Realization of Small and Low Profile Duplexer Using A CSSD Packaging Technology


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ABSTRACT —
This paper presents the realization of Duplexer with small size, high reliability and excellent performance. Good heat radiation, hermetic performance and small frequency drift against temperature shift are essential to achieve small size and highly reliable Duplexers.

In this paper, we will report on the advantage of the Chip Size SAW Devices (CSSD) structure for miniaturization and high reliability. In addition, we will discuss the possibility of further miniaturization.

Index Terms — SAW, Duplexers, CSSD

I. INTRODUCTION

The cellular RF Front End market has recently seen an increase in carrier spectrum due to the addition of several systems (i.e. NCDMA, GSM, WCDMA and LTE). Spectrum requirements and regulations are moving towards multi-band and multi-mode system for mobile phones.

‘RF front end’ has become the common term for the radio frequency components located between the RFIC and Antenna. In terms of function, the miniaturization of the Duplexer is required. For example, a 0.5mm height duplexer is mandatory for building a module with a 1.2mm maximum height. In addition to this, it is required to pass high reliability test (ex. high power handling and MSL1) and obtain stabilized electrical performance in the operating temperature condition.

In this paper, we will report on the realization of a 2.5x2.0x0.5mm (2520) sized Band II duplexer by using a CSSD technology of our original structure to meet the recent demands from the Cellular RF market.

II. CSP TECHNOLOGY AND ISSUES

We had developed a Band II Duplexer in a 3.0x2.5mm² (3025) package using CSP (Chip Size Package) structure as shown in Figure 1. The feature technologies shown in Table 1 are applied to the Duplexer for high reliability and better performances.

(1) Low profile
One of the features of this Band II Duplexer is 3 die in 1 package (PKG). There are Tx SAW, Rx SAW and the IPD (Integrated Passive Device), which provides the matching components. [1]. No matching circuit is required inside the package because IPD provides that function. The result in less number of package layers enables the low profile of 0.7mm height 3025 duplexer.

(2)High reliability
High power handling can be achieved by using certain techniques to control heat radiation. Divided resonator is used to reduce the concentration of power per area. Additional bumps and better thermal conductivity substrate improves heat radiation. AuSn sealing provides MSL1 hermetic sealing.

Fig-1. Cross section of 3025 CSP (Top and Side view)
Table-1. Technology for 3025 Band II CSP Duplexer

<table>
<thead>
<tr>
<th>Item</th>
<th>Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Low profile</td>
<td>IPD technology</td>
</tr>
<tr>
<td>(2) High Power handling</td>
<td>Divided resonator</td>
</tr>
<tr>
<td></td>
<td>Addition of Au bump</td>
</tr>
<tr>
<td></td>
<td>Better thermal conductivity</td>
</tr>
<tr>
<td></td>
<td>substrate</td>
</tr>
<tr>
<td>Hermetic (MSL1)</td>
<td>AuSn sealing</td>
</tr>
<tr>
<td>(3) Excellent Performance</td>
<td>Low TCF substrate</td>
</tr>
</tbody>
</table>

(3) Excellent performance

LiTaO₃/Sapphire bonded substrate [2][3] enables small frequency drift over temperature.

However, further miniaturization for Duplexers of including matching circuit is difficult.

Some type of seal is required to keep the hermetic properties. Clearance between the chips and the edge of cavity in package is required for the fabrication. As a result, the effective areas for chips are very limited.

Fig-2 shows the image of the chip and package layout in a 2.5x2.0mm². The matching component (IPD) is removed and external components are required.

Fig-2. Cross section of 2520CSP (top view)

Even if IPD chip is removed, the 2520 SAWs are smaller than the original 3025’s. Some divided resonator may compound again or some additional bumps may be removed. These mean the degradation of the heat radiation.

We tried to fabricate 2520 size CSP Band II duplexer using the same design rule as 3025. Tx and Rx SAW chip size should be smaller than the original 3025 design. Fig-3 shows the power durability test results of the 2520 CSP and the 3025 CSP duplexers. We confirmed that the 2520 CSP has poorer power durability than the 3025 CSP duplexer, due to the design limitations.

In the next section, we propose a new structure to realize Band II duplexers in 2520 package.

Fig-3. Power durability test results (3025CSP, 2520CSP)

III. CSSD STRUCTURE

In order to solve the issues mentioned in the previous section, we applied a CSSD packaging technology [4] to the 2520 Band II Duplexer. This is our original technology and has already been applied to mass-produced interstage SAW filters. Fig. 4 shows the cross section of CSSD structured Duplexer.

Fig-4. Cross section of CSSD (Top and Side View)
The features of the CSSD structure are mentioned below. First, while CSP structure uses ceramic PKG with cavity, CSSD structure uses plain PKG without a cavity. Because the chips are molded with a Sn-Ag solder, the gap between chips and seal ring of PKG can be smaller. In addition, the seal ring width can be narrower because the outside of the lid and solder is coated by Ni plating and can achieve the hermetic performance. These technologies enable us to mount 3 chips including the matching element (IPD) in 1 PKG.

Second feature is that the back and side of the chips are touching the metal lid and the Sn-Ag solder. There is no space between chip and lid, which helps realize a lower profile. Furthermore, the improvement of heat radiation can be expected because the CSSD structure has additional heat radiation route (chip to lid and solder) which the CSP structure does not have. This improvement leads to avoid dividing resonators and to reduce the number of Au bumps, which leads to further miniaturization of the dies and overall device size.

Based on 3025 CSP Band II Duplexer, LiTaO$_3$/Sapphire bonded substrate is applied to the substrate for Tx and Rx filter of 2520 CSSD Band II Duplexer. The temperature coefficient of frequency (TCF) of this bonded substrate is better than that of conventional LiTaO$_3$ substrate by approximately 11ppm/°C and this helps the design of the Band II Duplexer, which has a transition band that is narrower than other bands (20 MHz). Furthermore, better heat radiation is expected due to a better thermal conductivity of sapphire (42W/(m*K)). In Inter-Digital Transducer (IDT) designs, the ladder type SAW filter is selected for the Tx band filter due to its capabilities of handling higher power. The Double Mode SAW (DMS) filter design is preferred in the Rx band filter because of the ability to design both balanced and unbalanced outputs. The phase shifter at the Antenna port is formed by IPD on a glass substrate.

IV. EXPERIMENTAL RESULTS

Figure 5 shows the frequency drift value of the Tx filter when the transmitting power is applied to the Tx input terminal of a 2520 CSSD and 3025 CSP duplexer. According to our expectation, the drift value of the CSSD structure is less than that of the CSP structure. This result shows that temperature rise on the surface of the CSSD chip is lower than the CSP chip.

The difference of the frequency drift value between 3025 CSP and 2520 CSSD is approximately 0.6 MHz when Tx input power is 1W (30dBm). This result shows that the difference of the temperature on chip surface is 10° C because the TCF in the anti-resonance frequency of LT/Sapphire substrate is approximately -28 ppm/°C.

From past data, we can expect power durability to be about double since the life of power handling doubles if the temperature falls by 10°C.

Figure 6 shows the power durability test results for 2520 CSSD and 3025 CSP. Dramatic improvements were obtained according to the investigation shown figure 5. Therefore, the 2520 CSSD Band II duplexer has the enough capability to guarantee our target specification (+55°C, +30dBm, 10000hours).

Figure 7 and 8 show the electrical comparisons between 2520 CSSD and 3025 CSP duplexers. The antenna and Tx port are 50 Ohms single-ended. The Rx port has a balanced output of 100 Ohms. External matching components are unnecessary as explained above. The performance of 2520 CSSD duplexer is better than those of 3025 CSP. For the 2520 CSSD duplexer, Tx and Rx insertion loss is 2.3dB and 3dB respectively. Tx band isolation is 59dB and Rx band isolation is 54dB.
V. CONCLUSION

The CSP duplexer power handling capability degraded as the device was miniaturized. We applied CSSD packaging technology due to improve the heat radiation. As a result, UMTS Band II Duplexer with 2.5x2.0x0.5mm$^3$ has better power handling capability and better electrical characteristics than those of the 3025 CSP. The 2520 Band II duplexer has been developed and is currently in mass-production.

The CSSD structure has the possibility to achieve a 0.4mm max height. Our goal is realize a 0.4mm height by early 2010.

REFERENCES


