RF SAW Filters and Duplexers Using Plastic Package Technologies
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Abstract – In recent years, as rapid progress of mobile phone market, light-weight, smaller-size and low-cost SAW devices are desired. We propose SAW devices applying in our original plastic packaging technology. The plastic package has advantages of lightweight, low material cost and low assembly cost compared with that of conventional ceramic package. As examples of SAW device using plastic package, Japanese PDC triple-band SAW filter, EGSM/GSM850 dual-balanced SAW filter, SAW duplexer for PDC 800MHz and SAW duplexer for US-CDMA are introduced.

I. Introduction

In worldwide mobile phone markets, subscriber number and traffic data quantity are increasing drastically in recent years. For this reason, multi-band, multi-mode and high-functional handset has been spread rapidly and generally. Along with rapid progress of such mobile communication markets, a lot of requests to SAW devices for handset are rising. As for RF devices mounted on mobile handset, many requirements such as high-performance, smaller-size, light-weight, low-cost and stable supply are rising.

This paper describes various SAW devices using plastic packaging technology. The plastic package has a lot of merits and can solve above-mentioned issues. As examples of SAW device using the plastic package, triple-band RF SAW filter for PDC, EGSM/GSM850 dual-band balanced SAW filter, SAW duplexer for Japanese PDC 800MHz-band and SAW duplexer for US-CDMA are introduced.

II. Surface mount plastic package for SAW devices

In worldwide RF SAW device market, most popular package material is ceramic. Many SAW device manufactures generally have to buy “the ceramic package” from package maker, it restricts SAW device suppliers to material cost reduction of the SAW devices. Moreover, since the ceramic package has the demerit of being heavy, light-weight and smaller size SAW device is strongly desired. To solve these problems, surface mount plastic packages for SAW filter using our original plastic molding technology are developed. The upper side of the fig. 1 shows gold plated copper lead frame on which about one hundred pieces of 2.5*2.0 mm$^2$ sized SAW filters are mounted. Lower parts of fig. 1 shows enlargement picture of plastic packages size of 2.5*2.0mm$^2$, 3.0*2.5mm$^2$ and 3.0*3.0 mm$^2$.

Figure 1: Outline of the plastic package
Upper: 2520 size plastic packages on a lead frame.
Lower: Package line-up
To improve device handling in assembly process, each package is never divided into individual pieces before final electrical test. Therefore, assembly cost is very low compared with that of the conventional ceramic package.

The outer material is general plastic that is widely used for molding of plastic package for semiconductors. Therefore, it is possible to use general semiconductor mass-production line for the SAW filter assembly. Moreover, in-house manufacturing of the plastic package is possible. It enables very large number mass-production and short time for delivery.

The plastic package has also lightweight advantage. As for an example of 3.0x3.0 mm\(^2\) package application, weight of a SAW filter using conventional ceramic package is about 30-40 mg, however that of the new plastic package is about 17-20 mg.

The package-side trend on single-band and dual-band RF SAW filter are shown in fig.2. The miniaturization of the size of the package is progressing every year. Recently, for dual-band applications, 2520 size package are in use. And in a single band, 2016 sizes or 2014 sizes are in use. Thus such a recent trend of packages for RF SAW filter, we are developing very low-height and light-weight plastic package. The newly developed plastic package are available for RF front-end module product owing to its very low-height of 0.55 mm and light-weight (5 mg in 2520 size) features.

### III. Triple-Band RF SAW Filter for PDC 800M/1.5G Dual-Band Handset

Japanese PDC system is operated at frequency band of 800MHz and 1.5GHz. An example of the RF diagram of PDC 800M/1.5G dual-band handset is shown in Fig. 3.

The structure of RF block is different among each handset manufactures. In this case, this PDC dual-band handset has two triple-band SAW filters (Tx triple-band filter and Rx triple-band filter). Required specifications of PDC Rx triple-band filter are shown in table 1.

#### Table 1: Specifications of triple-band Rx SAW filter for PDC

<table>
<thead>
<tr>
<th>800 M Band</th>
<th>1.5G Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD-Band</td>
<td>A-Band</td>
</tr>
<tr>
<td>Center frequency [MHz]</td>
<td>826.5</td>
</tr>
<tr>
<td>Band width [MHz]</td>
<td>33</td>
</tr>
<tr>
<td>Relative bandwidth</td>
<td>3.99%</td>
</tr>
<tr>
<td>Maximum Insertion LOSS</td>
<td>2.5dB max</td>
</tr>
<tr>
<td>VSWR</td>
<td>2.0 max</td>
</tr>
<tr>
<td>Rejection</td>
<td>893-898 MHz</td>
</tr>
<tr>
<td></td>
<td>925-960 MHz</td>
</tr>
<tr>
<td></td>
<td>1429-1453 MHz</td>
</tr>
</tbody>
</table>

The PDC Rx triple-band SAW filter is developed. Three-transducer type longitudinal resonator filter are applied for all bands. 36Y-X LiTaO\(_3\) substrate is used for fabrication. The structure of the plastic package used for the triple-band filter is shown in fig.4 and measurement circuit is shown in fig.5.

The filter has two input terminals (800M-common and 1.5G Band), three output terminals (CD-Band, A-Band and 1.5G Band) and three ground terminals.

Figure 2: Package size trend of a single-band and dual-band SAW filter

Figure 3: An example of RF block diagram of dual-band PDC handset
IV. EGSM/GSM850 Dual-Band Balanced SAW Filter using Plastic Package

Using the plastic packaging technologies, EGSM/GSM850 Rx dual-band SAW filter having unbalanced-balanced ports are also developed. To realize of low-insertion loss and high-attenuation characteristics simultaneously, three-transducer type longitudinal resonator filter is applied. This structure is suitable for realization of balanced SAW filter [1].

Balanced filter is generally supposed to have excellent attenuation level at the high frequency range (up to 6 GHz) than usual unbalance filters. To obtain good filter characteristics, should be careful to maintain structural symmetry because filter characteristics of balanced filter are strongly affected by device structure. In balanced type filter application, amplitude balance and phase balance of balance port is important parameter.

Generally, as for balanced type filter, design of single-band filter is easy to realize symmetrical structure compared with a dual-band filter due to chip layout and package design flexibility. However, we could realize efficient dual-band filter by optimum design of number of IDT pairs, aperture width, patterns layout of IDT and mechanical structure of plastic package. Developed dual-band filter is enclosed in a 2.5*2.0*0.55 mm³ size plastic package. We selected 36Y-X LiTaO₃ for the substrate of the filter. The filter has unbalanced EGSM input port (50 Ω) and balanced output port (150 Ω), and has unbalanced GSM850 input port (50 Ω) and balanced output port (150 Ω).

Upper side of fig.7 shows frequency responses of EGSM-band of the dual filter. Insertion loss within pass-band is 2.0 dB and the attenuation level from 1 GHz to 6 GHz is more than 50 dB. As for the amplitude-balance of within 0.2 dB and phase-balance of less than 1 degree toward 180 degree are obtained. Lower side of the fig.7 shows frequency responses of GSM850-band of the filter. Insertion loss within passband is
2.0 dB and the attenuation levels at 3 GHz and at 6 GHz are 60 dB and 50 dB, respectively. The amplitude-balance of within 0.15 dB and phase-balance of around 1 degree toward 180 degree are obtained.

V. SAW duplexers using plastic package

V-1 SAW duplexer for PDC 800MHz band

A front-end SAW duplexer for Japanese PDC 800MHz cellular phone is developed. Wide channel separation of 130 MHz between Tx and Rx band is required for the PDC duplexer. It is difficult to realize such a wide channel separation by usual SAW ladder type filter and DMS type filter.

Conventional duplexer for PDC system was dielectric duplexer. However, its volume was too large and restricted realization of a compact cellular phone. Cellular phone manufacturers have been much eager to demand compact and lightweight duplexer.

To solve this issue, we controlled frequencies of pole and zero arbitrary by adding outer inductor and/or capacitor to SAW resonator. By using this technique, a very low loss and high attenuation duplexer for PDC system is realized [2]. As the feature of the duplexer, it can minimize insertion loss deterioration in duplex mode due to bulk-wave radiation loss. Moreover, the developed duplexer has the advantage that λ/4 phase shifter and matching circuit are not needed.

We applied this design method to SAW duplexers for Japanese PDC 800MHz. The composition and optimization of circuits are done by combining several SAW resonators, outer inductors and capacitors. As a result, excellent duplexer performances are achieved. Insertion loss of Rx filter is less than 1.0 dB, and Rx filter’s loss is less than 1.5 dB in duplex. In addition, the isolations of the Tx and the Rx band are more than 45 dB and 50 dB, respectively. The circuit structure and frequency responses of the SAW duplexer are shown in fig.8 and fig. 9, respectively.

Without any performance degradation, this new SAW duplexer realizes the size of 5.0 * 5.0 mm² (left side of fig.10) which is just 23 % of conventional dielectric duplexer and the weight of 50 mg that is just 5 % of that. As a result, it has contributed strongly to the realization of the state-of-the-art high performance PDC cellular phones.

Figure 7: Measured Frequency responses of EGSM/GSM850 Rx dual-band balanced SAW filter using the plastic package

Figure 8: Circuit structure of SAW duplexer for PDC 800MHz

Figure 9: Measured frequency responses of SAW duplexer for PDC 800MHz
V. Conclusion

Surface mount plastic packages for SAW devices are developed. They are made by our new plastic molding technology. The plastic package has advantages of lightweight, low material cost and low assembly cost. As for the PDC triple-band SAW filter, we achieved low insertion loss of with excellent high rejection levels. Another application of the plastic package, EGSM/GSM850 dual band balanced SAW filter, SAW duplexer for PDC 800MHz and for US-CDMA are introduced. It became clear that these SAW devices enclosed in plastic have almost the same performances compared with that of SAW devices using ceramic package.

References