

# R&D activities of radio-over-fiber technology in NICT

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# Acknowledgement

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Some resultants of the “Research and Development to Expand Radio Frequency Resources” project supported by the Ministry of Internal Affairs and Communications (MIC), Japan are included in this presentation.

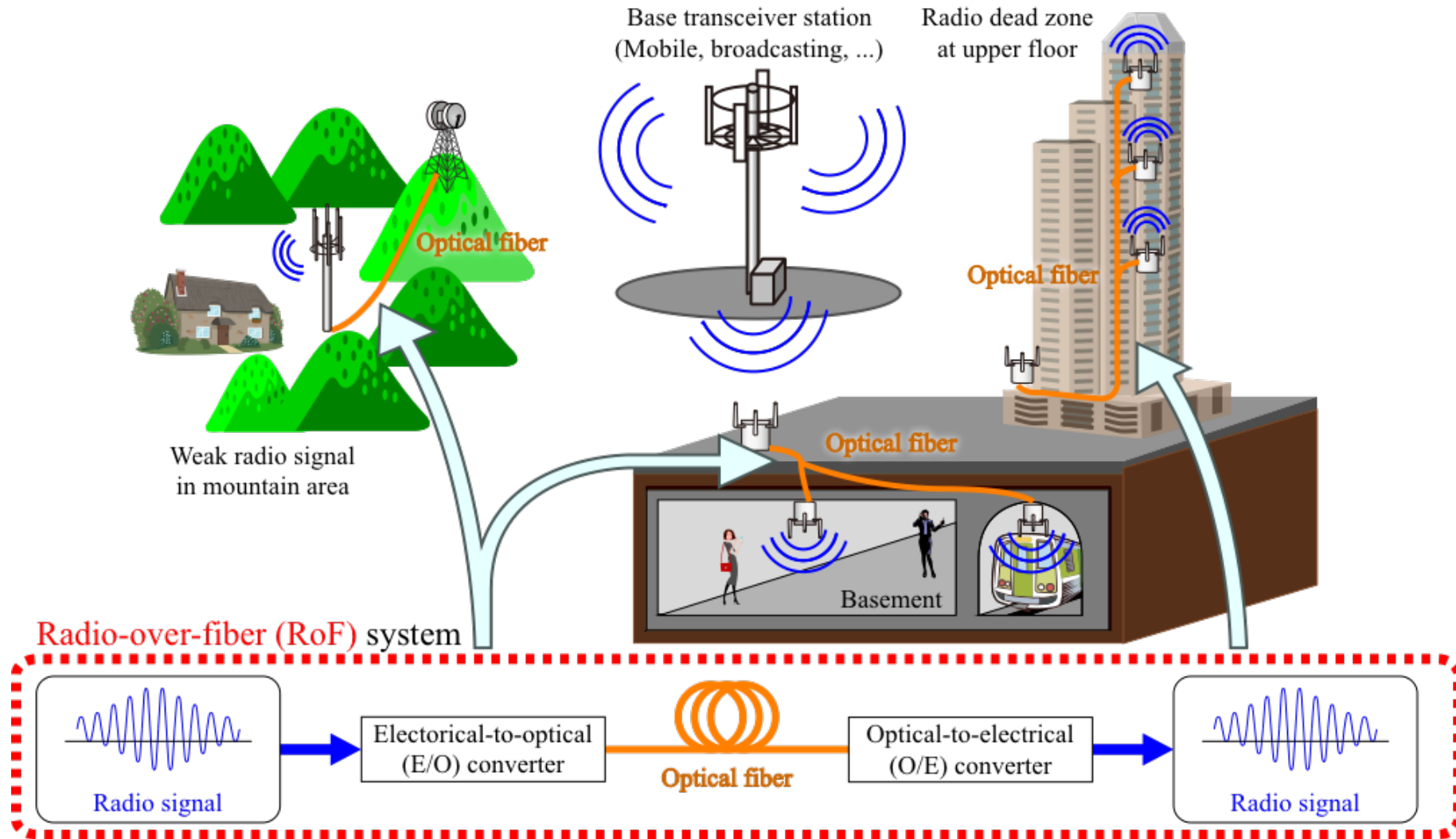
# Outline

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1. What is Radio-over-Fiber (RoF)
2. R&D Examples of RoF technologies
3. Standardization activities of RoF technologies at ITU-T SG15
4. Summary

# What is radio-over-fiber (RoF) ?

## Applications of RoF technologies



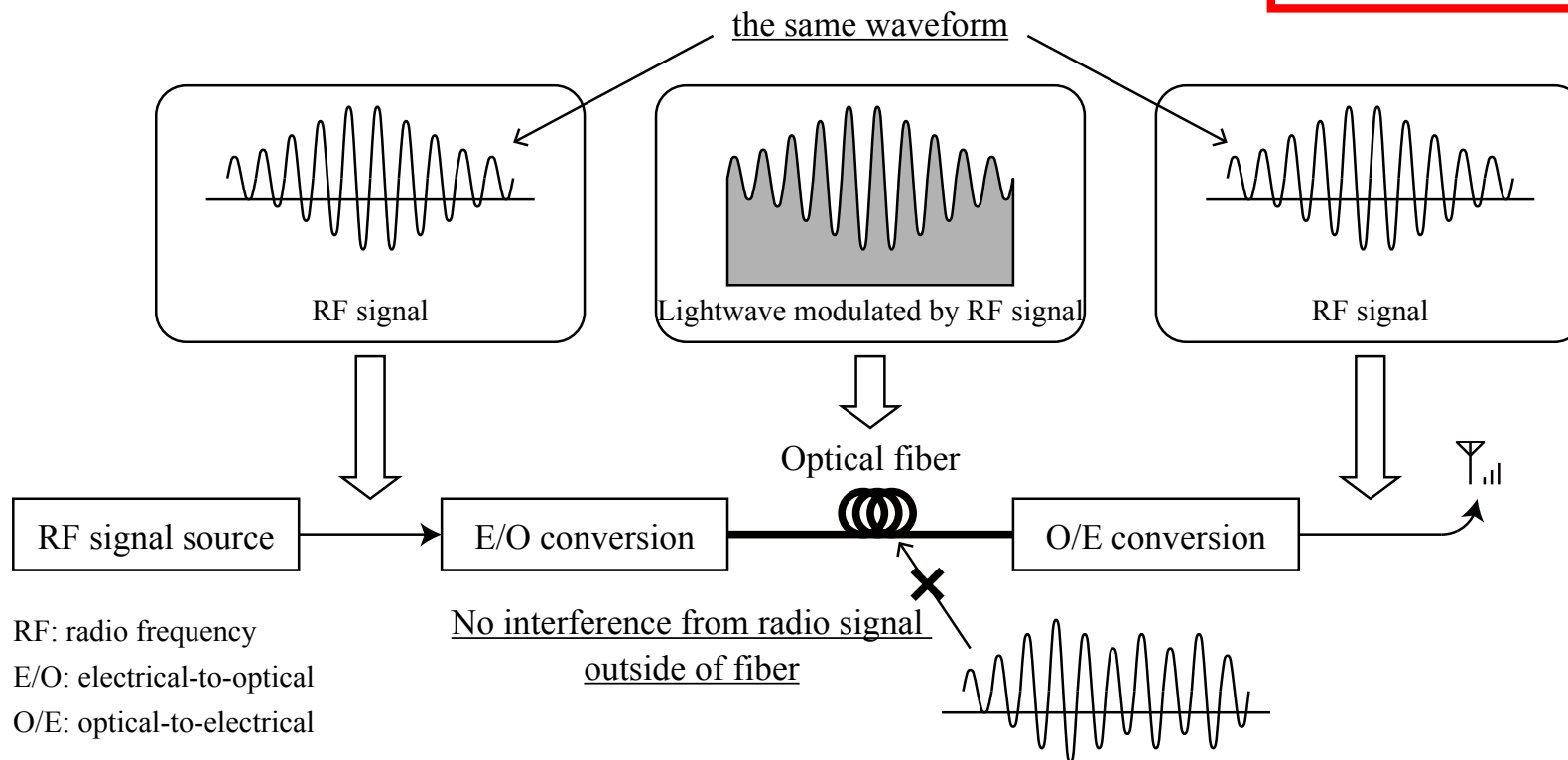
[Ref.] A. Kanno, T. Kuri, and T. Kawanishi, "Radio wave transmission via an optical link," *NICT NEWS*, no.432, pp.5-6, Sept. 2013. ([http://nict.go.jp/en/data/nict-news/NICT\\_NEWS\\_1309\\_E.pdf](http://nict.go.jp/en/data/nict-news/NICT_NEWS_1309_E.pdf)) [Figure is modified.]

# What is radio-over-fiber (RoF) ?

## Features of RoF technologies

- Two features
  - Preservation of waveform
  - Tolerance to electro-magnetic interference

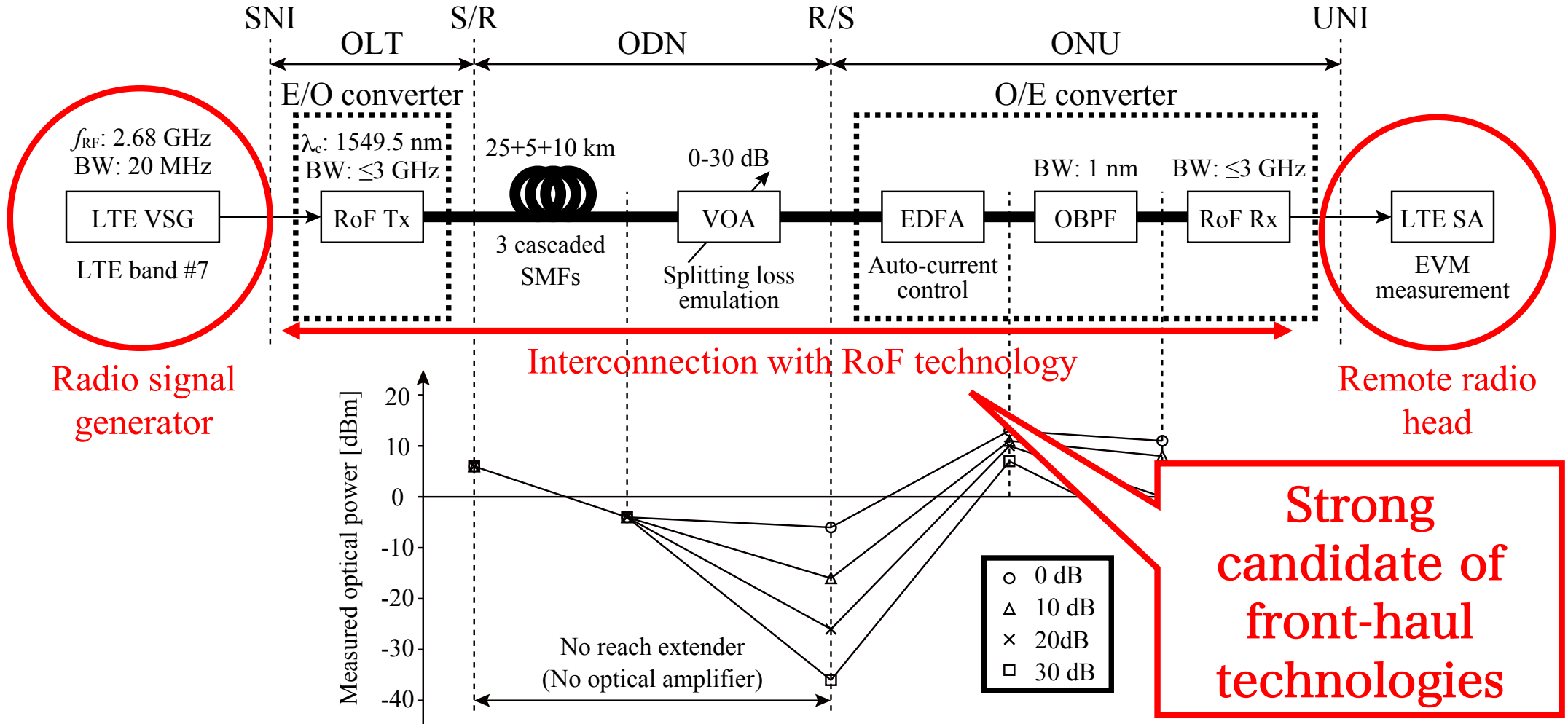
Applicable to  
IMT-2020/5G  
systems



[Ref.] ITU-T G-series Recommendations – Supplement 55 (07/2015), Radio-over-fibre (RoF) technologies and their applications (<http://www.itu.int/rec/T-REC-G.Sup55-201507-1>).

# R&D examples

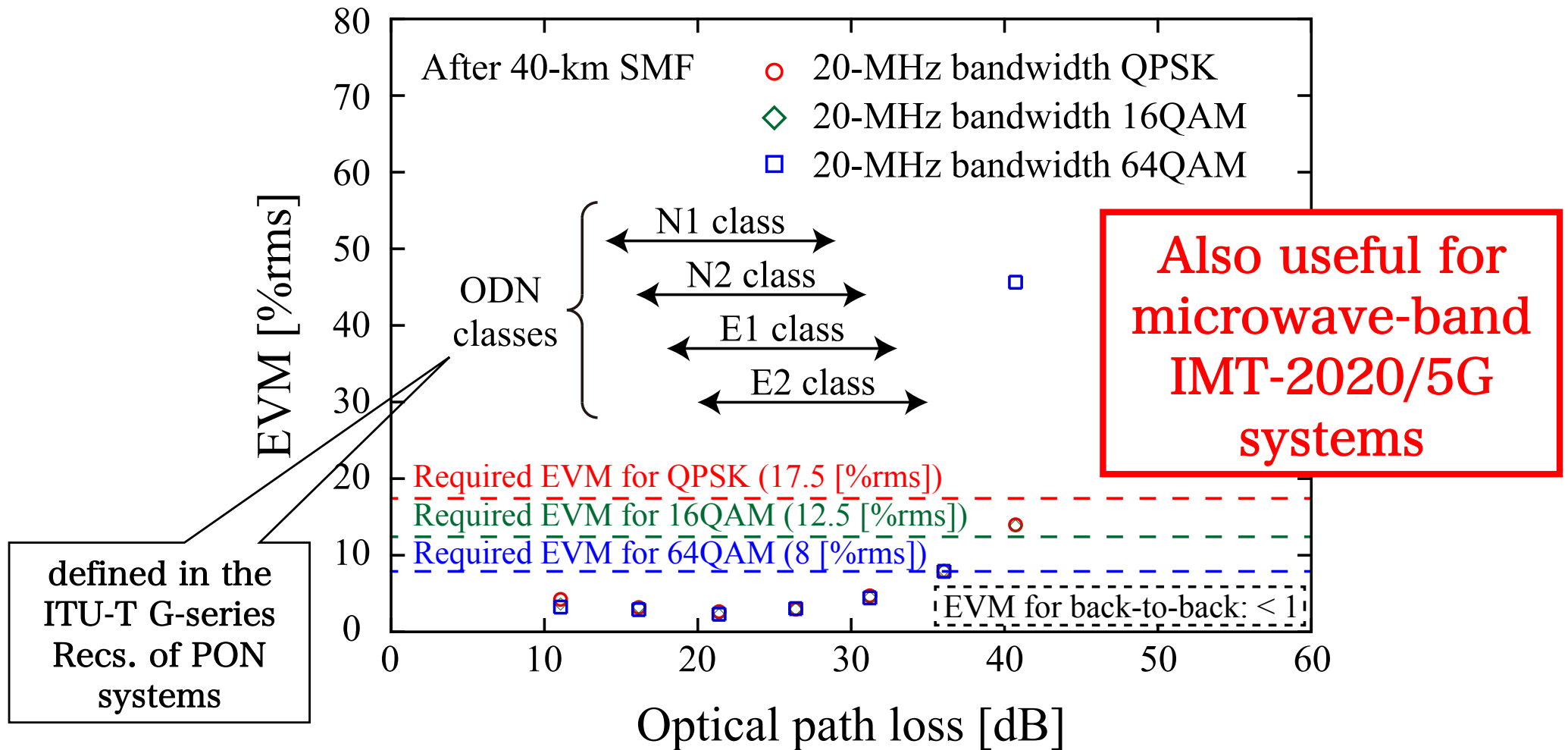
RoF transmission of an LTE signal over a typical optical distribution network (ODN) used in PON systems



[Ref.] ITU-T G-series Recommendations – Supplement 55 (07/2015), Radio-over-fibre (RoF) technologies and their applications (<http://www.itu.int/rec/T-REC-G.Sup55-201507-1>).

# R&D examples

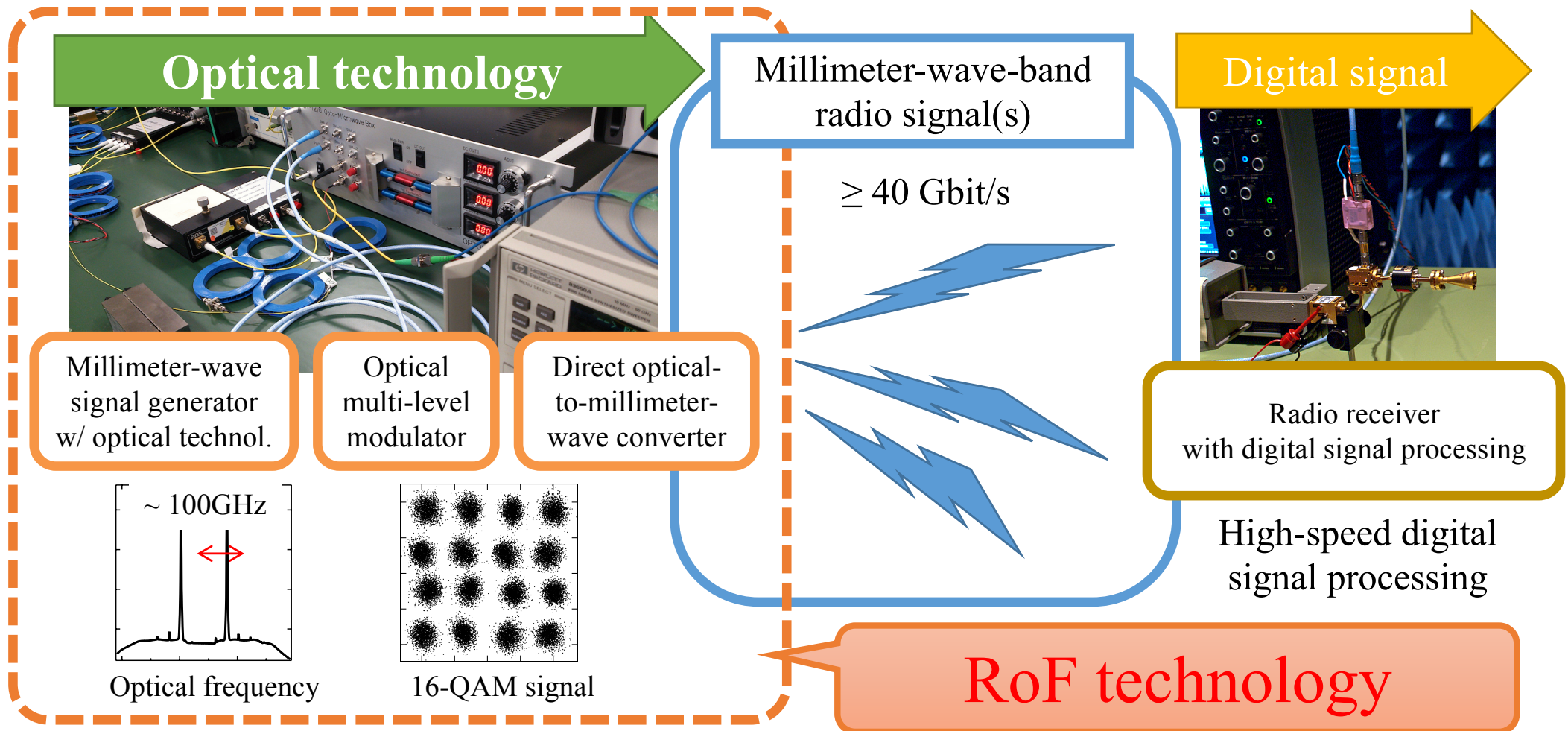
## Measured EVM (transmission quality)



[Ref.] ITU-T G-series Recommendations – Supplement 55 (07/2015), Radio-over-fibre (RoF) technologies and their applications (<http://www.itu.int/rec/T-REC-G.Sup55-201507-1>).

# R&D examples

## DSP-assisted analog RoF technologies (100-GHz-band)



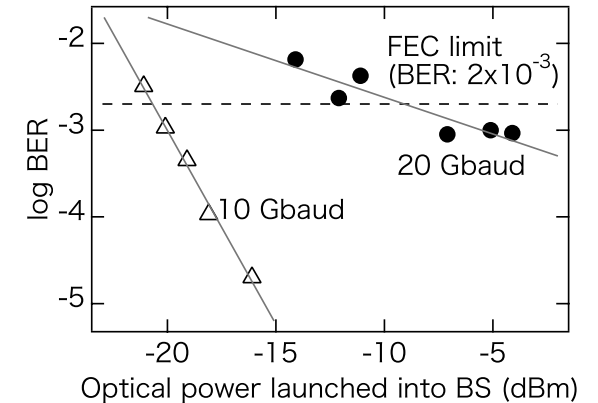
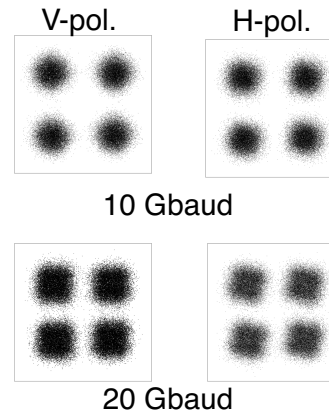
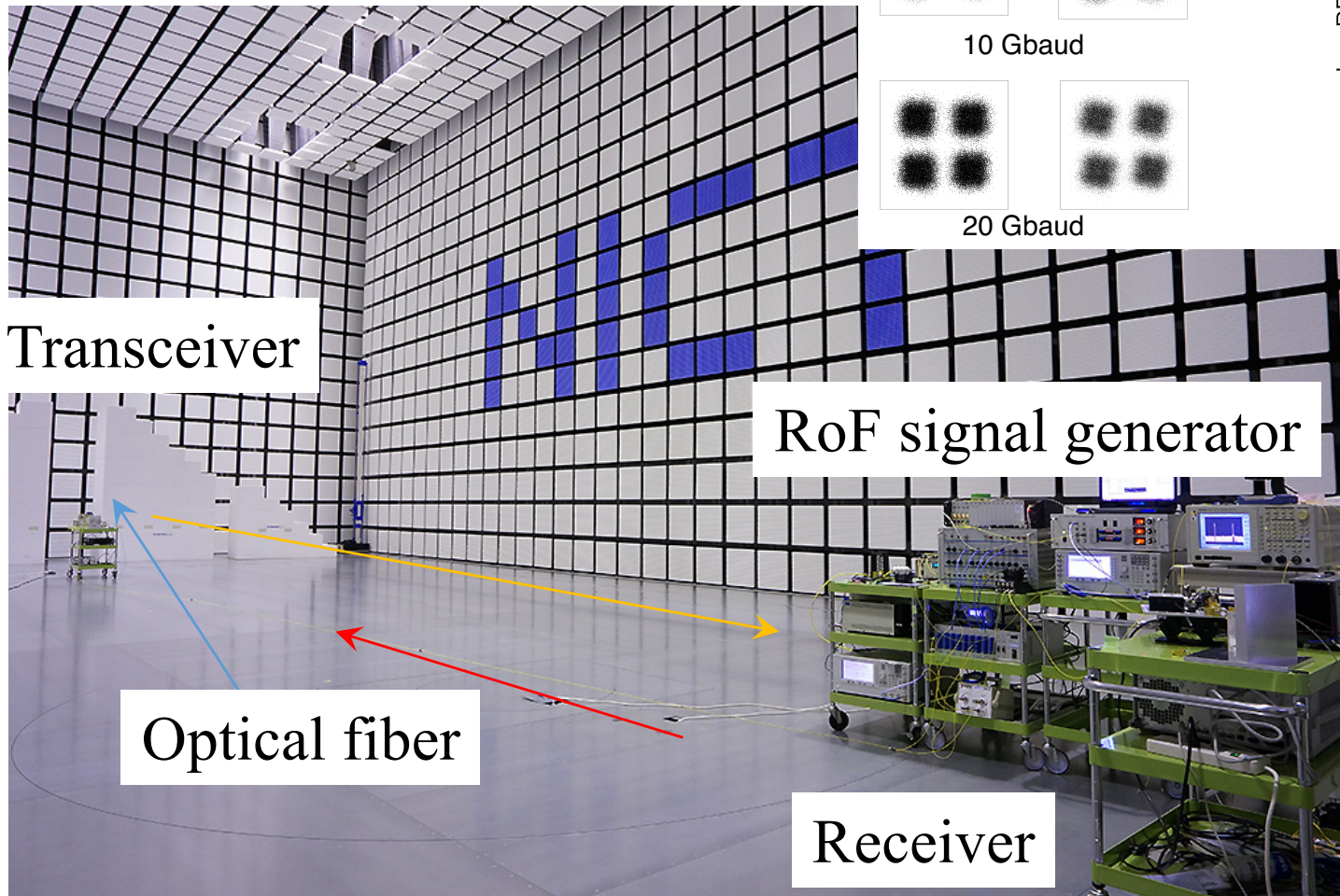
[Ref.] A. Kanno, T. Kuri, and T. Kawanishi, "Radio wave transmission via an optical link," *NICT NEWS*, no.432, pp.5-6, Sept. 2013. ([http://nict.go.jp/en/data/nict-news/NICT\\_NEWS\\_1309\\_E.pdf](http://nict.go.jp/en/data/nict-news/NICT_NEWS_1309_E.pdf)) [Figure is modified.]



# R&D examples

## RoF transmission experiment in shield room

RF shield room



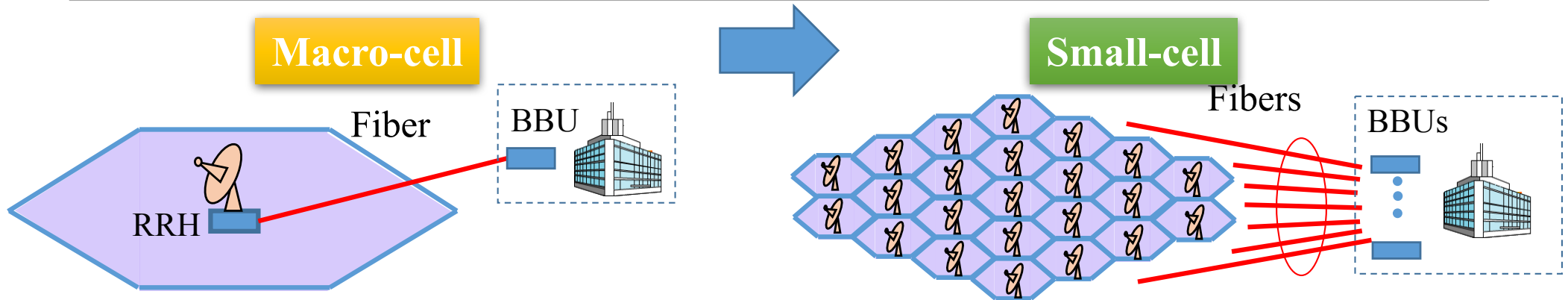
90-GHz wireless link  
20-Gbaud QPSK

Useful for future millimeter-wave-band and high-bit-rate 5G/B5G systems

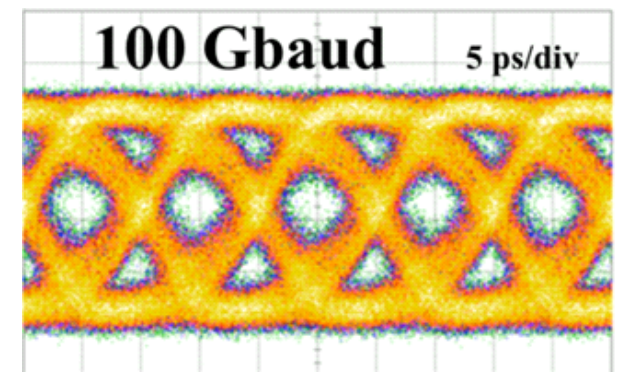
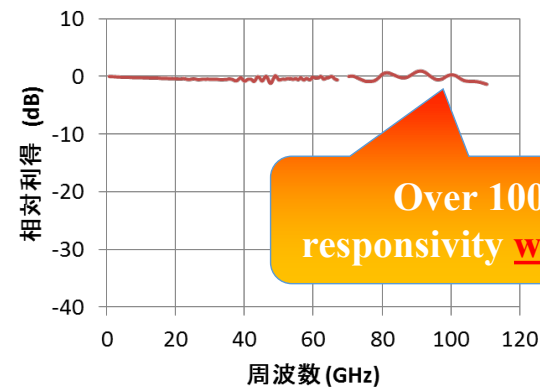
# R&D examples

## Advanced wireless network for IMT-2020/5G systems

- High data rate : > 10 Gbps
- High capacity
- Low latency
- Low cost



### Our developed key component for O/E conversion

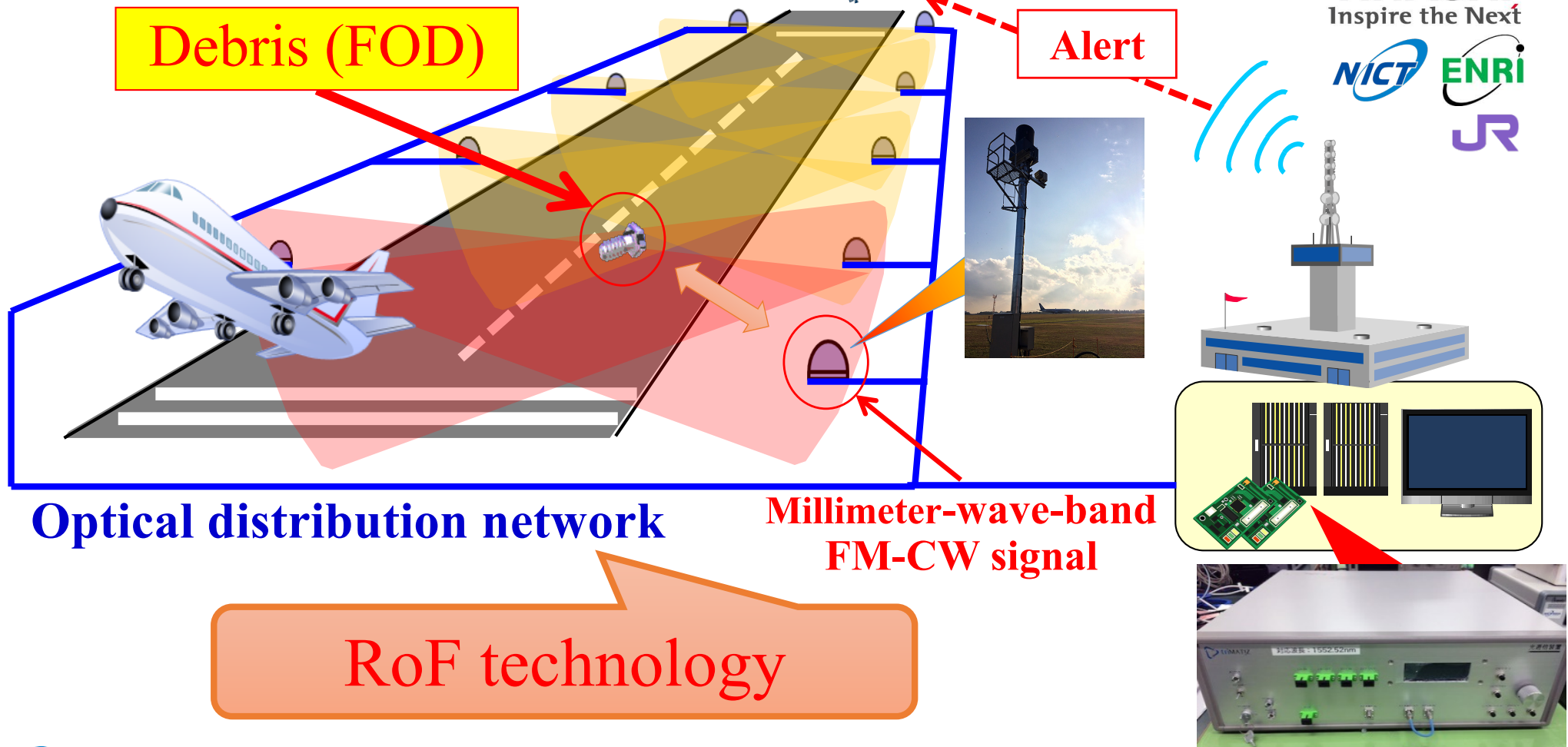


[Ref.] T. Umezawa, K. Kashima, A. Kanno, A. Matsumoto, K. Akahane, N. Yamamoto, and T. Kawanishi "100-GHz Fiber-Fed Optical-to-Radio Converter for Radio- and Power-Over-Fiber Transmission," IEEE J. Selected Topics in Quantum Elec., vol.23, no.3, May/June 2017.

# R&D examples

High-precision imaging technology using 90-GHz-band linear cells  
(Collaborative R&D project: FY2011- FY2015)

Foreign object debris (FOD) detection system by using millimeter-wave-band frequency-modulated continuous-wave (FM-CW) signal



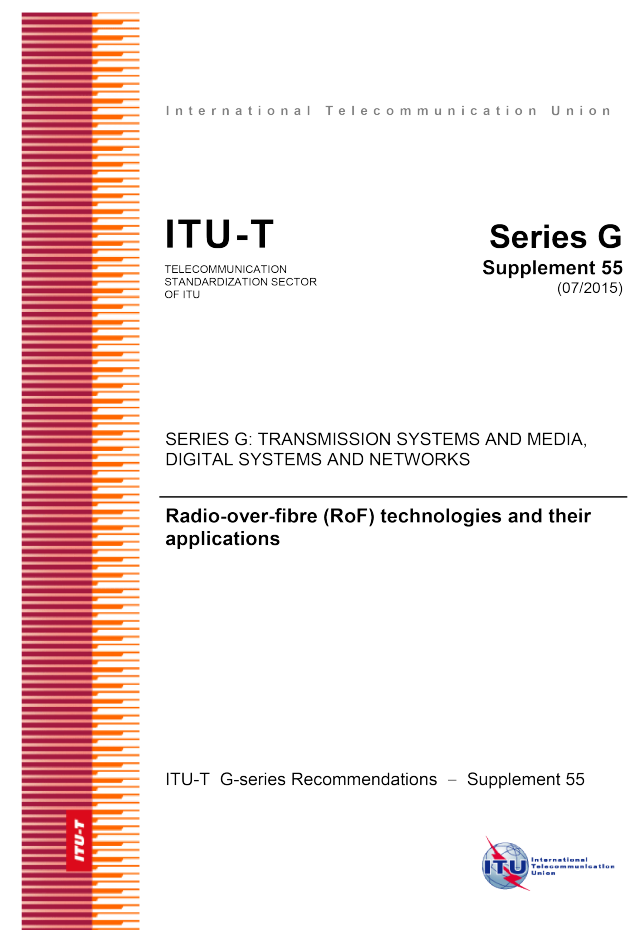


# Standardization activities at ITU-T SG15

## ITU-T G-series Recommendations – Supplement 55 (07/2015) Radio-over-fibre (RoF) technologies and their applications

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  5. General concept
  6. System architectures
  7. Fundamental technologies
  8. Network models
  9. System design for supporting radio access system over optical access network
- Bibliography



[Ref.] ITU-T G-series Recommendations – Supplement 55 (07/2015), Radio-over-fibre (RoF) technologies and their applications  
(<http://www.itu.int/rec/T-REC-G.Sup55-201507-1>).

# Standardization activities at ITU-T SG15

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## Draft ITU-T G-series Recommendations

### Radio over fiber systems (G.RoF) (from July 2015)

- Abstract (from draft version.0.6 (June 27, 2017))

This recommendation specifies radio over fiber transmission systems suitable for access network applications.

- Scope (from draft version.0.6)

This recommendation develops a new type of optical access network based on radio-over-fiber (RoF) technologies. In general, RoF technologies can be classified into two groups, analog RoF and digital RoF. The digital RoF requirements may be satisfied by elements of the G.989 series with necessary enhancements. The analog RoF system is currently unspecified in any other recommendation. The recommendation will include consideration of the common applications, the requirements that stem from these, the specification of the analog optical link and/or the necessary functions to digitally carry the radio signals over various optical access systems, the associated signal processing, and the management aspects of the systems.

- Co-editors (Q2/15: SG15 Question 2 “optical systems for fibre access network”)  
Seung-Hyun CHO (ETRI), Toshiaki KURI (NICT), Yuanqiu LUO (Futurewei Tech. Inc.)

[Ref.] ITU-T SG15 ([http://www.itu.int/ITU-T/workprog/wp\\_item.aspx?isn=10590](http://www.itu.int/ITU-T/workprog/wp_item.aspx?isn=10590))

# Summary

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## R&D activities of RoF technologies in NICT

- Overview of RoF technologies
- Introduction of some R&D examples
  - ✓ RoF transmission of LTE signal over PON ODN
  - ✓ RoF transmission of W-band signal
    - ✓ Communication system application
    - ✓ FM-CW radar system application
- Introduction of standardization activities at ITU-T SG15
  - ✓ G Suppl.55 “RoF technologies and their applications”
  - ✓ G.RoF “RoF systems”