

Status of Study on Terahertz Wireless Communications

- White papers & ITU-R (WP5D)
- Next Actions ?
 - From Characteristics of MMW/THz wave comm
- Large scale array antennas
- Revision of IEEE802.15.3d
- High Frequency Working Group activities

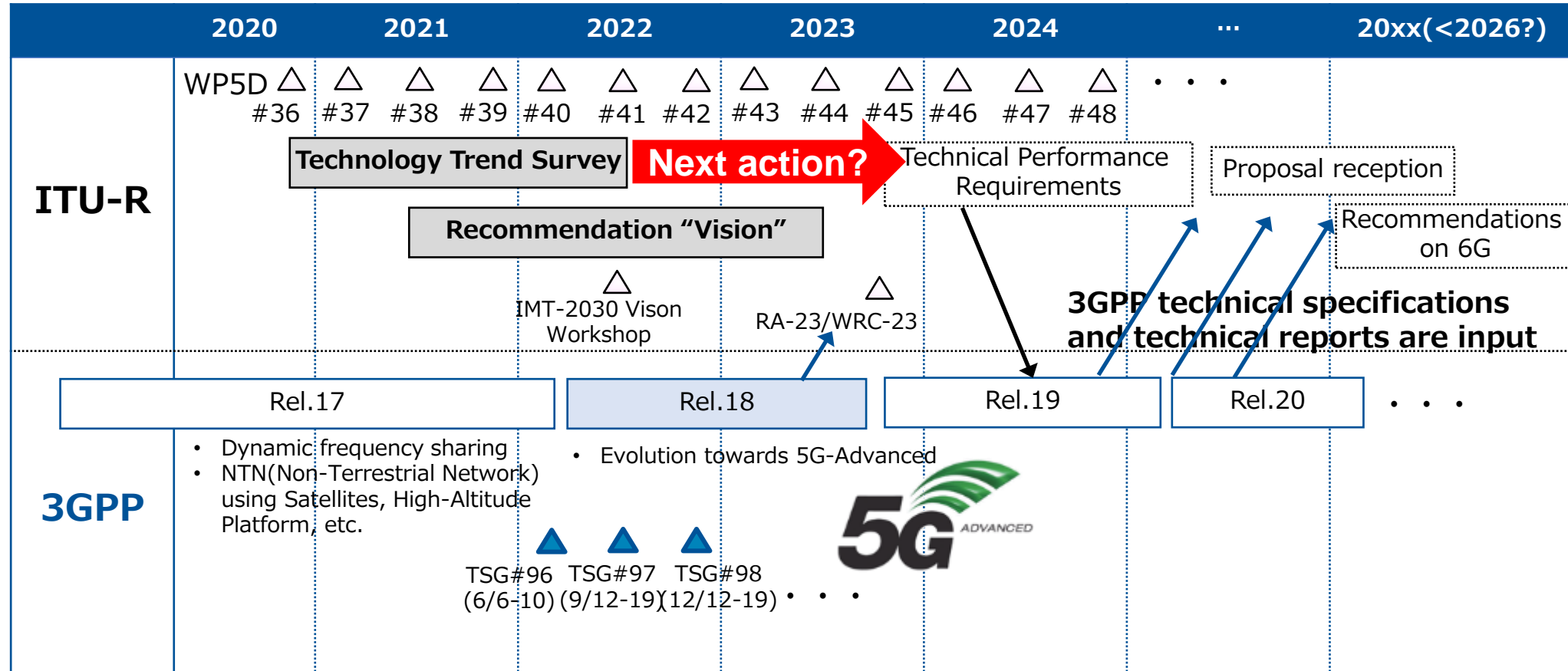
Beyond 5G Consortium,
International Committee,
High Frequency Working Group
WG-Chair : Iwao Hosako (NICT)



Many white papers describe the potential for THz use in 6G

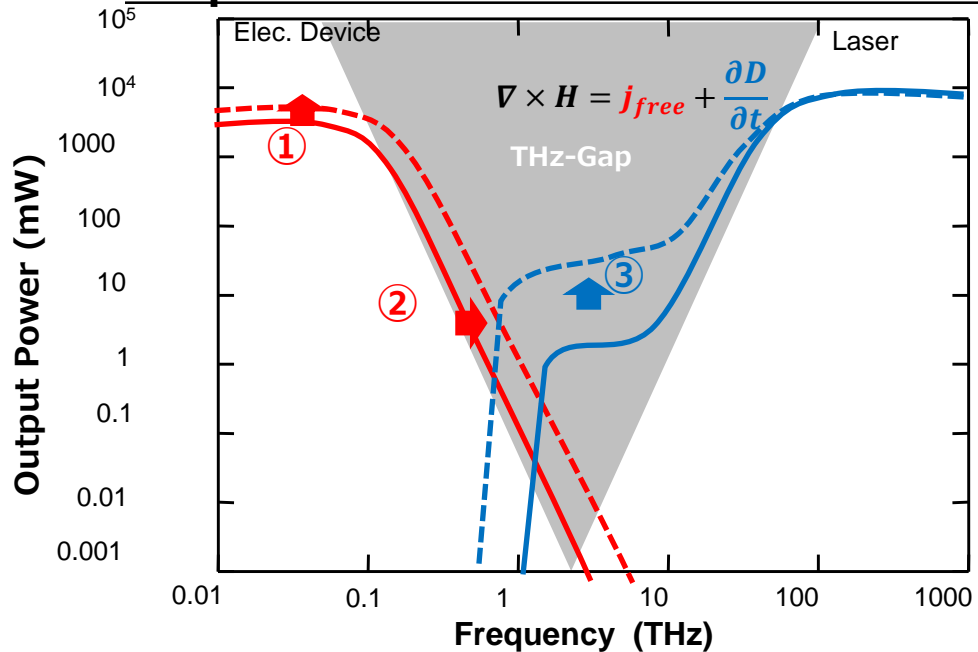


ITU document (FTT, Vision) also describes THz use in 6G

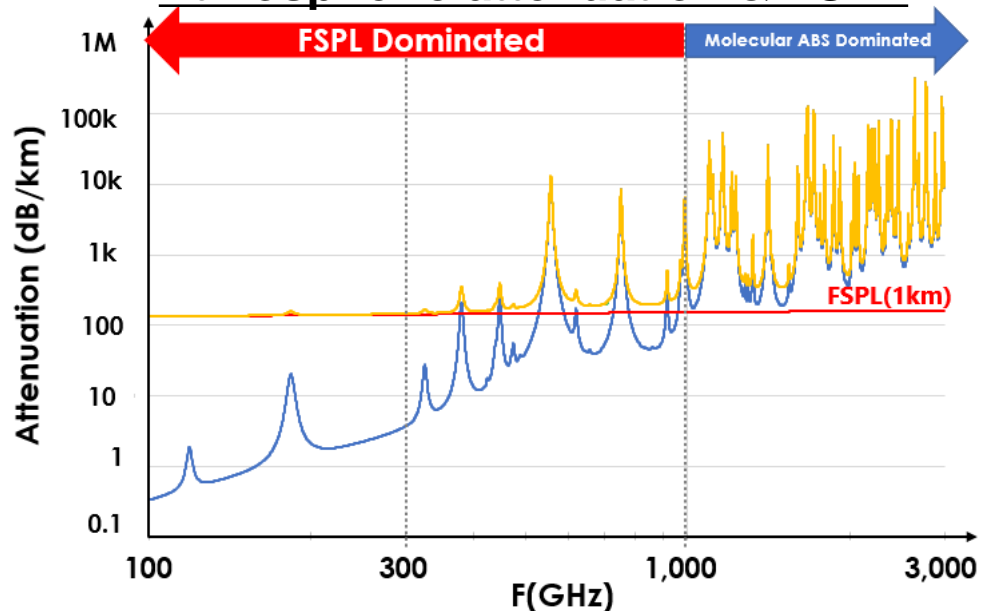


Characteristics of MMW/THz wave comm

Output Power of Semiconductor Devices

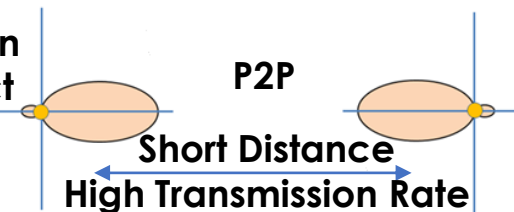


Atmospheric attenuation & FSPL



[General Characteristics of Terahertz Wave Radio]

High Gain
Compact
Antenna



- Narrow Beam
- Line of Sight

Friis transmission equation

$$P_{RX} = P_{TX} G_{TX} G_{RX} \left(\frac{c}{4\pi d f} \right)^2$$

Antenna Gain : $G = \eta \left(\frac{\pi D}{\lambda} \right)^2$ Free Space Path Loss (FSPL)

Shannon-Hartley theorem

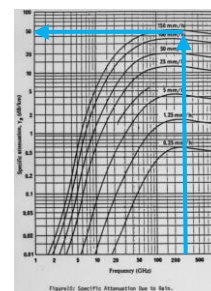
$$C = B \log_2 \left(1 + \frac{S}{N} \right)$$

RF EMF Guidelines 2020

100 kHz - 300 GHz



Specific Attenuation due to Rain

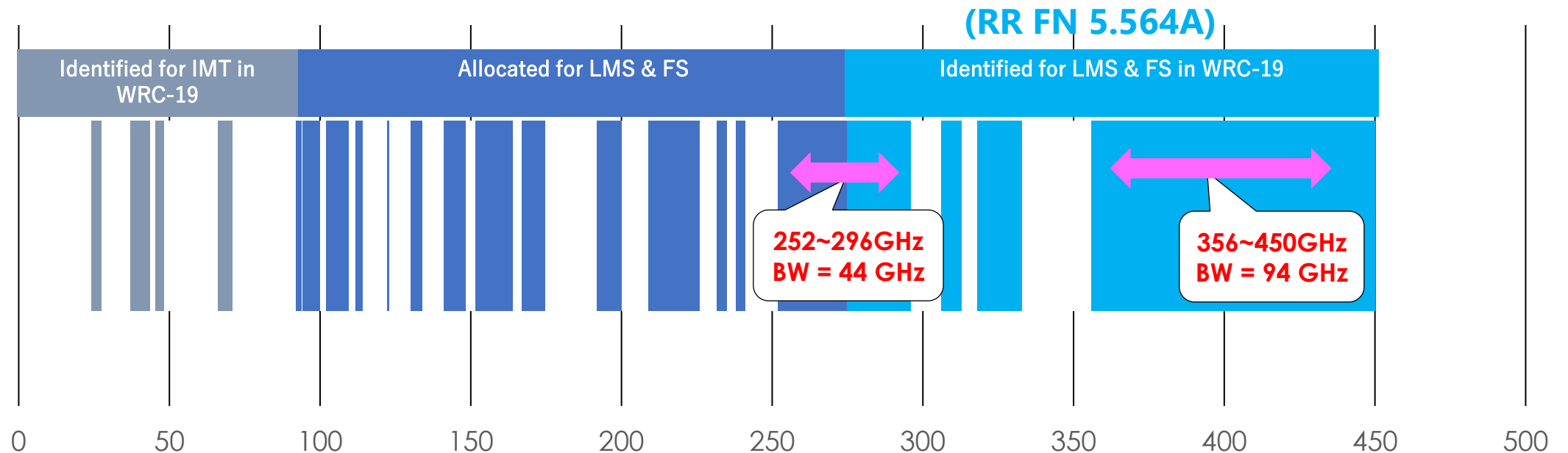


150 mm/h	300 GHz	50 dB/km
	30 GHz	30 dB/km
50 mm/h	300 GHz	20 dB/km
	30 GHz	10 dB/km

FEDERAL COMMUNICATIONS COMMISSION OFFICE OF ENGINEERING AND TECHNOLOGY Bulletin Number 70 July, 1997
Millimeter Wave Propagation: Spectrum Management Implications

Next Action → Channel models in the candidate bands

- ❑ A channel model for each use case is essential for system-level simulation.
- ❑ Up to 4G, the 3GPP channel model was limited to frequency bands below 6 GHz and quasi-static environments.
- ❑ With 5G, frequency bands expanded to the millimeter waves, and it was necessary to consider dynamic scenarios and environments for new use cases.
 - ❑ The resulting channel model cannot simply be extended to the bands where envisioned by 6G.
- ❑ Channel models in the frequency band above 100 GHz should be more site-specific and dynamic than in the 5G.
- ❑ Consideration must also be given to how to use the extremely wide bandwidth of 10 GHz to several tens of GHz.



Large scale array antennas become extremely compact



Aegis System Radar Antenna

AN/SPY-1D: S band (2-4GHz)
 $\lambda = 100\text{mm}$
Dimension: 3.66 m x 3.66 m

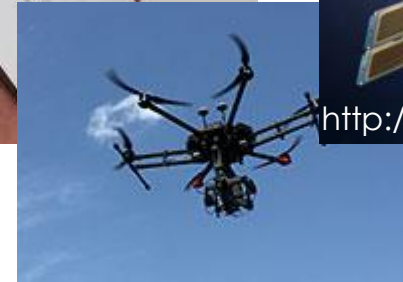
Number of array: 4,350
Beam width: 1.7 degree
Range: 500 km
Target: 200 (Multi-beam)



iPhone SE
(w:5.86 cm)



Nano satellite
(1-50 kg)



Drone

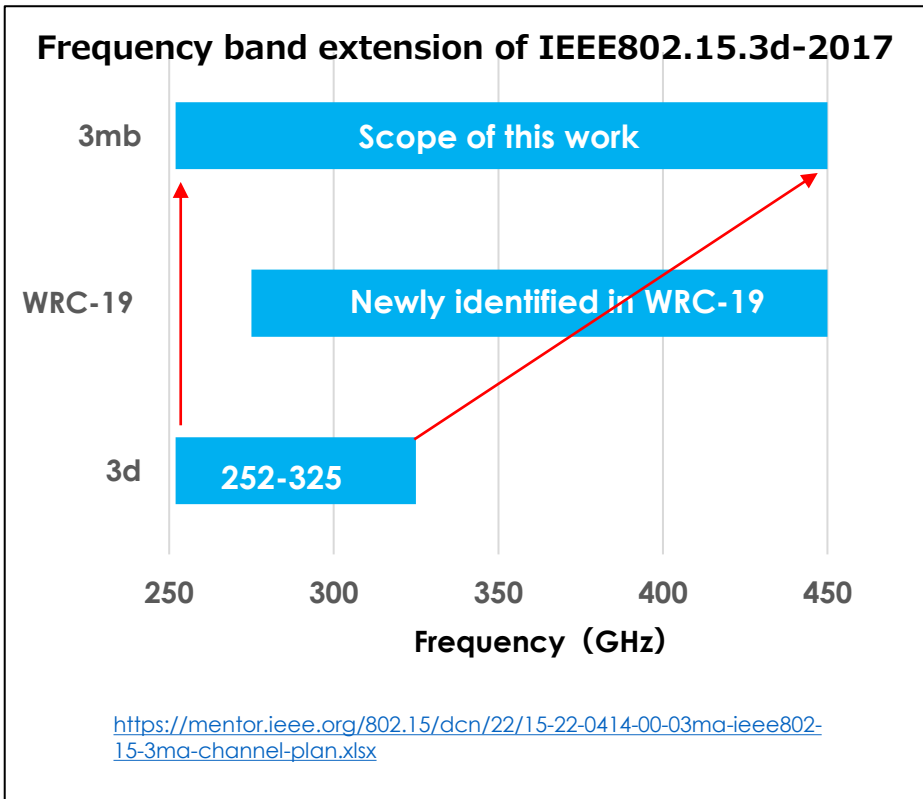
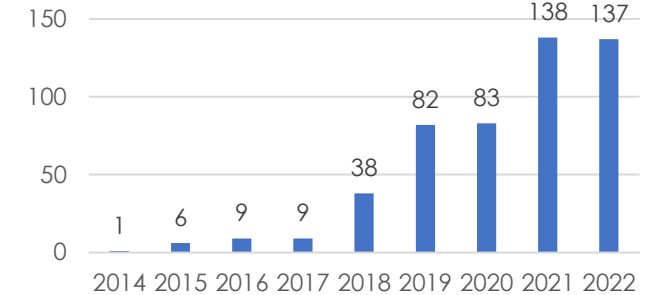
300 GHz band
 $\lambda = 1\text{mm}$
Dimension: 3.66 cm x 3.66 cm

Aegis functionality + 100 Gbit/s WL
on your palm,
drones, and
Nano satellites

Revision of IEEE802.15.3d-2017 is underway

- World's first 100 Gbps @ 300 GHz standard established in 2017.
 - Switched point-to-point link (KIOSK-DL, Intra-Device, Data Center, F/B-haul)
 - 2 PHY-modes (THz-SC PHY, THz-OOK-PHY) with 7 modulation schemes
 - BPSK, QPSK, 8-PSK, 8-APSK, 16-QAM, 64 QAM, OOK
 - 3 channel coding schemes (14/15-rate LDPC (1440,1344), 11/14-rate LDPC (1440,1056), 11/14-rate RS(240,224)-code)

Google Scholar: IEEE 802.15.3d



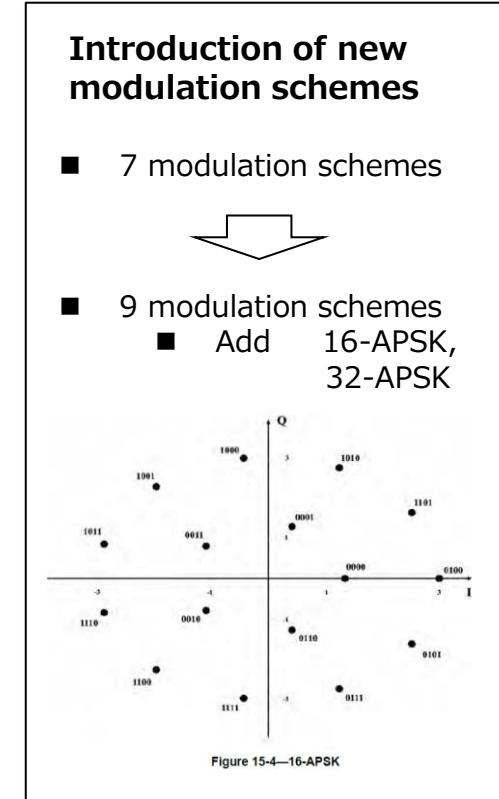
Retry Interframe Space (RIFS)

MAC Parameter		Corresponding PHY Parameter	Definition
SIFS		$pPHYSIFS\ Time$	11a.2.6.3
RIFS	PRC	$2 * pPHYSIFS\ Time + 3,01 \mu s$	7.4.1
	DEV	$4 * pPHYSIFS\ Time + 9,05 \mu s$	

MAC Parameter		Corresponding PHY Parameter	Definition
SIFS		$pPHYSIFS\ Time$	11a.2.6.3
RIFS	PRC	$2 * pPHYSIFS\ Time + 69.7 \mu s$	7.4.1
	DEV	$4 * pPHYSIFS\ Time + 142 \mu s$	

doc.: IEEE 802.15-21-0131-02-03ma-Proposal_RIFS_extension

***Based on the results of the Japan-EU Joint Call for Proposals project "ThoR (2018-2022)".**



High-frequency WG activity plan for FY2022

- Forums, etc.
 - Beyond 5G Consortium, International Committee, High Frequency WG
 - Terahertz Systems Consortium, THz-6G-WG
 - Terahertz Technology Forum, Information and Communication Division
- Academic societies, etc.
 - IEICE Technical Committee on Microwave Photonics and Terahertz Photonic-Electronics Technologies
- Others
 - Beyond 5G R&D Promotion Project, Trustee Collaboration Meeting Special Interest Group-7

To create a large flow encompassing the above activities.

- **Following the discussion of use cases in the THz-6G WG last year, the THz-6G WG will conduct in-depth discussions of technical issues (device performance improvement, assembly, packaging, subsystems, and systems).**
 - **SIG-7 members are invited to participate in this activity.**
 - **The results of the discussions will be disseminated internationally through discussions in the High Frequency WG.**



NICT

Beyond 5G R&D Promotion Unit