A Compact Elliptic-Function BPF using Triple-mode Cavities for Terrestrial Digital Television Transmitters

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Abstract **A compact six-pole elliptic-function BPF for terrestrial digital television transmitters is developed using two triple-mode cavities. The BPF needs a very sharp cut-off response to reject neighboring channels. Therefore, it needs to achieve exact coupling parameters without parasitic couplings. A new coupling method is presented to achieve these couplings independently of each other through one wall between two triple-mode cavities. A compact BPF test model which uses this method has resulted in good performance for digital television transmitters.**

Ⅰ. Introduction

In many countries, plans for terrestrial digital television broadcasting have been developed, and has begun broadcasting in some of them. The channel allocations of these plans are mixed analog and digital television channels without gird-bands. Therefore, the BPF of digital television transmitters needs a very sharp cut-off amplitude response to reject neighboring channels.

The specifications of the terrestrial digital television transmitters' BPF in Japan are shown in Fig. 1 and many of the currently developed BPFs are eight-pole elliptic-function BPFs using dual-mode cavities.

To develop compact BPF, we have designed carefully a six-pole true elliptic function BPF which met the specification and constructed it using two triple-mode cavities. However, there is a coupling problem when using the triple-mode cavities for six-pole true elliptic-function BPFs. The BPF needs a very sharp cut-off response to reject neighboring channels. Therefore, it needs to achieve exact coupling parameters without parasitic couplings. Specifically, it needs to have a construction with three couplings, two cross couplings and one cascade coupling, through one wall between two triple-mode cavities. Some coupling methods have been proposed [1][2][3]. However, these methods are not sufficient to independently control the couplings between the triple-mode cavities. In this paper, a newly coupling method is presented which controls these couplings independently of each other through one wall between two triple-mode cavities. A compact BPF test model using this newly developed method has resulted in good performance of digital television transmitters.

This paper describes the designed coupling parameters of the six-pole true elliptic-function BPF, the proposed coupling method and the experimental results of the test model.

Ⅱ Basic Design of the BPF

As shown in Fig.1, the BPF of the terrestrial digital television transmitters needs a very sharp cut-off response. Therefore, an elliptic filter construction is most suitable for the BPF. The elliptic filter can be achieved using a basic low-pass filter by using frequency transform. Fig. 2 shows the relationship between a basic low pass filter and an elliptic-function low-pass filter. "*Ap*" in Fig. 2 is the maximum attenuation in the pass band and "*As*" is the minimum attenuation in the stop band. The frequency of the pass-band edge $\sqrt{k}$ of the basic low-pass filter is converted to the elliptic-function low-pass filter's pass-band edge $\sqrt{h}$. These parameters are given as follow.

$$\sqrt{k} = \sqrt{\frac{(10^{-A_P/10} - 1)}{(10^{-A_S/10} - 1)}} \qquad \sqrt{h} = \sqrt{\frac{fp}{fs}}$$

From Fig.1, fp=2.8MHz and fs=3.2MHz, then the specified BPF's h=0.875.

When *Ap* is fixed at 0.01dB, RL=-26dB, and 0.1dB, RL=-16.4dB, the relationship of the required elliptic filter order N via. *As*, minimum attenuation in stop band, is shown in Fig.3.[4]

From this relationship, when 0.01dB is selected as *Ap*, a six-pole elliptic filter can achieve about 24dB of *As*. This means that the specifications, shown in Fig.1, can be met using the six-pole

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elliptic BPF.

If Ap=0.1dB(R.L.=-16.4dB) is selected As=30dB can be achieved.

Fig. 4 shows the optimized amplitude response of the six-pole elliptic-function BPF, and the coupling coefficients are shown in Table 1.

This calculated filter's insertion loss is about 0.1dB, and the pass band ripple is about 0.35dB using 20000 of resonator's Qo. The stop band rejection characteristics are larger than 21dB, and the return loss in the pass band is smaller than –25dB. As shown in Fig.5, the six-pole elliptic-function filter is constructed by two rectangular triple-mode cavities and the electrical cavities 1, 2, 3 of the BPF are assigned to resonance modes, TE1, TM2, TE3 respectively of the triple mode cavity 1 and the electrical cavities 4, 5, 6 are assigned to resonance modes TE4, TM5, TE6 respectively of the second triple-mode cavity.

To achieve these couplings independently through one wall, a new method is developed.

Ⅲ. Coupling method

Coupling k34, cascade coupling, k16 and k25, cross couplings, have to be achieved through one wall between two cavities as illustrated in Fig 5. The magnetic field distribution of the TE1, TE3 and TM2 modes on the surface of the wall are shown in Fig.7 with each coupling apertures. The coupling k34 between TE3 and TE4 modes is the largest value, as shown in Table 1, so it is desirable to control it independently. For this reason, slot 3, located at center and parallel to the magnetic field of TE3 mode, is selected for the k34 coupling as shown in Fig.6. Slot 3 is perpendicular to another mode's magnetic fields. Hence, k34 can be designed independently. It is desirable to give the slot longer length for a larger coupling value of k34. However, it has to be separated at the center, because a center hole aperture excites stronger electric coupling between TM2 and TM5. The coupling k25 between TM2 and TM5 is a smaller coupling as shown in Table 1, which means that the center hole coupling, like a cross shaped aperture [1], is not desirable for k25. Therefore, slot 3 is separated at the center and isolates the electric coupling of the TM2 and TM5 modes. The coupling k25 is achieved by slot 2, illustrated in Fig.6. It is located at an off-set position from the center and parallel to the magnetic field of TM2 and TE3 modes. Therefore, slot 2 performs two couplings of k25 and k34. The strength of the coupling of slot 3 becomes weaker due to the separation at the center portion.

Hence, the coupling k34 needs slot 2 with slot 3 to achieve the required design value of k34. Slot 1 is located parallel to the center of the magnetic field of TE1, separated at the center portion, and can control only k16. Fig.8 shows a simulated coupling coefficient of slot 1's k16 with and without slot 2 respectively.

When the length of slot 2 is changed, the coupling coefficient of k16 does not change. Therefore, k16 can be controlled independently from k25. The length of slot 1 for the required coupling coefficient of k16 is 11cm.

Fig.9 show a simulated coupling coefficient of slot 2's k25 with and without slot 1. It shows that k25 can be controlled independently and the length of slot 2 for the required k25 is 11.5cm. Fig.10 shows the simulated coupling coefficient of slot 3's k34 with fixed length of 11cm of slot 2. The required length of slot 3 is 14cm.

Ⅳ. Test Results

Fig.11 shows the test model of six-poles elliptic-function BPF. The tuning of each modes resonance and couplings were easier to complete. The measured amplitude response is shown in Fig. 12. The characteristics show a good performance for the terrestrial digital television transmitter.

Ⅴ. Conclusions

A compact six-pole elliptic-function BPF for terrestrial digital television transmitters has been developed by using two triple-mode rectangular cavities. The BPF needs a very sharp cut-off response to reject neighboring channels. Therefore, it needs to achieve exact coupling parameters without parasitic couplings. A new coupling method has been presented to achieve these couplings independently of each other through one wall between two triple-mode cavities. By using this method, a compact BPF has been tested which showed a good amplitude response.

[1] RENE R. BONETTI, AWILLIAMS "Application Dual TM modes to Triple- and Quadruple-Mode Filters" IEEE Trans. Microwave Theory Tech., vol.MTT-35, pp. 1143-1149, December 1987.

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[3] J. UHER, J. BOMEMANN, UWE ROSENBERG, Waveguide Components for Antenna Feed Systems:Theory and CDA Boston,London Artech House 1992 pp.227-248.

[4] RISABURO SATO "Transmission Circuit Theory" Tokyo Japan Corona Co.,Ltd. 1963.

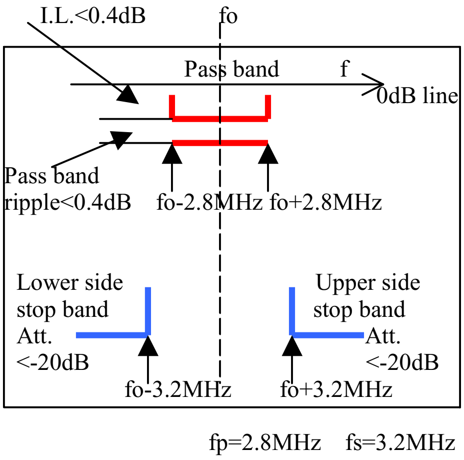


Fig. 1. A specification of the attenuation response of the BPF for terrestrial digital television transmitters in Japan.

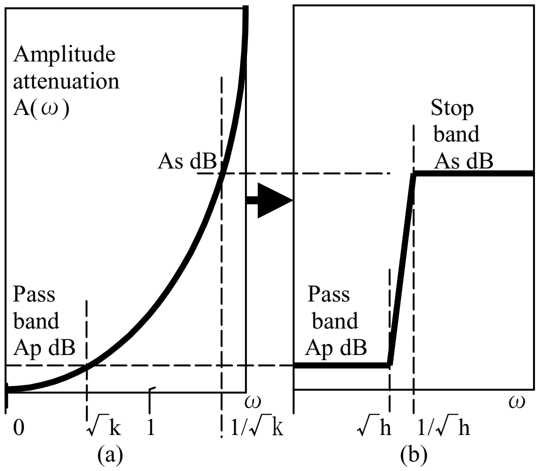


Fig. 2. Frequency transformation from a basic low pass filter to an elliptic low pass filter. (a)Basic low pass filter response. (b)Frequency transformed low pass filter response

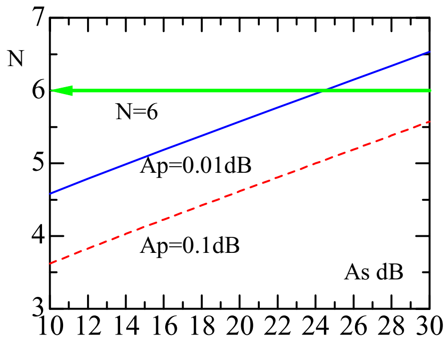


Fig. 3. The relationship of the required elliptic filter order N via. As, minimum attenuation in stop band.

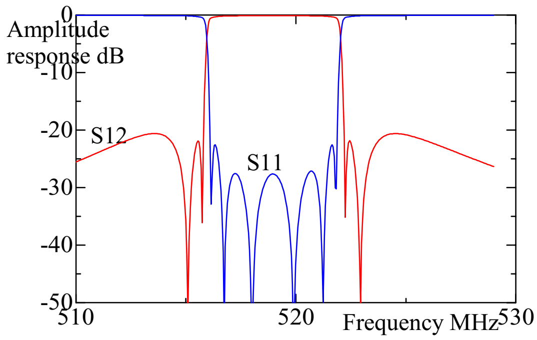


Fig. 4. The calculated amplitude response of six-pole elliptic-function BPF

TABLE Ⅰ
THE COUPLING CEFFICIENTS IN THE CALCULATED ELLIPTIC-FUNCTION FILTER

Coupling coefficient values and assigned modes of the triple-mode cavities		
Coupling coefficient values		Assigned modes
K12 K56	0.009753	TE1-TM2 TE4-TM5
K23 K45	0.005088	TM2-TE3 TE4-TM5
K34	0.010074	TE3-TE4
K16	0.002834	TE1-TE6
K25	-0.006010	TM2-TM5

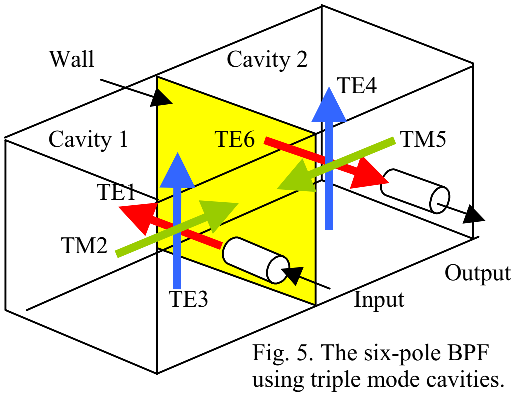
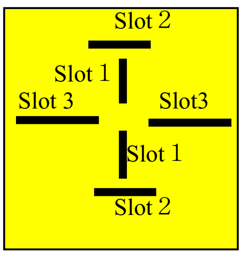
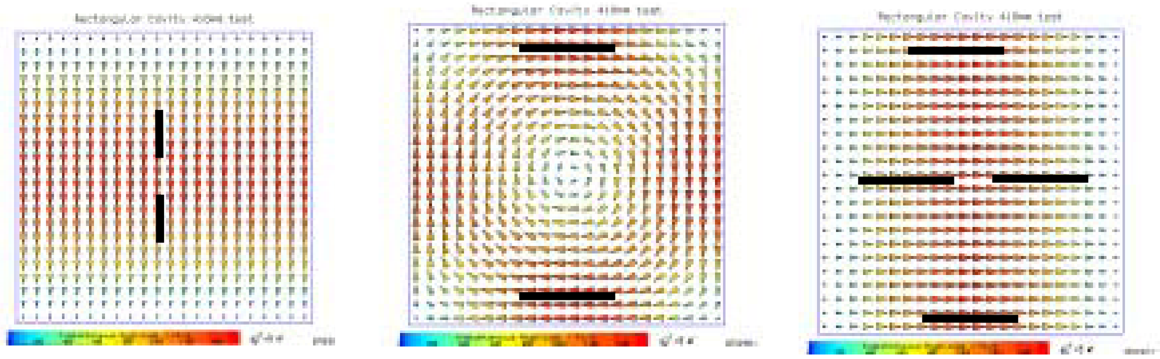


Fig. 5. The six-pole BPF using triple mode cavities.



Wall size=40×40cm

Fig.6.The wall between cavities and coupling apertures.



(a) (b) (c)

Fig. 7. The magnetic fields on the surface of the wall with each coupling apertures. (a) TE1 mode (b)TM2 mode. (c)TE3 mode

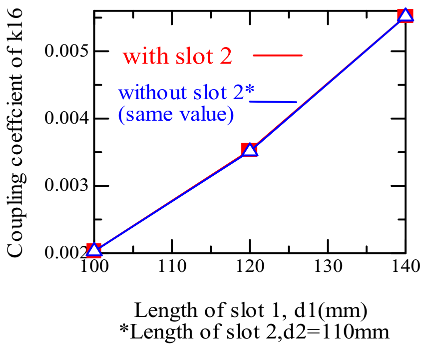


Fig. 8. Simulated k16.

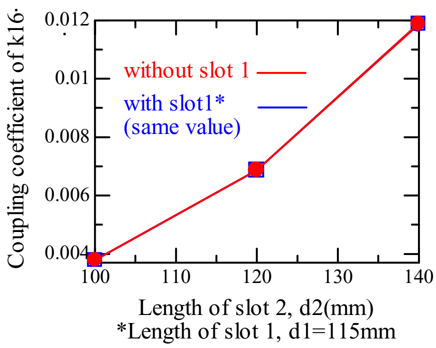


Fig. 9. Simulated k25

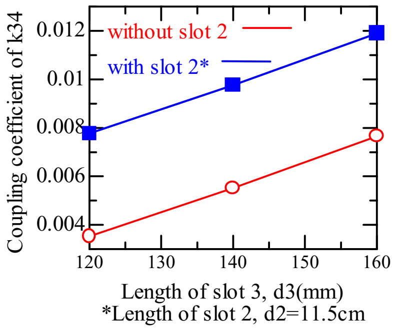


Fig. 10. Simulated k34

Fig. 11. The test model of the six-pole elliptic-function BPF.

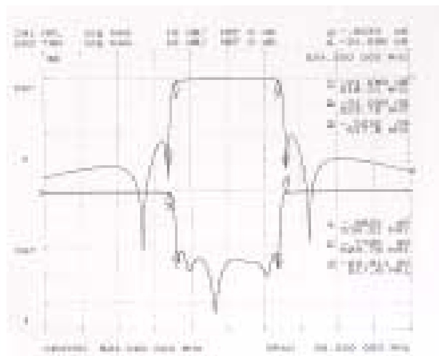


Fig. 12. Measured characteristics of the test model.