A Balanced-Type SAW Filter for PCN and PCS Systems

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ABSTRACT

A balanced-type RF-band (1.8GHz) SAW filter for use in PCN and PCS systems is presented. This SAW filter has balanced input and output terminals. The obtained characteristics showed excellent characteristics such as low insertion loss, enough bandwidth for PCN and PCS systems, high shape factor and high attenuation at stopbands in addition to much more flexibility than other types of SAW filter.

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 ladder type of 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. The shape factor is also important in RF filters. The shape factor means the attenuation near passband. It is difficult for both types of SAW filters, IIDT-type and ladder type, to obtain high shape factor and high attenuation at stopbands at the same time.

Both types of SAW filters have unbalanced input and output ports. On the other hand, a balanced type circuit has been often used 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. We reported a balanced type SAW filter for 900MHz band [(4)]. Such balanced-type SAW filters are also important to PCN and PCS systems.

In this paper, we present a balanced-type SAW filter at 1.8GHz band for PCN and PCS systems 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 4 SAW resonators as shown in **Fig.1**. In the figure, Re1 are SAW resonators connected in series-arms and Re2 are SAW resonators connected in crossed-arms. One unit of the lattice configuration comprises 4 SAW resonators. We used a one-port SAW resonator as the SAW

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resonator. The resonant characteristics of Re1 and Re2 are shown in **Fig.2**. The resonant frequency of Re1 is set equal to the anti-resonant frequency of Re2.

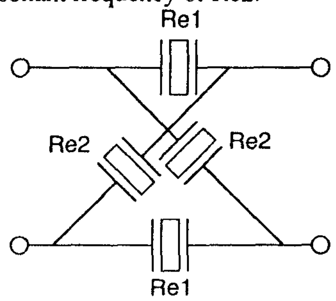

Fig.1 A basic configuration of the balanced-type SAW filter.

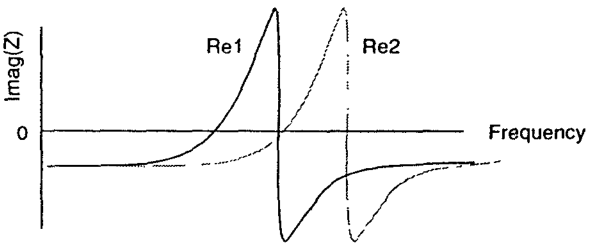

Fig.2 Resonant characteristics of Re1 and Re2.

We used 36° Y-cut X-propagation $LiTaO_3$ as piezoelectric substrates. This substrate has a fast SAW velocity of 4178 m/sec, a large electromechanical coupling coefficient of 7.6 %, and a small temperature coefficient of -33ppm.

3.COMPUTER SIMULATION

The basic equivalent circuit of the SAW resonator shown in Fig.2 is expressed as in **Fig.3**. In the figure, C1, L, R and C0 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. [5]

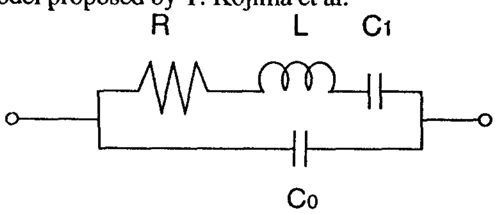

Fig. 3 Basic equivalent circuit of a SAW resonator.

The insertion loss and attenuation at stopbands as a function of capacitance ratio of crossed-arm resonator's C0 to series-arm resonator's C0 were obtained using the computer simulation. Typical frequency characteristics of the balanced type SAW filter is shown in **Fig.4**.

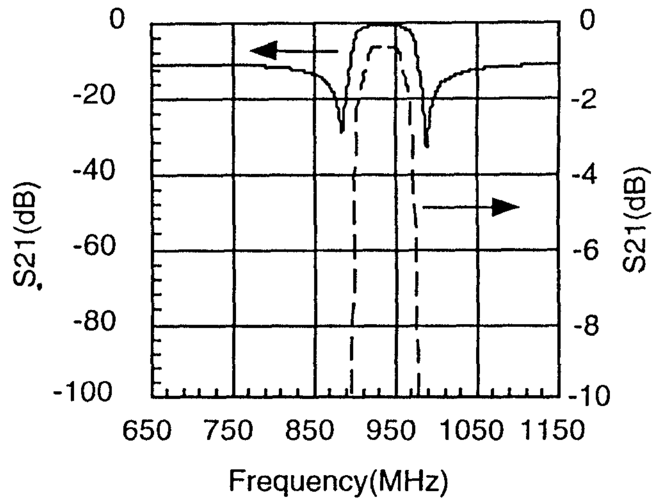

Fig.4 Typical frequency characteristics of the balanced type SAW filter

Under the simulation, the attenuation poles appeared lower than passband and higher than passband. The frequency of the attenuation pole depended on the parallel capacitance ratio of the SAW resonator. These attenuation poles appeared at the frequency that impedance of the Re1 and Re2 became equal. The parallel capacitance of Re1 must be smaller than Re2 to obtain attenuation poles as shown in **Fig. 5**.

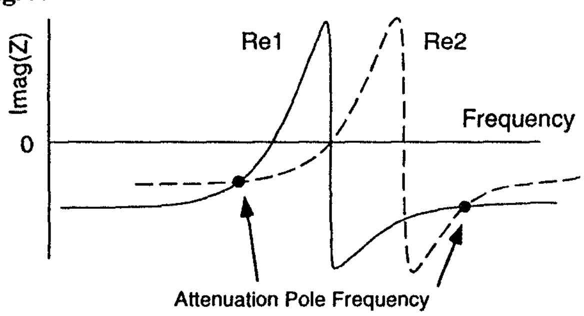

Fig.5 Resonant characteristics of Re1 and Re2 and attenuation pole frequency.

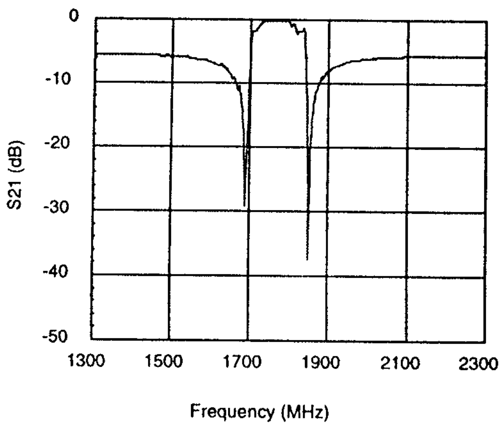

Fig.6 The simulated characteristics of the SAW filter when the capacitance ratio was 0.2

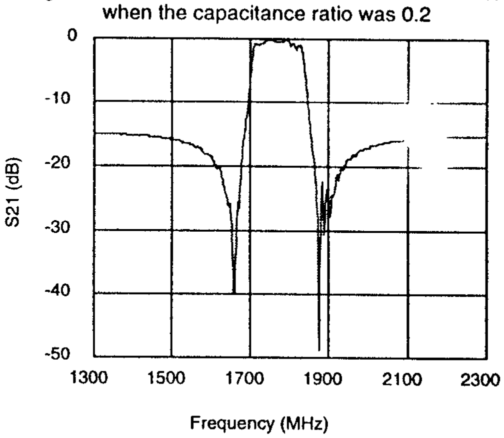

Fig 7 The simulated characteristics of the SAW filter when the capacitance ratio was 0.6

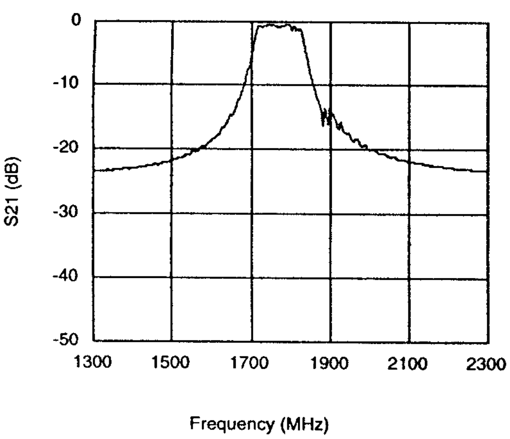

Fig.8 The simulated characteristics of the SAW filter when the capacitance ratio was 1.2

The simulated frequency characteristics of the balanced-type SAW filters when the capacitance ratios were 0.2, 0.6 and 1.2, are shown in **Fig.6, Fig.7** and **Fig.8**, respectively.

As can be seen from **Fig.6-8**, the frequency of the attenuation poles and stopband attenuation of the balanced-type SAW filters can be controlled by changing the capacitance ratio C0Re1/C0Re2. If the capacitance ratio are set small, the attenuation poles are located near the passband, the shape factor is high and the attenuation at the stopband is small. If the capacitance ratio are set large near 1.0, the attenuation poles are located far from the passband, the shape factor is low and the attenuation at the stopband is big. If two sections of lattice type circuits are connected in cascade with different capacitance ratio, the high shape factor and high attenuation at stopbands are available.
This balanced type SAW filter has more flexibility than other types of SAW filters.

4.EXPERIMENTAL RESULTS

We tried to fabricate the balanced-type SAW filter using 36° Y-Cut X-propagation $LiTaO_3$ as the piezoelectric substrates and aluminum as the electrodes. The thickness of the electrode was about 200 nm. The frequency characteristics were measured using an HP8753C network analyzer and baluns [6] in order to convert the unbalanced signals to balanced signals. Using the balun, the measured characteristics of the balanced-type SAW filters for PCN and PCS systems are shown in **Fig.9** and **Fig.10**. The capacitance ratio of the first section SAW filter for PCN was 0.38 and that of the second section was 0.97. The capacitance ratio of the first section SAW filter for PCS was 0.38 and that of the second section was 0.88. The obtained frequency characteristics showed a good agreement with the simulated results. The obtained insertion loss, passband, attenuation at stopbands, and VSWR for PCN system were, 3.5dB, 60MHz, 30dB, and 2.0, respectively. These characteristics are equal or even superior to conventional unbalanced-type SAW filters.

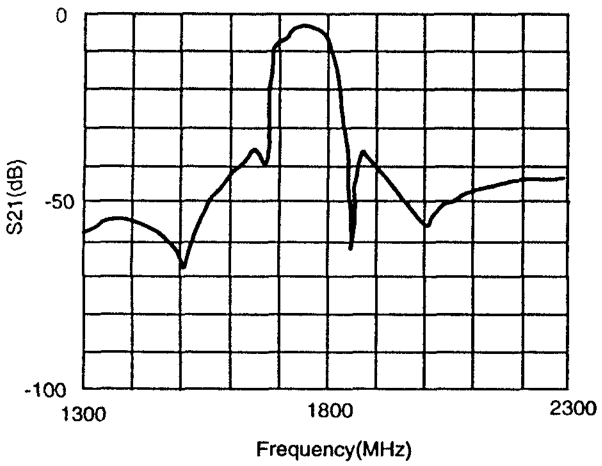

Fig.9 The measured characteristics of SAW filter for PCN

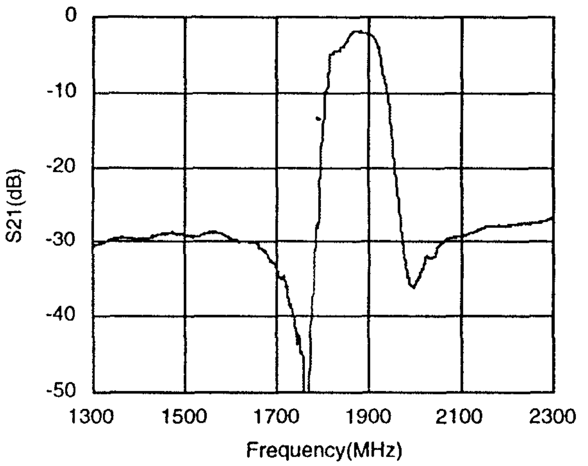

Fig.10 The measured characteristics of SAW filter for PCS

5.CONCLUSIONS

A balanced-type SAW filter for PCN and PCS systems 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°-Y cut X propagation LiTaO3. The obtained frequency characteristics showed low insertion loss, enough passband, high attenuation at stopbands, and small VSWR, in addition to the balanced-circuit configuration. These characteristics were satisfactory for PCN and PCS systems. The balanced-type SAW filter is very promising to improve the RF circuits.

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