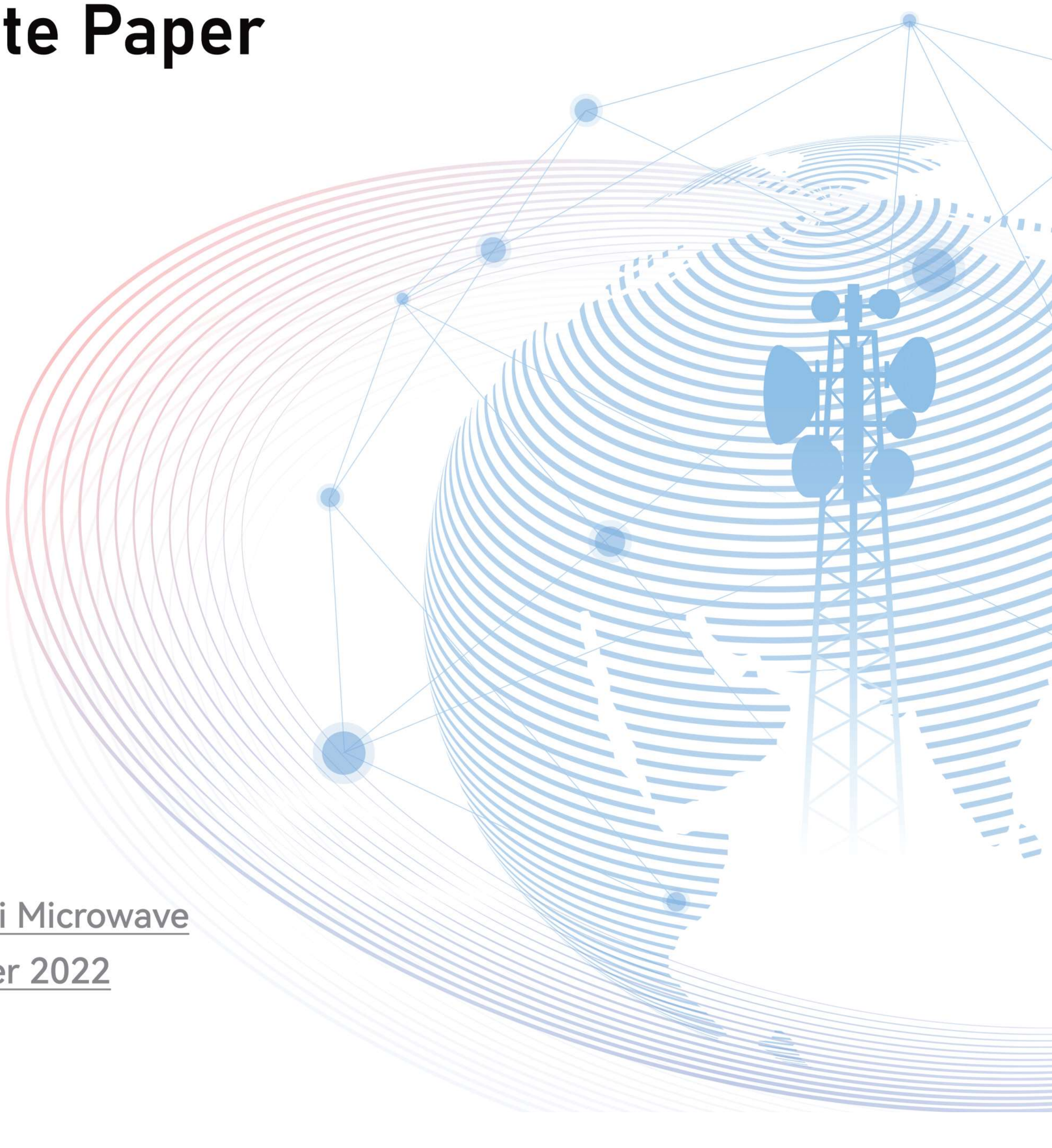
HUAWEI

2022

MICROWAVE INDUSTRY

White Paper



Huawei Microwave

October 2022

At a Glance

Overview of 5G Microwave Backhaul

Just like how water, electricity, and highways are important to our lives, a ubiquitous network connection acts as a critical infrastructure for a country. Since 5G was rolled out in 2019, the number of 5G sites around the world has exceeded 3 million, and this number is expected to exceed 7 million by 2025. Currently, the Middle East and Europe have widely deployed 5G networks not only in urban areas but also in suburban and rural areas. Asia, Africa, and Latin America are in the initial stage of 5G construction, and the number of 5G base stations in these areas will increase rapidly in the next three years. Furthermore, as mobile traffic is expected to grow sharply in the next five years, 5G multi-band and 5.5G new bands (including mmWave) will be deployed on a large scale.

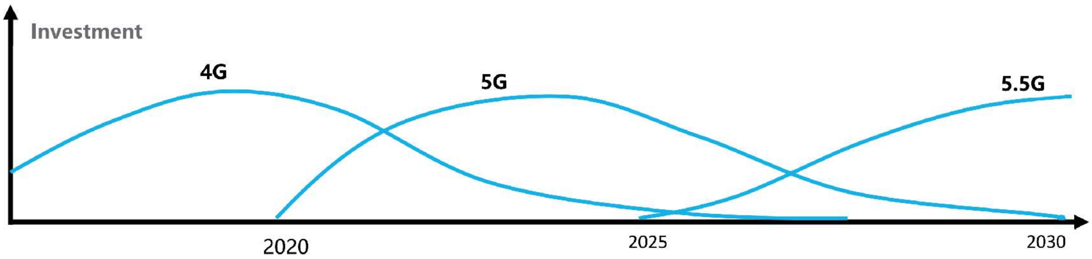


Fig.1 Development of global mobile communications networks

Microwave backhaul mainly includes base station backhaul, enterprise private network/private line, and video/home broadband backhaul. Base station backhaul accounts for 80% of microwave backhaul. Therefore, this white paper will focus on the base station backhaul market. Microwave plays an important role in mobile backhaul, accounting for around 70% of global mobile backhaul markets, stretching to 90% in some emerging markets. The current microwave spectrum ranges from 6 GHz to 86 GHz, of which 6–42 GHz are traditional bands, and 71–86 GHz are known as E-band. Microwave has become the main spectrum for 5G backhaul with a lower Total Cost of Operation (TCO) and faster Time to Market (TTM). Currently, more than 90 countries have allowed operators to use E-band.

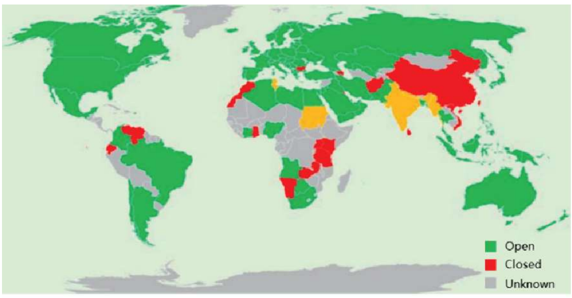


Fig. 2 E-band status of worldwide regulation (source: ETSI White Paper)

With the rapid growth of 5G sites, 5G sites are deployed not only in urban areas with a high fiber penetration rate, but also in suburban and rural areas with a low fiber penetration rate. This way, the proportion of E-band backhaul links will increase rapidly. For both 5G and 5.5G, E-band will be the main backhaul spectrum. However, it is necessary to improve E-band spectral efficiency or introduce new W/D-band if the spectrum of some links is insufficient. By 2026, the proportion of E-band will increase from 19% to 43%.

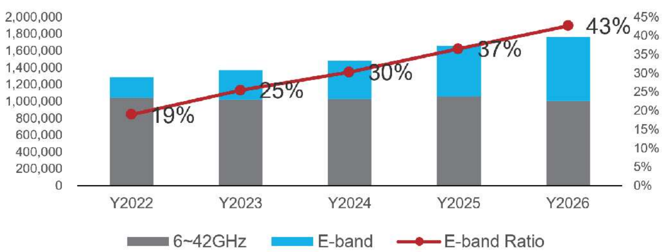


Fig.3 Traditional bands vs. E-band market forecast

5.5G Microwave Backhaul Target Network and Industry Challenges

In 2020, Huawei proposed the definition of 5.5G. It is an enhancement and extension of the three standard 5G scenarios — enhanced Mobile Broadband (eMBB), massive Machine-Type Communications (mMTC), and Ultra-Reliable Low-Latency Communication (uRLLC), and covers three new scenarios including Uplink Centric Broadband Communication (UCBC), Real-Time Broadband Communication (RTBC), and Harmonized Communication and Sensing (HCS).

In April 2021, 3GPP officially named 5G evolution as 5G-Advanced (also referred as 5.5G), indicating a new chapter for 5G technologies and standards.

The definition of 5.5G affects microwave backhaul. eMBB proposes a 10 Gbps ubiquitous experience, which requires a higher backhaul capacity. uRLLC and RTBC also support future real-time interactive services and are sensitive to latency. This means that backhaul requires deterministic latency.

5.5G requires for more spectrums to address the growing traffic demands, which means the backhaul capacity of a single site will increase dramatically. Figure 4 shows the 5.5G backhaul target network in 2025.

- **Urban areas:** 25 Gbps to site is required. In the cases of abundant spectrum resources, backhaul will evolve to E-band 2 GHz cross-Polarization Interference Cancellation (XPIC). However, with a total of 5 GHz of bandwidth available at E-band, spectrum will be insufficient in urban areas, which signals the need to improve E-band spectral efficiency or introduce W/D-band spectrum.
- **Suburban & rural areas:** The Super Dual Band (SDB also called band and carrier aggregation) solution used in the early stage of 5G will be still used in the 5.5G era. However, as site capacity increases, traditional bands need to provide larger capacity to ensure the transmission of high-priority services such as the control signaling of base stations.
- **Backbone:** The backbone capacity in rural areas will increase rapidly, which is expected to reach 10 Gbps. In order to provide long-distance backhaul, multi-band multi-carrier aggregation on traditional bands will be necessary.

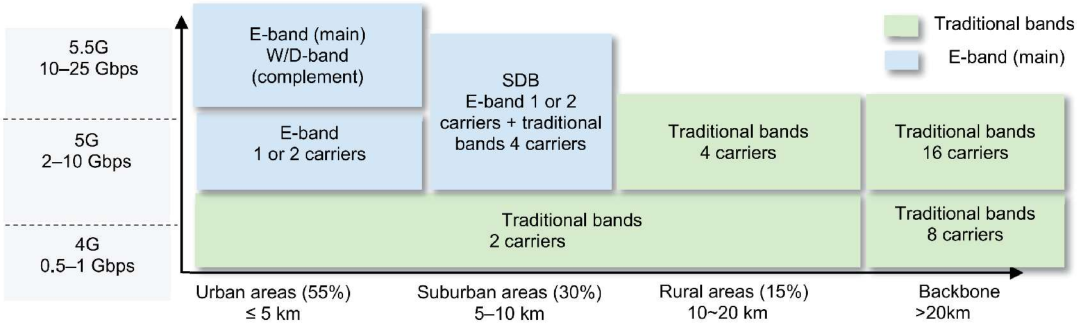


Fig. 4 5.5G microwave backhaul target network

To support the 5.5G backhaul target network, the microwave industry will face five challenges:

1. Higher capacity requires more microwave spectrums in 5.5G.

2. The E-band transmission distance is not enough, yet the SDB or traditional bands aggregation will increase the microwave backhaul cost.

3. Backbone spectrum is also inadequate, with some spectrum being used for RAN, which further aggravates the shortage of low-frequency spectrum.

4. The mode of cooperating with tower companies, puts more pressure on operators to save the tower space and reduce tower load.

5. Increasing electricity, O&M, and spectrum fees lead to higher OPEX.

Trend 1: 25 Gbps to Site for 5.5G, Larger Capacity for Aggregation Sites

With the wide deployment of 5G networks, 5G services are developing rapidly. According to GSMA's prediction, the number of global 5G users is expected to reach 1.4 billion by 2025, accounting for 25% of total mobile users. The proportion of 5G users in advanced markets will exceed 50%. In addition, the Data of Usage (DOU) will increase from 11.4 GB in 2021 to 41 GB in 2027, signaling a 3.6-fold increase, while in some advanced markets such as the Asia Pacific, the DOU will even increase by 6-fold.

New applications such as AR/VR, metaverse, Vehicle-to-Everything (V2X), and machine vision emerge and pose higher requirements on networks than ever before. This drives mobile networks to evolve to 5.5G, which increases network capacity by 10 times and provides users with a 10 Gbps experience.

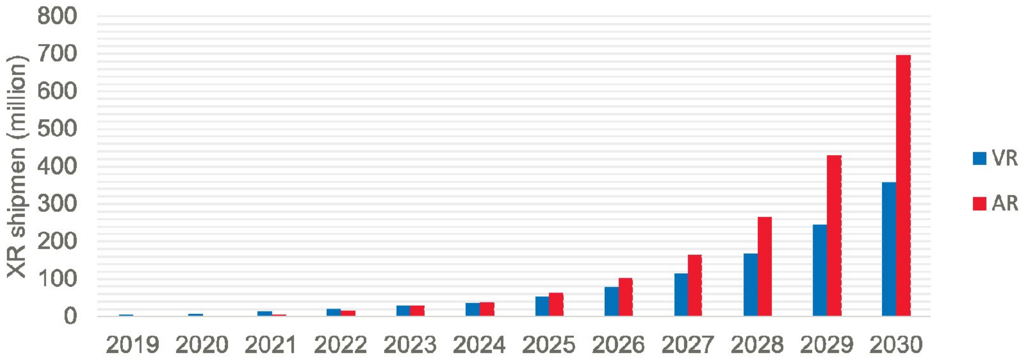


Fig. 5 XR shipment forecast (source: Huawei CBG)

The development of wireless networks poses higher requirements on backhaul bandwidth. To evaluate the future capacity demands of a single site, the following section will introduce the current bandwidth planning principles:

Planning principle 1. The sum of the average capacity values of three sectors: Due to rapid traffic growth, the backhaul may become a bottleneck and result in frequent capacity expansion.

Planning principle 2. The peak value of a single sector: This principle ensures that a single sector can reach its peak value.

Planning principle 3. Peak value of a single sector + average value of two sectors: This principle is able to ensure that optimal user experience is delivered.

According to our statistics, 71% of operators worldwide use the first two planning principles in the 4G era. When microwave is used for 5G backhaul, these two principles are still the most recommended.

Table 1 lists the single-site backhaul bandwidth requirements of 5G and 5.5G in different phases and under typical configurations. The 5.5G backhaul bandwidth of a single site can reach 25 Gbps.

Table 1 Typical backhaul bandwidth of 5G site

	One TDD Band	Two TDD Bands	Two TDD Bands + 6 Ghz	Two TDD Bands + mmWav
5G spectrum (MHz)	100 MHZ	200 MHZ	200 MHz + 200 MHz	200 MHz + 800 MHz
Principle 2 (Gbps)	3.3	6.5	20	18
Principle 1 (Gbps)	2.1	3.9	12.2	11
Principle 3 (Gbps)	4.7A	9.1	28.1	25

Moreover, due to constraints such as the transmission distance and line of sight (LOS) transmission, multi-hop to fiber hub sites still exist in 5G backhaul networking. Take operator Z in country S as an example. Currently, 30%–40% of E-band links are aggregation links, so higher capacity is required after multiple sites are aggregated. In the future, the capability of E-band can reach 50 Gbps after MIMO is used, and that of D-band can reach 100 Gbps.

Trend 2: Continuously Increasing the Transmission Distance of E-band

E-band's high bandwidth and low spectrum cost make it the leading choice for 5G backhaul in urban and sub-urban areas. E-band can have a maximum channel spacing (CS) of 2 GHz and enables 10 Gbps backhaul per carrier. From a global perspective, the spectrum fee of E-band is 20% that of traditional bands, allowing E-band to provide five times the backhaul bandwidth at the same spectrum fee. Figure 6 shows spectrum fees in some countries.

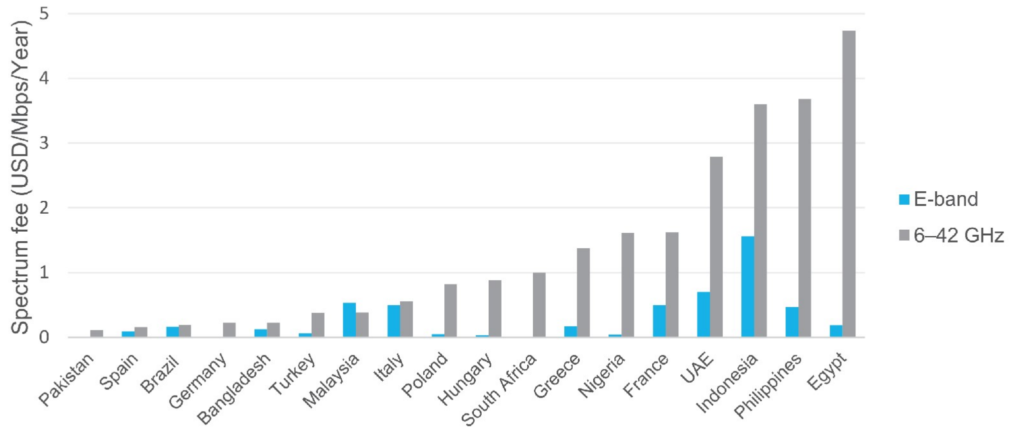


Fig. 6 Spectrum fee comparison between E-band and traditional bands

The transmission distance of E-band is 1 km in rain zone P and is 3 km in rain zone K (99.995% availability with 0.6 m antennas). Figure 7 illustrates the distances of legacy microwave links worldwide. According to the figure, E-band can cover 50% of backhaul links globally and is not applicable to the remaining 50%. As such, innovative technologies are urgently needed to improve the transmission distance of E-band for large-scale 5G/5.5G deployment.

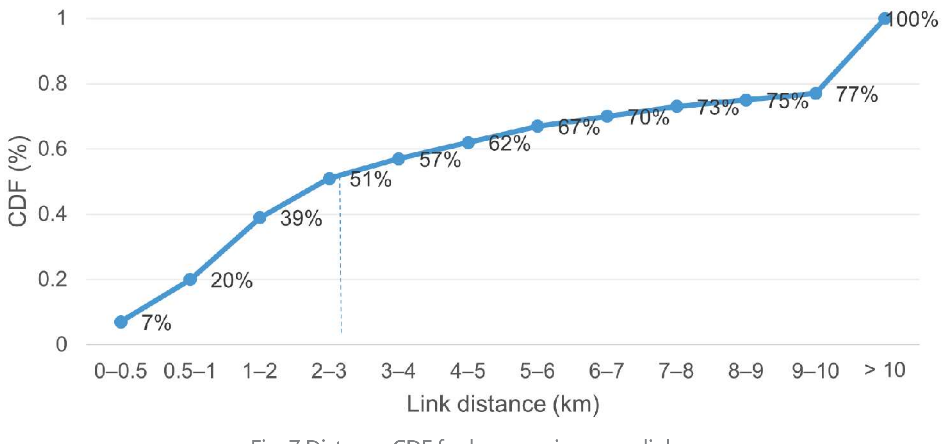


Fig. 7 Distance CDF for legacy microwave links

The typical equivalent isotropic radiated power (EIRP) is defined as follows:

$$\mathrm{EIRP} = \mathrm{P}_t - \mathrm{L}_c + \mathrm{G}_a$$

Where,

P_t = Transmitter output power (dBm)

L_c = Cable loss (dB)

G_a = Antenna gain (dBi)

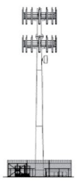
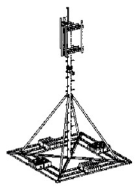
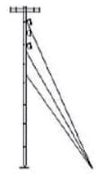
The industry's EIRP for E-band is now 70 dBm, with P_t equal to 20 dBm and Ga (0.6 m antennas) equal to 50 dBi. This is far lower than 85 dBm, the maximum EIRP specified in ITU Radio Regulations 2020.

As the cable loss is negligible, the following research directions are critical to improving the EIRP of the system.

- **Higher transmitter output power:** Increase the transmit power of E-band devices to extend the transmission distance. Currently, the maximum transmit power in the industry is 18 dBm to 20 dBm. Power amplifier (PA) technologies such as PA stacking and new PAs driven by advanced semiconductor technology, will enable higher transmitter output power in the future. E-band with 26dBm transmitter output power is on the way, and the ones with beyond 30dBm are under research now.

- **Higher antenna gain:** Use antennas with a larger diameter to increase the antenna gain. Currently, 0.3 m and 0.6 m antennas are typically used, but if tower load-bearing capacity and space allow, 0.9 m antennas will be used to extend the transmission distance. However, this will see a decrease in beam angle (from 0.5° to 0.2°) compared with 0.6 m antennas, which escalates the impact of tower sway/twist and brings a higher risk of beam alignment failures when a tower sways/twists. Table 2 lists the typical towers and their sway/twist angles.

Table 2 Sway/Twist angles of typical towers

	Self-supporting tower	Monopole	Rooftop pole	Guyed mast
Tower/Pole Type				
Sway/Twist Angle	< ±0.25°	< ±1°	< ±0.5°	< ±1°

- **Longer transmission distance via SDB:** Combine E-band and traditional bands to extend the transmission distance. In this solution, traditional bands are used for critical traffic such as control signaling of base stations. Usually, the availability of traditional bands is 99.995% and that of E-band is 99.95%. This way, the transmission distance is extended significantly. However, the E2E TCO of SDB links is relatively high due to the use of traditional bands.

Hence, using antennas with higher antenna gains and higher transmit power will significantly increase the transmission distance of E-band and SDB. Figure 8 shows the transmission distance calculated for each scenario based on the maximum EIRP of 85 dBm specified by ITU.

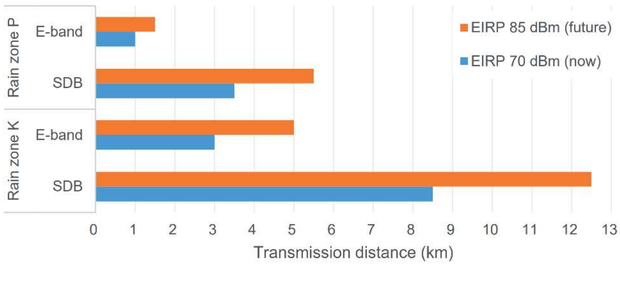


Fig. 8 Transmission distances under different EIRPs

Take rain zone K as an example. The transmission distance of E-band increases from 3 km to 5 km. E-band can replace SDB to lower the cost of traditional bands in both the device and spectrum, and specifically, reduce the TCO per link by more than 50%. On top of this, the transmission distance of SDB increases from 8 km to 12.5 km. SDB links can replace some traditional-band links used for long-distance transmission to decrease the spectrum fee. In rain zone P, however, the transmission distance of E-band is still short even though the maximum EIRP is used. In this case, new network planning approaches that suggest differentiated availability can be introduced to push the transmission distance even further.

Trend 3: Improving Ultra-dense Deployment Capability to Alleviate Spectrum Resource Shortage

Increased bandwidth, densified sites, and more optical fibers have seen the tree microwave topology evolve into a star microwave topology, and aggregation sites that require a large number of spectrum resources may be widely deployed to cover multiple directions. Effectively using existing spectrum resources is key, which is known as ultra-dense deployment capability herein. For aggregation sites, the included angle between intra-frequency deployment directions must exceed the minimum spectrum reuse angle, which is around 60° to 90° for traditional bands and about 30° for E-band. Given sufficient spectrum resources, operators can use different frequencies to enable ultra-dense deployment. While spectrum resources are increasingly insufficient with the rapid growth of capacity, how to reuse the same frequency for gradual ultra-dense deployment then becomes a key microwave capability.

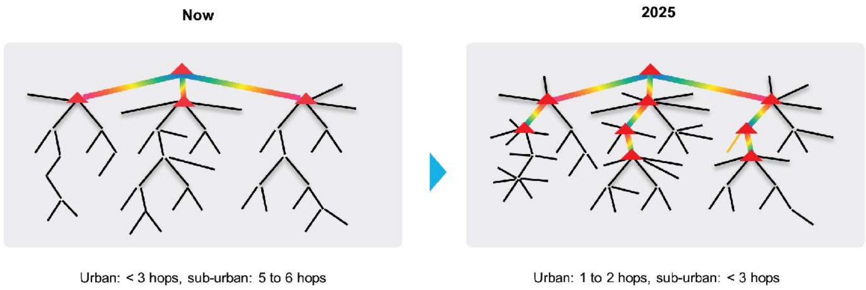


Fig. 9 Topology evolution from tree-topology to star-topology

According to the global microwave spectrum allocation modes, block, link-by-link, and unlicensed modes are currently the mainstream ones. As networks evolve, the responses to dense deployment and results vary with the spectrum allocation modes.

Block: Spectrum resources are dedicated for one operator and each operator can obtain fixed spectrum resources. It allows operators to control planning (interference, capacity) by themselves. Hence, for multi-direction deployment, operators can reduce the spectrum reuse angle to avoid purchasing new spectrum resources.

Link-by-link: Spectrum resources are applied for by link and allocated on a first-come-first-served basis. For multi-direction deployment, operators preferentially use different frequencies to deploy links with small included angles. Take traditional bands as an example. If there are three directions within the spectrum reuse angle of 90°, at least two frequencies are required. This will exhaust spectrum resources or cause severe interference on the live network, leading to unavailable spectrum resources for operators.

Unlicensed: Spectrum resources are free of charge and are unlicensed. The challenges in multi-direction deployment are the same as those in link-by-link mode.

The dense deployment of traditional bands is mainly required by operators with block spectrum. E-band supports only two 2 GHz channels, and supports a far lower number of channels than traditional bands (as shown in Figure 10). Therefore, the dense deployment capability of E-band affects both operators with block spectrum and operators with non-block spectrum. The rapid capacity growth of 5.5G will eventually render E-band spectrum resources insufficient. Therefore, it is necessary to improve the dense deployment capability of E-band to alleviate spectrum resource shortage.

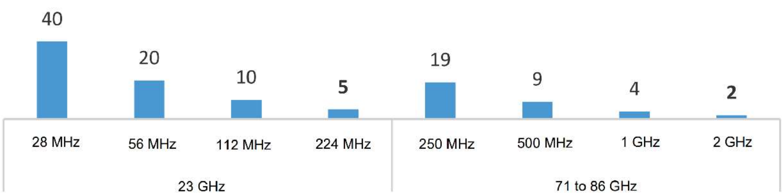


Fig. 10 Number of channels in the 23 GHz and E-band

With 5G deployment, operators with block spectrum address the shortage by dividing the spectrum into smaller blocks or purchasing new spectrums. These measures, however, will make network capacity expansion even challenging, as network capacity increases. The following are two cases where sites are deployed with small included angles.

Case 1: Operator A in country X has deployed around one thousand E-band links, with a total of 1 GHz E-band block spectrum. Figure 11 shows the distribution of angles between different directions on the live network. To isolate interference between directions in actual deployment, operators use 0.6 antennas for those distributed in the range of 15° to 30° (which accounts for 16%) and divide the spectrum into smaller blocks for those distributed in the range of 0° to 15° (which accounts for 21%).

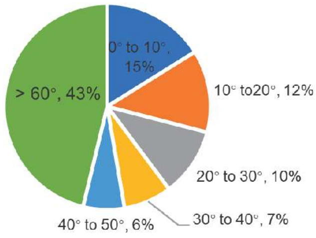


Fig. 11 Angle distribution

Table 3 lists the link bandwidth configuration in actual deployment. 1 GHz is configured for 426 aggregation links, and 500 MHz is configured for 537 access links. As the user capacity increases, and if the data rate of aggregation links evolves to 20 Gbps and that of access links evolves to 10 Gbps, the channel spacing of all links needs to be doubled. According to the simulation results, only 436 access links can be expanded to use the 1 GHz channel spacing, and 19% of them cannot. For all aggregation links, capacity expansion can be achieved only when a new 1 GHz frequency spectrum is obtained or new technologies that double the spectral efficiency are employed.

Table 3 Network configuration & upgrade evaluation

	Aggregation Link	Access Link
Channel spacing	1 GHz	500 MHz
Date rate	10 Gbps	5 Gbps
Number of sites on the live network	426	537
Number of sites with 1 GHz spectrum available	426	436
Capacity expansion challenge	Insufficient 1 GHz bandwidth	Failing to expand to 1 Ghz

Case 2: Operator B in country Y has 500 MHz E-band block spectrum and expects to deploy 56 backhaul links, with each link configured with 250 MHz channel spacing. Figure 12 shows the topology, in which the links with an included angle of less than 30° account for 47%. Even when 0.6 m antennas are adopted, there are eight links requiring extra spectrums.

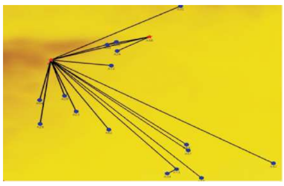


Fig. 12 E-band deployment of operator B in country Y

To sum up, inter-link interference is most severe when links are deployed with small included angles, so reducing inter-link interference is vital for dense deployment. Technically, following methods reduce inter-link interference and enable dense deployment:

1. Use antennas with better side lobe suppression. Given the same diameter, select antennas of a higher standard (for example, C3 to C4). However, if C4 antennas are deployed together with existing C3 antennas on the same site, it will result in a small reduction of the separation angles. Additionally, selecting antennas with larger diameters is another option.

2. Use inter-link dynamic power control.

3. Use interference cancellation technologies.

Trend 4: Accelerating 5.5G Real-Time Applications with Deterministic Latency

5G supports uRLLC applications, which require reliable, available, low-latency networks. On one hand, mission-critical services, such as automated factories and remote surgery, must be reliable. On the other hand, latency-critical services, such as autonomous driving and remote drone control, must meet the low-latency requirements. Meanwhile, 5.5G has launched RTBC broadband real-time interactive applications to provide an immersive experience. Typical applications include XR, holography, and et al.

The gradual implementation of 5G industrial control technologies requires lower communication latency with high network reliability to satisfy most real-time control applications for industrial automation. For example, the latency needs to reach 4 ms@99.999% which satisfies most real-time industrial automation control scenarios, or 1 ms@99.9999% which meets the preliminary requirements of industrial automation motion control scenarios.

From a microwave backhaul perspective, network planning parameters can be adjusted to achieve availability of 99.999% or even 99.9999%. However, from a deterministic latency perspective, both the latency and jitter of the microwave link need to be evaluated.

From a latency perspective, microwave backhaul has a short latency and it is negligible for uRLLC and RTBC services. The microwave E-band single-hop backhaul latency is about 30 μs, which is shorter than the transmission latency of the optical fiber. Take a transmission distance of 3 km as an example, microwave path latency is shorter than the optical fiber, as shown in Table 4. However, in addition to the transmission latency, the equipment latency also needs to be considered. The typical microwave equipment latency (represented by E-band) is about 20 μs. Therefore, the single-hop microwave E2E latency at a distance of 3 km is about 30 μs, which is shorter than the optical fiber transmission latency. Based on the live network deployment, the E2E latency of an operator using microwave backhaul is shorter than that of an operator using the optical fiber.

Table 4 Path latency comparison between microwave and optical fiber

	Site Distance	Transmission Distance	Transmission Speed	Path Latency
Microwave	3 km	3 km	3 x 105 km/s	10 μs
Optical fiber	3 km	4.5 km	2 x 105 km/s	22.5 μs

From a jitter perspective, a common QoS scheduling mechanism cannot adequately meet the requirements of services such as uRLLC. The main reason is that different queues share scheduling resources. Once a conflict occurs, retransmission occurs and the jitter increases significantly. To alleviate this conflict, hierarchical quality of service (HQoS) scheduling algorithms are often used to distinguish the traffic of different users and provide differentiated performance. Such algorithms can provide deterministic service level agreements (SLAs) for common applications such as a B2B private line. However, it is estimated that they are not enough for new 5.5G applications.

To better support latency sensitive applications such as 5.5G vehicle-to-everything (V2X), industrial automation, and differential protection for power grids, it is recommended that independent forwarding and scheduling resources be used to provide deterministic SLAs and differentiated services through slicing. Figure 13 shows a comparison between QoS and hardware slicing. For latency sensitive services such as uRLLC, the system provides dedicated hard channels to support a shorter latency and a smaller jitter.

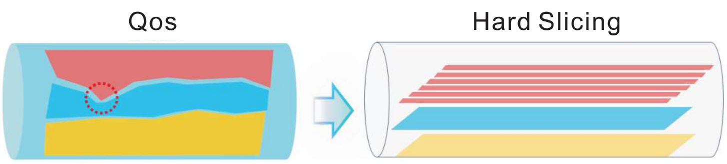


Fig. 13 Concept of slicing for 5G real-time applications

Trend 5: Evolving to a Greener and More Automated Future

Energy Efficiency and Overall Sustainability

Energy Efficiency and Overall Sustainability are global targets now universally accepted all over the world. It must be approached from all sides and lifecycle of the products: From production perspective, use of green energy and sustainable and recyclable materials in the production phase; From operational perspective, related product need to aggressively introduce power saving mechanisms and overall TCO efficiency provisions. Anyway, microwave has a carbon footprint that is a fraction of the laying of thousands of km of optical fiber.

Regarding power saving mechanisms, we need to consider both the legacy links and the future generation equipment. The legacy equipment, which is designed with maximal capacity and cost effectiveness, power saving not designed in. But remedies have been found, like muting the transmitter power amplifier of unused radio units, and other workarounds. Not the best solution, but given the millions of MW links in operation around the world, it is still significant. The new generation of equipment must have power saving and efficiency designed in from the beginning, which includes ability to monitor power consumption locally, and to optimize it both locally and End-to-End. The drive to ever increasing transmission capacity has made multi-bearer, multi-band link configurations common (referred to generically as 'N+0' in the following), and the trend will only continue in the future. The highest gains are reached by deactivating or setting in a low-power mode all physical resources that are not needed at a given time:

1. Boards, ports, and modules that are available for future expansion but currently not used/connected.
2. Muting, shutting off or setting in a low-power mode all radio bearers that are not needed at any given time, based on the user traffic that is generated by the RAN.
3. This includes mechanisms to measure, predict and coordinate instantaneous transmission resource requirements, in conjunction with the other network layers and segments: RAN, IP, Core Network.

Meanwhile, there are many challenges for a massive rollout of power saving mechanisms:

1. For the existing installed base of millions of traditional wireless links around the world, hardware reliability needs to be considered before implement of the power saving method, like channel mute.
2. Modern equipment employs a handful of powerful, highly integrated chipsets. These allow for orders of magnitude of power saving compared to less integrated technologies from just a decade ago, but make it hard to turn off parts of the system.
3. The outdoor units have higher requirements for both materials and components, because of the significant temperature variation they experience.

Automation for overall efficiency in all operational aspects

We have already mentioned that coordinating among network technologies (mobile, Wireless Transmission, Wireless Access, IP, Core functions) is going to play a key role in making the best use of the Telecommunication Networks, in terms of investment, resource allocation, monetization and power saving. Meanwhile, operating efficiency is another huge priority for Operators as pressures from the consumer marketing, supply chains, energy costs etc. put pressure on operating costs like never before. Cross-Domain Automation is the answer to many of those challenges, providing:

1. Automation of operations, from the basic ones like intelligent, efficient network-wide software upgrade to automatic re-configuration for specific hardware expansion schemes (as are now common in microwave networks), to automatic inventory
2. Ultra-fast service provisioning and lifecycle, both intra-domain and cross-domain
3. Specific wireless transmission use cases like local and multi-cluster interference management, dynamic spectrum management in a cluster of radio links
4. Adaptive power saving, as mentioned above, based on the actual transmission capacity requirement

Furthermore, coordination with other domains to achieve the power savings still need to be considered, i.e. End-to-End traffic requirement estimation and resource allocation optimization.

Trend 6: Securing Operators' Investments Through Smooth Network Evolution

With the rapid growth of wireless traffic, "on-demand and future assured investments" becomes the preliminary consideration for operators. Accordingly, smooth network evolution has become an essential capability of next generation microwave. Microwave evolution needs to consider various kinds of evolution, i.e. bigger channel spacing, multi-carrier aggregation, evolution from tractional bands to E-band, and etc.

Bigger Channel Spacing

In countries where XPIC is free of charge, the preferred capacity expansion method is to increase the backhaul CS. In the initial stages of network construction, it is advisable to select devices that meet the maximum CS requirements to avoid having to replace hardware during bandwidth expansion. That is, traditional bands support 224 MHz CS, and E-band supports 2 GHz CS.

Multi-carrier Aggregation

When the single-carrier capacity is insufficient, the microwave configuration evolves from single-carrier to multi-carrier, that is, from 1+0 to 2+0, et. al. In most countries, the spectrum cost of the dual polarization is the same as that of the single polarization. In addition, it is easy to obtain the same spectrum frequency but with different polarizations. Therefore, it is recommended that XPIC be used in 2+0 mode. Although 1+0 meets the current requirements, capacity expansion will soon be required as demands on the capacity grow. To avoid a second installation on the tower, the 2T2R RF and on-tower equipment can be safely and effectively installed at one time on the tower, and the off-tower intermediate frequency (IF) resources can be deployed as required.

For traditional bands, when the 2+0 spectrum is insufficient, 4+0 is used in a single direction. To better support smooth evolution, it is recommended that the devices support 2T2R carrier aggregation (CA). In this scenario, 4+0 capacity expansion can still follow the evolution mode of "off-tower capacity expansion without changes on the tower" as shown in Figure 14. In addition, long-distance links usually use 6 GHz to 11 GHz, and single-band resources are limited. More carriers such as 8+0 usually need to be implemented through multiple frequencies. In multi-band scenarios, multi-band antennas are required to avoid an increase in OPEX as a result of installations of multiple antennas.

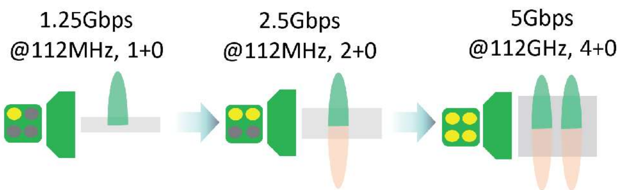


Fig. 14 Traditional bands evolution path with 2T2R 2CA

Evolution from Traditional Bands to E-band

To protect the legacy investments, microwave needs to have the capability of smooth evolution from 4G backhaul to 5G/5.5G backhaul. During 5G network construction, operators usually replace traditional bands with E-band or SDB to reduce the TCO of backhaul. From the perspective of investment protection, backhaul devices are expected to be capable of evolving from traditional bands to E-band. Currently, microwave backhaul devices do not support this evolution capability due to technical limitations. However, it should be supported by the next-generation of microwave backhaul devices. Additionally, the typical evolution path of E-Band is shown in Figure 15.

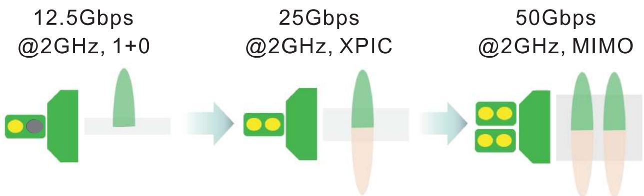


Fig. 15 E-band typical evolution path

Spectrum Consideration: Unleashing Spectrum Potential to Meet Ever-growing Capacity Demands

With the fast take up of 5G and with the planned introduction 5.5G from 2025, more capacity is needed to provide ubiquitous Gbps connectivity to end users through the deployment of 5G/5.5G in licensed spectrum. Integrated sensing and communications should also be taken into account as one of the most promising new trends. As the main backhaul option of IMT service, microwave will also need to evolve, especially in terms of spectrum utilization, to meet ever-growing capacity demands.

Traditional bands

Traditional bands are the main microwave spectrum for 3G/4G backhaul. In the 5G era, there are mainly two challenges for the traditional bands: limited spectrum resources make it difficult to fulfill backhaul requirements at mature stage of 5G; fragmented spectrum resources pose challenges to the benefits of economies of scale and global harmonized eco-systems for both microwave service and other services.

Given this, traditional bands evolve towards the following directions:

1. Traditional bands will gradually converge to several limited bands, to take benefit of economies of scale and global harmonized eco-systems.
2. Necessary methods including wider channel spacing, Multi-carrier and multi-band solution, etc., are needed to make full use of the existing traditional bands, then to meet the increasing capacity requirements.

E-band

With its 5 GHz FDD block of contiguous spectrum resources, E-band is the main backhaul band in 5G era and even 5.5G era. It could reach maximum 20Gbps transmission capacity for a single carrier.

E-band could be used with converged traditional bands in SDB solution, which complements E-band with longer transmission distance.

As mentioned in Trend 2, E-band could cover around 50% of 5G backhaul scenarios in urban/sub-urban areas. Microwave industry is aiming at unleashing the potential capability of E-band, including increasing the spectral efficiency and transmission distance, in order to make E-band fully meet urban/sub-urban backhaul requirements of both 5G and 5.5G.

Future spectrum

As the communications industry develops and capacity demands increase, the industry is discussing using higher bands for 6G IMT or microwave, including W-band and D-band (as shown in Figure 16). Currently, there is no clear conclusion on this discussion.

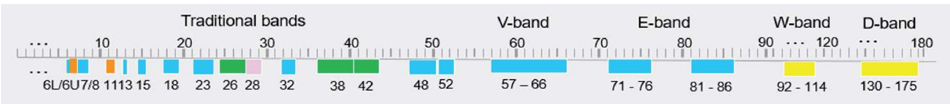


Fig. 16 Spectrum of W-band/D-band

W-band: covers 92–94 GHz, 94.1–100 GHz, 102–109.5 GHz, and 111.8–114.25 GHz, with 17.86 GHz in total. It is a non-contiguous band, and its transmission distance is 70% of that of the E-band. The W-band can be used as a supplement to E-band.

D-band: covers 130–134 GHz, 141–148.5 GHz, 151.5–164 GHz, and 167–174.8 GHz, with 31.8 GHz in total. It is also a non-contiguous band, but provides more spectrum. This makes it possible to achieve 25 Gbps with a single 5 GHz channel, and allows reaching 50 Gbps and 100 Gbps per channel by using such technologies as XPIC and MIMO. The transmission distance in D-band is limited, with typical transmission distance less than 1 km. Because the bandwidth of D-band is large, D-band can be applied in short distance transmission scenario such as wireless fronthaul.

Insight Update: Microwave for Fronthaul

Fronthaul is the transmission connection between the radio frequency (RF) module and the baseband processing unit (BBU) in wireless networks. In a traditional distributed radio access network (D-RAN), the fronthaul distance is short, and the RF module and BBU are directly connected through optical fibers. As wireless networks develop, BBUs need to be deployed in a centralized manner while RF modules can be deployed remotely. As result, D-RAN is no longer the optimal choice in some scenarios. Cases where RF modules are remotely deployed become more complex as the transmission distance increases. Consequently, fronthaul has gradually become a focal point for the industry, and microwave transmission has become one of the leading alternative solutions in remote RF scenarios.

This white paper will introduce three typical microwave fronthaul scenarios:

Macro sites with centralized BBUs in urban areas

In the 5G era, new NR frequency bands, such as C-band, have been developed to meet user experience improvement and service development requirements. The higher the frequency band, the shorter the coverage distance. Therefore, the site density must be increased. Centralized BBU deployment can solve problems such as difficult site acquisition, high rentals, and high power consumption, thus reducing the TCO. 5G networks in China, South Korea, and Japan generally adopt the centralized radio access network (C-RAN) mode, with an average C-RAN deployment rate of 90%.

The TCO for C-RAN is lower when compared with D-RAN. However, it is difficult to convert D-RAN into C-RAN, with obstacles including obtaining space for equipment and reconstructing the fronthaul. In the global market, D-RAN is still the first choice in regions outside China, Japan, and South Korea, and C-RAN pilots have been planned for some sites. Hence, there is still great uncertainty about the wide-scale deployment of C-RAN around the world.

Pole site densification in urban areas

In urban areas, pole sites are ideal to extend macro coverage and fill coverage holes. The BBU can be deployed with adjacent macro sites to bypass the problem of limited space on the tower and reduce the TCO. This solution simplifies deployment, and can be widely promoted. However, the pole height must be higher than 15 m as required by microwave NLOS transmission, and this limits the application of microwave fronthaul.

Rural network coverage

As of the end of 2021, 6% of the world's population have no mobile network coverage. Most of them live in sparsely populated rural and suburban areas, where deploying independent sites is expensive and often provides few benefits and low returns on the investment. By deploying RF modules onsite and connecting them to BBUs in remote macro sites, both energy consumption and the TCO can be reduced. Therefore, microwave fronthaul can be adopted in large scale in regions without mobile network coverage in Europe, Africa, and Latin America.

Table 5 outlines the bandwidth requirements for microwave fronthaul in typical configurations. In urban areas, transmission bandwidth is a key challenge. Two-band TDD deployment requires a bandwidth of 50~200 Gbps, calling for D-band microwave. In suburban areas, the main challenge is common public radio interface (CPRI) conversion. In addition, CPRI bandwidth compression is required to compress the bandwidth to between 10 Gbps and 20 Gbps for E-band transmission. In rural areas, which are characterized by long transmission distances, traditional microwave frequency bands, CPRI bandwidth compression, and interface conversion are also necessary.

Table 5 Bandwidth requirements of fronthaul

	Transmission Distance (km)	Bandwidth (Gbps)	Typical Interface Type
Urban area	5	65-200	eCPRI
Suburban areas	10	15-50	CPRI
Rural area	20	1.2-5	CPRI

Summary

5G has entered large-scale deployment phase. And 5.5G deployment is expected to start in 2025. Six trends have been identified in the microwave industry after the 10-fold growth in the capacity of 5.5G and real-time services:

Trend 1: 25 Gbps to site for 5.5G, larger capacity for aggregation sites

Trend 2: Continuously increasing the transmission distance of E-band

Trend 3: Improving ultra-dense deployment capability to alleviate spectrum resource shortage

Trend 4: Accelerating 5.5G real-time applications with deterministic latency

Trend 5: Evolving to a greener and more automated future

Trend 6: Securing operators' investments through smooth network evolution

Additionally, traditional bands will gradually converge to several limited bands to take benefit of economies of scale. And E-band will keep developing to unleash its potential capability.

Microwave backhaul has accelerated 5G construction and made great contributions to the digitalization of everyday life. Microwave transmission will continue to develop and meet future 5.5G and 6G backhaul requirements.

Abbreviation

Abbreviation	Full Name
TCO	Total Cost of Ownership
TTM	Time to Market
eMBB	Enhanced Mobile Broadband
mMTC	Massive Machine-Type Communications
uRLLC	Ultra-Reliable Low-Latency Communication
UCBC	Uplink Centric Broadband Communication
RTBC	Real-Time Broadband Communication
HCS	Harmonized Communication and Sensing
XPIC	Cross-Polarization Interference Cancellation
SDB	Super Dual Band
OPEX	Operational Expenditure
AR/VR	Augmented Reality Virtual Reality
CS	Channel Spacing
EIRP	Equivalent Isotropic Radiated Power
PA	Power Amplifier
QoS	Quality of Service
HQoS	Hierarchical Quality of Service
SLA	Service Level Agreement
V2X	Vehicle-to-everything
CA	Carrier Aggregation
MIMO	Multiple-Input Multiple-Output
TDM	Time Division Multiplexing
ACM	Adaptive Code and Modulation
UX	User Experience
RF	Radio Frequency
BBU	Baseband Unit
D-RAN	Distributed Radio Access Network
C-RAN	Centralized Radio Access Network
CPRI	Common Public Radio Interface

Huawei Technologies Co., Ltd.

Address: Huawei Industrial Base
Bantian, Longgang
Shenzhen 518129
People's Republic of China

Website: https://www.huawei.com