ITU-T Kaleidoscope 2009
Innovations for Digital Inclusion

RoFSO: A Universal Platform for Convergence of Fiber and Free-Space Optical Communication Networks

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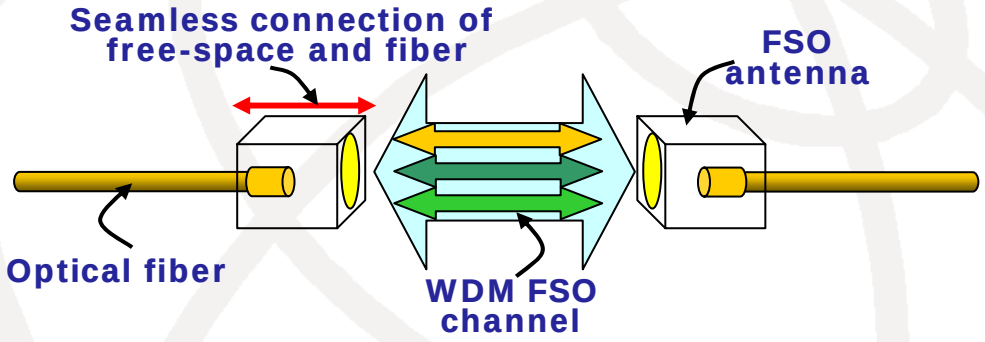
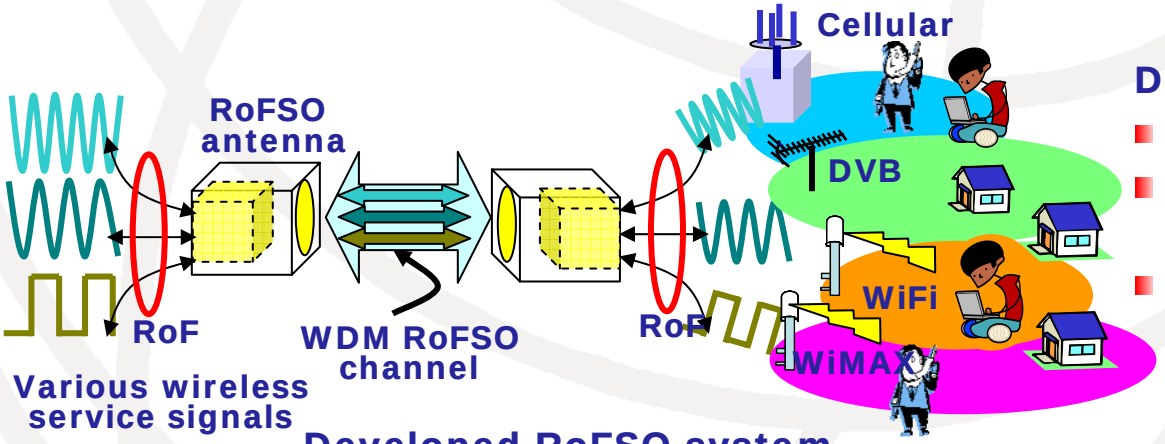
- Overview of FSO systems
- Proposed RoFSO system
- Performance evaluation of RoFSO system
  - Mobile cellular W-CDMA service
  - Wireless LAN service
- Conclusion

Overview of FSO systems

- **FSO**: Transmission of a modulated visible or infrared beam through the atmosphere to obtain broadband communication.
  - **Advs**: Secure, **easy to deploy**, **license free**, **high data rate**.
  - **Disadvs**: Influenced by weather and can not propagate through obstacles.



New generation FSO system



Developed RoFSO system

New generation FSO system

- Uses 1550nm wavelength
- Seamless connection of free-space and optical fiber.
- Multi gigabit per second data rates (using optical fiber technology)
- Compatibility with existing fiber infrastructure
- Protocol and data rate independent

Developed RoFSO system

- Uses 1550nm wavelength
- Transport multiple RF signals using WDM RoFSO channels
- Universal platform for providing heterogeneous wireless services e.g. WLAN, 3 GPP Cellular systems, terrestrial digital TV etc

Proposed RoFSO system 1

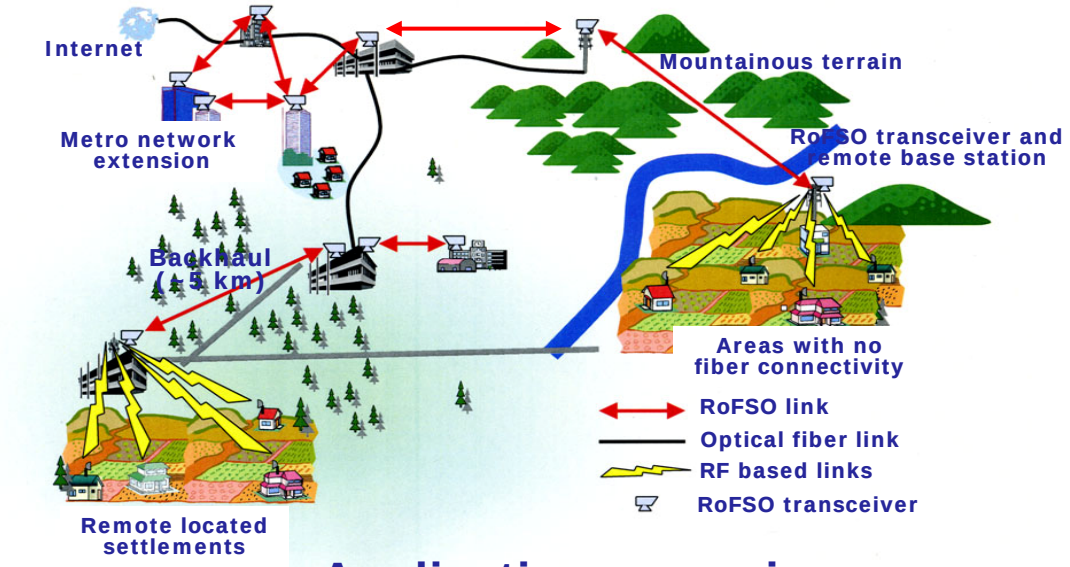
Features of Radio-on-FSO technology

RoFSO = FSO + RoF

- **RoF**: Technique of modulating RF subcarriers onto an optical carrier for distribution over fiber network.
  - **Advs**: Transmission of RF signals at **low costs**, **longer distance** and **low attenuation.**
  - **Disadvs**: Dependent on **availability of installed optical fiber**.

Application areas

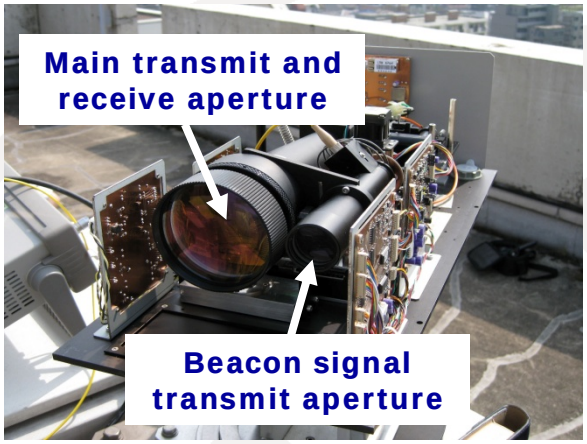
- Metro network extension
- Last mile access
- Enterprise connectivity
- Fiber backup
- Interconnectivity of distributed antenna systems



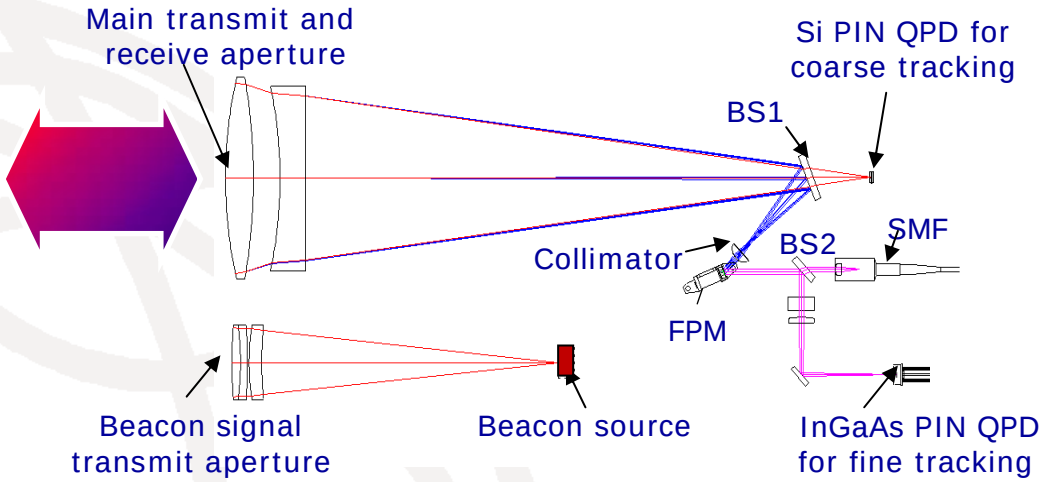
Application scenario

Proposed RoFSO system 2

RoFSO terminal



RoFSO antenna photo



RoFSO antenna optical path and devices layout

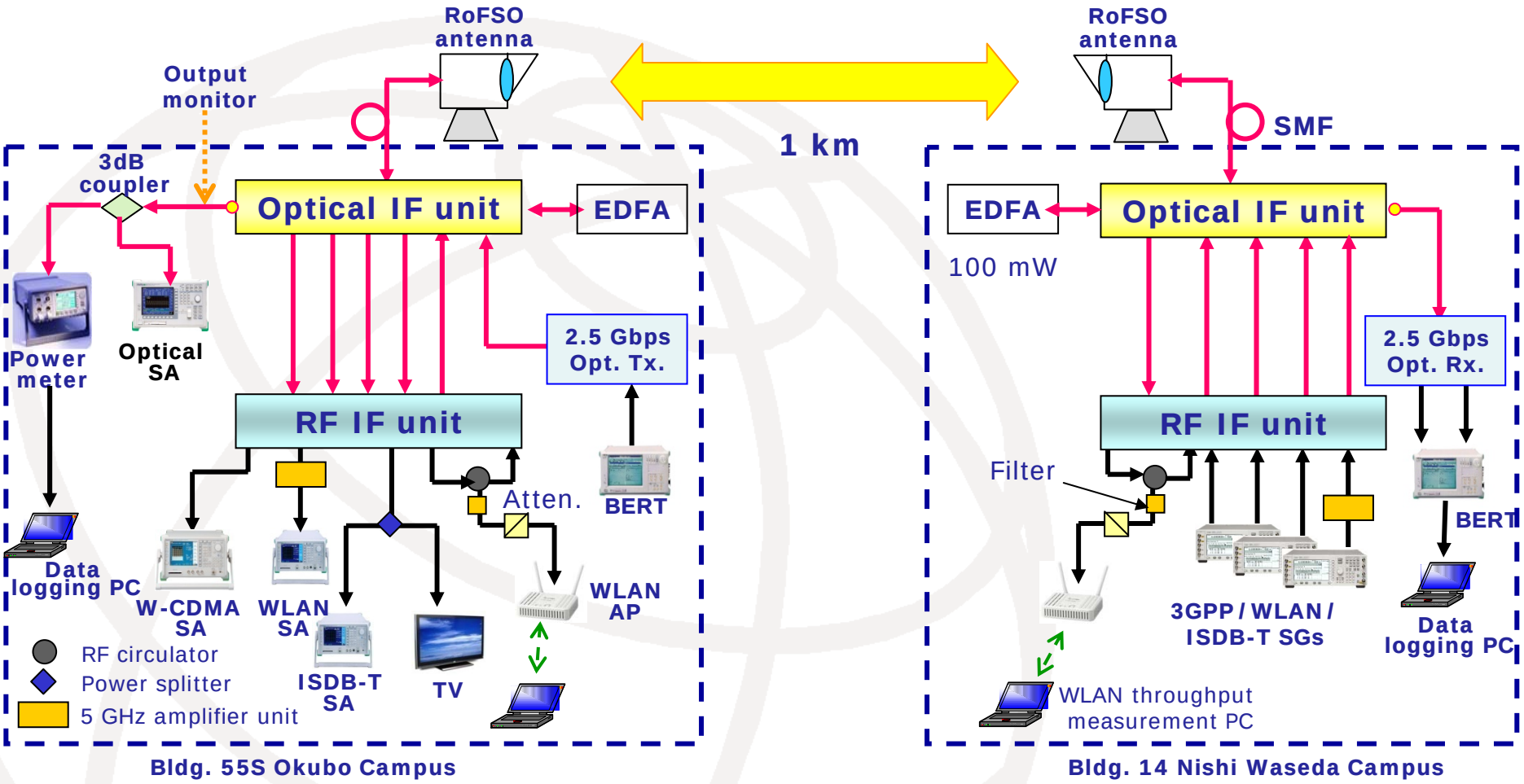
Specifications of the RoFSO antenna

Parameter	Specification
Operating wavelength band	1550 nm
Transmit power	100 mW (20 dBm)
Antenna aperture	80 mm
Coupling loss	5 dB
Beam divergence	± 47.3 μrad
Frequency range of operation	more than 5 GHz
Fiber coupling technique	Direct coupling using FPM
Tracking method	Automatic using QPD Rough: 850 nm; Fine: 1550 nm

Key features:

- **Optimized for transmission of RF signals** with frequency range of operation more than 5 GHz.
- Can **suppress most atmospheric turbulence induced effects** like scintillation, beam wander, AOA fluctuations which have significant impact on performance of RoFSO signal propagating through free-space.

Performance evaluation of RoFSO system 1

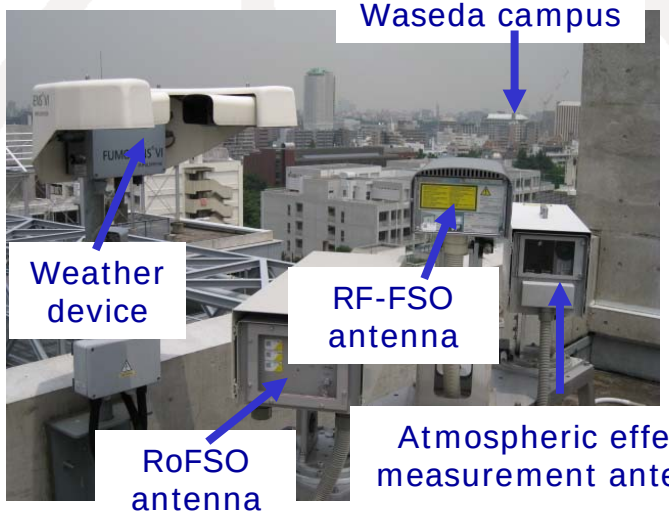


SA: Signal Analyzer
SG: Signal Generator

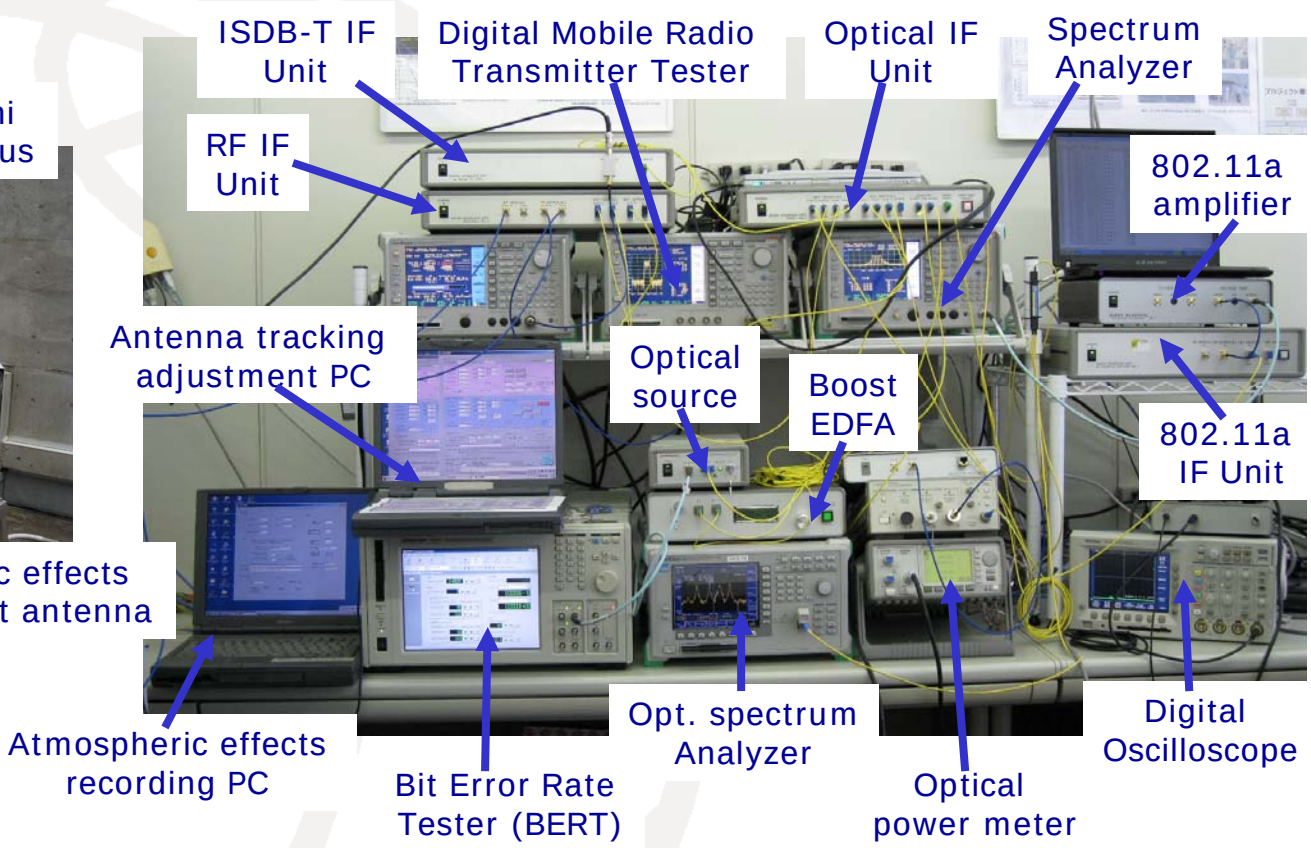
Experimental setup for evaluation of the RoFSO system.

Performance evaluation of RoFSO system 2

RoFSO system experiment devices



Devices setup on the rooftop

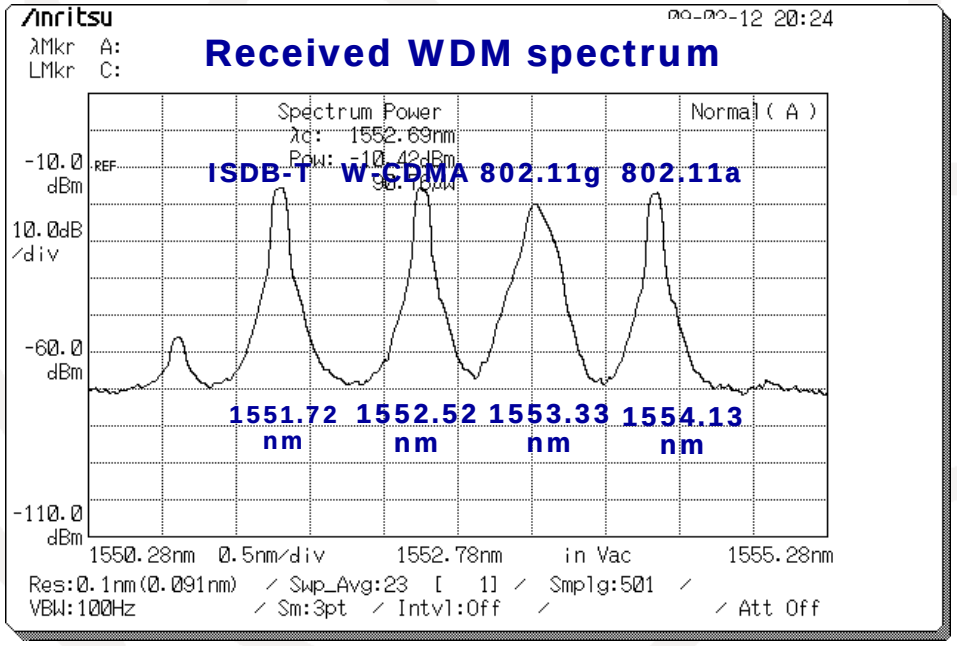


Devices setup in the laboratory

Performance evaluation of RoFSO system 3

Wireless signal wavelength assignment

	Channel #	Wavelength	Wireless service	Frequency
Downlink	29	1554.13 nm	WLAN IEEE 802.11a	5.2 GHz
	30	1553.33 nm	WLAN IEEE 802.11g	2.4 GHz
	31	1552.52 nm	Cellular W-CDMA	2 GHz
	32	1551.72 nm	ISDB-T*1	473 MHz
Uplink	33	1550.92 nm	Free*2	
	34	1550.12 nm	Cellular W-CDMA	2 GHz
	35	1549.32 nm	WLAN IEEE 802.11g	2.4 GHz
	36	1548.52 nm	WLAN IEEE 802.11a	5.2 GHz



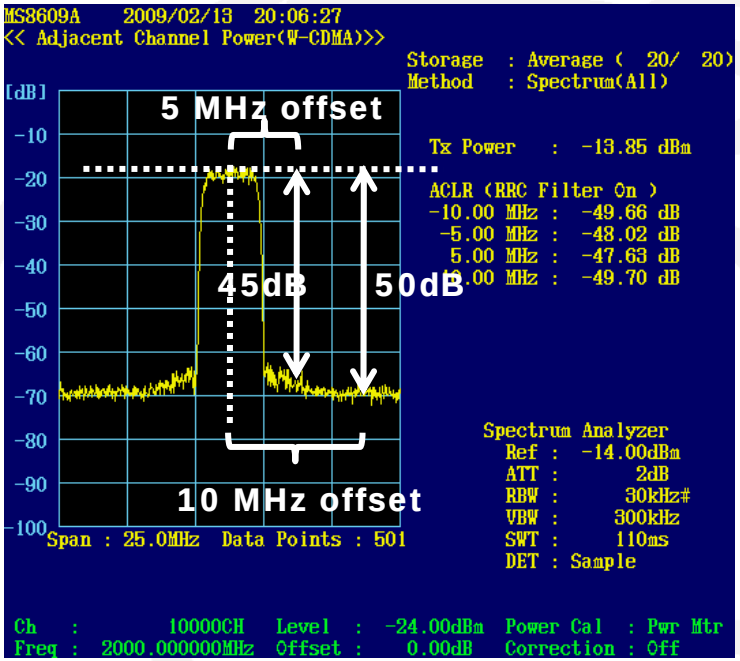
Note:

*1**ISDB-T**: **I**ntegrated **S**ervices **D**igital **B**roadcasting – **T**errestrial is Japanese standard for digital television (DTV).

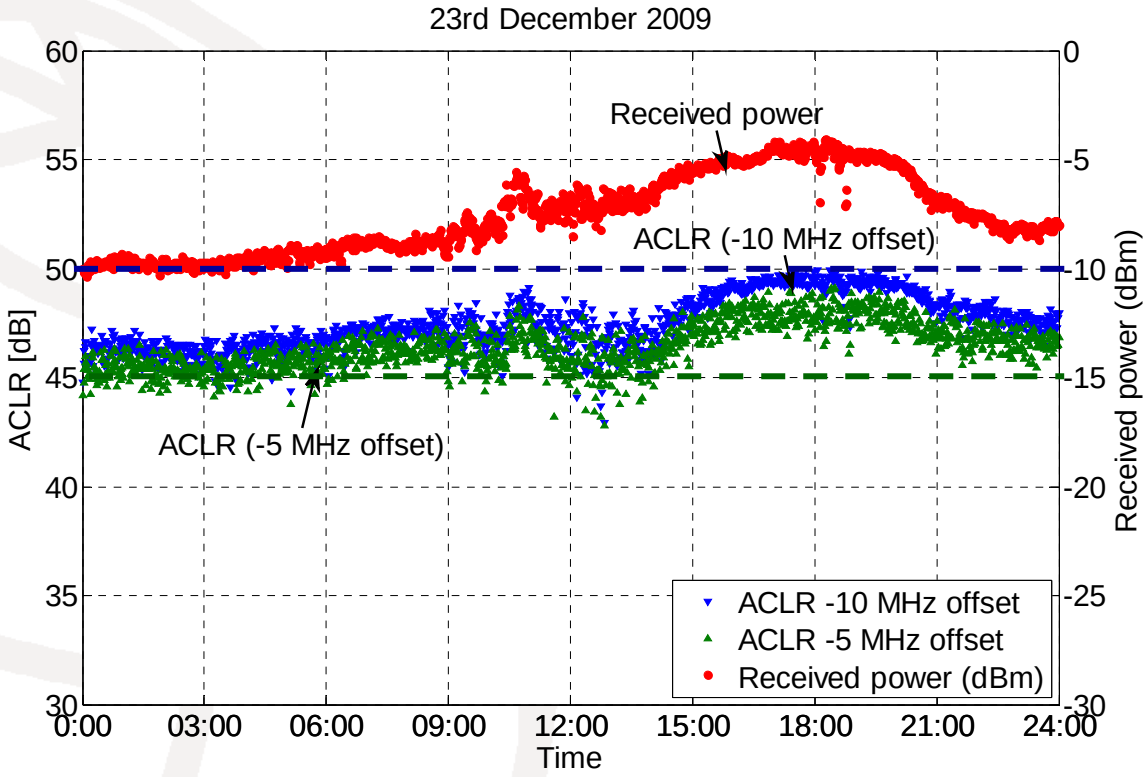
*2 Channel 33 is used for evaluating the RoFSO system performance in terms of BER by transmitting digital signal at 2.5 Gbps.

Performance evaluation of RoFSO system 4

Mobile cellular W-CDMA service



Received W-CDMA signal ACLR spectrum (3GPP Test Signal)

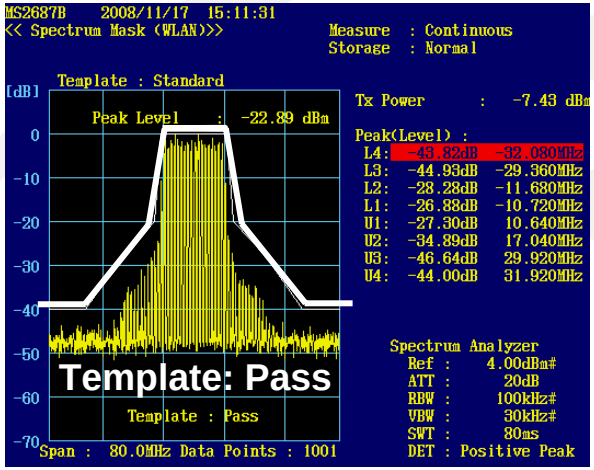


ACLR and received optical power characteristics

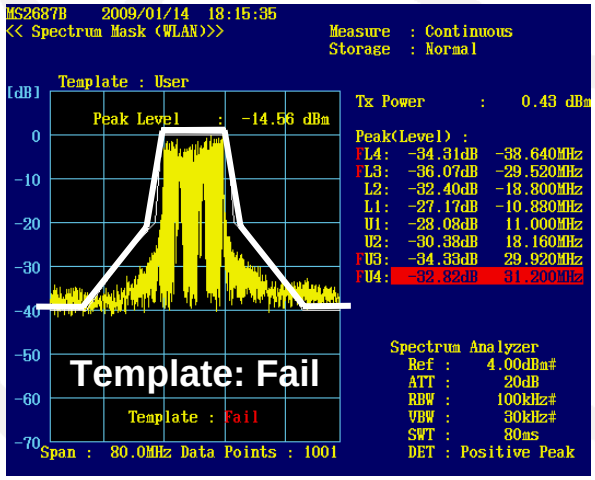
- **ACLR** is a quality metric parameter specified by the 3GPP for evaluating W-CDMA signal transmission.
- 3GPP specifies ACLR value of 45 dB at 5 MHz offset and 50 dB at 10 MHz offset.
  ACLR: Adjacent Channel Leakage Ratio

Performance evaluation of RoFSO system 5

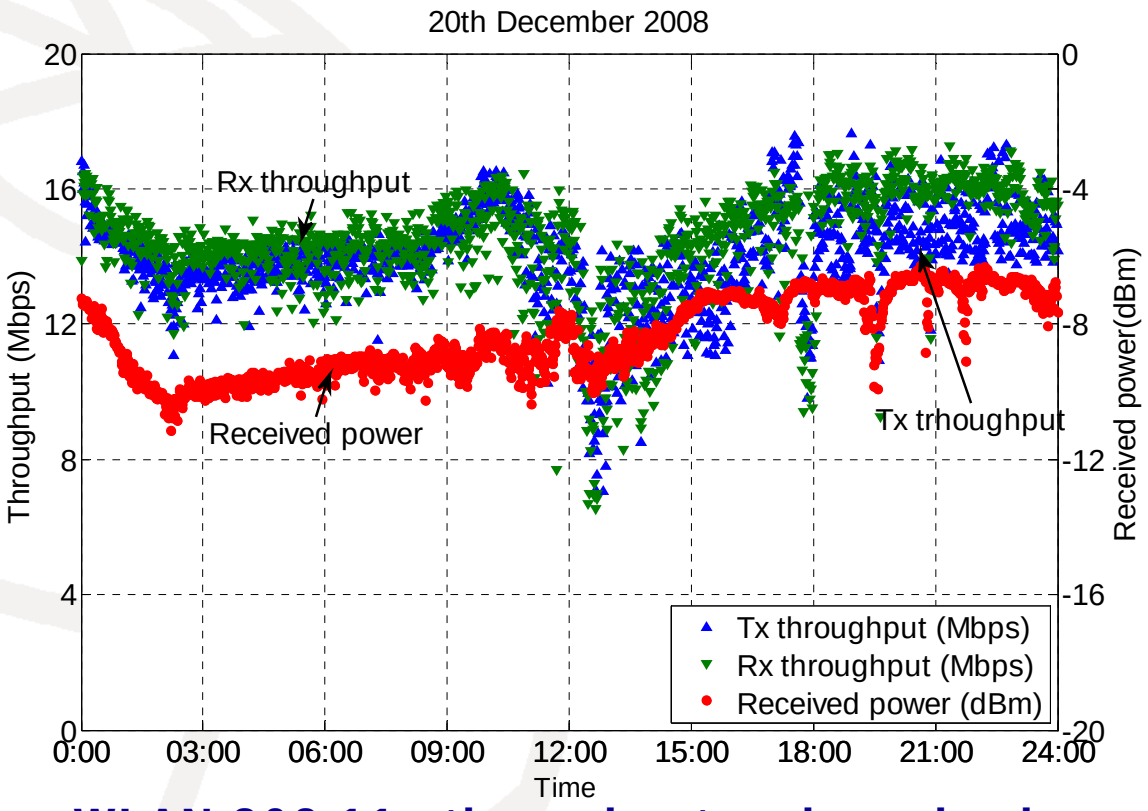
Wireless LAN service



WLAN 802.11g spectrum mask 2.4 GHz with 54 Mbps, 64 QAM



WLAN 802.11a spectrum mask 5 GHz with 54 Mbps, 64 QAM



WLAN 802.11g throughput and received optical power characteristics

Conclusion

- Presented a new **innovative broadband wireless communication** system based on **RoFSO suitable for application as universal platform for providing convergence of fiber and free-space**.
- Transmission performance evaluation of the proposed RoFSO system has **demonstrated consistent performance in terms of specified quality metric parameters for the various wireless service signals** in the **absence of severe weather conditions** and using **properly design interface units**.
- Confirmed that the technology is well suited for **deployment as an advanced wireless communication system in the emerging NGN** having potential to play a key role in Digital Inclusion.
- For **rapid maturity and adaptation of the technology**, early **initiatives for standardization** studies will be beneficial.
- Future work involves further experiments with **redesigned interface units** and in different weather conditions to derive data for the **system design optimization and performance enhancement**.

Supported by

NiCT

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Thank you for your attention!

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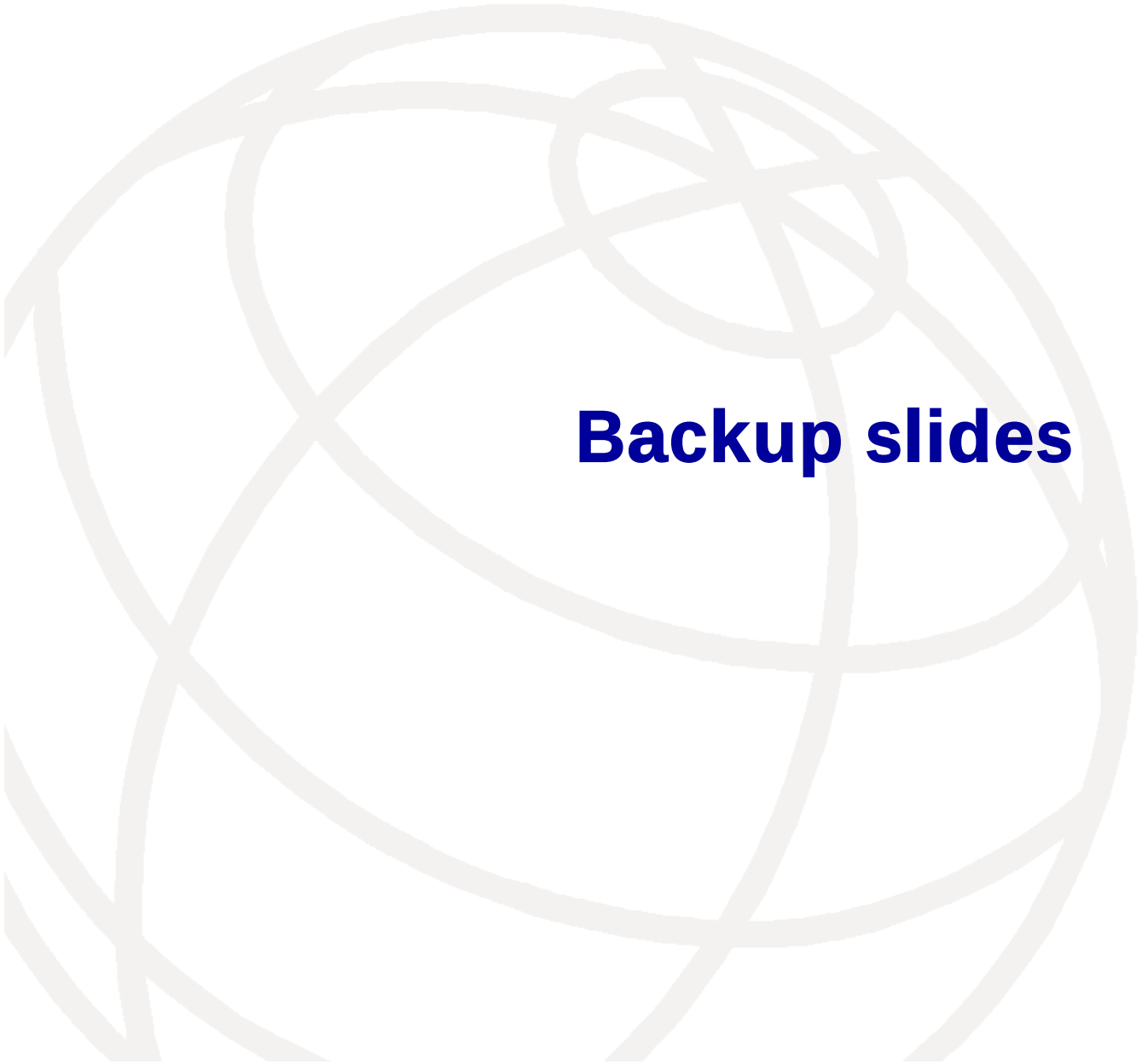
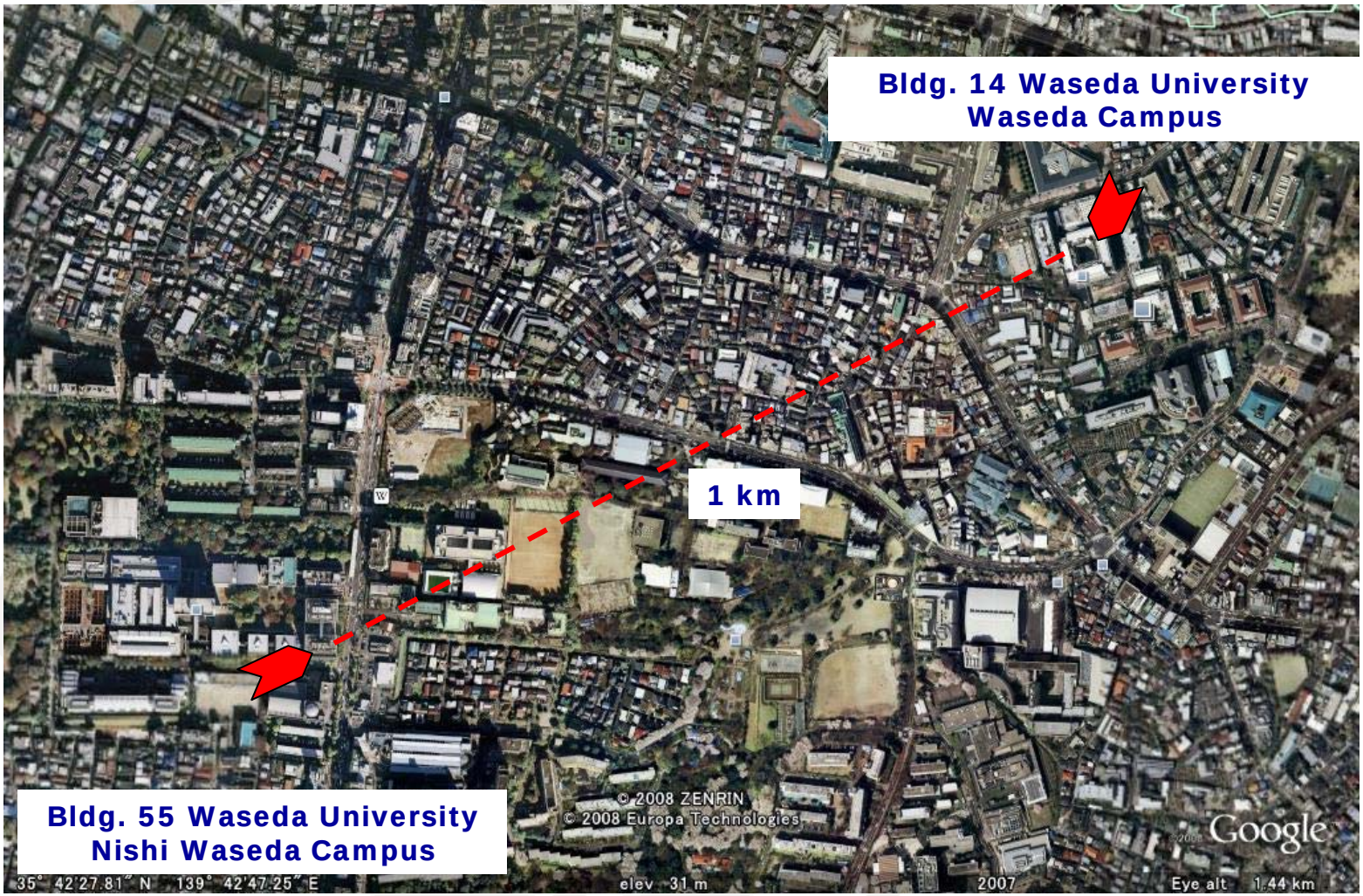


Backup slides

Performance evaluation of RoFSO system

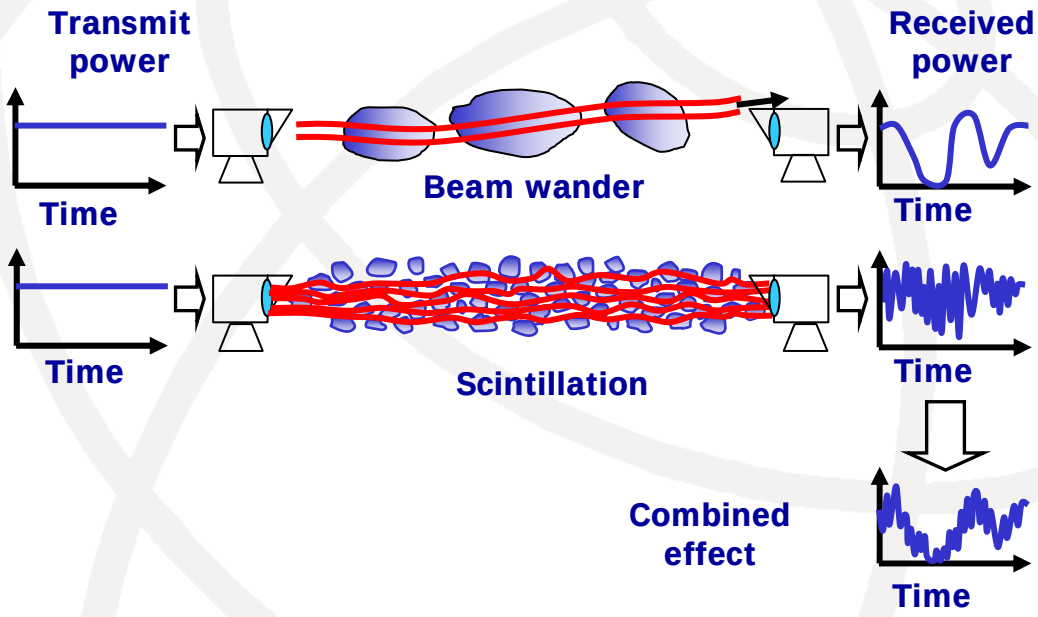
Experimental field



Satellite view of the test area Source: Google earth

Overview of FSO systems

Atmospheric turbulence has a significant impact on the quality of the optical wireless beam propagating through the atmosphere.



Reduces the optical beam power at the receiver point and causes burst errors

Other effects include

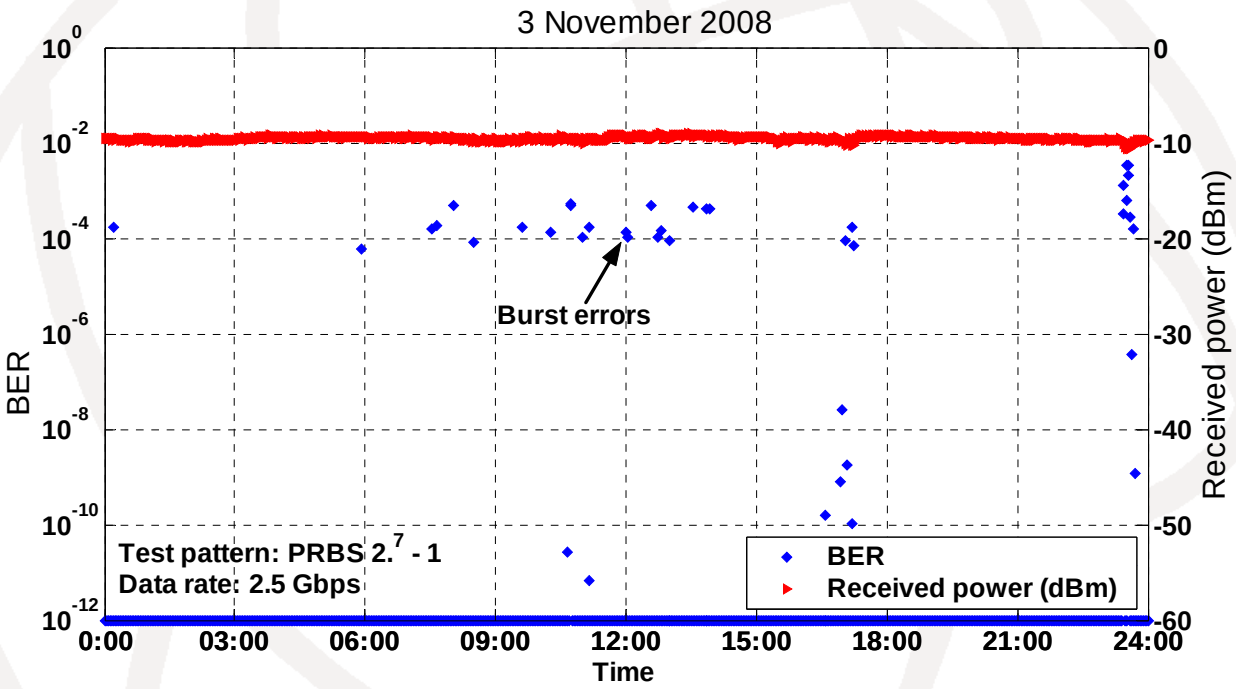
- Beam broadening and
- Angle-of-arrival fluctuations

Mitigation techniques include:

- Aperture averaging
- Diversity techniques
- Adaptive optics
- Coding techniques
- Fast tracking technique

Performance evaluation of RoFSO system

Digital signal transmission



Received signal BER and received optical power characteristics.

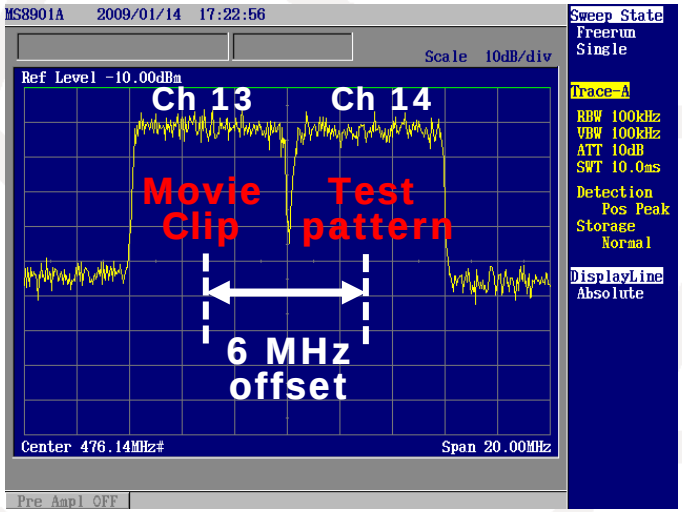
- Continuous error free transmission BER of 10^{-12}.
- Stable optical received power average –10 dBm.
- Receiver sensitivity –27 dBm.
- Occasional bursts errors are recorded due to insufficient tracking dynamic range

Performance evaluation of RoFSO system

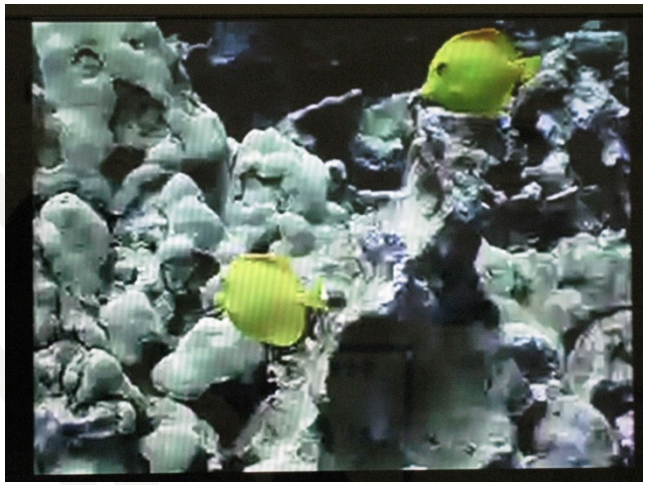
Terrestrial digital TV broadcasting service

ISDB-T Transmission parameters.

Parameter	Value	
Mode	3	
Guard interval	1/8	
Layer	A	B
Number of segments	1	12
Modulation scheme	16 QAM	64 QAM
Convolution code rate	1/2	7/8
Time interleaving	0	1
Required CNR (dB)	11.5	22.2



Received ISDB-T signal spectrum

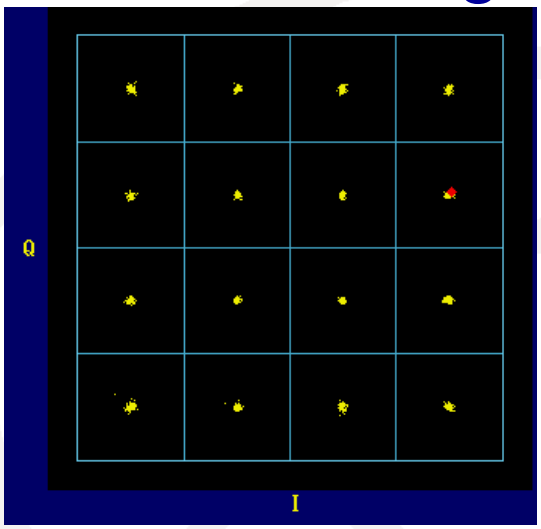


Layer A 1seg video

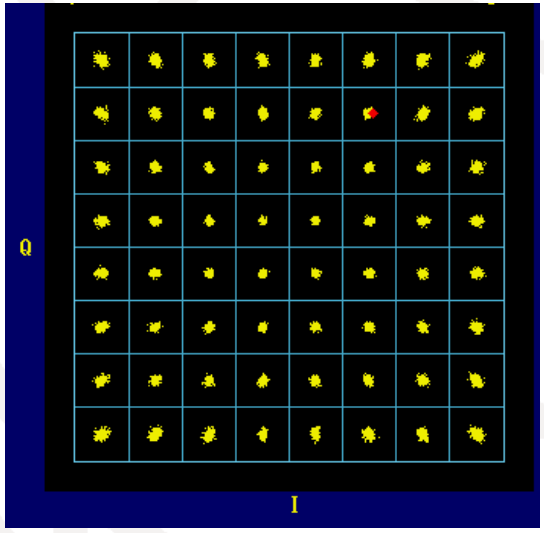
Layer B 12-segment video

Performance evaluation of RoFSO system

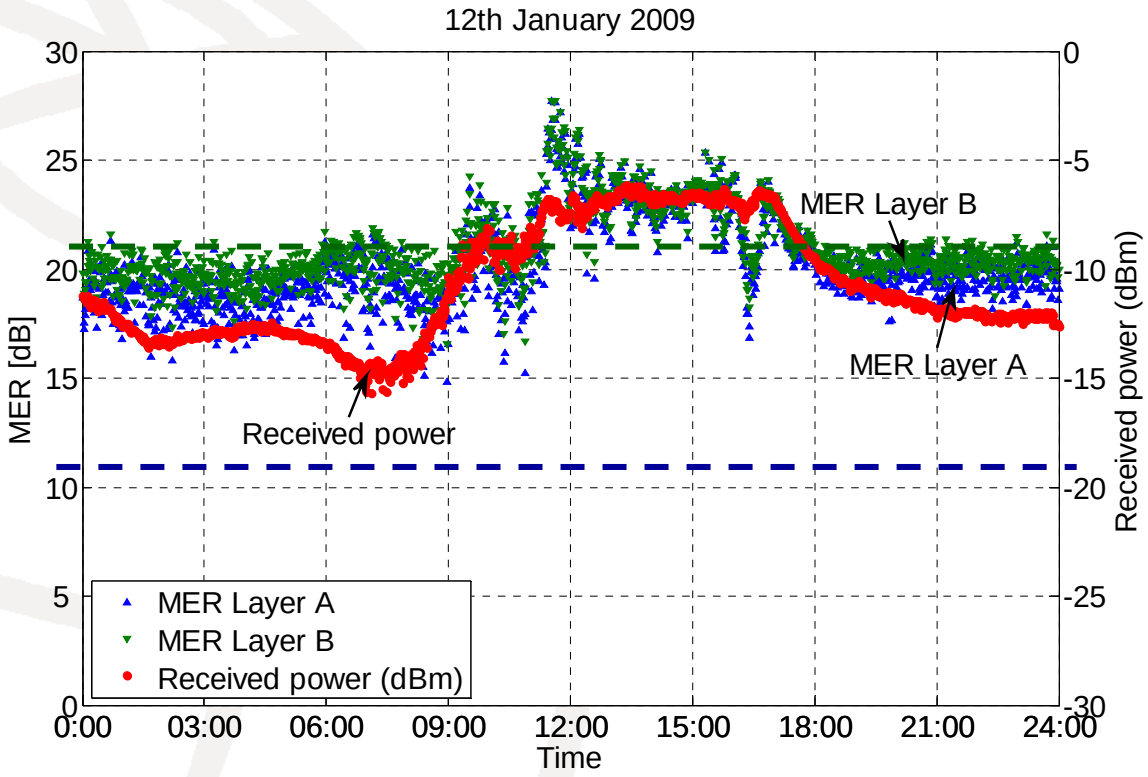
Terrestrial digital TV broadcasting service



Layer A – 1 seg (16QAM)



Layer B – 12 segnment (64QAM)



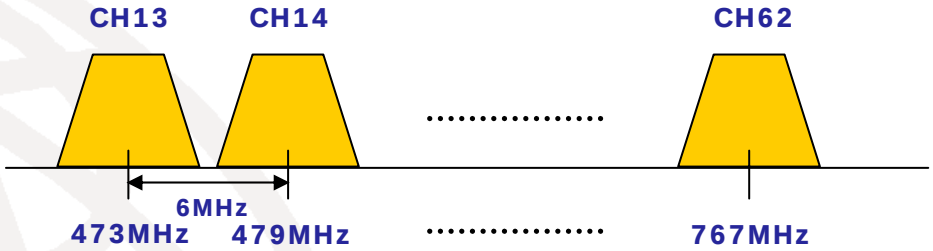
ISDB-T MER and received optical power characteristics.

Standard specifies a minimum required MER values for Layer A to be 11.5 and Layer B to be 11.5 dB and 22.2 dB.

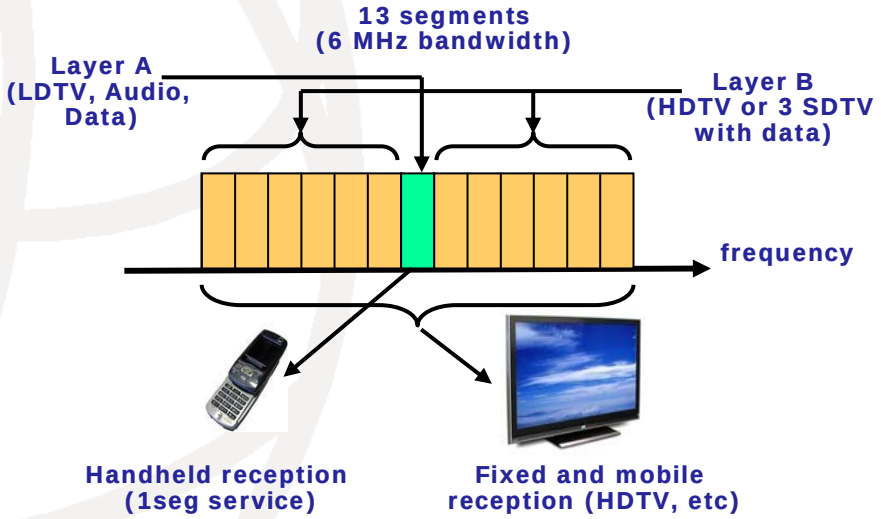
Introduction 1

Features of ISDB-T

- ISDB-T is one of **international standard for terrestrial digital television broadcasting format** developed and adopted in Japan.
- Provides reliable **high-quality video, audio and data broadcasting** for both fixed and mobile receivers.
- Operates in the **UHF band** at frequencies between **470 MHz and 770 MHz**, with total bandwidth of **300 MHz** divided into 50 channels.
- Each channel is further divided into **13 OFDM segments** which includes a single segment (Layer A) for mobile receivers and remainder 12 segments (Layer B) for HDTV.
- Started in Japan at the end of 2003 with complete switchover planned in July 2011.
- For complete national coverage various delivery systems will be required and are under consideration.



ISDB-T frequency band



ISDB-T channel segments and services