (7\text{-b})$$

$$y_{22} = (Z^{-1})_{nn} \qquad (7\text{-c})$$

According to normalized and unnormalized scheme in Fig. 2, the relationship between unnormalized and normalized short-circuit admittances can be represented as follows:

$$y'_{11} = n_1^2 y_{11} \qquad (8\text{-a})$$

$$y'_{21} = n_1 n_2 y_{21} \qquad (8\text{-b})$$

$$y'_{22} = n_2^2 y_{22} \qquad (8\text{-c})$$

From Eq. (4-a), (7-b), and (8-b), we can obtain the final equations for extracting the network parameter:

$$|Z(s)| = A(s) \qquad (9\text{-a})$$

$$n_2^2 \cdot (Adj(Z))_{nn} = B(s) \qquad (9\text{-b})$$

$$n_1 n_2 \cdot (Adj(Z))_{n1} = P(s)/\varepsilon \qquad (9\text{-c})$$

where *Adj(z)* is the adjoint of a n×n matrix Z[10].

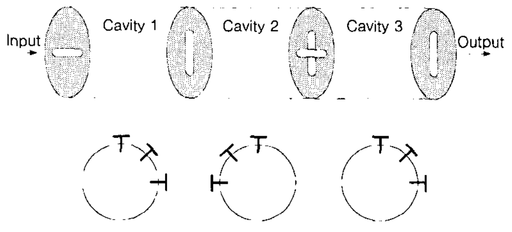
Ⅲ. Example

Let the transfer function is given from the filter specification by determining pole and zero locations:

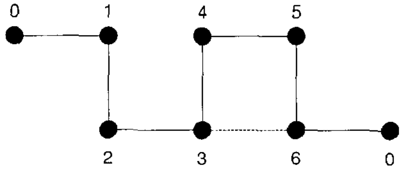
$$t(s) = \frac{1}{\varepsilon} \frac{s^2 + a^2}{s^6 + a_5 s^5 + a_4 s^4 + a_3 s^3 + a_2 s^2 + a_1 s + a_0} \qquad (10)$$

where

a_5=2.190090
a_4=3.969029
a_3=4.385213
a_2=3.595277
a_1=1.901726
a_0=0.546886
a^2=2.25
ε=4.12556



(a) Configuration



(b) Signal Flow

Fig. 4. 6-Pole dual-mode filter with cross coupling at M36

Since, the discussion of pole and zero locations is well presented in [5] and [6], it is not repeated in this paper. According to the transfer function of the filter, two possible dual-mode filter structure(Fig. 4 and Fig. 6) can be taken into consideration.

To realize the dual-mode filter of the type shown in Fig. 4, six mutual coupling parameters(m_{12}, m_{23}, m_{34}, m_{45}, m_{56}, m_{36}) and two in/output coupling parameters(n_1, n_2) must be obtained. From the signal flow of the filter, the coupling matrix of the filter can be written as

$$M=\begin{bmatrix} 0 & m_{12} & 0 & 0 & 0 & 0 \\ m_{12} & 0 & m_{23} & 0 & 0 & 0 \\ 0 & m_{23} & 0 & m_{34} & 0 & m_{36} \\ 0 & 0 & m_{34} & 0 & m_{45} & 0 \\ 0 & 0 & 0 & m_{45} & 0 & m_{56} \\ 0 & 0 & m_{36} & 0 & m_{56} & 0 \end{bmatrix} \qquad (11)$$

Therefore, the coupling matrix and in/output coupling parameters can be obtained form Eq. (9):

$$M=\begin{bmatrix} 0 & 0.6508 & 0 & 0 & 0 & 0 \\ 0.6508 & 0 & 0.5930 & 0 & 0 & 0 \\ 0 & 0.5930 & 0 & 0.4856 & 0 & -0.5028 \\ 0 & 0 & 0.4856 & 0 & 0.9956 & 0 \\ 0 & 0 & 0 & 0.9956 & 0 & 1.3092 \\ 0 & 0 & -0.5028 & 0 & 1.3092 & 0 \end{bmatrix}$$

$$n_1 = 0.8440$$

$$n_2 = 1.4799 \qquad (12)$$

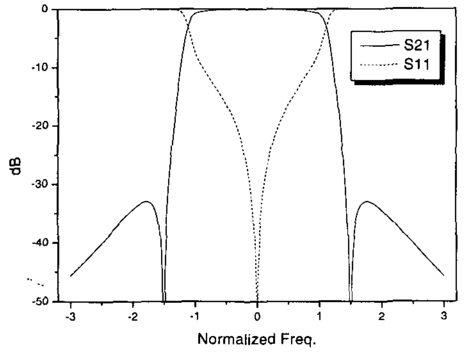


Fig. 5. Normalized transmission and reflection response of the filer shown in Fig. 4.

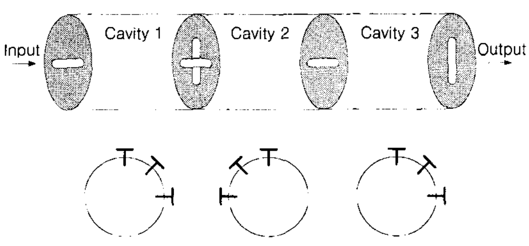
From the coupling matrix and the in/output coupling parameters of the filter, the transmission and reflection characteristics can be obtained as shown in Fig. 5.

Fig. 6 shows another possible configuration and signal flow of the filter. With the same method described for the filter of Fig. 4, the coupling matrix and in/output coupling parameters of the filter of Fig. 6 can be obtained.

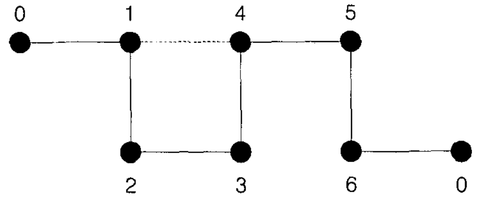
$$M=\begin{bmatrix} 0 & 0.6264 & 0 & -0.1763 & 0 & 0 \\ 0.6264 & 0 & 0.7524 & 0 & 0 & 0 \\ 0 & 0.7524 & 0 & 0.6300 & 0 & 0 \\ -0.1763 & 0 & 0.6300 & 0 & 0.7847 & 0 \\ 0 & 0 & 0 & 0.7847 & 0 & 1.4024 \\ 0 & 0 & 0 & 0 & 1.4024 & 0 \end{bmatrix}$$

$$n_1 = 0.8440$$

$$n_2 = 1.4799 \qquad (13)$$



(a) Configuration



(b) Signal Flow

Fig. 6. 6-Pole dual-mode filter with cross coupling at M14.

Filter response can be predicted from the coupling matrix and in/output coupling parameters. Fig. 7 shows the transmission and reflection response of the filter of which the configuration is shown in Fig. 6 and the coupling coefficients are given in Eq. (13).

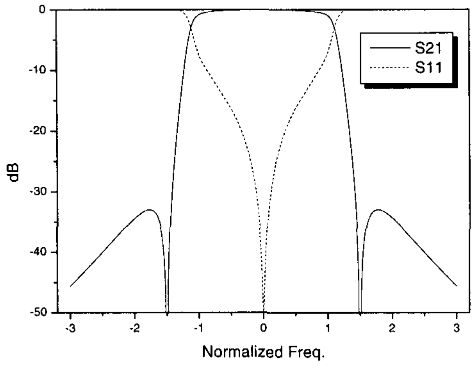


Fig. 7. Normalized transmission and reflection response of the filter shown in Fig. 6.

It is shown that two singly terminated dual-mode filters of different configuration have the same filter response since their coupling matrices and in/output coupling parameters are obtained from the same transfer function.

V. Conclusion

This paper has dealt with the simple method to extract the network parameters of 6-pole dual-mode singly-terminated filter. The network parameters have been obtained easily without complicated algebra such as orthogonal projection and similarity transformation. Network parameters of two 6-pole singly terminated filters have been obtained from the same transfer function, which causes that two filters have the same response. The method described in this paper can also be applied to the other order singly terminated filter

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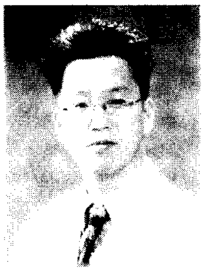

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