RF Modules & Components Review in Smartphones

Apple iPhone 7 Plus, Samsung Galaxy S7, Huawei P9, Xiaomi Mi5, LG G5

MEMS report by Stéphane ELISABETH
February 2017
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Executive Summary

- This comparative technologies study has been conducted to provide insight on technology data for RF components in Smartphones. The report includes the study of at least 16 Front-End Modules and several components found in five flagships smartphone (Apple iPhone 7 Plus, Samsung Galaxy S7 Edge, Huawei P9, LG G5, Xiaomi Mi5).

- With teardowns of a large variety of smartphones, the main RF components has been extracted and analyzed. Sizes and technologies are studied to provide a large panel of OEM technical and economical choice and an overview of the market. Major players remain Broadcom/Avago and Qorvo but several other players like Skyworks, Murata, Epcos/TDK also exist and has been analyzed.

- The report includes a description of each components and statistical analyses for most of front-end modules. All of this technologies have been physically analyzed and compared.

- **Note:** Wifi and Bluetooth Module analyses are not included in this report
Apple Smartphone History & RF Major Players

Apple try and succeed to developed one processor each year in order to improve the last series or to propose a new series.

2013  ➤  2014  ➤  2015  ➤  2016
Apple iPhone 7 Plus Teardown

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Samsung Galaxy S7 Physical Analysis
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iPhone 7 Plus Physical Analysis

Samsung Galaxy S7 Physical Analysis

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Apple iPhone 7 Plus RF Components Summary

<table>
<thead>
<tr>
<th>RF Components (Marking)</th>
<th>Manufacturer</th>
<th>Type</th>
<th>Dimensions</th>
<th>Area</th>
<th>RF Board Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFEM-8050</td>
<td>Broadcom</td>
<td>Mid-Band FEM (PAMiD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AFEM-8060</td>
<td>Broadcom</td>
<td>High-Band FEM (PAMiD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RF6110</td>
<td>Qorvo</td>
<td>Low-Band FEM (FEMiD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D5313</td>
<td>TDK-Epcos</td>
<td>Filter bank</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D5325</td>
<td>TDK-Epcos</td>
<td>Filter bank</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SKY13702</td>
<td>Skyworks</td>
<td>Diversity Receiver Module (RxDM)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SKY13703</td>
<td>Skyworks</td>
<td>Diversity Receiver Module (RxDM)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total
**AFEM-8050 – Package View & Dimensions**

- **Package:**
- **Dimensions:**
- **Pin Pitch:**

**Marking:**

<Avago Logo>

AFEM-8050
KA1629
KM134
320102AA

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**Company Profile & Supply Chain**

- **Apple iPhone 7 Plus Physical Analysis**
  - Synthesis
  - Avago AFEM-8050
  - Avago AFEM-8060
  - Qorvo RF6110
  - Epcos/TDK D5313
  - Epcos/TDK D5325
  - Skyworks SKY13702
  - Skyworks SKY13703

- **Samsung Galaxy S7 Physical Analysis**
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**Comparison Analysis**

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**About System Plus**
AFEM-8050 – Package Opening
AFEM-8050 – Active Devices – Power Amplifier

iPhone 7 Plus Physical Analysis
- Synthesis
  - Avago AFEM-8050
  - Avago AFEM-8060
  - Qorvo RF6110
  - Epcos/TDK D5313
  - Epcos/TDK D5325
  - Skyworks SKY13702
  - Skyworks SKY13703

Samsung Galaxy S7 Physical Analysis

Huawei P9 Physical Analysis

LG G5 Physical Analysis

Xiaomi Mi5 Physical Analysis

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*Power Amplifier #1 – Optical View*

*Power Amplifier #2 – Optical View*
AFEM-8050 – Active Devices – SPxT Switch

iPhone 7 Plus Physical Analysis
- Synthesis
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  - Avago AFEM-8060
  - Qorvo RF6110
  - Epcos/TKD D5313
  - Epcos/TKD D5325
  - Skyworks SKY13702
  - Skyworks SKY13703

Samsung Galaxy S7 Physical Analysis

Huawei P9 Physical Analysis

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SPDT Switch # 1 – Optical View

- Die #1 Area:

- Die #1 Marking:
  - Die #2 Area:
  - Die #2 Marking:
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- Synthesis
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  - Avago AFEM-8060
  - Qorvo RF6110
  - Epcos/TDK DS313
  - Epcos/TDK DS325
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AFEM-8050 – Passive Devices – BAW Filters

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  - Epcos/TDK DS325
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AFEM-8050 – Components Summary

<table>
<thead>
<tr>
<th>PAMiD</th>
<th>Number of Die in Module</th>
<th>Total Die Area (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter (Type)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Amplifier</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RFIC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passives SMD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blank Space</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Module Area: 

% of the RF Board Area

Area Repartition

- Filter
- Switch
- Power Amplifier
- RFIC
- Passives SMD
- Blank Space

Die Repartition

- Filter
- Switch
- Power Amplifier
- RFIC
- Passives SMD
- Blank Space

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RF Front End Modules and Components for Cellphones

A dynamic market with high responsivity to technical innovation, the RF front end industry is set to grow at 14% CAGR to reach $22.7B in 2022. Released in March 2017

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Founded in 1998, Yole Développement has grown to become a group of companies providing marketing, technology and strategy consulting, media and corporate finance services. With a strong focus on emerging applications using silicon and/or micro manufacturing, the Yole Développement group has expanded to include more than 50 collaborators worldwide covering MEMS, Compound Semiconductors, LED, Displays, Image Sensors, Optoelectronics, Microfluidics & Medical, Advanced Packaging, Manufacturing, Nanomaterials, Power Electronics and Batteries & Energy Management.

The “More than Moore” company Yole and its partners System Plus Consulting, Blumorpho, KnowMade and PISEO support industrial companies, investors and R&D organizations worldwide to help them understand markets and follow technology trends to develop their business.

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• Reports business: David Jourdan (jourdan@yole.fr)
• Press relations: Sandrine Leroy (leroy@yole.fr)
The radio-frequency (RF) front end and components market for cellphones is highly dynamic. From being worth $10.1B last year, it is expected to reach $22.7B in 2022. Such high growth is definitely something that players in other semiconductor markets would envy. However, the growth is not evenly distributed. Filters represent the biggest business in the RF front end industry, and the value of this business will more than triple from 2016 to 2022. Most of this growth will derive from additional filtering needs from new antennas as well as the need for more filtering functionality due to multiple carrier aggregation (CA).

Power amplifiers (PAs) and low noise amplifiers (LNAs), the second biggest business, will be almost flat over the same period. High-end LTE PA market growth will be balanced by a shrinking 2G/3G market. The LNA market will grow steadily, especially thanks to the addition of new antennas.

Switches, the third biggest business, will double. This market will mainly be driven by antenna switches.

Lastly, antenna tuners, a small business today with an estimated $36M market value, will expand 7.5-fold to reach $272M in 2022. This growth is mainly due to tuning being added to both the main and the diversity antennas.

RF FRONT END MODULES AND COMPONENTS FOR CELLPHONES
Market & Technology report - March 2017

A dynamic market with high responsibility to technical innovation, the RF front end industry is set to grow at 14% CAGR to reach $22.7B in 2022.

A MARKET THAT WILL MORE THAN DOUBLE IN SIX YEARS!

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A HIGHLY COMPLEX INDUSTRY

However, the RF front end market’s double digit annual growth rate comes with a severe penalty: added complexity!

Deployment and access to the 3G/4G network has accelerated the smartphone trend. It allows consumption of more messaging, music, photo, movie streaming and video chatting. High quality video download and upload is definitely driving needs for enhanced bandwidth and peak data rates.

This continual growth of mobile data has led to a need to use more of the radio spectrum. In mobile communication, this resource becomes scarce as the number of users and technologies explodes.

In order to face this overflowing demand, handsets have to meet complex requirements such as:

- Multi-band for regional and global roaming
RF FRONT END MODULES AND COMPONENTS FOR CELLPHONES

- Multi-mode to support multiple cellular modes including 2G, 3G, 4G, WiFi/Bluetooth (BT), Near Field Communications (NFC) and Global Positioning System (GPS)
- Multiple-Input Multiple-Output (MIMO) to allow higher data rates and higher effective range
- Smart antenna techniques such as beamforming or diversity to enhance the performance of a single data signal

- CA to support broader bandwidths, which improves broadband experience, offering higher peak data rates, higher overall network capacity and lower latency. This was introduced in 3GPP release 10 in 2012 and has been since used and enhanced in LTE-Advanced.

All these requirements bring a huge challenge to handset RF front end architecture, design and manufacturing to handle bands that span from low- to high-frequency.

Thus an extremely interesting aspect of the RF front-end industry is its high responsivity to innovation. Innovation in RF front-ends can come from three different sources:

- **Materials**: e.g. the development of a new RF silicon-on-insulator (SOI) substrate, like SOITEC’s e-Si substrate, in order to reduce current leakage from the transistors into the substrate or to reduce parasitic capacitances

- **Design**: e.g. new internal component design such as ACCO Semiconductor’s power amplifiers that can improve SOI-based PA performance and be cost competitive with GaAs PAs for low- and mid-band frequencies

- **Architecture**: e.g. the integration of three duplexers into a hexaplexer, or the creation of multi-mode multi-band PA modules working on all low-band, high-band or mid-band frequencies.

三种可能的RF前端创新

**Materials**
(SOI, Bulk Si, SiGe,等…)

**Design**
(Transistor types, PA internal design, etc…)

**Architecture**
(Converged and hybrid modules, PAMiD, etc…)

（Yole Développement, March 2017）

FOUR PLAYERS ACCOUNT FOR 90% OF THE RF FRONT END MARKET: HOW CAN NEW PLAYERS PENETRATE?

Broadcom, Skyworks, Qorvo and Murata are well established. New players have to be able to deliver high volumes and fit all industry requirements, while being supported by the large corporates that today own the market.

On the other hand, once a new technology arrives, it can literally take over the market in five years’ time, completely reconfiguring the manufacturer and supplier landscape.

As an example, in antenna RF-switches, SOI switches went from less than 20% market share in 2010 to 95% in 2016, with players such as Peregrine Semiconductor switching from silicon-on-sapphire to SOI.

When such innovation occurs, other players have to adapt or leave the market. This is what happened with Sony’s GaAs-based switch market share, which has shrunk over the years. Similar technology replacements are expected with the SOI PAs, for example, which will replace GaAs PAs over time.

Leading organizations and potential disruptive players

（Yole Développement, March 2017）
When such changes occur, the complete industrial chain and the value flow changes. Substrate suppliers as well as foundry service providers can be deeply impacted by such a rapid technology change.

Over the short term, players like Cavendish Kinetics with its low loss RF MEMS xPxT switches can enable new RF front end architecture without costly diplexers/multiplexers.

In the longer term, possible developments could even render RF front-ends obsolete. Seamless Waves, for example, is developing a CMOS-based tunable analog-to-digital converter and tunable digital-to-analog converter that can actively center on a specific frequency and adjusts its bandwidth, thus converting only the needed part of the incoming signal. If this technology manages to get the low power consumption and small size required for smartphones, it could disrupt the industry and allow more innovative developments such as on-phone cognitive radio. This would create a totally different industry!

COMPANIES CITED IN THE REPORT (non exhaustive list)

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Claire TROADEC is leading the RF activity at Yole Développement. She has been a member of the MEMS manufacturing team from 2013. She graduated from INSA Rennes in France with an engineering degree in microelectronics and material sciences. She then joined NXP Semiconductors, and worked for 7 years as a CMOS process integration engineer at the IMEC R&D facility. During this time, she oversaw the isolation and performance boost of CMOS technology node devices from 90 nm down to 45 nm. She has authored or co-authored seven US patents and nine international publications in the semiconductor field and before joining Yole Développement managed her own distribution company.

Antoine BONNABEL is an analyst for RF devices and technologies at Yole Développement. He holds a M.S. in Microelectronics from Grenoble Institute of Technologies and a M.S. in Management from Grenoble Graduate School of Business. Prior to Yole Développement, Antoine was R&D Program Manager for DelfMEMS, a company specialized in RF Switches, where he supervised R&D projects, IP and Business Intelligence. Antoine has co-authored several market reports from Yole Développement and filed three patent applications on RF MEMS design.
Business Models Fields of Expertise

- Custom Analyses
  (>130 analyses per year)

- Reports
  (>40 reports per year)

- Costing Tools

- Trainings

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