QAM VDSL & SHDSL

Combined EFM PHY using Single Carrier Modulation

Combining SHDSL & QAM VDSL in an EFM PHY

802.3ah EFM Copper

June 2003, Ottawa

Supporters

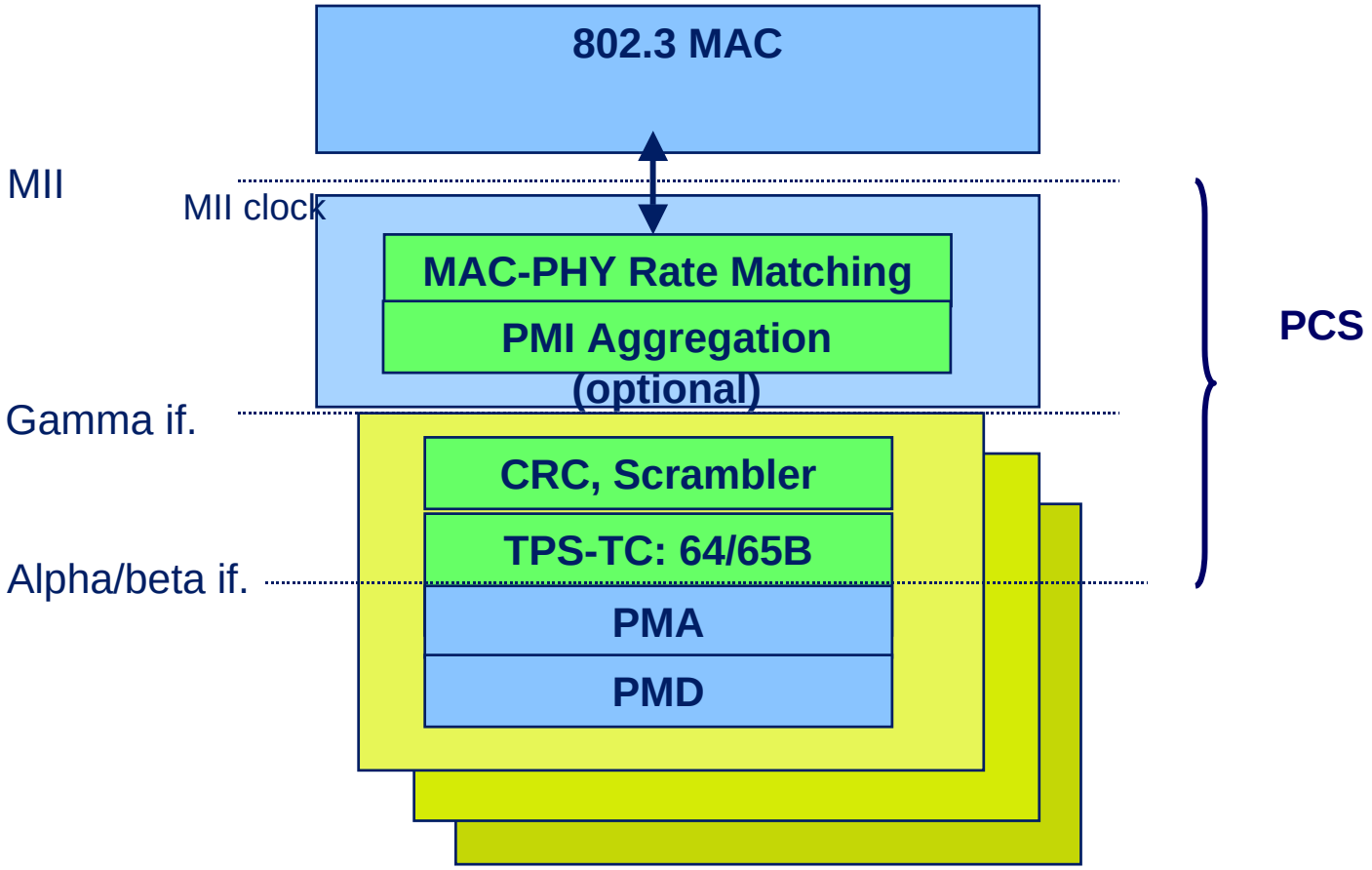
The Vision

- **SCM technology used over copper by IEEE**
  - 1000BaseT, considered for 10GBaseT
- **Autonegotiation is the best way to achieve simplicity for the end user and provider**
- **Single EFM Copper PHY enables all the above**
- **Single EFM Copper PHY means new entrants get a chance to catch up, no market hogs**
- **The cost of a combined EFM PHY is slightly more than a QAM VDSL PHY today, which is ½ to 1/3 of DMT VDSL PHY**

EFM Copper Objectives

- **Long reach objective**
  - 2Mbps @ 2700m
  - SHDSL adopted by 802.3ah in January
- **Short reach objective**
  - 10Mbps @ 750m
  - VDSL is the technology
  - Line code: we need to decide now between QAM and DMT

EFM PHY structure



- Green blocks: common to both objectives
- PMA & PMD: QAM VDSL and SHDSL have much in common

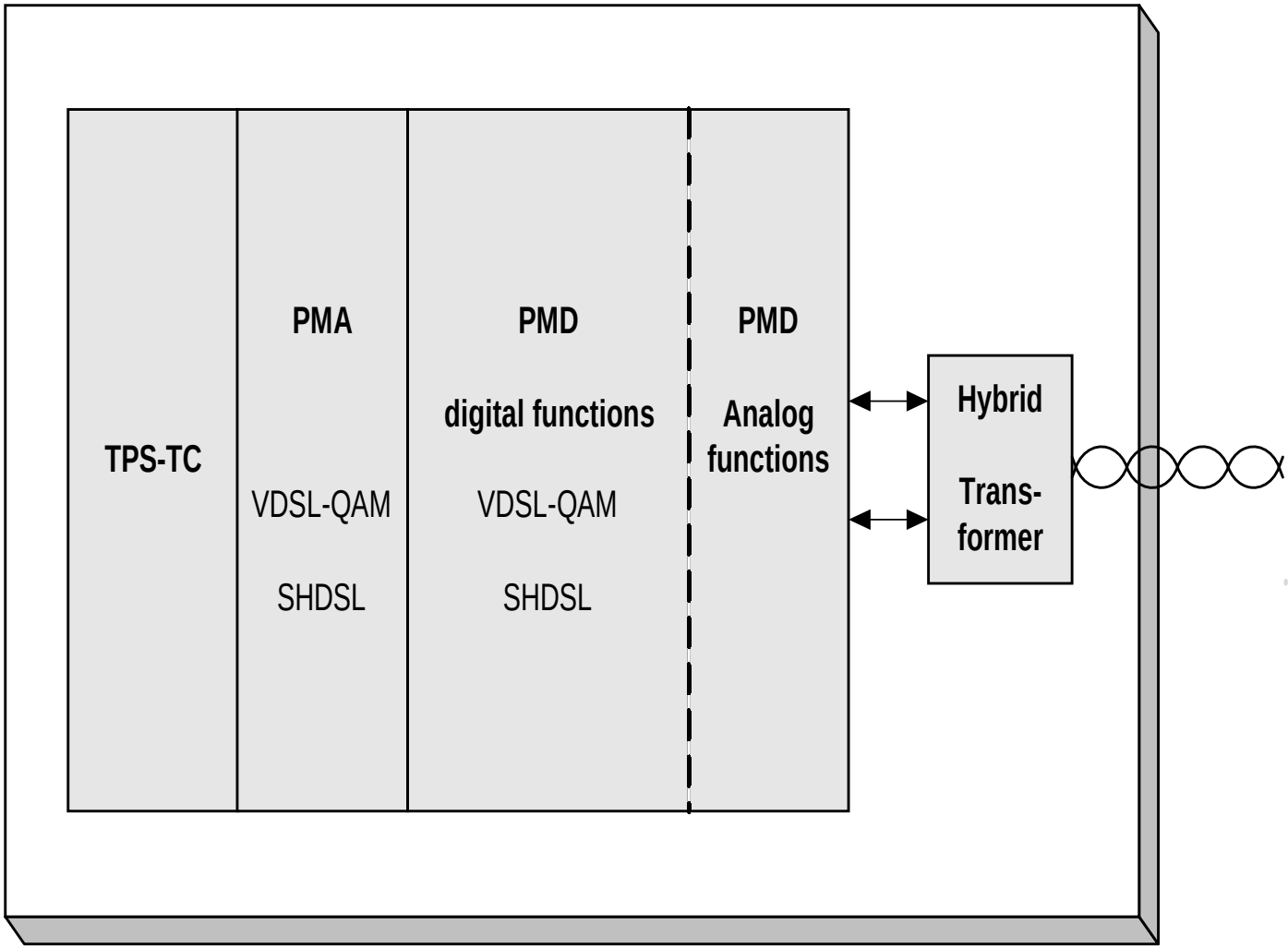
Introduction – the two SCM technologies

- **Target: Single PHY for Long and Short reach objectives**
- **G.SHDSL**
  - PAM (Pulse Amplitude Modulation); base band
  - (Standardized) Symmetrical rates 192kBit/s …2.3Mbps
  - (Capability) Aggregated bit rates of up to 11.4 Mbps
- **QAM VDSL**
  - QAM (Quadrature Amplitude Modulation)~ Modulated PAM; pass band
  - Symmetrical and Asymmetrical transmission technology
  - Duplex aggregated bit rates of more than 100 Mbps

Combining the SCM technologies

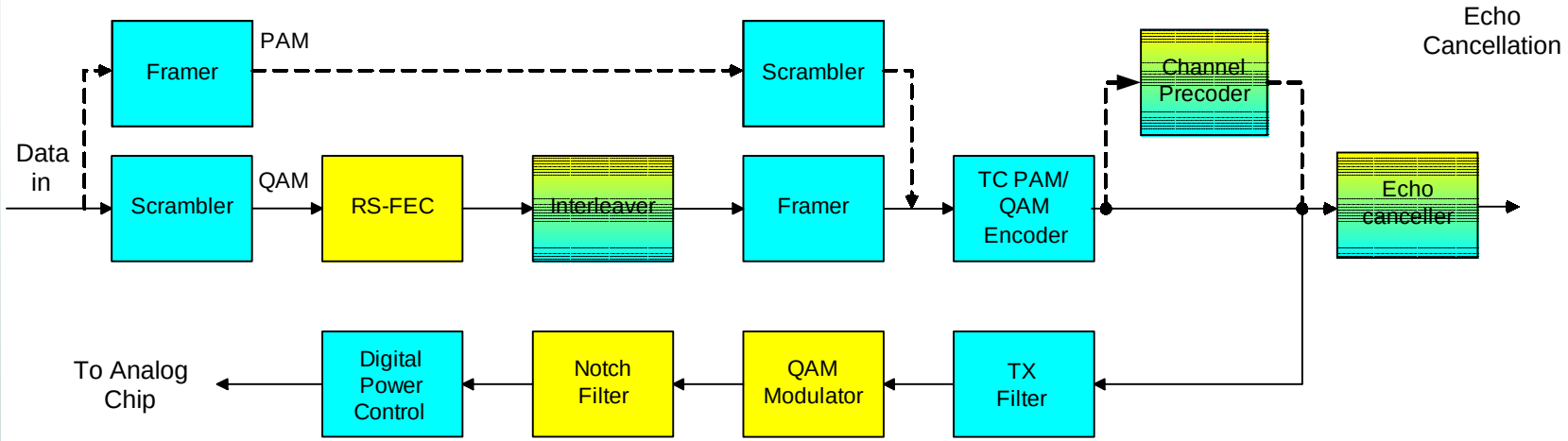
- **G.SHDSL and QAM VDSL in a single chipset**
  - Highest re-use of functional blocks
    - Means smaller die size (cost)
  - Realized at almost no cost overhead and minimal additional space for VDSL
    - Means little additional complexity and die size increase over QAM VDSL die size
  - VDSL Functions and Calculation Power fulfills most Requirements of SHDSL
  - Optimal for EFM applications and for businesses broadband access
  - Follows same Autonegotiation concept of 10BaseT and 100BaseT
  - One PHY handles all EFM Copper needs

Structure of a common SHDSL / VDSL-QAM Transceiver

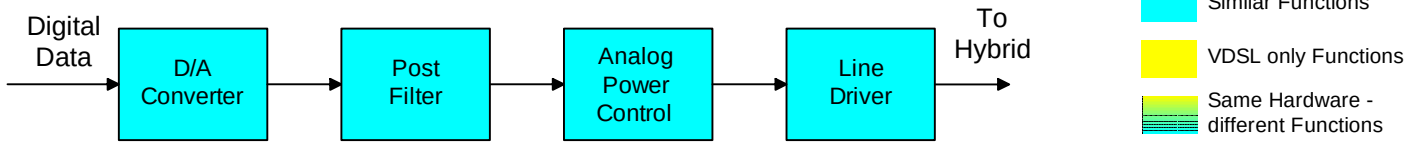


Common Functions in VDSL QAM and SHDSL Transmit Path

The transmit path (digital)

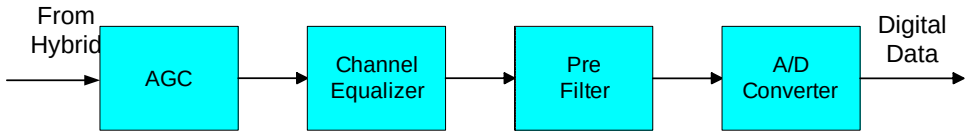


The transmit path (analog)

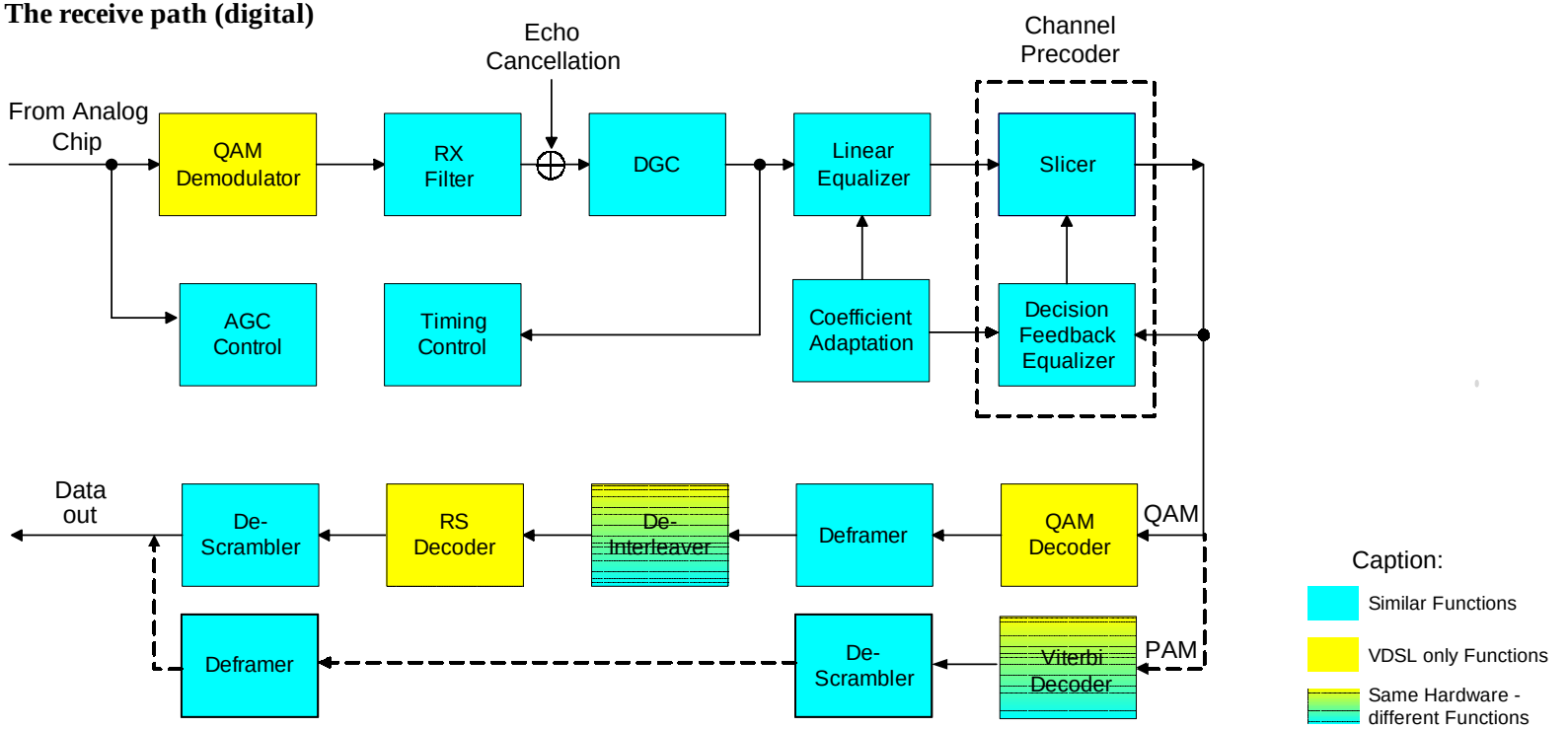


Common Functions in VDSL QAM and SHDSL Receive Path

The receive path (analog)



The receive path (digital)



Function Blocks of VDSL that can be used by SHDSL

- **Scrambler / Descrambler and Framer / Deframer**
- **QAM Encoder and TC PAM Encoder (w/o Tomlinson)**
- **Decision Feedback Equalizer, LEQ, Slicer**
  - DFEq used as SHDSL Tomlinson Encoder at show time
- **Tx Filter / Rx Filter**
- **Power control / AGC / DGC**
- **DA converter / AD Converter**
  - Same Hardware requirements for high Bandwidth of VDSL and high resolution of SHDSL selected by Noise Shaping / Decimation parameters
- **Line Driver**
  - 135 Ohm nominal Impedance (SHDSL and VDSL QAM)
  - 14.5 dBm Transmit Power (SHDSL and VDSL QAM)
  - Crest-factor: SHDSL= 2.9 ; VDSL= 3.5
- **G.hs: SHDSL and VDSL are members of the 4 kHz Carrier set signaling family**

Blocks that can be used for different functions for SHDSL and for VDSL

- **RAM:**
  - SHDSL needs in total 75% of the amount of RAM as QAM VDSL for signal processing
  - When FEC and interleaver comes into a standard, SHDSL will use the unused 25% for interleaving
- **(De-)Interleaver for VDSL:**
  - SHDSL will use the RAM for Viterbi and Echo cancellation
  - All these blocks consist of 85% of RAM

Coverage of SHDSL Development in Standardization

A combined QAM VDSL and SHDSL PHY provides sufficient signal processing resources to perform the new SHDSL features currently discussed in standardization bodies

- Higher Data Rates up to 5.7 Mbps
- Wide PSD of 713 kHz
- Higher constellations of 32, 64 and 128 levels (4, 5, 6 Bits per Symbol)
- Operation with underlying POTS (SHDSL over POTS)
- Forward error correction and Interleaving
- Bonding of high numbers of loops

Comparison of VDSL-DMT vs. SHDSL

SHDSL	DMT VDSL
Amplitude Modulation	Discrete multi tone
Symbol frequency 64 kHz … 770 kHz (1426 kHz)	Symbol frequency 4 kHz
Bit processing	250 or 125 µs Block processing
DFE	*Not available*
Not available	(I)FFT
Trellis Viterbi for PAM with 5dB coding gain	*Not available*
Digital Echo cancellation	*Not available*
Synchronization on Symbols (3 or 4 bits)	Pilot tone
Crest factor 2.9	Crest factor 5.6
g.hs tones: 4 KHz	g.hs tones: 4.3125 KHz

Summary: DMT VDSL provides many functions that cannot be used for SHDSL and vice versa. A combined chip carries a lot of overhead and is far from being optimized.

Summary

- SCM all the way through
- Follows the IEEE view of combined PHYs and Autonegotiation
- QAM and SHDSL PHYs have many blocks that can be shared or re-used
- QAM vendors have proven expertise and field experience in SCM - both QAM and SHDSL technologies
- VDSL QAM and SHDSL are easy to implement
- Development cycle for a combined SHDSL & QAM VDSL will be shorter
- Size and cost of chip-set will be lower than a DMT VDSL and SHDSL PHY