Qualcomm’s First 5G mmWave Chipset

SDX50M and QTM052

SP19482 - Packaging report by Stéphane ELISABETH
Laboratory Analysis by Nicolas RADUFFE
September 2019 – Sample
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Executive Summary

This full reverse costing study has been conducted to provide insight on technology data, manufacturing cost and selling price of the Qualcomm SDX50M and QTM052.

The complete solution has been specially designed for smartphone application, starting with Samsung but quickly spread with Motorola, Xiaomi, ... The module in the Samsung Galaxy S10 5G USA, comes with four systems spread in the smartphone. The first SiP is the baseband processor using a standard BGA SiP packaging coupling Flip-Chip and Wire bonding integration. The other systems are the antenna module that are spread at the corner of the smartphone in order to provide a spherical coverage. The modules are placed in the smartphone in order to provide a full coverage without any hand blocking constraint.

Two generation of the antenna module are integrated in the flagship. The first generation come with dipole antenna coupled with patch antenna. The patch antenna is designed in order to provide a wide band radiating system. Among the innovation in the antenna design, Qualcomm seems to integrate Aperture coupling patch, Dual Polarized Antenna, and Dual band Antenna. In the second generation, the component has been shrunk by almost 30% in order to fit in the smartphone’s z-height.

This report includes a full investigation of the system, featuring a detailed study of the SiPs including die analyses, processes and board cross-sections. It contains a complete cost analysis and a selling price estimation of the system. Finally, it features an exhaustive comparison with the structure of the Sub-6 GHz chipset and the Qualcomm’s WiGig Chipset dedicated to handset.
Samsung Galaxy S10 5G US Teardown

Company Profile & Supply Chain
- Qualcomm
- 5G technology
- 5G mmWave challenges
- 5G mmWave configuration
- Samsung Galaxy S10 5G USA Teardown

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- Board Cross-Section
- Baseband SiP
  - Package
  - SiP Cross-Section
  - SiP Active Dies
- Antenna SiP
  - Overview
  - X-Ray Overview
  - Package
  - Antenna SiP Cross-Section
  - Transceiver and PMIC Dies
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Baseband SiP
- Package:
- Dimensions:
- Pin Pitch:

Antenna SiP
- Gen. 1
  - Package:
  - Dimensions:
- Gen. 2
  - Package:
  - Dimensions:
The PCB is made with three parts. Two main boards connected with a via frame.

The baseband processor is soldered on the main board #1.

The on board AiP is soldered on the main board #2.
Baseband Processor Module – Bill of material

<table>
<thead>
<tr>
<th>Est. Manufacturer</th>
<th>Device</th>
<th>Type</th>
<th>Dimensions (mm)</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samsung</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SK Hynix</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Antenna Module – Package Opening

Package Top View
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Package Top View – Optical View
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• Tomographic X-Ray view has been made on both generation of AoP to reveal the differences and the similarity. This analysis is nondestructive and allows us to virtually made cross section of the board. In this view, the silicon dies aren’t visible.
Antenna Module – Package Overview – Gen. 1 – X-Ray View – Dipole
Antenna Module – Package Overview – Gen. 1 vs. Gen. 2 – X-Ray View

Physical Analysis
- Synthesis
- Module
- Board Cross-Section
- Baseband SiP
  - Package
  - SIP Cross-Section
  - SIP Active Dies
- Antenna SiP
  - Overview
    - X-Ray Overview
  - Package
    - Antenna SIP Cross-Section
    - Transceiver and PMIC Dies

Physical Comparison

Manufacturing Process Flow

Cost Analysis

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Antenna Module – Transceiver Die Dimensions

- Die Area:
- Nb of PGDW per 6-inch wafer:
- Pad number:

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Antenna Module – Transceiver Die Overview
5G technology – Sub-6 GHz vs. mmWave

Samsung Galaxy S10
5G (Korea) – Sub-6 GHz

- 5G band: n78 (3550 MHz)

Samsung Galaxy S10
5G (USA) – mmWave

- 5G band:
  - n260 (39000 MHz)
  - n261 (39000 MHz)
Baseband Processor Module – Modem Front-End Cost

<table>
<thead>
<tr>
<th>Front-End</th>
<th>Low Yield</th>
<th>Medium Yield</th>
<th>High Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost</td>
<td>Breakdown</td>
<td>Cost</td>
</tr>
<tr>
<td>Raw wafer Cost (Si)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clean Room Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumable Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield losses Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Modem Front-End Cost

Foundry Gross Profit

Modem Front-End Price

The front-end cost for Modem Die ranges from \( \ldots \) according to yield variations.

The largest portion of the manufacturing cost is due to the \( \ldots \).

We estimate a gross margin of \( \ldots \) which result in a Front-End price ranging from \( \ldots \). This corresponds to the selling price to Qualcomm.
Baseband Processor Module – Component Cost

Component Cost Breakdown (Medium Yield)

- Modern Die Cost
- SMD Components Cost
- Yield losses cost
- Modulator Die Cost
- Packaging cost
- Memory Die Cost
- Final test & Calibration cost

Cost Analysis
- Cost Analysis Summary
- Yields Explanation & Hypotheses
- Baseband FE Cost & Wafer/Die Cost
- BB SIP Packaging Cost
- BB SIP Component Cost
- Transceiver/PMIC FE Cost & Wafer/Die Cost
- Antenna SIP Packaging Cost
- Antenna SIP Component Cost

Selling Price Analysis

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Antenna Module – Transceiver Front-End Cost

By adding the probe test cost, the bumping, the thinning and the dicing, the transceiver wafer cost ranges from  to  according to yield variations.

The number of good dies per wafer is estimated to ranges from  to  according to yield variations, which results in a die cost ranging from  to .
## Antenna Module – Packaging Cost

<table>
<thead>
<tr>
<th>Package Manufacturing</th>
<th>Low Yield</th>
<th>Medium Yield</th>
<th>High Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost</td>
<td>Breakdown</td>
<td>Cost</td>
</tr>
<tr>
<td>PCB Substrate Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clean Room Cost</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Equipment Cost</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Consumable Cost</td>
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<td></td>
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<tr>
<td>Labor Cost</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Yield Losses Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Package Manufacturing Cost</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Gross Profit</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Package Price</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The **Packaging cost** for the SiP ranges from a certain value according to yield variations. The largest portion of the manufacturing cost is due to the [certain component].
Estimated Manufacturer Price

We estimate that Qualcomm realizes a gross margin of [x]% on the modules, which results in a final component price ranging from [low] to [high] for the baseband processor, from [low] to [high] for the first generation of Antenna Module and from [low] to [high] for the second generation of the Antenna Module.

This corresponds to the selling price for large volume to OEMs.
Chipset estimated Manufacturer Price

<table>
<thead>
<tr>
<th></th>
<th>Low Yield</th>
<th></th>
<th>Medium Yield</th>
<th></th>
<th>High Yield</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost</td>
<td>Breakdown</td>
<td>Cost</td>
<td>Breakdown</td>
<td>Cost</td>
<td>Breakdown</td>
</tr>
<tr>
<td>Component cost</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qualcomm Gross Profit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Component price</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

We estimate that Qualcomm realizes a gross margin on the modules, which results in a final chipset price ranging from

This corresponds to the selling price for large volume to OEMs.
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- RF Front-End Module Technical Comparison 2019
- Broadcom AFEM-8092 System-in-Package in the Apple iPhone Xs/Xr Series

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- Trainings

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