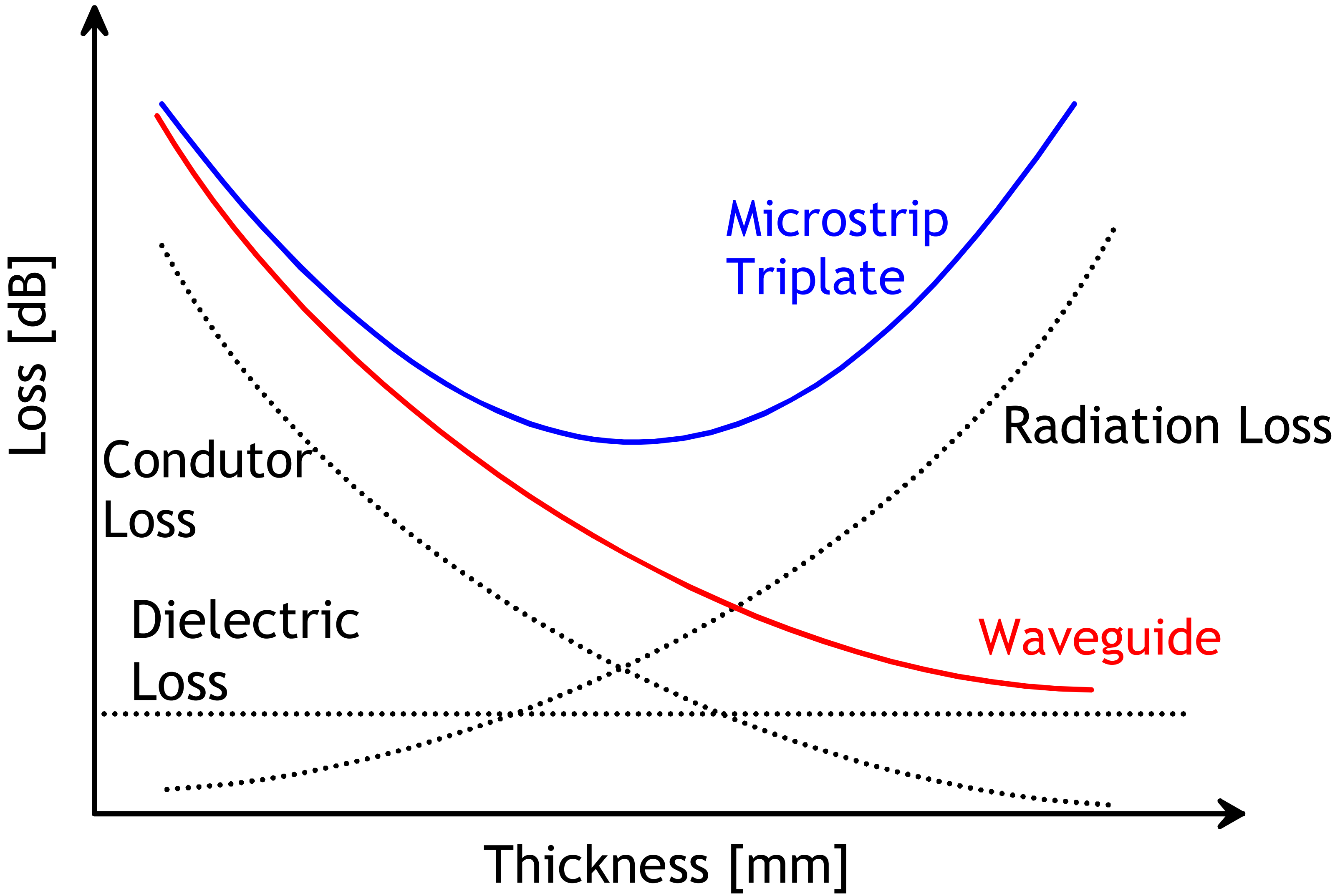
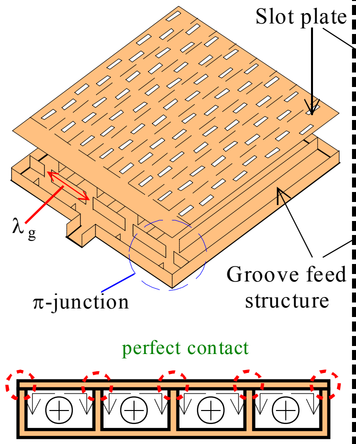
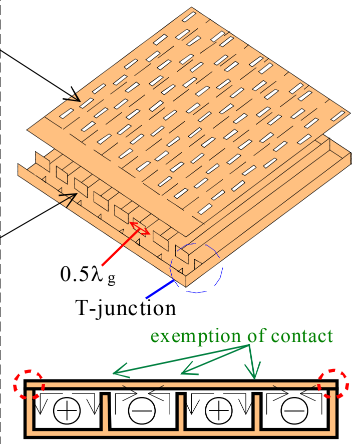
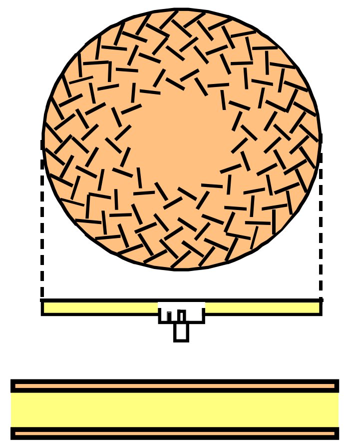
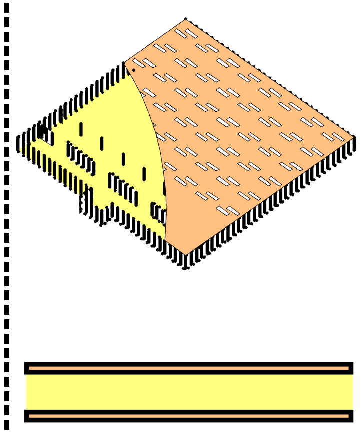
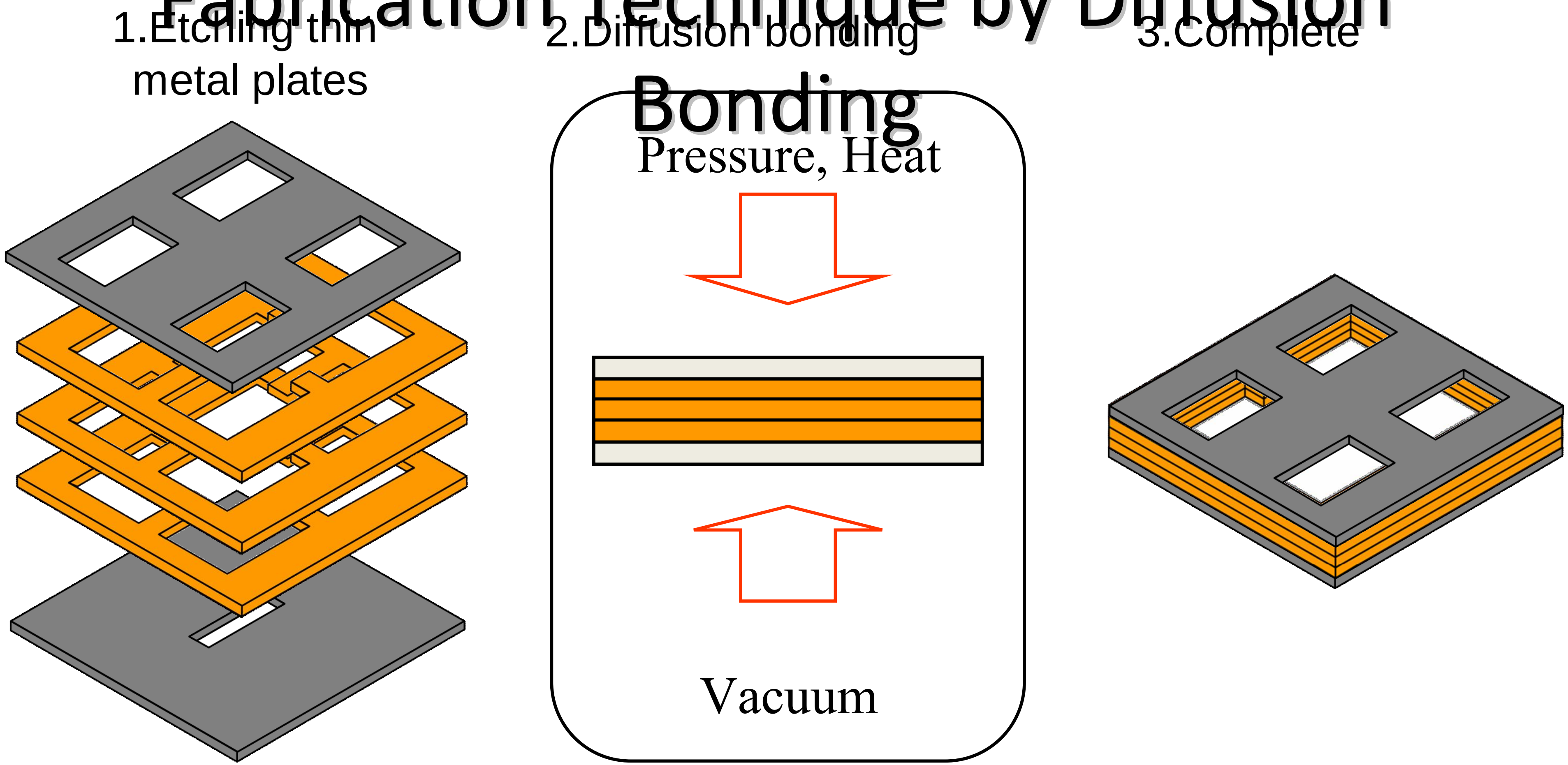


Loss in Planar Structure

Single-Layer Slotted Waveguide

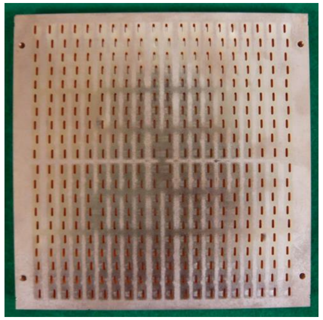
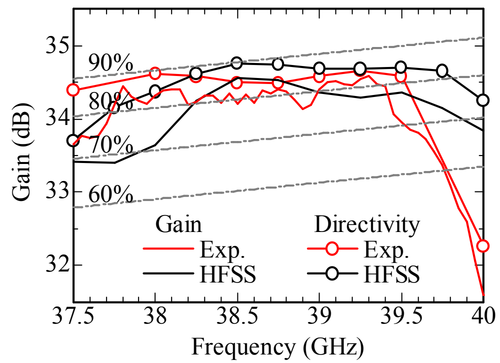
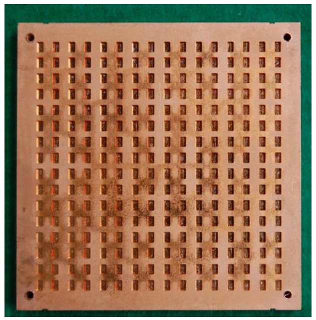
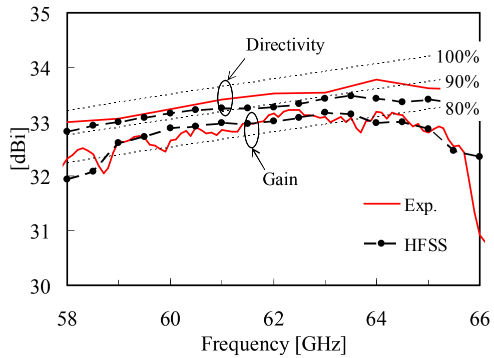
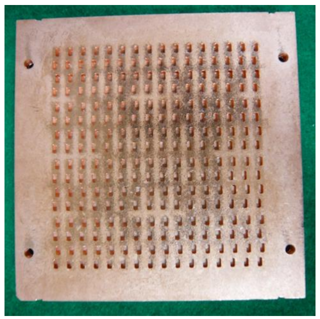
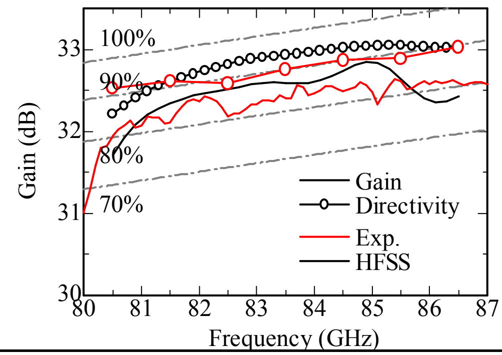
Modes	Single-mode		Oversize	
	Co-Phase	Alternating-Phase	Stacking Substrate RLSA	Post-Wall Waveguide
Structure				

Fabrication Technique by Diffusion Bonding



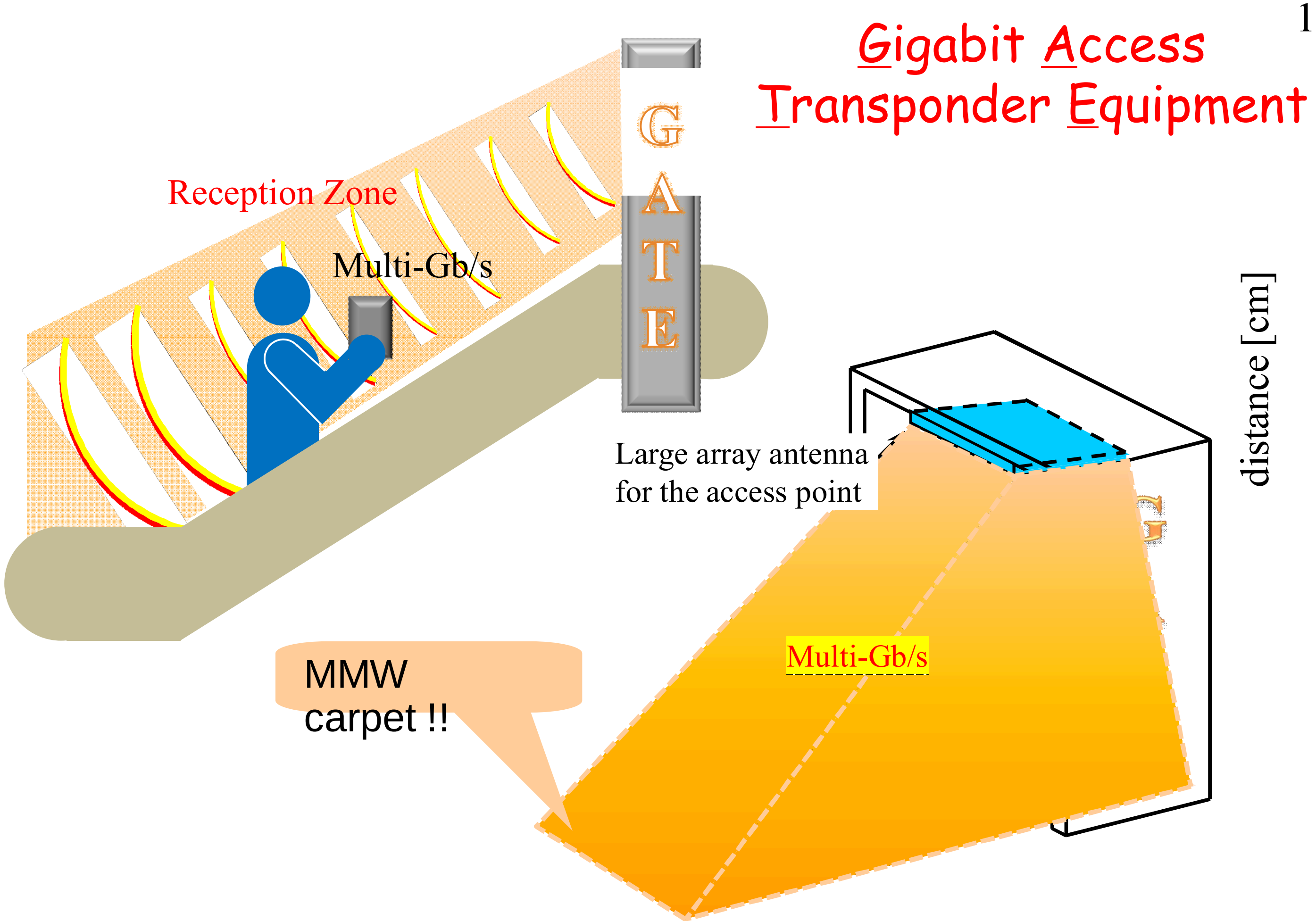
- Etching: high precision (20μm), Diffusion bonding: electric contact
- Expensive die is not needed, Easy to make multi-layers

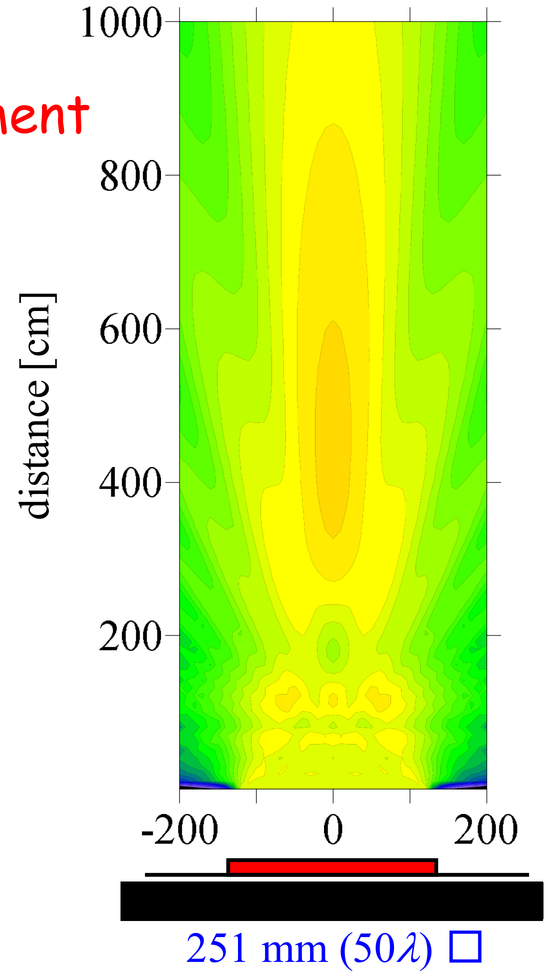
Fabrications in Various Bands

Band	Picture	Array Size	# of slots	# of sub arrays	1dB-down gain BW	Gain
Q		131mm x 123mm	20 x 20	2 x 2	5%	
V		68mm x 68mm	16 x 16	8 x 8	11%	
E		45mm x 48mm	16 x 16	4 x 4	9%	

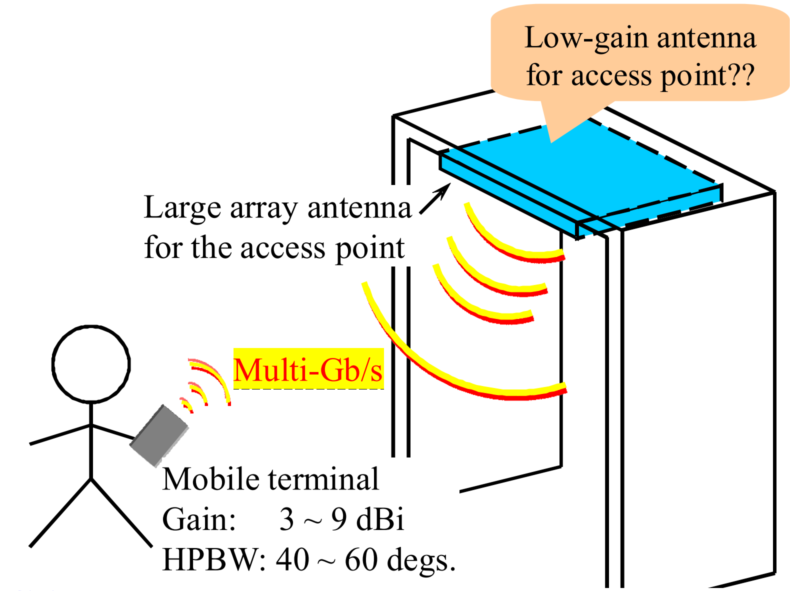
Compact-Range Wireless Access System

- Adopting large aperture antennas in the 60 GHz-band GATE;
- Communication in the near-field region (convention: far-field region);
- Reception zone : distance (~ 10 m) & cross-section area (tens of cm square);
- Antenna size: uniform intensity, wide & long zone, small interference;

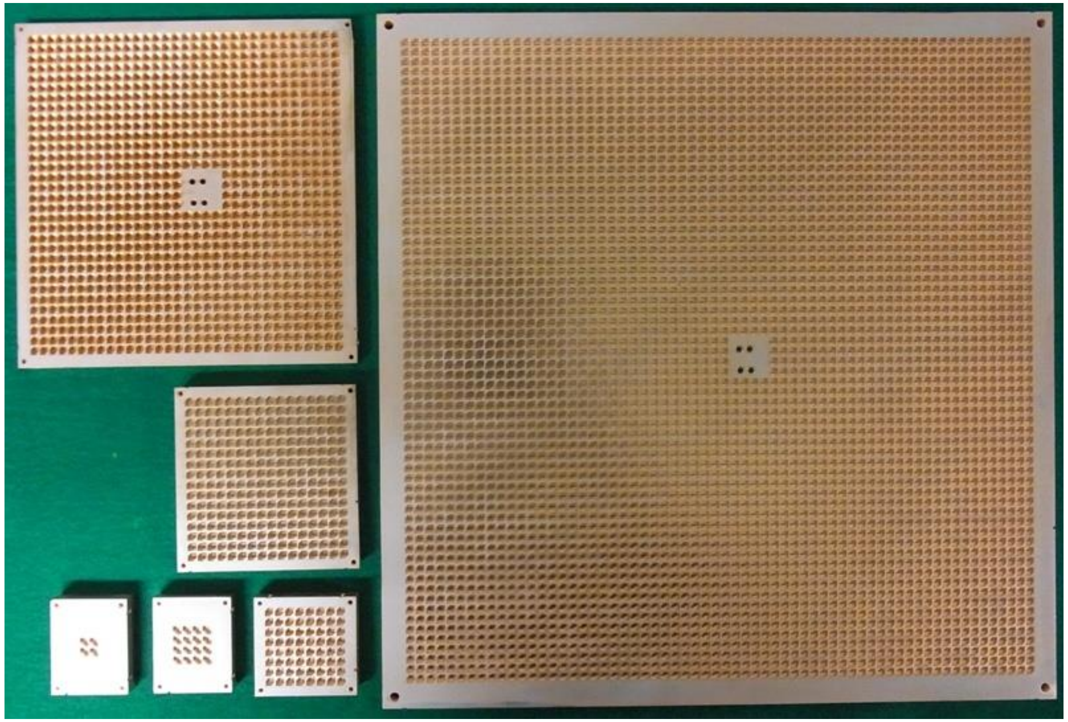




Intersymbol Interference in a 60 GHz Band Compact Range Wireless Access System adopting a Large Aperture Antenna

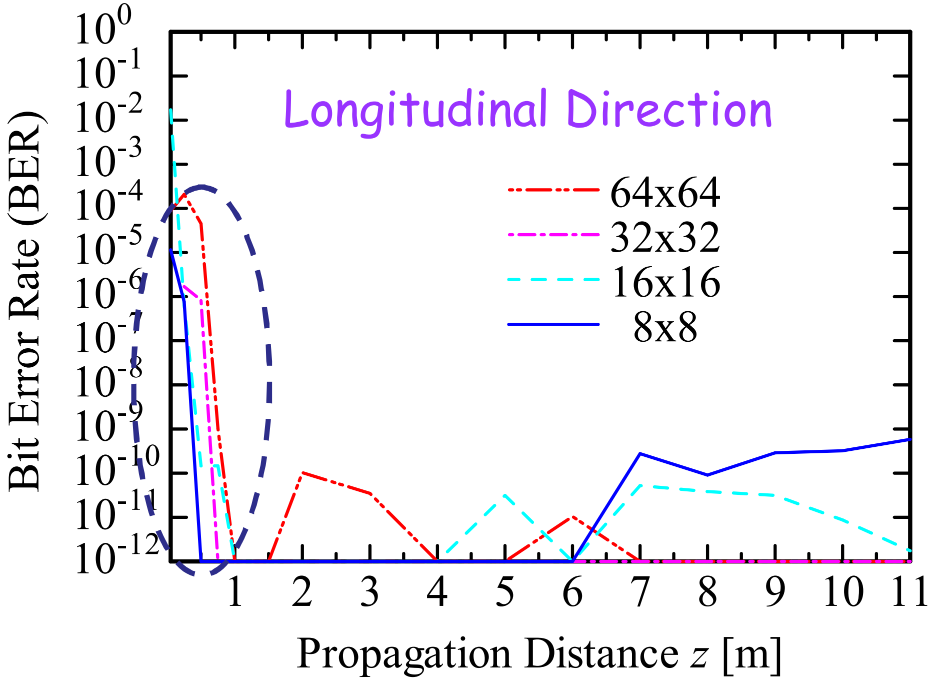


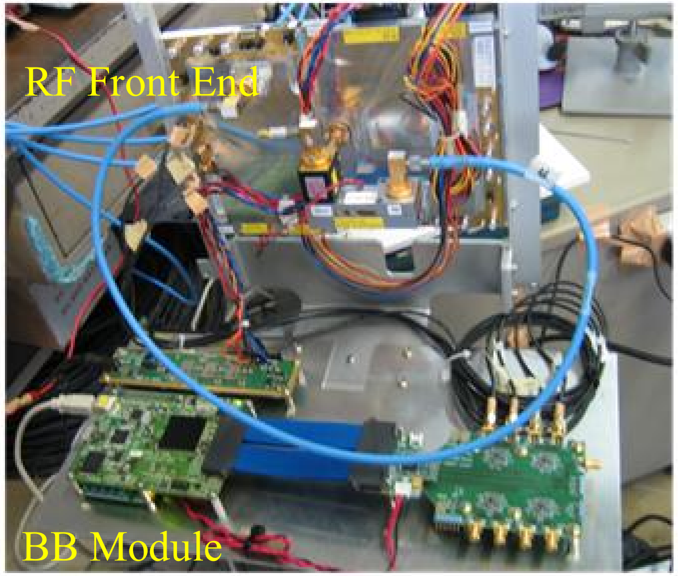
GATE *Gigabit Access Transponder Equipment*



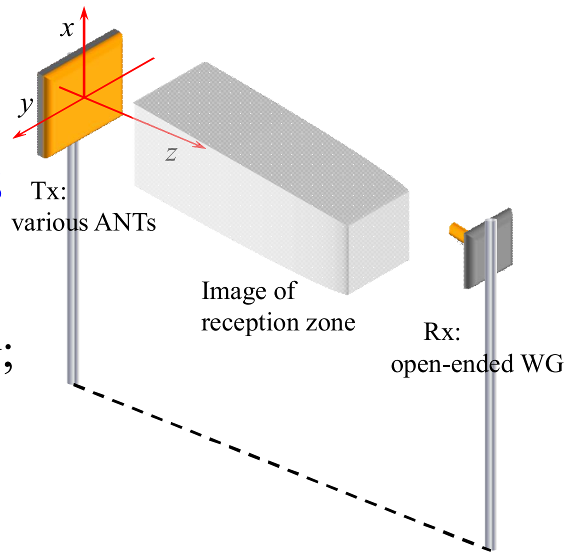
Ando & Hirokawa Lab., Tokyo Institute of Technology

System Evaluation of GATE



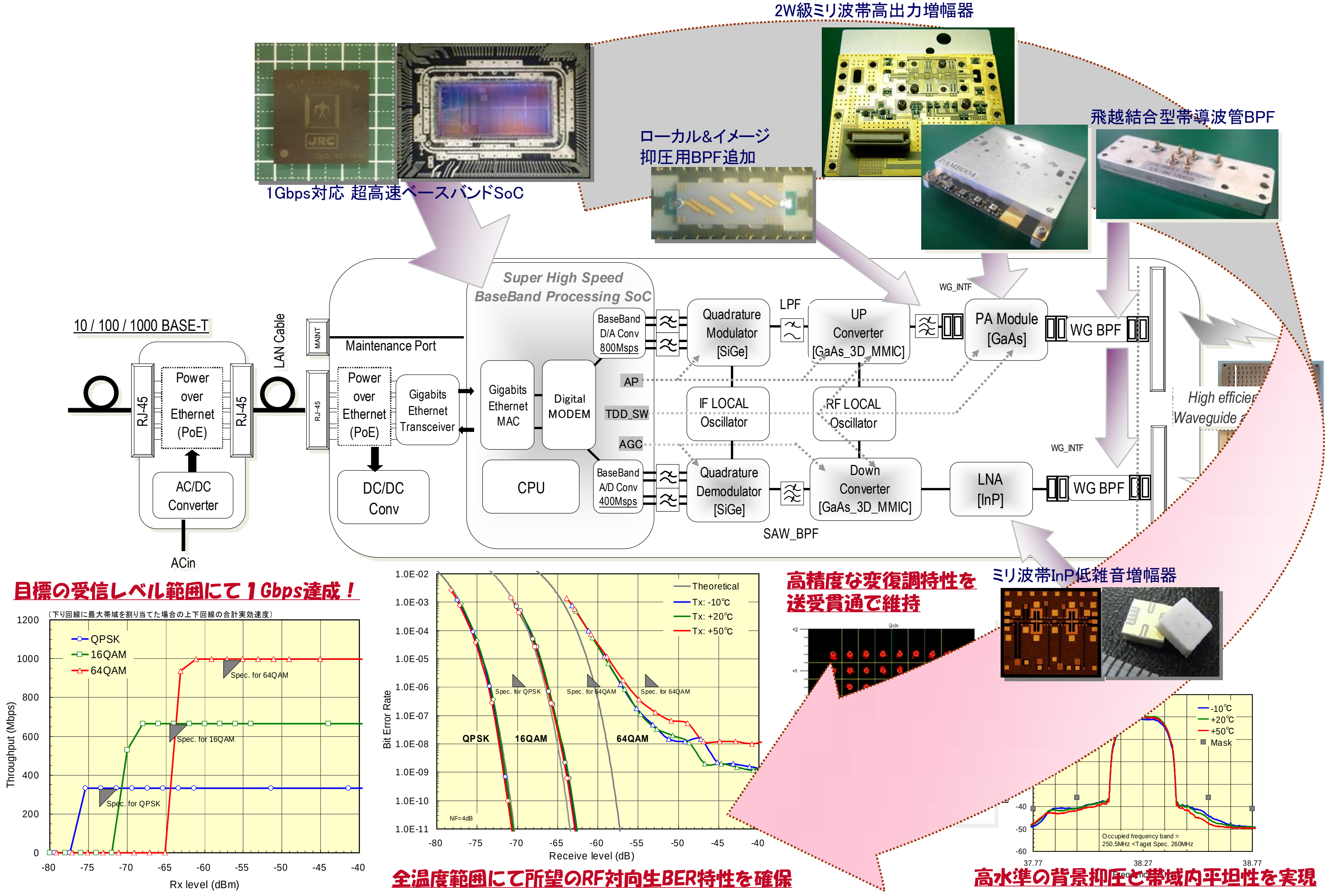


- Prototype of GATE: BB module + RF front end + Antenna;
- Maximum data rate is 3.1 Gbit/s by QPSK;
- Adopting a rate-14/15 low-density parity-check (LDPC) code;
- 3 min. measurement, error-free is indicated by BER $= 10^{-12}$
- Stable reception zone related to the antenna size is realized;
- Tx ANT (CP): different sizes; Rx ANT (LP): open-ended WG;
- Tx ANT is fixed, and the position of Rx ANT is changed.
- Large ANT: long & wide reception zone (multipath-free)
- Problem: degradation for short distance (< 1 m)

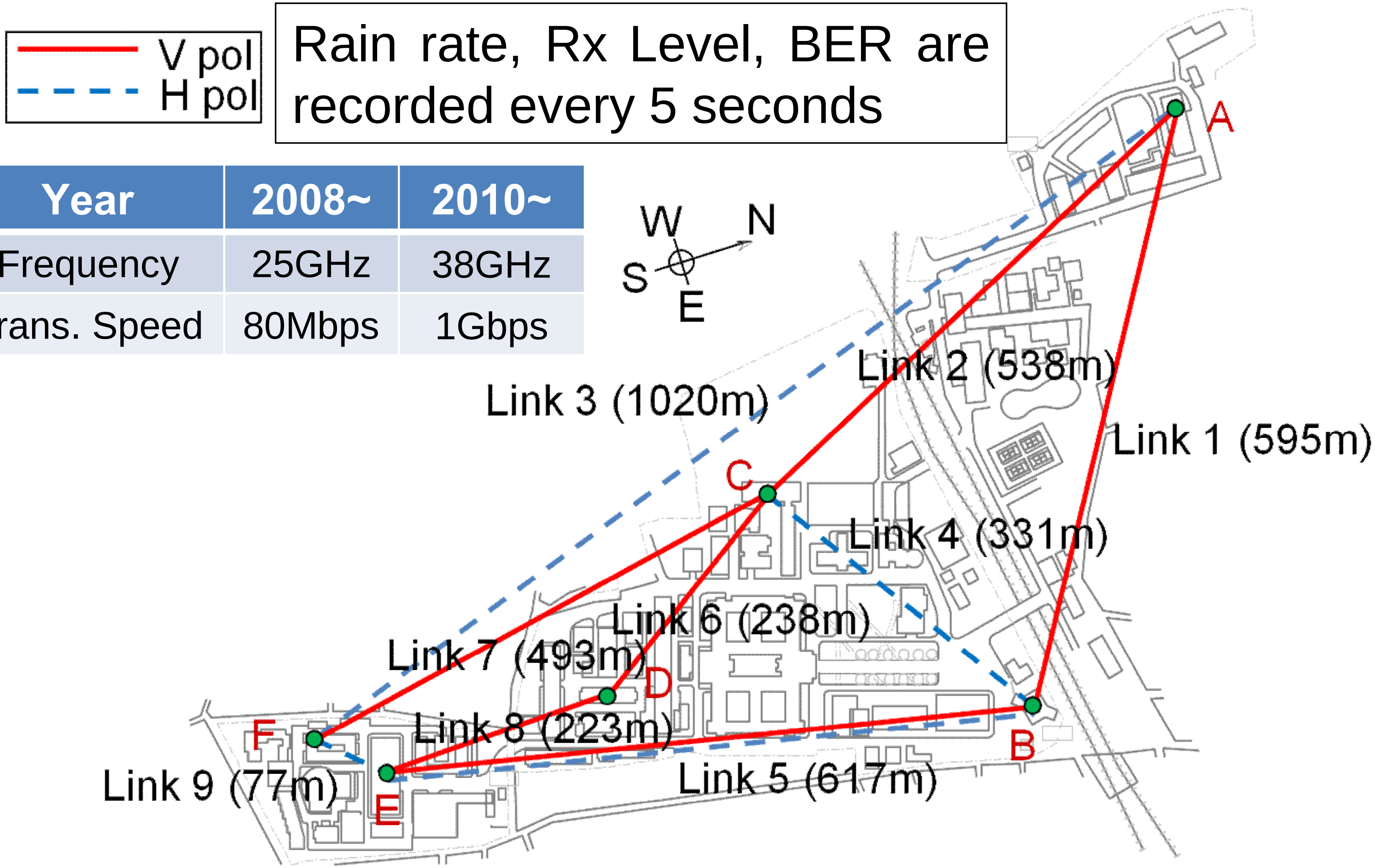


38GHz　1Gbps Outdoor system

Colaboration for 38GHz outdoor system



Tokyo Tech MMW Model Network

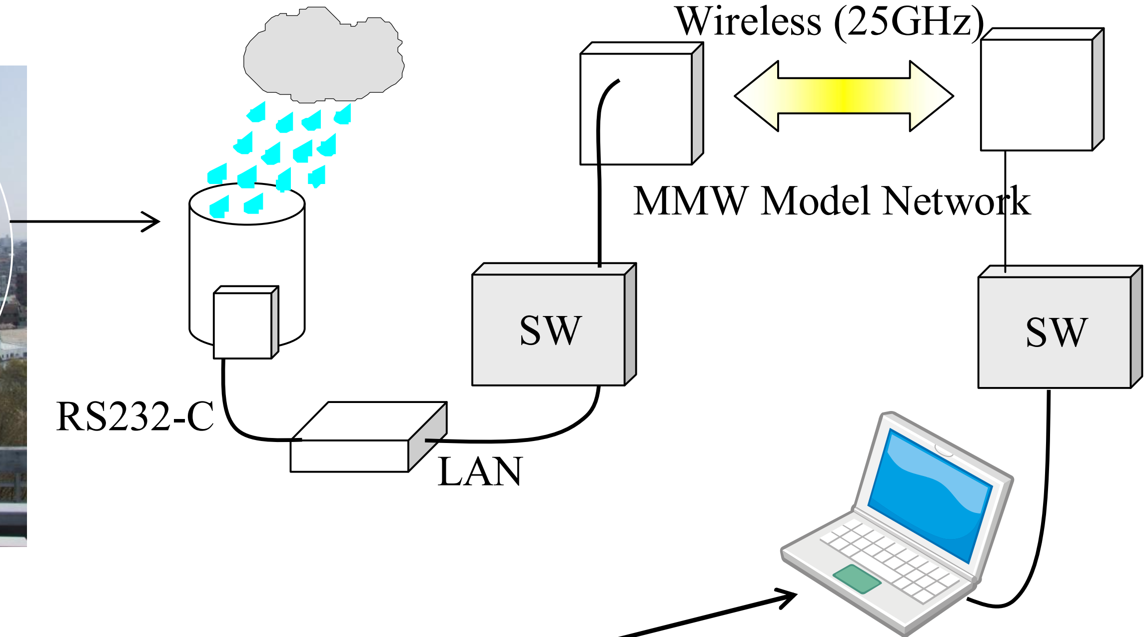


Rain rate, Rx Level, BER are recorded every 5 seconds

Year	2008~	2010~
Frequency	25GHz	38GHz
Trans. Speed	80Mbps	1Gbps

Monitoring System

Tipping-bucket rain gauge

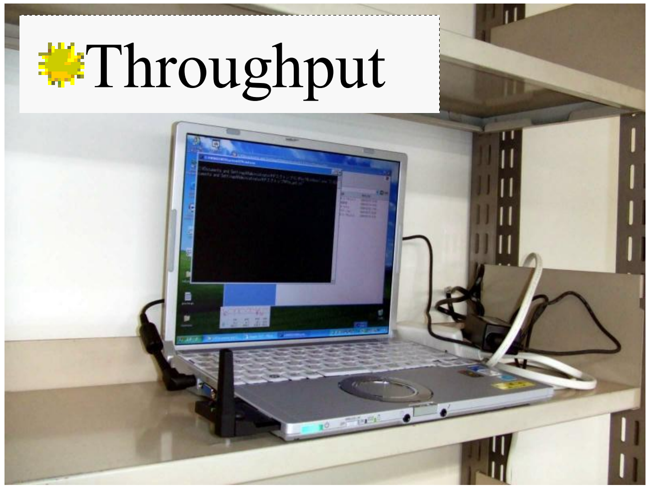


- Rain rate
- Rx level
- BER

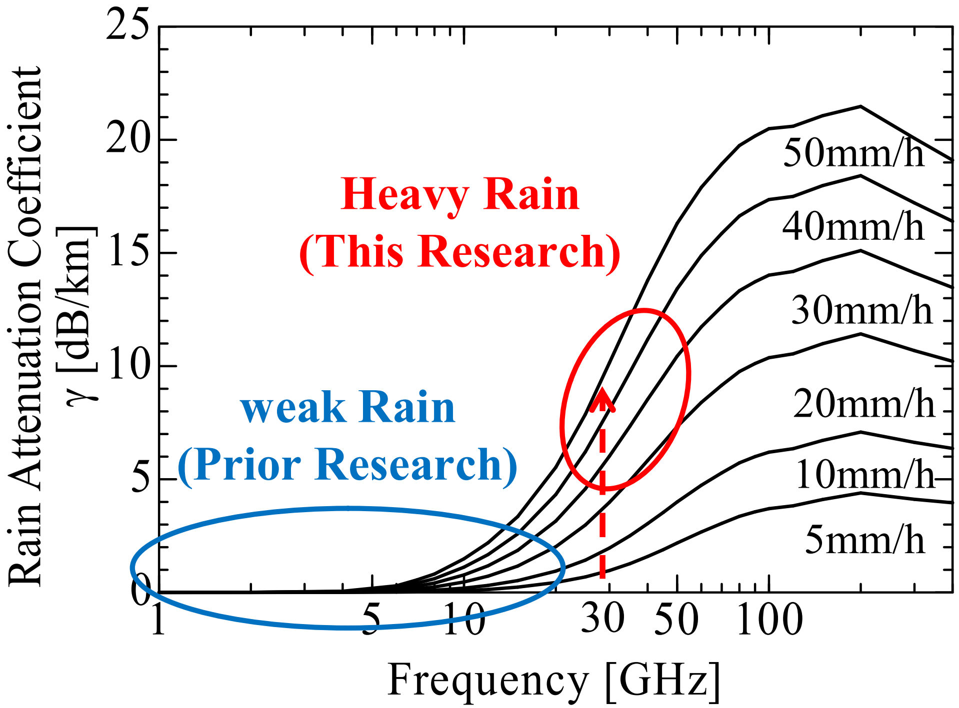
(every 5sec)

Monitoring PCs

PHS Monitoring PC



Comparison to Prior Researches –Rain Rate



Backgrounds

More and more base stations

The link length shorter than 1km (in most cases)

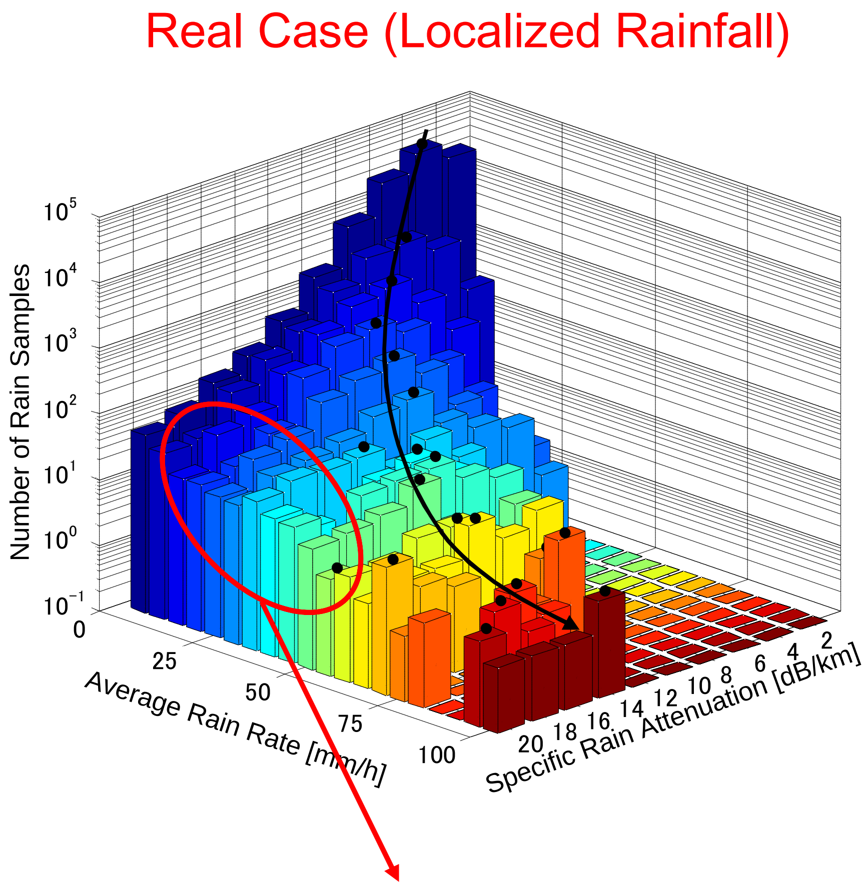
Heavy rain & Short distance

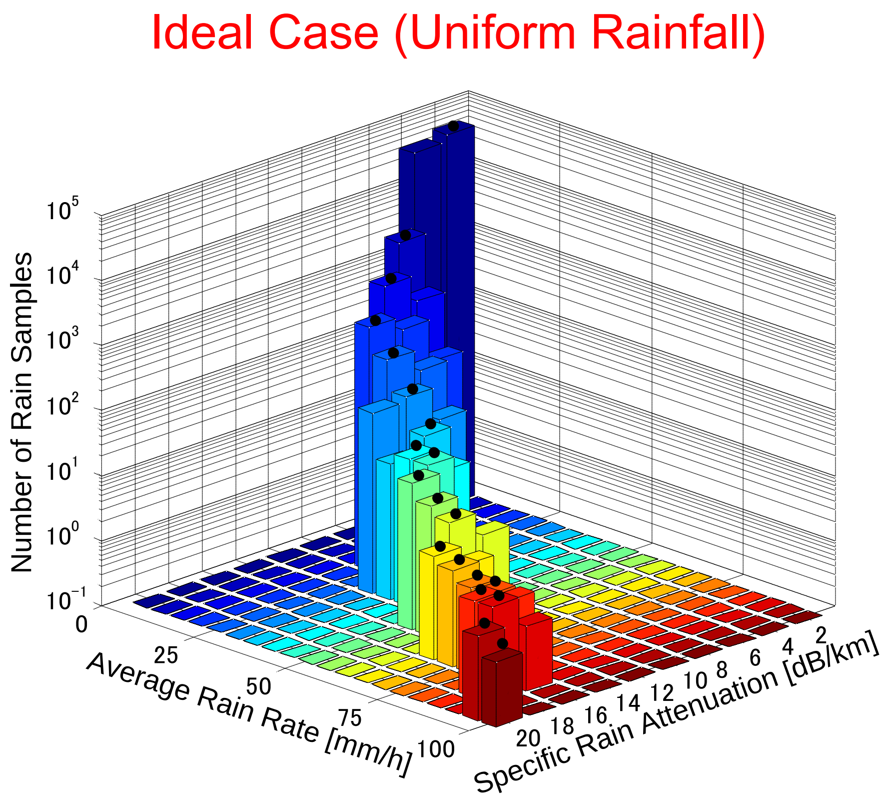
- Conventional propagation study: assuming weak and uniform rain in large area. Diversity effects for macro scale.
- Focusing on the behavior of *localized rain*, we may obtain *the diversity effect even in small mesh networks*.

3 Years (2010/3-2012/5)

Frequency Distribution of Rainfall

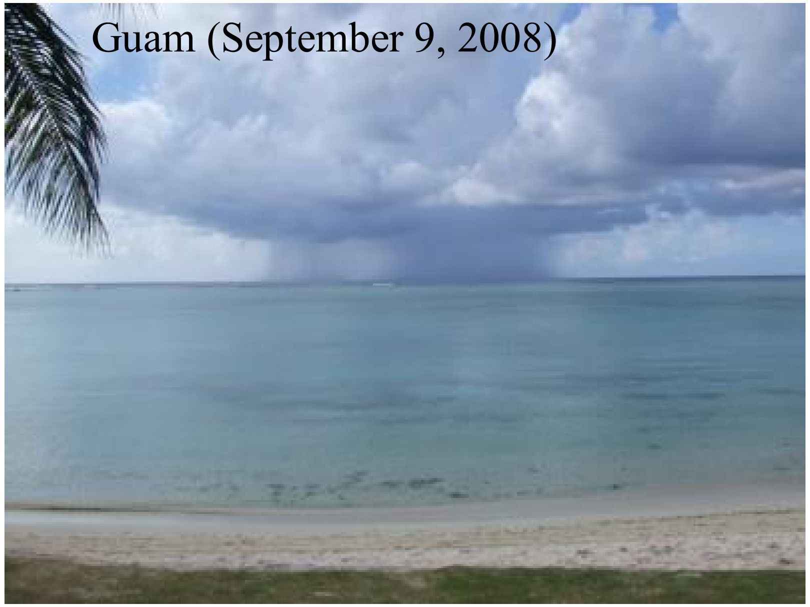
- Rainfall distribution classified according to rain attenuation





Localized Behavior of Rainfall

Intensive Heavy Rain

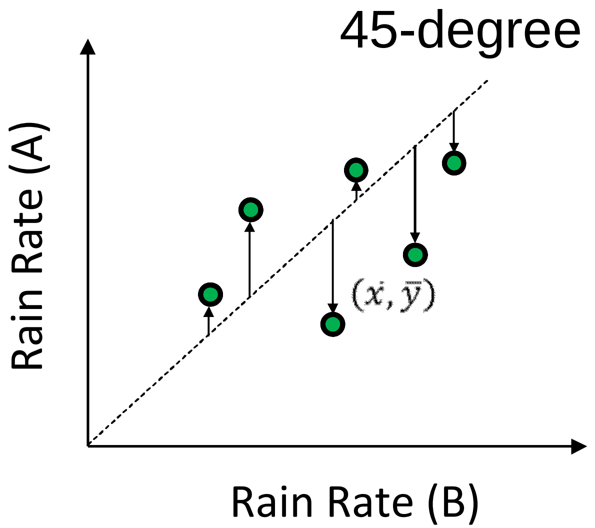


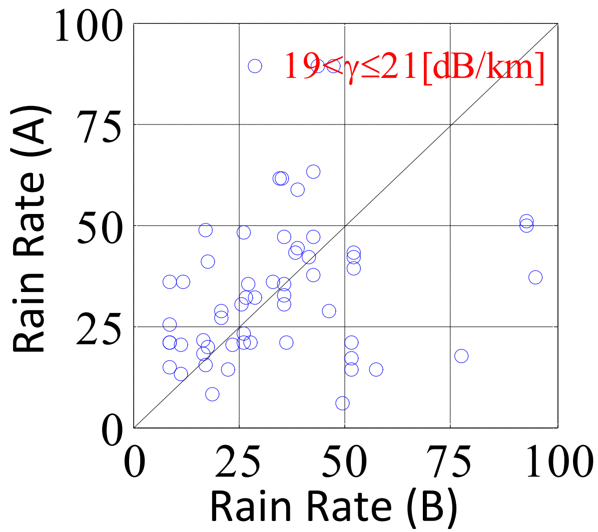
Guam (September 9, 2008)

Saitama, Japan (August 2006)

- Recent metropolitan intensive heavy rain is localized.
- Densely located millimeter-wave line can be better rain gauge.

Variogram of Rainfall





➢ Quantitative analysis of rainfall variability

$$\gamma(\boldsymbol{d}) = \frac{1}{2N} \sum_{\boldsymbol{x}_2 - \boldsymbol{x}_1 \approx \boldsymbol{d}} \left\{ \left[z(\boldsymbol{x}_2) - z(\boldsymbol{x}_1) \right]^2 \right\}$$

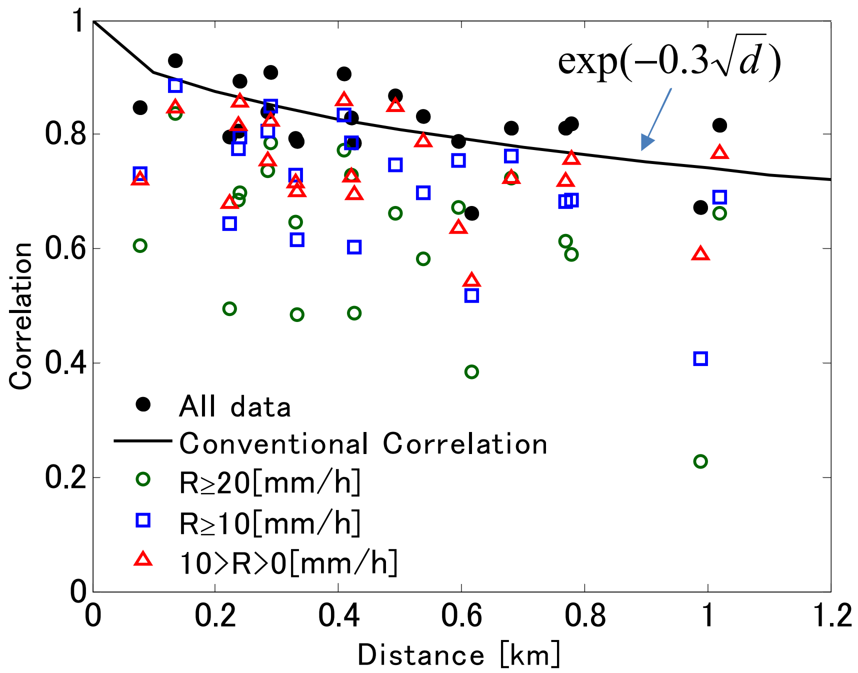
Å where N denotes the number of pairs (x_1, x_2) separated by a distance equal to $\boldsymbol{d}$

TOKYO TECH
Pursuing Excellence

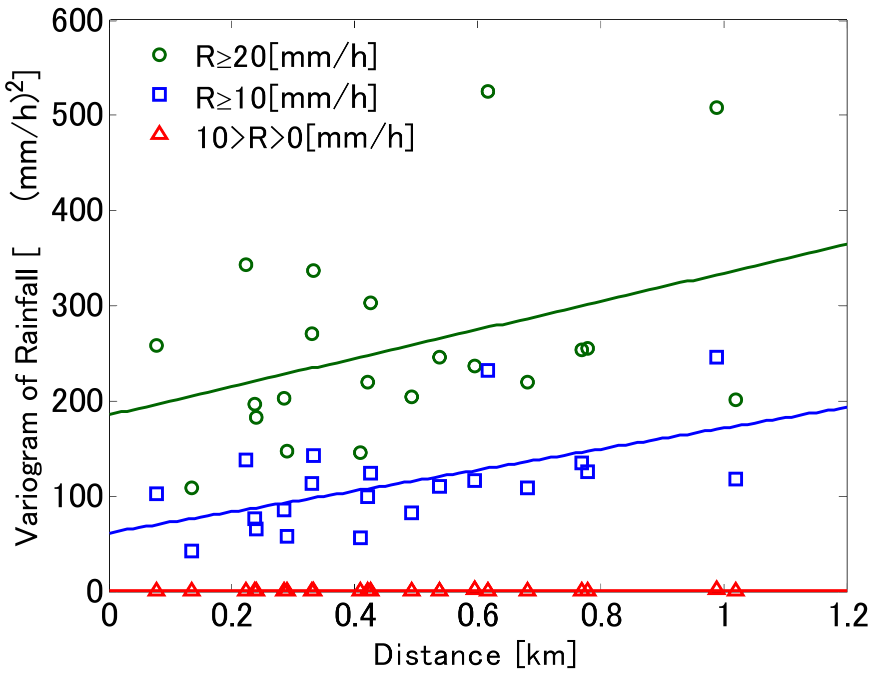
3 Years (2010/4-2012/5), 1-min data

Correlation vs. Variogram of Rainfall

Spatial Correlation of rainfall



Variogram of rainfall

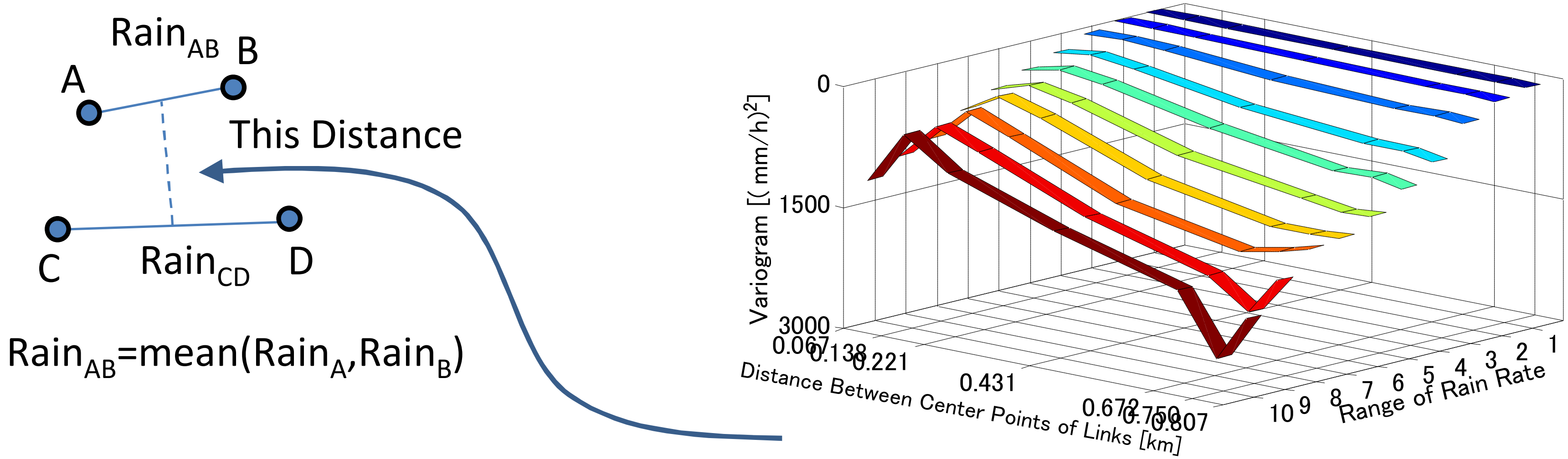


	Correlation	Variogram
Distance ↗	↘	↗
Rainfall Intensity ↗		↗

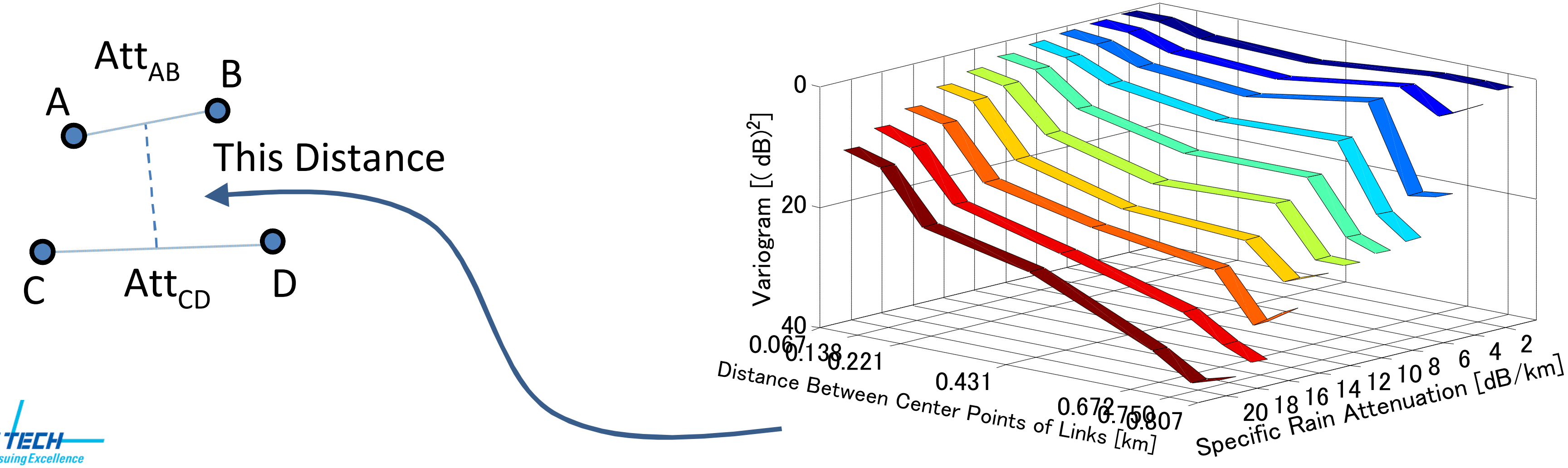
3 Years (2010/4-2012/5), 1-min data

Variogram of Rainfall, Attenuation

Variogram of average rain rate between links

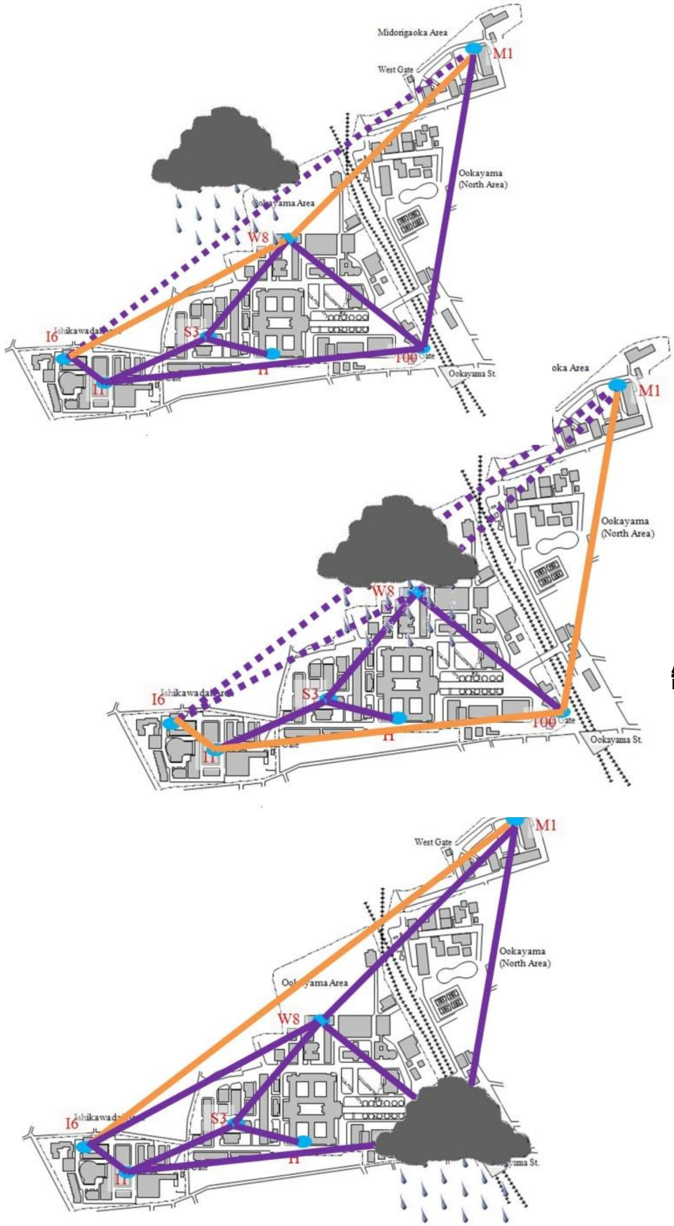


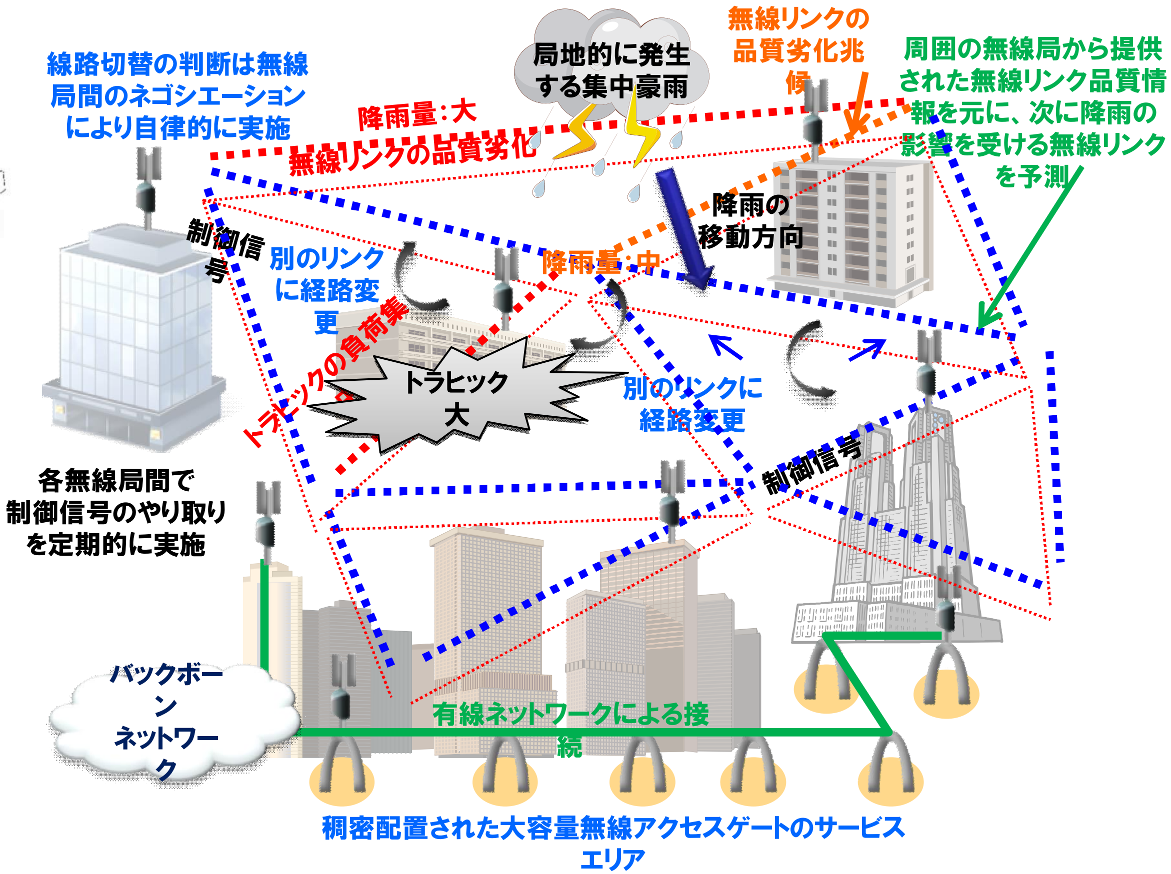
Variogram of rain attenuation between links



TOKYO TECH Pursuing Excellence

40GHz band wireless mesh network and proactive re-routing against localized strong rain



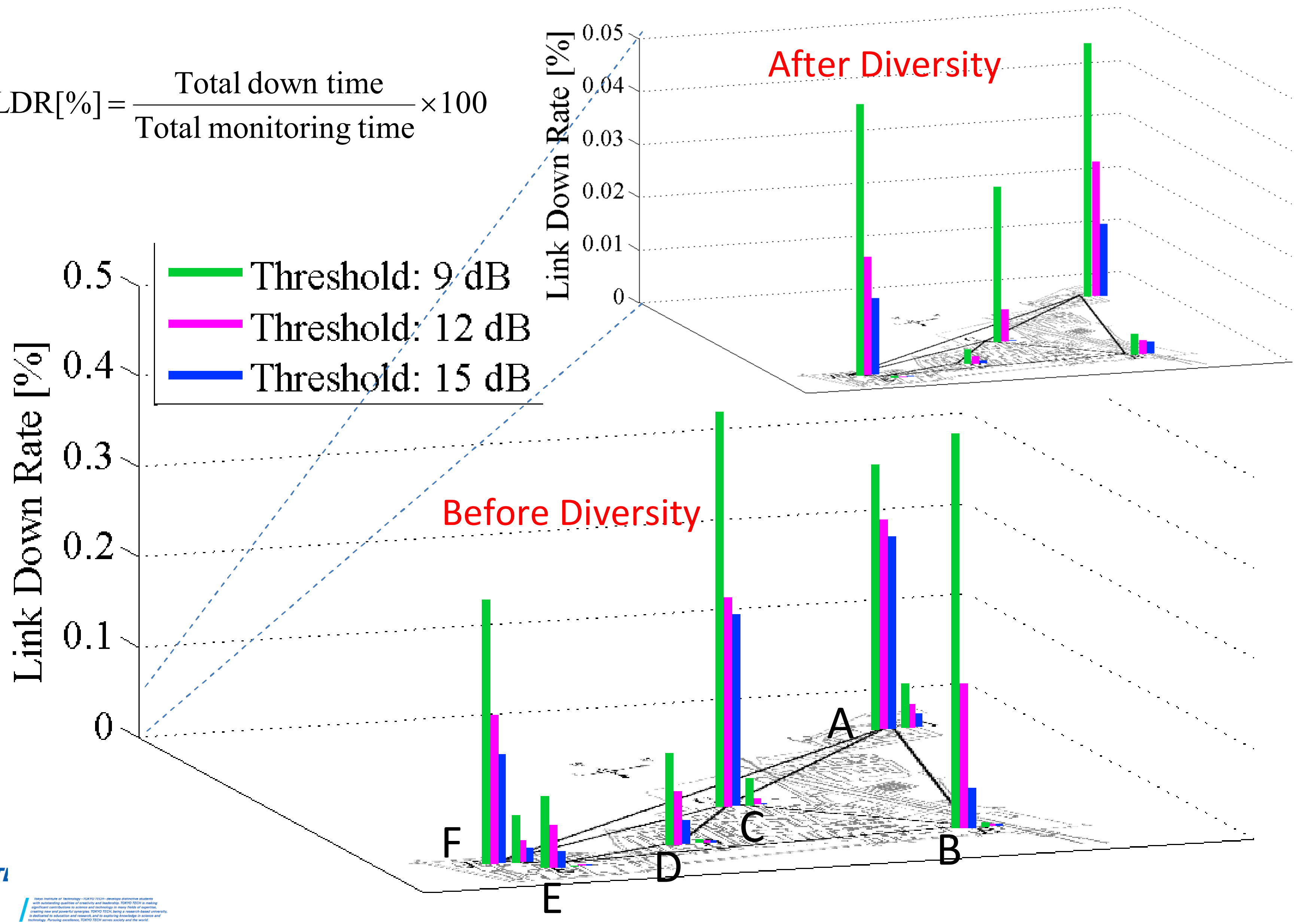


Network throughput degradation <10%

1 year data (2010/3-2011/2)

Link Down Rate at Nodes

$$LDR[\%] = \frac{\text{Total down time}}{\text{Total monitoring time}} \times 100$$



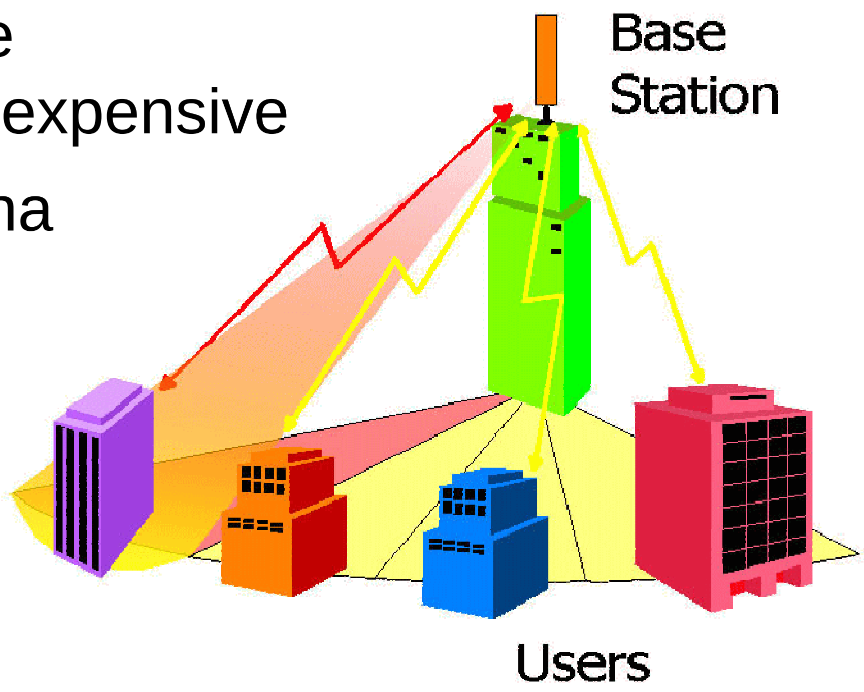
Background

In millimeter-wave band

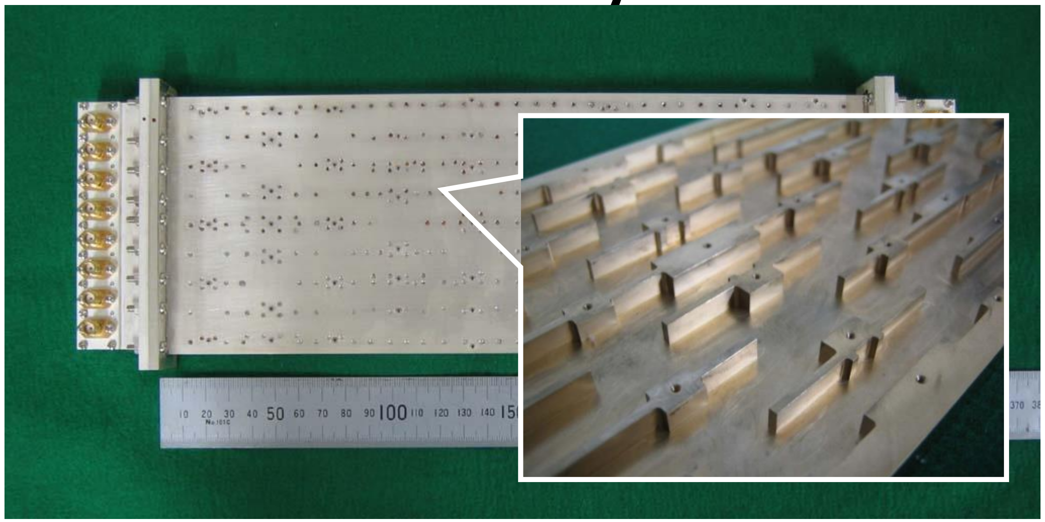
ÅPropagation loss is large
ÅHigh power devices are expensive

Directive antenna

Horizontal plane :
Beam switching
Vertical plane :
Cosecant pattern



8-Way Butler Matrix



Insertion Loss

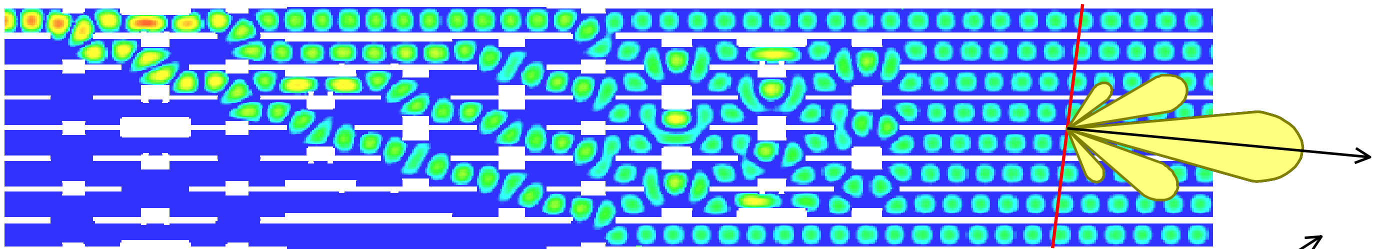
Measured

< 0.25 dB at 22 GHz

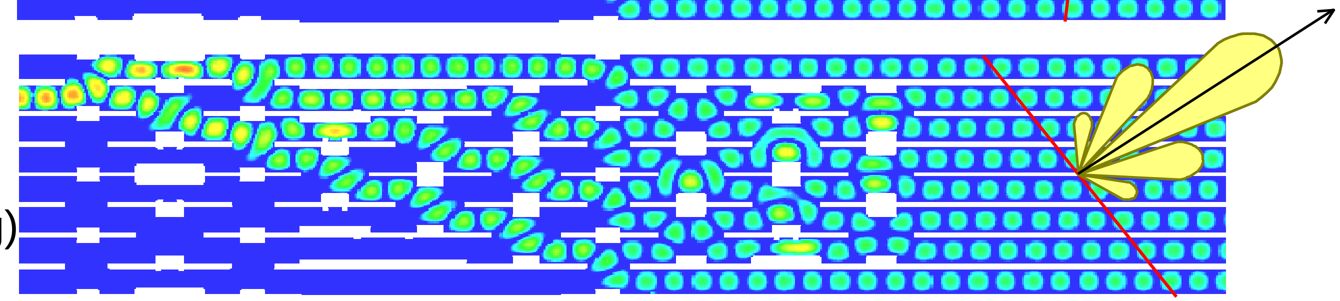
Calculated

< 0.15 dB at 22 GHz

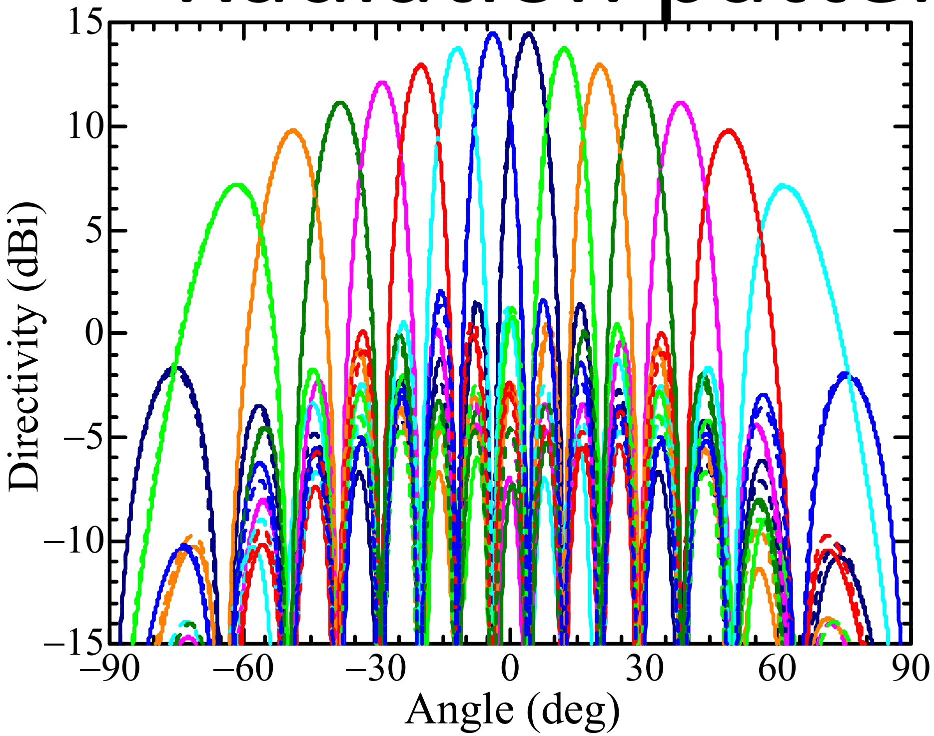
Port #1
input
(-22.5 deg)



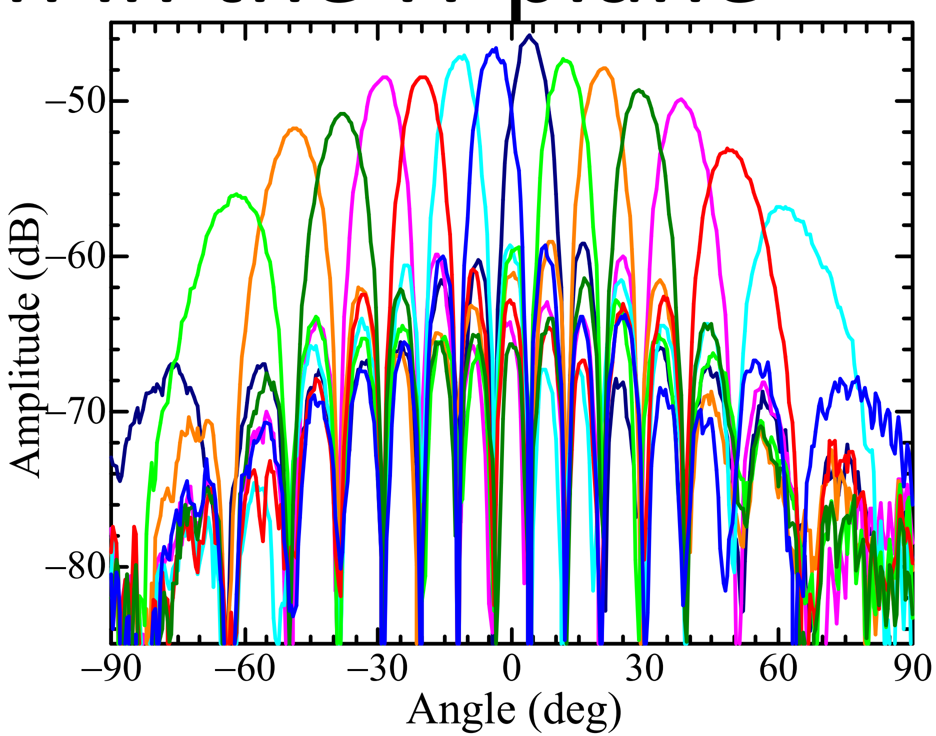
Port #2
input
(+157.5 deg)



Radiation pattern in the H-plane



(a) Calculated directivity



(b) Measured radiation pattern

Ideal power distribution
Measured power distribution

Relative amplitude

Port #1 input
Port #2 input
Port #3 input
Port #4 input
Port #5 input
Port #6 input
Port #7 input
Port #8 input

8-element infinitesimal dipole array excited by the 8-way Butler matrix in calculation