HOW PASSIVE ANTENNAS AFFECT THROUGHPUT AND ENERGY EFFICIENCY IN 5G NETWORKS

Author: Dimitris Mavrakis, Senior Research Director, ABI Research

Mobile network data traffic is projected to nearly triple by 2030, requiring a shift toward high-performing, programmable networks powered by openness and cloud technologies. This evolution enables service providers to offer performance based services rather than relying solely on data volume. Establishing a strong foundation for network evolution is essential for driving 5G business growth.

Advanced antenna technologies play a critical role in this evolution, delivering improved uplink and downlink performance, increased throughput, and enhanced coverage and signal quality. Several studies have illustrated that different antennas, even in similar configurations, have varying beam efficiencies, resulting in a considerable different network performance and energy efficiency. This parameter impacts Signal to Interference and Noise (SINR) directly and must be a Key Performance Indicator (KPI) to be considered when choosing passive antennas. For example, an Ericsson study[1] illustrates that an 11% beam efficiency improvement translates to an 18% increase in downlink and 21% increase in uplink user throughput at the cell edge.

MARKET OVERVIEW

5G has introduced several key innovations, such as Massive MIMO, network slicing, and beamforming, and the next few years will likely see, further efficiency, performance and power consumption improvements. ABI Research estimates that mobile operators in developed markets will spend more than $1tn in the next 5 years to continuously upgrade and maintain their cellular networks.

There are also many trends that are now changing the way networks are being designed, deployed, optimized and maintained. For example, new device categories are redefining how traffic is generated while AI will place additional burden on the network and several mobile operators are already facing uplink capacity constraints due to video calls and high-definition social media posts. For instance, Ray-Ban smart glasses can record and transmit 1440x1920 video at 30 frames per second, requiring an uplink capacity of 2 to 15 Mbps. Moreover, the higher the frequency, the more constrained uplink coverage becomes, a fact that is reversely proportional to capacity improvements through more bandwidth in higher frequencies. A solution to these uplink constraints is using FDD below 3GHz which are today enabled by passive cellular antennas.

[1] https://www.ericsson.com/en/antenna-system/antenna-efficiency

HOW PASSIVE CELLULAR ANTENNAS AFFECT THE NETWORK

Passive antennas are components of the broader Radio Access Network (RAN) system that must deliver high speed broadband connectivity with as high coverage as possible, while consuming as little energy as possible. They can affect the performance of the 5G network and can affect the user experience, especially when considering the uplink, which typically limits the user experience and communication quality at the cell edge. Moreover, passive antennas can reduce the energy consumption of said networks and can help operators reach their embodied emissions targets. The following sections discuss these aspects in more detail.

UPLINK PERFORMANCE

The uplink link budget limits the communication range and in many cases, defines the user experience. However, link budget typically focuses on antenna gain and transmitted power which represent one dimension of the communication link, and it is more important to consider the overall cell performance and how interference is managed. The uplink performance is also limited by the power a smartphone of User Equipment (UE) device can transmit and depends on the performance of the passive antenna and the Low-Noise-Amplifier of the receiving Radio Unit as well as other parameters, including the noise from neighboring cells. As such, all the components in this chain need to be optimized.

Passive antennas impact uplink performance by defining received signal strength, coverage, and interference management. Several studies indicate that focusing on high gain, narrow beamwidths and antenna positions – including tilt – are not enough to maximize performance. More elements need to be considered, including beam efficiency, Passive Intermodulation (PIM), side lobe suppression, cross polar ratio and many more aspects, all of which have a significant impact on uplink performance. In short, optimizing the overall beam pattern performance is more important than the gain of the antenna.

ENERGY EFFICIENCY

An antenna with a better beam profile, reduced side lobes and higher energy efficiency will translate to lower transmitted power from the radio unit, which will in turn reduce energy consumption. This has already become a key network parameter as mobile operators aim to reduce their carbon footprint while improving their energy operational expenditure. At the same time, a better antenna will improve the link budget, meaning that mobile phones will need to transmit with a lower power, translating to even further energy efficiency and improvement.

It is important to consider the overall antenna energy efficiency rather than gain by itself. For example, high gain can be achieved through a narrower beamwidth but this typically translates to narrower and smaller coverage area, especially near the base station. Moreover, imperfections in the beam profile will amplify with higher gain, causing further problems.

HOLISTIC AND END-TO-END CONSIDERATIONS FOR PASSIVE ANTENNAS

Ericsson is a leading telecom infrastructure vendor whose equipment are highly regarded by mobile operators worldwide. The company also develops and provides passive cellular antennas under its Ericsson Antenna System (EAS) product line, that caters for a variety of traffic scenarios and cell site profiles and range from 2- to 24-ports. The EAS portfolio also supports a wide spectrum, from 600MHz to 6GHz and variety of technologies, including TDD, FDD, multi-beam and beamforming. In addition to its range of passive antennas, EAS offers integrated Active + Passive antenna solutions, such as the Interleaved AIR and Hybrid AIR. The portfolio also includes specialized antennas, like FRMCS antennas, sub-terrain antennas, small-cell antennas, stadium antennas, and indoor antennas, each designed to meet specific deployment needs.

More importantly, Ericsson's position as an end-to-end vendor can provide a glimpse into the real network performance of network components, including antennas. As such, it is important to consider the following arguments and how Ericsson's expertise plays into these.

1) Cellular antennas are highly integrated equipment with complex designs that are affected by a myriad of network parameters, channel conditions, antenna positioning and many more factors. It is thus critical that passive antennas are benchmarked according to live network performance, rather than their specifications and data sheets.

   For example, antennas that illustrate higher gain and better 2-dimensional radiation patterns - on paper - may compromise other parameters that will lead to an overall lower network performance. Furthermore, traffic patterns will also change energy consumption that could be impacted by antenna characteristics.

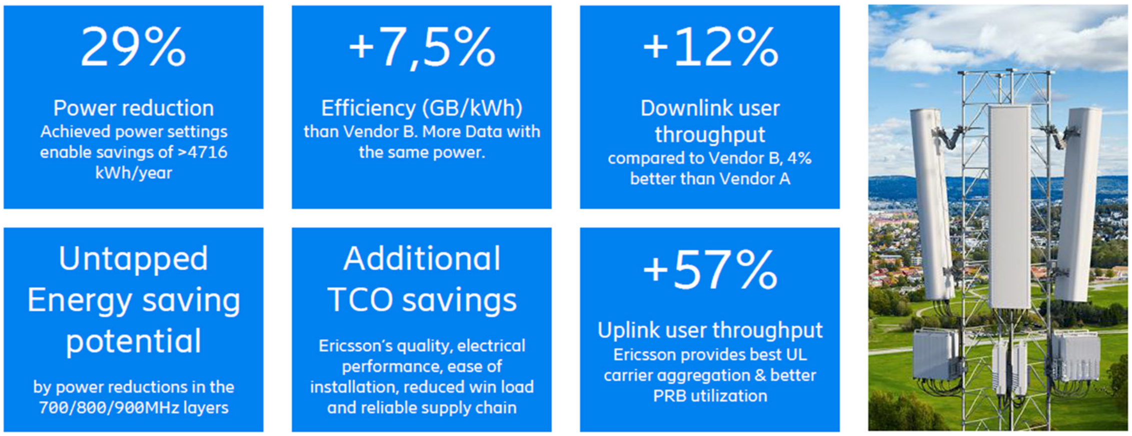
   According to Ericsson experience, 3-dimensional radiation pattern and balanced interplay of multiple RF parameters play a key role in improving radio network performance while reducing energy consumption. For example, in real life network benchmark it has been observed:

   - 7.5% improved efficiency (GB/KWh) combined with 29% reduced radio energy consumption. Improved user throughput (+12% downlink, + 57% uplink)

2) The design of antennas should take holistic network performance into consideration, rather than optimization of individual antenna parameters such as gain and beam width. Optimizing these parameters individually may result in inefficiencies in other network domains and need to be designed to provide the best network performance for the whole radio network. Ericsson estimates that an 11% improvement in beam efficiency can potentially result in up to 21% user throughout gains in the uplink and 18% in downlink for cell-edge users.

3) Lastly, passive antennas need to be considered as part of an integrated, end-to-end network. They cannot be considered in an isolated manner, as their separate deployment requires integration in any case. Ericsson's expertise in end-to-end systems can result in better overall network performance and the vendor claims that it has measured a15% downlink peak throughput improvement enabled by better carrier aggregation (+12%) and higher 256 QAM modulation (+15%) utilization when the system is optimized in an end to end manner.

Ericsson’s expertise in 5G radios, network design and optimization, coupled with passive cellular antenna capabilities, will ensure that radio networks are high performance and low energy consumption, in a sustainable manner. The following figure illustrates a few test results undertaken by Ericsson.



CONCLUSIONS AND RECOMMENDATIONS

Passive antennas remain an indispensable and critical component of 5G networks. Modern passive antennas support multiple frequency bands while maintaining operational simplicity and reliability, without electronic components that require cooling and power. Further advancements in passive antenna technology, including meta-materials, sustainable technologies and active-passive antenna integration, keeps these solutions at the forefront of network innovation.

As networks expand and become more complex, the importance of passive antennas will keep growing. In a world driven by connectivity, passive antennas are the silent yet critical component that ensure networks are efficient, reliable, flexible and future-ready. Ericsson’s end to end portfolio, commitment to open standards and Ericsson Antenna System capabilities make the Swedish vendor a key partner for 5G infrastructure and passive cellular antennas.