This project is co-funded by

Horizon 2020

National Institute of Information and Communications Technology

THOR

Study of terahertz antenna and propagation for Beyond 5G mobile communication

H2020 EU-Japan Project ThoR Final Workshop
Akihiko Hirata, Braunschweig, 29-30 June 2022

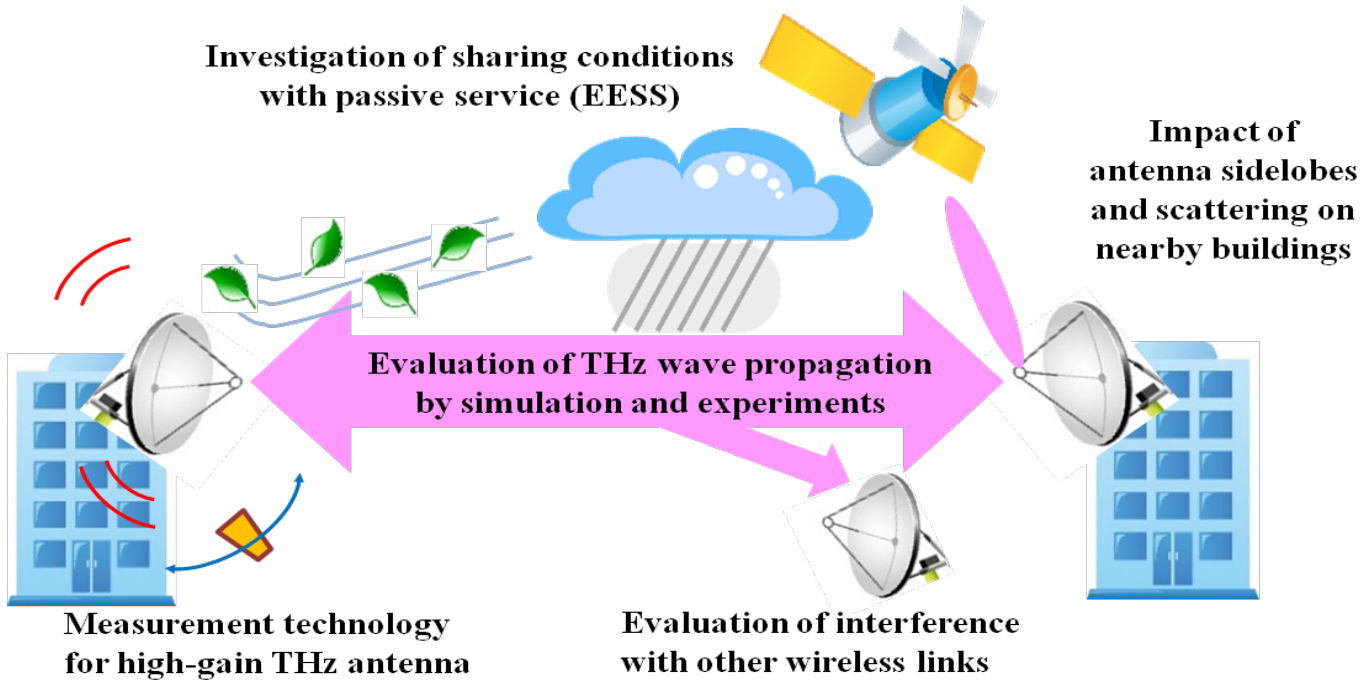
Agenda

1. Overview of work package 5 (WP5)
2. Evaluation of antenna pattern
3. Evaluation of attenuation by tree
4. Dielectric constant of building materials
5. Summary

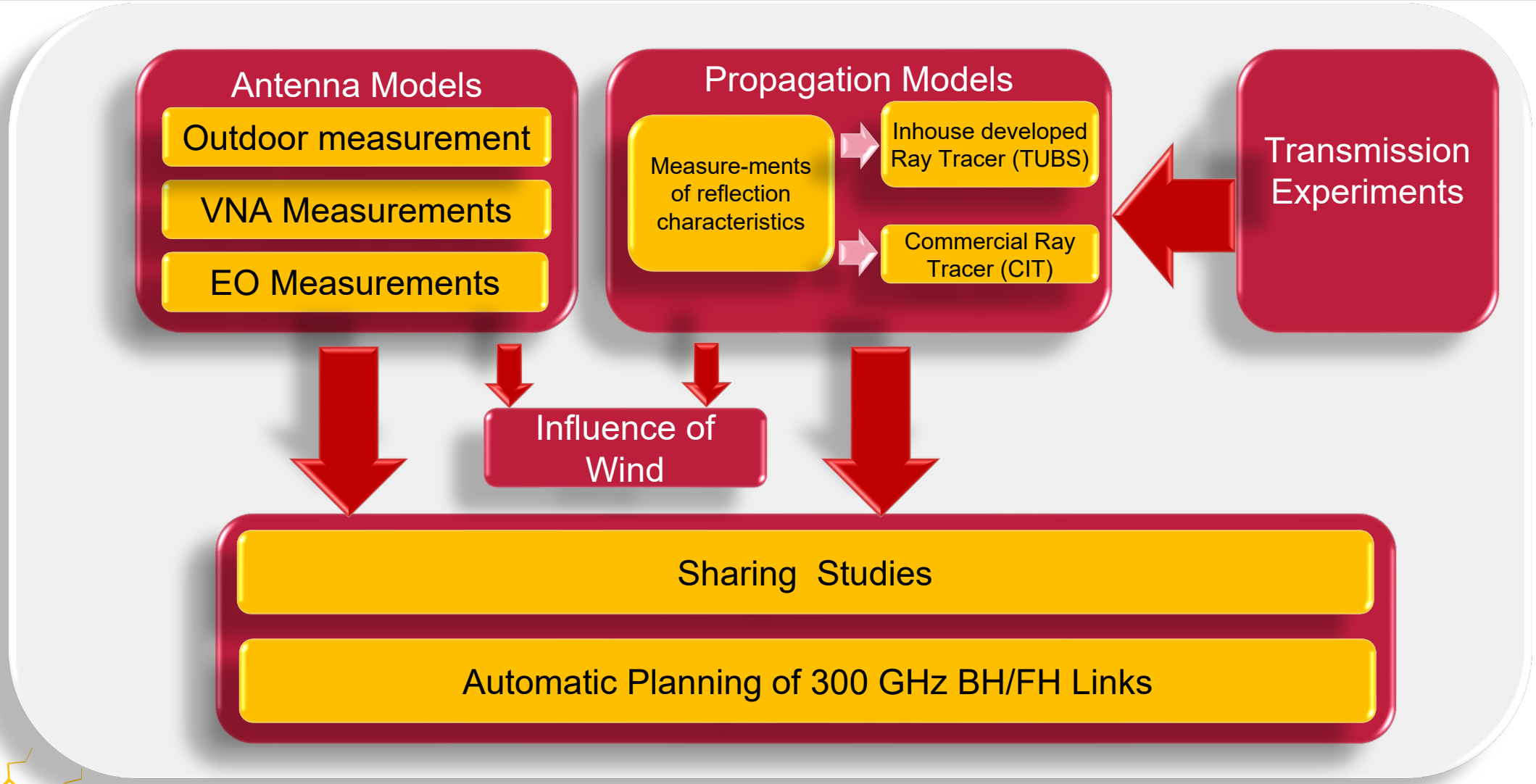
Propagation, Antennas and Sharing Studies

T5.1 Sharing investigations with passive services, development of interference mitigation techniques

T5.2 Evaluation of THz antenna and propagation



T5.2 Evaluation of THz antenna and propagation



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Antenna pattern measurement (High gain antenna)

- Boundary of far field (r) : $r = \frac{2D^2}{\lambda}$

  λ: 1 mm @300GHz, D: 0.15m @45 dBi

  ⇨ Boundary of far field (r) : 45 m

- Free-space propagation loss (FSPL)@45 m : $\left(\frac{4\pi r}{\lambda}\right)^2 = 115\ \mathrm{dB}$

- Antenna gain : 90 dBi (Tx and Rx)

- Target dynamic range : >70 dBi (Tx and Rx)

- Required minimum sensitivity P_r (dBm) @ 0 dBm Tx output power :

$P_r = 0 + 90 - 115 - 70 = -95$ dBm

Antenna pattern measurement (High gain antenna)

Carrier frequency：293.4 GHz

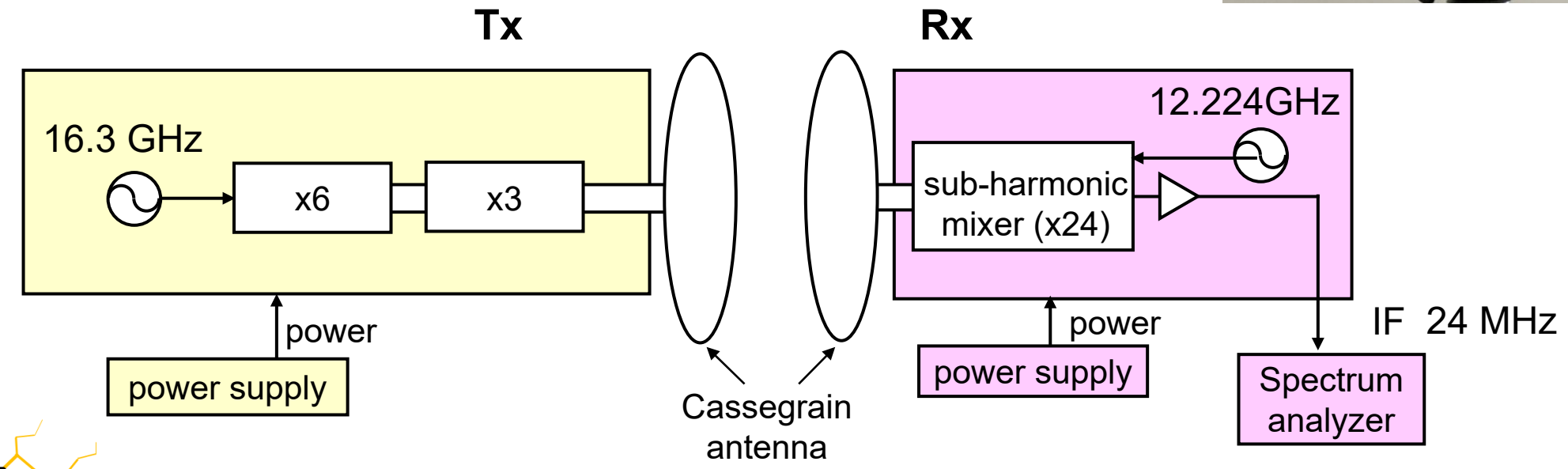
Modulation：no modulation

Output power：1.2 mW

Rx Output ：IF frequency 24 MHz

Antenna: Cassegrain (45 dBi), orthogonal horn (25 dBi)

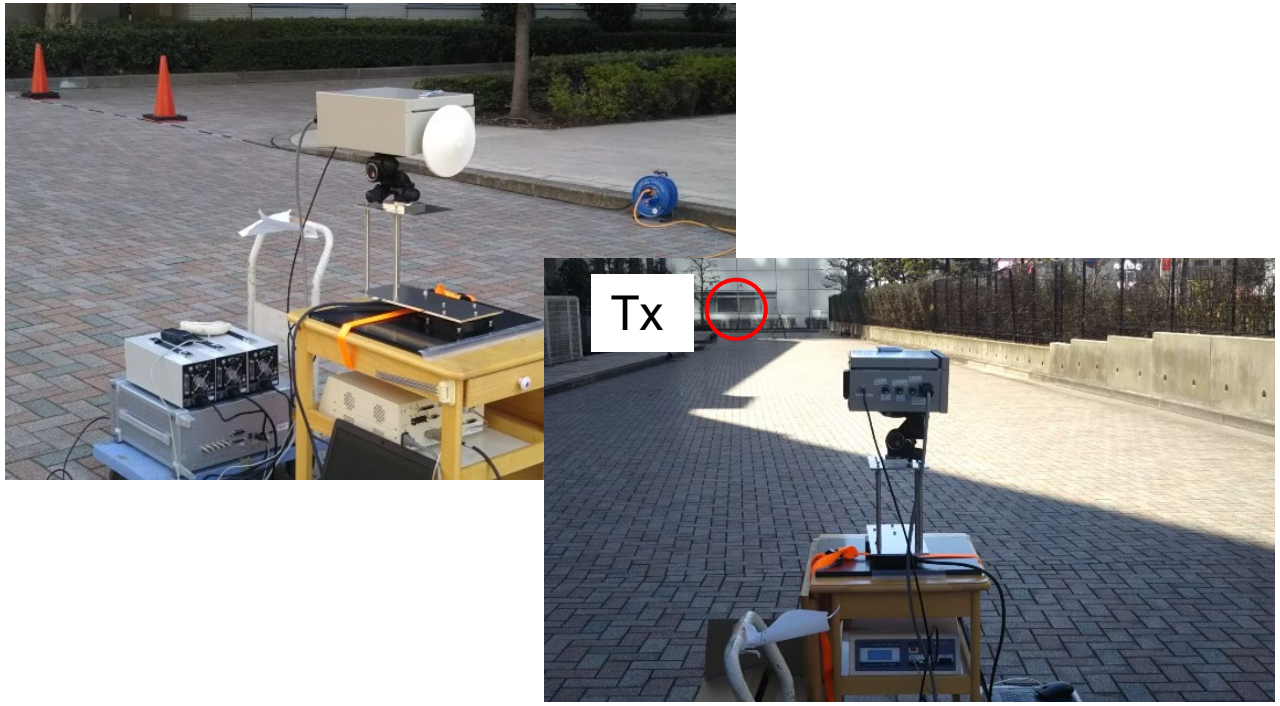
Experimental radio station license on Nov. 2020.



Cassegrain Antenna pattern measurement (47 dBi)

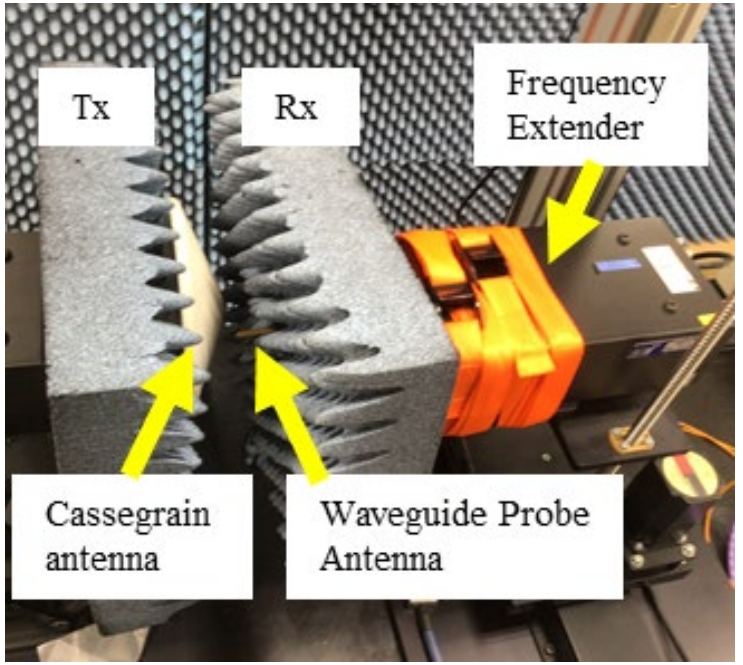
Far field measurement

- Tx-Rx distance: 50 m

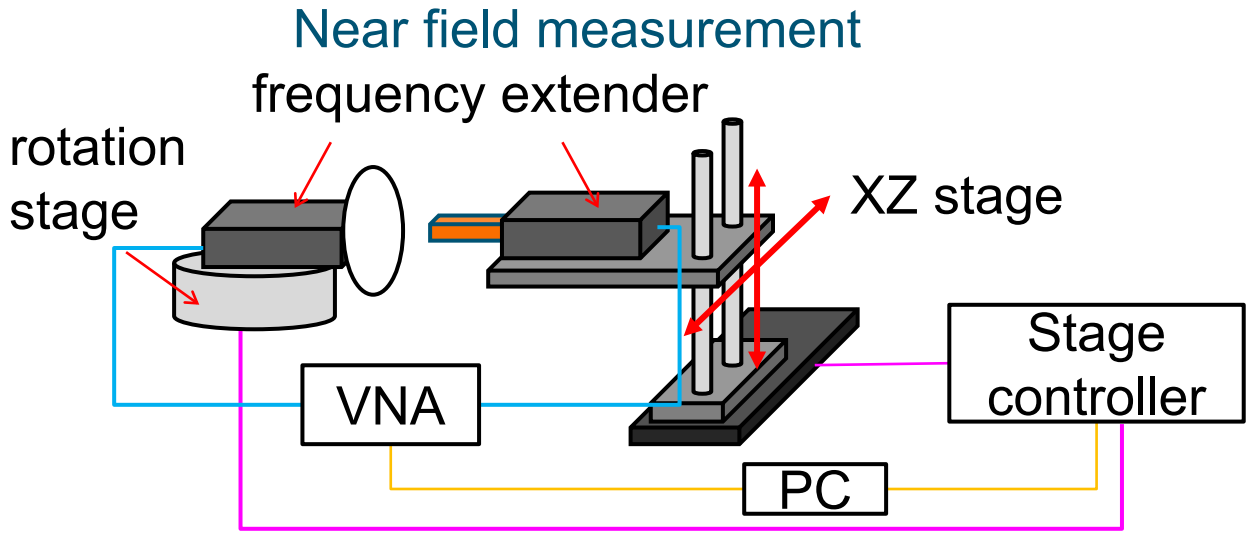


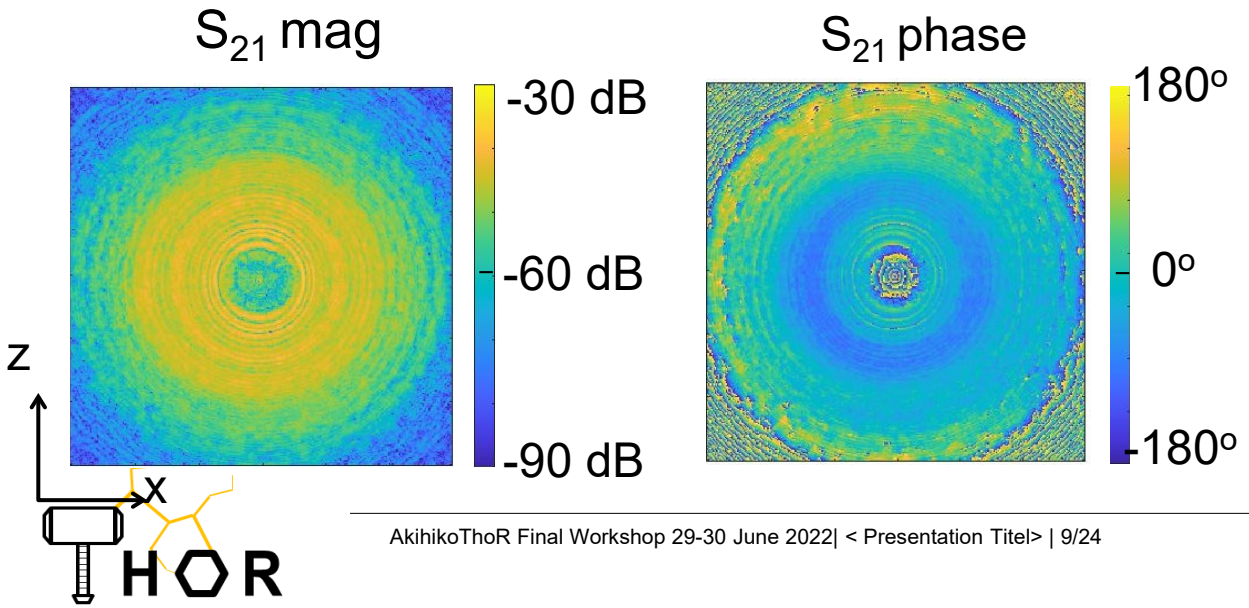
Near field measurement

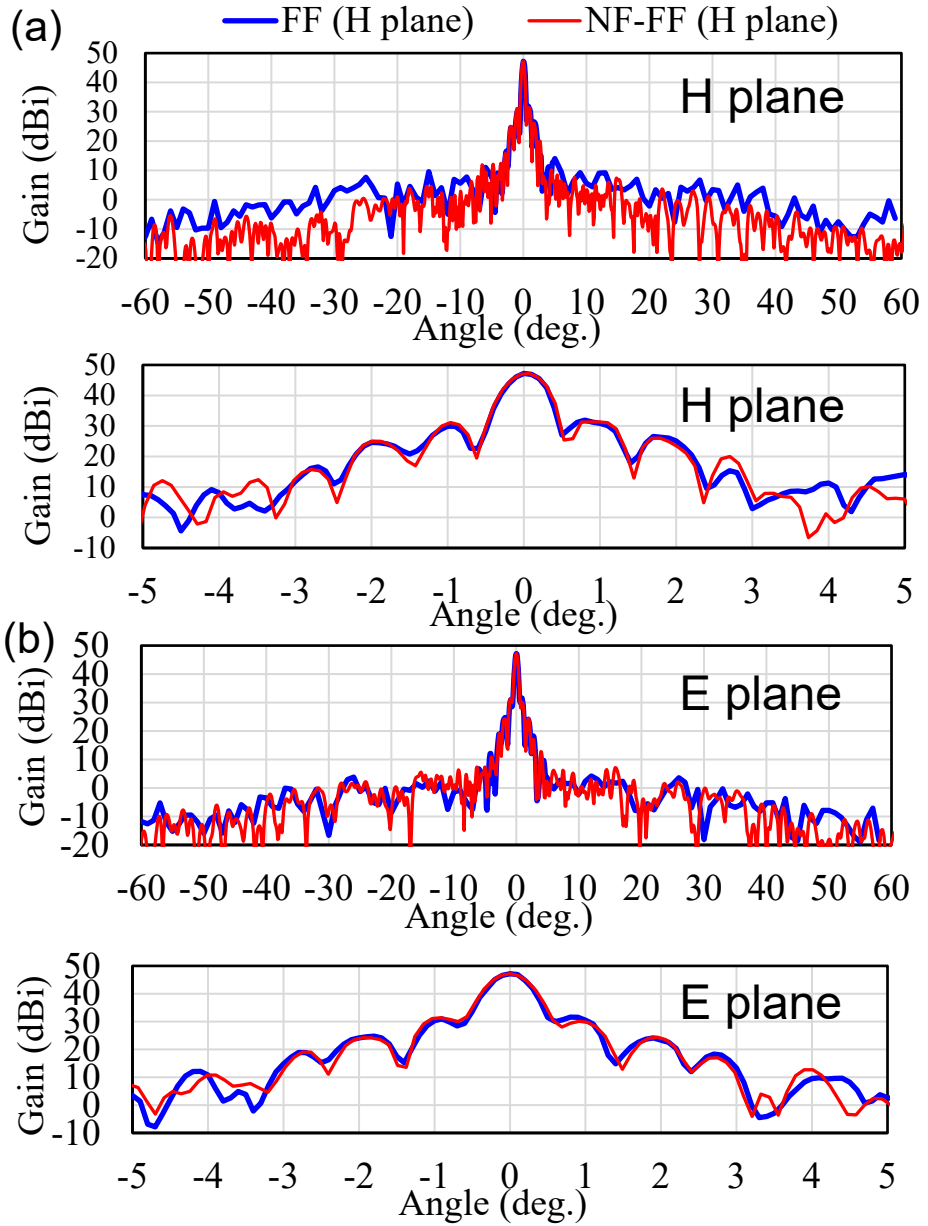
- Tx-Rx distance: 2 mm
- Map area:150 mm × 150 mm
- The pitch: 0.5 mm



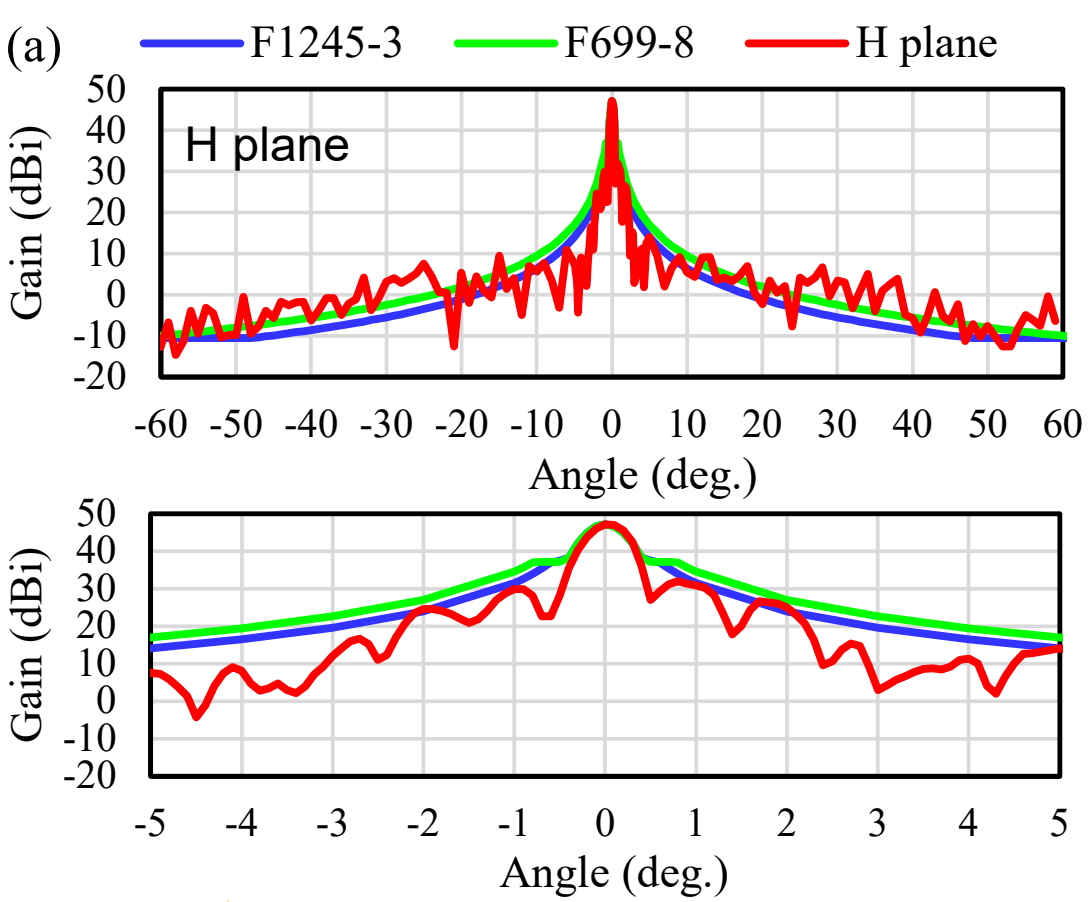
Antenna pattern measurement (High gain antenna)

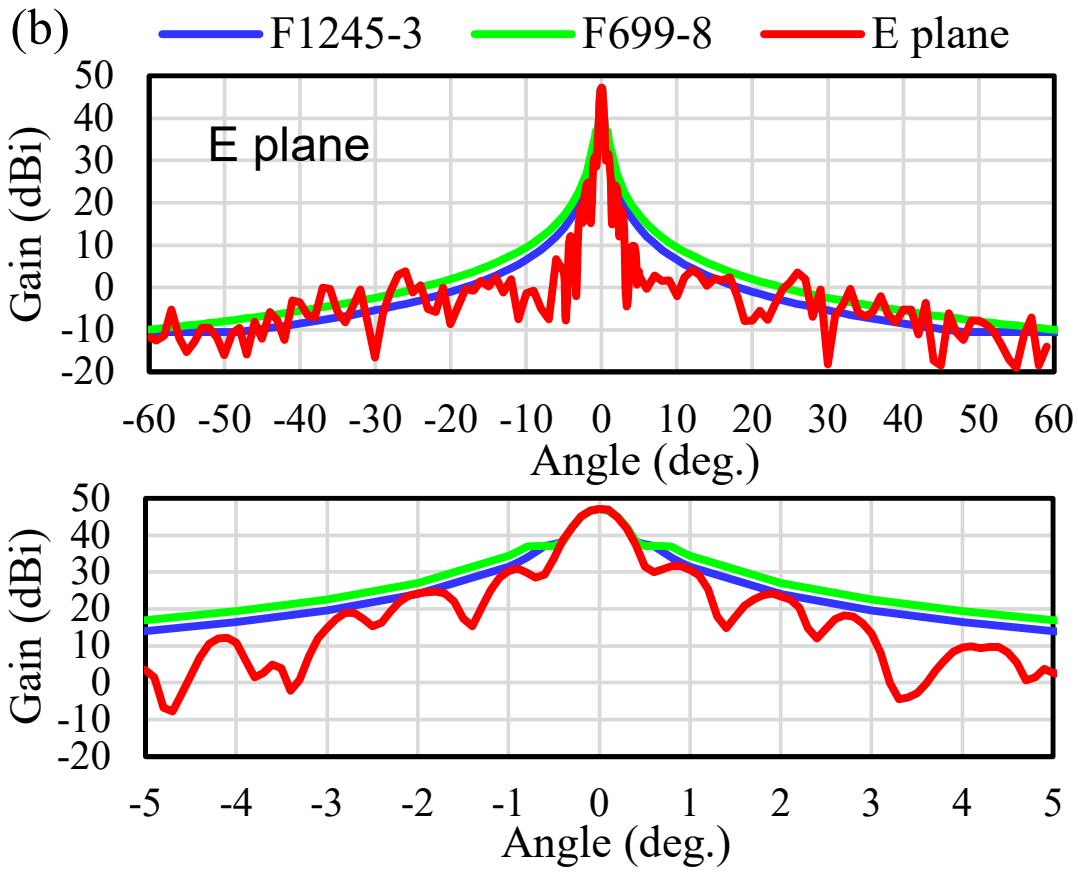






Comparison with ITU-R models





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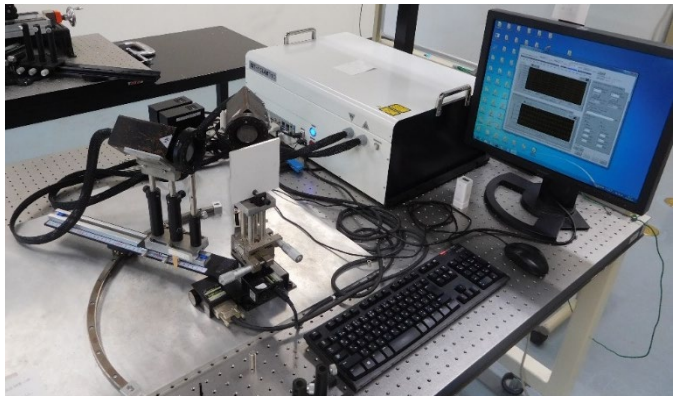
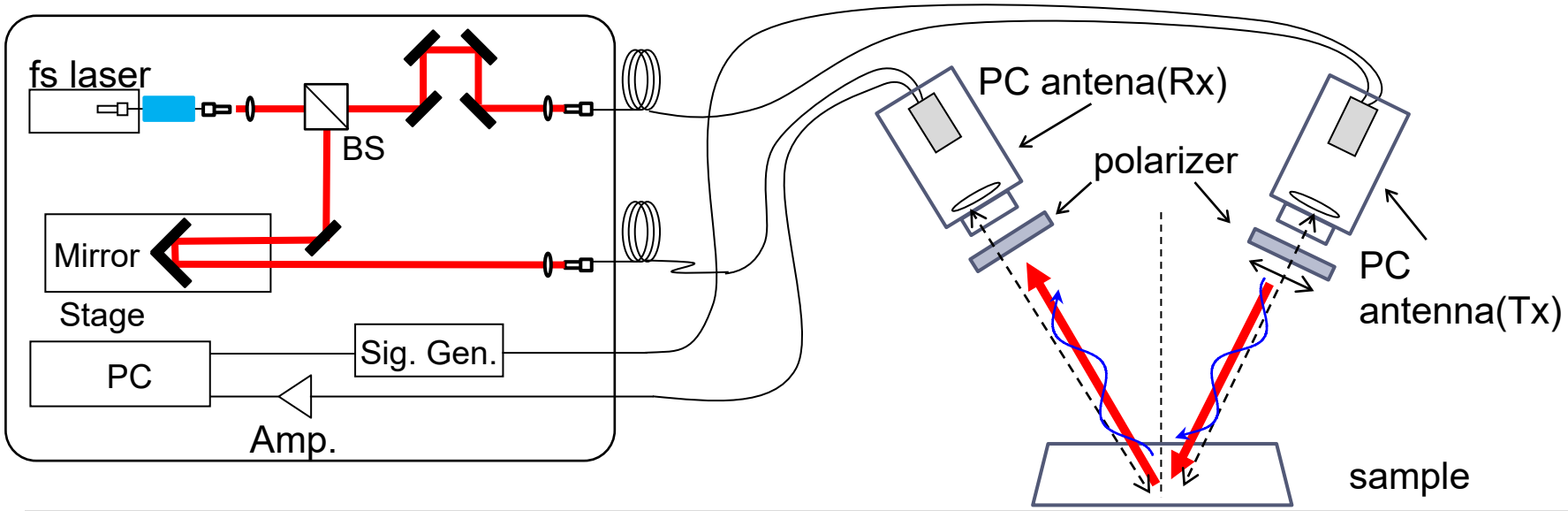
Measurement of complex permittivity by THz-TDS

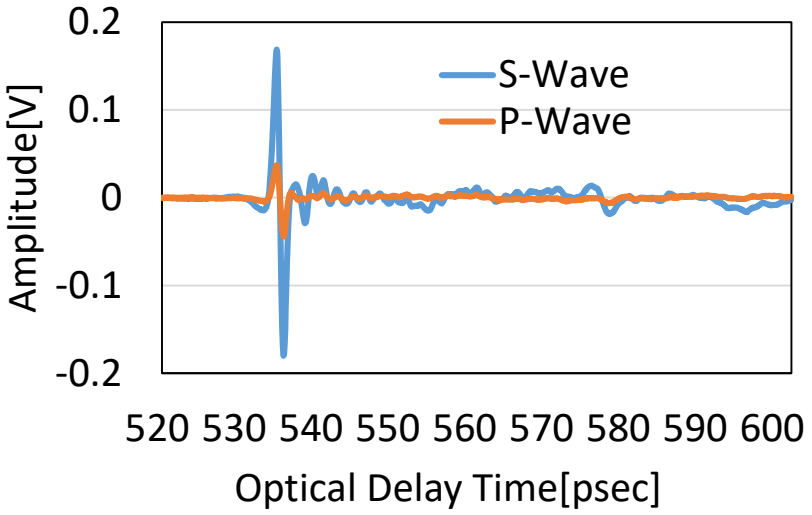
- it can easily eliminate the effects of multiple reflection, because its probe signal is ultra-narrow (>1ps) pulse signal.

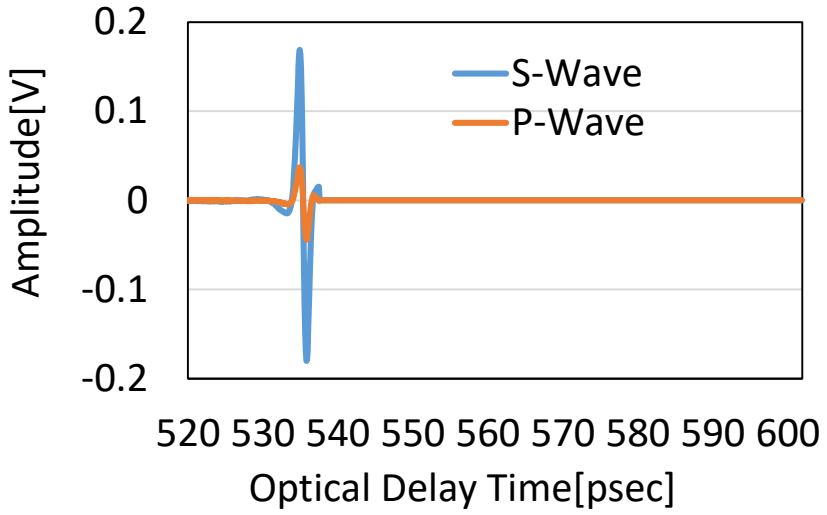
$$N^2 = \sin^2\theta + \frac{\sin^4\theta}{\cos^2\theta}\left(\frac{1-\frac{r_p}{r_s}}{1+\frac{r_p}{r_s}}\right)^2 = \varepsilon_1 + i\varepsilon_2$$

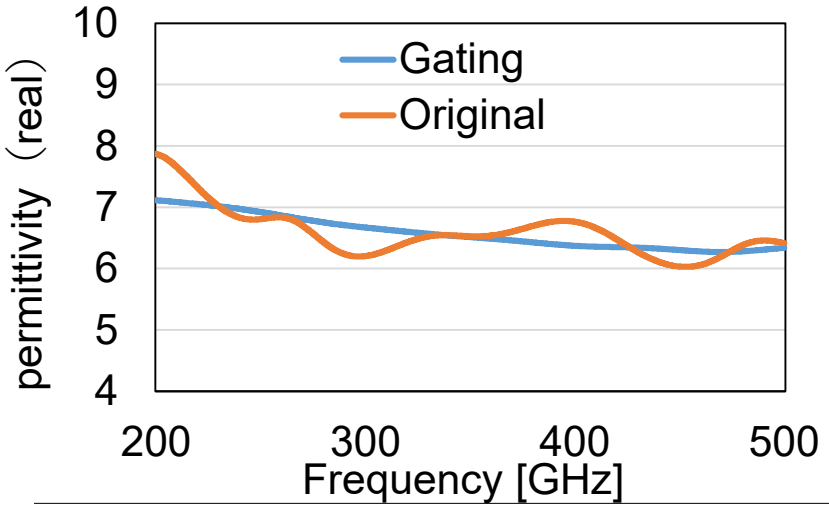


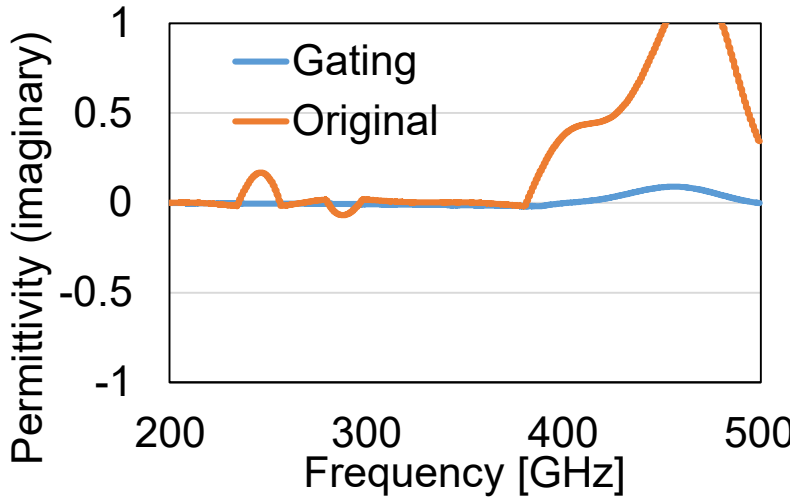


Complex permittivity of concrete

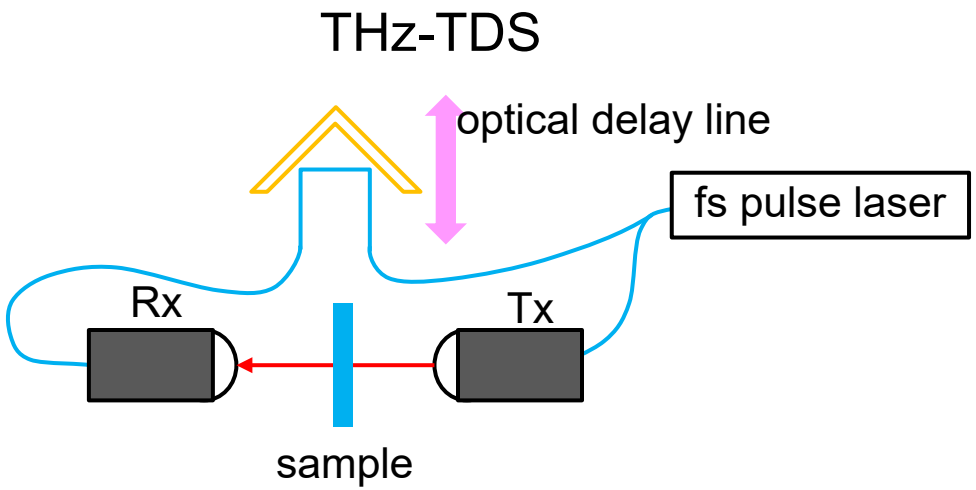


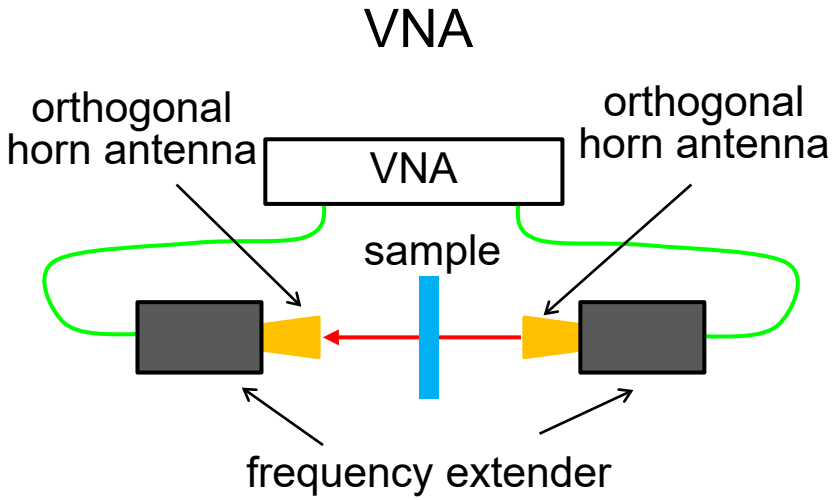






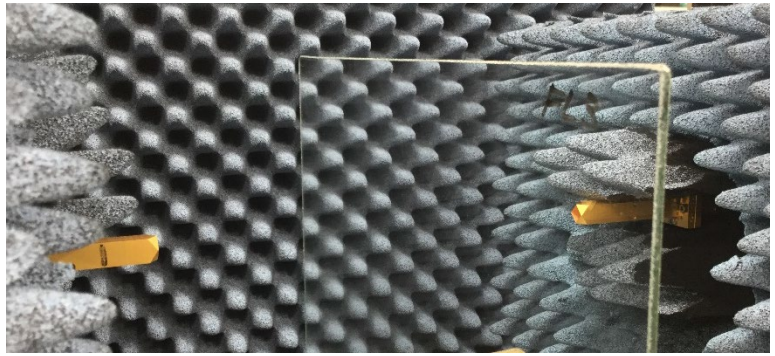
Complex permittivity calculated by transmission characteristics



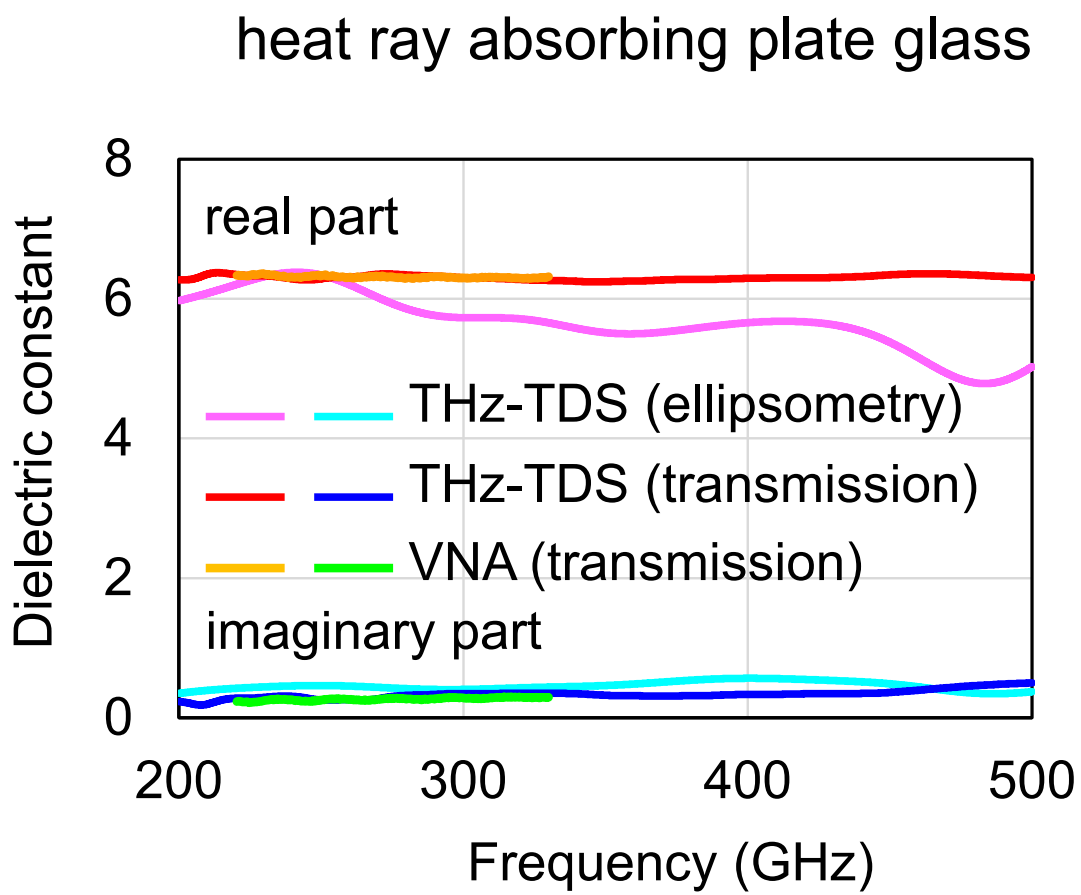


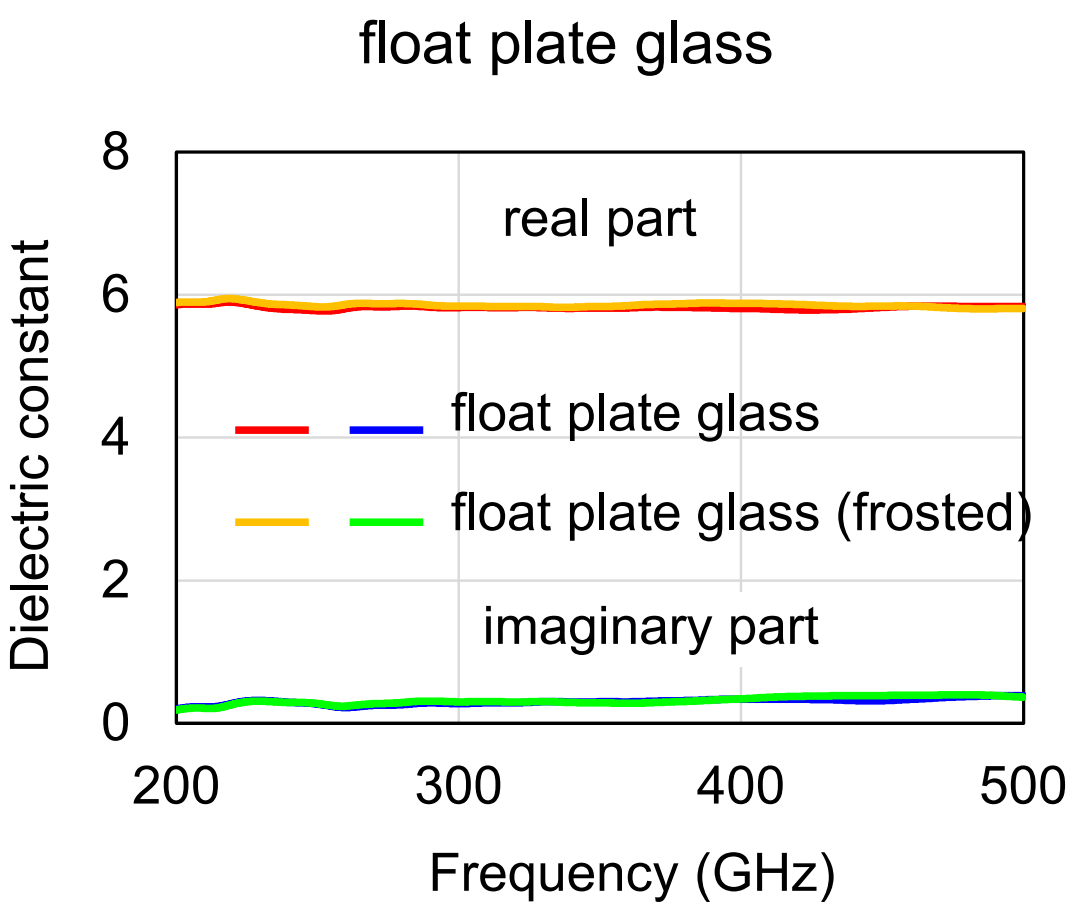
$$\left(x + \frac{1}{x}\right) sinh(xP) + 2\cosh(xP) - \frac{2}{S_{21}} = 0$$

$$\mathrm{x} = \sqrt{\varepsilon_1 - i\varepsilon_2},\ \mathrm{P} = \mathrm{j}\beta_0 d,\ \beta_0 = 2\pi f/c$$



Complex permittivity of glass



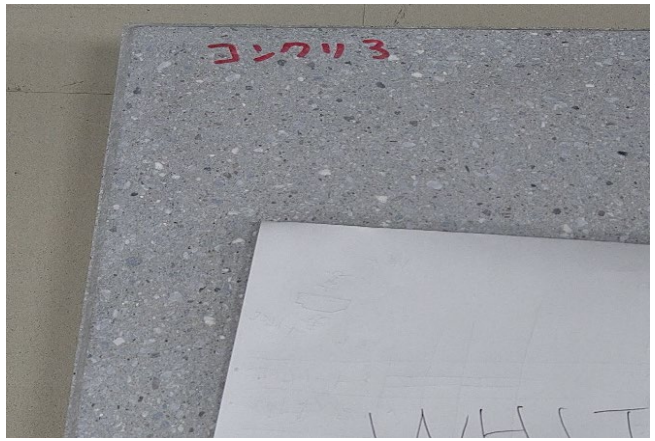


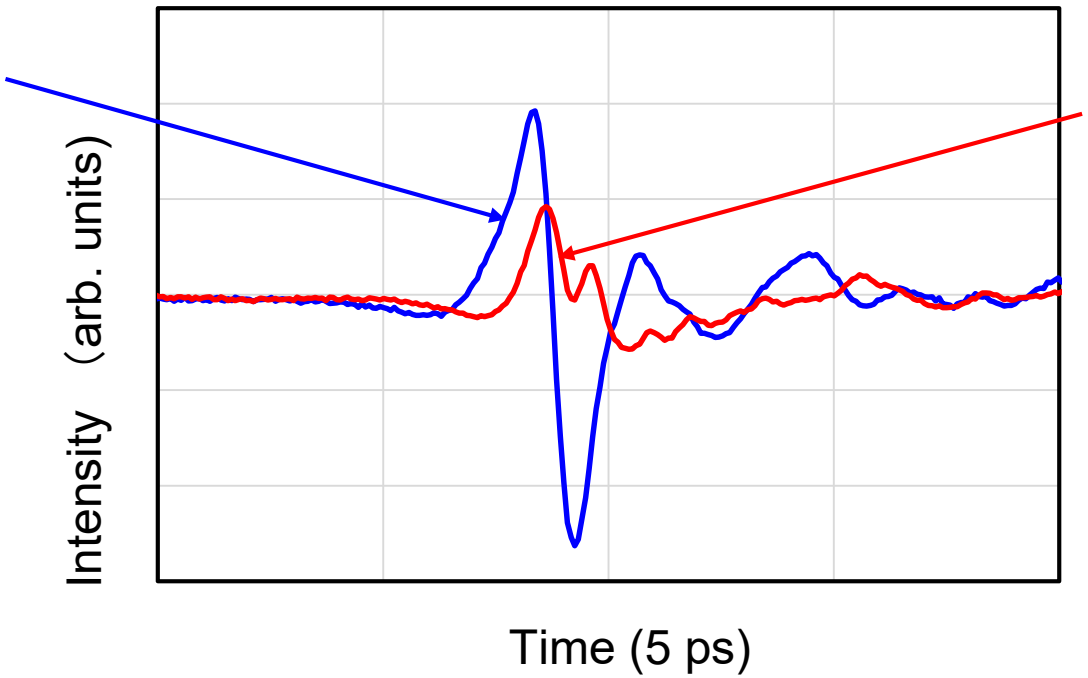
Complex dielectric constant of building material

Material	Type	Real Part	Imag. Part
Glass	Float Glass	5.8~6.3	0.2~0.3
	Heat-Absorbing Glass	6.2~7.3	0.3~0.4
	Heat-Reflecting Glass	5.9	3
Wood	Depends on the direction of annual rings	2.2~3.7	0.1~0.2
Rubber		5.6	0.4
Teflon		2.1	0.002
Plastic		2.3	0.002

Complex dielectric constant of building material

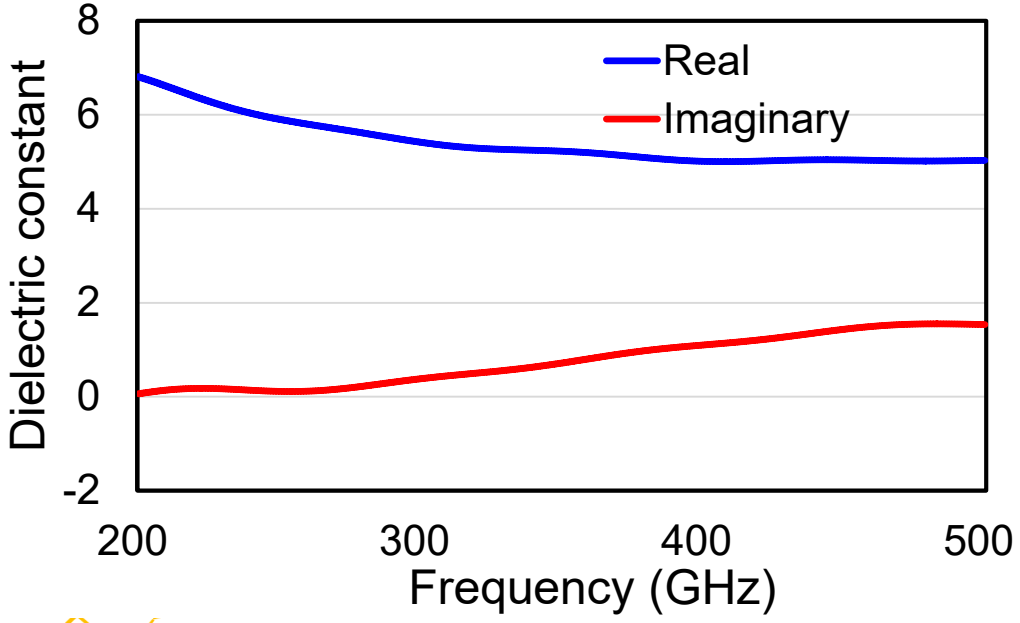
If the concrete surface is not a mirror surface, the reflected signal intensity is greatly reduced due to scattering from the micro surface roughness

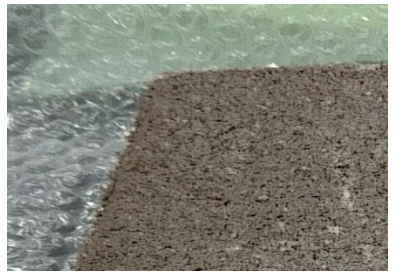


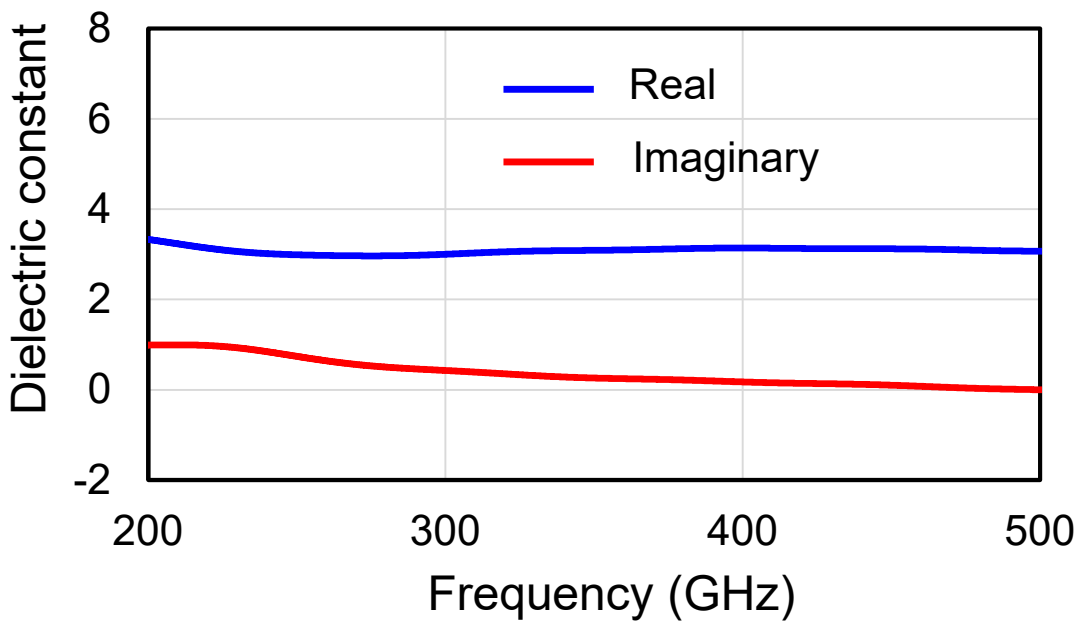


Dielectric constant of concrete

Dielectric constant is calculated to be low for samples with surface roughness that cause scattering of terahertz waves.



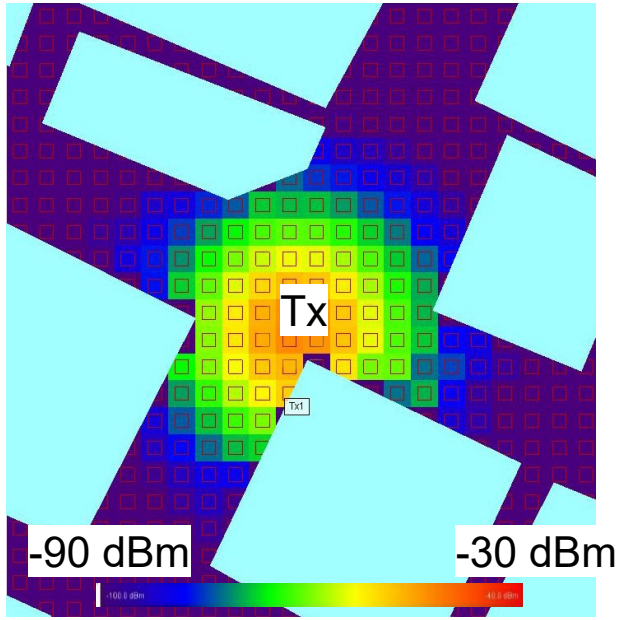




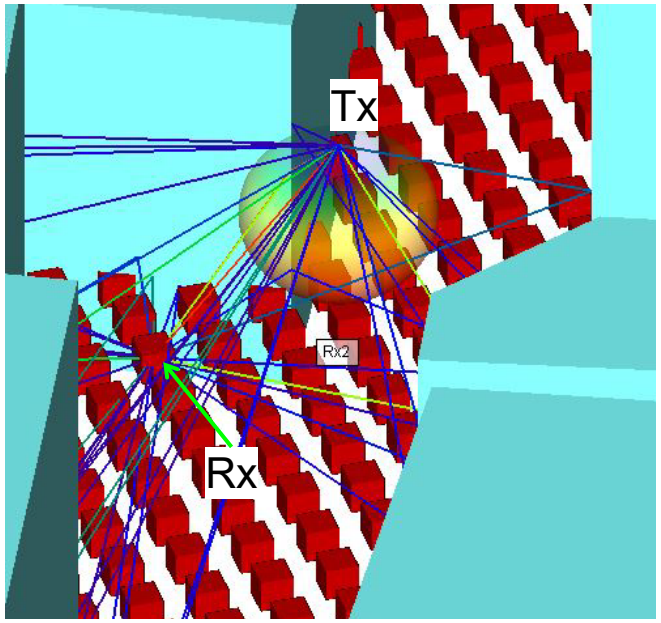
Simulation results of propagation paths

- Height of Tx: 5 m, Rx: 1.2 m
- Antenna: directional antenna with a half power beam width of 60^{o}
- Output power of Tx : 30 dBm

Received power map



Propagation path



(b)

Summary

- It is important to build precise antenna models and propagation models at 300-GHz-band for the frequency sharing studies and design of fronthaul links
- Far-field radiation pattern of high-gain antennas was measured by an experimental radio station, and measured far-field pattern coincides with the near-field-to-far-field conversion results.
- Attenuation by tree is about 20 dB, and two attenuation modes are observed.
- The small surface roughness of the building material affects the calculation results of dielectric constant.

Thank you for your attention!

ご清聴ありがとうございました

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