ROSENBERGER JOINS THE **TOP 4** AS IT READIES FOR 5G

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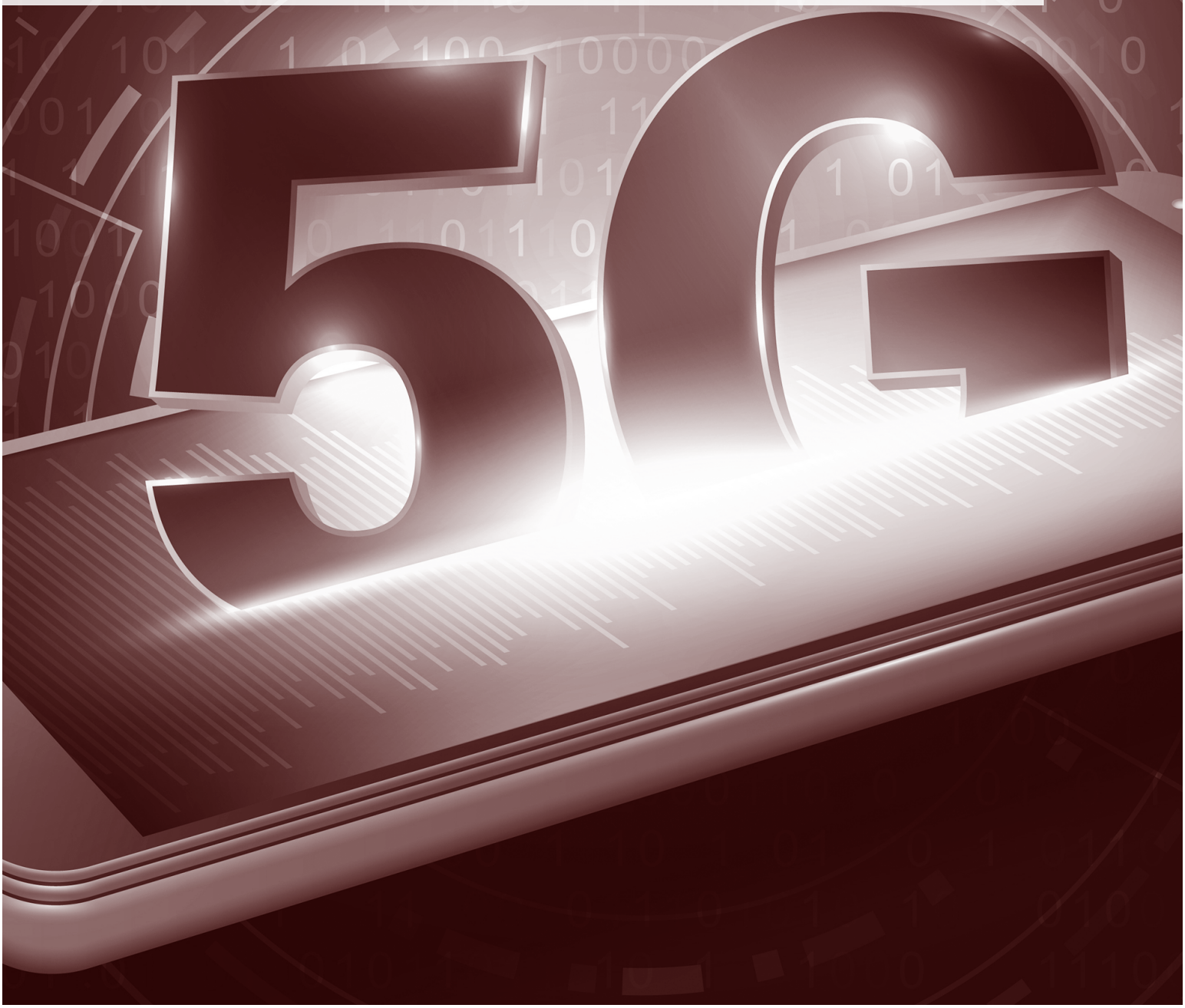
ABIresearch for visionaries

Rosenberger



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1. INTRODUCTION

At the end of 2018, total mobile subscriptions reached 8.4 billion with an annual year-on-year growth rate of 4.1%. In the future, ABI Research estimates that there will be almost 10 billion mobile subscriptions in 2026, with the highest growth occurring in Long-Term Evolution (LTE) and 5G access technologies, and with the Asia-Pacific, European, North and South American, and African regions accounting for the clear majority of these.

The growth in LTE and its LTE-Advanced, LTE-Advanced Pro and Gigabit LTE variants, and the advent of 5G is driving innovation and technology in the mobile cellular antenna ecosystem. Techniques such as Multiple-Input Multiple-Output (MIMO), massive MIMO for multiple bands, multiple beams, both Time Division Duplex (TDD) and Frequency Division Duplex (FDD) access techniques, and high order component carrier aggregation all render the design and manufacture of antennas a field ripe for innovation and invention.

In addition, space at the top of mobile cellular macro basestation towers is increasingly constrained. In developed markets, mobile operators report that 30% of macro cell sites only have access to a single antenna mount, while 40% of cell sites only have access to two antenna mounts. As mobile operators acquire additional spectrum, existing antennas need to adopt these additional technologies and features and offer more compact antenna form factors. Antennas also need to manage Total Cost of Ownership (TCO), mitigate Passive Inter-Modulation (PIM) distortion, and minimize weight and wind load, while integrating the maximum number of mobile telco frequency bands.

Successful antenna vendors will meet these challenges head-on and the sheer size of the market in many regions will reward them with revenue and growth.

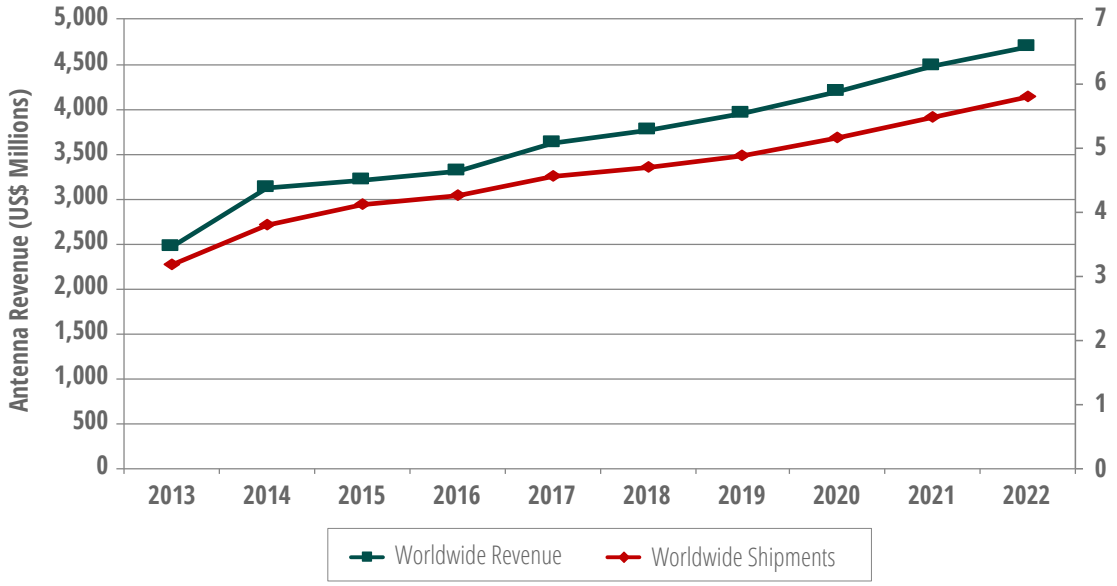
2. ANTENNA MARKET DETAIL

2.1 2017 ANTENNA MARKET SHARE ANALYSIS AND 2018 MARKET OUTLOOK

In the run up to 2010, the market for macro cellular basestation antennas was largely driven by the deployment of new macro cell sites for 3G coverage. Between 2010 and 2014, carriers built out the coverage of their LTE networks and then densified those networks to remove black spots and improve coverage and capacity for 4G data services. Between 2014 and 2018, the rate of growth in macro cellular antenna shipments had flattened to single-digit growth, as shown in Figure 1 below.

Figure 1: Mobile Cellular Antenna Revenue and Shipments World Markets, Forecast: 2013 to 2022

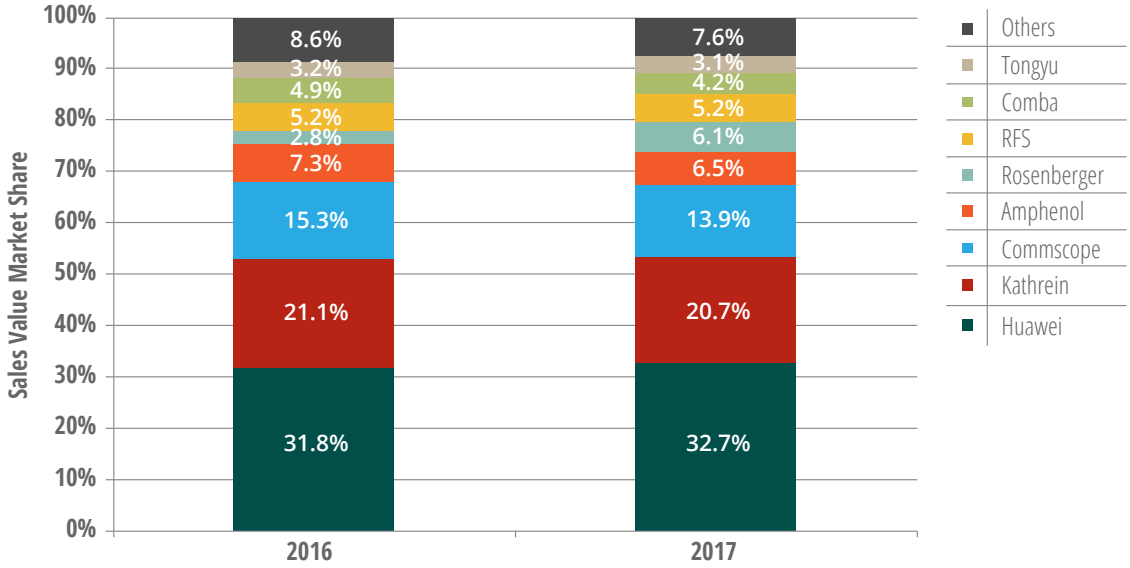
(Source: ABI Research)



In 2017, while mobile cellular antenna unit shipments grew at 7%, antenna sales revenue increased at a slightly higher rate of 9.5%, to reach US$3.62 billion. In 2018, ABI Research expects that the antenna market continued to grow at 4% year-on-year thanks to the adoption of new frequency bands for 4G and 5G in many regions worldwide. The market reached US$3.76 billion in 2018 and will grow to US$4.69 billion in 2022.

Figure 2: Mobile Cellular Antenna Revenue Market Share World Markets, 2016 versus 2017

(Source: ABI Research)



According to ABI Research's calculations, the largest antenna vendor is Huawei with a market share of 32.7% in 2017. The number 2, 3, and 4 spots are held by Kathrein, CommScope, and Amphenol, respectively, as shown in Figure 2 above. While most antenna vendors held market share from 2016 to 2017, Rosenberger stands out for having grown its share by more than 2X from 2.8% in 2016 to 6.1% in 2017. This revenue growth, which was larger than the 2016/2017 9.5% year-on-year growth of the total market, came at the expense of corresponding share reductions from CommScope, Kathrein, and Amphenol.

Rosenberger experienced a rapid increase in 2017, ranking number 5 globally. Market traction came from significant antenna sales in the Asia-Pacific region, especially in India and Southeast Asia. Antenna shipment contracts can be dependent on variable but potentially significant contract awards from mobile telcos, but there should also be significant opportunities for antenna sales due to multi-band and multi-port support as additional 4G and 5G spectrum comes online, as well as higher-order MIMO deployments.

Rosenberger continued to gain market share in 2018 thanks to continued traction in Asia, the Middle East, and the United States. The company also extended its presence into Russia, Africa, Europe, and Latin America. ABI Research discusses these market share gains in Section 2.2.1 below.

2.2 ROSENBERGER 2018 MARKET PROGRESS SUMMARY

While results for full year 2018, at the time of writing, have not yet been published by the majority of antenna vendors, ABI Research has started to observe a few trends for 2018 and future years. The outlook for 2018 to 2020 will be shaped by the mobile infrastructure telco landscape, with 2018 as one of 5G trials and 2019 producing the first 5G commercial Radio Access Network (RAN) deployments. The year 2020 will produce the first commercial at-scale 5G deployments. The year 2018 is likely to show single-digit antenna sales revenue growth of around 4%.

The larger number of commercial 5G deployments starting in 2020 will provide antenna vendors with a significant boost as 5G rollouts, higher order multi-port, and higher order MIMO and massive MIMO shipments shift the market up a gear to more than 6% year-on-year growth. Massive MIMO deployments will start to take a material hold on the market from 2020, but it should be noted that massive MIMO is not an exclusive 5G opportunity, but also a 4.5G opportunity, as LTE-Advanced Pro supports higher order MIMO.

It is against this background that Rosenberger has been making rapid strides in the mobile cellular antenna market. The vendor has been able to leverage not just its Research and Development (R&D) to create innovative antenna design, but also its manufacturing in many of the large and high growth regions worldwide.

Rosenberger is a family-owned business with a strong and steady financial cash flow and a healthy organizational structure. With new advanced R&D centers in Australia, Germany and the United States, Rosenberger has hired highly experienced engineers and experts to focus on 5G antenna design as one of its priorities. In 2018, Rosenberger set up local company offices in several countries in Southeast Asia and smaller regional offices in Europe, the Middle East, Africa, and South America. The company also built a new antenna factory in India to boost production, with the goal of meeting the fast delivery requirements of Indian operators.

Rosenberger's global footprint is shown below in Figure 3.

Figure 3: Rosenberger's Global Footprint

(Source: Rosenberger)

2.2.1. Sales Revenue and Market Share

In 2018, Rosenberger further extended its reach in existing markets in Asia, India, the Middle East, and the United States, while maintaining strong relationships with radio or Original Equipment Manufacturer (OEM) equipment suppliers. The company has also established a significant presence in Russia, Africa, Europe, and Latin America. Overall, in 2018, Rosenberger supplied almost 700,000 antennas to 45 operators covering more than 30 countries. Rosenberger has been able to extend its presence in the highly competitive Asian market.

ABI Research calculates that Rosenberger's antenna sales revenue in 2018 increased by almost 29% compared to 2017, once again outpacing the overall market, which grew at 4%. This growth is enough to secure a number 4 position in the market share rankings with a market share of 7.6%, compared to a rank of number 5 and a share of 6.1% in 2017. This improves the company's global ranking in ABI Research's Vendor Matrix, as discussed below in Section 3.

2.2.2. Technology Innovation

Rosenberger maintains six modern manufacturing and R&D base locations in Beijing, Kunshan, Shanghai, and Dongguan in China, as well as New Delhi and Goa in India, for the development and manufacturing of basestation antennas. Rosenberger's antenna R&D center is based in Kunshan, Jiangsu Province in China, with more than 4,000 employees. It develops advanced antenna technology for multi-band and multi-port antennas, and has more than 300 professional Radio Frequency (RF) experts with relevant telecommunications academic and professional qualifications.

The company also has its own advanced, near-field test chamber, an outdoor far-field test range, and several other environmental test equipment and chambers. These test facilities serve to deliver the high-performance characteristics of Rosenberger's antenna products based on strict variable environmental conditions testing.

2.2.3. Supplier Support

Rosenberger works with many telco and radio equipment vendors in high growth markets in regions like China, Southeast Asia, Europe, the Middle East & Africa, Latin America, and the United States.

In the **Asia-Pacific region**, the company ranks among the top antenna vendors in India, completing successful trials with 4 Transmit 4 Receive (4T4R) twin-beam, low band twin-beam, and 16-port dual twin-beam antennas, and has supplied more than 40,000 units of these antennas to the Indian market. Rosenberger has three factories in India and offices in various parts of the country to support local services.

Rosenberger has also established itself as a key supplier for the Bangladesh market and has shipped more than 3,000 units to Robi Axiata and supplied multi-band antennas to Grameenphone and Banglalink.

The company is also the core antenna supplier to the SingTel Group (Singapore), Telkomsel, Smartfren, and XL (Indonesia). Rosenberger continues to maintain its role as a key supplier for the Axiata Group (Malaysia).

In the Philippines, the company claims a majority market share for Smart in the Philippines for 4G network deployment.

In Taiwan, the company supplies Taiwan Mobile T STAR and is in trials with FarEasTone.

In Vietnam, Rosenberger reports it has significant relationships with the country's 2G/3G/4G networks.

In the **Middle East**, Rosenberger is expanding, having received approval from du in the United Arab Emirates, in addition to Zain and STC in Saudi Arabia.

In **North America**, Rosenberger has become a key antenna supplier to AT&T and T-Mobile for 5G small cell projects, supplying several products including basestation antennas for the FirstNet public safety network.

In **Latin America**, Rosenberger conducted successful trials with TIM and Anatel in Brazil.

In **Africa**, Rosenberger entered the market in 2018 and became the key supplier for the two largest operators in Africa, with more than 20,000 antennas delivered to Nigeria, Kenya, Zambia, Tanzania, Uganda, and others.

In **Europe**, Rosenberger participated in Requests for Proposals (RFPs) and Requests for Quotations (RFQs) for major Tier One European operators, such as Vodafone Group, Orange Group, Telefonica Group, and others. Also, the company is active with Salt in Switzerland, Wind3 Hutchinson in Italy, Polkomtel and Play in Poland. The company also successfully sold multi-band and multi-beam antennas to Russia and Azerbaijan by demonstrating high-performance products with fiberglass radomes.

3. 1Q 2018 ANTENNA VENDOR MATRIX

In 2Q 2018, ABI Research published an Innovation versus Implementation Vendor Matrix as part of its competitive assessment of the antenna market. Below is a summary of the results.

3.1 VENDOR MATRIX METHODOLOGY

Underpinning the implementation and innovation axes of the vendor matrix are a series of quantitative and qualitative benchmarks. The implementation benchmarks provide insight into the vendor's market reach, or its ability to turn product into traction and revenue in the market. The innovation benchmarks reflect the vendor's ability to innovate and generate new products. Assessing the state-of-the-art level of innovation is a complex process. Some firms, such as Huawei, conduct the R&D, antenna manufacture, and sales in-house. In other cases, firms like Rosenberger conduct their own R&D, antenna manufacture, and sales in-house, but also collaborate with OEMs or radio vendors. The focus of the vendor matrix is on the wholesale antenna manufacturers.

The underlying benchmarks for the innovation y-axis are:

- **Multi-Band Capabilities:** Degree of support for multi-band capabilities, but also need to deliver high gain and coverage.
- **Ultra-Wideband Capabilities:** How extensive is the vendor's antenna support for ultra-wideband capabilities, but also supporting high gain and coverage?
- **Advanced MIMO Capabilities:** To what degree does the vendor support advanced MIMO functionality? This includes 4x4 MIMO, Multi-User MIMO (MU-MIMO), and Full Dimensional MIMO (FD-MIMO), as well as massive MIMO.
- **Essential Intellectual Property and R&D:** Level of intellectual property also factors into collaborative partnerships, and quality of the antenna design and manufacturing process.
- **Active Antenna Capability:** How capable is its Active Antenna System (AAS) capability and the maturity of its AAS product? Consideration is given for beamforming in the horizontal and vertical planes.
- **Antenna Configurability and Maintenance:** Degree of maintenance, quality of materials and components to resist downtime of antenna, and simplicity of configuration for its Self-Organizing Network (SON).

The underlying benchmarks for the implementation x-axis are:

- **Overall Antenna Sales Market Share:** The greater the market share, the better the ranking.
- **Antenna Sales Regional Geographical Penetration:** Partly based on sales presence in each global region. Also, the more regions the vendor's clients are in, the better the ranking.

- **Financial and Organizational Health:** Based on the size of overall firm sales and operating margin. Tries to assess how robust the vendor is to shocks and to fund internal needs, such as R&D, regional distribution, channel expansion, *etc.*
- **Vendor's Antenna Portfolio:** Range of portfolio. Supports all the protocols? Wide range of spectrum bands? Competitive pricing?

3.2 ANALYSIS

The previous Vendor Matrix ranking is shown below:

Figure 4: 1Q 2018 Vendor Matrix Ranking

(Source: ABI Research)

Company	1Q-2018	
	Score	Rank
Huawei	94.3	1
Kathrein	89.6	2
CommScope	85.1	3
Amphenol	73.5	4
RFS	73.0	5
Rosenberger	72.6	6
Comba	57.1	7
Mobi	49.1	8
Tongyu	47.9	9

As might be expected from ABI Research's market share discussion in Section 2.1, the top vendor was Huawei, scoring high marks in both innovation and implementation. Huawei is joined in the top 4 by Kathrein, CommScope, and Amphenol, in that order.

A notable entrant into the vendor matrix analysis was Rosenberger. The German vendor has been an antenna vendor since 2008, and in the past 3 years, it has built up traction in several Asian markets, including India. Several high-profile trials in the United States and in Europe contributed to a strong innovation score.

It should be noted that, from a technical standpoint, the top five vendors have similar product offerings in both multi-band and multi-port antennas. However, the ever-widening range and combinations of spectrum bands needed, along with space and wind/weight load limitations at the cell site, will place competitive pressure on the vendors to keep innovating.

3.3 4Q 2018 UPDATE

As discussed in Section 2.2.1, ABI Research calculates that Rosenberger's antenna sales revenue in 2018 grew almost 29% year-on-year, outpacing the market's growth rate. This was enough to improve Rosenberger's position to the number 4 slot in the vendor matrix ranking with a score of 74.6 as shown in Figure 5.

Figure 5: 4Q 2018 Vendor Matrix Ranking Interim

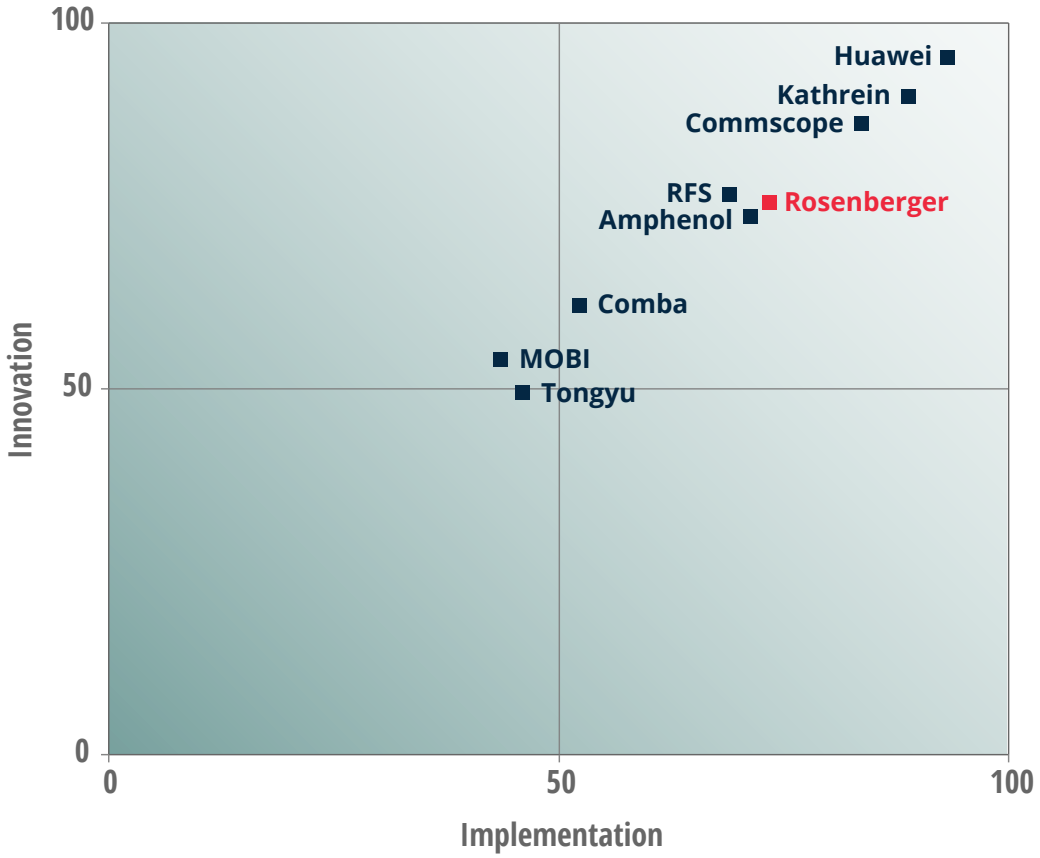
(Source: ABI Research)

Company	Interim 4Q-2018	
	Score	Rank
Huawei	94.3	1
Kathrein	89.6	2
CommScope	85.1	3
Rosenberger	74.6	4
RFS	73.0	5
Amphenol	72.5	6
Comba	57.1	7
Mobi	49.1	8
Tongyu	47.9	9

As a result, the company's global ranking for the antenna sector is now number 4 in the Vendor Matrix, with Huawei at the number 1 position, followed by Kathrein and CommScope in the 2nd and 3rd positions. RFS and Amphenol took the 5th and 6th positions, respectively. The interim Vendor Matrix is illustrated below in Figure 6.

Figure 6: 4Q 2018 Innovation versus Implementation Vendor Matrix Interim

(Source: ABI Research)



With the current pace of network improvement and expansion, mobile operators are planning their antenna deployment strategies to maximize the capacity of LTE-Advanced mobile communication to be able to keep up with a steady increase in network data traffic. These companies are also planning for the near future needs of 5G, so that the migration and upgrade to the new standard will be a smooth process. ABI Research believes that Rosenberger will continue its efforts to bring to the market quality antennas at competitive prices to meet the requirements and needs of operators worldwide.

4. ROSENBERGER'S SOLUTIONS

In 2018, Rosenberger invested significant resources in the development of new antenna products responding to the upgrade plans for existing networks, to consolidate existing antennas to make way for MIMO deployments of higher order across all bands, and to prepare the sites to accommodate new requirements for 5G, particularly in the L-band. Rosenberger also helps its clients respond to the limitations imposed by increased tower loading with solutions for two or even a single antenna per basestation sector.

Rosenberger's portfolio includes antenna solutions meeting the requirements of existing access technologies, LTE, LTE-Advanced, and LTE Advanced Pro, which are 5G ready. These solutions can be grouped into four categories:

- Multi-band solutions
- Multi-beam hybrid solutions
- FDD+TDD hybrid solutions
- 5G solutions

4.1 MULTI-BAND SOLUTIONS

In this category, the main goal is to offer a large number of antenna ports, so that it becomes possible to consolidate all existing sub-2.7 Gigahertz (GHz) bands into one antenna, with sufficient tower space remaining to accommodate a second antenna or massive MIMO for 5G. An important consideration is to be able to support LTE-Advanced MIMO capabilities to their full potential and provide 4T4R for all LTE bands, particularly in the high band from 1,427 Megahertz (MHz) to 2,690 MHz.

Currently, over 45% of the FDD antennas that are delivered in the global market have six or more ports. Multi-band and multi-port antennas are expected to be widely acknowledged as mainstream products by 2021. Rosenberger is offering multi-port antennas with up to 24 and 30 ports, covering all sub-2.7 GHz bands with field-exchangeable Remote Electrical Tilt (RET) systems. In the case of the 30-port antenna, it can adapt to various band combinations, such as 3 low and 12 high bands. This gives mobile operators a choice of deploying one 4T4R and one 2T2R in the low band (700 MHz and 900 MHz), two 2T2R, three 4T4T, and one 8T8R in the high band, or up to six 4T4R in high bands, or any other combination according to their individual demands. The antenna also offers 4 ports to cover bands from 1427 MHz to 2690 MHz.

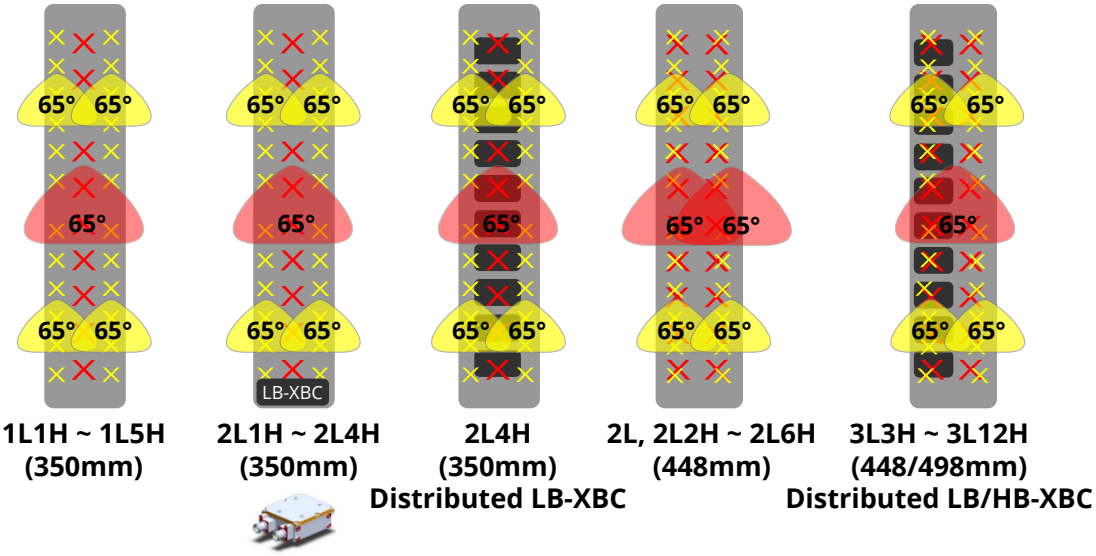
Various duplexed configurations are also available for lower port count antennas to support 4T4R using external low-loss combiners. Several models also provide support for sub-2.7 GHz and 3.5 GHz bands in the same antenna. This is particularly useful for sites that are shared by multiple mobile operators, where

each operator may not be allowed to deploy more than one antenna per sector. Antennas are generally available in three sizes: high gain 2.7 meters (m), mid gain 2.0 m, and low gain 1.6 m. These allow for flexible deployment in the network, from urban to rural locations.

Figure 7 below summarizes Rosenberger's multi-band portfolio.

Figure 7: Multi-Band Antenna Modules

(Source: Rosenberger)



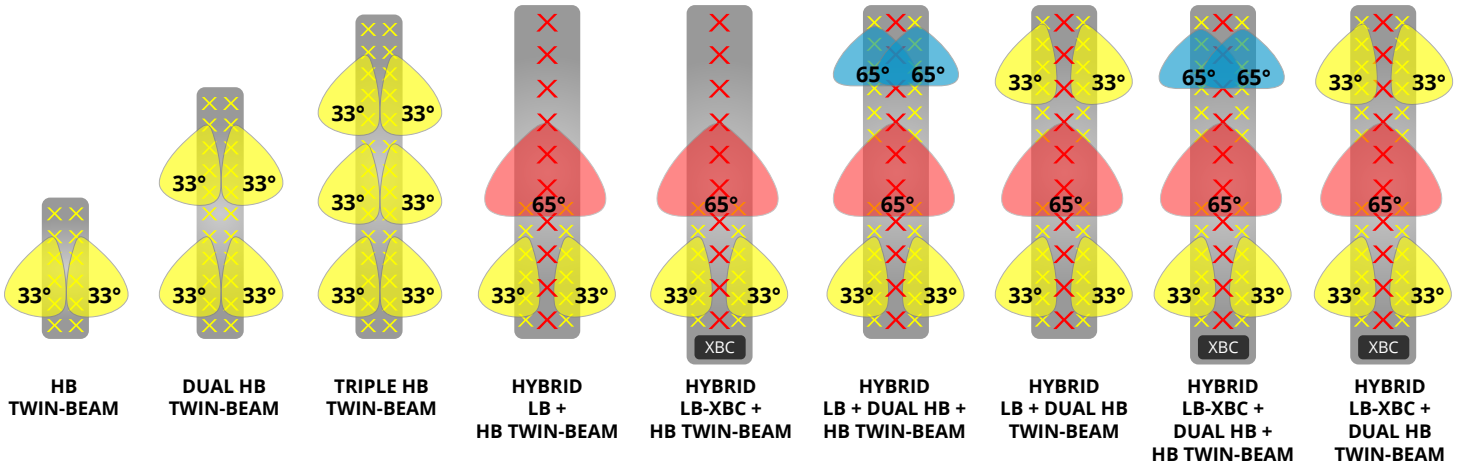
4.2 MULTI-BEAM HYBRID SOLUTIONS

In the case of multi-beam solutions, the goal is to achieve cell densification using the already existing sites within the network by increasing the number of sectors without increasing the number of antennas or new sites. This requires one antenna to have two or more beams to support multiple sectors. With two beams deployed in one antenna covering the same 65-degree horizontal width commonly seen in single-beam antennas, the beams in twin-beam antennas are approximately halved, thus allowing for a higher gain, while remaining conveniently sized. Consequently, this solution provides both capacity and coverage improvements.

Figure 8 shows the high-band twin-beam (yellow) models and hybrid models that combine twin-beam configurations with single-beam models for both high-band (blue) and low-band (red) support. Various choices are available, such as 3-sector high-band 4T4R, 6-sector high-band 2T2R, 6-sector high-band 4T4R, and 3-sector low-band 2T2R. Twin-beam models are also available for the 3500 MHz band.

Figure 8: Twin-Beam and Hybrid Antenna Models

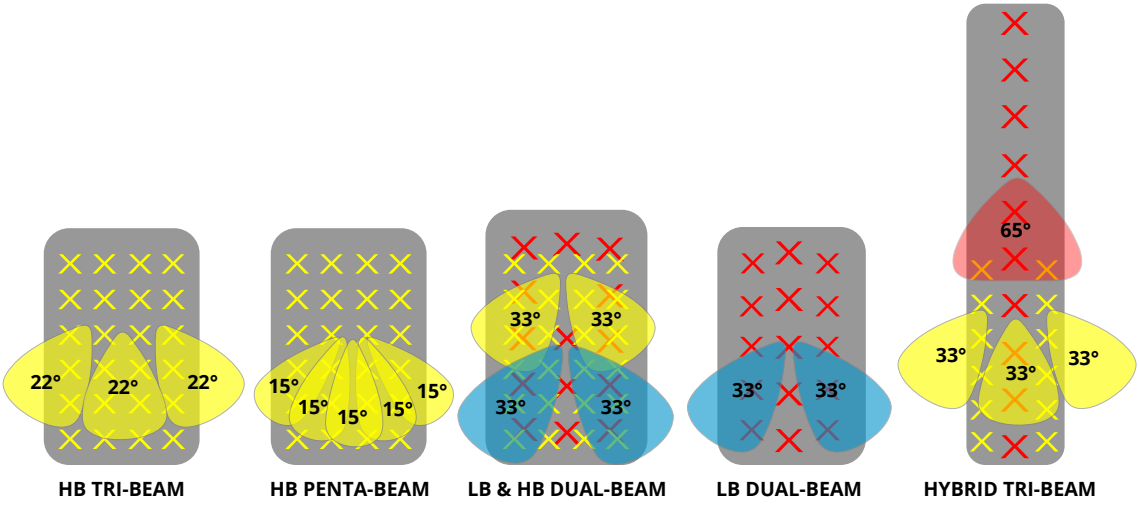
(Source: Rosenberger)



For higher order sectorization and capacity improvements, tri-, penta-, and nona-beam models supporting 2T2R in each beam are also available, as illustrated in Figure 9, including dual-band twin beams. Currently, there are 18 multi-beam products under development, with a focus on achieving very high-capacity data rates per single site.

Figure 9: Multi-Beam and Hybrid Antenna Models

(Source: Rosenberger)

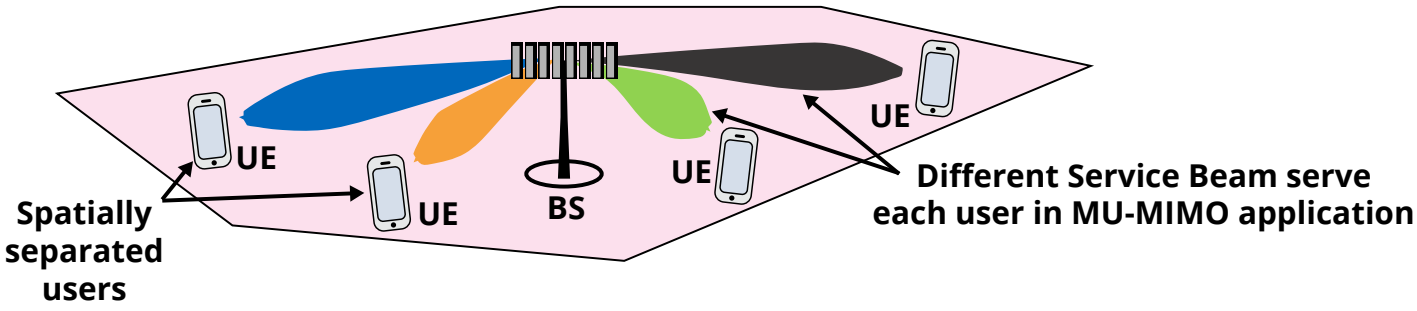


4.3 FDD+TDD HYBRID SOLUTION

In TDD multiplexing schemes, the reciprocity in the uplink and downlink channels is used to perform antenna beam steering using 4 antenna arrays with 8 antenna ports. This allows the Remote Radio Unit (RRU) to generate narrow antenna beams that can be steered in the azimuth plane. If users are spatially separated, then the same resource array can be reused in each beam for different users, leading to an increase in capacity. Presently, TDD networks are more effective at implementing beamforming than FDD.

Figure 10: Sector Capacity Increase Using Beamforming

(Source: Rosenberger)



Beamforming can be implemented using an 8T8R antenna, with a calibration port also being required to measure and calibrate the phase errors in any of the 8 paths. TDD beamforming can also be deployed in 5G, providing a cost-effective alternative to massive MIMO, and offering low-power consumption at the cell site, as compared to a massive MIMO. This is an important consideration for countries without an adequate power supply system.

Rosenberger has developed several TDD beam-forming antennas and hybrid FDD+TDD antennas consisting of 8T8R TDD antennas with 4 ports of FDD low band. Various FDD port configurations are possible, such as 4 ports for low band and 6 ports for high band. The TDD array in this 18-port antenna may operate in B40 (2,300 MHz), B41 (2,500 MHz), or B42/B43 (3,500 MHz band).

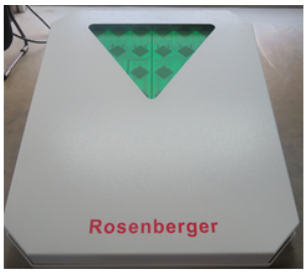
4.4 5G ANTENNA SOLUTIONS

When considering 5G, massive MIMO antennas are part of the toolkit because this technology increases spectral efficiency and cell capacity in the sector. Massive MIMO works on similar principles to TDD beam-forming, but in this case, the antenna arrays are spaced out both horizontally and vertically. This allows the antenna beam to be steered in both planes by the RRU, using very narrow beams. Massive MIMO solutions accomplish 3D beamforming, which can provide high gain and adjustable beams that improve the signal coverage, while also reducing hardware costs because the sub-array needs less power and does not call for expensive high-power amplifiers. As an additional advantage, massive MIMO generates considerably less interference precisely because of the narrow beams and offers multi-path support, which enhances the reliability of the signal and increases the channel capacity.

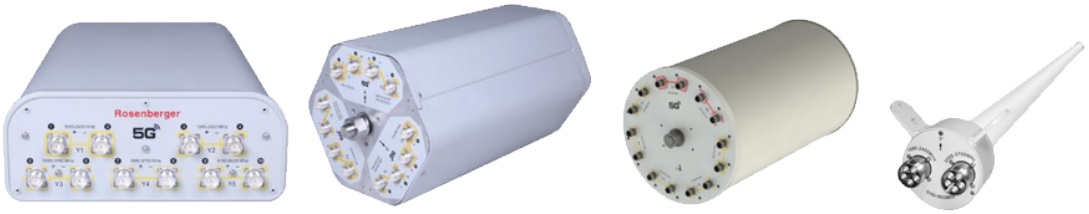
Rosenberger supplies massive MIMO, beam-forming, small cells, and twin-beam antenna solutions for 5G applications, and these are illustrated in Figure 11. Massive MIMO antennas operate in B40 (2,300 MHz), B41 (2,500 MHz) and B42/43 (3,500 MHz).

Figure 11: Variety of 5G Antennas

(Source: Rosenberger)

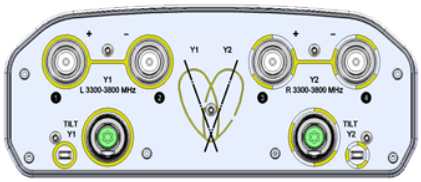


(a) Massive MIMO

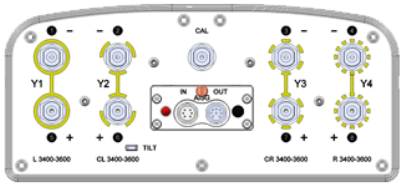


(b) Small Cell Panel, Tri-sector, Quasi-Omni, and Lamp-post

(c) 8T8R 3500 MHz



(d) Twin Beam 2T2R 3500 MHz



(e) 8T8R Beamforming 3500 MHz

Rosenberger has partnered with two key OEM suppliers to develop 5G massive MIMO AASs in more than 10 projects, and it is also the preferred partner for one of the OEM main suppliers of 5G antenna designs.

While massive MIMO increases sector capacity, in some situations, alternative solutions can be more effective, such as when users are not sufficiently separated or are clustered together. In these situations, the use of small cells or sectorization may be more effective for handling traffic at the hotspot. Another drawback of massive MIMO is high-power consumption due to the large amount of digital signal processing occurring in the baseband and basestation. Hence, depending on the mobile environment and deployment scenario, small cell antenna solutions may offer better results than massive MIMO.

For small cells and macro antennas, Rosenberger provides antennas that operate in 4x4 and 2x2 MIMO in the 2 GHz, 3.5 GHz, and 5 GHz bands, supporting License Assisted Access (LAA). These include quasi-omni antennas, single and tri-sector antennas, twin-beam, and 8T8R beam-forming antennas. Advanced MIMO antennas include panel antennas for macro sites that feature a massive MIMO antenna array integrated with traditional sub-2.7 GHz elements, so a single antenna may be used for both technologies.

In summary, Rosenberger has a wide antenna portfolio consisting of more than 100 multi-band antenna models, and more than 50 multi-beam and hybrid antenna models.

4.5 RET SOLUTIONS

RET requirements have increased significantly over the last 2 years. Keeping up with customers' expectations and the need to control the tilt in high-port-count antennas in an economical way, Rosenberger's RET solution now features an integrated field-replaceable RET module that supports Single RET (SRET) and Multiple RET (MRET) systems, using multi-daisy chain functions implemented on two RET motors with a "gearbox" mechanism to allow a single RET motor to provide independent tilts for all bands. The RET also supports two operators' RRU in site sharing applications for simplicity of antenna system configuration. In

some regions, the RETs have Light-Emitting Diode (LED) indicators to reflect their working status, so that engineers can easily monitor the signals from the bottom of the site. Manual override is also available for the engineers to control the antenna tilt on site. Rigorous electrical and mechanical testing of the RET motors prior to integration into the antenna helps ensure high reliability of the RET system in the field.

5. STRATEGIC RECOMMENDATIONS

So that the market can best take advantage of antenna solutions from antenna vendors, ABI Research makes the following strategic recommendations.

5.1 RECOMMENDATIONS FOR TELCOS

Compact Design and Weight Constraints: Mobile telcos need to take into consideration antenna form factor size and weight when evaluating antenna options. Telcos and tower management companies have evolved LTE mounts to support up to 350 Kilograms (kg) and consist of 6 m2 of space. However, it is still common to find cell sites that only support a payload of 200 kg. Mobile telcos in Europe and Asia have informed ABI Research that mobile antennas often must be limited to 1.2 m to 1.5 m.

Environmental Considerations: Macro cell and small cell deployments, both indoor and outdoor, are increasingly requiring a discrete, more environmentally friendly profile. Lampposts are proving to be an ideal form factor to integrate the basestation hardware into the urban landscape, as are slim-line omnidirectional wall-mounted antennas and slim-line rooftop units.

Support for the Latest Connectors: Many incumbent antenna systems use 7/16 connectors, which is a design that goes back to before World War II. It has been a fairly successful design, but issues due to incorrect tightening/coupling can result in water ingress, corrosion, and PIM. Therefore, mobile telcos need to migrate to more robust design solutions, such as the NEX10 and 4.3-10 connectors.

Quality of Service: Modern antennas are highly innovative, but they consist of multiple components. It is essential that the mobile telco fully test the antennas to eradicate or minimize PIM, which is an essential requirement for the mobile carrier. PIM is a constant challenge. Welded joints are becoming the requisite, rather than screws, to assemble antennas to reduce the possibility of PIM.

Massive MIMO: Rapidly becoming an essential part of 4G and 5G RAN infrastructure, telcos must evaluate massive MIMO not only on power, cost, size, and weight, but also based on other factors. These factors include performance in low Signal-to-Interference plus Noise (SINR) scenarios, such as the cell edge, effectiveness in discriminating users in clusters with low angular spread, elevation or Three-Dimensional (3D) beamforming performance, effectiveness in FDD mode, speed limitations for high-mobility end users, 5G readiness, and the ability to integrate digital filtering in the antenna to allow coexistence with incumbent and alternative radio systems in neighboring bands.

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