A SOPHISTICATED DESIGN PROCEDURE FOR A TRIPLE MODE SAW FILTER SUPPRESSING ADJACENT CHANNEL INTERFERENCES IN DIGITAL MOBILE TELEPHONES

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ABSTRACT

A triple mode SAW filter is practicably developed as a first mass production model. Although the basic concept had been well known, the effective design procedure has not been reported so far due to the difficulties of the analysis. The authors have developed a sophisticated design procedure for triple mode SAW filter successfully. The filter samples show excellent performances. It will be a key component for digital mobile communication systems.

INTRODUCTION

Recently, SAW filter is widely used in various digital cellular systems. In these systems, the channel spacing are usually very narrow. Thus the IF filter must have a steep out-of-band rejection shape to suppress the interferences near the pass band. So far, the double mode SAW transversely coupled resonator filter[1] has been commonly used. M. Tanaka had reported the eigen-mode analysis[2] using the waveguide model to analyze the double mode filter. Also various coupling of modes analysis or stack matrix analysis have been reported[3,4,5,6].

However, the performance is not enough because this type of filter has just a second order filtering factor which has insufficient rejection level. Thus the realization of triple mode filter is strongly expected. This type of filter has a steeper shape factor than the double mode filter. The concept of triple mode filter has been well known. But the design of this filter is extremely difficult. Therefore the filter which satisfies all specifications of digital mobile telephones have not been developed until now.

In this paper, the authors present a sophisticated design procedure for a triple mode SAW filter, applying the extended eigen-mode analysis. The practicable filters are developed according to a specification of a digital mobile telephone. The performance example will be demonstrated later.

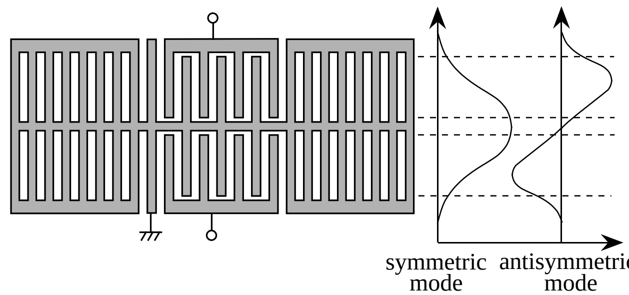

Figure 1: Schematic view of the electrode of double mode filter, and excited waveforms.

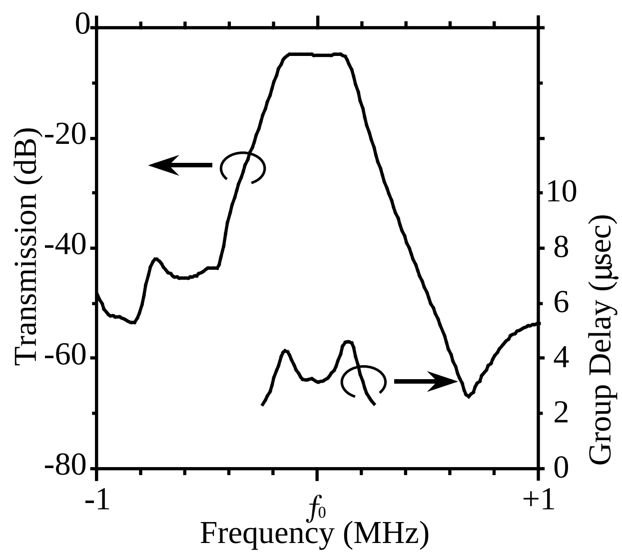

Figure 2: Frequency response of double mode filter.

FILTER CONFIGURATION

First, the authors explain a structure and principle of double mode filter for basic understanding of transversely coupled resonator filter. Figure 1 shows a schematic view of a double mode filter. The excited waveforms are also illustrated in the same figure. The filter consists of two pieces of energy-trapping SAW resonator which are closely disposed to each other. The acoustic coupling between symmetric mode and antisymmetric mode creates a band pass filter of second order. Figure 2 shows the performance of a double mode filter. The attenuation near the pass band will be compared with that of a triple mode.

Next, a triple mode filter is explained. Figure 3 shows a schematic view of a triple mode filter. The excited waveforms are also illustrated. Three pieces of SAW resonator are closely disposed, then three excitation modes are observed. The IDT electrodes of the middle resonator have the same structure of a reflector. They are all grounded. In this structure, the acoustic coupling of three modes creates a band pass filter of third order.

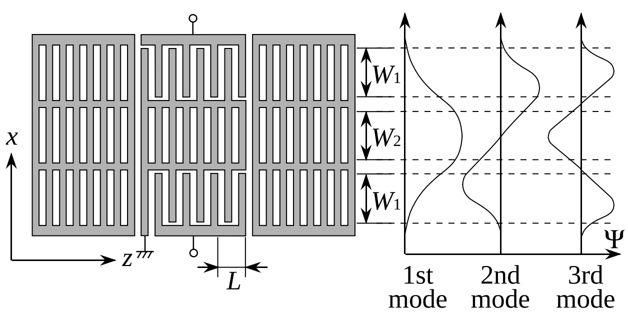

Figure 3: Schematic view of the electrode of triple mode filter, and excited waveforms.

DESIGN PROCEDURE

For designing band pass filter, the resonance frequencies of each mode have to be calculated. The SAW propagation is described by the scalar Helmholtz equation[7] as

$$\frac{\partial^2 \Psi}{\partial x^2} + \frac{\partial^2 \Psi}{\partial z^2} + \frac{\omega^2}{v^2}\Psi = 0 \qquad (1)$$

where Ψ is a scalar potential, v is a SAW velocity, and ω is an angular frequency. Directions of x and z refer to Figure 3.

In the eigen-mode analysis[2], equation (1) is used for calculation and double mode filter is designed in such a way. However, some extended techniques are required for a triple mode filter design. Because the calculation for double mode was approximated along the x-axis of the pattern. The pattern of the double mode filter was divided into only two kinds of regions grossly which are uniform metalized regions and

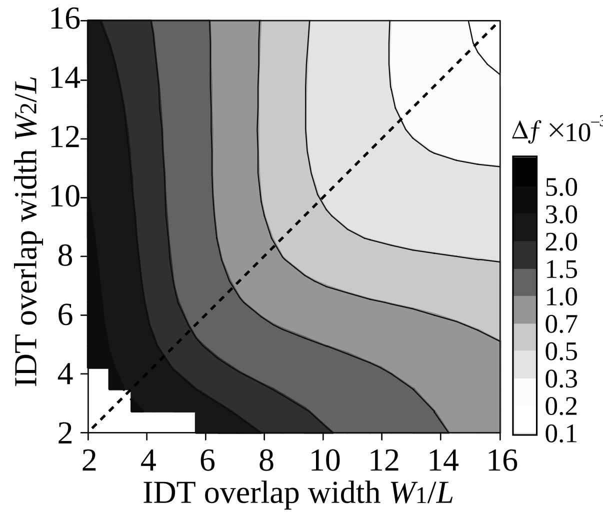

Figure 4: Resonance frequency chart of triple mode filter.

periodically metalized regions. It gave enough approximation for design of double mode filter. On the other hand, the design of triple mode filter requires more precise calculation. The pattern along x-axis is divided into four kinds of regions which are uniform metalized regions, periodically metalized regions, gap regions between previous two regions and non-metalized outside regions. In each region, propagation velocity is calculated including an effect of the electrode thickness.

As a result, a precise mode chart can be obtained. Exact calculation of mode chart is a key point of triple mode design. Figure 4 shows the resonance frequency characteristics of triple mode filter regarding IDT overlap width W_1 and W_2 normalized by IDT pitch L. W_1 and W_2 mainly determine the resonance frequencies. The filter

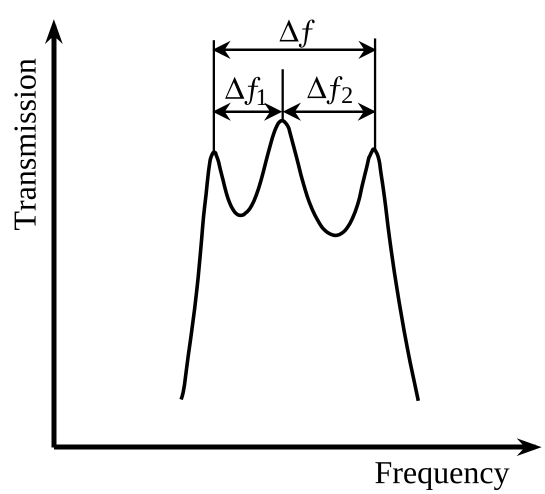

Figure 5: Frequency difference parameters of triple mode filter.

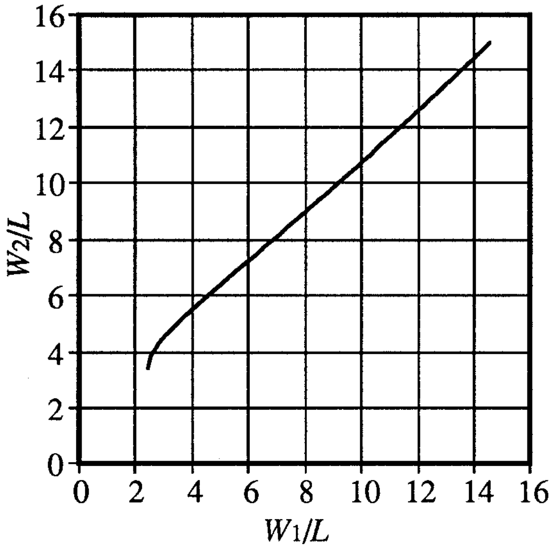

Figure 6: Relation between normalized IDT overlap width W_1 and W_2, under the condition of $\Delta f_1 = \Delta f_2$.

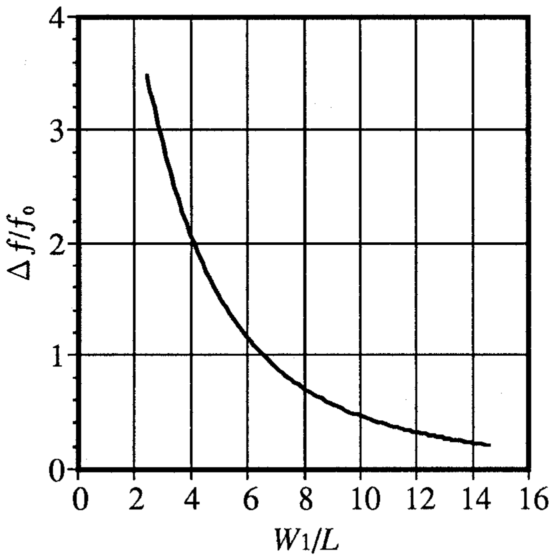

Figure 7: Relation between W_1 and frequency differences of 1st and 3rd mode Δf, under the condition of $\Delta f_1 = \Delta f_2$.

band width, which is nearly equal to Δf, can be designed from this figure. Here Δf is the normalized resonance frequency difference of 1st and 3rd excitation modes.

Another key point is a flat pass-band characteristic. In order to obtain the flatness, the frequency differences of each mode, Δf_1 and Δf_2 in Figure 5, should be equated. Figure 6 shows the relation between W_1 and W_2, and figure 7 shows the relation between W_1 and Δf, under the condition of $\Delta f_1 = \Delta f_2$. Then the best parameters for flat passband characteristics can be obtained.

PERFORMANCE EXAMPLE

The triple mode filters were designed according to specifications of digital cellular communication terminal. For example, parameters of the structure are W_1=5.9L and W_2=7.0L on the ST-cut quartz substrate. Figure 8 shows the frequency response near the passband. Figure 9 shows the performance in the wide span. The passband width is 350kHz with the center frequency of 250MHz. The group

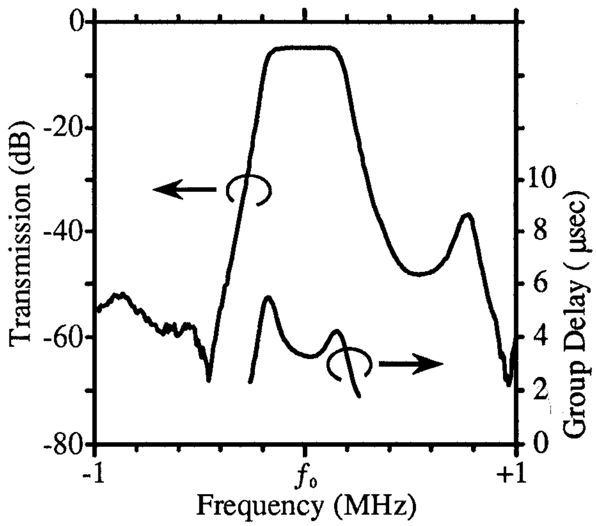

Figure 8: Frequency response of triple mode SAW filter (passband).

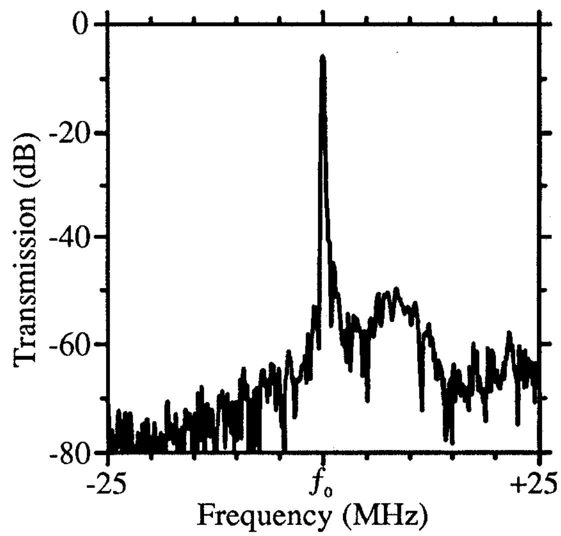

Figure 9: Frequency response of triple mode SAW filter (wide span).

delay deviation in the passband is about 2μsec. The rejection level of the triple mode filter is -40dB at -300kHz offset. It is compared with the conventional double mode filter of -22dB.

Figure 10 shows the photograph of the outside view of the mass production model of triple mode filter. The dimensions are 7.0mm x 5.0mm x 1.7mm. Although the package size is same as double mode filter, a large rejection can be obtained.

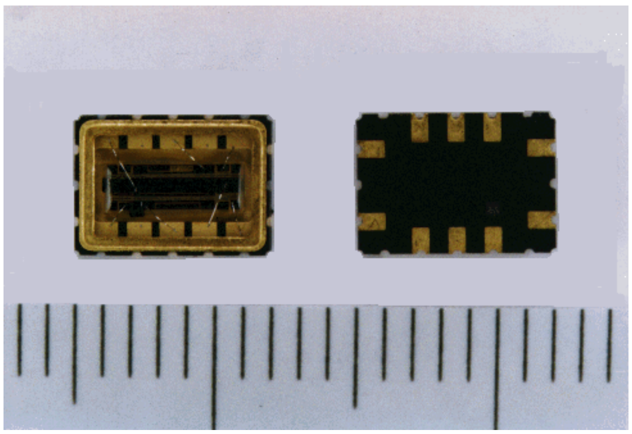

Figure 10: Photograph of triple mode SAW filter.

CONCLUSION

A practicable design procedure of triple mode SAW filter has been developed. The resonance frequencies of each excitation mode was derived exactly by using the extended eigen-mode analysis. The performance example of mass production model shows excellent characteristics.

Thus the triple mode SAW filter is very attractive as an IF filter of digital cellular applications. Therefore it will be used commonly in those systems.

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