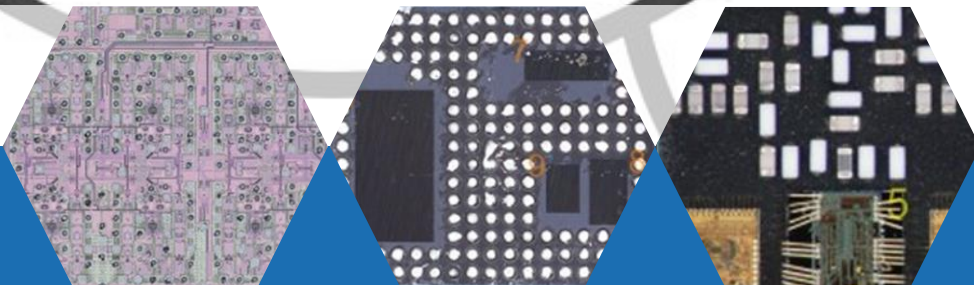


# iPhone Series



## RF Front-End Module Comparison 2021 – Vol. 1 – Focus on Apple

Technical and cost overview of the evolution of the radio frequency front-end module technologies integrated in the iPhone series from 2016 - 2020.

SPR21588 - RF report by Stéphane ELISABETH

Laboratory analysis by Nicolas RADUFFE

March 2021 – Sample

**SAMPLE**

# Table of Contents

<a href="#">Overview / Introduction</a>	4	<a href="#">Physical Analysis</a>	74
o Executive Summary		o Summary of the Analyzed RF Components	
o Key Take Away		o Summary of Comparative Study	
o Reverse Costing Methodology		o Baseband - Front-End Analysis	76
<a href="#">Company Profile</a>	11	o Qualcomm Front-End Analysis	
o Apple iPhone Series		✓ Package Views & Dimensions	
o Smartphones Teardown:		✓ Package Opening	
iPhone 7series, SE, 8 series, X, Xs max, Xr, 11 series, SE (2020), 12 series		✓ Die Views And Dimensions	
o Intel vs. Qualcomm version		✓ Die Summary	
o Apple iPhone 11 <sup>th</sup> vs. 12 <sup>th</sup> generation		✓ Components Summary and Cost	
<a href="#">Physical Analysis Summary</a>	32	o 4G LTE - Front-End Analysis	97
o Component Summary		o Broadcom, Murata, Skyworks Front-End Analysis	
o Database Content: RF Area, LTE/5G bands per smartphones, Module in RF area		✓ Package Views & Dimensions	
o Component Summary: Evolution of supplier, Evolution of RF packaging		✓ Package Opening	
o Comparative Analysis: Design win in RFFE and connectivity, Main supplier, Function		✓ Die Views And Dimensions	
		✓ Filter Die Schematic	
<a href="#">Physical Comparison</a>	51	✓ Die Summary	
o Area Distribution per Supplier & Function		✓ Estimated Front-End Bloc Diagram	
o Qualcomm Content – 4G LTE vs. 5G NR		✓ RF Components Summary and Cost	
o Apple iPhone 12 Pro Max vs. Samsung Galaxy Note20 5G and OnePlus 8 5G – 5G Chipset Cost and Component		o 5G Sub-6 - Front-End Analysis	164
o Die Design Win in Number & Area		o Murata, Skyworks Front-End Analysis	
o Die Distribution per Function		o Antenna Adaptation - Front-End Analysis	198
o Filter Distribution per Smartphone: Technology & Substrate		o Qorvo, Murata, Broadcom Front-End Module Analysis	
o PA/LNA/Switch Distribution per Smartphone: Technology & Substrate		o 5G mmWave - Front-End Analysis	226
o Material Substrate Distribution per Smartphone		o Apple Front-End Module Analysis	
<a href="#">Cost Comparison</a>	65	o UWB/Wifi/BT/GPS - Front-End Analysis	248
o Chipset Cost evolution		o Broadcom, Murata, Skyworks, USI Front-End Module Analysis	
o Cost Distribution per Supplier & Function			
o Qualcomm Content – 4G LTE vs. 5G NR			
<a href="#">Market Analysis</a>	70	<a href="#">Feedbacks</a>	313
o RFFE & Connectivity Market Forecast		<a href="#">Related Analyses</a>	314
o Current Technology Landscape		<a href="#">SystemPlus Consulting Services</a>	316
o Smartphone and Supplier OEM market share			

# Executive Summary – 2020 Volumes

## [Overview / Introduction](#)

- Executive Summary
- Reverse Costing Methodology
- Glossary

## [Company Profile & Supply Chain](#)

## [Physical Analysis Summary](#)

## [Physical Comparison](#)

## [Cost Comparison](#)

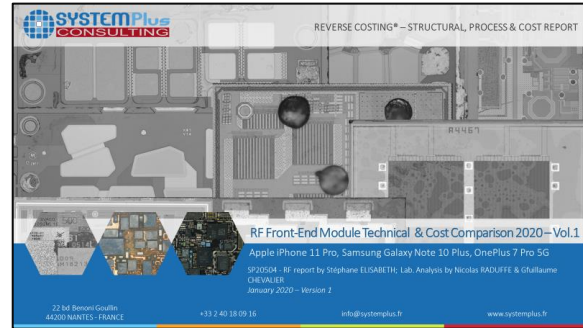
## [Market Analysis](#)

## [Physical Analysis](#)

## [Related Analyses](#)

## [About System Plus](#)

### RF Front-End Module Comparison 2020 – Vol. 1 Study on smartphones on Q3 2019



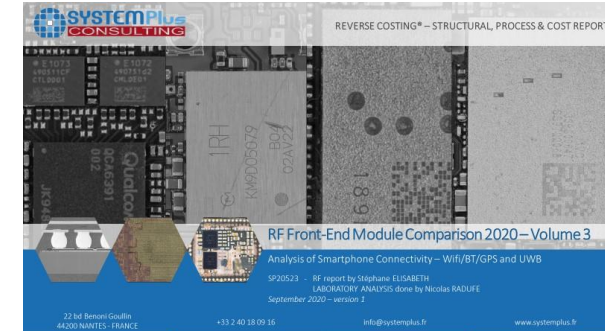
The report includes the study of at least twenty FEM and several components found in three smartphones: **Apple iPhone 11 Pro, Samsung Galaxy Note10+ and OnePlus 7 Pro 5G**. Also, it comes along with a database including information on 485 components in 17 smartphones.

### RF Front-End Module Comparison 2020 – Vol. 2 Study on Huawei smartphones



The report includes the study of at least eighty FEM and several components found in ten smartphones: **Mate and P series from 2015 to 2019**. Also, it came along with a database including information on 483 components in 13 smartphones.

### RF Front-End Module Comparison 2020 – Vol. 3 Wifi & Connectivity



The report includes the study of several FEMs and components found in 14 smartphones: **From Apple to Xiaomi**. Also, it came along with a database including information on 281 components in 44 smartphones.

### RF Front-End Module Comparison 2020 – Vol. 4 Study on Chinese/Asian OEMs

The report includes the study of at least 50 FEM and several components found in Five smartphones: **Huawei P40 Pro, OnePlus 8 5G, Oppo Reno3 5G, Vivo X30 Pro, Xiaomi Mi 10 Pro 5G and ZTE Nubia Red magic 5G**. Also, it comes along with a database including information on 516 components in 19 smartphones.





# Apple Smartphone History and RF Front-End Major Players

[Overview / Introduction](#)

[Company Profile & Supply Chain](#)

- ▶ Apple
- Apple iPhone Teardown: From SE (2016) to 12
- CDMA version Study
- 11<sup>th</sup> vs. 12<sup>th</sup> Generation

[Physical Analysis Summary](#)

[Physical Comparison](#)

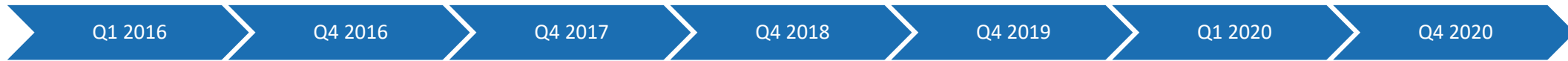
[Cost Comparison](#)

[Market Analysis](#)

[Physical Analysis](#)

[Related Analyses](#)

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iPhone SE



iPhone 7



iPhone 8



iPhone X



iPhone XS



iPhone 11



iPhone SE



iPhone 12

- Apple used to release a single high-end series of phones per year. This year, we have seen the release of 3 high-end series of phones, a significant change in Apple's product strategy.
- For the supply chain, the company has relied on Broadcom, Avago and Skyworks since 2011. Avago and Skyworks have a role in the supply chain mainly for antenna tuners.
- Since the iPhone 11, Murata integrates the supply chain mainly with directly modules along with Avago.



# Apple Smartphone Teardown

[Overview / Introduction](#)

[Company Profile & Supply Chain](#)

- Apple
- ▶ Apple iPhone Teardown: From SE (2016) to 12
- CDMA version Study
- 11<sup>th</sup> vs. 12<sup>th</sup> Generation

[Physical Analysis Summary](#)

[Physical Comparison](#)

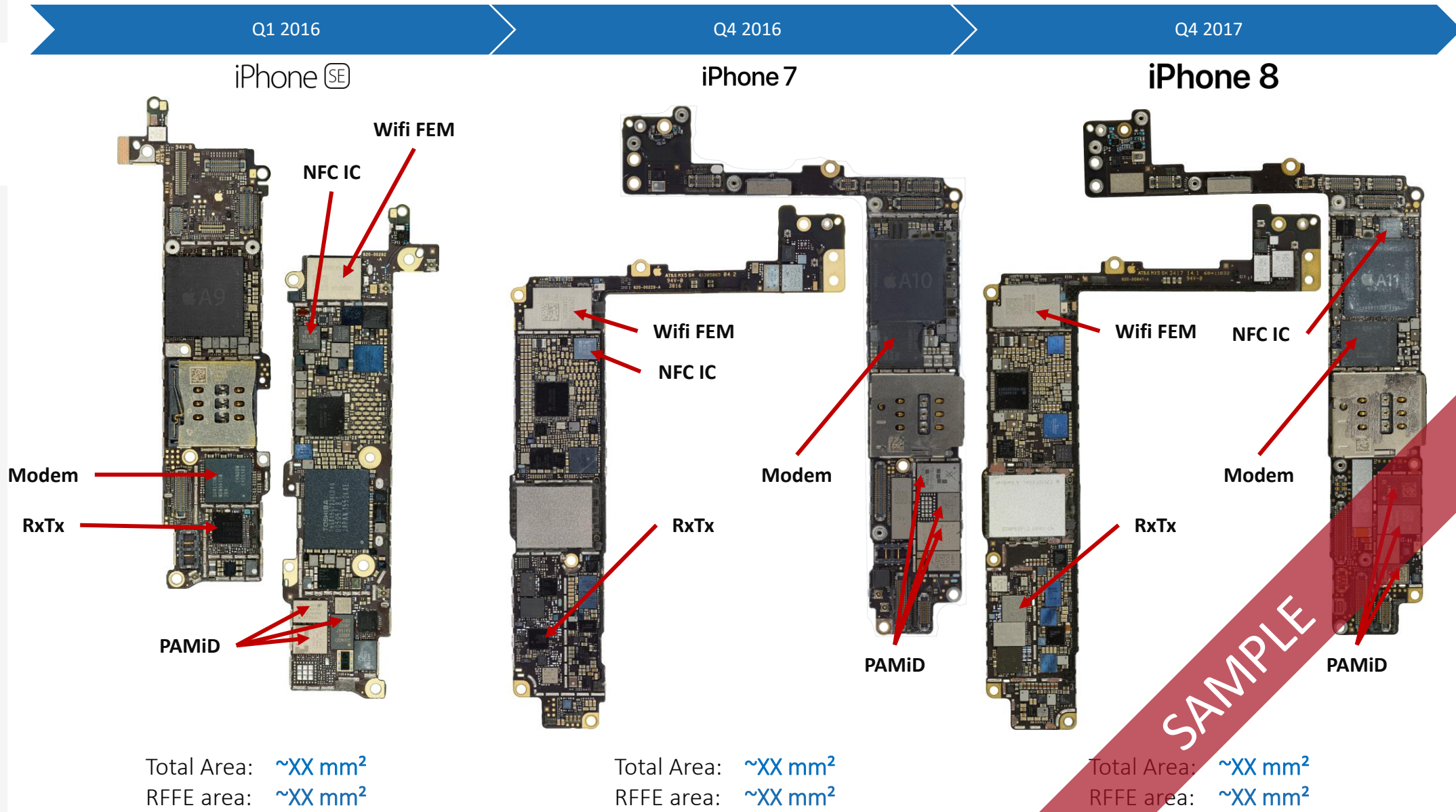
[Cost Comparison](#)

[Market Analysis](#)

[Physical Analysis](#)

[Related Analyses](#)

[About System Plus](#)



# RF Components Summary

[Overview / Introduction](#)

[Company Profile & Supply Chain](#)

[Physical Analysis Summary](#)

[Physical Comparison](#)

[Cost Comparison](#)

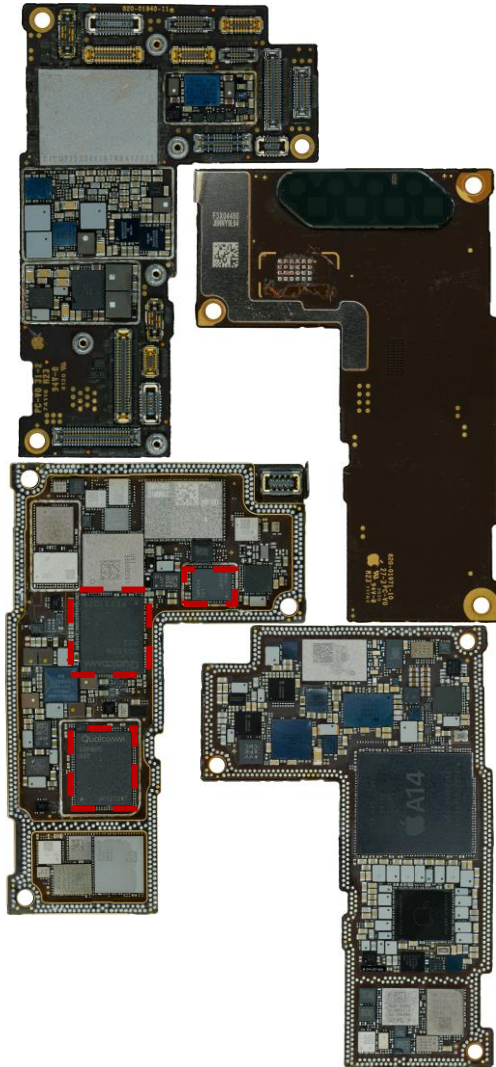
[Market Analysis](#)

[Physical Analysis](#)

- Summary
- ▶ Baseband - Front-End Analysis
- 4G LTE - Front-End Analysis
- 5G Sub-6 - Front-End Analysis
- Antenna Adaptation - Front-End Analysis
- 5G mmWave - Front-End Analysis
- UWB/Wifi/BT/GPS - Front-End Analysis

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RF Components (Marking)	Manufacturer	Functional	Type	Band	Area (mm²)	Quantity	RF Board Proportion	Cost (\$)
SDX55M	QUALCOMM	Baseband	Modem	2G/3G/4G/5G	XX	X	XX	\$ XX
132#	MURATA	Connectivity	FEM	Wifi 2.4 GHz	XX	X	XX	\$ XX
AD0W	BROADCOM	Connectivity	Filter		XX	X	XX	\$ XX
339S00761	USI	Connectivity	FEM	Wifi ax	XX	X	XX	\$ XX
SN210V	NXP	Connectivity	RFIC	NFC	XX	X	XX	\$ XX
SKYxxx34	SKYWORKS	Connectivity	FEM	GPS	XX	X	XX	\$ XX
U1 V3	USI	Connectivity	FEM	UWB	XX	X	XX	\$ XX
SKYxxx24	SKYWORKS	Connectivity	FEM	GPS	XX	X	XX	\$ XX
XMSS002 V2	MURATA	Front end	Switch		XX	X	XX	\$ XX
SKY5xx17	SKYWORKS	Front end	Diversity	4G MB/HB	XX	X	XX	\$ XX
K79	MURATA	Front end	Diversity	4G LB	XX	X	XX	\$ XX
QM18839	QORVO	Front end	RFIC		XX	X	XX	\$ XX
AYA032	BROADCOM	Front end	Multiplexer		XX	X	XX	\$ XX
ACI030	BROADCOM	Front end	Multiplexer		XX	X	XX	\$ XX
583#	MURATA	Front end	PAMiD	5G n79	XX	X	XX	\$ XX
QM18857	QORVO	Front end	RFIC		XX	X	XX	\$ XX
QM81030	QORVO	Front end	ET		XX	X	XX	\$ XX
SKY53807	SKYWORKS	Front end	FEM	5G	XX	X	XX	\$ XX
AFEM8200	BROADCOM	Front end	PAMiD	4G MB/HB	XX	X	XX	\$ XX
SKY58245	SKYWORKS	Front end	PAM	5G n77/78	XX	X	XX	\$ XX
QET5100	QUALCOMM	Front end	ET		XX	X	XX	\$ XX
137#	MURATA	Front end	Switch		XX	X	XX	\$ XX
ASIO32	BROADCOM	Front end	Multiplexer		XX	X	XX	\$ XX
AH 0U	BROADCOM	Front end	Multiplexer		XX	X	XX	\$ XX
1XR-484	MURATA	Front end	FEM	5G n260; n261	XX	X	XX	\$ XX
SKYxxx04	SKYWORKS	Front end	FEM	Wifi 5 GHz; B46	XX	X	XX	\$ XX
AA0U	BROADCOM	Front end	Filter		XX	X	XX	\$ XX
ALIO36	BROADCOM	Front end	Multiplexer		XX	X	XX	\$ XX
SKY58240	SKYWORKS	Front end	PAMiD	4G LB	XX	X	XX	\$ XX
SKY58242	SKYWORKS	Front end	PAM	2G	XX	X	XX	\$ XX
SDR865	QUALCOMM	RF	RxTx	2G/3G/4G/5G	XX	X	XX	\$ XX
SMR526	QUALCOMM	RF	RxTx	5G n260; n261	XX	X	XX	\$ XX
37U727	USI	RF	AiP	5G n260; n261	XX	X	XX	\$ XX
QM18395	QORVO	RF	Tuner		XX	X	XX	\$ XX
QM18392	QORVO	RF	Tuner		XX	X	XX	\$ XX
QM18325	QORVO	RF	Tuner		XX	X	XX	\$ XX
QM18311	QORVO	RF	Tuner		XX	X	XX	\$ XX
ER10	MURATA	RF	Tuner		XX	X	XX	\$ XX
QM18389	QORVO	RF	Tuner		XX	X	XX	\$ XX
QM18303	QORVO	RF	Tuner		XX	X	XX	\$ XX
QM18396	QORVO	RF	Tuner		XX	X	XX	\$ XX
QM18250	QORVO	RF	Tuner		XX	X	XX	\$ XX
QM18301	QORVO	RF	Tuner		XX	X	XX	\$ XX
QM18349	QORVO	RF	Tuner		XX	X	XX	\$ XX
Total					XX	X	XX	\$ XX

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# RF Components Summary

[Overview / Introduction](#)

[Company Profile & Supply Chain](#)

[Physical Analysis Summary](#)

[Physical Comparison](#)

[Cost Comparison](#)

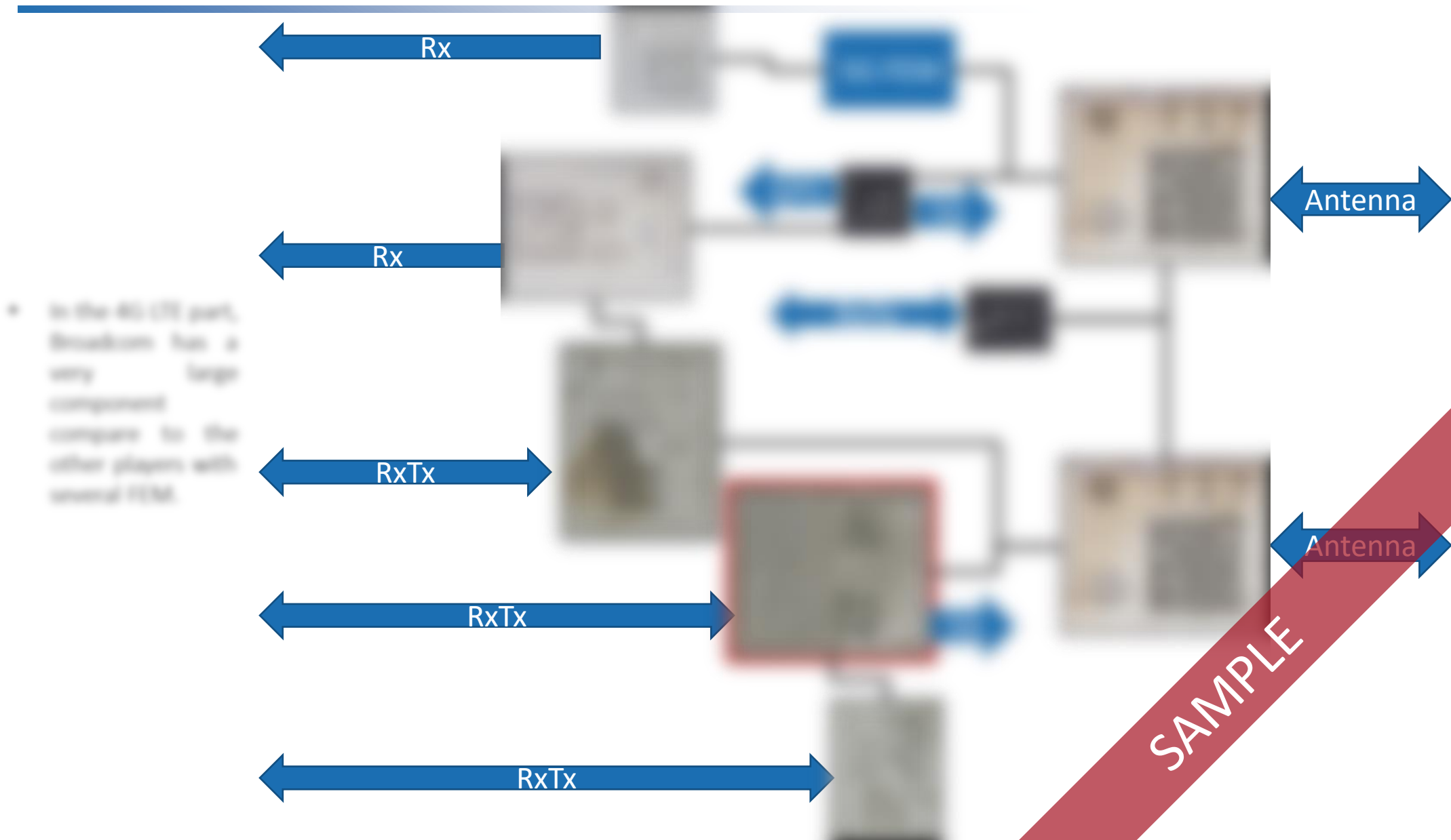
[Market Analysis](#)

[Physical Analysis](#)

- Summary
- Baseband - Front-End Analysis
- ▶ 4G LTE - Front-End Analysis
- 5G Sub-6 - Front-End Analysis
- Antenna Adaptation - Front-End Analysis
- 5G mmWave - Front-End Analysis
- UWB/Wifi/BT/GPS - Front-End Analysis

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In the 4G LTE part, Broadcom has a very compact design. In the other players with several FEMs.

# Package Views & Dimensions

[Overview / Introduction](#)

[Company Profile & Supply Chain](#)

[Physical Analysis Summary](#)

[Physical Comparison](#)

[Cost Comparison](#)

[Market Analysis](#)

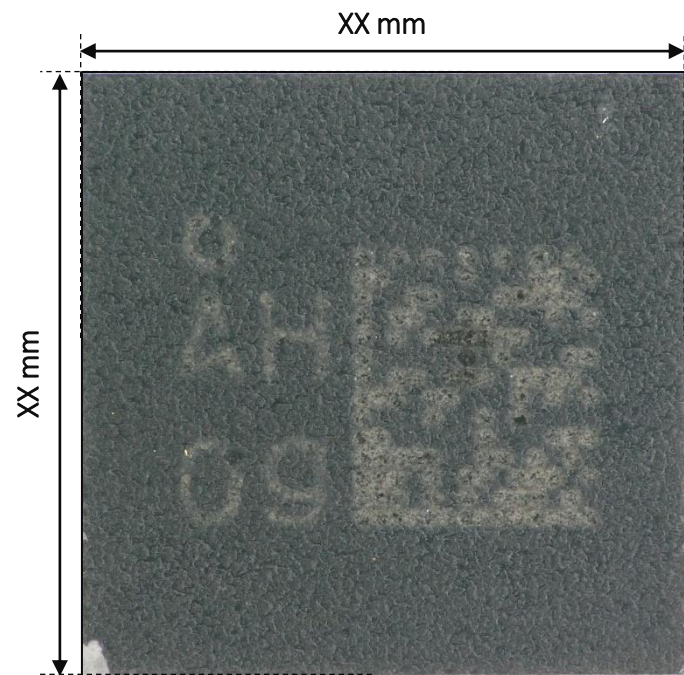
[Physical Analysis](#)

- Summary
- Baseband - Front-End Analysis
- ▶ 4G LTE - Front-End Analysis
- 5G Sub-6 - Front-End Analysis
- Antenna Adaptation - Front-End Analysis
- 5G mmWave - Front-End Analysis
- UWB/Wifi/BT/GPS - Front-End Analysis

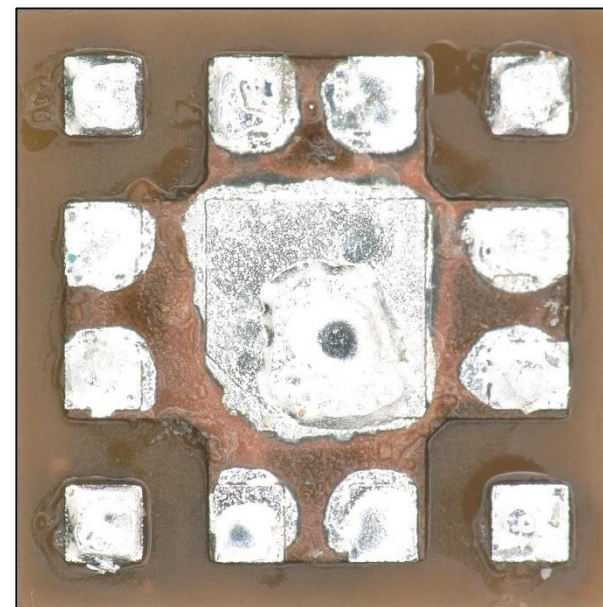
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- Package Type: **XX LGA**
- Dimensions: **XX mm<sup>2</sup> x XX mm**  
(XX x XX x XX mm)
- Pin Pitch: **XX mm**
- Marking: **<Logo Avago> H**  
**09**



Package Top View – Optical View  
©2021 by System Plus Consulting



Package Bottom View – Optical View  
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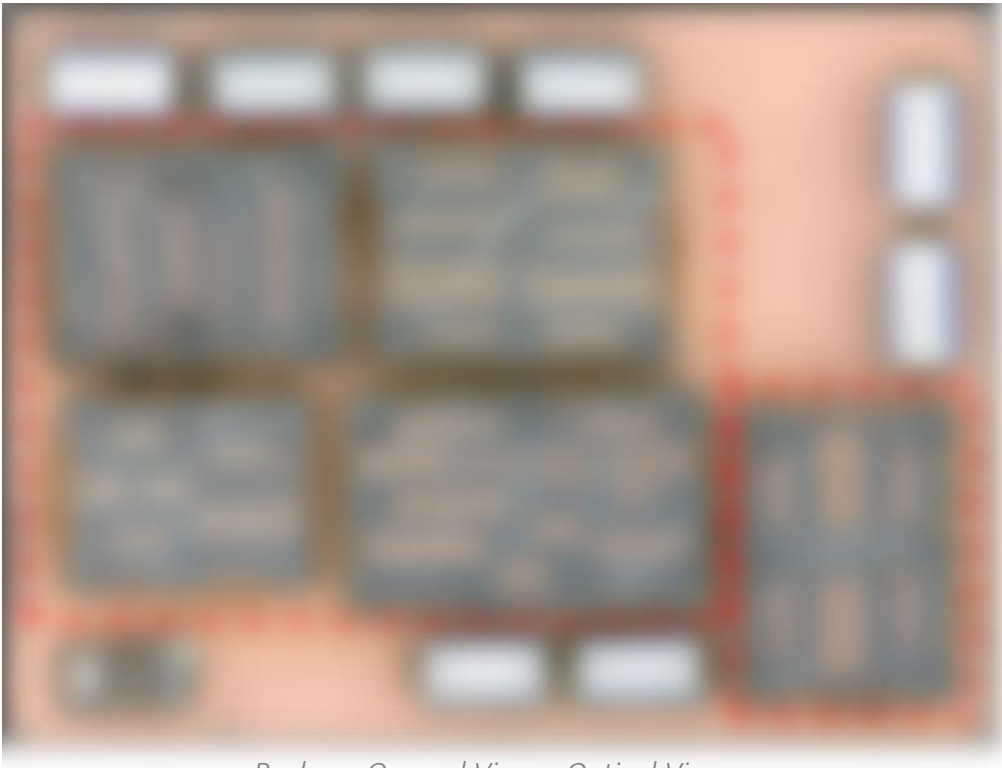
Package Side View – Optical View  
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- Summary
- Baseband - Front-End Analysis
- ▶ 4G LTE - Front-End Analysis
- 5G Sub-6 - Front-End Analysis
- Antenna Adaptation - Front-End Analysis
- 5G mmWave - Front-End Analysis
- UWB/Wifi/BT/GPS - Front-End Analysis

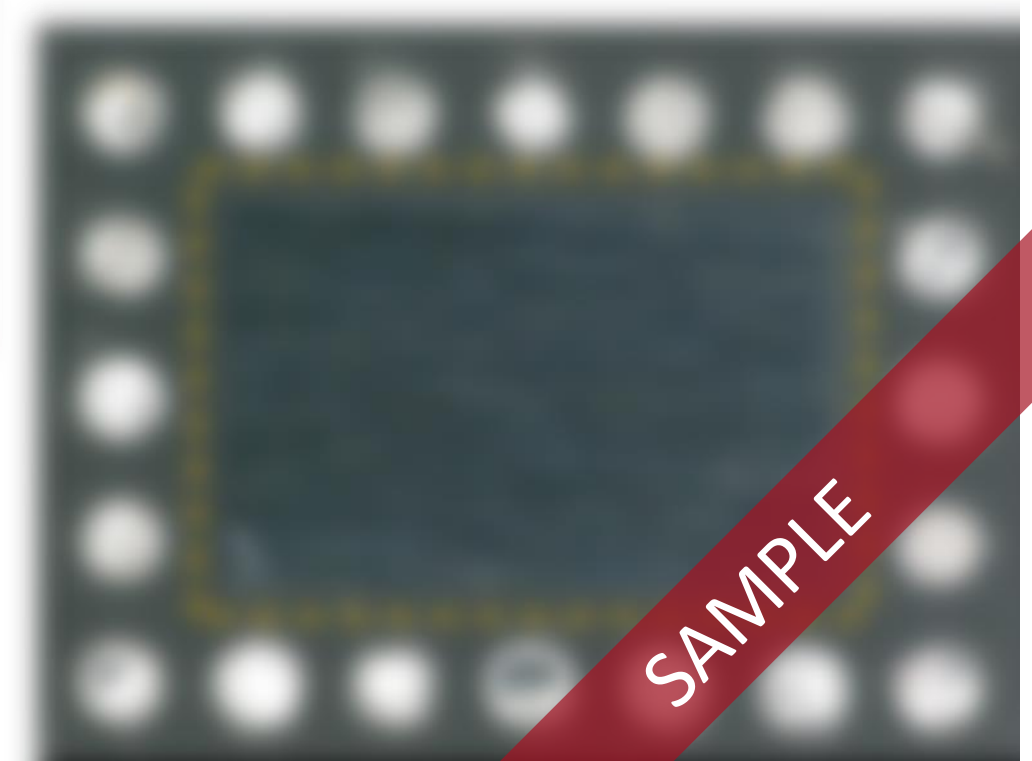
## Component Overview



Package Opened View – Optical View  
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- The functions of the 6 dies inside the packaging have a following repartition.

- SAW Filter: XX
- LNA: XX



Package Bottom View – Optical View

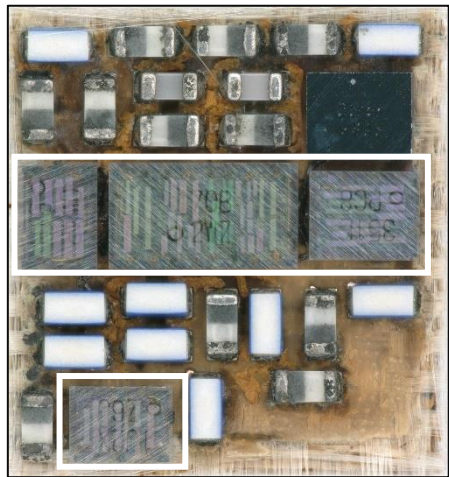
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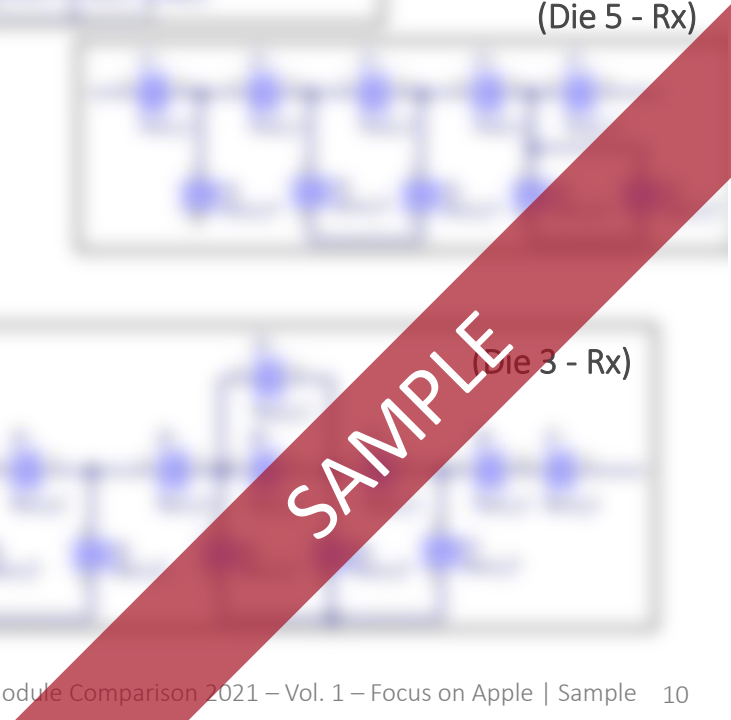
**Physical Analysis**

- Summary
- Baseband - Front-End Analysis
- ▶ 4G LTE - Front-End Analysis
- 5G Sub-6 - Front-End Analysis
- Antenna Adaptation - Front-End Analysis
- 5G mmWave - Front-End Analysis
- UWB/Wifi/BT/GPS - Front-End Analysis

# Filter – Die Overview – Rx – Schematic



Package Opened View – Optical View  
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[Overview / Introduction](#)

[Company Profile & Supply Chain](#)

[Physical Analysis Summary](#)

[Physical Comparison](#)

[Cost Comparison](#)

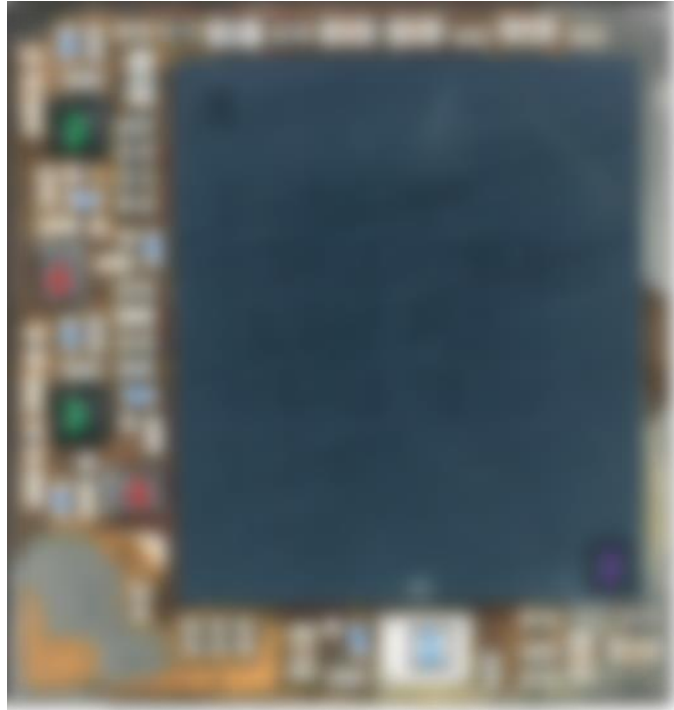
[Market Analysis](#)

[Physical Analysis](#)

- Summary
- Baseband - Front-End Analysis
- 4G LTE - Front-End Analysis
- 5G Sub-6 - Front-End Analysis
- Antenna Adaptation - Front-End Analysis
- 5G mmWave - Front-End Analysis
- ▶ UWB/Wifi/BT/GPS - Front-End Analysis

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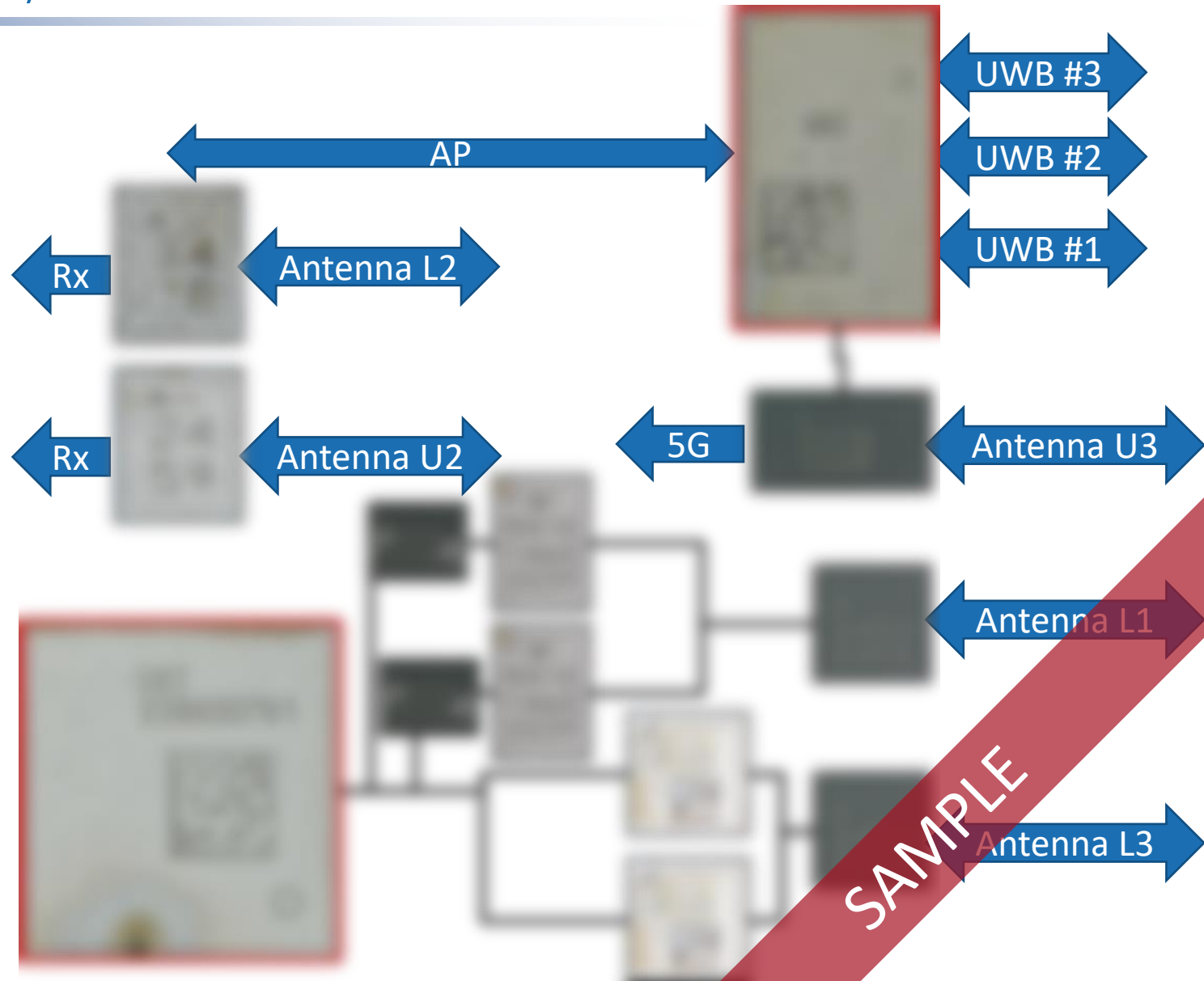
- Summary
- Baseband - Front-End Analysis
- 4G LTE - Front-End Analysis
- 5G Sub-6 - Front-End Analysis
- Antenna Adaptation - Front-End Analysis
- 5G mmWave - Front-End Analysis
- ▶ UWB/Wifi/BT/GPS - Front-End Analysis

**UWB FEM**

XX Die/mm<sup>2</sup>  
LGA Packaging  
\$XX  
\$XX/mm<sup>2</sup>  
\$XX/Die

**Wifi FEM**

XX Die/mm<sup>2</sup>  
LGA Packaging  
\$XX  
\$XX/mm<sup>2</sup>  
\$XX/Die



# Module in RF: Front-End and Connectivity

[Overview / Introduction](#)

[Company Profile & Supply Chain](#)

[Physical Analysis Summary](#)

- Summary of the Analyzed RF Components
- ▶ Comparative Analysis

[Physical Comparison](#)

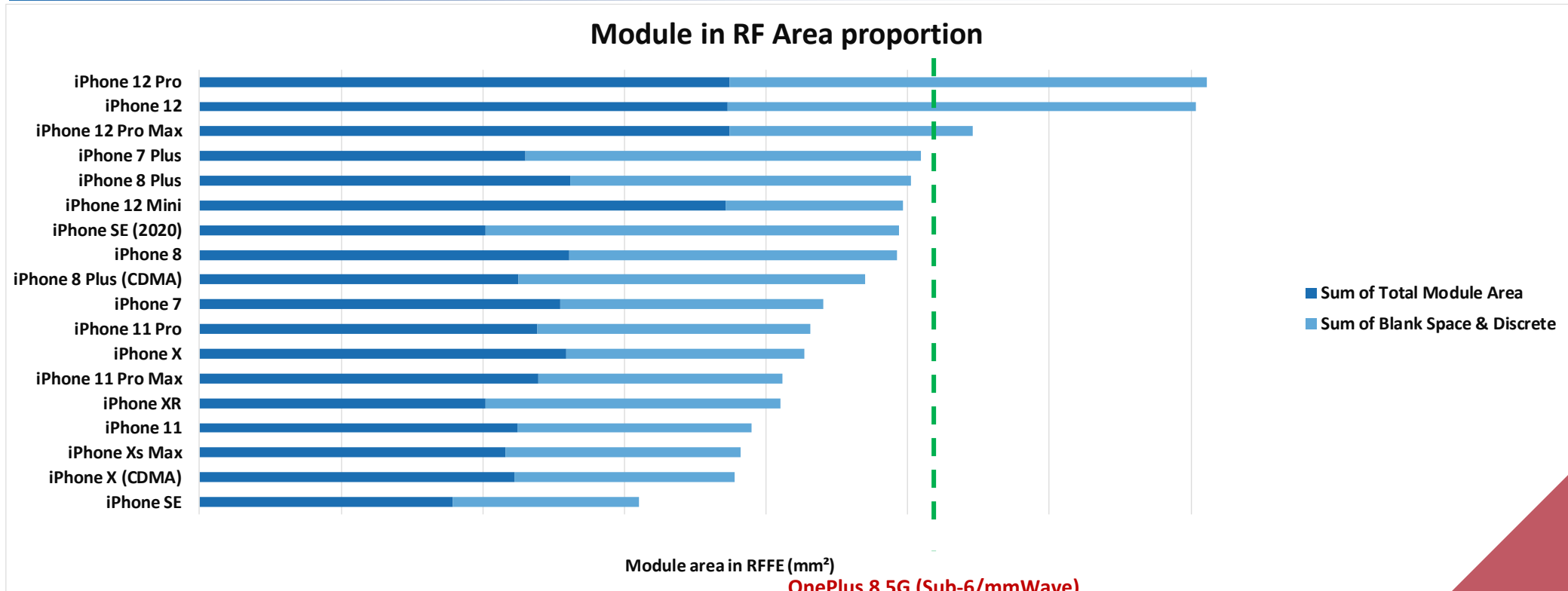
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[Market Analysis](#)

[Physical Analysis](#)

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Module area in RFFE (mm<sup>2</sup>)

OnePlus 8 5G (Sub-6/mmWave)

Proportion of Module over RF Area

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- There is the evolution of the RF area in the iPhone series. The smallest RF area appears to be integrated in the iPhone 12 series, with less than half of the area with discrete and space.
- The part of total integrated modules are generally closed to 50% of the RF area for the iPhones (55.5% is reached for the iPhone 12 Pro to the 12 Pro generation). The smallest value is given to the iPhone 12 (2020) with only 48% of the RF area for the module, mainly because of the high level of integration in the modules. The highest value is given to the iPhone 12 Mini with almost 52% of the RF area, mainly because of the 5G millimeter RF which is integrated outside the main board but connected to the main board. Without 5G, the part of modules is still high (48% of the RF area).
- For comparative analysis, the OnePlus 8 5G RF area size has been placed in the graphic. It shows that the OnePlus 8 5G has the same integration proportion for millimeter. The standard and the Pro show almost 50% more area for the module than the OnePlus 8 5G.

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# Components Summary – Module

[Overview / Introduction](#)

[Company Profile & Supply Chain](#)

[Physical Analysis Summary](#)

- Summary of the Analyzed RF Components
- ▶ Comparative Analysis

[Physical Comparison](#)

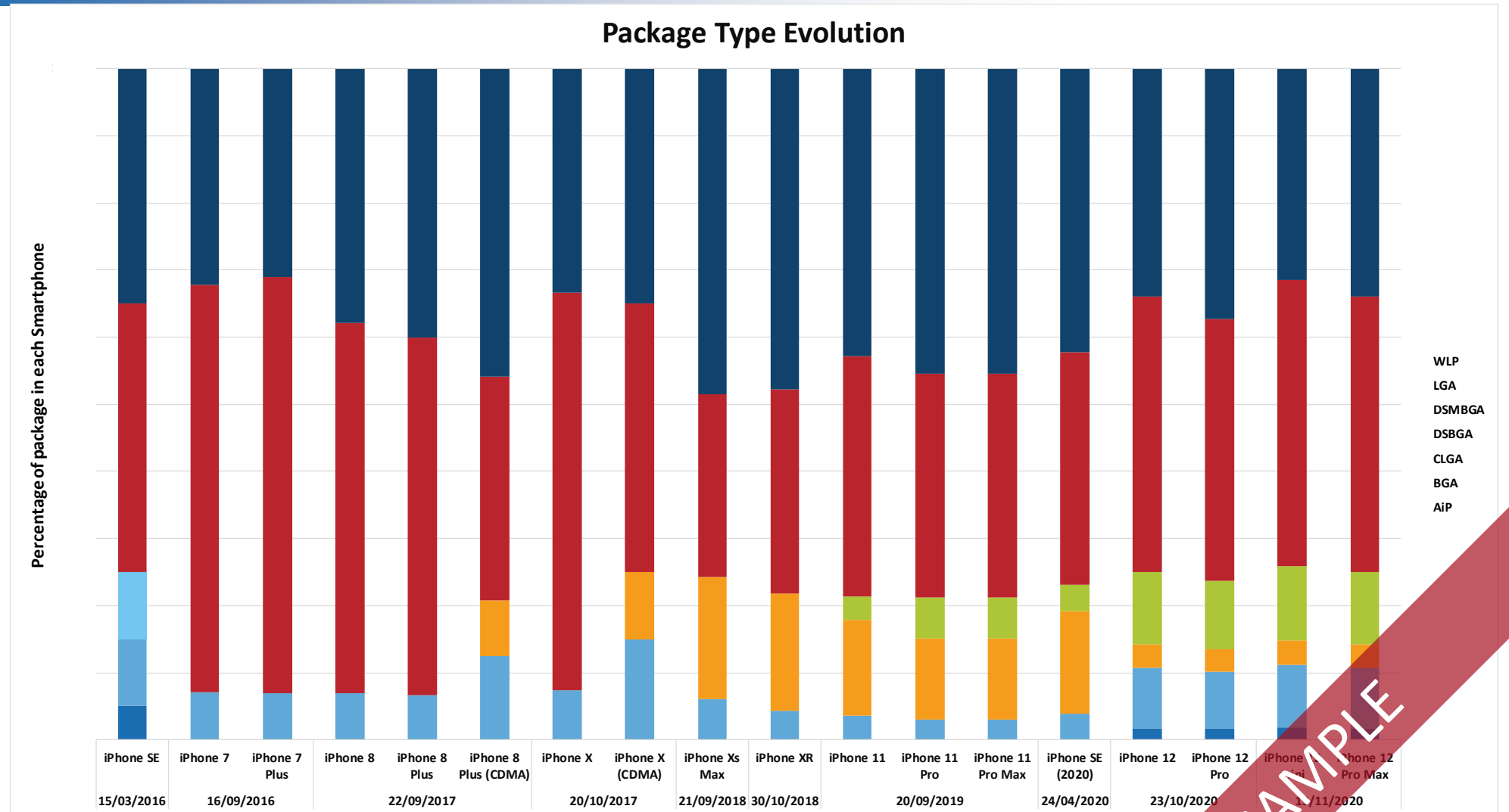
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Evolution of Module Packaging

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This chart shows the reduction of the LGA part with the increase of DSMBGA. The appearance of DSBGA is due to the replacement by DSMBGA. LGA components has been decrease since 2017 but has a huge increase in the latest generation. The appearance of AiP for 5G wireless communication is shown.



# Sub-6 GHz (FR1) and mmWave (FR2) Phones

[Overview / Introduction](#)

[Company Profile & Supply Chain](#)

[Physical Analysis Summary](#)

[Physical Comparison](#)

- Area Distribution per Supplier & Function
- Qualcomm Content – 4G LTE vs. 5G NR
- ▶ 5G Sub-6 vs. mmWave
- Die Design Win in Number & Area
- Die Distribution per Function
- Filter Distribution
- PA/LNA/Switch Distribution
- Material Substrate Distribution

[Cost Comparison](#)

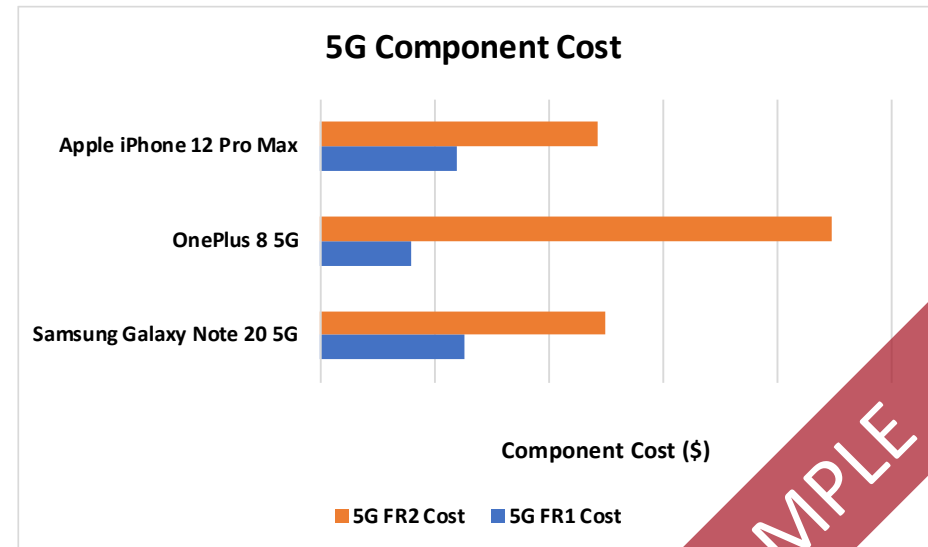
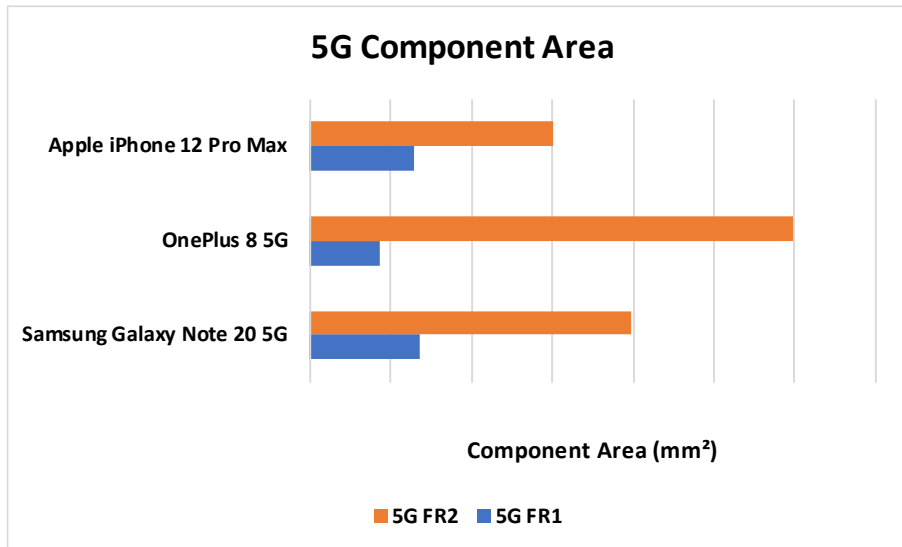
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Model	Manufacturer	Quantity	Component	Function	Band	Simplified Function
Samsung Galaxy Note 20 5G	QORVO				n78	
	QUALCOMM				n77/n78	
	QORVO				n41	
	QORVO				n43	
	QUALCOMM				n260/n261	
OnePlus 8 5G	QUALCOMM				n28/n5/n2/n66	
	QUALCOMM				n28/n5/n2/n66	
	QUALCOMM				n77/n78	
	QUALCOMM				n260/n261	
		MURATA				n79
Apple iPhone 12 Pro Max	SKYWORKS				FR1	
	SKYWORKS				n77/78	
	MURATA				n260; n261	
	USI				n260; n261	



Sub-6 GHz (FR1) and mmWave (FR2) Phones

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# Filter Distribution

[Overview / Introduction](#)

[Company Profile & Supply Chain](#)

[Physical Analysis Summary](#)

[Physical Comparison](#)

- Area Distribution per Supplier & Function
- Qualcomm Content – 4G LTE vs. 5G NR
- 5G Sub-6 vs. mmWave
- Die Design Win in Number & Area
- Die Distribution per Function
- ▶ Filter Distribution
- PA/LNA/Switch Distribution
- Material Substrate Distribution

[Cost Comparison](#)

[Market Analysis](#)

[Physical Analysis](#)

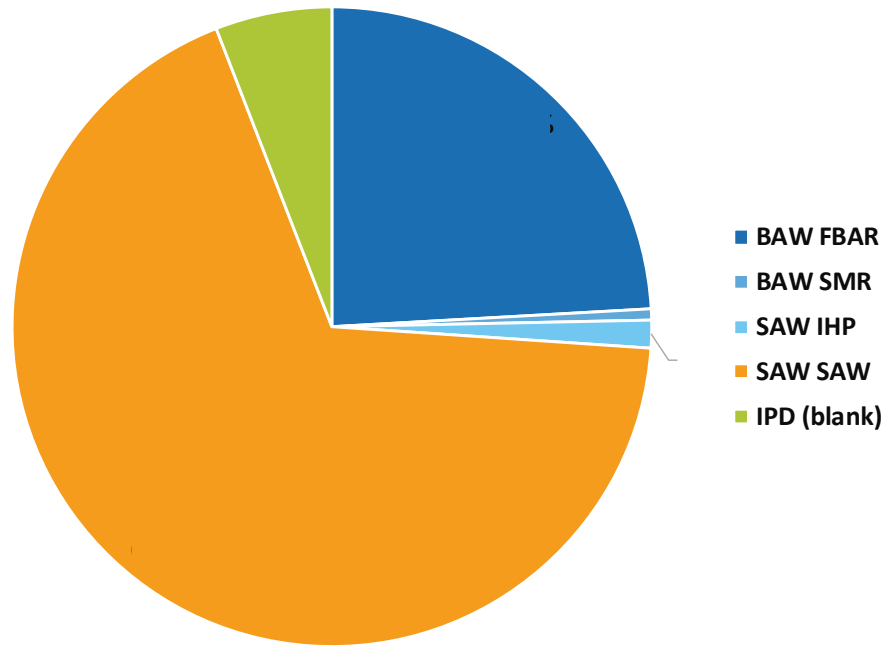
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In the 18 smartphones, 68% of the found filters are SAW filters with 1% for BAW technology. SAW filters follow with 21%, BAW filters show a majority of BAW technology mainly provided by Broadcom and Skyworks recently. The 1% appears to be mainly from Qorvo. Recently, 5G technology is developing thanks to the 5G resulting in 6% of the filter share.

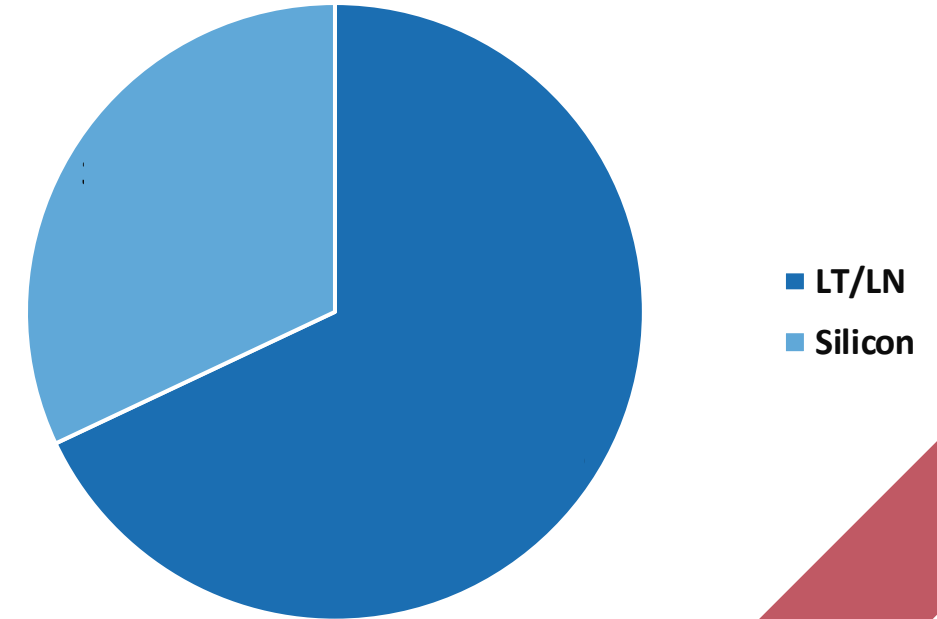
## Filter Distribution per technology



18 Smartphones; From 2016 to 2020; 521 Components; 1,925 Dies

Filter die type distribution  
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## Filter substrate Area



18 Smartphones; From 2016 to 2020; 521 Components; 1,925 Dies

Filter die substrate distribution  
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- Leadership of SAW filter leads to a high percentage of SAW substrate in the filter.
- 68% of the share is given to the LT/LN substrate SAW filter, 5G and 5G SAW filter.

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# Material Distribution per Smartphone

[Overview / Introduction](#)

[Company Profile & Supply Chain](#)

[Physical Analysis Summary](#)

[Physical Comparison](#)

- Area Distribution per Supplier & Function
- Qualcomm Content – 4G LTE vs. 5G NR
- 5G Sub-6 vs. mmWave
- Die Design Win in Number & Area
- Die Distribution per Function
- Filter Distribution
- PA/LNA/Switch Distribution
- ▶ Material Substrate Distribution

[Cost Comparison](#)

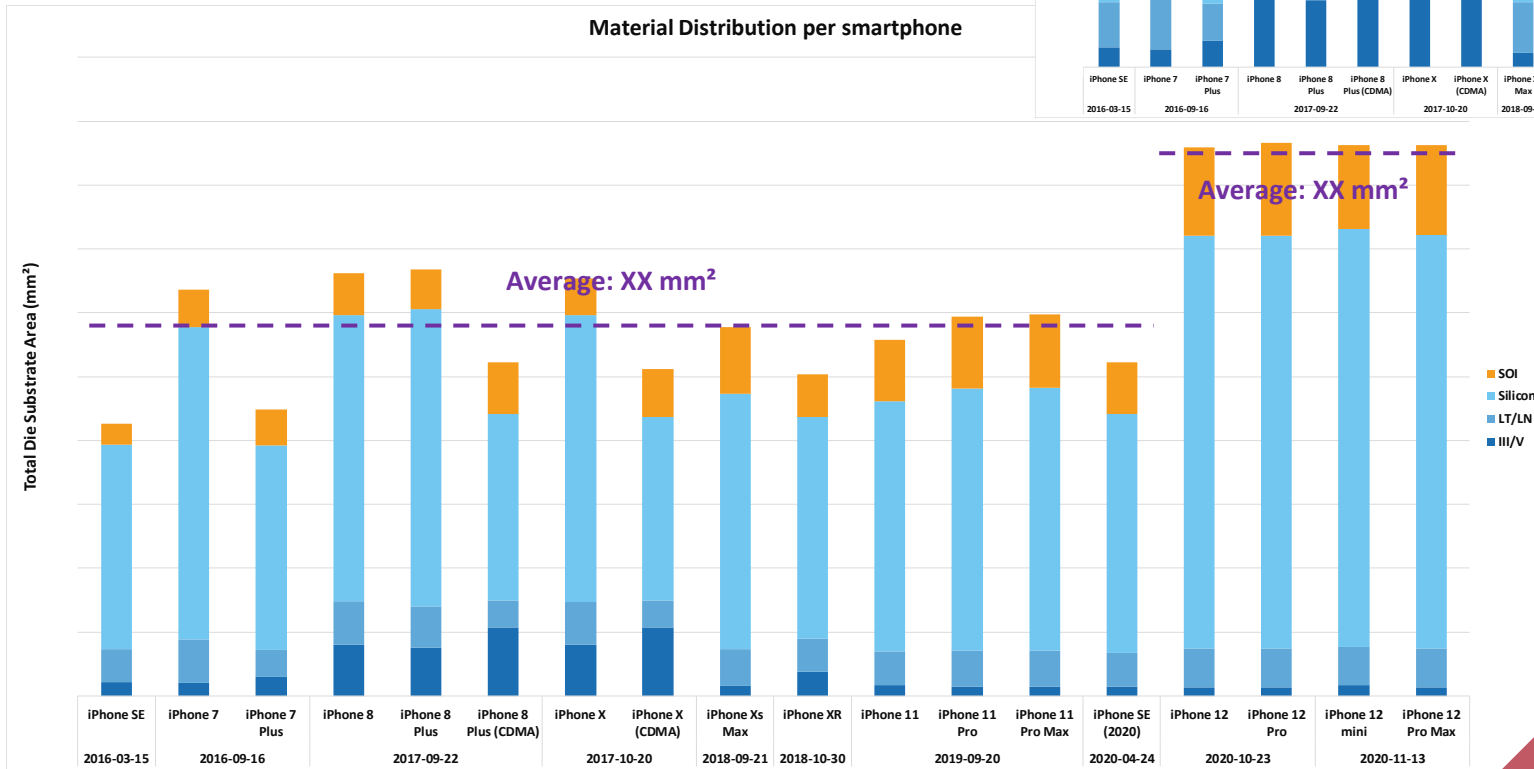
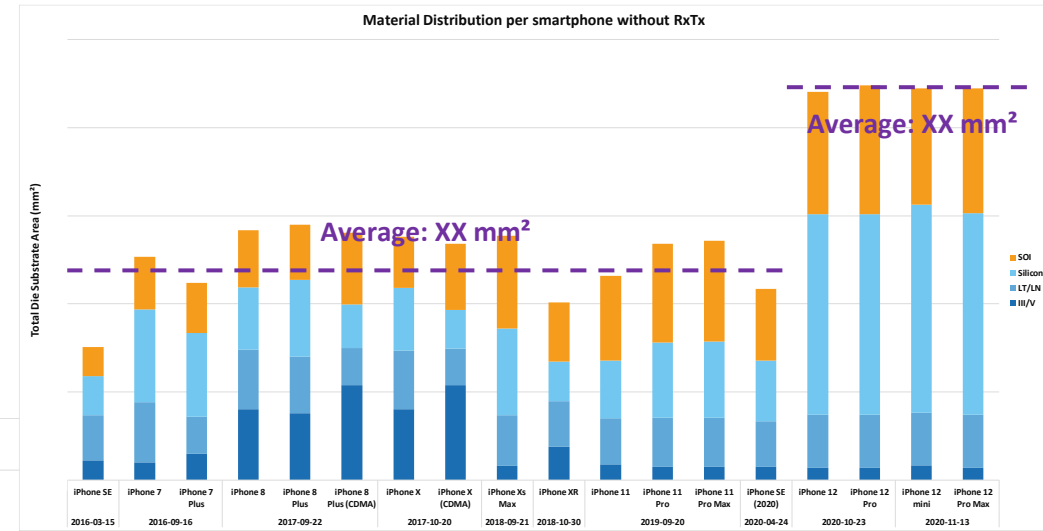
[Market Analysis](#)

[Physical Analysis](#)

[Related Analyses](#)

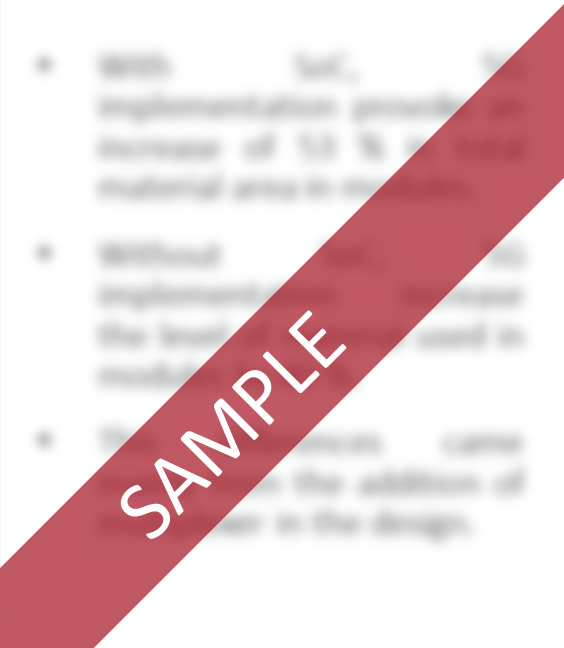
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In the material distribution, silicon substrate is clearly the leader. Indeed, as all test are based on silicon substrate, the area related is high, but even without 5G, test and module, the part related is still high. This mainly comes from 5G test. For 5G module implementation, a large additional test is added based on silicon, but the difference is higher when the 5G is withdrawn.



Material Substrate area distribution

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# Chipset Cost per Supplier

[Overview / Introduction](#)

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[Physical Analysis Summary](#)

[Physical Comparison](#)

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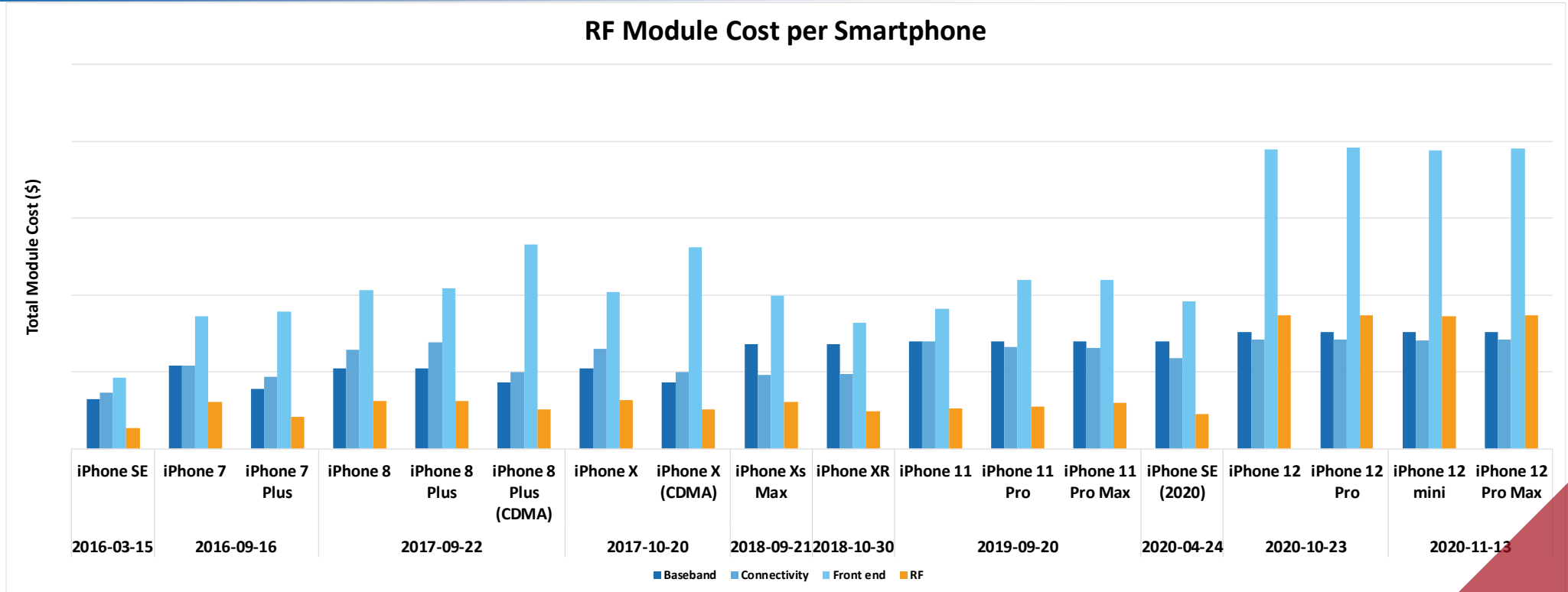
- ▶ Chipset Cost per Supplier
- Qualcomm Content – 4G LTE vs. 5G NR
- Cost Distribution per Supplier & Function

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[Physical Analysis](#)

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Chipset cost distribution per smartphones

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- This view allows the appreciation of each RF segment in the smartphones.
- The Baseband cost shows two steps before 2017, the cost was stable at \$4.8 per smartphones. Between 2018 and 2019, the cost increased by 10% to \$5.3. In the last generation with the 5G implementation, this cost growth slowly to reach \$7.6 which is a 45% of increase.
- The connectivity is the only segment that has a stable cost before 2019, \$5.3 per smartphones and after 2019, the cost increased to \$7.6 per smartphones.
- Front end represent all the module and discrete required for 4G and 5G communication and RF components like antenna tuner. Again, 5G play a huge role in cost increase in the last generation. The increase of antenna tuner, multiplexer and duplexer provide a huge increase in the cost related. The total cost is multiplied by 1.25 in the last series.

SAMPLE

# Qualcomm Content – 4G LTE (CDMA) vs. 5G NR FR1 & FR2

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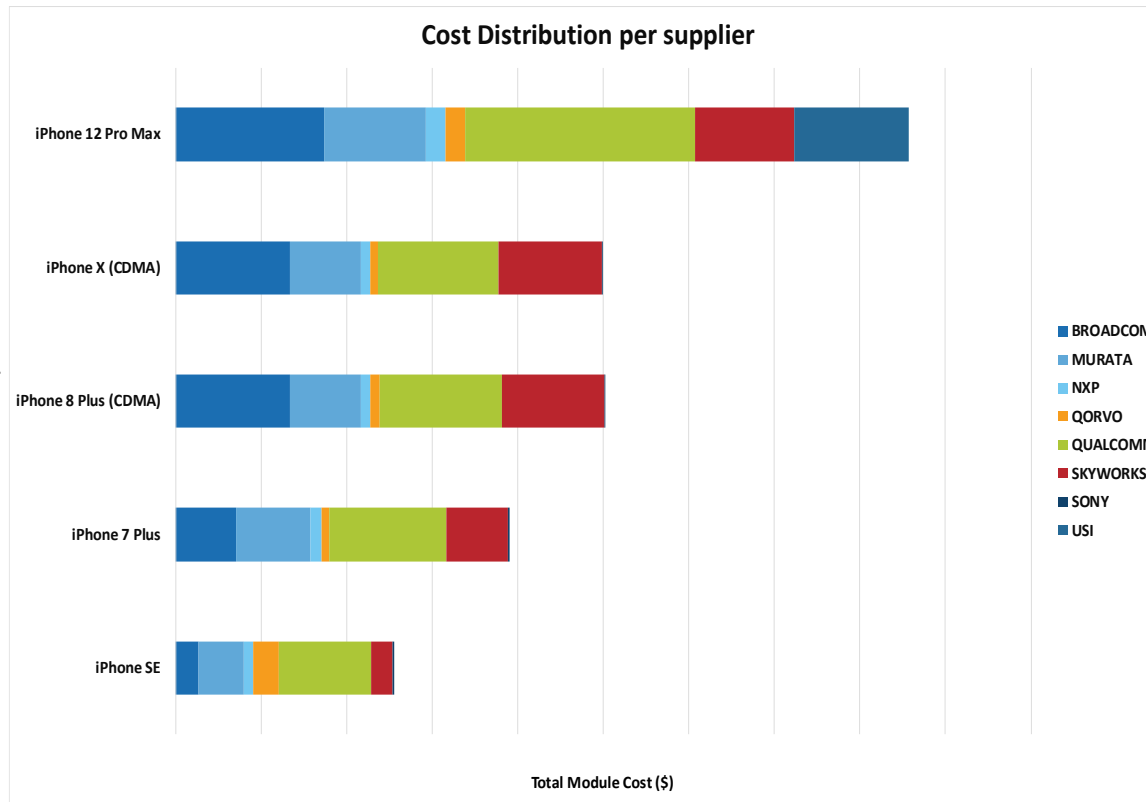
- Chipset Cost per Supplier
- ▶ Qualcomm Content – 4G LTE vs. 5G NR
- Cost Distribution per Supplier & Function

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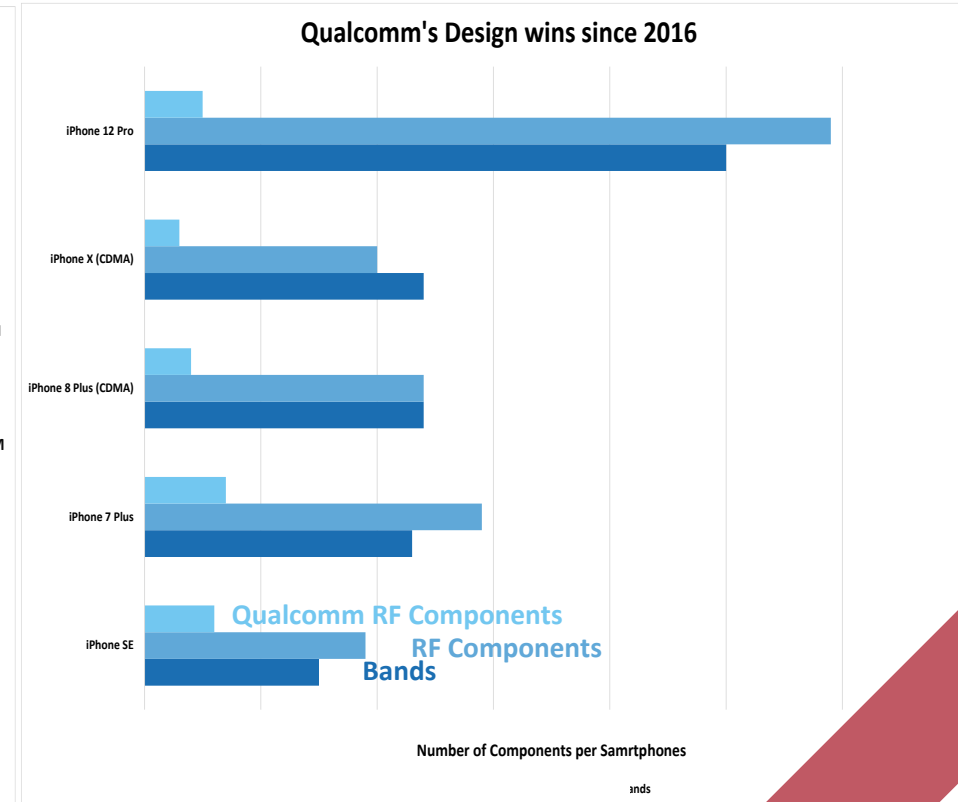
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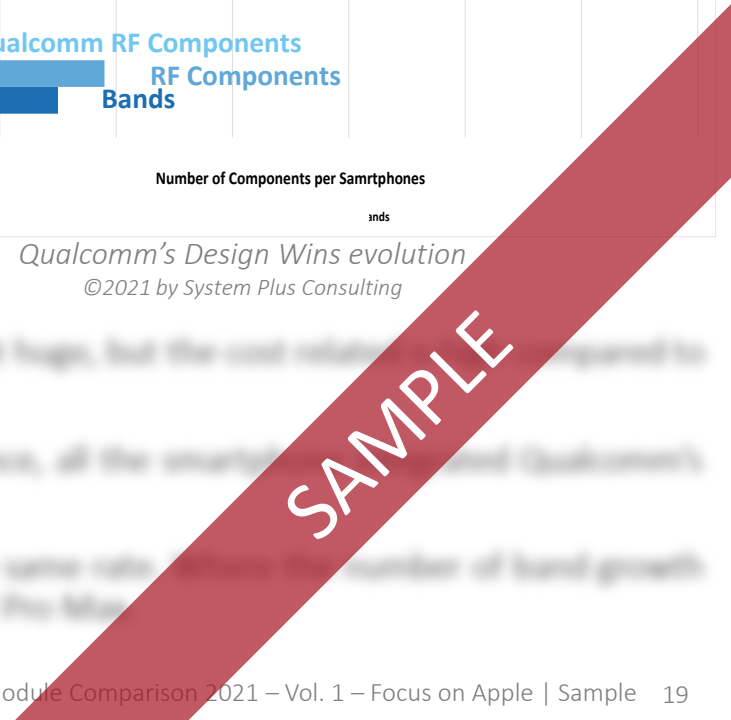


Chipset Cost of smartphones featuring Qualcomm's Components  
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Qualcomm's Design Wins evolution  
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- In all the designs integrated Qualcomm's components, the number of component is not huge, but the cost relative is compared to the other suppliers.
- In the iPhone 12, the contribution of Qualcomm represent 42 % of the total cost. Since, all the smartphones use Qualcomm's components has 30% cost coming from this supplier even in the last generation.
- As the number of band increases, the total cost follows the same trend but not at the same rate. Between the number of band growth with 130%, the cost growth at 70% between the iPhone 8 (CDMA) and the iPhone 12 Pro Max.





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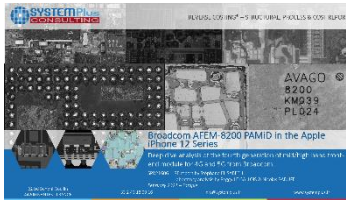
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## RELATED REPORTS



By System Plus Consulting:

- [Broadcom AFEM-8200 PAMiD in the Apple iPhone 12 Series](#)
- [Apple iPhone 12 series mmWave 5G Chipset and Antenna](#)
- [RF Front-End Module Comparison 2020 – Volume 3](#)

By Yole Développement:

- [5G's Impact on RF Front-End and Connectivity for Cellphones 2020](#)
- [System-in-Package Technology and Market Trends 2020](#)



## RELATED TEARDOWN TRACKS



By System Plus Consulting:

- [Consumer Track – Phone](#)

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# COMPANY SERVICES

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# Our Core Activity : The Reverse Costing®

## *A Structure, Process and Cost Analysis*

Reverse Costing® consists in disassembling a device or a system, in order to identify its technology and determine its manufacturing processes and cost, using in-house models and tools.



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[Overview / Introduction](#)

[Company Profile & Supply Chain](#)

[Physical Analysis Summary](#)

[Physical Comparison](#)

[Cost Comparison](#)

[Market Analysis](#)

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# Fields Of Expertise

[Overview / Introduction](#)

[Company Profile & Supply Chain](#)

[Physical Analysis Summary](#)

[Physical Comparison](#)

[Cost Comparison](#)

[Market Analysis](#)

[Physical Analysis](#)

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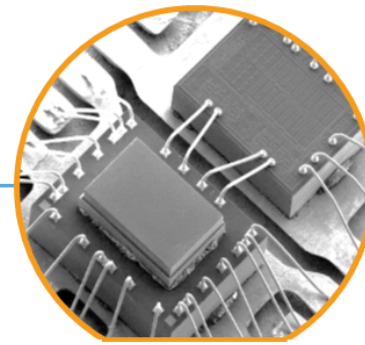
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## Electronic System

- **Automotive**
  - ADAS
  - Infotainment
  - Telematics
  - Electrification
  - Safety
- **Consumer**
  - Smartphone
  - Smart Home
  - Wearable
- **Telecom**
  - Router/Set-Top Box
  - Base Station
- **Industrial**
- **Medical**



## Semiconductor Device

- **Advanced Packaging**
  - WLP (Fan in, Fan out)
  - SiP
  - Embedded
  - 3D Packaging
- **Imaging**
  - Infrared
  - Visible
- **Integrated Circuit**
  - ASIC
  - SOC
  - MPU/GPU/MCU/DSP
- **MEMS & Sensors**
  - Inertial Sensor
  - Environmental Sensor
  - Fingerprint Sensor
  - Oscillator
  - Microphone
  - Inkjet
  - RF MEMS
  - Light / Optics
- **Memory**
  - NAND
  - DRAM
  - Emerging
- **Power Electronics**
  - Discrete
  - Module
  - Compound (GaN, SiC)
  - Power RF
- **RF**
  - Radar
  - Filter
  - Module (FEM, Wifi/BT)
  - Power Amplifier
- **Solid State Lighting**
  - LED
  - Laser / VCSEL
- **Photonics**

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# Business Model

[Overview / Introduction](#)

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[Physical Analysis Summary](#)

[Physical Comparison](#)

[Cost Comparison](#)

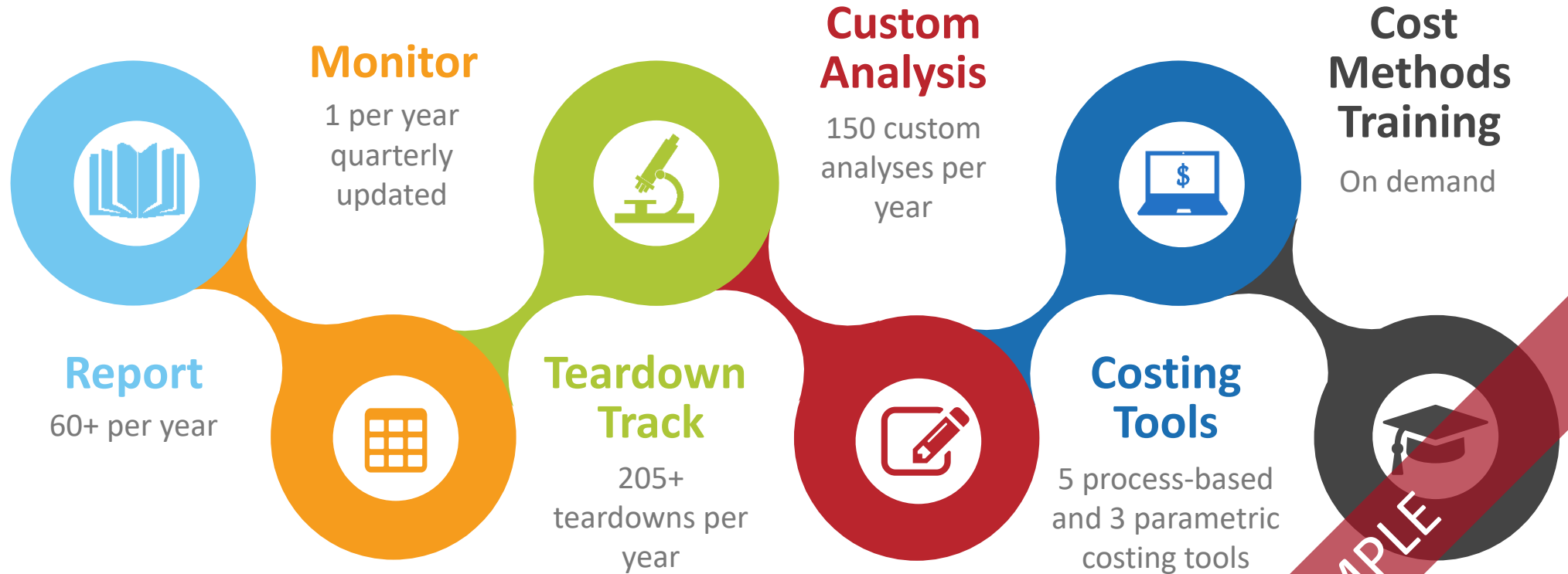
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# Worldwide presence

100+ collaborators in 8 different countries



## Headquarters

- > Nantes – System Plus Consulting
- > Lyon – Yole Développement

[Overview / Introduction](#)

[Company Profile & Supply Chain](#)

[Physical Analysis Summary](#)

[Physical Comparison](#)

[Cost Comparison](#)

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