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High sensitive vector measurement of nonlinear harmonic responses in RF SAW/BAW devices

Seiya Himata[1†], and Tatsuya Omori[1]
([1]Graduate School Engineering, Chiba University)

1. Introduction

SAW and BAW RF devices with excellent linearity are widely used in current mobile radio communication systems. Since the system has become sophisticated, these devices' weak but non-negligible nonlinearity has been extensively investigated to gain knowledge of their behavior, suppress them, etc. [1,2]. Amongst them, the vector measurement acquiring both amplitude and phase information of the nonlinear responses has been believed to be a powerful tool giving valuable information about how these responses are generated and propagated in the devices. Although some techniques for vector measurement have been reported [3, 4], they require special equipment, or the dynamic range is insufficient for evaluating faint nonlinear responses from the SAW devices.

From this point of view, the paper proposes the method enabling high-sensitive vector measurement of nonlinear harmonic responses from the RF SAW/BAW devices with more generic measurement equipment.

2. Vector measurement system for harmonic responses

Figure 1 shows the vector measurement system of harmonic responses from the SAW/BAW devices. This system, one of the applications of the Ref [5], consists of the down converter and the lock-in amplifier (LIA: NF corporation, LI5660) as a highly sensitive vector signal detector. The nonlinear n^{th} order harmonic component of its frequency nf_0 generated by the DUT driven by a source of its frequency f_0 from the signal generator 1 (SG1) is converted to a middle-frequency signal of its frequency f_{IF} by mixing the local of its frequency (nf_0+f_{IF}) from the SG2. The reference signal of its frequency f_{IF} required for detection by the LIA is generated by a build-in oscillator in the LIA in this work. An external 10 MHz reference clock from SG3 synchronizes the SG1, SG2, and LIA.

The proposed measurement system has two signal paths selectable by two RF single-pole double-throw (SPDT) switches, as shown in Fig. 1. For proper phase measurements, it is necessary to compare the phases between the target and the reference signal that are synchronized with each other. The corresponding harmonic component included in the output of SG1, via an attenuator (ATT) through the lower path, is used as this reference [3].

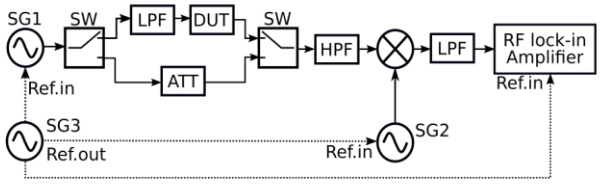


Fig. 1 Proposed vector measurement system for nonlinear responses using a LIA.

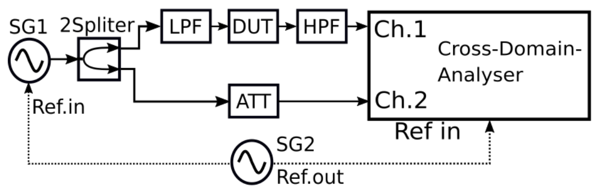
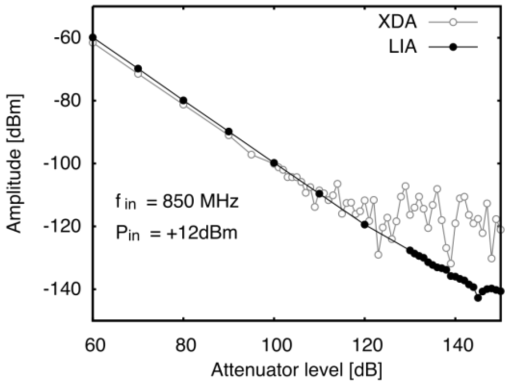
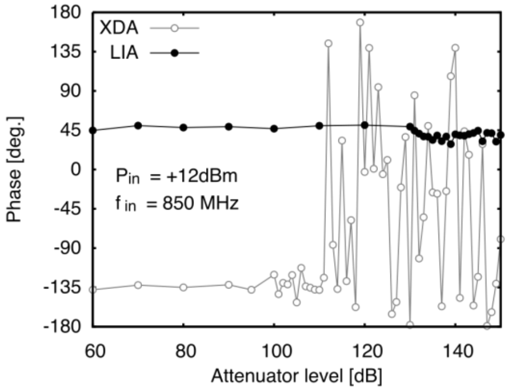


Fig. 2 Conventional vector measurement system for nonlinear responses using an XDA [3].

Experiments were performed to demonstrate the advantage against the conventional measurement method that is using the cross-domain analyzer (XDA: ADVANTEST, U3851) shown in **Fig. 2**[3]. In the experiments, a series connection of a frequency doubler (input side) and variable attenuator (output side) was used as the DUT. The 2nd-order harmonic responses (H2) at 1700 MHz from the DUT driven at 850 MHz were measured. The input power to the frequency doubler was adjusted to +12 dBm. **Figure 3** shows the measurement results of amplitude (a) and phase (b) of the H2 responses as functions of the attenuation setting level of the variable attenuator. From Fig. 3(a), it is seen that the noise floor was around -110 dBm for the conventional system using the XDA, whereas it was less than -140 dBm for the proposed. It is also confirmed from Fig. 3(b) that the phase of the H2 responses was successfully evaluated even if the H2 level was less than -130 dBm for the proposed system. Note that the measured phase differs between the proposed and the conventional methods. This is because the absolute value of the phase cannot be determined since no calibrations were done in the experiments.

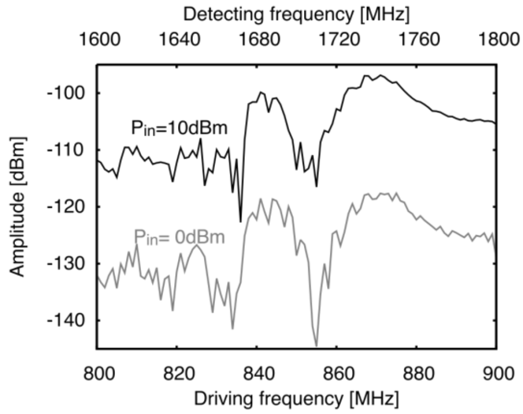


(a) Amplitude

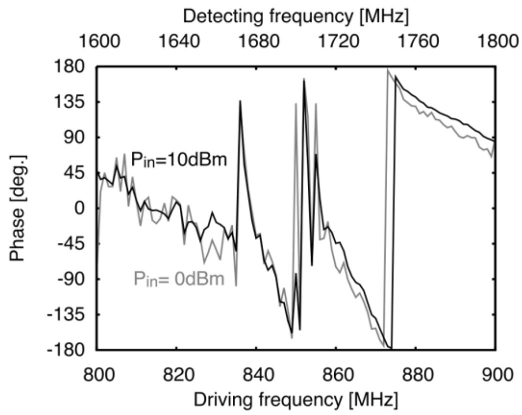


(b) Phase

Fig. 3 Measurement result of H2 from the frequency doubler.



(a) Amplitude



(b) Phase

Fig.4 Frequency dependence of H2 responses from the SAW resonator.

3. Measurement of 2nd order harmonic responses from SAW resonator

To verify the applicability of the proposed method to vector measurement of nonlinear responses from the RF SAW devices, H2 responses from a SAW resonator were measured. The driving frequency was swept from 800 to 900 [MHz]; thus, the receiving frequency was tuned from 1600 to 1800 [MHz].

Figure 4 shows the amplitude (a) and phase (b) of H2 responses from the SAW resonator measured by the proposed method. It is seen in Fig. 4(a) that the amplitude of H2 was reduced by 20 dB when the input power was changed from +10 to 0 dBm. Since the strength of H2 is proportional to the square of the driving level, it is verified that the H2 responses from the SAW resonator were successfully detected even if the output level is lower than -130dBm. Furthermore, the phases are also successfully evaluated, as shown in Fig. 4(b).

4. Conclusion

This paper discussed the measurement method enabling high-sensitive vector measurement of nonlinear harmonic responses generated in RF SAW devices. It is demonstrated that the proposed measurement system consisting of a lock-in amplifier has around 30dB lower noise floor than the conventional method. The measurement results of 2nd order harmonic responses from a SAW resonator using the proposed system showed that the measurement system could acquire the vector data even if the H2 level is around -140 dBm. The authors believe in applying the method to vector measurements more general.

Acknowledgments

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References

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