APT/ITU Conformance and Interoperability Event 2015
7 – 8 September 2015, Bangkok, Thailand

Document C&I-3/INP-14
07 September 2015

NICT, Japan

WAVEFORM TRANSFER FOR SEAMLESS NETWORK SHOWCASING

Contact: Email:
NICT, Japan

Waveform transfer for seamless access communication systems

Tetsuya KAWANISHI

National Institute of Information and Communications Technology
Tokyo, Japan

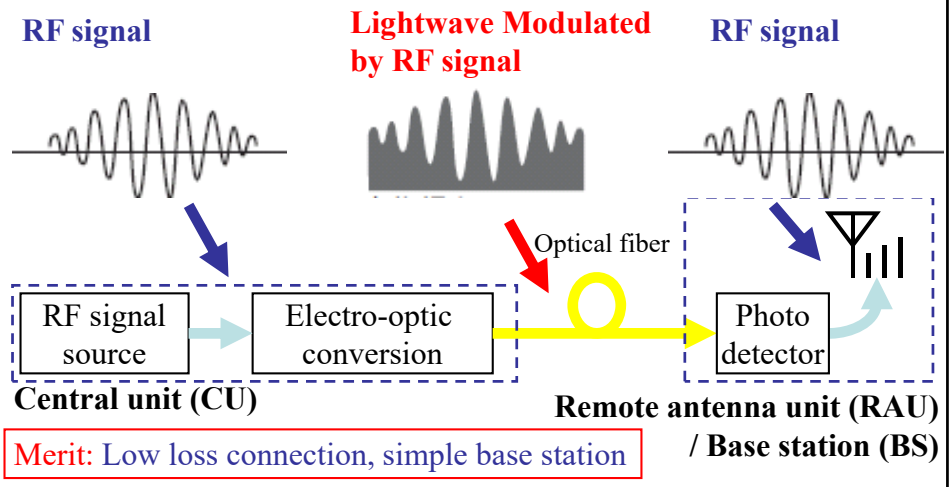
This study was conducted as part of research projects “supported by the Japanese Government funding for “R&D to Expand Radio Frequency Resources” from the Ministry of Internal Affairs and Communications.

Outline

- Radio-over-fiber (RoF) for waveform transfer
- Concept of seamless links using RoF
- Possible applications
  - High resolution radars for FOD detection
  - High speed wireless links of high-speed trains
- Field trial of FOD rader at CU Saraburi

Basic concept of Radio-on-fiber (RoF) system

RF signal is transmitted via optical fiber from central to antenna

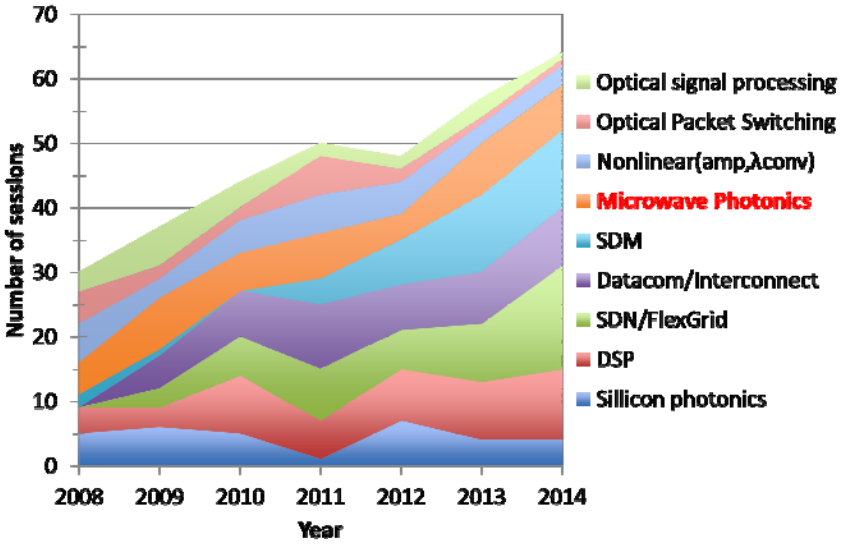


Merit: Low loss connection, simple base station

Recent Trends on RoF

- Application to 5G mobile fronthaul/backhaul
  - Digital and/or analog
- High-speed transmission at millimeter-wave/terahertz wave
  - Protection/temporal link in resilient network

Recent Trend of the session on OFC



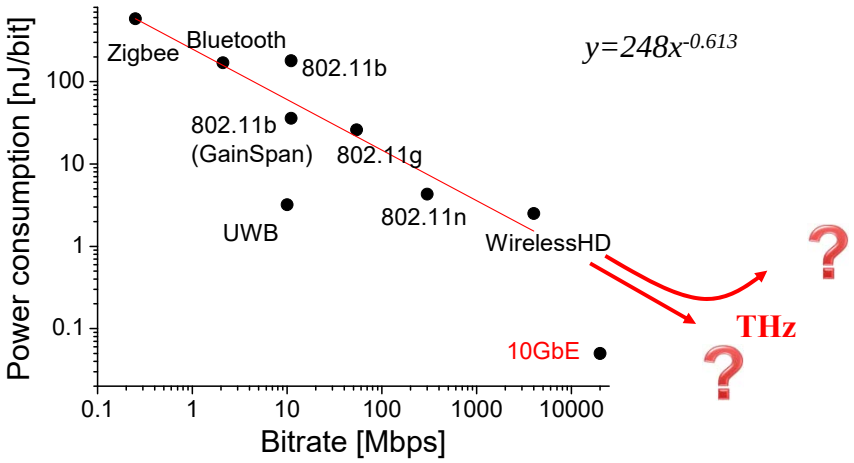
MWP has a good presence in the communication conference

Bitrate and power consumption of wireless data transmitters

	MBit/s	nJ/Bit		
Zigbee (TYP)	0.25	580		
Bluetooth3.0+EDR (Planex)	2.1	170	Product	BT-Micro3E2X
802.11b (TYP)	11	180		
802.11b/g (iodata)	54	26	Product	WN-G54/CB3L
UWBDice	10	3.2	R&D	
802.11b/g/n (iodata)	300	4.3	Product	WN-G300U
802.11b GainSpan (Alps)	11	36	Sample	UGFZ1
WirelessHD SiBeam (Panasonic)	4000	2.5	Product	TU-WH1
Optical transceiver 10GbE(SEI)	20000	0.05	Product	SPP5000

T. Kawanishi, A. Kanno, T. Kuri and N. Yamamoto, "Transparent wave-form transfer for resilient and low-latency links," IEEE Photonics Society Newsletter, **28** (2014) 4

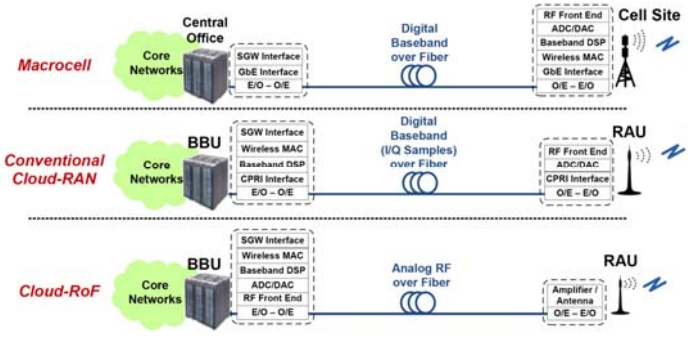
Bitrate and power consumption of wireless data transmitters



T. Kawanishi, A. Kanno, T. Kuri and N. Yamamoto, "Transparent waveform transfer for resilient and low-latency links," IEEE Photonics Society Newsletter, **28** (2014) 4

RoF for Next Mobile Services

4G(LTE/LTE-A) mobile fronthaul technology such as CPRI, OBSAI and ORI is based on digitized RoF.



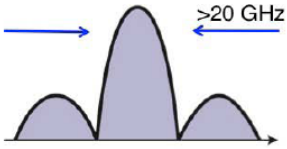
From G.-K. Chang, et el., IEEE ICC'13 WS Optical-Wireless

For Next-Gen. 5G?, we have to discuss in the MWP.

TuB: RoF for Mobile Communication Systems will be held tomorrow.

Wideband wireless and high-speed transmission

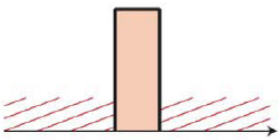
For **Wired (optical) domain**



High-speed transmission > 10 Gb/s
XG-PON, 100GbE, …

High symbol rate = Large bandwidth

For **Wireless domain**



High spectral efficiency
Spectral shaping, OFDM, …

Spurious should be reduced

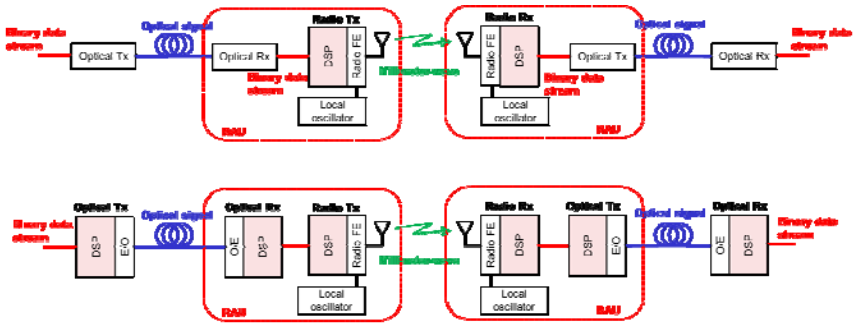
Optical Digital Coherent Technology

- Spectral-optimized signal generation/detection with spectral shaping and OFDM techniques.

RoF-based Technique

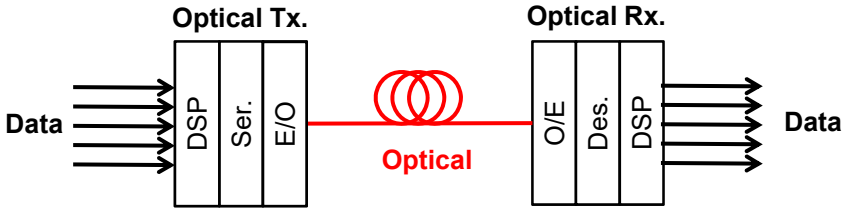
- Direct convergence between wired/wireless signal without spurious

Combination of optical digital links and radio transmitters



APT REPORT ON WIRED AND WIRELESS SEAMLESS CONNECTIONS USING MILLIMETER-WAVE RADIO ON FIBER TECHNOLOGY FOR RESILIENT ACCESS NETWORKS

Digital coherent optical transmission

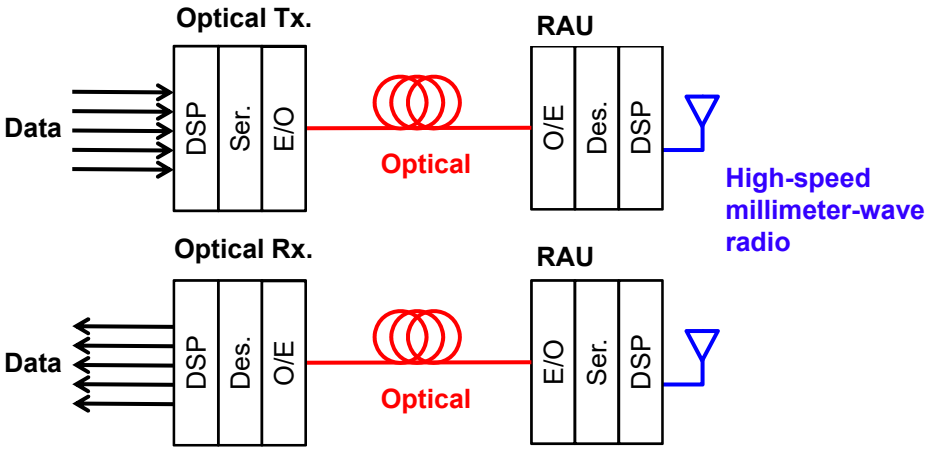


High-performance digital signal processing (DSP) at Tx. and / or Rx.

High-speed and precise lightwave control and detection (Vector E/O and O/E)

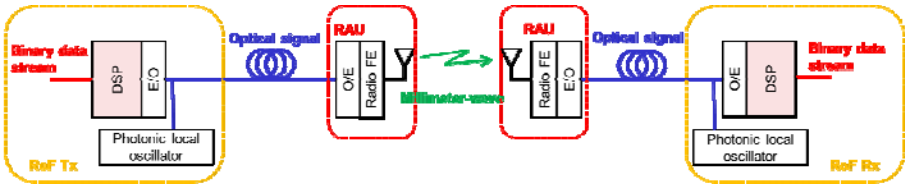
Combination of DSP and vector lightwave control can generate high-frequency broadband wireless signals.

Expansion of optical connection by high-speed wireless based on Radio-over-Fiber



Seamless optical/radio link

RF signal over fiber

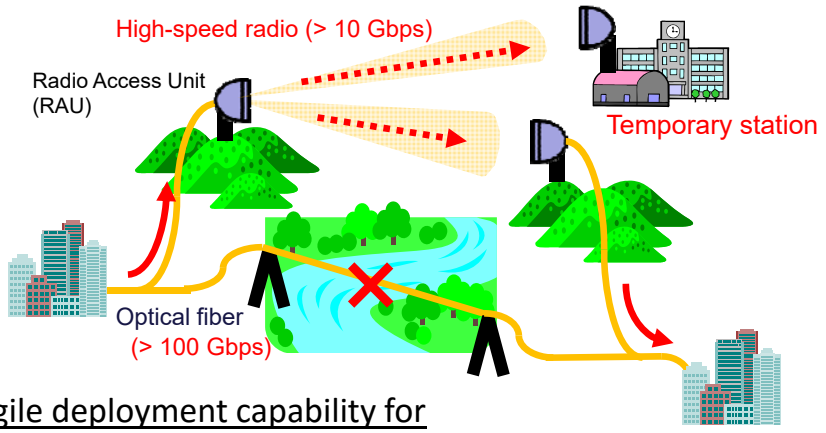


Wideband IF signal over fiber

Spectral efficiency in optical domain can be large. IF can be zero. (M2D.3)

APT REPORT ON WIRED AND WIRELESS SEAMLESS CONNECTIONS USING MILLIMETER-WAVE RADIO ON FIBER TECHNOLOGY FOR RESILIENT ACCESS NETWORKS

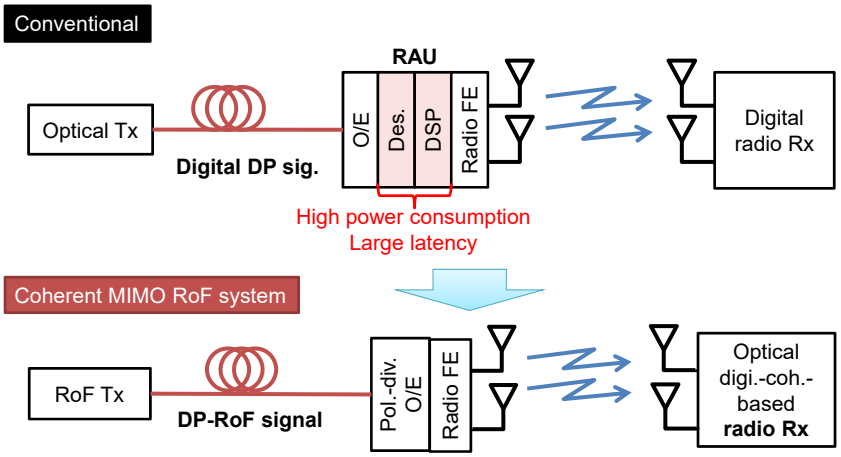
Concept of wired and wireless seamless transmission for resilient network



<u>Agile deployment capability for</u>

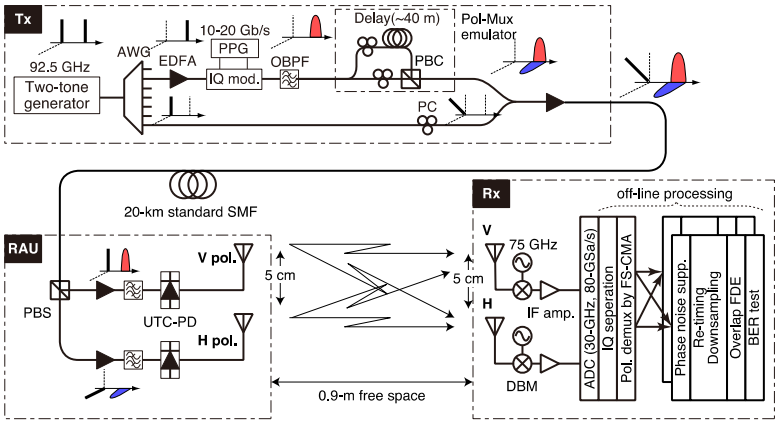
- Protection link against fiber being cut at disaster
- Temporal link to temporary station at disaster recovery
- “Last mile” solution until optical fiber deployment

MIMO: to Enhance Total Capacity



- "Radio-friendly" optical signal by RoF Tx
- Polarization diversity O/E derivers MIMO radio signal directly.

Optical-PDM/RF-MIMO transmission setup

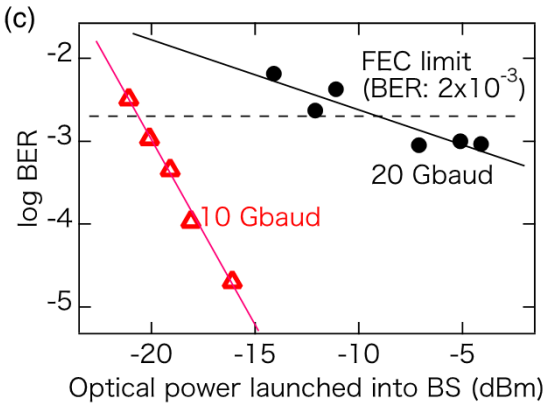


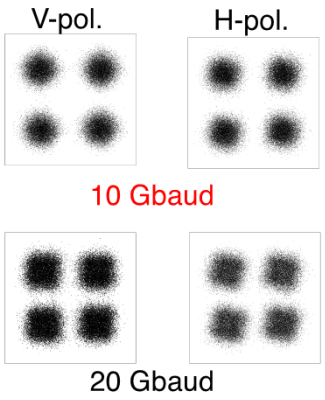
A. Kanno, ECOC2012, We.3.B.2 (2012).

Pol.-diversity OE converters
Optical DP-QPSK-detector-based digital coherent Rx.
Coherent two-tone generation: See a. Kanno, IPC11, TuJ4 (2011)

Observed BERs (74.4 Gb/s in 20 Gbaud)

A. Kanno, Opt. Express, 20, 29395 (2012).





High-speed 60-GHz Trans.

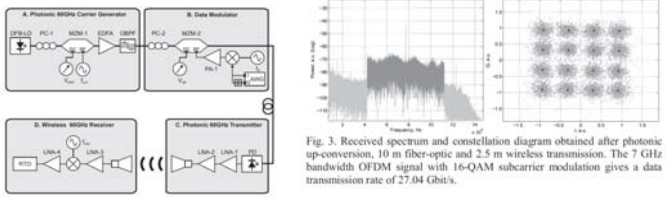


Fig. 3. Received spectrum and constellation diagram obtained after photonic up-conversion, 10 m fiber-optic and 2.5 m wireless transmission. The 7 GHz bandwidth OFDM signal with 16-QAM subcarrier modulation gives a data transmission rate of 27.04 Gbit/s.

27 Gbit/s at 60 GHz

M. Weiss et al., **MWP 2009**, Valencia, Spain, 2009, (post deadline paper)

5 years

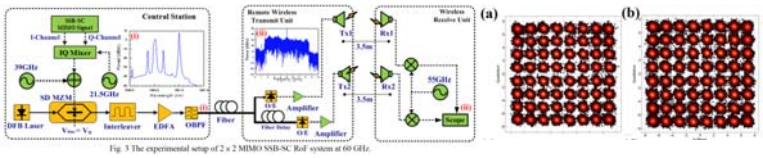


Fig. 3 The experimental setup of 2 x 2 MIMO SSB-SC RoF system at 60 GHz

84 Gbit/s by 2x2 MIMO at 60 GHz

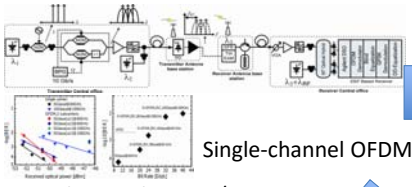
C.-T. Lin et al., **OFC2014**, M3D.1 (2014).

MWP plays a role as advanced technology testbed of future wireless communication.

Millimeter-wave Trans at >60 GHz

- W-band, 120 GHz, 220 GHz,…

100-Gb/s capability at W-band



Single-channel OFDM

D. Zibar et al., MWP/APMP2011

4 yrs.

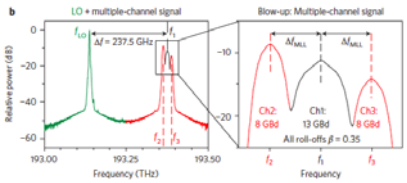
400-Gb/s demonstration at W-band

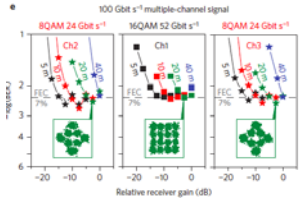
4x4 MIMO 28Gbd 16-QAM

J. Yu et al., ECOC2014, We3.6.6

Doubled freq.

100-Gb/s demo at 220 GHz



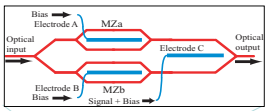


S. Koenig et al., Nature Photonics 7, 977 (2013)

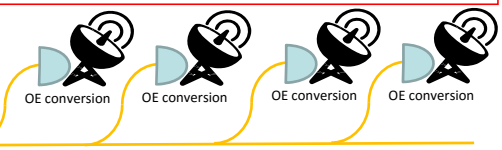
Highly-precise Optical Clock Signal Gen.

ALMA Photonic LO System by NAOJ, NICT

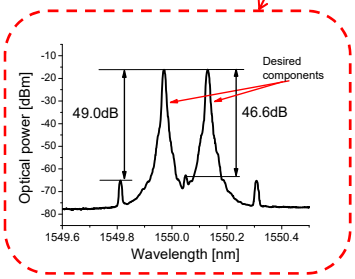
High-ER modulator



Distribution of stable LO signal (31-120 GHz) over fibers



Pure two-tone source



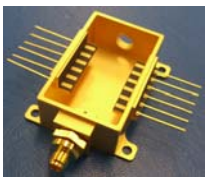
ALMA: Atacama Large Millimeter/sub-millimeter Array

The site is at height of 5000m above sea level.
The longest baseline is 14km and the resolution is 0.001 arcsec which is better than the Hubble space telescope.
Receiving frequency: 31-950 GHz.

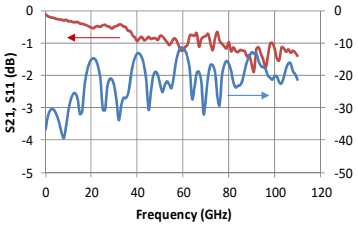
T. Kawanishi et al., CLEO/QELS 2008, CFA1

High-Speed Photodiodes

- Zero-biased ultra-high-speed photodiodes beyond 110 GHz.

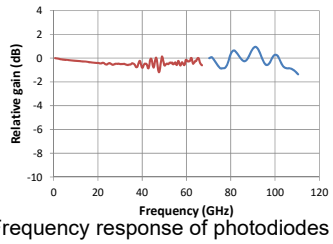


Package photo with 1mm connector



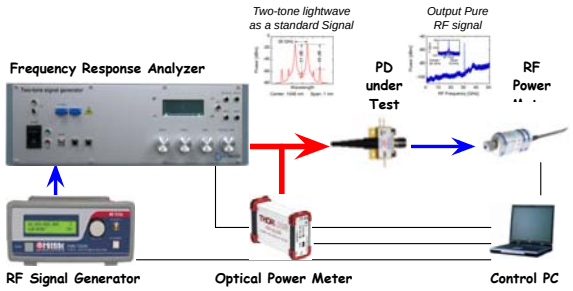
S-parameter measurement of packaged PD

Fabricated unitraveling-carrer photodiode



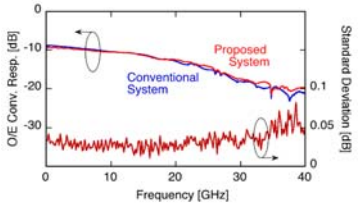
Frequency response of photodiodes
3dB Bandwidth > 110 GHz with bias=0

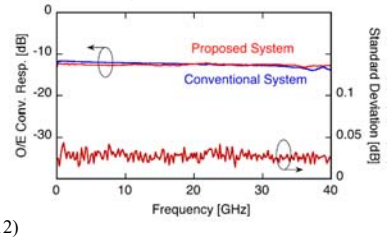
Frequency Response Analyzer



Frequency range：
0.1～40GHz
Measurement time：
< 2 sec
Accuracy： <0.1dB

APT Report on Characteristics and Requirements of Optical and Electric Components for Millimeter-wave Radio on Fiber systems ASTAP/REPT 3

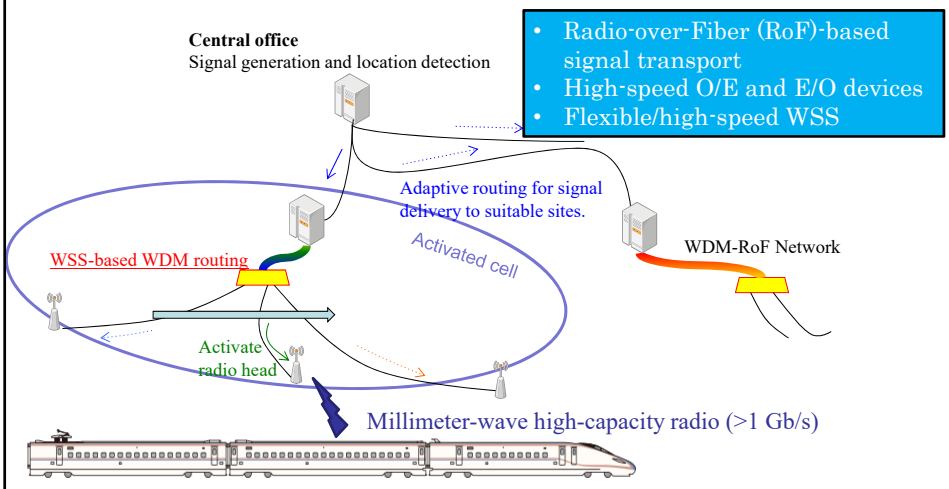




K. Inagaki, et al., IEICE Electronics Express, Vol. 9, 220 (2012)

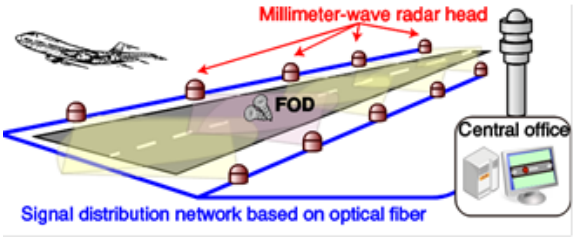
High-Capacity MMW-RoF Backhaul for Railways

1–10-Gb/s signal transport to high-speed trains



High-speed signal transport and adaptive routing with tracking the location of the trains.

R&D of high-precision imaging technology using 90 GHz band linear cells

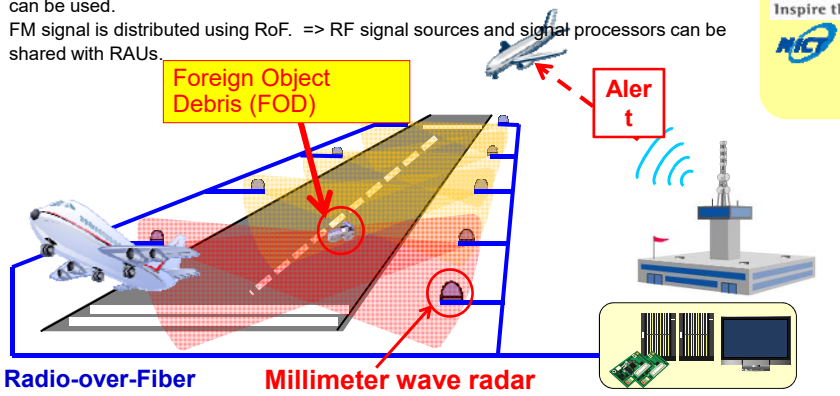


This study was conducted as part of the research project “R&D of high-precision imaging technology using 90 GHz band linear cells,” supported by the Japanese Government funding for “R&D to Expand Radio Frequency Resources” from the Ministry of Internal Affairs and Communications.

FOD Detection using Millimeter-wave RoF for Airport Runways

MIC-PJ※

W-band FM-CW radar with many small RAUs. => Low-cost semiconductor amplifiers can be used.
FM signal is distributed using RoF. => RF signal sources and signal processors can be shared with RAUs.

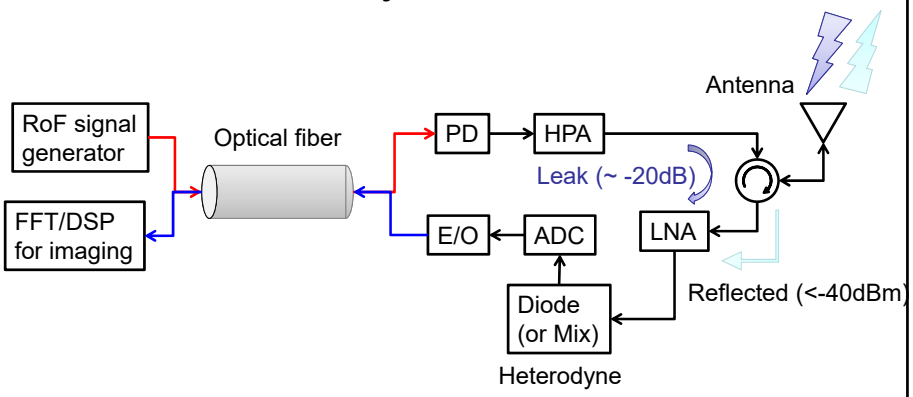


- Low operation cost
- Low radio-wave emission
- Scalability:
  - High-performance systems for busy airports
  - Low-cost systems for local airports
- Agile scan capability

※This research was conducted as part of the project entitled "Research and development of high-precision imaging technology using 90 GHz band linear cells," with funding from "Research and Development to Expand Radio Frequency Resources" supported by the Ministry of Internal Affairs and Communications, Japan.

25

Configuration of RoF-based Radar System



- Downlink (from CO to RAU): Analog-RoF
- Uplink (from RAU to CO): Digitized RoF or conventional 10GbE

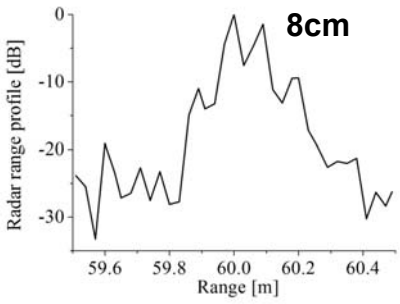
FOD Experiment @CU Saraburi

2015 July @Churalonkong University Saraburi Campus

CU,NiCT,ENRI and Hitachi Ltd.

Site overview

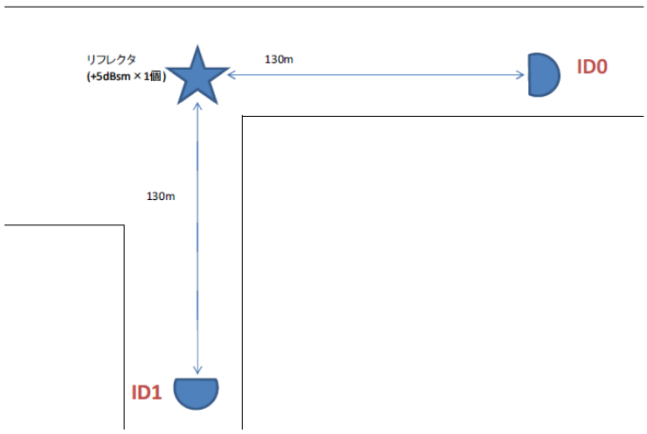
Range Resolution



 29

Imaging by using two radar units

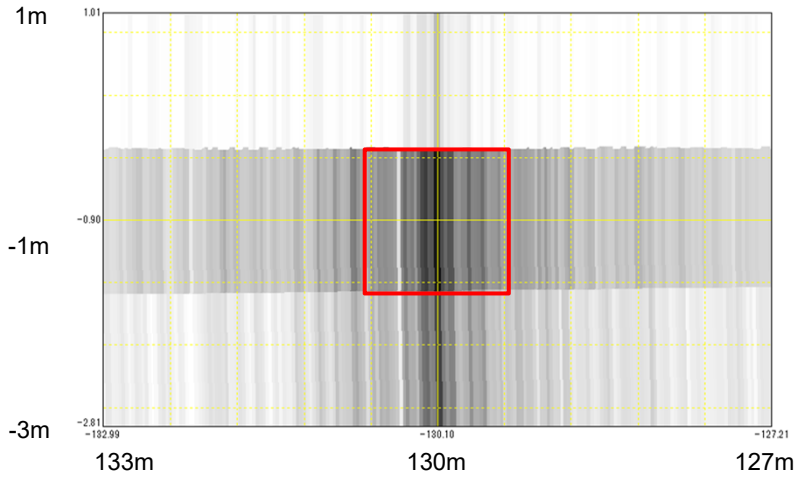
130m（ +5dBsm ）



Preliminary data from two radar units

Range resolution 1.8cm
Angular resolution 0.8deg

130m x sin 0.8deg = 1.8m



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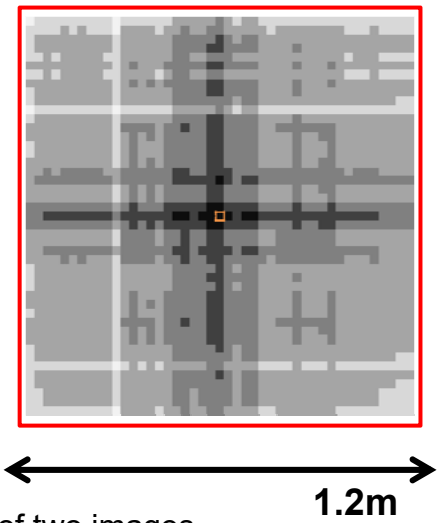

Geometric mean of two images

Issues

- Interfaces between RoF and digital networks
- RoF network archtechture
- Control of cells and networks
- Requirements on RoF links
- Measurement techniques for RoF components
  - APT Report on Characteristics and Requirements of Optical and Electric Components for Millimeter-wave Radio on Fiber systems ASTAP/REPT 3