| 1st-Classification | 2nd-classification | Proposer | Contents | 3rd-Classification | Motion / Communication Time | Group |
|---|---|---|---|---|---|---|
| Downlink only | Links established at a particular location | NICT, Chiba IT | KIOSK Downloading | A-1 | A-1 Wideband<br>A-2 Low Latency<br>A-3 Beam Tracking<br><br>In addition to classification (1-,2-,3), if it can be summarized from the viewpoint of the movement of the terminal (whether the link is fixed or tracking is necessary), it can be summarized as a separate use case.<br>(The items in red are from another group, so we will discuss them in duplicate. If they don't come together after discussion, you can remove them or add other items. The ones in blue are those that the terminal etc. may need to follow the movement.)<br><br>Use cases with different performance requirements in terms of communication time and reliability are summarized as separate use cases. | A |
| | | Kitazato Univ. | Temporary broadband line installation | A-1 | | |
| | | Kyushu Univ. | Downloading large amounts of data while passing through hotspots | A-1 | | |
| | | NEC SNS, Sumitomo Bakelite | Radio for automatic operation | A-3 | | |
| | | Anritsu | Uncompressed high-resolution video distribution service | A-1 | | |
| High-capacity bi-directional links<br>+<br>Acquisition of sensing information such as images | Large amounts of data such as images and movies are exchanged and manipulated by humans | Keio Univ. | Wireless Brain Machine Interface (BMI) technology | A-3 | | |
| | | NEC System | High-quality telemedicine | A-2 | | |
| | | Sumitomo Bakelite | High-quality telemedicine | A-2 | | |
| | | Keysight, Keio Univ. | Remote control in mission-critical fields with high-performance VR/AR goggles | A-2 | | |
| | | Kyushu Univ. | Remote control of equipment while viewing high-definition images | A-2 | | |
| | | Kyushu Univ., Chiba IT | Aerial work using drones, drone control, video data transmission | A-3 | | |
| | Use of large volume data for automatic driving, etc. | Waseda Univ. | Wireless communication use of radar signals from vehicle-mounted radar, etc. | | | B |
| | | NEC SNS | Radio for automatic driving | | | |
| | | Sumitomo Bakelite | Radio for automatic driving | | | |
| | | Kyushu Univ., Chiba IT, and Tokyo IT | Aerial work using drones, drone control, video data transmission, and communications between drones | | | |
| | | Kyushu Univ. | Downloading large amounts of data while passing through hotspots | | | |
| | Information exchange without human intervention | Chiba IT | M2M (Robot to Robot, Robot to Facility / Car, etc.) | | | |
| | | Anritsu | High-resolution uncompressed image transmission, environment monitoring and sensing at smart factories | | | |
| For existing wireless networks Expansion and replacement | | Maxell | Data center | | | C |
| | | Chiba IT | Railway radio | | | |
| | | NEC SNS | Last one hop, inter-building communication | | | |
| | | Tokyo IT | Laying Internet infrastructure in remote areas and developing countries | | | |
| | | Softbank | Replacement of optical fiber networks | | | |
| | | Chiba IT | Beam control to maintain wireless communication | | | |
| Use of wireless signal for sensing | | Chiba IT | Use of wireless signal for sensing | | | D |

# Use Case A Group

# Use Case A : Volumetric Data Transmission

Communication type :

- For telepresence technology that provides the same effect as being in the field even in remote areas, volumetric sensor data relating to people and the environment is wirelessly transmitted through a large-capacity network.
- Spatial information such as multi-view images obtained by arraying cameras and diffraction images obtained by radar sonar obtained by arraying transducers becomes volumetric data, which increases the amount of data.
- In order to acquire or transmit information that changes in real time without preventing people from moving freely (on foot, in a car, etc.), it is necessary to establish a wireless connection with low delay while tracking beams.
- Even in fixed use situations such as treatment rooms and studios, wireless access to a large array of cameras and transducers is important for building lightweight and flexible systems.
- Communication distance : several tens of meters or less
- P2P Network

Data rate, delay, etc. :

- Downlink : 100 Gbps
- Uplink : about 10 Gbps, separate line available
- Delay time : 1 ms or less Setup time : 1 ms or less

- 8K, 8bit, 60 fps → 48 Gbps without compression If you have four views, it's 192 Gbps. You can increase the number of views by lowering other values or adding compression.
- Ultrasonic echo requires a sampling rate several orders of magnitude higher than that in the audible range, so a data rate of the Gbps class is required. (It is not clear whether such a large capacity is required in the audible range. Assuming 192kHz/24bit as a high-resolution sound source, it is 5 Mbps without compression, so 5 Gbps if 1000 channels are available.)
- Papers on brain measurement technology published as of 2021
  Ultrasonic echo (non-invasive type) : 128 ch × 15.6 MHz × 14 bit → 28 Gbps in non-compression
  S. L. Norman et al., Neuron 109 (2021).

  Electrode signal (invasive type) : 3072 ch × 18.6 kHz × 10 bit → 0.6 Gbps
  E. Musk, J. Med. Internet Res. 21 (2019)

**<u>Example Volumetric Data</u>**

Multi-viewpoint high-definition images and wide-color range data
Multi-array acoustic transducer data
Brain and biometric data

**Use Case A-1 : Remote Control**
**Use Case A-2 : Telemedicine**
**Use Case A-3 : Biometric**

# Use Case A-1 : Remote Control

Communication type :

- Realization of remote control in mission-critical fields using volumetric data from multiple arrayed cameras and transducers.
- Communication between the remotely controlled object and the control terminal (direct or indirect)
- The terminal is fixed or walking.
- The remotely controlled object is fixed or moving (moving speed ~ 1-10m/s).
- Range : several meters to several hundred meters (worldwide in combination with wired network)
- Terahertz communication part is expected.
- P2P Network

Data rate, delay, etc. :

- Downlink : 10-100Gbps
- Uplinks : control line only
- Delay time : 1 ms or less. In addition to network delay time, low-delay video processing is required.
- Setup time : less than a few ms

Other performance requirements :

- High reliability is required for both data and control lines. Low delay is also required.
- Beam tracking is required when the remote control target is moving.
- Security. Anti-hacking

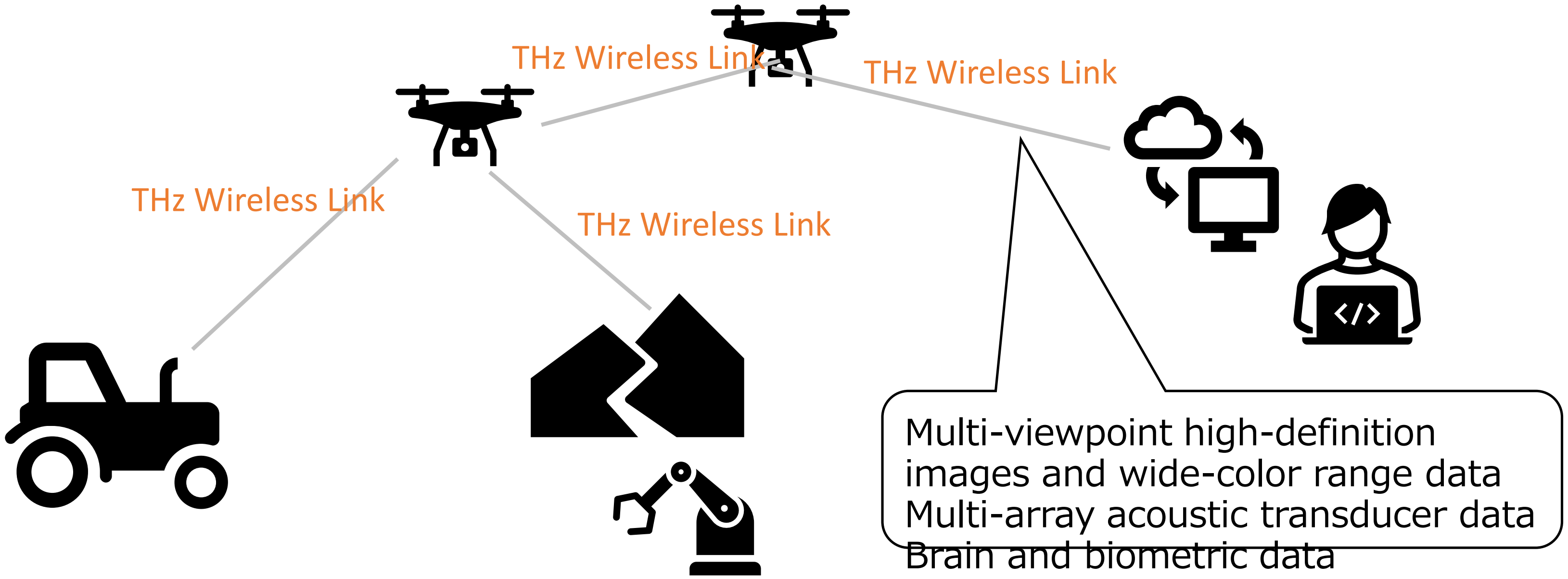
**Detailed use cases and characteristics :**

- For robot work at disaster sites and dangerous locations.
- Remote control of construction machinery and agricultural machinery.
- Detailed observation of sites and objects is essential. With the large volume of data obtained by mounting a large number of arrayed cameras and acoustic transducers, etc., the texture and internal structure of objects can be recognized with the ability exceeding human visual observation.
- Improve productivity while making up for operator shortages due to the declining birthrate and aging population.
  In a field where there are no fixed base stations, the terahertz wave beam may be relayed from the field to the base stations via a plurality of relay drones. This will improve productivity while making up for the shortage of operators due to the declining birthrate and aging population.

# Use Case A-1 : Remote Control

Summary :

- By using volumetric data from a large array of cameras and transducers, it is possible to recognize the texture and internal structure of an object with a capability that surpasses human vision.
- Low-voltage compressed signals are transmitted in order to transmit full-spec 8K video without delay.
- Robot operation at disaster sites and dangerous locations, remote control of construction equipment and agricultural machinery.
- By transmitting 8K images to smart goggles (VR display, AI assist function, etc.) connected to the flight control terminal by terahertz radio, telepresence as if you are flying on the spot is provided.
- The video delay tolerance of the entire system is 1 ms or less (by making it about 1/10 of the human reaction speed of 10 ms, it becomes possible to control without discomfort).
- In a field where there are no fixed base stations, the terahertz wave beam may be relayed from the field to the base stations via a plurality of relay drones. This will improve productivity while making up for the shortage of operators due to the declining birthrate and aging population.



# Use Case A-2 : Telemedicine

Communication type :

- Realization of remote surgery and remote diagnosis using volumetric data from a large number of arrayed cameras and transducers.
- Communication (direct or indirect) between the remote control object and the control terminal
- The terminal is fixed or walking.
- Remote-controlled object is fixed or moving (moving speed ~ 1-10m/s)
- Range : several meters to several hundred meters (worldwide in combination with wired network)
- Terahertz communication part is expected.
- P2P Network

Data rate, delay, etc. :

- Downlink : 10-100Gbps
- Uplinks : 4G-5G lines
- Delay time : 1 ms or less. In addition to network delay time, low-delay video processing is required.
- Setup time : less than a few ms

Other performance requirements :

- High reliability is required for both data and control lines. Low delay is also required.
- Beam tracking is required when the remote control target is moving.
- Security. Anti-hacking

**Detailed use cases and characteristics :**

1. Telesurgery

・ In the medical field, high resolution, wide color range and multi-gradation expression brought about by 8K video transmission are expected.

- 8K video signals need to be transmitted with low delay, and communication speeds of several 10 Gbps are required.

・ 100 Gbps is required to transmit multiple images when transmitting VR display, images with different angles, and images outside the visible range at the same time.

・ Video data is complemented by the visualization of sound sources with high-dimensional sound data.

・ It is also possible to share images with multiple people.

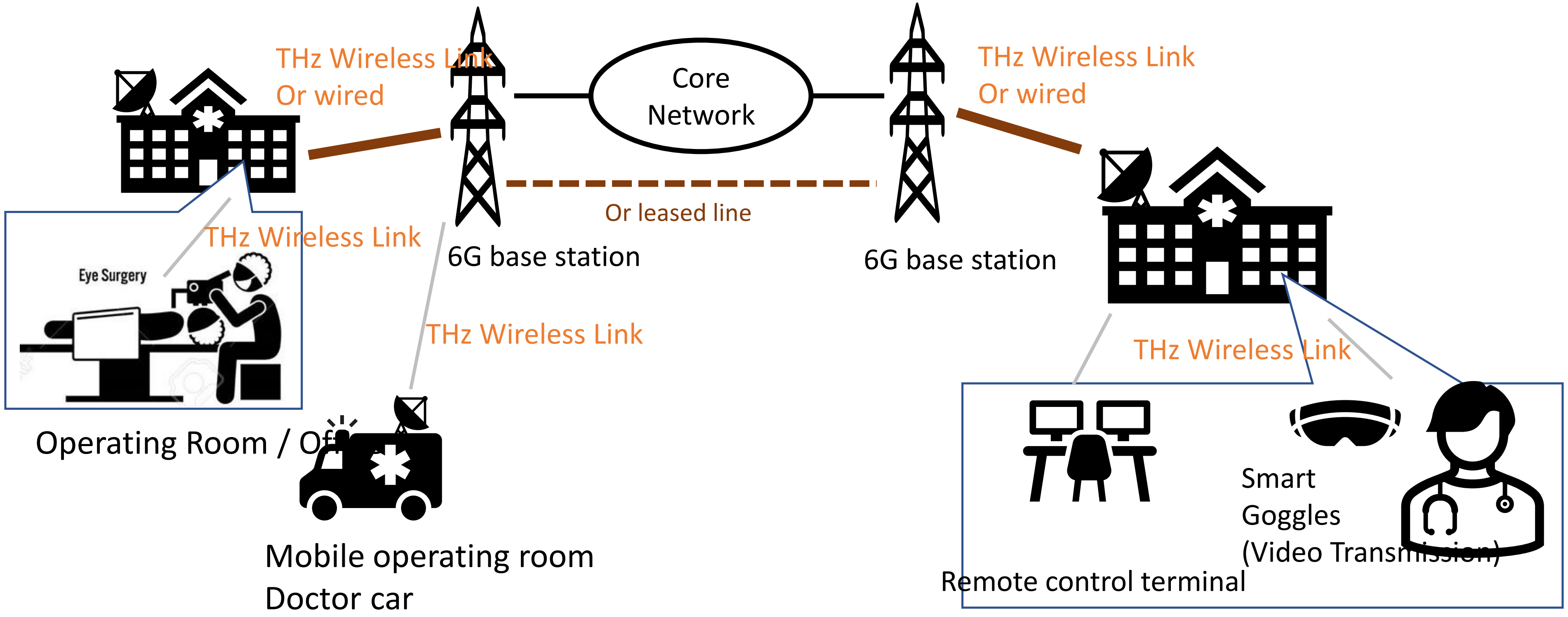
・ By using terahertz communication between the doctor car and the base stations, constraints on doctor car placement locations are reduced.

Reference : Use cases in medical fields such as 5G (draft)
https://www.soumu.go.jp/main_content/000758049.pdf

# Use Case A-2 : Telemedicine

Summary :

- It can recognize the texture and internal structure of an object with the ability to exceed human vision with the large volume of data obtained by mounting a large number of arrayed cameras and acoustic transducers.
- Low-voltage compressed signals are transmitted in order to transmit full-spec 8K video without delay.
- Remote examinations and operations were performed by connecting operating rooms or doctor car with remote control terminals via 100 Gbps lines.
- Robot operation at disaster sites and dangerous locations, remote control of construction equipment and agricultural machinery.
- By transmitting 8K images to smart goggles (VR display, AI assist function, etc.) that are connected to the operation terminal by terahertz radio, it provides the feeling of operation as if treatment is being done on the spot.
- Acceptable image delay of the entire system is 1 ms or less (by making it about 1/10 of the human reaction speed of 10 ms, operation can be performed without discomfort).



# Use Case A-3 : Biometric

Communication type :

- Basically, line-of-sight communication. However, if an arbitrary complex aperture function can be synthesized by phased array, the quality may be improved by using multi-paths (the system can automatically select the best path).
- Travel speed 1-10m/s (3.6-36km/h)
- Communication distance 1-10m

Data rate, delay, etc. :

- > 100 GbpsUSB4 (40 Gbps), HDMI2.1 (48 Gbps), PCIe6.0 (16 Gbps), etc.
- Delay 1 ms
- Topology P2P, star, mesh

Other performance requirements :

- The diffraction loss of antenna directivity> 30 dbi at 300 ghz is suppressed to 20 db or less at 1m and 40 db or less at 10m.
- When the beam scanning range of the base station is ± 30 °, the base station installation height and base station installation interval must be approximately the same in order to perform handover (cf. The height of the signal is approximately 6m).
- High speed is required for both up and down lines.

**Detailed use cases and characteristics :**

・ Approximately 10 billion neurons in the human brain exchange binary signals. Therefore, the total bit rate of brain information obtained by the rapidly developing brain-machine interface terminals will greatly exceed that of video and audio, and it is possible that 6G lines will be required for its transmission.

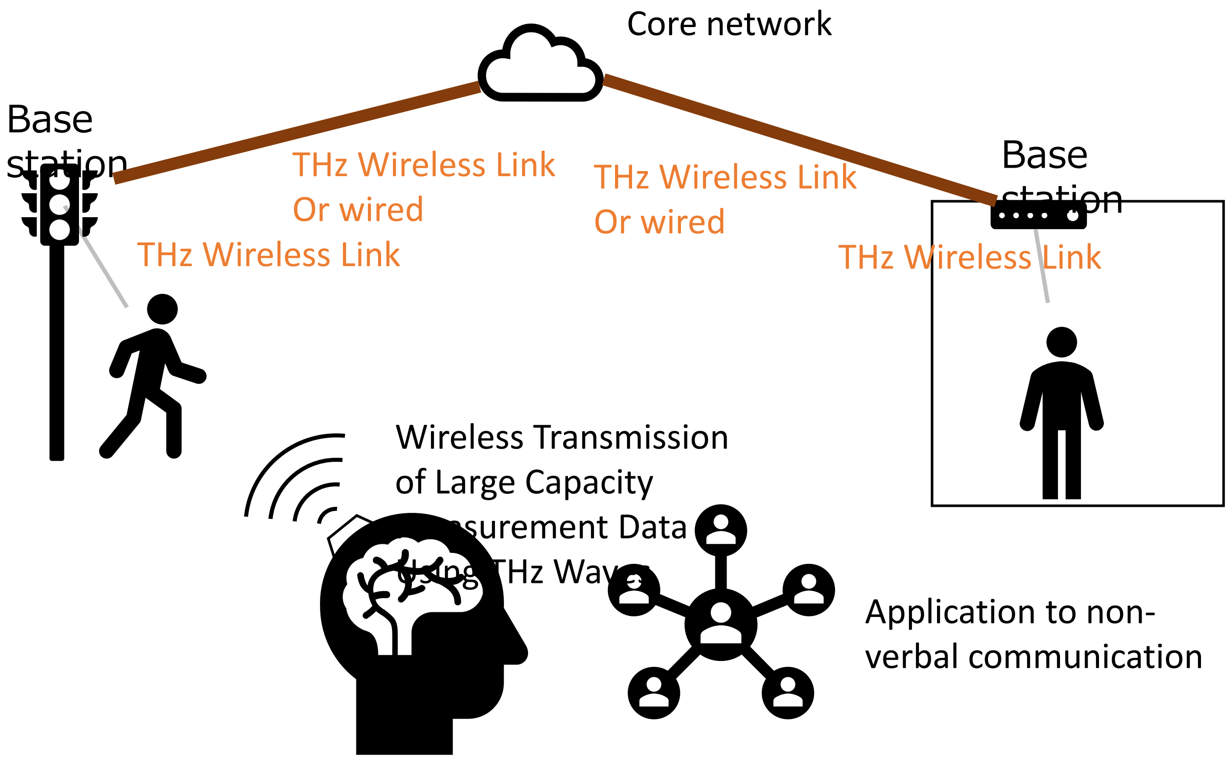
If large-capacity data is uncompressed and transmitted to and from the base station by a terahertz wave beam, the head terminal can be reduced in size and power consumption.

・ This may lead to the development of new industries such as providing support and content according to the user's brain condition, or providing users with their own brains and memories as computing resources and information sources.

# Use Case A-3 : Biometric

Summary :

- It is said that about 10 billion nerve cells are exchanging binary signals.
- In the future, the total bit rate of brain information obtained by terminals of brain-machine interfaces, which are progressing rapidly, will greatly exceed that of video and audio, and there is a possibility that 6G lines will be required for its transmission.
- Non-compressed transmission of large amounts of data to and from base stations using terahertz wave beams has the potential to open up new industries such as providing support and content according to users' brain conditions, or providing users' brains and memories as computing resources and information sources to others.



# Use Case B Group

# Summary

**Concept**

- Use cases without human intervention, such as M2M communication (including autonomous vehicles as M)
- The communication target moves, but the movement pattern is simple.
  Equipment in factories, automobiles on highways, trains and aircraft (in airports)
- Communication with relatively high-speed actuation such as control of equipment
- Optimal control using AI in edge computing

**Requirements for hardware**

- Wide band communication of the terahertz band is required for uncompressed communication of images, etc.
- Configuration close to fixed communication + narrow range beam control
- Low latency and high reliability

# Use Case B-1 : Vehicle-to-vehicle (image) transmission

Communication type :
- Sharing of video images between running vehicles and between vehicles and road infrastructure
- Communication distance : 5-200m
- Basically line-of-sight communication (reflection and diffraction are not used)

Data rate, delay, etc. :
- Downlink : 10-100Gbps
- Uplinks : 10-100Gbps
- Delay time : less than a few ms

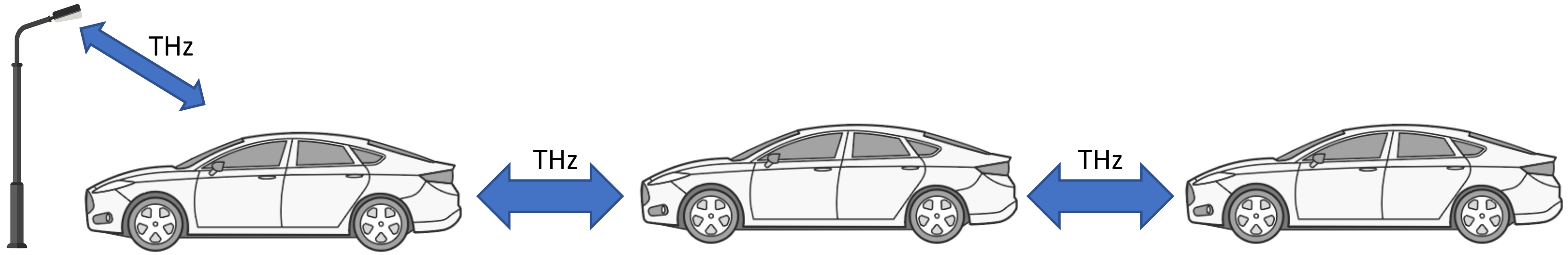
Other performance requirements :
- Radiant power : 50 mW
- Directional (terminal) : 30 dBi
- Beam Scanning : Required (Scanning range is about ± 20 °)
- Reliability : receiving 100 meters dash line by line
- Relative movement speed :
  - 130km/h (between road and vehicle)
  - 40km/h (between cars) : If the speed between cars exceeds this speed, there is a risk of rear-end collision, so the brakes will work. If the speed exceeds this speed, the automatic brakes will control it.

**Detailed use cases and characteristics :**
- Inter-vehicle communication collects information (position, speed, control status, etc.) about vehicles traveling in the vicinity through wireless communication between vehicles.
- Since vehicles exchange information directly with each other, services can be provided even in places where infrastructure such as RSU is not established.
- When running in a line, each vehicle shares information about its surroundings and properly controls the line (ensuring distance between vehicles, stabilizing running position between road and vehicle, etc.).
- Road-to-vehicle vehicle communications, RSUs and on-board equipment communicate to obtain signal information, traffic control information, pedestrian information, etc., and to support driving as needed
- By integrating inter-vehicle communication and road-to-vehicle communication, it is possible to notify traffic signal information and the presence of oncoming vehicles at intersections with poor visibility. It is also possible to notify traffic conditions in the vicinity, such as traffic congestion and accidents, and the presence of straight vehicles and pedestrians when turning right.
- Low-delay communication of large-capacity data such as uncompressed images is possible by using the terahertz band.
- Integration and spectrum sharing with sensing functions such as detection of forward obstacles

# Use Case B-1 : Vehicle-to-vehicle (image) transmission

Summary :

- Large-capacity images acquired by each vehicle are wirelessly transmitted and shared by neighboring vehicles.
- Low-delay transmission is also required to quickly respond to obstacles.
- Integration with sensing functions to ensure both safety and effective use of radio resources
- Contribute to easing traffic congestion, improving transport volume with limited road resources, and reducing $CO_2$ emissions
- Road-to-vehicle communication enables sharing of signal information, traffic control information, and pedestrian information.




Integration with sensing functions shares even hardware
Options such as sharing only radio resources
Mainly radar functions and limited transmission speeds
System is also possible
Can be coordinated with existing systems such as ITS spots and traffic signals

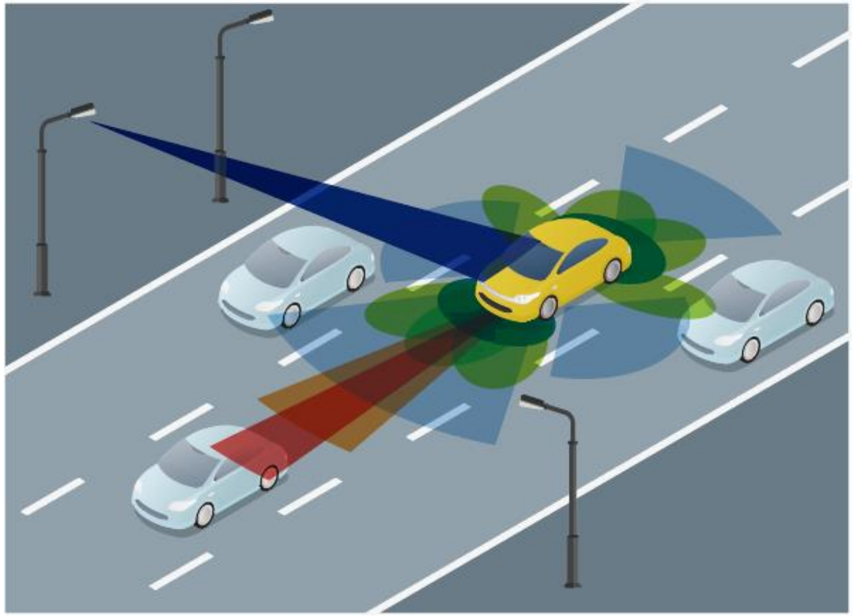


Figure : System Image (All transmissions using terahertz waves. Different beam patterns are color-coded.)

* ITS (Intelligent Transport Systems) is a system that transmits and receives information between people, roads, and automobiles to solve various problems such as road traffic accidents, traffic congestion, and environmental measures.

# Use Case B-1 : Hyperspectral Data (Image) Transmission in Smart Factories

Communication type :
- Communication between the manufacturing and inspection equipment and the local server
- Fixed communication distance for terminals and base stations : 1-20m
- Basically, line-of-sight communication (reflection and diffraction are not used. Or reflection plates such as RIS * are used)
- Client-server network

Data rate, delay, etc. :
- Downlink : several Mbps
- Uplinks : 10-100Gbps
- Delay time : less than a few ms

Other performance requirements :
- Base station radiation output : 10 mW
- Terminal radiation power : 10 mW
- Directional (terminal) : 40 dBi
- Beam scanning : not required
- Introduction of RIS and other technologies depending on equipment installation and radio interference conditions

* RIS (Reconfigurable Intelligent Surface), a functional device that adaptively and dynamically controls the radio wave environment

**Detailed use cases and characteristics :**

1. Uncompressed multi-spectral image transmission The amount of data available at manufacturing sites is increasing significantly. For example, when a hyperspectral camera is used to monitor defective products flowing onto a conveyor belt and AI is used to sort out defective products, it is necessary to handle tens of terabytes of data every day. In addition, since data processing requires low delay and real-time performance, it is necessary to perform "edge computing" where information processing is performed near the data source and the place where it is used. In line-of-sight communication with a base station server, each terminal can occupy a wide THz carrier by transmitting to a pinpoint with a sharp beam so that there is no interference. In particular, terahertz broadband is effective because the amount of uplink data needs to be as large as optical communication.

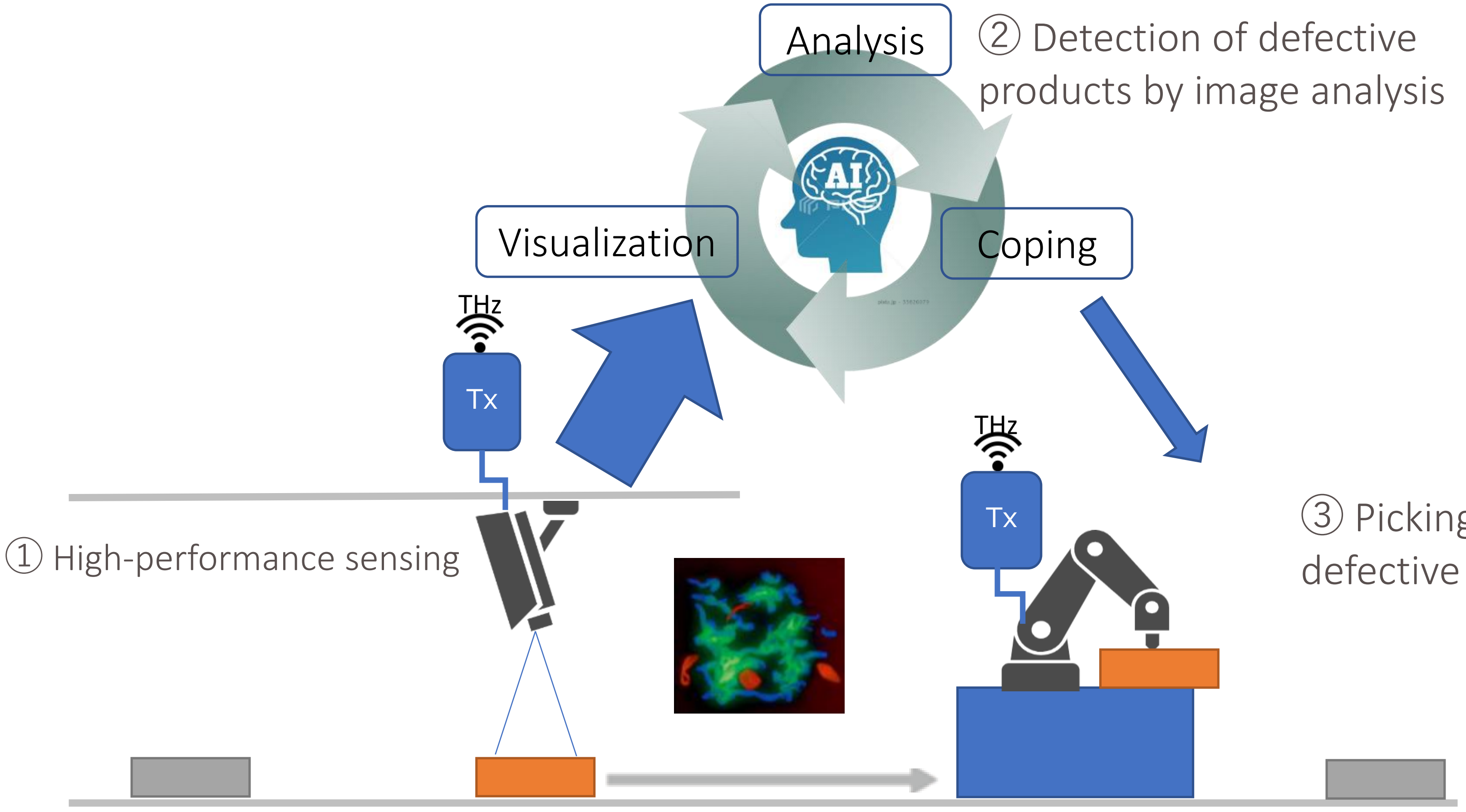
**Data Rate Justification Example :**

At a belt speed of 30m / min, the required image processing capability of the object to be inspected is 5 fps.
At 4K resolution, the image size per capture is
8M pixel x 10 bit x 200 band = 16 Gbit
Throughput : 16 Gb x 5 fps = 80 Gbps

# Use Case B-1 : Smart Factory Hyperspectral Data (Image) Transmission

Summary :

- An inspection object is photographed by a hyperspectral camera with abundant information, and a large-capacity image is wirelessly transmitted to an AI server by THz. The AI inspects the quality of the inspection object with high accuracy.
- Low-delay transmission is also necessary to transmit the quality of an inspection object to a sorting machine such as a flipper.
- By local 6G which can realize low delay using THz, it becomes possible to realize production sites without relying on human hands.



# Use Case B-2 : M2M Communication in Smart Factories

Communication type :

- Communication between manufacturing and inspection equipment and local servers.
- Fixed communication distance for terminals and base stations : 1-20m
- Basically, line-of-sight communication (reflection and diffraction are not used. Or reflection plates such as RIS * are used)
- Client-server network

Data rate, delay, etc. :

- Downlink : several Mbps
- Uplinks : 10-100Gbps
- Delay time : less than a few ms

Other performance requirements :

- Base station radiation output : 10 mW
- Terminal radiation power : 10 mW
- Directional (terminal) : 40 dBi
- Beam scanning : not required
- Introduction of RIS and other technologies depending on equipment installation and radio interference conditions

* RIS (Reconfigurable Intelligent Surface), a functional device that adaptively and dynamically controls the radio wave environment

**Detailed use cases and characteristics :**

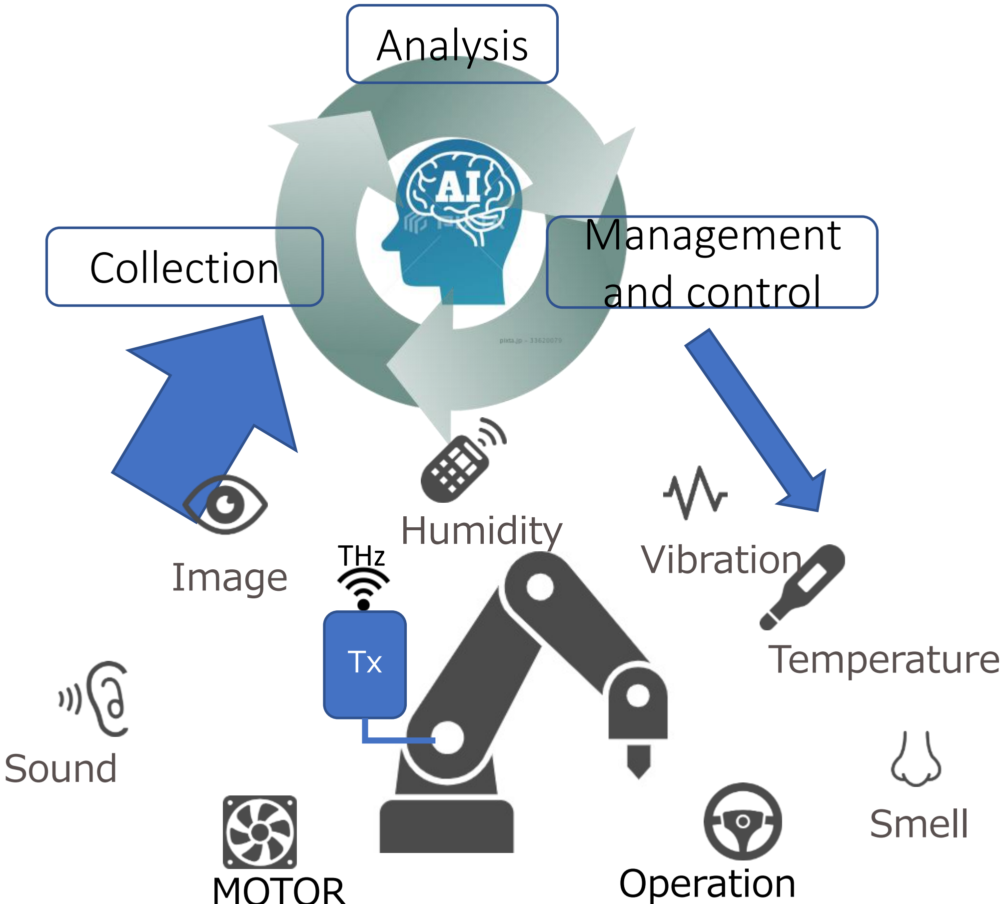
1. Transmission of high-definition appearance inspection data using 3D images and large-capacity image transmission in robot vision.
2. By transmitting huge amounts of sensor data with low delay using 6G and performing high-precision analysis in real time, productivity can be improved and remote control of equipment can be realized. By connecting equipment, robots and high-definition cameras in factories to networks, various information can be visualized and causal relationships between information can be clarified. By having sensors, various data can be acquired and collected, and product manufacturing conditions and lot information can be searched and tracked.
3. Collecting data on devices to be monitored and managed, and understanding their state, puts the entire system under optimal control. Storing and analyzing the collected data provides new added value.

**Data Rate Justification Example :**

60 million pixels x 10 bits x 60 fps = 38 Gbps
200 million pixels x 10 bits x 60 fps = 144 Gbps

# Use Case B-2 : M2M Communication in Smart Factories

Summary :
- High-resolution visual inspection using 3D images and large-capacity image transmission in robot vision.
- The sensor network collects all kinds of information such as the status of the equipment, the condition of non-measurement objects, and environmental information to carry out process control and optimum control of manufacturing equipment.
- A large-capacity, multi-connection network collects, analyzes, and predicts all kinds of information, including quality control associated with 4M changes, trends in product performance variations, and investigation of causes when defects occur.
- 6G, which uses THz and achieves low delay, makes it possible to realize production sites that do not rely on human hands.



# Use Case B-3 : High-resolution transmission in CBM (Condition Based Maintenance) System

Communication type :
- Communication between manufacturing and inspection equipment and local servers.
- Fixed communication distance for terminals and base stations : 1-20m
- Basically, line-of-sight communication (reflection and diffraction are not used. Or reflection plates such as RIS * are used)
- Client-server network

Data rate, delay, etc. :
- Downlink : several Mbps
- Uplinks : 10-100Gbps
- Delay time : less than a few ms

Other performance requirements :
- Base station radiation output : 10 mW
- Terminal radiation power : 10 mW
- Directional (terminal) : 40 dBi
- Beam scanning : not required

* RIS (Reconfigurable Intelligent Surface), a functional device that adaptively and dynamically controls the radio wave environment

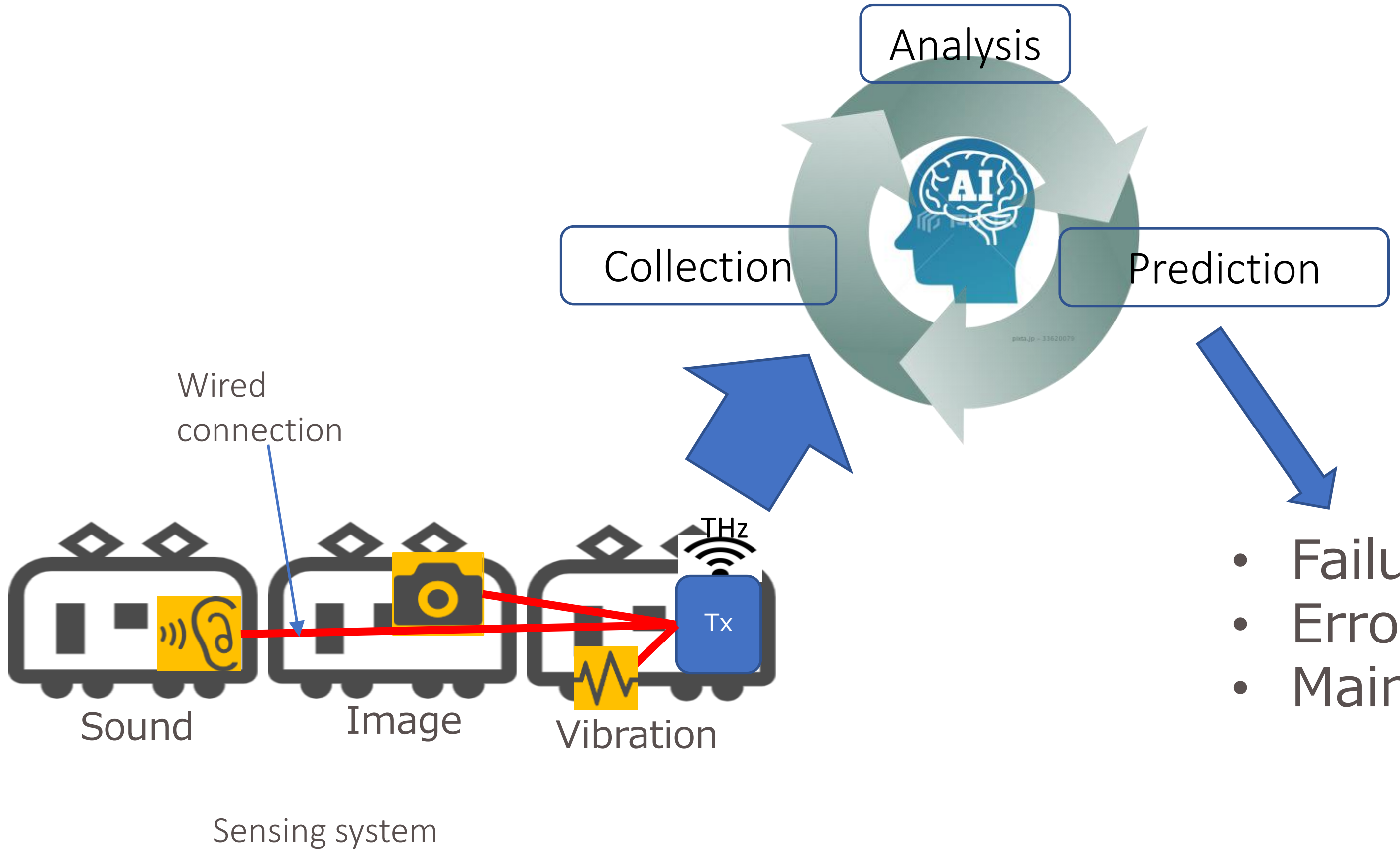
**<u>Detailed use cases and characteristics :</u>**
1. The lifetime of equipment, such as railways and aircraft, which require highly reliable operation, is operation, with high-definition images, etc., it is possible to detect signs of failure and predict the life of equipment while managing its progress.
2. By using high-resolution and wide-field images, details can be captured clearly and inspection accuracy can be greatly improved. The data is sent to an edge server to provide timely diagnostic results. An AI at the edge server constantly monitors and diagnoses the condition of equipment and facilities and recommends the best repair method if it predicts failure / failure risks.
3. By changing the focus of maintenance, repair, and parts replacement from "periodic standard response" to "condition standard response", companies can reduce maintenance costs, reduce failure risks, minimize downtime, and optimize facility asset decisions from a cost perspective.

**<u>Data Rate Justification Example :</u>**
60 million pixels x 10 bits x 60 fps = 38 Gbps
200 million pixels x 10 bits x 60 fps = 144 Gbps

# Use Case B-3 : High-resolution image transmission in CBM (Condition Based Maintenance) system

Summary :

- Large-capacity image transmission for high-definition visual inspection over tens of millions of pixels.
- The sensor network collects all kinds of information such as the status of the equipment, the condition of non-measurement objects, and environmental information to carry out process control and optimum control of manufacturing equipment.
- Real-time operation tracking of large-scale facilities and equipment such as large-scale manufacturing equipment such as factories and gas turbines, electric power company transformers, and transportation and distribution infrastructure.




- Failure prediction
- Error detection
- Maintenance plan

# Use Case C Group

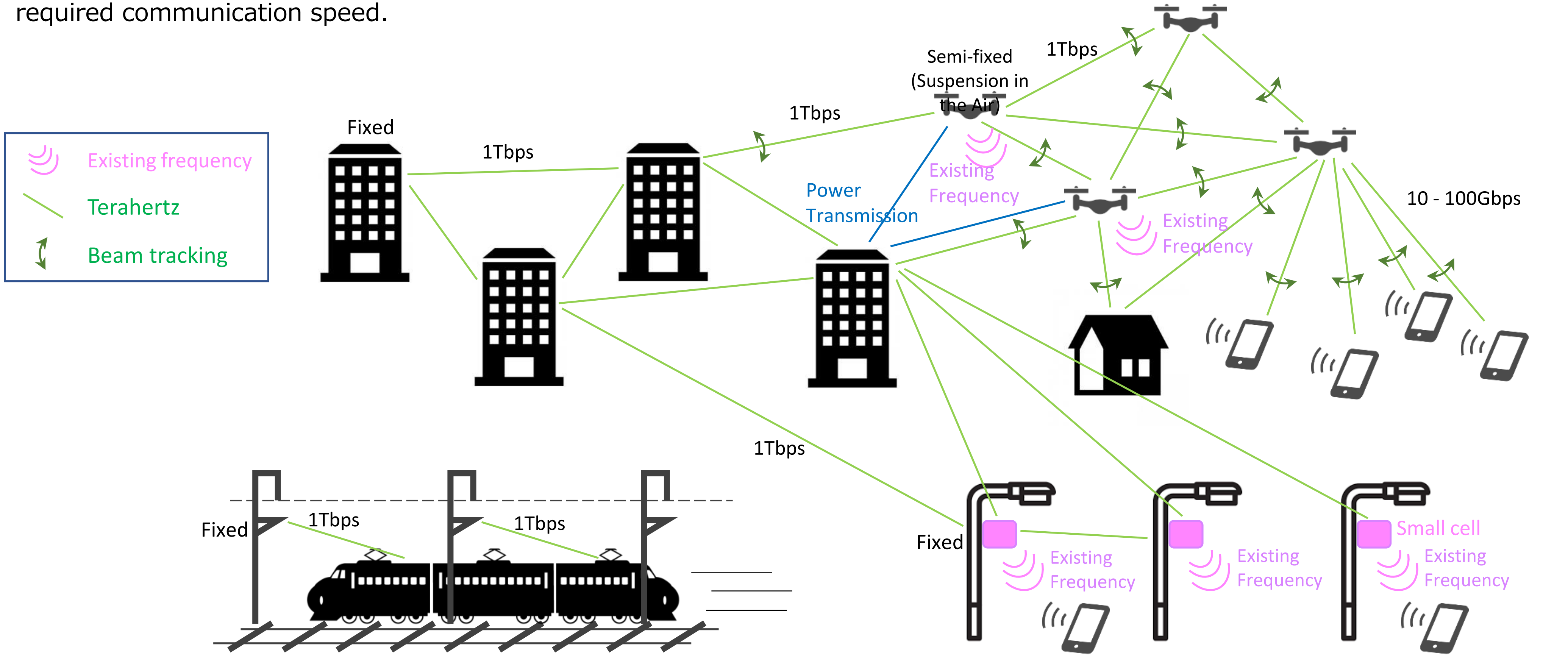
# Use Case C-1 : Fixed (Semi-fixed) Mesh Network

| | | |
|---|---|---|
| Type of communication | Type of communication | • Communications between mobile terminals and drone base stations<br>• Communications between drone base stations<br>• Provision of front holes to small cell base stations<br>• Inter-building communication<br>• Provision of backhaul lines for Shinkansen and other railcars |
| | Travel speed | • Fixed to Semi-fixed<br>  • The drone is almost 0 speed because it's still in the air.<br>  • A fixed beam is used to provide an area for the Shinkansen (bullet train travels at 100m/s). |
| | Communication distance | • 10m - several hundred m<br>• Basically line-of-sight communication |
| | Network topology | • MultiPoint to MultiPoint<br>• Mesh network |
| Data rate, delay, etc. | Data rate | • Order of several hundred Gbps-Tbps |
| | Delay | • <1 msec (comparable to optical communication) |
| | Setup Time | • About 10 msec (in the case of Shinkansen, the distance is about 1m)<br>• #Basically, the link is always up. |
| Other performance requirements | Output power(Base station) | • 20 to 30 dBm (bandwidth is assumed to be several GHz to several 10 GHz) |
| | Output power(Terminal) | • 20 to 30 dBm / GHz (bandwidth is assumed to be several GHz to several 10 GHz) |
| | Beam scanning | • Beam tracking technology for drones and from drones to user terminals |
| | Multiplexing technology | • Various multiplexing technologies such as frequency multiplexing, polarization multiplexing, OAM, and MIMO are used in combination depending on the required communication speed. |
| | Wireless power to drones | • 180W (dji phatom4 reference value) |
| Detailed use cases | Short-time network construction<br>#Construction of a large-capacity network in an ultra-short time using small drones as base stations for emergencies, disasters, large-scale events, etc. | Point-to-point line-of-sight communication allows each terminal to occupy a wide range of the same THz carrier by transmitting to pinpoint with a sharp beam to avoid interference. Since communication between base stations requires a large capacity comparable to that of optical communication, terahertz broadband is effective. |
| | Replacing optical fiber networks | Optical radio is greatly affected by weather. It is possible to construct a backbone network resistant to weather fluctuation by THz. |

# Use Case C-1 : Fixed (Semi-fixed) Mesh Network

## Summary :

- Flexible and short-time construction of wide-area networks using drones as base stations
- Construction of networks between buildings where optical fiber cables cannot be installed. Construction of high-speed communication networks to replace aging optical fiber
- Front hole for small cells
- High-bandwidth backhaul for railways (converted to Wi-Fi inside trains for comfortable communication)
- By following with a sharp beam and performing line-of-sight communication, bandwidth can be monopolized without interference. Communication speed comparable to optical networks. 10-100Gbps for user terminals, Tbps between APs.
- Construction of backbone network with THz that is resistant to weather changes that cannot be achieved with optical wireless
- Various multiplexing technologies such as frequency multiplexing, polarization multiplexing, OAM, and MIMO are used in combination depending on the required communication speed.



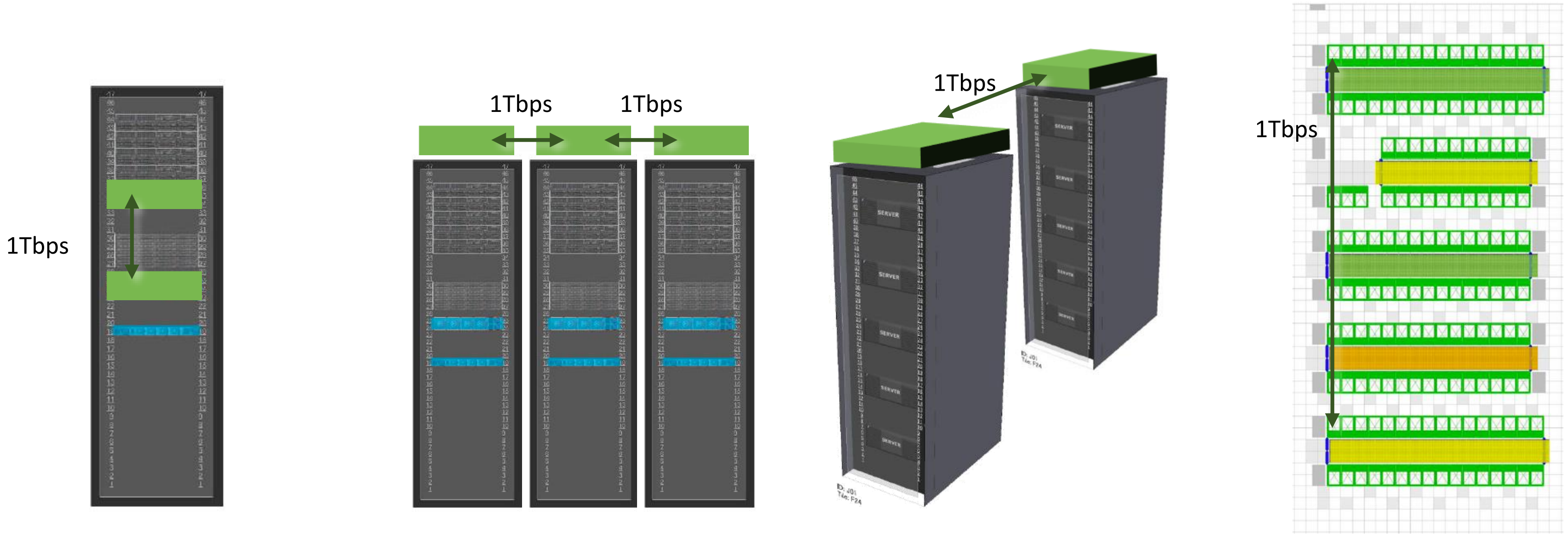
# Use Case C-2 : Optical Line Replacement in the Data Center

| | | |
|---|---|---|
| Type of communication | Type of communication | • P2P communication between racks in the data center |
| | Travel speed | • Fixed |
| | Communication distance | • 1m - several 10m<br>• Basically outlook communication, some PVC panels, etc. |
| | Network topology | • Point to Point |
| Data rate, delay, etc. | Data rate | • Order of several hundred Gbps-Tbps |
| | Delay | • <1 msec (comparable to optical communication) |
| | Setup Time | • About 10 msec<br>• #Basically, the link is always up. |
| Other performance requirements | OUTPUT | • 5 to 30 dBm (bandwidth is assumed to range from several GHz to several 10 GHz) |
| | Beam scanning | • Not required |
| | Multiplexing | • Various multiplexing technologies such as frequency multiplexing, polarization multiplexing, OAM, and MIMO are used in combination depending on the required communication speed. |
| Detailed use cases | Making cables in the same rack wireless | Cables in the same rack are made wireless.<br>Eliminates heat retention and simplifies maintenance |
| | Wireless cables between adjacent racks | In adjacent racks, cables may pass through narrow windows. As the number of racks increases, cables cannot pass through. By using wireless technology, flexible wiring can be achieved and the problem of heat can be solved. |
| | Use of wireless cables between stacks | The wiring that crosses the line must pass through free access under the floor or through the overhead catwalk. However, since both are common areas, the degree of freedom is low and maintenance is difficult.<br>Free wiring is realized by using wireless technology. Unnecessary detour is eliminated. |

# Use Case C-2 : Optical Line Replacement in the Data Center

## Summary :

- Existing problems include : (1) If there are too many wires, heat will be trapped and damage to equipment. (2) The data center underfloor / catwalk wires are routed and require several tens of meters in length even for adjacent racks, making design difficult.
- Perform P2P communication as a substitute for optical cables inside the data center.
- (1) Wiring between equipment in the rack is made wireless to reduce heat accumulation caused by cables.
- ② Increase the freedom of wiring by making wiring between racks wireless.
- ③ Simplify wiring design by making communication between stacks wireless
- ④ Simplify the wiring design by using wireless communication in the floor that crosses multiple train lines.
- Various multiplexing technologies such as frequency multiplexing, polarization multiplexing, OAM, and MIMO are used in combination depending on the required communication speed.




① Intra-rack communication

② Communication between racks

③ Inter-track communication

④ floor Tsushin

# Use Case D Group

# Use Case D-1 : Spatial Detection System

## Sensing application : Assuming use cases where radio waves used for wireless communication are used for sensing

Communication (sensing) form :

- Sensing ambient conditions within several meters of a Terminal Adaptor (TA) or Remote Antenna Unit (RAU), such as indoors or outdoors (using indoor LAN and Mobile Access communication systems).
- Use channels not used for communication and scan all directions with phased array. Measure intensity, phase and direction of arrival of the reflected signal with RA or RAU or another terminal.
- It detects human presence, movement, motion, heartbeat, expiration, etc. from the difference from the normal reflection state.
- In a wide band channel, identification of substances and detection of dangerous gases are possible by spectrum analysis.
- Communication distance : several meters
- Differentiation from microwave and millimeter-wave systems

⇒ Resolution : submillimeter
⇒ Identification of the substance : Difference in reflectance due to the reflector
⇒ Gas detection

Data rate, delay, etc. :

- Compatible with shared communication systems

**<u>Detailed use cases and characteristics :</u>**

1. Room monitor

- The method of use is the same as that of the microwave spatial detection system, except for resolution and material identification.
- It is assumed to be used in combination with a microwave (WiFi) system. The WiFi system detects moving objects such as people. An unused terahertz channel is applied in that direction, reflection is measured. From the reflection intensity, phase and arrival direction, the material of the reflective object is identified and minute movement is detected.
- Specifically, it includes motion control, health sensing such as expiration, heartbeat and blinking, and monitoring of wind flow.

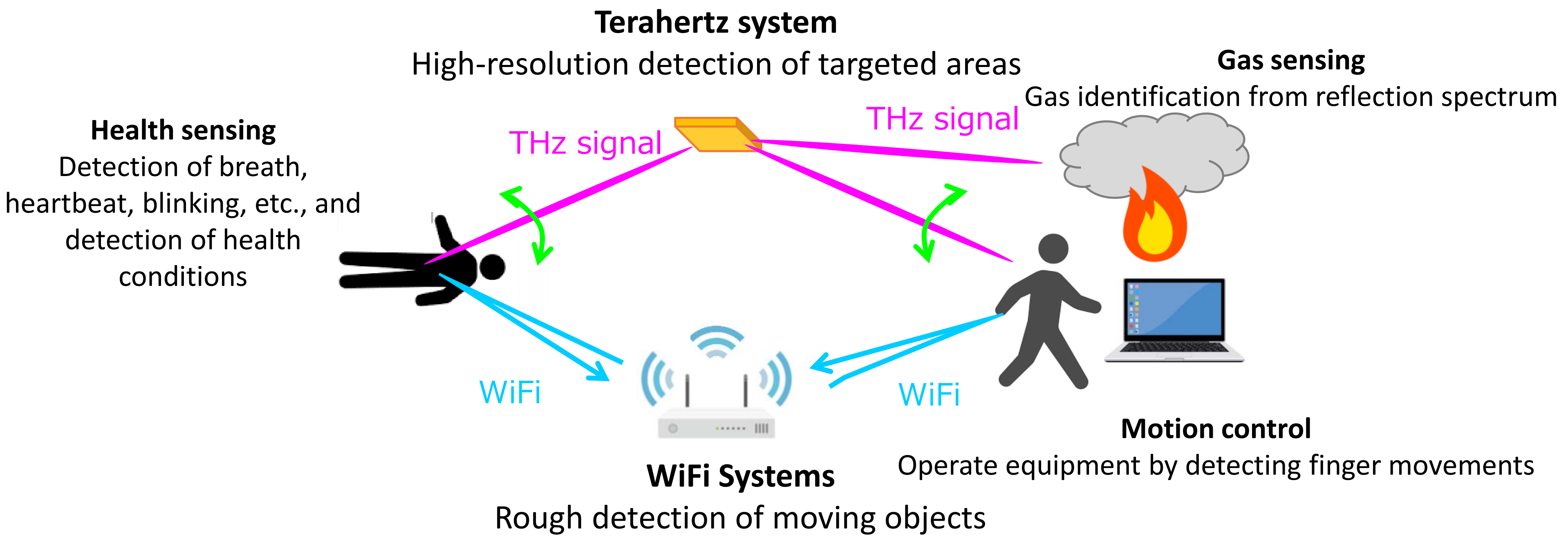
2. Gas Component Analysis

- Gas with strong absorption in the frequency range of the channel to be used (HCN : 265 GHz, 355 GHz, $H_20$, etc.) is detected.

# Use Case D-1 : Spatial Detection System

Summary :

- Sensing of ambient conditions within several meters of TA and RAU, such as indoor and outdoor (using indoor LAN and mobile access communication systems).
- Use channels not used for communication and scan all directions with phased array. Measure intensity, phase and direction of arrival of the reflected signal with RA or RAU or another terminal.
- Intended to be used in combination with a microwave (WiFi) system. The WiFi system detects moving objects such as people. An unused terahertz channel is applied in that direction to measure reflection.
- It detects human presence, movement, motion, heartbeat, expiration, etc. from the difference from the normal reflection state.
- In a wide band channel, identification of substances and detection of dangerous gases are possible by spectrum analysis.



# Use Case D-2 : people's flow Monitoring System

## Sensing application : Assuming use cases where radio waves used for wireless communication are used for sensing

Communication (sensing) form :

- Massive MIMO is used to detect the movement of people in nanocells made up of signal and street RAU. Using channels not used for communication, scanning is done in all directions with phased array. RAU measures the intensity, phase and arrival direction of the reflected signal.
- It can detect which part of a road or square you have passed with accuracy of several centimeters.
- Sensing people's flow over a wide area by linking information obtained from macrocells with people's flow obtained from nanocells
- Differentiation from microwave and millimeter-wave systems

⇒ Resolution : several cm

⇒ Identification of substances : Detection of information on clothes worn and presence / absence of dangerous materials

Data rate, delay, etc. :

- Compatible with shared communication systems

**Detailed use cases and characteristics :**

- High-precision location identification is possible with mobile location information services and GPS.
- Detection of people's flow over a wide area by combining with microcells and linking terminals with people's flow information in nanocells
- Taking advantage of the high density capability of 5G and 6G, it is possible to grasp individual people's flow even when there are many people such as events.
- By using the interaction and permeability of terahertz waves with materials, it can detect information worn and the presence or absence of dangerous materials are detected.
- Can also be applied to crime prevention and disaster prevention. Handling of personal information protection is an issue

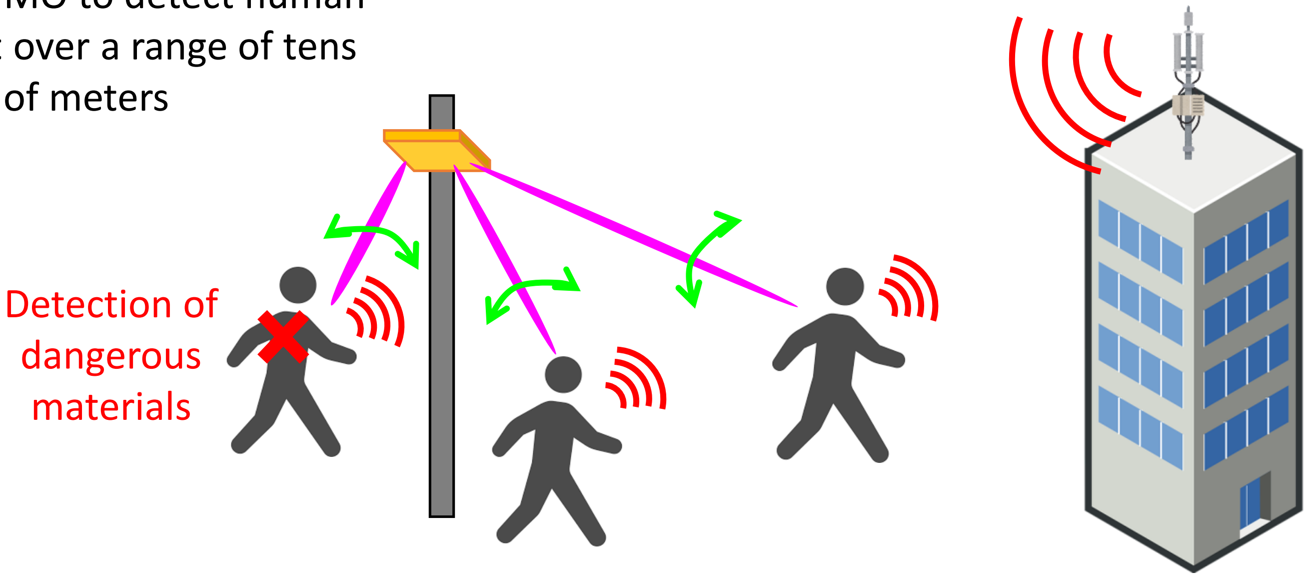
# Use Case D-2 : people's flow Monitoring System

Summary :

- Scan all directions with phased array using channels not used for communication. Detects movement and movement of people with a resolution of several centimeters from reflected signals
- Sensing people's flow over a wide area by linking information obtained from macrocells with people's flow obtained from nanocells
- By using the interaction and permeability of terahertz waves with materials, it can detect information worn and the presence or absence of dangerous materials are detected.
- Can also be applied to crime prevention and disaster prevention. Handling of personal information protection is an issue

**Nanocell**
Massive MIMO to detect human movement over a range of tens of meters

**Macro cell**
Sensing people's flow over a wide area from people's flow obtained with nano-cells and terminal information obtained with macro-cells



# Supplement

# Reference : Desired Base Station Output Calculation 2 (Use Case C-1)

**Increased bandwidth to 10 ghz**

| Item | Value | CUM | Remarks |
|---|---|---|---|
| Transmit Power [dBm] | +28 | +28 | 600 mW/10GHz |
| Transmit antenna gain [dBi] | 15 | +43 | Securing a wide beam in consideration of the Shinkansen case |
| Free space propagation loss [dB] | 122 | -79 | 300GHz 100m |
| Propagation loss margin [dB] | 5 | -84 | 2 dB loss @ 50 mm rainfall (300 GHz) |
| Receive antenna gain [dBi] | 40 | -44 | |
| **Receive SINR [dB]** | **15** | | **→ 64 QAM** |
| Receiver Nf [dB] | 15 | -59 | |
| Thermal noise Nt [dBm] | -74 | -74 | BW 10GHz (-174dBm/Hz) |

40 Gbps / 10 GHz (w/o overhead) with 64 QAM
80 gbps / 10 ghz with polarized MIMO

# Reference : Desired Base Station Output Calculation 3 (Use Case C-1)

**Bandwidth is extended to 10 GHz and antenna gain on terminal side is**

| Item | Value | CUM | Remarks |
|---|---|---|---|
| Transmit Power [dBm] | +28 | +28 | 600 mW/10GHz |
| Transmit antenna gain [dBi] | 40 | +68 | Consider use cases between buildings |
| Free space propagation loss [dB] | 122 | -54 | 300GHz 100m |
| Propagation loss margin [dB] | 5 | -59 | 2 dB loss @ 50 mm rainfall (300 GHz) |
| Receive antenna gain [dBi] | 40 | -19 | |
| **Receive SINR [dB]** | **40** | | **→ 4096 QAM (R = 1)** |
| Receiver Nf [dB] | 15 | -59 | |
| Thermal noise Nt [dBm] | -74 | -74 | BW 10GHz (-174dBm/Hz) |

90 Gbps / 10 GHz (w/o overhead) at 4096 QAM
180 gbps / 10 ghz with polarized MIMO

# Reference : Desired Base Station Output Calculation 2 (Use Case C-2)

Transmit power is changed to 600 mw.

| Item | Value | CUM | Remarks |
|---|---|---|---|
| Transmit Power [dBm] | +28 | +28 | 600 mW / 10GHz |
| Transmit antenna gain [dBi] | 40 | +68 | Consider use cases between buildings |
| Free space propagation loss [dB] | 116 | -48 | 300GHz 50m |
| Propagation loss margin [dB] | 10 | -58 | Consider vinyl curtains, etc. |
| Receive antenna gain [dBi] | 40 | -18 | |
| **Receive SINR [dB]** | **41** | | **→ 4096 QAM (R = 1)** |
| Receiver Nf [dB] | 15 | -59 | |
| Thermal noise Nt [dBm] | -74 | -74 | BW 10GHz (-174dBm/Hz) |

90 Gbps / 10 GHz (w/o overhead) at 4096 QAM
180 gbps / 10 ghz with polarized MIMO

# Reference : Desired Base Station Output Calculation 3 (Use Case C-2)

**Transmit power changed to 600 mW and bandwidth changed to 100 GHz**

| Item | Value | CUM | Remarks |
|---|---|---|---|
| Transmit Power [dBm] | +28 | +28 | 600 mW / 100GHz |
| Transmit antenna gain [dBi] | 40 | +68 | Consider use cases between buildings |
| Free space propagation loss [dB] | 116 | -48 | 300GHz 50m |
| Propagation loss margin [dB] | 10 | -58 | Consider vinyl curtains, etc. |
| Receive antenna gain [dBi] | 40 | -18 | |
| **Receive SINR [dB]** | **31** | | **→ 4096 QAM (R = 3/4)** |
| Receiver Nf [dB] | 15 | -49 | |
| Thermal noise Nt [dBm] | -64 | -64 | BW 100GHz (-174dBm/Hz) |

900 Gbps / 100 GHz (w/o overhead) at 4096 QAM
1800 Gbps / 100 GHz with polarized MIMO