ETSI TR 103 712 V1.1.1 (2020-10)

Fixed Radio Systems;
New PtMP technologies and solutions
for microwave backhaul in 5G era

Reference

DTR/ATTM-0448

Keywords

5G, backhaul

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

Modal verbs terminology

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Executive summary

The 5th Generation of Access Network (5G) has raised new requirements for backhaul networks. Besides the traditional solutions using higher frequency bands e.g. W/D bands, which are suitable to transport multi-Gbit/s over several hundred meters due to large channel bandwidths but limited by almost flat gas attenuation and rain attenuation, a new PtMP structure is applicable when transmission distance is for example from 1 km to 5 km, when the room for the antennas is limited in the hub site and when it is not so easy to get higher frequency bands such as W/D band in some country/area.

The new PtMP structure operates within traditional frequency bands where block license is allowed for traditional PMP applications, such as 26/28/32/42 GHz, by using sectored multi-beam antennas to connect multiple leaf sites with a variety of multiplexing method/ multiple access method such as TDM/TDMA, FDM/FDMA, SDM/SDMA or any combinations of those above.

In the present document, the effectiveness of evolving new technologies enabling the new PtMP structure are discussed and addressed. These include: phase array antenna, beam-forming/beam nulling, side lobe interference mitigation, radiated test, etc.

Furthermore simulation results are provided to identify the appropriateness of new PtMP structure for backhaul networks with longer transmission distance, reduced required antenna number, high transmission capacity and adaptation to star-based topology in dense network area.

1 Scope

The present document discusses and addresses the effectiveness of evolving new technologies and new PtMP structures, including phase array antenna, beam-forming/beam nulling, side lobe interference mitigation, and radiated test to answer the challenges of the coming 5G backhaul network, in frequency bands above 50 GHz and lower frequency bands where PtMP/block license is allowed, such as 26/28/32/42 GHz.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ECC Report 173 (04-2018): "Fixed Service in Europe Current use and future trends".

[i.2] Recommendation ITU-R M.2083-0: "IMT Vision - Framework and overall objectives of the future development of IMT for 2020 and beyond".

[i.3] ETSI White Paper No. 25 (first edition): "Microwave and Millimetre-wave for 5G Transport".

[i.4] 3GPP TS 38.141-2 (V16.2.0): "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; NR; Base Station (BS) conformance testing Part 2: Radiated conformance testing".

[i.5] 3GPP TR 38.803 (V14.2.0): "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Study on new radio access technology: Radio Frequency (RF) and co-existence aspects".

[i.6] 3GPP TS 37.145-2 (V16.3.0): "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Active Antenna System (AAS) Base Station (BS) conformance testing; Part 2: radiated conformance testing".

[i.7] ETSI White Paper No. 15 (second edition): "mmWave Semiconductor Industry Technologies: Status and Evolution".

[i.8] ECC Report 282: "Point-to-Point Radio Links in the Frequency Ranges 92-114.25 GHz and 130-174.8 GHz".

[i.9] Recommendation ITU-R P.837-7: "Characteristics of precipitation for propagation modelling".

[i.10] Recommendation ITU-R P.530-17: "Propagation data and prediction methods required for the design of terrestrial line-of-sight systems".

[i.11] ETSI GR mWT 008: "millimetre Wave Transmission (mWT); Analysis of Spectrum, License Schemes and Network Scenarios in the D-band".

[i.12] ETSI GR mWT 018: "Analysis of Spectrum, License Schemes and Network Scenarios in the W-band".

[i.13] ECC Recommendation 18(01): "ECC Recommendation of 27 April 2018 on radio frequency channel/block arrangements for Fixed Service systems operating in the bands 130-134 GHz, 141-148.5 GHz, 151.5-164 GHz and 167-174.8 GHz".

[i.14] ECC Recommendation 18(02): "ECC Recommendation of 14 September 2018 on radio frequency channel/block arrangements for Fixed Service systems operating in the bands 92-94 GHz, 94.1-100 GHz, 102-109.5 GHz and 111.8-114.25 GHz".

[i.15] ECC Recommendation (11)01: "ECC Recommendation of 2 February 2011 on guidelines for assignment of frequency blocks for Fixed Wireless Systems in the bands 24.5-26.5 GHz, 27.5-29.5 GHz and 31.8-33.4 GHz".

[i.16] ECC Recommendation T/R 13-02: "Recommendation T/R of 1993 on preferred channel arrangements for fixed service systems in the frequency range 22.0-29.5 GHz, revised 15 May 2010 and amended 29 May 2019".

3 Definition of terms, symbols and abbreviations

3.1 Terms

Void.

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

5G fifth Generation of mobile networks
ADC A/D-Converter
BEM Block Edge Mask
CIR Committed Information Rate
CMOS Complementary Metal Oxide Semiconductor
DAC D/A-Converter
DPD Digital Pre-Distortion
DSP Digital Signal Processing
EIRP Equivalent Isotropically Radiated Power
FDD Frequency Division Duplex
FDM Frequency Division Multiplexing
FDMA Frequency Division Multiple Access
FSL Free Space Loss
IMT International Mobile Telecommunication
LOS Line Of Sight
MP Multi Point
PIR Peak Information Rate
PMP Point to Multi Point
QAM Quadrature Amplitude Modulation
QPSK Quadrature Phase Shift Keying
RF Radio Frequency
RPE Radiation Pattern Envelope
SDM Space Division Multiplexing
SDMA Space Division Multiple Access
SINR Signal to Interference and Noise Ratio
SNR Signal to Noise Ratio
TDD Time Division Duplex
TDM Time Division Multiplexing

TDMA	Time Division Multiple Access
XPIC	cross Polarization Interference Cancelling

4 New requirement from 5G to microwave backhaul

Mentioned by many administrations and companies, 5G (IMT-2020) has been initialized at the end of 2019 or in 2020 depending on different countries. As the latest mobile technology, 5G (IMT-2020) has raised new requirements to its backhaul networks, especially microwave backhaul. Figure 1 is the famous requirements of 5G (IMT-2020) network, described in Recommendation ITU-R M.2083-0 [i.2]. From the analysis of the figure, the following requirements to microwave backhaul can be seen.

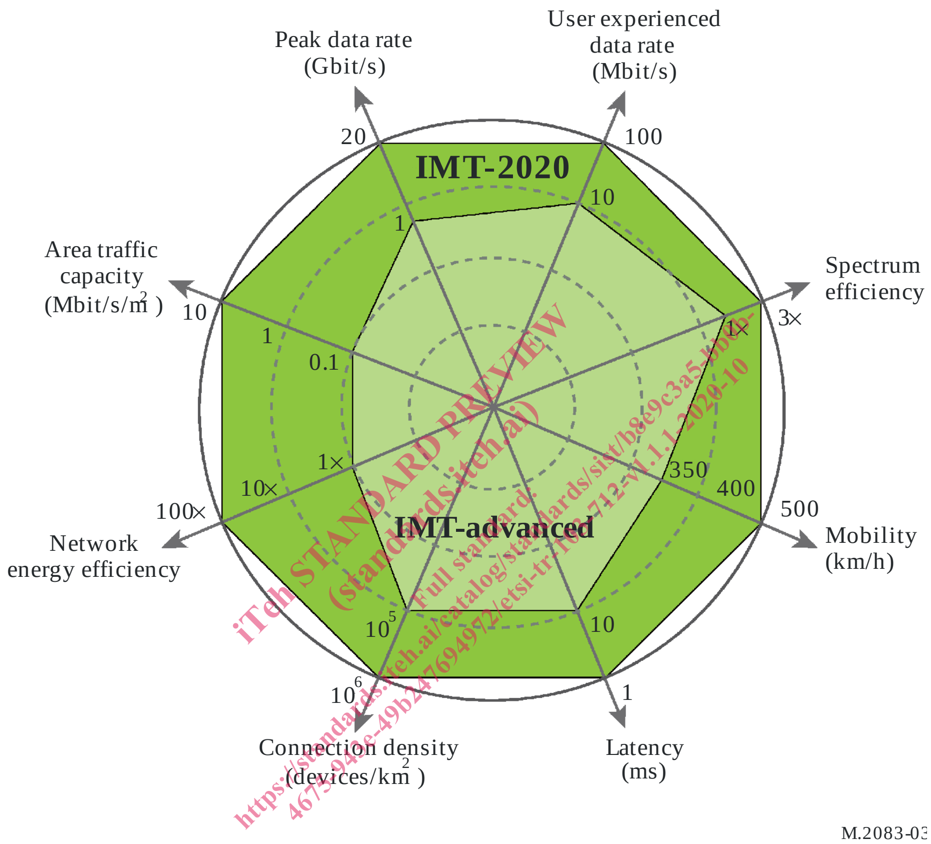

Figure 1: Enhancement of key capabilities from IMT-Advanced to IMT-2020

1) Capacity requirement. From Figure 1 above, it can be seen that the user experienced data rate will grow 10 times in 5G (IMT-2020) than in 4G (IMT-advanced). And furthermore, the peak data rate will even grow in a higher speed, 20 times in 5G (IMT-2020) than in 4G (IMT-advanced). And then researches have been done, from typical macro sites to small-cells, from dense area to urban area, from tail links to aggregation links, to determine the transport capacity requirement across the network. The result, showing the backhaul capacity requirement of 5G site, has been published in table 1, by ETSI mWT in ETSI White Paper No. 25 [i.3].

Table 1: Backhaul capacity requirement of 5G site

Site Type	Mobile spectrum and type	Cell type	Backhaul Capacity
Dense Urban	• LTE up to 50 MHz • 5G 200 MHz 16L MIMO ~4GHz • 5G ≥ 400 MHz 16L MIMO ~30GHz	Macro-cell: ~4GHz *and* ~30GHz Small-cell: ~4GHz *or* ~30GHz	>10 Gbps
Urban	• LTE up to 50 MHz • 5G 100 MHz 8L MIMO ~4GHz • 5G 200 MHz 8L MIMO ~30GHz	Macro-cell: ~4GHz Small-cell: ~4GHz *or* ~30GHz	<10 Gbps
Sub Urban	• LTE up to 50 MHz • 5G 100 MHz 8L MIMO ~4GHz	Macro-cell	<4 Gbps
Rural	• LTE up to 50 MHz • 5G 50 MHz 4L MIMO ~2GHz • 5G 20 MHz 4L MIMO ~700MHz	Macro-cell	<2 Gbps

2) Topology requirement. Also from Figure 1, area traffic capacity and connection density are both increasing in a large scale, which brings the site densification. Meanwhile, the fibre is penetrating to the edge of the network. The above two aspects have two main effects:

- Shortening of chains of cascaded radio links as the number of hops from microwave site to fibre is getting less, approaching the limit of one radio link to the fibre.

- Increase of the number of links originating from a hub site to the leaf sites.

In general, these considerations lead to define different network segments:

- Dense Urban and Urban scenarios: where previously the network was based on a hub-and-spoke kind of topology, there is a strong increase in fibre Points of Presence (PoP), from which a star topology of high capacity tail links originate; the fan-out of such hubs tends to be high. The depth of the MW/mmW network tends to become 1 to 1,5 hops from the fibre PoP.

- Sub-urban scenarios: the trend is the same, but here the MW/mmW network depth is going towards an average of 1,5 to 2 hops from the fibre PoP.

- Rural scenarios: here the variance will be greater due to the widely different geographical conditions, but it is expected that the average network depth should tend towards 2,5 hops from the fibre PoP.

- Mixed scenarios: in some places, it may happen that a small cluster of urban or suburban sites are situated at a certain distance from the fibre PoP, so that the MW/mmW link length for the aggregation link towards the PoP is not directly related to the cell radius.

As a result, the network topology, especially in dense area, is evolving from linear style to a star-based, high-capacity, and shorter distance style as shown in Figure 2. This kind of backhaul is expected to be characterized by variable behaviour, also closer to the access behaviour than for traditional backhaul. Traffic asymmetry, time variability, weather and style of living- dependent characteristics can be examples of possible sources of variability. Such new backhaul requirements could be possibly addressed by using links /network configurations other than point to point.

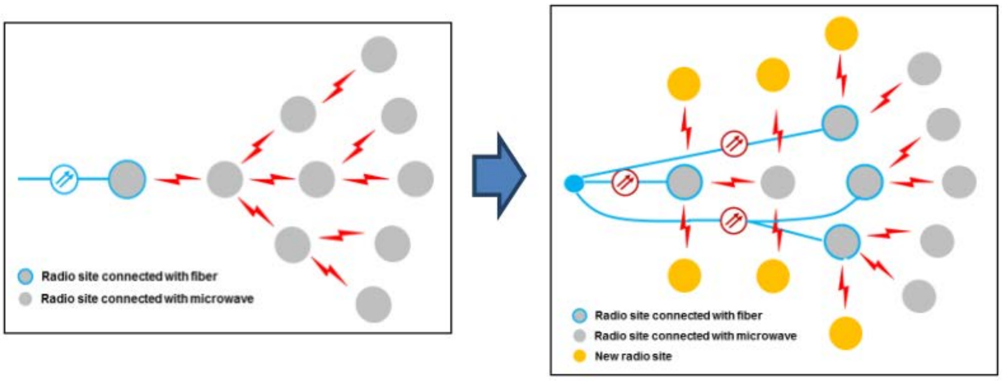

Figure 2: Topology evolution in the backhaul network

3) Mitigation of heavy burden of antenna on installation sites. Frequency resource is limited, and site resource for antennas is also limited. As for traditional PtP microwave service, each link will use one pair of parabolic antennas. As capacity increases and network topology evolves to star-based style, the number of links will increase at hub site, and then the number of antennas increases accordingly at hub site. As a result, more weight and more space are required for antenna installation site to accommodate the increasing antennas, as shown in Figure 3.

   However, the weight and space that the antenna installation site can provide is limited. In most countries, the number of antennas at the site is strictly constrained, and the application of adding new antennas on the site is also under stringent control. So the mitigation of heave burden of antenna installation site and easier installation of antennas should be taken into consideration, especially at the hub site in dense-populated area and installation over residential building.

Figure 3: More antennas on installation site

According to the analysis above, traditional PtP microwave system can hardly meet the new requirements. Along with the development of communication industry, there are several new technologies emerging now, which can facilitate the adaptation to the new requirements.

5 Key technologies to facilitate adaptation to the new requirements

5.1 Active phase array antenna

The active phase array antenna is an array of antenna elements designed to change the antenna radiation pattern in order to adjust the shape and direction of the beam. In an active phase array antenna, the RF signal from the transmitter is fed to the individual antenna with the correct phase relationship so that the radio waves from separate antennas adding together increase the radiation in a desired direction, while cancelling to suppress radiation in undesired directions. In a phased array, the power from the transmitter is fed to the antennas through beamforming technology described in clause 5.2 in the present document, which can alter the phase electronically, thus steering the beam combination of radio waves to a different direction.

An active phase array antenna contains antenna array and Digital Signal Processing (DSP) running algorithms, and then make it possible for the antenna to transmit and receive signals to perform adaptation in a desired way, shown in Figure 4. A typical block diagram of a T/R module for an antenna element in an active phase array antenna in shown in Figure 5.

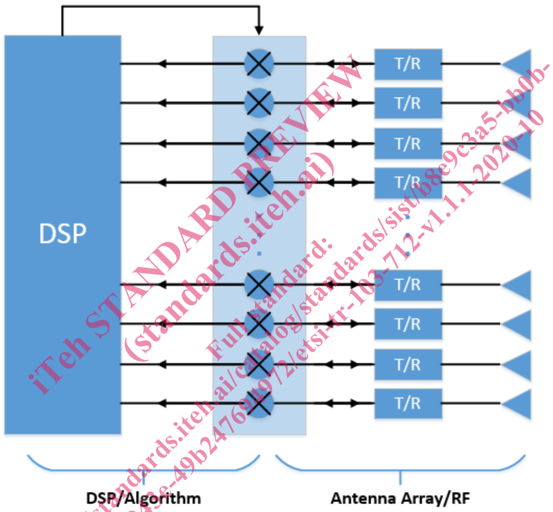

Figure 4: Block diagram of an active phase array antenna

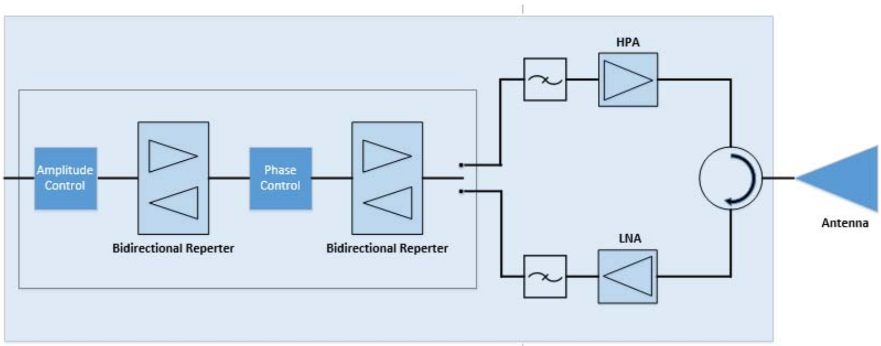

Figure 5: Block diagram of a T/R module for an antenna element in an active phase array antenna

As active antenna contains active components which are much smaller than passive components, active phase array antenna can integrate multiple array antennas inside as shown in Figure 6, with comparable size to the traditional parabolic antenna, and then make multi-antenna array implementation possible, thereby reducing the number of antennas at hub site.

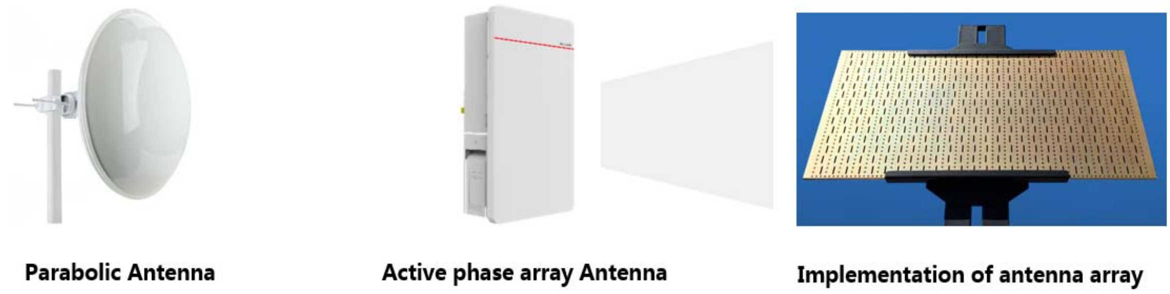

Figure 6: Parabolic antenna and integrated phase array antenna

5.2 Beamforming

Beamforming is a signal processing technology used to change the direction and the shape of radiation pattern of the array antenna for either signal transmission or signal reception. It is achieved by combining elements in the array in a way where signals at particular angles experience constructive interference and while others experience destructive interference.

Beamforming technology is used in the new PtMP structure introduced in clause 7 to automatically make alignment with hub site and leaf site. Figure 7 shows the internal diagram of beamforming. Multiple RF channel signals are transmitted at the same time and are combined in the air. The amplifier and phase shifter of each RF channel could be adjusted, in order to change the shape and phase of the beam, and then change the pointing direction of the beam combination.

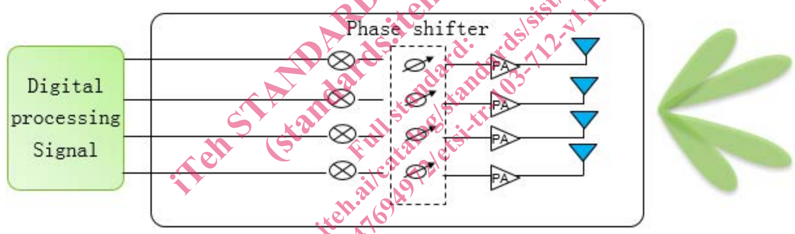

Figure 7: Internal diagram of beamforming

Figure 8 shows the operation interface and illustration of beamforming. If the four array antennas are kept with the same phase in the left figure, the combination beam just goes straight. If the phase of four array antennas are changed in the right figure, the combination beam will change its direction accordingly.

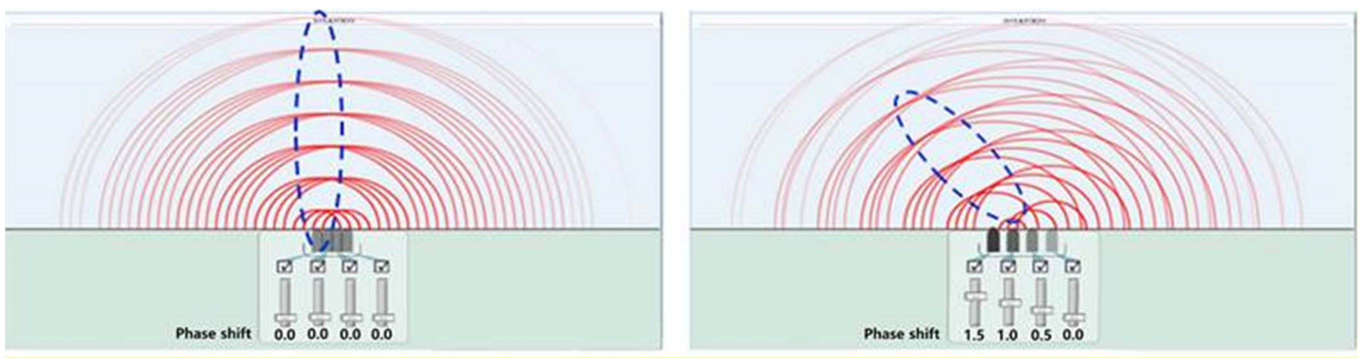

Figure 8: Operation interface and illustration of beamforming