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

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) [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

RF signal source → E/O conversion → Optical fiber → O/E conversion

RF signal

Lightwave modulated by RF signal

RF signal

No interference from radio signal outside of fiber

RF: radio frequency
E/O: electrical-to-optical
O/E: optical-to-electrical

R&D examples

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

Radio signal generator

$f_{RF}: 2.68$ GHz
BW: 20 MHz

LTE VSG

LTE band #7

Radio signal generator

Interconnection with RoF technology

Strong candidate of front-haul technologies

R&D examples

Measured EVM (transmission quality)

- Required EVM for QPSK (17.5 [%rms])
- Required EVM for 16QAM (12.5 [%rms])
- Required EVM for 64QAM (8 [%rms])

EVM for back-to-back: < 1 [%rms]

After 40-km SMF
- 20-MHz bandwidth QPSK
- 20-MHz bandwidth 16QAM
- 20-MHz bandwidth 64QAM

ODN classes
- N1 class
- N2 class
- E1 class
- E2 class

Also useful for microwave-band IMT-2020/5G systems

**R&D examples**

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

- **Optical technology**
  - Millimeter-wave signal generator w/ optical technol.
  - Optical multi-level modulator
  - Direct optical-to-millimeter-wave converter
  - Optical frequency
  - 16-QAM signal

- **Millimeter-wave-band radio signal(s)**
  - $\geq 40$ Gbit/s

- **Digital signal**
  - Radio receiver with digital signal processing
  - High-speed digital signal processing

- **RoF technology**

R&D examples
RoF transmission experiment in shield room

RF shield room

Transceiver

RoF signal generator

Optical fiber

Receiver

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

Macro-cell

Fiber

BBU

Small-cell

Fibers

BBUs

Our developed key component for O/E conversion

- High O/E efficiency
- High output power

Over 100GHz responsivity with no bias

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

Optical distribution network

Millimeter-wave-band FM-CW signal

RoF technology
Standardization activities at ITU-T SG15

Radio-over-fibre (RoF) technologies and their applications

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9. System design for supporting radio access system over optical access network

Bibliography

Standardization activities at ITU-T SG15

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.)

Summary

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”