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2-Dimensional SAW device simulation performed by COMSOL Multiphysics
COMSOL Multiphysics を用いた 2D SAW デバイスシミュレーション

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1. Introduction

In SAW device simulation, it is often difficult to analyze response of SAW by full 3D Finite Element Method (FEM) because of intolerable computational burden. Therefore 1D or 2D models described by simplified equations which express SAW propagation approximately are frequently adopted in device simulation. 2D models are more desirable than 1D models. 2D P-Matrix method [1] and 2D-COM equation [2, 3] has been proposed for such 2D simplified models.

Though previous 2D models are very practical to design in terms of computational burden, they lack versatility and simplicity in terms of necessity of heavy preparation before analysis. Whenever device structure is changed dramatically, the set of equations and boundary conditions have to be redefined. Therefore it is difficult to arrange arbitrary structure in surface plane.

In this report, we propose a method performed by COMSOL Multiphysics which is commercial FEM tool, and show that we can remove the complexity of the modeling at 2D-COM analysis by using this tool.

2. Concept of method

COMSOL Multiphysics has the application mode called 'Partial Diffrrential Equation (PDE) mode'. By using PDE mode, user can let FEM-solver-engine solve not only built−in equations but also arbitrary equations e.g. 2D-COM equation.

In PDE mode, simultaneous partial differntial equations are expressed generalized form as follws:

$$\nabla \cdot \mathbf{\Gamma} = \mathbf{F} \tag{1}$$

where Γ denotes arbitrary equations including partial differentiation and F are the terms which expressed contribution of external force. Equation (1) are vector equations so each terms are vector or matrix.

On the other hand, 2D-COM equations which describe SAW propagation are defined simultaneous equations as follws:

$$\begin{aligned}
\frac{\partial A^+}{\partial x} &= -j\delta A^+ - j\kappa_{12}A^- - j\frac{g}{2k_0}\frac{\partial^2 A^+}{\partial y^2} + \alpha V \\
\frac{\partial A^-}{\partial x} &= j\delta A^- + j\kappa_{12}A^+ + j\frac{g}{2k_0}\frac{\partial^2 A^-}{\partial y^2} - \alpha V \\
\delta &= k - j\gamma + \kappa_{11} - k_0
\end{aligned} \tag{2}$$

Equations (2) include partial differentiation of x and y with COM parameters which are function of (x, y), so the solutions express 2 dimensional wave propagations. By assigning each terms of formula (2) to Γ or F in formula (1), we can apply 2D-COM equations to PDE mode.

In COMSOL, user has only to draw domains expressing each periodic structure of SAW device (IDTs, reflectors, etc.) and to set equations every domain before executing calculation. Generating meshes and finding solutions of equations are executed by software automatically. All operations can be made on GUI. Because of all these things, we can easily arrange arbitrary structure in surface plane.

3. Comparison with previous analysis

In Ref. [3], authors analyzed 2-port SAW resonators on 36.5° Y-X quartz by using 2D-COM equations and compared with measured response shown in **Fig.1.** Well agreements were observed between the analytical results and measured ones about the frequencies and levels of resonant peaks of the first order and second order symmetric guided mode. However, there was difference between both near the upper stopband edge (The area in circle in Fig.1). About this disagreement, authors described there was insufficient point in analytical model because they considered only guided mode.

We tried to analyze the same SAW resonator with the same COM parameters shown in Fig.1 by using COMSOL PDE mode. **Fig.2** shows the model geometry drawn on COMSOL GUI window. **Fig.3** shows the result calculated by COMSOL. Not only frequencies and levels of resonant peaks of guided mode but response of near the upper edge of

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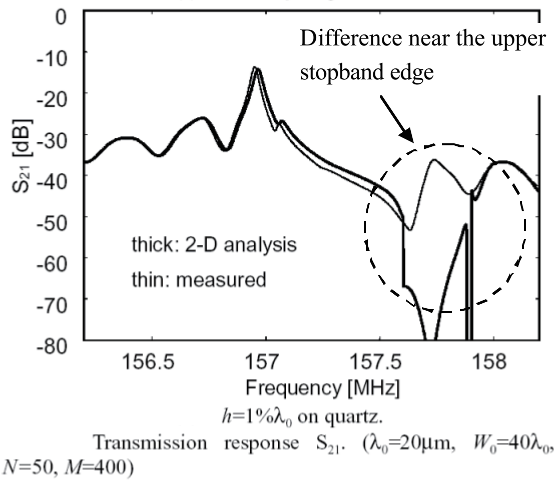

Fig.1 Comparison of transmission response between conventional 2-D analysis and measured result given in Ref. [3]

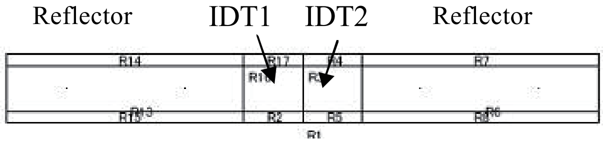

Fig.2 Geometry of 2-port SAW resonator drawn on COMSOL GUI window

stopband have well agreed with result of [3]. **Fig.4** shows distribution of displacement at frequencies (a) to (c) in Fig.3. From Fig.4 (a) and (b), we can observe mode profile of first and second mode visually. From Fig. 4 (c), we can observe not only guided mode but radiated mode and diffraction effect.

As has been described, conventional analysis considered only guided mode so the contribution of radiation mode and diffraction effect were not included. On the other hand, the method using by COMSOL enables to calculate the SAW response including these effects automatically.

4. Conclusion

We carried out 2-dimensional analysis for 2-port SAW resonator by using COMSOL PDE mode.

The result we obtained by using COMSOL agreed with measured result in previous research and we recognized this method have enough accuracy. Furthermore, we could calculate transmission response in the frequency region where conventional method was impossible.

For reason mentioned above, we regarded the method using COMSOL PDE mode as feasible for 2-dimensional SAW analysis. It is expected to apply this method to various cases in future.

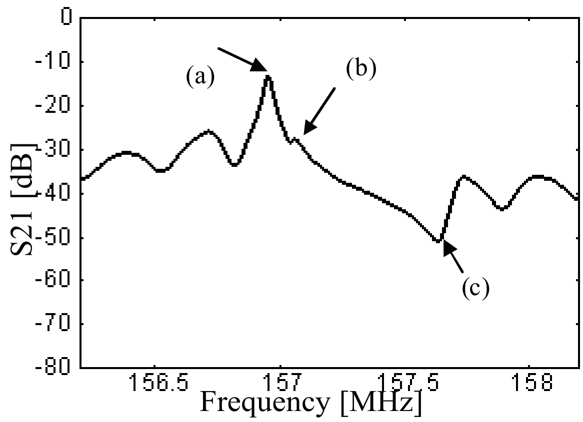

Fig.3 Transmission response calculated by using COMSOL PDE mode

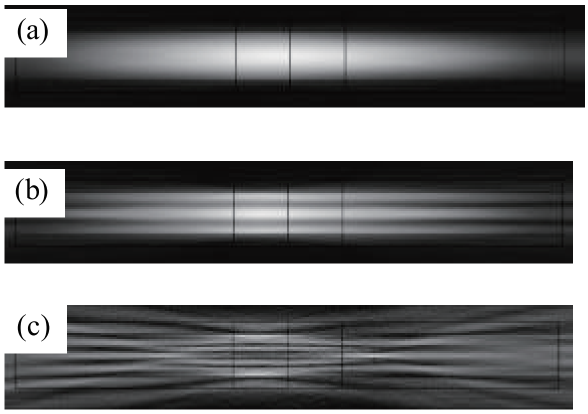

Fig.4 Distribution of displacement at frequencies (a) to (c) in Fig.3
(a). First order (b). second order
(c). near the upper stopband edge

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