A NEW NARROW DUAL-MODE BANDSTOP WAVEGUIDE FILTER

B-5

Qian Jing-ren
Department of Electrical Engineering
China University of Science and Technology
Hefei, Anhui, China
and Zhuang Wei-chen
Xian Institute of Radio Technology
Xian, Shanxi, China

Summary

A complementary relation between a dual mode bandpass and bandstop waveguide filter is found. Then a new idea for constructing bandstop filter is developed. Two trial samples of bandstop filters are constructed to demostrate the principle.

Introduction

Bandstop waveguide filters have been exclusively realized by resonators connected in cascade and spaced an odd multiple of a quarter wavelength apart along the waveguide. In order to improve the frequency selectivity, the number of sections of this type of filters must be increased, which leads to considerable increase in size and weight of the filters.

In this paper a new idea for constructing bandstop waveguide filters is presented. There are only two coupling slots by which a multi-coupled-cavity structure is coupled to the main waveguide of the filter. The multi-coupled-cavity structure has been described by several authors[1,2] for realizing high quality narrow-band bandpass waveguide filters. The same structure is now used to realize bandstop filters.

Theory

A multi-coupled-cavity structure contains several cavities, and in each cavity the orthogonal or dual modes are excided. The couplings take place not only among the modes of different cavities, but also between the dual modes within each cavity. Its equivalent circuit is shown in Fig. 1.

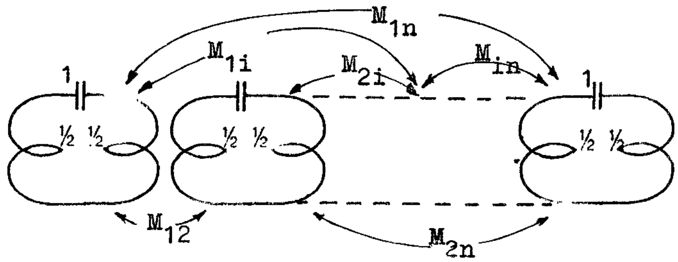
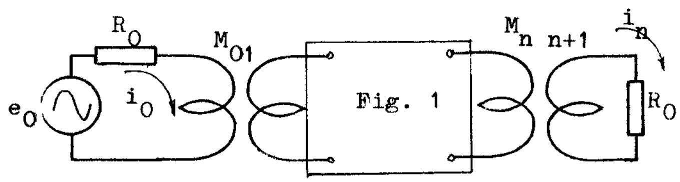
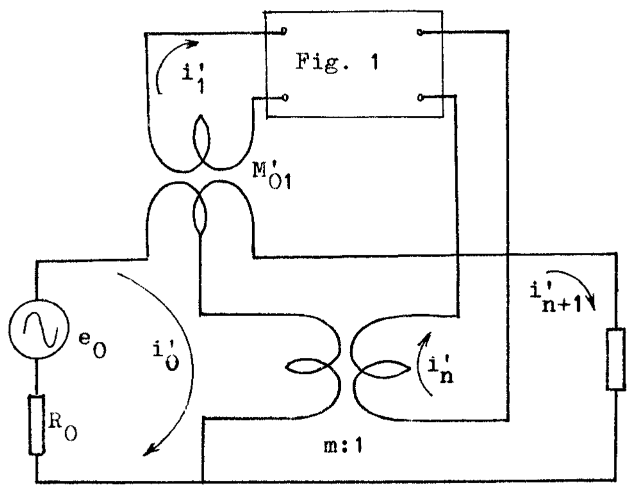


Figure 1. Equivalent Circuit for Multi-Coupled-Cavity Structure

Multi-coupled -cavity structures which have been used to realize bandpass waveguide filters, are now used to construct bandstop waveguide filters. Filter circuits, with a blank block for representing the corresponding circuit shown in Fig. 1, are illustrated in Fig. 2a and 2b, respectively.



(a)Bandpass Filter



Main Waveguide

(b)Bandstop Filter

Figure 2. Filter Circuits

The equivalent circuit for the bandpass filter is shown in Fig. 2a. The first and the last circuits in Fig. 1 are coupled to the source and the load, respectively, through the couplings M_{01} and $M_{n\ n+1}$.

With reference to the equivalent circuits in Fig.1 and Fig. 2a, the loop equations for narrow bandwidths can be written as

$$\begin{bmatrix} e_1 \\ o \\ o \\ \vdots \\ o \\ o \end{bmatrix} = \begin{bmatrix} Z+R & jM_{12} & jM_{13} & \cdots & jM_{1n} \\ jM_{12} & Z & jM_{23} & \cdots & jM_{2n} \\ jM_{13} & jM_{23} & Z & \cdots & jM_{3n} \\ \cdots & & & & \cdots \\ \cdots & & & Z & jM_{n-1\,n} \\ jM_{1n} & jM_{2n} & \cdots & jM_{n-1\,n} & Z+R_n \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \\ \vdots \\ \vdots \\ i_n \end{bmatrix} \quad (1)$$

where

$$R=M_{o1}^2/R_o, \quad R_n=M_{n\,n+1}^2/R_o, \quad Z=j(\omega-1/\omega), \quad e_1=-je_oM_{o1}/R_o \quad (2)$$

and the meaning of e_o, R_o is shown in Fig. 2a.

In Fig. 2b, an equivalent circuit for the new type of bandstop filter is shown. The first and the last circuits in Fig. 1 are coupled to the main waveguide at the same place but with a 90° phase difference. Thus if coupling M'_{o1} is expressed as a series mutual inductance, then coupling $M'_{n\,n+1}$ will be expressed as a shunt ideal transformer with ratio m:1. This can be realized by opening a longitudinal and a transverse slots at the same place of the broad wall of a rectangular waveguide. The required phase differences are achieved, because in the main waveguide the magnetic field components H_z and H_x, which link the fields of the dual modes through the longitudinal and the transverse slots, respectively, are 90° out of phase with each other.

With reference to Fig. 1 and Fig. 2b, the loop equations for narrow bandwidth can be written as:

$$\begin{bmatrix} e_o \\ o \\ o \\ \vdots \\ o \\ o \end{bmatrix} = \begin{bmatrix} R_o & jM'_{o1} & o & \cdots & o & R_o \\ jM'_{o1} & Z & jM_{12} & \cdots & jM' & o \\ o & jM_{12} & Z & \cdots & jM_{2n} & o \\ \cdots & & & & & \\ o & jM' & jM_{2n} & \cdots & Z & -R_o/m \\ m & o & o & \cdots & -1 & -m \end{bmatrix} \begin{bmatrix} i'_o \\ i'_1 \\ i'_2 \\ \vdots \\ i'_n \\ i'_{n+1} \end{bmatrix} \quad (3)$$

where $M'=M_{1n}-M'_{o1}/2m$.

From Fig. 2, the transmission and reflection coefficients for both filters can be found

$$t=2i_{n+1}R_o/e_o, \qquad r=1-2i_oR_o/e_o \,. \quad (4)$$

Under the symmetry conditions

$$M_{ij}=M_{n+1-i\;n+1-j}, \qquad M_{o1}=M_{n\,n+1} \quad (5)$$

and identity conditions

$$2M_{o1}=M'_{o1}\,, \qquad 2M_{n\,n+1}=M'_{n\,n+1}\,, \quad (6)$$

we find, from (1)-(4) and $m=R_o/M'_{n\,n+1}$,

$$t=jr', \qquad r=-t' \,. \quad (7)$$

Where the letters with or without prime sign denote quantities for bandpass or bandstop filter, respectively.

As the equivalent circuits in Fig. 2 are assumed to be loss free, then from the power conservation law we have

$$|t|^2+|t'|^2=1\,, \qquad |r|^2+|r'|^2=1 \quad (8)$$

This is the complementary relation between the bandpass and bandstop filters. Their transmission responses are complementary to each other. The passbands correspond to the stopbands and the transmission poles and zeros of one filter correspond to the zeros and poles of the another. It can also be proved that both the two complementary filters have same time delay response.

This complementary relation makes it possible to synthesize the bandstop filters by the methods of synthesizing bandpass filters with coupled cavities.

Experimental Results

To demostrate the principle discussed, two sample filters working on 5 cm wavelength were constructed. The first sample is a fourth-order antimetric elliptic bandstop waveguide filter. Its complementary filter is the bandpass filter described by Williams[1]. It seems difficult to use the in-line configuration of Williams' filter in our case. But it is easy to transform the in-line configuration to folded configuration by exchanging the mode numbers 2 for 4 only. As shown in Fig. 3, the output mode 4 is coupled to the main waveguide by the coupling slot which is perpendicular to the input coupling slot.

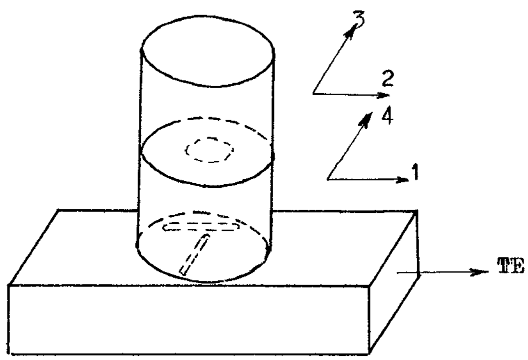


Figure 3. A Four-Mode Elliptic Bandstop Waveguide Filter

The second sample is a six-mode waveguide bandstop filter. Its construction is similar to the first one as shown by the photograph of Fig. 4. The method of synthesis of this filter is the same as that described by Atia and Williams.[2]

Experiments on these two samples were made. One of the results, the transmission and return loss characteristics of the second sample, is shown in the Fig. 5.

From the experimental results, it is concluded that the new type of waveguide bandstop filters is realized and the complementary principle is confirmed.

Acknowledgement

We wish to thank Prof. Huang Hung-chia for his interest in this work.

References

1. A.E. Williams, "A Four-Cavity Elliptic Waveguide Filter," IEEE Trans. On MTT Vol. MTT-18, No.12, pp 11o9-1114, (197o).
2. A.E. Atia and A.E. Williams, "Narrow-Bandpass Waveguide Filter," IEEE Trans. On MTT Vol. MTT-2o, No.4, pp 258-265, (1972).

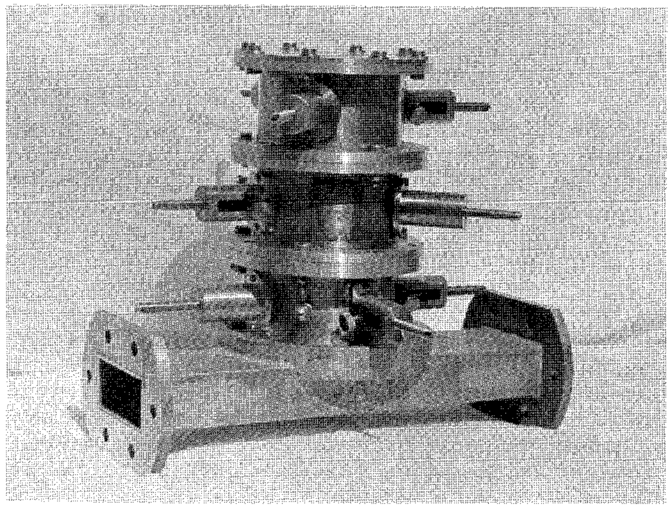


Figure 4. Photograph of the Six-Mode Bandstop Filter

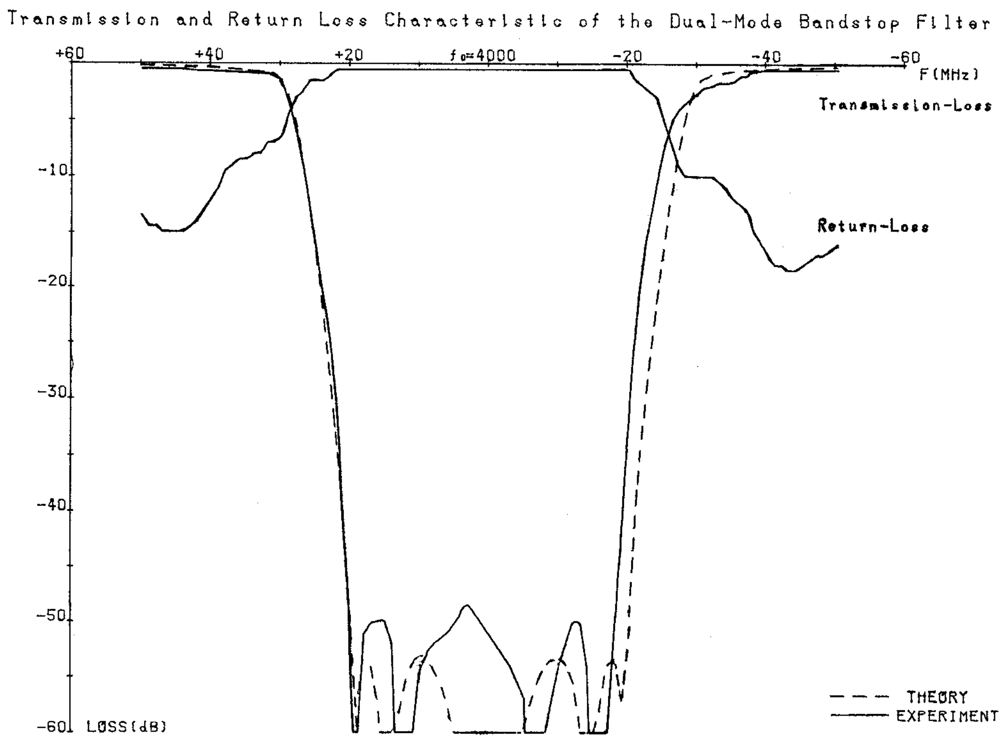


Figure 5. Transmission and Return Loss Characteristics of the Six-Mode Bandstop Filter (Center frequency: 4oooMHz, Bandwidth: 4oMHz)