

DSL for MUSE

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With

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Magesacher, Lund University
Bas van den Heuvel, TNO



Time schedule

- **Start 16:45, end 18.30**
- **Five-minute break included**

Program

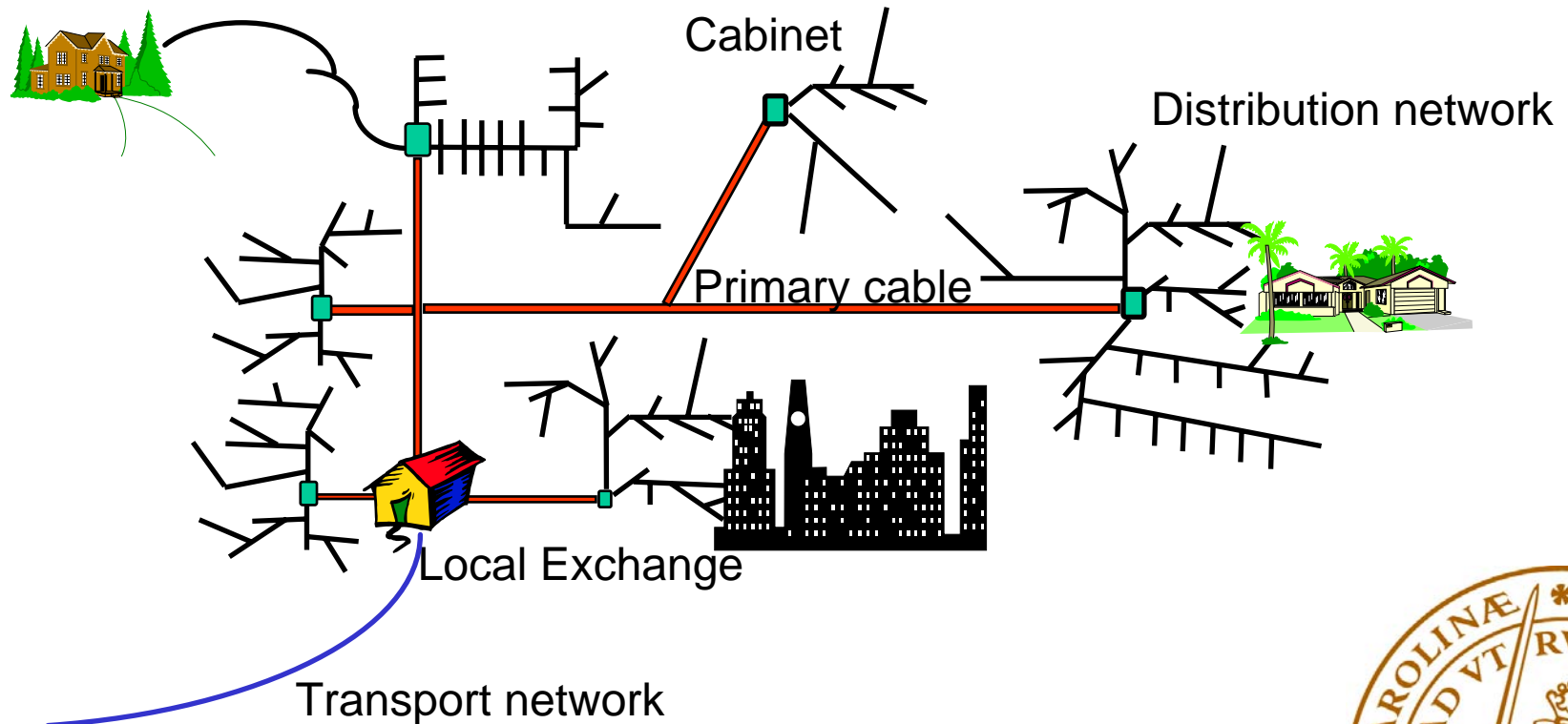
- **What can you do with copper lines?**
- **What are the relations in the DSL-family?**
- **The challenge in DSL**



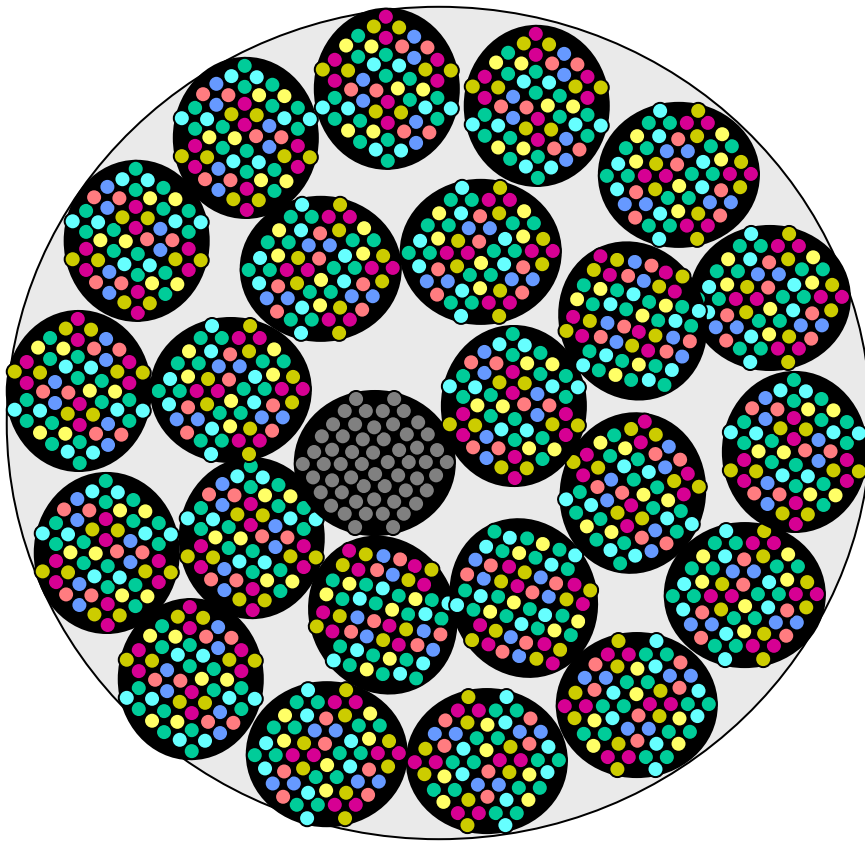
Copper



Access network From Local Exchange (Central Office) to subscriber



The twisted pairs are bundled



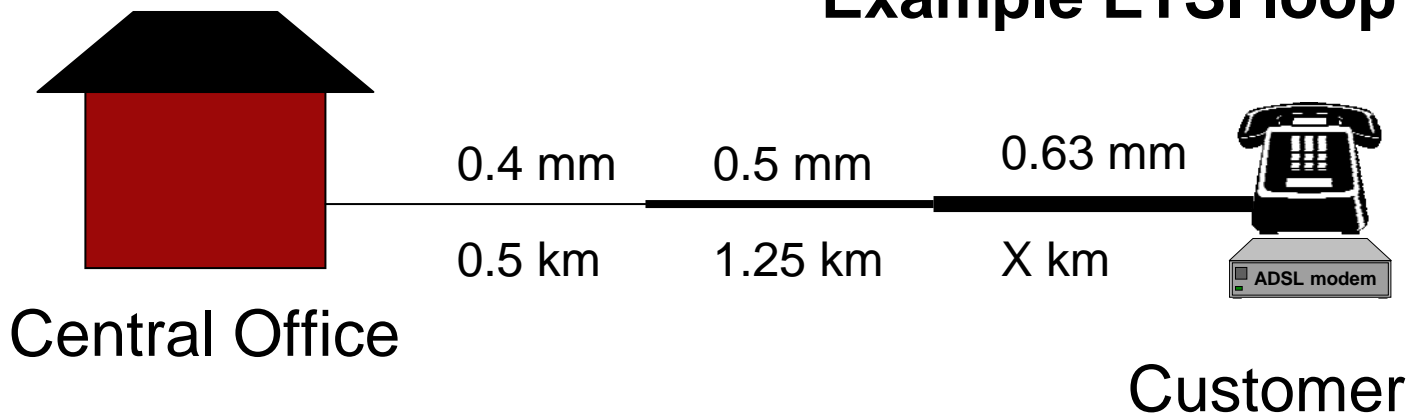
Bundles/binders of 1500 pairs and more. Some with plastic, some with paper insulation, and pressurized air.



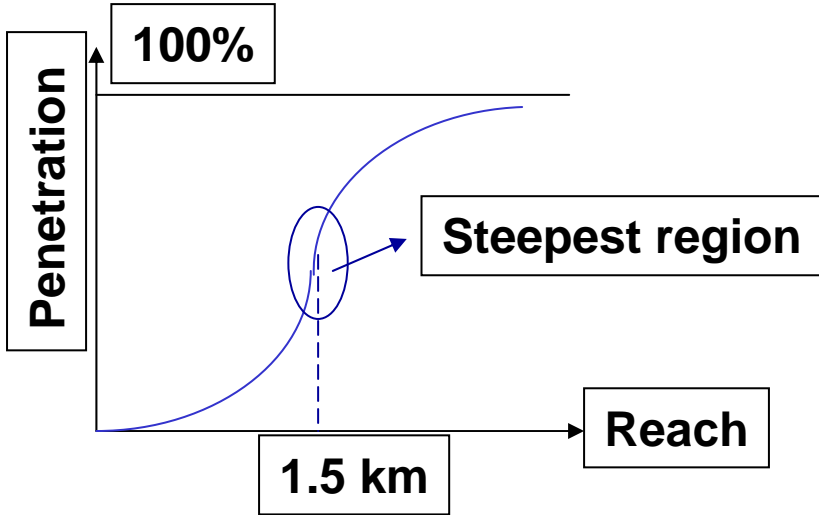
Cable types

- 0.32 mm
- 0.4 mm or AWG26
- 0.5 mm or AWG24
- 0.63 mm
- 0.9 mm

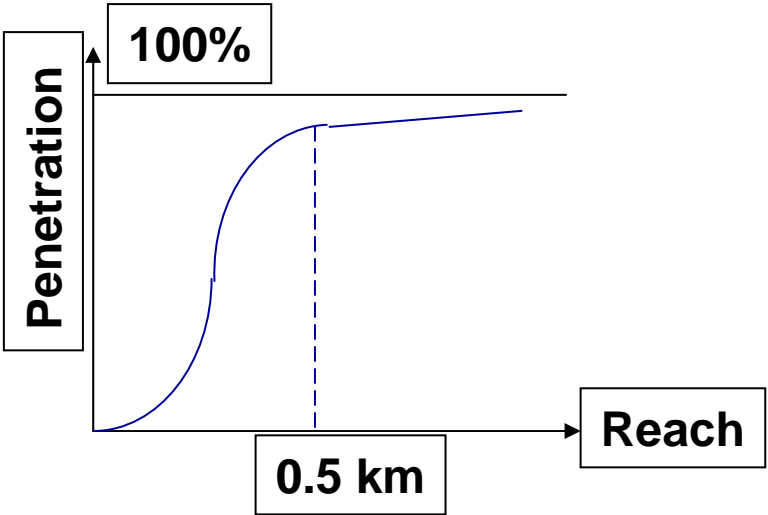
Example ETSI loop #6



How long are the wires? (Sweden)



From the local exchange



From the street cabinets



So what?

**Why should I care about line length
and stuff???**

I ordered ADSL with an 8:1 service!!!



DSL - An perfectly reliable technology?

- How often does a ...
 - 10 Mbit Ethernet deliver 10 Mbit? – Always
 - 1 Gbit Ethernet deliver 1 Gbit? – Always

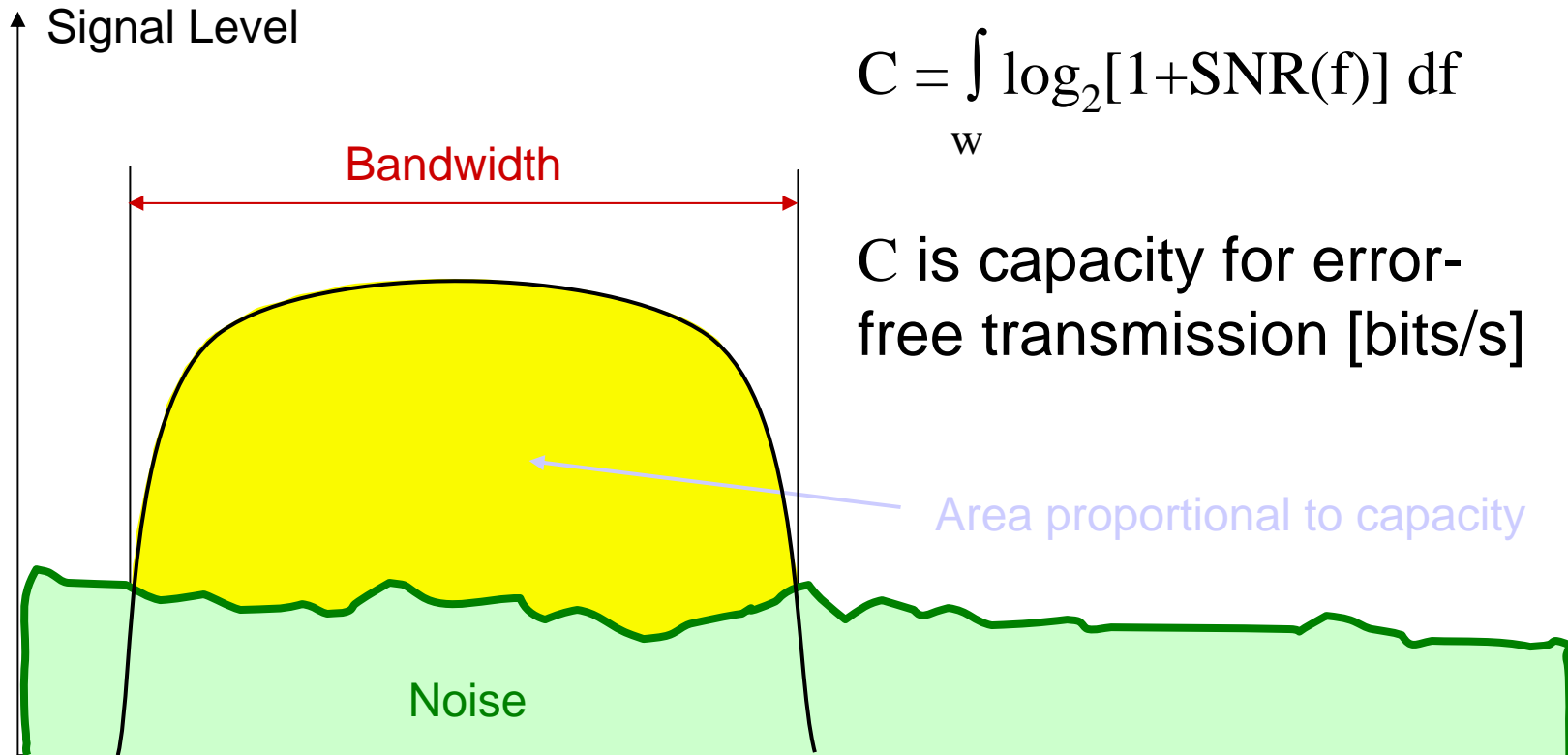
 - 8 Mbit ADSL deliver 8 Mbit? – NEVER!
 - 24 Mbit ADSL2+ deliver 24 Mbit? – NEVER
- How often does a 24 Mbit ADSL2+ deliver 15 Mbit? -
 - Sometimes, always, never; it depends. *It really depends!*

DSL is used because it is cheap and because the copper is everywhere, i.e. for economical, not technical, reasons.





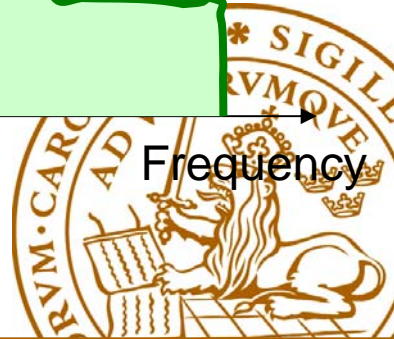
The theoretical capacity of a cable (Shannon)



$$C = \int_w \log_2[1 + \text{SNR}(f)] df$$

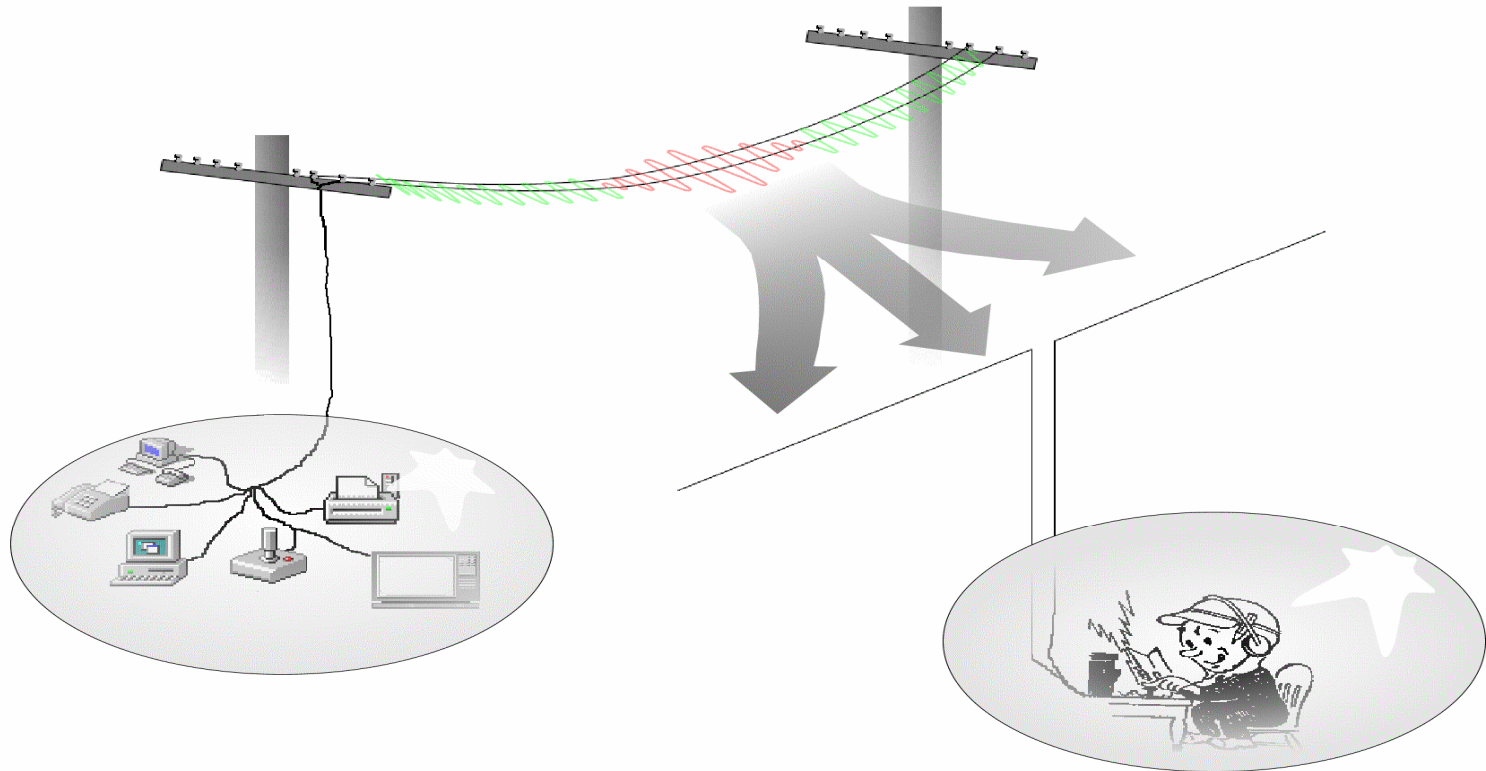
C is capacity for error-free transmission [bits/s]

Area proportional to capacity

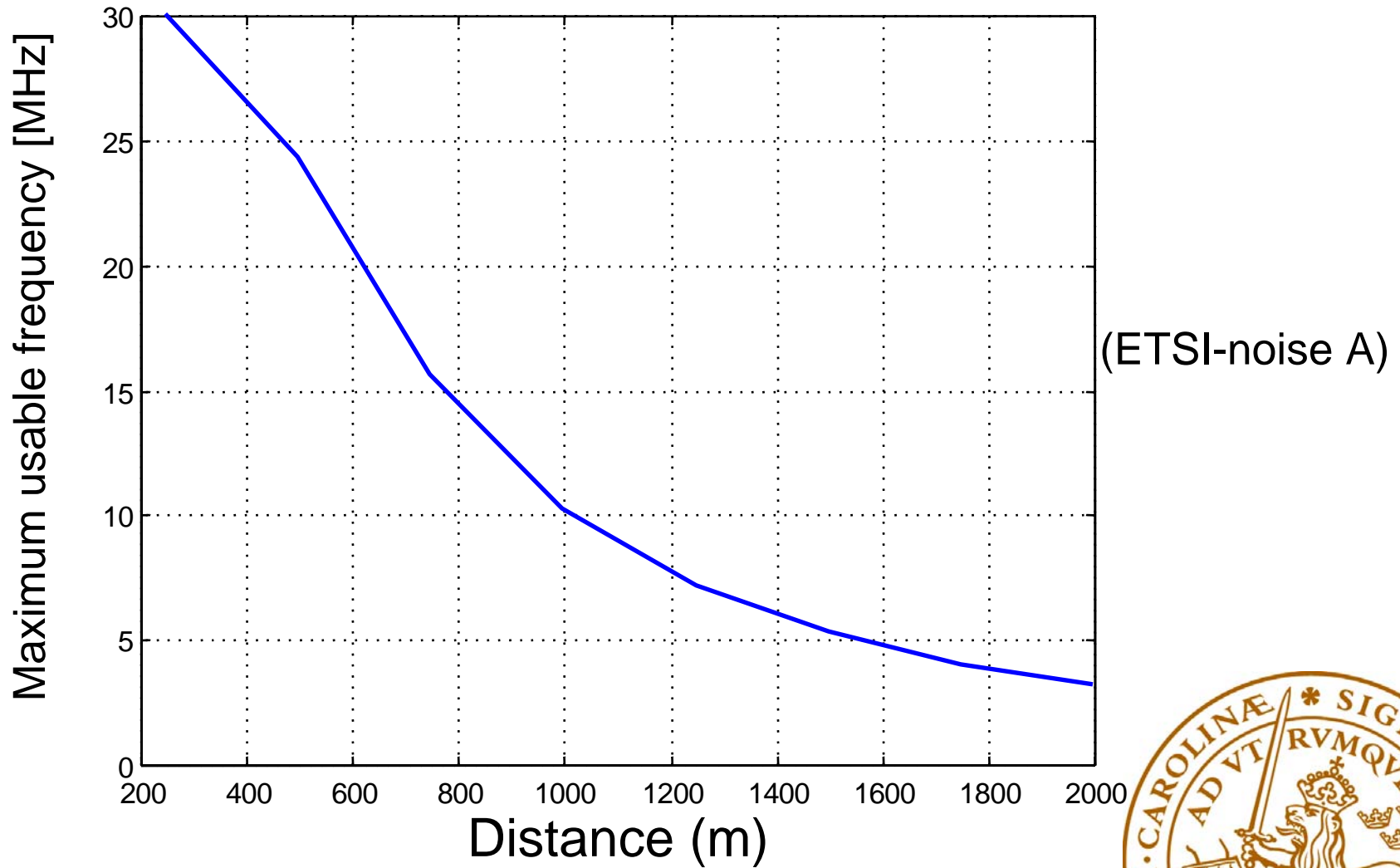


Frequency

PSD masks to limit radiation



DSL: Spectrum vs Reach



Noise sources

- **Distortion in transmitter (e.g. line driver)**
- **Clipping (digital, analog)**
- **Crosstalk (NEXT, FEXT)**

- **Impulse noise**
- **RFI (5% of the lines, van Helsing campaign of MUSE)**
- **Background noise (default -140dBm/Hz)**

- **Receiver noise**
 - Thermal noise, quantization, say -120 dBm/Hz
- **Echo**

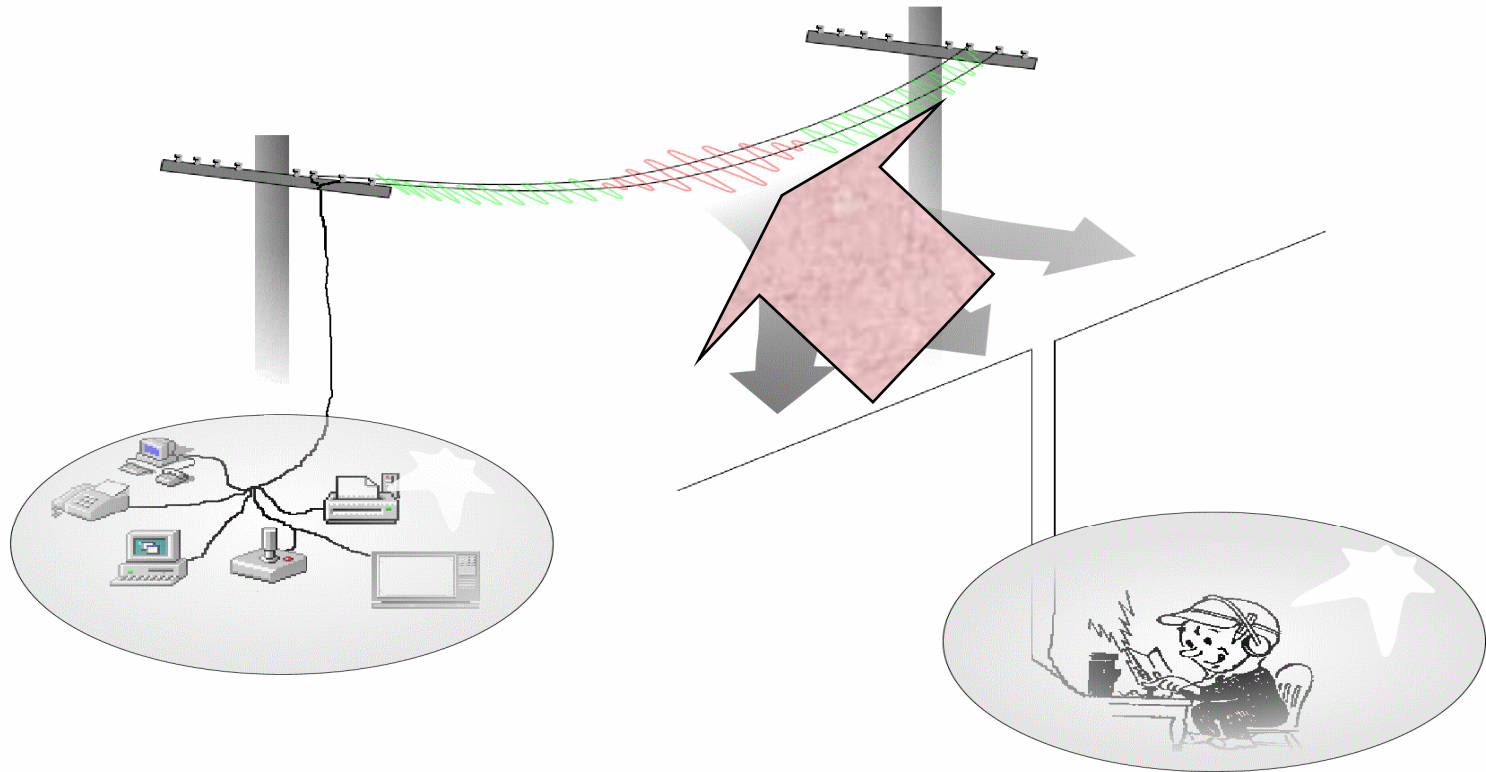




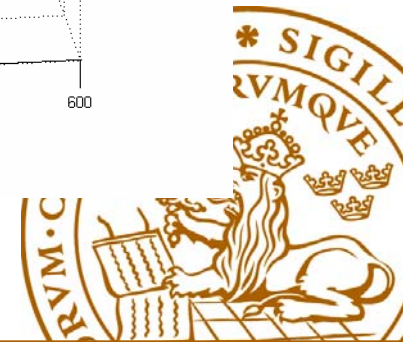
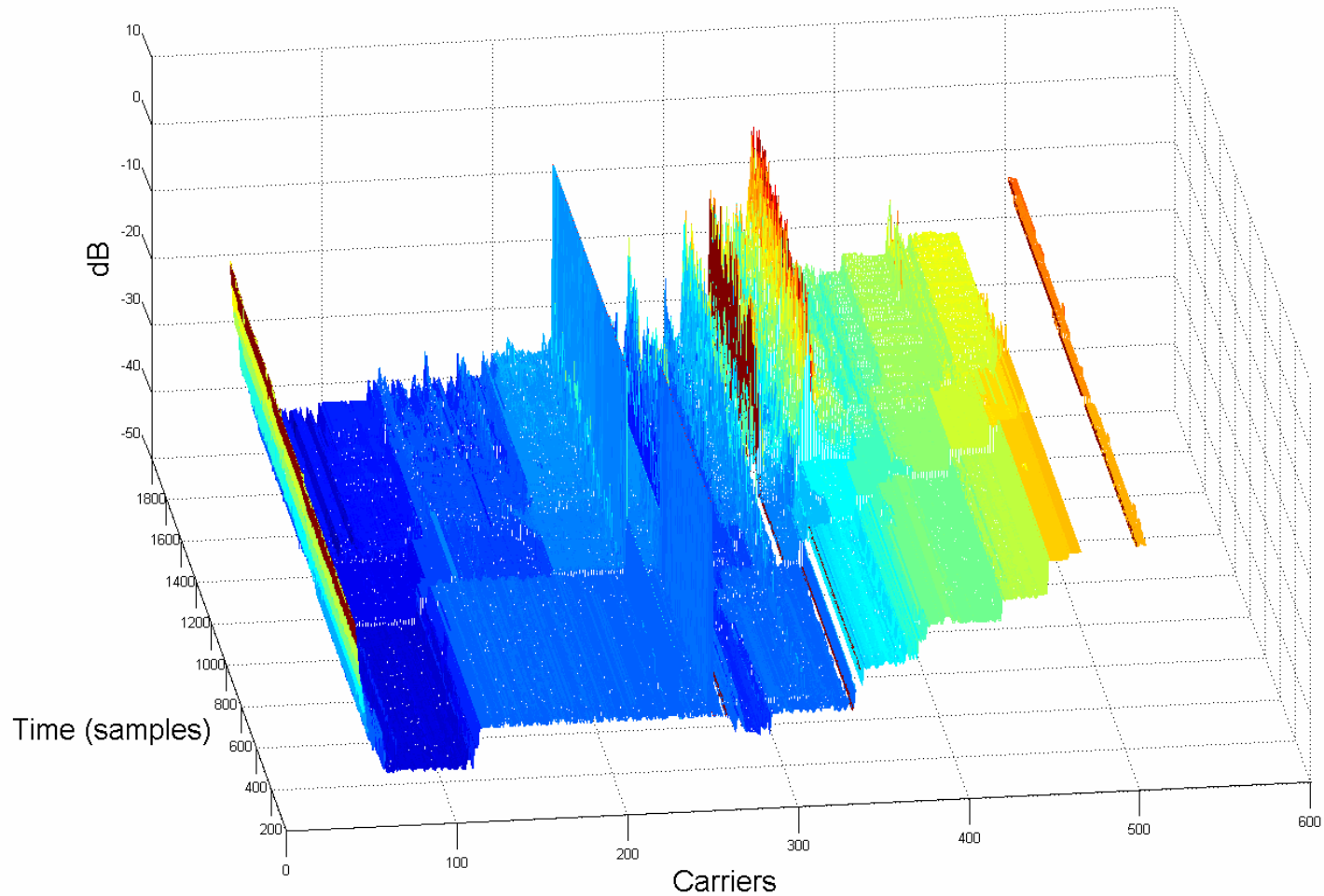
The van Helsing campaign – a DSL vampire hunt



Radio Frequency Interference



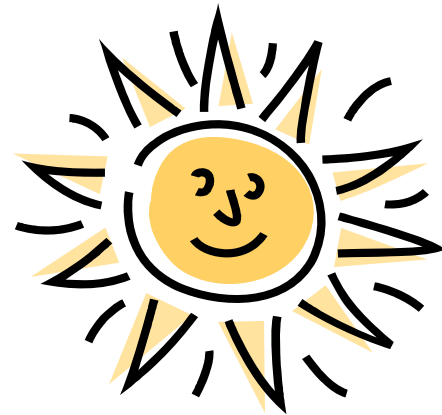
3-D Plots of Instantaneous SNR (Stockholm 2005-10-27)



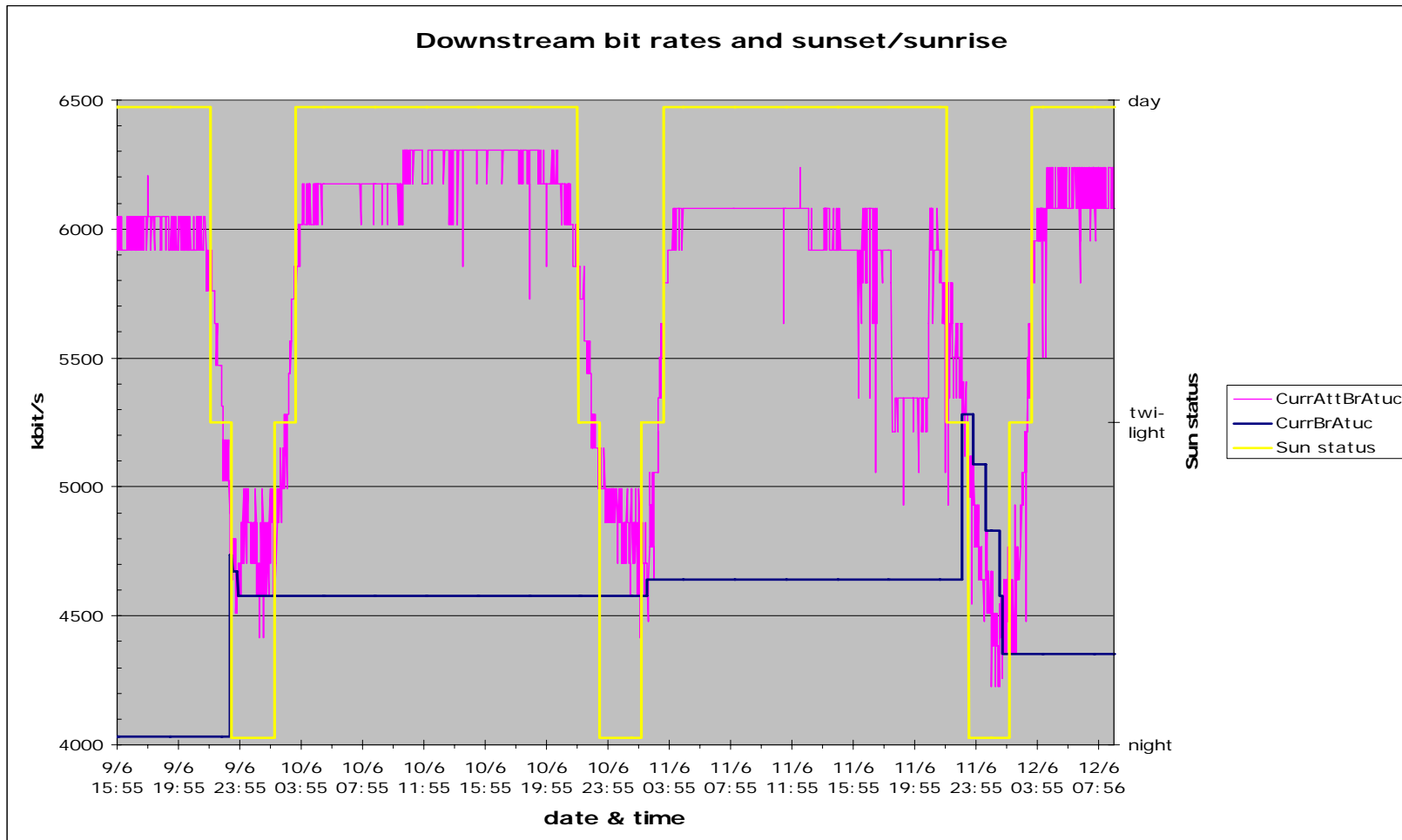
Vampires flee the sun...

On about 5% of the lines:

- During daytime, even the really bad lines are usually fine
- From our measurements, there is a very interesting correlation between line performance and sunset/sunrise time



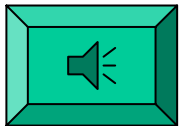
Bit-rate Measurements (Älvsjö 9 – 12 June -06)



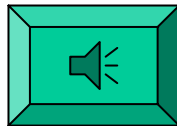
Not Only a Swedish Plague – Examples from Holland

- **Data recorded in Holland in April**
 - Sunrise at 06:35, sunset at 20:46
- **Bit loading variations show interesting pattern**
 - very stable during the day
 - stable 24 hours for low and high frequencies
 - large fluctuations during the night in the upper MW band (1000 – 1600 kHz)

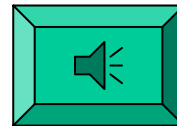
Movie 1



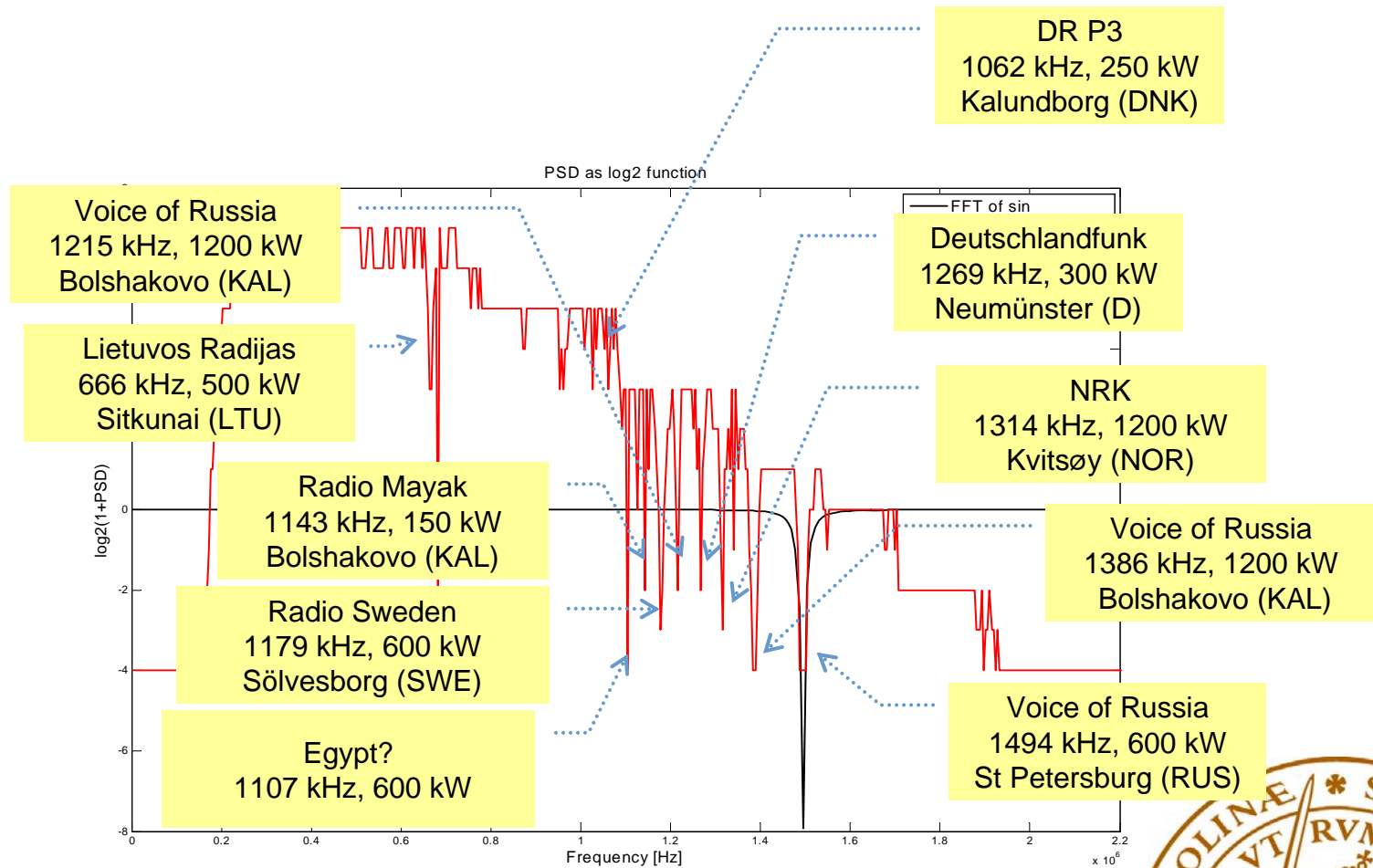
Movie 2



Movie 3



Example of modelling work: Sine wave as disturber



Photo

- Foto från källaren



Noise sources

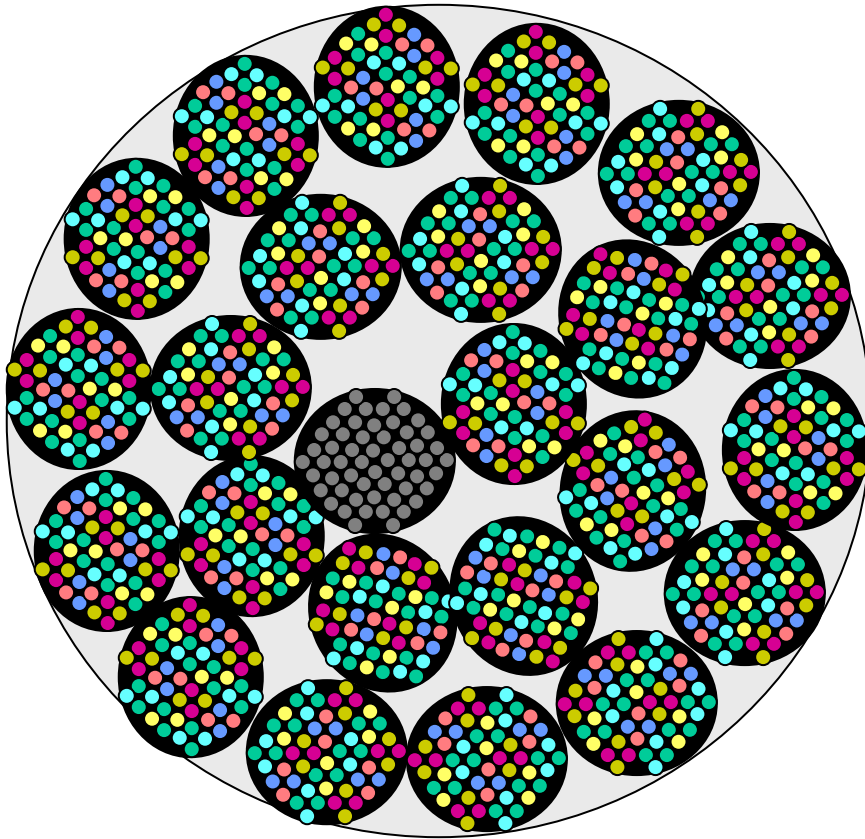
- **Distortion in transmitter (e.g. line driver)**
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The twisted pairs are bundled: Crosstalk



Crosstalk between cables:

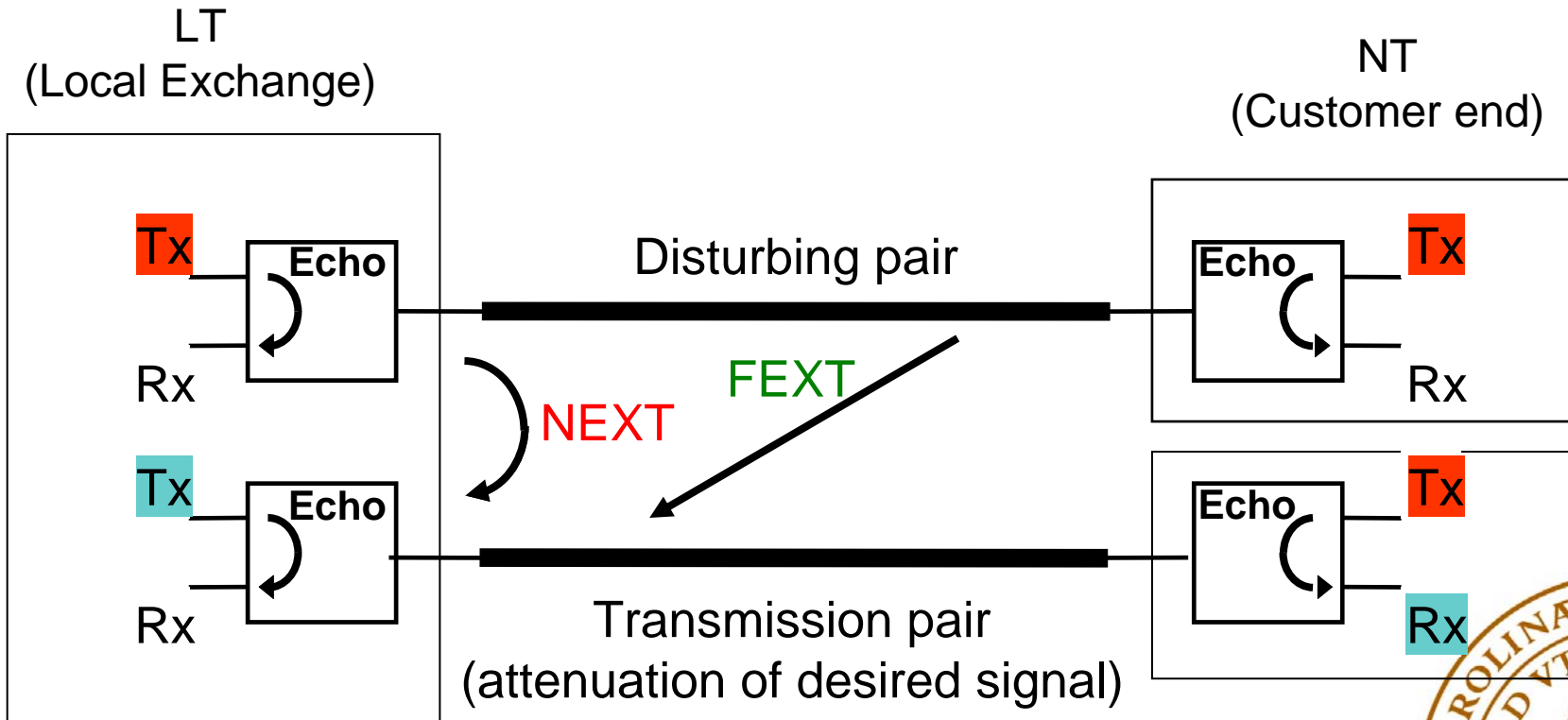
Transmission on one
line disturbs
transmission on
neighbouring lines



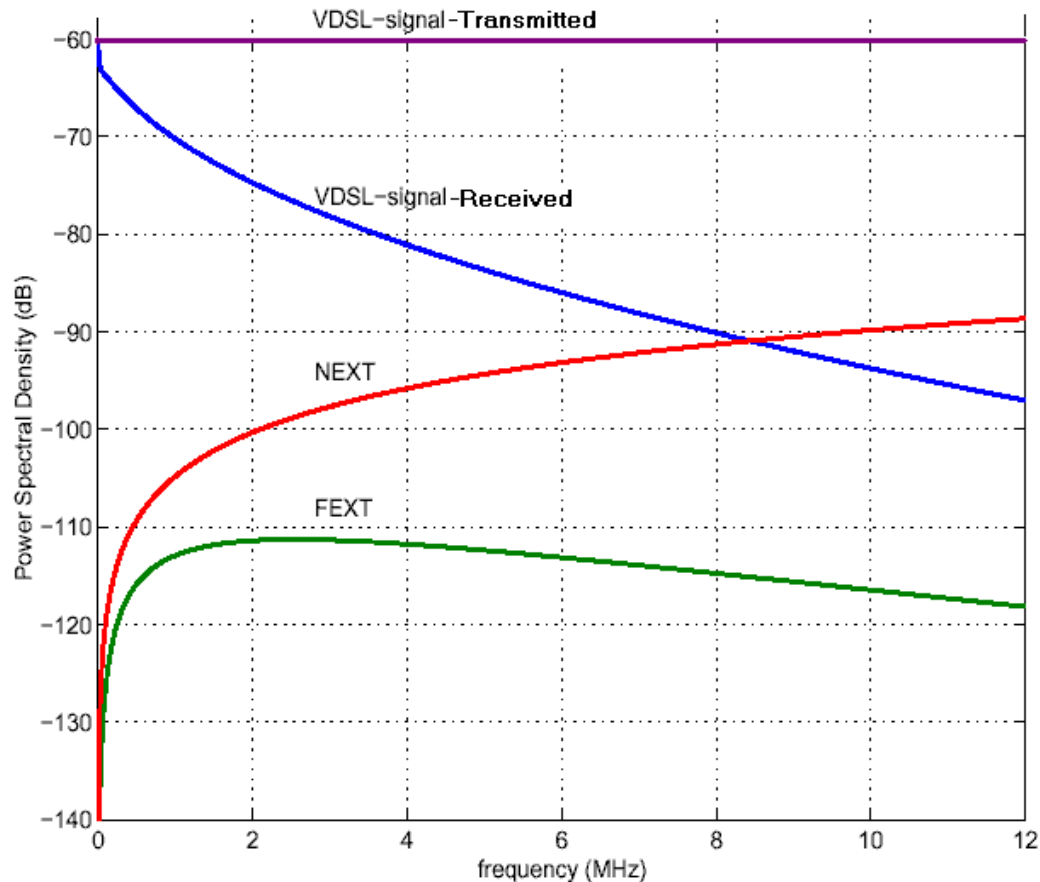
Transmission model - Crosstalk per cable

NEXT - Near End X-Talk

FEXT - Far End X-Talk



Crosstalk: Performance limiting

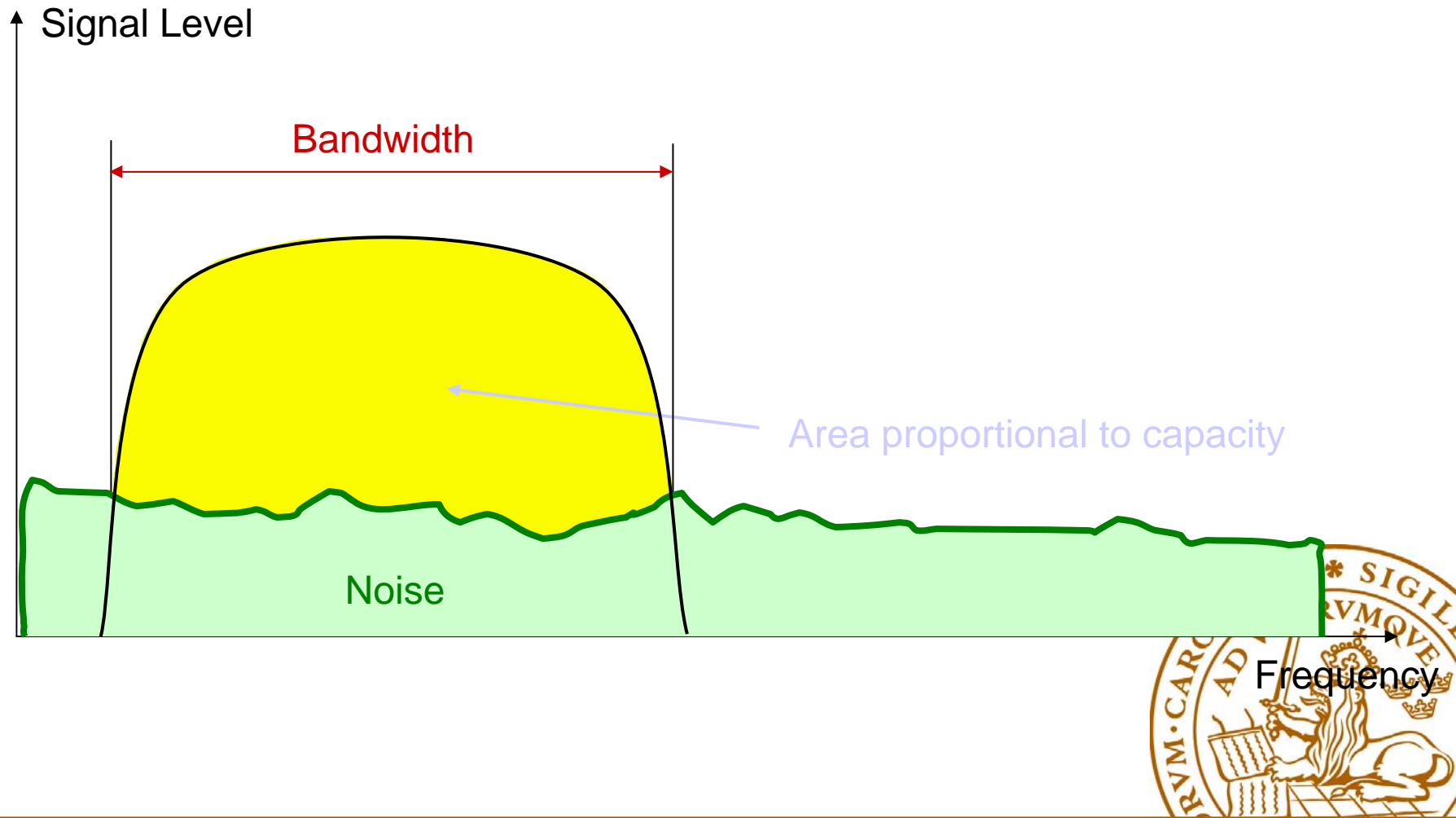


Bas's slide

- How much do I get then?

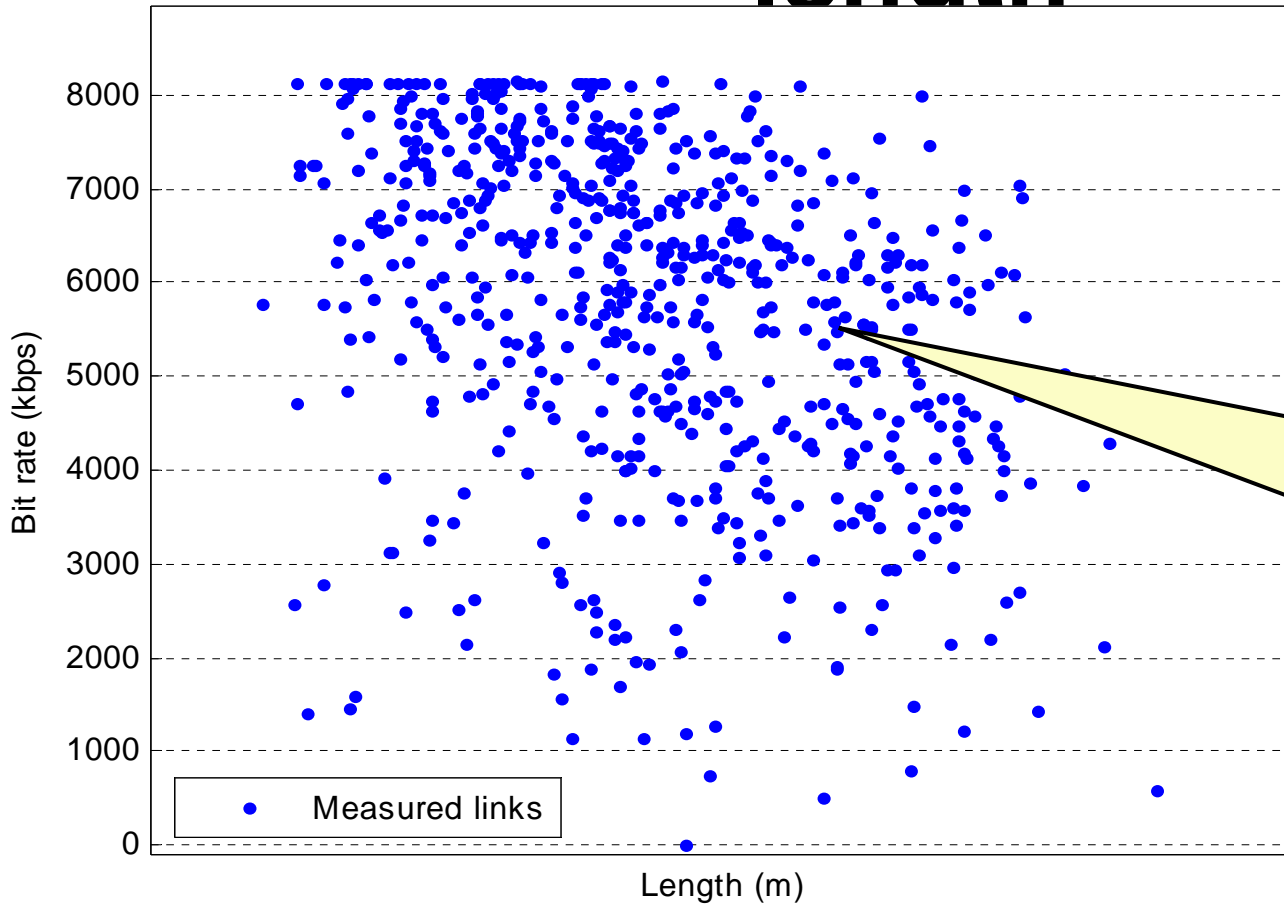


Remember this? Capacity!



Attainable bit rate versus

NT, POTS, **** *, 218 links
length



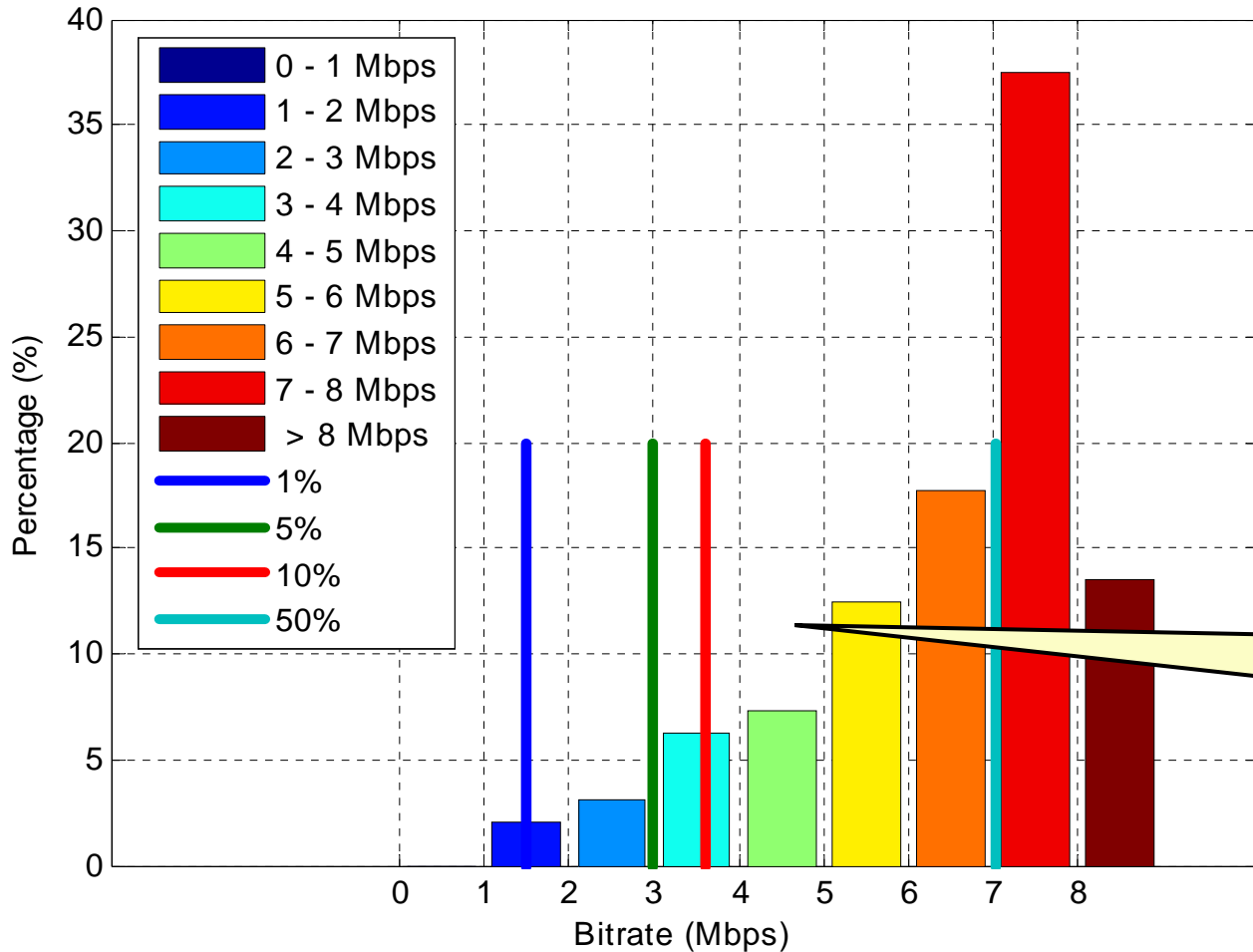
- 668 ADSL/POTS links
- Downstream bit rate
- Length determined from attenuation

**Small Correlation
between loop
length and
attainable bit rate**



Performance in a single cable

NT, POTS, Polyhymnia, 96 links.

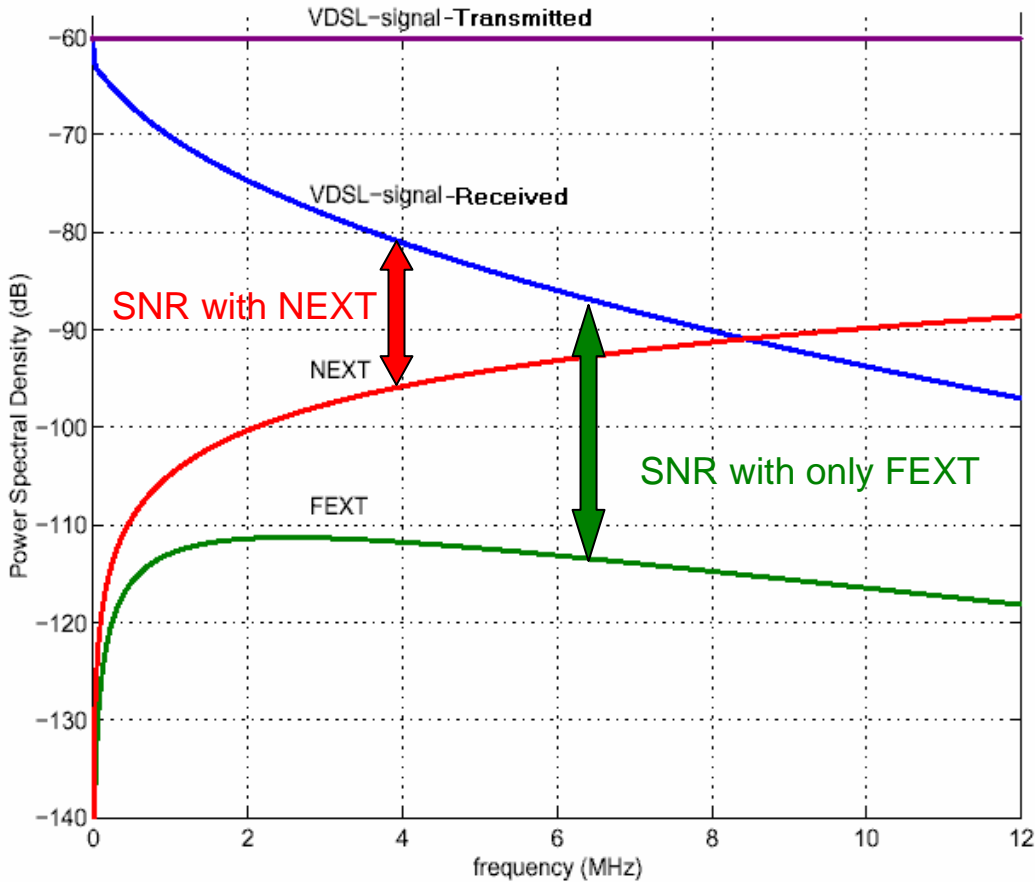


- 96 ADSL/POTS links
- Downstream bit rate
- All at essentially same loop length (± 200 m)
- All experiencing same noise environment

Large spread in performance !



Echo-cancelled or FDD?



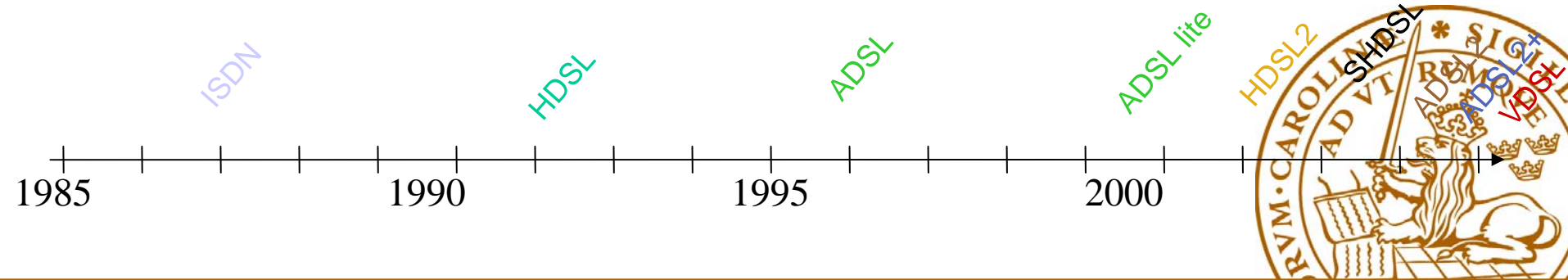
The xDSL family

Compressed crash-course time



The xDSL Family

- **ISDN** **1987** **Low-speed data & POTS replacement**
- **HDSL** **1991** **Trunk applications**
- **ADSL** **1995** **(Asymmetric) Internet access**
- **ADSL lite** **1999** **Simplified ADSL (half capacity)**
- **HDSL2** **2000** **Single-pair HDSL (ANSI)**
- **SHDSL** **2001** **Single-pair HDSL (ITU)**
- **ADSL2** **2002** **Improved ADSL**
- **ADSL2+** **2002** **ADSL2 with double downstream, Tr.p.**
- **VDSL** **2003** **Video-on-demand, Triple play**
- **VDSL2** **2005** **Video-on-demand HDTV, Triple play**



The xDSL Family downstream bit rates

	<u>Downstream [Mbits/s]</u>	<u>Upstream [Mbits/s]</u>
• ISDN	0.128 (0.144)	0.128 (0.144)
• HDSL	0.768 • N*	0.768 • N*
• ADSL	<10	<1.0
		Annex J will give double upstream
• SHDSL	0.192 - 2.3	0.192 - 2.3
• ADSL2+	<25	<1.0
• VDSL	< 50-12	<2-25
• VDSL2	<100	<100

*N=number of pairs, usually 2-3



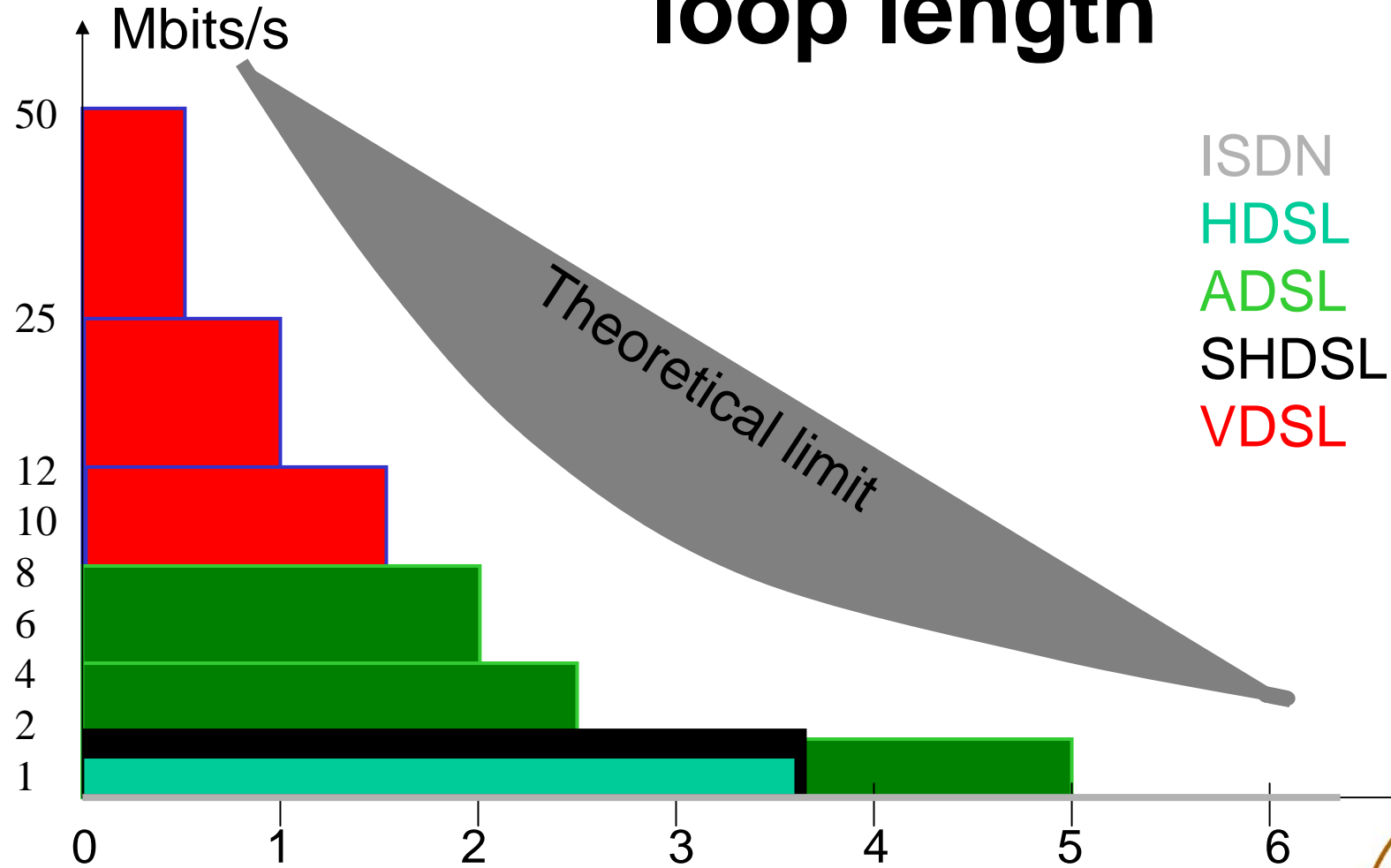
The xDSL Family: Reach

- ISDN **5.5 km**
- HDSL **3.5 km**
- ADSL/ADSL2 **4.5 km** (depends on bitrate)
- HDSL2 **3.5 km**
- SHDSL **3 - 6 km** (dep. on bitrate)
- VDSL **0.5 - 1.5 km** (dep. on bitrate)
- VDSL2 **0 – 1.8 km** (dep. on bitrate)

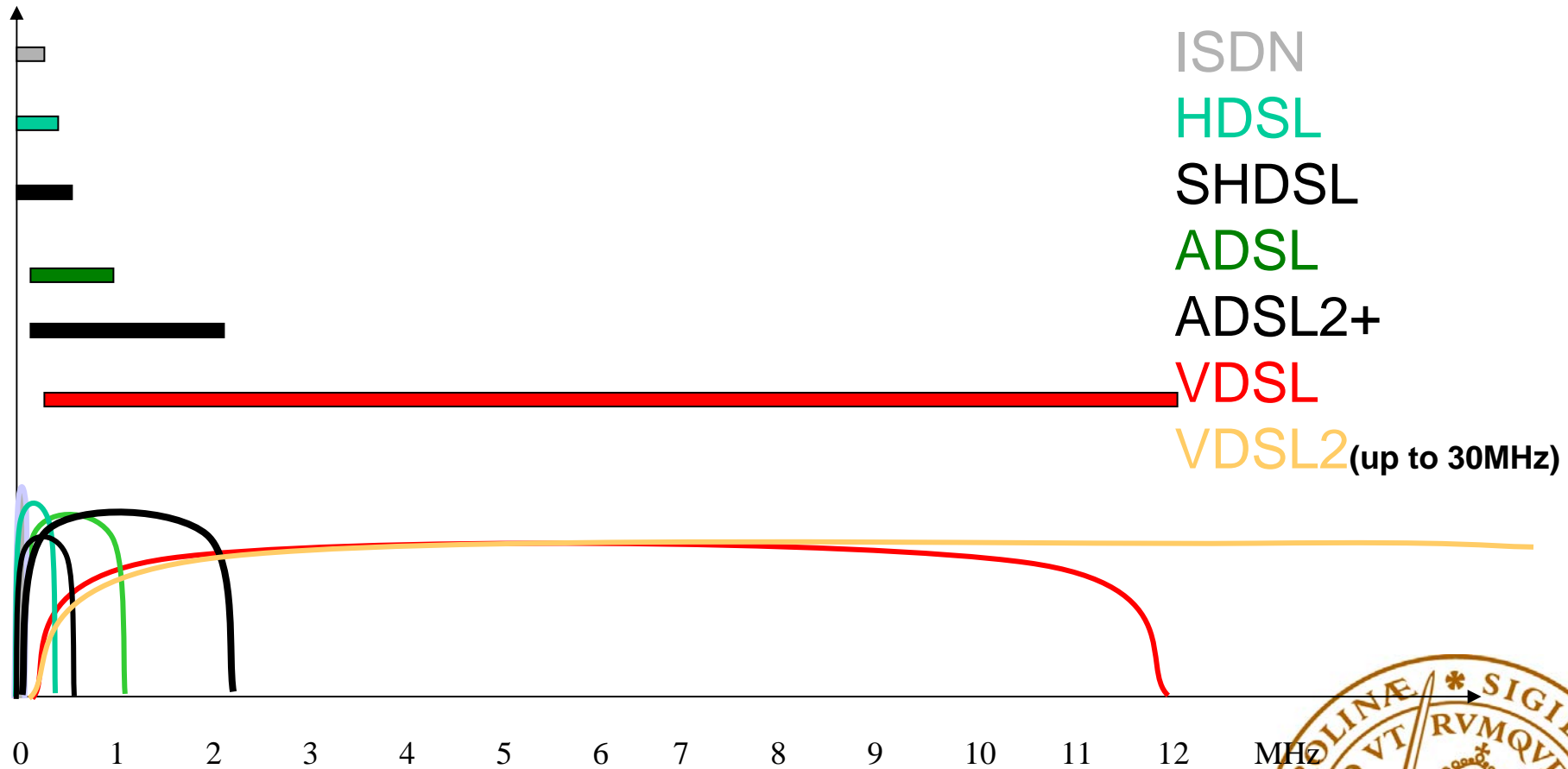
Compare with Ethernet 100BaseT: 0.1 km on cat-5 cable using many wire pairs.



Bitrate versus loop length



Bandwidth for different DSL types

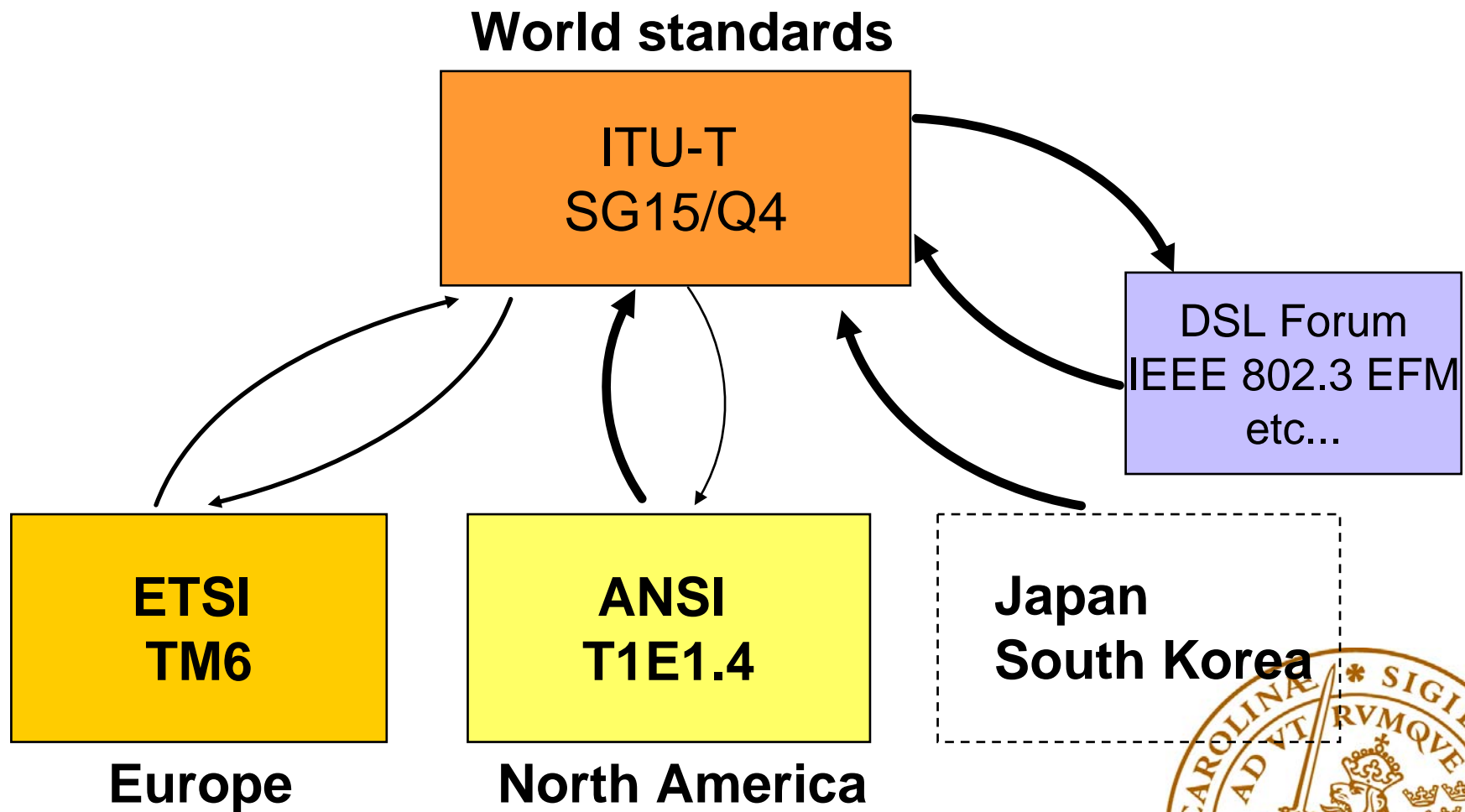


Conclusions

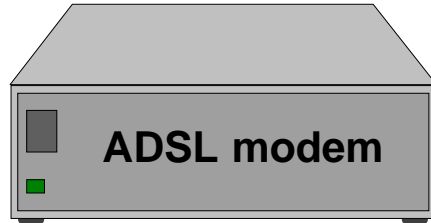
- There are a lot of different types of DSL
- Each DSL type targets a certain service, bit rate and reach
- Some DSL technologies have high bit rates, some have long reach, but *never* at the same time
- High bit rates requires high bandwidth, which is possible only on short loops



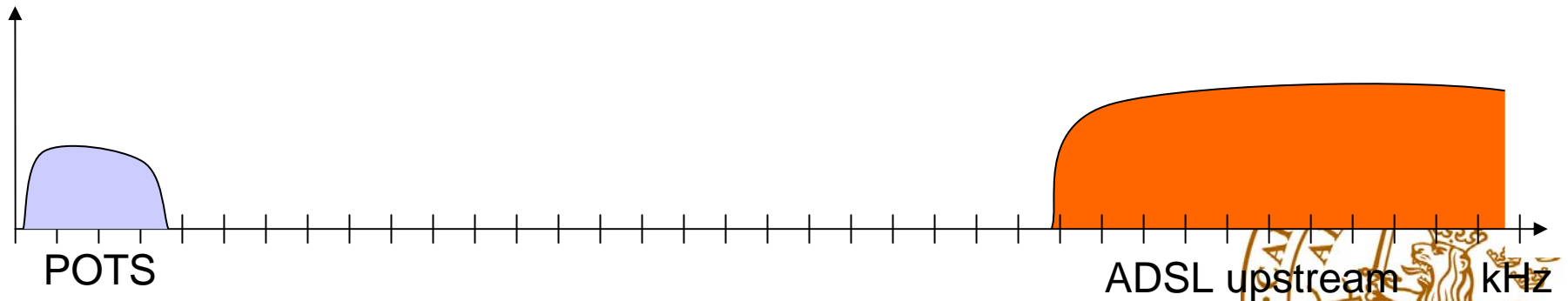
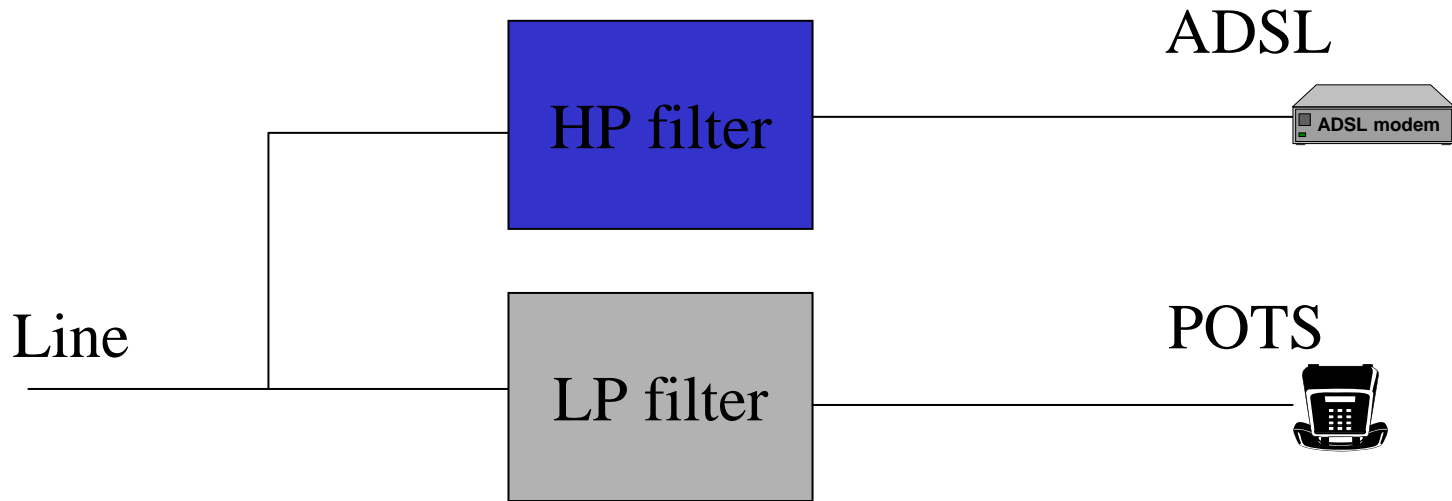
xDSL Standardization



How can we keep the POTS service on the same cable?



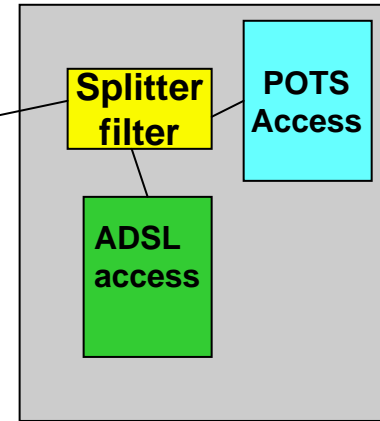
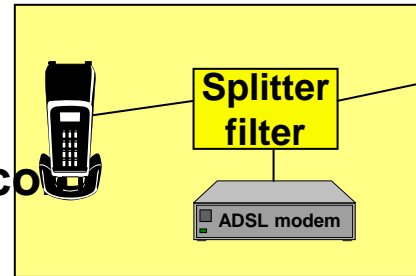
Splitter filter



Alternative POTS transmission methods

- **Splitter filters**

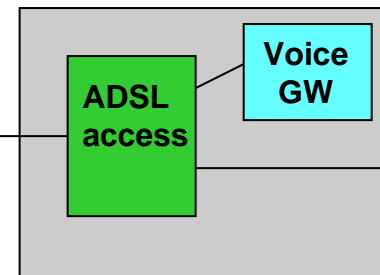
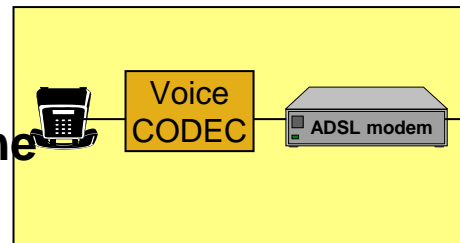
- Used in ADSL
- Large, expensive hardware
- Impossible to integrate on silicon
- Complicates installation



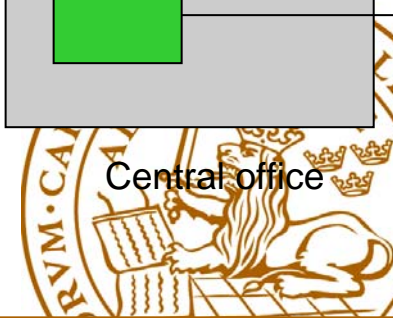
Central office

- **All-Digital Loop (sometimes called Dry Loop)**

- Uses Voice over ATM, Voice over STM or Voice over IP
- Voice CODEC at the customer side
- No life-line (emergency phone in case of power failure)



Central office



ADSL All-Digital Loop

- No splitter filter, allowing extended low frequencies
- No POTS, voice over DSL
- More symmetric (like SHDSL)
- Longer reach
- Candidate for replacing POTS, ISDN and SHDSL
 - Unified access systems
- Migration of POTS to All-Digital Loop

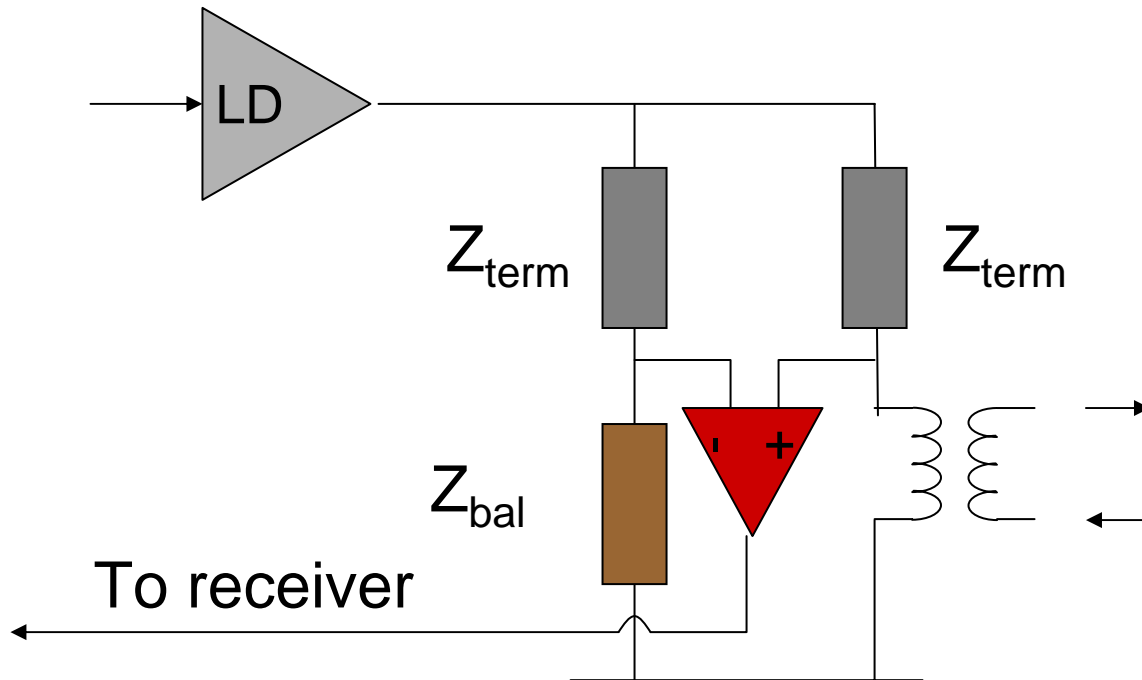
Threat or opportunity?



The xDSL family



The Hybrid



ADSL startup



ADSL startup

1. Handshake



2. ADSL training



3. Showtime



Handshake



- **Described in ITU 994.1**
- **Common start procedure for all DSL types**
- **Used to detect DSL type and some properties of the modem**
- **Uses PSK (Phase Shift Keying) to**



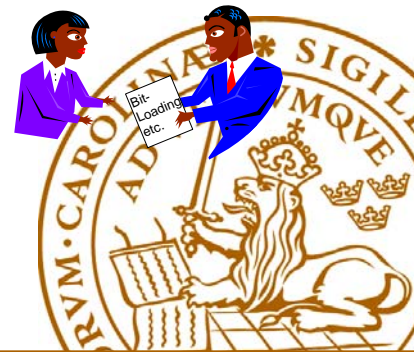
ADSL training

Described in the ADSL standard ITU 992.1

1. Line parameter training used to adapt e.g. AGC and echo canceller

2. Channel analysis analyze line transfer function and noise

3. Exchange used to transfer bit-loading etc.



Showtime



- **Showtime is when data traffic is ongoing**
- **Bitloading can be changed slowly by bitswapping**



Power Control



- Used to reduce output power from CO transmitter on short lines
- The CO side uses the received upstream level as indication of line-length
- Saves power in the line driver and reduces crosstalk (NEXT/FEXT)
- Power cutback will reduce power on short loops. Reduced number of used tones will



The challenge in DSL: IP-TV User tolerance

Excerpt from Berglin's "How to deal with the plagues of summer":

"But against the world championship in soccer, not even Death from Ingmar Bergman's Seventh Seal would stand a chance."

Death - "Do you play chess?"

IP-TV-user - "QUIET!!
I am watching soccer.
There is beer in the fridge."



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