Press Release
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LYON, France

TF-SAW vs. BAW: RF companies set their objectives and make strategic choices [1]

OUTLINES:

- The market for RF front-end and connectivity should reach US$26 billion by 2025.
- Technology status:

  The use of BAW technology, developed by Qorvo, Qualcomm/RF360 and others, will grow with the introduction of 5G NR bands with steep out-of-band rejection requirements.

  SAW is the dominant technology in the RF front-end industry, but SAW's growth will be low due to the penetration of other technologies targeting the high-performance filter needed for 5G NR.

  TF-SAW (for instance IHP SAW from Murata) is the new forthcoming technology that will grow the most, since it is a good tradeoff between performance and cost.
- Competitive landscape:
  Qorvo is a rare IDM within the RF electronics market. The company can perform all steps in-house, from the packaging to the software.
  Since 2019, Skyworks has SAW, TC-SAW and BAW filters in its portfolio, all manufactured in Asia.
  The TF SAW filter has opened the door to the high frequency market for Murata.
  Recently, Qualcomm has shown its capability to provide the TF-SAW filter with better performance than its own BAW filter on certain bands.
  Etc.

"Qualcomm and Murata are today leading the RF filters market," asserts **Stéphane Elisabeth, Technology & Cost Analyst from System Plus Consulting.** *"In the*

[1] Extracted from :

- SAW Filter Comparison 2020 report, System Plus Consulting, 2020
- RF Front-End Module Comparison 2020 – Volume 2 report, System Plus Consulting, 2020
- 5G's Impact on RF Front-End Module and Connectivity for Cell phones report, Yole Développement, 2019
- Murata Incredible High Performance (IHP) SAW Filter report, System Plus Consulting, 2019
- Broadcom AFEM-8100 System-in-Package in the Apple iPhone 11 Series report, System Plus Consulting, 2020

smartphone industry, within the filter market segment, the two companies are today facing off, and competition is fierce."

For many years, BAW[2] filters have been the leading RF filter technology for high frequency bands in mobile communication. Last year, Murata released a new filter based on TF-SAW[3][4] technology, the Incredible High Performance (IHP) SAW filter. Without doubt, this technology allowed Murata to address multiple smartphone functions, including PAMiD[5] and diversity receivers.

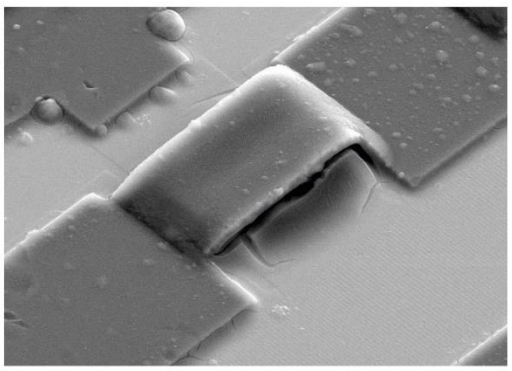
TF-SAW filter technology definitely disrupts the market, and in performance directly competes with the BAW filter. Murata has taken advantage of this technology to develop a large panel of customers and applications and to reinforce its strategic market positioning. This innovative RF front-end module has been analyzed in-depth by System Plus Consulting in a dedicated Murata IHP SAW Filter report.

"With this technology choice, Murata is now able to enter the high frequency market, reaching Wi-Fi front-ends, for instance," explains **Stéphane Elisabeth, from System Plus Consulting.** *"The IHP SAW filter has shown results comparable to competing BAW filters in this field."*

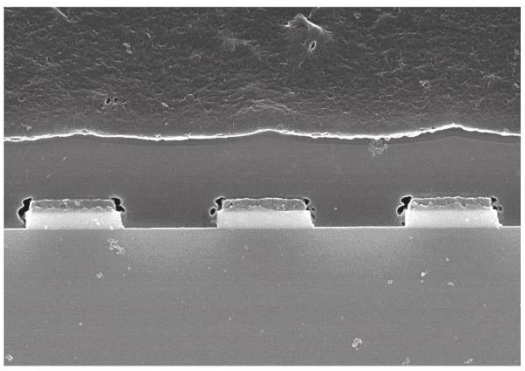
The story does not stop there as Murata's challenger, Qualcomm, is challenging this year with its own TF-SAW RF filter. With this announcement, the US company could dominate the market…

SAW filters – Two examples

(Source: SAW Filter Comparison report, System Plus Consulting, 2020)



Air Bridge implementation



InterDigital transducer cross-section

[2] BAW: Bulk Acoustic Wave
[3] TF: Thin-Film
[4] SAW: Surface Acoustic Wave
[5] PAMiD: Low Band Power Amplifier Integrated Duplexers

Yole Développement and System Plus Consulting combine their expertise to deliver all year long comprehensive RF electronics reports and teardowns. Both partners investigate the latest innovations and offer an in-depth added-value vision of the RF electronics industry.
This month, System Plus Consulting announces its new comparative report, SAW Filter Comparison 2020. This study is an impressive structural, process and cost review of key SAW filter technologies developed by leading companies as well as others. Indeed, this comparison includes filters developed by leading players, including Murata, Skyworks, Qorvo, Qualcomm, Taiyo Yuden, Kyocera, as well as smaller companies such as Wisol, Tai-SAW, SAWNICS and Shoulder Electronics.
The company offers a complete study of 9 SAW filters which uses standard piezoelectric as substrate, 4 TC-SAW Filters which use a thermo-compensated layer to avoid thermal drift, and 1 TF-SAW filter which uses Lithium Tantalate on Silicon substrate. This analysis points out the direct relation between function and structure of those SAW filters.
System Plus Consulting's team discloses the technical choices made by leading OEMs, from low to high-end products. Process flows for the 13 SAW technologies have been identified and deeply analyzed, allowing System Plus Consulting to reveal a relevant manufacturing cost comparison.
Physical data for each component have been compared in terms of process flow, cost, and integration to provide a large panel of technical and economic choices. For example:

- Standard SAW technology from emerging Asian companies compared to leaders in the market;
- TC and High-Performance SAW filters using oxide layers, air cavity and protective layer;
- TF-SAW from Murata using ceramic/silicon wafer bonding to improve standard SAW technology.

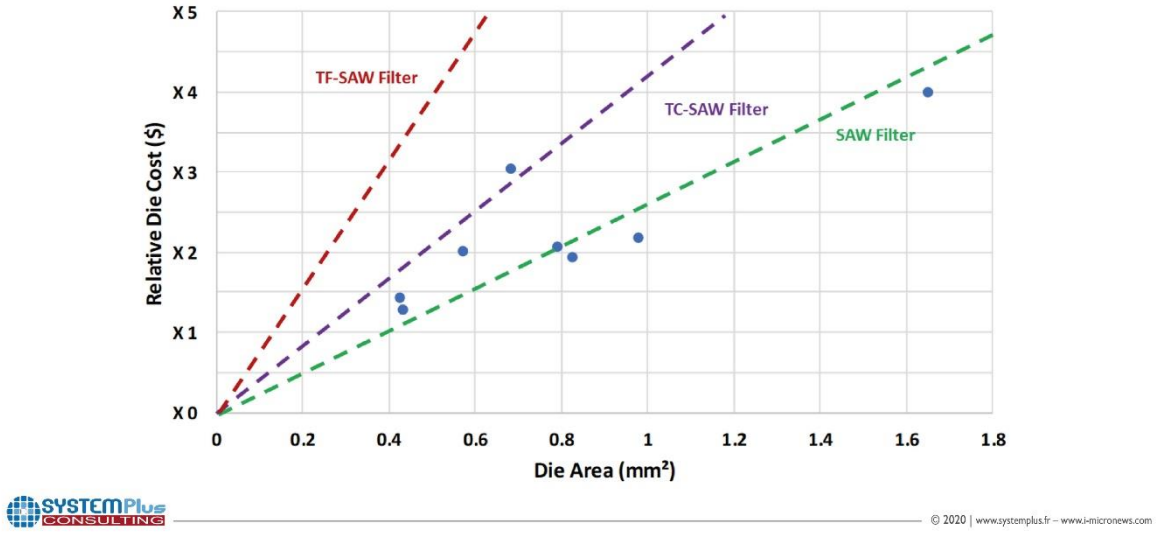
Of course, this latest report from System Plus Consulting takes into account the China-US trade war and its direct impact on the smartphone industry, especially the RF filter market segment.
Who is doing what? Who is leading the SAW filter industry? What is the status of the competitive landscape? Which technology choices have been made by the companies? What are the benefits and the costs of each technology? System Plus Consulting invites you to dive deep into the SAW filters market.

In 2018, the market for RF front-end and connectivity was worth US$15 billion. According to Yole, this figure should reach US$26 billion by 2025, at an 8% CAGR during this period.
In 2018, the leader of this market was Murata with a quarter of the market, mainly with its discrete filters. In this segment, more than 60% of the filters are based on SAW technology in

2020. SAW filters are based on the three main manufacturing processes: SAW, TC-SAW[6] and TF-SAW.

Evolution of main surface acoustic wave filter die cost per area: SAW, thermo-compensated SAW and thin-film SAW

(Source: SAW Filter Comparison report, System Plus Consulting, 2020)



Regarding pure SAW, several Asian companies are involved, like Wisol and Kyocera, explains System Plus Consulting in its comparative analysis. Wisol bought the SAW filter manufacturing capability from Samsung back in 2008. Since then, Wisol has developed a portfolio offering a broad band of modules from the single filter to FEMiD[7], exclusively based on the SAW filter. Today, Wisol is working with Samsung.

TC-SAW technology is more complex, and System Plus Consulting has identified four main players: two of which are Skyworks and Qorvo. Both companies made large investments 10 years ago to develop and offer innovative solutions focused on TC-SAW filters with complex packaging and high performance. Solutions are available in the market.
Of course, Skyworks and Qorvo look for innovation. As an example, Qorvo is currently developing a TF-SAW based solution. Both companies would like to keep their leading position within the filter markets.

The other two companies have now also introduced TF-SAW technology into their portfolio, Murata in 2019 and Qualcomm in 2020.
SAW filters, along with passives components, are the primary technology developed by Murata. With several acquisitions over the years, the company has improved their portfolio

[6] TC: Temperature-Compensated
[7] FeMIB : Front-End Module integrated Duplexer

with silicon capacitors and RF switches, for example. And the SAW filter is still being improved, as evident with the recent development of the TF-SAW filter. *"The performance can be comparable to BAW filters at a lower cost,"* asserts Stéphane Elisabeth from System Plus Consulting.
Qualcomm is the only player with a full capability to supply the entire RF chain from the modem to the antenna. Regarding its filter activity, thanks to its acquisition of TDK-Epcos via RF360 joint venture, Qualcomm was able to provide SAW (Standard, TC-SAW) and BAW filters. Recently, Qualcomm has demonstrated its ability to provide TF SW filters with higher performance than its own BAW filter in certain bands.

Behind the technology competition, the US & China trade war is there and is clearly impacting the RF industry. As an example, Huawei worked in the past with Skyworks and Qorvo and will tomorrow work with Murata. The market evolves and the supply chain is changing… So, who will lead the market in the future?

All year long, System Plus Consulting and Yole Développement publish numerous RF Electronics reports. In addition, our experts realize various key presentations all year long.
Discover them on i-Micronews and well as the 2020 program. Stay tuned!

Press contacts

Sandrine Leroy, Director, Public Relations, sandrine.leroy@yole.fr
Marion Barrier, Assistant, Public Relations, marion.barrier@yole.fr

Le Quartz, 75 Cours Emile Zola – 69100 Villeurbanne – Lyon –France – +33472830189

www.yole.fr - www.i-micronews.com – LinkedIn – Twitter

About our Analysts

Antoine Bonnabel works as a Technology & Market Analyst for the Power & Wireless team of Yole Développement (Yole). He carries out technical, marketing and strategic analyses focused on RF devices, related technologies and markets.
Prior to Yole, Antoine was R&D Program Manager for DelfMEMS (FR), a company specializing in RF switches and supervised Intellectual Property and Business Intelligence activities of this company. In addition, he also has co-authored several market reports and is co-inventor of three patents in RF MEMS design.
Antoine holds a M.Sc. in Microelectronics from Grenoble Institute of Technologies (France) and a M.Sc. in Management from Grenoble Graduate School of Business (France).

Guillaume Chevalier has joined System Plus Consulting in early 2018 to perform physical analyses. He holds a two-year university degree in technology of physical measurements and instrumentation technics.

Dr. Stéphane Elisabeth has joined System Plus Consulting's team last year. He has a deep knowledge of Materials characterizations and Electronics systems. He holds an Engineering Degree in Electronics and Numerical Technology, and a PhD in Materials for Microelectronics.

As a Technology & Market Analyst, specialized in RF devices & technologies within the Power & Wireless division at Yole Développement (Yole), **Cédric Malaquin** is involved in the development of technology & market reports as well as the production of custom consulting projects. Prior his mission at Yole, Cédric first served Soitec as a process integration engineer for 9 years, then as an electrical characterization engineer during 6 years. He deeply contributed to FDSOI and RFSOI products characterization. He has also authored or co-authored three patents and five international publications in the semiconductor field.

Cédric graduated from Polytech Lille in France with an engineering degree in microelectronics and material sciences.

Nicolas Radufe is in charge of physical analysis at System Plus Consulting. He has a deep knowledge in chemical and physical analyses. He previously worked in microelectronics R&D for CEA/LETI in Grenoble and for STMicroelectronics in Crolles.

About the reports

SAW Filter Comparison 2020
Deep dive analysis and cost review of key SAW filter technologies from Murata, Skyworks, Qorvo, Qualcomm, Wisol, Taiyo Yuden, Kyocera, Tai-SAW, SAWNICS and Shoulder. - Performed by System Plus Consulting.

RF Front-End Module Comparison 2020 – Volume 2
Technical and cost overview of Huawei's Mate and P series Radio Frequency Front-End Module technologies from 2015 to 2019. - Performed by System Plus Consulting.

Broadcom AFEM-8100 System-in-Package in the Apple iPhone 11 Series
Cost effective third generation of mid/high band Front-End Module with advanced and innovative packaging. – Performed by System Plus Consulting.

Murata Incredible High Performance (IHP) SAW Filter
The first thin-film SAW filter for 2.4 GHz Wi-Fi smartphone front ends. - Performed by System Plus Consulting.

5G's Impact on RF Front-End Module and Connectivity for Cell phones 2019
The battle for 5G still rages: integration in-module or with discrete parts? - Performed by Yole Développement.

About System Plus Consulting

System Plus Consulting specializes in the cost analysis of electronics, from semiconductor devices to electronic systems. Created more than 20 years ago, System Plus Consulting has developed a complete range of services,

costing tools and reports to deliver in-depth production cost studies and estimate the objective selling price of a product… More

About Yole Développement

Founded in 1998, Yole Développement (Yole) has grown to become group of companies providing marketing, technology and strategy consulting, media and corporate finance services, reverse engineering and reverse costing services.
With a strong focus on emerging applications using silicon and/or micro manufacturing, the Yole group of companies has expanded to include more than 80 collaborators worldwide… More

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