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Generation Mechanisms of 2nd Order Nonlinear Signals of SAW Devices and Suppression Method of Them

SAW デバイスにおける 2 次非線形信号発生メカニズム
およびその抑圧方法

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1. Introduction

Linearity of the RF front-end part for cellar phone handsets is getting one of the most important performances. This is because the very high power simultaneous two-tone signals transmission is scheduled in the up-link carrier aggregation, which is the transmission technique of LTE-Advanced in fourth generation telecommunication system, in several years. In this situation, for SAW duplexers, which are components of RF front-end portion, the requirement of high linearity has become strong.

In this work, the generation mechanisms of the second-order nonlinear signals of SAW devices and their effective suppression methods are discussed. As the one possibility of the cause of the second-order nonlinear signals, the asymmetry properties of piezoelectric crystalline substrates are focused on. In addition, based on this assumption, an IDT design for the cancellation of the crystalline asymmetry is proposed. As the result of the verification of the fabricated resonator in which the proposed structure is applied, drastic improvement is confirmed in the second-order nonlinear signal level.

2. Mechanism of 2nd Nonlinearity

First, a measurement result of the second-order harmonics (H2) of the one-port SAW resonator is shown in Fig. 1. The resonance frequency and the anti-resonance frequency of the resonator are 837.1MHz and 866MHz, respectively. On the measurement of the H2, the input signal with 15dBm power was applied to the one terminal of the resonator and the signal output from the other terminal was observed. The drive frequency of the input signal is 650 to 900MHz, and the frequency of the H2 correspond to the twice of that of the input signal.

The second-order nonlinear signals of SAW devices have been considered to be not picked up effectively because of their symmetry structure[1]. However, from the measurement result, it could be confirmed that the H2 signal is picked up actually, and it surely affect the receiver sensitivity in SAW

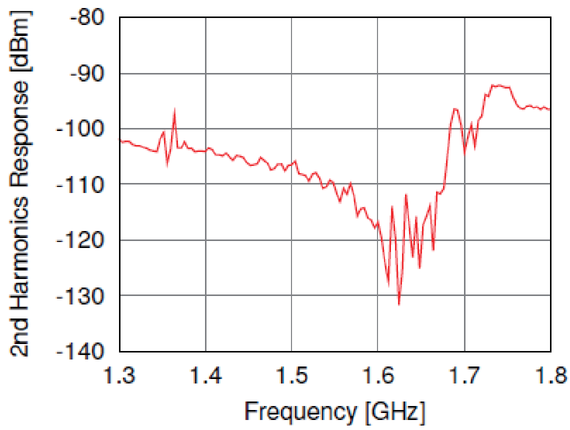

Fig. 1. Measurement result of H2 level of one-port SAW resonator.

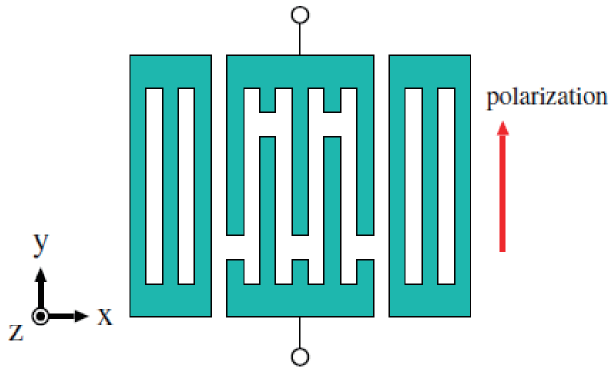

Fig. 2. Lean of polarization axis.

duplexers. In this study, as the cause of the second-nonlinear signals, the crystalline asymmetry properties of substrates are considered.

Generally, optimal cut angle of piezoelectric substrates for SAW devices are selected to achieve good characteristics such as low insertion loss, enough electromechanical coupling factor, and good temperature stability[2]. In such substrates, the polarization axis of the substrate leans toward the transverse direction crossing SAW propagation as shown in Fig. 2, thus, the electric and the acoustic properties are asymmetric on the surface of the substrate with respect to the wave propagation axis (x-axis).Therefore, there is a possibility that the second-order nonlinear products arise in the direction of transverse, and they cannot be canceled by the normal structure IDTs.

In the measurement result in Fig. 1, the H2 level reaches the minimum point at around the resonant response and the maximum point at around the anti-resonance response. In addition, in the frequency below the resonance point and above the anti-resonance point, the H2 response changes gradually. This profile is considered to correspond to the voltage level which applied to the resonator. Furthermore, for the reason that the H2 signal is generated in the frequency range in which acoustic waves are not excited, the nonlinear dielectric constants are considered to be one of the main factors of the second-order nonlinear signals generation.

On the other hand, a steep peak exists in between the resonance and the anti-resonance frequencies (around 1.69GHz), and it is considered to be not related to the applied voltage. In this frequency range, it is known that the asymmetric wave radiations toward oblique directions occur due to the crystalline asymmetry[3)]. Therefore, there is high possibility that the peak was caused by the asymmetric wave radiation and the electrostrictive effect of the substrate.

3. Parallel Divided and Reverse Connected Structure

Based on the assumption in Sect. 2, an IDT structure shown in Fig. 3 is proposed to cancel the crystalline asymmetry. This structure is called "Parallel Divided and Reverse Connected (PDRC)" structure. Specifically, an IDT is equally divided in two and they are connected in parallel. In addition, the divided IDTs are allocated so that they are symmetric about the x-axis. This structure is completely mirror symmetric not only about substrate y-axis but also about x-axis, thus, all second order nonlinear signals caused by the crystalline asymmetry are canceled electrically.

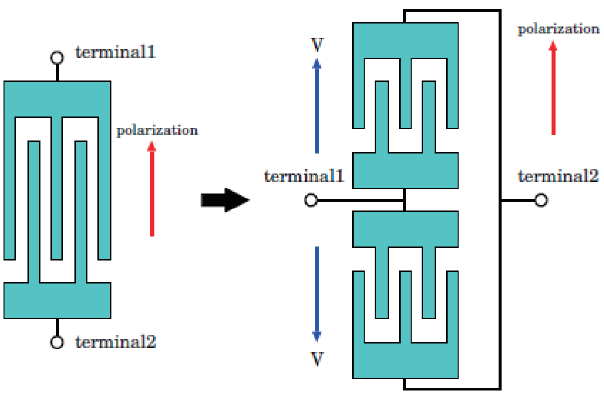

Fig. 3. Parallel divided and reverse connected structure.

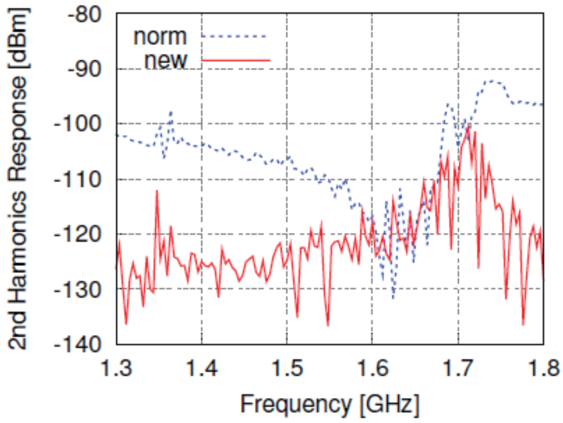

Fig. 4. Measurement result of H2 level of PDRC structure.

The measurement result of the H2 of the one-port SAW resonator based on PDRC structure is shown in Fig.4. In the figure, the dashed line is a response of the conventional resonator and the solid line is a response of the resonator based on the PDRC structure. Drastic suppression of the H2 response is achieved in the frequency below 1.58GHz by using the PDRC structure. The improvement is from 10 to 25dBm. In addition, the steep peak around 1.69GHz is also suppressed. From these results, it is revealed that the main factor of the second-order nonlinearity of SAW devices is the crystalline asymmetry of piezoelectric substrate and proposed structure is effective to cancel this asymmetry.

4. Conclusion

In this work, as generation mechanisms of second-order nonlinear signals of SAW resonator, crystalline asymmetry properties of substrates have been focused. Based on this assumption, the PDRC structure has been proposed to cancel the asymmetry. On the one-port resonator based on PDRC structure, drastic improvement of H2 signal level has been realized. Therefore, the validity of the hypothesis has been confirmed.

Acknowledgment

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