Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: Sub-Terahertz Band Wireless Fronthaul with Commercially Available Fronthaul Equipment and Optical Transceiver

Date Submitted: November 04, 2024

Source: Seung-Hyun Cho, Sang-RoK Moon, Sooyeon Kim, Wonkyoung Lee, Minkyu Sung, and Joon Ki Lee (ETRI)

218, Gajeong-ro, Yuseong-gu, Daejeon, 34129, Republic of Korea

Telephone: +82-42-860-5721, E-Mail: shc@etri.re.kr

Re: n/a

Abstract: This contribution presents the wireless fronthaul network with ultra high-speed and low latency, which utilize the sub-THz band as a carrier frequency that can be interoperable with currently deployed optical fiber-based mobile fronthaul network equipment and off-the-shelf MSA-compatible optical transceiver.

Purpose: Information of SC_THz

Sub-Terahertz Band Wireless Fronthaul with Commercially Available Fronthaul Equipment and Optical Transceiver

November 12. 16:00~18:00

Seung-Hyun Cho, *Sang-Rok Moon, Sooyeon Kim, Wonkyoung LEE, Minkyu Sung, and Joon Ki Lee*

Optical Network Research Section, ETRI

ETRI

Outlines

I. Introduction

II. Sub-THz band wireless fronthaul architecture

III. Experimental demonstrations

IV. Summary

1. Introduction

- Background

Mobile data traffic forecast

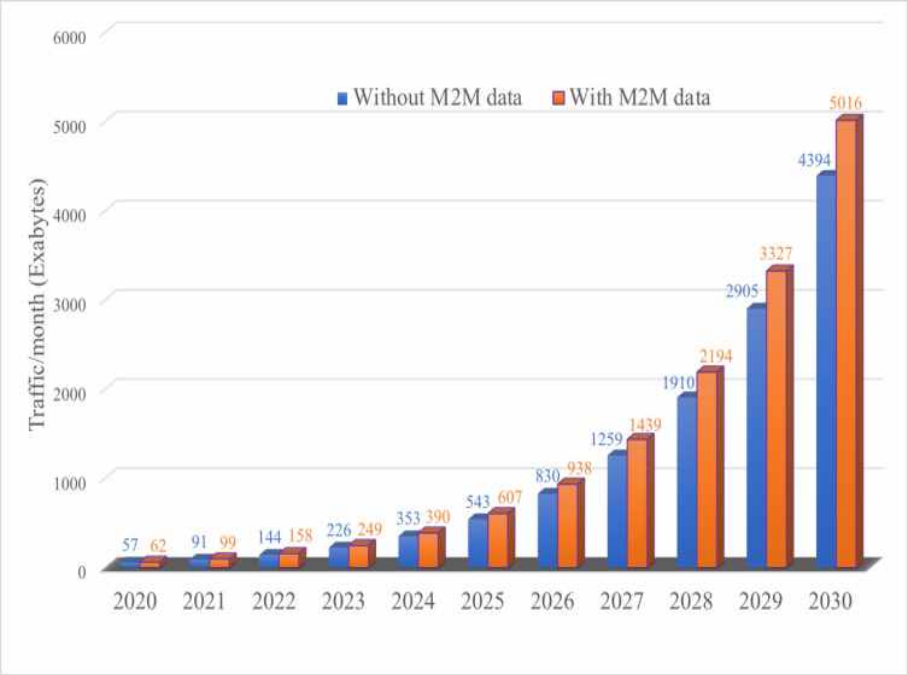


Fig. Global mobile data traffic forecast by ITU.

Reference: https://www.researchgate.net/figure/Global-mobile-data-traffic-forecast-by-ITU-Overall-mobile-data-traffic-is-estimated-to_fig1_331159423

Spectrum for future RAT

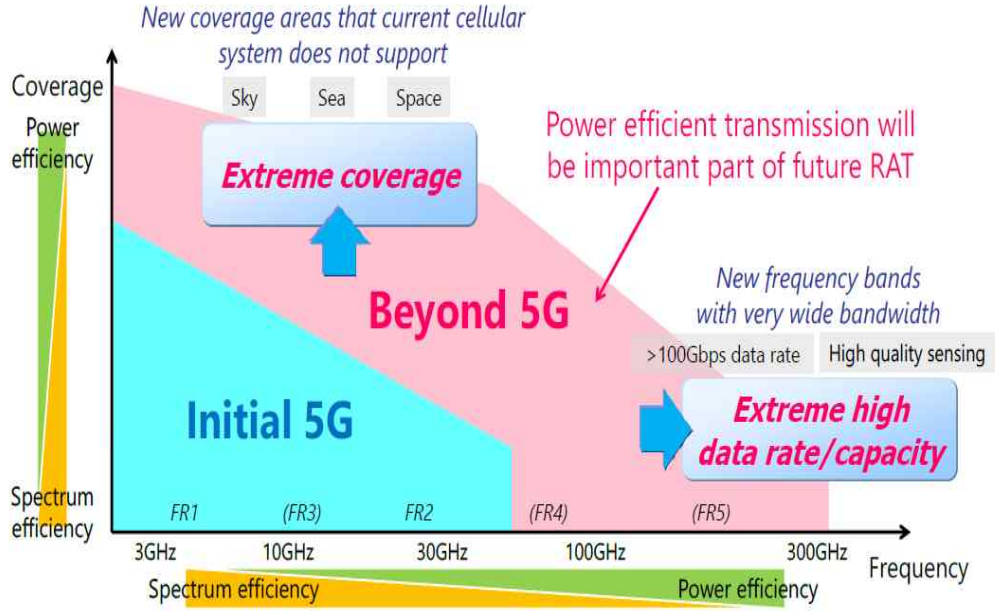


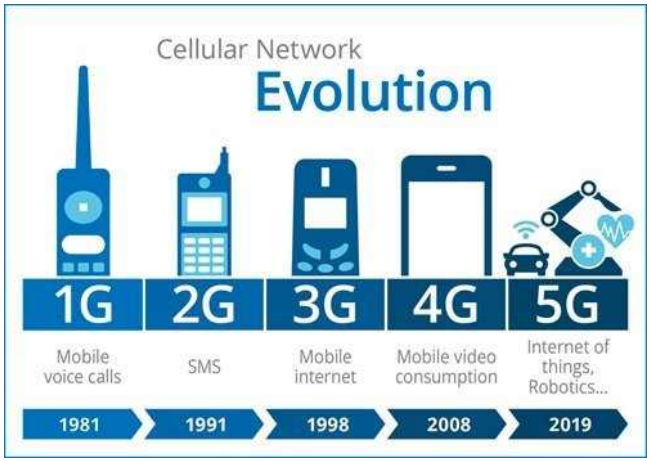
Fig. Expansion of radio access technology for higher frequency band exploration and coverage expansion.

Reference: White Paper “5G Evolution and 6G”, NTT Docomo, 2022.

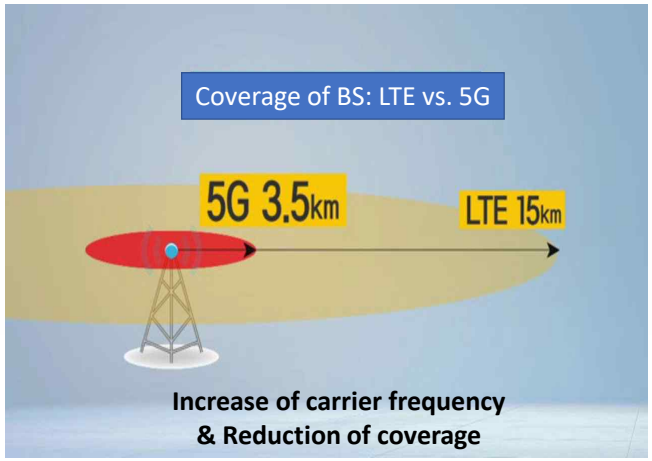
1. Introduction

- Motivations

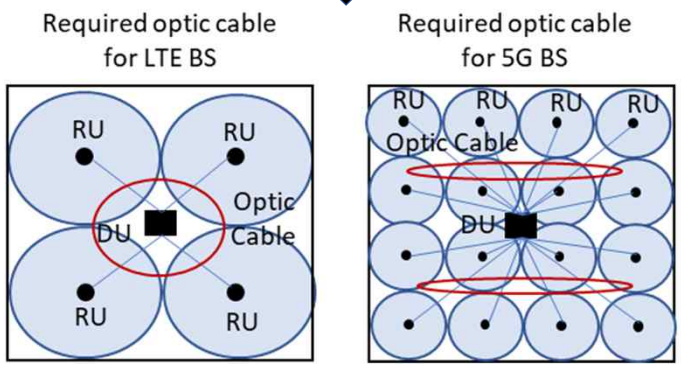
Why do we need a wireless X-haul technology?



Evolution of mobile communications



Increase of carrier frequency
& Reduction of coverage



Explosion of fiber-optic cable

Increase of cost for fiber-optic infrastructure

1. Introduction

- Motivations

Applications of wireless X-haul (for BS)

Historic sites in Europe

Open areas in North America/Australia

Destruction of infra due to natural disaster

Estimated fronthaul data traffic vs. evolution of standard

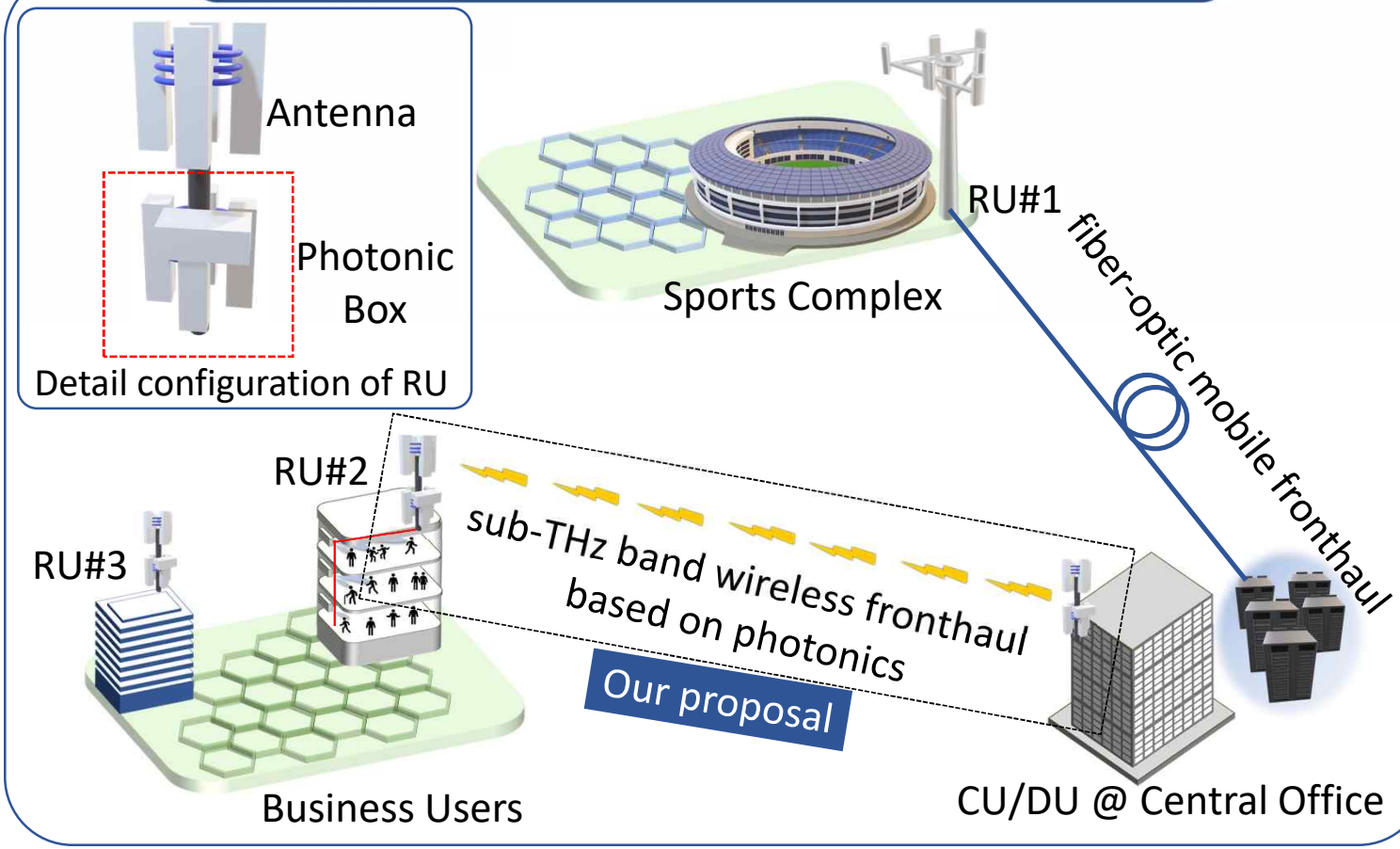
Number of antenna ports	Radio channel bandwidth			
	IMT-Adv.	IMT-2020	IMT-2030	
	20 MHz	100 MHz	500 MHz	1 GHz
2	2 Gb/s	10 Gb/s	50 Gb/s	100 Gb/s
8	8 Gb/s	40 Gb/s	200 Gb/s	400 Gb/s
64	64 Gb/s	320 Gb/s	1.6 Tb/s	3.2 Tb/s
256	256 Gb/s	1.28 Tb/s	6.4 Tb/s	12.8 Tb/s

Ref: ITU-T G.Sup66 : 5G wireless fronthaul requirements in a passive optical network context

2. sub-THz band wireless fronthaul architectures

- Basic architecture

Basic configuration of sub-THz band wireless fronthaul



Characteristics

① **Compatible with commercially available fiber-optic mobile fronthaul equipments including O-RAN**

② **Compatible with off-the-shelf fiber-optic transceivers**

③ **Supporting various kinds of line rate (10 Gb/s ~ 100 Gb/s)**

④ **Easy installation of photonic box with current mobile fronthaul equipments like CU/DU/RU**

2. sub-THz band wireless fronthaul architectures

- As-Is vs. To-be

As-Is

Fiber-optic mobile fronthaul

- 10G NRZ-OOK
- 25G NRZ-OOK
- 50G-PAM4
- 100G-PAM4
- 200G-DP-QPSK

CU/DU

Commercially available optical transceiver-1

Fiber-optic cable

Commercially available optical transceiver-2

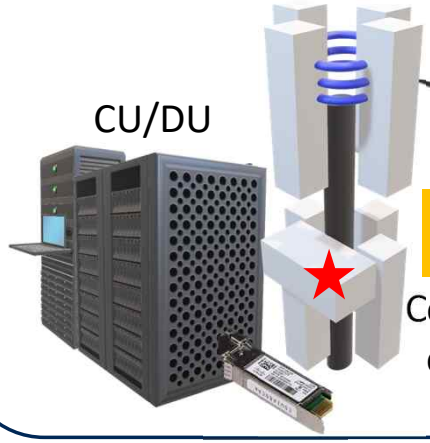
RU

EX) SFP, XFP, SFP-28/56, QSFP-28-DD/DCO, etc…

To-Be

Sub-THz band wireless fronthaul

CU/DU



Photonic box

Commercially available optical transceiver-1

Sub-THz wave @300GHz

RU

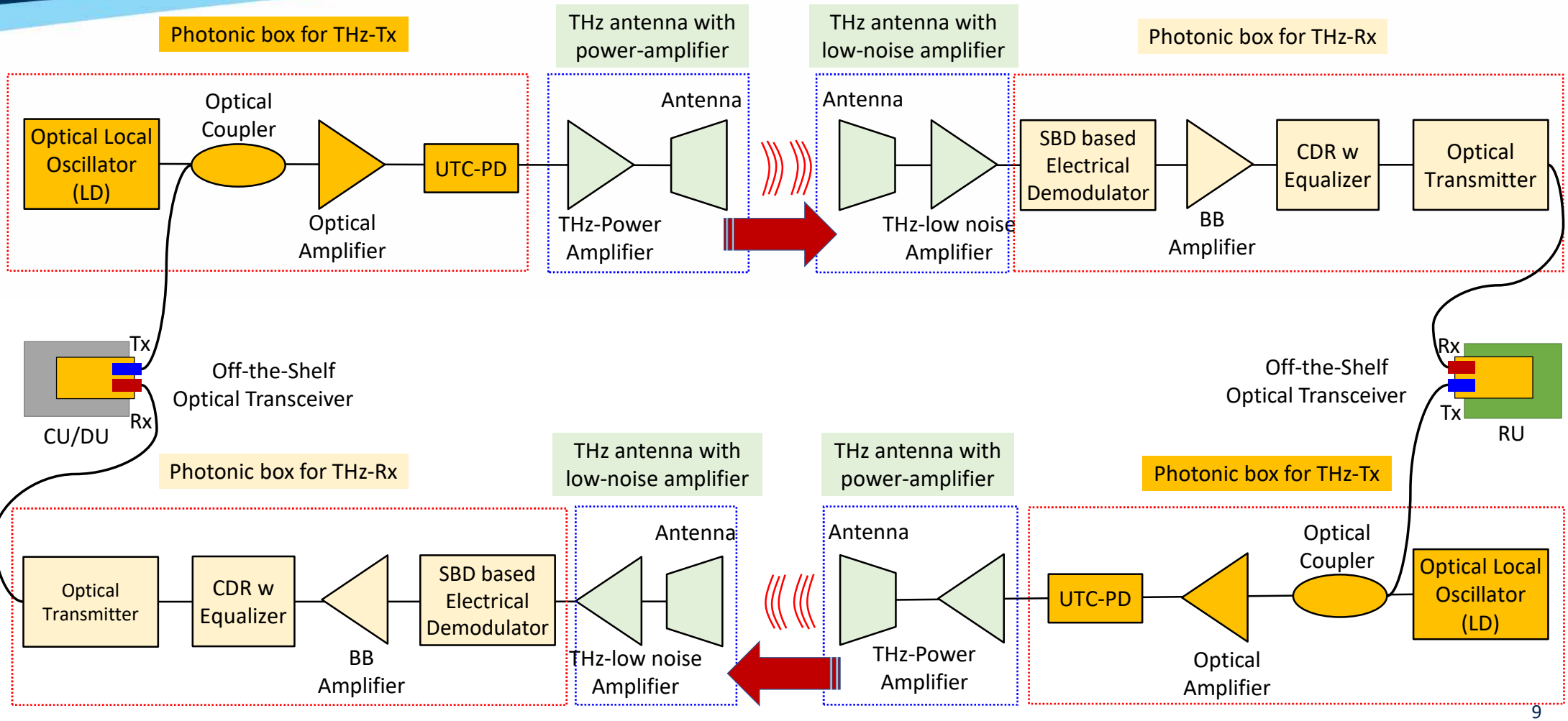
Photonic box

Commercially available optical transceiver-2

EX) SFP, XFP, SFP-28/56, QSFP-28-DD/DCO, etc…

2. sub-THz band wireless fronthaul architectures

- Detail configurations



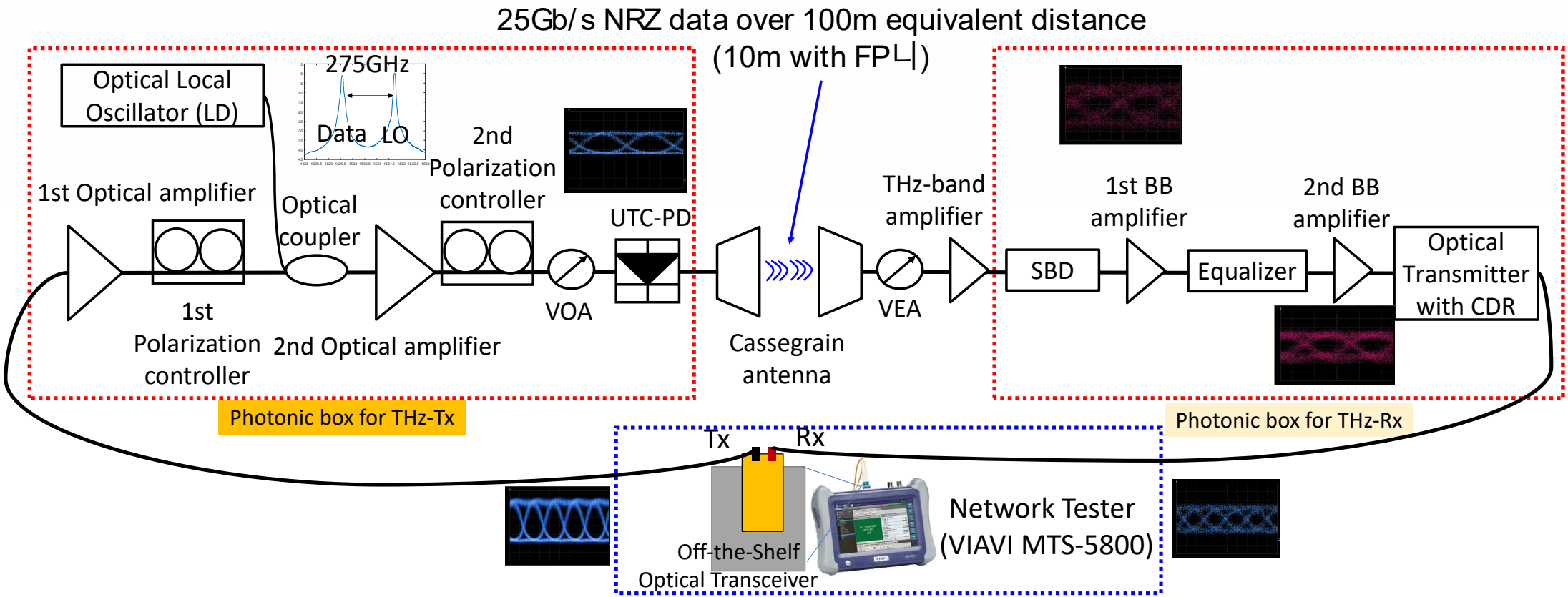
2. sub-THz band wireless fronthaul architectures

- Comparison of fiber-optic mobile fronthaul and sub-THz wireless fronthaul

Item	Fiber-optic	Sub-THz wireless	Note
Max. link capacity	1~100 Gbps/λ	1~100 Gbps/line	
Max. link distance	20 km (fiber)	100 m (free space)	current status
Link aggregation	CWDM/DWDM	FDM/SDM	
Protocol/standard support	CPRI/OBSAI/eCPRI	CPRI/OBSAI/eCPRI	protocol transparent
Operating frequency	~ 193 THz	~300 GHz	
Equipment support	CU/DU/RU	CU/DU/RU	sharing with existing equipment
Function split support	Yes	Yes	

3. Experimental demonstrations

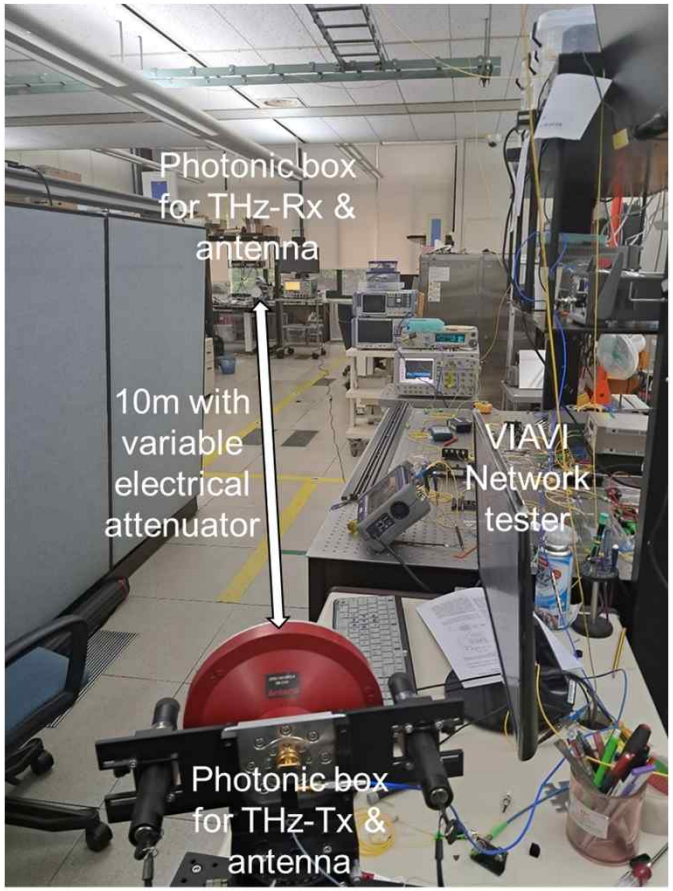
- Experimental setup for real-time wireless fronthaul with 25Gb/s NRZ signal

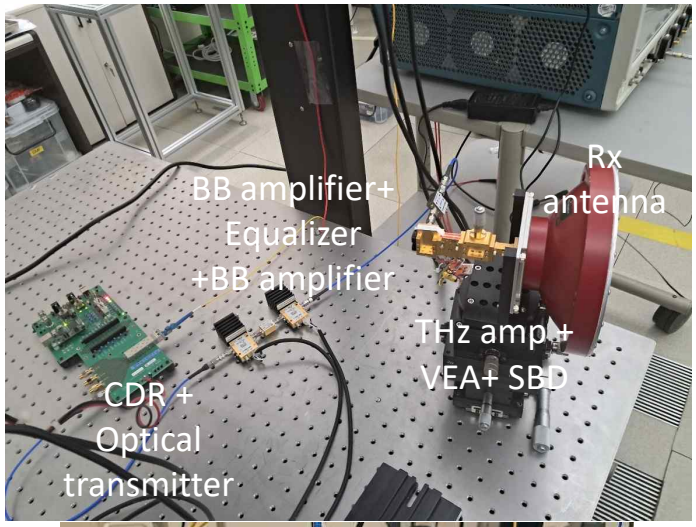


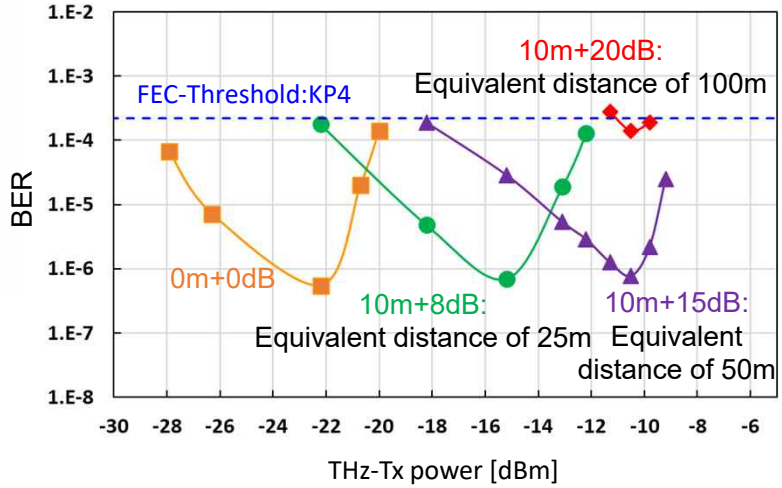
Commercially available CU/DU/RU with optical transceiver

3. Experimental demonstrations

- Experimental setup and results for real-time wireless fronthaul with 25Gb/s NRZ signal







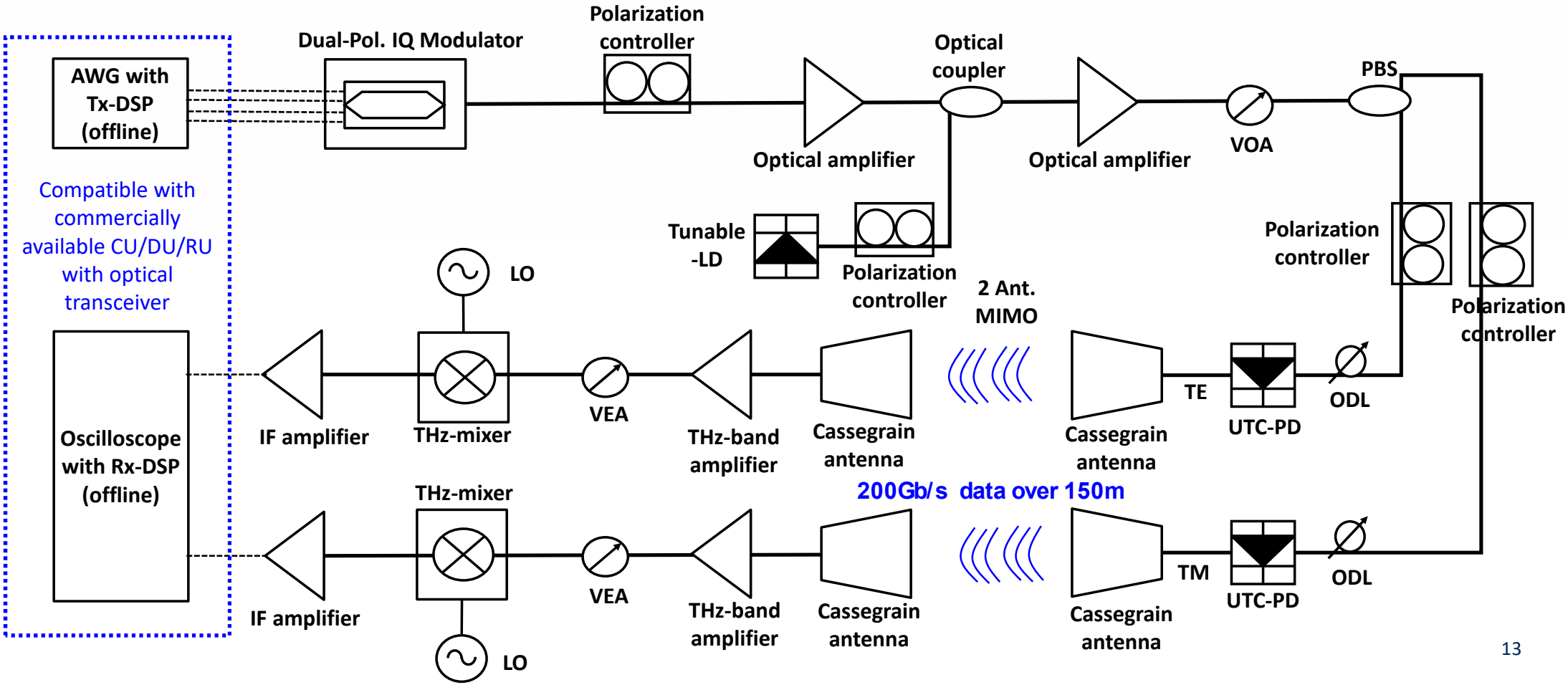
Measured real-time BERs

Configuration	Round-trip time delay
Optical loop-back (from Tx to Rx at optical transceiver with 1m fiber)	12 ns
Wireless back to back	435 ns
10 m of free space	572 ns

Measured end-to-end round-trip time delay

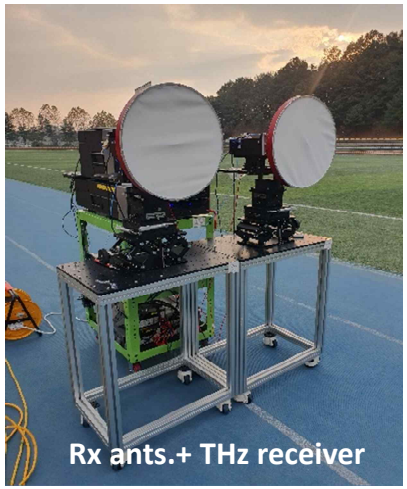
3. Experimental demonstrations

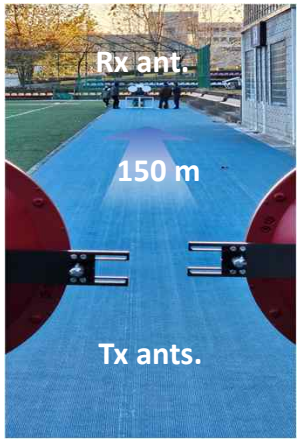
- Experimental setup for offline wireless fronthaul with 200Gb/s 16-QAM signal

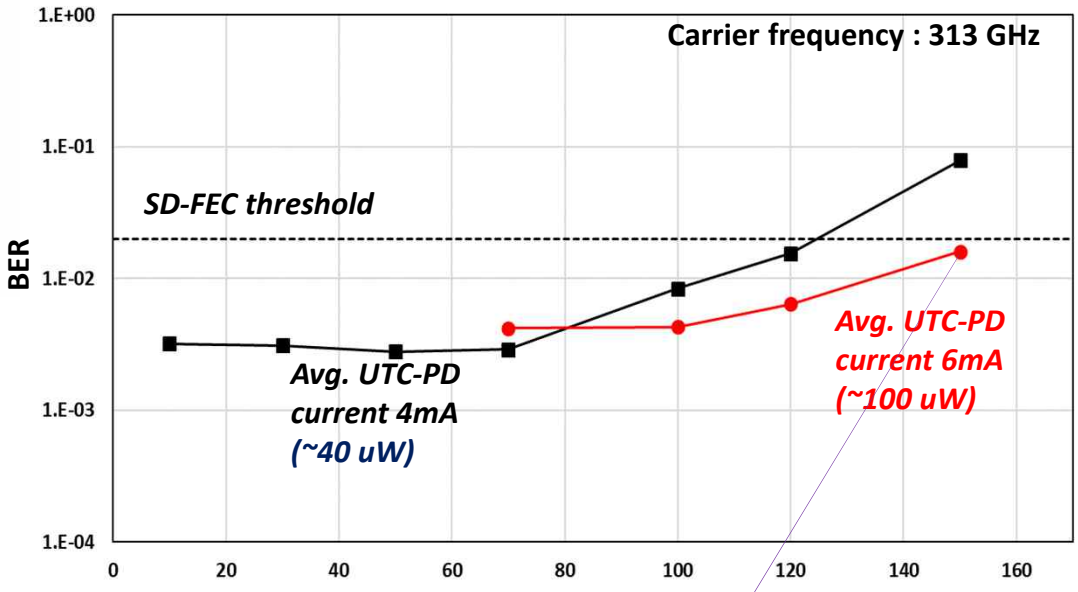


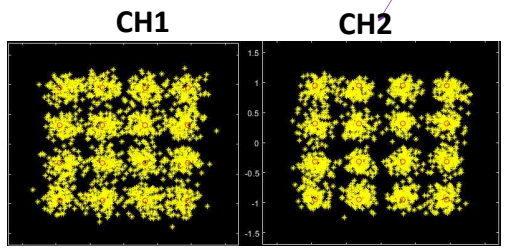
3. Experimental demonstrations

- Experimental setup and results for offline wireless fronthaul with 200Gb/s 16-QAM signal





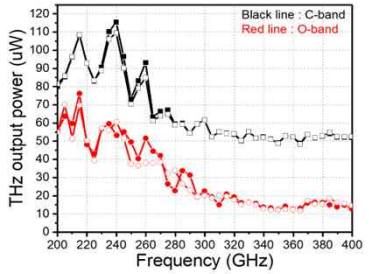




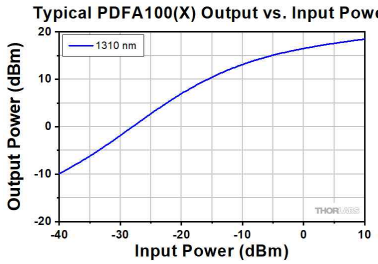
3. Experimental demonstrations

- Considerations for realization of sub-THz band wireless fronthaul based on photonics

Wavelength dependent characteristics

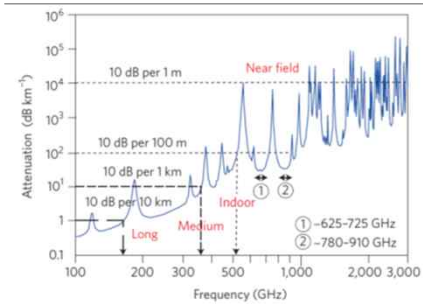


UTC-PD output dependent on λ

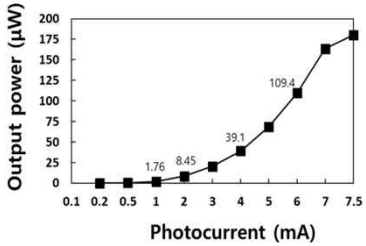


Low saturated output for PDFA

Improvement of output power of UTC-PD

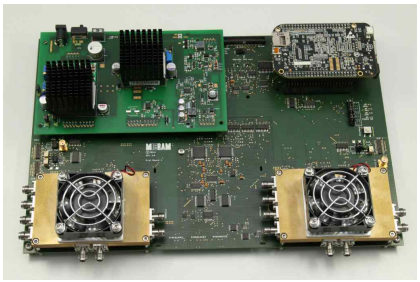


THz-band attenuation



UTC-PD output power

Real-time verifications above 100 Gbps



High speed DAC/ADC

FPGA with low sampling

PAT technology for sharp beam

1. Pointing: Aligning Tx/Rx to the direction of Rx/Tx

2. Acquisition: Compensation of initial pointing errors and detection of signal

3. Tracking: Maintaining the alignment by compensating local angular disturbances

4. Summary

- **Sub-THz band wireless fronthaul**
  - mobile data explosion and available spectrum
  - evolution of mobile communications
  - throughput demands and limitations on wireline infrastructure

- **Photonics aided wireless fronthaul with existing fronthaul equipment and optical transceiver**
  - compatible with existing fronthaul equipment
  - employing with commercially available optical transceivers
  - additional usage of photonic box

- **Experimental demonstrations**
  - real-time wireless fronthaul with 25Gb/s NRZ signal
  - offline wireless fronthaul with 200Gb/s 16-QAM signal
  - a few things to be overcome

THANK YOU!

contact to shc@etri.re.kr

ETRI