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Generation Mechanisms of 3rd Order Nonlinear Signals of SAW Devices

SAW デバイスにおける 3 次非線形信号の発生メカニズム

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1. Introduction

In coming several years, the very high power two-tone signals transmission is scheduled in the up-link carrier aggregation, which is the transmission technique of LTE-Advanced in the next fourth generation telecommunication system. Under this situation, high linearity of the RF front-end part for cellar phone handsets has been strongly desired, thus, the improvement of the linearity performances of each element of the RF front-end part such as the switches and the duplexers, is getting one of the most important tasks.

In this work, the generation mechanisms of the third-order nonlinear signals of SAW devices, which are components of the RF front-end, are discussed. According to the measurement results of the third-order harmonics signals, the electrode fingers in the IDT are focused as the generation point of the third-order nonlinear signals. In addition, detailed studies about the occurrence factor of the third-order nonlinear signals are carried out by 2D-FEM calculations. As the result, it becomes obvious that the strain S_4 in Al electrodes contributes the generation of the third-order nonlinear signals of SAW resonators.

2. Measurement of Third-order Harmonics

First, measurements of the third-order harmonics (H3) of the some one-port SAW resonators fabricated on the 42°Y-X $LiTaO_3$ substrate were performed. All prepared resonators are based on the same IDT design, and only their electrode film compositions are different as Table. 1. The electrode films in the resonators are constructed by two materials as shown in Fig. 1. The one is Ti which is used as the base layer, and the other one is Al which is used as the main layer. The basis resonator is type A, and its resonance and anti-resonance frequencies are 835.6MHz and 864.4MHz, respectively. The film thicknesses of the other resonators were estimated, by the program SYNC[1)] based on the finite element method and the spectral domain analysis, so that their impedance characteristics are to be almost same as that of the type A resonator. On the measurements of H3, the input signal with 15dBm power was applied to the one terminal of each resonator, and the signal output from the other terminal was observed. The drive frequency of the input signal is 800 to 900MHz, and the frequency of the H3 corresponds to the thrice of that of input signal.

Table. 1. Thickness of electrode layer in each resonator.

	Ti thickness[nm]	Al thickness[nm]
Type A	30	430
Type B	110	300
Type C	184	200

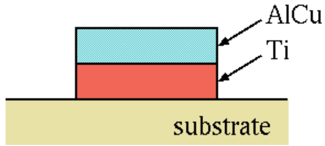


Fig. 1. Electrode construction of sample resonators.

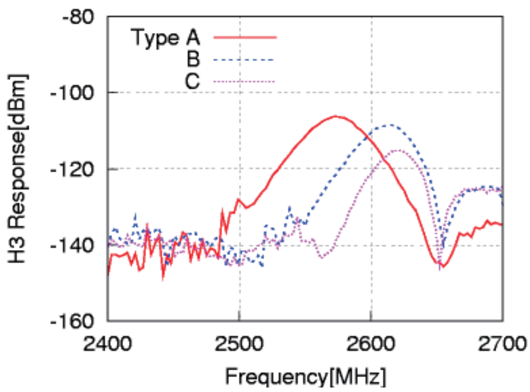


Fig. 2. Measurement results of H3 level of 1port SAW resonators.

The measurement results are shown in Fig. 2. In this figure, the H3 responses have very characteristic profiles. These profiles are formed by the combination of the acoustic and the electric contributions[2)]. The peak which appears in between the resonance and the anti-resonance frequencies is due to the acoustic effect. This acoustic response in the H3 decreases with the increase of Ti film thickness. Compared the type C resonator with the type A, the H3 peak level is improved approximately 10dB. This result denotes that the H3 levels are affected by the electrode construction.

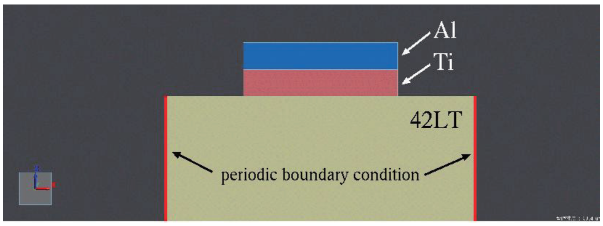


Fig. 3. Calculation model of 2D-FEM.

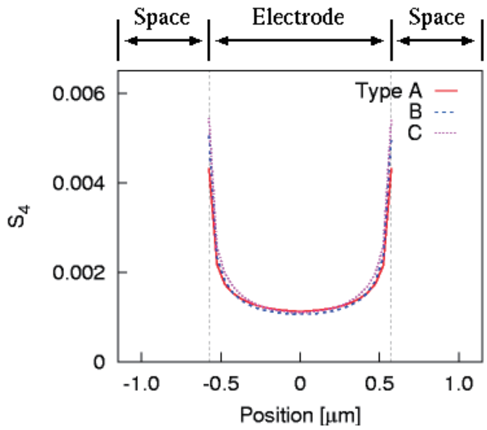
Furthermore, all resonators used in this study are designed so that their impedance characteristics are to be equal, thus, total weight of their electrodes considered to be almost same. Accordingly, it is thought that the H3 change is not due to the change of the electrode weight but due to the change of the electrode construction itself. This implies that the main generation point of the third-order nonlinear signals is in the electrodes.

3. Calculation of Strains by 2D-FEM

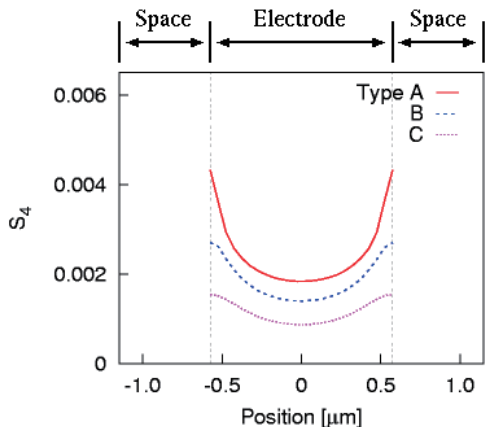
For more detailed studies about the cause of the third-order nonlinear signals, calculations of the strains at the resonant point in the electrodes were performed by the two-dimensional finite element method (2D-FEM). In the calculations, the one finger model using the periodic boundary condition, as shown in Fig. 3, was prepared for each resonator corresponding to the structural parameters in Table. 1, and the strains at the boundaries, (a) between the Ti film and the substrate, and (b) between the Al film and the Ti film, are calculated. The FEM software Femtet®[3] developed by Murata Software Co., Ltd. was used for these calculations.

The calculation result of the strain S_4 in each structure is shown in Fig. 4. The other elements S_1 to S_3, S_5 and S_6 are not shown here, because they only had the negligible changes in these calculations.

At the boundary between the substrate and the Ti film, there is very little change in S_4. This result suggests that the strain in the base film is almost determined by the total weight of the electrode and it does not depend on the film construction in this case. On the other hand, S_4 between the Al film and the Ti film decreases drastically with the increment of Ti film thickness. This means that S_4 in the Al films is affected by the electrode construction, in contrast to that in the base Ti films. As the reason of this phenomenon, it is considered that the strain in the Al film is affected only by the weight of the material above the Al-Ti boundary and it changes with the electrode construction. In addition, this S_4 change corresponds to the change in H3 response, that is, the H3 response level is decrease with the decrement of S_4 in the Al film. These all results



(a) Between Ti and substrate



(b) Between Al and Ti

Fig. 4. Calculation results of S_4 at each boundary.

suggest that the generation point of the third-order nonlinear signals is the Al film and their levels depend on the magnitude of the strain S_4 in the Al film.

4. Conclusion

In this work, the generation mechanism of the third-order nonlinear signals has been discussed. The measurement results of the H3 of fabricated resonators have implied that the generation point of third-order nonlinear signals is IDT finger. In addition, as the results of 2D-FEM calculations, it has been revealed that the occurrence factor of them is the strain S_4 in the Al film.

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