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CAD OF RECTANGULAR AND RIDGED WAVEGUIDE BANDPASS FILTERS

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ABSTRACT

The parameters of equivalent circuit of an inductive strip inserted in ridged waveguides are analyzed. A CAD of bandpass filters is developed. The experimental results are in good agreement with theoretical calculation.

Introduction

The design of waveguide bandpass filters with inductive strips inserted in rectangular and ridged waveguide was first developed by Konishi [1] [2]. However, computer-aided design of rectangular waveguide and ridged waveguide bandpass filters have not been revealed to date. The main features of the present work are: (1) the solution of boundary problems including the evaluation of eigenvalues of ridged waveguides and the equivalent parameters of inductive strips in ridged waveguides. We obtained a set of curves reprensenting series and parallel reactances in equivalent T networks which has not been published; (2) the development of a computer program containing main program and subroutines on the bases of microwave network synthesis theory and field theory.

Theory

A strip inserted in rectangular and ridged waveguide shown in Fig.1(a) and 1(b) respectively is equivalent to a T network shown in Fig.1(c). The parameters Xs and Xp are related to input admittance $y^{(1)}$ and $y^{(2)}$ on plane T_1 [3].

$$jXs=1/y^{(1)}\ ;\quad jXp=\tfrac{1}{2}(1/y^{(2)}-1/y^{(1)}) \qquad (1)$$

where $y^{(1)}$ is the input admittance when plane T_O is an electric wall and $y^{(2)}$ is that when T_O is magnetic wall. Since the principles of deriving the variation expression for $y^{(i)}$ (i=1,2) have been reported in [1], only the final result will be given. The general expression of $y^{(i)}$ is as follows [1]:

$$y^{(i)}=\frac{\sum\limits_{n=3,5,\cdots}^{\infty} Y_{on}\langle \bar{\mathcal{E}}^{(i)}\cdot \bar{e}_n^{(1)}\rangle^2+\sum\limits_{m=1}^{\infty} Y_m Q_m^{(i)}\langle \bar{\mathcal{E}}^{(i)}\cdot \bar{e}_m^{(2)}\rangle^2}{Y_{01}\langle \bar{\mathcal{E}}^{(i)}\cdot \bar{e}_1^{(1)}\rangle^2} \qquad (2)$$

where Y_{on}=wave admittance for TE_{no} mode in region I

$\bar{e}_n^{(1)}$ =vetor mode function of nth order mode in region I

Y_m=wave admittance for TE_{mo} mode in region II

$\bar{e}_m^{(2)}$ =vetor mode function of mth order mode in region II

$Q_m^{(1)}$ =coth(T_m W/2)

$Q_m^{(2)}$ =1/$Q_m^{(1)}$

T_m=propagation constant of TE_{mo} mode in region II

$\bar{\mathcal{E}}^{(i)}$=electric field on the interface T_1

Various methods for the evaluation of eigenvalues in ridged waveguides which is contained in Y_{on} and e_n have been presented by Hopfer [4], Pyle [5] and Montgomery [6]. The present paper describes an application of Galerkin's method, developed by Montgomery, to thin ridge waveguide case. For the sake of simplicity we make two assumptions: (1) the effect of x components of transverse electric fields in region I is negligible, (2) the mode function of $\bar{e}_n^{(1)}$ is represented by 1st term of an infinite series. The transcendental equation of the eigenvalue of nth mode in ridged waveguide k_{Tn} was solved by the recursion formula presented by Barlow [7].

Since the ridge used in filters is very thin, an alternative method is used for accuracy check. In Fig.2(a) the single-ridged waveguide (zero thickness) has an eigenvalue

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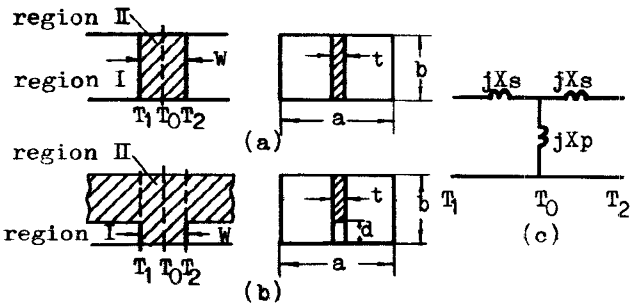

Fig.1 Strip inserted in (a) rectangular waveguide, (b) ridged waveguide and (c) their equivalent T network.

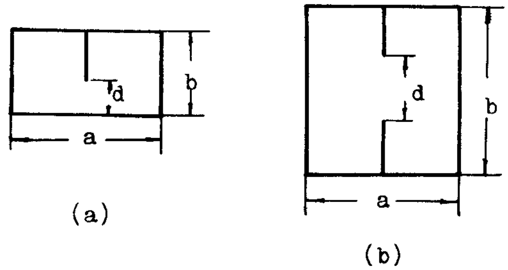

Fig.2 (a) Single-ridged waveguide and (b) double-ridged waveguide

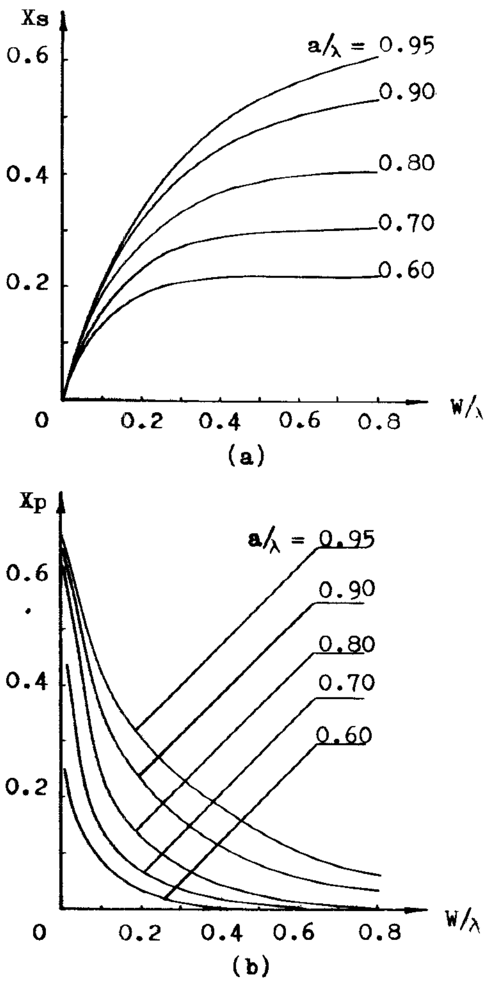

Fig.3 The parameters of equivalent T network of a strip inserted in a ridged waveguide. (a) Xs and (b) Xp.

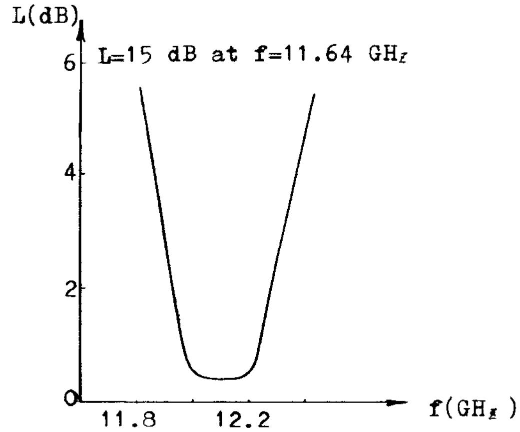

Fig.4 Measured frequency characteristics of a rectangular waveguide bandpass filter.

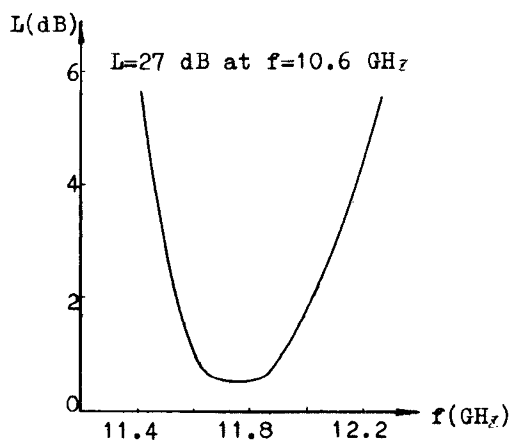

Fig.5 Measured frequency characteristics of a ridged waveguide bandpass filter.

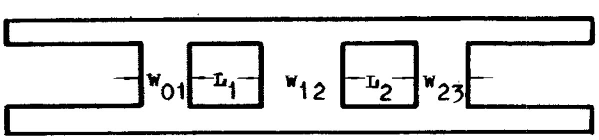

Fig.6 Strips in rectangular waveguide.

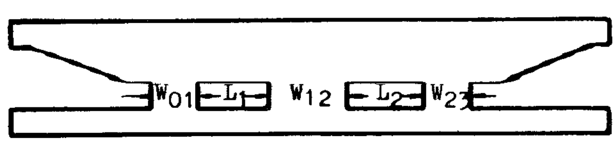

Fig.7 Strips in ridged waveguide.

approximately equal to that of a double-ridged waveguide shown in Fig.2(b). The later is only a special case of a fin line, whose eigenvalue can be evaluated by spectral domain technique(SDT) as presented by Knorr [8]. The results shown in table I given by two methods are in good agreement.

A computer subroutine was developed to calculate the eigenvalues of ridged waveguide and the equivalent parameters Xs and Xp of a strip. A set of Xs and Xp curves for ridged waveguides with b/d=2, $a/\lambda = 0.6 \sim 0.95$ and $t/\lambda = 0.02$ were shown in Fig.3. The subroutine for filter synthesis developed in 9 is re-used to complete the computer program.

Table I

(a=22.86 mm)

	b mm	d mm	k_T 1/m
Single-ridged (by Galerkin)	10.16	5.08	111
Double-ridged (by SDT)	20.32	10.16	110

Features of the Computer Program

The program is user-oriented. The input data are specifications of filters to be designed, such as frequencv band, passband ripple, stopband insertion loss. The main program in corporation with the subroutine will give out all the necessary dimensions of structure. The input frequency has to be increased by 2% in rectangular waveguide case in order to compensate the end effect of the strip.

Fig. 4 and Fig. 5 are the measured frequency characteristics of a rectangular waveguide bandpass filter and a ridged waveguide bandpass filter respectively. Their original specifications are as follows:

Specifications

	Rectangular	Single-ridged
Frequency Band	12-12.2 GH	11.7-11.9 GH
Passband Ripple	0.01 dB	0.01 dB
Stopband Attenuation	15 dB	20 dB
Stopband Frequency	11.6 GH	9.3 GH
Waveguide Dimension	a×b=22.86 ×10.16 mm	a×b=22.86× 10.16 mm d=5.08mm
Thickness of Strip	t=0.5 mm	t=0.5 mm

The computed dimensions referring to Fig. 6 and Fig. 7 are as follows:

Fig. 6 $W_{01}=W_{23}=5.20$ mm $W_{12}=15.6$ mm $L_1=L_2=8.59$ mm

Fig. 7 $W_{01}=W_{23}=2.63$ mm $W_{12}=10.98$ mm $L_1=L_2=9.79$ mm

It is obvious that the measured characteristics are in good agreement with original specifications.

Conclusions

We presented the CAD of waveguide bandpass filters. It is based on the boundary problem solutions and the theory of microwave network synthesis, the program is checked by various experiments. The curves of equivalent parameters of the strips are believed useful in practice.

References

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