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Executive summary

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A special thank you to Lineox and Tusass.

As part of our exploration of what lies ahead for microwave, we investigate whether E-band will continue to fit the bill for future backhaul capacity demands. The introduction of 5G has seen E-band spread to most parts of the world, and we examine simulations that show how E-band spectrum fulfills the capacity needs for most deployments up to 2030 and beyond.

Delivery of mobile services will continue to rely on microwave solutions. With continuing site growth and increasing numbers of transceivers per site, we expect that microwave backhaul will remain of key importance. By 2030, when 6G deployment is expected to start, Ericsson forecasts that 50 percent of macro sites will be connected and backhauled using microwave solutions.

Selecting the right antenna from the large range of new and innovative antenna designs gives an opportunity for increased capacity and hop length. It also enables better use of spectrum in dense networks and lowers operational costs.

For example, sway compensation enables the use of 0.9 m antenna sizes, that provide 80 percent longer hops than regular 0.3 m antennas.

Long haul can be a perfect backhaul solution for providing people in remote locations with easy access to the high-speed mobile communications that are integral to modern life. A prime example of this is Tusass connecting isolated settlements across 2,134 km of the west coast of Greenland.

Operational costs for managing a microwave network can be significantly reduced by applying network automation. The benefits include spending less time on troubleshooting, reducing site visits by 40 percent or more, and improving overall prediction and planning.

As this is the 10th edition of the Microwave Outlook report, we conclude by taking a look at our forecasts in the previous 9 issues with the benefit of 20/20 hindsight.



Backhaul media for 5G and beyond

By 2030, when 6G deployment is expected to start, Ericsson forecasts that 50 percent of macro sites will be connected and backhauled through microwave solutions.

Microwave solutions continue to be a key enabler for building timely, cost-effective mobile coverage and capacity across the globe. Usage varies considerably across different regions, countries and service providers – and even within different parts of a service provider's network.

Advances in technology including higher modulation schemes, broader channel bandwidth and the introduction of new spectrum, such as E-band, are examples of new developments introduced to keep pace with evolution in the RAN domain.

In the mid-1990s, when GSM networks were established and deployed, copper cable for fixed telephony was the main infrastructure used in the access portion of the networks. These were mostly operated by government-owned service providers. Microwave provided an opportunity for new private service providers to

build their networks and compete with the established incumbent wireline organizations. Additionally, microwave became an opportunity for existing service providers to expand beyond the grid of the copper cables. Aggregation networks in developed regions were mostly deployed using fiber, while long-haul microwave solutions were used in developing regions.

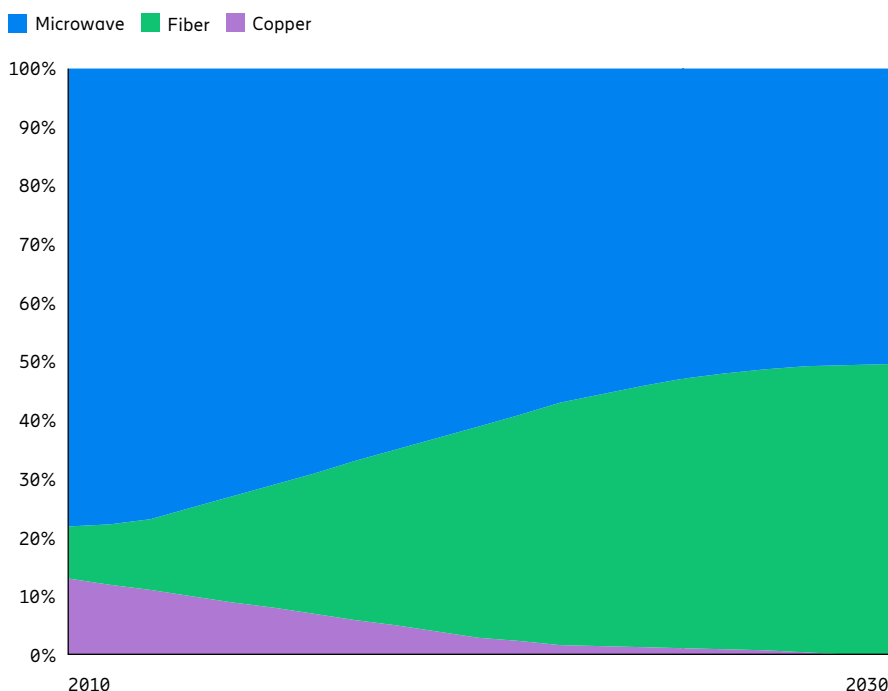
With the evolution of mobile technologies over time – from 2G up to today's 5G deployments, and shifting usage from voice to data – backhaul capacity requirements have shifted from a few Mbps to multiple Gbps – over 1,000 times higher. Over this period, microwave and fiber-based solutions have become the media of choice. Some copper is still used today, but is expected to be taken out of service by 2030. Additionally, in remote rural areas, sites can be connected through satellite

services when no other solutions provide adequate coverage. However, use of satellites for backhaul is not expected to grow dramatically in the coming years as capacity and performance requirements will continue to increase.

Fiber development

Governmental and regulatory considerations are key when it comes to fiber availability, both in terms of the quantity of fiber deployed and who owns the fiber assets. As highlighted in a previous report, in Egypt only government-owned companies are allowed to deploy fiber, which limits usage by privately-owned service providers. Another issue is right-of-way permissions, which can constrain the deployment of fiber across land, and is constraining fiber deployment in many parts of the world, for example in India.

Figure 1: Predicted global backhaul media distribution up until 2030



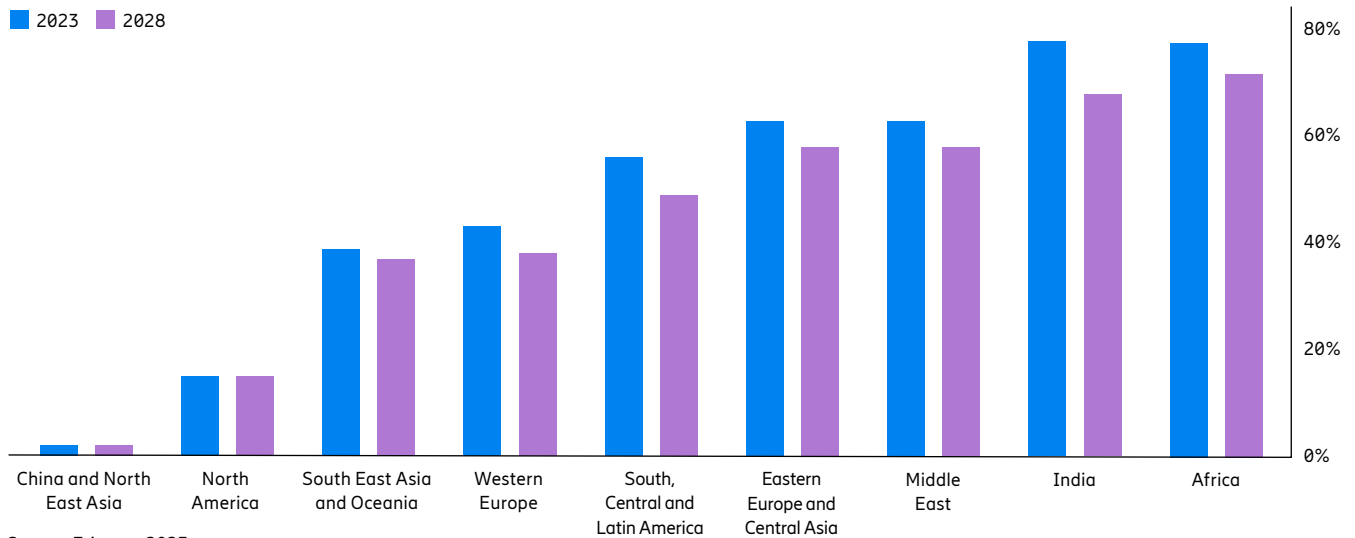
We foresee a 50/50 split between microwave and fiber for mobile backhaul by 2030.*

50%

*Excluding North East Asia

Source: Ericsson 2023

Figure 2: Predicted regional differences in deployment of microwave backhaul 2023 and 2028



Source: Ericsson 2023

Fiber is mainly deployed for fixed and broadband services, or in combination with mobile services, rather than solely for mobile services because of the effect on market forces. A trend observed in Europe, but likely to be present in other global regions, is that fiber assets are acquired when mobile service providers invest in national or regional fixed broadband service providers. Typically, the fiber asset is not the only reason for mergers and acquisitions but is a good additional benefit. Also, in network-sharing scenarios, service providers can share and reuse fiber assets across different operations.

Reaching 50/50

Going forward to 2030, the general trend is expected to be a gradual increase in the share of installed sites connected through fiber, reaching a 50/50 share of the media used. Existing microwave connections, especially those in urban areas closer to the aggregation network, will slowly be replaced with fiber. For new mobile sites, the key factor is the availability of fiber. In 2030 there will still be new sites where fiber is unavailable, in which case a microwave solution will be the main option for connecting to the grid. In rural areas, microwave is most often preferred, as the business case to motivate fiber investments can be challenging.

Regional aspects

When considering the global average of media usage in backhaul, the deployment of mobile sites is key due to significant variations around the world. Initial 5G deployments were centered upon markets where fiber is very present, such as China,

North East Asia and the US. Now there is a shift in 5G deployments to more microwave-centric markets such as Europe, the Middle East, South East Asia, Latin America and India, which is impacting the deployment ratio. With this transition, Ericsson expects the increase in the fiber share of total backhaul links will slow down and even flatten out by the end of the period. This will result in a 50/50 split between microwave and fiber for mobile backhaul by 2030, excluding North East Asia. The new fiber share estimation is slightly higher than in previous forecasts, as in a few regions, such as South East Asia and parts of Europe, the shift to fiber has been slightly faster than anticipated. However, the main reason for the deviation is that site growth in some regions with a high microwave share has been lower than expected. One example is India, where a large operator consolidation has taken place in recent years, resulting in a lower site count – impacting the country's global share. Another example can be seen in parts of the Middle East that have been economically challenged, resulting in investments in the rollout of mobile networks being delayed.

While fiber continues to dominate backhaul deployment in China and large parts of North East Asia, in other parts of the world the different technologies complement each other. In some cases, microwave is the only way to achieve mobile services, and is also being used as a backup solution to increase network reliability when there is a high risk of getting fiber cuts, such as when a cable is severed during roadworks, resulting in loss of service.

India is one of the markets with the highest usage of microwave in the backhaul domain, and the highest deployment rate of 5G systems. With attractive pricing, and with mobile being the primary broadband connection, India is projected to have the highest global average mobile data traffic per smartphone in 2023 and up to and including 2028.¹ As India is a country with one of the largest growth expectations in terms of 5G subscriptions and the highest levels of usage, it is expected to continue to have a high share of microwave backhauled sites. A key component in this is the introduction of E-band spectrum for backhaul, allotted to the mobile operators where they hold 5G spectrum. E-band is crucial for supporting the expected 5G evolution in India, both in standalone deployment, covering shorter distances, and in multi-band combination, combining E-band with 13, 15 and 23 GHz to support longer distances.

Delivery of mobile services will continue to rely on microwave solutions. With continuing site growth and increasing numbers of transceivers per site – driven by multi-carrier and multi-band solutions – we expect the microwave market to continue to be of key importance. The 5G capacity needs of both today and tomorrow can be met by E-band solutions. When required in the future, new frequency bands, such as W and D, are in the pipeline to support the next generations of mobile networks.

¹ Ericsson Mobility Report (June 2023)

E-band fits the bill

With the roll-out of 5G, E-band has become a commonplace mobile backhaul around the world. What is the current situation and what does the future look like?

The E-band world today

The ever-expanding list of countries opening up for E-band deployments shows that another 20 countries have allowed usage of E-band since 2021. Today, the global E-band map covers most of the world's countries and inhabitants. This very much aligns with global 5G RAN preparations and deployment.

The major differences in E-band approvals compared to 2021 have been China ratifying the usage of E-band in late spring of 2023, and India opening up for E-band in 2022. Service providers in India immediately started to use the E-band frequency to backhaul their massive 5G RAN roll-out and this has had a major impact on the number of E-band radios deployed globally.

A look into the future

We know that E-band can deliver high backhaul capacities in 5G networks thanks to its large amount of spectrum, which provides wide channels. We also know that some countries are early adopters of E-band, while other countries have only recently opened up their spectrum for deployment. But will E-band be able to provide the backhaul capacities required to meet future traffic demands as 5G networks evolve and become increasingly capable and densified? How soon will new technologies such as W- and D-band be needed to complement E-band? These are all questions into which we can provide some interesting insights by examining results from a recent simulation of urban E-band networks in three real European cities.

These cities have different sizes and network topologies, and the total number of links in each city ranges from 300 to 1,000. In each network, it is assumed that 10 x 500 MHz channels are available, effectively a total of 5 GHz of spectrum in each direction of a backhaul link. Network channel planning is conducted by allocating as many as possible of the available 500 MHz channels to each link, while a maximum interference over noise (I/N) requirement of -6 dB is fulfilled. In other words, the planning aims to maximize the total bandwidth of each link in the network while fulfilling the I/N requirement.

Figure 3: Global E-band deployment status

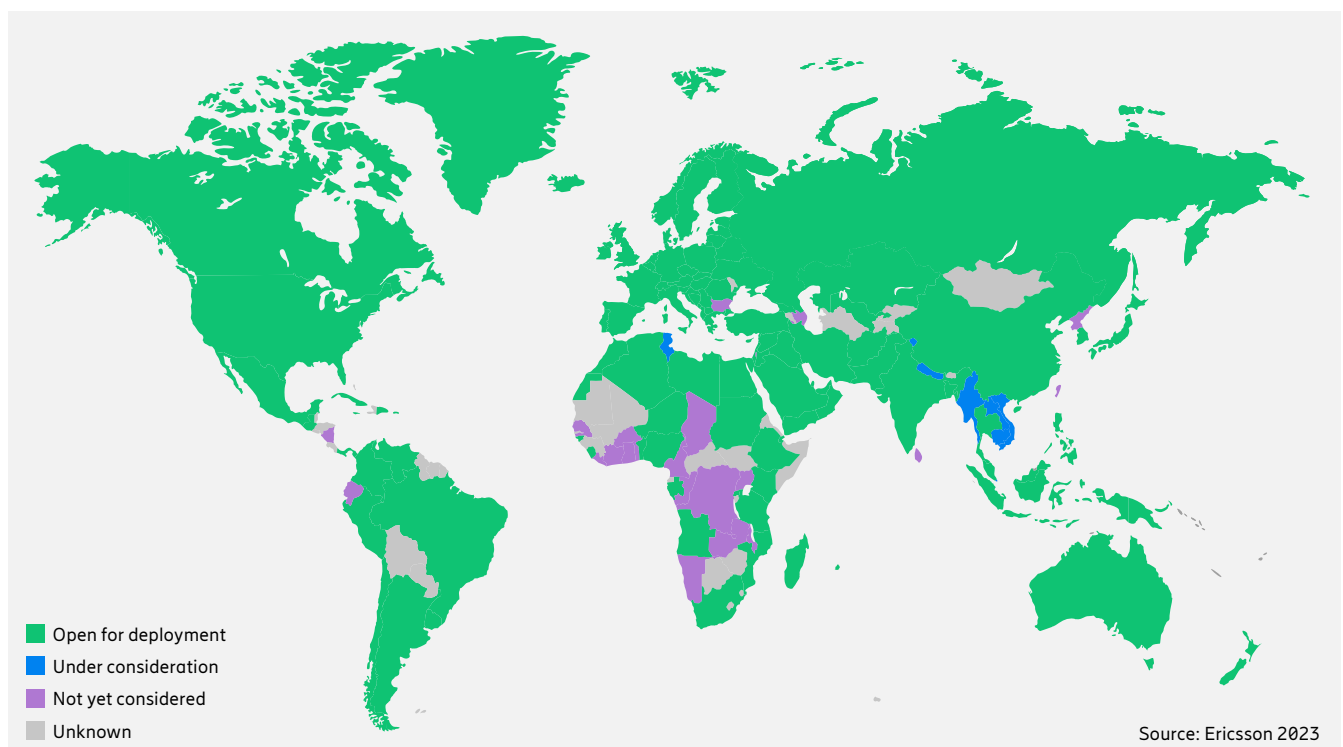


Figure 4: Potential E-band capacity averaged over three different European cities

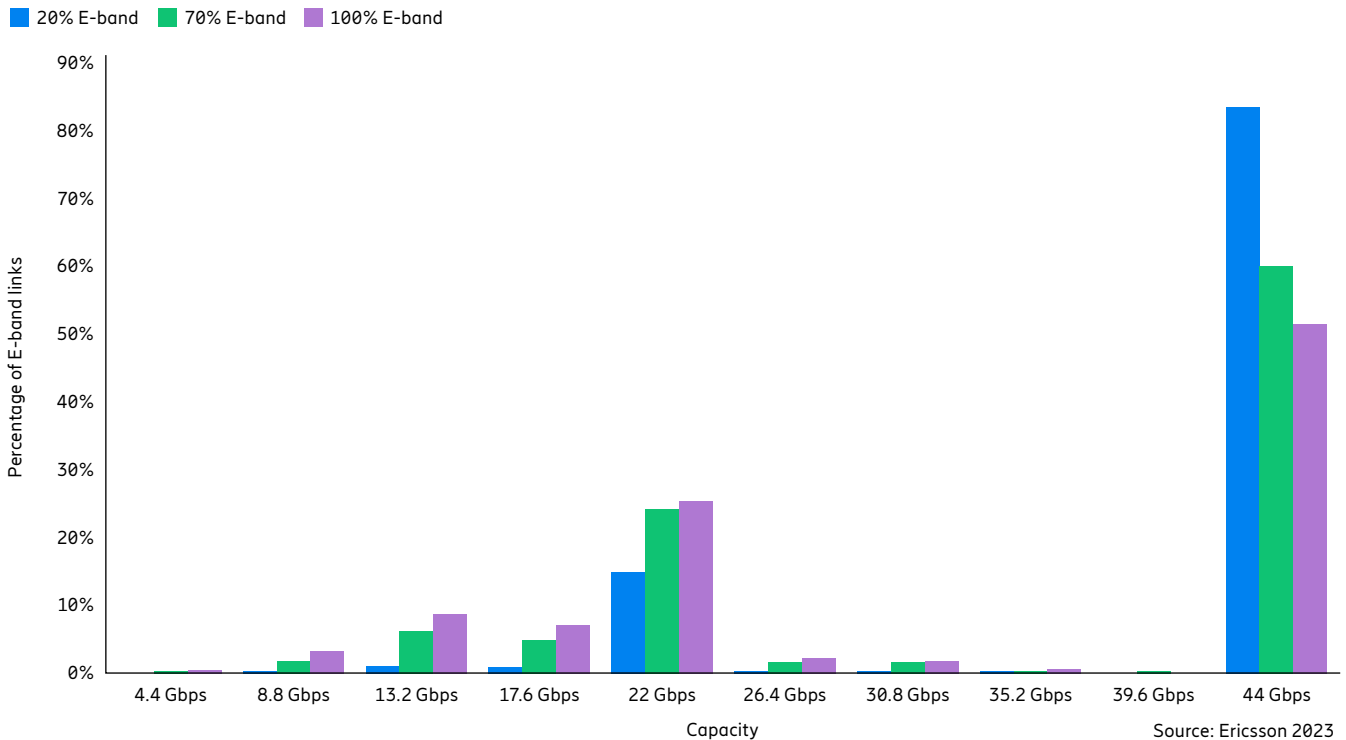


Figure 5: Crowded hub site if 100 percent E-band



Source: Ericsson 2023

The Y-axis in Figure 4 shows the percentage of E-band links (averaged statistically over all networks) that can achieve the capacity given by the X-axis with at least 99.9 percent availability (assuming 64 QAM and XPIC). Three different E-band penetration percentages are assumed, with the blue color corresponding to the 20 percent (sparse E-band) of all links in the network using E-band while the remaining 80 percent is using alternative microwave frequencies or fiber. Green and purple respectively correspond to 70 percent (dense E-band) and 100 percent (extreme E-band).

The different percentages thus represent different choices and strategies when deploying backhaul networks where some networks may aggressively use a lot of E-band while others are more selective. It is interesting to note that more than 80 percent of all the E-band links can achieve 44 Gbps (corresponding to using all 10 of the 500 MHz channels) for a sparse network that has 20 percent of its links using E-band. An extreme network that uses E-band for all links can achieve 44 Gbps for more than 50 percent of its links. We also note that there are very few links that only achieve the lowest capacity of 4.4 Gbps (which corresponds to a single 500 MHz channel), and these are identified as links in extremely dense deployments, for example, dense hub sites that strictly limit the number of channels that can be used due to the I/N requirement. Figure 5 shows examples of crowded hub sites from one of the real networks used within the simulations, where links can only use a limited number of channels without causing too much interference to each other. It is in these crowded hub sites with many dense links that more advanced solutions are required to achieve higher capacities. For example, super high-performance ETSI Class 4 antennas (only 0.3 m and 0.6 m ETSI Class 3 antennas are used in the simulation),

and future W- and D-band spectrum and related technologies will be needed to reach higher capacities in very dense hubs. It is difficult to predict capacity requirements far into the future with accuracy. However, predicted backhaul capacity figures for the most advanced urban distributed RAN sites by 2027² are around 25 Gbps – but these extreme capacities would only be needed by a few advanced sites. Therefore, it can be seen as an indication that E-band with 44 Gbps will be more than sufficient for 5G and 5G Advanced backhaul in most deployments by 2030 and beyond.

In conclusion, our simulation of backhaul networks from three real European cities with different densities of E-band links shows that E-band can provide sufficient backhaul capacity for many years to come. This is, of course, based on the proviso that sufficient E-band spectrum is made available by national spectrum regulators. Some extreme deployments, like dense hubs, can experience congestion, and will therefore be the first to need alternative backhaul solutions as the demand for capacity grows.

What will happen beyond 2030 and after the introduction of 6G is difficult to predict with accuracy. But we can certainly conclude that E-band will provide an effective backhaul solution for most 5G and 5G Advanced deployments toward 2030 and beyond.

² Ericsson Microwave Outlook Report 2022

Opportunities with antenna innovations

Gone are the days when the choice of antenna was limited to what frequency band and which reflector size to use. Driven by advancements in microwave technology, the antenna toolbox has expanded to provide diverse options and possibilities.

Innovations and new requirements are expanding the antenna palette, fueled by increased capacity demand, spectrum scarcity, and denser networks. Selecting the right antenna from the wide range available can yield significant increases in both capacity and spectrum efficiency.

Dual-polarized antennas

Dual-polarized antennas have been around for decades, but with increasing capacity demands and the introduction of Cross Polarization Interference Cancellation (XPIC). Dual-polarized antenna volumes have surged to around 70 percent (see Figure 6). These antennas make it possible to double capacity over a single antenna by combining both polarizations in the same hardware. Most new installations either use XPIC from the start or are at least hardware-prepared for it.

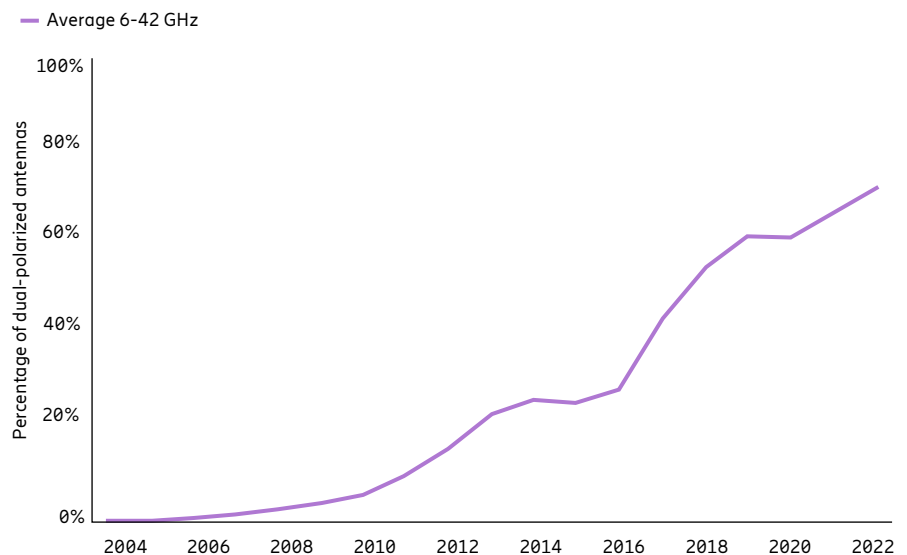
A further doubling of capacity can be achieved by using radios with built-in carrier aggregation, or symmetric power splitters, to combine two radios on one antenna polarization. In combination with dual polarization, four times the capacity can be gained in a 4+0 hop over one antenna.

Class 4 antennas

ETSI Class 4 antennas have been around for about 10 years, but usage is still low in most markets. There is significant untapped potential here for densifying microwave networks and reducing spectrum costs. A class 4 antenna's sidelobes are 10–15 dB lower than class 3, which increases the ability to reuse frequencies in the network.

When using the same number of frequency channels, it is possible to have 40 percent additional links in the same geographical area – and when combined with automatic transmit power control (ATPC), network capacity can even be doubled.

Figure 6: New deployment of dual-polarized antennas



Source: Ericsson 2023

E-band and sway compensation

The introduction of E-band frequencies enables multi-gigabit capacities with compact antennas, of which the most common antennas today are 0.3 m and 0.6 m reflectors. E-band can also be combined with a traditional frequency band in the same multi-band antenna. This reduces weight and space occupied in the mast and combines the best of both worlds in one link: High E-band capacity, with high availability over long distances. Since the emergence of combined E-bands and traditional bands, their numbers have steadily grown and interest in combining two or more traditional bands is increasing.

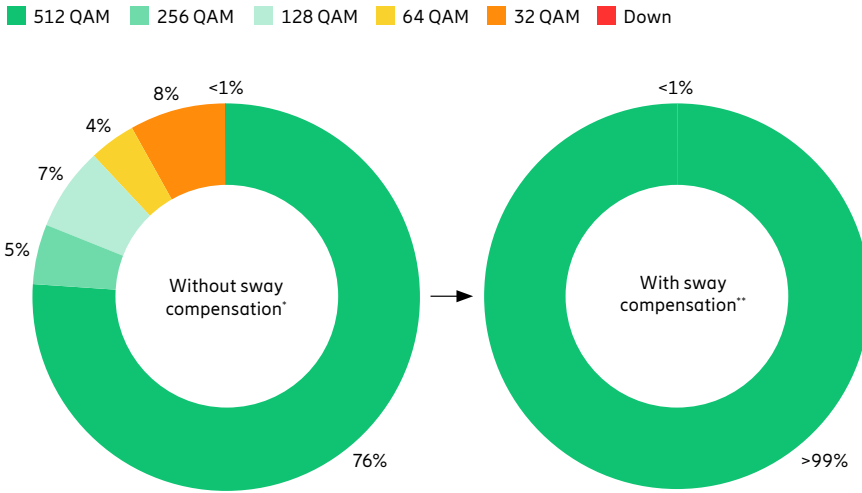
E-band also drives innovation in the antenna domain. Compact high-gain E-band antennas focus the signal into a narrow beam, but with greater focus comes a higher risk of misalignment that puts tougher requirements on the stability of the mounting structure.

Sway profiles can be divided into two groups: a fast variant, which is typically induced by winds, and a slow variant, which finds its origin in non-uniform thermal deformation, also called the sunflower effect. In many cases, the sway is so small that it does not affect the link, but there are masts where this can be an issue.

Mast sway can be neutralized by a sway compensation antenna. This is similar to a conventional reflector antenna with the ability to detect misalignment and adapt the beam direction to keep the highest possible gain pointing towards the far end.

This innovative antenna is a solution to known problems and creates new possibilities. In Figure 7, we can see the benefits of link stabilization. The pie diagrams show the modulation that a 6.7 km E-band link in southern Europe can sustain.

Figure 7: Sway compensation antenna field trial on 28 m monopole



Source: Ericsson 2023

* 3-day period with solar-induced bending

** 1 month with solar-induced bending, rain, wind, multipath

A sway compensation field trial was performed with a 6.7 km E-band hop in southern Europe, near the coast. A link with traffic, with a sway compensation antenna at 28 m height, was monitored.

A 0.6 m sway compensation antenna enables 30 percent longer hops than a 0.3 m regular antenna.

30%

A 0.9 m sway compensation antenna enables 80 percent longer hops than a 0.3 m regular antenna.

80%

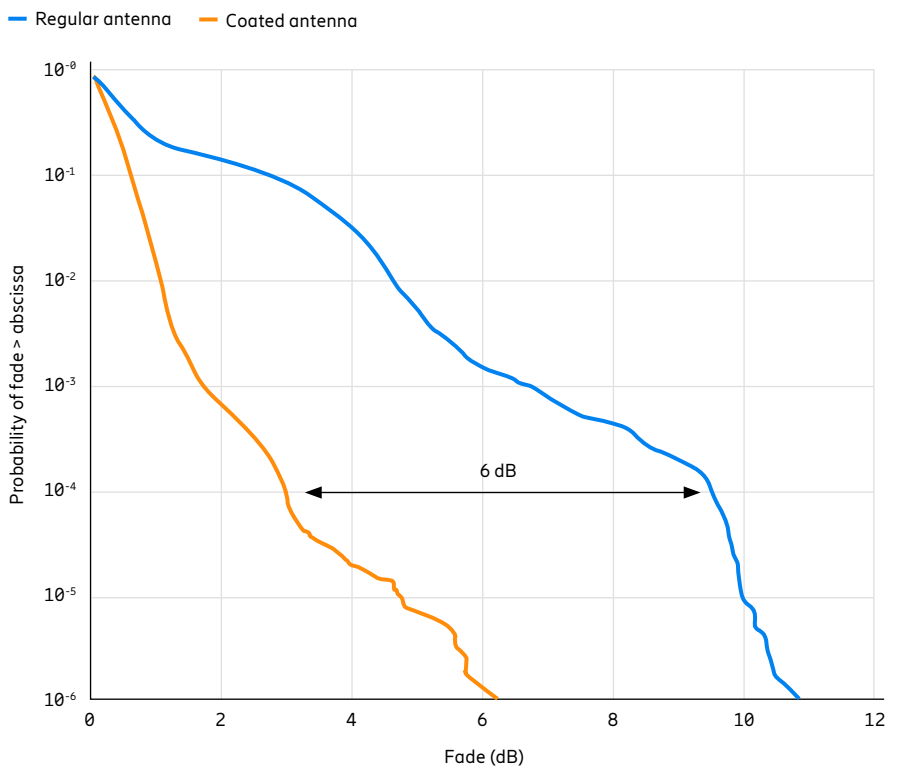
Configuration: 10 Gbps E-band link, 64 QAM, 2 GHz CS, 99.9 percent availability, typical European rain zone.

The link is equipped with a 0.6 m reflector (half-power bandwidth at around 0.5 degrees) mounted at the top of a monopole. When sway compensation is off, the variation of received power throughout the day is too large to keep the highest modulation for about one-quarter of the time. The effect of turning on sway compensation is visible in the diagram on the right, where the adverse effect of sway has disappeared.

In addition to widening deployment options, sway compensation enables even higher antenna gains by extending range or boosting link availability. Let's look at some concrete examples for 10 Gbps E-band links and assume the available infrastructure suffers from sway, and only 0.3 m reflectors, or smaller, can be used. The maximal distance of this link with 99.9 percent availability is 3.8 km. By eliminating sway, a 0.6 m antenna can be used without problem and the maximal link distance becomes 4.9 km, an increase of about 30 percent.

The stabilization algorithms enable use of even larger antennas: A 0.9 m antenna gives a maximal distance of 7 km, which is an 80 percent increase compared to distance achieved by a 0.3 m antenna without sway compensation.

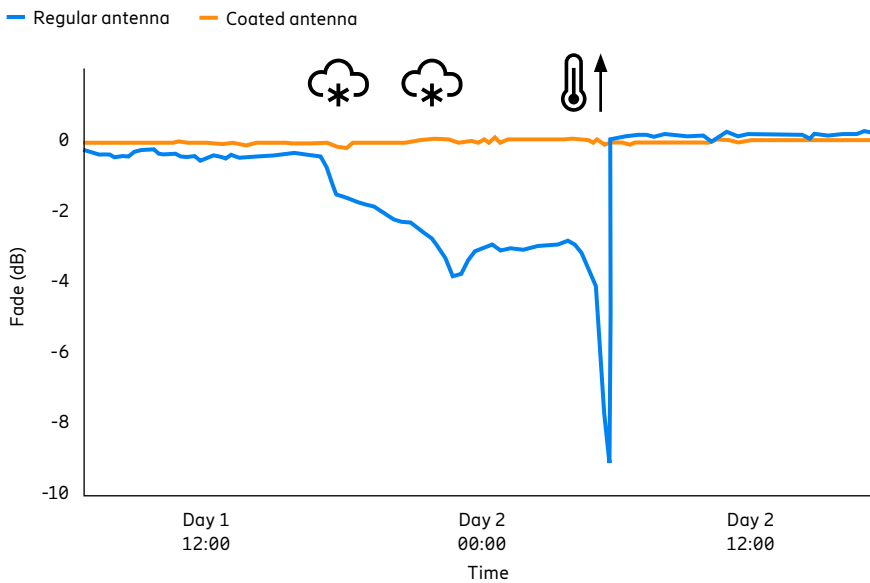
Figure 8: Comparing fading on E-band links with water-repellent coated and non-coated antennas



Source: Ericsson 2023

Statistics collected from December 2021 to June 2022 on a 200 m E-band hop with 2 parallel links, 1 with and 1 without water-repellent radome coating. The water-repellent coating gives up to 6 dB less fading at 10⁻⁴ level.

Figure 9: Snow fading event – field trial with water-repellent radome coating on E-band links



Source: Ericsson 2023

A snow fading event: The uncoated link is attenuated by 4 dB while the snow is dry, and >9 dB when the snow is wet. The coated link stays unaffected.

Water-repellent radome

Sway is not the only environmental influence on performance. The most common culprit is water. In raindrop form, it is a well-known source of attenuation. There is also the wet-radome effect. This moisture can be water drops, ice, or (melting) snow. Especially during heavy precipitation, the film formed on the radome can eat away dBs in the link budget. This effect is most

pronounced at E-band, but also noticeable at lower frequencies. This attenuation can be compensated with higher output power or larger antennas, or accepted by planning for shorter links or lower availability.

Fortunately, water on the radome can be reduced by water-repellent coatings for microwave antennas, which add protection that does not affect radio wave propagation, and can significantly reduce water build-up on antennas.

The performance benefits can be evaluated by examining two parallel E-band links. Both are equipped with identical reflector antennas, but the radomes of one are treated with a water-repellent material. The short distance, less than 200 m, is well-suited for this analysis since the rain attenuation in the air is negligible and the fading is due to the wet radome alone.

The hydrophobic coating removes water quickly and there is no (or much less) water film build-up. This results in fades of shorter duration that are less pronounced.

Figure 8 shows the fading statistics over a multi-month period. The benefit is clear: The probability of all fades, large and small, is reduced significantly.

For microwave link planners, the times of year when the weather is at its worst are the most relevant for predicting availability. At the tail of the curve, we can see that this is where the coating really makes a difference. If we consider the 0.01 percent worst fades (corresponding to the 99.99 percent percentile), we can see the link with water-repellent coating has fades that are 6 dB less than those of the link without special coating.

Snow affects microwave links differently to water, as can be seen in Figure 9. When it is dry, the impact is limited, but wet snow introduces much higher losses, and as it melts the link experiences increasing degradation until suddenly it slides off the antenna and the received power is restored to its nominal level.

In a worst-case scenario, the temperature drops again before the thawed snow slides off, and the wet snow refreezes solid on the antenna. This can cause sustained periods of lower received power and if the blockage is severe it has to be cleared manually from the antenna.

Water-repellent radome coatings prevent this by protecting against water or snow clinging to the antenna's radome and building up a film (shown in the second image in Figure 10). The potential resulting opex savings is evident from a trial in the Nordics where the amount of (cumbersome and costly) site visits to an antenna susceptible to snow and ice blockages dropped to one-third compared to the previous year.

Antennas are now, more than ever, playing a key role in getting the most out of microwave links. The diverse set of antenna options and innovations discussed in this article testify to the positive impacts that conscious choices of antennas can have on capacity, hop length, spectral efficiency, network densification and reduction of opex.

Figure 10: Snow sliding off the coated radome



Regular antenna



Antenna with water-repellent coated radome

Source: Ericsson 2023

In this figure we see two parallel E-band links, one with a regular antenna and one with an antenna coated with water-repellent material. Wet snow sticks to the uncoated radome, while it slides off the coated one.

Reducing opex with AI

AI-based network automation can reduce operational expenses in many different areas of microwave networks. An interesting example is the Spanish service provider Lineox, which has reduced site visits by 40 percent by using automatic scripts.

With the rapid evolution of artificial intelligence (AI), network automation in combination with AI can, with a relatively small outlay, decrease the operational expenses (opex) of a microwave network. Resource-intensive areas such as power consumption, troubleshooting, site visits, and even spectrum costs can all be reduced. Examples of this can be seen in the use cases shown in Figure 11. Power consumption may be reduced with the help of automatic radio deep sleep scheduling. Network problems such as tower sway, antenna misalignment and signal propagation degradation can be identified and quickly addressed thanks to precise root cause analysis. In addition, preventive maintenance such as hardware degradation alerts, high-temperature early warnings and network traffic growth forecasts can mitigate costly firefighting events. Another benefit is improved network availability as a result of fewer outages, leading to increased and maintained revenues.

Access to relevant network data is the foundation of any automated solution. Network topology data is essential for automatic upgrades of network software, while frequent measurements of signal quality are needed for the classification of signal propagation events. Access to historical data is also important, as it provides insights that can help to identify areas for improvement, enable informed decisions, and create trend predictions. Although a modern microwave network may consist of more than 20,000 microwave links and data being collected every few seconds, the amount of data processing, storage, and transport capacity needed are still negligible compared to the media streaming and cloud services used in daily life.

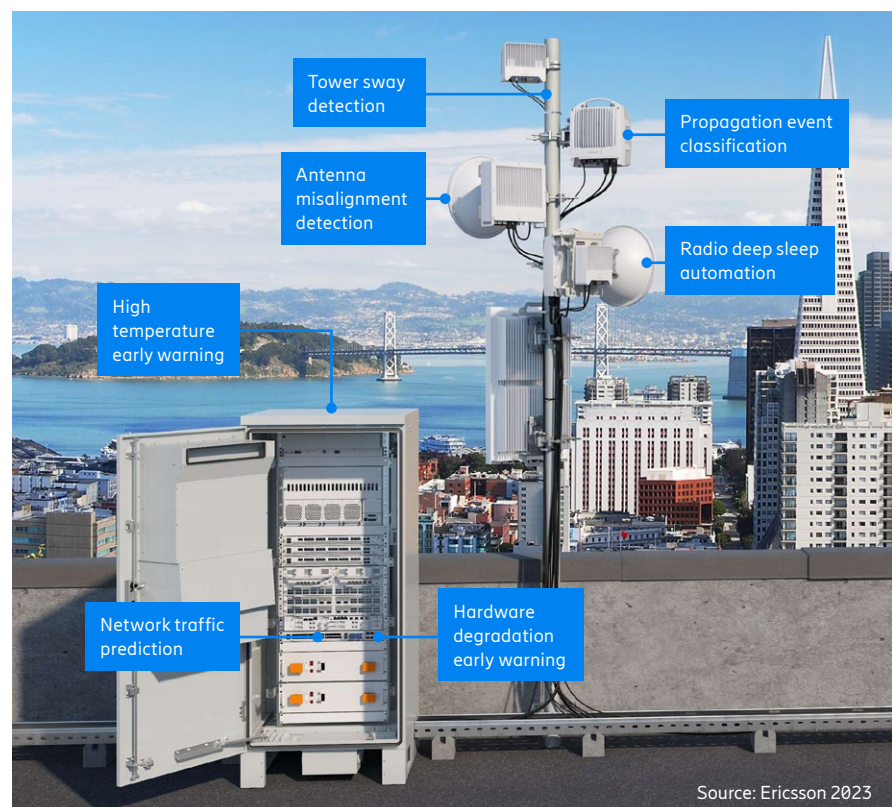
The reliability and accuracy of predictions and event classifications depends on both access to relevant network data, and also on the amount of data and the algorithms applied. With AI-based training and

close cooperation between equipment manufacturers and operators, it has been shown it is possible to reach over 99 percent accuracy.

Lineox is a neutral broadband operator in Spain with 100 percent radio link technology. To ensure connectivity throughout its entire territory, Lineox owns a network of more than 10,000 radio links, used mainly to transport telecom traffic. In recent years, Lineox has focused on improving network operation efficiency. Substantial operation costs are related to numerous closed work orders and site visits, where highly trained personnel could travel for hours to visit and inspect remote sites using specialized equipment.

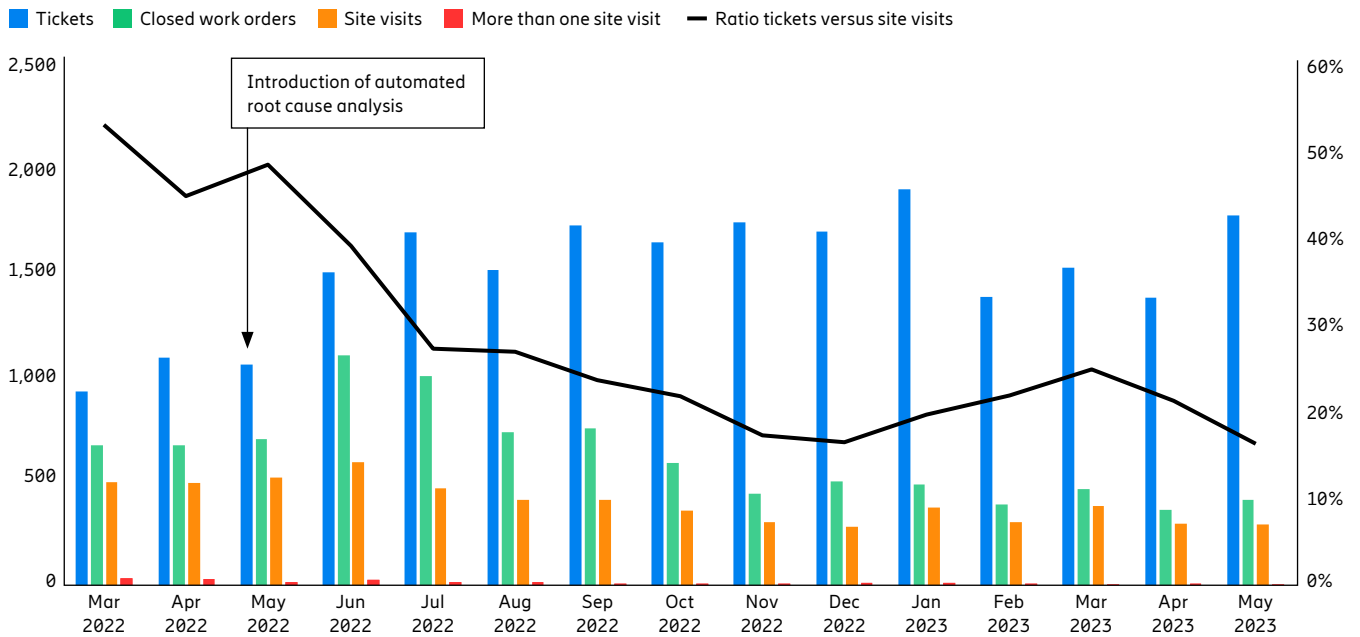
Figure 12 shows the number of site visits per month due to microwave-related tickets over a period of 15 months. Before May 2022, 50 percent of all tickets raised resulted in a site visit. Site visits dropped by 40 percent after June 2022, when Lineox introduced automated alarm filtering on top of their network manager. Although the total number of tickets increased, as the tool was able to detect network issues that had previously been missed or neglected, the number of actual work orders issued was reduced as the tool helped the service provider to prioritize whether a work order needed to be opened or if the network impact was negligible so that no action was needed.

Figure 11: Benefits of applying AI in microwave links



Source: Ericsson 2023

Figure 12: Microwave analytics improve operations



Source: Lineox 2023

Automated root cause analysis applied in Lineox microwave network

When investigating the reasons for site visits, it was concluded that common reasons were software problems, no-fault-found, misalignment of antennas due to strong winds and hardware failures. While the number of site visits to fix hardware failures and antenna misalignments remained the same, software-related and no-fault-found site visits declined significantly as a result of the implementation of automated root cause analysis. The cost savings from the reduced amount of site visits alone were enough to justify the investments in the automated root cause analysis tool.

It is worth noting that the automated root cause analysis tool used by Lineox was based on alarm filtering and performance management data, collected every 15 minutes. With more frequent data collection (for example, every 10 seconds) and by applying AI, it is possible to assess performance management data with greater precision to provide more in-depth root cause analysis. As a result, it will be possible to detect even smaller misalignments and schedule realignments before there is an outage. Thus, AI will enable service providers to create an effective preventive maintenance program to avoid expensive emergency site visits. Moreover, it will also make it possible for service providers to add new use cases such as propagation event classification, hardware degradation, radio deep sleep optimization, and network traffic prediction.

In the 2018 Microwave Outlook report, we discussed for the first time how AI can be used to automatically recognize propagation events impacting received signal quality. Figure 13 shows different propagation events that could cause signal degradation in a real microwave network including rain, temporary line-of-sight blockage and multipath and antenna movements due to wind or solar bending of a telecom tower (thermal sunflower effects). The final solar bending figure shows real measured data from a site in the Middle East in March 2022 and how the signal could have daily strength variations of more than 35 dB. The red (maximum) and blue (minimum) lines illustrate the signal strength measured over a 15-minute interval.

Automation reduces site visits by 40 percent, and AI will reduce it even further.

40%

Events impacting received signal quality are often time-consuming to detect manually and troubleshoot, and may result in unnecessary site visits if not properly identified. Being able to automatically identify and define propagation events is a strong value add.



Source: Ericsson 2023

Pre-emptive maintenance

In addition to the pre-emptive maintenance cases mentioned in the introduction of this article (early warnings of hardware degradation and high temperatures, and network traffic forecasting) there are several other more specialized pre-emptive maintenance use cases. One example is highlighted in the “Opportunities with antenna innovations” article in this Microwave Outlook report, which examines the benefits of using a water-repellent coating to reduce snow and ice on antennas. The coating effect slowly degrades over the years in UV-intense climate zones and AI can be used to monitor when it needs to be refreshed. This will help in planning site visits well in advance, preferably when a site must be maintained for other reasons, or if the customer is planning a service visit to a nearby site.

Another example is the degradation of radio cables. Water in a cable, or bending of a cable, will impact the signal quality of the receiver as well as internal signal levels and can be detected at an early stage with the help of AI. This avoids unnecessary troubleshooting at the site and eliminates the risk of swapping fully functional radio units (“no fault found”).

Traffic prediction

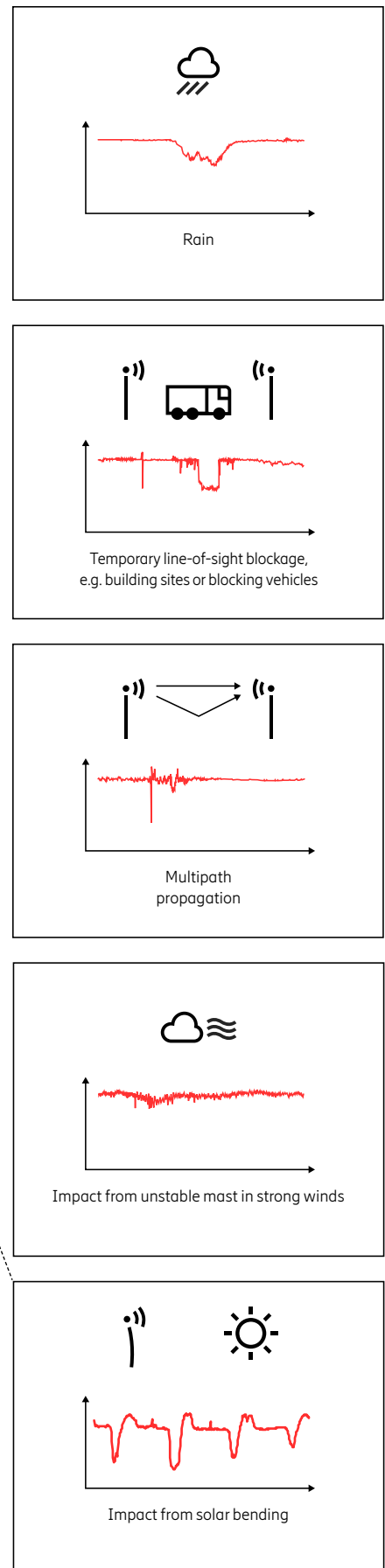
Today, the monitoring of network traffic is often goal-based (using key performance indicators) and focused on the current status, but AI can take this a step further and predict what will happen next by looking at network trends and simulating future network upgrades. For example, the pace of network traffic growth per link can be analyzed to make a projection that helps service providers plan network investments well ahead of time.

Energy consumption – radio deep sleep automation

An AI-enabled network orchestrator, such as a software-defined network (SDN) controller, is a useful tool for closed-loop optimization of a network. Radio deep sleep automation is one example of closed-loop optimization, used to reduce energy consumption and meet network targets on carbon footprint. By leveraging network traffic prediction, one or more carriers in a multi-carrier link are turned off during hours of low traffic load and AI is used to set and manage the windows for sleep hours. The sleep hours may vary depending on whether a site is rural or urban, as well as on the day of the week. Continuous machine learning is ongoing to set the windows correctly, and any solution must be ready to handle a sudden change in the traffic pattern due to local events, for example, a music festival. It is impossible for a human to manually set the correct windows for thousands of links on a daily basis, but an AI-enabled SDN controller can do this very effectively and the savings could be as high as over 20 percent of power consumption.³

To summarize, the data and findings from the Spanish operator Lineox show that introducing automated root cause analysis resulted in less time spent on troubleshooting and a reduction of site visits by 40 percent or more. Taking this a step further by applying AI, the operational costs of managing a microwave network can be significantly reduced – leading to better predictions of site visits, optimized microwave network performance, higher energy efficiency and superior end-user experience.

Figure 13: Using AI algorithms to identify events



Source: Ericsson 2023

³ Ericsson Microwave Outlook Report 2022

When long haul makes a difference

Mobile communications have made easy access to news, social media, high-speed mobile communications, online shopping and banking an integral part of modern life that most of us take for granted.

In addition, modern healthcare requires broadband communication services for a range of medical services, such as X-ray analysis from experts.

But the benefits of the array of services enabled by connectivity are not available to all, as geographical constraints continue to be a major barrier to inclusion via a modern 5G network.

Establishing 5G services requires access sites, electrical power and some means of signal transport to the core network. This transport often uses optical fibers, but this network option may not be feasible in remote locations such as distant islands or in the rural outback. In these situations, the alternatives are satellite communication or long haul microwave, with the latter often enabling higher capacity and lower total cost of ownership. Mobile communications connectivity is a challenge that occurs all over the globe from Greenland and Alaska in the north and through to Africa and Australia in the south.

In large parts of the world, there are connectivity challenges, where there are long distances between towns and out

to islands. Long haul has emerged as the perfect high-capacity solution for enabling wideband services, and in doing so is bringing communities access to modern communications. Common issues in these areas include:

- Existing SDH transport over traditional long haul is already fully utilized.
- Replacement with optical cables is costly and takes time.

Modernizing the microwave to a packet-based transport service unleashes more capacity, allows for adding additional spectrum into the multi-band link, and provides end users with increased digital connectivity.

The positive impacts on business, education and health services from having access to HD services such as video calls cannot be underestimated. Even small things such as being able to pay with a credit card at the market in an African village can make a large difference to people.

Let us look at the 6 GHz band as an example, since it is widely used for long-distance communication in

remote areas. Traditional long haul has been using SDH/SONET as the layer 1 technology and even if the full 6 GHz spectrum has been available for use, the capacity has still been heavily restricted by limitations imposed by the underlying technology. A maximum of 4 Gbps could be achieved when using the spectrum of 6L and 6U with SDH/SONET radio technology at the expense of 32 radio channels. With modern microwave technology and packet-based systems, it is possible to better utilize the spectrum with wider channels and adaptive modulation. This makes it possible to enable up to 10 Gbps with only 16 radio channels and still have the same availability. Space diversity protection is in most cases being used to further secure the availability of the link. This means that at each site, there are two wide-band dual-polarized antennas covering the 6L and 6U bands. A transport solution like this will also enable local deployment of 5G access sites in remote towns and islands and thus include people in the modern digital lifestyle of the city.



Salesperson in Africa benefiting from mobile services in everyday life

Greenland

An interesting example can be found in Greenland. The west coast of Greenland has a long series of settlements over the extreme distance of 2,134 km, and these settlements also need access to modern digital services. Since 1977, the local service provider, Tusass, has been using a microwave network to serve the needs of these settlements. It started with telephony and evolved with SDH services in 1996, and then later into IP and internet. Now, Tusass is upgrading and expanding the network to cater for the even higher capacities of 5G. The expansion is using 6L and 6U spectrum, but increasingly, links are also being added in higher bands to meet capacity requirements.

In Greenland, challenges include remote sites that are difficult to electrify, many of which have been using diesel generators and are now starting to use solar panels and windmills. Therefore, power consumption is a vital parameter in order to reduce the need to send out helicopters with fuel as well as being able to cope with locally generated power. The total chain of sites in Greenland stretches over 2,134 km, from Kullorsuaq in the north to Ikerasassuaq in the south with multiple sites in between. Many of these sites can only be visited during the summer months, so redundant functionality is vital. With helicopters needed to access many of the sites, it is essential that equipment is easy to transport and install to keep time on-site as low as possible.

The enablers

The combination of using wide channels, multiple frequency bands, adaptive modulation and radio-link bonding of all the available capacity creates the possibility of achieving high capacities with high availability, where SDH links could provide up to 50 percent of the capacity with the same number of channels. But using wide channels also reduces the hardware required, as fewer radios are needed.

This is visualized in Figure 15 where SDH and modern technology are compared in terms of what can be achieved. Using the full 6L and 6U band with traditional SDH/SONET links would have required the use of the lowest static modulation possible, for example, in 56 MHz (16 QAM) or 40 MHz (64 QAM) channels. This would also be used in combination with 7+1 protection to

Figure 14: West coast of Greenland with 5G-ready backhaul transport

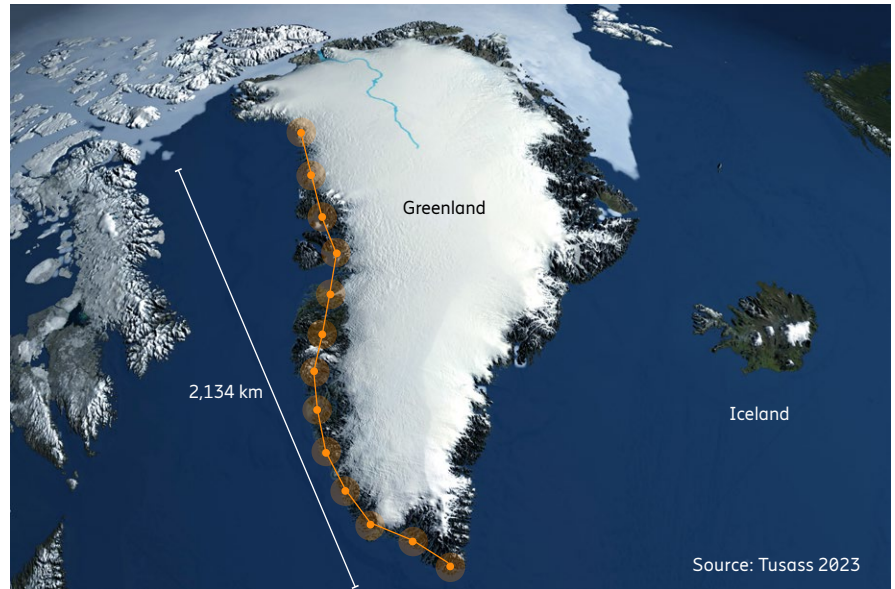


Figure 15: Comparing SDH and packet-based link capabilities



reach 5 9's availability, using 24 separate channels with 150 Mbps in each or a maximum of 3.1–3.6 Gbps. The same amount of equipment operating in wide channels can now enable up to 10 Gbps of services in the same spectrum.

In summary, modern long haul provides a resilient, high-capacity transport solution that can handle demanding conditions in remote areas where an optical network may be too expensive to deploy.

A glance in the rearview mirror

Normally we focus on the future, but in this milestone 10th edition we are also briefly glancing back to review our predictions in the spectrum domain and see how accurate they have been.

A recurring topic in Microwave Outlook has been spectrum usage and trends, as spectrum is the foundation for all wireless communication.

As previously mentioned, change in spectrum usage is normally a very slow process, especially for new bands. The reason is that new spectrum needs to undergo multiple stages before reaching maturity: standardization, chipset development and product iterations. And market demand is needed.

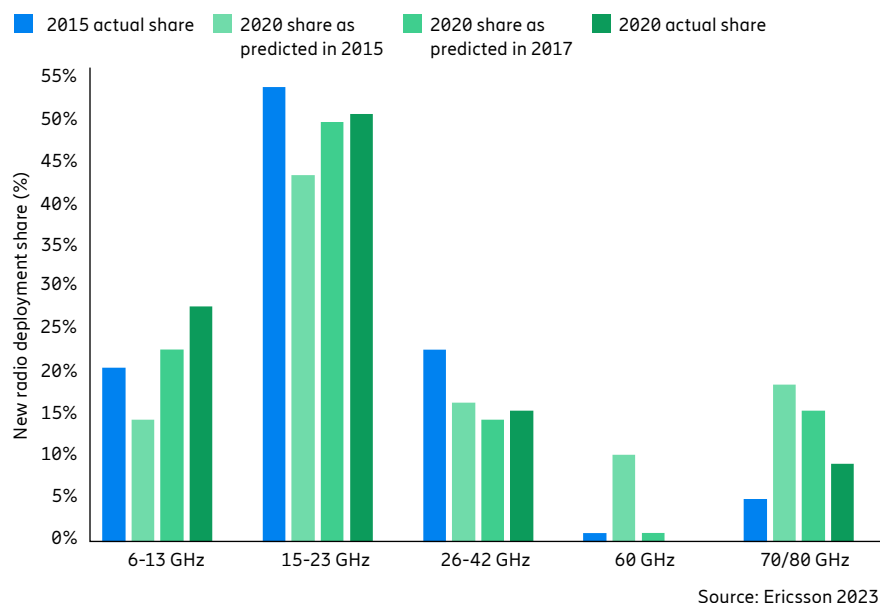
In Figure 16 we present the new radio deployment share in five high-level frequency ranges, from 6 to 80 GHz. The first column shows the actual share in 2015, then predictions for 2020 made in 2015 and 2017 are shown, and finally the actual share in 2020.

From 2015 to 2020, a major topic was how fast V- and E-band would ramp up and how large a share they would grab from the traditional bands (6–42 GHz). V-band volume predictions were driven by future small cell deployments, requiring short-range backhaul with highly integrated and easy-to-deploy products. E-band volumes were driven by very high capacity 5G backhaul needs, with shorter inter-site distances in urban environments, as well as low spectrum fees.

In 2015, we predicted V-band would grow to 10 percent in 2020. However, this forecast was reduced significantly in 2017 as we saw that small cells were not taking off, and also service providers wanted to continue using licensed spectrum instead of unlicensed spectrum, to guarantee performance. Today we can see that V-band for backhaul never made it across the product introduction chasm. It will instead be used by unlicensed services.

Our forecast in 2015 was that E-band would grow to some 18 percent by 2020, but this was revised in 2017 and by 2020 it ended up with an even lower actual value (which was still double the actual value in 2015).

Figure 16: Accuracy in new deployment share predictions



The largest contributing factor to slower E-band uptake was the delayed start of 5G in India, the world's largest microwave market. Other influences included late opening of the band and unfavorable spectrum fees, in various markets.

But now, E-band is open in most countries. 5G is being rolled out in India. Multi-band solutions have a clear growth trajectory. So although our 2020 predictions were not met, the E-band market is catching up and will reach even higher numbers, albeit a few years beyond 2020.

For the 26–42 GHz bands, our predictions were almost spot on. Even though some bands in this range have been allocated to high band 5G access, such deployments have not yet taken off in most markets, and the bands continue to be used for fixed services. Some volume drop in 26/28/38/42 GHz has been offset by an increase in 32 GHz, an important band going forward.

In the 15–23 GHz range, the predicted drop was revised in 2017 and the actual 2020 number is very close to our forecast.

For the low frequencies 6–13 GHz, the predicted drop was revised in 2017 and a small increase was forecast. By 2020 there was instead a significant increase. While some countries have allocated parts of these bands for 5G access, it has been shown repeatedly how vital this spectrum is, for example in securing 5G backhaul in rural areas.

In conclusion, while our V- and E-band predictions were more conservative than those of many others in the market, we were still slightly too optimistic. It is important to keep this in mind for the new W- and D-bands. These bands will ramp up, but maybe not as fast as many anticipate.

Predicting the future accurately requires a good understanding of the past in combination with market and technology insights. This is why Microwave Outlook is, and will continue to be, important.

About Ericsson

Ericsson enables communications service providers and enterprises to capture the full value of connectivity. The company's portfolio spans the following business areas: Networks, Cloud Software and Services, Enterprise Wireless Solutions, Global Communications Platform, and Technologies and New Businesses. It is designed to help our customers go digital, increase efficiency and find new revenue streams. Ericsson's innovation investments have delivered the benefits of mobility and mobile broadband to billions of people globally. Ericsson stock is listed on Nasdaq Stockholm and on Nasdaq New York.

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