A New Balanced-Type RF-Band SAW Filter Using SAW Resonators

Yutaka Taguchi, Shunichi Seki, Keiji Onishi and Kazuo Eda

Matsushita Electric Industrial Co., Ltd.
Materials and Devices Laboratory

ABSTRACT

A new balanced-type RF-band (950MHz) surface acoustic wave (SAW) filter using SAW resonators for use in portable telephones is presented. This SAW filter has balanced input and output terminals. Based on the computer simulation, balanced-type SAW filters having a pass-band at 950MHz were fabricated. The obtained characteristics showed excellent characteristics such as low insertion loss, wide bandwidth, high attenuation at stopbands, and small VSWR. Using the SAW filter, one can realize balanced-type RF circuits in portable telephones.

1.INTRODUCTION

Surface acoustic wave (SAW) filters have many advantages in that they are small,light weight, highly reproducible, do not need adjustment, and have sharp cut-off frequency response and high sidelobe suppression. Hence, SAW filters are key devices for portable telephones. For applications to portable telephones, Hikita et al. reported the interdigitated interdigital transducer (IIDT)-type SAW filter used in RF bands(1). This type of SAW filter has large attenuation at stopbands. But its insertion loss is slightly large such as 4-5dB. Ikata et al. reported a different type of SAW filter, so called resonator-type SAW filter(2). This type of SAW filter has low insertion loss of 2-3dB. But the attenuation at stopbands is not so large as that of the IIDT-type.

Both types of SAW filters, IIDT-type and resonator-type, have unbalanced input and output ports. On the other hand, a balanced mixer or a balanced amplifier has been often used in RF circuits because of its low noise and low operating voltage performance due to the balanced circuit configuration. In order to connect the balanced circuit to the unbalanced SAW filter, a balun is needed (3), which is not preferable. However, research on balanced-type SAW filters has been very few so far (4)(5). Such balanced-type SAW filters would become much more important in portable telephones, because balanced circuits have essentially great advantages such as low noise, low voltage operation, and no grounding.

In this paper, we present a new balanced-type RF-band SAW filter using a lattice configuration with one-port SAW resonators. The computer simulated frequency characteristics and obtained characteristics of the balanced-type SAW filters fabricated are also presented.

2.CONFIGURATION OF THE BALANCED-TYPE SAW FILTER

A basic configuration of the balanced-type SAW filter comprises four SAW resonators as shown in **Fig.1**. In the figure, Re_1 is a SAW resonator connected in the series-arm and Re_2 is a SAW resonator connected in the crossed-arm. One unit of the lattice configuration comprises four SAW resonators. We used a one-port SAW resonator as the SAW resonator.

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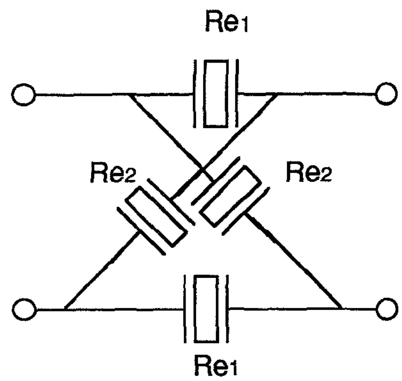

Fig.1 A basic configuration of the balanced-type SAW filter.

The resonant characteristics of Re_1 and Re_2 are shown in **Fig.2**. The resonant frequency of Re_1 is set equal to the anti-resonant frequency of Re_2. We used 36° Y-cut X-propagation $LiTaO_3$ substrates as piezoelectric substrates. 36° Y-cut X-propagation $LiTaO_3$ has a fast SAW velocity of 4178 m/sec, a large electro-mechanical coupling coefficient of 7.6 %, and small temperature coefficient of -33ppm. Typical configuration of the balanced-type SAW filter which we used is shown in **Fig.3**. In order to avoid a cross connection on the SAW chip, two sets of the lattice configuration were connected in cascade. This configuration is very useful for mass-production.

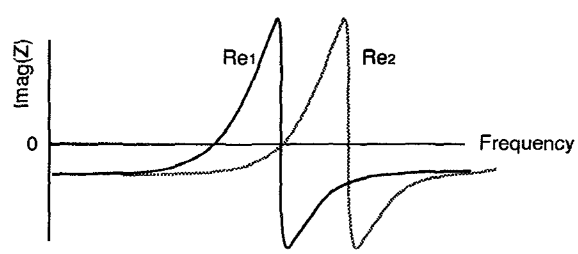

Fig.2 Resonant characteristics of Re_1 and Re_2

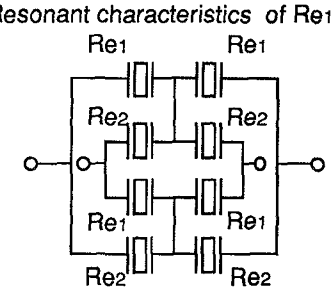

Fig. 3 Typical configuration of the balanced-type SAW filter.

3.COMPUTER SIMULATION

The basic equivalent circuit of a SAW resonator shown in **Fig.2** is expressed as in **Fig.4**. In the figure, C_1, L, R and C_0 are series capacitance, series inductance, series resistance and parallel capacitance, respectively. For simulation of the frequency characteristics of the balanced-type SAW filters, we used the improved Smith's second model proposed by T.Kojima et al. (6)

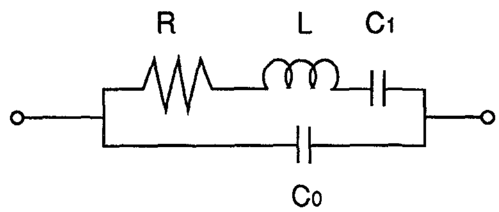

Fig. 4 Basic equivalent circuit of a SAW resonator

The insertion loss and attenuation at stopbands as a function of capacitance ratio of the crossed-arm resonator's C_0 to series-arm resonator's C_0 were obtained using this computer simulation. The results are shown in **Fig.5**. The simulated frequency characteristics of the balanced-type SAW filters when the capacitance ratios were 0.6 and 0.8, are shown in **Fig.6** and **Fig.7**, respectively. As can be seen from **Fig.5-7**, the stopband suppression and insertion loss of the balanced-type SAW filters can be controlled by changing the capacitance ratio.

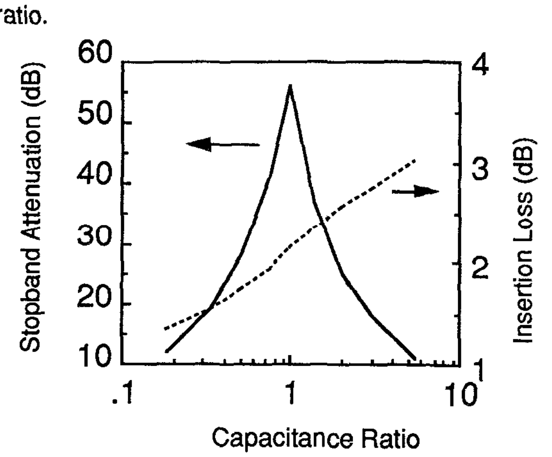

Fig. 5 Simulated relationship among capacitance ratio, stopband attenuation and insertion loss.

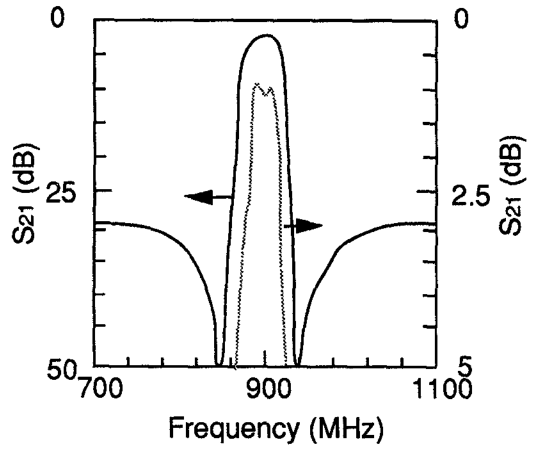

Fig. 6 Simulated characteristics of the SAW filter when the capacitance ratio was 0.6.

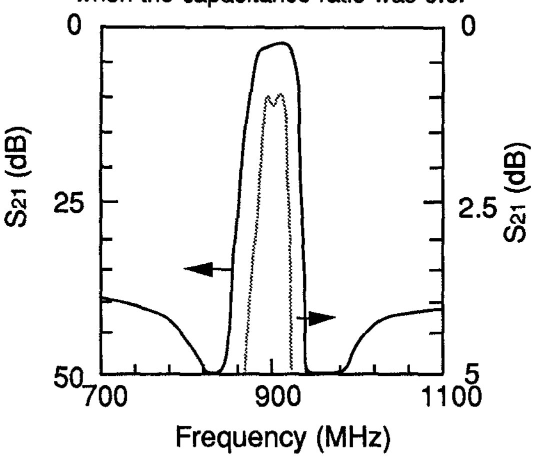

Fig. 7 Simulated characteristics of the SAW filter when the capacitance ratio was 0.8.

4.EXPERIMENTAL RESULTS

We tried to fabricate the balanced-type RF-band SAW filter using 36° Y-Cut X-propagation $LiTaO_3$ as the piezoelectric substrates and aluminum as the electrodes. The thickness of electrode was about 400 nm. The frequency characteristics were measured using an HP8753C network analyzer and baluns in order to convert the unbalanced signals to balanced signals. We used a folded Marchand type balun [7] as shown in **Fig.8**. The frequency characteristics of the balun are shown in **Fig.9**. The insertion loss of the balun was 0.25dB and the return loss was 20dB, which were good enough for measurements. Using the balun, the measured characteristics of the balanced-type SAW filters are shown in **Fig.10** and **Fig.11**, of which capacitance ratios were 0.6 and 0.8, respectively. The obtained frequency characteristics showed a good agreement with the simulated results. The obtained insertion loss, bandwidth, attenuation at stopbands, and VSWR were, 3dB, 33MHz, 40dB, and 2.0, respectively, at a 950MHz-band. These characteristics are equal or even superior to conventional unbalanced-type RF-band SAW filters.

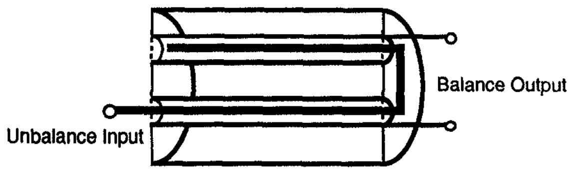

Fig. 8 Configuration of the folded Marchand balun.

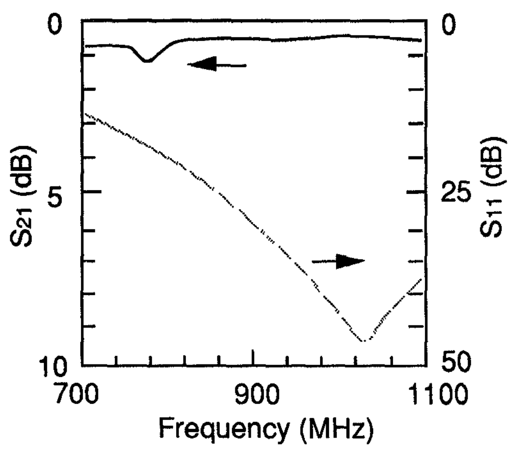

Fig. 9 Characteristics of the balun.

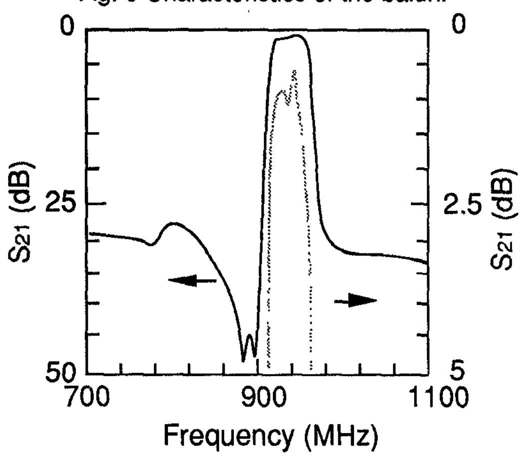

Fig. 10 Measured characteristics of the SAW filter when the capacitance ratio was 0.6.

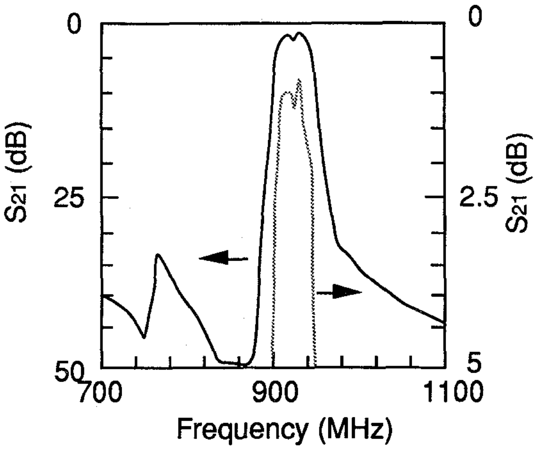

Fig. 11 Measured characteristics of the SAW filter when the capacitance ratio was 0.8.

The outlook of the fabricated balanced type SAW filter is shown in **Fig.12.**

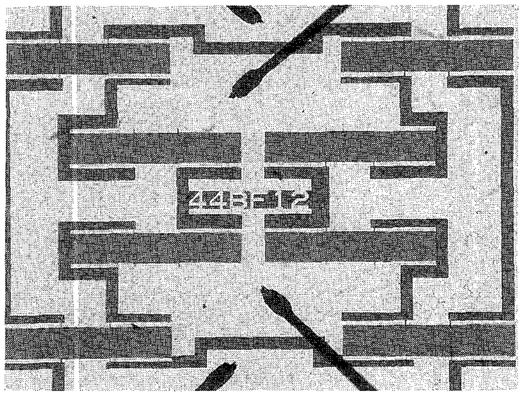

Fig.12 Outlook of the fabricated balanced type SAW filter

5.CONCLUSIONS

A new RF-band balanced-type SAW filter using lattice-type configurations with one-port SAW resonators has been developed. We simulated its frequency characteristics, designed a preferable configuration, and fabricated it using 36° $LiTaO_3$. The obtained frequency characteristics showed low insertion loss, wide passband, high attenuation at stopbands, and small VSWR, in addition to the balanced circuit configuration. These characteristics were satisfactory for application to portable telephones. The balanced-type SAW filter is very promising to improve the RF circuits in portable telephones.

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