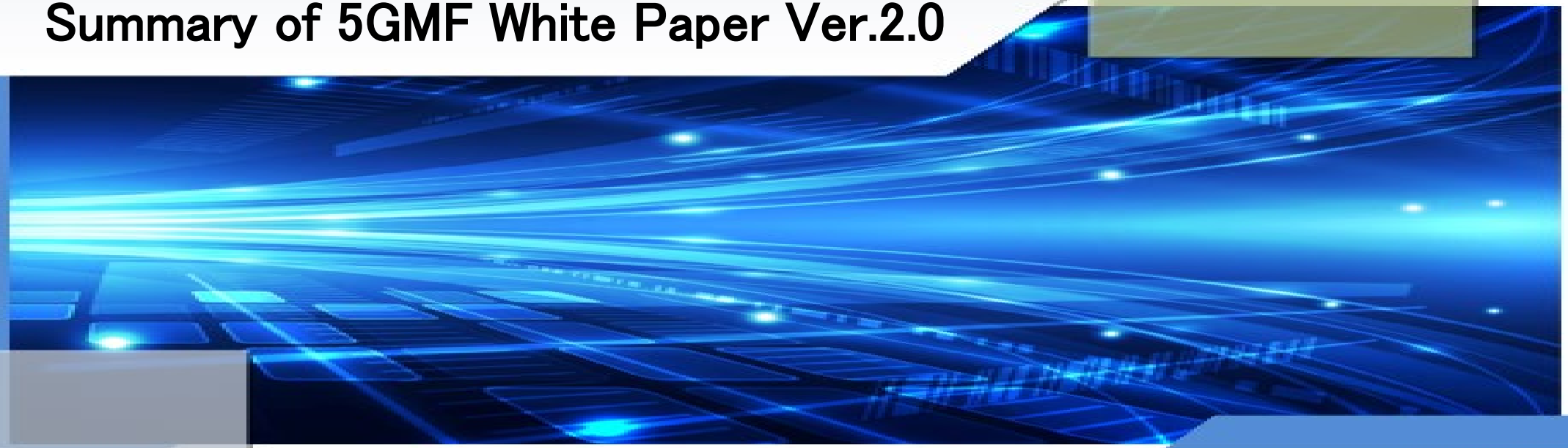
The Fifth Generation Mobile Communications Promotion Forum（5GMF）
Millimeter Wave Promotion Ad Hoc
Summary of 5GMF White Paper Ver.2.0



5GMF Strategy & Planning Committee

Millimeter Wave Promotion Ad Hoc

Outline of Millimeter Wave Promotion Ad Hoc Activities

Purpose : To contribute to industrial use and the resolution of social issues, promote the spread of millimeter wave as a prerequisite for new 5G/6G frequency allocation, and promote international initiatives related to millimeter wave in Japan.

Establishment : January 20, 2023

Participating companies: 29：Includes 2 observers. A total of 59 members including concerned persons.

Major activities :
- Monthly regular meetings : Discussions for the millimeter wave promoting (Discussion results are reflected in the white paper)/Preparation of events for promotion, etc.
- White paper publication: March 31, 2023 Version 1.0 , July 3, 2023 Version 2.0 released on the 5GMF website.
- Promotion activities at events:
  1) Participation in Wireless Technology Park (May 24–26 at Tokyo Big Sight)
     → Exhibition : Exhibits related to millimeter waves by 8 Ad Hoc member companies
     → Holding a seminar : Lecture for promotion of millimeter waves (5/24 at Tokyo Big Sight Exhibition Hall)
  2) CEATEC2023 5G Special day V (October 18 at Makuhari Messe International Exhibition Hall)
     → Millimeter wave Promotion Global Summit (TBD)

CEATEC : Combined Exhibition of Advanced Technologies

Item	FY2022				FY2023											
	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
Millimeter wave Promotion Ad Hoc meetings	Prep	△ 1st 1/20	△ 2nd 2/21	△ 3rd 3/17	△ 4th 4/18		△ 5th 6/2	△ 6th 6/26	△ 7th 7/19	→	Monthly meetings					
Promotion Events					△(5/11) 5G-ACIA WS		△(5/24-26) WTP (Tokyo Big Sight)				△(10/17-20) CEATEC(Makuhari Messe)	△(10/30-31) Global 5G Event#10 (Korea)				
White Paper milestones				△ Ver.1.0(3/31)				△ Ver.2.0(7/3)								

White Paper “5G Enhancement with Millimeter Wave Deployment” Ver.2.0

White paper “5G Enhancement with Millimeter Wave Deployment”Version 2.0 released on July 3rd, 2023
5GMF Website：https://5gmf.jp/en/news/3029/

Chapter setting (96 pages in total)

Chapter	Contents
–	Introduction
1	Clarifying the need for millimeter wave
2	Trends in Japan and overseas
3	Challenges for widespread use of millimeter wave
4	Millimeter wave technology overview
5	Performance evaluation
6	Millimeter wave introduction scenario
7	Affinity with local 5G
8	Millimeter wave use case
9	Existing solutions for millimeter wave dissemination
10	Millimeter wave business outlook
–	Conclusion

Major changes from Version 1.0

- Added latest information.
- Improved readability by adding figures, etc.
- Inclusion of other 5G-related activity literature.(e.g., 5G Business Design WG Report)
- New addition of millimeter wave business outlook (Chapter 10).

White Paper

1. Clarifying the need for millimeter wave

☐ Clarifying the need for millimeter wave from the following 5 points

- ■ Securing frequency resources for future traffic increases
- ■ Support for future high-speed, large-capacity, low-latency services
- ■ Economy, energy efficiency
- ■ Developing new use cases
- ■ A foothold for additional frequency allocations in the future

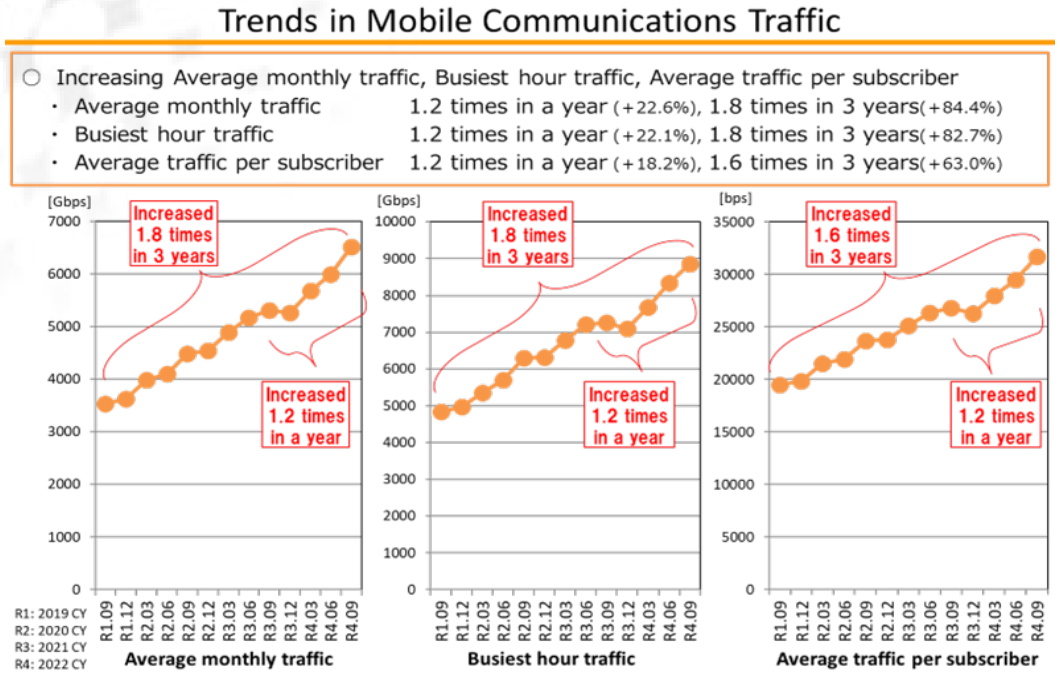


Fig. 1-1 Changes in mobile communication traffic
Ministry of Internal Affairs and Communications, Information & Communications Statistics Database
https://www.soumu.go.jp/johotsusintokei/field/data/gt010602.pdf

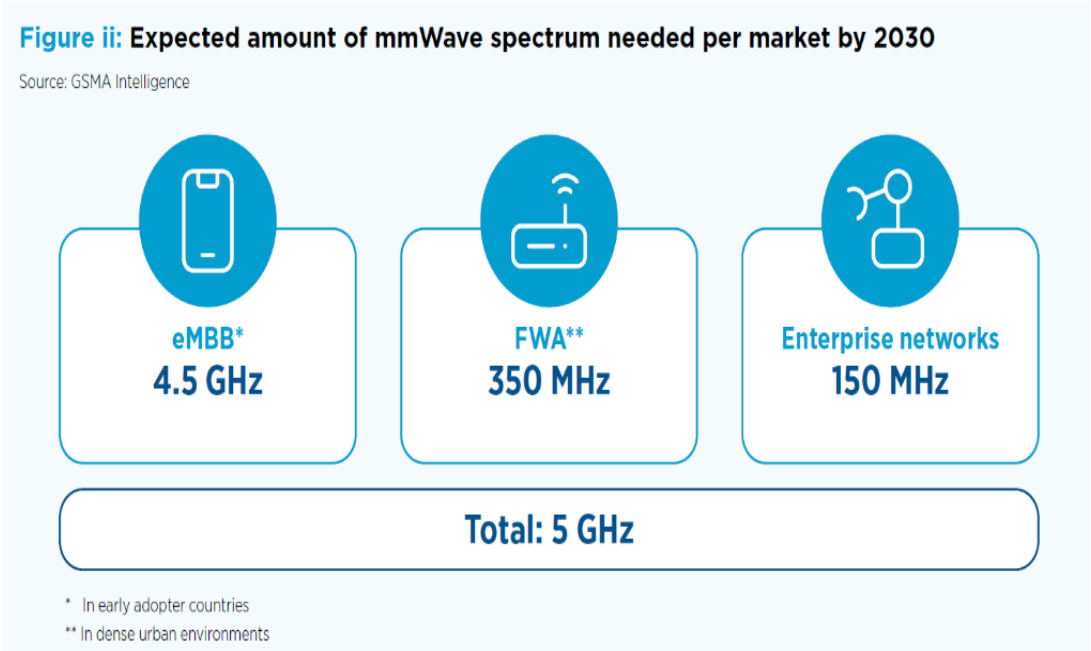


Fig. 1-2 Millimeter wave frequency demand forecast up to 2030
GSMA Vision 2030: mmWave Spectrum Needs, Full Report
https://www.gsma.com/spectrum/wp-content/uploads/2022/06/5G-mmWave-Spectrum.pdf

2. Trends in Japan and overseas

- While 5G services are progressing around the world, the use of millimeter waves remains limited despite progress in frequency allocation.
- Trends in millimeter wave in Japan and overseas are summarized from the following points.
  - Frequency allocation
  - Commencement status of millimeter wave commercial services, etc.
  - Status of millimeter wave terminals
  - 3GPP standardization trends

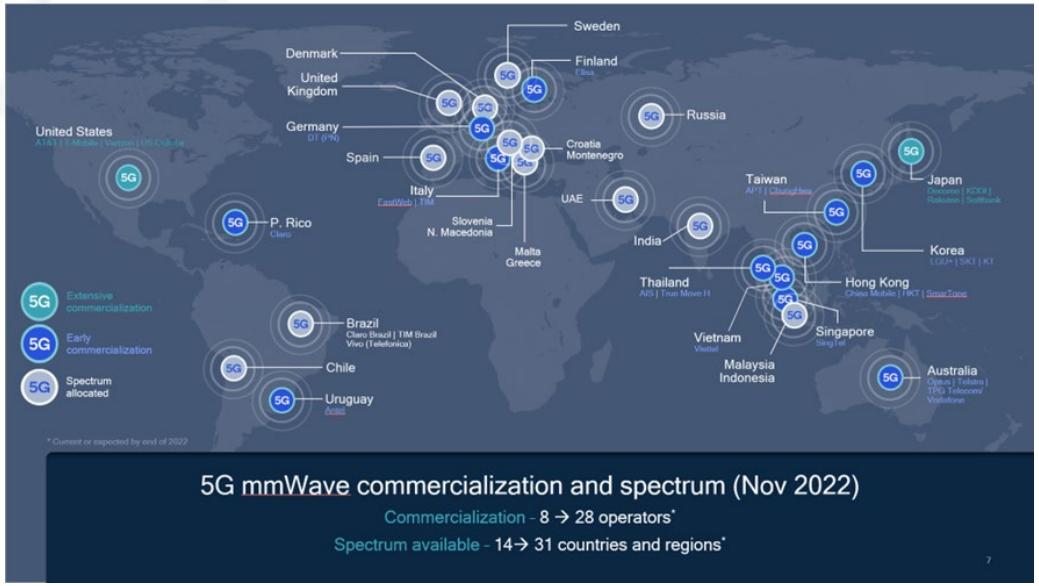


Fig. 2-1 5G millimeter wave commercialization and spectrum (as of November 2022)
Qualcomm Japan, 5G Business Design WG 2nd meeting Qualcomm materials.
https://www.soumu.go.jp/main_content/000860192.pdf

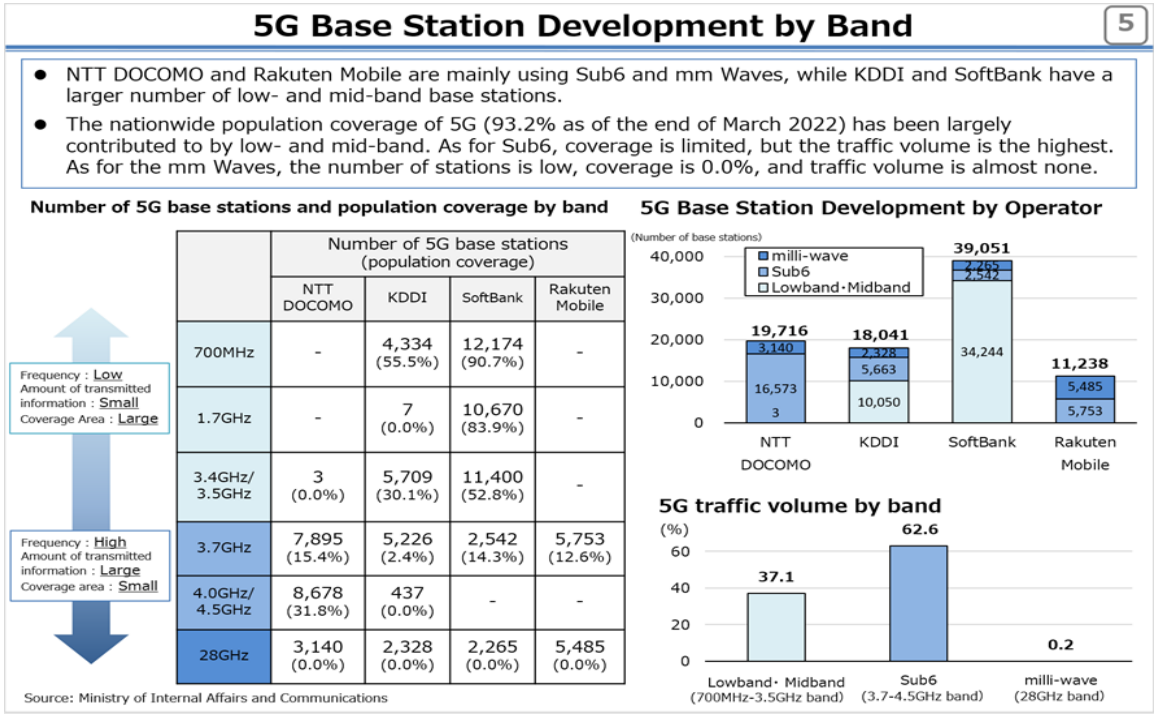


Fig. 2-4 5G Base Station Development by band
Ministry of Internal Affairs and Communications, 5G Business Design Working Group (3rd) handout
https://www.soumu.go.jp/main_content/000860636.pdf

3. Challenges for widespread use of millimeter wave

- Currently the traffic accommodation ratio of millimeter wave is extremely low because the 5G area is mainly developed around low band, mid band, and sub6.
- The report analyzes the challenges in improving the millimeter wave situation from the following 4 points. At the same time, it explains that all of the issues are interconnected and that the current situation is creating a negative chain reaction.
  - Millimeter wave introduction area
  - Base station equipment for millimeter wave
  - Millimeter wave terminal
  - Millimeter wave use cases
- The situation and challenges of millimeter waves are not limited to Japan, but are global issues.
- In the future, it will be extremely important to share millimeter wave issues and solutions globally and build a global ecosystem for its widespread use in Japan.

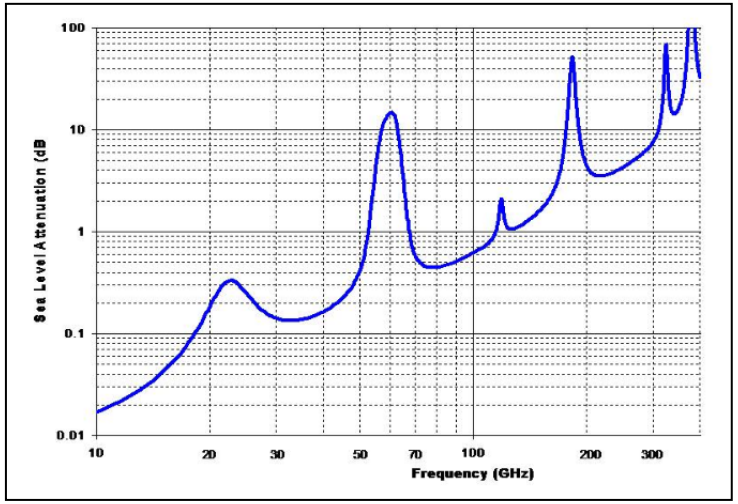


Fig. 3-1 Atmospheric and molecular absorption

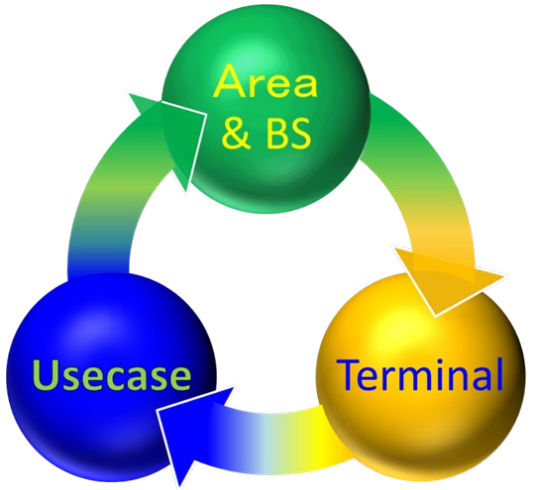


Fig. 3-3 Cross-correlation and positive chain for wide spread of mm-wave

4. Millimeter wave technology overview

- Chapter 4 provides an overview of the technologies that are considered effective in solving the problems of widespread use of millimeter wave, as description in Chapter 3, and millimeter wave related technologies that have been specified or are being considered for specification in standardization such as 3GPP, as shown in the figure below.

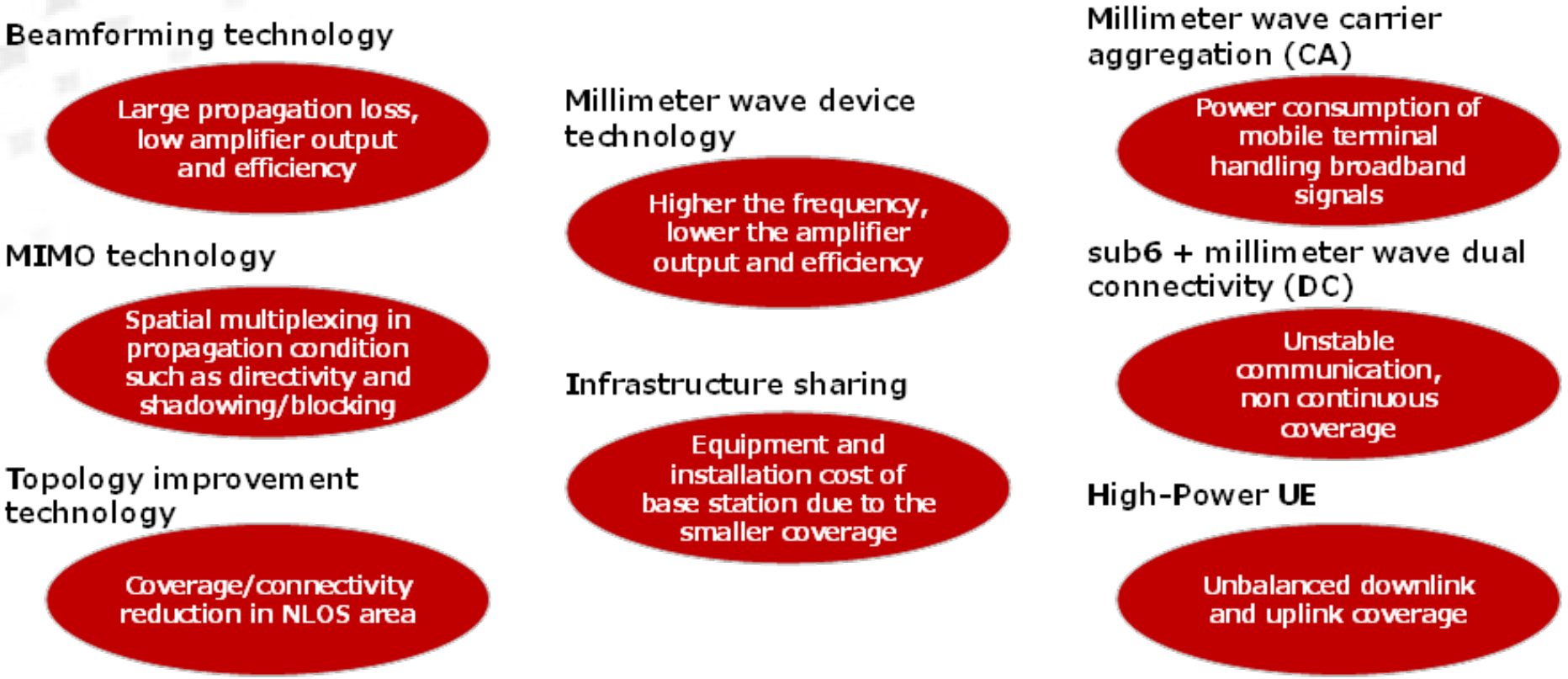
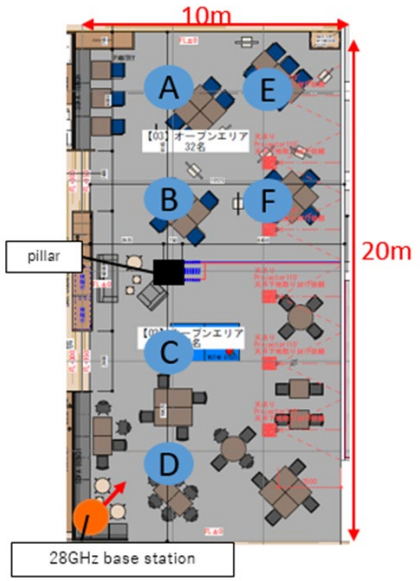


Fig. 4–1 Millimeter wave technology and challenges to be solved

5. Performance evaluation

- Chapter 5 introduces experimental and measurement results using 5G millimeter wave. The results demonstrate that millimeter wave can achieve extremely high throughput and low latency performance and can be utilized in various environments including non-line-of-sight scenario as shown below.
  - Measurement of 5G millimeter wave throughput and latency performance (one-to-one communication, ideal environment)
    - Achieves throughput of 1 Gbps or higher and maintains Ping RTT of 7 ms or less even in a low received power environment.
  - 5G millimeter wave indoor environment measurement
    - Not only high throughput can be obtained near the base station, but the same throughput as near the base station can be achieved even in places where there is blocking from pillars.
  - 5G millimeter wave outdoor environment measurement
    - Formation of an area where millimeter-wave communications is possible within a range of about 100 m.
    - By using millimeter wave, the maximum downlink throughput is about 2 Gbps, and the average is about 1 Gbps. The throughput is roughly four times that of Sub6 and ten times that of LTE.
  - 5G millimeter wave Challenges and Solutions
    - Research and development efforts such as Repeaters, RIS, and applications of Dielectric waveguides.



A : 1666.54Mbps
B : 1586.91Mbps
C : 1851.24Mbps
D : 1842.28Mbps
E : 1602.87Mbps
F : 1643.85Mbps

Fig. 5-4 Indoor measurement of 5G mm Wave throughput

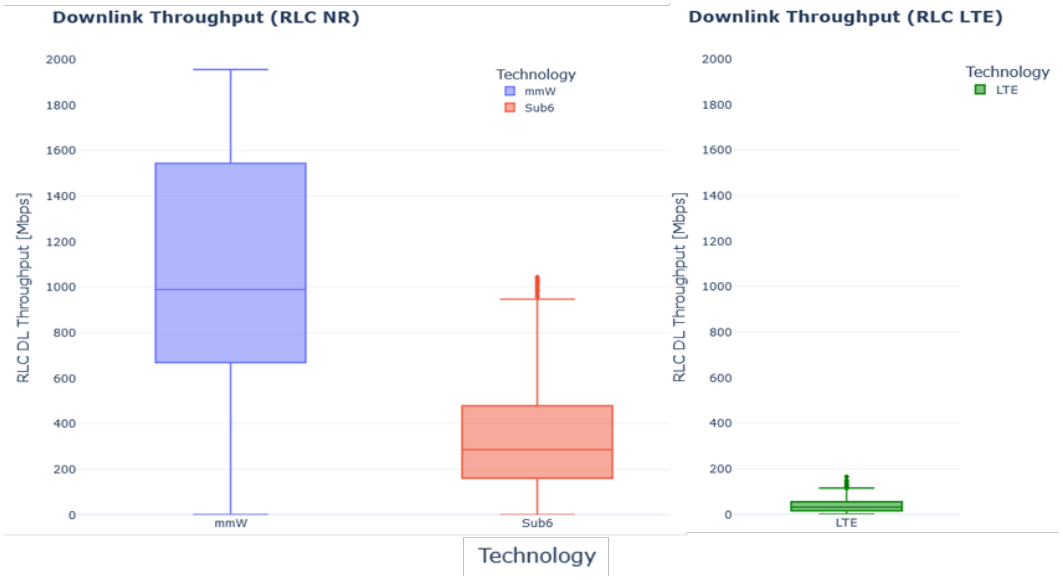


Fig. 5-8 Outdoor walking measurement of 5G mm-wave downlink throughput

6. Millimeter wave introduction scenario

- Since millimeter wave is in a particularly high frequency band, it is important to make use of their characteristics.
- Although the cell radius becomes relatively small due to the large propagation loss, it is effective for applications in narrow and closed areas.
- High-speed and large-capacity capability due to a large frequency bandwidth is effective in places where heavy traffic is generated and high-speed services are required.
- Based on these characteristics, the following millimeter wave introduction scenarios can be considered.
  1) Hotspots, stadiums, event venues
  2) Office, indoor
  3) Private NW/Local 5G
  4) Urban sidewalks, roads and intersections
  5) FWA

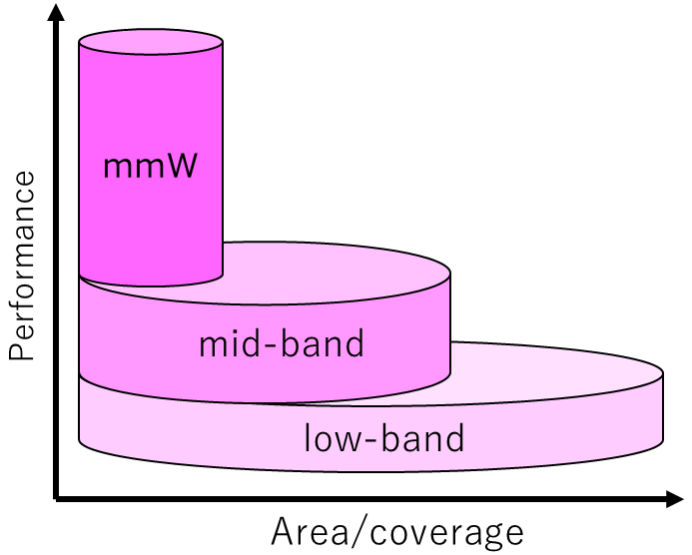


Fig. 6-1 Image of proper use of frequency bands

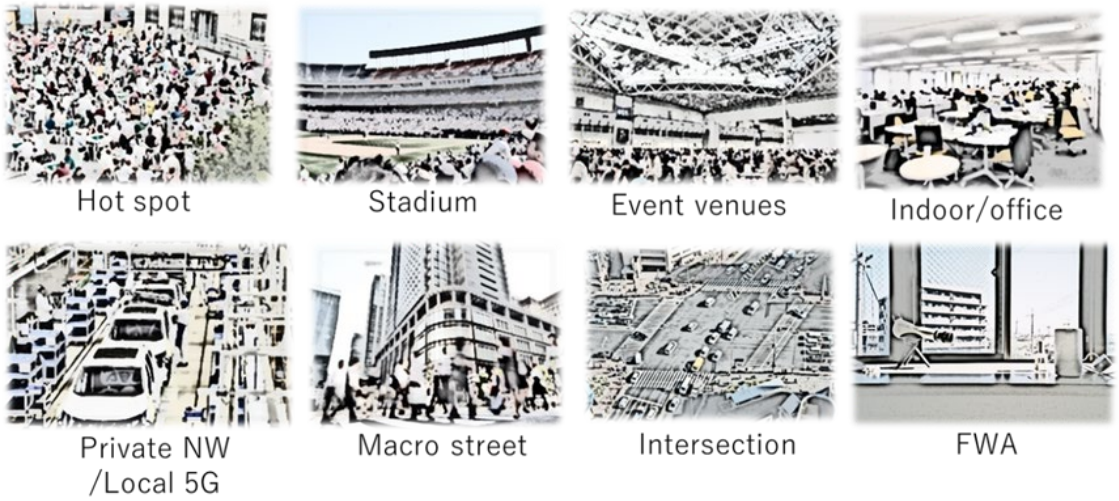


Fig. 6-2 Example of millimeter wave introduction scenarios

7. Affinity with local 5G

- Local 5G is assumed that many terminals will be used intensively at the same time in a relatively small area, it can be said that millimeter waves which can handle ultra-wideband, have a very high affinity with local 5G.
- Chapter 7 describes the background and the situation of widespread of local 5G, as well as the limited use of millimeter waves and the issues involved. On the other hand, the effectiveness of millimeter wave utilization in local 5G is explained from the following points.
  - Area scale and radio wave characteristics
  - Communication capacity and communication demand
  - Compact system scale (ultra-low latency)

  } Also explains how to distinguish between millimeter waves and sub6 and the usefulness of their combinations.

Fig.7-4 Image of local 5G, which is expected to be used in various places such as “in the city”

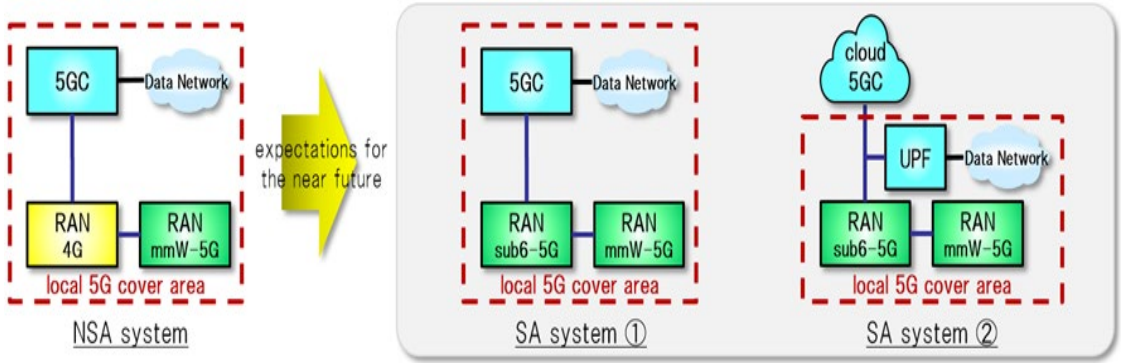


Fig. 7-6 System configuration example for local 5G millimeter wave

8. Millimeter wave use case

- Chapter 8 is divided into the following three categories. The contents are not limited to those that have already been introduced commercially using millimeter waves and those that are currently undergoing demonstration experiments, but also specific use cases that utilize millimeter waves that are considered effective in the future.
  - Increase capacity and speed in facilities such as stadiums where many people gather (eMBB)
    - NFL Finals Exclusive Experience
    - New watching experience in soccer
    - Exclusive experience at the theater
    - Individually optimized signage for AR glasses
  - FTTH alternative with FWA
    - Alternative to FTTH using 3.7GHz, 28GHz, and 39GHz 5G networks for mobile use in urban areas, etc.
    - Eliminate the digital divide in rural areas
  - Enterprise networks
    - Manufacturing industry：Sharing machine failure points from a remote location, Quality control in flash memory manufacturing factories, etc.
    - Automobiles：Application to autonomous driving
    - Medical care：Introduction to medical research facilities, Transmission of high-definition images between hospitals, Robot replaces sterilization work
    - Media：Broadcasting of news and sports by portable high-quality video transmission equipment

Fig 8-3 Smart glasses and experience image

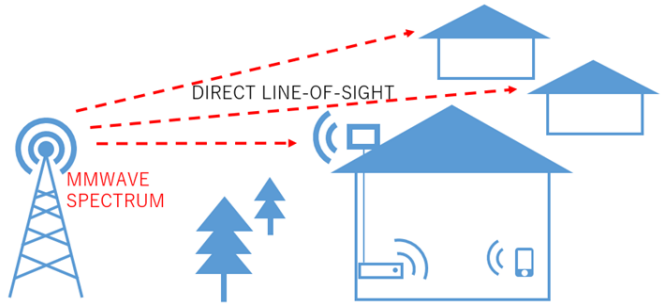


Fig 8-5 Image of provision of FWA

Fig 8-6 Image of remote work support

- In the future, it is expected to create a total use case that combines not only the use of millimeter wave, but also various elements such as SA, network slicing, MEC, AI, XR, Metaverse, etc.

9. Existing solutions for millimeter wave dissemination

- In order to disseminate millimeter wave, it is important to be able to procure enough devices and measuring instruments for developing and manufacturing the equipment that constitutes the network.
- This chapter introduces solutions for terminals, base stations, antennas, measuring instruments, etc. based on actual product examples.
- As an appendix, "List of existing solutions for millimeter wave discrimination reference information links" is posted. Information on each company providing the solution can be referenced.

Fig. 9-1 Millimeter Wave CPE (by Nokia)

Fig. 9-2 Smartphones that support high-quality video transmission that supports millimeter wave (by Sony)

Fig. 9-3 Appearance of millimeter wave RU (by NEC, Fujitsu)

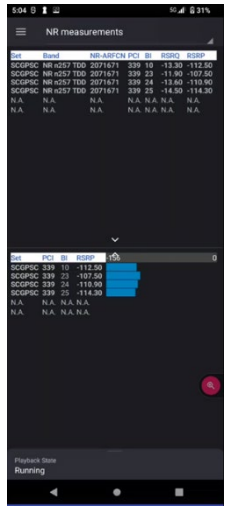


Fig. 9-7 FR2 monitor example on smart phone by Keysight Nemo Handy

Fig. 9-8 Network Installation and Maintenance Test Tools and Network Performance Capacity Testers (by VIAVI)

Fig. 9-9 Millimeter Wave Repeater (by DX Antenna)

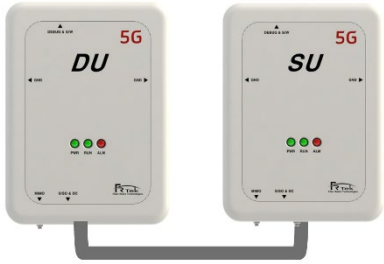


Fig. 9-10 Millimeter wave repeater consisting of two enclosures, a donor unit and a service unit (by FR-Tech)

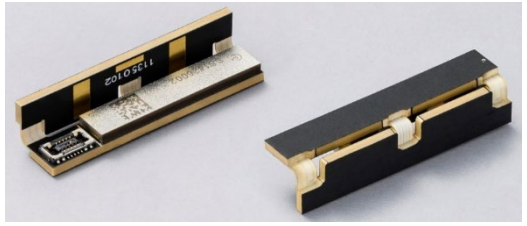


Fig. 9-4 L-shape Antenna Array Integrated Module (by Murata)

Fig. 9-6 Global Millimeter Wave band antenna modules (24 – 29 GHz & 39 – 41 GHz) (by Qualcomm)

10. Millimeter wave business outlook

- Solutions for millimeter waves are being in place, and the development of 5G utilizing these is desired. The key to future business outlook is how to convert the negative spiral of millimeter wave penetration into a positive spiral.
- This chapter summarized possible efforts to transform into a positive chain reaction as following points.
  - Area development
    - sub6- millimeter wave NR-DC, infrastructure sharing, subsidy support in disadvantaged areas, development of system that enables the use of repeaters and high-power terminals, speeding up and simplifying licensing procedures, millimeter wave for local 5G＋implementation of millimeter wave standalone operation
  - Promoting and supporting 5G/millimeter wave to other industries
    - Activities to appeal the effectiveness and use cases of 5G/millimeter waves to other industries, support for system introduction, and cooperation among mobile communication related ministries, companies, and organizations as a cooperative areas
  - Providing a place to promote the spread of millimeter wave
    - Prepare a place where the benefits of millimeter wave can be tested and demonstrated as to promote open innovation. It can participate for companies, organizations, and academia in all industries in these forums without charge and operate them as cooperative areas
    - For consumer users, for consumer services developers, for local 5G developers
  - 5G wireless human resource development
    - Human resources development on the 5G/millimeter wave providers as well as human resources on the user side. Develop and secure human resources who can connect and combine users, companies, universities, etc.

Conclusion

- 5GMF released white paper version 2.0 on 5GMF website on July 3rd.
- 5GMF will continue to carry out activities to promote the spread of millimeter waves in Japan and overseas, including the promotion of the content of the white paper.
  - Plans to open millimeter wave media : Established information dissemination site for domestic and overseas, introduction of white papers, introduction of related industries, etc.
  - Plans for workshops, and lectures, etc. which are held or planned for domestic related industries and academic societies by using white paper contents.
  - Participating and giving lectures at overseas events in Europe, the United States, Asia, etc. Promote collaboration and cooperation with stakeholders globally through holding international conferences in Japan, etc.
  - Plan and implement specific activities to promote the spread of millimeter waves in accordance with the newly added “Millimeter wave business outlook” in the 2.0 version of the white paper.