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IAFI

PROPOSED FURTHER UPDATES TO WORKING DOCUMENT TOWARDS A DRAFT NEW APT REPORT ON TERAHERTZ (THZ) FIXED WIRELESS SYSTEMS OPERATING IN THE FREQUENCY ABOVE 450 GHZ

1. Background

The AWG is developing a new APT report on Terahertz (THZ) fixed wireless systems operating in the frequency above 450 GHz. Fixed Wireless Systems (FWS) use wireless transmission to connect two fixed locations without the need for physical cables. These systems are commonly used for broadband internet, point-to-point data transmission, and video surveillance. Specific frequency bands have been designated for fixed service (FS) applications by Radio Regulations No. 5.564A, offering 137 GHz of bandwidth in the 275-450 GHz range for global use. However, transmitting data signals over 100-Gbit/s in these bands using simple modulation techniques like Amplitude-Shift Keying (ASK) is challenging due to limited bandwidth. With increasing demand for high-definition video transmission, especially 8K video, fiber optics are often used but are impractical in moving environments. In such cases, terahertz (THz) links provide an alternative, supporting high-speed data transmission to and from optical networks. THz transceivers, operating above 450 GHz, offer a compact and efficient solution for dynamic applications where traditional fiber optics cannot be used. This report examines the technical and operational characteristics of FWS above 450 GHz, highlighting the potential of THz transceivers in high-speed, mobile data scenarios.

2. Discussion

This report focuses on the technical and operational characteristics of fixed wireless systems operating above 450 GHz, exploring their potential to connect high-speed data signals to optical networks and their adaptability for different usage scenarios. The report also highlights the capabilities of THz transceivers, particularly in scenarios requiring compact, efficient designs capable of handling high data rates and mobile environments. However, it is important that the report also covers the the technical and operational characteristics of THz transceivers, emphasizing their potential for streamlined, compact configurations and their capability to transmit 8K video in mobile environments.

2. Proposal

Contact: **Email:**

IAFI proposes some modifications to the working document, as contained in Attachment. The proposed revisions are highlighted in turquoise

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WORKING DOCUMENT TOWARDS A DRAFT NEW APT REPORT ON TERAHERTZ (THZ) FIXED WIRELESS SYSTEMS OPERATING IN THE FREQUENCY ABOVE 450 GHZ

Table of Contents

1. Introduction

Fixed Wireless Systems refer to communication systems that use wireless transmission to connect two fixed points or locations without requiring physical cables or wires. The term "fixed" refers to the fact that the system is set up in a fixed location, rather than being portable or mobile. Fixed wireless systems can be used for a variety of applications, including broadband internet access, point-to-point data transmission, video surveillance, etc.

Radio regulations (RR) No. **5.564A** identifies four frequency bands (275-296 GHz, 306-313 GHz, 318-333 GHz and 356-450 GHz) for land mobile service (LMS) and fixed service (FS) applications. A total bandwidth of 137 GHz can be globally used for FS applications such as point-to-point fixed wireless systems without specific conditions to protect Erath exploration-satellite service (EESS) (passive) applications whose frequencies are identified in RR No. **5.565**. However, it may be difficult to utilize those bands to transmit data signals over 100-Gbit/s using a simple modulation such as ASK and a direct detection method due to lack of bandwidth.

There have been many applications to transmit 8K video through optical fiber cable, but some usage scenarios cannot utilize optical fiber links because of moving environment. This Report introduces usage scenarios utilizing THz link which supports transmission of 8K video from/to high-speed optical links and provides technical and operational characteristics of THz transceiver which can also support simplified and compact transceiver configurations.

2. Scope

This Report provides technical and operational characteristics of fixed wireless systems operating in the frequency range above 450 GHz which can connect data signals from/to high-speed optical links.

3. References

Report ITU-R F.2416	Technical and operational characteristics and applications of the point-to-point fixed service applications operating in the frequency band 275-450 GHz
Report ITU-R M.2417	Technical and operational characteristics and applications of the land mobile service operating in the frequency band 275-450 GHz
Report ITU-R SM.2352	Technology trends of active services in the frequency range 275-3 000 GHz
APT/AWG/REP-66	Short range radiocommunication systems and application scenarios operating in the frequency range 275-1000 GHz
APT/AWG/REP-118	Point-to-point radiocommunication systems operating in the frequency range 252-296 GHZ
IEEE Std 802.15.3d™-2017	IEEE Standard for High Data Rate Wireless Multi-Media Networks, Amendment 2: 100 Gb/s Wireless Switched Point-to-Point Physical Layer

4. Abbreviations and acronyms

FWA	Fixed Wireless Access
GHz	Gigahertz

RR [ITU] Radio Regulations

[mmWave Millimeter-wave]

THz Terahertz

UHDTV Ultra-high-definition TV

5. THz features and propagation characteristics

5.1 Features of THz systems

The frequency range between 450 GHz and 1 000 GHz is the main part of Terahertz band, where Fixed Wireless Systems likely to operate in future. These systems use high-frequency electromagnetic waves to transmit information wirelessly between two points. The main reason for using these high carrier frequencies is that the availability of large contiguous bandwidth compared to previous wireless technologies, even capable of fitting state-of-the-art optical channels.

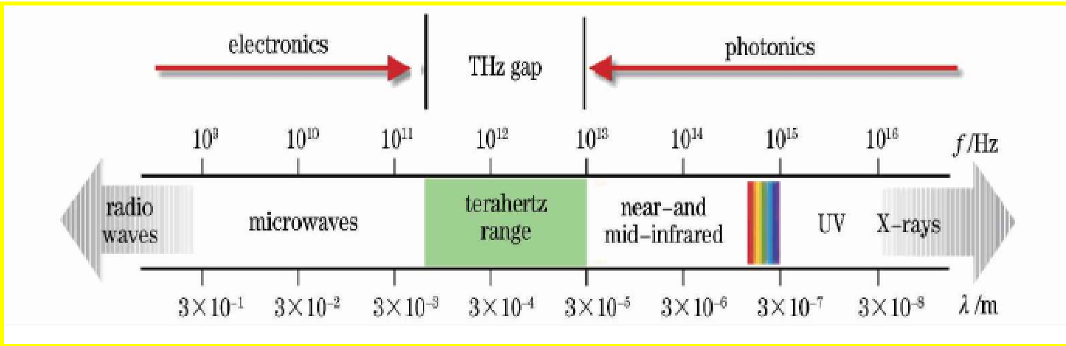


Figure 1 – Position of THZ waves in the electromagnetic spectrum

THz wireless systems offer the potential for extremely high data transfer rates, up to several terabits per second and low latency communication. In addition to this, Terahertz waves have the ability to penetrate through many materials that are opaque to visible and infrared light, such as plastics and clothing, and can be used for imaging applications in medicine, security screening, and industrial inspection. Similarly, Terahertz waves can be used for sensing and monitoring applications, such as detecting hidden weapons or explosives, and monitoring the moisture content in crops and soil.

However, THz frequencies are highly susceptible to atmospheric absorption and attenuation, which can limit their range and reliability. This makes it challenging to develop THz wireless systems for use in practical applications. Despite these challenges, frequencies above 300 GHz offer some advantages, such as the availability of larger frequency bands, which can enable higher data rates and greater capacity for communication systems. These frequencies are also used in remote sensing applications such as atmospheric monitoring, environmental sensing, and imaging, where the atmospheric attenuation and scattering properties can be exploited for specific applications.

For a long time, THz spectrum was described as the last virgin land of the radio spectrum. Only a few scientific and astronomical services are deployed in these frequency bands, especially in bands above 450 GHz. In recent years, terahertz frequency band, has attracted a great deal of interest among various types of users due to their potential for use in a wide range of future technologies.

THz frequency band shows a great deal of promise for building the next generation of wireless technology. THz wireless systems offer the potential for extremely high data transfer rates, up to several terabits per second and low latency communication. Discussions are now gaining momentum with ecosystem partners including chip manufacturer, software and hardware vendors to manufacturer Fixed Wireless Access device in Terahertz frequency band. Many administrations are pursuing with international bodies for opening up more spectrum across all bands, including sub-mm-Wave band (THz band).

In addition to use for communication, Terahertz waves, due to their inherent propagation characteristics, can be used for a variety of applications, from communications to defense, security, space-exploration and medical imaging etc.

5.2 Propagation characteristics in the frequency bands above 275 GHz

AWG has developed APT Report on short range radiocommunication systems and application scenarios operating in the frequency range 275 - 1 000 GHz (APT/AWG/REP-66(Rev.1)) and this Report estimated available contiguous bands in the frequency range 100-1 000 GHz, as shown in Table 1 and Figure 2. Those bands with attenuation losses by gasses of less than 100 dB/km are estimated by avoiding the specific resonant attenuation lines by oxygen and water vapour. Contiguous bandwidths over 50 GHz are achievable in the frequency ranges 200-320 GHz, 275-370 GHz, 380-445 GHz, 455-525 GHz, 625-725 GHz and 780-910 GHz, as shown in Table 1. The whole frequency band 200-320 GHz (1) cannot be used fixed services because the bands 200-209 GHz, 226-231.5 GHz, 235-238 GHz and 241-252 GHz are not allocated for fixed services in accordance with the Table of Frequency Allocations in Radio Regulations. The whole frequency band 275-370 GHz (4) cannot be used for fixed services because the frequency bands 296-306 GHz, 313-318 GHz and 333-356 GHz may only be used by fixed and land mobile service applications when specific conditions to ensure the protection of Earth exploration-satellite service (passive) applications are determined in accordance with RR No. **5.564A**. The whole frequency band 380-445 (5) can be used for fixed service applications because the frequency band 356-450 GHz is identified for those applications in accordance with RR No. **5.564A**. The other bands 455-525 GHz (6), 625-725 GHz (7) and 78-910 GHz (8) can provide the contiguous bandwidth over 70 GHz which is sufficient bandwidth to transmit data rates over 100 Gbit/s using a widely used QPSK modulation scheme.

Table 1

Estimation of frequency ranges and contiguous bandwidth provided by APT Report (APT/AWG/REP-66(Rev.1)).

No.	Frequency range (GHz)	Contiguous bandwidth (GHz)	Loss (dB/km)
(1)	200-320	120	< 10
(2)	275-320	45	< 10
(3)	335-360	25	< 10
(4)	275-370	95	< 100
(5)	380-445	65	< 100
(6)	455-525	70	< 100
(7)	625-725	100	< 100
(8)	780-910	130	< 100

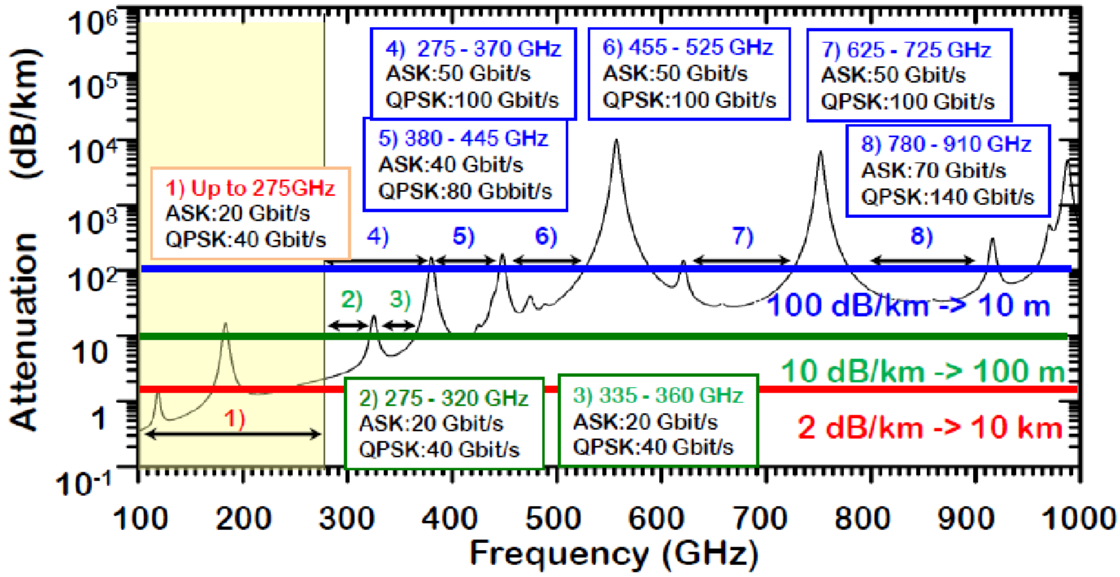


Figure 2

Attenuation characteristics and available contiguous bands in the frequency range from 100 GHz to 1000 GHz provided by APT Report (APT/AWG/REP-66(Rev.1)).

6. Typical use cases for FWS operating in the frequency range above 450 GHz

6.1. Usage scenarios to support UHDTV transmission

Usage scenarios transmitting 8K video which are difficult to use optical fiber cables in short-range environment are introduced in this section.

Table 2 summarizes streaming data rates required for transmitting uncompressed or compressed ultra-high-definition TV signals (8K). It may be preferable to send uncompressed 8K video to avoid large latency, but the uncompressed 8K video requires ultra-high-speed data rates depending on video parameters, as shown in Table 2. Latency is determined from a tradeoff between streaming data rates and signal processing capabilities. As discussed in the section 5, THz spectrum provides sufficient bandwidths for transmitting uncompressed 8K video.

Table 2

Example of streaming data rate of uncompressed and compressed UHDTV.

Resolution	Frame frequency (Hz)	Multilevel gradation (bit)	Color depth (bit)	Streaming data rate (Gbit/s)	
				Uncompressed	H.265 (1/300)
7680 × 4320	120	12	36	144.0	0.48
	120	8	24	96.0	0.32
	60	8	24	48.0	0.16
	30	8	24	24.0	0.08

6.2 Factory monitoring system

THz fixed wireless systems have been studied for use of factory monitoring systems and train platform surveillance systems. Figure 3 illustrates factory monitoring systems where huge production items are moved by crane trucks. The operator on the mobile operation station can produce items by looking at 8K monitor whose video is captured by 8K camera and sent through THz transceivers. Since the factory monitoring systems require high-resolution and low-latency video transfer from the floor to the truck, uncompressed 8K video may satisfy the requirements.

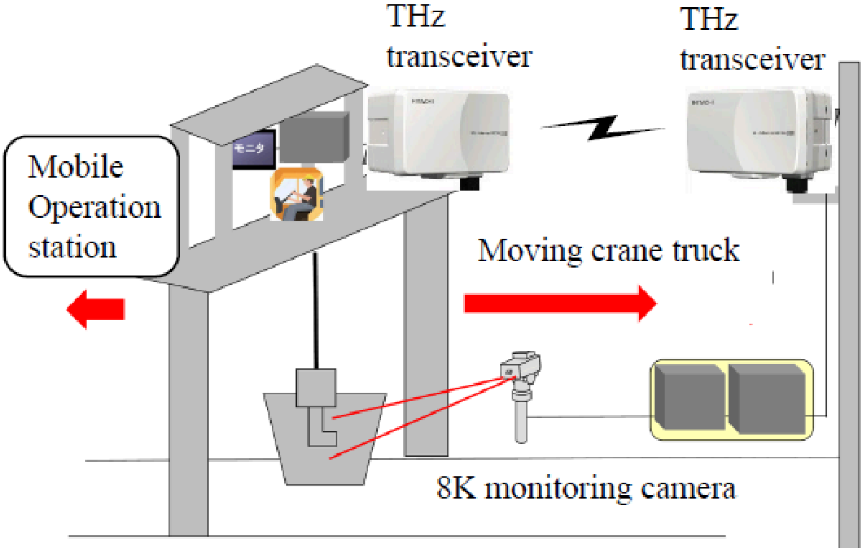


Figure 3
Factory monitoring system using THz transceivers.

6.3 Train platform surveillance system

The other application is shown in Figure 4 which illustrates train platform surveillance systems. The train platform surveillance system is widely introduced using 40 GHz and 60 GHz bands for safety operation of railway systems. However, in order to assist train crews to open/close train doors safely and keep passengers' movement on the platform under surveillance by looking at the monitor equipped in the train driver's room, high-resolution and low-latency video transfer from the platform to the driver's room is required. The uncompressed 8K video may satisfy the requirements and maintain passenger safety at the station.

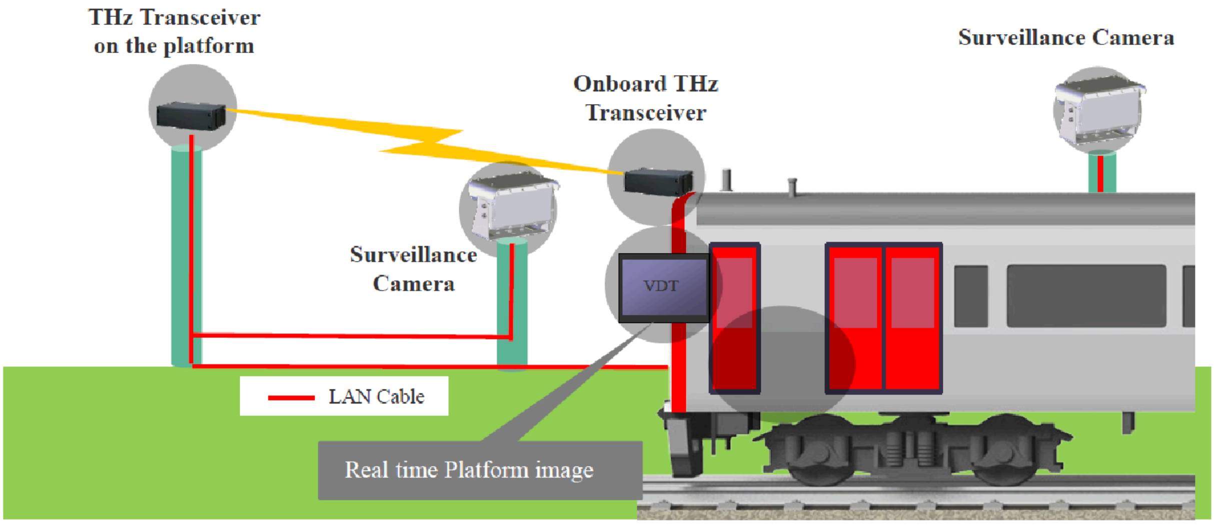


Figure 4
Train platform surveillance system using THz transceivers.

6.4 Fronthaul and backhaul to support future IMT-2030

The terahertz (THz) band (0.1–10 THz) is expected to be one of many promising pillar technologies that could be a good option for front-haul and back-haul connectivity needs of future IMT communication technologies, as it can facilitate extremely high-data-rate connection of the existing wireless transmission applications. THz communication technologies can facilitate extremely high-data-rate connection front-haul and back-haul by supporting several Gbit/s or even several Tbit/s, which is truly comparable to the connection experiences of optical fiber.

7. Technical and operational characteristics of THz systems in the frequency above 450 GHz

7.1 Channel arrangement and spectrum mask

An example of the frequency channel arrangement is shown in Figure 5 which utilizes the broad contiguous band obtained in the frequency above 450 GHz. The maximum channel bandwidth of 103.68 GHz could be arranged due to the wide range of frequency bands. Figure 6 and Table 3 show spectrum mask and parameters of each mask, respectively.

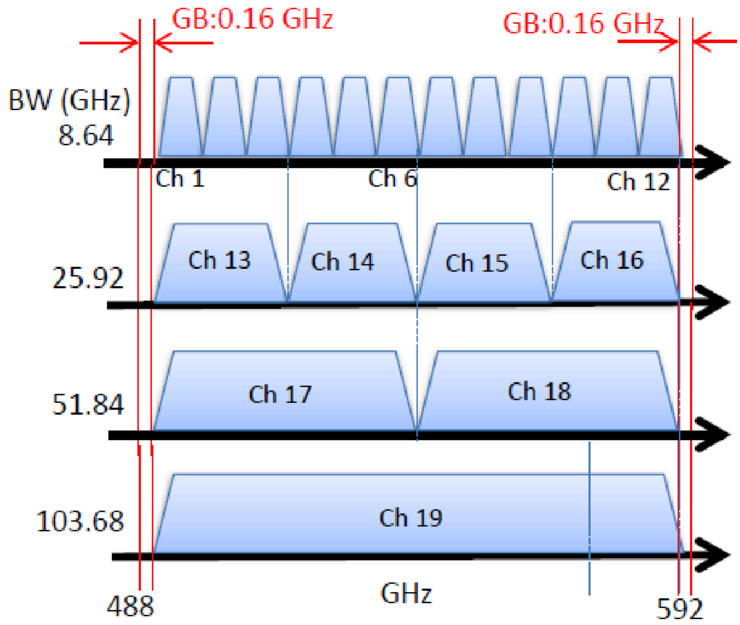


Figure 5
Example of frequency channel arrangement.

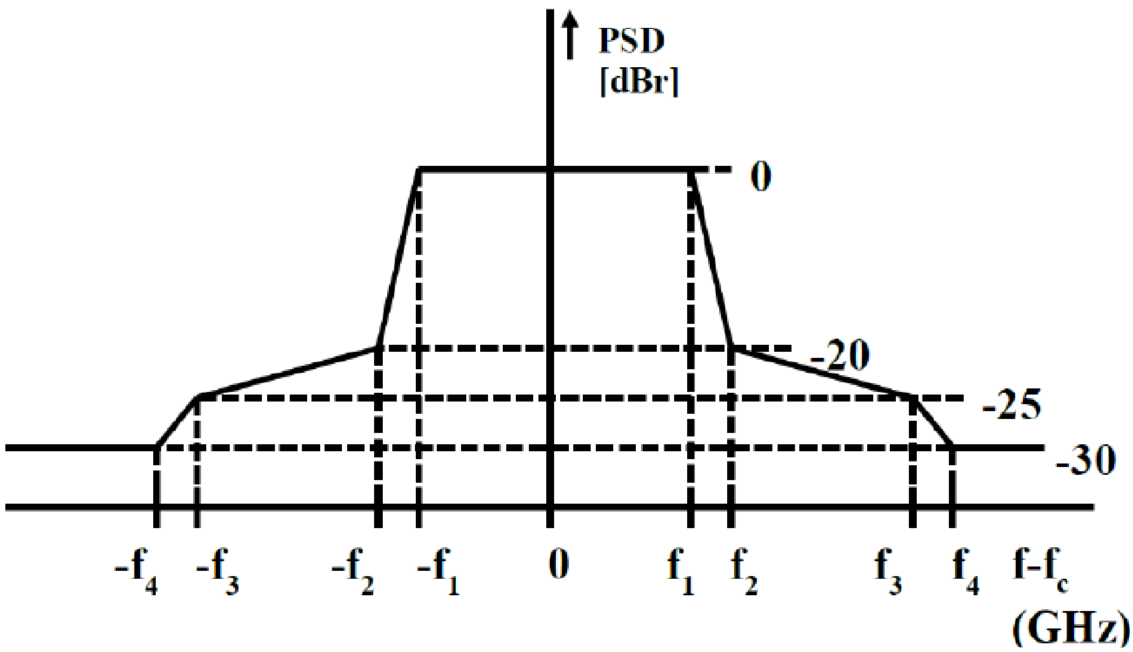


Figure 6
Generic transmit spectral mask

Table 3
Transmit spectrum mask parameters.

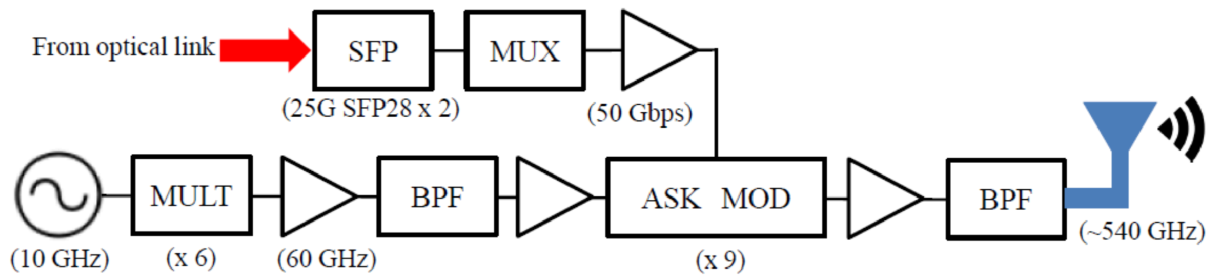
Channel bandwidth (GHz)	f_1(GHz)	f_2(GHz)	f_3(GHz)	f_4 (GHz)
8.64	4.18	4.34	4.84	5.44
25.92	12.82	12.98	13.48	14.08

51.84	25.78	25.94	26.44	27.04
103.68	51.7	51.86	52.36	52.96

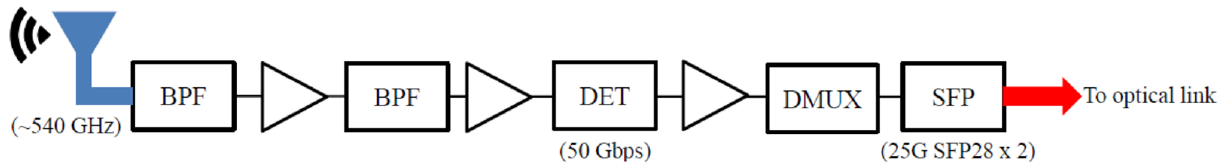
7.2 Transceiver technology

[Further description will be provided at the next meeting.]

Figure 7 shows examples of blockdiagrams for transceiver which can be connected between high-speed fiber links. SFP standard interface, ASK modulation scheme and direct detection method are utilized to simplify transceiver configurations.



(a) Blockdiagram of transmitter



(b) Blockdiagram of receiver

Figure 7
Configuration of transceiver with SFP connection

7.3 Antenna technology

[TBD]

7.4 Technical and operational characteristicsa

Table 4 summarizes technical and operational characteristics of THz fixed wireless systems.

Table 4
Technical and operational characteristics.

Parameters	Values
Frequency band (GHz)	488-592
Bandwidth (GHz)	8.64, 25.92, 51.84, 103.68
Frequency arrangement	See Figure 4
Duplex method	FDD
Modulation	ASK, FSK, PSK

Link distance (m)	10-100
TX output power (dBm)	TBD
RX noise figure (dB)	TBD
Spectrum mask	See Figure 5 and Table 3
Antenna gain (dBi)	TBD
Antenna pattern	TBD
Antenna height (m)	TBD
Antenna elevation (dgree)	TBD
Deployment density	TBD
Optical interface	SFP+, SFP28

8. Possible other applications operating in the frequency above 450 GHz

8.1 High resolution sensing

THz technologies are extremely promising for future wireless sensing systems, so emergence of new services that are beyond just communication. Shorter wavelengths imply smaller antennas, so small devices can be packed with tens or hundreds of antennas, which are beneficial for angle estimation. Ultra-fine beam generated by the ultra-large-scale antenna array can be implemented in the THz frequency band, which makes high-precision positioning and high-resolution sensing possible.

8.2 Medical imaging

THz signals, due to their characteristics, can penetrate materials and provide high resolution, without causing harm to human tissue. Microwaves are also penetrating but have low resolution, while X-ray radiation has higher resolution but may damage living tissues and DNA. Terahertz waves have the ability to penetrate through biological tissues without damaging them, making them ideal for medical imaging applications. Radio signal between 450 and 1000 GHz has a severe attenuation in water. This property can be used in medical field, as measuring the water content in tumor tissues which is significantly different from the normal tissue cells, so the cancer tissues can be located by analysing the tissue water content.

They can be used to detect early-stage skin cancer, as well as to study the structure and properties of other biological tissues, as not harmful to human beings, unlike high energy X-rays.

8.3 Security screening

THz waves can be used for security screening purposes, such as detecting concealed weapons or explosives. They can penetrate through most non-metallic materials, such as clothing or plastic, without posing any health risks to humans and with the help of the penetration loss value, detection of concealed weapon etc., is very easy using THz waves.

8.4 Material characterization

THz waves can be used to study the properties of various materials, such as semiconductors and polymers. This can be useful for developing new materials with specific properties, or for understanding the behaviour of existing materials in different environments.

9. Summary

[TBD]