COMPUTER-AIDED OPTIMIZATION DESIGN OF BANDPASS FILTER WITH DIELECTRIC RESONATORS

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Abstract By way of employing a multimode method together with the multimode transmission matrix technique based on the theory of planar circuits, the paper presents computer-aided design and optimized design of bandpass filters with dielectric resonators and their sample was tested. The experimental result of the sample shows a reasonable agreement with the designed one.

Key words Filter; Bandpass filter; Dielectric resonator; CAD

I. Introduction

Many methods of planar circuit theory, such as: FEM, BEM and Rayleigh – Ritz methods\(^\text{[1]-[3]}\), employed in designing filters with dielectric resonators have been reported. As it is known they do provide accurate descriptions of properties to some extent. However, they cannot be used in optimization design due to the fact of consuming too much computing time. Reference [4] presents a dominant mode transmission matrix technique for optimized design, which is simple, but is not accurate enough. In order to improve the accuracy of design and reduce the computing time as well, the paper suggests a multimode expansion method together with the multimode transmission matrix technique, which has more advantages than the methods mentioned above.

II. Theory and Procedure

1. Multimode impedance matrix of cascade network and scattering matrix

An arbitrary shaped planar circuit (e.g. a filter as shown in Fig. 1(a)) divided into several sections (e.g. 5 sections) can be regarded as a cascade network as shown in Fig. 1(b). The equivalent multiport network for each section of the filter is characterized by the following impedance matrix equation:

\[
\begin{bmatrix}
V^k \\
V^{k'}
\end{bmatrix} =
\begin{bmatrix}
Z^{11} & Z^{12} \\
Z^{21} & Z^{22}
\end{bmatrix}
\begin{bmatrix}
f^k \\
f^{k'}
\end{bmatrix}
\]

where \(V^k = \begin{bmatrix} V^{(k)}_1, V^{(k)}_2, \ldots \end{bmatrix}^T, V^{k'} = \begin{bmatrix} V^{(k')}_1, V^{(k')}_2, \ldots \end{bmatrix}^T, f^k = \begin{bmatrix} f^{(k)}_1, f^{(k)}_2, \ldots \end{bmatrix}^T, f^{k'} = \begin{bmatrix} f^{(k')}_1, f^{(k')}_2, \ldots \end{bmatrix}^T\).

From Eq. (1), we can obtain the expression in transmission matrix form:

\[
\begin{bmatrix}
V^k \\
f^k
\end{bmatrix} =
\begin{bmatrix}
A^{11} & A^{12} \\
A^{21} & A^{22}
\end{bmatrix}
\begin{bmatrix}
f^k \\
V^k
\end{bmatrix}
\]
And then the entire transmission matrix and the corresponding impedance matrix of the filter can be deduced

\[ B = A_{i} \cdot A_{ii} \cdots A_{v} \]  

(3)

\[
\begin{bmatrix}
V^+ \\
V^-
\end{bmatrix} = \begin{bmatrix}
Z^{ij}_1 & Z^{ij}_2 & \cdots & Z^{ij}_n \\
Z^{ij}_p & Z^{ij}_q & \cdots & Z^{ij}_r
\end{bmatrix} \begin{bmatrix}
I \\\nF
\end{bmatrix}
\]

(4)

In matrix Eq. (4), if \( n \) denotes the highest mode order of ports \( i \) and \( j \) under consideration, then the submatrix of the impedance matrix is \( n \times n \) square matrix:

\[
Z^{ij} = \begin{bmatrix}
Z^{ij}_{11} & \cdots & Z^{ij}_{1q} & \cdots & Z^{ij}_{1n} \\
\vdots & \ddots & \vdots & \ddots & \vdots \\
Z^{ij}_{p1} & \cdots & Z^{ij}_{pq} & \cdots & Z^{ij}_{pn} \\
\vdots & \ddots & \vdots & \ddots & \vdots \\
Z^{ij}_{n1} & \cdots & Z^{ij}_{nq} & \cdots & Z^{ij}_{nn}
\end{bmatrix} = [Z^{ij}_{pq}]
\]

(5)

where \( p \) and \( q \) represent the mode order of ports \( i \) and \( j \) respectively.

Taking normalization by the following relation

\[
[\overline{Z}^{ij}_{pq}] = [r^{(u)}_p \cdot Z^{ij}_{pq}]
\]

(6)

where \( r^{(u)}_p = \sqrt{(p \pi \lambda^{(u)})^2 - k^2} \), one obtains the result of the normalized impedance matrix:

\[
\overline{Z}_{pq} = \begin{bmatrix}
\overline{Z}^{ij}_{pq} & \overline{Z}^{ij}_{p1} & \cdots & \overline{Z}^{ij}_{pq} \\
\overline{Z}^{ij}_{q1} & \overline{Z}^{ij}_{q2} & \cdots & \overline{Z}^{ij}_{qq}
\end{bmatrix}
\]

Fig. 1 Irregular shape planar circuit

Fig. 2 Equivalent multimode network of the \( K \)-th section