

Proposal of RoF Extension Link Backhaul for Category 4

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Abstract

RoF (Radio on Fiber) extension link is proposed as one of usage models of 11aj backhaul. RoF extension link can extend wireless access area to the different location without additional requirements. RoF extension link has broadband transmission capability because of O/E and E/O broadband conversion characteristics and can transmit signals at 45-GHz and 60-GHz bands simultaneously. The additional experimental results of RoF extension link are presented.

The aim of this contribution is to add usage model 4c in the IEEE 802.11aj Usage Models Document IEEE 802.11-12/1145r2.

Overview of WFA VHT usage models for 802.11ad

Category	#	Usage Model
1.Wireless Display	1a	Desktop Storage & Display
	1b	Projection to TV or Projector in Conf Rom
	1c	In room Gaming
	1d	Streaming from Camcorder to Display
	1e	Broadcast TV Field Pick Up
	1f	Medical Imaging Surgical Procedure Support
2.Distribution of HDTV	2a	Lightly compressed video streaming around home
	2b	Compr. video steaming in a room/ t.o. home
	2c	Intra Large Vehicle (e.g. airplane) Applications
	2d	Wireless Networking for Small Office
	2e	Remote medical assistance
3.Rapid Upload / Download	3a	Rapid Sync-n-Go file transfer
	3b	Picture by Picture viewing
	3c	Airplane docking
	3d	Movie Content Download to car
	3e	Police / Surveillance Car Upload
4.Backhaul	4a	Multi-Media Mesh backhaul
	4b	Point to Point backhaul
5.Outdoor Campus /Auditorium	5a	Video demos / telepresence in Auditorium
	5b	Public Safety Mesh
6.Manufacturing Floor	6a	Manufacturing floor automation
7.Cordless computing	7a	Wireless IO / Docking

Category 4: Backhaul

a. Multi-Media Mesh Backhaul

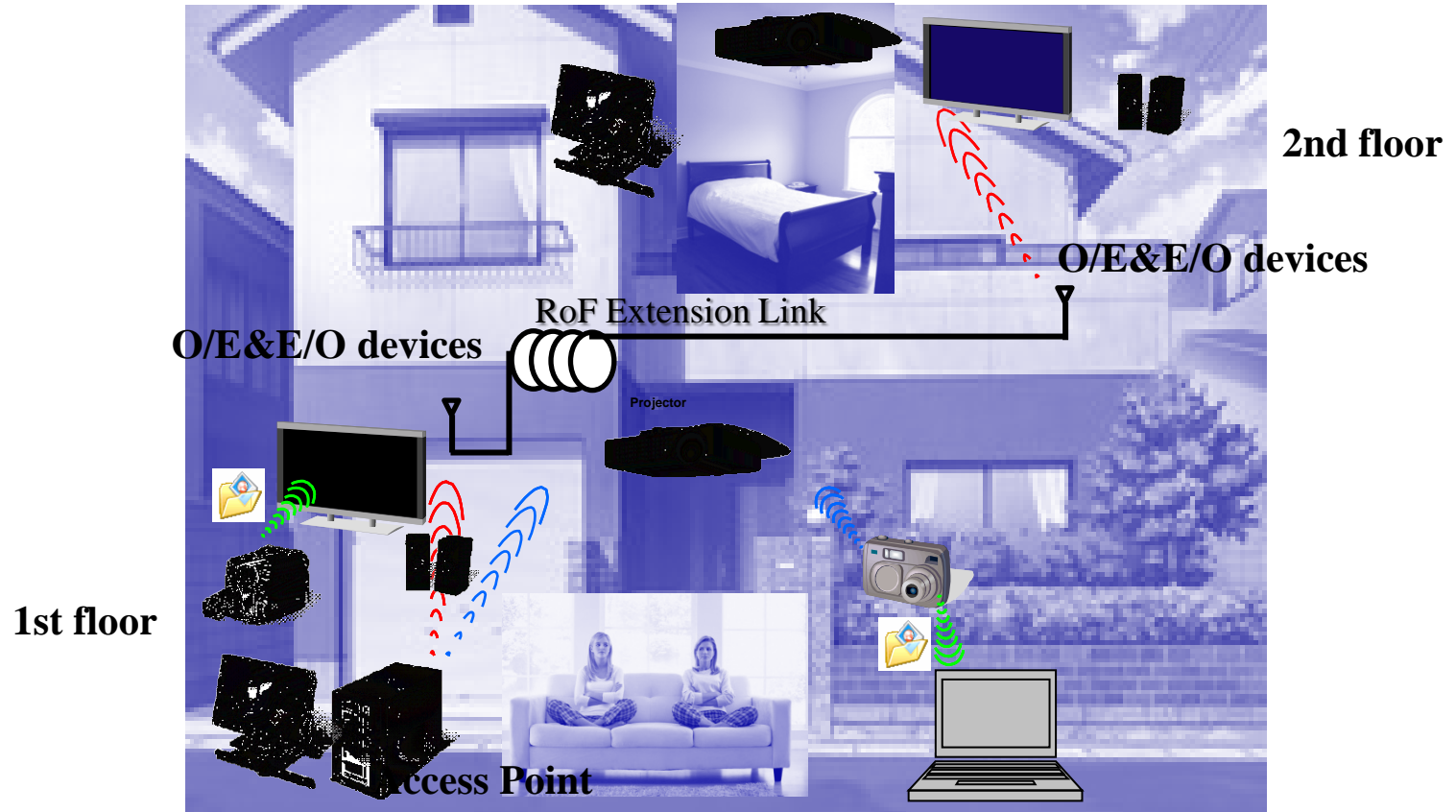
- Hotspot
- Enterprise
- Small Office or Home
- Campus-wide deployments
- Municipal deployments

b. Point-to-Point Backhaul

c. RoF* Extension Link Backhaul

* Radio on Fiber

Usage Model 4c: RoF Extension Link Backhaul



Usage Model 4c: RoF Extension Link Backhaul

Pre-Conditions:

Wireless zones are connected via RoF extension link. The individual wireless zones can support high-speed-data traffic requirements that are limited by the VHT link capabilities.

Application:

Traffic is bidirectional and is comprised of subcarriers which include data, voice, video, and any kinds of signals. These subcarriers are equivalent to radio frequencies, i.e. either 45GHz or 60 GHz bands. RoF extension link extends coverage areas without any performance degradation of traffic requirements.

Environment:

Environment can be home, office, manufacturing floor, etc.

Point-to-point link distance can be extended up to 20 km due to low insertion loss of optical fiber cables.

Typically locations are Non-Line-of-Sight. No frequency interferences can be managed by use of optical fiber cable.

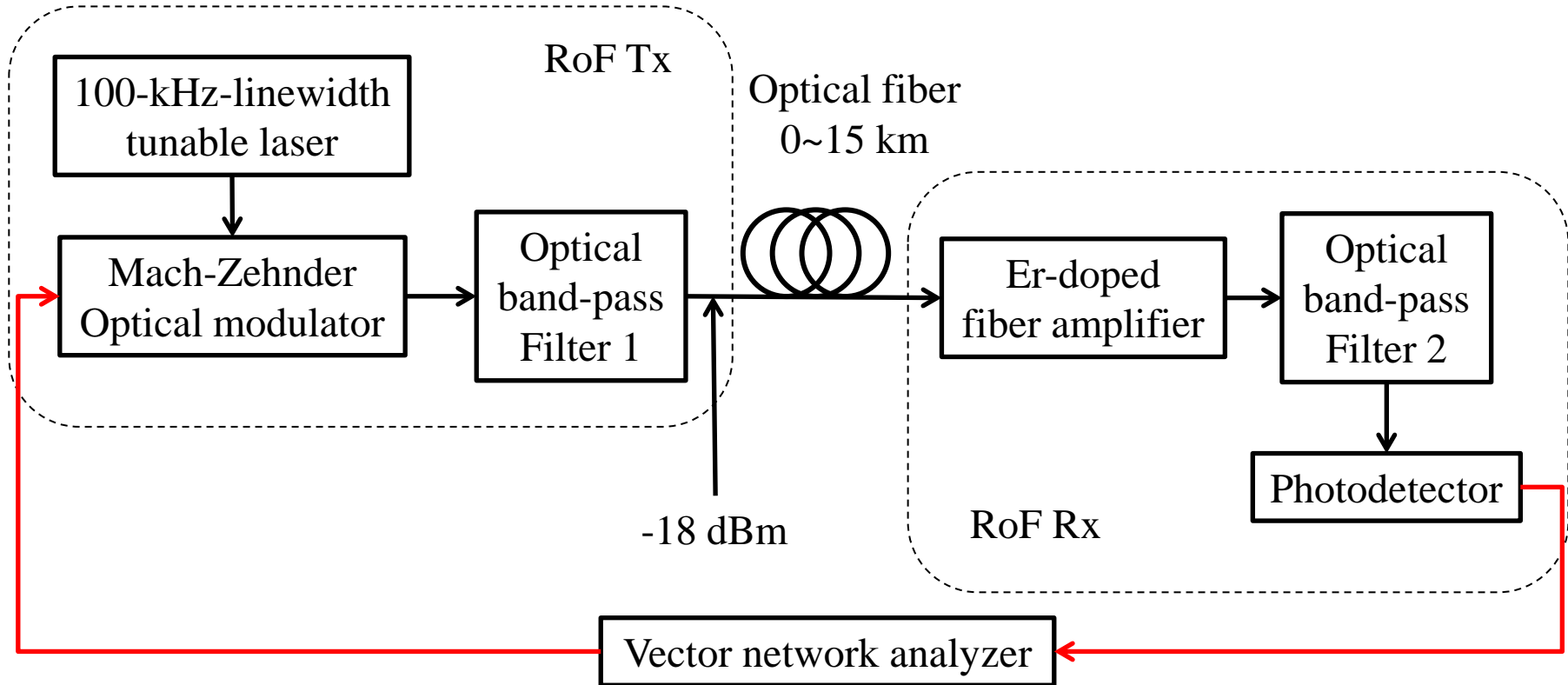
Traffic Conditions:

RoF extension link can carry any type of traffic due to broadband transmission capability of RoF devices. End of each link is heavily loaded with equal amount of traffic in both directions.

Use Case:

1. Wirelessly separated spaces such as rooms of houses surrounded by concretes are directly connected through RoF extension link without any digital signal processing units.
2. In spite of physical and electromagnetic separation, one wireless zone is extended to another wireless zone which has the same characteristics of the original one.
3. Users at different locations can take advantage of broadband multi-media applications.

Experimental Setup of RoF Link



Tunable laser: Yenista optics OSICS TLS-AG (Power stability: ± 0.03 dB)

MZ modulator: GIGOPTIX LX8901 (3-dB BW: > 65 GHz)

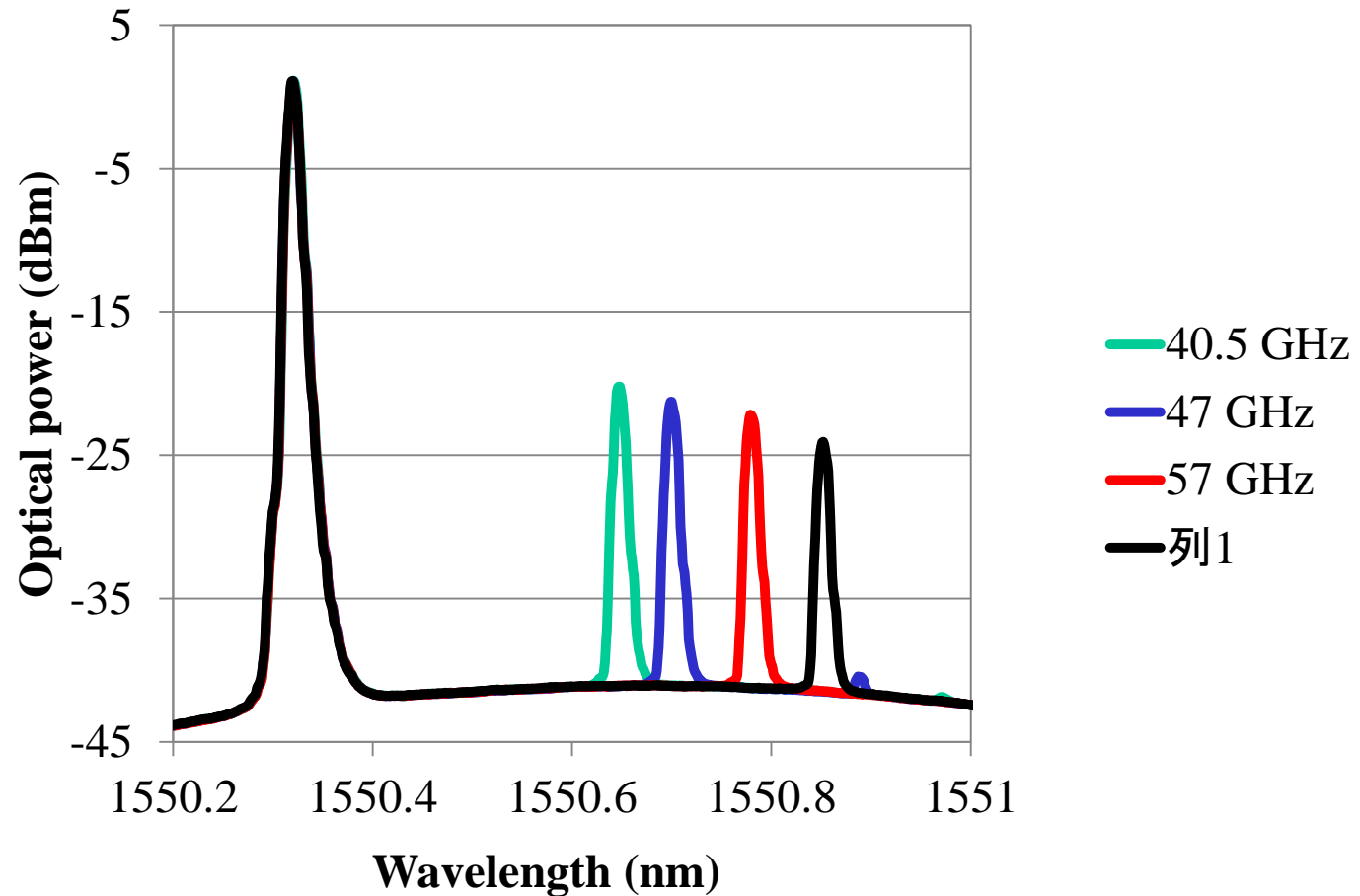
Photodetector: u2t photonics XPDV4120 (3-dB BW: 100 GHz)

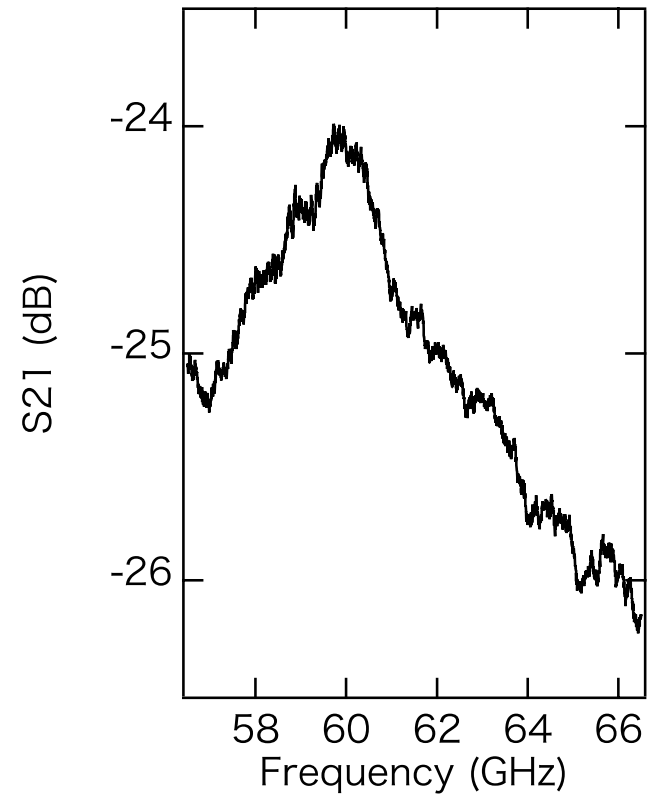
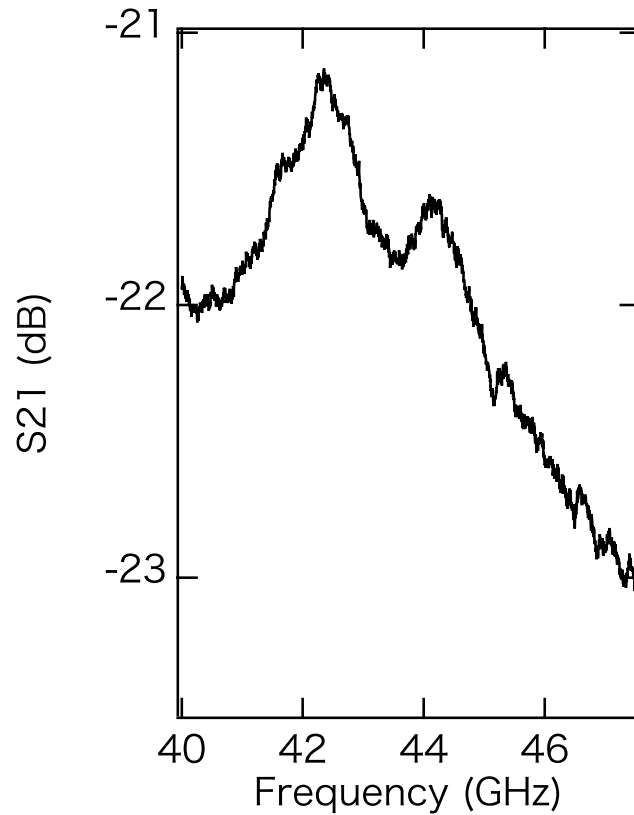
EDFA: Amonics Burst-mode EDFA (Sat. power 20 dBm, NF: < 5.5 dB)

Bandpass filter1: BW > 1 nm for generation of single sideband signal

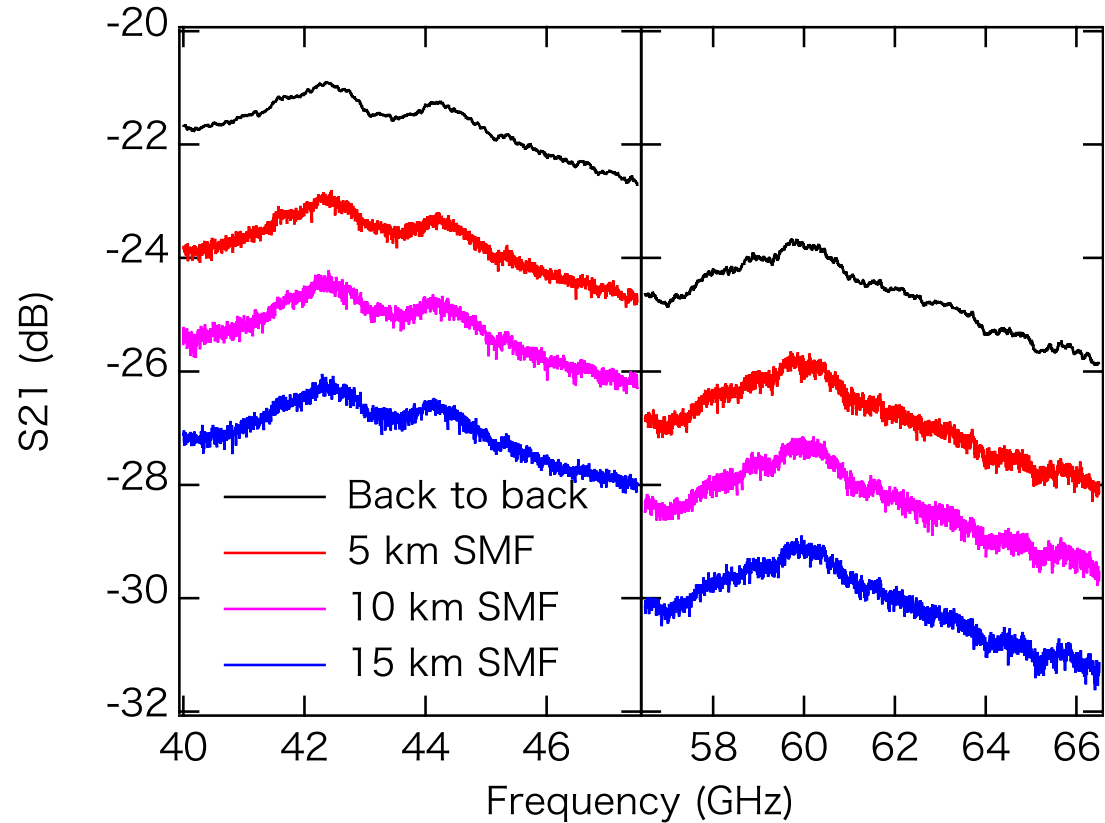
Bandpass filter2: BW ~ 1 nm for suppression of ASE noises from EDFA

Subcarrier Transmission of RoF Extension Link

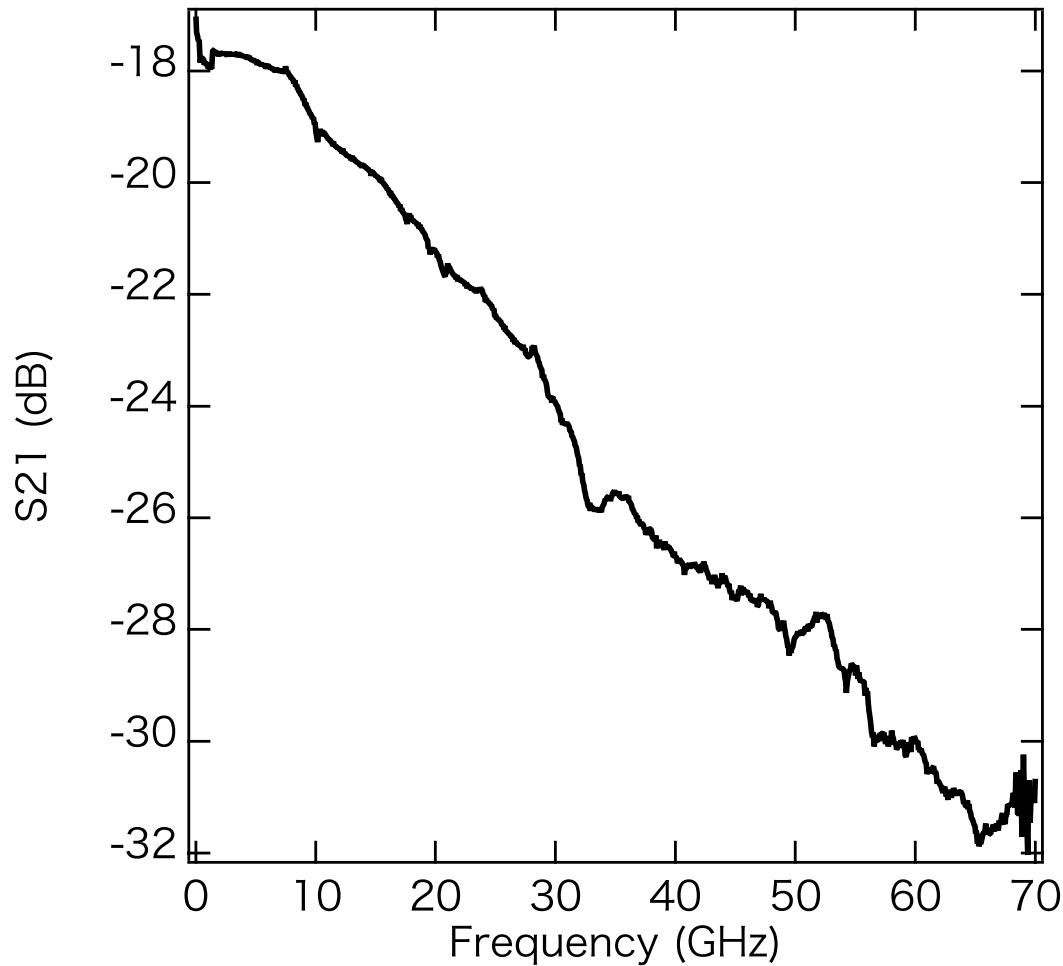




Amplitude Deviation: < 2 dBp-p at 40.5-47 GHz
~ 2 dBp-p at 57-66 GHz



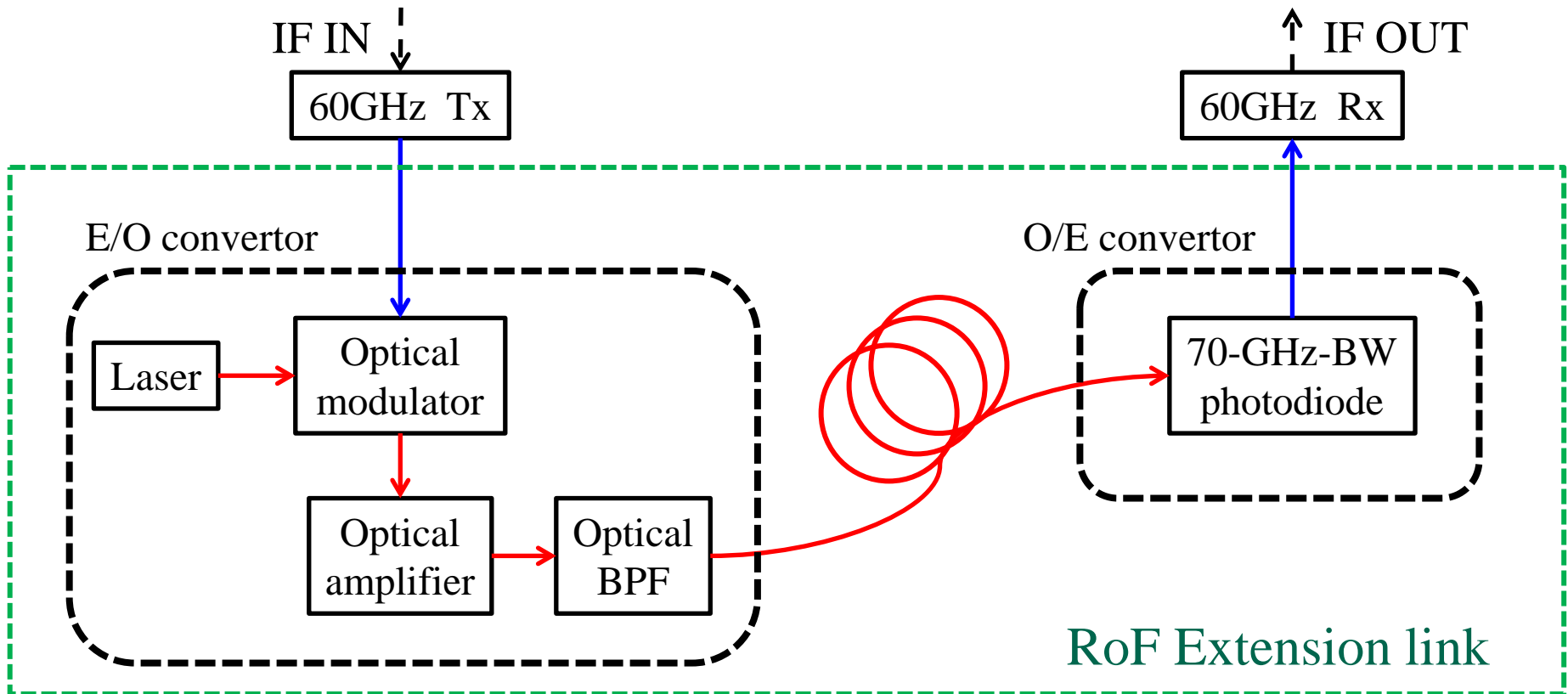
Frequency response of RoF link at 40-48 GHz and 56-67 GHz bands



Measured link loss:
~ -28 dB @ 40GHz
~ -31 dB @ 60GHz

Broadband frequency characteristics of RoF link

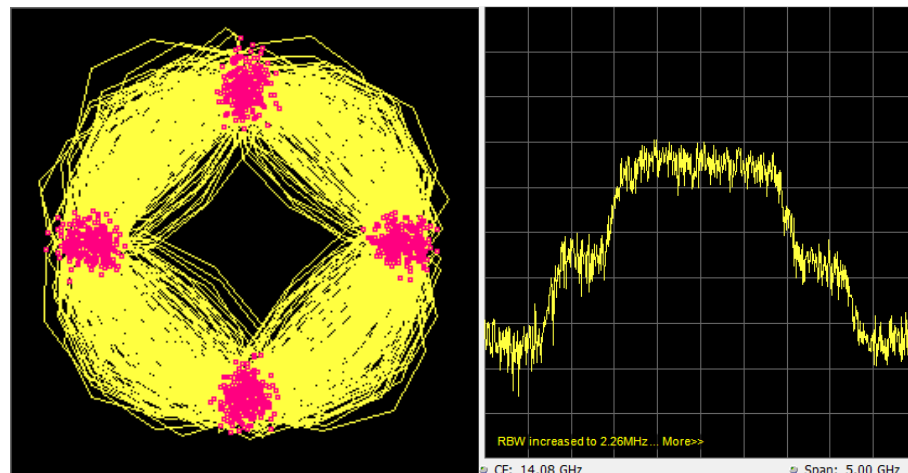
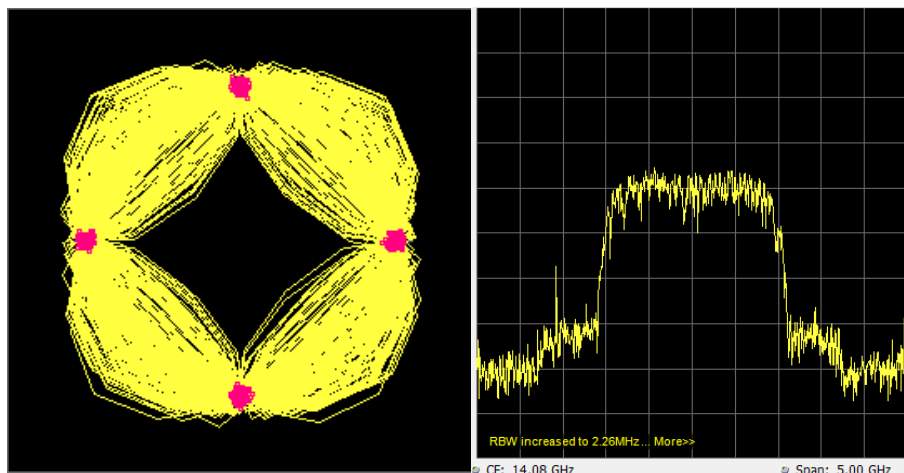
Blockdiagram of Single-Side-Band Signal Transmission Experiment of RoF Extension Link using IEEE802.11ad Signal



60-GHz $\pi/2$ -BPSK Signal Transmission Experimental Results (1)

RF Back to Back

180m RoF Extension link

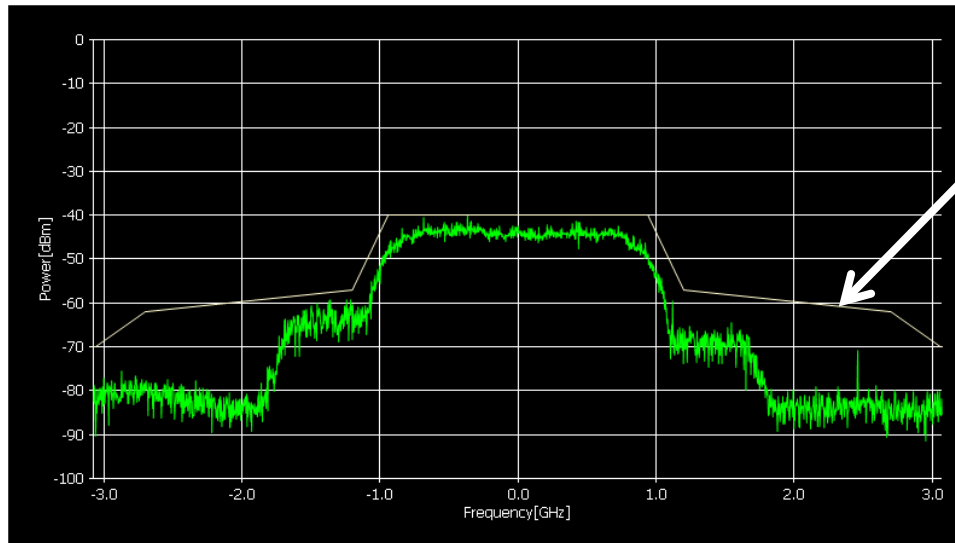


EVM: 3.3% (-29.6dB)

EVM: 12.7% %(-17.9dB)

60-GHz $\pi/2$ -BPSK Signal Transmission

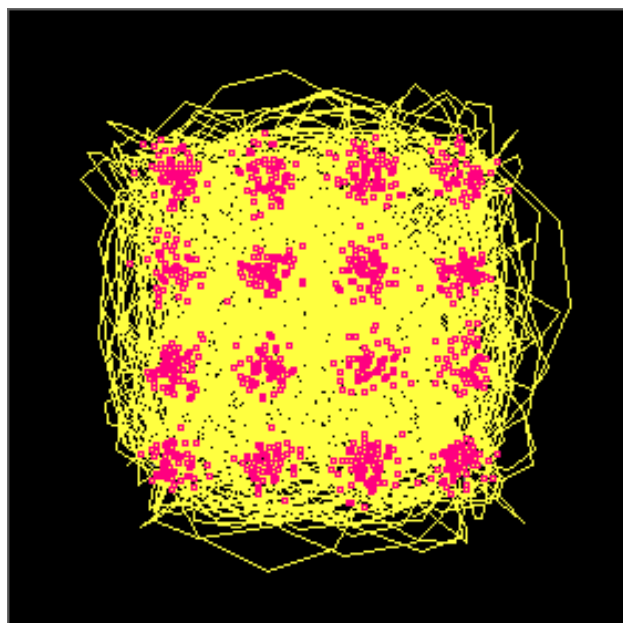
Experimental Results (2)



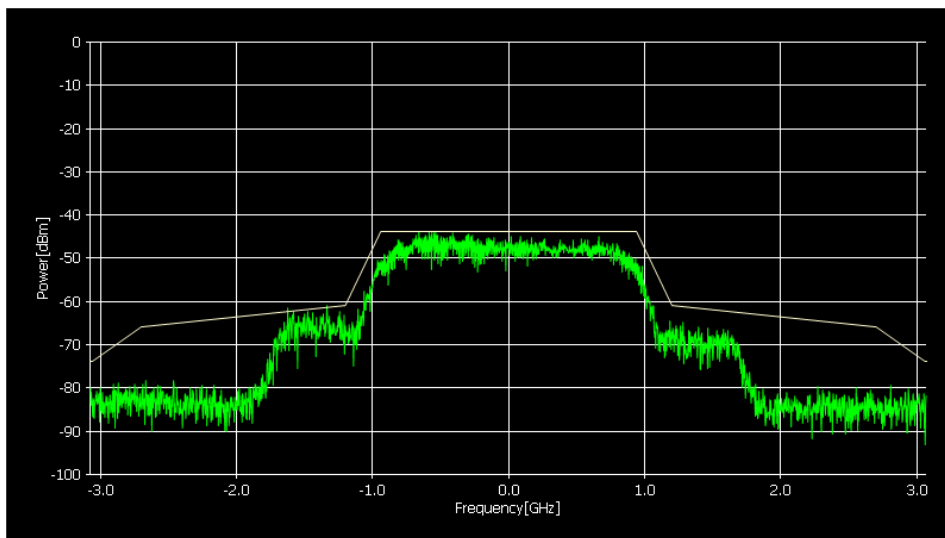
Required spectrum
mask at channel 4
of 802.11ad

Ch.4 ($f_c=64.80$ GHz)

60-GHz 16QAM Signal Transmission Experimental Results

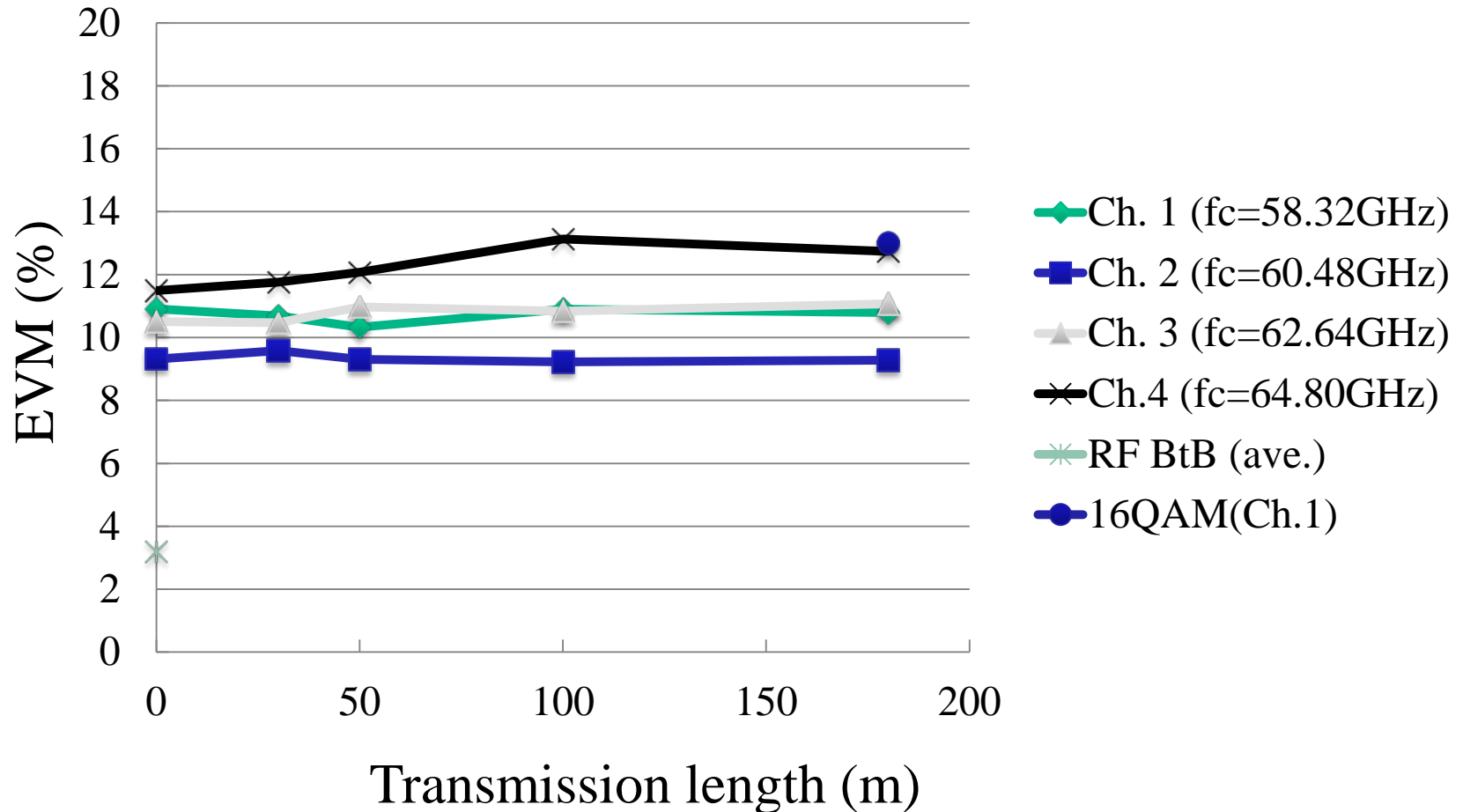


EVM : 14% (-17dB)

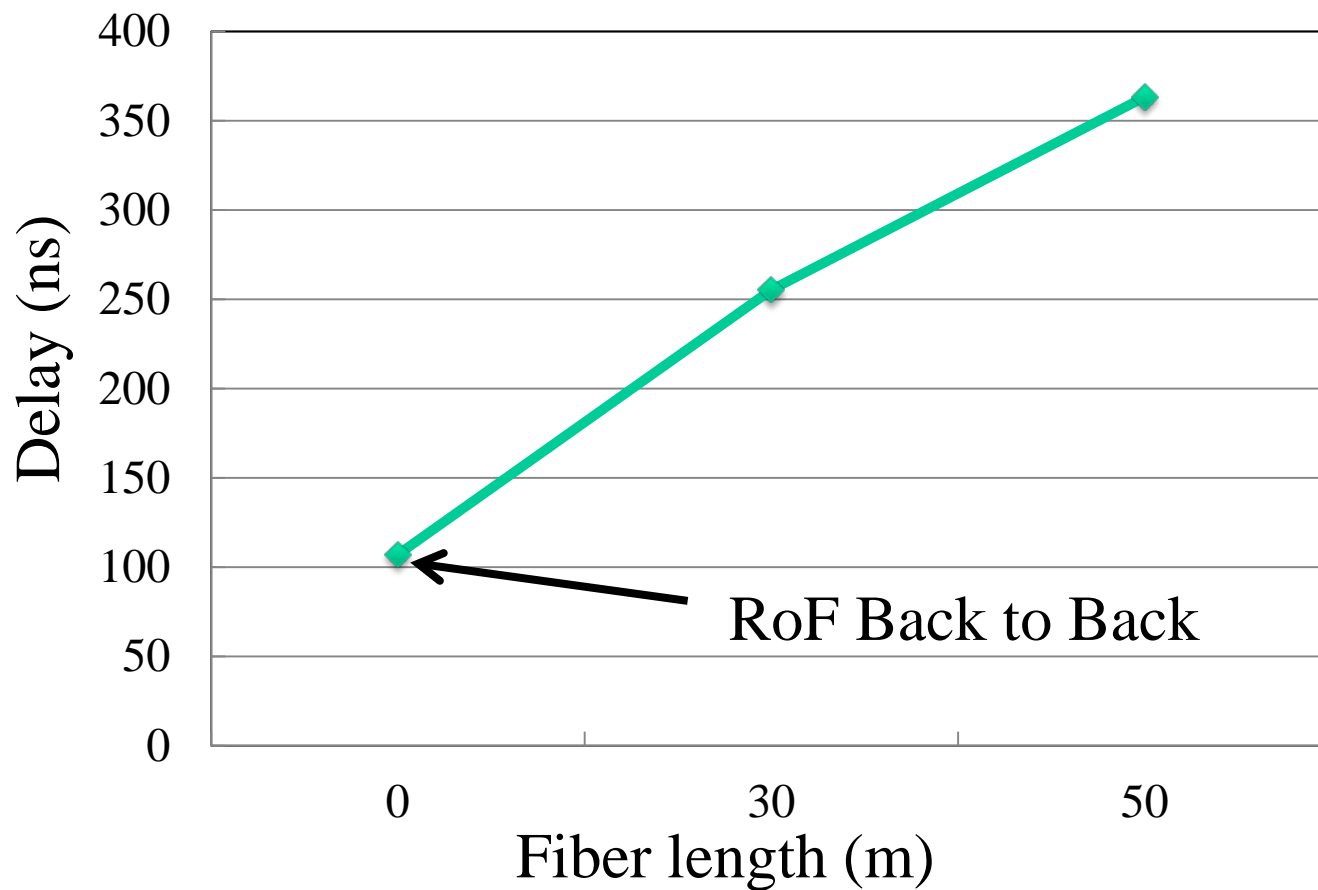


Ch.4 (fc=64.80 GHz)

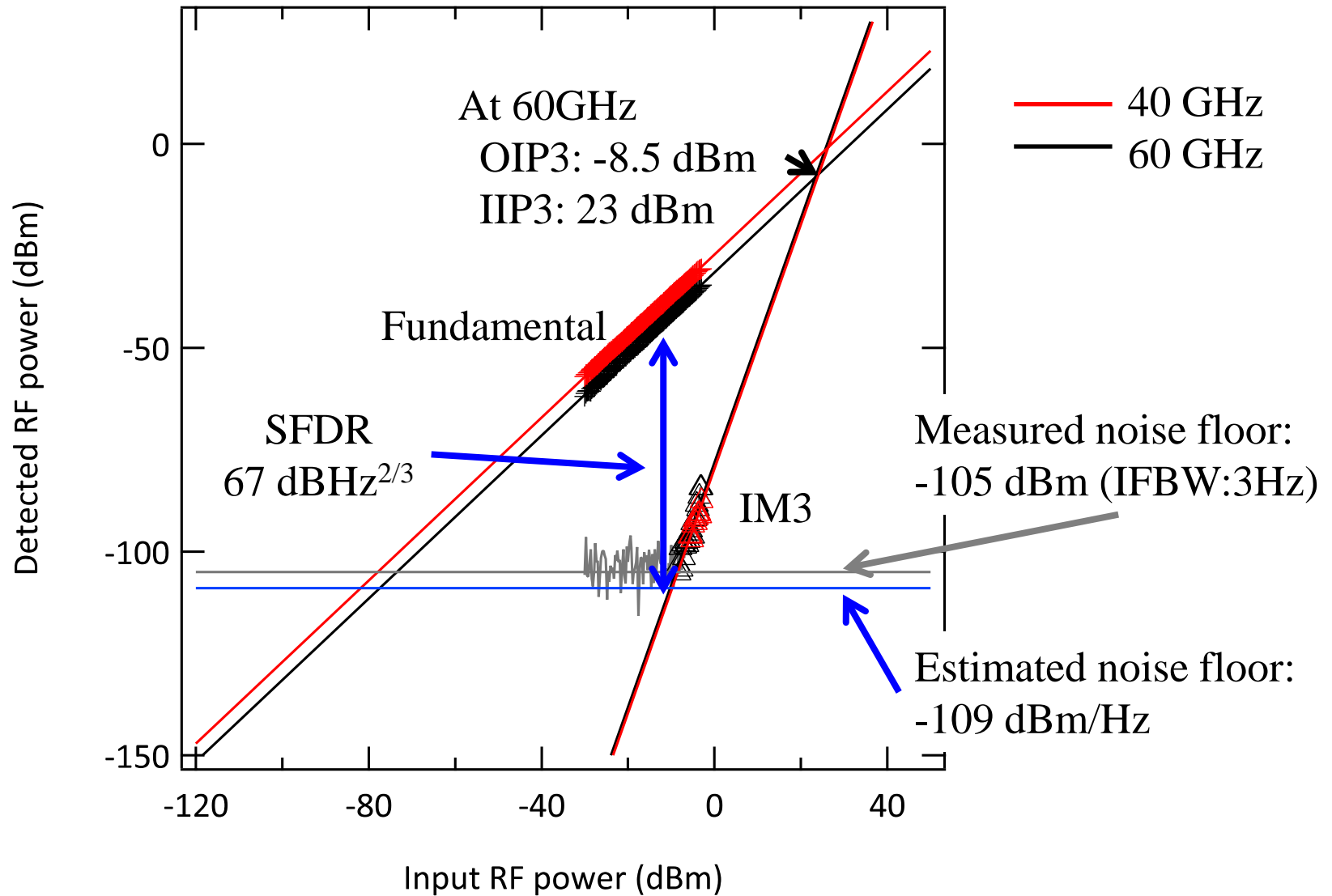
EVM (Error Vector Magnitude) vs. Fiber Length



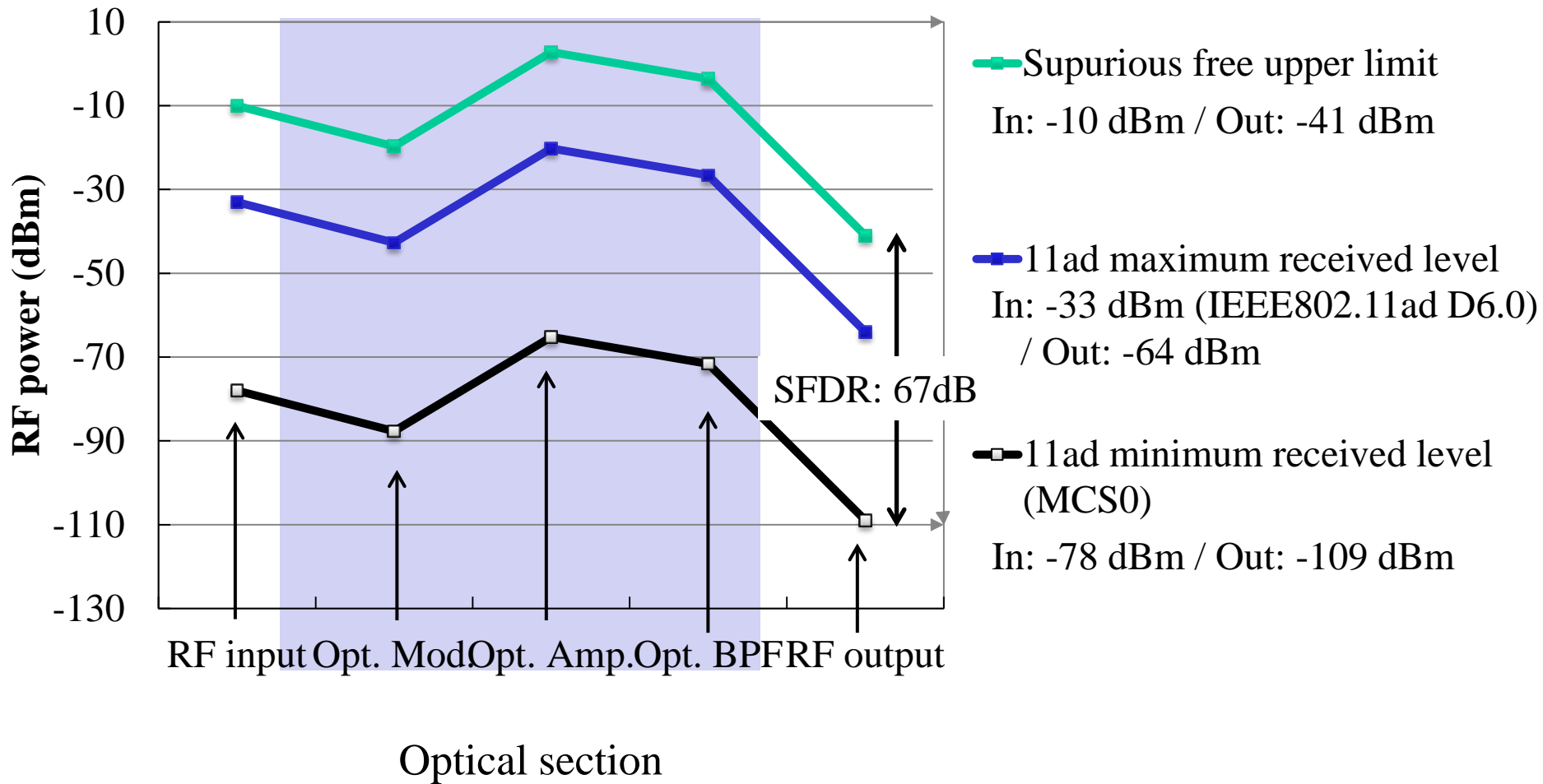
Delay Time of RoF Extension Link



Spurious Free Dynamic Range of RoF Extension Link

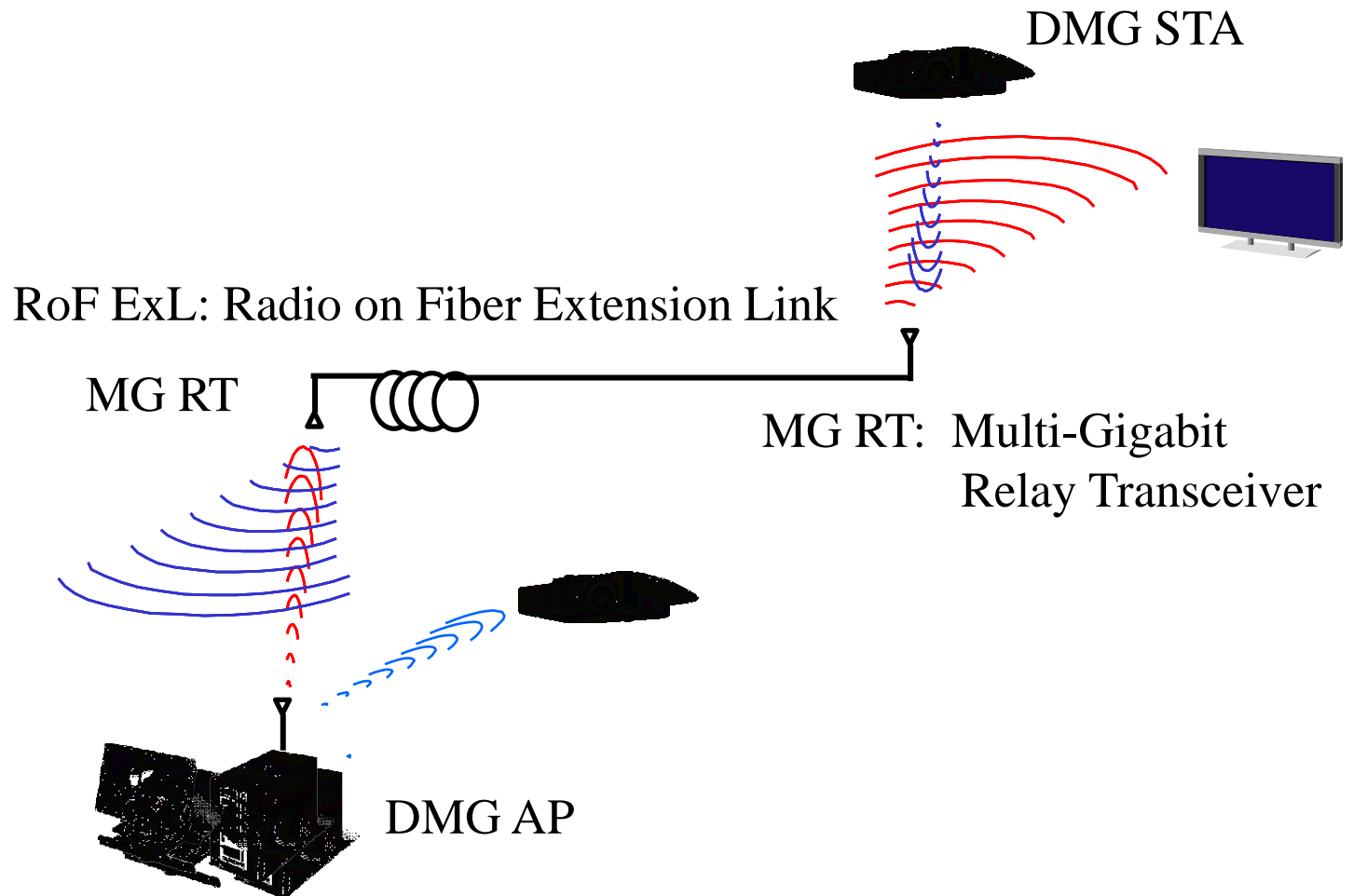


Level Diagram of RoF Extension Link



AP-MG RT-RoF ExL-MG RT-STA Uplink/Downlink

- No additional requirement for Beamforming Training -



Standards related to Indoor Use of Optical Fiber Cable

- IEC60793-2-40 Ed.4.0 Optical fibers – Part 40: Product specifications – Sectional specification for category A4 multimode fibers

Technical Paper published by Optoelectronic Industry and Technology Development Association (Japan)

- TP02/BW-2011 - Optical fiber distribution system for apartment houses in FTTH
- TP01/BW -2011 - Optical fiber distribution system for detached houses in FTTH
- OITDA/TP03/BW-2012 - Optical fiber distribution system for customer premises

Summary and Consideration

- RoF extension link backhaul was proposed for Category 4 (Backhaul)
- RoF extension link backhaul can extend wireless access area through optical fibre without additional requirements.
- Data transmission experiment of RoF extension link using 802.11ad signal were presented and EVM of transmitted signals are less 14 %.
- Additional delay time caused by RoF extension link is about 350 ns at a fibre cable length of 50 m.
- Maximum length of fibre cable is about 440 m which satisfies the maximum propagation delay time requirement of $4.5\mu\text{m}$ between STA and AP.
- Spurious free dynamic range of RoF extension link is $67\text{ dBHz}^{3/2}$, however, SFDR can be improved by connecting low noise amplifiers with the optical modulator.
- Required technical specification of RoF extension link which satisfies with all requirement to 801.11aj will be presented at the next meeting.

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