VDSL2 Vectoring
Architecture and System Aspects

Dr. Axel Clausen
Principal
Systemarchitect VDSL2 Vectoring

Lantiq

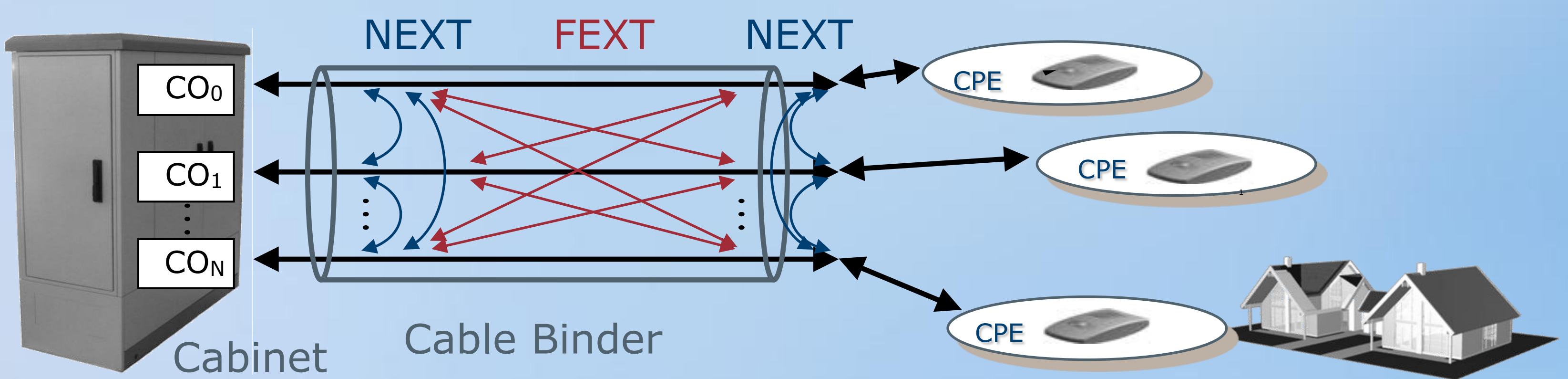
Infineon Wireline Business Unit became Lantiq

Some Facts:

- Closing on November, 6^{th}, 2009
- Private company – 100% ownership by Golden Gate Capital
- Revenue: approx. 500M US$
- Employees: ≈900
- All wireline & home networking products have been transferred from IFX to Lantiq

Introduction

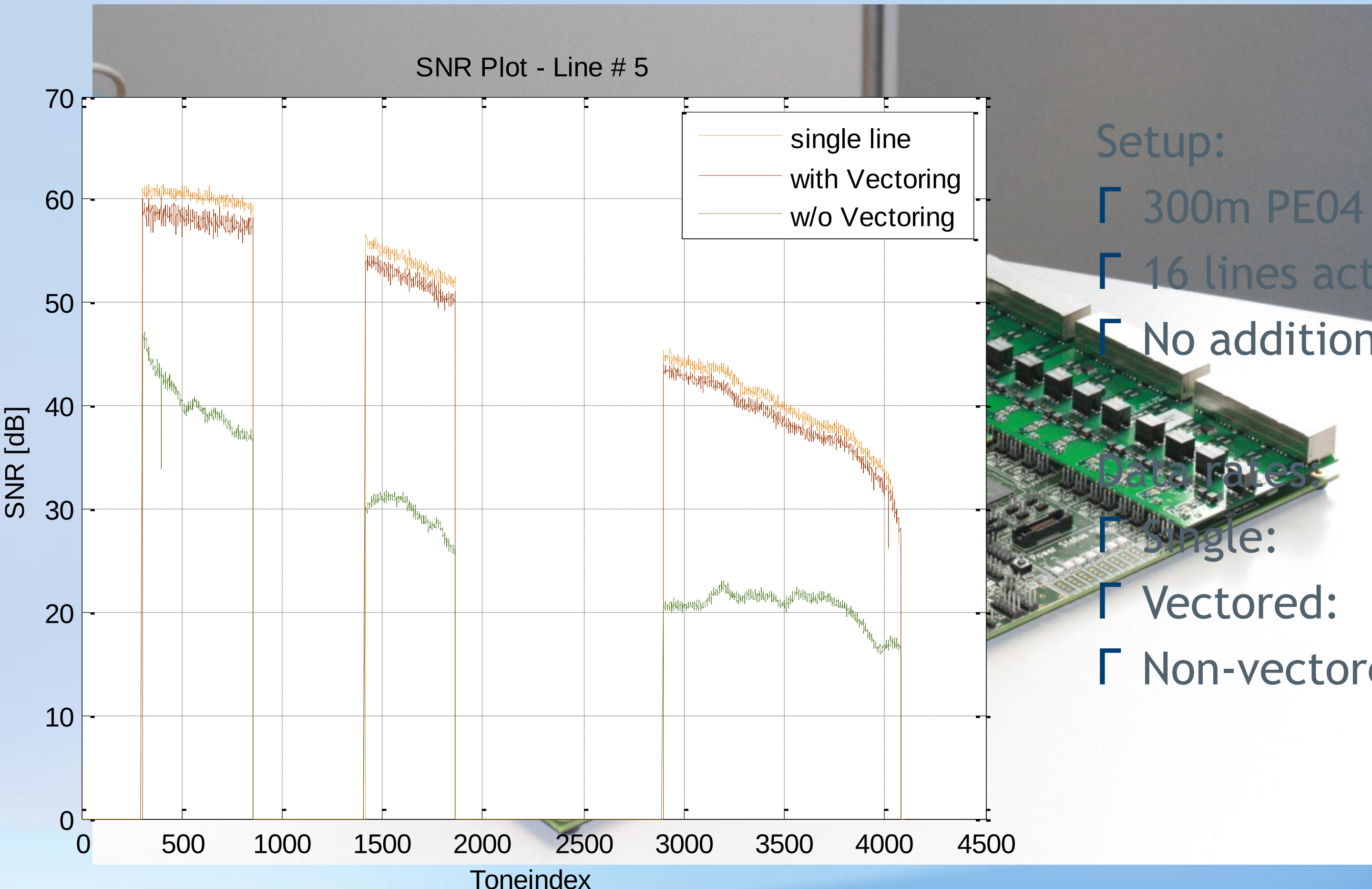
- Performance of VDSL2 systems is limited by Crosstalk:
  - VDSL2 uses Frequency Division Duplexing
  - NEXT can be avoided by proper symbol alignment
  - FEXT compensation requires common processing → Vectoring



- ITU Standard G.993.5 (g.vector) has been consented in October 2009
  - Standard defines joining procedure, training sequences, and backchannel for error reporting
  - Publication probably in Spring '10

Where are we now …

Vectoring Demonstration System is available
Almost perfect crosstalk cancellation possible



Setup:

- 300m PE04 cable
- 16 lines active
- No additional noise

Data rates:

- Single: 104 Mbps
- Vectored: 101 Mbps
- Non-vectored: 48 Mbps

Major Challenges for commercial deployments

Focus for this presentation:

1 Robustness

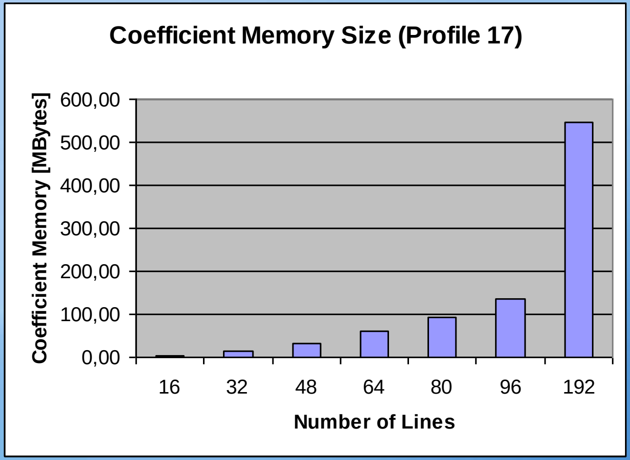
2 Support of large cable bundles

3 Acceptable Training Times

4 Unbundling and Legacy Systems

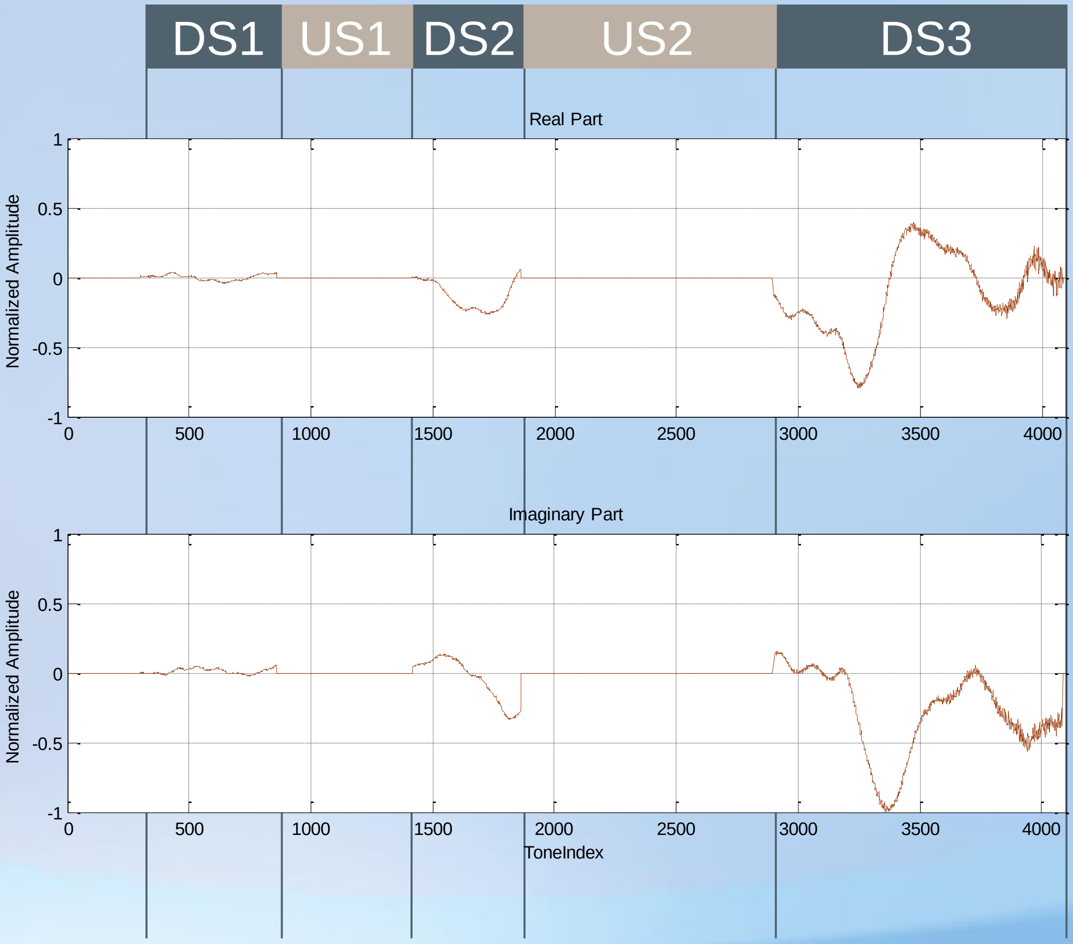
Typical Deployment Scenario

- Topology:
  - Telephone cables are distributed in cable bundles
  - Up to 500 pairs are located in one cable bundle
- Cancellation Requirements:
  - Measurements show that not all pairs in a bundle contribute equally to the crosstalk experienced by one victim
  - Dominant disturbers are not limited to pairs of the same binder
  - Vectoring architecture needs to be capable to select disturbers from all active lines of a bundle
- Scalability:
  - Computations, memory size, and memory access speed increase quadratic with number of supported Lines
  - Example: Full cancellation of 192 lines requires more than 500 MByte of Coefficient Memory



Smoothness of Crosstalk Coefficients

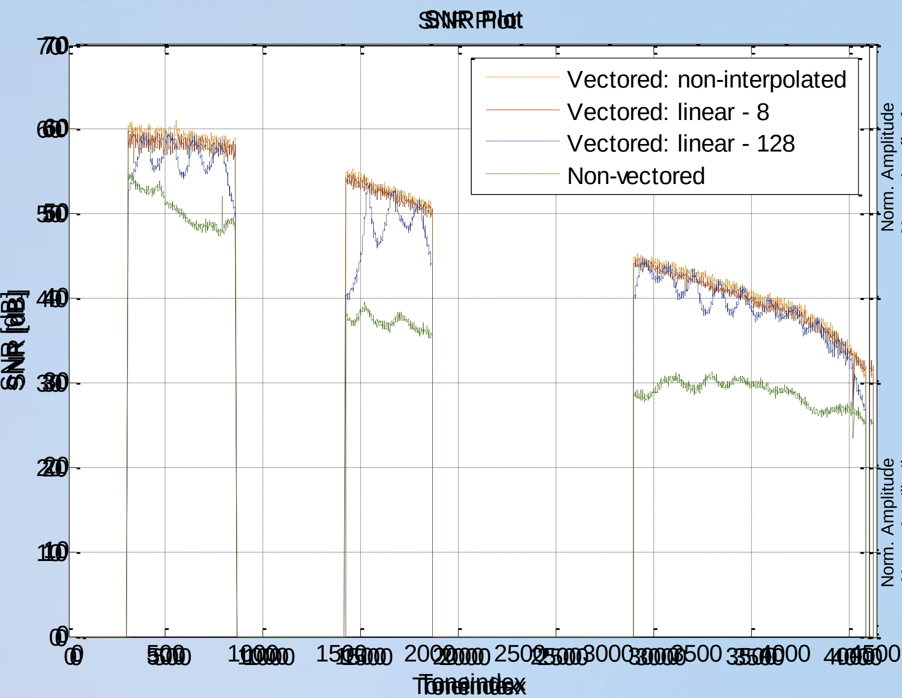
- Downstream Crosstalk Coefficients (Measurement):

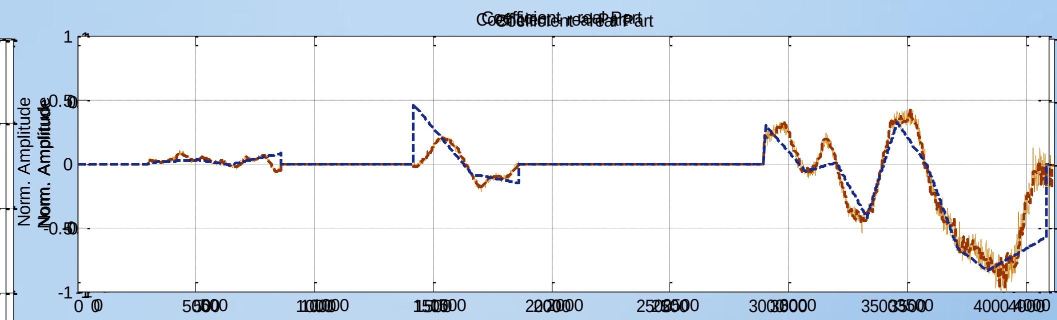


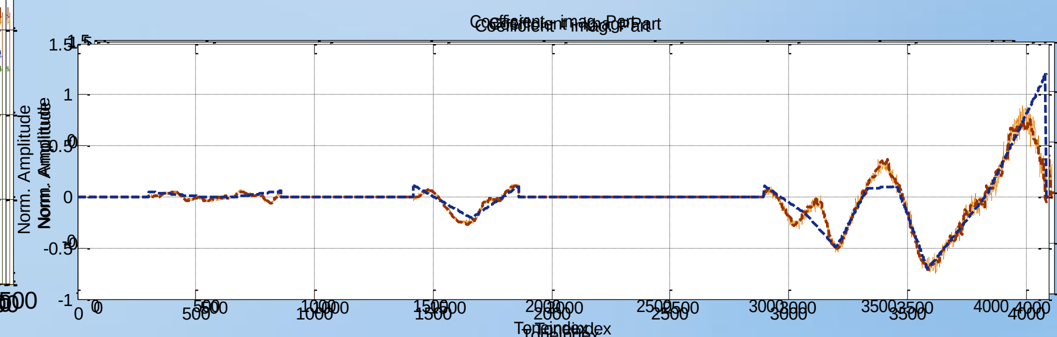
- Crosstalk Coefficients are slowly changing (“smooth”) over frequency

- Smoothness can be utilized for vectored systems:
  1. Backchannel Datarate: Slicer error values are only reported for every n^{th} carrier
  2. Coefficient Memory: Storing coefficient matrices for every n^{th} carrier - other coefficient matrices will be interpolated

Crosstalk Coefficient Interpolation

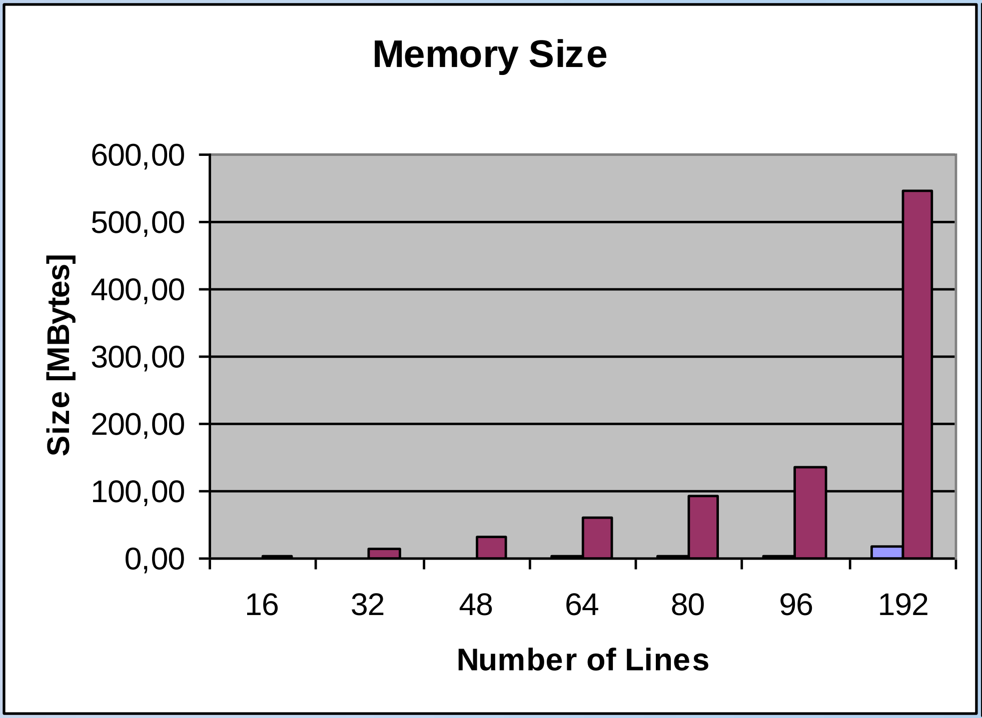


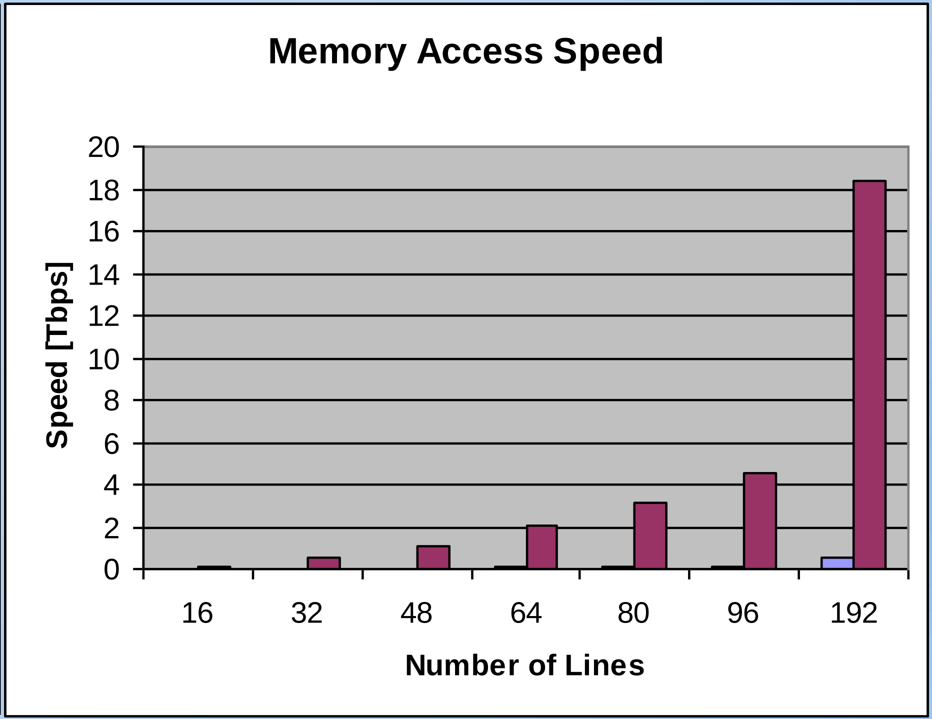




Interpolation Factor	Required Coeff Memory		Datarate	
No Interpolation	3664 kByte	100.0%	102.6 Mbit/s	100.0%
8	458 kByte	12.5%	102.3 Mbit/s	99.7%
128	29 kByte	0.8%	98.0 Mbit/s	95.6%
No Vectoring			72.2 Mbit/s	70.4%

Crosstalk Coefficient Interpolation

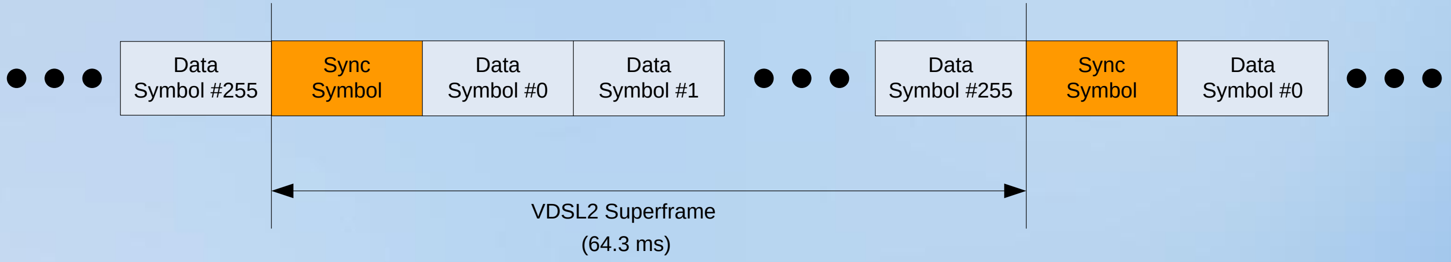




Reduction in memory size and access speed allows support of large cable bundles!

Initialization Time

- Coefficient calculation and update is based on pilot symbols and orthogonal sequences:

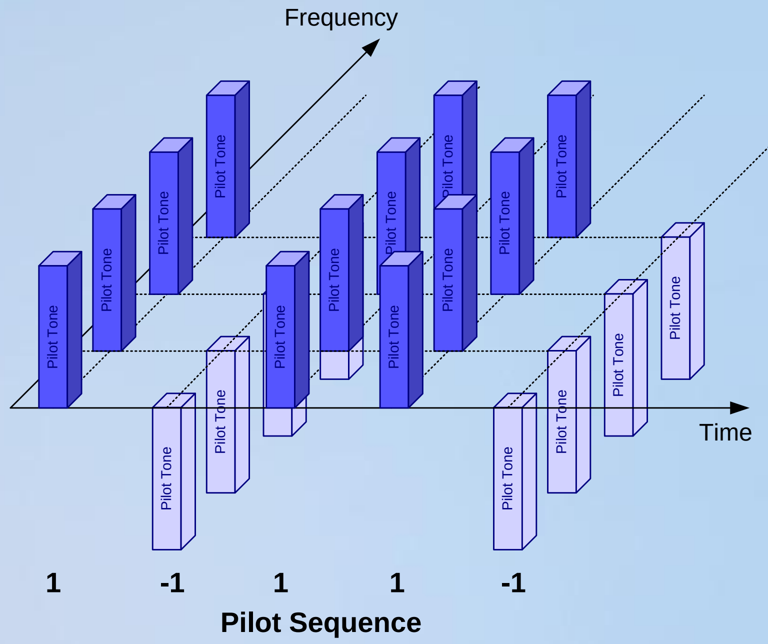


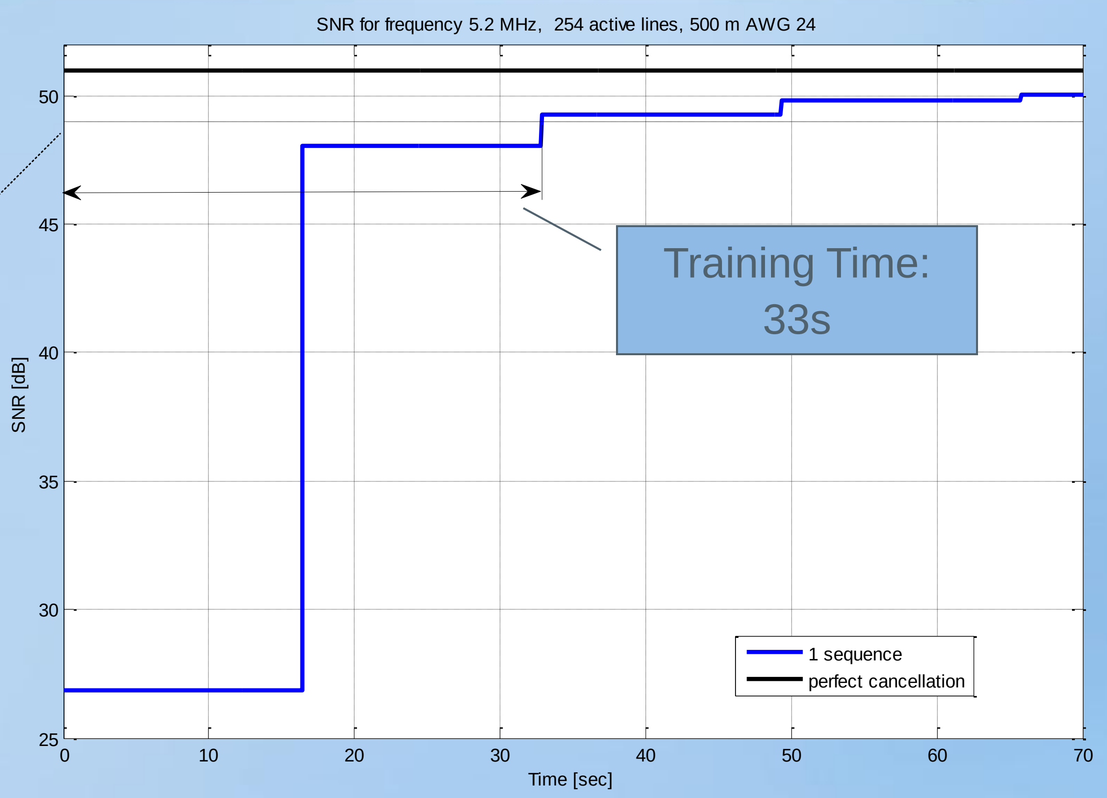
- Duration of two orthogonal sequences:

Active Lines	# SyncSymbols	Training Time
64	128	8.2 s
128	256	16.4 s
256	512	32.9 s

- Complete Initialization consists of g.handshake, VDSL2 initialization, and crosstalk coefficient training

Initialization Time

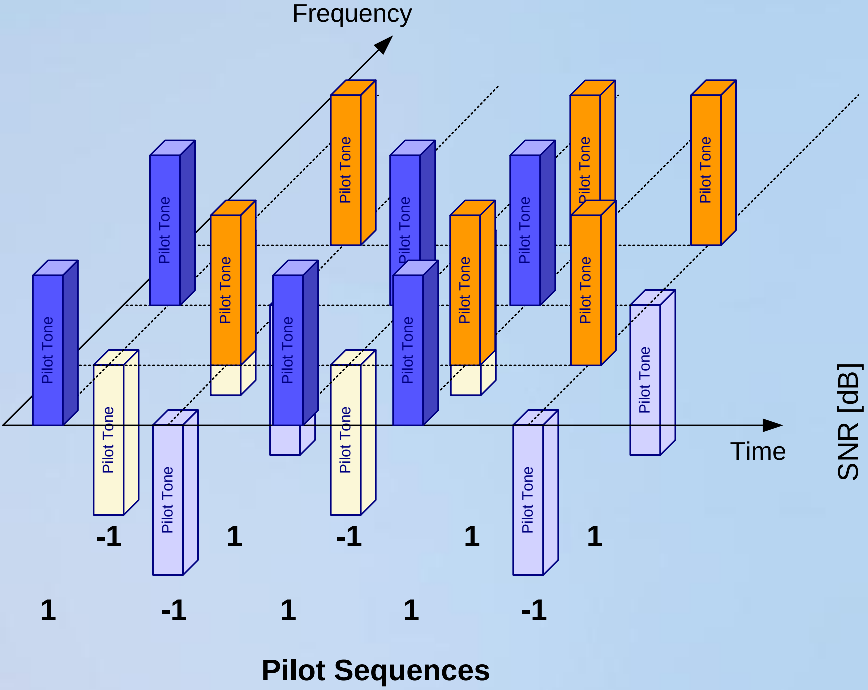


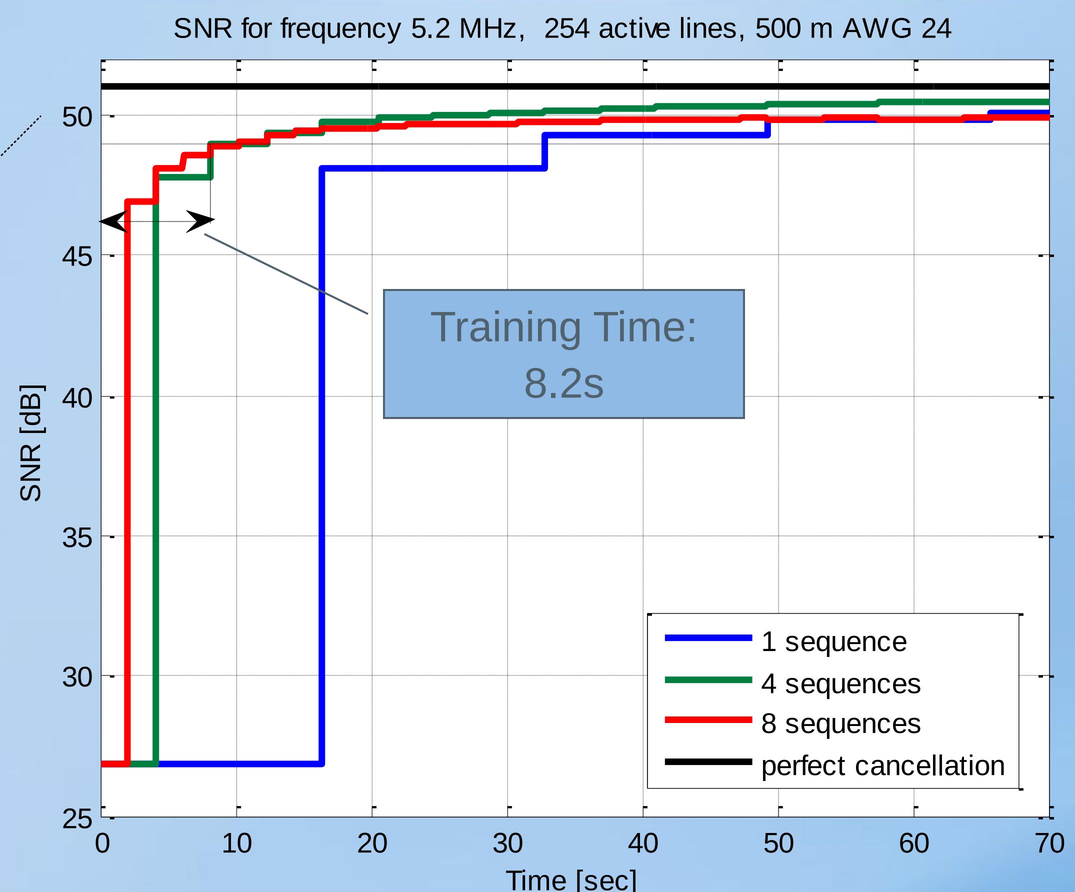


- G.vector defines the same pilot sequence for all frequencies
- Crosstalk Coefficient Calculation requires approx. 33s for a system with 255 active lines
- Overall VDSL2 initialization will be larger than 1 minute

→ Long Initialization Time might reduce customer acceptance of vectoring technology

Initialization Time





- Using different sequences on neighboring carriers allows a reduction of the orthogonal sequence length
- Crosstalk coefficients are determined by interpolation techniques

Training Time can be reduced by at least a factor of four!

Conclusions

- Vectoring Performance has been demonstrated successfully with commercial VDSL2 chipset
- Rate improvements of more than 100% have been achieved
- “Smoothness” of crosstalk coefficients can be utilized to solve key issues of large vector systems
- Commercial deployments of vectoring become realistic even for cabinet applications

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