WAVEGUIDE FILTER DESIGN BY REDUCING MODAL INTERFERENCE THROUGH CROSS-SHAPED SLOTS

Sungtek Kahng
Dept. of Information and Telecommunication Eng., University of Incheon,
Dohwa-dong, Nam-gu, Inchoen, Republic of Korea
E-mail : s-kahng@incheon.ac.kr

I. Introduction

Waveguide filters are important passive RF and microwave components and their design techniques have been presented up to date as [1- 4].

Multiple-mode couplings through cross-shaped slots [2-4] are frequently used to bring lighter and less bulky features to circular waveguide filters. In particular, the question is raised that vertical and horizontal couplings will possibly ruin their mutual independence with regard to each of the cross-shaped slots of the filter, to assure the performance as well as the removal of unnecessary tuning events.

This paper, proposes a new method to reduce the undesirable modal interference created through the cross-shaped slot, while keeping the required coupling relation. A 4th-order dual-mode filter is designed and the simulation results obtained before and after deciding proper slot sizes are compared for validating the proposed method.

I1. Theory

The coupling coefficients of $\overline{\overline{M}}$ for a filter has M_{pq} as the inter-cavity couplings, but $M_{pp} = 0$. Also, M_{pq} can be concerned with inverter constant K_{pq} as in [4]

$$K_{pq} = M_{pq} \frac{3\pi \cdot \Delta f}{2 f_0} \quad (1)$$

f_0 is the center frequency and Δf is the bandwidth. If an 4th order dual-mode filter is selected, it has the following signal flow as in Fig.1. This shows the way the nodes(number as resonance modes) are related

ISBN: 89-86522-79-9 94460©KEES

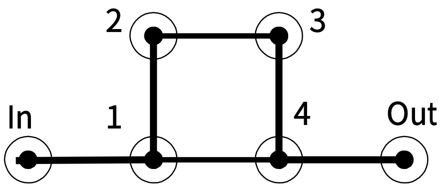

Fig. 1 Signal flow of an 4th-order dual-mode filter

In each cavity of a circular dual-mode waveguide filter, a pair of degenerate modes(or polarizations) occur according to boundary condition. In Fig. 2, horizontal and vertical polarizations in cavity 1 are shown and coupled through a cross-shaped slot, with those in cavity 2

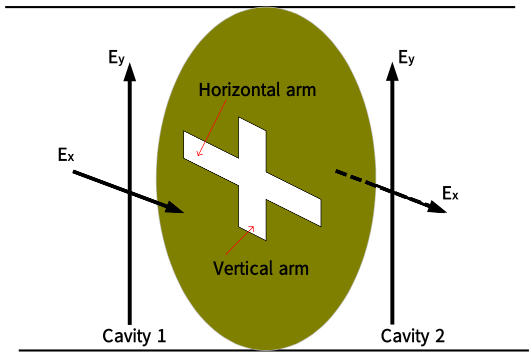

Fig. 2 Coupling through a cross-shaped slot

With calculated coupling coefficients, the horizontal and vertical arms of a cross-shaped slot can be separately obtained in accordance to the conventional and quick ways. If only the vertical and horizontal couplings are completely independent, the conventional methods will hold good where the following procedural equations relate the coupling coefficients to physical dimensions of the slot. In the first place, the coupling values of modes *p* and *q* are converted into magnetic polarizabilities $P_{M,\text{int},pq}$.

$$P_{M,\text{int},pq} = \frac{l_c^3 (3R_c^{\,2})}{\lambda_0^2}\frac{\Delta f}{f_0} M_{pq} \qquad (2)$$

R_c, l_c and λ_0 denote the cavity radius, the cavity length and the waveguide wavelength at the center frequency, respectively. And then, $P_{M,\text{int},pq}$ or P_m is put as goal values and the sizes are sought via the following approximate formula[5].

$$P_m(L_s) = P_m'(L_s)10^{-\alpha}/[1-(\frac{\lambda_l}{\lambda_0})^2] \qquad (3)$$

where $P_m'(L_s) = L_s^3[0.187+0.052(\frac{W_s}{L_s})(1-\frac{W_s}{L_s})]/[\ln(1+2.12\frac{L_s}{W_s})]$, $\alpha = \frac{8.19t_s}{\lambda_l}\sqrt{1-(\frac{\lambda_l}{\lambda_0})^2}$

L_s, W_s, t_s and λ_l denote the slot length, width, thickness and slot resonance length, respectively.

The physical dimensions obtained via Equation (3) compose a cross-shaped slot. This ends up with too much of manual tuning caused by the mutual interference between the vertical and horizontal couplings through the slot. To circumvent this undesirable situation, the following methodology is proposed. First, a cross-shaped slot is decomposed into the vertical and horizontal arms and their initial sizes are independently evaluated using Equation (3). Second, any trustworthy full-wave analysis methods are employed to observe possible change of the couplings, when the two arms are combined into the cross-shaped discontinuity. Third, it is checked how much the change in couplings varies the overall performance. Fourth, if it does not satisfy the specification, returning to the first step, taking into consideration feasibility, the new width and length will be sought. Then, the slot will be narrower and longer to suppress the undesirable modal interference.

III. Numerical experiments and results

A 4th order filter is designed for 12.475GHz as center frequency, 0.25dB as ripple, a 35MHz wide pass-band, attenuation less than -25dB at 12.44GHz and 12.51GHz. Initially, desired K_{14} is –0.003093 and K_{23} 0.010020. The slot lengths become 4.045mm for K_{14} and 5.920mm for K_{23} with 1.2mm as the common width. When these form a cross-shaped slot, K_{14} changes to –0.002851 and K_{23} to 0.008280 found by a commercial FEM tool use

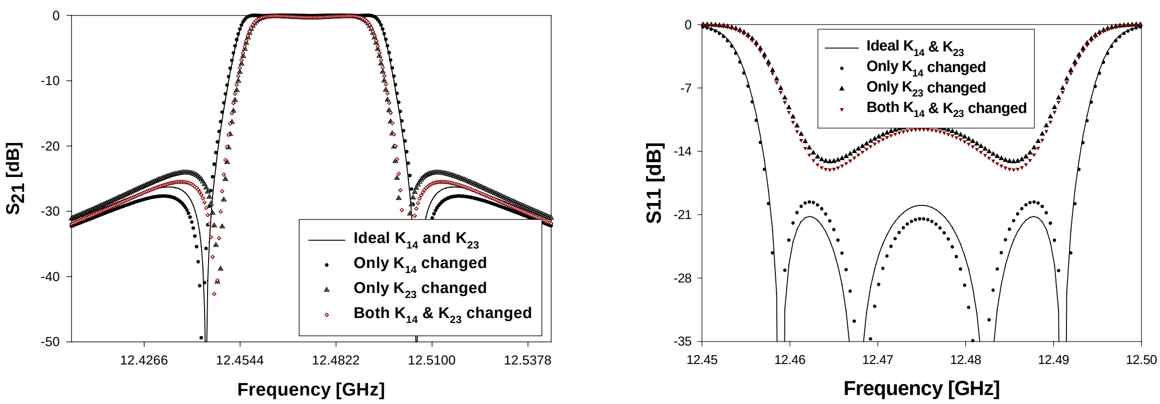

Fig. 3 S_{21} and S_{11} by the conventional method

In Fig. 3, resultant S21 and S11 show discrepancy from their corresponding ideal curves and it is mostly due to the unwanted interference between the horizontal and vertical polarizations.

To keep the desired K_{14} and K_{23}, the proposed method provides the width of 0.7mm, slot lengths 4.390mm for K_{14} and 6.580mm for K_{23}. Figure 3.shows the results before and after the improvement.

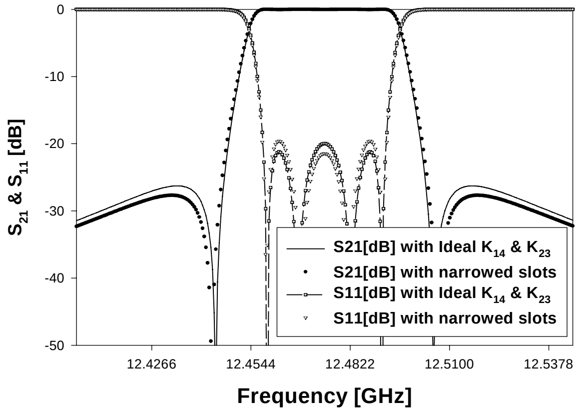

Fig. 4. Improved frequency responses

This makes the proposed methodology confirmed in its validity. The resultant and ideal curves of in-band insertion loss fit completely in $S_{21}$and, particularly the cases of S_{11} agree well that are very sensitive to the small change in the coupling coefficients.

IV. Conclusion

A method is proposed to reduce the undesirable modal interference, examining its level, changing the slot dimensions for a given coupling value, ultimatley creating good performance It has been observed with an example of 4 order dual-mode filter and proves that the suggested method can enhance the design and relaization.

References

[1] G. L. Matthaei et al, *Microwave Filters, Impedance Matching Networks, and Coupling Structures*, Dedham, MA: Artech House Books, 1964

[2] A. E. Williams, “A Four-Cavity Elliptic Waveguide Filter,” *IEEE Trans. on Microwave Theory and Technique*, vol. 18, No. 12, pp. 1109-1114, Dec., 1970

[3] A. E. Atia and A. E. Williams, “Narrow-Bandpass Waveguide Filters,” *IEEE Trans. on Microwave Theory and Technique*, vol. 20, No. 4, pp. 258-265, April, 1972

[4] J. Bornemann et al, *Waveguide Components for Antenna Feed Systems*, Nordwood, MA: Artech House Books, 1993

[5] McDonald, “Simple approximations for the longitudinal magnetic polarizabilities of some small apertures,” *IEEE Trans. MTT*, Vol. 36, No. 7, pp. 1141 – 1144, July, 1988