# DRIVING INNOVATION IN THE MOBILE CELLULAR ANTENNA MARKET

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# PART A: PREPPING THE NETWORK FOR 5G

## IMPACT OF 5G ON THE NETWORK

The increasing number of 5G subscriptions and total subscriptions will continue to make greater demands on the operators' networks. **5G subscriptions is forecast to reach 3 billion in 2025 from about 0.2 billion in 2020**, representing a Compound Annual Growth Rate (CAGR) of 56%.

Global annual data traffic in exabytes will continue to increase at a CAGR of about 52%, **reaching 4,150 exabytes by 2025 from 331 exabytes in 2020. The amount of data traffic generated by 5G in 2020** accounts for about 23% of total data traffic, but will reach just under 80% by 2025, while 5G subscriptions make up 58% of total subscriptions.

It is not just video and website traffic that are contributing to the growth, but also new applications. Applications like **Virtual Reality (VR), Augmented Reality (AR)**, and real-time video monitoring-based streaming are some of the new examples. In all, video streaming traffic demand is expected to account for 70% of total mobile traffic globally by 2025. Applications like **Intelligent Transport Systems (ITS), fleet management**, and smart manufacturing will also contribute to the increasing data traffic as 5G deployments continue to roll out.

*Chart 1: Annual Subscriptions by Generation*
*Top 30 Markets, Forecast: 2020 2025*

*(Source: ABI Research)*

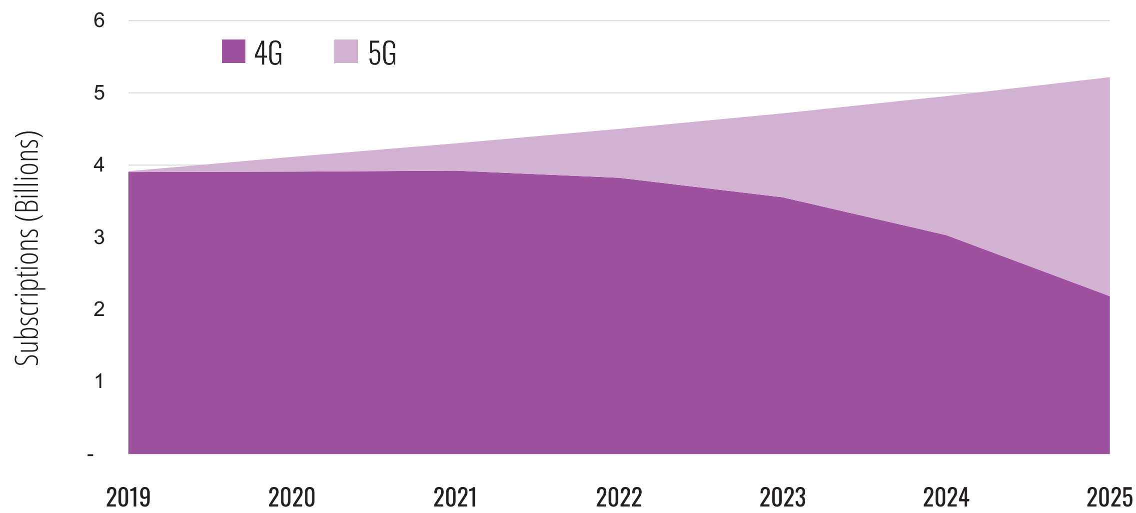
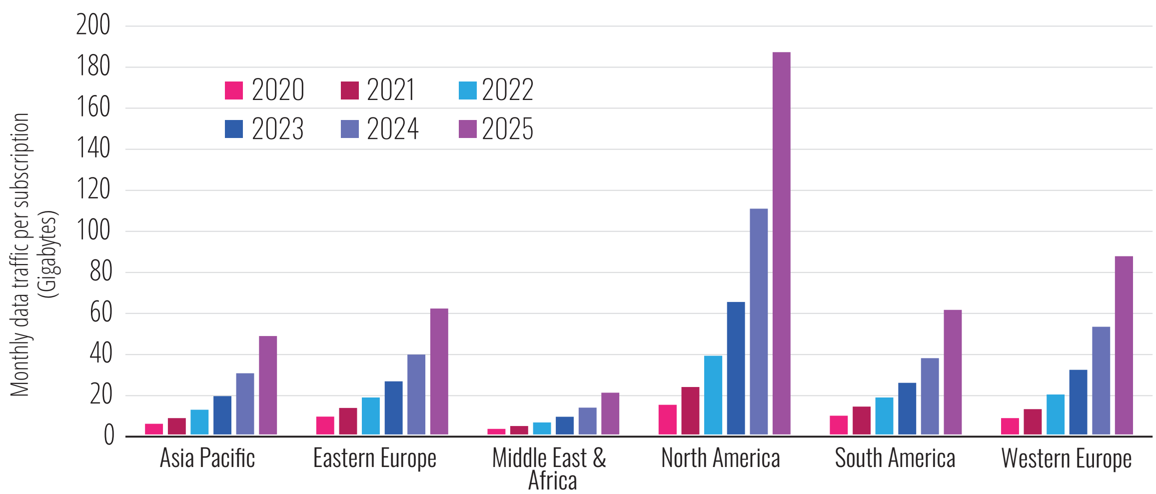



*Chart 2: Monthly Data Traffic per Subscription (4G + 5G only) by Region*
*World Markets, Forecast: 2020 to 2025*

*(Source: ABI Research)*




## DELIVERING 5G QUALITY OF EXPERIENCE

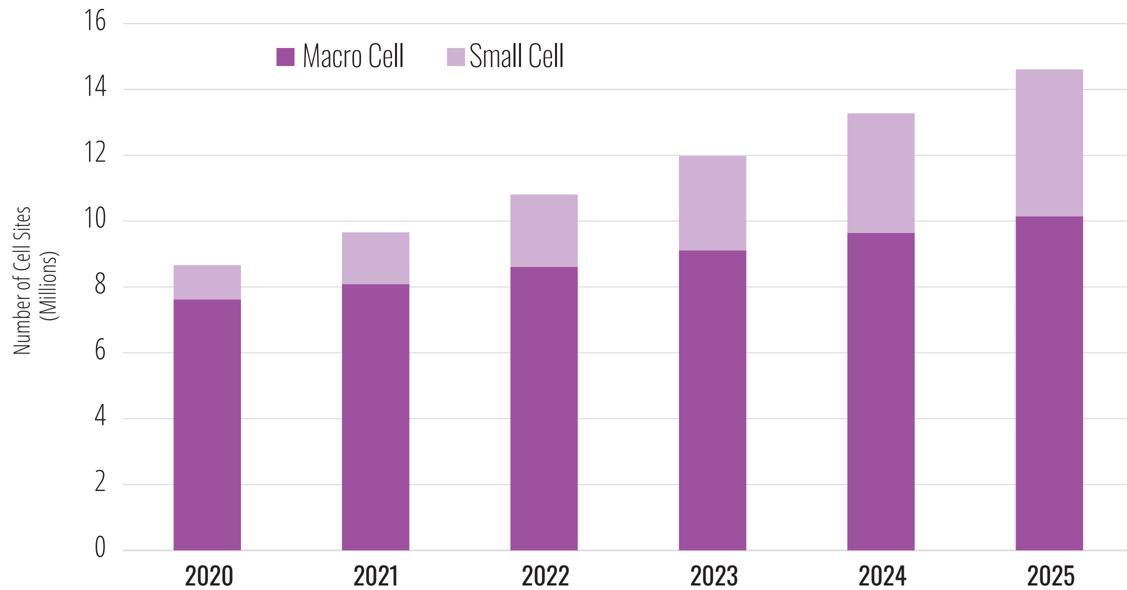
Given the data-demanding applications that come with 5G, operators face the challenge of ensuring the quality of the user experience. Operators also have to ensure that coverage, both indoors and outdoors, for data usage are sufficient to meet the growing demand.

To improve the connectivity and bandwidth for users, operators can look to bring the connection closer to the location of demand. **Operators will, therefore, need to resort to cell densification as a means of increasing the network capacity**. Cell densification will help manage the traffic flow of data within areas that are capacity strained. One method for cell densification is to deploy many small cells on lamp posts, street furniture, sides of building (which can either cover the street or even "push" the signal into the building).

Small cell solutions will help operators overcome the coverage challenges and provide quality of service and continuous connectivity. Small cells can also provide coverage for areas where macro cells are unable to reach.

***Chart 3: Total (Marco + Small) Cell Sites by Technology***
***World Markets, Forecast: 2020 to 2025***

*(Source: ABI Research)*




The number of cell sites is forecast to increase from about 8.6 million cell sites in 2020 to reach about 14.6 million sites in 2025. Small cell sites are forecast to increase at a CAGR of 27.4% to reach 4.4 million sites in 2025 as compared to the increase in macro cell sites at a CAGR of 4.9%. It is forecast that small cell sites will account for about 30% of the total number of cell sites by 2025.

## 5G OPERATOR MOMENTUM

As of **April 2020, the Global mobile Suppliers Association (GSA) reported that 73 operators in 41 counties have launched commercial 5G services**. This represents an increase of 27 operators in 15 countries compared to the number reported by the GSA in October 2019. The number of 5G mobile services launched by operators has also increased by 32 operators to 66 operators in April 2020 as compared to October 2019.

### ASIA GOES INTO OVERDRIVE

In Asia, Japan's operators, **NTT DOCOMO**, KDDI, and **SoftBank** launched their 5G services at the end of March 2020 while **Rakuten Mobile** plans to launch its 5G network by mid-2020. A total of about US$14 billion will be earmarked for 5G development by the four operators. It is estimated that, by 2022, Japan will have about 48,000 5G base stations constructed by the three operators. **Hong Kong Telecom, Hutchison 3**, and **China Mobile Hong Kong** also launched 5G services in April 2020. **China is expected to build out a total 500,000 5G base stations** by the end of 2020 with cities expanding the number of base stations. Shenzhen City planned to deploy 30,000 new 5G base stations in 2020, which is on top of the existing 15,500 5G base stations as of the end of 2019.

### EUROPE BUILDS CONFIDENCE

In Europe, multiple launches have also been observed. **Telenor**, the first to launch in Norway, switched on its 5G mobile services in March 2020 and planned to upgrade 8,500 base stations over the next 4 to 5 years. **Three UK** launched its 5G network in February 2020 for smartphone users, although its broadband service was up earlier in August 2019. **Vodafone Ziggo** also launched its 5G services at the end of April 2020 in the Netherlands and planned for nationwide coverage by July 2020.

### NORTH AMERICA DIVERSIFIES COVERAGE

T-Mobile, which completed a merger with SPRINT, plans to invest about US$60 billion over the next 5 years to achieve its "layer cake" 5G network. The company will upgrade 30,000 of its existing sites and build out 15,000 new towers. In March 2020, Verizon increased its CAPEX guidance from US$17.5 to US$18.5 billion to address its network infrastructure needs, including a 5G network. AT&T aims to make an investment of US$20 billion in 2020 for its network with a focus on 5G networks and fiber. Dish, a new player in the U.S. market, has planned to invest US$10 billion to build its 5G network across the United States and deploy about 10,000 5G sites by 2022.

Canada had its first 5G launch by Roger Communications in January 2020, while Telus Corp plans to launch its 5G network by the end of 2020. Bell Canada will invest about US$2.8 billion in 5G.

### KEY TAKEAWAYS

5G rollouts are gaining pace and 73 deployments have already taken place. Different regions will move at difference rates, but the overwhelming technological advantages of 5G over 4G will stimulate adoption and the swap-out of existing 4G equipment. Ultimately, 5G will supersede 4G, even in existing 4G and 3G spectrum bands, as it offers higher capacity per Hertz (Hz), as well as lower latency and higher reliability. By 2025, ABI Research forecasts there will be 3 billion 5G subscriptions up and running.

## PREPARING THE CELL SITE FOR 5G

In 5G New Radio (NR), the mainstream frequency bands will typically be based on Time Division Duplex (TDD) in the mid (3 GHz to 6 GHz) and high (24 GHz to 40 GHz) bands. The use of mid and high bands makes it possible to deploy networks with much larger bandwidths to meet enhanced mobile broadband requirements.

For initial 5G launches in most countries, the 3.5 GHz band (3.3 GHz to 3.8 GHz) has been the most dominant mid-band choice. Many Radio Frequency (RF) engineers in the wireless communication industry associate deployments in high-frequency bands with poor coverage; thus the need for additional cell sites, which adds to high deployment costs.

There are three main reasons for challenges with mid and high bands, compared with existing low-band deployments:

- Transmitter output power limitations
- Physical limits of antenna power reception
- Increased propagation losses

## POWER VERSUS PROPAGATION TRADE-OFFS

The achievable output power at higher frequency bands is limited by power amplifier technology and by regulatory requirements, particularly at microwave and millimeter-wave bands. At higher frequencies, antenna sizes can come down in size for the same gain as at lower frequencies. Hence, higher antenna gains may be needed at higher frequencies.

Diffraction and transmission through walls or foliage are highly frequency dependent, while free space loss, reflection, and scattering have some variation over frequency in the mid band. Compared to 1.8 GHz, the free space loss is 5-6 Decibels (dB) higher at 3.5 GHz, but it is around 24 dB higher at 28 GHz. Outdoor to indoor propagation loss tends to be higher, particularly for larger and thermally efficient buildings. These losses can be around 2 dB to 3 dB (at 1.8 GHz) and 10 dB to 20 dB (at 28 GHz) higher than at 1.8 GHz.

## ADVANTAGES OF BEAMFORMING

Higher propagation losses at mid and high bands can be mitigated by using higher gain antennas at both the gNB base station and the end-user terminal. In 5G NR, beam management for both gNB and the end-user terminal are supported, allowing the beams to be set up and maintained in the best direction. The beams are steerable, casting strong signals in the desired direction, with little interference in the other directions. This allows the received Signal-to-Interface-Plus-Noise-Ratio (SNIR) to be maximized, giving better channel quality and higher transmission throughput. Beamforming can help significantly increase capacity through Multi-User Multiple Input, Multiple Output (MU-MIMO) techniques. If users are sufficiently separated in space, then the same resource block can be allocated to different users at the same time in different beams.

In the Uplink (UL), the ability of the end-user device to perform beamforming (using precoding techniques) also improves the UL budget, as compared to Long-Term Evolution (LTE). In LTE, the UL is around 5 dB to 7 dB weaker than the Downlink (DL), primarily due to power differences between the eNode B base station and the end-user terminal, and the number of antennas deployed at the eNode B versus the end user terminal.

## DOWNLINK COVERAGE

NR uses similar Orthogonal Frequency-Division Multiplexing (OFDM) as LTE. In considering the link budget, particularly the reference signal, the bandwidth of the RF carrier (and, hence, the number of resource blocks and sub-carriers) affects the power of each sub-carrier. Therefore, NR operating with 100 Megahertz (MHz) channels will have a much lower reference signal received power, as compared to LTE operating with 20 MHz channels. The reference signal received power is usually used as a gauge for the coverage level of the cell. In LTE, this level is usually set at -95 Decibel-Milliwatts (dBm) with a reception probability of 95%, while in NR, this will be around -100 dBm to 105 dBm.

## PROS AND CONS OF DEPLOYING NON-STANDALONE

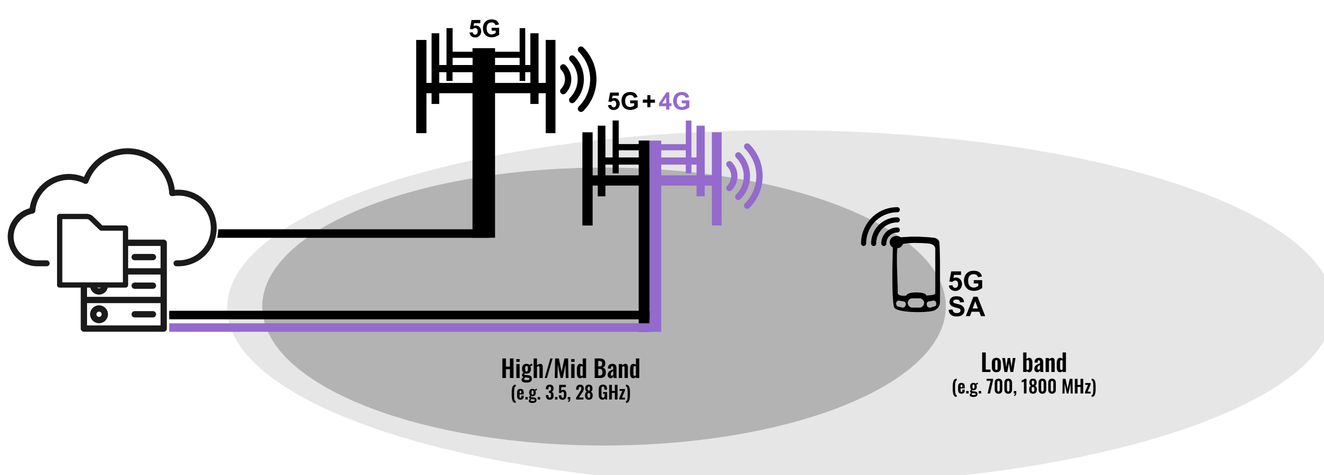
When NR 3.5 GHz is co-located with exiting LTE sites, it may still be difficult to cover some restricted terrain (e.g., urban or rural canyons) or indoor locations, even with beamforming antennas. Lower frequency bands, such as 900 MHz and 1800 MHz, are used for current LTE networks, so it is possible for NR 3.5 GHz to fall back to these lower LTE bands, using inter-working techniques, such as dual-connectivity (or carrier aggregation) in Non-Standalone (NSA) mode. This allows NR 3.5 GHz to offload traffic from congested LTE sites, so NR 3.5 GHz does need not to achieve 100% cell coverage. This is one of the considerations for deploying NSA mode.

All initial launches of 5G in the last year were based on the NSA deployment mode. In NSA mode, 5G NR makes use of existing 4G LTE radio and core network for implementation. The NSA User Equipment (UE) is capable of dual-connectivity to 5G NR and 4G LTE. When the 5G coverage is weak, the UE will handover to LTE to maintain call continuity. Hence, from a link budget perspective, the limiting coverage of 5G NR in the higher band will not cause any call discontinuity. However, such handovers from 4G to 5G NR may lead to considerable increase in latency, especially if 5G operates in the millimeter-wave spectrum, due to large variations in signal strength of the latter. Considerable optimization efforts are required for NSA implementations.

## PROS AND CONS OF STANDALONE

During this year, many operators are moving to NR Standalone (SA) mode, where 4G and 5G are connected to a 5G core, as shown in Figure 1. The SA mode does not rely on LTE and will be able to address all three requirements of 5G: 1) Enhanced Mobile Broadband (eMBB), 2) Massive Machine-to-Machine Communications (mMTC), and 3) Ultra-Reliable Low-Latency Communications (uRLLC). It also allows network slicing activities to support a variety of 5G use cases. There are two main drivers for mobile operators to move to SA mode.

*Figure 1: Standalone Mode of Operation*




Firstly, 5G NR SA has the potential to build momentum quickly for the operator. A significant number of mobile devices are already using Qualcomm's X55 modem, which supports a wide range of spectrum bands and/or modes, from 5G millimeter-wave and sub-6 GHz, SA and NSA modes, TDD and Frequency Division Duplex (FDD), spectrum sharing, LTE, and legacy modes (3G, 2G). The X55 modem is paired with the Snapdragon 855 and 865.

Secondly, as 5G NR is a new interface, it has incorporated advanced techniques to compensate for the additional propagation losses at 3.5 GHz when operating in SA mode. In particular, the SA mode supports a technique called Direct Spectrum Sharing (DSS), which allows an operator to operate 5G and LTE in the same lower FDD or TDD band, based on user demand in 5G and LTE. Unlike in LTE spectrum refarming, where fixed spectrums are allocated for LTE and GSM technologies, DSS allows dynamic allocation of spectrum at the millisecond level for optimal performance of any mix of 4G and 5G devices in the cell. Hence, NR at mid and high bands can fall back to NR at lower LTE bands (800 MHz, 1800 MHz, 2600 MHz, etc.) using inter-band NR Carrier Aggregation (CA).

## EVOLUTION OF CELLULAR SPECTRUM

The high band (28 GHz millimeter-wave) does have very wide channels to deliver eMBB. However, due to the nature of microwave propagation, ubiquitous and reliable coverage cannot be achieved using existing 4G cell site locations. Therefore, the mid band, ranging from 2 GHz to 6 GHz (primarily the 3.5 GHz C-band), will be needed to deliver wide-area eMBB, uRLLC, and mMTC. To ensure deep and reliable coverage, the low band (<2 GHz) will also be required. It is very likely that all existing bands will converge to support NR, using DSS in SA mode.

## MASSIVE MIMO, MASSIVE POWER

Massive MIMO, implemented as an integrated baseband, radio, and antenna in Advanced Antenna System (AAS), is being deployed prominently in the high and mid bands. The shift toward AAS at the cell site is timely, as it gives superior performance in both UL and DL. Unlike 3G and 4G antennas with fixed beam patterns and directivity, **5G antennas must support on-demand beam coverage based on user location and application scenarios.**

In the mid band, the use of Massive MIMO is a major factor for NR colocation with lower LTE FDD bands, such as 1800 MHz and 2600 MHz. With a large array solution, such as 64T64R, a Massive MIMO antenna can deliver beamforming capabilities in both vertical and horizontal directions, enhance cell edge throughput, minimize intercell interference (and maximize SNIR), and implement both Single-User- (SU) and Multi-User- (MU) MIMO to boost the peak user throughput and cell capacity. However, with these large arrays comes multiple transceivers, significant processing power, and, therefore, high-power consumption, all of which adds significantly to the cost of building and deploying an NR network.

## ADDRESSING LOW RISE URBAN, SUB-URBAN AND RURAL CELL SITES

In low rise urban, sub-urban or rural scenarios where building heights are much lower, vertical beamforming is usually not needed. A more cost-effective AAS with 32 or 16 transceivers, having fewer MIMO layers, is usually enough without sacrificing the performance. Many operators are also exploring other antenna options to reduce the deployment cost and to meet tower constraints—of major interest are TDD 8T8R beamforming, multi-beam antennas, and a combination of these, along with lower bands in a single hybrid antenna. It is worthy to note that a 4T4R antenna implemented using two cross-polar arrays can generate four different horizontal beam shapes (center, left, right, and split beam) using precoding techniques. In 8T8R beamforming, four antenna arrays are used, giving narrower horizontal beams and horizontal beam steering. Vertical beam control is implemented using Remote Electrical Tilt (RET) systems in 4T4R and 8T8R beamforming.

## ANTENNA DEPLOYMENT OPTIONS

5G sites are expected to be made up of a combination of **active (AAS)** and **passive antenna systems**. There are three main antenna options for operators to choose from:

- **N+1**: Add the new NR antenna to the site with the existing antennas for legacy systems. This applies to sites with no constraints and the new NR antenna may be an AAS or passive.
- **1+1**: Consolidate all existing antennas for a legacy system into one antenna and add the NR antenna as the second antenna. The single consolidated antenna will support 4T4R for all LTE bands and may include a twin or triple beam in a hybrid antenna structure. Low-band NR using DSS will share the same antenna port as LTE. The new NR antenna may be an AAS or passive antenna.
- **All-in-One**: Single antenna to support legacy systems and NR. Mid-band NR may be implemented using AAS, TDD 8T8R BF, or 4T4R.

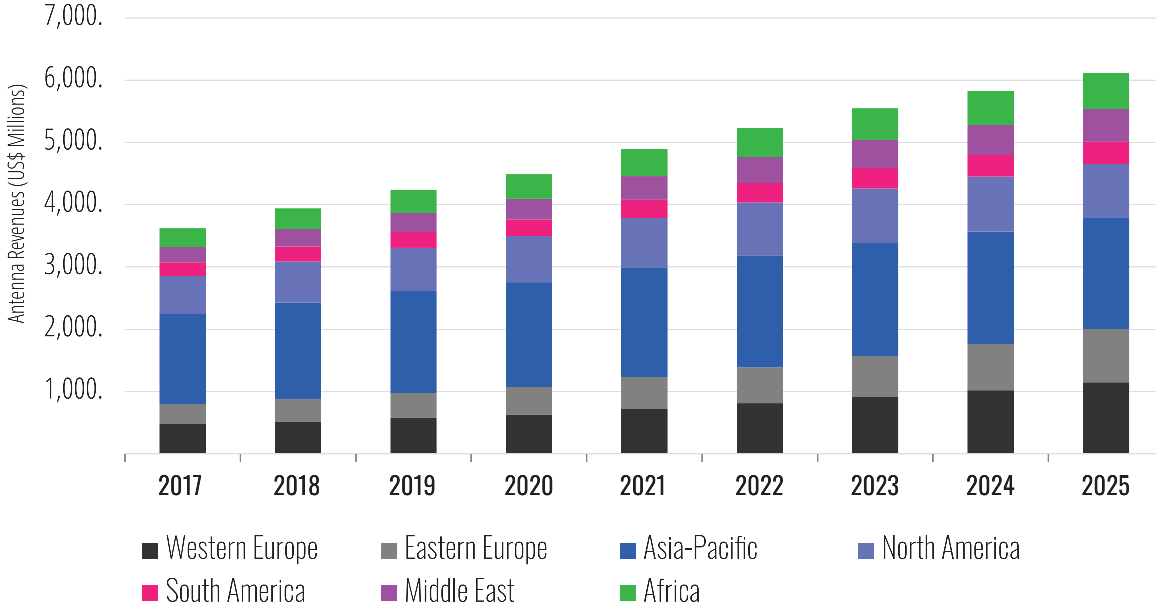
Traditionally, Massive MIMO antennas are implemented in TDD bands, using UL pilot measurements at the gNB base station and exploiting channel reciprocity for DL channel characterization. With the focus on DSS using existing FDD bands, it is now possible to achieve DL beamforming using a grid of beams from the gNB base station and the end-user terminals reporting their preferred beams. Due to increased complexity in the base station, FDD Massive MIMO is limited to 16 or 32 transceivers. FDD Massive MIMO can help operators reduce the cost per bit with approximately 3X to 5X capacity increases.

## MOBILE CELLULAR ANTENNA MARKET OUTLOOK

The outlook for 2020 has been marginally hit by COVID-19, but not to the same extent as other industrial sectors that rely directly on the consumer making a purchase or face-to-face interactions. Furthermore, in many countries, telcos have been deemed "essential services," so essential staff have been able to attend to telco infrastructure upgrades.

As mentioned in the first section, in addition to the 73 5G commercial deployments, 5G trials are still continuing. Furthermore, a number of countries, mostly in mid-tier and emerging markets, are either migrating from 3G to 4G, or even upgrading their LTE solutions to LTE-Advanced or LTE-Advanced Pro. These latest iterations of LTE support higher-order MIMO. Starting in 2020, a larger volume of 5G commercial deployments should provide mobile antenna vendors with a significant boost.

*Figure 2. World-wide Mobile Cellular Antenna Market, by Region*




## KEY TAKEAWAYS

- The year 2020 is likely to show low single-digit antenna sales revenue growth of around 6%. The outlook for growth should prick up from 2021 as COVID recedes and 5G roll-outs further build out. This will require higher order multiport and higher order MIMO and Massive MIMO shipments shift up a gear to 9%.
- Additional mobile spectrum delivers additional capacity, but it comes with additional cell site and antenna challenges. One of the principal capacity gain strategies will be allocating spectrum at higher frequencies. At these higher frequencies, higher antenna gains may be needed.
- MU-MIMO lends itself to beamforming. If users are sufficiently separated in space, then the same resource block can be allocated to different users at the same time in different beams.
- DSS will be a key technology, as it allows an operator to operate 5G and LTE in the same lower FDD or TDD band, based on user demand in 5G and LTE.
- In urban areas, a likely Massive MIMO solution will be 64T64R. Such a Massive MIMO antenna can deliver beamforming capabilities in both vertical and horizontal directions, enhance cell edge throughput, minimize intercell interference (and maximize SNIR), etc.

# PART B: VIRTUAL FIRESIDE CHAT

Rosenberger

## ROSENBERGER: DELIVERING EXCELLENCE

**Jake Saunders (JS), Vice President (VP) for Asia-Pacific**: "ABI Research 'was' meant to meet face-to-face with Rosenberger for this fireside chat, but, sadly, COVID-19 has locked us in our home offices, so we have had to rely on our mobile phones and Internet connections to make this virtual fireside chat possible. Thank you Caesar Cai (CC), VP for Antenna and Passive Business Unit, and Denis Ng (DN), VP of Marketing and Infrastructure Solutions, for joining us.

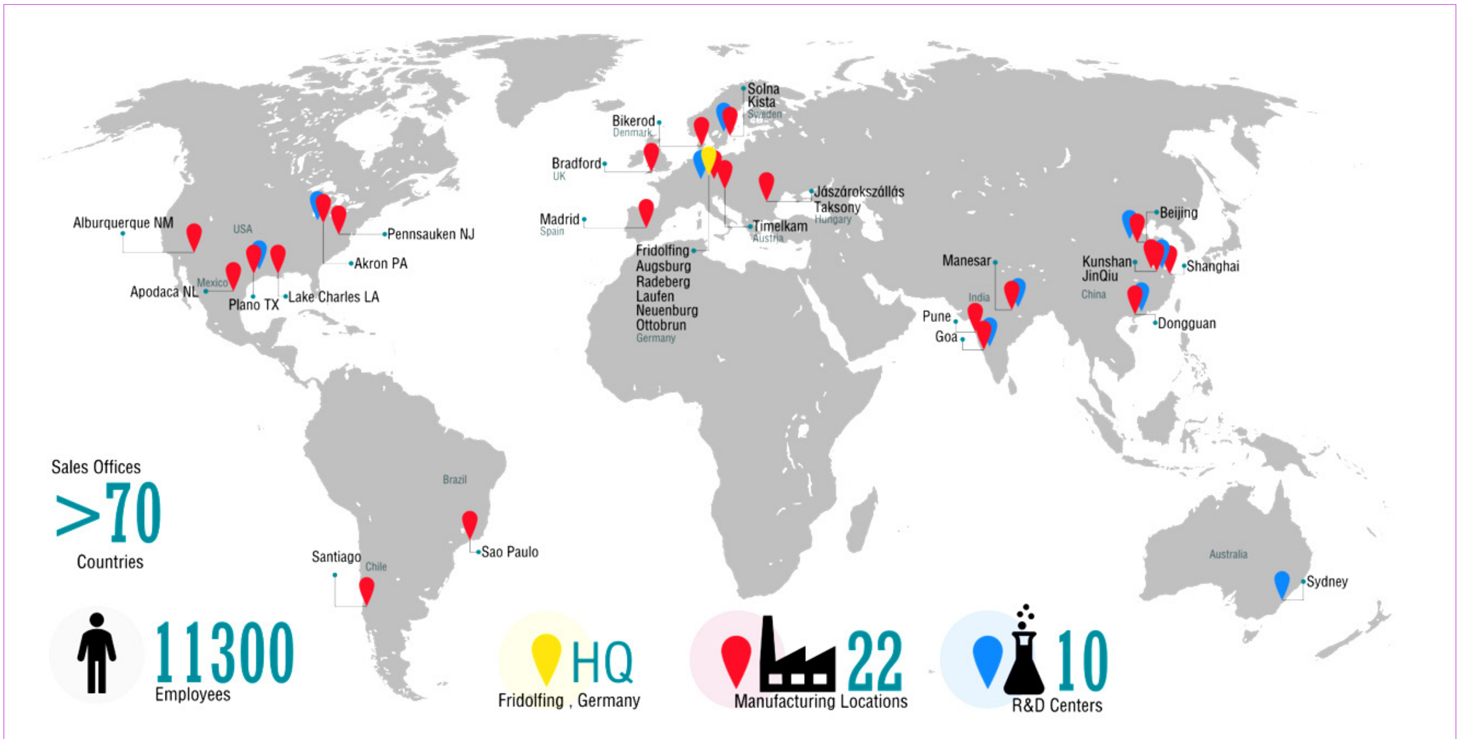
*JS: "Rosenberger was founded in Germany in 1958. My understanding is that for over half a century, Rosenberger has been a leading supplier of impedance-controlled and optical connectivity technology. But the company has diversified into a number of innovative sectors. Where does Rosenberger's mobile cellular antenna innovation business unit fit into the organizational structure?"*

**DN**: "Rosenberger started as an RF connector company. Over the years, we have evolved into other areas of connectivity, such as optical fiber and automotive connectivity. Among the numerous other telecommunication products, such as RF repeaters, optical repeaters, data centers, and tower ancillary products, base station antennas fit as the product line that complements our core RF connectivity portfolio. In particular with 5G technologies and the advanced antenna systems, the need to integrate the Massive MIMO antennas to the radio unit requires the use of precision board-to-board connectors to ensure proper phase alignment of all transceiver ports, and this is one of our areas of expertise."

**JS**: *"How many factories and Research and Development (R&D) centers are now dedicated to mobile cellular antenna manufacturer? And where are its main centers of excellence?"*

**DN**: "We have 19 factories and 9 R&D centers across the globe. Our main centers of excellence are in Kunshan in China, Pune in India, New Jersey in the United States, and Sydney in Australia (R&D Center)."

*Figure 3. Key Rosenberger Locations and Statistics*




*JS: "There are a number of mobile cellular antenna manufacturers around the world? What makes Rosenberger stand out? What is Rosenberger's industrial philosophy?"*

**DN**: "Yes, the mobile cellular antenna market has been in intensive competition in the last decade with many vendors joining the race. As a global leader, we are distinguished by our high level of innovative technological competence, responsibility for consistent quality and cost control, customer-oriented thinking, and a flexible world-class manufacturing process. Our industrial philosophy includes the 3P Spirit—Principles of Professionalism, Precision, and Perfection—as the guiding standards of everything we do."

*JS: "How do you build in innovation into Rosenberger's antenna design?"*

**CC**: "Shaping the technology for the future is deeply rooted at Rosenberger. We have our own pre-development team to study and finalize the latest innovative technologies, which can be used in mass production for our antennas. Not all the initiatives make it to the final stage, but we make sure that the team is motivated and stimulated to think outside the box to overcome the broad technical challenges when dealing with new antenna technologies."

*JS: "Where does the process start? What are the key ingredients for a successful antenna design?"*

**CC**: "The process starts from the brainstorming of ideas, and goes through feasibility evaluation, prototype design, and pilot testing. The key ingredients for a successful antenna design include meeting both the electrical and mechanical parameters, fulfilling the highest industry standards of quality and reliability, and achieving cost efficiency and good manufacturability, among other factors."

*JS: "How long is the R&D process?"*

**CC**: "It usually takes 1 to 8 months to complete a project depending on its complexity. More advanced 5G antennas will usually take a longer time to develop than 4G antennas."

*JS: "What are some of the major challenges in mobile antenna design and development?"*

**CC**: "The major challenges include:

1. Increasing demands for multi-band, multi-port, multi-beam, miniaturization, and RET functionalities.
2. More advanced antenna technologies, including support for LTE-Advanced, 5G NR, 4x4 MIMO, beamforming and Massive MIMO, and a hybrid combination of these.
3. Increasing requirements for superior antenna pattern and Passive Intermodulation (PIM) performance.
4. Diversified local customization and fast development cycle."

*JS: "Where do your R&D personnel come from? How many years of training, both academic and within Rosenberger, are required?"*

**CC**: "70% of our R&D personnel are university graduates from renowned local universities, and the remaining 30% are external recruits. It usually takes 1 to 3 years to train an engineer."

*JS: "There are approximately 700 mobile operators worldwide, many with quite distinctly different spectrum requirements and operational conditions. How do you listen to the customer? How does the feedback get incorporated into current design and production processes?"*

**DN**: "Although there are many operators with diversified demands, the use of spectrum will mostly fall into several common bands like (698-960 MHz, 1695-2690 MHz, and 3,300-3,800 MHz). We have paid special attention to establish several wideband antenna platforms to cover these common bands. Most of the time, we could fulfill the customer demands directly from our existing product portfolios. In case some customization is needed, it is relatively easy and fast to develop products derived from these standard platforms as the building blocks. Of course, there are always exceptions and we make sure we develop customized solutions where we believe the market needs it."

*JS: "Can you walk me through a case example?"*

**DN**: "For instance, with our 2LxH platform, any customer demand of antennas with 2 antenna arrays of low band 698-960 MHz, plus 0 to 5 arrays of high band 1695-2690 MHz, within the length of 1.4 Meter (m) to 2.7 m can be quickly developed."

*JS: "How varied are mobile operator needs? What was the most challenging antenna order?"*

**DN**: "The needs vary dramatically. The frequency bands range from 600/700/800/900 MHz to 1400/1800/2100/2300/2600 MHz, and up to 3.5/5.8 GHz and millimeter wave in 5G NR. The antenna lengths vary from less than 1 m to more than 2.7 m. The connectors usually vary between 7/16, N, 4.3-10, and Next-10.

Some very challenging projects include active antennas with different Original Equipment Manufacturer (OEM) partners, 4G antennas with as many as 30 ports, hybrid antennas with 4x4 MIMO plus multi-beam, and 8T8R beamforming capabilities, just to mention some examples."

***Figure 4. Rosenberger Production Floor Processes***

*JS: "A great antenna design is a great achievement, but then you have to scale up product, so how do you assure the 500, 1,000, or 10,000 antennas a mobile operator orders meet their expectations?"*

**CC**: "We currently have large-scale production capacity distributed in different facilities mainly in Asia. Our factories can produce more than 70,000 4G antenna units per month, or 15,000 5G antenna units per month. We are currently working on expanding our footprint to meet the demands of our customers around the globe."

*JS: "What are the three largest challenges? And how do you overcome them on the factory floor?"*

1. **CC**: "Skills of Personnel: We make sure continuous training programs are implemented to transfer the necessary skills to all new personnel. At the same time, we have different programs organized to make sure the latest trends in design, leadership, and management are studied and discussed by all our team members to help develop their careers.
2. On-Time Delivery: Skilled supplier management and advance material preparation to guarantee everything is in place when needed at the right cost.
3. Demand Fluctuations Lead to Reduced Efficiency: Modular design of our antennas helps us to deal with the diverse market needs and stay competitive."

*JS: "A perennial issue I hear from mobile operators is about logistics. Seems they are constantly in need of mobile cellular antennas. How do you address the challenge of supplying just-in-time, [customized] antennas?"*

**CC**: "Continuous innovation and rapid response are key ingredients in this mix. For some cases we make sure inventory, distribution centers, or even production bases are located near the customer to guarantee the product availability according to the project's needs."

*JS: "Let's dig into Rosenberger's mobile antenna portfolio. 5G deployment is ramping up. What antenna configurations are meeting the needs of 5G?"*

**CC**: "Multi-port MIMO antennas, 4G/5G hybrid antennas, and Massive MIMO antennas."

*JS: "For the macro cell site?"*

**CC**: "Multi-band ultra-wide band minimized 4x4 MIMO antennas with low weight. The current trend is to use one antenna covering 698-2700 MHz with 4x4 MIMO for all bands."

*JS: "And there is a big expectation for an increased rollout of small cells. How are they being catered for?"*

**CC**: "5G requires a lot more sites for coverage in which the small cell antennas will come in handy. We have a comprehensive small cell antenna portfolio to fulfill such needs."

*JS: "Cell sites are becoming busy places—especially at the top! It seems it is an arms race to shoehorn more ports into antenna housing. Which configurations are proving most popular? What are they catering for?"*

**CC**: "Multi-band, multi-port, and small-sized antennas. This is very difficult and requires a lot of technical resources, so we have developed our own specific radiators and arraying technologies to achieve this."

*JS: "PIM can destroy the RF profile of an antenna and it can come from multiple causes... How do you mitigate against PIM?"*

**CC**: "Through advanced technical design and strict manufacturing process control. Rosenberger is well known globally for its PIM analyzers, so we use all the available resources and technical expertise to better understand and control PIM."

*JS: "5G will require MIMO, a crucial technology for boosting capacity. What are you seeing in terms of demand for MIMO and Massive MIMO configurations? Any key electronics vendor collaborations you can mention?"*

**CC**: "MIMO and Massive MIMO technologies are integral aspects of 5G standards for high-speed throughput and huge capacity. We have had collaborative projects of advanced antennas with OEM vendors like Ericsson and Nokia for years."

***Figure 5. Rosenberger Multibeam Antenna***

*JS: "Most cell sites now, in fact, belong to tower management companies, but surely the addition of 5G layers presents additional challenges on top of 4G. Are hybrid antennas the answer?"*

**CC**: "A hybrid antenna is a good solution for the coexistence of 4G and 5G. It provides a smooth transition from 4G to 5G with no increase in the antenna count."

*JS: "4G antenna transmission ranges typically top out at 2.7 GHz, but 5G will operate in the C-Band, as well as potentially in the millimeter band. How is this being addressed?"*

**CC**: "It's possible to extend the 4G radiators to cover the C-Band (3.5 GHz). Alternatively, a separated 3.5 GHz array can be placed along the 4G array. In the case of the millimeter band, a separated array, or even a separate antenna, is needed due to the difference in cell coverage."

*JS: "What about power supply? As well as dissipation of heat?"*

**CC**: "Power supply will generate a lot of heat, so the ventilation system needs to be well designed, and the antenna needs to meet the corresponding requirements to work in harmony with the whole system."

*JS: "Is it true that optimizing the coverage from a Massive MIMO antenna can be a complex analysis. Can Artificial Intelligence (AI) come to the rescue?"*

**CC**: "The full optimization of Massive MIMO antenna coverage can be very complex and computationally intensive, considering the large number of RF channels and variables involved. AI technology certainly can help solve this problem by collecting and analyzing the on-site user data patterns and reducing the network optimization complication to a more manageable scale."

*JS: "Pulling away from AI for a moment, I hear the bane of many a field engineer is the 'connector'. An incorrectly connected connector can lead not just to loss of signal, but ingress of water. Rosenberger can be incorporating the NEX10 connector into its products. What is the innovation?"*

**CC**: "The NEX10 connector generally is too big to be integrated into the 5G antennas. We have corresponding multi-coax connector products to solve this problem. Nevertheless, the NEX10 connector can guarantee excellent PIM stability (−166 dBc) of the site with a significantly smaller footprint, which saves valuable space."

*JS: "Thank you for the insights into Rosenberger. It is exciting to see the level of innovation and excellence being generated in Rosenberger's R&D centers."*

# ACRONYMS & DEFINITIONS

| Acronyms | [[LIST OF ACRONYMS BEING | FINALISED]] | |
|---|---|---|---|
| eMMB | Enhanced Mobile Broadband | MU-MIMO | Multiuser Multiple-Input, Multiple-Output |
| URLLC | Ultra-Reliable Low-Latency Communications | DSS | Direct Spectrum Sharing |
| CC | Caesar Cai | AAS | Active Antenna Systems |
| DN | Denis Ng | OEM | Original Equipment Manufacturer |
| JS | Jake Saunders | OFDM | Orthogonal Frequency-Division Multiplexing |
| CAGR | Compound Annual Growth Rate | NSA | Non-Standalone |
| GSA | Global mobile Suppliers Association | SA | Standalone |
| NR | New Radio | UE | User Equipment |
| TDD | Time Division Duplex | mMTC | Massive Machine-to-Machine Communication |
| FDD | Frequency Division Duplex | UL | Uplink |
| RF | Radio Frequency | DL | Downlink |
| gNB | Next Generation NodeB | SNIR | Signal-to-Interference-Plus-Noise Ratio |
| BF | Beamforming | 4T4R/8T8R | Four/Eight Antenna Transceiver |
| MIMO | Multiple-Input, Multiple-Output | RET | Remote Electrical Tilt |
| SU-MIMO | Single User Multiple-Input, Multiple-Output | PIM | Passive Intermodulation |
| MU-MIMO | Multiuser Multiple-Input, Multiple-Output | 2LXH | |

**Published July 2020**





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