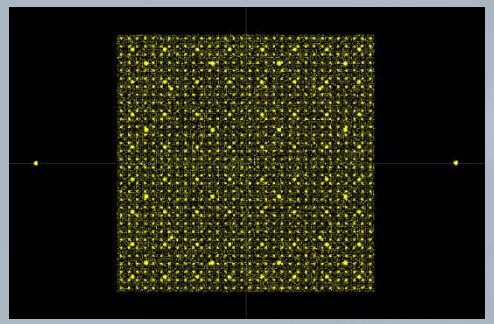
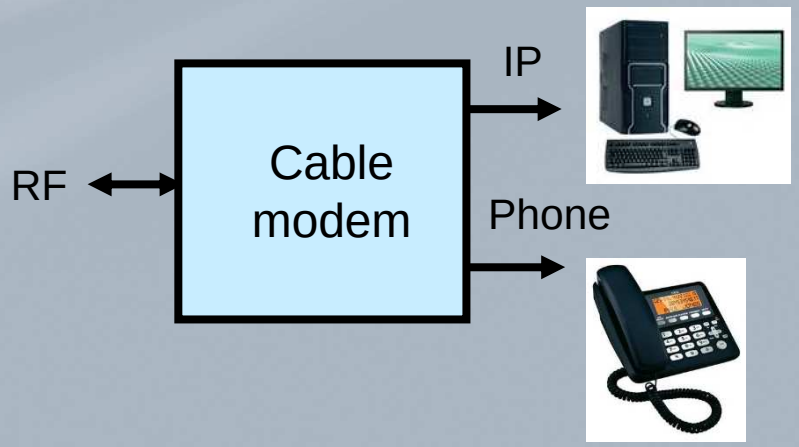
DOCSIS 3.1 – Technischer Überblick

DOCSIS = Data over Cable Service Interface Specification

Vortrag anlässlich der Cabletech 2017, Spielberg, März 2017

Walter Fischer
Rohde&Schwarz Trainingszentrum München





ROHDE&SCHWARZ

16.3.2017

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Agenda

- DOCSIS Intro and Principle
- Single Carrier Modulation Principle
- Time Domain and Spectrum Domain
- QAM and SNR Requirement
- OFDM in CATV
- DOCSIS 3.1 Physical Layer Parameters
- DOCSIS 3.1 Demo Transmission

DOCSIS Intro and Principle

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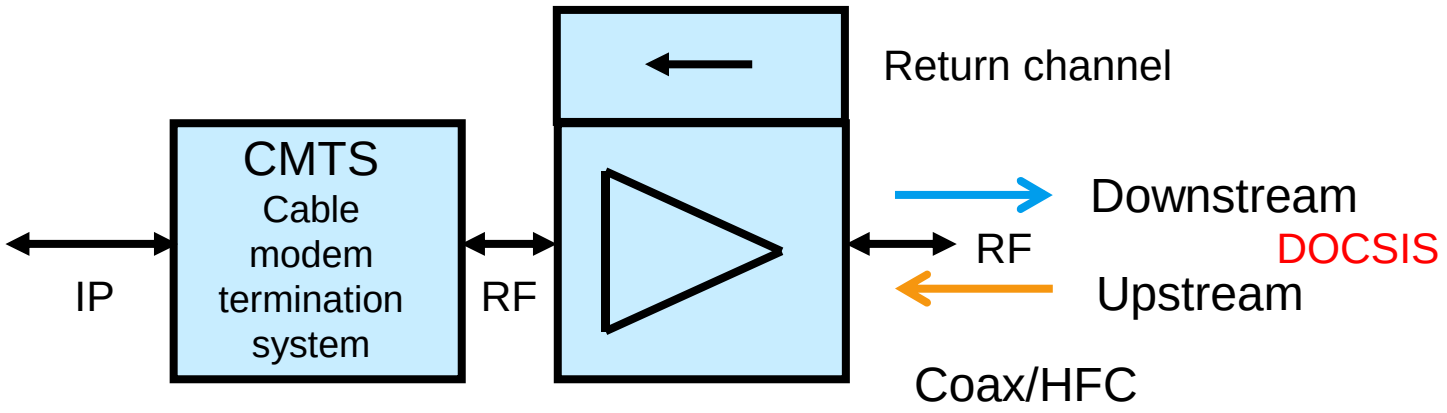
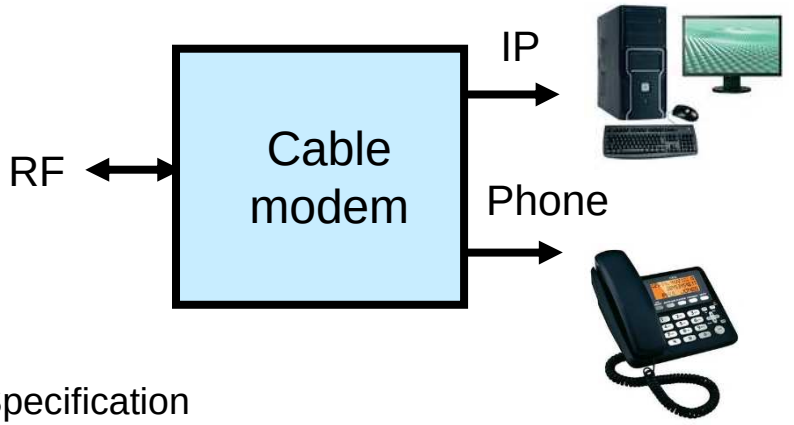
Broadband Internet & Telephone via CATV





DOCSIS – Data-over-Cable Service Interface Specification

DOCSIS – Data over Cable Service Interface Specification

DOCSIS 1.0	1997 Cable Labs, ITU-T spec. ITU-T J.112
DOCSIS 1.1	1999 QoS capabilities
DOCSIS 2.0	2001 enhanced upstream speeds ITU-T J.122
DOCSIS 3.0	2006 increase of both up and downstream speed, IPv6 ITU-T J.222
DOCSIS 3.1	2013 10Gbit/s downstream, 1Gbit/s upstream, OFDM, 4096QAM

DOCSIS standard =
bidirectional transmission of high-speed data over
broadband cable networks using hybrid fiber-coaxial infrastructure

all DOCSIS standards are backward compatible

DOCSIS Physical Layer

DOCSIS 1.0 ... 3.0:
Downstream =
ITU-T J83B [US] Single Carrier 64QAM/256QAM
or
ITU-T J83A (DVB-C) [EURO-DOCSIS] Single Carrier 64QAM/256QAM

Upstream = Single Carrier, QPSK ... 64QAM, TDMA, CDMA

DOCSIS 3.1:
Downstream = OFDM, 4096 (4K) QAM and higher (16K QAM)
4K/8K OFDM, 50/25 kHz carrier distance

Upstream = OFDM, minislots in time and frequency domain
up to 4096 (4K) QAM, 2K/4K OFDM, 50/25 kHz carrier distance

DOCSIS 1.0 ... 3.0 Downstream Data Rates

Standard	Data rate per down stream channel
DOCSIS, J83B, 64QAM, 6 MHz	26.97 Mbit/s
DOCSIS, J83B, 256QAM, 6 MHz	38.81 Mbit/s
EURO-DOCSIS, DVB-C, 64QAM, 8 MHz	38.15 Mbit/s
EURO-DOCSIS, DVB-C, 256QAM, 8 MHz	51 Mbit/s

Single Carrier Modulatin Principle

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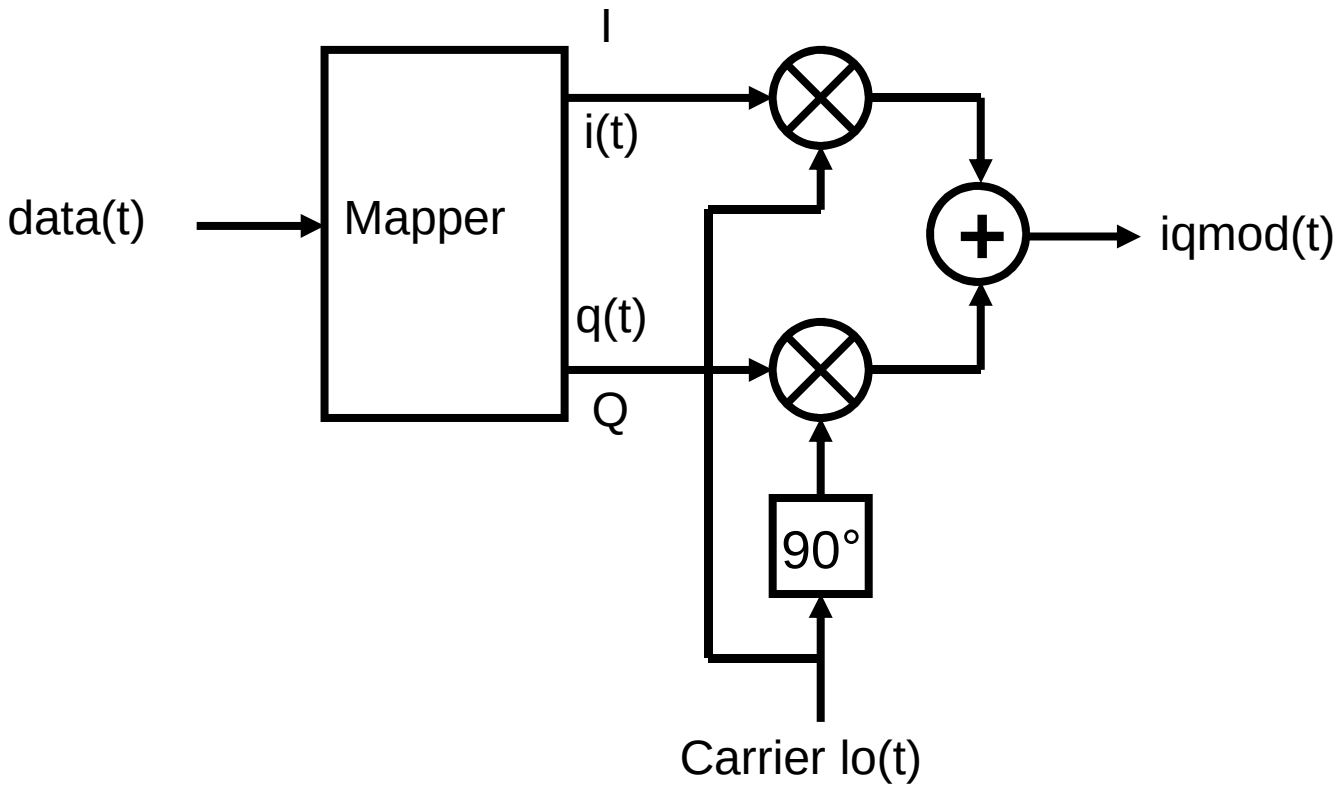
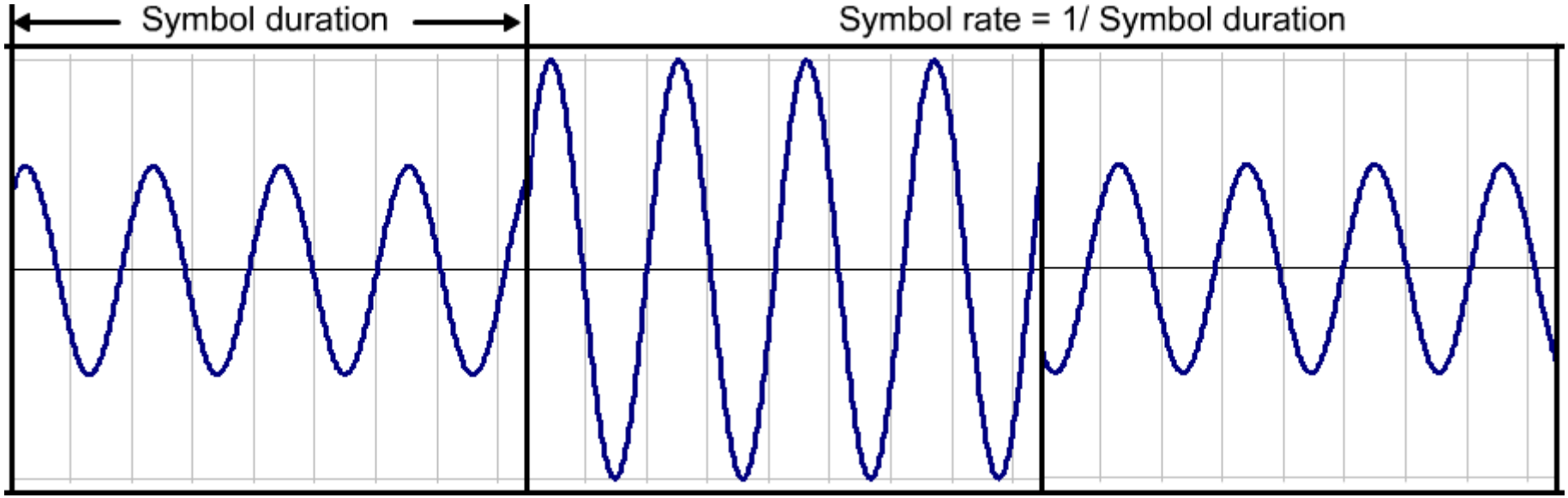
IQ Modulator / Single Carrier Modulation

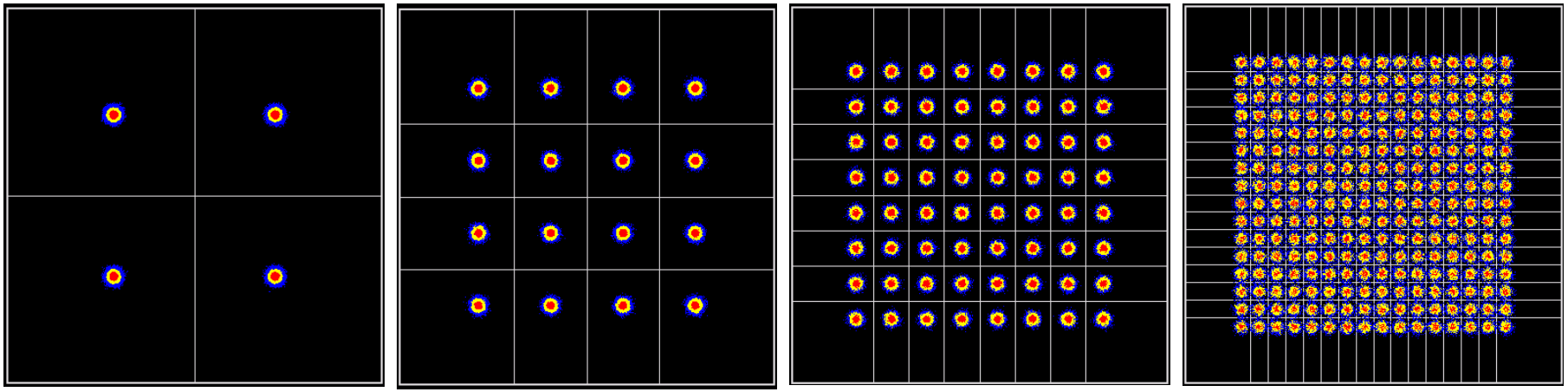


Single Carrier Modulation … very short Symbols

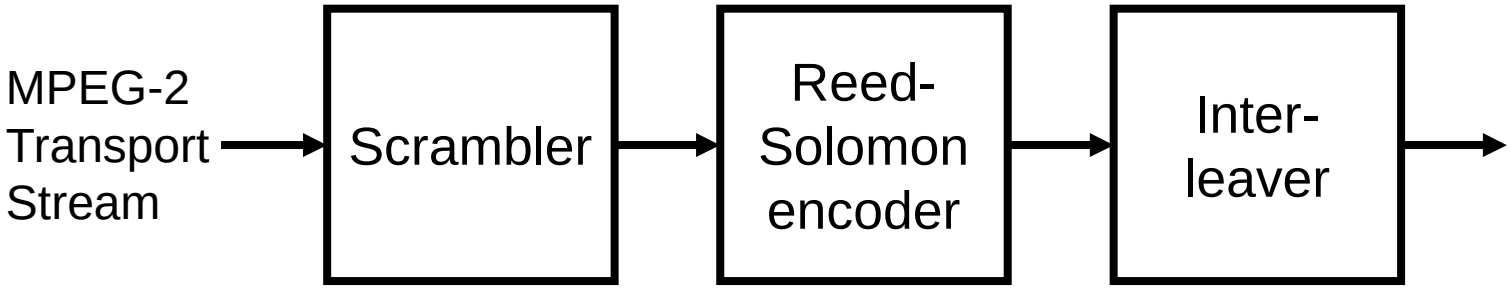


Example: DVB-C, 6.9 MS/s; Symbol duration = 1/6.9 µs = 144 ns

Constellations QPSK, 16QAM, 64QAM, 256QAM



DVB-C FEC


MPEG-2
Transport
Stream
Scrambler
Reed-
Solomon
encoder
Inter-
leaver

Time Domain and Spectrum Domain

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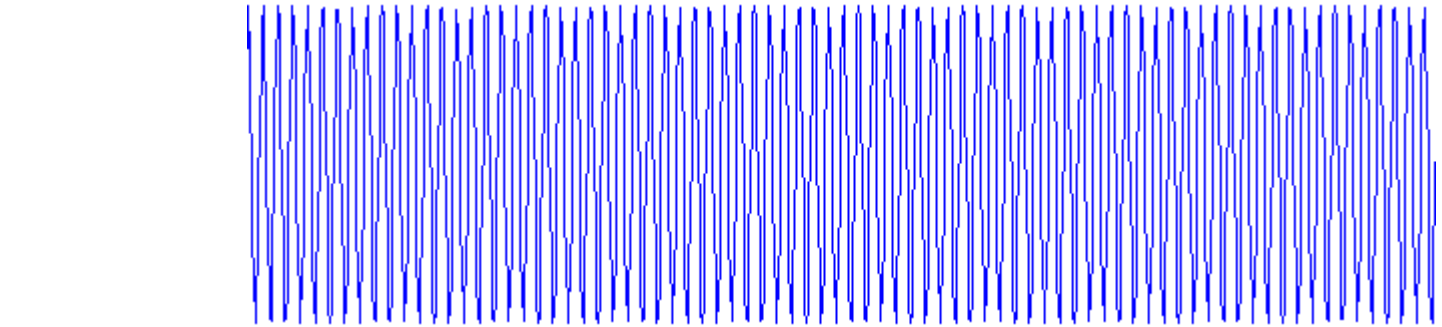
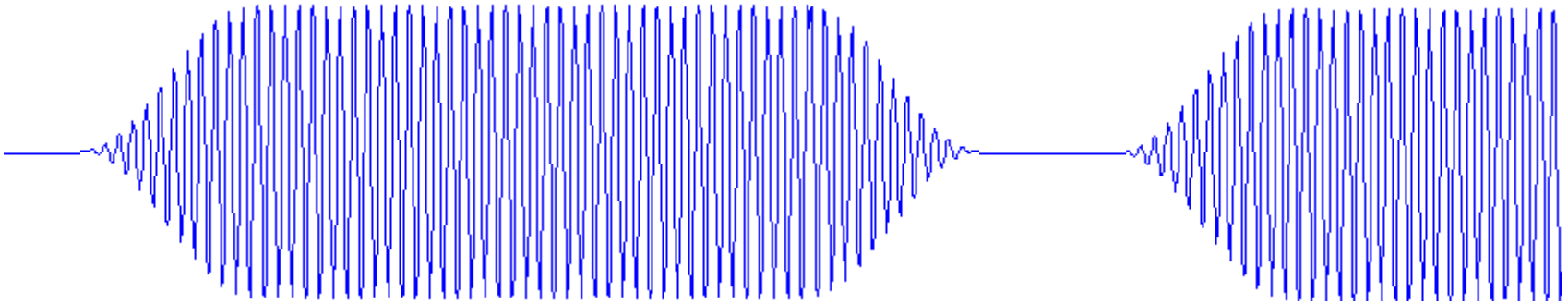
Continuous Streams and Bursted Streams

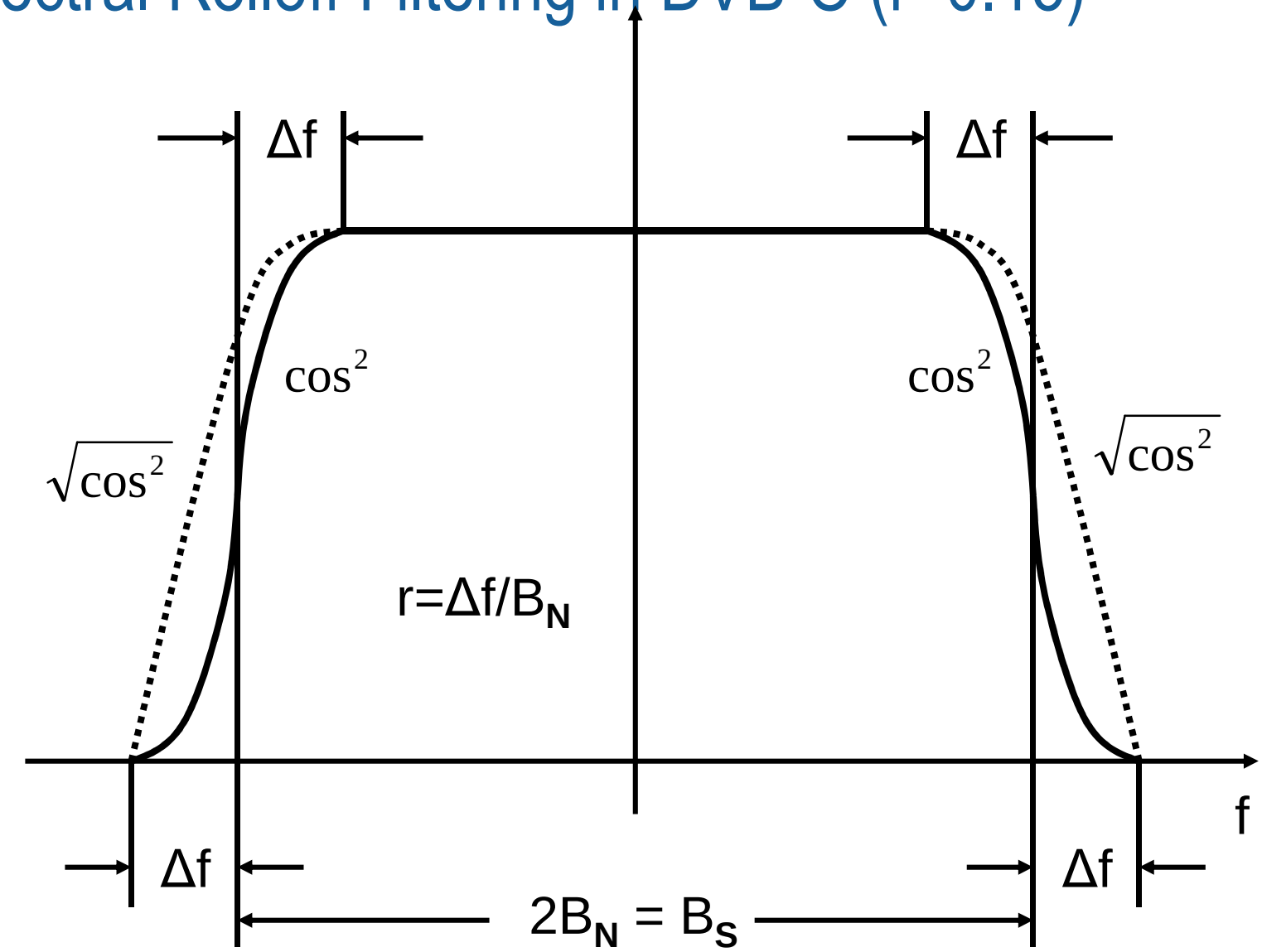


Downstream

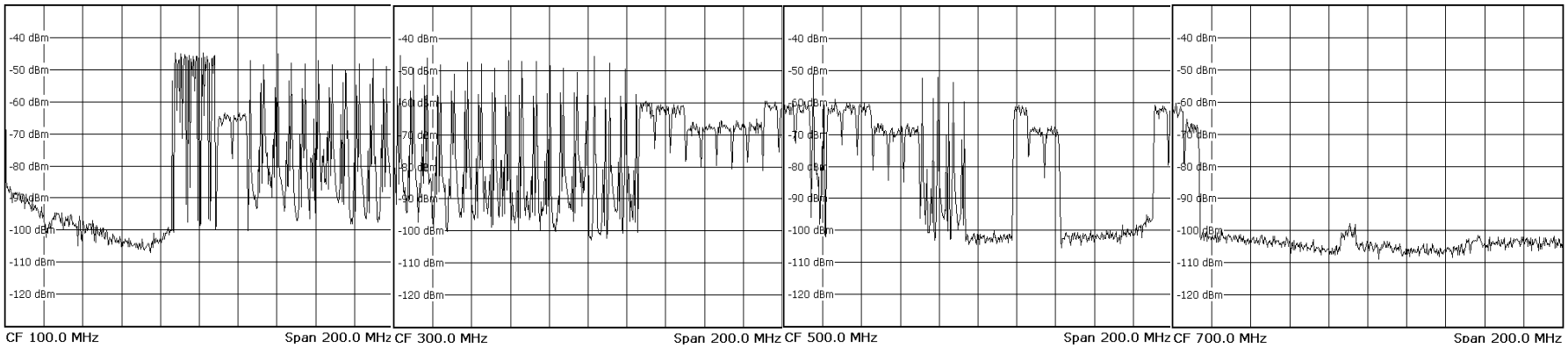


Upstream

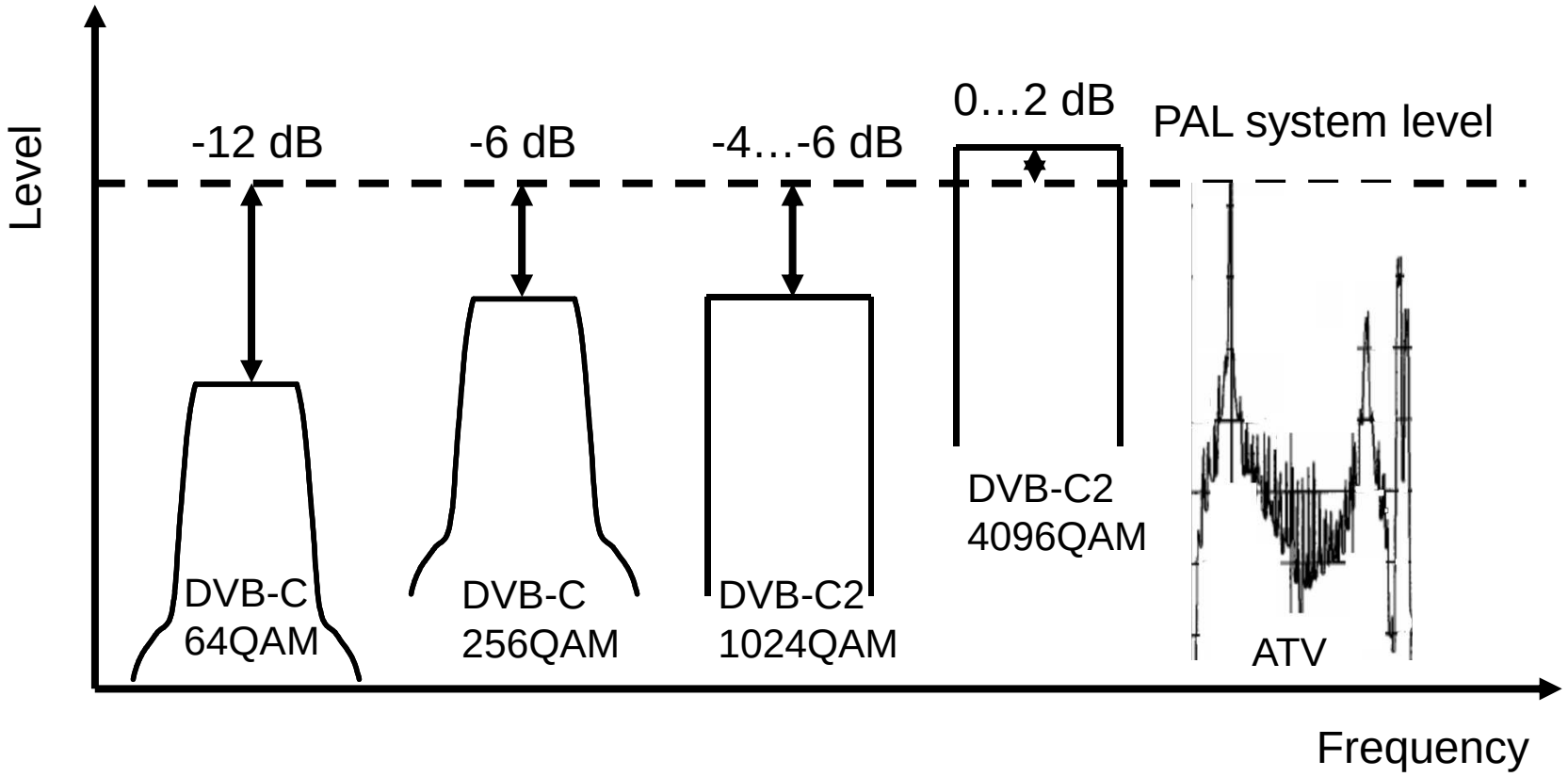
Spectral Rolloff Filtering in DVB-C (r=0.15)



Spectrum, CATV Network



RF Characteristics



QAM and SNR Requirement

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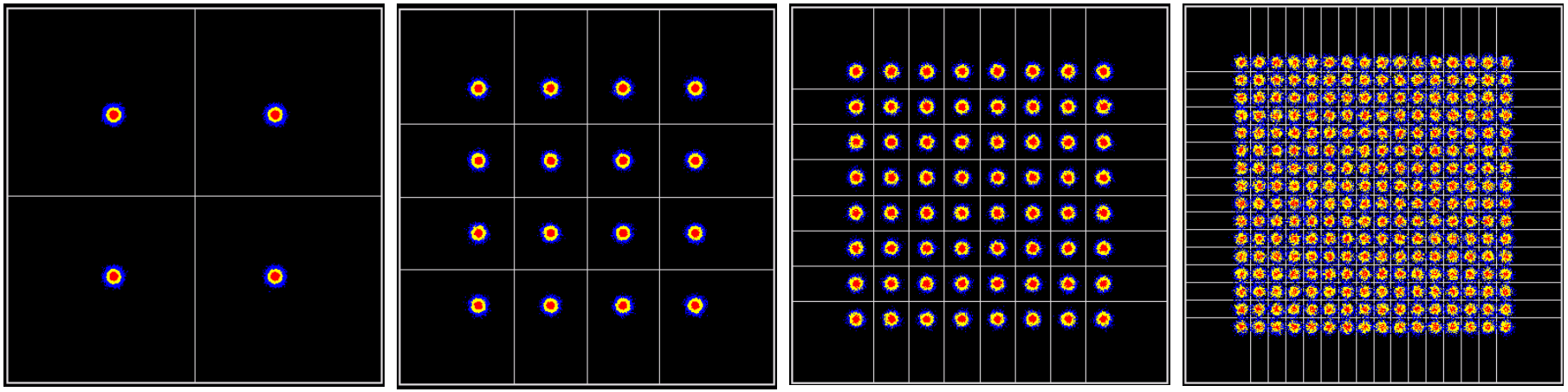
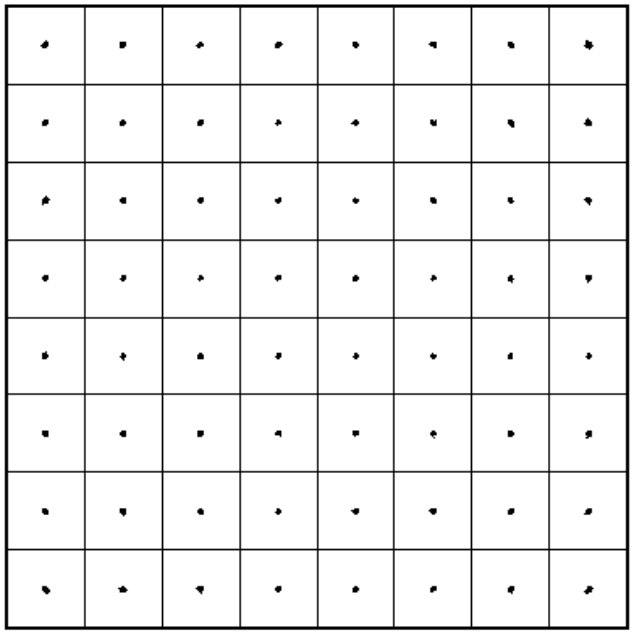
Required SNR(QAM Order)



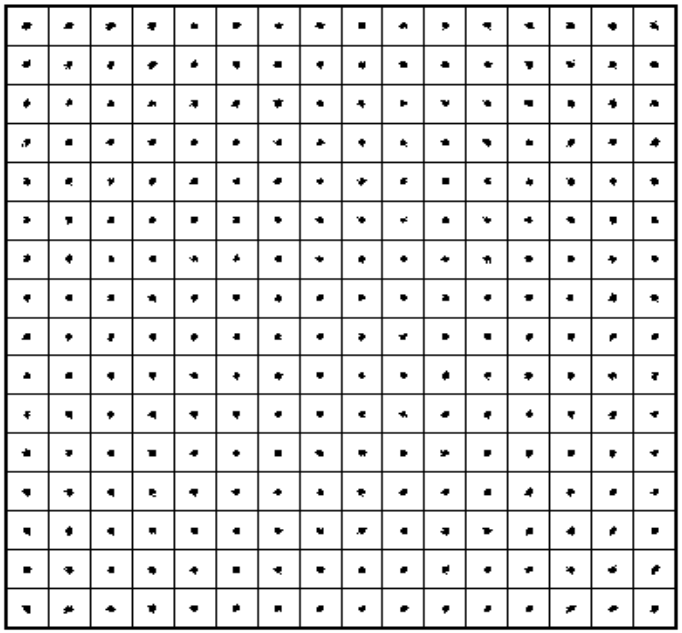
SNR4+6dB SNR16+6dB SNR64+6dB SNR256+6dB

4QAM, 16QAM, 64QAM, 256QAM, 1024QAM, 4096QAM, ...

Mainly used Modulation in Cable: 64QAM, 256QAM



64QAM



256QAM

SNR64+6dB = SNR256

OFDM Basics, OFDM in CATV

- DOCSIS Intro and Principle
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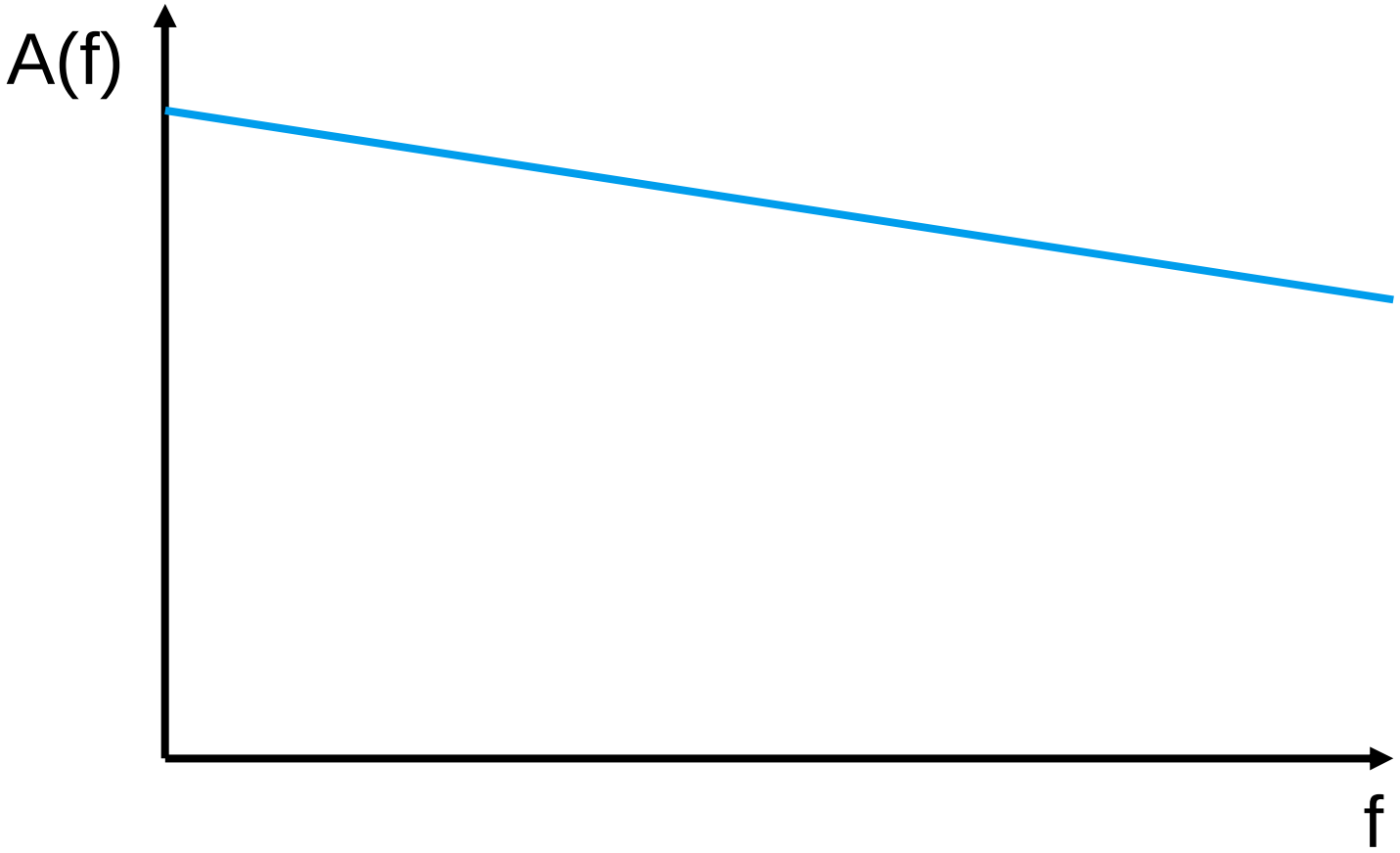
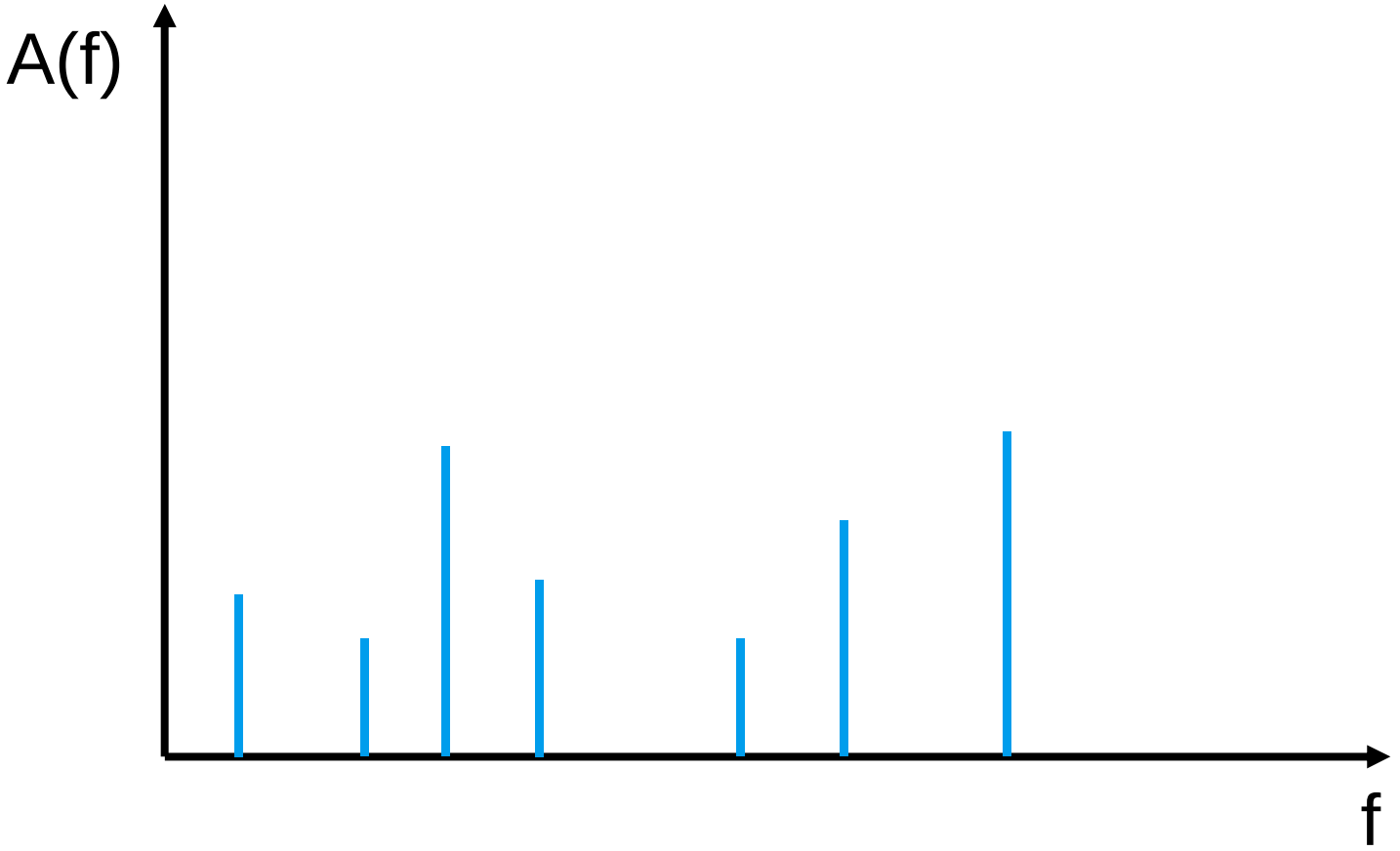
Interferences in a CATV Network

- Linear distortions (amplitude response, group delay)
- Non-linear distortions (... amplifiers ...)
- Intermodulation (multi-channel load and non-linearity)
- Short echos (micro-reflections)
- Noise (AWGN)
- Noise, frequency selective interferer
- Ingress noise
- Leakage (in both directions ...)
- ...

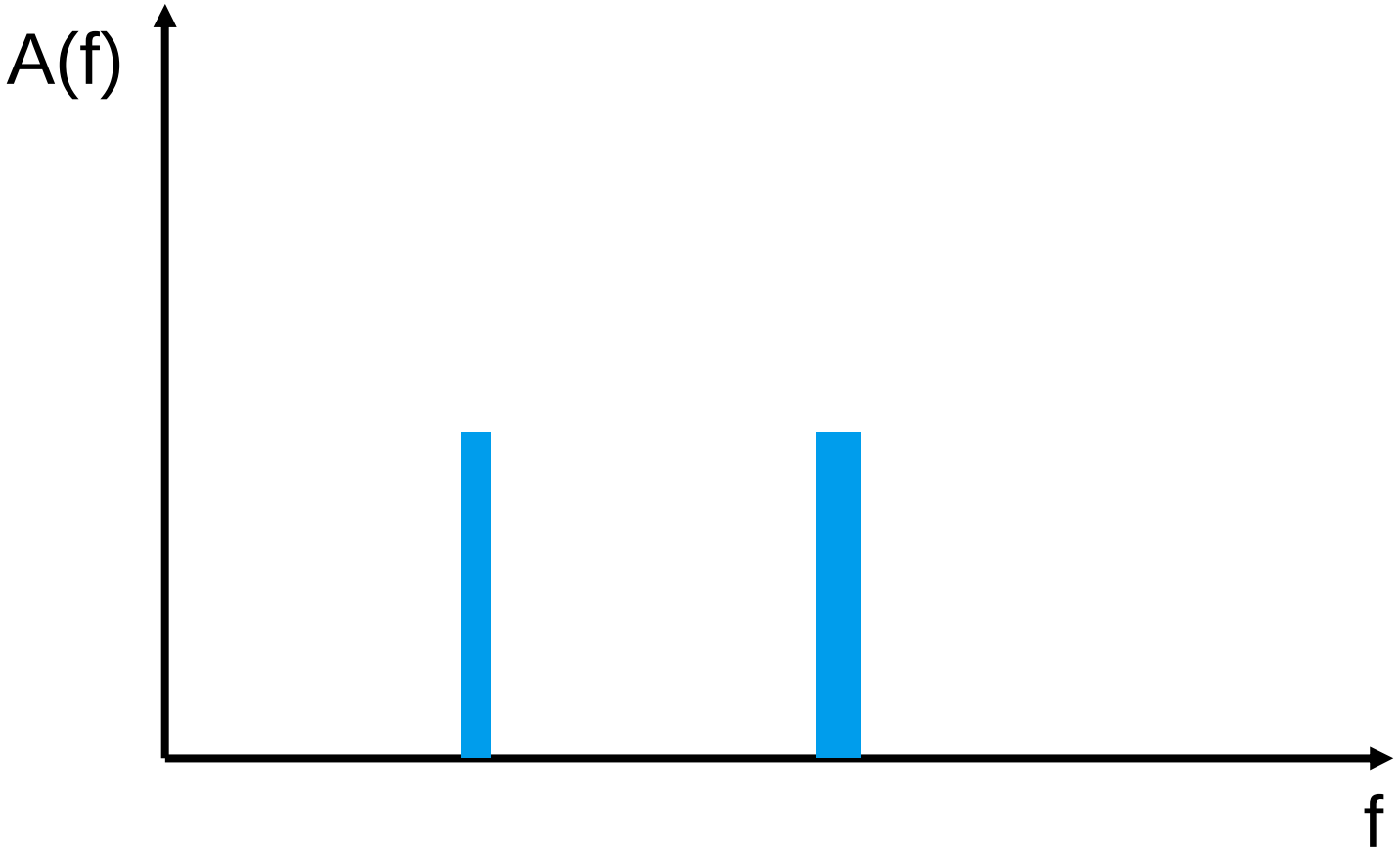
Amplitude Response in CATV - Tilt



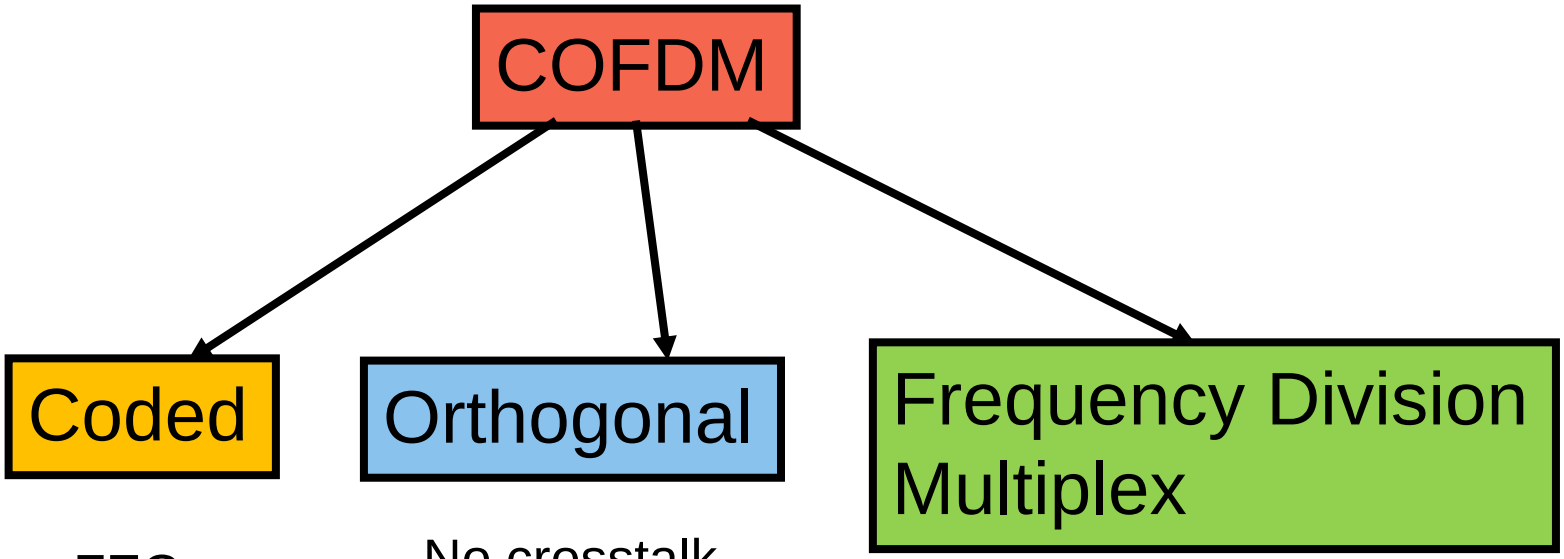
Interferer in CATV (Ingress, DVB-T/T2 Interferer, ...)



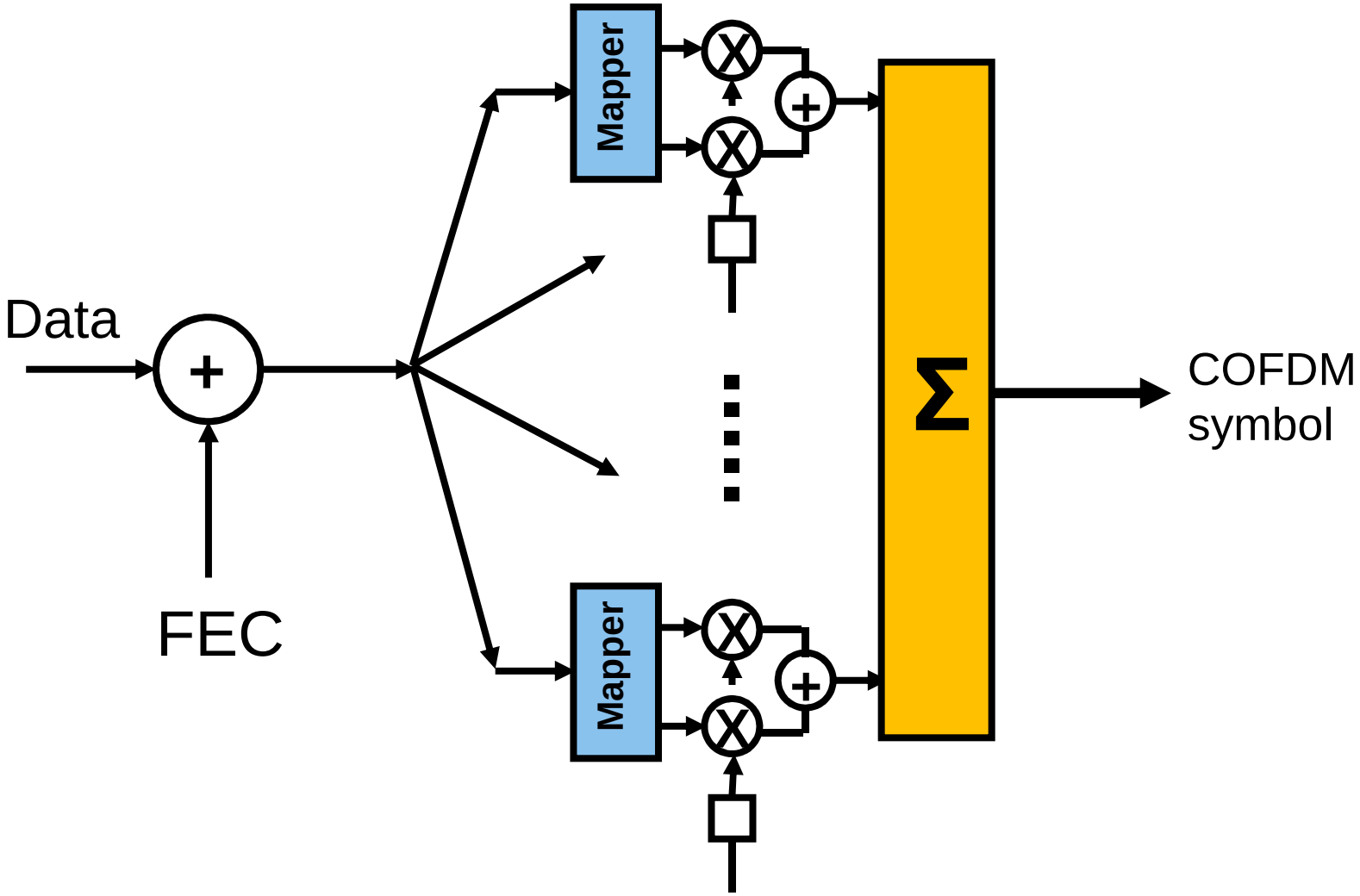
Unused, ... Forbidden Frequencies ... in CATV („Notches“)



OFDM – Orthogonal Frequency Division Multiplex



COFDM Principle



Mapping of OFDM carrier

Data stream: 0110 | 1110 | 0001 | 1010 | 1111 | 0011 | 0000 | 1010 | 0101

Forming of groups of 4 bit at 16QAM

carrer no. 0 1 2 3 4 5 6 7 8

Δf

Δf = 1/Δt = carrier spacing

mapped carrier vector

each carrier is described via a (I,Q) pair in the frequency domain

each carrier corresponds to a narrow-band modulated transmission channel

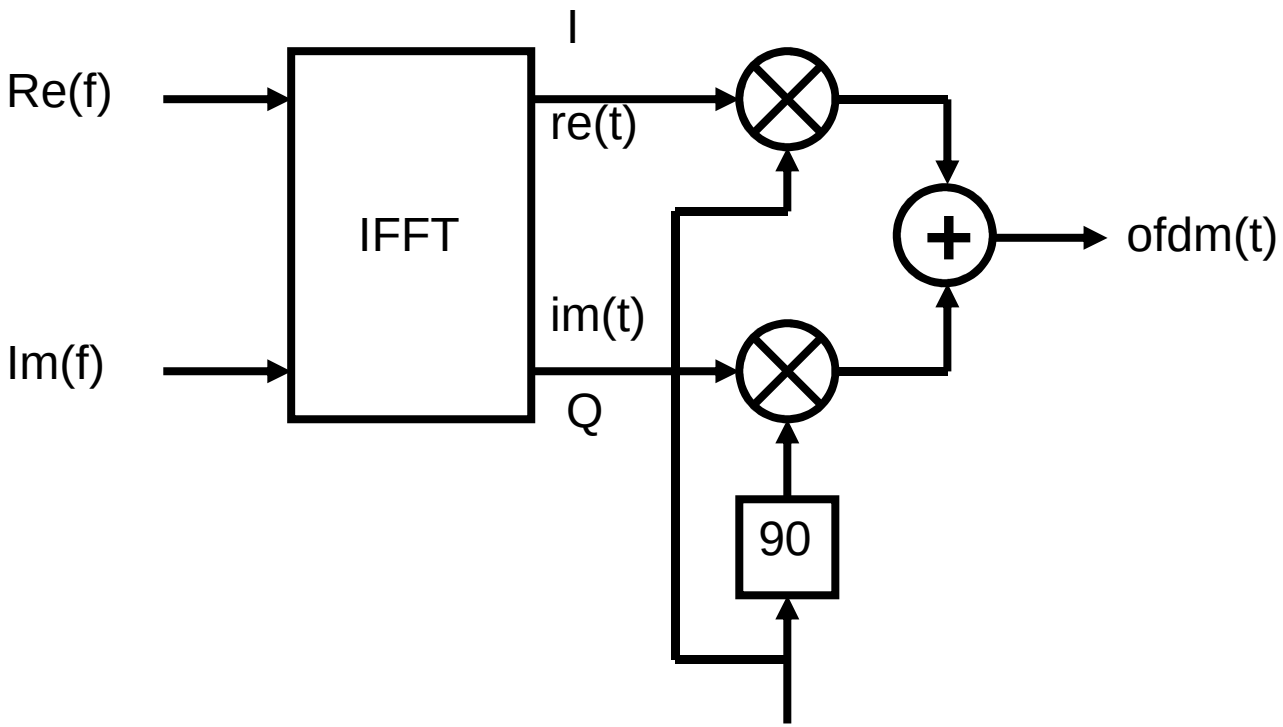
at DVB-T: 6817 or 1705 carriers in a distance of approx. 1kHz or 4kHz

6817 or 1705 carrier plus guard band = 2^N carrier = 8192 or 2048 carrier

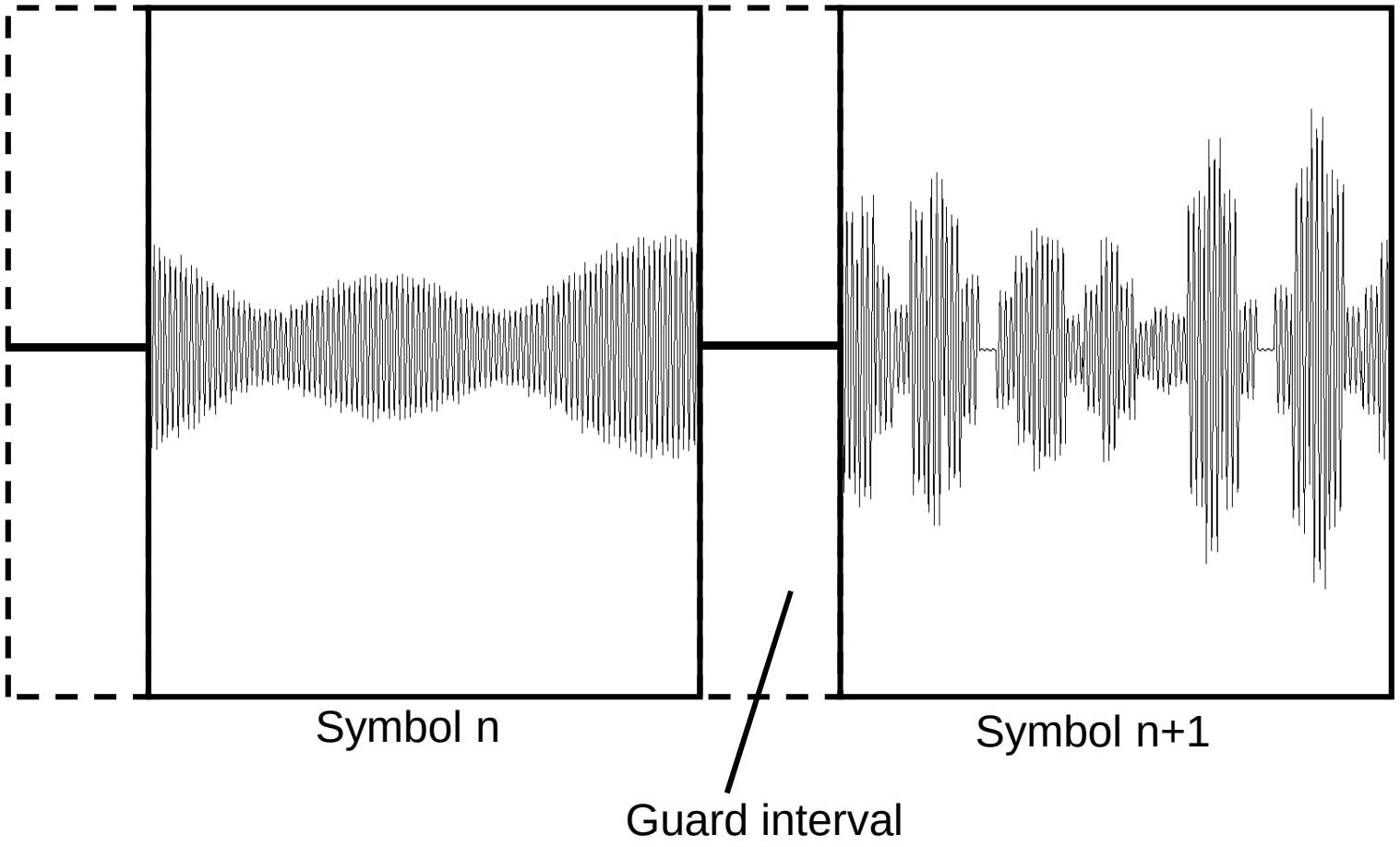
IFFT = Inverse Fast Fourier Transformation

OFDM symbol in time domain

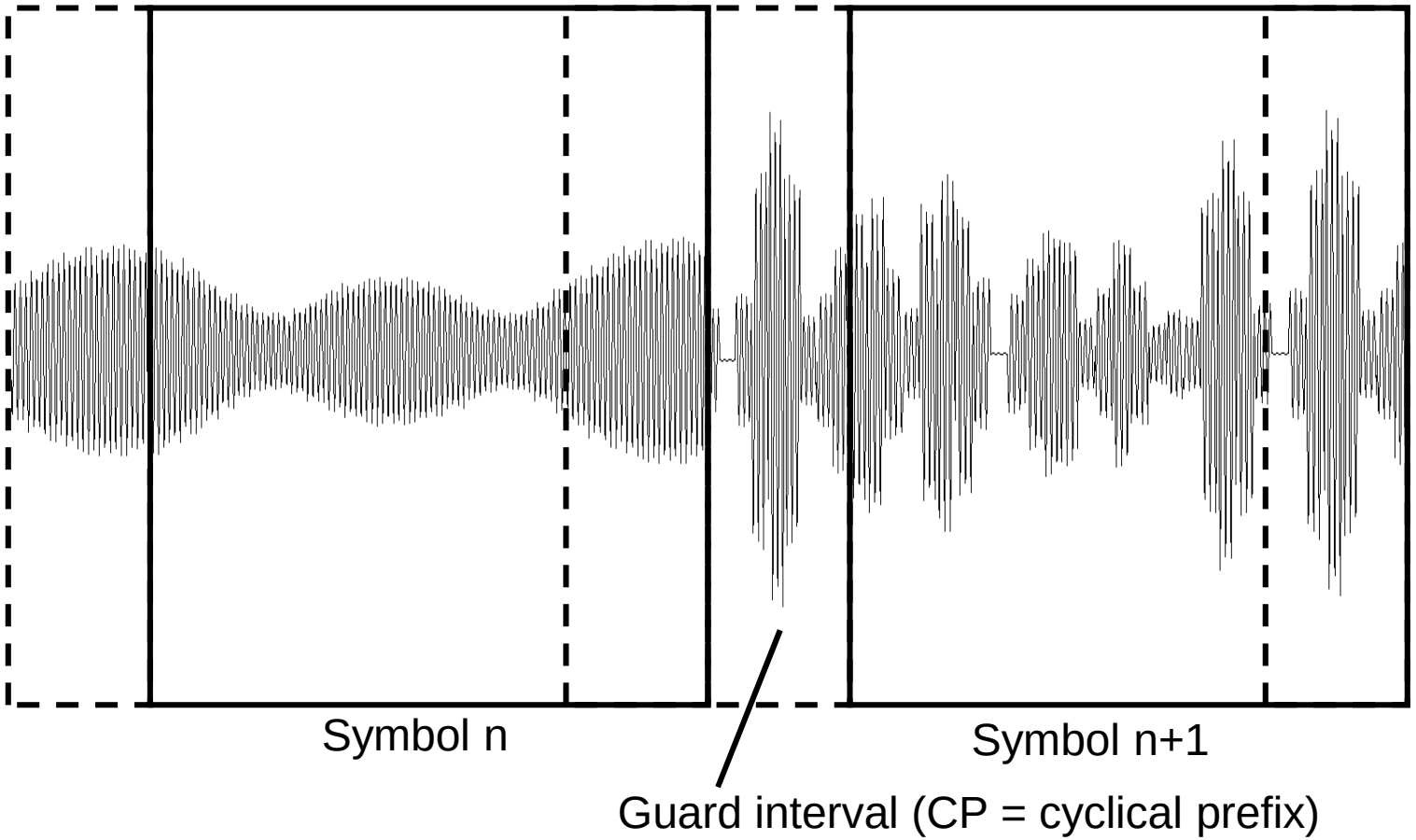
IFFT and I/Q Modulator



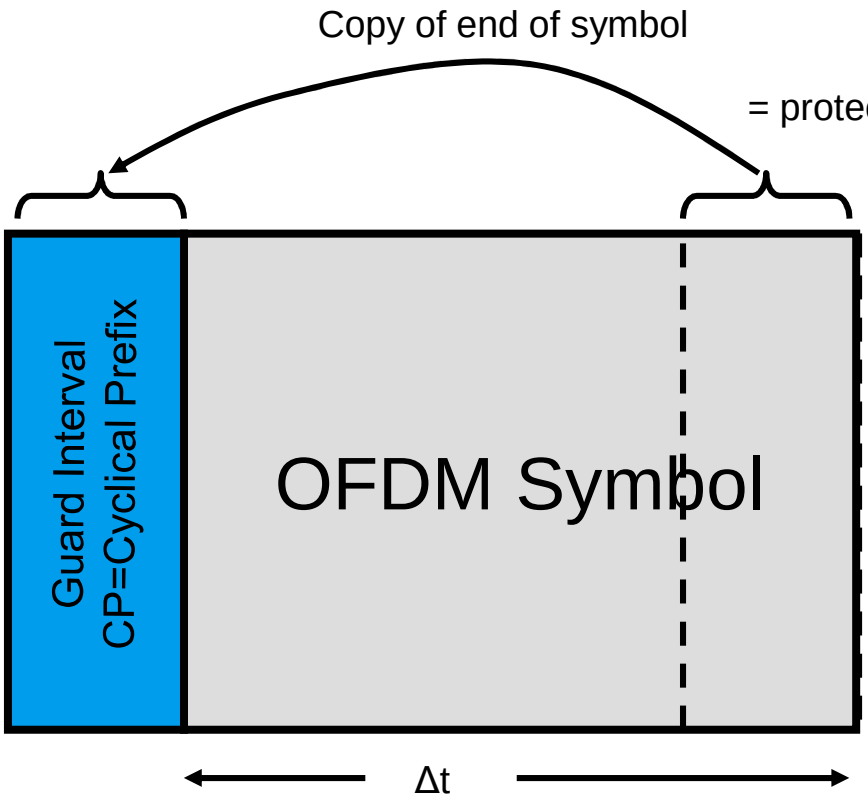
OFDM Symbols with Guard Interval



OFDM Symbols with Guard Interval



Guard Interval – Cyclical Prefix



Guard Interval

= protection against intersymbol interference

in OFDM systems

DVB-T

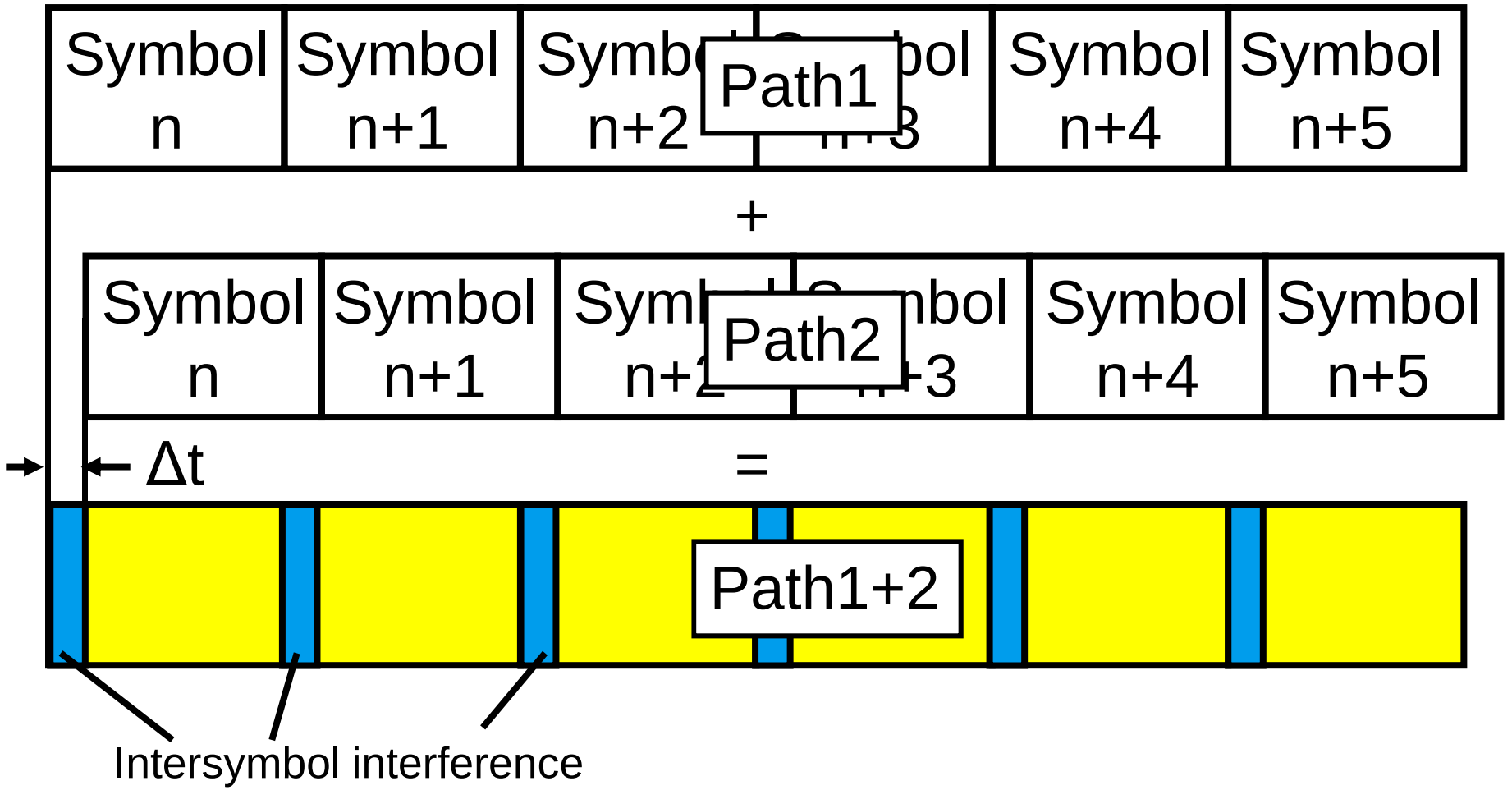
2K	8K
Δf ~ 4kHz	Δf ~ 1kHz
Δt~250us	Δt~1ms

Symbol duration $\Delta t = 1/\Delta f$

Guard interval = „quasi-break“ =

Mechanism against problems in time domain at multipath reception

Intersymbol Interference (ISI)



Δt = Echo delay time

(Only) Micro Reflections in CATV

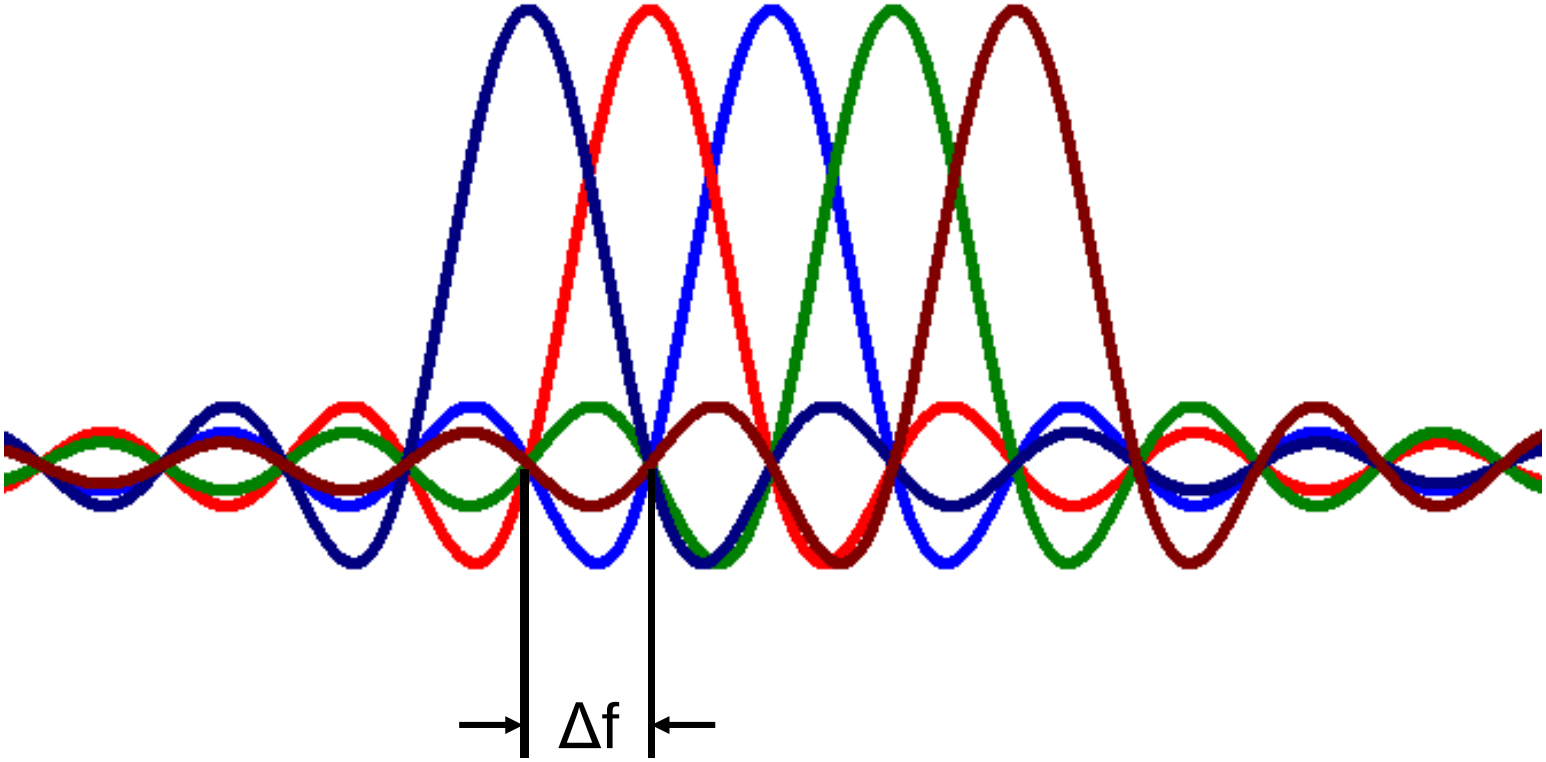
Micro-reflections in downstream (DOCSIS 3.1)

Time	Attenuation
≤0.5 µs	-20 dBc
≤1.0 µs	-25 dBc
≤1.5µs	-30 dBc
>2.0 µs	-35 dBc
>3.0 µs	-40 dBc
>4.5 µs	-45 dBc
>5.0 µs	-50 dBc

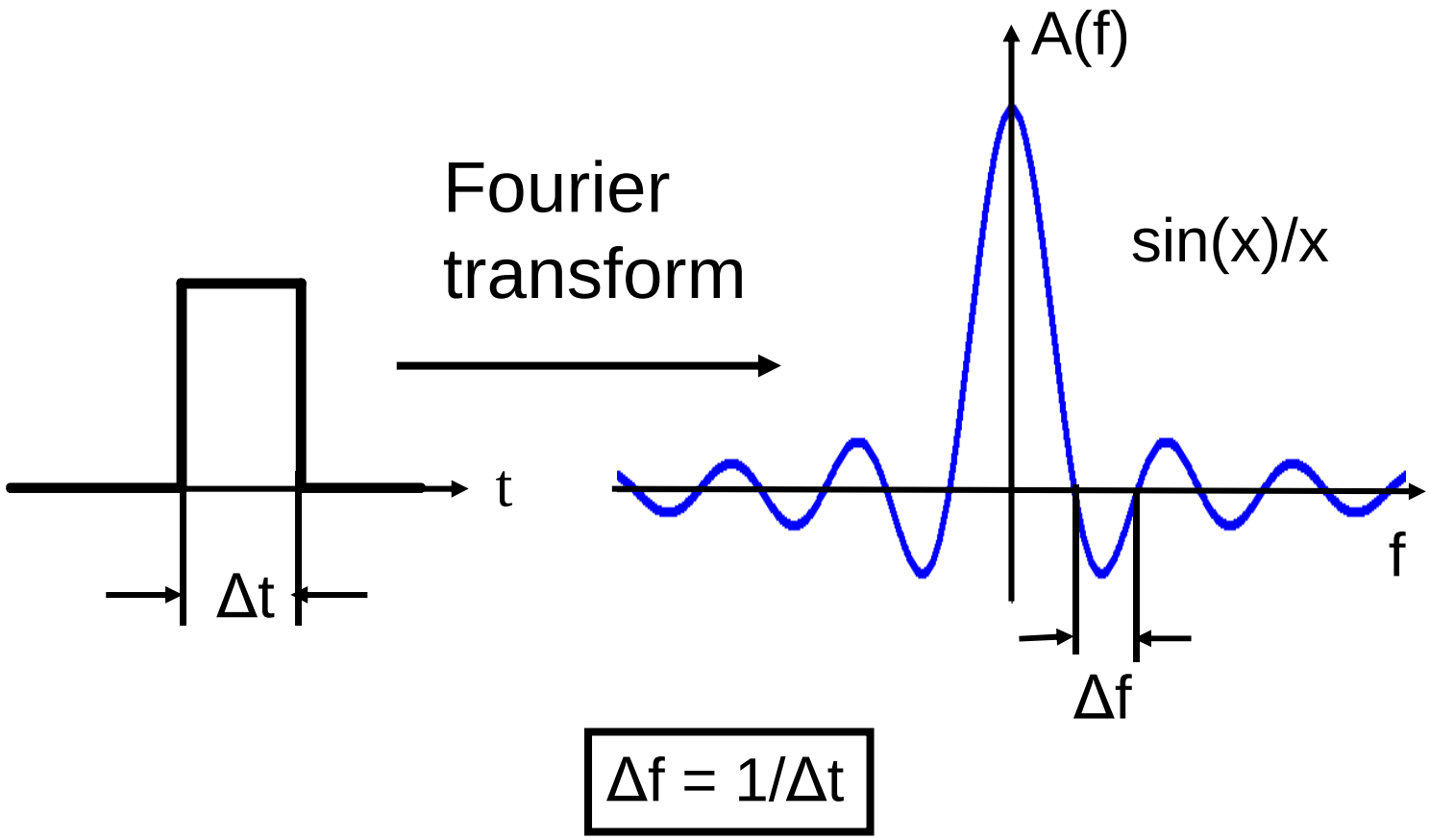
Micro-reflections in upstream (DOCSIS 3.1)

Time	Attenuation
≤0.5 µs	-16 dBc
≤1.0 µs	-22 dBc
≤1.5µs	-29 dBc
>2.0 µs	-35 dBc
>3.0 µs	-40 dBc
>4.5 µs	-42 dBc
>5.0 µs	-51 dBc

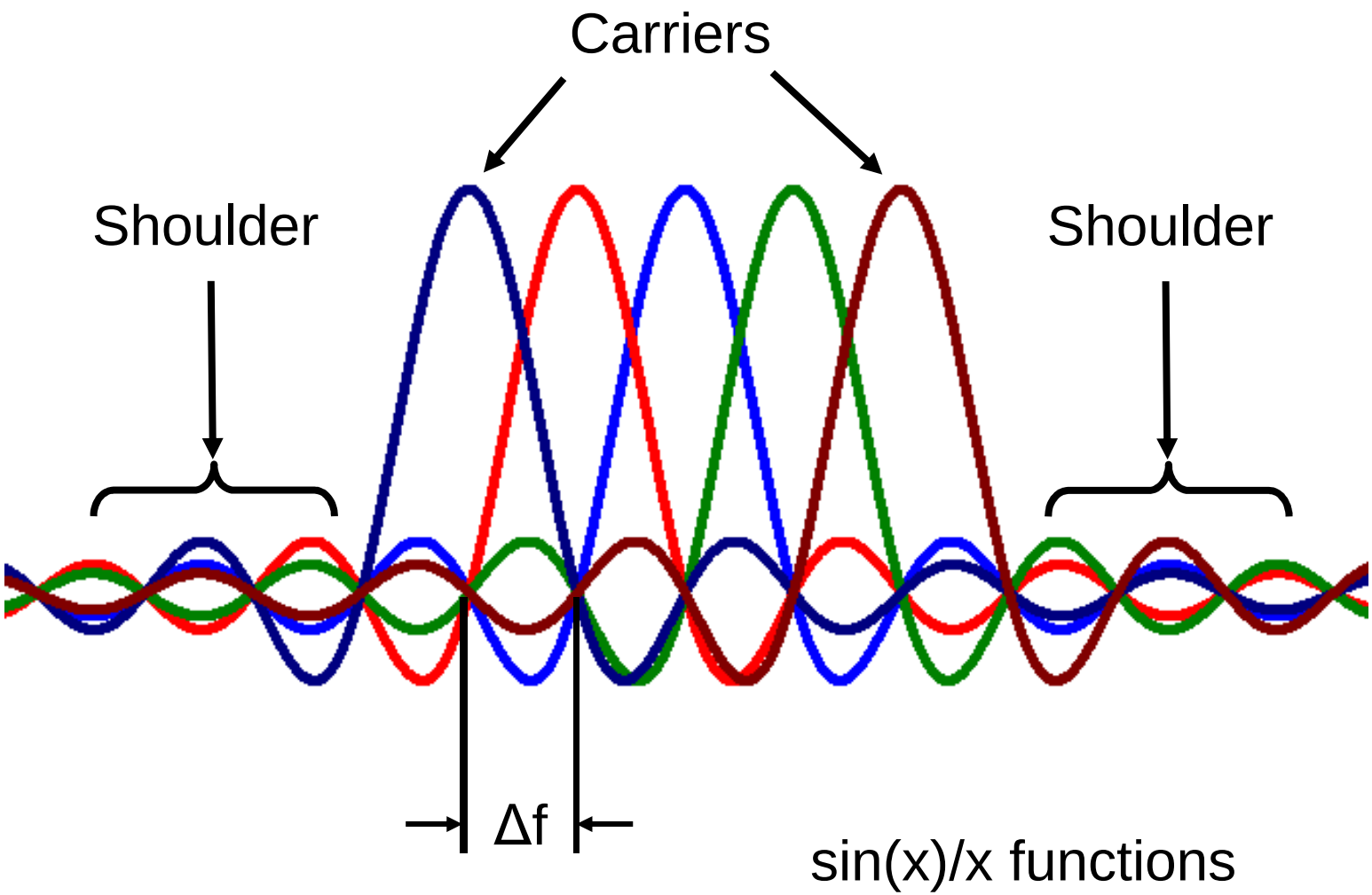
OFDM Spectrum



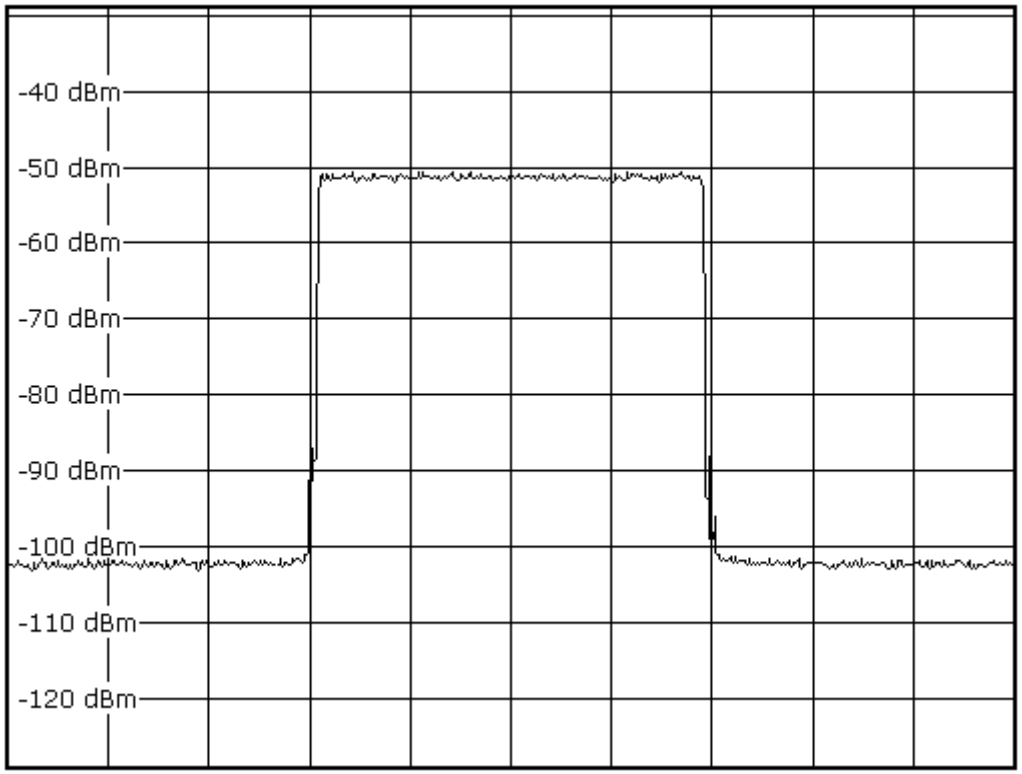
Orthogonality



OFDM Spectrum



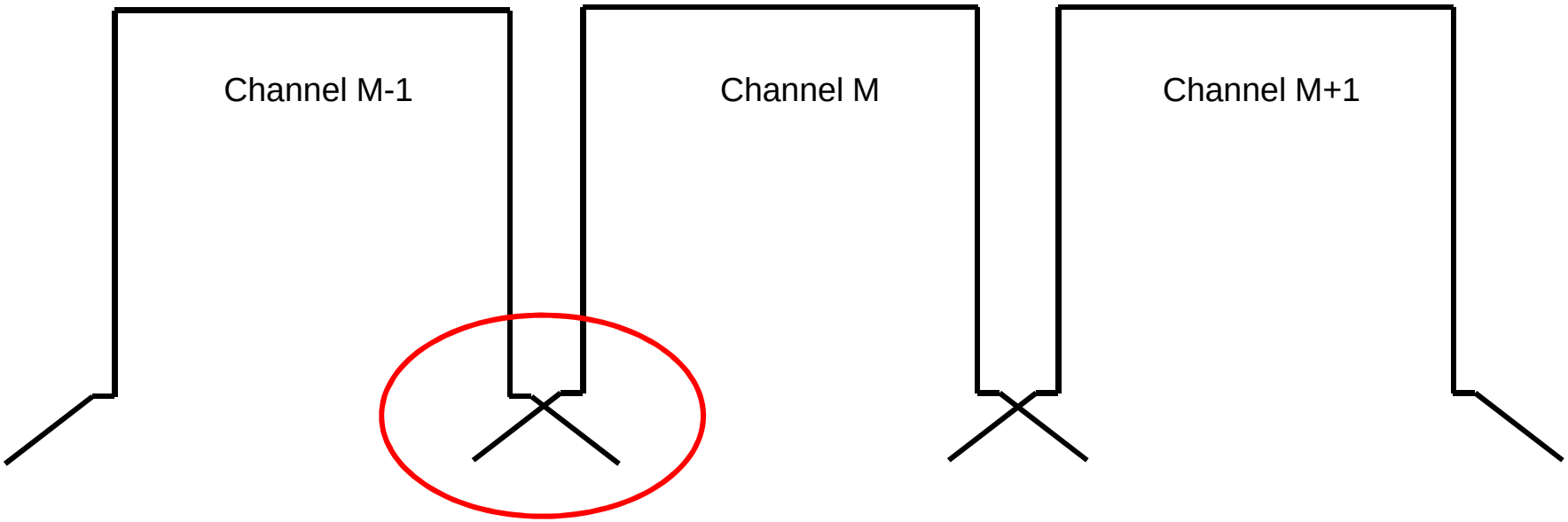
OFDM Spectrum



OFDM – Edge Carriers switched off

„Guard band“

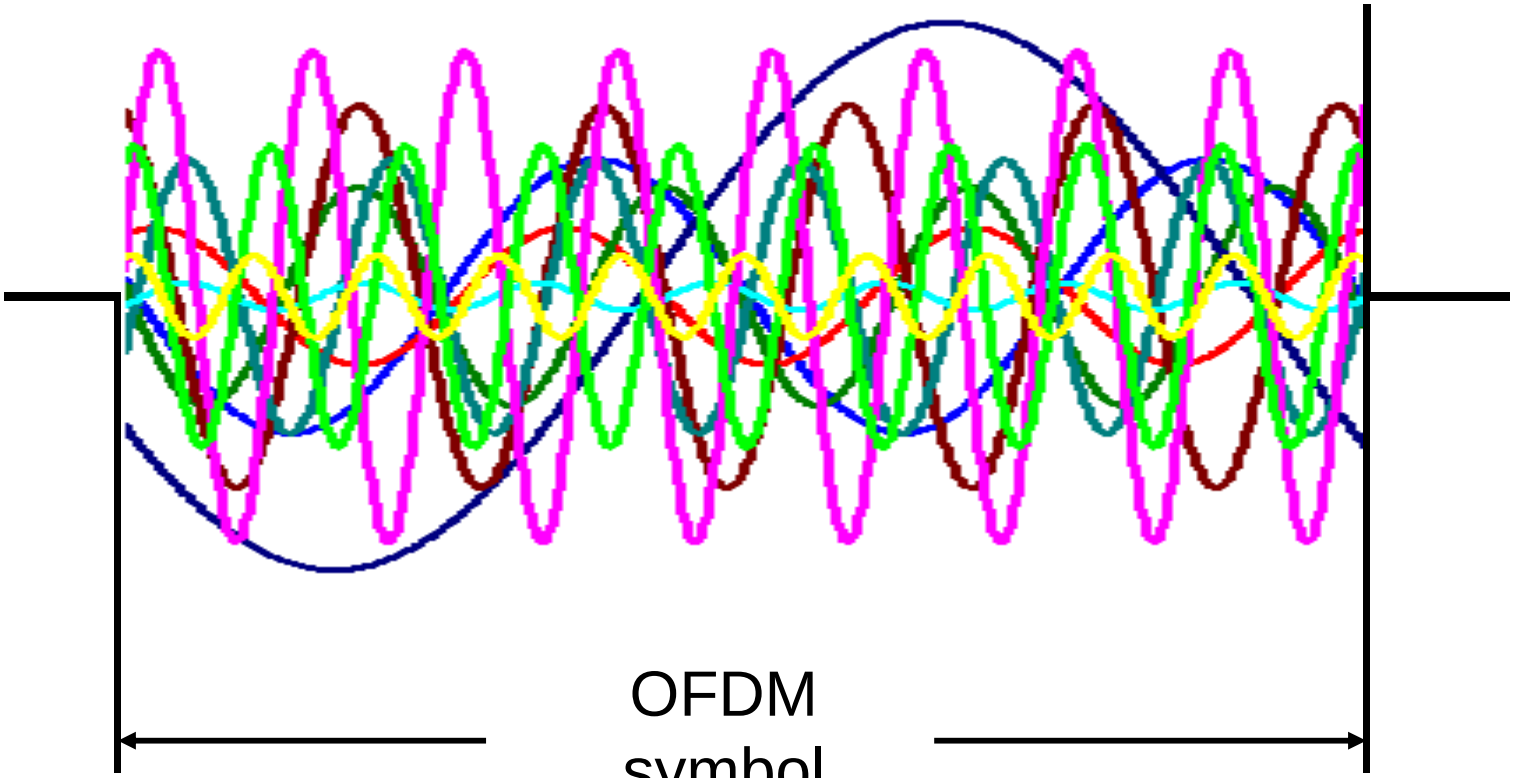
2^N carrier, but edge carriers are switched off: guard band to attenuate the shoulders of the OFDM spectrum



Shoulders of OFDM spectrum

OFDM-Symbol

modulated OFDM carriers in time domain,
discrete carriers ...



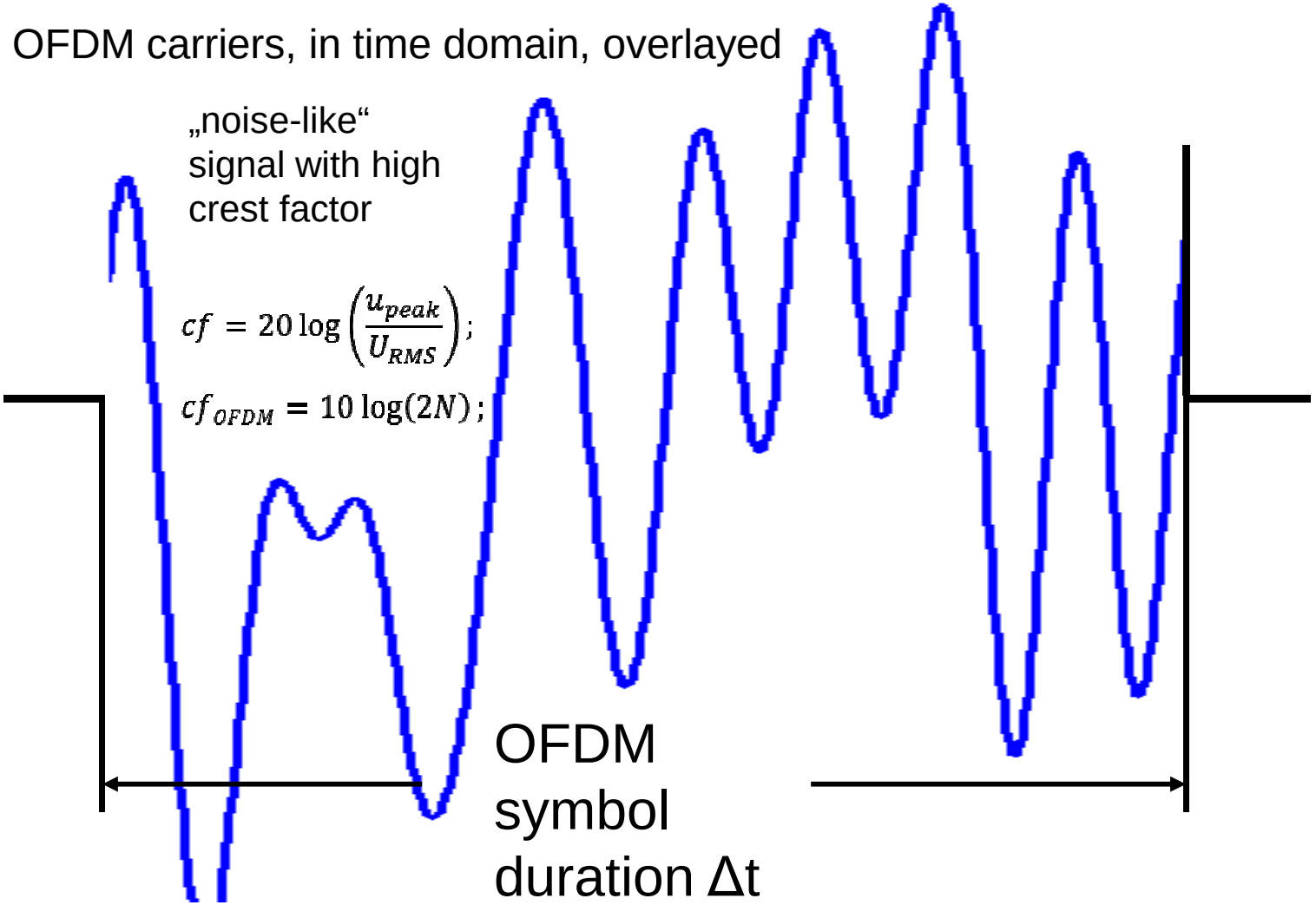
OFDM Symbol

OFDM carriers, in time domain, overlayed

„noise-like“
signal with high
crest factor

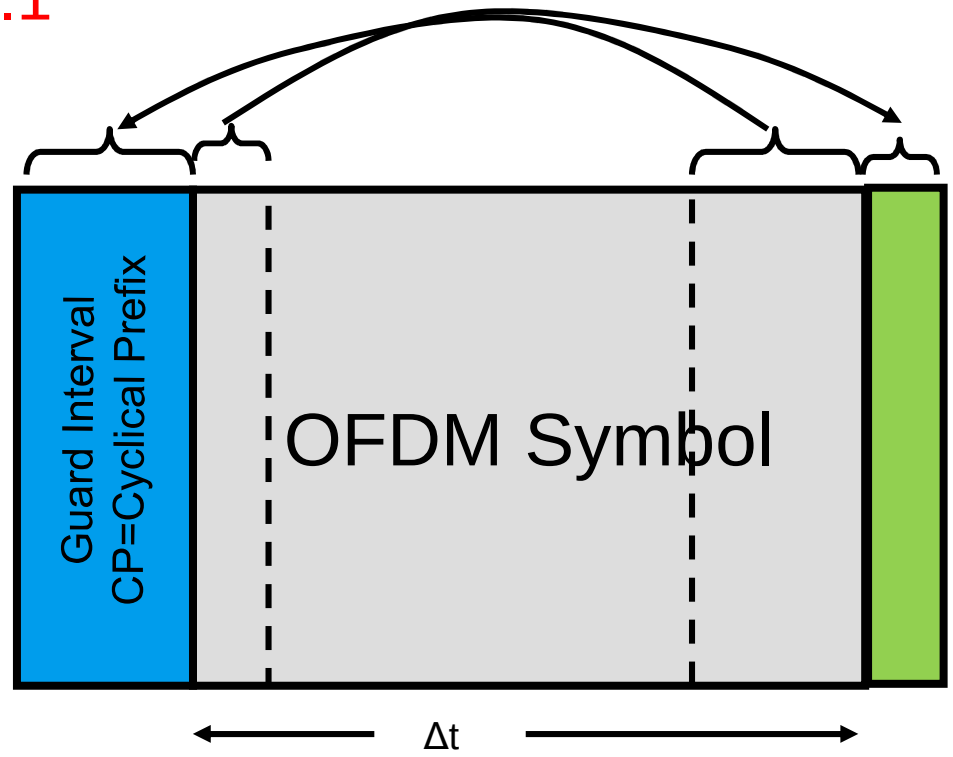
$$cf = 20 \log\left(\frac{u_{peak}}{U_{RMS}}\right);$$

$$cf_{OFDM} = 10 \log(2N);$$



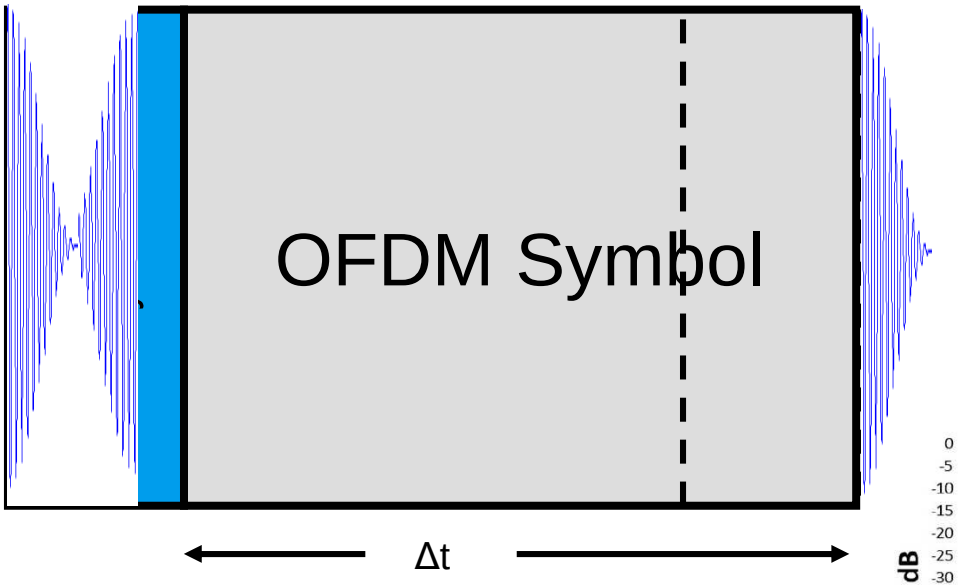
Guard Interval / CP before and behind of the Symbol

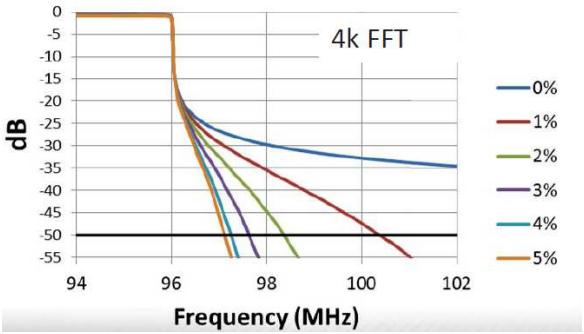
DOCSIS 3.1



Guard Interval & Windowing

DOCSIS 3.1





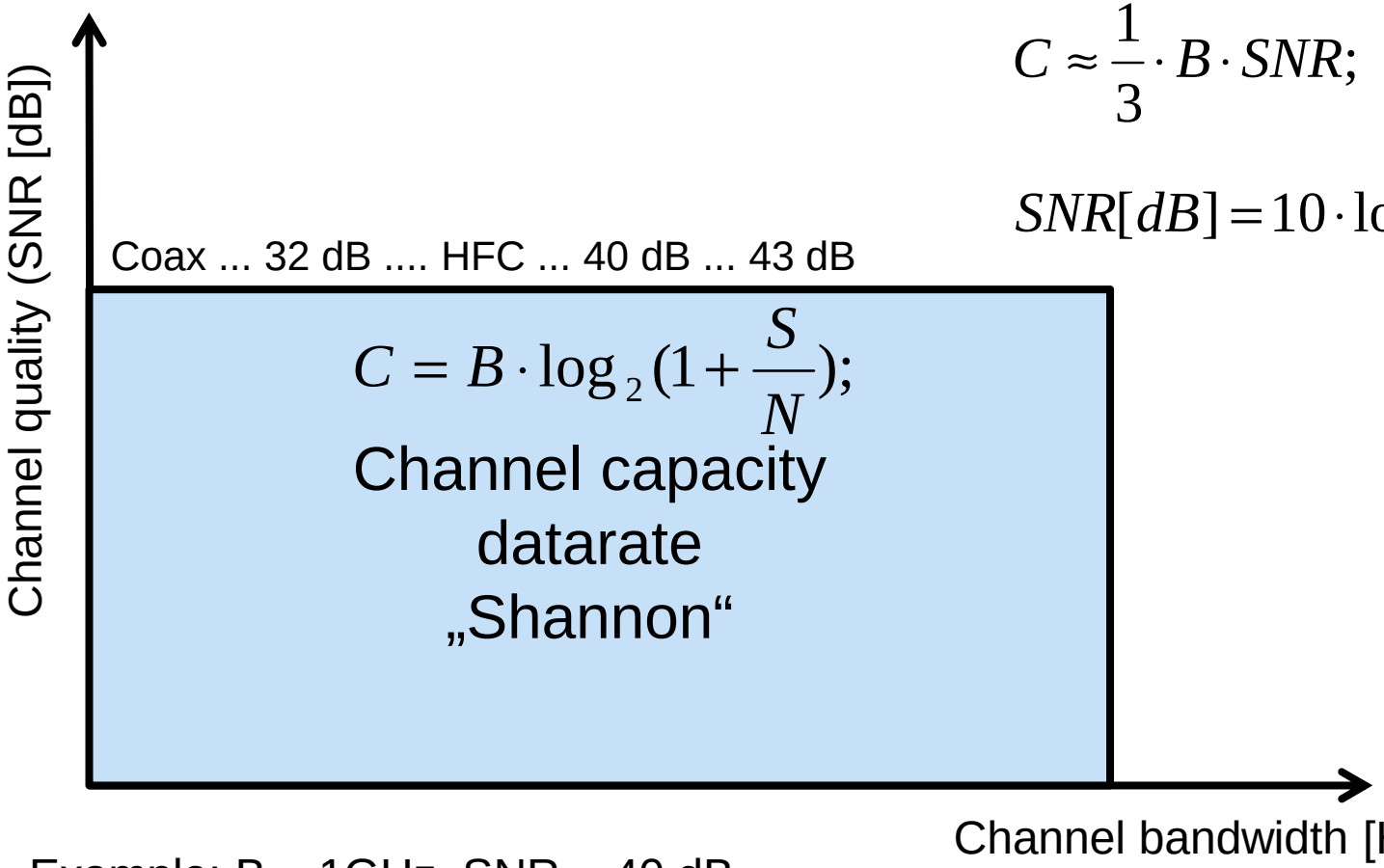
Forward Error Correction
FEC

Transmission Channel – Channel Capacity

S/N>>1:

$$C \approx \frac{1}{3} \cdot B \cdot SNR;$$

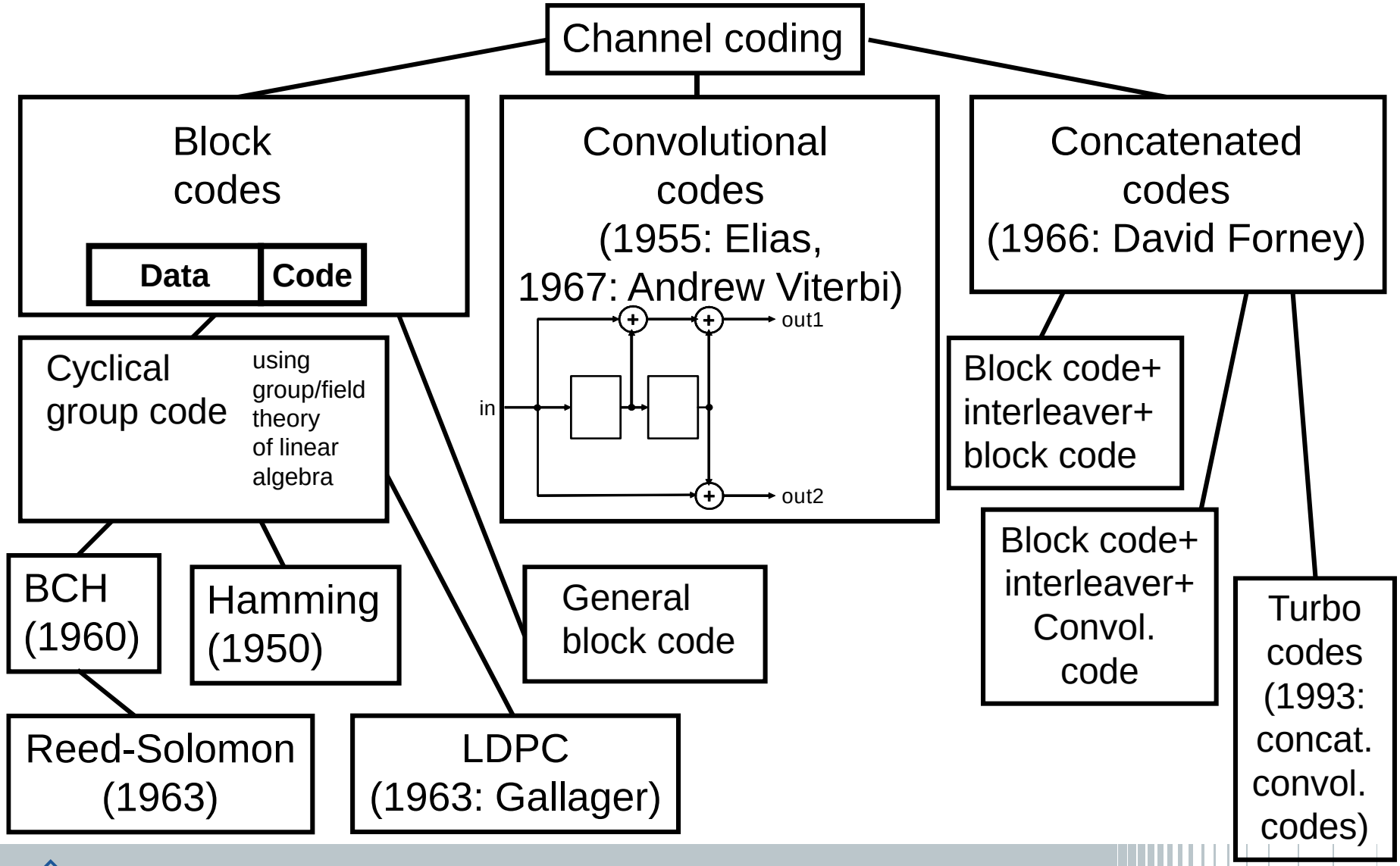
$$SNR[dB] = 10 \cdot \log(\frac{S}{N});$$



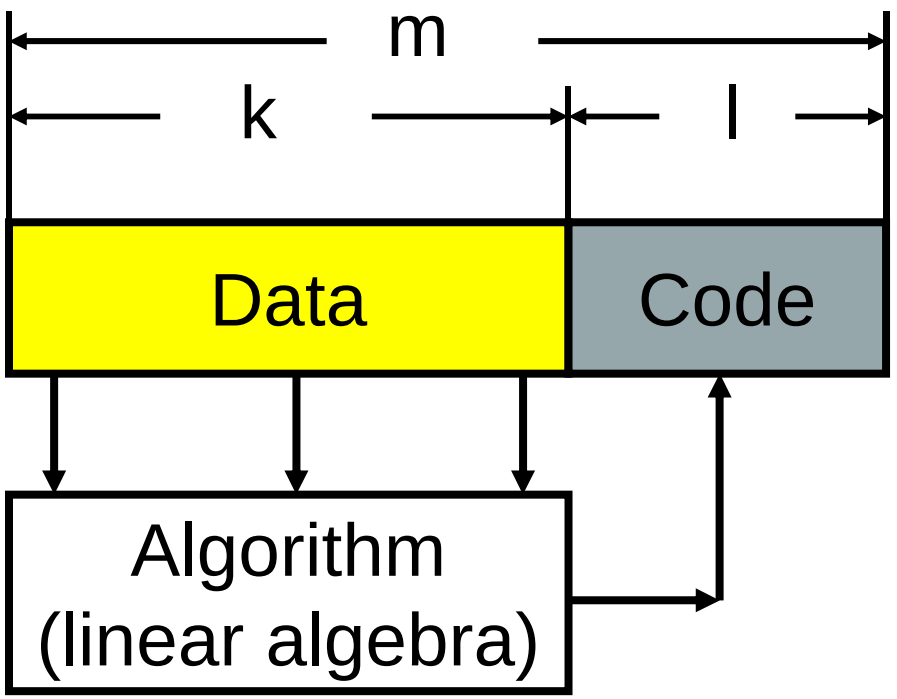
Example: B = 1GHz, SNR = 40 dB
C = 13.3 Gbit/s;

CATV 6, 7, 8 MHz

Channel coding



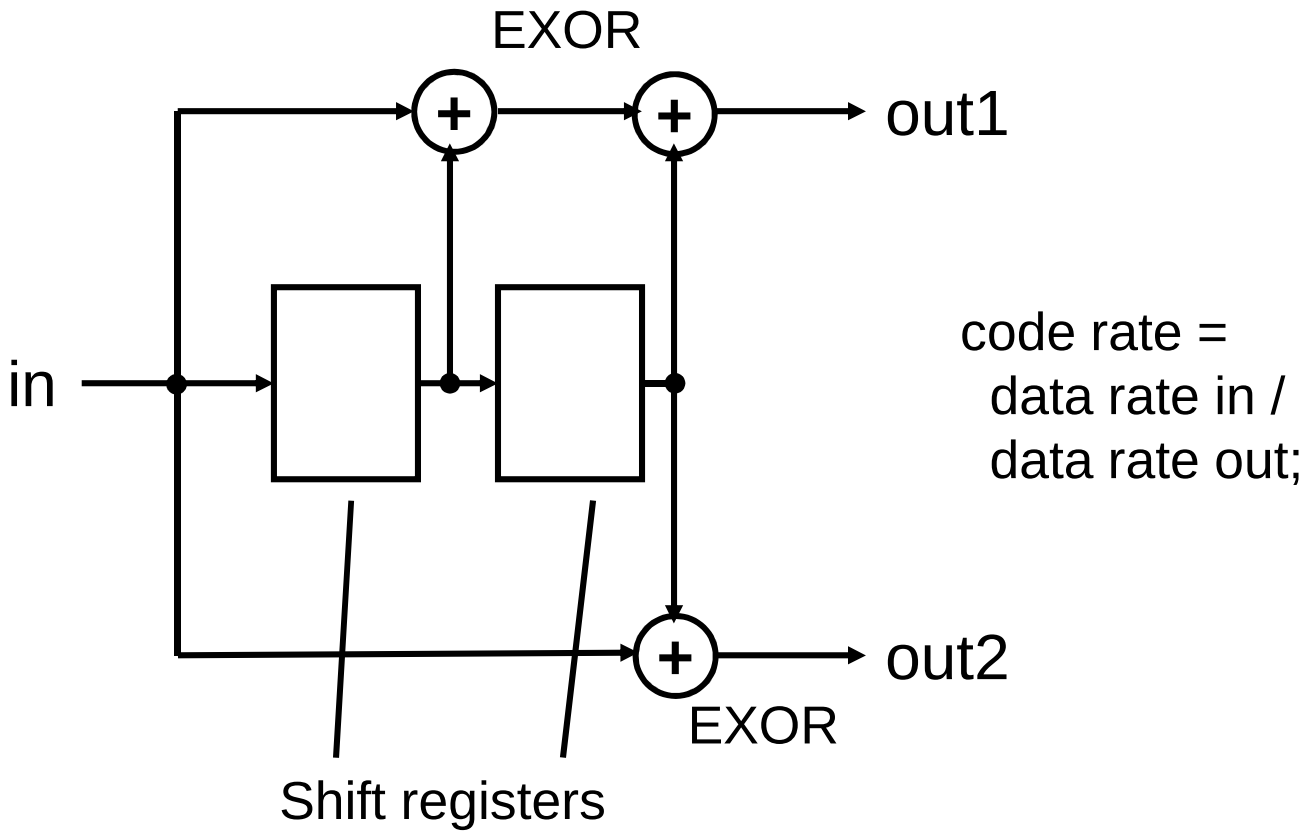
Block Code



$m = k + l$

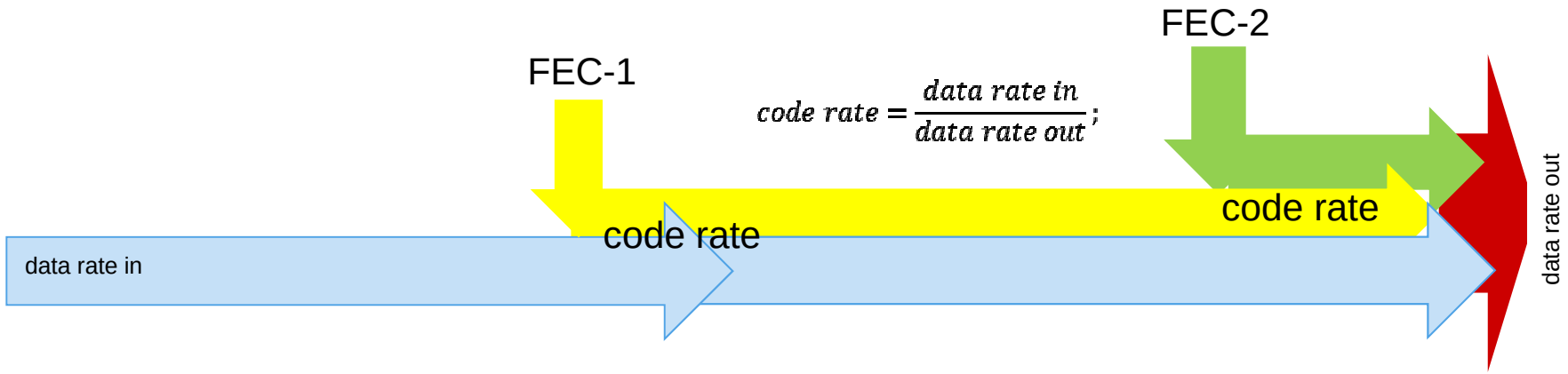
Example: DVB Reed-Solomon code:
k = 188 byte, l = 16 byte, m = 204 byte

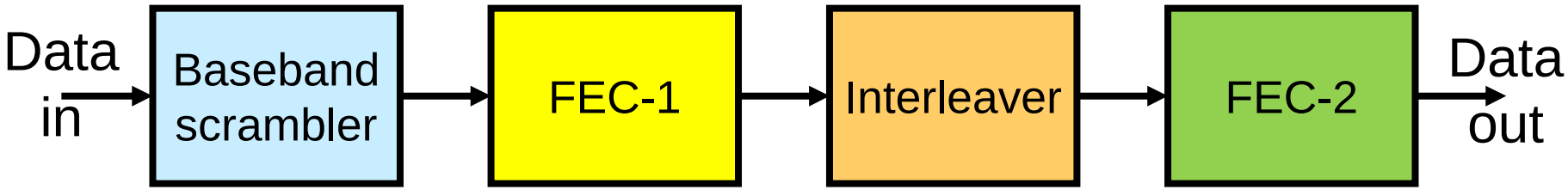
Convolutional Coding



Example: GSM, UMTS, DVB inner coder

Typical FEC Structure





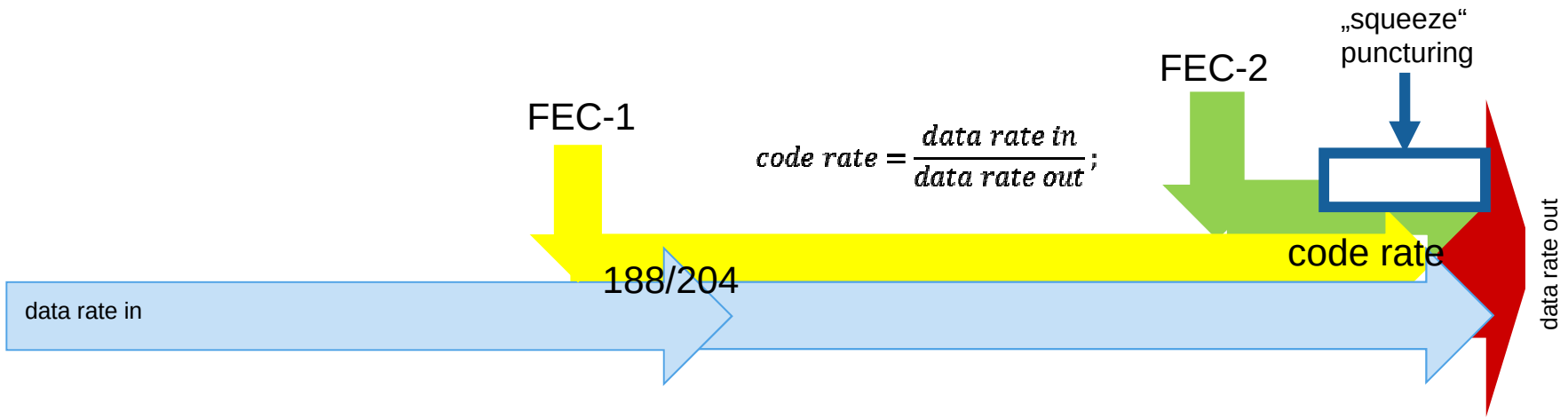
... brakes up ones and zeros sequences

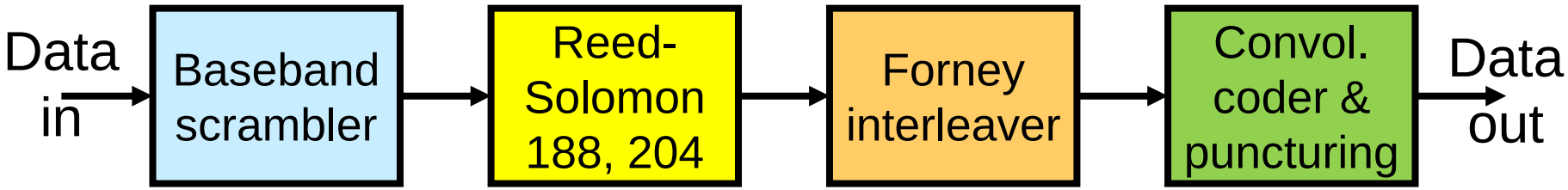
... adds data overhead to the data stream

... distributes information over time ...

... adds data overhead to the data stream

DVB-T FEC Structure





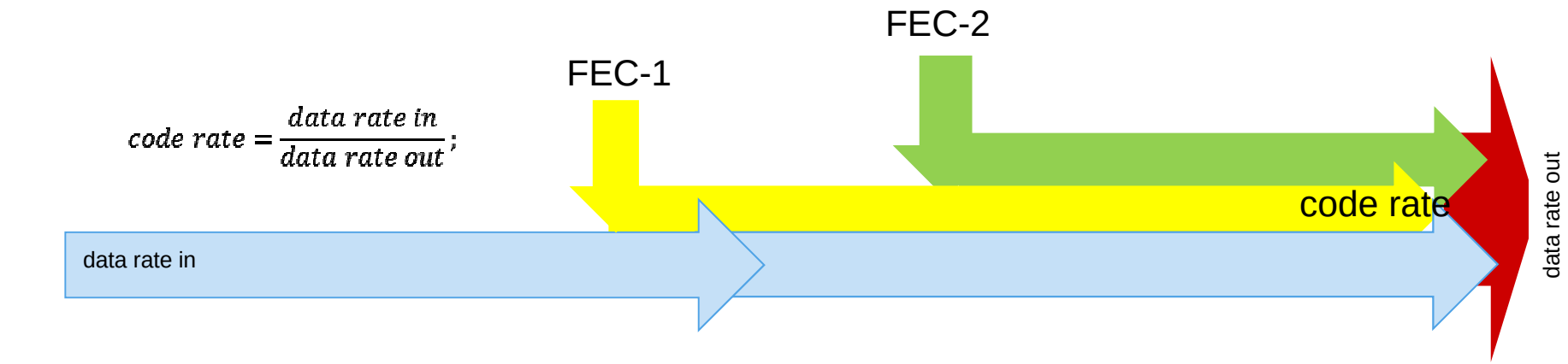
... brakes up ones and zeros sequences

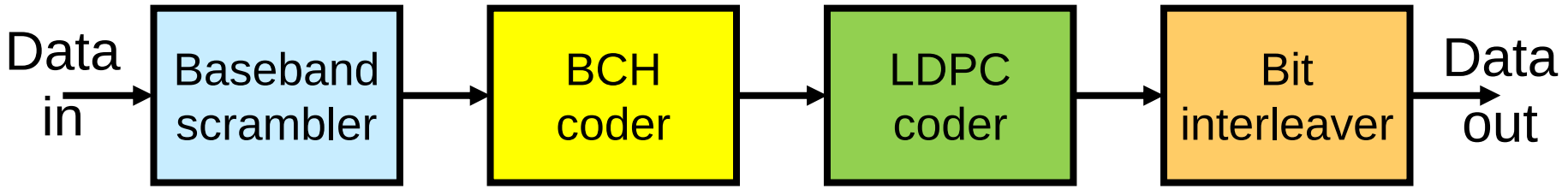
... adds data overhead to the data stream

... distributes information over time ...

... adds data overhead to the data stream

DVB-T2 & DOCSIS3.1 FEC Structure





... brakes up ones and zeros sequences

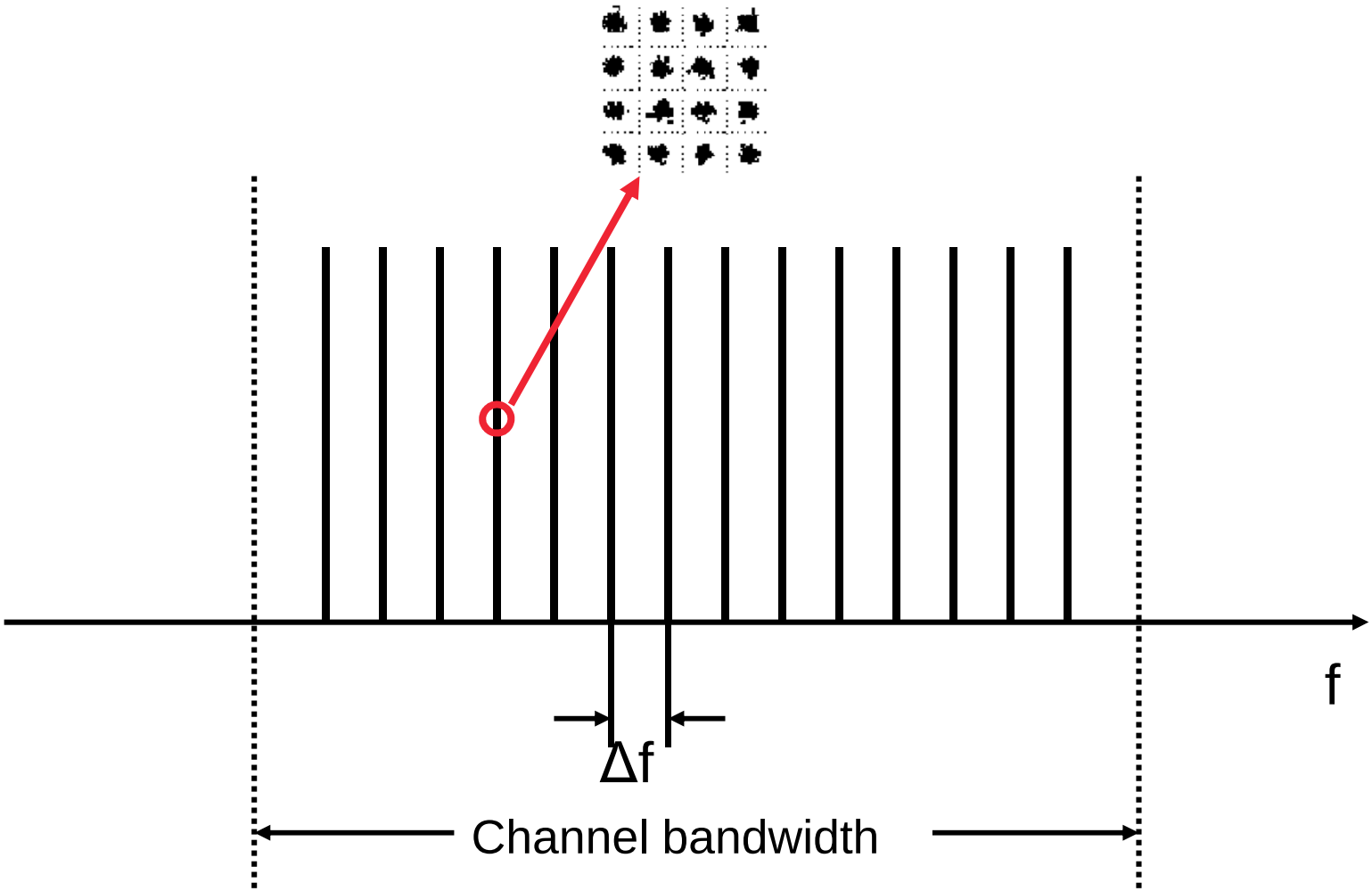
... adds data overhead to the data stream

... adds data overhead to the data stream „Low Density Parity Check Coding“

... distributes information over time ...

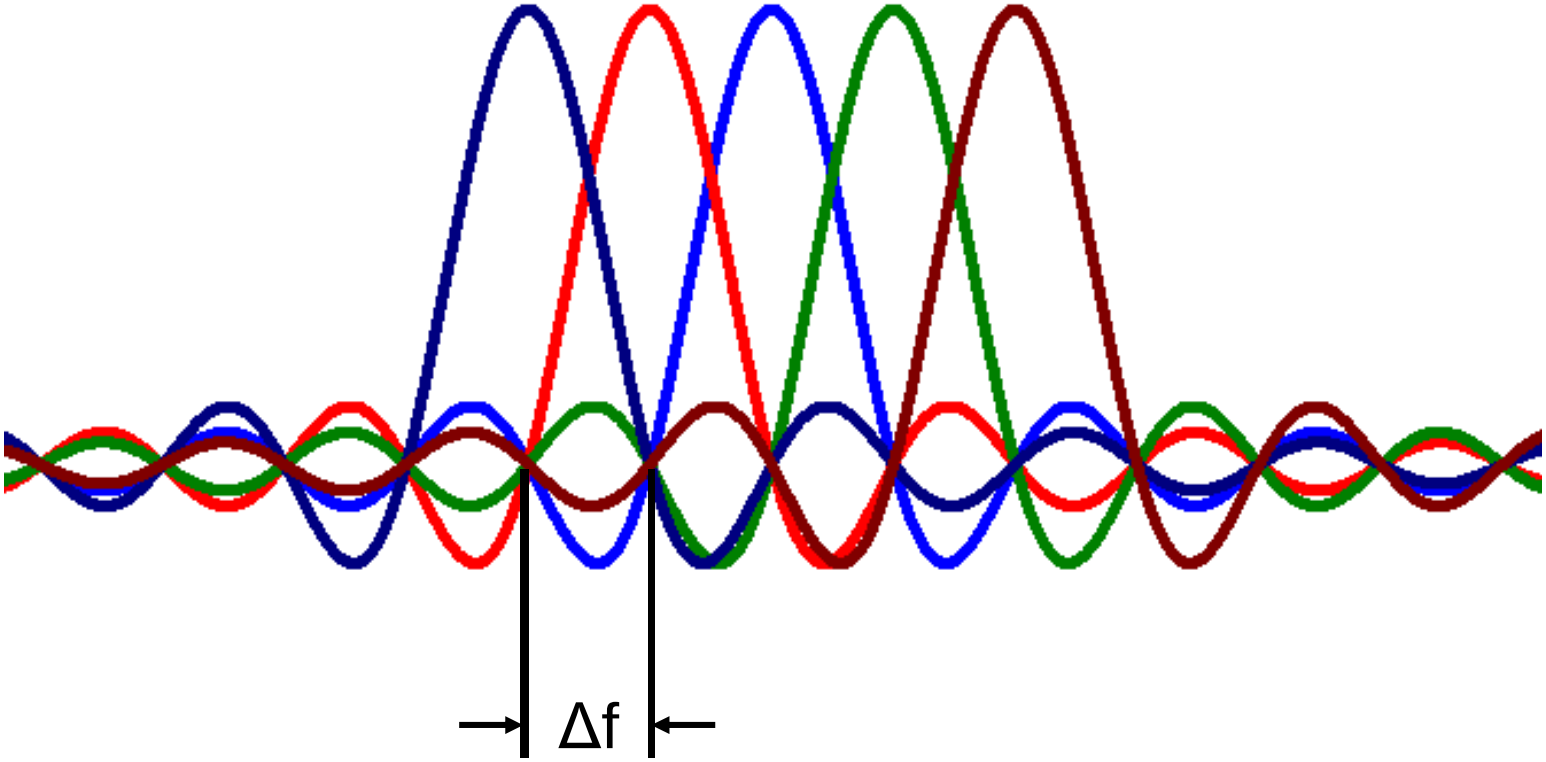
BCH=Bose-Chaudhuri-Hocquenghem
LDPC=Low Density Parity Check Code

OFDM Subcarriers



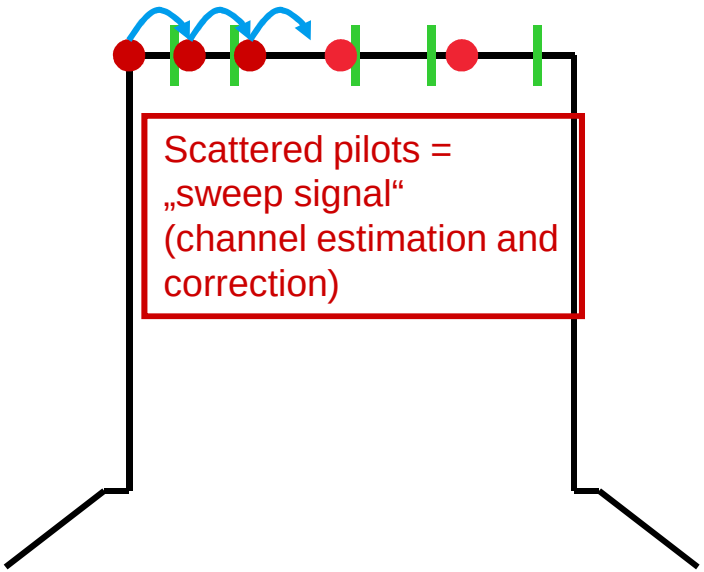
Orthongonality

Orthogonality condition: $\Delta f = 1/\Delta t$



OFDM ... Pilots ... (Example: DVB-T)

TPS= Transmission Parameter Signalling; BPSK modulated; signalling of DVB-T transmission parameters

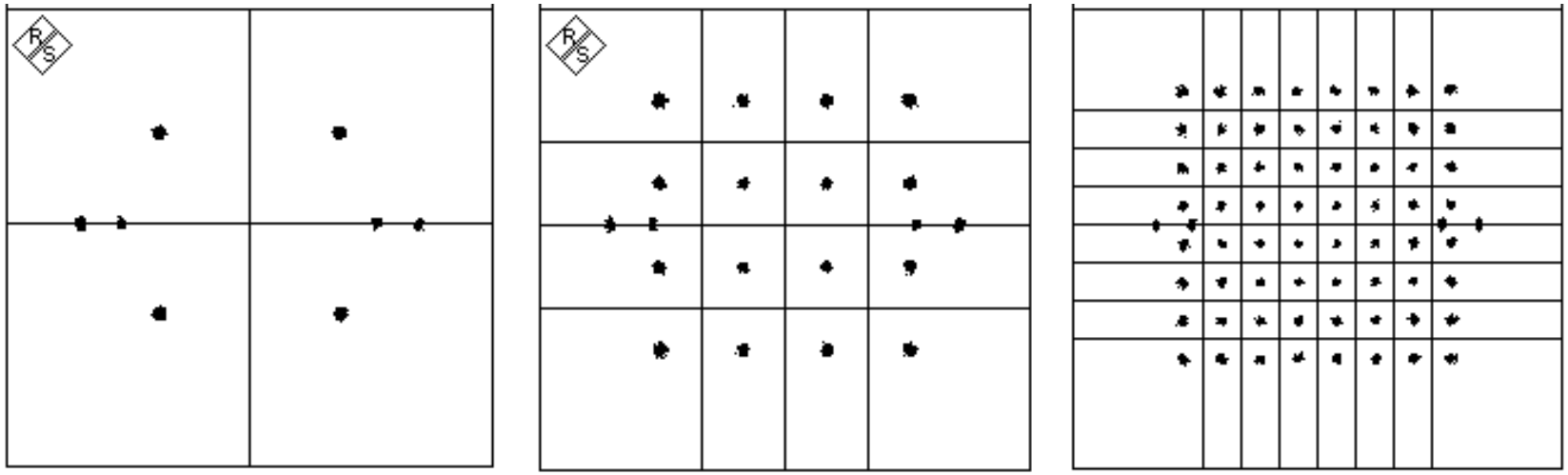


Scattered pilots = „sweep signal“ (channel estimation and correction)

Continual Pilots, fixed position in spectrum and in constellation diagram (AFC = Automatic Frequency Control)

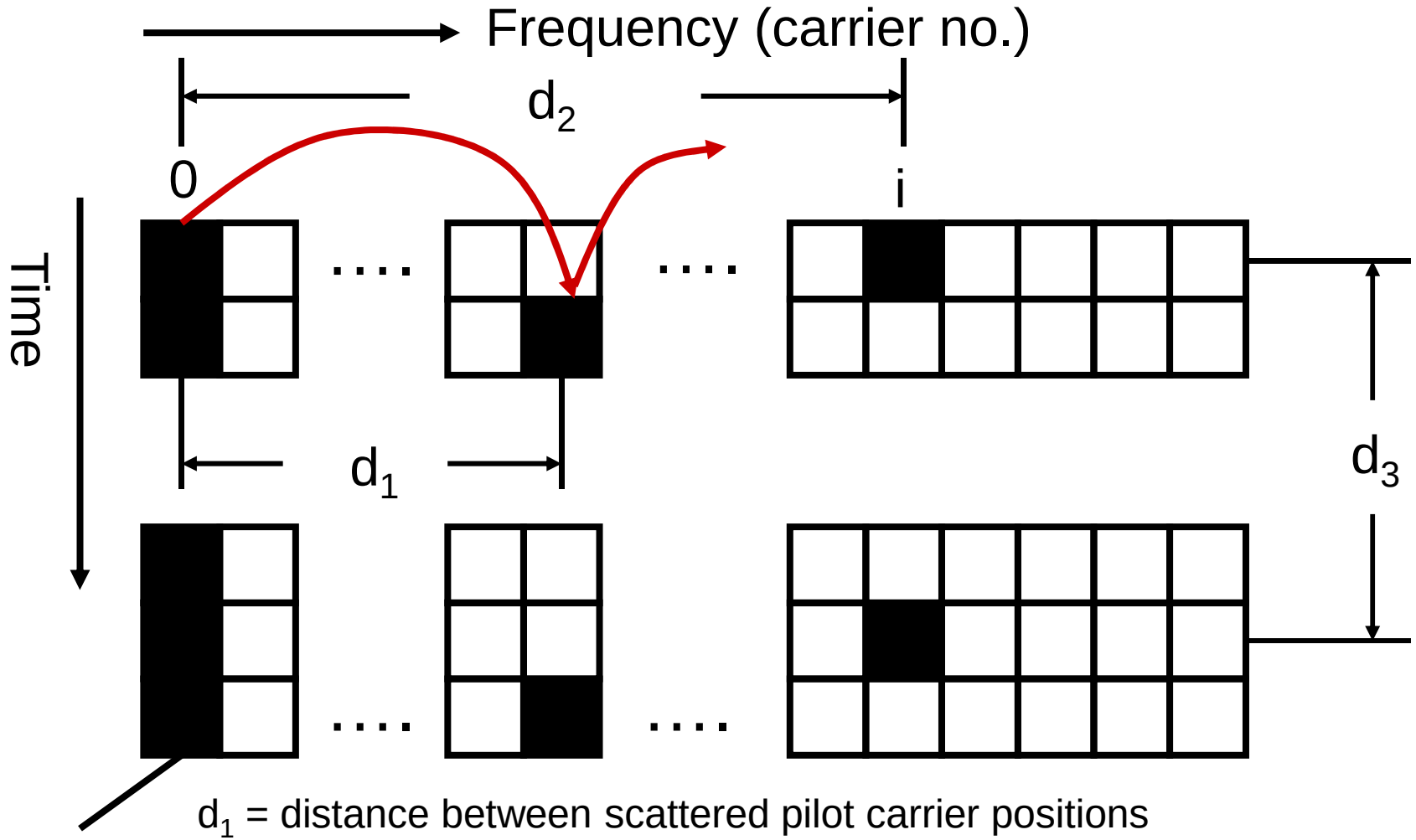
Rotating constellations in the receiver in case of a frequency deviation;
→ frequency correction (AFC) using continual pilots

Constellations Diagram, showing Pilot Signals



Example: DVB-T

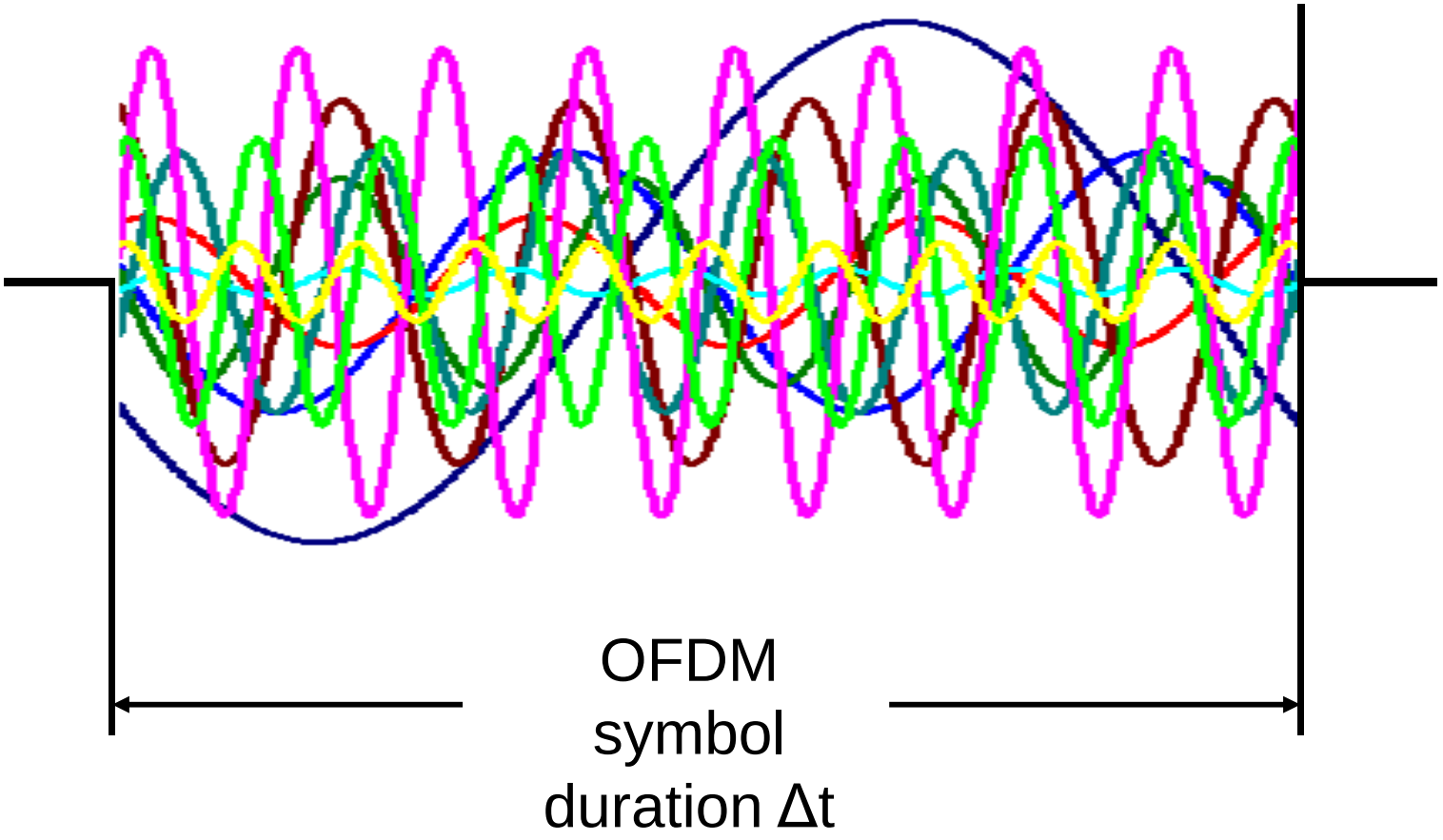
Pilot Pattern



d_1 = distance between scattered pilot carrier positions
d_2 = distance between scattered pilots in one symbol
d_3 = symbols forming one scattered pilot sequence

Bulding OFDM Frames ... (1)

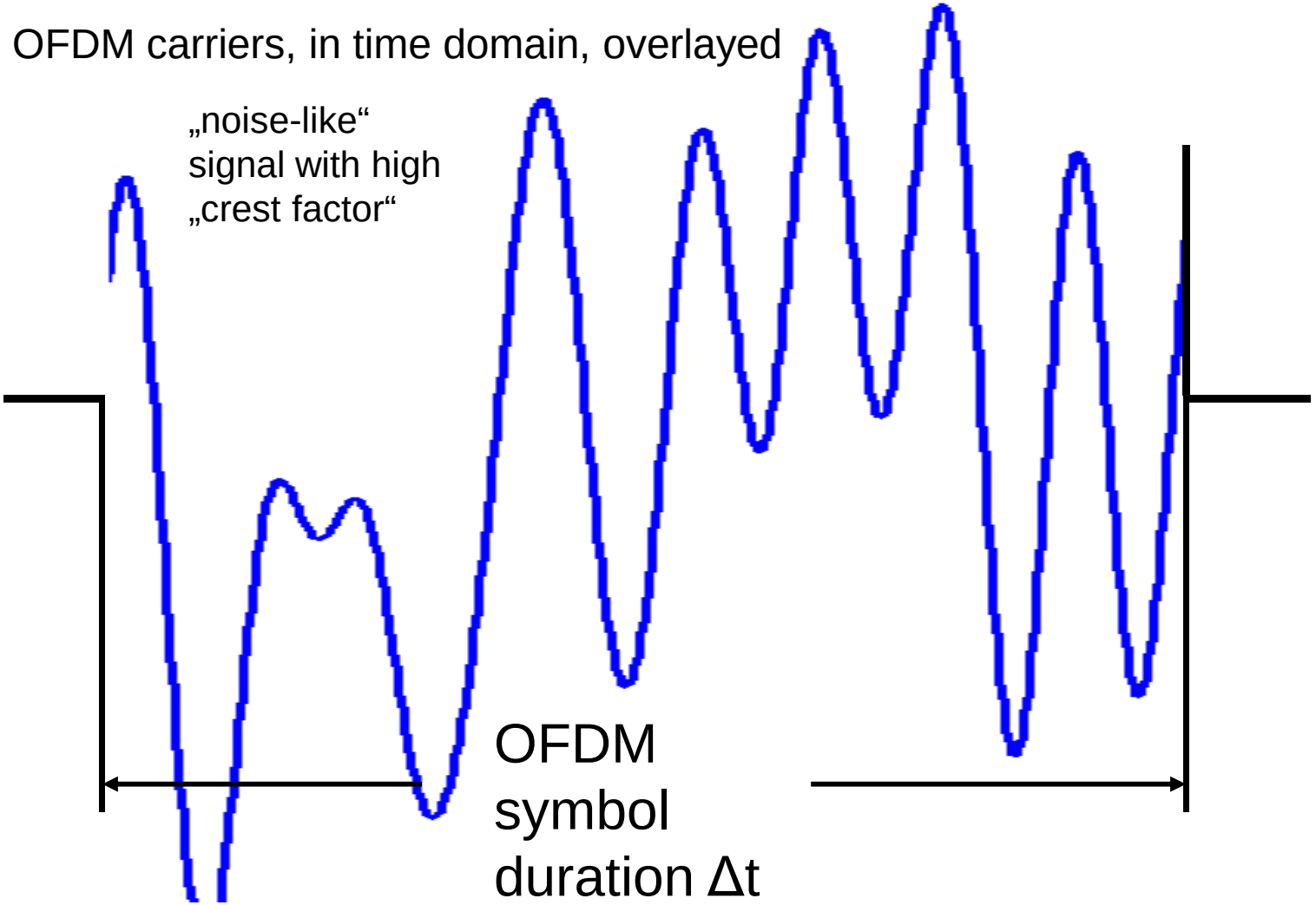
Modulated OFDM carrier signals in time domain,
discrete carriers shown ...



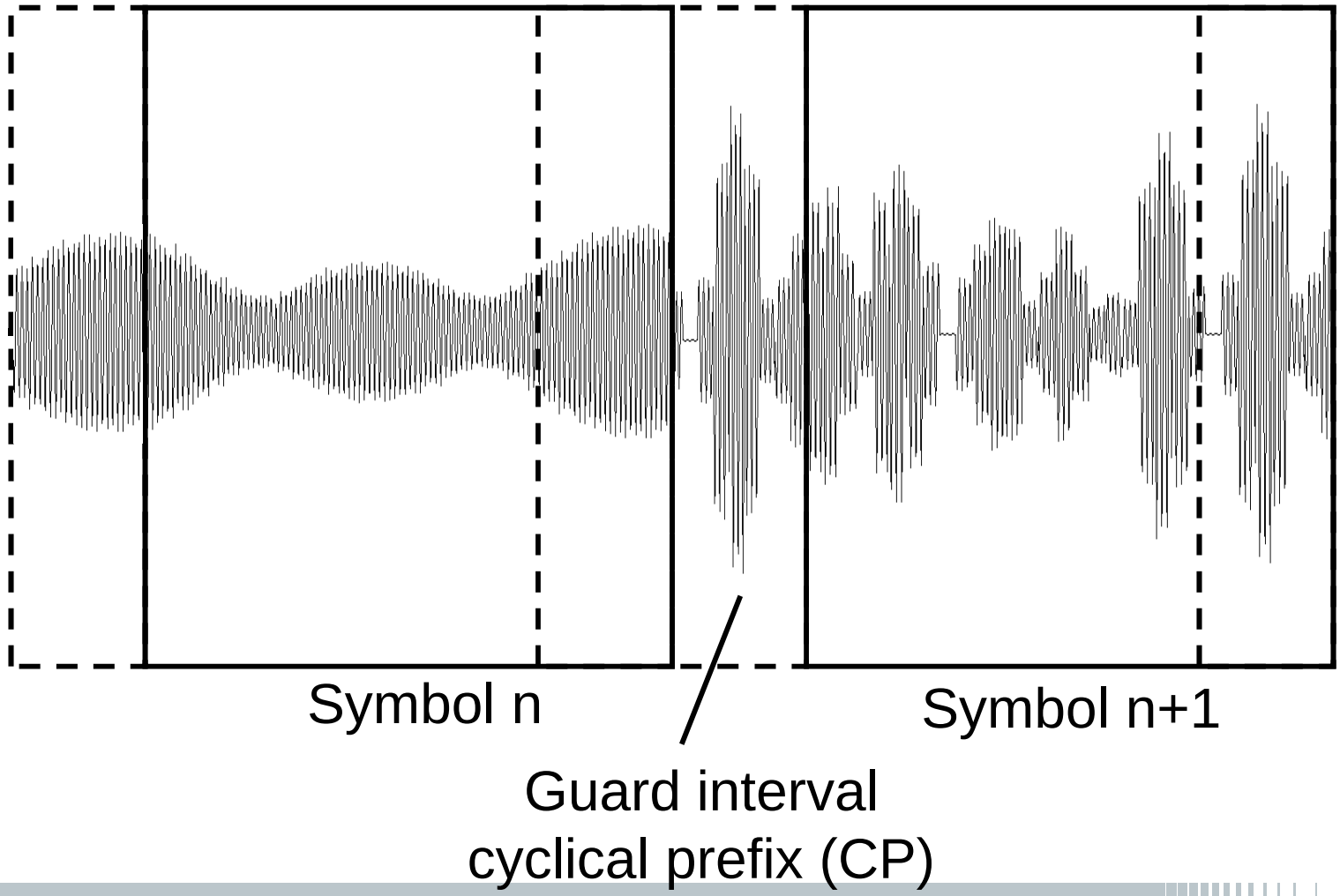
Building OFDM Frames ... (2)

OFDM carriers, in time domain, overlayed

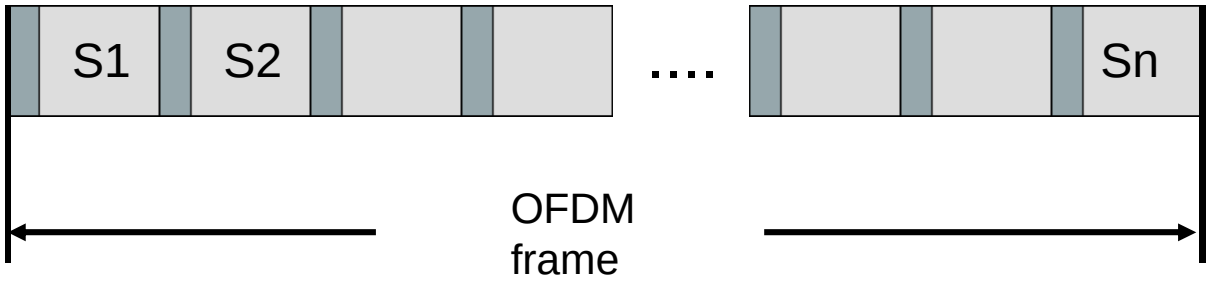
„noise-like“
signal with high
„crest factor“



Building OFDM Frames ... (3)



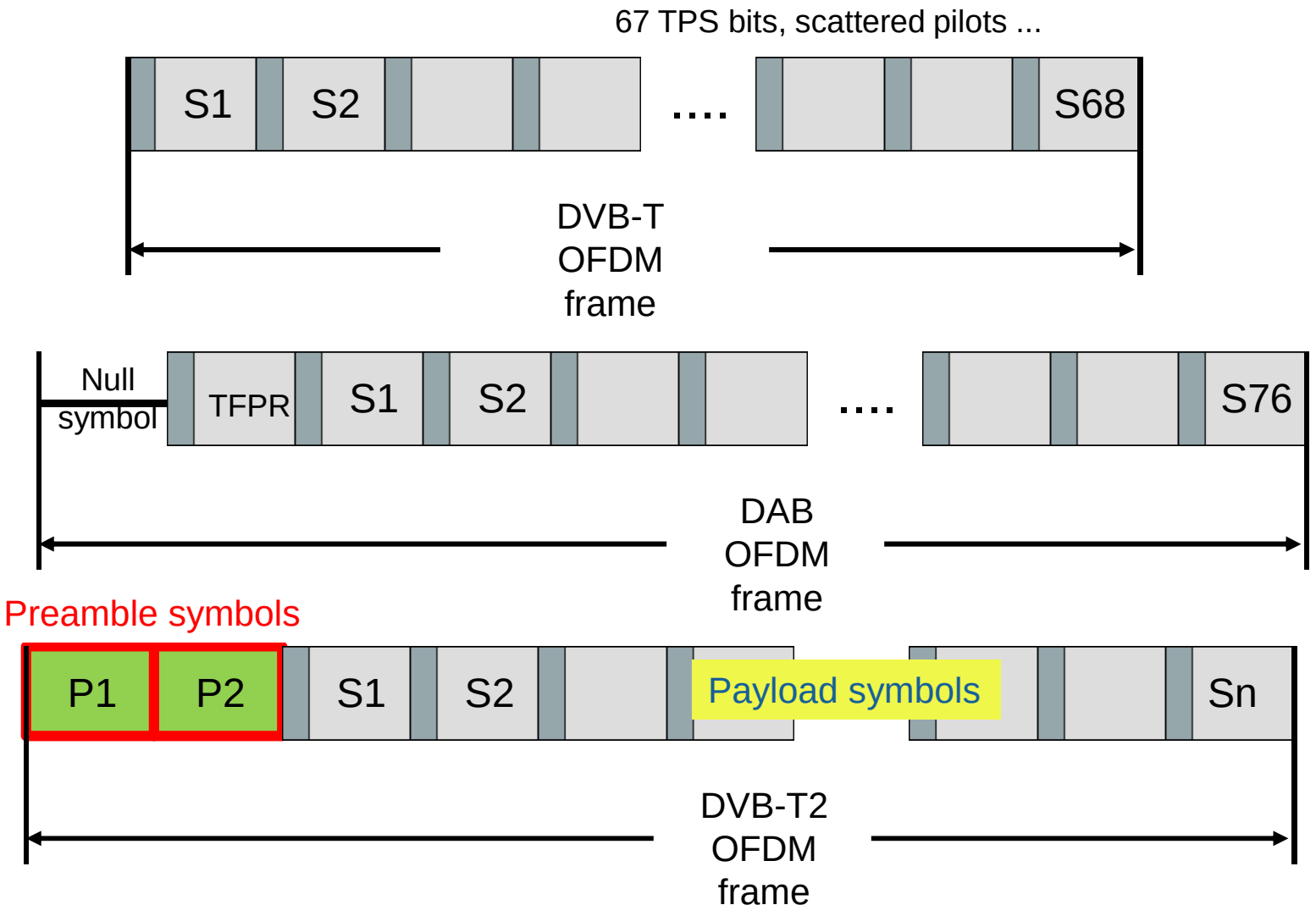
From a OFDM Symbol to a OFDM Frame (4) ...



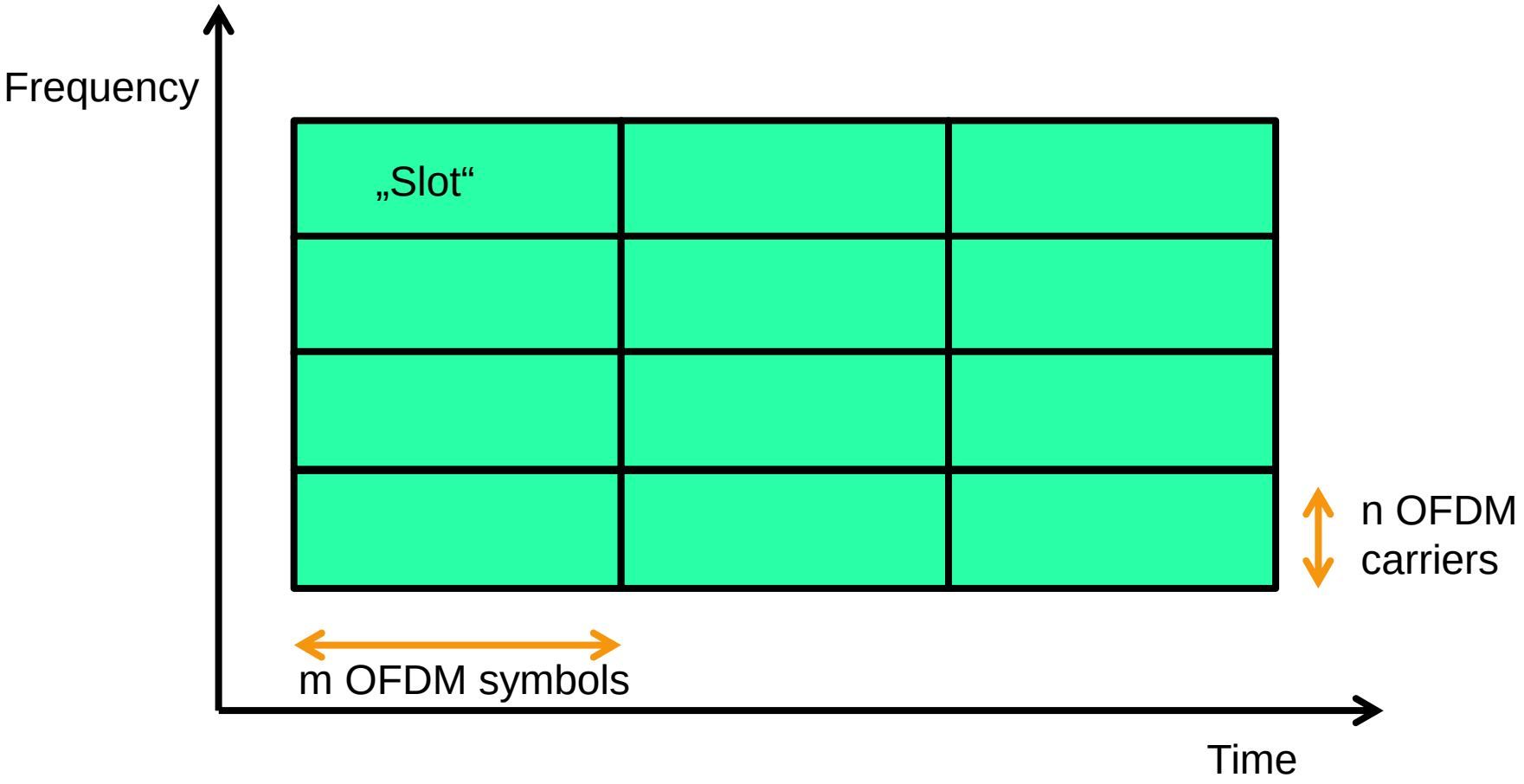
S1 ... Sn = OFDM symbols incl. guard interval

n symbols = 1 frame

From a OFDM symbol to a OFDM Frame ... (5)

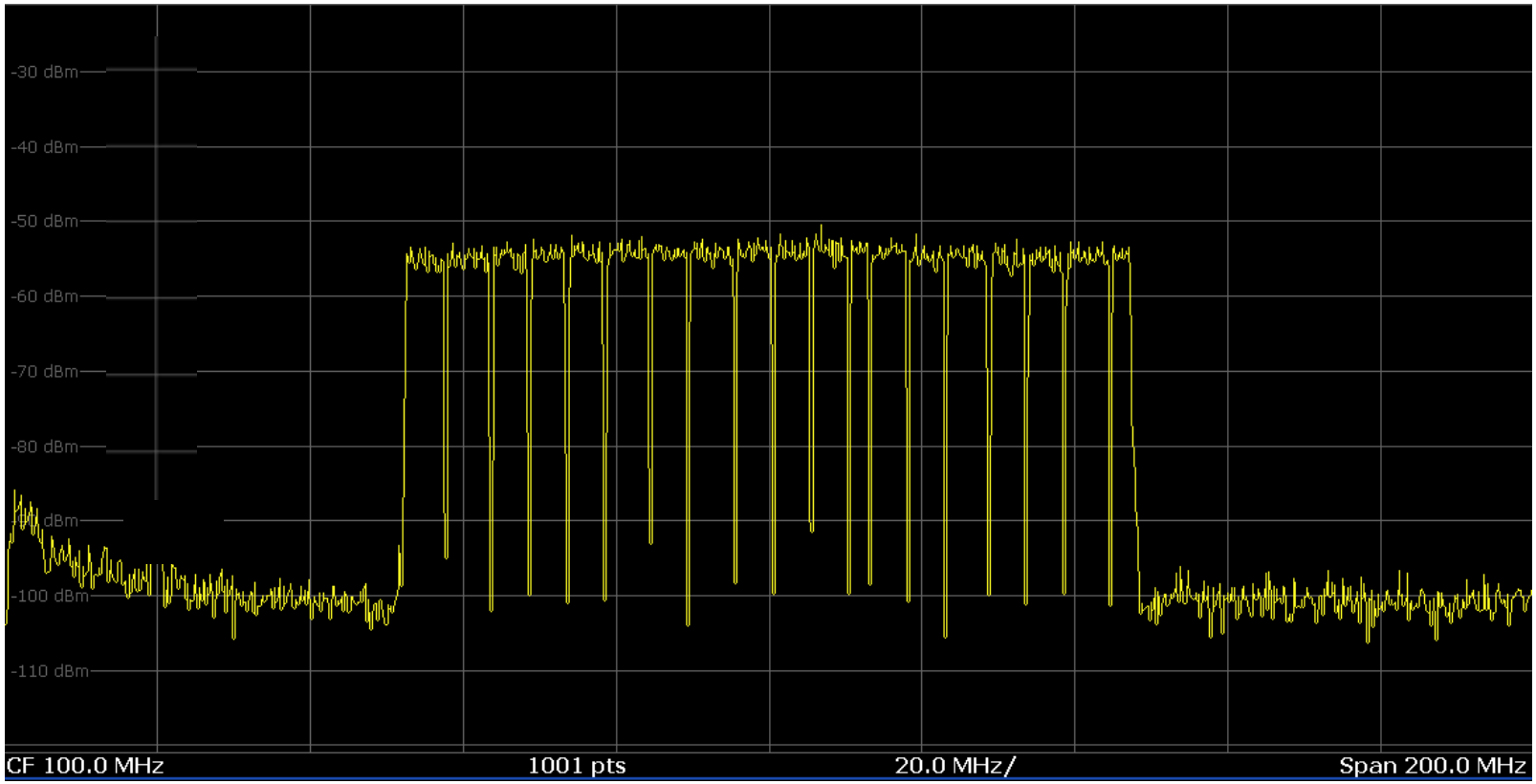


OFDM in Time and Frequency Domain (6)



DOCSIS 3.1 Upstream

DOCSIS3.1
Upstream



From DVB-C2 to DOCSIS 3.1

- DOCSIS Intro and Principle
- Single Carrier Modulation Principle
- Time Domain and Spectrum Domain
- QAM and SNR Requirement
- OFDM Basics, OFDM in CATV
- DOCSIS 3.1 Physical Layer Parameters
- DOCSIS 3.1 Demo Transmission

From DVB-C2 ... to ... DOCSIS 3.1

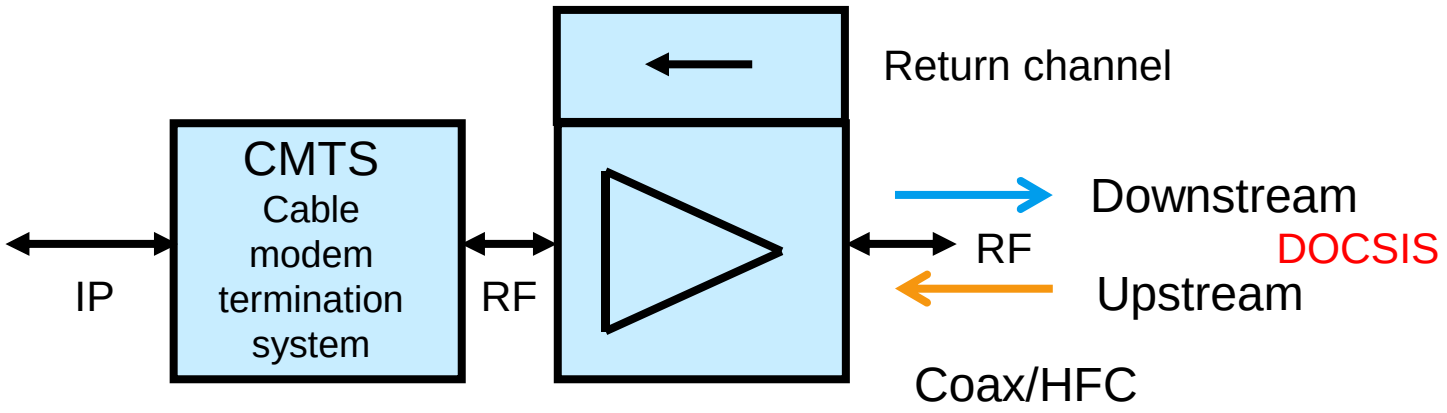
DVB-C2 based on DVB-T2

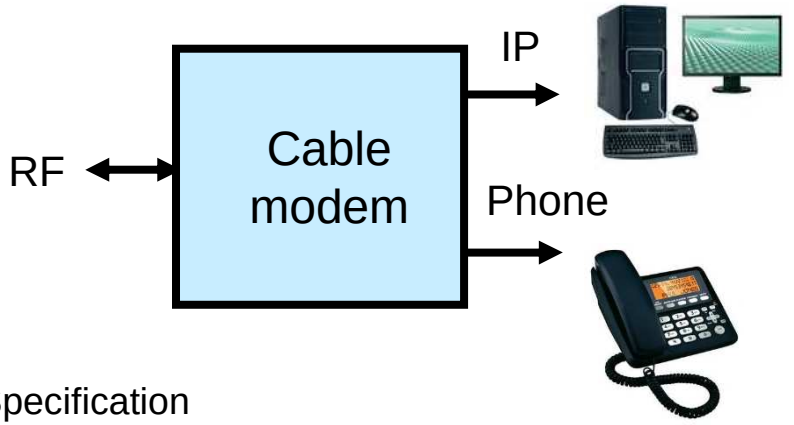
- narrow-band channel design (6, 8 MHz) with wide-band channel-bonding option
- Long interleaver design for broadcast applications
- Narrow OFDM subcarrier distance 1.7/2.2 kHz (4K mode in 6, 8 MHz)
- Only downstream, no upstream defined

DOCSIS 3.1 design

- wideband-band channel design (192 MHz) with narrow band option (... 24 MHz)
- Optimized for short response time ... 1 ms
- Wide OFDM subcarrier distance 25/50 kHz (4K / 8K mode in 192 MHz)
- Downstream and upstream

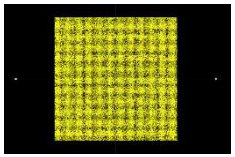
DOCSIS 3.1 Downstream, Upstream





DOCSIS – Data-over-Cable Service Interface Specification

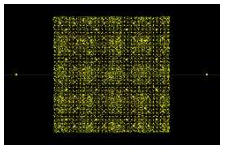
DOCSIS 3.1 Downstream

up to 16384QAM 

Parameter	DOCSIS 3.1	DOCSIS 3.0
Type of modulation	OFDM 4K and 8 K FFT	single carrier (J.83/B, DVB-C)
Frequency range	108 MHz to 1218 MHz (1794 MHz)	45 MHz to 1002 MHz
Channel bandwidth	up to 192 MHz	6 MHz / 8 MHz
QAM constellations	up to 4096, 8k, 16k	up to 256
Cyclic prefix length	0.9375 µs to 5 µs	n/a
Pilots	scattered and continuous	n/a
Forward Error Correction	BCH-LDPC	Reed-Solomon
DS capacity (bps)	8 G (10 G)	300 M (1 G)

25 kHz / 50 kHz carrier spacing
7680 / 3840 carriers in 192 MHz bandwidth

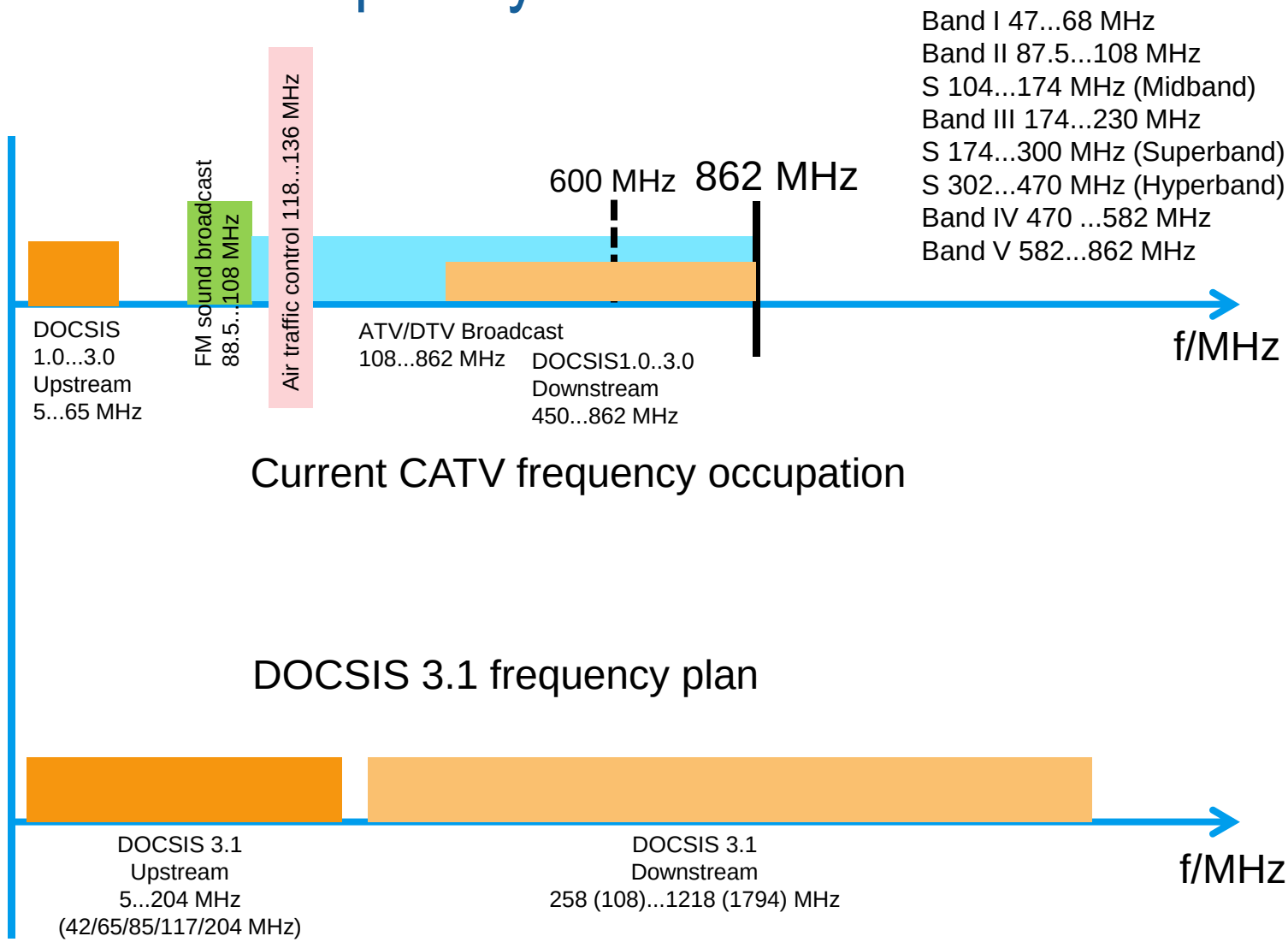
DOCSIS 3.1 Upstream

up to 4096QAM 

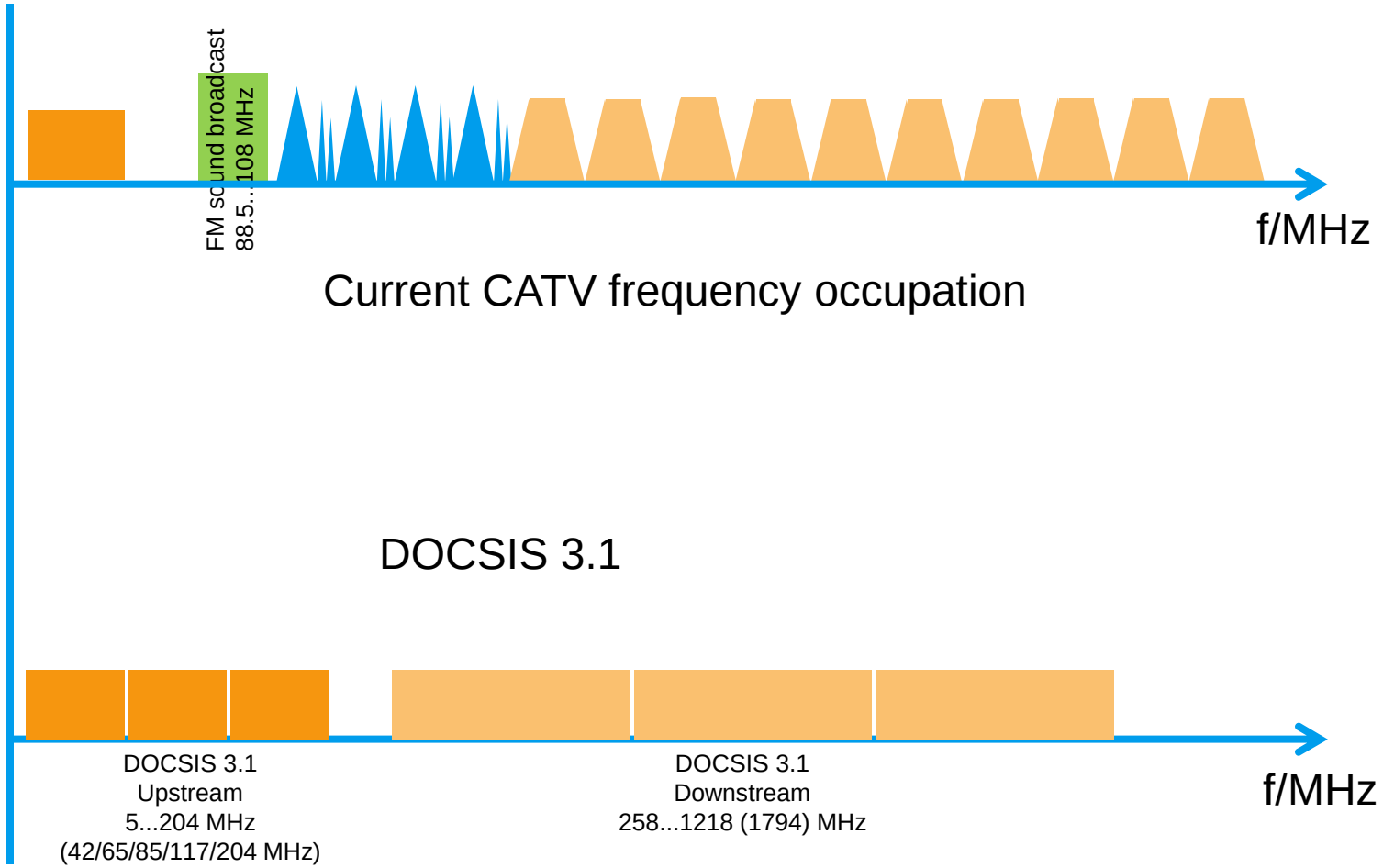
Parameter	DOCSIS 3.1	DOCSIS 3.0
Type of modulation	OFDM 2K and 4 K FFT	single carrier TDMA, S-CDMA
Frequency range	5 MHz to 204 MHz	5 MHz to 85 MHz
Channel bandwidth	up to 96 MHz	up to 6.4 MHz
QAM constellations	up to 4096	QPSK to 64
Cyclic prefix length	0.9375 µs to 6.25 µs	n/a
Pilots	complimentary and continuous	n/a
Forward Error Correction	LDPC	Reed-Solomon
DS capacity (bps)	400 M (1 G to 2.5 G)	100 M (300 M)

25 kHz / 50 kHz carrier spacing
3840 / 1920 carriers in 96 MHz bandwidth

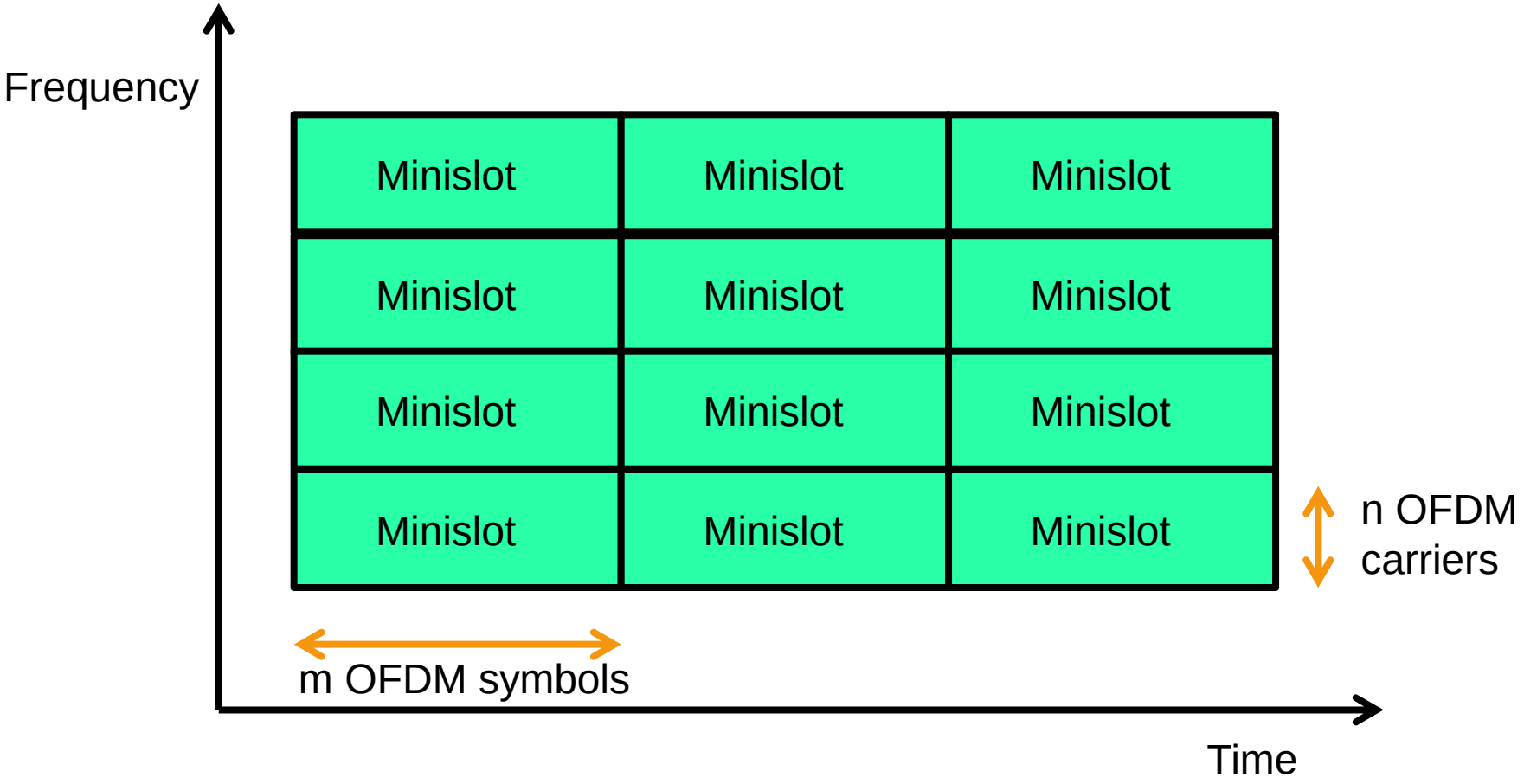
DOCSIS 3.1 Frequency Plan



DOCSIS 3.1 Channel Occupation



DOCSIS 3.1 Upstream Structure

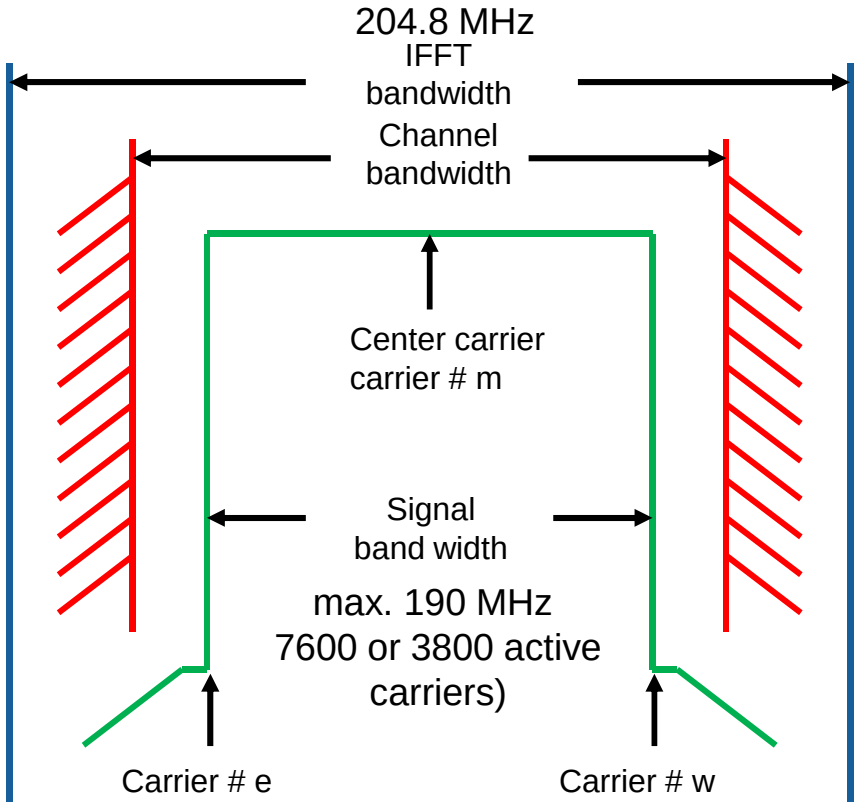


DOCSIS 3.1 Downstream Spectrum

4K/8K mode

configurable downstream channel spacing from 24 ... 192 MHz

downstream operating frequency range 54 ... 1002 MHz (1218/1794 MHz)



Channel bandwidth 192 MHz (7680 or 3840 total no. of carriers)

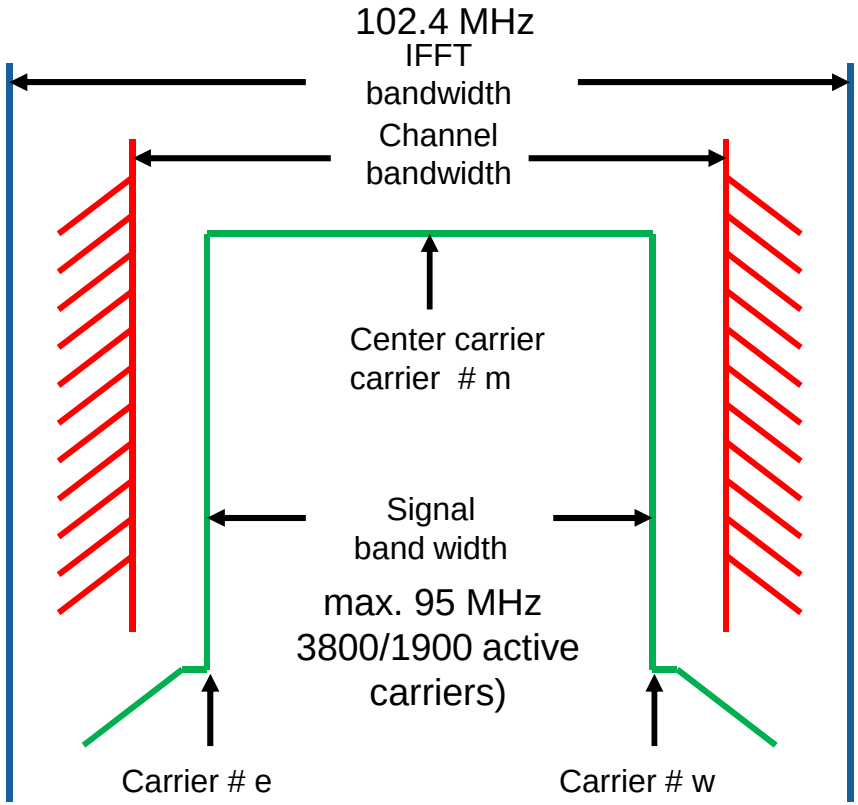
25 kHz / 50 kHz carrier spacing
7680 / 3840 carriers

DOCSIS 3.1 Upstream Spectrum

2K/4K mode

configurable upstream channel spacing up 96 MHz

upstream operating frequency range 5 ... 204MHz



Channel bandwidth max. 96 MHz (3840 or 1920 total no. of carriers)

25 kHz / 50 kHz carrier spacing
3840 / 1920 carriers

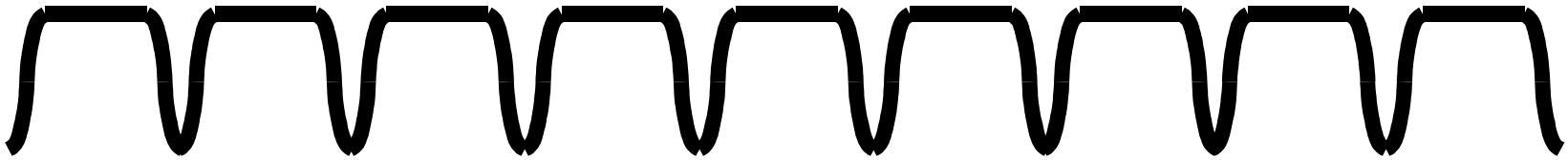
Single Carrier Spectrum versus OFDM Spectrum

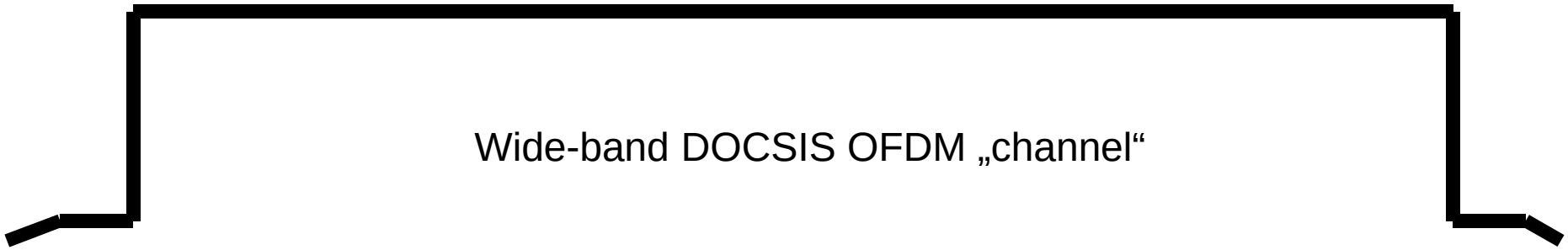
Typical single carrier spectrum with roll-off

Typical OFDM spectrum

Single Carrier Spectrum versus OFDM Spectrum

Typical single carrier spectrum
with roll-off



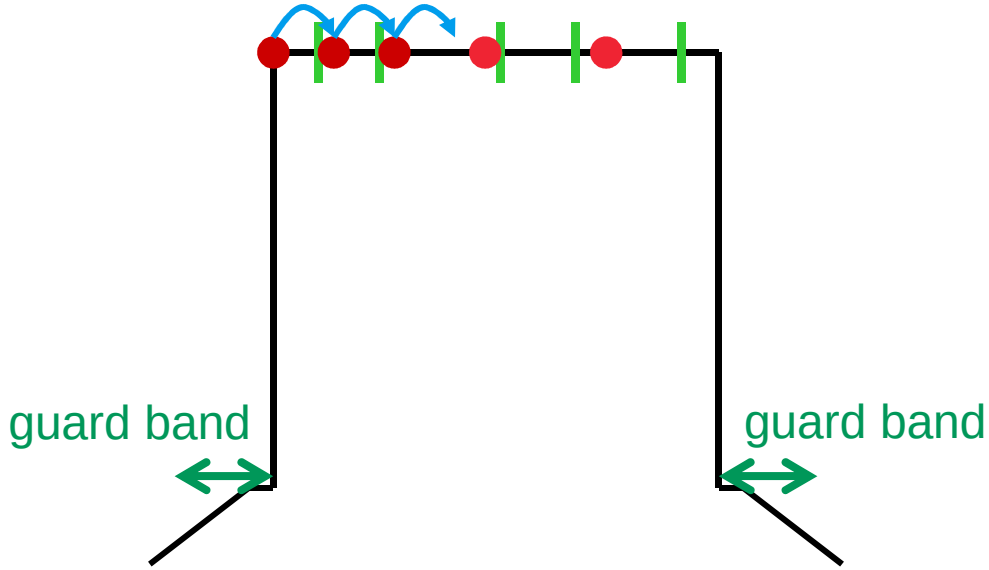


Wide-band DOCSIS OFDM „channel“

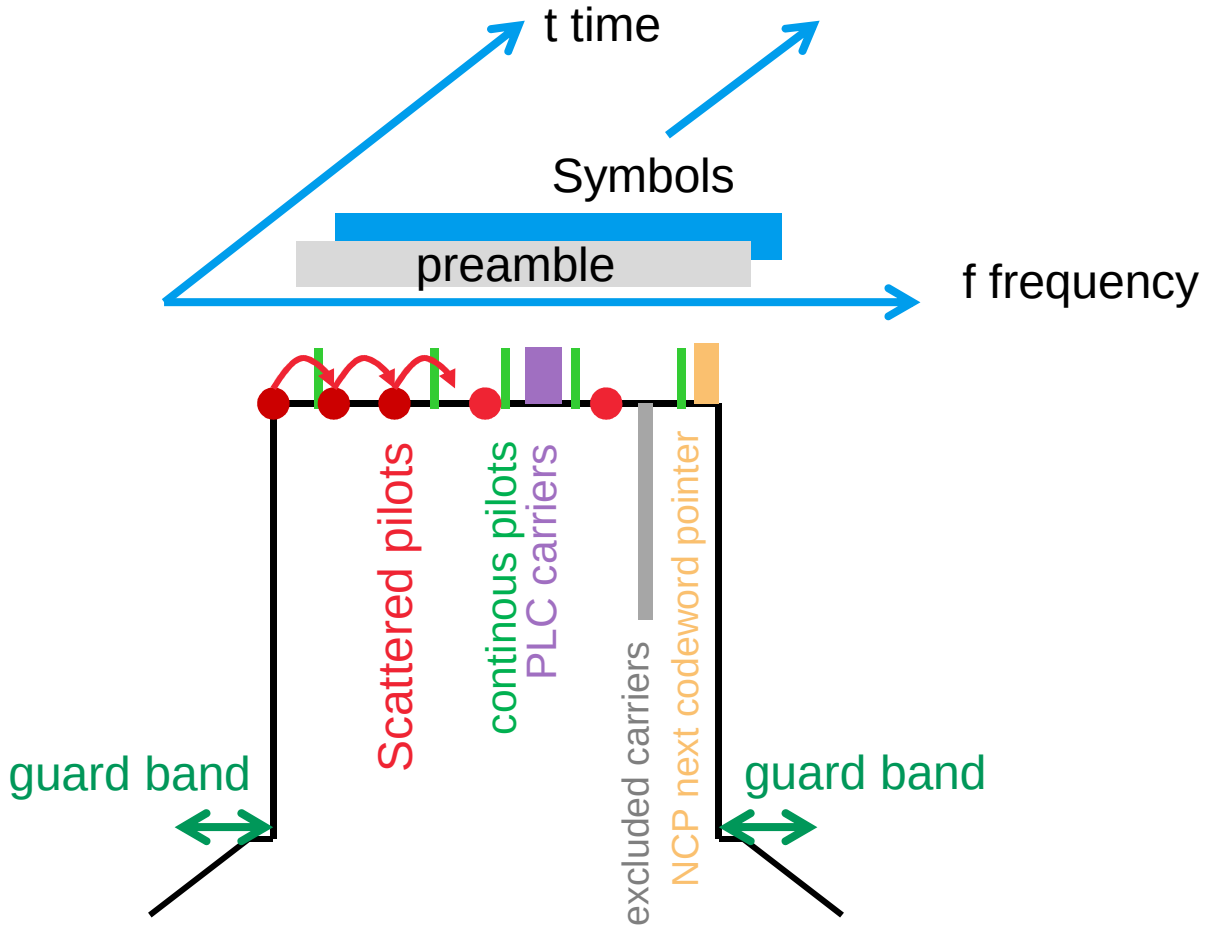
Pilots in DOCSIS 3.1

DOCSIS 3.1 spectrum contains

- data subcarriers, different modulation parameters due to profiles
- continous pilots (fix position, for AFC)
- scattered pilots (var. position for measurement purposes)
- PLC subcarriers
- exluded carriers that are set to zero



Pilots in DOCSIS 3.1



PLC = physical layer link channel

PLC – Physical Layer Link Channel

FFT size	Subcarrier spacing	Number of PLC subcarriers per symbol
4096	50 kHz	8
8192	25 kHz	16

PLC contains physical layer parameters for the cable modem (CM)

PLC constists of preamble and PLC data

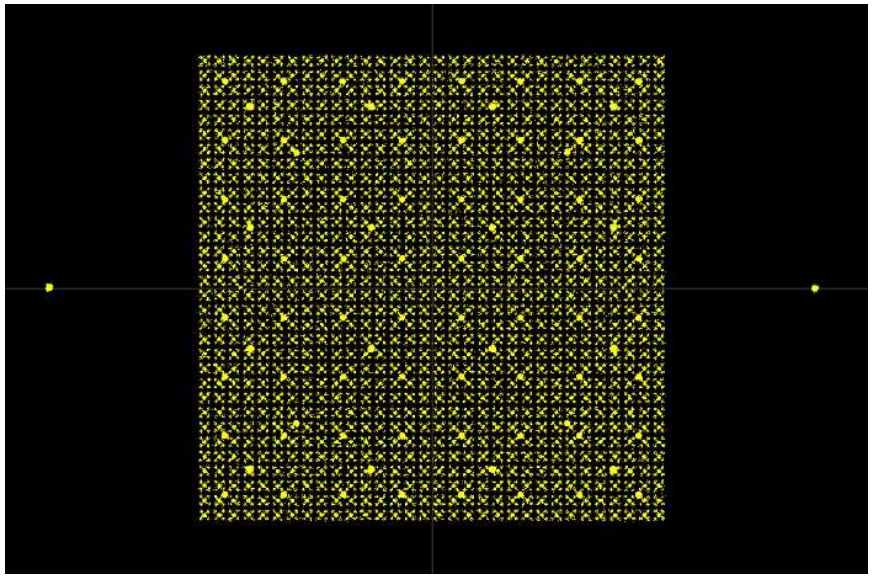
Modulation of PLC carriers is BPSK for preamble and 16QAM for PLC data

Profiles

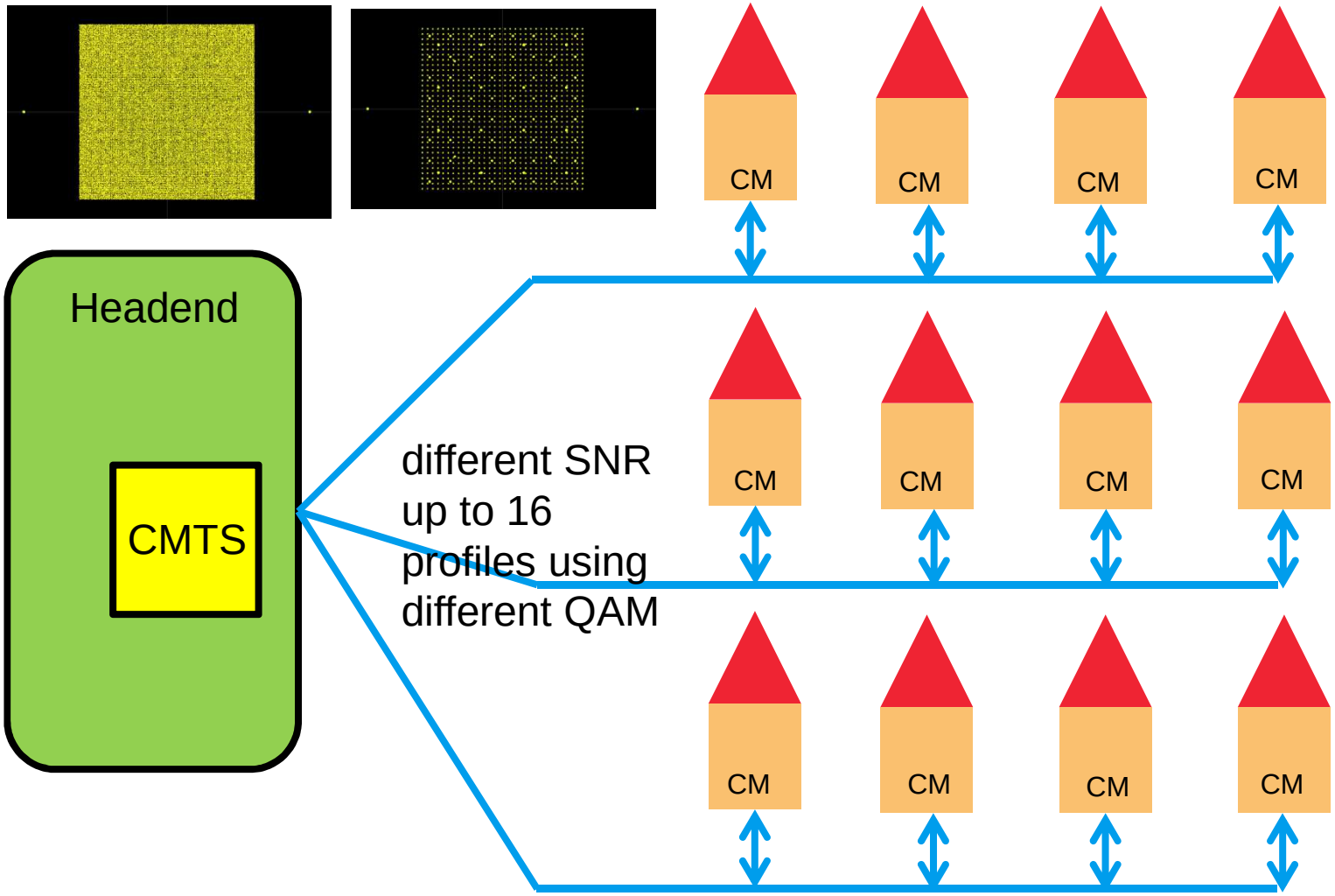
NCP = Next Codeword Pointer = lowest layer; QPSK, 16QAM, 64QAM
NCP points to the beginning of the codewords of the profiles in a symbol

16 profiles (QPSK, ... 16KQAM)

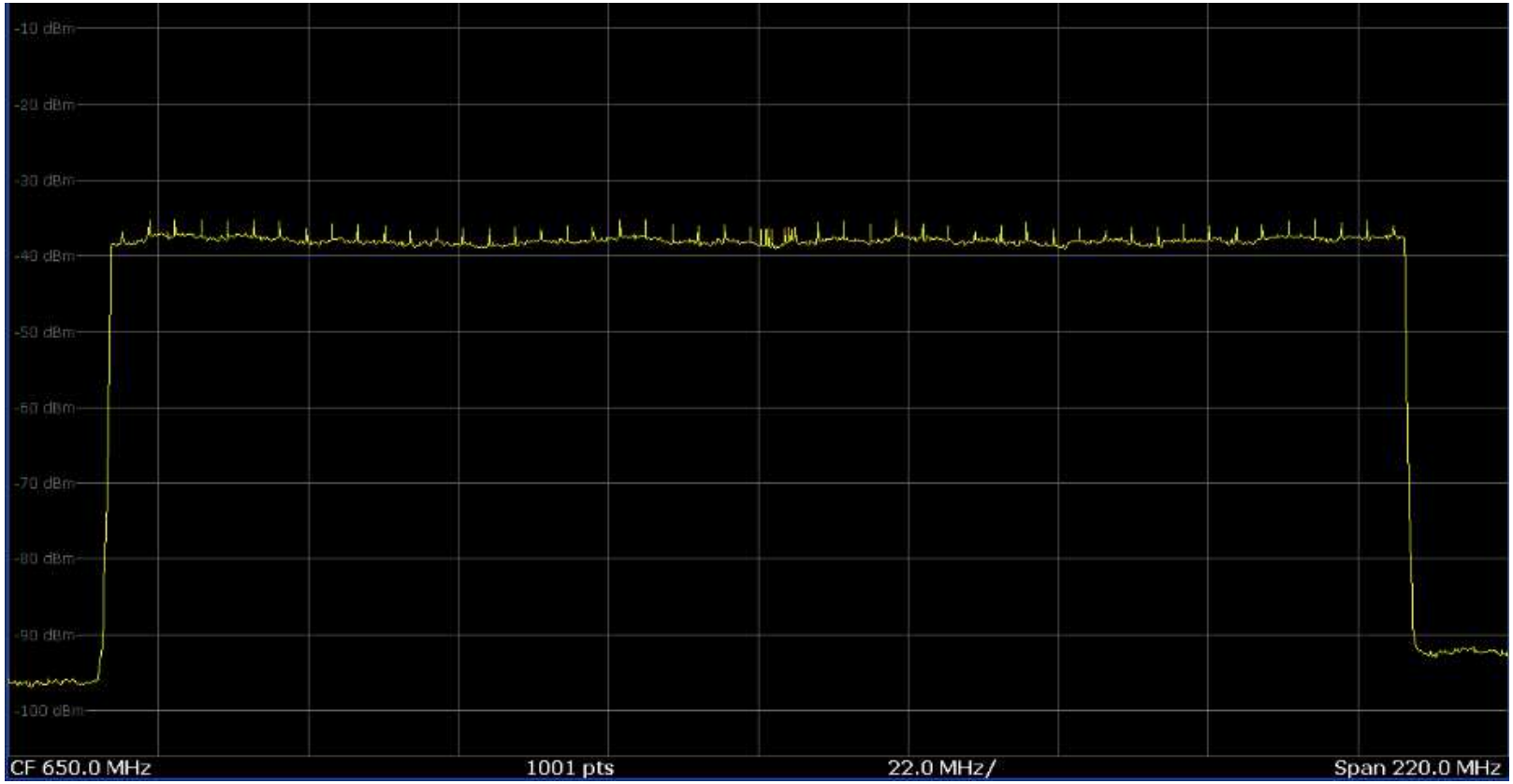
Profile data are interleaved (interleaver depth 1...32)



Profiles in DOCSIS 3.1 ...



DOCSIS 3.1 Downstream Spectrum



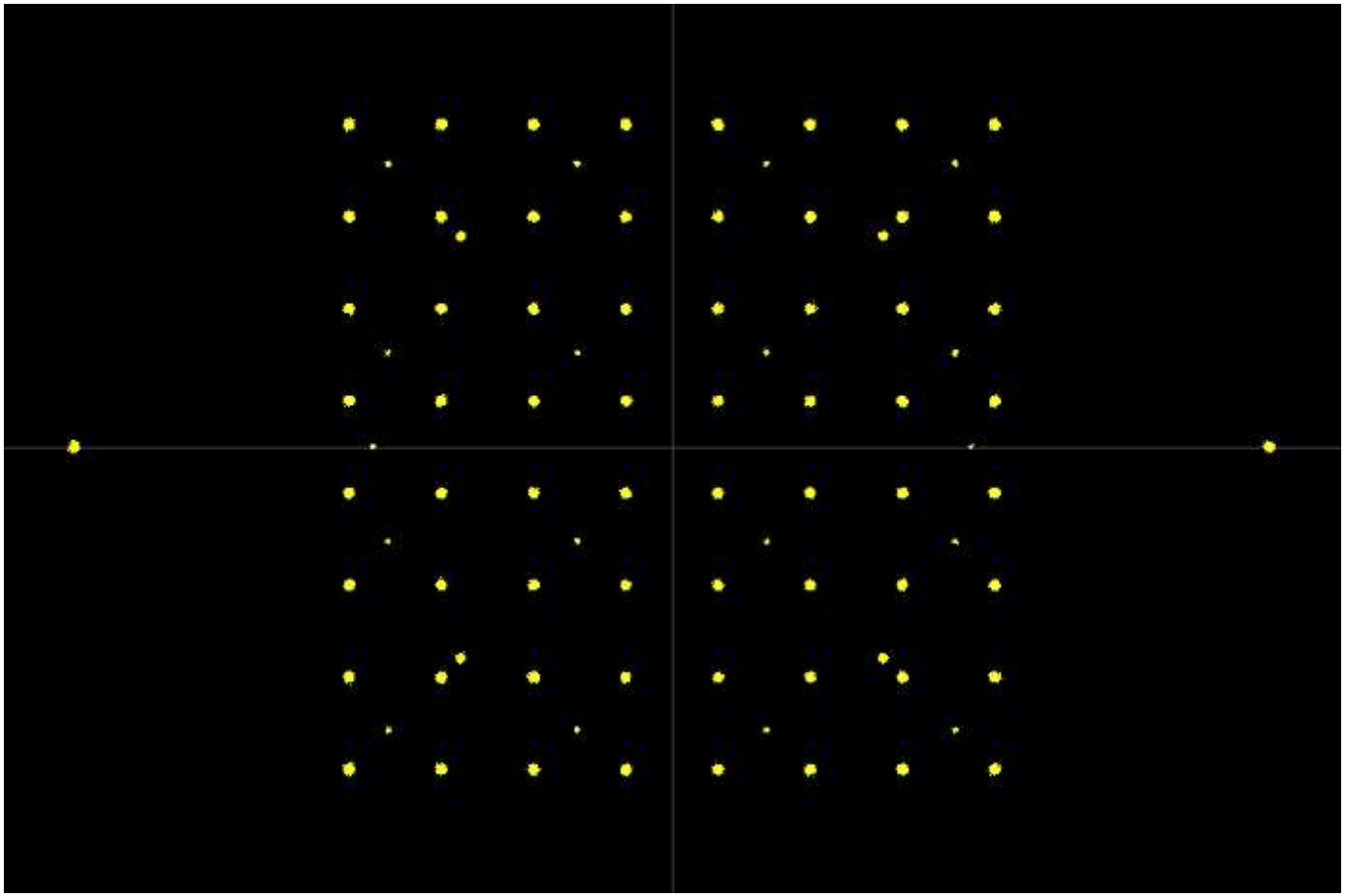
DOCSIS 3.1 Modulation Parameter

Modulation mode downstream	min CNR (AWGN) (... 1GHz)	min CNR (AWGN) (...1.2GHz)
16QAM	15.0 dB	15.0 dB
64QAM	21.0 dB	21.0 dB
128QAM	24.0 dB	24.0 dB
256QAM	27.0 dB	27.0 dB
512QAM	30.5 dB	30.5 dB
1024QAM	34.0 dB	34.0 dB
2048QAM	37.0 dB	37.5 dB
4096QAM	41.0 dB	41.5 dB
8192QAM		
16384QAM		

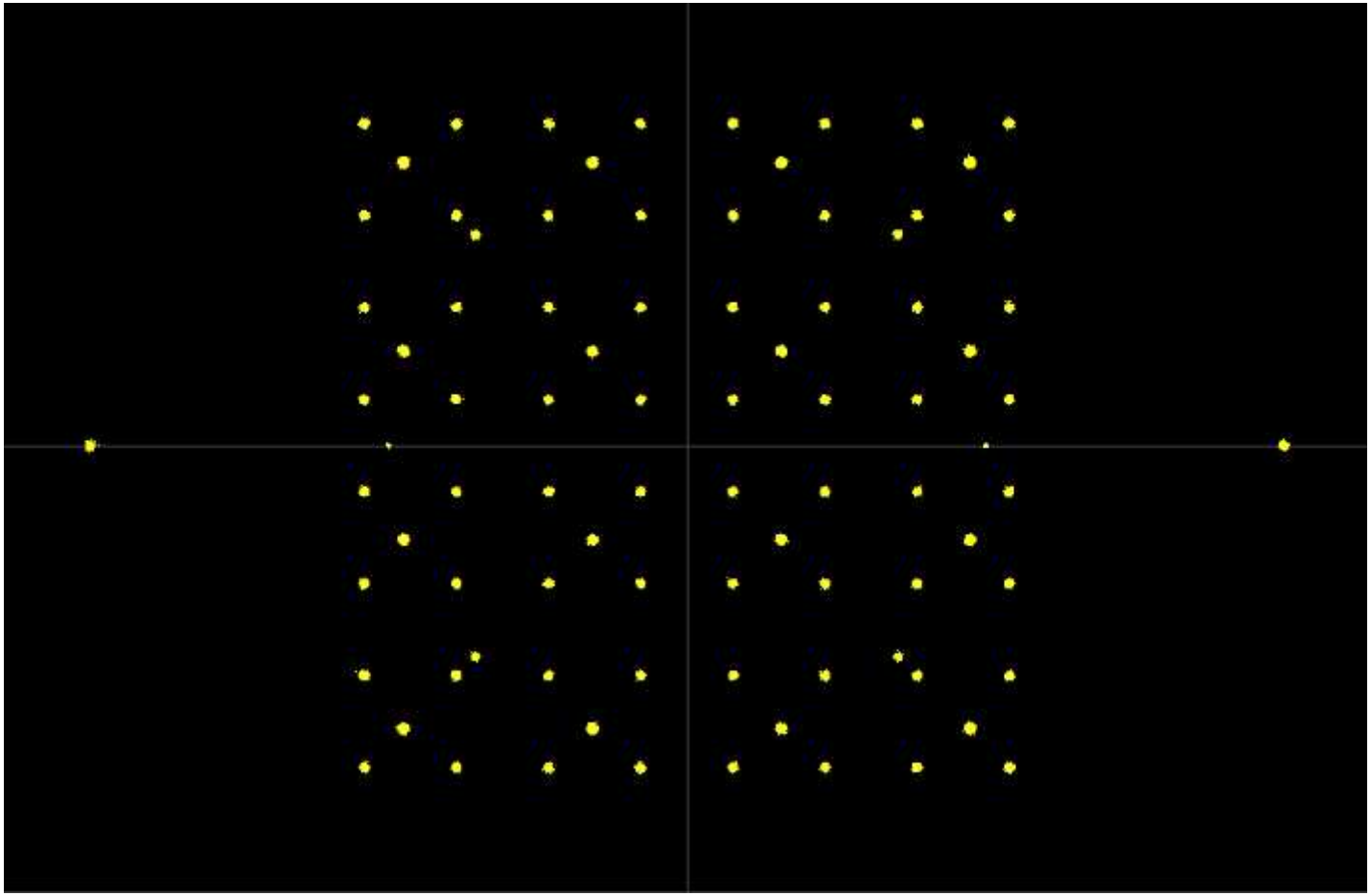
Modulation mode upstream	min CNR (AWGN)
QPSK	11.0 dB
8QAM	14.0 dB
16QAM	17.0 dB
32QAM	20.0 dB
64QAM	23.0 dB
128QAM	26.0 dB
256QAM	29.0 dB
512QAM	32.5 dB
1024QAM	35.5 dB
2048QAM	39.0 dB
4096QAM	43.0 dB

DOCSIS 3.1 Constellation Diagram, No Payload, only PLC and Pilots

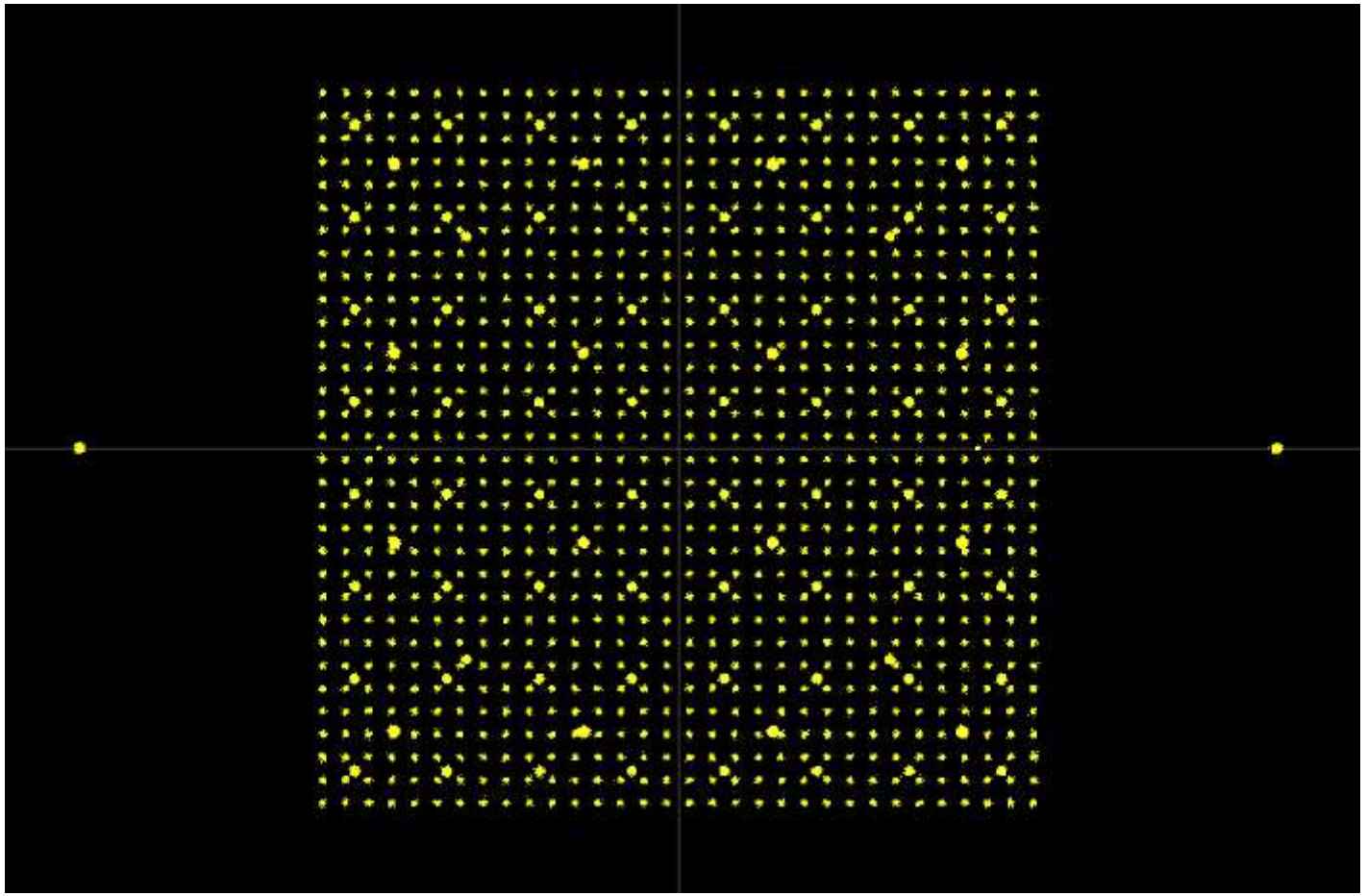
PLC = physical layer link channel



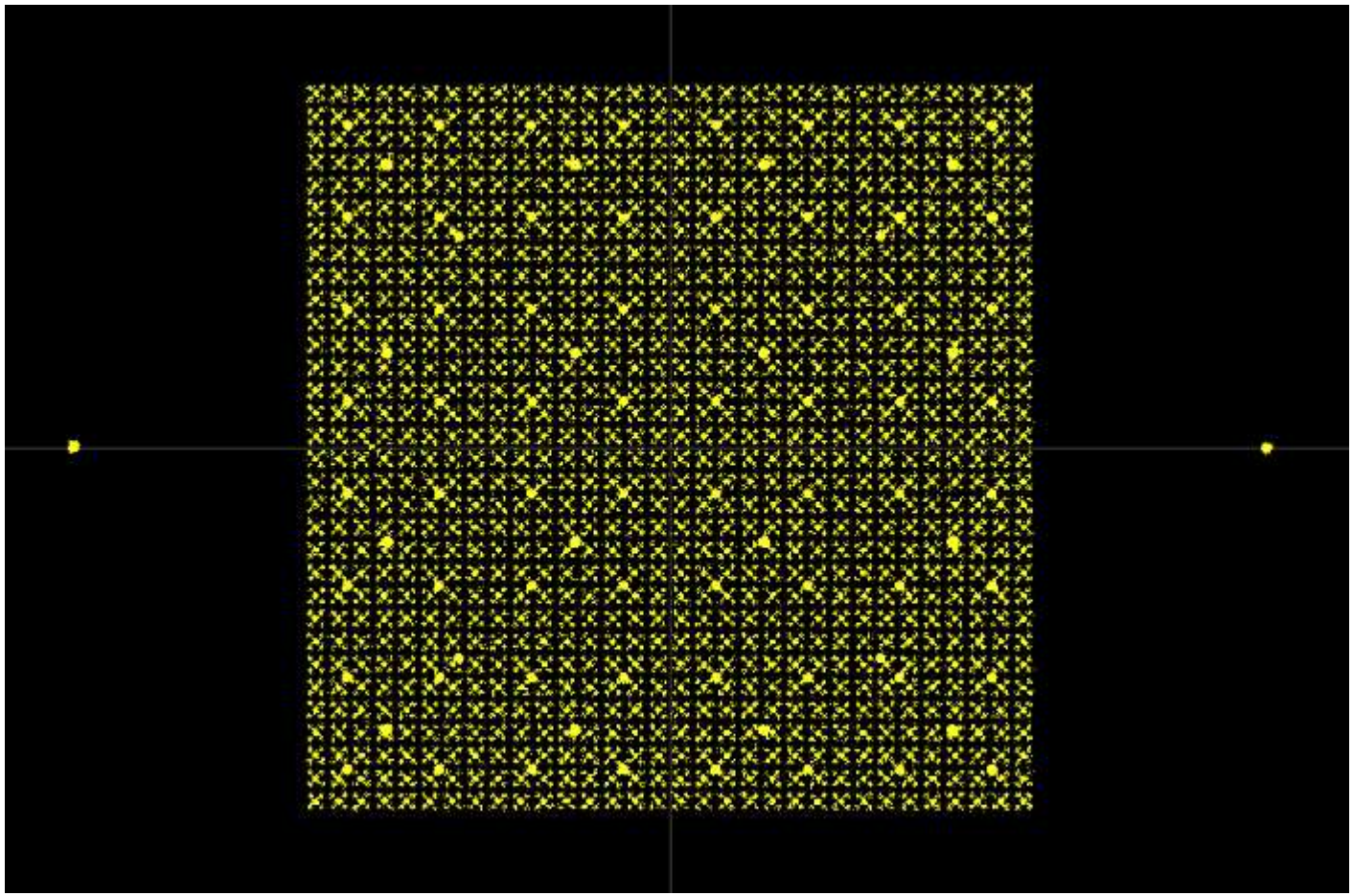
DOCSIS 3.1 Downstream, Pilots, Signalling and 64QAM Payload Profile



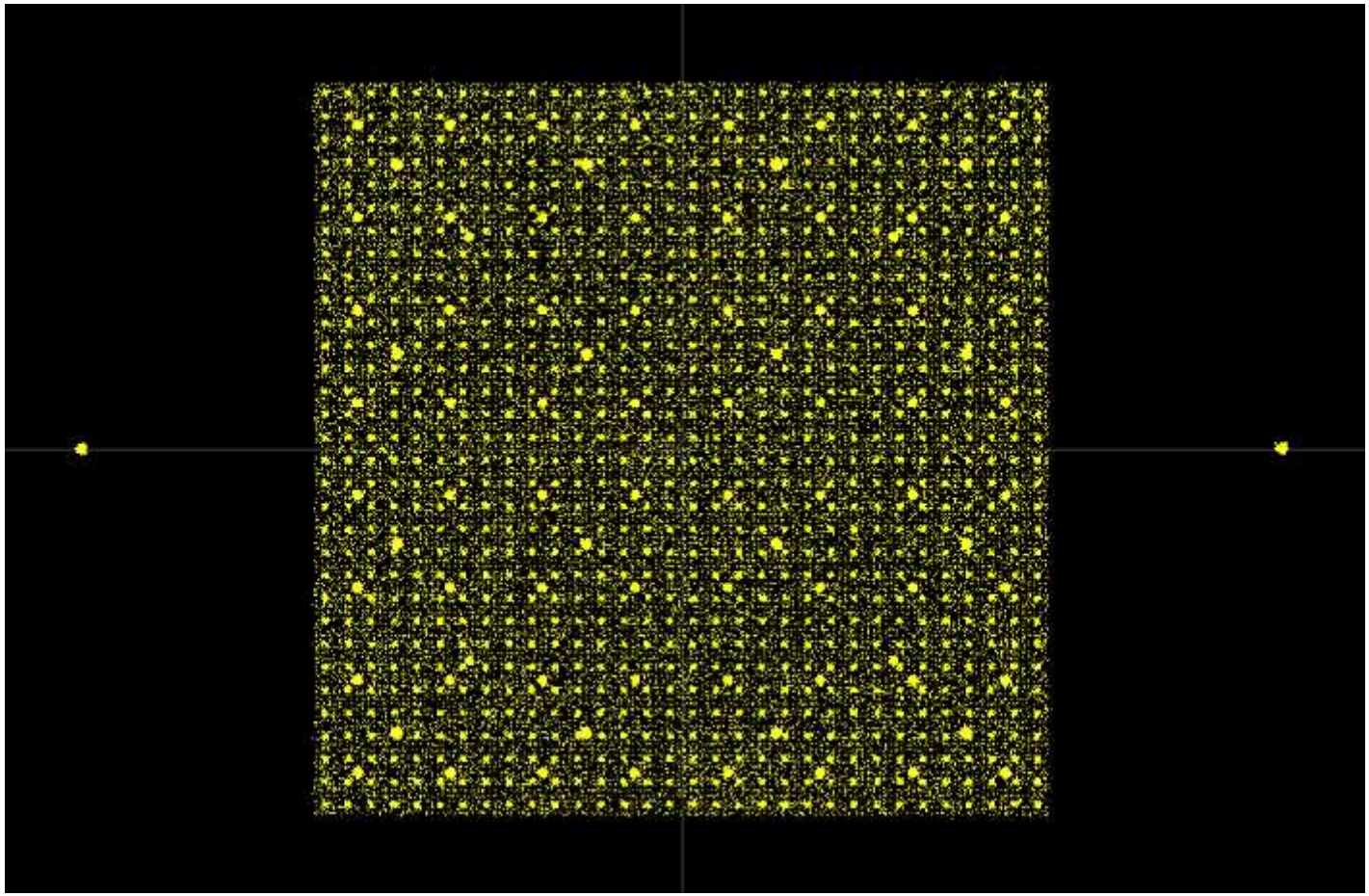
DOCSIS 3.1 Downstream, Pilots, Signalling, 64QAM, 256QAM Payload Profile



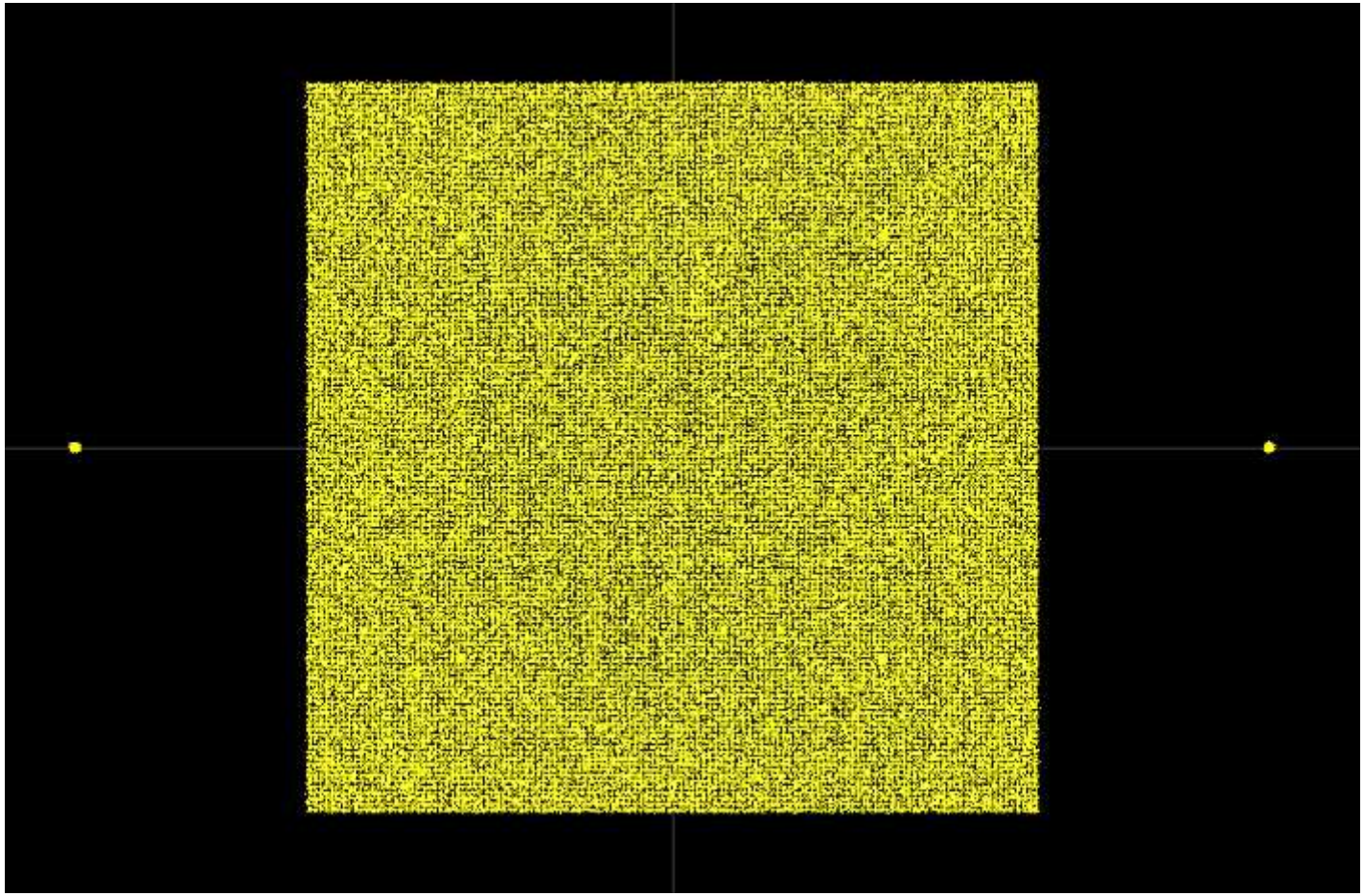
DOCSIS 3.1, ... 1024QAM



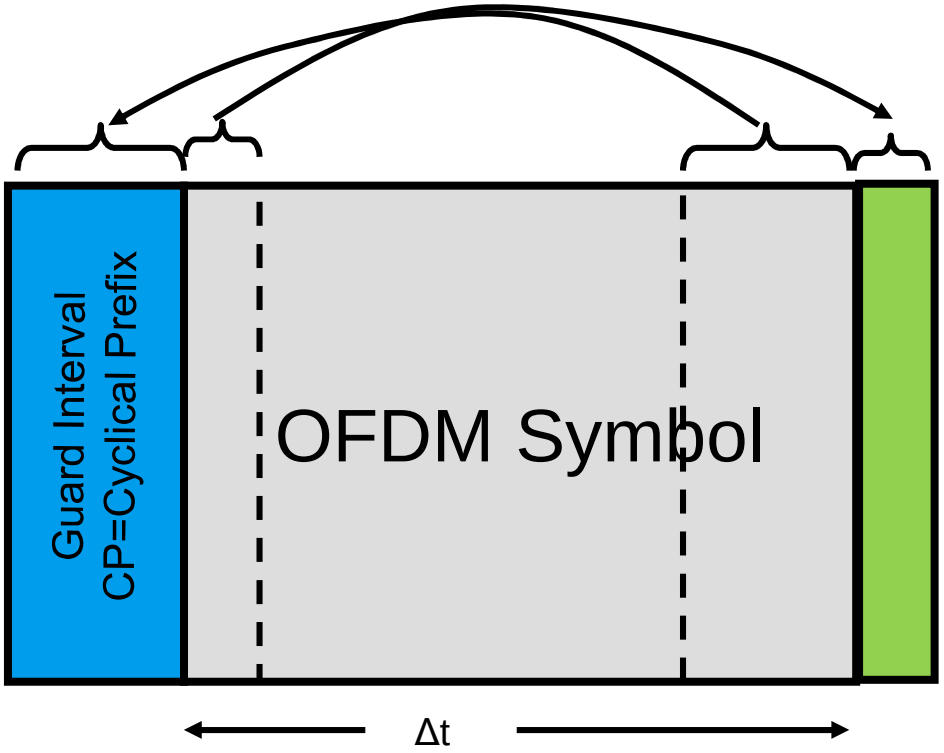
DOCSIS 3.1 Downstream, ... 4096QAM



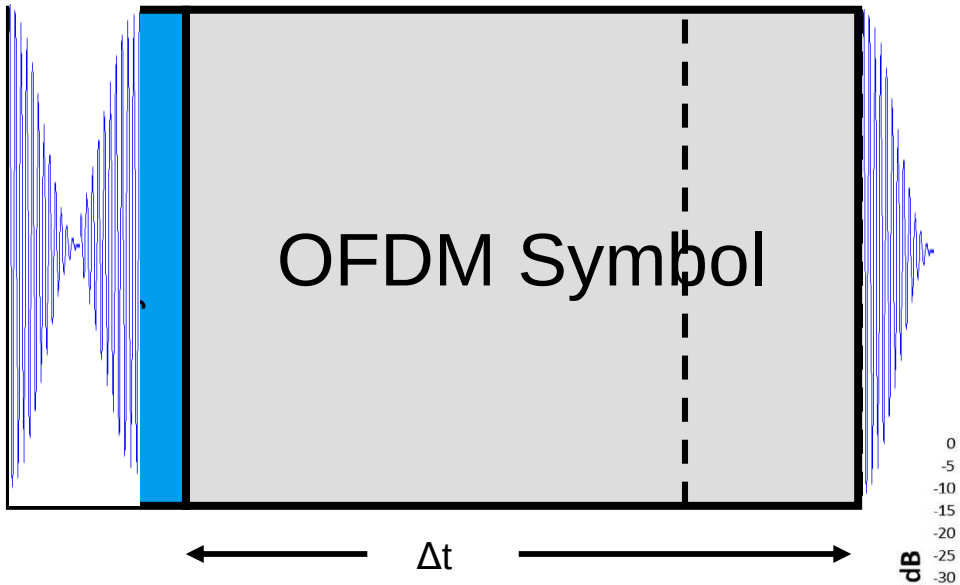
DOCSIS 3.1, ... 16KQAM



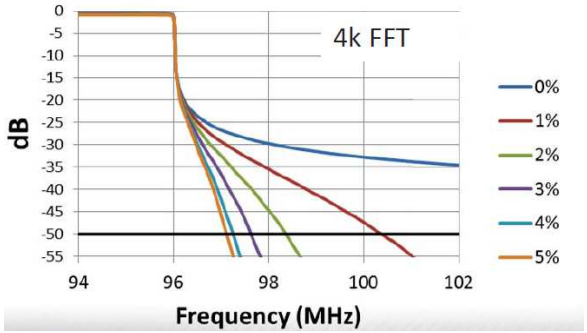
Guard Interval / CP before and behind of the Symbol



Guard Interval & Windowing



Tukey-rised cosine windowing
in DOCSIS 3.1



DOCSIS 3.1 Cyclic Prefix

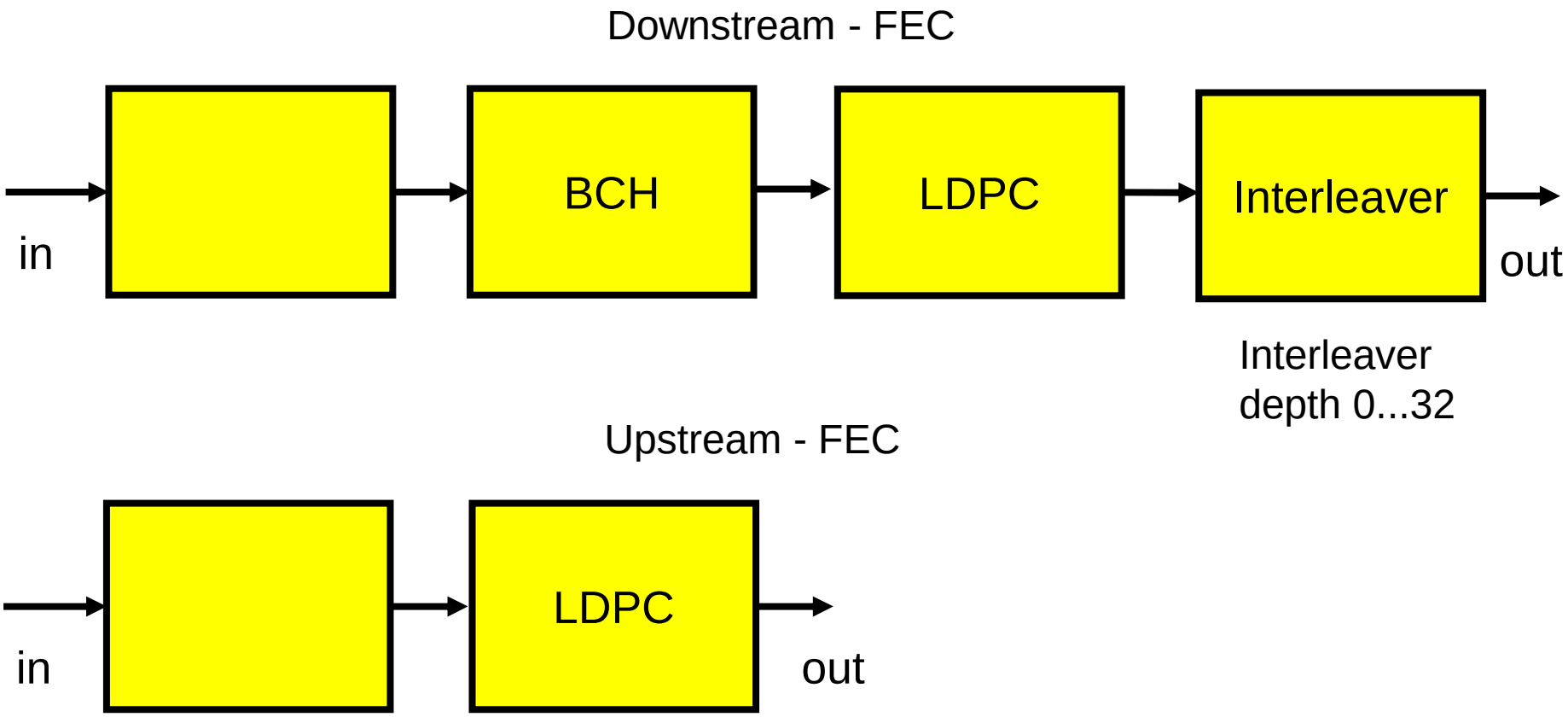
CP length upstream 2K / 4K mode	CP length in elementary periodes
0.9376 µs	96 • T_{SU}
1.25 µs	128 • T_{SU}
1.5625 µs	160 • T_{SU}
1.875 µs	192 • T_{SU}
2.1875 µs	224 • T_{SU}
2.5 µs	256 • T_{SU}
2.8125 µs	288 • T_{SU}
3.125 µs	320 • T_{SU}
3.75 µs	384 • T_{SU}
5.0 µs	512 • T_{SU}
6.25 µs	640 • T_{SU}

CP length downstream 4K / 8K	CP length in elementary periodes
0.9376 µs	192 • T_{SD}
1.25 µs	256 • T_{SD}
2.5 µs	512 • T_{SD}
3.75 µs	768 • T_{SD}
5 µs	1024 • T_{SD}

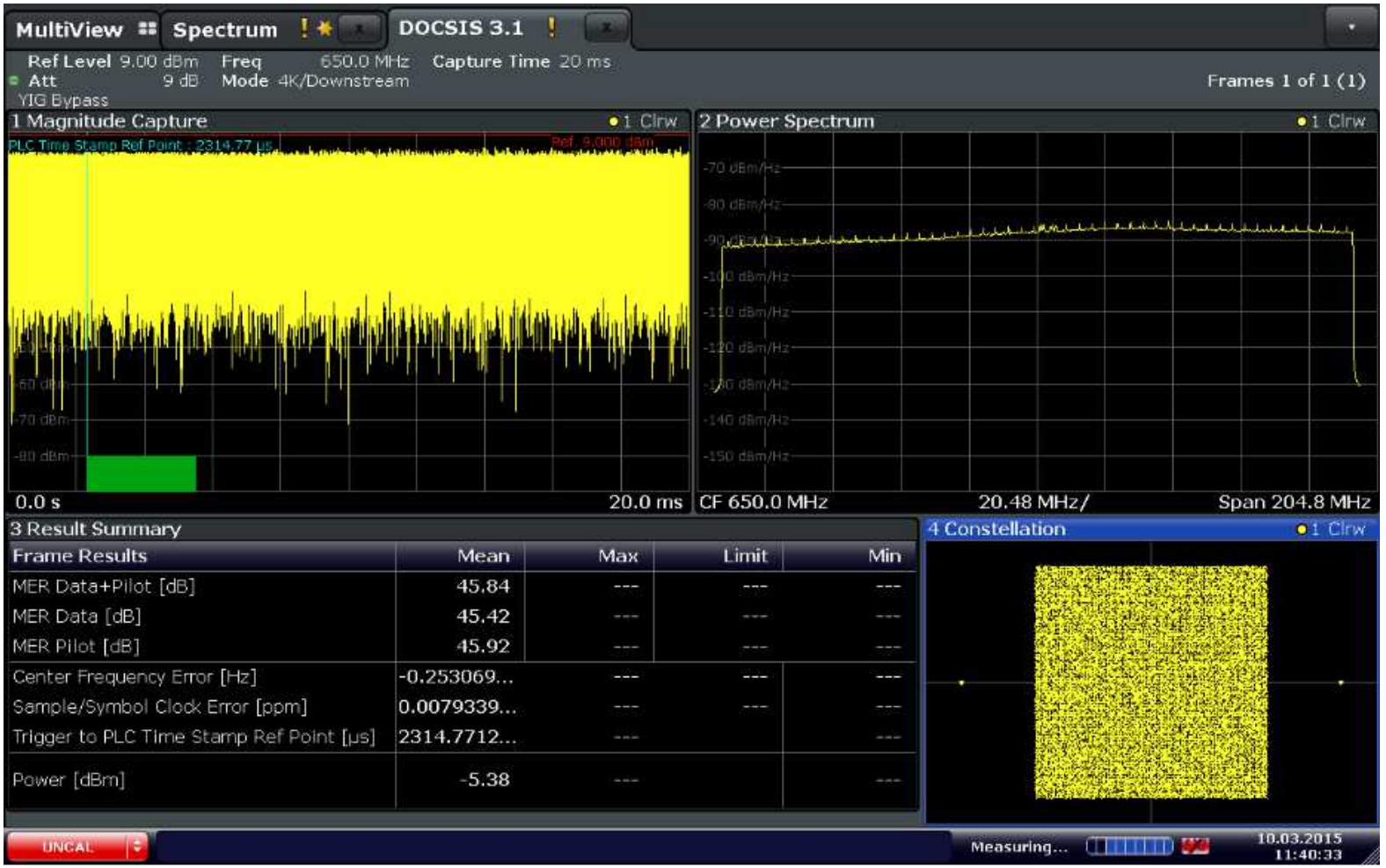
DOCSIS 3.1 Cyclic Prefix

CP length downstream 4K / 8K	CP length in elementary periodes
0.9376 µs	192 • T_{SD}
1.25 µs	256 • T_{SD}
2.5 µs	512 • T_{SD}
3.75 µs	768 • T_{SD}
5 µs	1024 • T_{SD}

DOCSIS 3.1 FEC – Forward Error Correction



FSW DOCSIS 3.1 Analysis



From DVB-C2 to DOCSIS 3.1

- DOCSIS Intro and Principle
- Single Carrier Modulation Principle
- Time Domain and Spectrum Domain
- QAM and SNR Requirement
- OFDM Basics, OFDM in CATV
- DOCSIS 3.1 Physical Layer Parameters
- DOCSIS 3.1 Demo Transmission

CLGD … Simulating Multichannel CATV Load

ATV
DVB-C
DOCSIS

SFD … Single Channel DOCSIS 3.0/3.1/ARB Generator

DOCSIS 3.1 Signal Analysis … using R&S FSW

R&S FSW-**K192** DOCSIS 3.1 Downstream Measurement Application
R&S FSW-**K193** DOCSIS 3.1 Upstream Measurement Application

CATV Demo Transmission Link

Source
„CATV“ Headend
signal source:
SFD
CLDG
BTC

Optical link

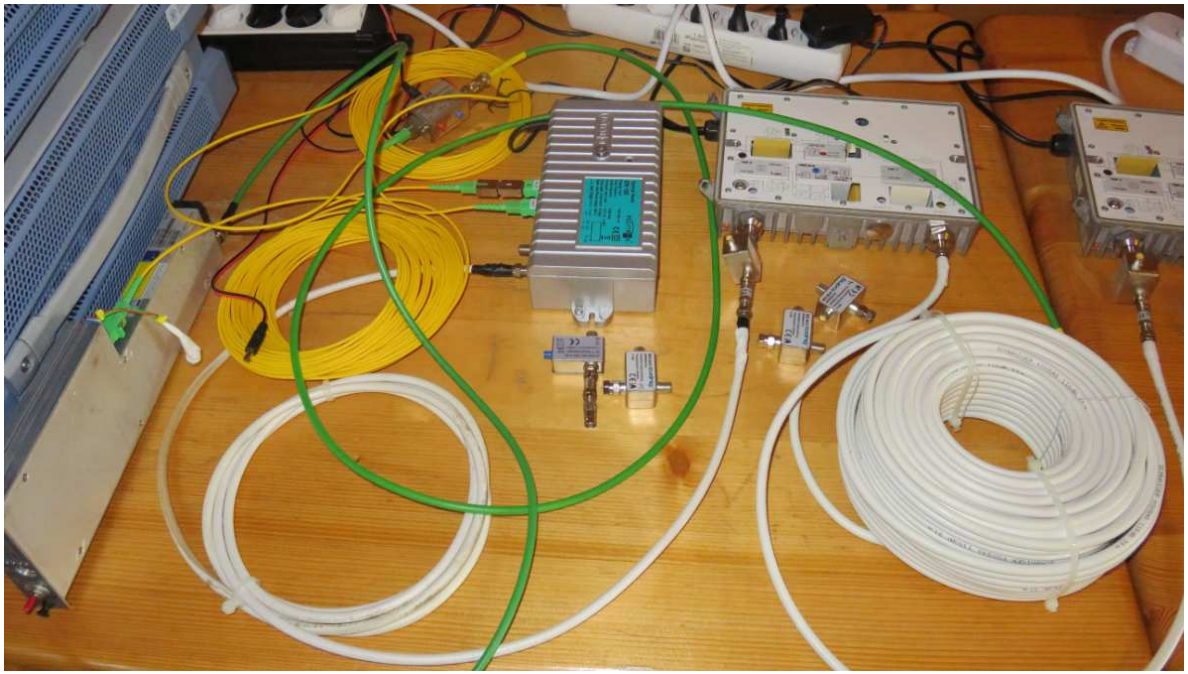
3 CATV amplifier plus
coax cable simulation

Sink
„CATV“
enduser equipment
analyzer:
ETL
FSW

Demo setup in Teisnach, Germany, June 2016

CATV Demo Transmission Link

Optical fibre link



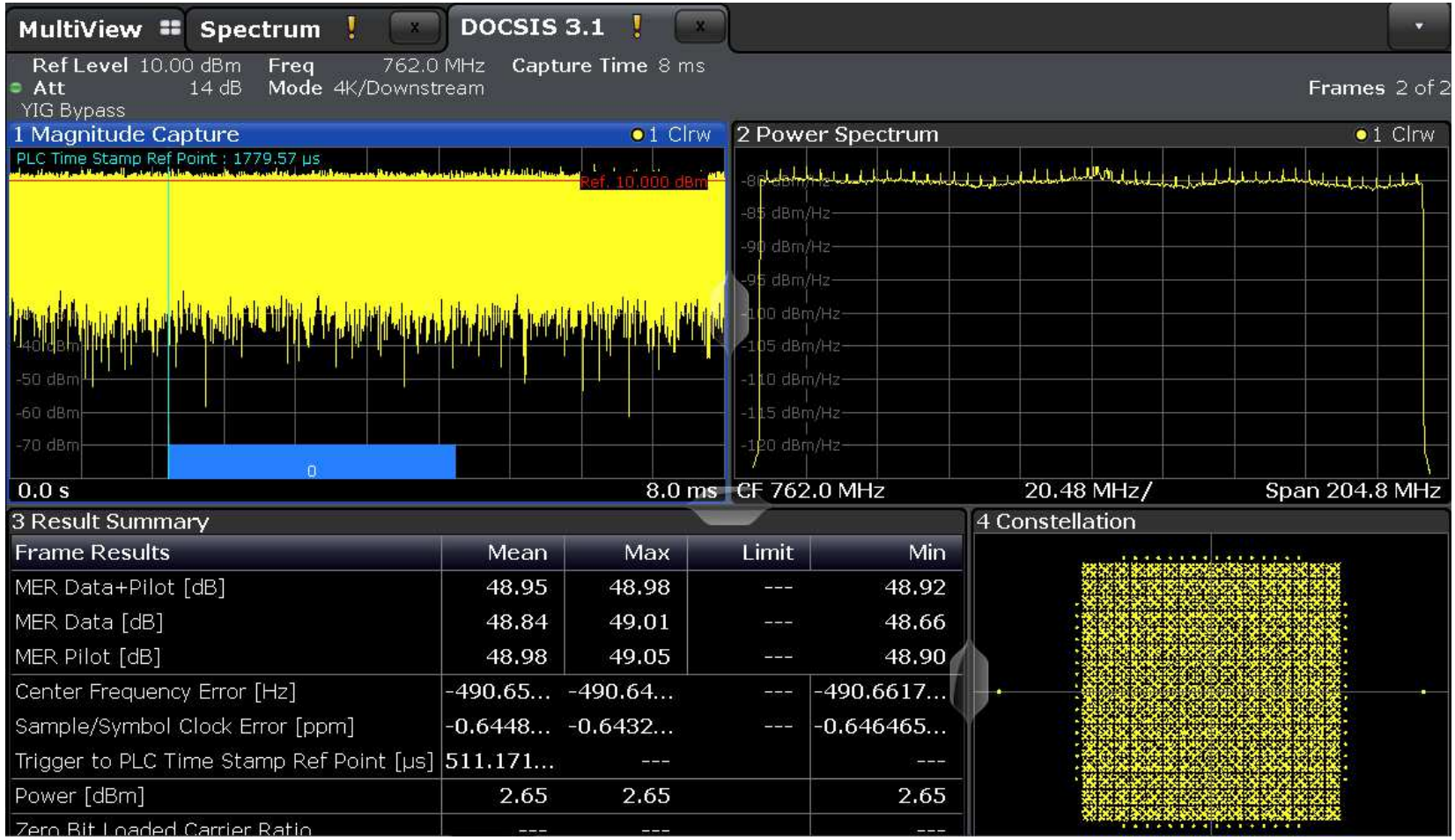
Laser

Optical node

CATV Demo Transmission Link

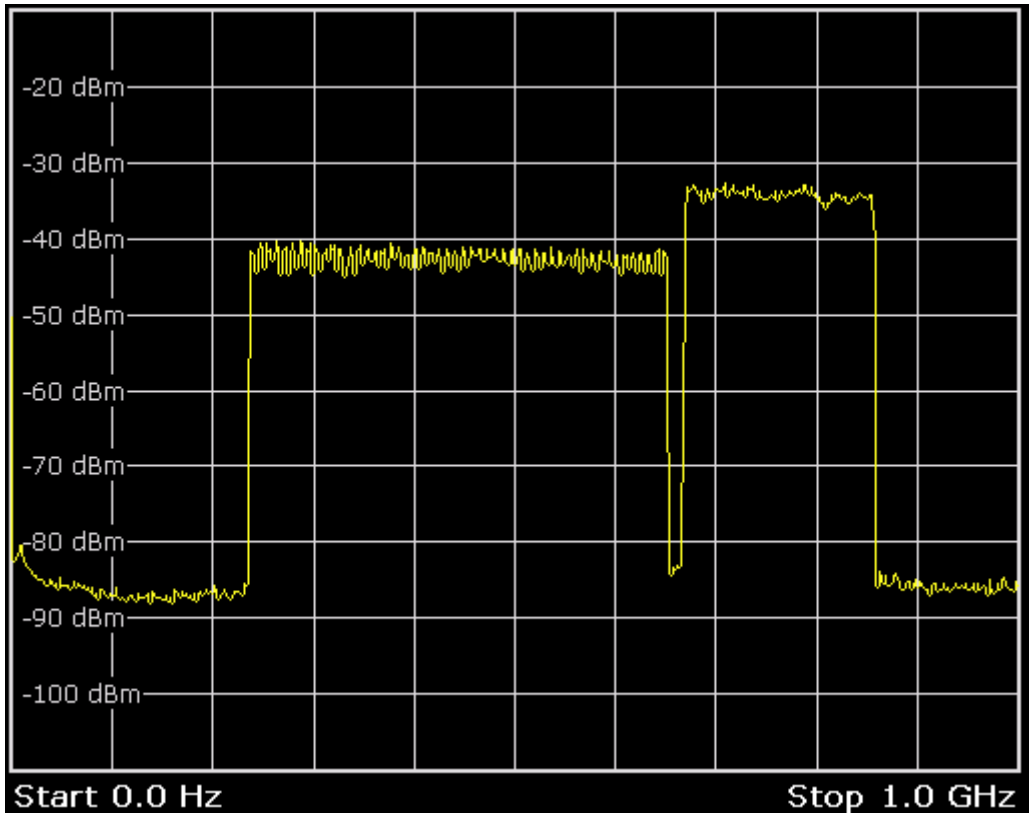
3 CATV amplifier plus
coax cable simulation

DOCSIS3.1 – Signal from CLGD, measured with FSW

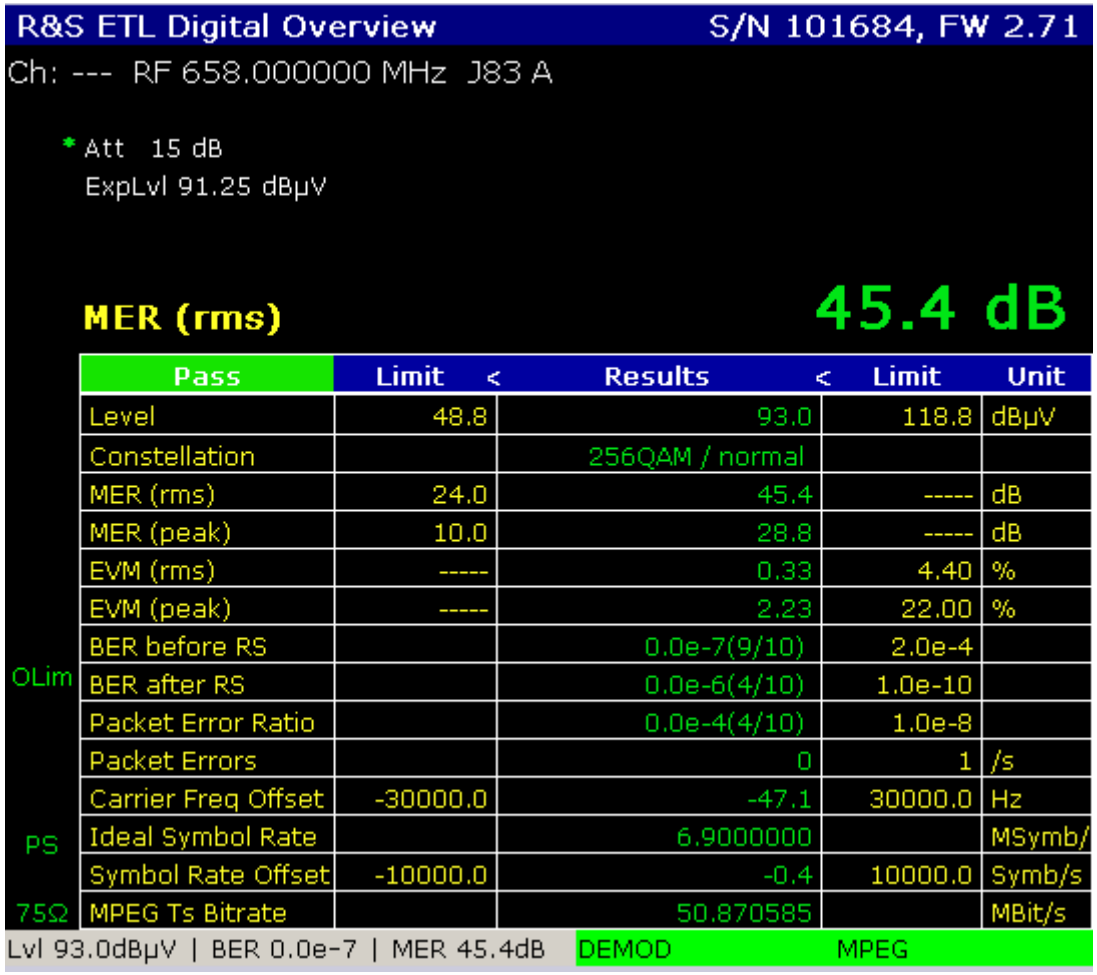


Frame Results	Mean	Max	Limit	Min
MER Data+Pilot [dB]	48.95	48.98	---	48.92
MER Data [dB]	48.84	49.01	---	48.66
MER Pilot [dB]	48.98	49.05	---	48.90
Center Frequency Error [Hz]	-490.65...	-490.64...	---	-490.6617...
Sample/Symbol Clock Error [ppm]	-0.6448...	-0.6432...	---	-0.646465...
Trigger to PLC Time Stamp Ref Point [µs]	511.171...	---		---
Power [dBm]	2.65	2.65		2.65
Zero Bit Loaded Carrier Ratio	---	---		---

CLGD Signal (DVB-C Multi-Channel and DOCSIS3.1)

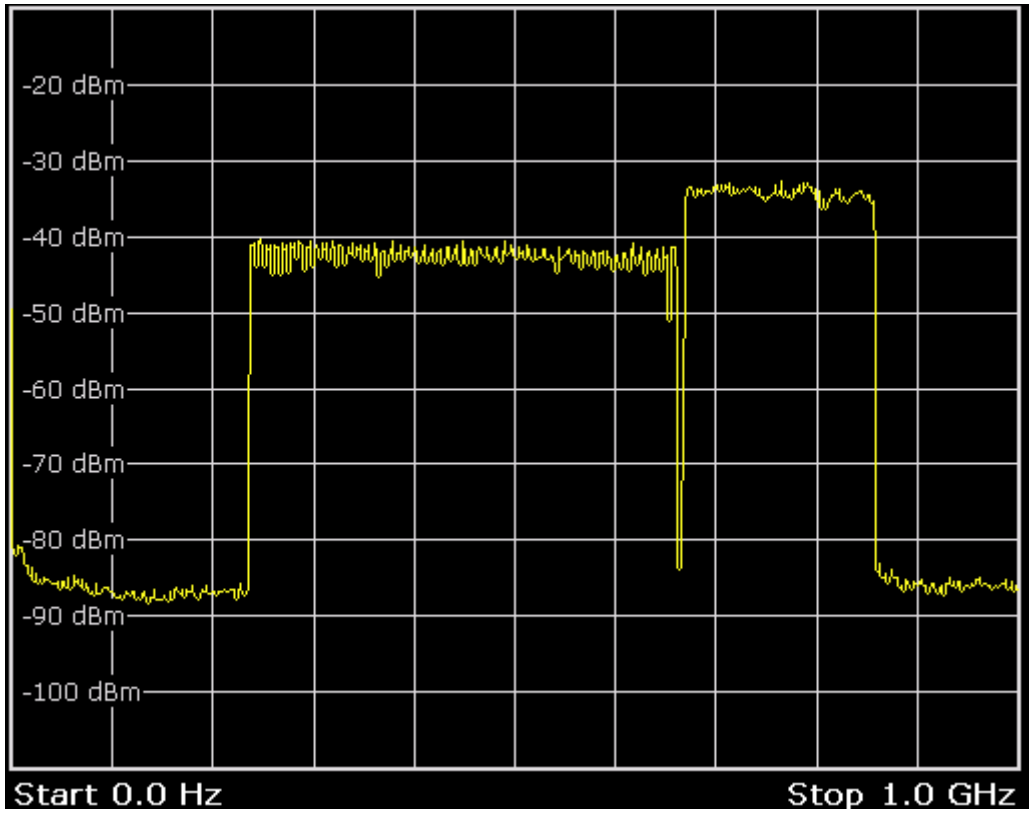


Single DVB-C Signal from SFU



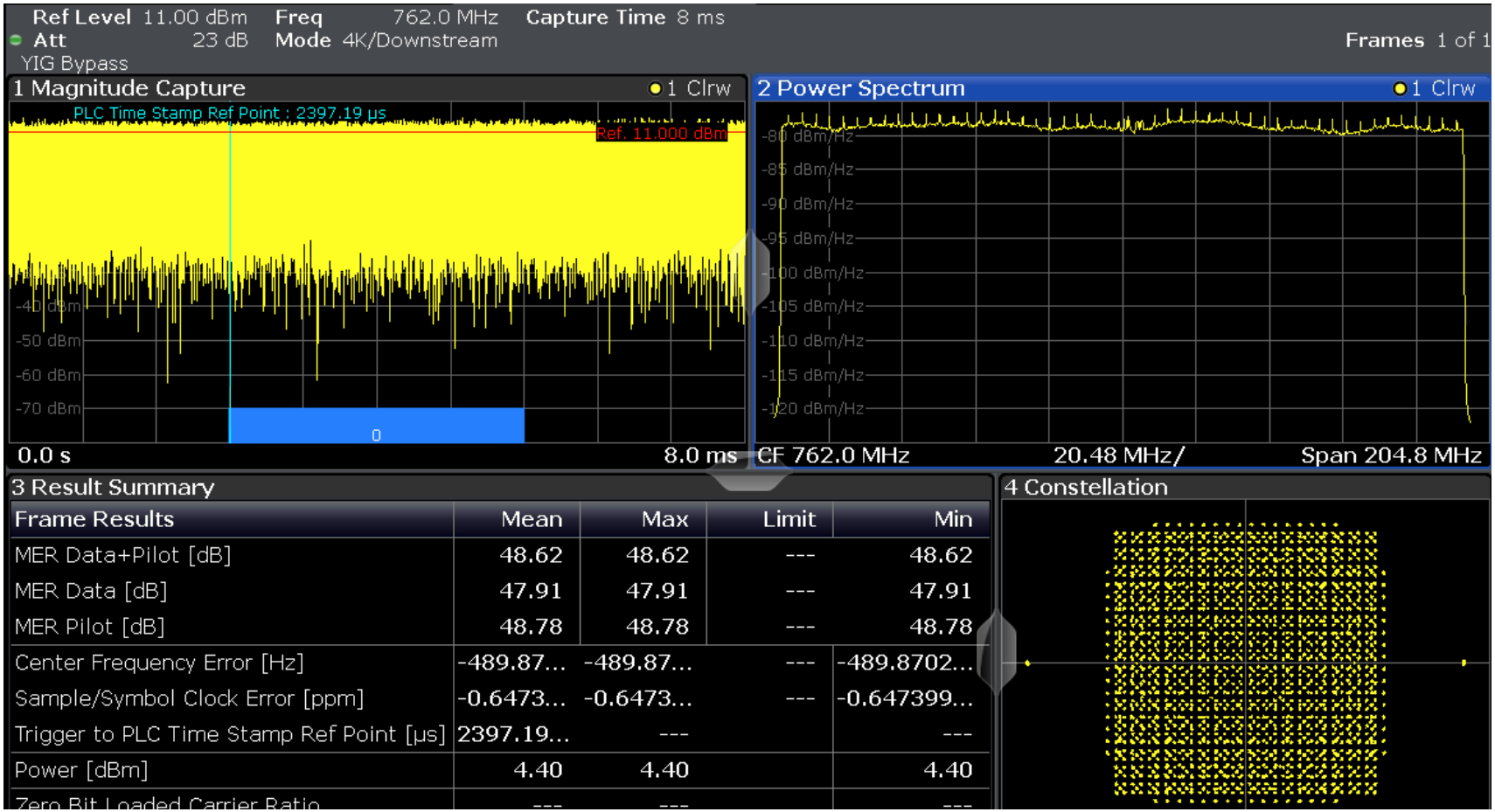
Pass	Limit <	Results	< Limit	Unit
Level	48.8	93.0	118.8	dBµV
Constellation		256QAM / normal		
MER (rms)	24.0	45.4	-----	dB
MER (peak)	10.0	28.8	-----	dB
EVM (rms)	-----	0.33	4.40	%
EVM (peak)	-----	2.23	22.00	%
BER before RS		0.0e-7(9/10)	2.0e-4	
BER after RS		0.0e-6(4/10)	1.0e-10	
Packet Error Ratio		0.0e-4(4/10)	1.0e-8	
Packet Errors		0	1	/s
Carrier Freq Offset	-30000.0	-47.1	30000.0	Hz
Ideal Symbol Rate		6.9000000		MSymb/
Symbol Rate Offset	-10000.0	-0.4	10000.0	Symb/s
MPEG Ts Bitrate		50.870585		MBit/s

Signal before Optical Link at Network Input



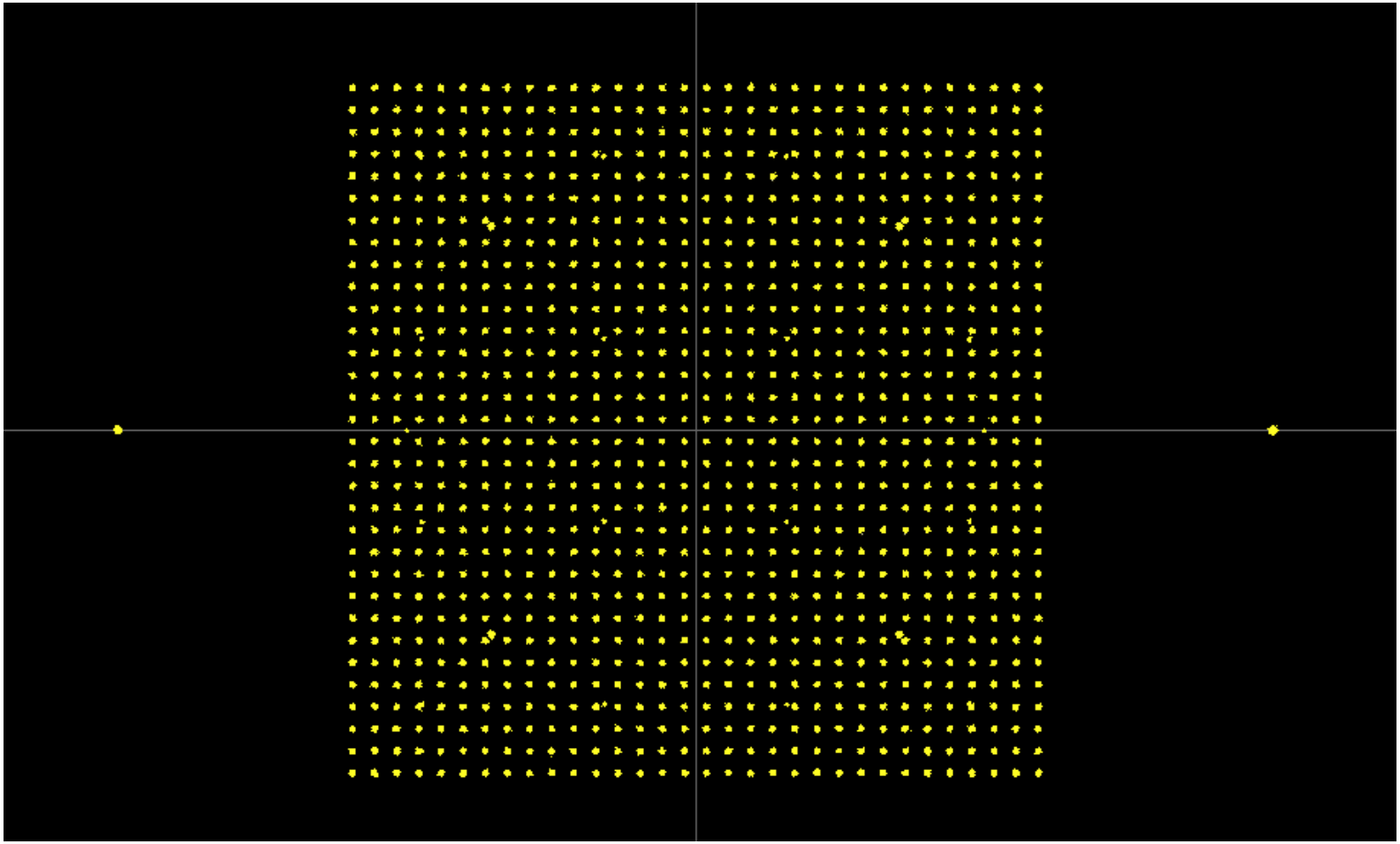
DOCSIS at Network Input

MER = 48 dB

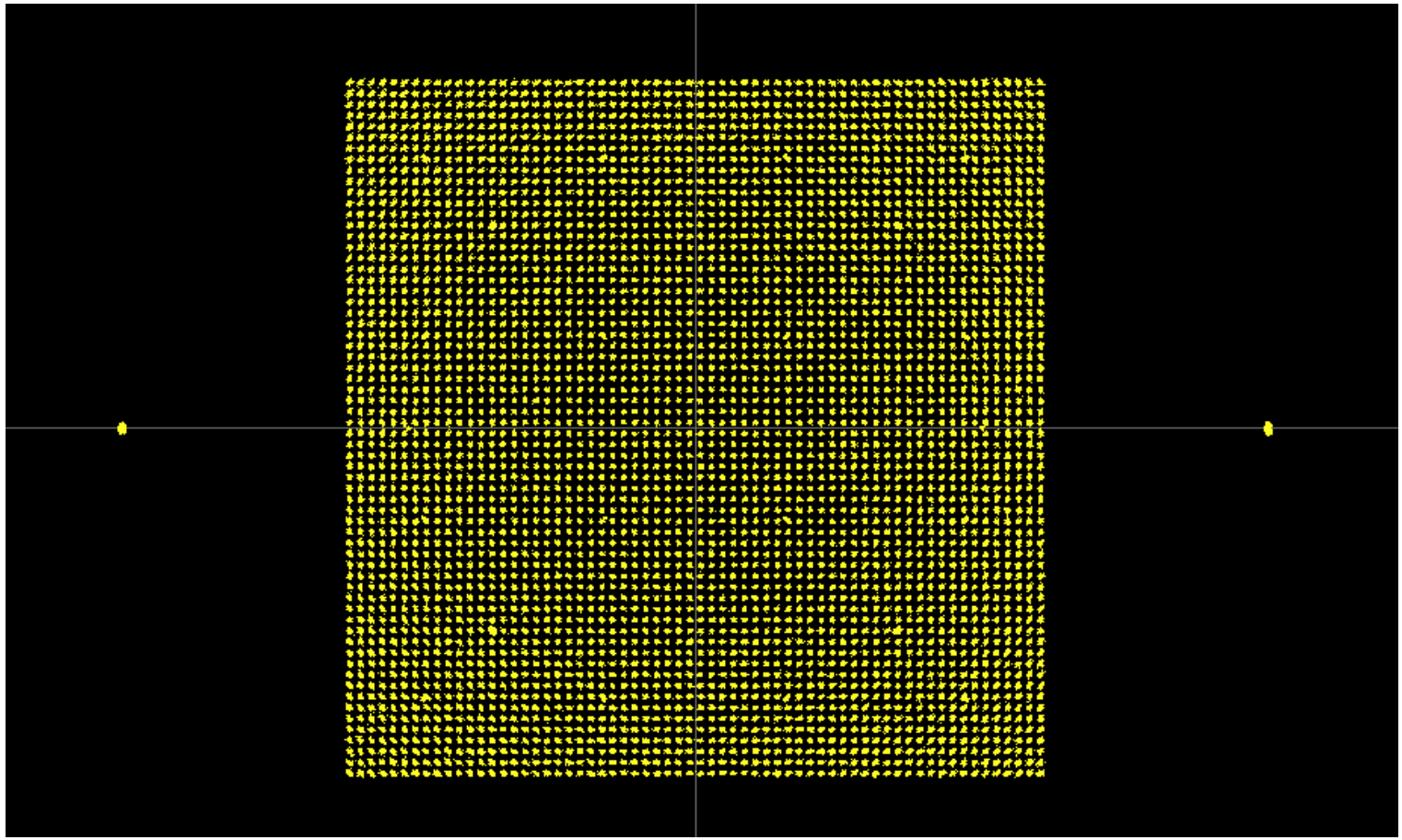


Frame Results	Mean	Max	Limit	Min
MER Data+Pilot [dB]	48.62	48.62	---	48.62
MER Data [dB]	47.91	47.91	---	47.91
MER Pilot [dB]	48.78	48.78	---	48.78
Center Frequency Error [Hz]	-489.87...	-489.87...	---	-489.8702...
Sample/Symbol Clock Error [ppm]	-0.6473...	-0.6473...	---	-0.647399...
Trigger to PLC Time Stamp Ref Point [µs]	2397.19...	---		---
Power [dBm]	4.40	4.40		4.40
Zero Bit Loaded Carrier Ratio	---	---		---

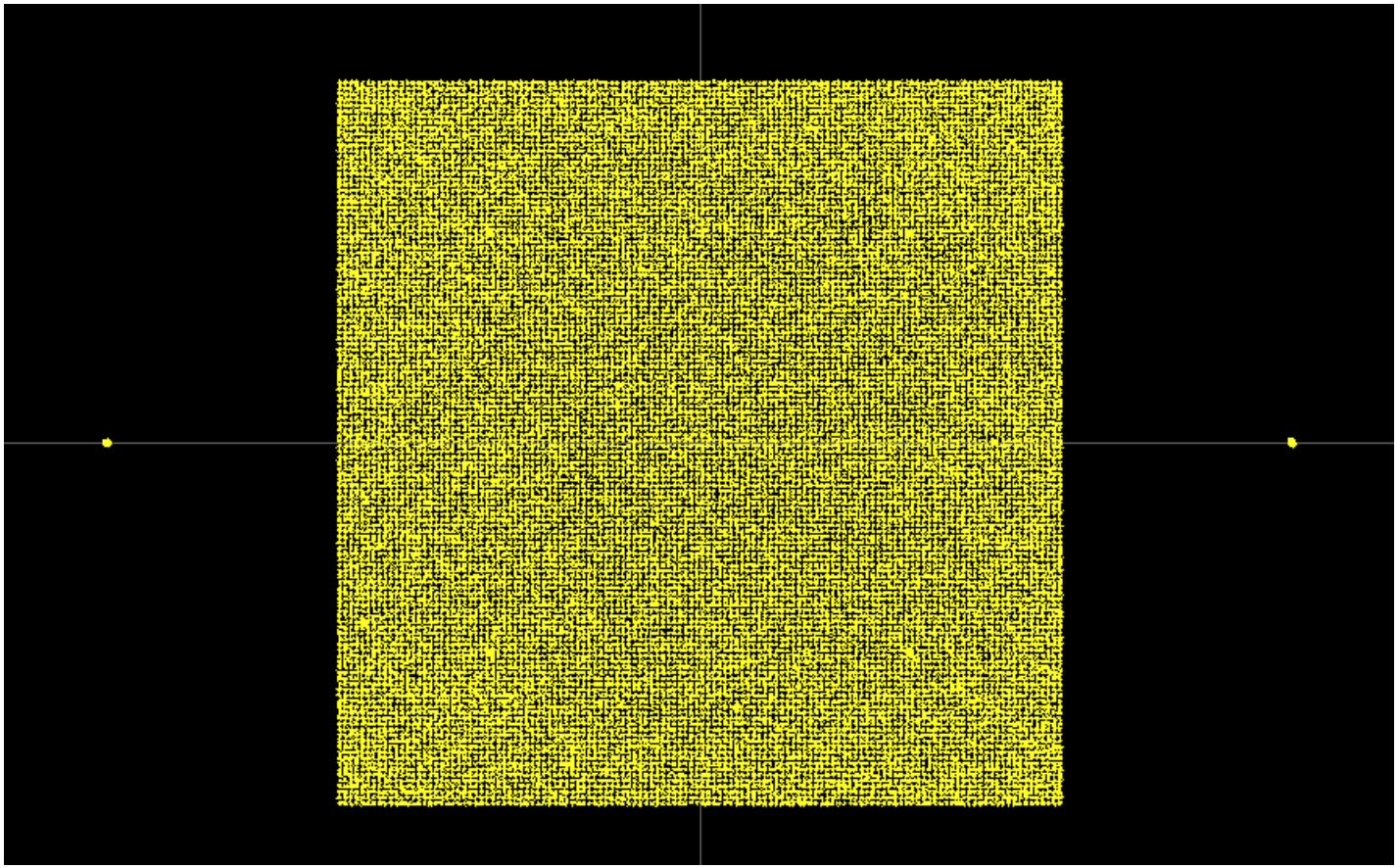
DOCSIS - 1024QAM at the Input of the Cascade (CLGD Output)



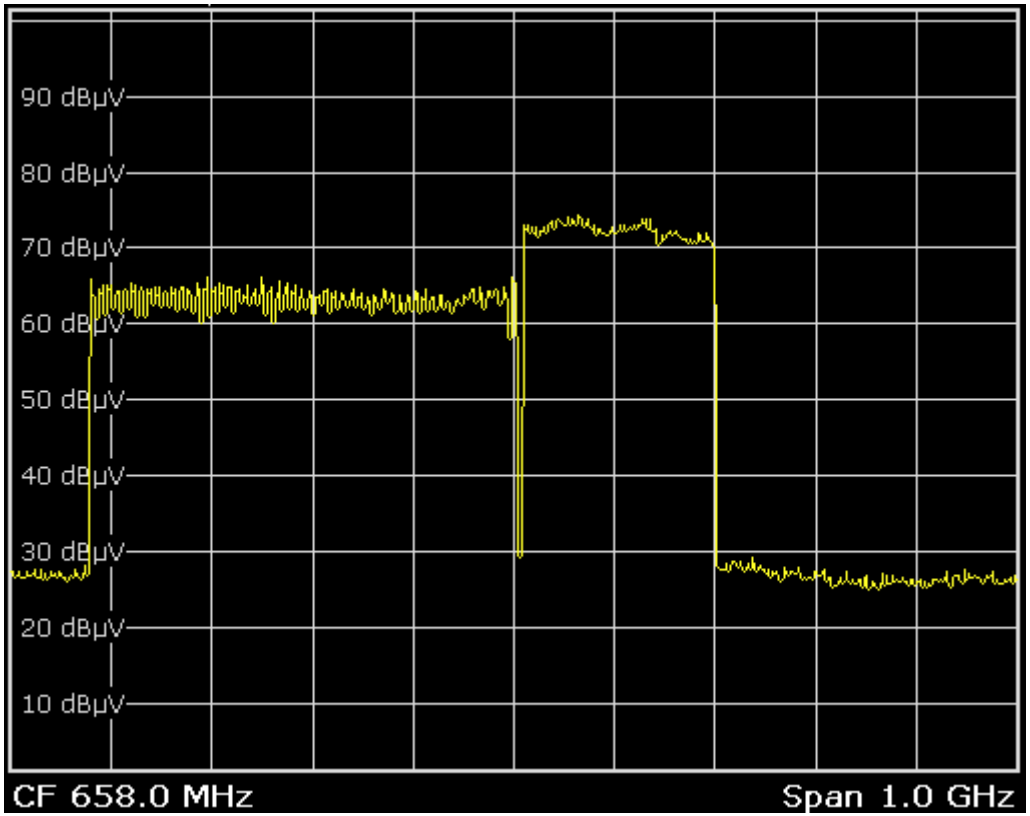
DOCSIS - 4kQAM at CLGD Output (Begin of Cascade)



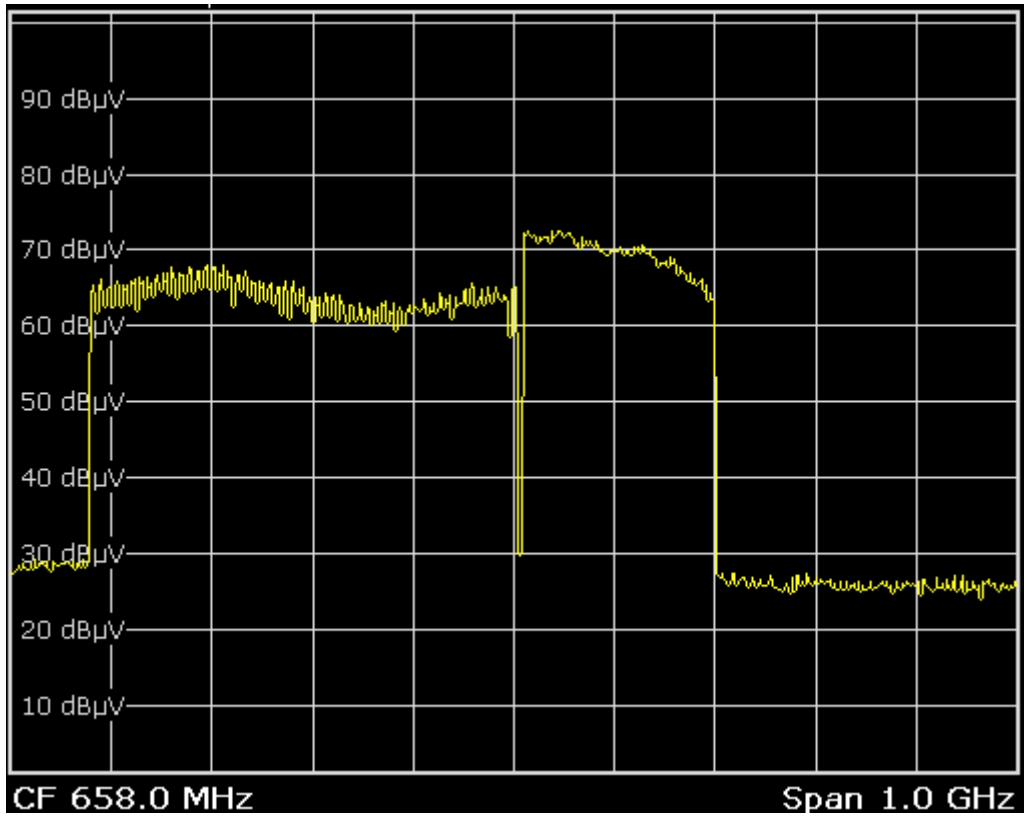
DOCSIS - 16kQAM at CLGD Output (Begin of Cascade)



Spectrum, after Optical Link

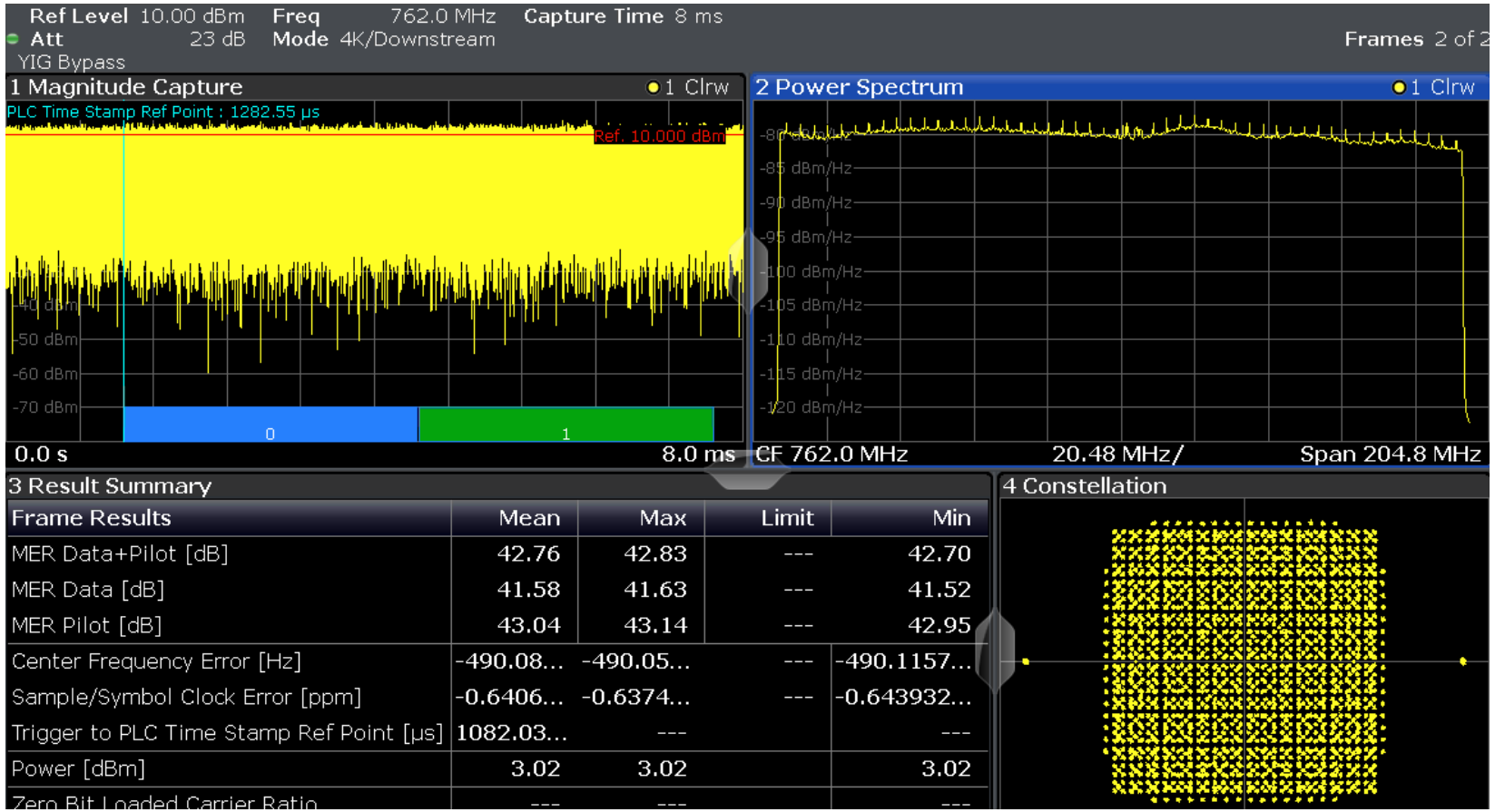


Spectrum after 3rd Amplifier



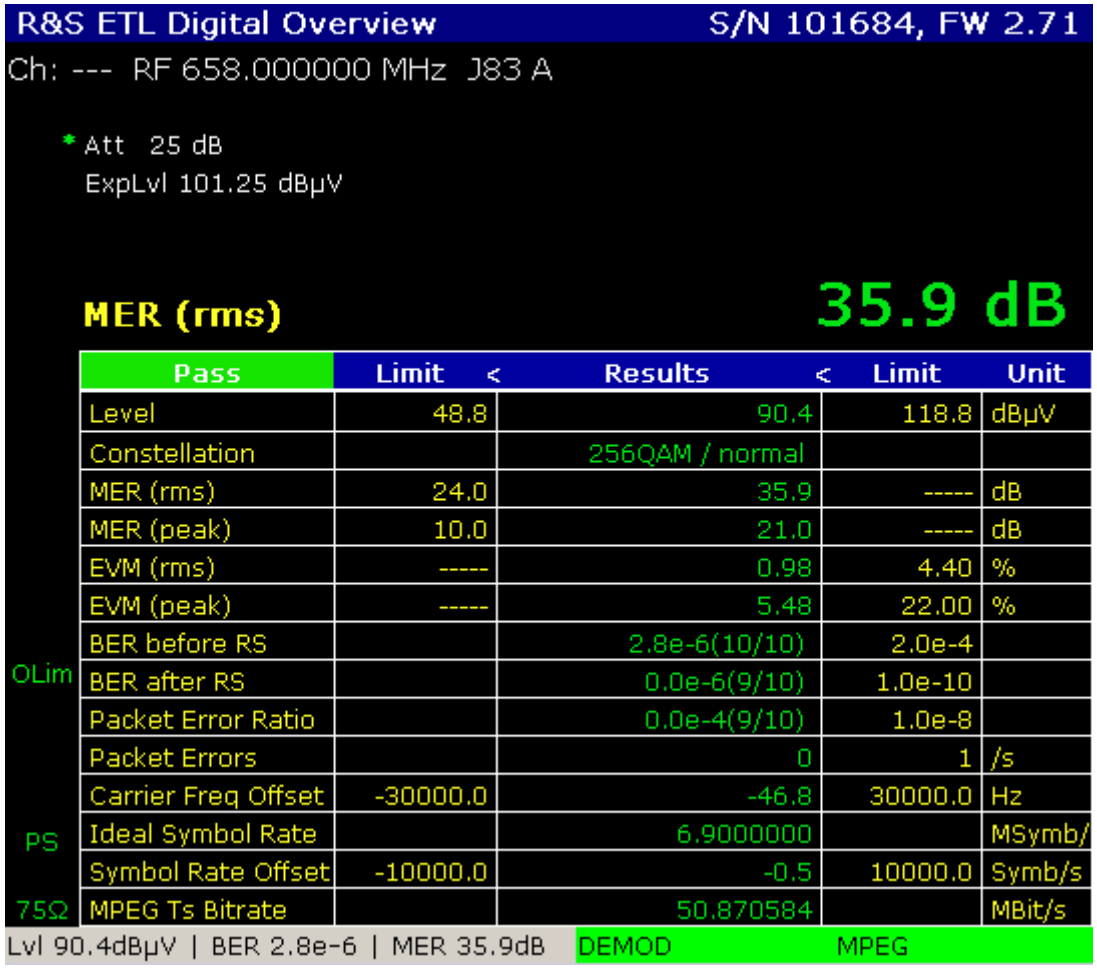
DOCSIS3.1 after Optical Link

MER = 43 dB



Frame Results	Mean	Max	Limit	Min
MER Data+Pilot [dB]	42.76	42.83	---	42.70
MER Data [dB]	41.58	41.63	---	41.52
MER Pilot [dB]	43.04	43.14	---	42.95
Center Frequency Error [Hz]	-490.08...	-490.05...	---	-490.1157...
Sample/Symbol Clock Error [ppm]	-0.6406...	-0.6374...	---	-0.643932...
Trigger to PLC Time Stamp Ref Point [µs]	1082.03...	---		---
Power [dBm]	3.02	3.02		3.02
Zero Bit Loaded Carrier Ratio	---	---		---

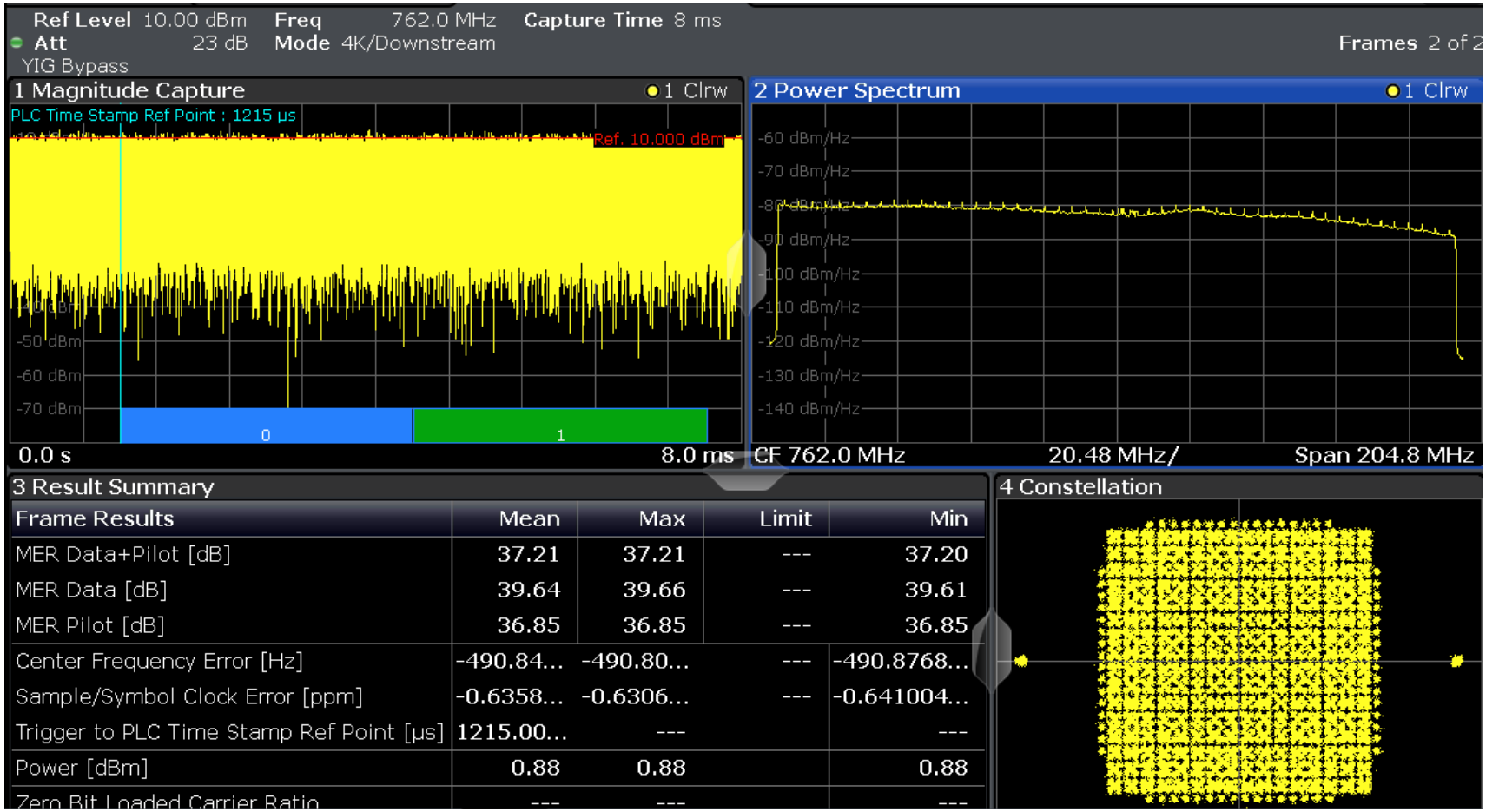
DVB-C at the End of the Cascade



Pass	Limit <	Results	< Limit	Unit
Level	48.8	90.4	118.8	dBµV
Constellation		256QAM / normal		
MER (rms)	24.0	35.9	-----	dB
MER (peak)	10.0	21.0	-----	dB
EVM (rms)	-----	0.98	4.40	%
EVM (peak)	-----	5.48	22.00	%
BER before RS		2.8e-6(10/10)	2.0e-4	
BER after RS		0.0e-6(9/10)	1.0e-10	
Packet Error Ratio		0.0e-4(9/10)	1.0e-8	
Packet Errors		0	1	/s
Carrier Freq Offset	-30000.0	-46.8	30000.0	Hz
Ideal Symbol Rate		6.9000000		MSymb/
Symbol Rate Offset	-10000.0	-0.5	10000.0	Symb/s
MPEG Ts Bitrate		50.870584		MBit/s

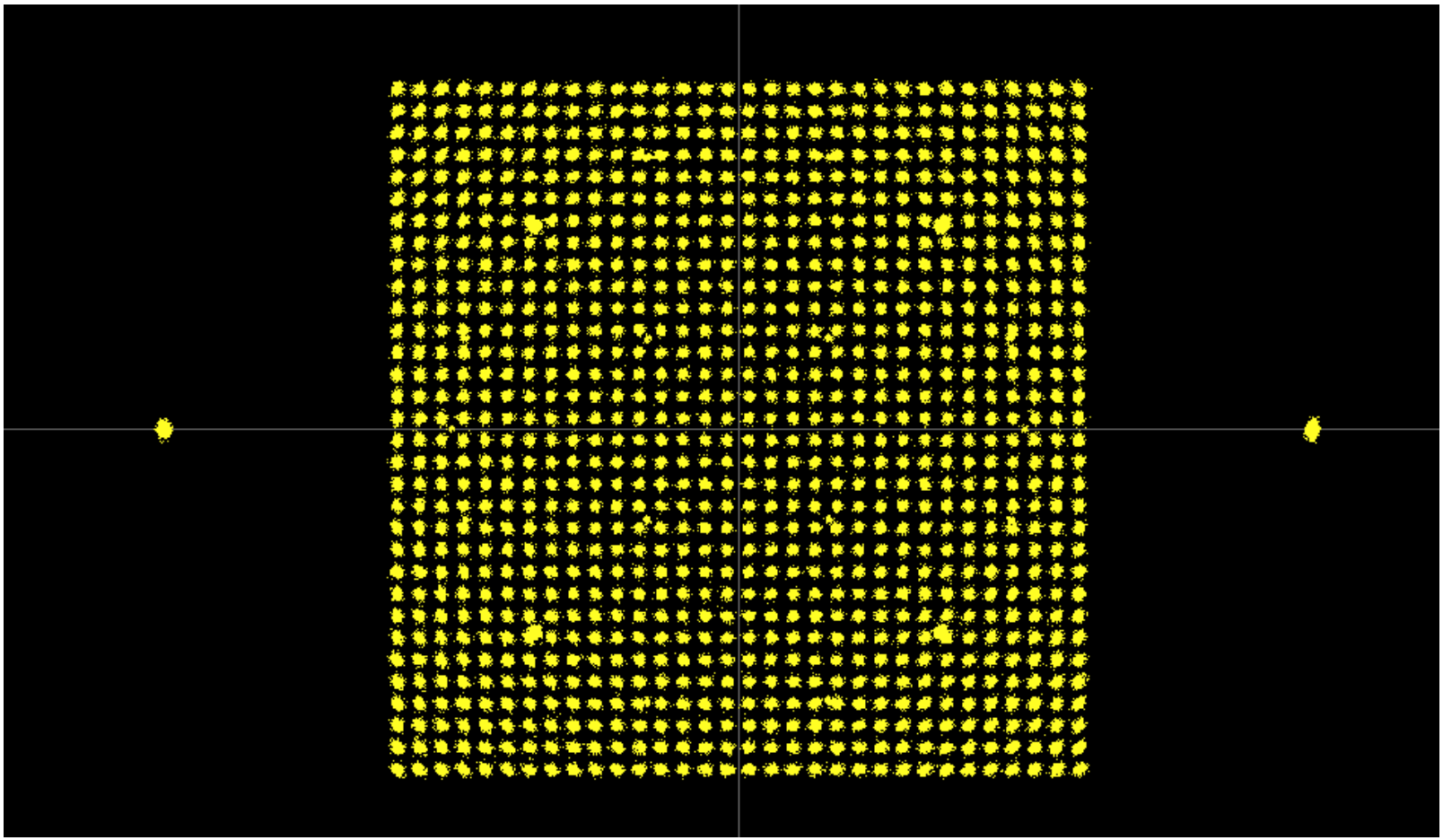
DOCSIS3.1 at the End of the Cascade

MER = 37 dB

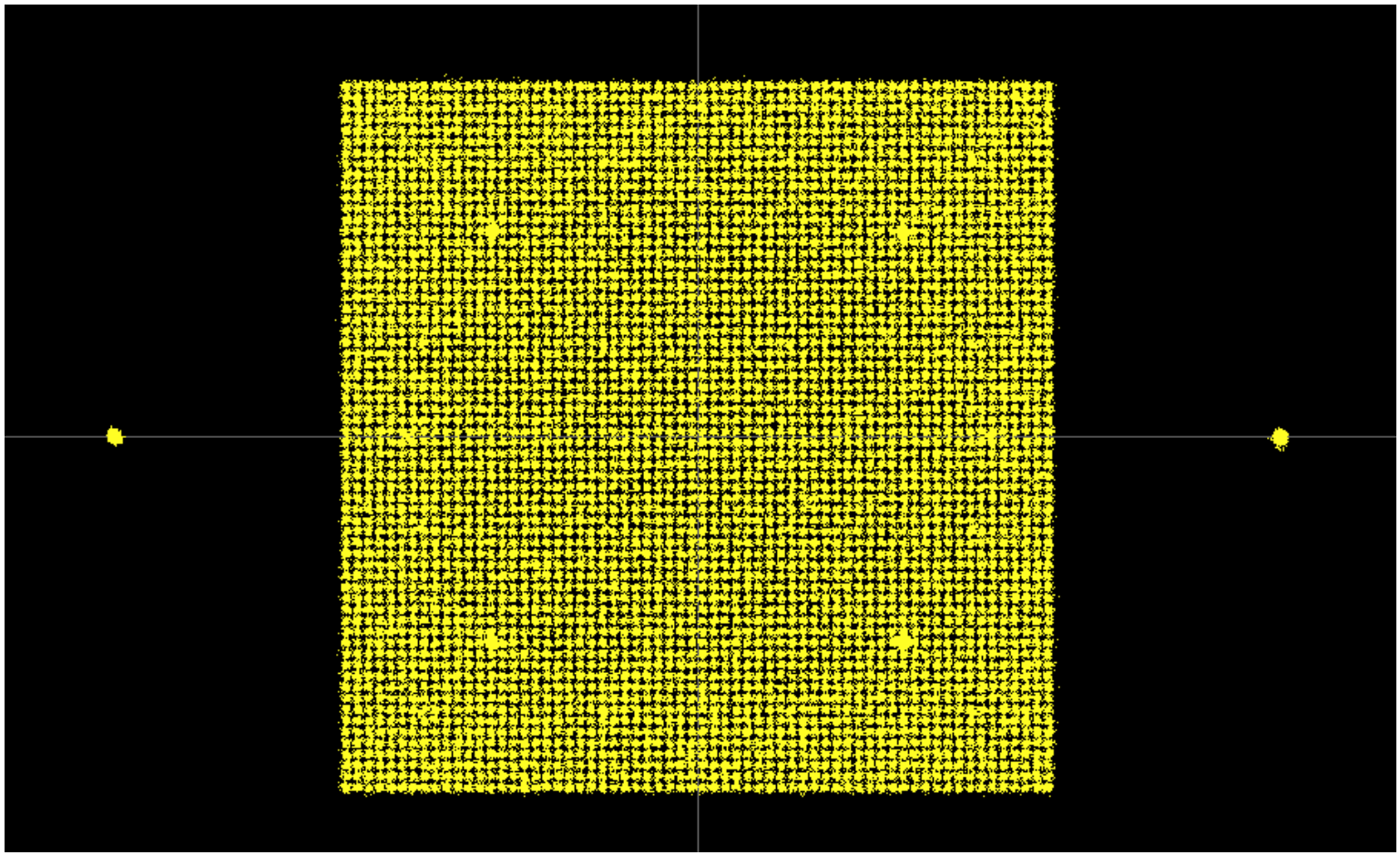


Frame Results	Mean	Max	Limit	Min
MER Data+Pilot [dB]	37.21	37.21	---	37.20
MER Data [dB]	39.64	39.66	---	39.61
MER Pilot [dB]	36.85	36.85	---	36.85
Center Frequency Error [Hz]	-490.84...	-490.80...	---	-490.8768...
Sample/Symbol Clock Error [ppm]	-0.6358...	-0.6306...	---	-0.641004...
Trigger to PLC Time Stamp Ref Point [µs]	1215.00...	---		---
Power [dBm]	0.88	0.88		0.88
Zero Bit Loaded Carrier Ratio	---	---		---

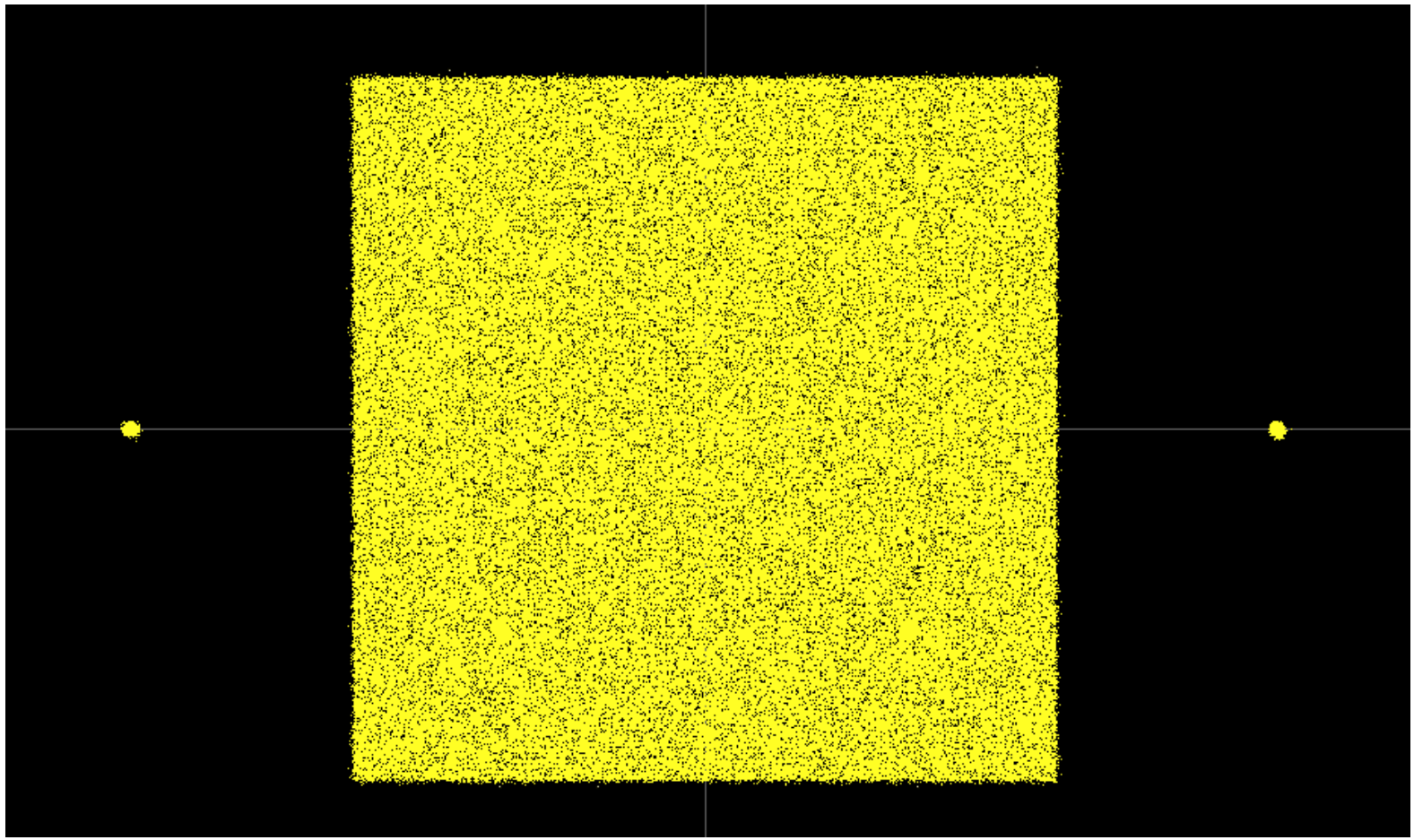
1024QAM at the End of the Cascade



4096QAM at the End of the Cascade



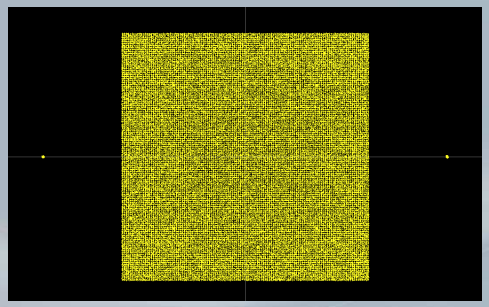
16384QAM (16kQAM) at the End of the Cascade

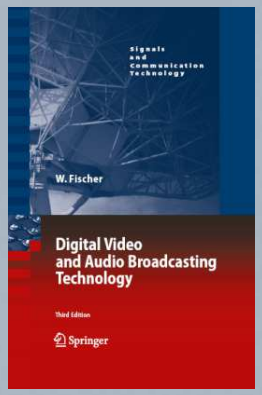


CableTech

16.3.2017

Thank you very much!





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