Ethernet over VDSL

DMT Concepts and Advantages

IEEE 802.3ah Ethernet in the First Mile

Saint Louis, March 11-14 2002

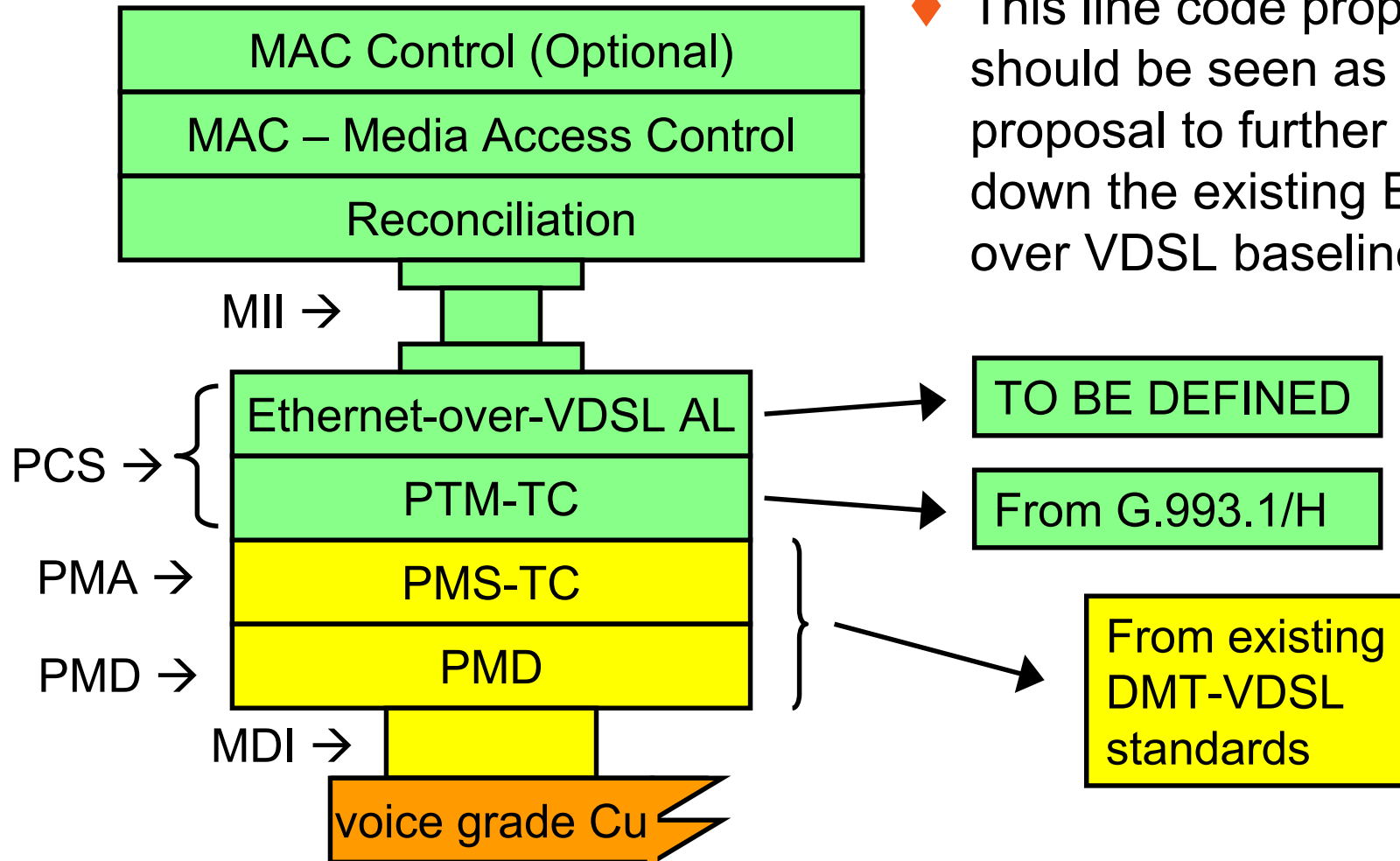- Michael Beck, **Alcatel**

- Behrooz Rezvani, **Ikanos**

- Christophe Del-Toso, **ST Microelectronics**

- Sedat Oelcer, **IBM**

- Tariq Haddad, **Zarlink**

- Massimo Sorbara, **GlobespanVirata**
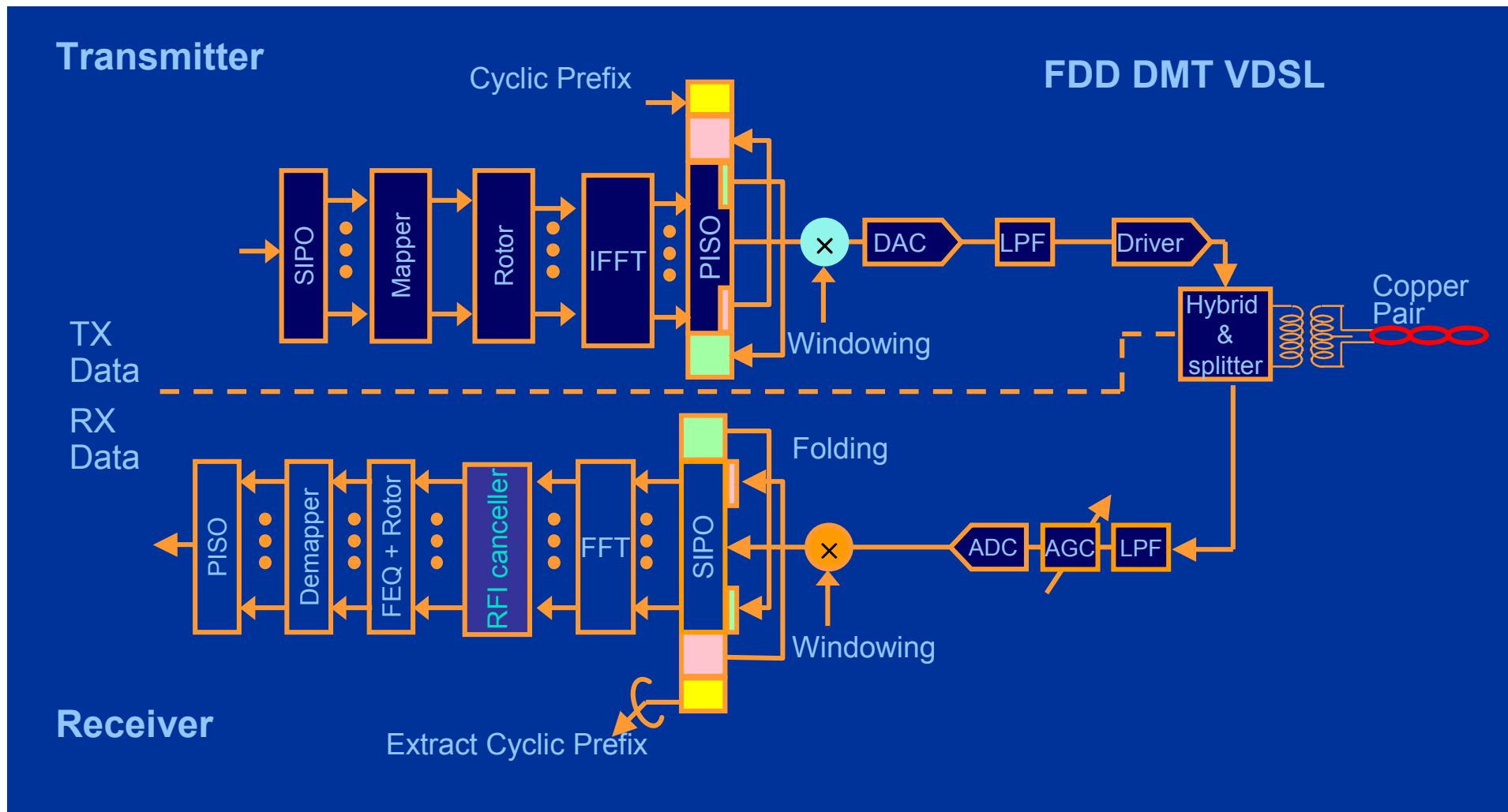
- Doug Artman, **Texas Instruments**

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◆ **Ethernet over VDSL** for EFM over Point-to-Point Copper

◆ **DMT Concepts**

- Modulation Technique
- Windowing, RFI Canceling
- Digital Duplexing

◆ **Specification of DMT-VDSL**

◆ **Advantages of DMT-VDSL**

- RFI Robustness
- EMC Friendly
- Spectral Flexibility
- PSD Control

◆ **Availability of DMT-VDSL**

◆ **Possible Additions to DMT-VDSL**

◆ **Conclusions**
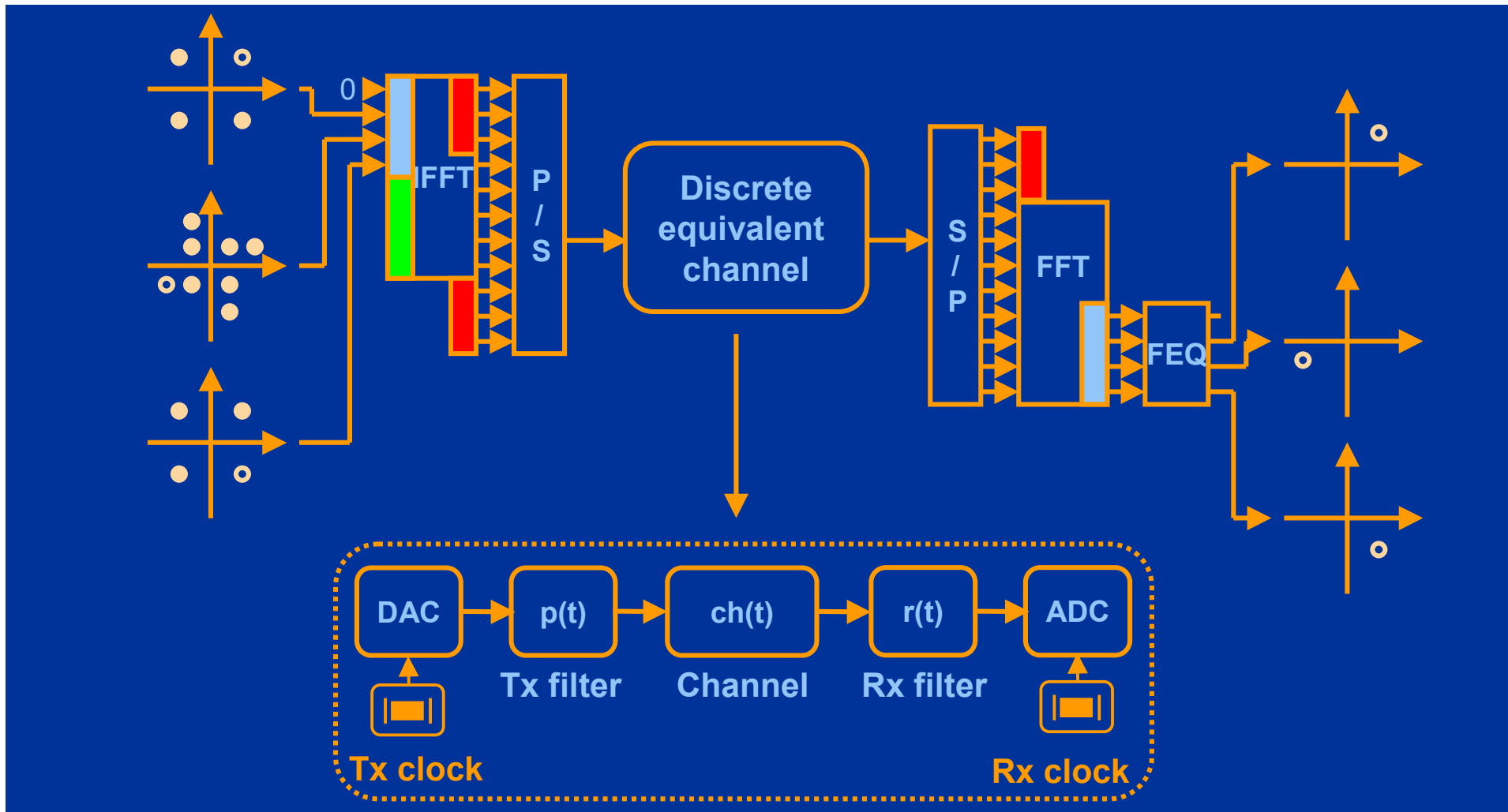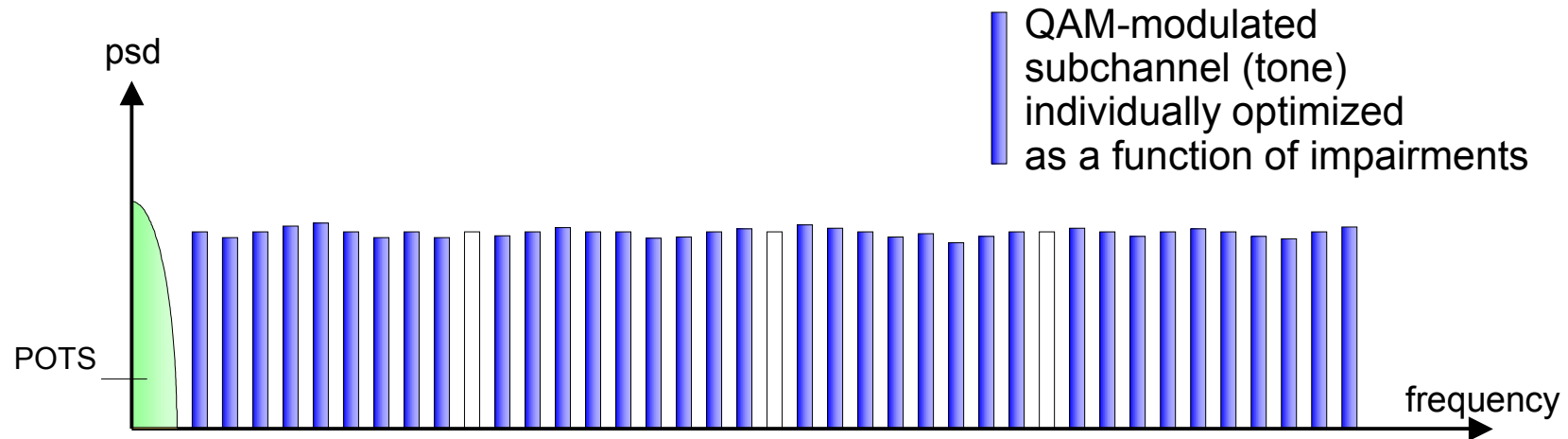
EFM over Point-to-Point Copper
Ethernet over VDSL

◆ This line code proposal should be seen as a proposal to further narrow down the existing Ethernet over VDSL baseline.

MAC Control (Optional)

MAC – Media Access Control

Reconciliation

MII →

Ethernet-over-VDSL AL

PCS →

PTM-TC

PMA →

PMS-TC

PMD →

PMD

MDI →

voice grade Cu

TO BE DEFINED

From G.993.1/H

From existing DMT-VDSL standards

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QAM-modulated
subchannel (tone)
individually optimized
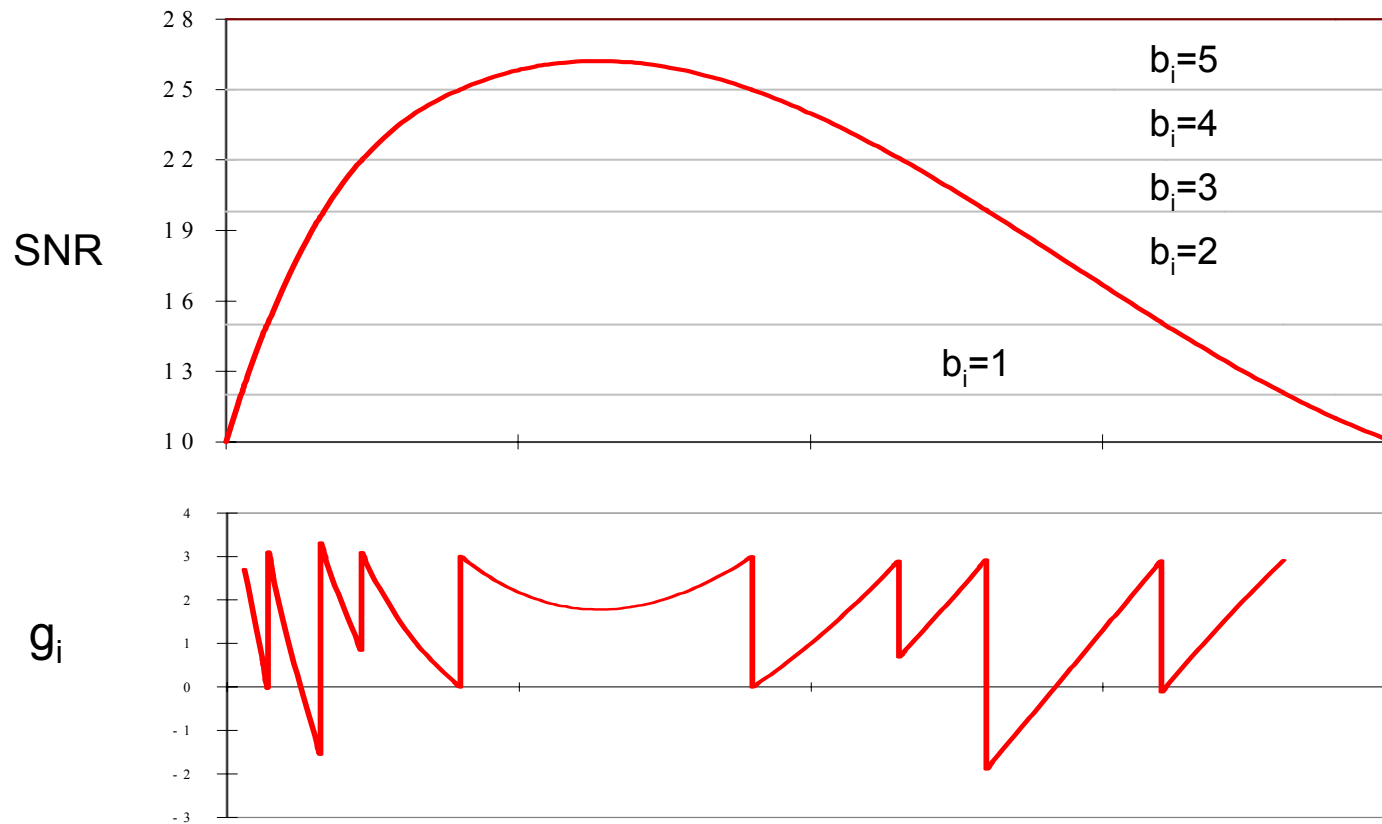as a function of impairments

psd

POTS

frequency

- ◆ DMT is similar to OFDM (as used in 802.11a, DAB, DVB)

- ◆ ADSL compatible tone spacing (4.3125 kHz)
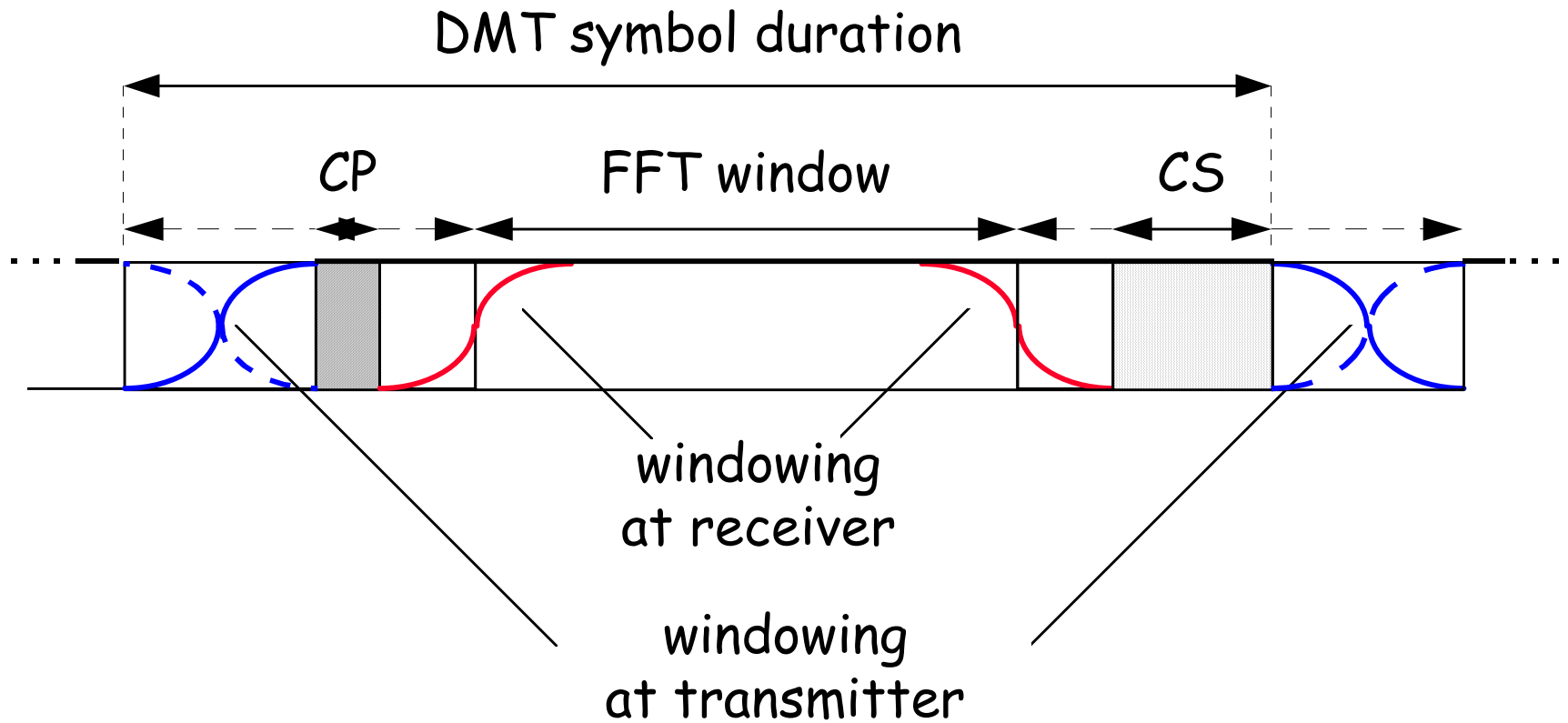
- ◆ 12 MHz bandwidth, as specified in ITU-T

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♦ constellation size and power of each tone are optimized in function of loop attenuation and noise environment

♦ optional rate adaptation at startup to provide maximum rate over given loop

♦ optional dynamic rate adaptation to track variations in loop attenuation or noise environment

♦ optional power boost on long lines

♦ power reduction on short lines (politeness)

♦ optional spectral shaping (including tone masking)

Target Bit error rate= 10^{-7}

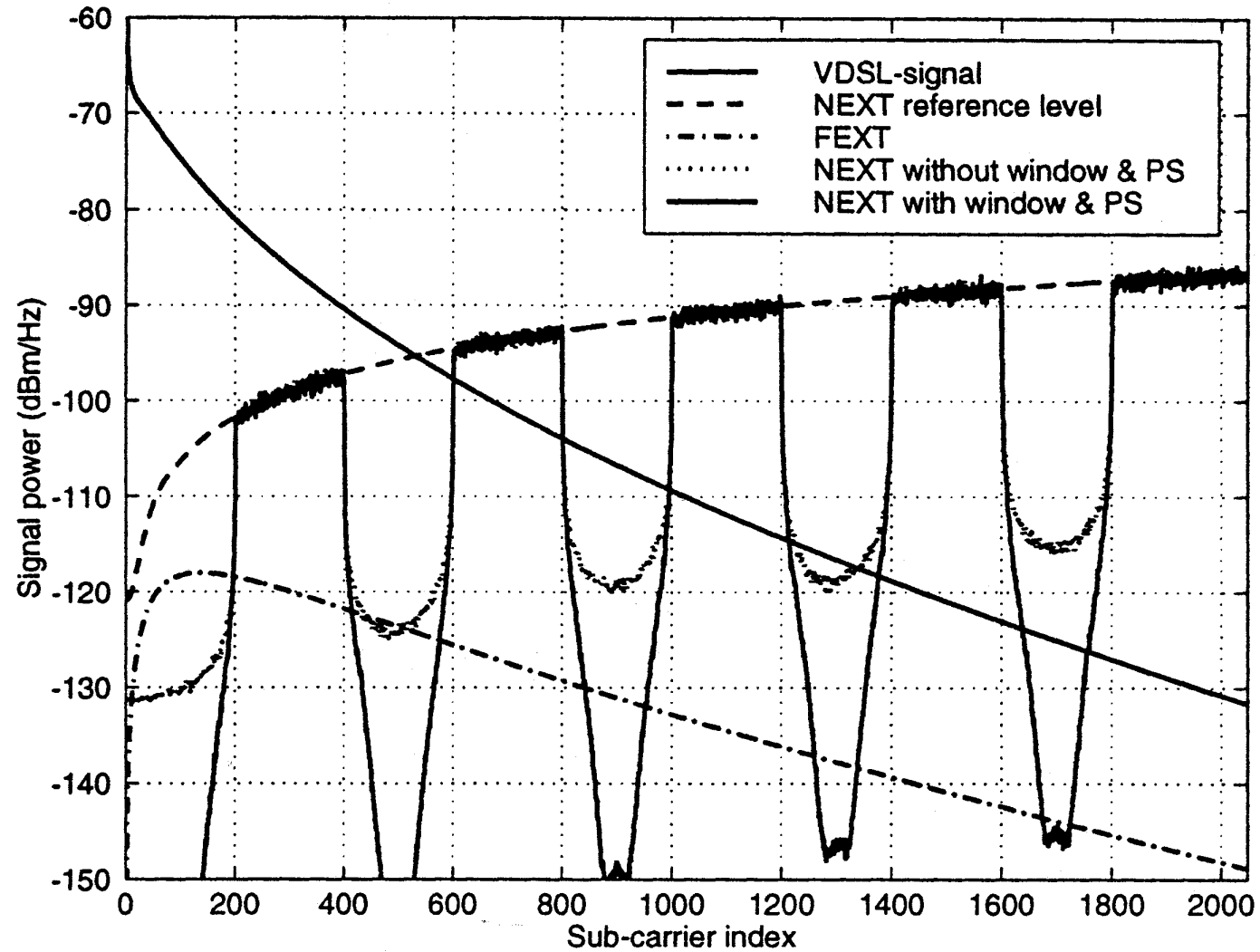$$b_i = \log_2(1 + \frac{SNR}{\gamma} \cdot \frac{gain}{m \arg e})$$

SNR

b$_i$=5

b$_i$=4

b$_i$=3

b$_i$=2

b$_i$=1

g$_i$

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DMT symbol duration

CP   FFT window   CS

windowing
at receiver

windowing
at transmitter

♦ **Windowing at the transmitter:**

- ■ **Reduces frequency domain sidelobes**

  - ➔ Reduces the out of band power of the NEXT signal

  - ➔ Allows for digital duplexing
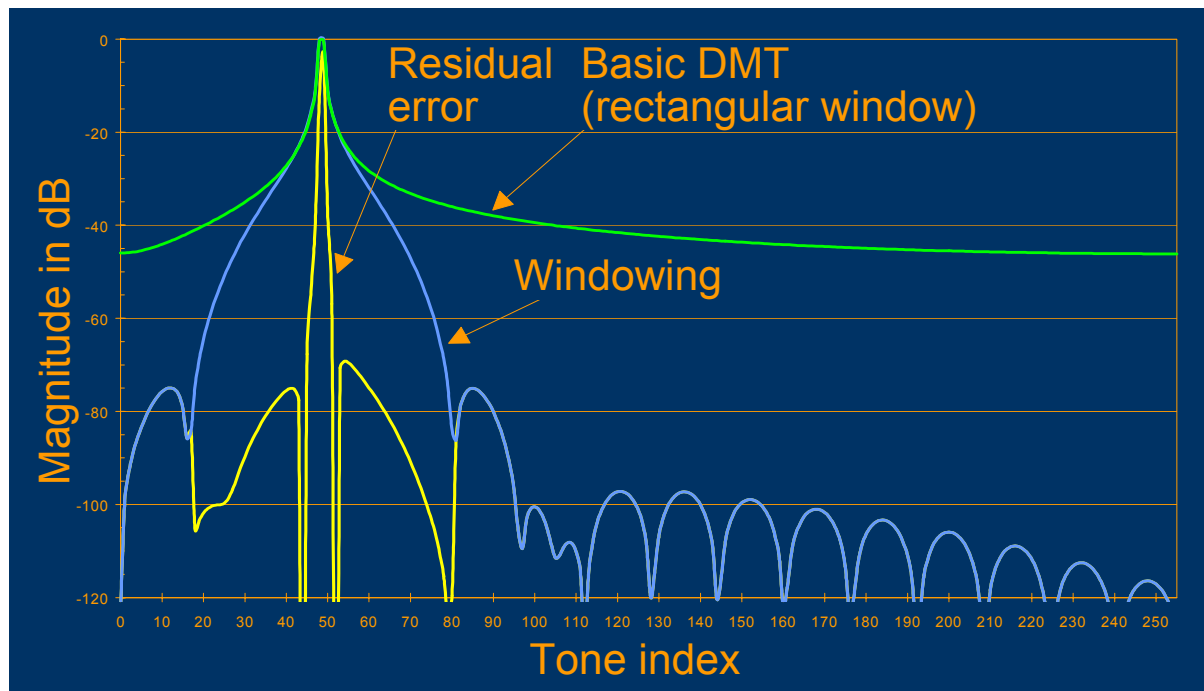
  - ➔ Guarantees spectral compatibility with other services

A L C ▲ T E L

◆ Windowing at the receiver :

  ■ Reduces Inter Symbol Interference (ISI)

  ■ Reduces the susceptibility to RFI

♦ Interferer:

- 4 kHz wide single side-band signal

- AM modulated with Gaussian noise

time

NT Tx

LT Rx
useful

propagation delay   1 symbol

LT Tx

echo

LT Rx
echo

LT Rx FFT-window

prefix (CP)

suffix (CS)   CS > propagation delay

FFT-size

Digital Duplexing
Single Solution Supporting Multiple Frequency Plans

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ADSL
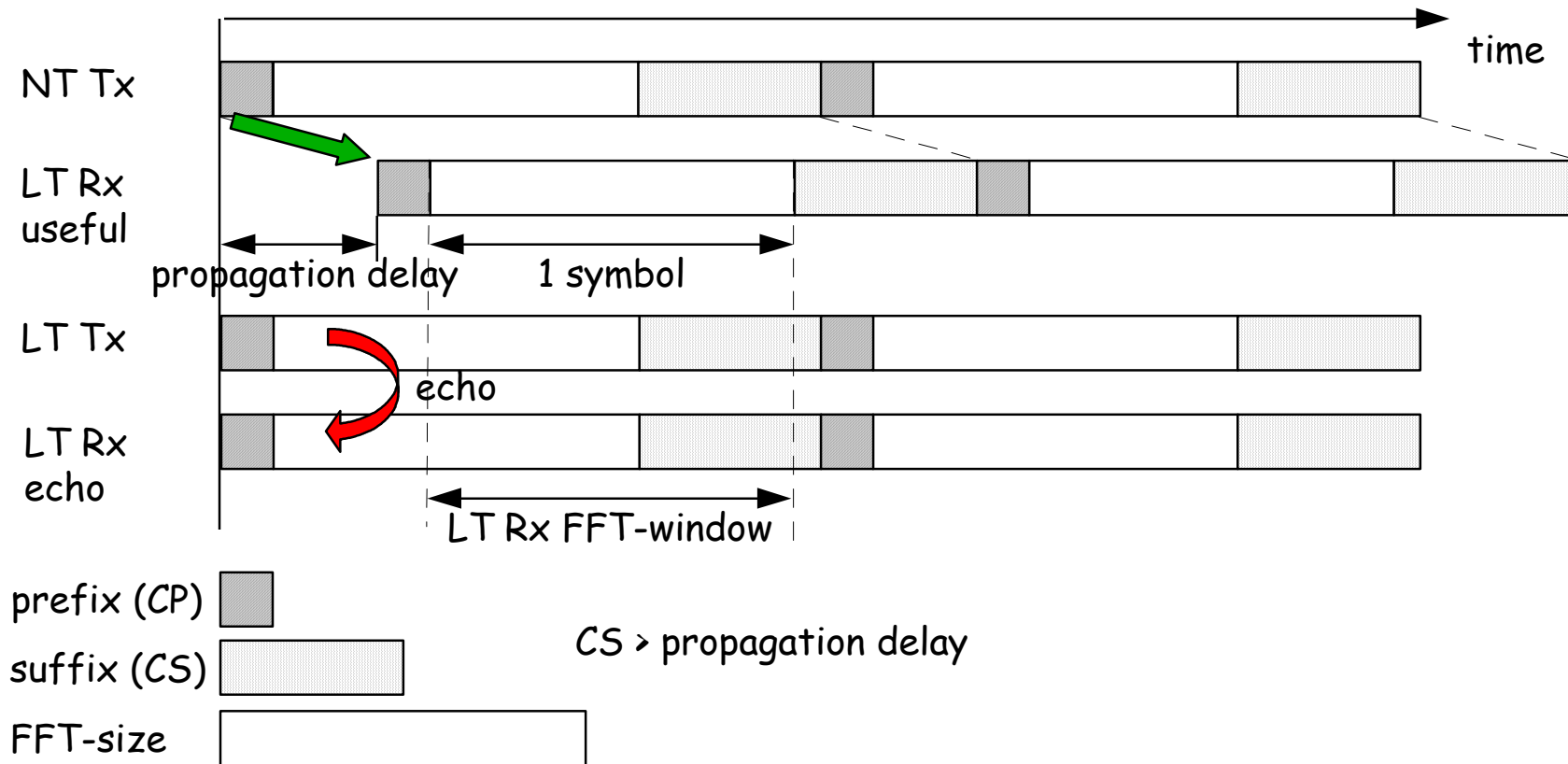
0.138   1.1 MHz

◆ **plan 997** (ETSI + ITU-T) - optimized for **symmetry**

down	up	down	up

0.138   3.0   5.1   7.05   12.0 MHz

◆ **plan 998** (ETSI + T1E1 + ITU-T) - optimized for **asymmetry**

down	up	down	up

0.138   3.75   5.2   8.5   12.0 MHz

◆ **flexible plan Fx** (ITU-T)

down	up	down	up

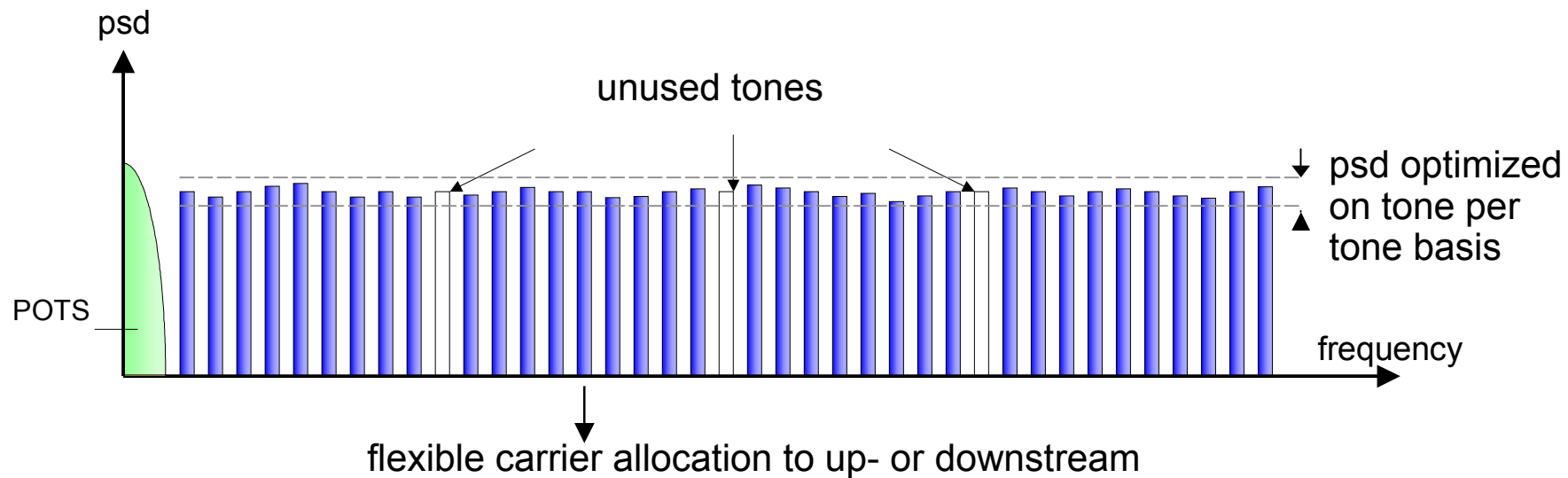0.138   2.5   3.75   ← *Fx* →   12.0 MHz

◆ DMT-VDSL standards are available:

■ Very-High-Speed Digital Subscriber Lines (VDSL) Metallic Interface, Part 3: Technical specification of Multi-Carrier Modulation (MCM) Transceiver, ANSI, T1E1.4/01-013R2, Draft Specification.

■ Transmission and Multiplexing (TM); Access transmission systems on metallic access cables; Very High speed Digital Subscriber Line (VDSL); Part 2: Transceiver specification, ref : ETSI, TS 101 270-2.

◆ DMT is also the line code of ADSL (standardized in ETSI, T1E1 and ITU-T) and G.Lite (ITU-T).

Advantages of DMT-VDSL

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psd

unused tones

psd optimized
on tone per
tone basis

POTS

frequency

flexible carrier allocation to up- or downstream
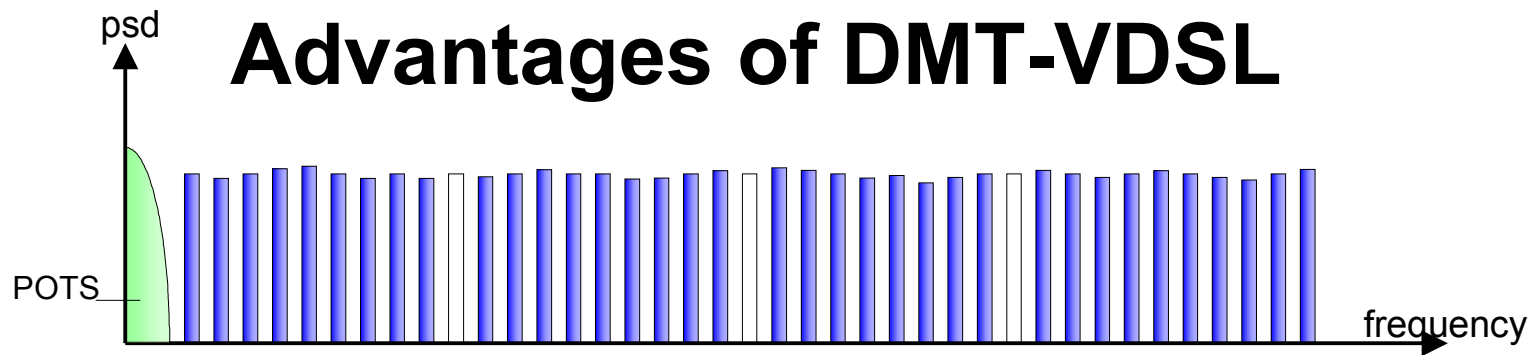
♦ digital duplexing – different spectral plans with same hardware

♦ easy spectral shaping

- ADSL/VDSL co-existence/co-location

- upstream power back-off

♦ prevent radio ingress/egress (HAM radio)

♦ **Three existing bandplans for public networks can be supported by the same hardware (the IFFT/FFT performs the filtering).**

♦ **New bandplans may be defined to suit specific requirements:**

  ■ **Improved symmetry in private networks**

  ■ **Improved spectral compatibility with legacy in-building networks (HPNA, 10/100BASE-T, …).**

♦ **Upstream Power Back-Off:**

■ Standard UPBO requires shaped PSDs

♦ **Improved Spectral Compatibility (fine granularity)**

■ w.r.t. other DSLs

■ w.r.t. legacy in-building services

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The flexibility of
DMT modems is
impressive. We
can even draw
pictures on
the spectrum
analyzer !

Castle

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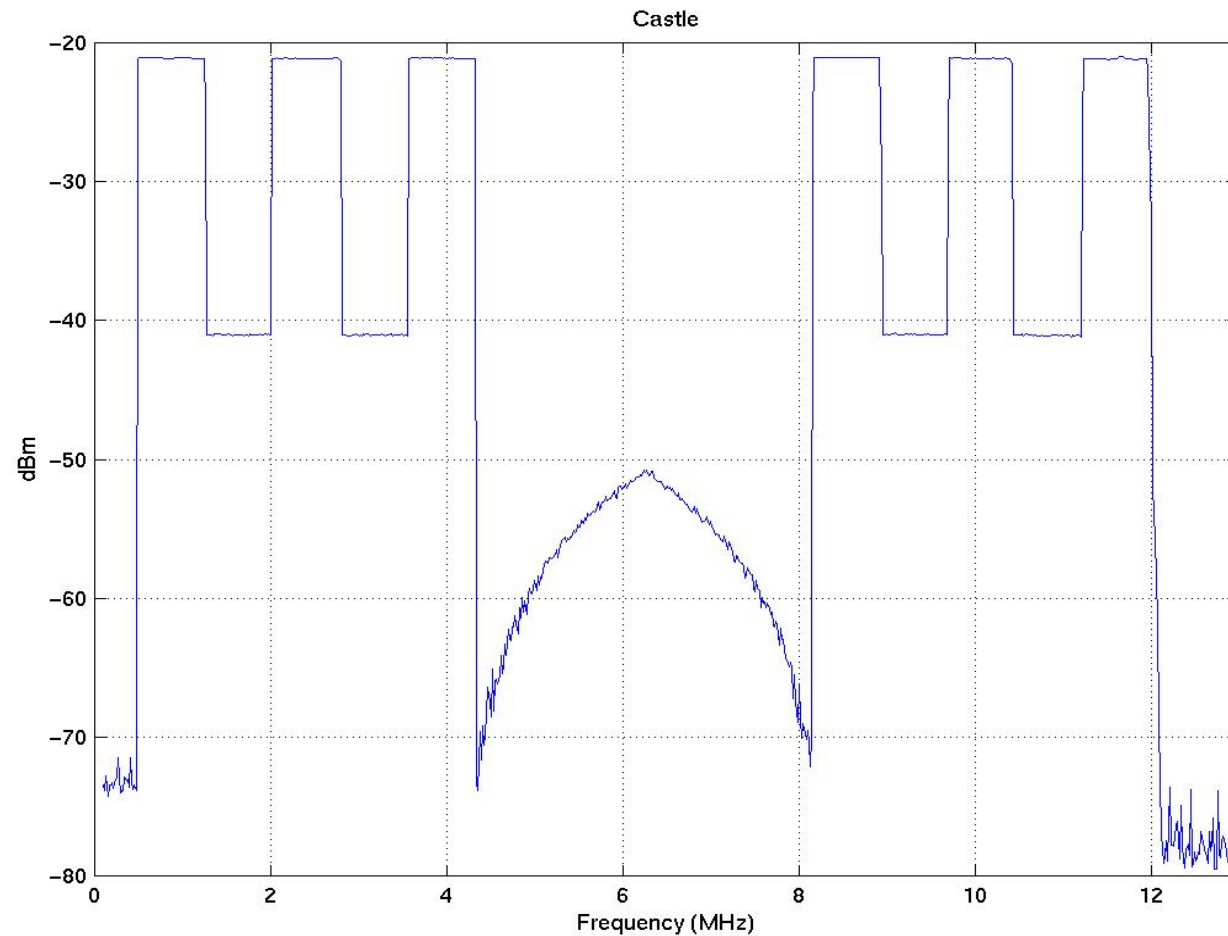
♦ DMT adapts itself to all line and noise conditions.

♦ DMT is the dominant line code in deployed DSL systems. ADSL has millions of lines active in the field.
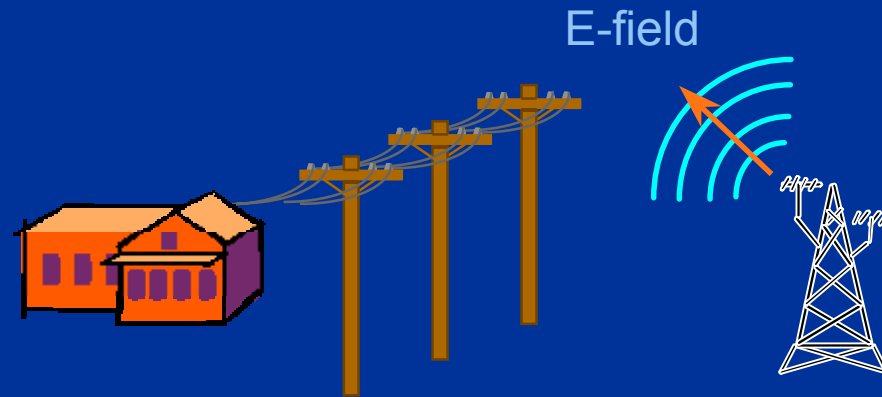
♦ DMT-VDSL is available today.

- ♦ DMT is the line code used by ADSL.

- ♦ DMT-VDSL hardware can be designed to be backward compatible with ADSL.

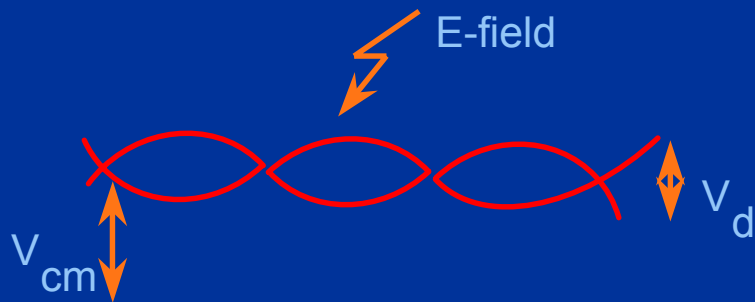- ♦ DMT-VDSL can be used to create a scalable multi-mode system as described in `nov01/del-toso_1_1101.pdf` .
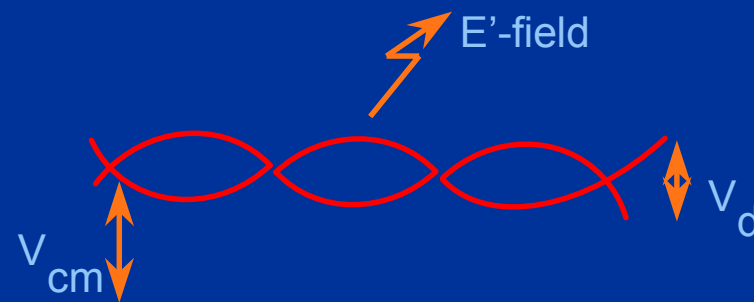
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E-field

Types of interferers :

a   AM broadcast (MW and SW)

a   Amateurs radio bands (HAM radio)

a   Public safety & distress bands

Ingress

E-field
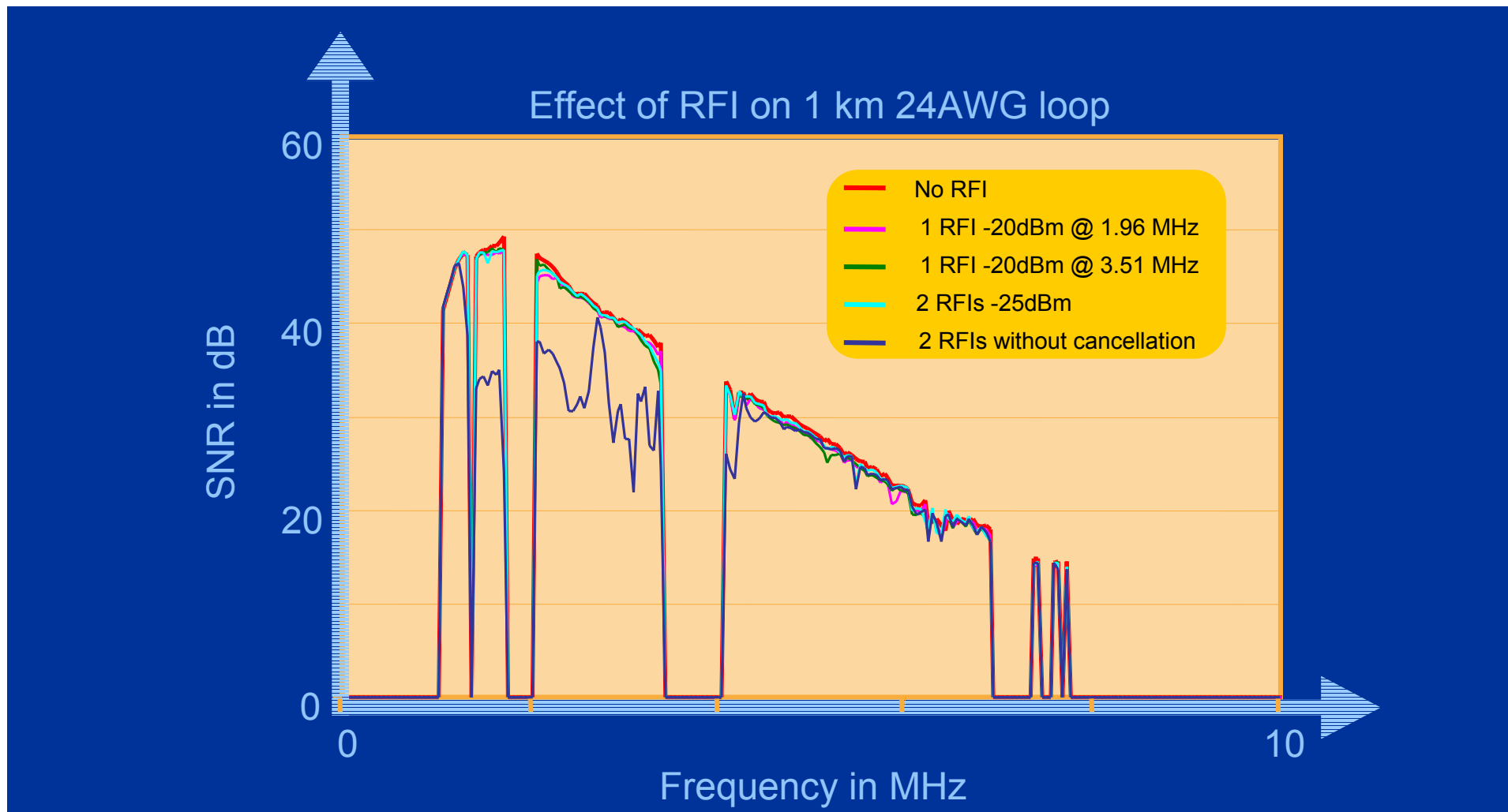
V_d

V_{cm}

Egress

E'-field

V_d

V_{cm}

Common mode to differential mode conversion

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Effect of RFI on 1 km 24AWG loop

Legend:
- No RFI
- 1 RFI -20dBm @ 1.96 MHz
- 1 RFI -20dBm @ 3.51 MHz
- 2 RFIs -25dBm
- 2 RFIs without cancellation

Y-axis: SNR in dB (0, 20, 40, 60)
X-axis: Frequency in MHz (0 to 10)

◆ New band plans (e.g. use of extended optional upstream band to provide more symmetry)

◆ Alternative Power Back-Off

◆ Advanced Coding Schemes

Availability of DMT-VDSL

- ◆ Multiple vendors have DMT-VDSL silicon on the market today.

- ◆ Several other vendors will have DMT-VDSL silicon on the market by end of 2002.

- ◆ Five of these have declared their intention to provide interoperable systems by end of 2002.

♦ **DMT-VDSL is well suited for use in EFM/Copper:**

- Frequency plan flexibility thanks to digital duplexing.

- Flexible PSDs thanks to IFFT based modulation.

- Similar architecture as ADSL allows for backward compatibility with this very successful technology.

- DMT-VDSL is fully standardized in ETSI and T1E1.4.

- Standard compliant transceiver chipsets are available from multiple vendors.