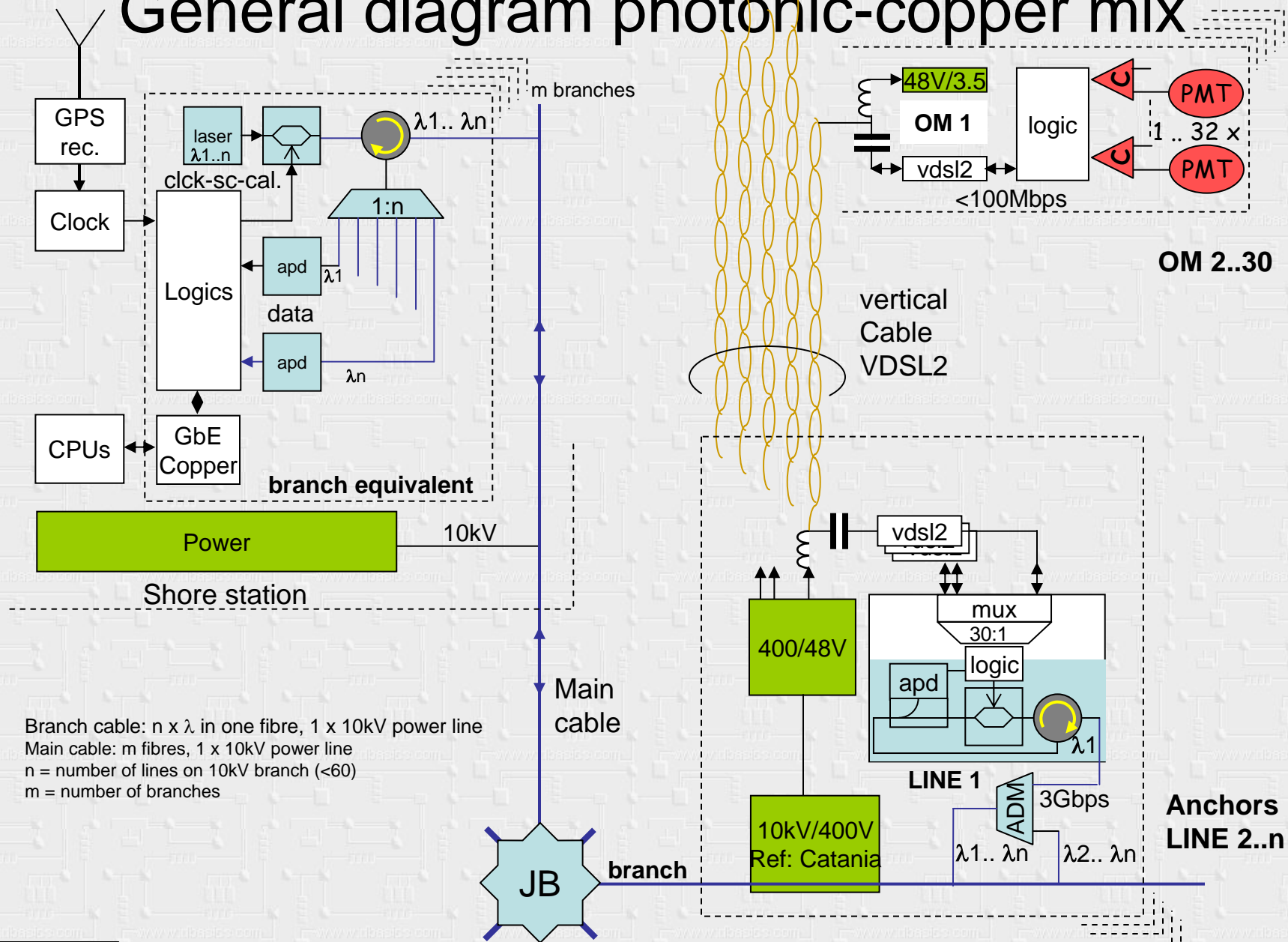# Photonic-copper mix study for KM3NeT

Using VDSL2 in the riser
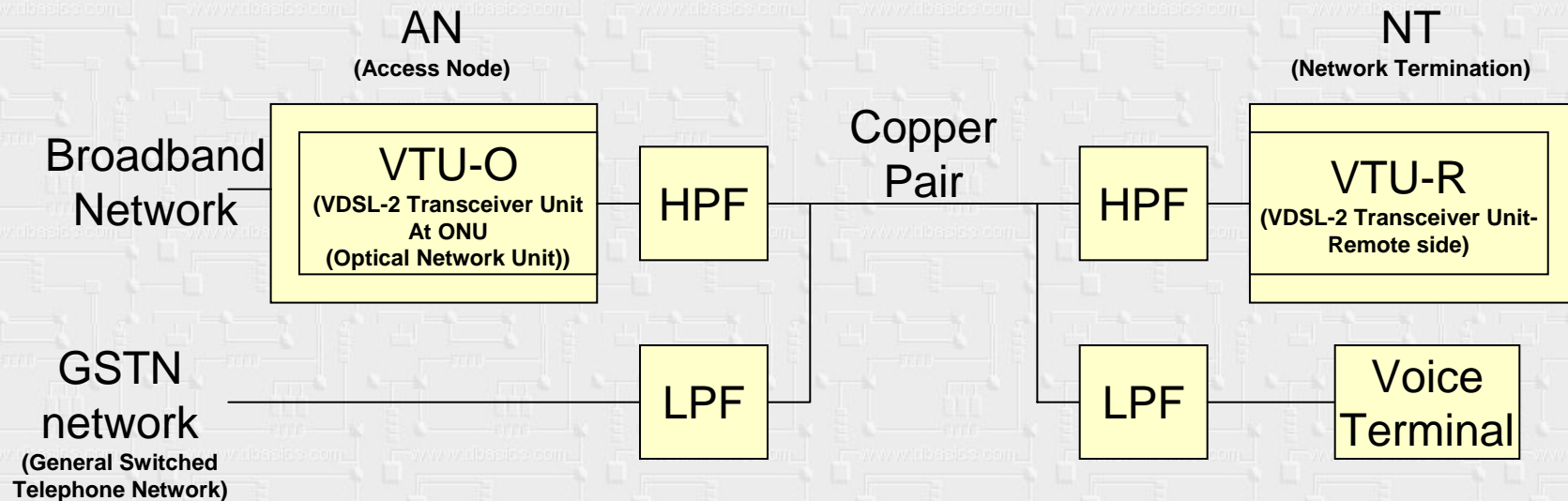
Status 1 November 2006

contributed by: NIKHEF electronic department

Eric Heine, Mar van der Hoek, Jelle Hogenbirk, Peter Jansweijer, Lex Kruijer, Sander Mos, Henk Peek, Paul Timmer.
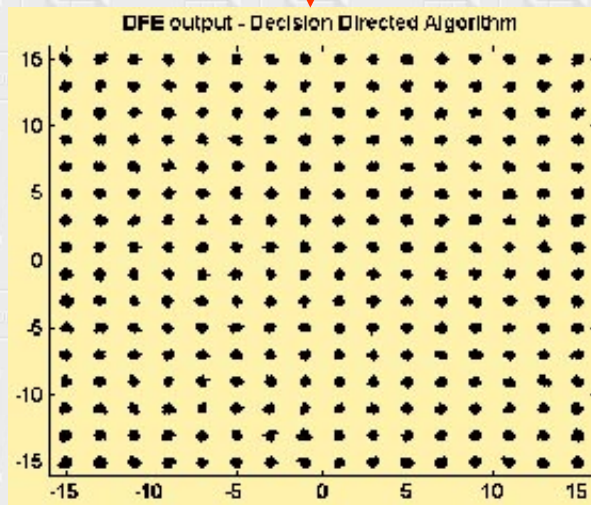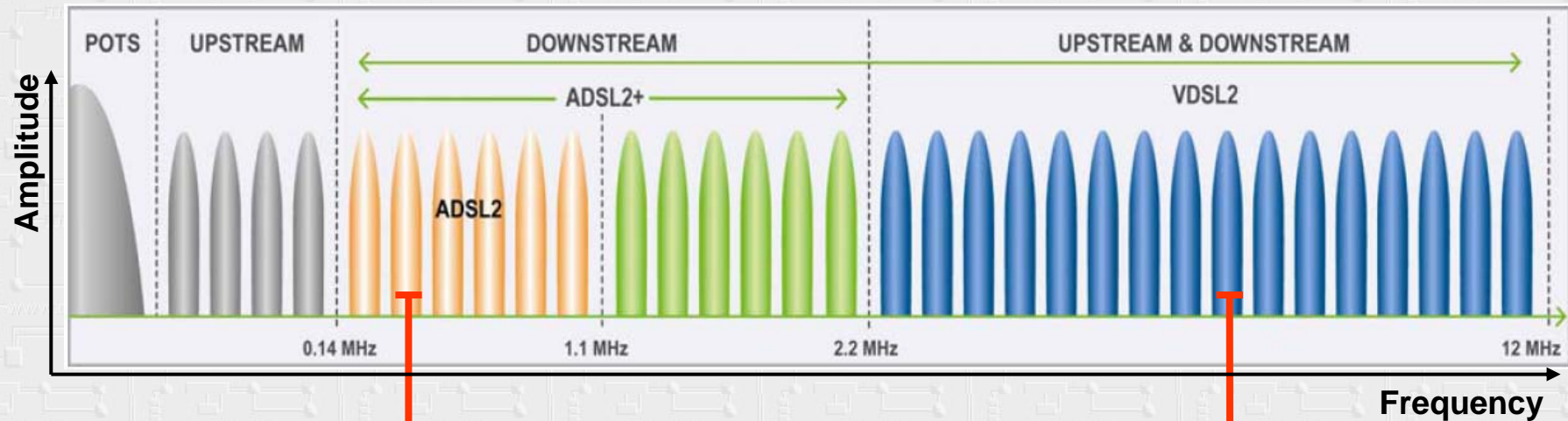
General diagram photonic-copper mix

GPS rec.

Clock

clck-sc-cal.

laser λ1..n

Logics

apd λ1

data

apd λn

1:n

λ1.. λn

m branches

48V/3.5

OM 1

vdsl2

logic

C

PMT

C

PMT

1 .. 32 ×

<100Mbps

OM 2..30

CPUs

GbE Copper

branch equivalent

Power

10kV

Shore station

vertical Cable VDSL2

Branch cable: n x λ in one fibre, 1 x 10kV power line
Main cable: m fibres, 1 x 10kV power line
n = number of lines on 10kV branch (<60)
m = number of branches

Main cable

vdsl2

400/48V

mux
30:1

logic

apd

λ1

LINE 1

ADM

3Gbps

Anchors LINE 2..n

10kV/400V
Ref: Catania

λ1.. λn

λ2.. λn

JB

branch

KM3NeT
KM3NeT

VDSL2 Channel

AN
(Access Node)

NT
(Network Termination)

Broadband Network

VTU-O
(VDSL-2 Transceiver Unit At ONU (Optical Network Unit))

HPF

Copper Pair

HPF

VTU-R
(VDSL-2 Transceiver Unit- Remote side)

GSTN network
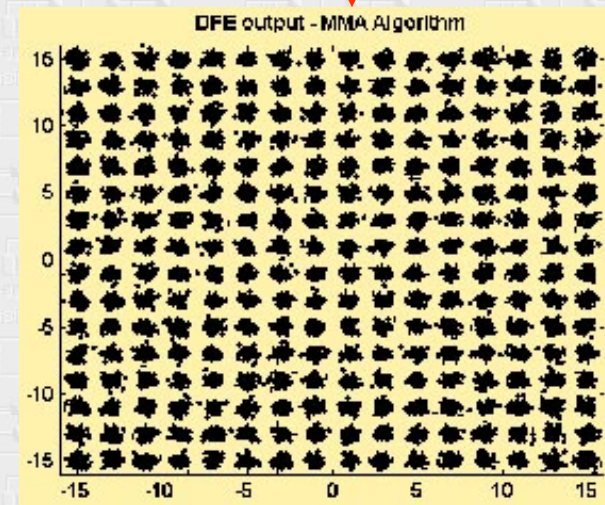**(General Switched Telephone Network)**

LPF

LPF

Voice Terminal

Data with Plain Old Telephone Service (POTS) service application
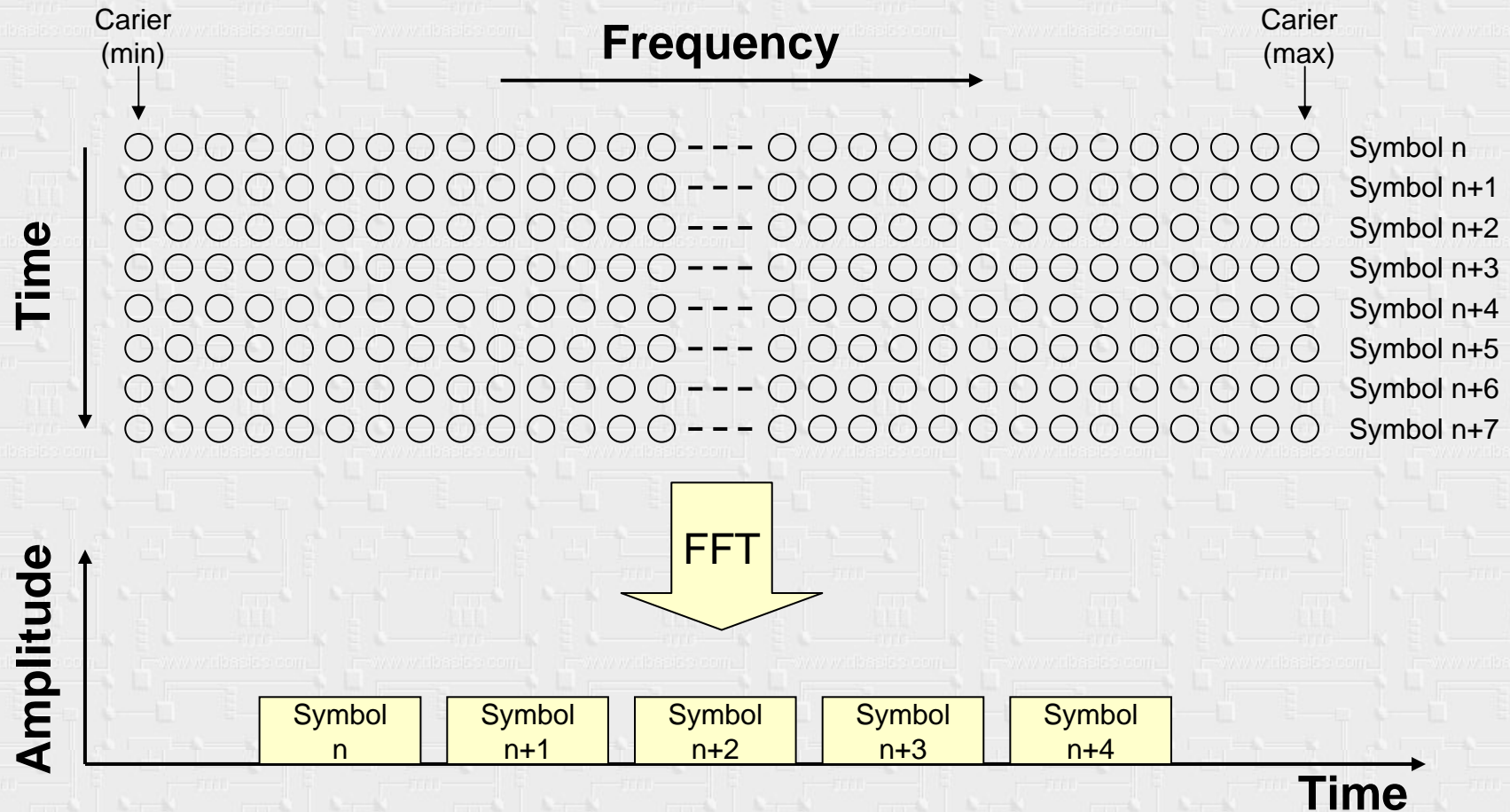Model for remote deployment with splitter
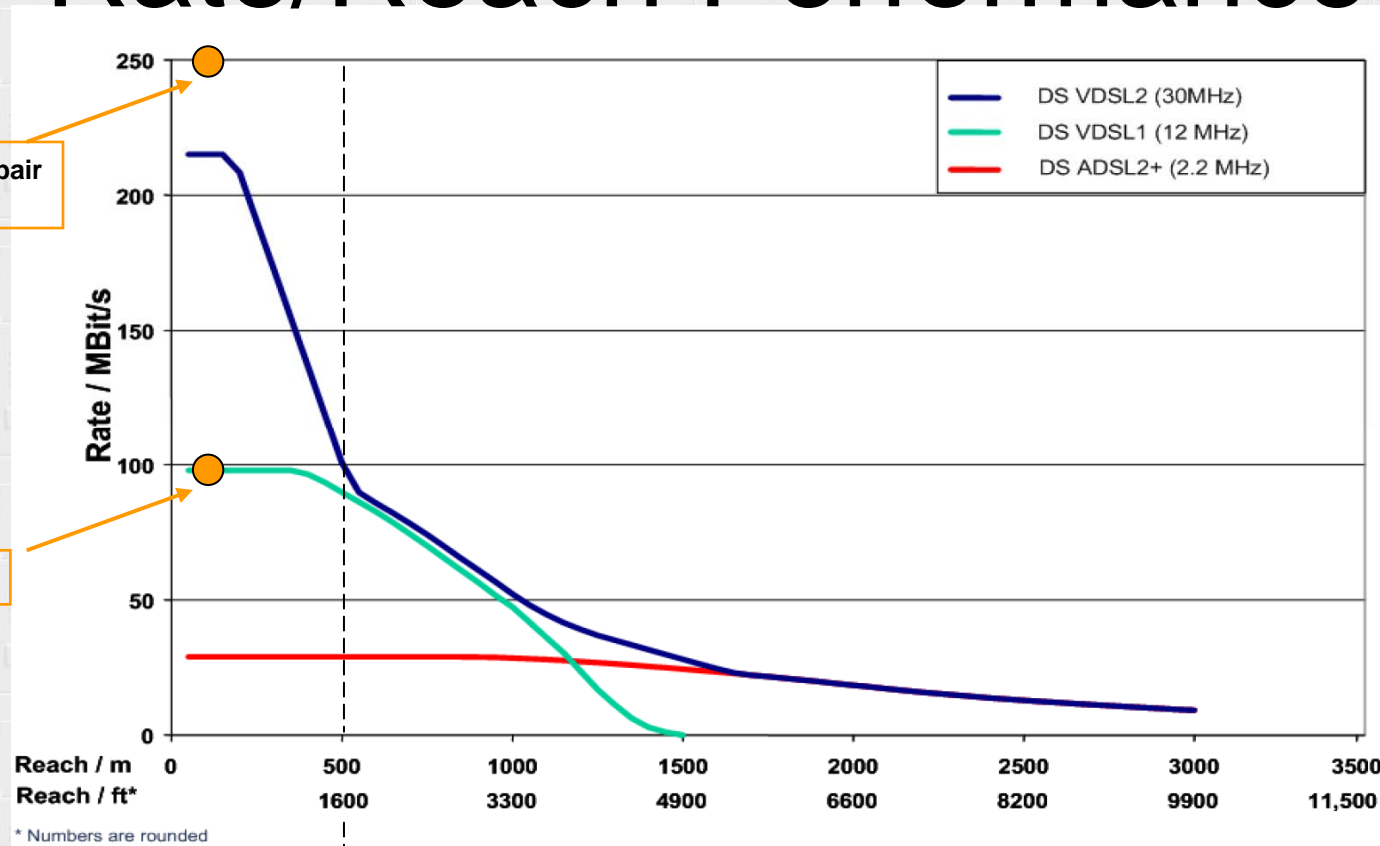(ITU G.993.2 standard figure 5-7)

VDSL2 Spectrum

VDSL2 structure

Rate/Reach Performance

One twisted pair 1000BaseT

100BaseT

DS VDSL2 (30MHz)
DS VDSL1 (12 MHz)
DS ADSL2+ (2.2 MHz)

500 Meter VDSL2:
100 Mbit/s downstream 10 Mbit/s upstream

Source:
http://www.infineon.com//upload/Document/VDSL2_WP_072005_v1.1.pdf

General properties

- Attenuation 24 AWG (0.5 mm copper)

$$\alpha = 16.5 \, \text{dB/Km}/\sqrt{\text{MHz}} \, (\text{Bingham} \, 3.5.6)$$

$$500 \, \text{M}, \, 30 \, \text{MHz} \Rightarrow \alpha = 57.5 \, \text{dB}$$

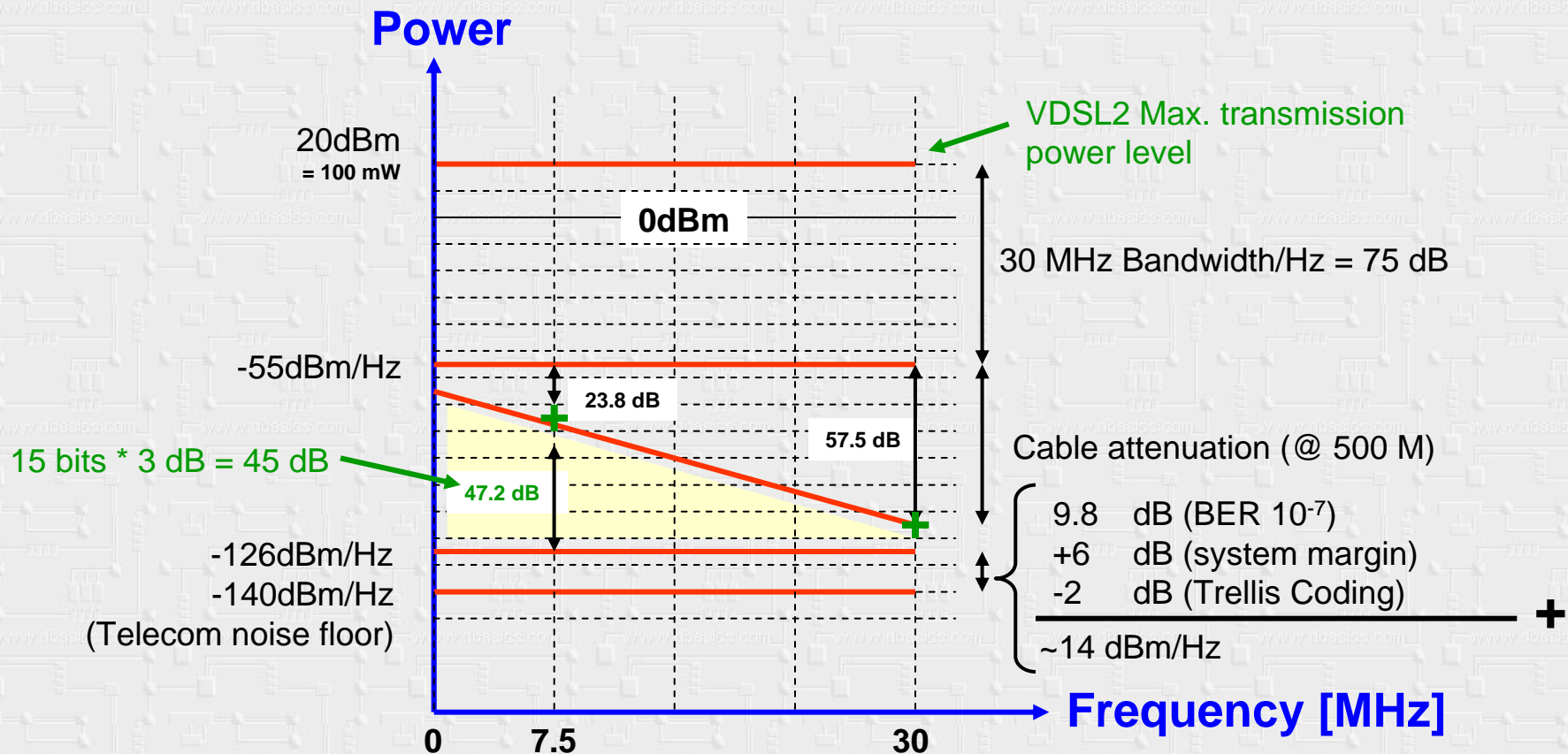$$500 \, \text{M}, \, 50 \, \text{MHz} \Rightarrow \alpha = 74.1 \, \text{dB}$$

- Bit Error Rate

$$\text{BER} < 10^{-7} \text{ for any of the supported carriers}$$

$$(\text{ITU-T G}.993.2 \, (\text{VDLS2}) \, \text{Chapter} \, 9.8)$$

$$\text{Note}: \text{This includes Forward Error Correction (FEC)}$$

VDSL2 power levels

Power

20dBm
= 100 mW

0dBm

VDSL2 Max. transmission power level

30 MHz Bandwidth/Hz = 75 dB

-55dBm/Hz

23.8 dB

57.5 dB

15 bits * 3 dB = 45 dB

47.2 dB

Cable attenuation (@ 500 M)

9.8   dB (BER 10^{-7})
+6   dB (system margin)
-2   dB (Trellis Coding)

-126dBm/Hz
-140dBm/Hz
(Telecom noise floor)

~14 dBm/Hz   **+**

Frequency [MHz]

0   7.5   30

Custom KM3Net VDSL2 Channel
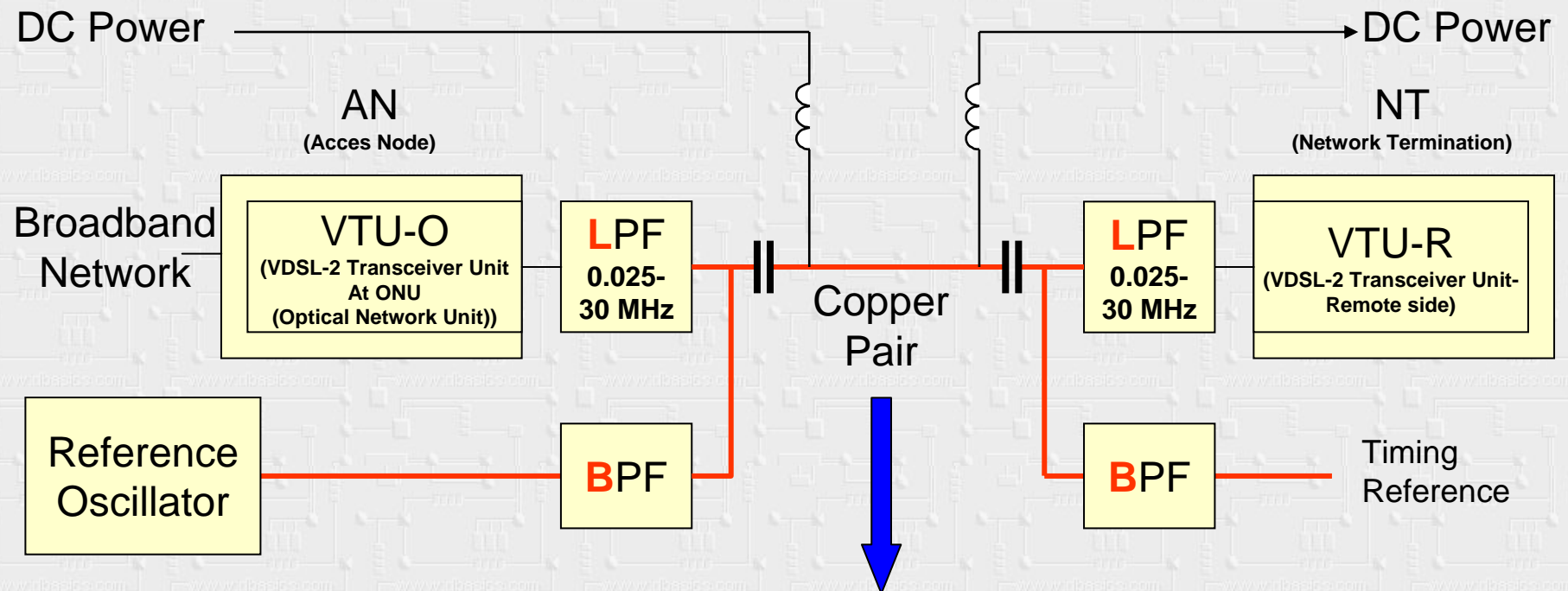
Calibration in general

- Local Clock stamp => Need local time calibration

t_0 $t_0 + t_{pd}$ $t_0 + 2t_{pd}$

Time

Shore Station   Optical Module   Shore Station

Calibration example

t_a

Optical Module A

Shore Station

t_b

Optical Module B

t_0 $t_0 + t_a$ $t_0 + 2t_a$

$t_0 + t_b$ $t_0 + 2t_b$

Calibrate

@ Shore		15	21	30	42
@ A			0	6	15	27
@ B			x	0	9	21

t_a t_a

t_b t_b

Example, t_a : 15 Clock ticks, t_b : 21 Clock ticks
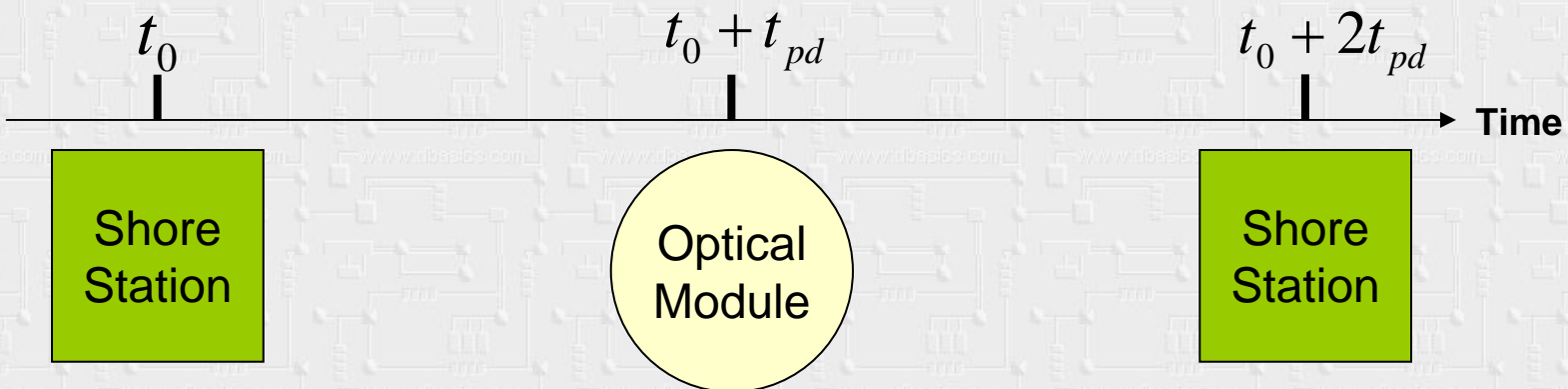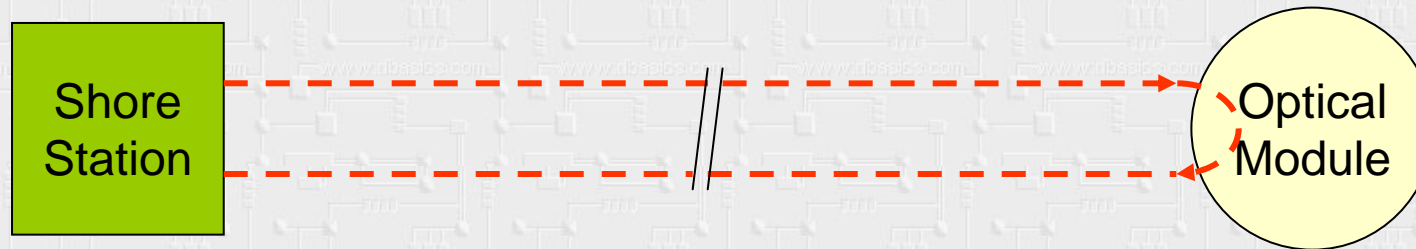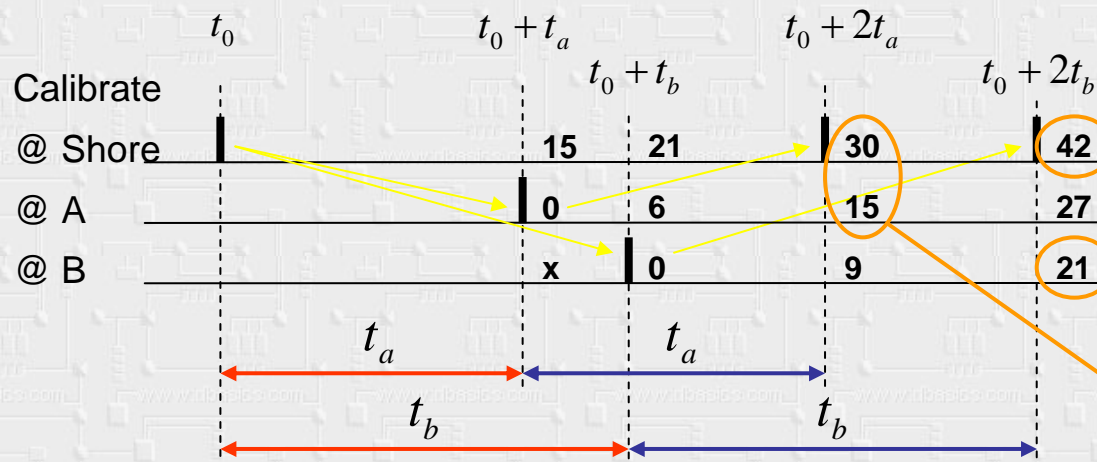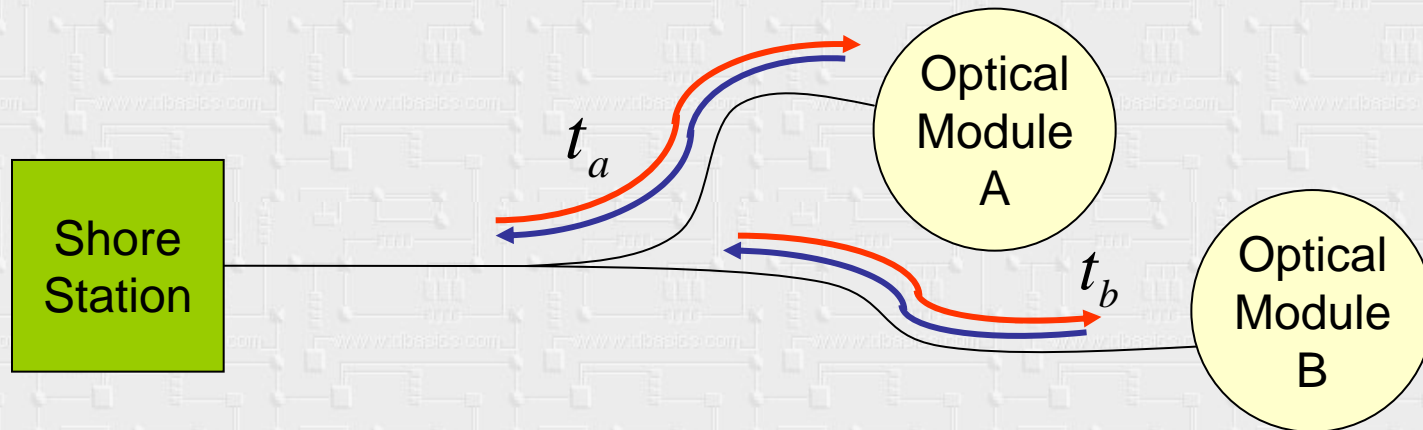
Loopback B

Shore time $42 = 2\,t_b$

$\Rightarrow t_b = 21$

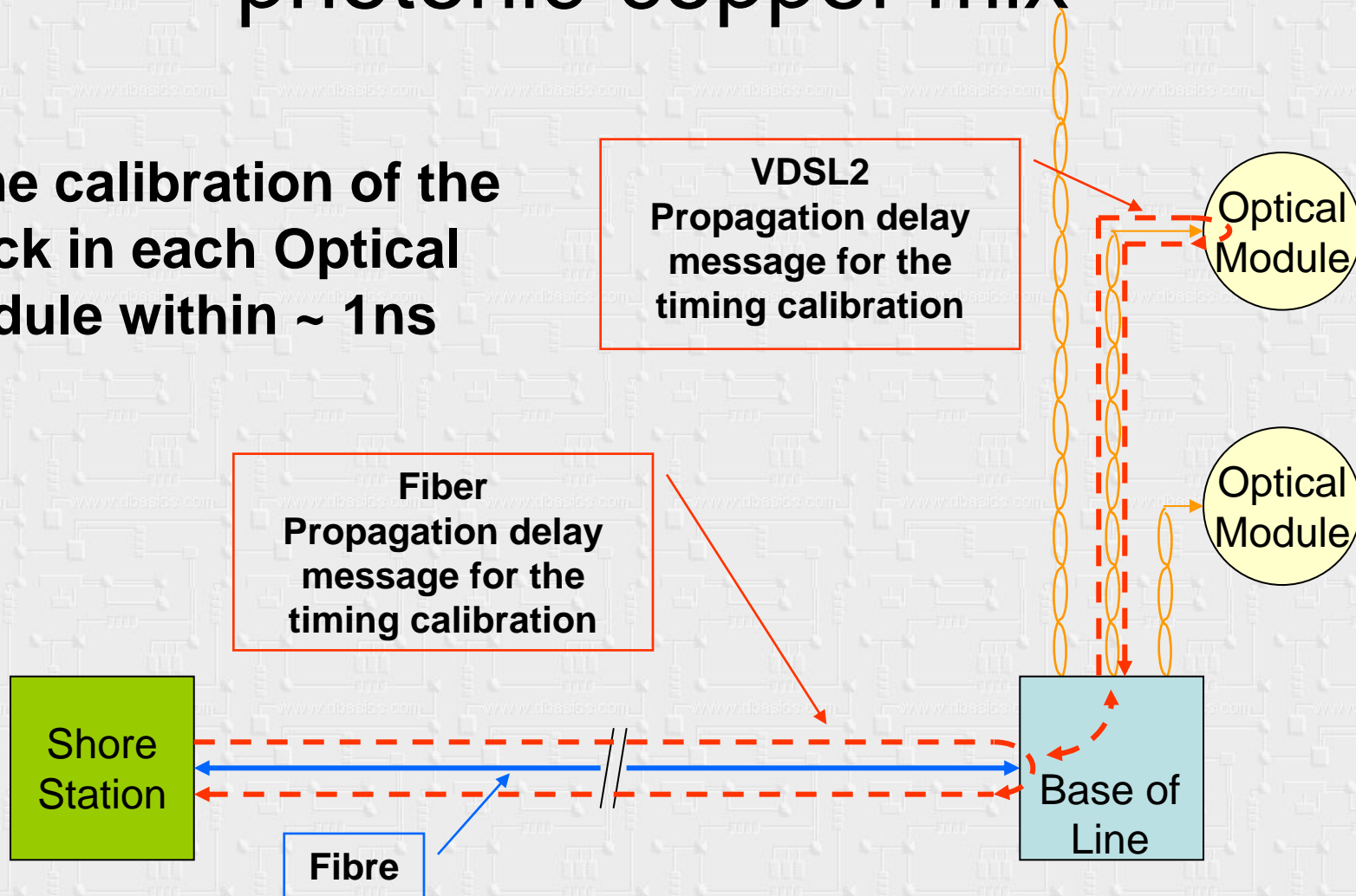$\Rightarrow$ time @ B is currently 21

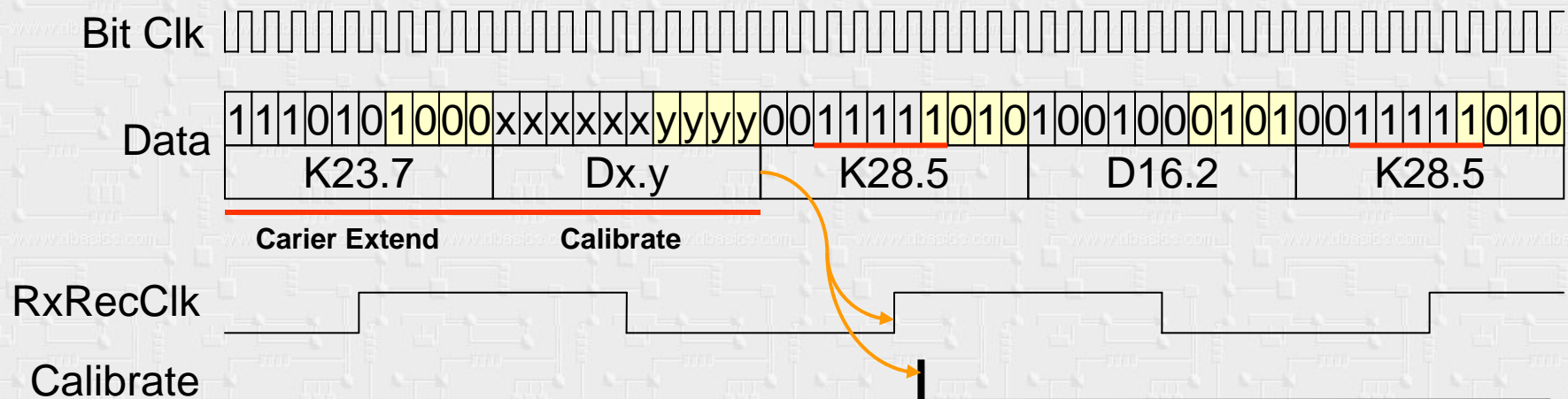Loopback A

Shore time $30 = 2\,t_a$

$\Rightarrow t_a = 15$

$\Rightarrow$ time @ A is currently 15

Calibration with photonic-copper mix

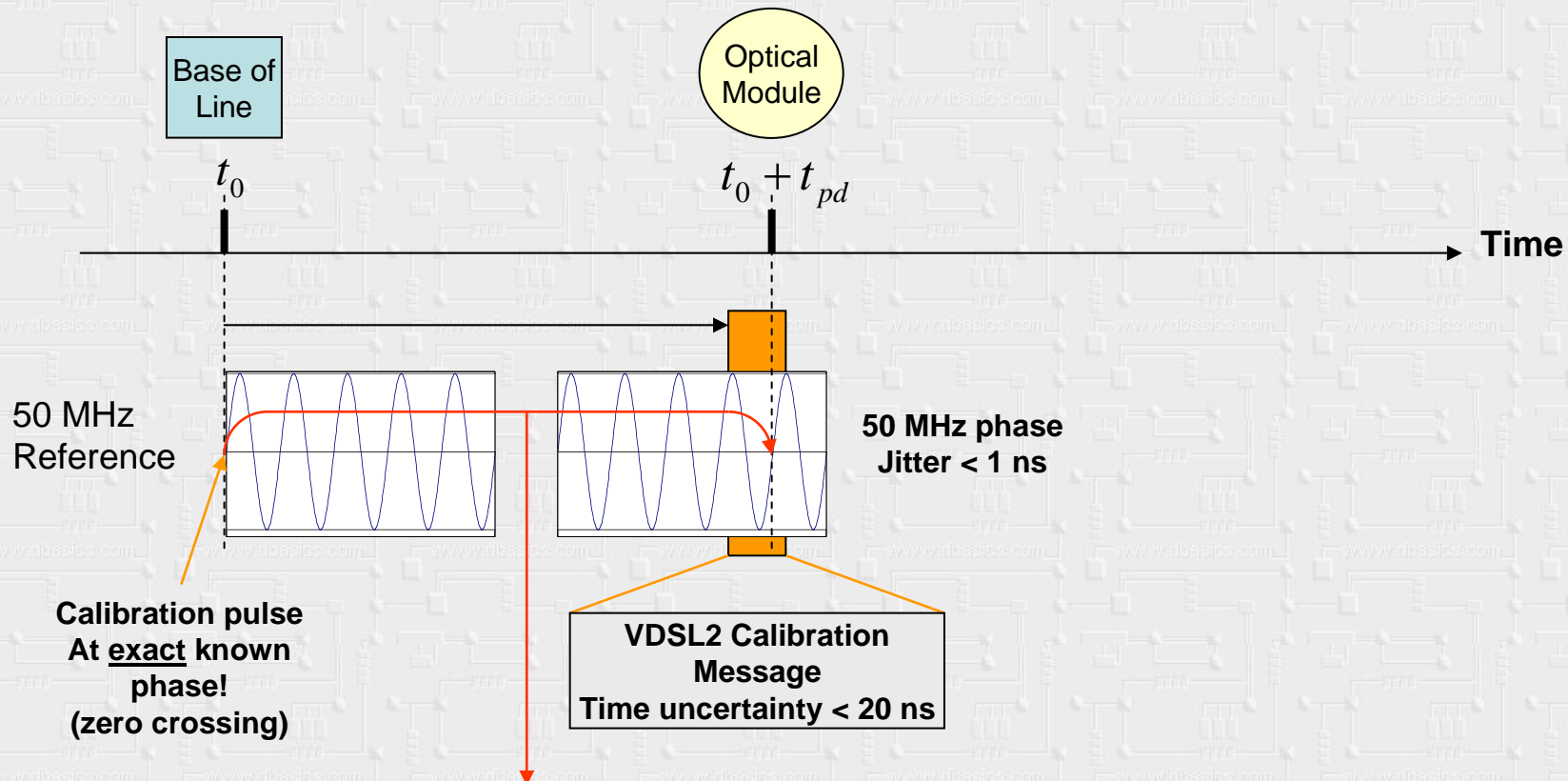**Time calibration of the clock in each Optical Module within ~ 1ns**

VDSL2
Propagation delay
message for the
timing calibration

Optical Module

Optical Module

Fiber
Propagation delay
message for the
timing calibration

Shore Station

Base of Line

Fibre

Calibration over optical channel

Bit Clk | Data

Data: `1110101` `1000` `xxxxxx` `yyyy` `00` `1111` `1010` `1001000` `0101` `001111` `1010`

K23.7   Dx.y   K28.5   D16.2   K28.5

**Carier Extend**   **Calibrate**

RxRecClk

Calibrate

- <u>fixed</u> latency between the data and the RxRecClk
  => The Calibration pulse may be encoded in the 8B/10B data, for example via Carrier Extend sequence

KM3NeT

Calibration over copper channel

Base of
Line

Optical
Module

t_0

$t_0 + t_{pd}$

Time

50 MHz
Reference

**50 MHz phase
Jitter < 1 ns**

**Calibration pulse
At _exact_ known
phase!
(zero crossing)**

**VDSL2 Calibration
Message
Time uncertainty < 20 ns**

VDSL2 Calibration message determines 50 MHz period (= n * 20 ns)
50 MHz phase (zero crossing) determines < 1 ns
Thus propagation delay is known with < 1 ns accuracy.

Calibration over copper channel
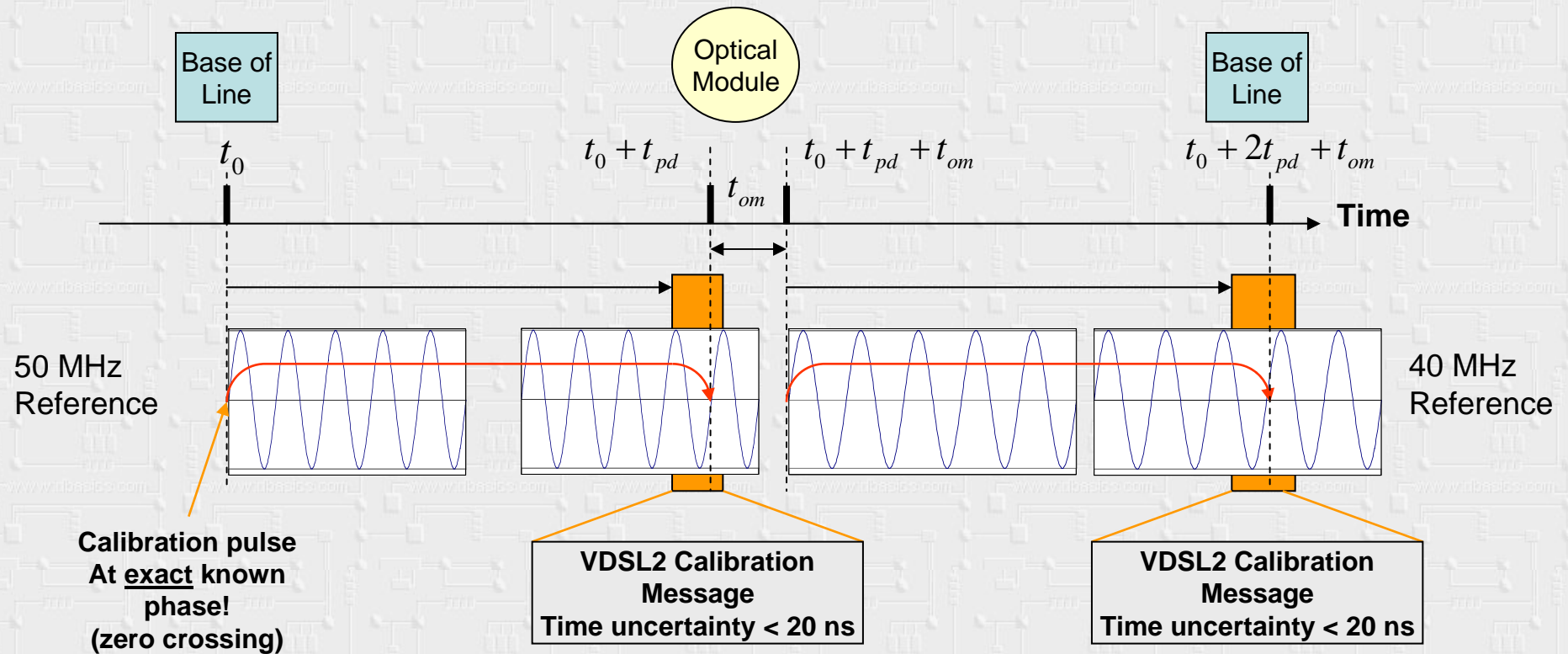
- Need to know propagation delay from the base to the optical module.
- Use a second (phase locked) reference signal for calibration from Optical Module to the Base of Line.

Progress of photonic-copper mix

- Copper in the riser seems possible, it needs a single twisted pair to each Optical Module
- VDSL2 chipsets are in production, detailed documentation is under disclosure
- Attenuation of copper twisted pair needs attention
- A copper transmission system needs rather complex electronics
- EMC is a point of concern

Near future:

- Nikhef has a disclosure agreement with Infineon and gets a set of VDSL2 evaluation boards