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DSL Technology

2nd European Next Generation Access Network Forum, FTTx

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Fraunhofer Institute for Communication Systems ESK
in Munich

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Contents

- DSL History
- DSL Technology and Performances
- VDSL2
- Spectral Compatibility
- Dynamic Spectrum Management
- VDSL2 In-house Transmission
- Power Consumption
- Summary and Outlook

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Latest DSL News

Copper-PON proposed by Prof. J.M. Cioffi

- CuPON announces
  - Total data rates of up to 100 Gbps over a 200-pair binder
  - Line rates of up to 500 Mbps on lines of up to 400 m
- Data rate improvement will be reached by single-wire transmission
  - Exploitation of 2n wires of a binder with n DSL lines (n wire pairs)
  - Shield or one wire serves as a reference for many sources
- Canceling of common mode crosstalk by vectoring

Reference: J.M. Cioffi, S. Jagannathan, M. Mohseni, G. Ginis, CuPON: The Copper Alternative to PON 100 Gb/s DSL Networks, IEEE Communications Magazine, Vol. 45, Issue: 6, pp. 132-139, June 2007.

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DSL History

History

- Law of physics for broadband transmission over copper lines was formed by Shannon in 1940 (Shannon limit)
- Signal processing for Multicarrier Modulation was developed in the 70s and 80s
- Development of powerful DSPs allows world wide propagation of DSL systems in early 90s
- Today DSL is one of the most important technologies for broadband access
- Upper limit of transmission capacity has not been reached

Digital Subscriber Line (DSL)

- DSL provides the transmission of digital information over telephone loops initially only designed to carry POTS signals
- Digital wideband signals will be placed above analog POTS signals (and ISDN)
- Advantage: High-bit-rate transmission over existing network

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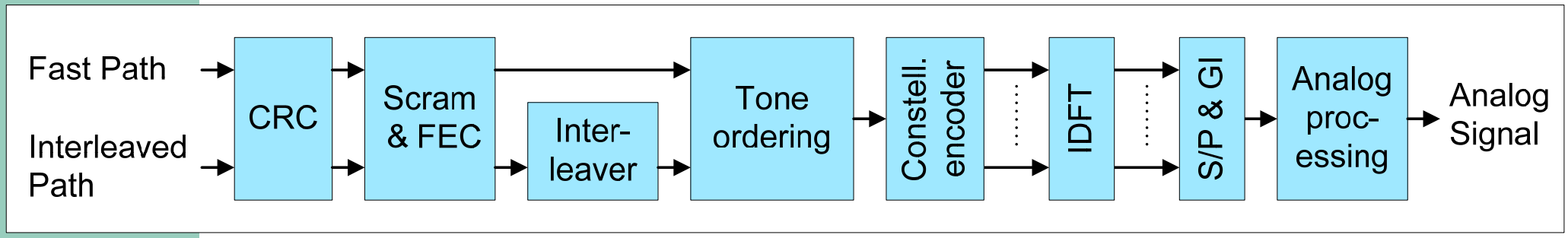
DSL Transmitter

Components

- Devices for error detection and correction, modulation, …
- Receiver performs opposite operations, additionally including synchronization and equalization



Discrete Multi Tone (DMT)

- Sub-carrier frequencies are modulated by QAM
- Frequency multiplexing (FDM) enabled by IDFT
- Sub-carrier frequencies are orthogonal to each other (Orthogonal Frequency Division Multiplexing, OFDM)

DSL Technologies

Asymmetric DSL

- Full duplex transmission with asymmetrical data rates for US and DS direction
- Reducing NEXT between DSL systems by spectral separation of US and DS
- Broadband access for private clients
- ADSL, ADSL2, ADSL2+, VDSL2

Symmetric DSL

- Full duplex transmission with symmetrical data rates for UP and DS direction
- Date transmission for business clients
- SHDSL (SDSL)

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DSL Performances

Family	ITU	Ratified	Maximum speed
ADSL	G.992.1	1999	DS/US: 7Mbps/0,8Mbps
ADSL2	G.992.3	2002	DS/US: 8Mbps/1Mbps
ADSL2-RE	G.992.3	2003	DS/US: 8Mbps/1Mbps
ADSL2+	G.992.5	2003	DS/US: 24Mbps/1Mbps
SHDSL	G.991.2	2003	DS/US: 5,6Mbps
VDSL	G.993.1	2004	DS/US: 55Mbps/15Mbps
VDSL2 (12 MHz, long reach)	G.993.2	2005	DS/US: 55Mbps/30Mbps
VDSL2 (30MHz, short reach)	G.993.2	2005	DS/US: 100Mbps/100Mbps

Reference: DSL-Forum

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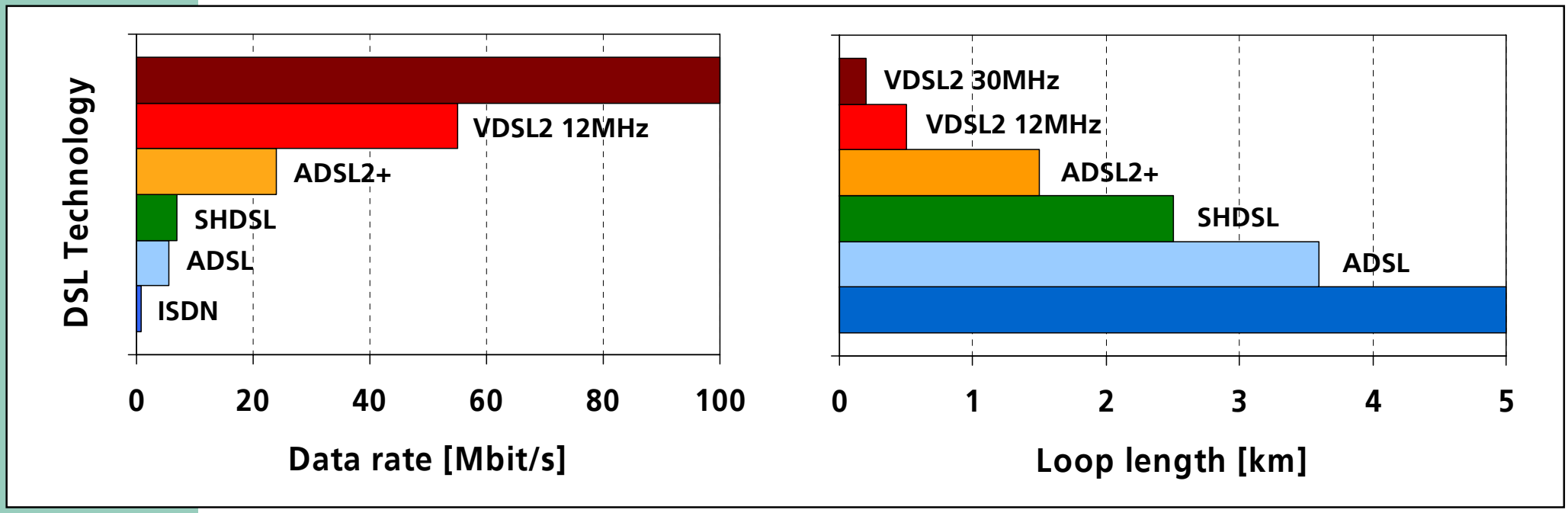
DSL Performances

Dependency on date rate, reach and technology

- Higher date rates result from higher frequency ranges used for transmission
- Higher frequency requires shorter loop lengths



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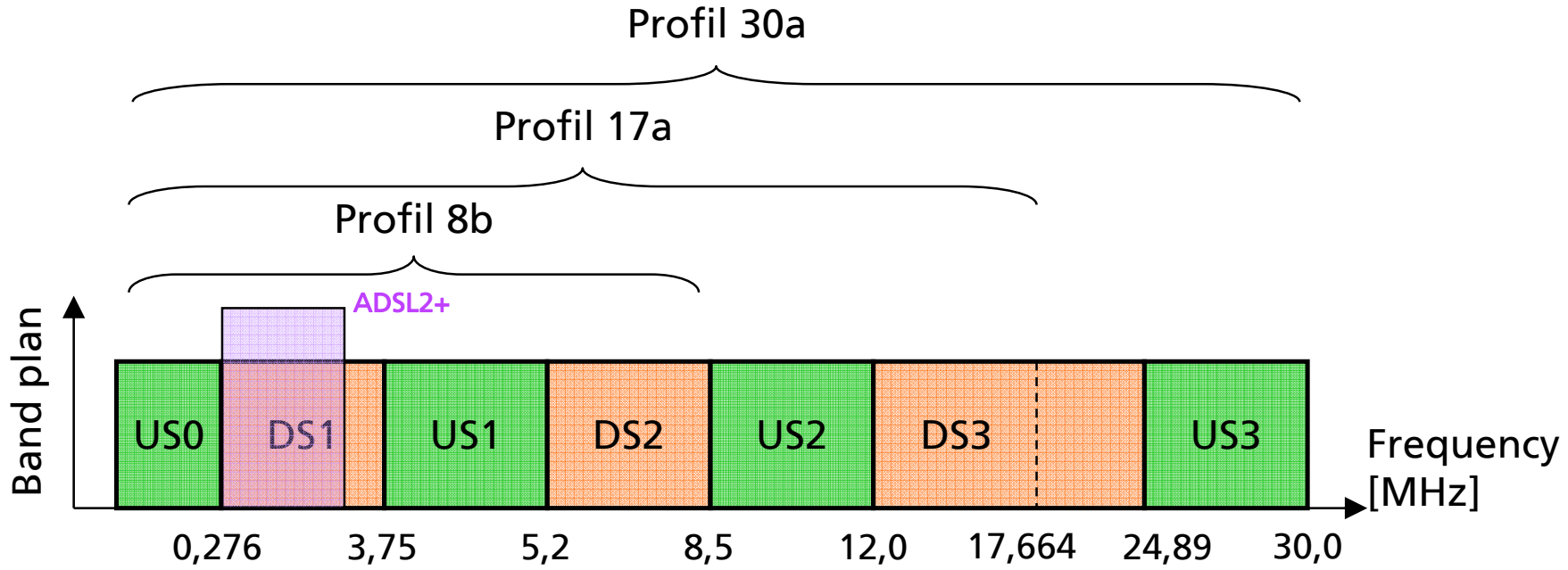
VDSL2 Spectrum

Profiles

- VDSL2 allows the use of higher frequency ranges for short transmission lines
- Frequency range is divided into different sub-bands for US and DS transmission
- Optional use of US0 band



- Profile design for different VDSL2 scenarios

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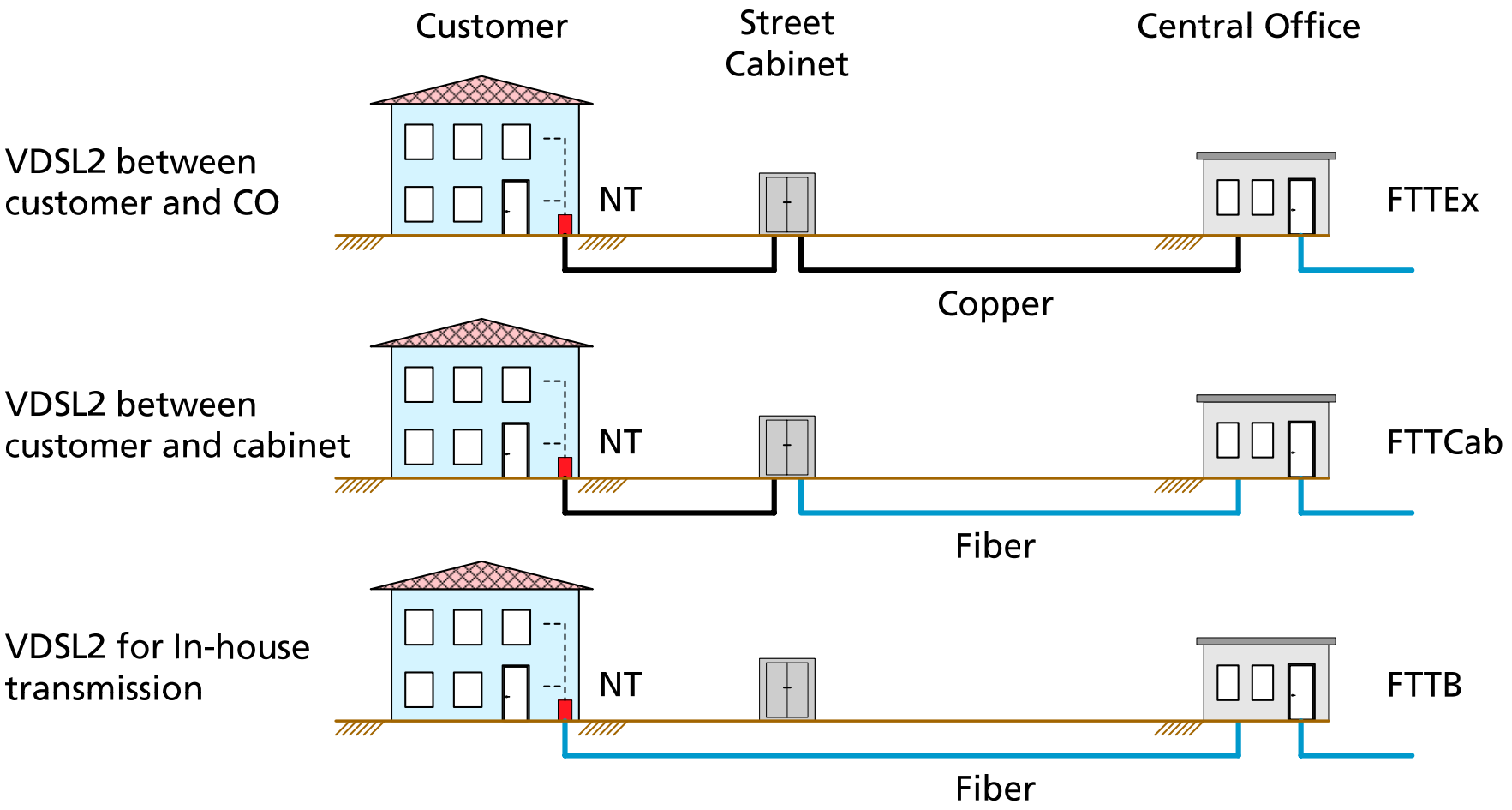
VDSL2 Scenarios

Currently existing scenarios



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Spectral Compatibility

Performance limitations

- Line attenuation
- Impulse noise
- Crosstalk

Crosstalk

- NEXT is the major impairment for DSL systems using shared frequencies for US and DS
- Self NEXT can be avoided by FDM
- FEXT power depends on loop length and is more critical for DSL systems using short loops

VDSL2 Crosstalk

- VDSL2 FEXT influences DSL systems
- FEXT influence among VDSL2 systems

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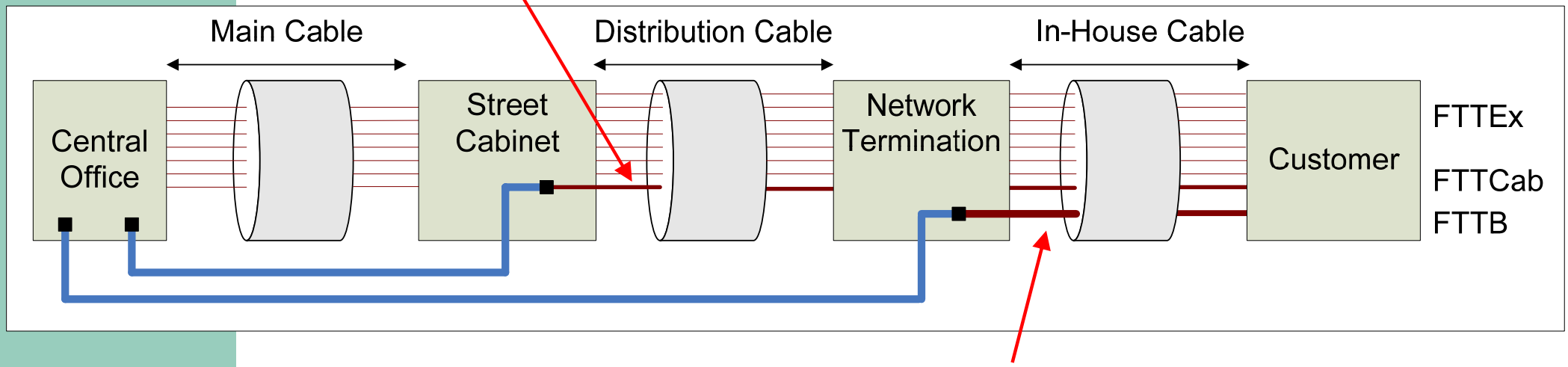
Spectral Compatibility

Crosstalk in mixed DSL scenarios

- High transmission power on short loops disturbs DSL systems on long loops
  - VDSL2 applied from street cabinet disturbs DSL transmission from central office (e.g. ADSL)



  - In-house VDSL2 disturbs VDSL2 applied from street cabinet and DSL transmission from central office
- Protection of DSL signals on long loops against VDSL2 crosstalk from short loops necessary

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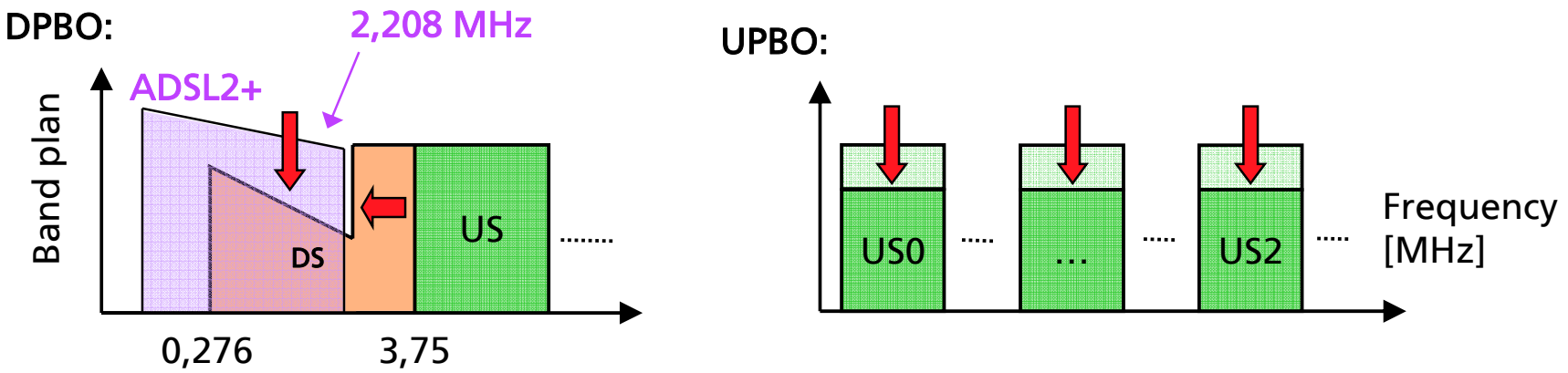
Power Back Off

Downstream Power Back Off (DPBO)

- Reduction of VDSL2 transmit power at the frequency range to protect CO systems
- Power reduction and frequency range depends on electrical loop length
- Principle of equal crosstalk conditions on FTTEx , FTTCab, FTTB loops

Upstream Power Back Off (UPBO)

- Protection against FEXT between VDSL2 systems deployed at same binder caused by shorter loops on longer loops
- Power reduction depends on frequency and loop length



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Dynamic Spectrum Management

Static Spectrum Management (SSM)

- Ensures spectral compatibility between DSL systems deployed at the same binder considering a worst case crosstalk environment
- Static restriction of transmit power ignores the varying crosstalk conditions and wastes transmission capacity

Dynamic Spectrum Management (DSM)

- Optimization of transmission capacity by adapting the transmit power of all DSL lines deployed at the same binder
- Adjustment of transmit power depends on actual crosstalk conditions varying with time
- Unbundling types affect the efficiency of DSM:
  - Different service providers transmit DSL signals on lines within the same binder
  - Service providers lease bit streams from a common carrier who controls all binder signals
- Distinction between DSM levels depends on degree of coordination between DSL lines

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DSM Overview

Level	Principle	Description	Algorithms	Status	Improve-ment
0	Avoidance of crosstalk	• SSM (transmit power restrictions) • Performance optimization of each line without considering other lines	RA mode, MA mode	applied	
1		• Performance optimization • Avoidance of crosstalk by reduction of unnecessary transmit power	PA mode (FM mode), IWF	started	< 25 %
2		• Performance optimization of each line considering other lines • Coordination between lines	OSB (OSM)	R&D, Demo	
3	Reduction of crosstalk	• Mitigation of crosstalk by joint signal processing of multiple lines in a binder	Vectoring	R&D	< 50 %

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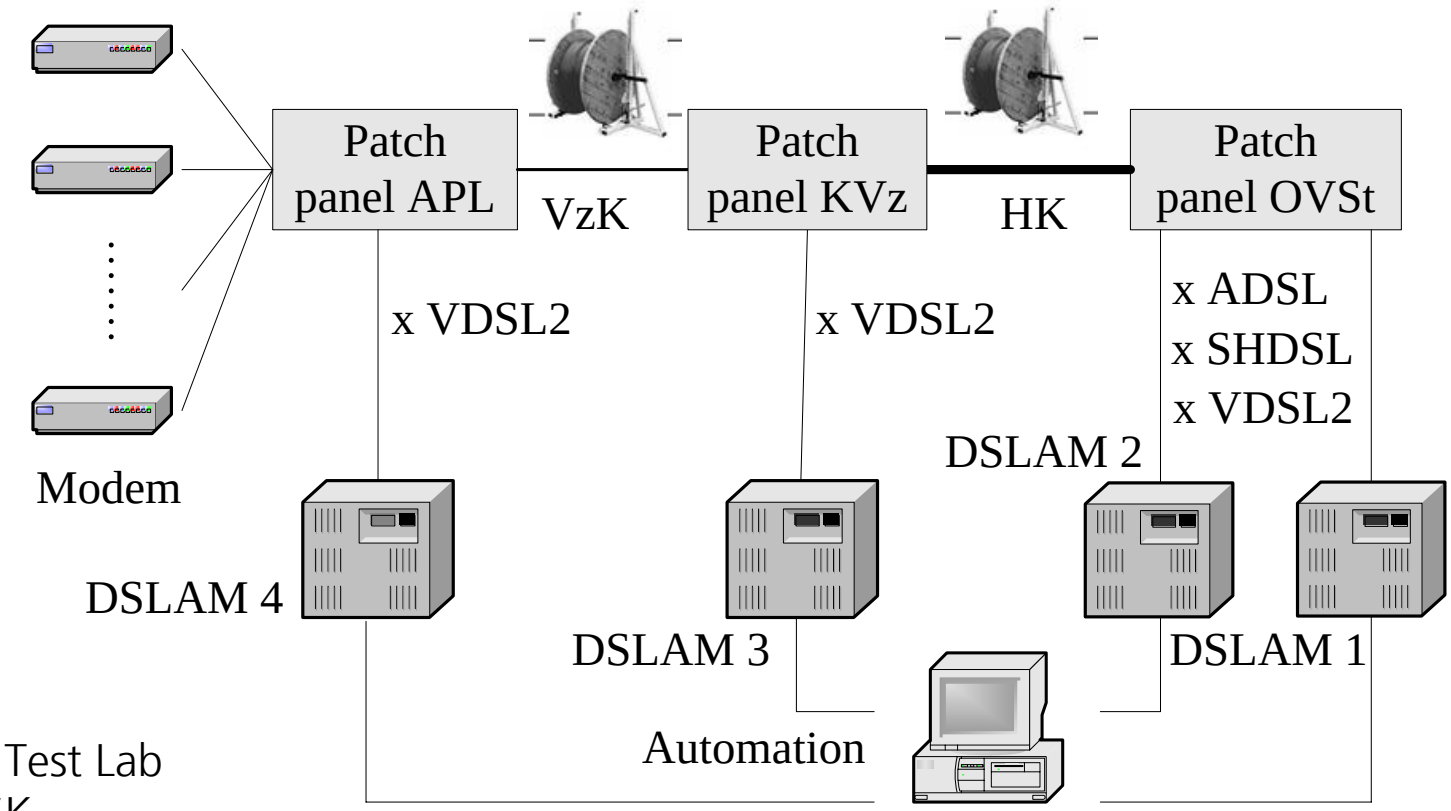
Verification of Spectral Compatibility

Test environment

- Characteristic of real scenarios
- Standard conformance



- Reference:
  DSL & Access Test Lab
  Fraunhofer ESK

VDSL2 In-house Transmission

Why is the in-house wiring important for VDSL2 transmission?

- Access network was initially designed and built for voice transmission
- Today data transmission applies frequencies up to 30 MHz

In-house wiring

- Cables and wires used for in-house wiring are often of different type and quality
- In-house is affected by bridged taps, different line sections including splices, improper connections (soldering, twisting, screw ...)
- Experts do not always install and enlarge in-house wiring
- Often in-house wiring is not documented

Effects

- Radiation, induction and conduction of signals, signal reflections, impulse noise

Result: Performance degradation

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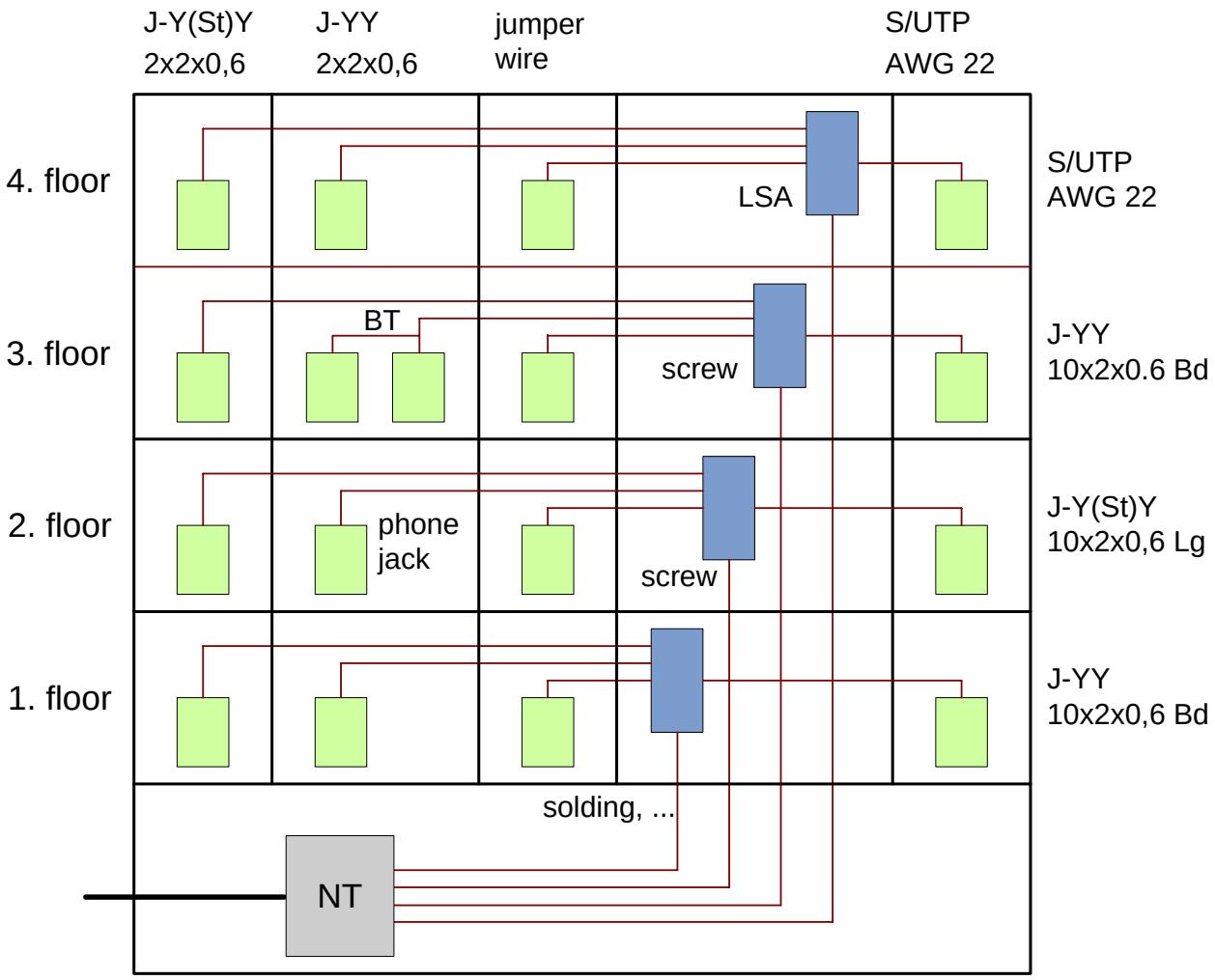
In-house Measurement

Demonstrator

- 4 floors and 16 flats
- Different cables
- Variable connections
- Bridged taps
- Connection to cable plant



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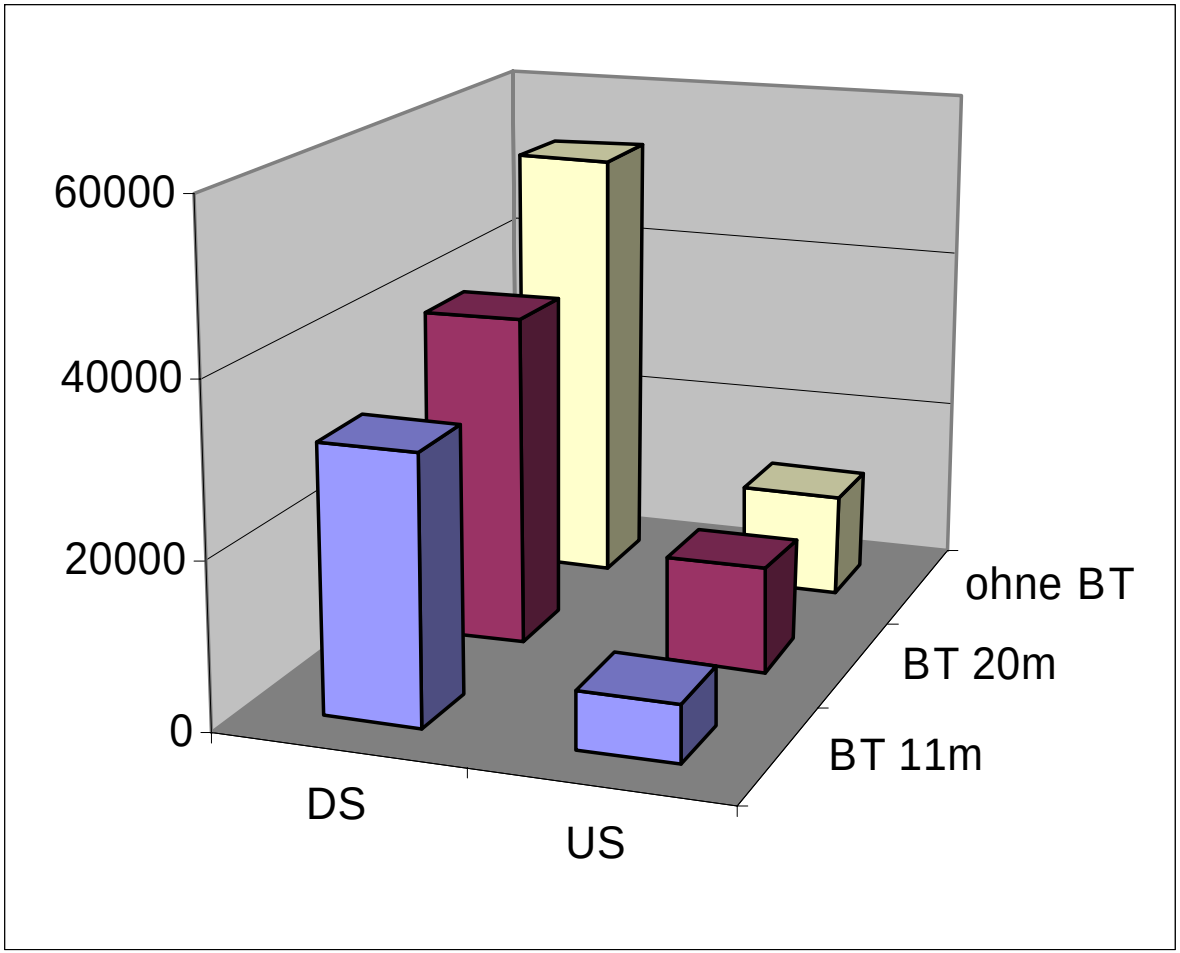
In-house Measurement

Example: Bridged Taps

- Data rate comparison for access lines with bridged taps of different length (noise free)
- Worst case performance degradation could be up to 10 Mbps



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Power consumption

Motivation

- Electrical power consumption will increasingly be influenced by broadband equipment
- Up to now, energy efficiency of DSL systems was not improved significantly
- Low power modes introduced by ADSL2 were not successful

Requirements

- Advanced power management considering time variant transmission properties
- Improvement and extension of low power modes

Code of Conduct on energy consumption of broadband equipment

- Initiative founded by European Commission with the goal to define principles and targets for the reduction of power consumption of broadband equipment
- Platform for discussions between stakeholders

ETSI TM6 is in discussion about power saving for broadband equipment

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Summary

DSL provides high bit rate data transmission over the local telephone network

- Cost-efficient broadband access
- DSL supports currently offered and future services
- Benefit of DSL knowledge and experience (technology, installation, …)

Actual topics

- Spectral compatibility (PBO, PSD settings)
- In-house transmission
- Reduction of power consumption
- DSL coverage for rural areas

Future trend

- DSL is indispensable for broadband access currently and for a long time to come
- DSL advancements are still to come
- Transmission capacity can be significantly improved by novel approaches

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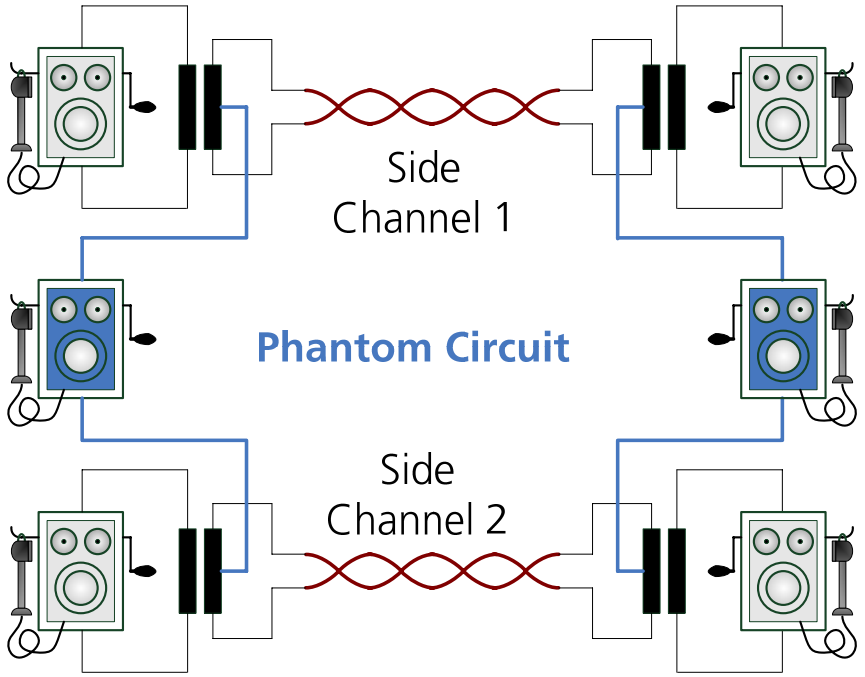
Outlook

Application of Phantom Circuits for DSL transmission

- Phantom Circuit was used to create a 3rd voice channel between two transmission line pairs around the turn of the 20th century
- Is it possible to transmit DSL signals over Phantom circuits?

Research

- Fraunhofer ESK shows that Phantom Circuits can be used for DSL transmission
- Measurements were taken using ESK's demonstration system
- Phantom Circuit performs up to 75% of a standard transmission lines



Latest DSL news: Copper-PON

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Thank you for your attention!

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