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Review

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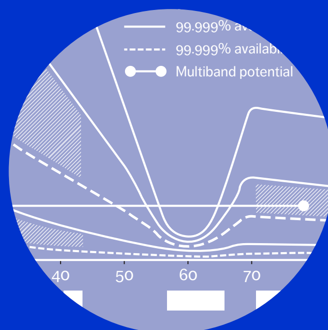
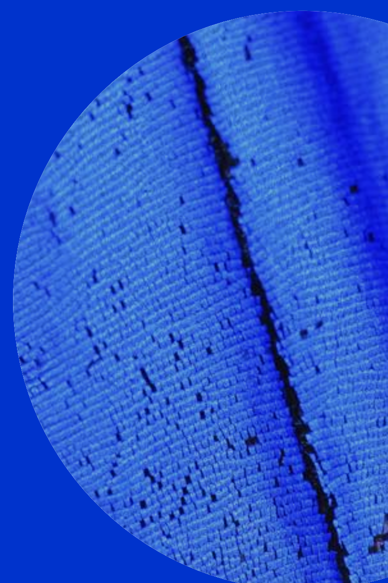
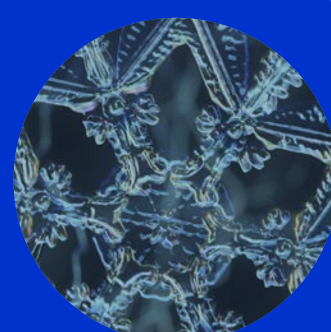




MICROWAVE BACKHAUL GETS A BOOST WITH MULTIBAND



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Microwave backhaul

GETS A BOOST WITH **MULTIBAND**

JONAS EDSTAM

Is there a spectrum shortage? The answer to the question is both yes and no; in some locations spectrum is severely congested, while in other places it is highly underutilized. As the performance level demands on services like mobile broadband continue to rise, networks are going to need some innovative tools. New methods that will maximize spectrum efficiency, and new technologies that can exploit unused spectrum are going to be needed. Multiband booster is one such method. This concept fundamentally shifts the way spectrum can be used, with a promise to deliver a massive improvement in the performance levels of microwave backhaul, while at the same time accelerating the much needed shift toward the use of higher frequency bands..

TECHNOLOGY EVOLUTION, increased mobility, and massive digitalization continue to place ever more demanding performance requirements on networks – a trend that shows no signs of leveling off. As the dominant backhaul media in today's networks, microwave plays a significant role in providing good mobile network performance. However, the constant pressure to increase performance levels translates into a need for more spectrum, and more efficient use of it – not just when it comes to radio access, but for microwave backhaul as well.

As a finite natural resource, radio spectrum is governed by national and international regulations to ensure that social and economic benefits are maximized. Spectrum is divided into frequency bands that are allocated to different types of radio services, such as communication, broadcasting, radar, as well as scientific use. Allocation is based on propagation characteristics, which vary with frequency. Lower frequencies, for example, enable radio signals to be transmitted over longer distances, and can penetrate building facades. Higher frequencies, on the other hand, are more limited in terms of reach and coverage, but they can generally provide wider frequency bands, and as such have high data-carrying capacities. Driven by growing communication needs, ever higher frequencies have been taken into use over the past few decades. Historically, microwave backhaul has used much higher frequencies (from about 6GHz to 86GHz) than mobile radio access, which today uses spectrum ranging from about 400MHz to 4GHz.

For 5G radio access, research is currently underway on the use of much higher frequencies (above 24GHz). The findings of this work will be presented at the next ITU World Radiocommunication Conference, due to be held in 2019 (WRC-19) [1].

By 2020, 65 percent of all cell sites (excluding those in Northeast Asia) will be connected to the rest of the network using microwave backhaul technology [2]. Between now and then, the performance of microwave backhaul will continue to improve, supporting growing capacity needs through technology evolution and more efficient use of spectrum. The decision-making process used to establish what media can best provide backhaul to a given site will also change; it will no longer be determined by capacity needs, but rather which solution – fiber or microwave backhaul – provides the lowest total cost of ownership (TCO).

Multiband solutions, which enable enhanced data rates by combining resources in multiple frequency bands, already constitute an essential part of modern radio access systems. Their significance will, however, increase in the coming years, as they enable efficient use of diverse spectrum assets, and as such will support the evolution of LTE and 5G technologies.

The question today, however, is how to exploit the multiband concept for backhaul. And how can a holistic view enable more efficient use of diverse backhaul spectrum assets.

Use of spectrum for backhaul

Spectrum in different frequency ranges is used by backhaul solutions to support communication in many types of locations, from sparsely populated rural areas to ultra-dense urban environments.

Terms and abbreviations

PDH–Plesiochronous Digital Hierarchy | QAM–quadrature amplitude modulation | SDH–Synchronous Digital Hierarchy

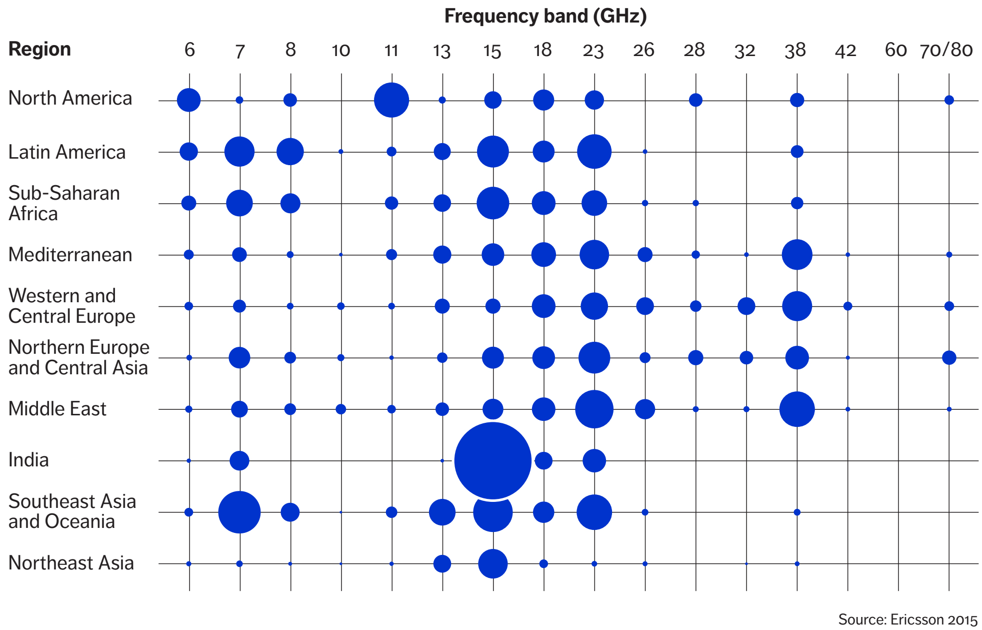

Figure 1: Global use of microwave backhaul

Globally, about 4 million microwave backhaul hops are in operation today. *Figure 1* illustrates the extent of microwave backhaul usage by region and band – the size of each circle is relative to the number of microwave hops in operation. Which frequency band is used varies greatly from one place to the next, because the most appropriate band is chosen depending on regional climate and national spectrum regulations [3]. Other factors like inter-site distance, target performance requirements, and fiber penetration are also taken into consideration when selecting the backhaul frequency band that best fits a given location.

As capacity needs have grown, the use of spectrum has shifted. Higher, previously less utilized frequencies have grown in popularity. About a decade ago, new 26GHz, 28GHz, and 32GHz bands were introduced, and since then, the use of these bands to support LTE backhaul has become popular in parts of Europe, Central Asia, the Mediterranean, and the Middle East. The older 38GHz band is quite popular in these regions, and its attractiveness is currently growing in the rest of the world. The newer 70/80GHz band is today gaining popularity [2, 4], as it offers wide spectrum and channels alike, enabling capacities in the 10Gbps range over a few kilometers.

Looking to the future, industry has an interest in the use of frequencies above 100GHz, as they will enable capacities in the 40Gbps range over hop distances of about a kilometer [2].

Technologies are being investigated [5], and regulatory studies are examining channel arrangements and deployment scenarios in the 92-114.5GHz, and 130-174.7GHz frequency ranges, commonly referred to as the W- and D-band for microwave backhaul [6].

Unfortunately, the use of spectrum is unbalanced: hotspots occur in bands that are heavily used, while there are large geographical areas with untapped spectrum in all frequency bands.

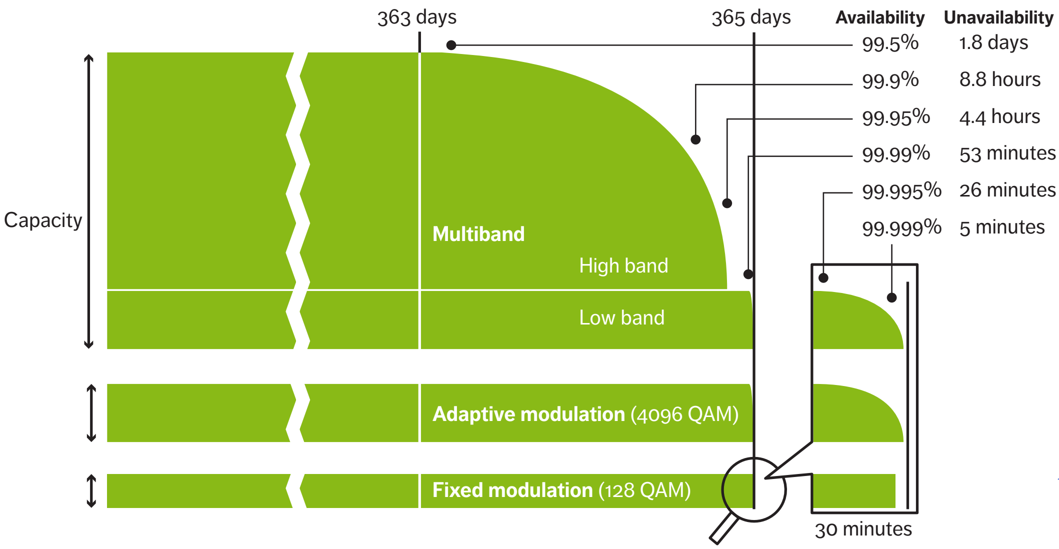

Figure 2: Evolution of microwave backhaul technology

Microwave backhaul technology

Unlike the various generations of radio access technology (2G, 3G, and 4G), there is no formal classification for microwave backhaul technology evolution. Nevertheless, its performance has improved tremendously over the past few decades with the introduction of innovative technologies and enhanced features [2, 7, 8].

One issue that in some way characterizes microwave backhaul is the impact on signal strength of adverse propagation effects, such as those caused by rain. Planning and dimensioning of microwave links need to be carried out using recommended propagation prediction methods and long-term statistics, to ensure that targeted service availability (the ratio of actual service provided to the targeted service level, measured over 365 days, and expressed as a percentage) can be secured [9].

Originally, microwave supported PDH and SDH transport using fixed modulation designed for a service availability of up to 99.999 percent (five-nines availability), which allows for five minutes of total outage in a year.

Since then, adaptive modulation has been introduced for packet transport: a technique that is now well established, and supports extreme order modulation with up to 4096 QAM. Adaptive modulation maximizes the bit-error-free throughput under all propagation conditions. It can be configured to provide guaranteed capacity for high-availability services, and still provide more than double the capacity with somewhat lower availability, as illustrated in *Figure 2*.

Multiband booster for backhaul

Radio-link bonding is a well-established method for microwave backhaul, enabling multiple radio carriers to be aggregated into a single virtual one [7] – somewhat similar to carrier aggregation in radio access. Bonding not only enhances peak capacity,

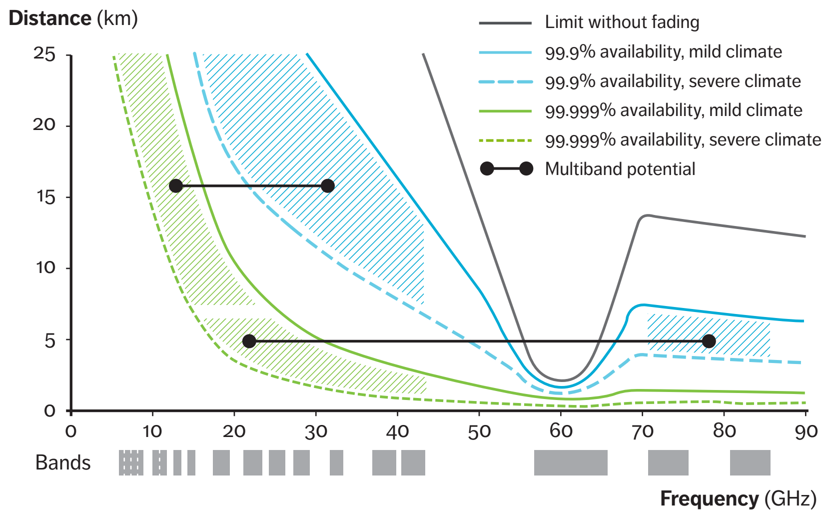

Figure 3:
Achievable distances with high-capacity microwave backhaul

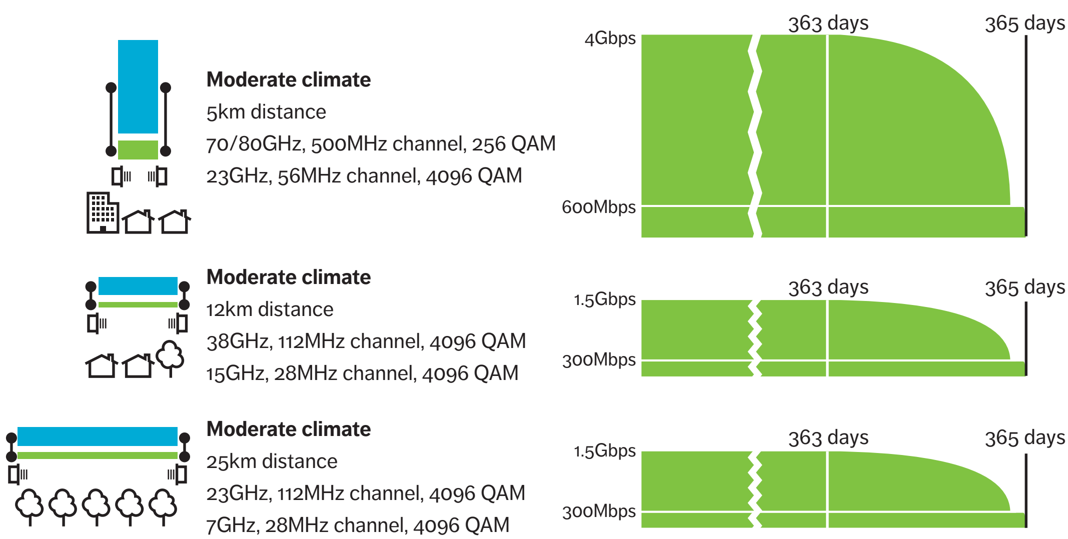

Figure 4:
Examples of multiband microwave backhaul configurations

it also increases effective throughput by using statistical multiplexing. Since its introduction, the technology has evolved continuously, supporting ever-higher capacities and more flexible carrier combinations. So far, focus has been on bonding carriers within the same frequency band. The beauty of the multiband booster concept lies in the fact that it uses radio-link bonding to aggregate carriers in different frequency bands, enabling the full spectrum potential to be unleashed.

Wider channels are easier to obtain at higher frequencies, but as rain attenuation increases with frequency, availability drops for a given distance. Multiband booster overcomes this issue by bonding a wide high-frequency channel with a narrow low-frequency channel, as illustrated in Figure 2. The resulting combination provides the best of both channels, giving higher capacities over much longer distances – drastically changing the way spectrum can be used for backhaul. Multiband booster brings about a huge increase in performance, and introduces a high degree of flexibility into the design of the backhaul solution. Ultimately, it enables the performance and availability requirements for different services to be met.

How different microwave backhaul frequency ranges can be used is to a large extent determined by propagation properties [9]. As rain attenuation and free-space losses increase with frequency, the achievable hop distance at higher frequencies is limited. The maximum distances for high-capacity microwave are shown in ***Figure 3*** for different climates and levels of availability. The mild climate has a rain zone of about 30mm per hour (rain rate exceeded for 0.01 percent of the year), and is typical for large parts of Europe. The severe climate is for a rain zone of about 90mm per hour, which is typical for India. The availability targets in this example are set for half the maximum link capacity, which corresponds to 64 out of 4096 QAM in the 6-42GHz range, and to 16 out of 256 QAM in the 60GHz and 70/80GHz bands. The full link capacity has lower availability, but is maintained for most of the year. For applications that require lower capacities, longer distances can be achieved using lower modulation levels. Figure 3 also shows the limit for maximum modulation without fading, still including free-space loss and atmospheric attenuation. The oxygen absorption peak, which occurs at around 60GHz, severely limits hop distance – this phenomenon is clearly illustrated by the dip in the curve.

The width of a frequency band generally scales with frequency; the higher the frequency, the more bandwidth it offers. Backhaul frequency bands can be roughly categorized into three frequency ranges:

- **6-15GHz bands with an average of 750MHz per band**
- **18-42GHz bands with an average of 2.2GHz per band**
- **70/80GHz band that is 10GHz wide.**

For a given hop distance, the typical multiband combinations that would boost capacity are illustrated in Figure 3. They include: 18-42GHz bands bonded with the very wide 70/80GHz band for hop distances of up to about 5km; or the narrow 6-15GHz bands bonded with the wider 18-42GHz bands for longer hop distances. The multiband solution is, however, highly flexible, and any locally available frequency combinations that meet the targeted performance can be used.

Boosting backhaul performance

The multiband booster is an excellent tool for upgrading the capacity of microwave backhaul networks up to tenfold. ***Figure 4*** shows three different multiband examples with typical hop distances found in different parts of the network – in suburban areas hops tend to be a few kilometers long, and tens of kilometers in remote rural regions. Examples are given for a moderate climate, with a rain zone of about 60mm per hour (which is typical for places like Mexico). Bearing in mind that these configurations are just examples, the multiband booster provides a highly flexible way to bond different carrier and frequency band combinations. Combining different frequency bands makes it possible to get more out of available spectrum, and so help networks meet the performance and availability requirements of future services.

Unleashing spectrum potential

It is clear that if networks are to meet future performance requirements, efficient use of spectrum

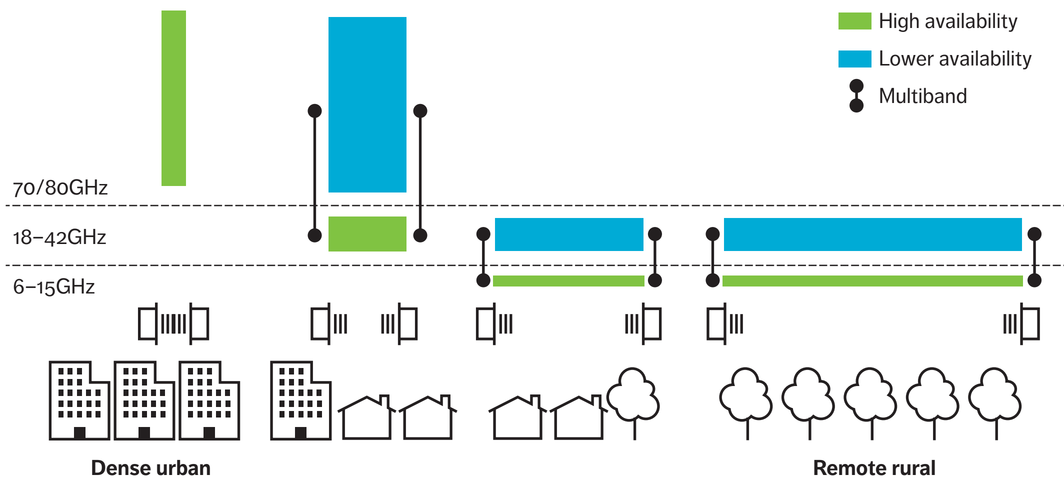

Figure 5:
Efficient use of microwave backhaul spectrum

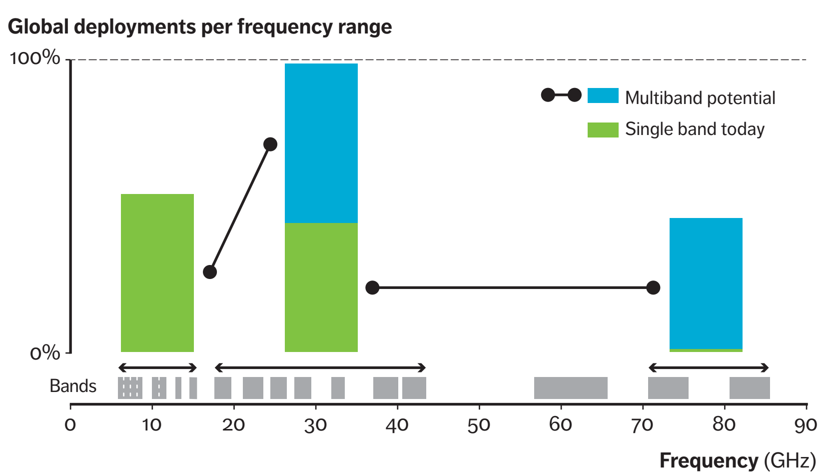

Figure 6:
Increased use of high frequencies with multiband microwave backhaul

is essential. There are, however, many different aspects to spectrum efficiency, and the level that can be achieved directly depends on the local deployment density and topology of microwave hops.

Microwave backhaul performance is, for the most part, determined by the propagation properties of different frequencies. At higher frequencies, rain attenuation and free-space losses are greater, while antenna size drops for the same antenna gain. Best practice dictates using the highest frequency band possible that can still meet the availability and performance objectives for a given link distance. This approach preserves the lower frequency bands for use by greater link distances. In many countries, regulatory incentives promote the use of higher bands through lower spectrum-licensing costs, and by imposing policies that dictate minimum hop-length distances.

Increasing the spectral efficiency of a link can be achieved by using higher-order modulation, but this comes at the cost of increased sensitivity to interference – which may in turn limit the use of more extreme order modulation in local hotspots. Consequently, the significance of interference mitigation technologies, like super high performance antennas (Class 4 [10]), is growing.

Today, the use of higher frequency bands is limited to shorter hop lengths, which tend to be most common in urban environments. As a result, higher-frequency spectrum is seldom used outside these areas. Clearly such biased usage is inefficient, and a significant amount of valuable spectrum remains untapped.

As ***Figure 5*** illustrates, the multiband booster enables higher backhaul frequency bands to be used over longer distances and much wider areas. The concept can be applied to advantage in all geographical areas, although different frequency bands are appropriate depending on the desired hop distance. Wider channels should also be much easier to obtain in these less congested areas, further increasing the benefit of multiband solutions.

Regulatory authorities can apply different licensing models to encourage efficient use of spectrum, weighing in factors like frequency bands, geographic region, and local microwave hop density. Introducing and allowing wider channels in less deployed areas would further encourage the use of multiband solutions.

Future backhaul spectrum use

In most geographical areas, hop distances are generally becoming shorter due to the densification of the macro cell network and introduction of small cells. Likewise, the distance to a fiber point-of-presence is dropping as fiber penetration increases.

As hop distances fall, the use of higher frequency bands rises. For example, use of the 70/80GHz band is growing significantly, and if the growth curve continues, will account for 20 percent of new deployments by 2020 [2]. Today, bands in the 26-42GHz range are predominately used in Europe, the Mediterranean, Central Asia and Middle East (see Figure 1), but use in other regions is beginning to show signs of growth.

Figure 6 shows the relative amount of single-band microwave hops in global operation today in the 6-15GHz, 18-42GHz, and 70/80GHz frequency ranges (see also Figure 1). The multiband booster is a highly attractive solution to enhance performance for microwave backhaul. Upgrading existing single-band microwave links to multiband solutions will result in the accelerated use of higher frequency bands, as illustrated in Figure 6.

Denser networks, increasing performance needs, and new efficient technologies, such as multiband booster, will all lead to a dramatic increase in the use of the 70/80GHz band, as well as a large increase in the use of bands in the 18-42GHz range.

Summary and conclusions

The performance of microwave backhaul has evolved continuously with new and enhanced technologies and features that make ever better use of available spectrum [2, 7, 8]. Today, microwave backhaul can provide fiber-like multi-gigabit capacity – even in locations where there is no direct line-of-sight [11].

Multiband solutions are essential for mobile systems, as they enable diverse spectrum assets to be used efficiently. The importance of these types of solutions for mobile communication will rise as

LTE evolves and 5G becomes a reality. A number of years ago, we documented the benefits of adapting multiband for microwave backhaul in a previous article [7]. It's now time to fully exploit the concept.

Multiband booster provides a massive increase in the performance of microwave backhaul, and is an excellent tool that can increase network capacity up to tenfold. It supports flexible bonding of different carriers and frequency band combinations, enabling networks to meet the performance and availability requirements for future services. Multiband booster represents a paradigm shift toward much more efficient use of diverse backhaul spectrum assets, unleashing the use of higher frequencies over much wider geographical areas.

The technology evolution for spectrum – how it is used and how it is allocated – is moving fast, with many new innovations becoming available for both radio access and microwave backhaul. Regulatory authorities are carefully considering the current and future use of frequency bands, not only for mobile systems but also for microwave backhaul.

As networks become denser, and performance needs grow, new efficient technologies, like the multiband booster, will dramatically increase the use of the 70/80GHz band, as well as the bands in the 18-42GHz range. To support evolving technology, and ensure good backhaul performance, regulatory incentives that promote efficient and holistic use of backhaul spectrum are key.

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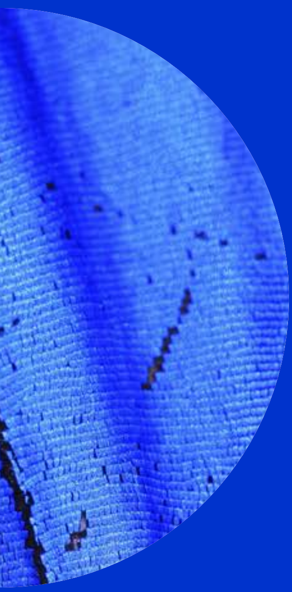

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