

CELLULAR RF FRONT-END TECHNOLOGIES FOR MOBILE HANDSET 2021

Market & Technology Report - June 2021

5G reaching the mass market is an opportunity and threat for RF front-end legacy players, and is unifying Chinese companies.

WHAT'S NEW

- Ecosystem analysis and US/China trade war analysis
- Market forecast and shares extracted at die level
- RF front-end bill of material analysis
- RF front-end architecture analysis

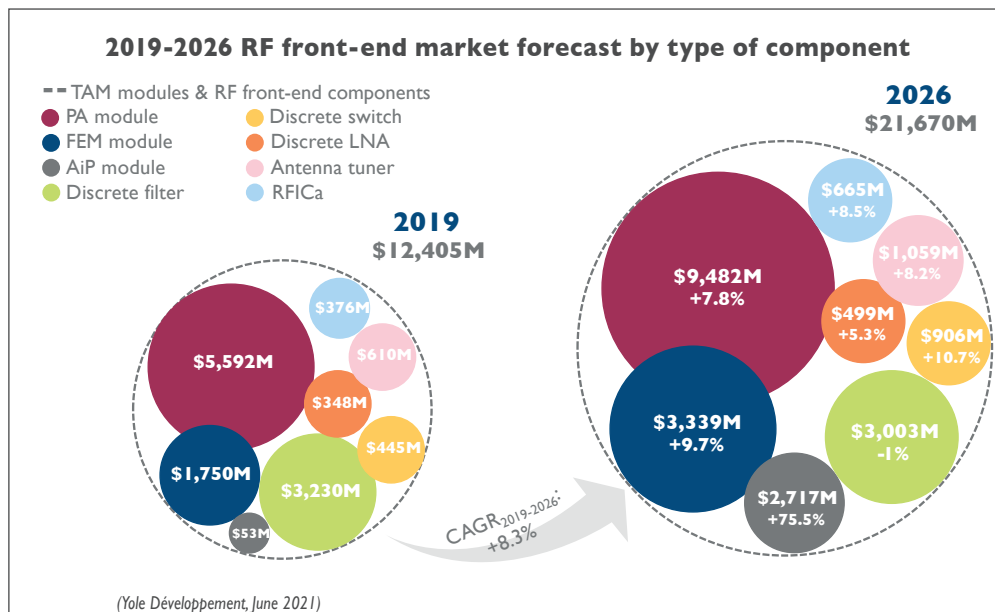
KEY FEATURES

- RF front-end market forecast 2015–2026, in Munits and \$M
- Market share \$M and ecosystem analysis
- RF front-end technology breakdown forecast
- Wafer-start forecast per year 2015–2026
- 5G market trends and key features

5G TO BOOST THE RF FRONT END MARKET

A sharp transition toward 5G is ongoing in mobile devices. The number of 5G phones will more than double in 2021 compared to 2020. This is a significantly faster penetration rate than the LTE standard 10 years ago. And 5G is leading to an unprecedented increase in content of radio frequency (RF) devices, while previous radio standards still need to be supported. As a result, hundreds of RF components must be fitted into handheld format devices. This is now impacting mid-tier and entry-level phones, not only flagships. 5G features implemented in handsets focus on improving download speed and make the uplink more robust. In addition, there is an entirely new radio path created at

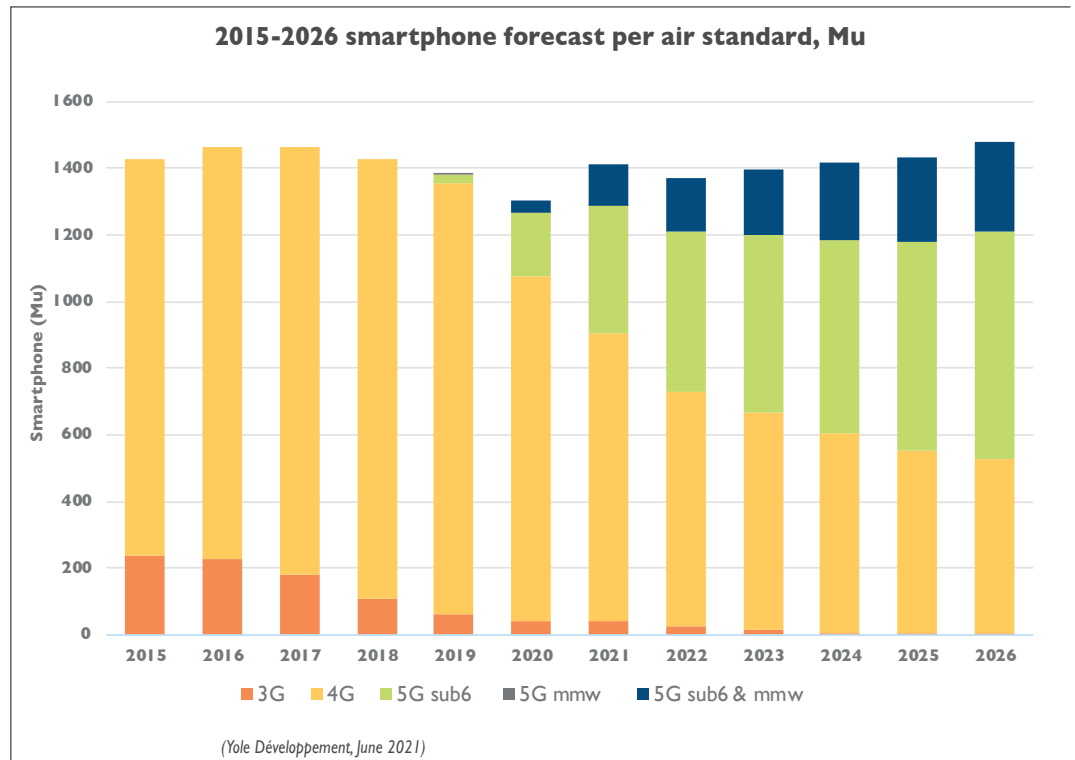
millimeter wavelength (mmWave) frequencies, though this only applies to flagships right now. We estimate the RF content as \$5-\$8 higher in a 5G phone compared to a 4G version and an additional \$10 for a mmWave version. As a result, the RF front-end market is booming. It should reach \$17B by the end of 2021, up from \$14B in calendar year 2020. From there, RF front-end market growth should slow. Average Selling Price (ASP) erosion will be stronger when 5G is mainstream and competition grows further. Overall, we expect an 8.3% annual growth rate (CAGR) between 2019, the year of 5G's introduction, and 2026, leading to a \$21B RF front-end market.



A CHANGE IN THE HANDSET MARKET DYNAMIC

5G has entered the cell phone industry at a tough time, with health and geopolitical issues to be resolved. Despite this, the industry has remained fully committed to deliver 5G, from Mobile Network Operators, who are highly motivated to demonstrate the new technology's value, to smartphone manufacturers and their suppliers. The initial 5G pull came from South Korea and China. Now post-COVID recovery is ongoing, 5G is spreading across North America, Europe and through the rest of the world. As a result, most smartphone manufacturers' projects related to network

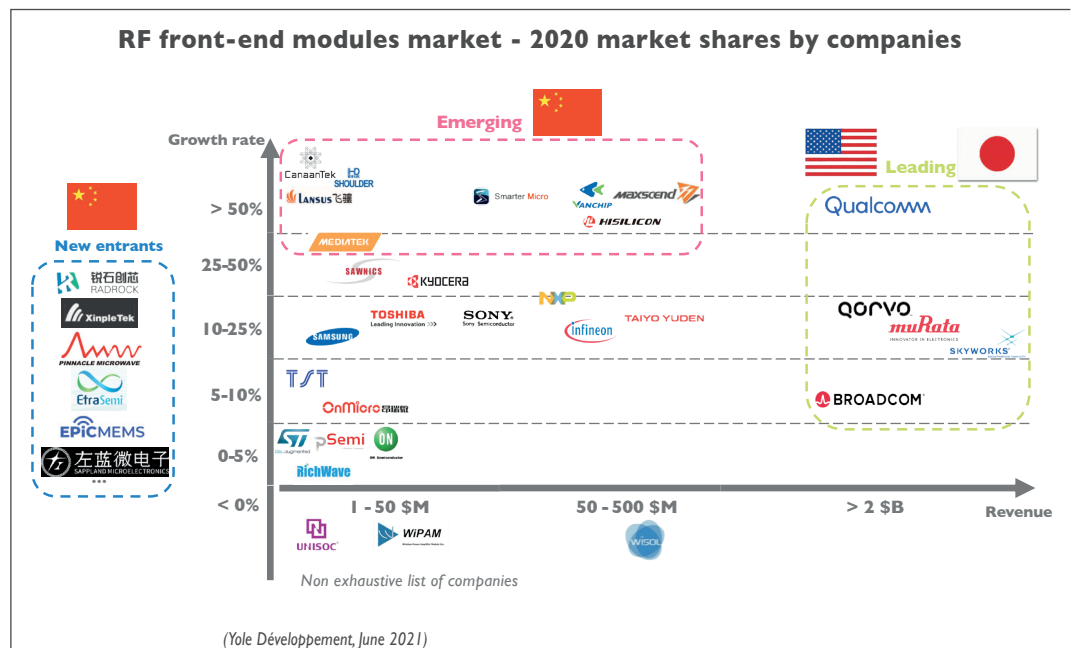
connectivity are about 5G, which relates to the number of 5G phone models available or to be launched. With 5G becoming the new normal, competition between OEMs is increasing and the question of profitability is being raised. As an example, LG is giving up its mobile business. For others, 5G is about a growth opportunity, especially with Huawei facing supply difficulties. Oppo, Vivo and Xiaomi are among those gaining stronger momentum and growing their footprint in China. Samsung and Apple will also likely reinforce their market positions in Europe.



OPPORTUNITIES AND THREATS FOR THE RF FRONT-END PLAYERS

The introduction of 5G adds complexity to phones along with RF content. Building 5G phones using discrete components while keeping an acceptable form factor is a challenge, driving more integration. The RF front-end market leaders all have flexible module offerings adapting to multiple market requirements. Besides that, some also have custom-built modules for the flagships. As a result, Skyworks, Murata, Qualcomm, Qorvo and Broadcom together share 85% of the RF front-end market. Skyworks is the market leader. Qualcomm has the strongest growth. However, a variety of companies coming from China are emerging and experiencing double digit growth in the RF front-end space. Most started

in the discrete business with standalone Low Noise Amplifiers (LNAs) or switches, which enabled them to accumulate know-how and establish trust with OEMs. The next step for these fabless Chinese companies is to bring integrated modules to the market. This has been supported by more investments in China over the past two years. It's likely that not all will succeed, but we can expect more cooperation and consolidation over the next few years. A major difficulty for success will be the access to wafer capacity. There is not a shortage of RF components per se, more like tightness in the industry. This is pushing long term supply agreements that only big players can afford.



REPORT OBJECTIVES

The cellphone industry has entered a transition toward 5G. First use cases of the technology have matured and Mobile Network Operators (MNO) are proposing new services to the consumer. MNOs are strongly motivated to invest more resources and to demonstrate 5G's added value to the consumers, as 5G is not the first thing they are thinking about. In addition, MNOs have developed advantageous commercial 5G packages, particularly in China, adding some more motivation to consumers to upgrade. In this context, 5G has strongly penetrated the smartphone market in 2020 and is expected to further grow as the network is expanding in China, in Europe and in the USA. A 5G phone is relatively more complex than a 4G phone at the RF Front End level. Therefore, it's worth analyzing the technical trends and anticipating future changes to understand this complex market better.

Indeed, as for every new air standard, 5G represents a significant opportunity for industry players to differentiate, innovate and win the market in the end. In this report, we give our view on RF Front End market evolution and its associated ecosystem.

COMPANIES CITED IN THE REPORT (non exhaustive list)

Active Semi, AGC, Airoha, Akoustis, Anhui YUNTA Electronic, Apple, ASE, Asus, AT&T, AwinIC, AXT, Broadcom, CanaanTek, Cavendish Kinetics, China Mobile, China Telecom, China Unicom, ChipBetter, CoolPad, Corning, Cypress Semiconductor, DB-HiTek, Dow, EE, Elisa, Epic MEMS, Ericsson, Etisalat, EtraSemi, Ferfics, Freiburger, GlobalFoundries, Global Wafer, Google, HH Grace, HiSilicon, HMD Global, Honor, HTC, Huawei, Huntersun-MEMS, Infineon, Intel, IQE, Jio, JRC, KDDI, KT, Kyocera, Lansus, Lenovo, LG, LG Siltron, LG U+, Maxscend, MediaTek, Meizu, Menlo Micro, Microgate, Murata, NationZ, Nokia, NSI, NTT Docomo, NXP, Okmetic, Omnivision, ON Semiconductor, OnePlus, Onmicro, Oppo, Orange, Pinnacle Microwave, pSemi, Qorvo, Qualcomm, Radrocktech, Realme, Resonant, Richwave, RoFS microsystems, Sappland Microelectronics, Samsung, Samsung Electro Mechanical, Sana, SAWNICS, Shin-Etsu, Shoulder, Siltronic, SK Telecom, Skyworks, Smarter Micro, SMIC, SoftBank, Soitec, Sony, Sprint, ST Microelectronics, Sumco, Sumitomo Electric, Sumitomo Metal Mining, Sunrise, Sunway Communication, SWI, Swisscom, Taiyo Yuden, TCL, TDK EPCOS, Telefonica, Telia, Telstra, TIM, T-Mobile, Toshiba, Tower Semi, Tpsco, TSMC, UMC, Unisoc, USI, Vanchip, Verizon, Vivo, Vodafone, WaveTek, WillSemi, WIN Semiconductors, WIPAM, Wisol, Xfab, Xiaomi, Xinplettek, Xpeedic, Yamaju Ceramics, Yuzhen IC, ZTE.

TABLE OF CONTENTS (complete content on i-Micronews.com)

Glossary	2	Wafer starts (kwafers)	108
Table of contents	4	Market trends	117
Scope of the report	5	5G market dynamics	118
Methodologies and definitions	6	Spectrum and network status	135
About the authors	7	Market shares and supply chain	151
Companies cited in this report	8	Smartphone market shares	152
What we got right, what we got wrong	9	RF Front-End market shares	156
3-page summary	10	Component market shares	159
Executive summary	14	Focus on top RF FEM maker	165
Why this report?	11	Ecosystem and technology landscape	169
Key takeaways	52	Technology trends	187
Market forecasts	54	Radio access technology trend	188
Market segmentation	56	Focus on 5G key features	198
RF Front-End market forecast (\$M, Mu)	70	RF architecture trend	218
Component level market forecast (\$M, Mu)	85	Technology and components	227
Technology breakdown (\$M, Mu)	92	Outlook and conclusions	254

RELATED REPORTS, MONITORS & TRACKS



- 5G's Impact on RF Front-End for Telecom Infrastructure 2021
- 5G Packaging Trends for Smartphones 2021
- RF Front-End Module Comparison 2021 – Vol. 2 – Focus on 5G Chipset
- Apple iPhone 12 series mmWave 5G Chipset and Antenna

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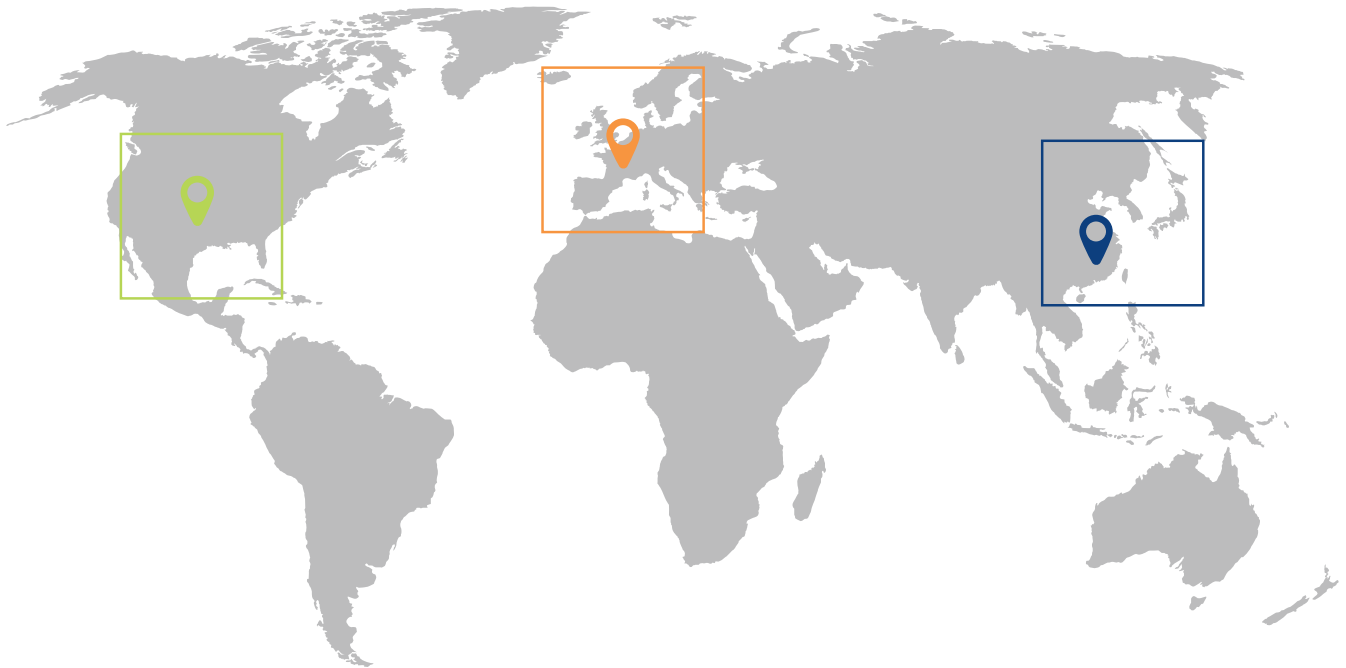
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ABOUT YOLE DEVELOPPEMENT

Founded in 1998, Yole Développement (Yole) has grown to become a 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 120 collaborators worldwide covering MEMS and Image Sensors, Compound Semiconductors, RF Electronics, Solid-state Lighting, Displays, Software, Optoelectronics, Microfluidics & Medical, Advanced Packaging, Manufacturing, Power Electronics, Batteries & Energy Management and Memory.

The “More than Moore” market research, technology and strategy consulting company Yole Développement, along with its partners System Plus Consulting, PISEO and Blumorpho, supports industrial companies, investors and R&D organizations worldwide to help them understand markets and follow technology trends to grow their business.

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Definitions: **“Acceptance”**: Action by which the Buyer accepts these General Terms and Conditions of Sale in their entirety. It is done by signing the purchase order which states “I hereby accept Yole Développement’s General Terms and Conditions of Sale”.

“Buyer”: Any business user (i.e. any person acting in the course of its business activities for its business needs) placing an order pursuant to these General Terms and Conditions of Sale, with the exclusion of any individual consumer acting for his/her sole personal interest.

“Seller”: Headquartered in Villeurbanne (France), Yole Développement provides marketing, technology and strategy consulting, media and corporate finance services, reverse engineering/costing services as well as IP and patent analysis. With dedicated teams of technology & market analysts, Yole Développement operates worldwide with the key industrial companies, R&D institutes and investors to help them understand the market and technology trends.

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1. SCOPE

1.1 Both Contracting Parties undertake to comply with these General Terms and Conditions of Sale.

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1.3 Orders are deemed to be accepted only upon written acceptance and confirmation by the Seller, within [7 days] from the date of order, to be sent either by email. In the absence of any confirmation in writing, no order shall be deemed to have been accepted.

2. MAILING OF THE PRODUCTS

2.1 Products are sent by email to the Buyer after Seller’s confirmation:

- Within a few days from the Seller’s confirmation of the order for Products already released and paid; or
- Within a reasonable time for Products ordered prior to their effective release. In this case, the Seller shall use its best endeavours to inform the Buyer of an indicative release date and the evolution of the work in progress.

2.2 The Seller shall by no means be responsible for any delay pursuant to Article 2.1 above, in particular in cases where a new event or access to new contradictory information would require the Seller analyst to dedicate extra time to compute or compare the data in order to enable the Seller to deliver a high quality Product.

2.3 The mailing of the Product will occur only upon payment by the Buyer, in accordance with the conditions contained in Article 3 above.

2.4. The mailing is operated through electronic means either by email via the sales department or automatically online via an email/password. The Buyer is responsible for ensuring that the Buyers platform has the required capacities and authorisations to receive the Product(s) emailed by the Seller. If the Product’s electronic delivery format is defective, the Seller undertakes to replace it at no charge to the Buyer provided that the Seller is informed of the defective formatting within 90 days from the date of the original download or receipt of the Product.

2.5 The person receiving the Products on behalf of the Buyer shall immediately verify the quality of the Products and their conformity with the order. Any claim for apparent defects or for non-conformity shall be sent in writing to the Seller within 8 days of receipt of the Products. For this purpose, the Buyer agrees to produce sufficient evidence of such defects.

2.6 No return of Products shall be accepted without prior written notification from the Buyer to the Seller, even in case of delayed delivery. Any Product returned to the Seller without the Buyer providing prior notification to the Seller as required under Article 2.5 above shall remain at the Buyer’s risk. In no event shall the Seller incur any liability for Products erroneously ordered by the Buyer, or for any request from the Buyer to replace a Product previously ordered by a different Product.

3. PRICE, INVOICING AND PAYMENT

3.1 Prices are given in the orders corresponding to each Product sold on a unit basis or corresponding to annual subscriptions. They are deemed to be inclusive of all taxes applicable in the country where the Seller is based (except for France where VAT will be added). The prices are re-evaluated from time to time by the Seller. The effective price is deemed to be the one applicable at the time of the order.

3.2 Payments due by the Buyer shall be sent by cheque payable to Yole Développement, or made by credit card or by electronic transfer to the following account:

HSBC, 1 place de la Bourse 69002 Lyon France
Bank code: 30056
Branch code: 00170
Account n°: 0170 200 1565 87
BIC or SWIFT code: CCFRFRPP
IBAN: FR76 3005 6001 7001 7020 0156 587

To secure the payments due to the Seller, the Seller reserves the right to request down payments from the Buyer. In such case, the need for a down payment will be mentioned on the corresponding order.

3.3 Payment is due by the Buyer to the Seller within 30 days from invoice date, except as otherwise specifically agreed in writing by the Buyer and the Seller. If the Buyer fails to pay at the due date and fails to request and obtain from the Seller a payment extension, the latter shall be entitled to invoice interest in arrears based on the annual rate Refi of the “BCE” + 7 points, in accordance with article L.441-6 of the French Commercial Code.

3.4 The Seller publications (reports, monitors, tracks...) are due for delivery only after receipt by the Seller of any payment due by the Buyer prior to delivery.

3.5 In the event of termination of the contract by the Seller attributable to Buyer misconduct during the contract, the Seller will have the right to invoice all work performed at the time of termination, and to take legal action for damages.

4. LIABILITIES

4.1 The Buyer or any other individual or legal person acting on its behalf, being a business user buying the Products for its business activities, shall be solely responsible for the choice of the Products purchased as well as for the use and interpretations the Buyer makes of the documents it purchases, of the results the Buyer obtains, and of the advice and acts the Buyer bases thereon .

4.2 In no event shall the Seller be liable for:

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- b) Any claim attributable to errors, omissions or other inaccuracies in a Product or interpretations thereof.

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4.6 The deadlines that the Seller is asked to provide for the mailing of a Product are given for information purposes only and are not guaranteed. If such deadlines are not met, this shall not, without the agreement of the Seller lead to any claim for damages or right of cancellation of one or more orders by the Buyer, except for non-acceptable delays exceeding [3] months from the stated deadline. In such case only i.e. only in the event of a delay exceeding (3) months from the stated deadline the Buyer shall be entitled to ask for a reimbursement of any down payment previously made to the Seller, to the exclusion of any other damages.

4.7 The Seller does not make any warranties, express or implied, including, without limitation, those of sale ability and fitness for a particular purpose, with respect to any Products. Although the Seller shall take reasonable steps to screen Products for infection of viruses, worms, Trojan horses or other codes containing contaminating or destructive properties before making Products available, the Seller cannot guarantee that any Product will be free from infection.

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The Seller shall not be liable for any delay in performance directly or indirectly caused by or resulting from acts of nature, fire, flood, accident, riot, war, government intervention, embargoes, strikes, labour difficulties, epidemics, major health event (e.g. Corona virus), equipment failure, late deliveries by suppliers or other difficulties which are beyond the control, and not attributable to the fault of the Seller.

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- Use in any timesharing, service bureau, bulletin board or similar arrangement or public display;
- Posting any Product to any other online service (including bulletin boards or the Internet);
- Licensing, leasing, selling, offering for sale or assigning a Product or any derivative thereof.

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6.7 It is further acknowledged and agreed by the Buyer that any investor in the Buyer Company, any external consultant of the Buyer Company or any joint venture done with a third party in which the Buyer Company is involved , is not entitled to use a Product, without paying to the Seller the full price for a license to the required Product..

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If the Buyer cancels the order in whole or in part or postpones the date of mailing, the Buyer shall indemnify the Seller for the entire costs that have been incurred as at the date of notification by the Buyer of such delay or cancellation. This may also apply for any other direct or indirect consequential loss that may be incurred by the Seller, pursuant to such cancellation or postponement.

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8.2 The Seller may, from time to time, update these General Terms and Conditions of Sale, and the Buyer, shall be deemed to have accepted the latest version of such General Terms and Conditions of Sale, once they have been duly communicated to the Buyer by the Seller.

9. GOVERNING LAW AND JURISDICTION

9.1 Any dispute arising out or linked to these General Terms and Conditions of Sale or to any Licenses or Products purchased in application thereof shall be submitted to the French Commercial Court of Lyon, which shall have exclusive jurisdiction upon such issues.

9.2 French law (without reference to any applicable conflict of law provisions) shall apply to these General Terms and Conditions of sale and any agreement between the Buyer and the Seller made pursuant thereto.