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Study on Low-Loss SAW Gas Sensor Consisting of Resonators with Large Spaces between IDTs and Reflectors

IDT と反射器間距離の大きい共振器による低損失 SAW ガスセンサの検討

Natsuki Tobita and Mitsutaka Hikita (Kogakuin Univ.)
飛田夏希[†]，疋田光孝 （工学院大学）

1. Introduction

Sensor network has been proposed with the development of mobile communications system such as cellular phone and wireless LAN. To detect CO, environmental gas and hydrogen leakage from future fuel cars, we published the novel SAW sensor with self-temperature-compensated characteristics on the assumption of garage use at -40 to 80°C [(1)]. However, the sensor network which operates under extreme low-power consumption requires small losses for delay-line-type sensors. We have developed a new low-loss resonator-type sensor delay lines which have large spaces between IDTs and reflectors, where reactive films are formed.

In this paper, a new SAW sensor constructed with resonator-type delay lines are explained compared with the previous one. Simulation and experimental results for the above delay lines consisting of large spaces between IDTs and reflectors are also presented.

2. New low-loss sensor with SAW resonator-type delay lines

The previously developed self-temperature-compensated SAW sensor, which consists of three delay lines, D-1, D-2 and D-3, is shown in Fig.1 [(1)]. In order to achieve low insertion loss characteristics, we have invented a new sensor structure constructed with three lattice-circuit resonator-type delay lines as shown in Fig.2. The lattice circuit LD-2 and LD-3 provide standard phases with π/2 difference same as the D-2 and D-3 in Fig.1's previous one. The lattice circuit LD-1 is used for sensing. Relative phase relations between output signals are unchanged against variation in temperature, which can ensure self-temperature-compensation (right figure).

hikitami@cc.kogakuin.ac.jp

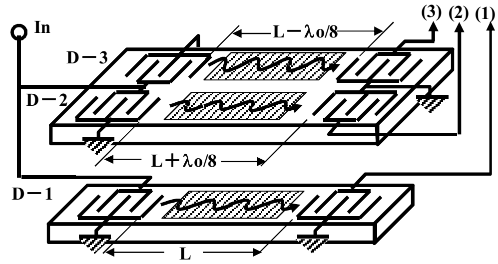

Fig. 1 Previously developed self–temperatutre -compensated SAW sensor.

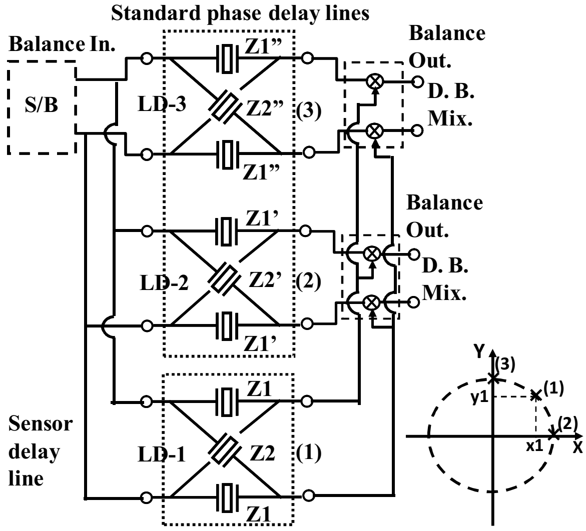

Fig. 2 New low-loss SAW sensor with three lattice-circuit resonator-type delay lines. Self-temperatutre-compensated characteristics are also kept.

3. Lattice-circuit delay lines consisting of SAW resonators with large spaces between IDTs and reflectors

We have designed Fig.2's LD-1 lattice circuit developing two SAW resonators whose impedances are Z1 and Z2. As shown in Fig.3, they have large spaces, P or P + λo/4 respectively, between IDTs and reflectors. The space difference of λo/4 is required to adjust the resonant frequencies of Z1 to the anti-resonant frequencies of Z2 and vice versa. In Fig.2's lattice circuit, direct electric couplings between the input and output through capacitances of IDT fingers shown in Fig.3 are cancelled out one another between Z1 and Z2. The round-trip SAWs reflected from reflectors shown in Fig.3 can only contribute to synthesize delay-line characteristics. Thus the spaces between IDTs and reflectors are very important to provide long delay time. At that time the sensing gas interacts with reactive films formed between IDTs and reflectors.

Other SAW resonators used in Fig.2's LD-2 and LD-3 lattice circuits are shown in Fig.4. The space differences of ±λo/16 between Z1'/Z2' and Z1"/Z2" respectively are required to provide π/2 phase difference between the standard phases of two delay lines, LD-2 and LD-3, which is essential feature to ensure the self-temperature-compensation characteristics.

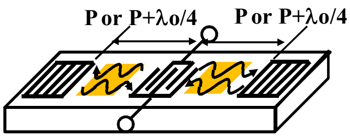

Fig. 3 SAW resonator constructed with large spaces between IDT and reflectors.

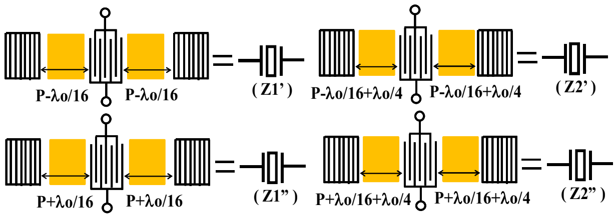

Fig. 4 SAW resonators used in Fig.2's LD-2 and LD-3.

4. Simulation and experimental results

Simulation results used to design the new lattice-circuit delay line are shown in Fig.5. In the simulation, 128° YX LiNbO3 as the substrate and the reflectors constructed with 50 pairs of shorted electrodes are assumed. Amplitude, phase and delay-time characteristics of the designed delay line are shown in Fig.5. The 50-λo length is used as P, spaces between IDT and reflectors in Fig.3, in the simulation.

Experimental results for amplitude, phase and delay-time characteristics are shown in Fig.6. The insertion loss of about 4dB is achieved. Good agreement between simulation and experimental results is also obtained. The delay time of about 1 μsec corresponds to an equivalent propagation distance of about 160 λo, which is larger than twice the length of P due to SAW penetration effect into the IDT and reflectors.

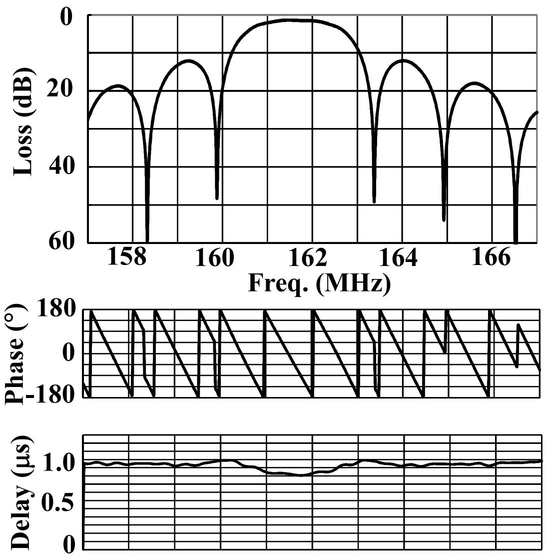

Fig. 5 Simulation results for new delay line

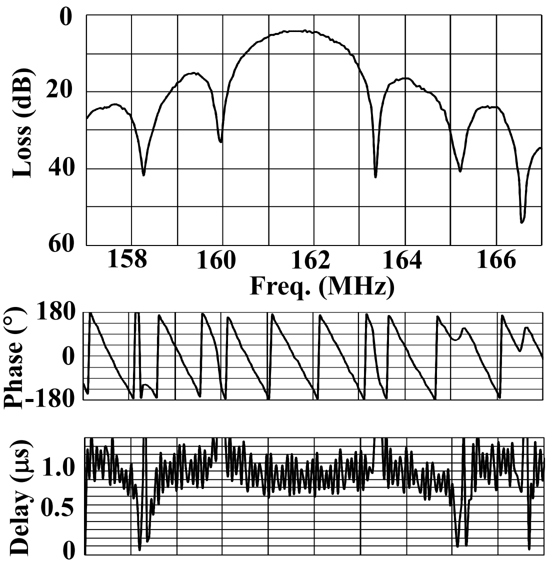

Fig. 6 Experimental results for new delay line

5. Conclusion

In order to improve insertion losses and expand the interaction areas where reactive films are formed, we invented a new lattice-circuit sensor consisting of SAW resonators with large spaces between IDTs and reflectors keeping the self –temperature -compensation characteristics. From the simulation and experimental results, we obtained the possibility to achieve compatibility between improving losses and expanding interaction areas.

References

1. J. Hosaka and M. Hikita, in IEEE Ultrason. Symp. Proc., 2011, pp.2285-2288.