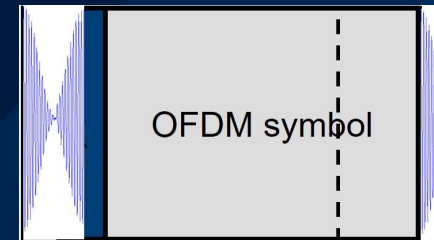
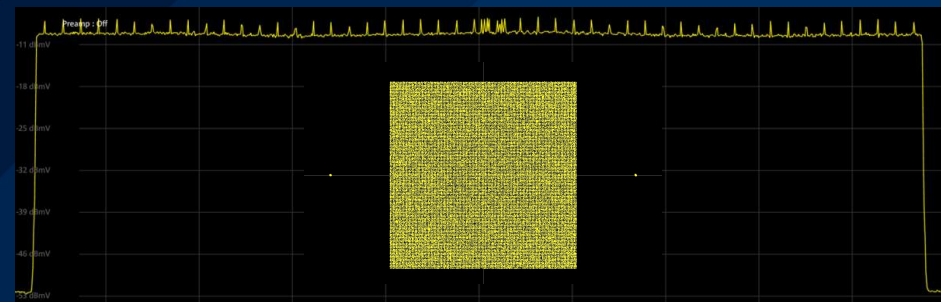


„CYCLIC PREFIX UND WINDOWING BEI DOCSIS3.1 – (THEORIE UND) PRAKTISCHE AUSWIRKUNGEN“



Walter Fischer
Rohde&Schwarz Trainingszentrum München



ROHDE & SCHWARZ

Make ideas real

Cable Days Salzburg
13. November 2019



REFERENT

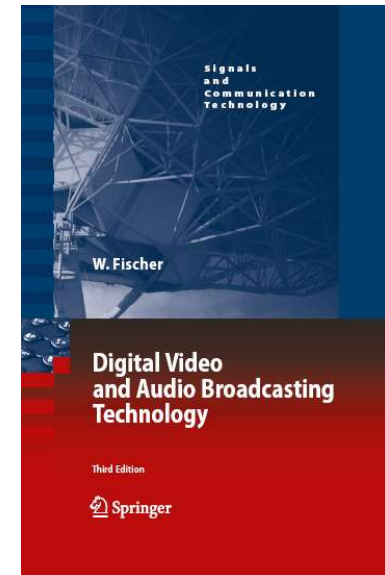
Walter Fischer

Dipl.Ing.(FH)

Rohde&Schwarz

Training Center, Munich

Walter.Fischer@ROHDE-SCHWARZ.COM



AGENDA

DOCSIS3.1 Overview

OFDM Principle

Guard Interval – Cyclical Prefix (CP) in OFDM

OFDM Spectrum and Shoulders

Principle of „Windowing“

„Windowing“ in DOCSIS3.1

Summary

DOCSIS3.1 ÜBERBLICK

DOCSIS3.1 Overview

OFDM Principle

Guard Interval – Cyclical Prefix (CP) in OFDM

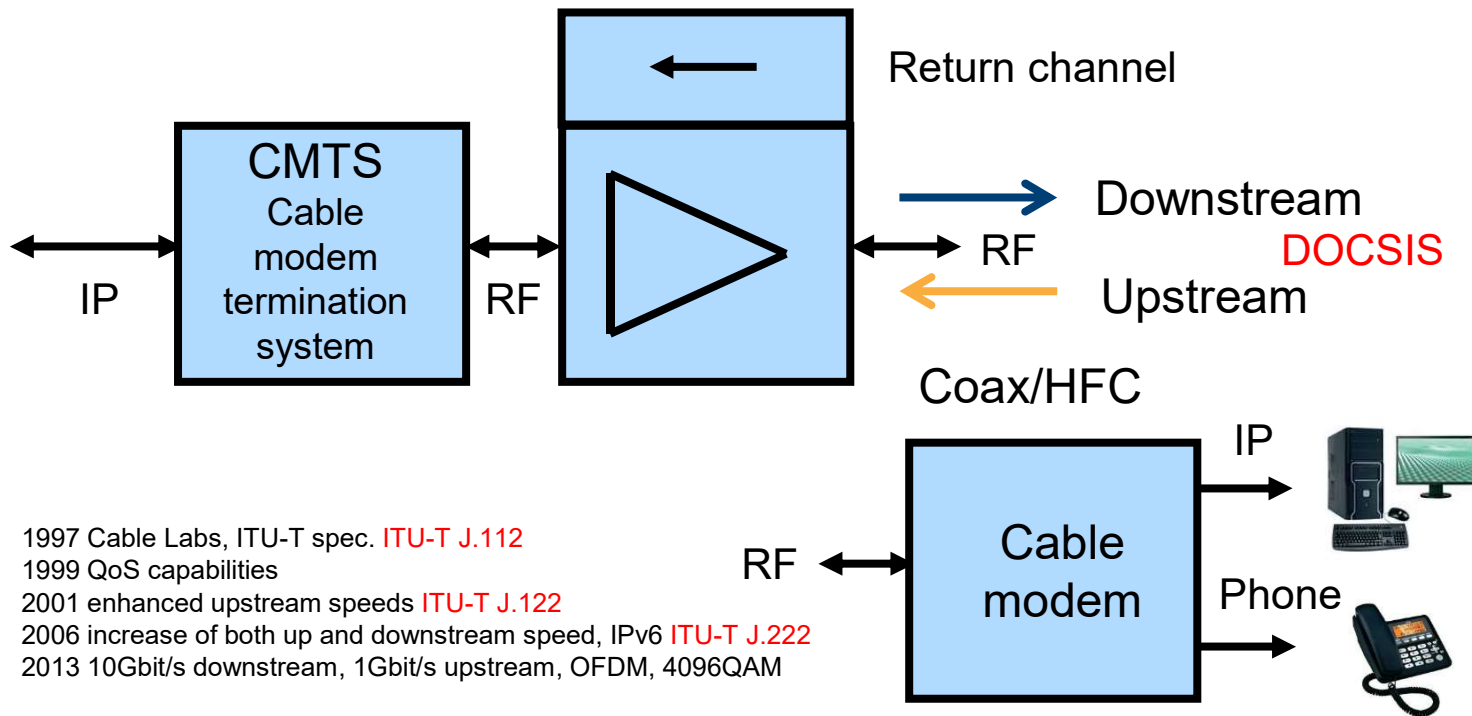
OFDM Spectrum and Shoulders

Principle of „Windowing“

„Windowing“ in DOCSIS3.1

Summary

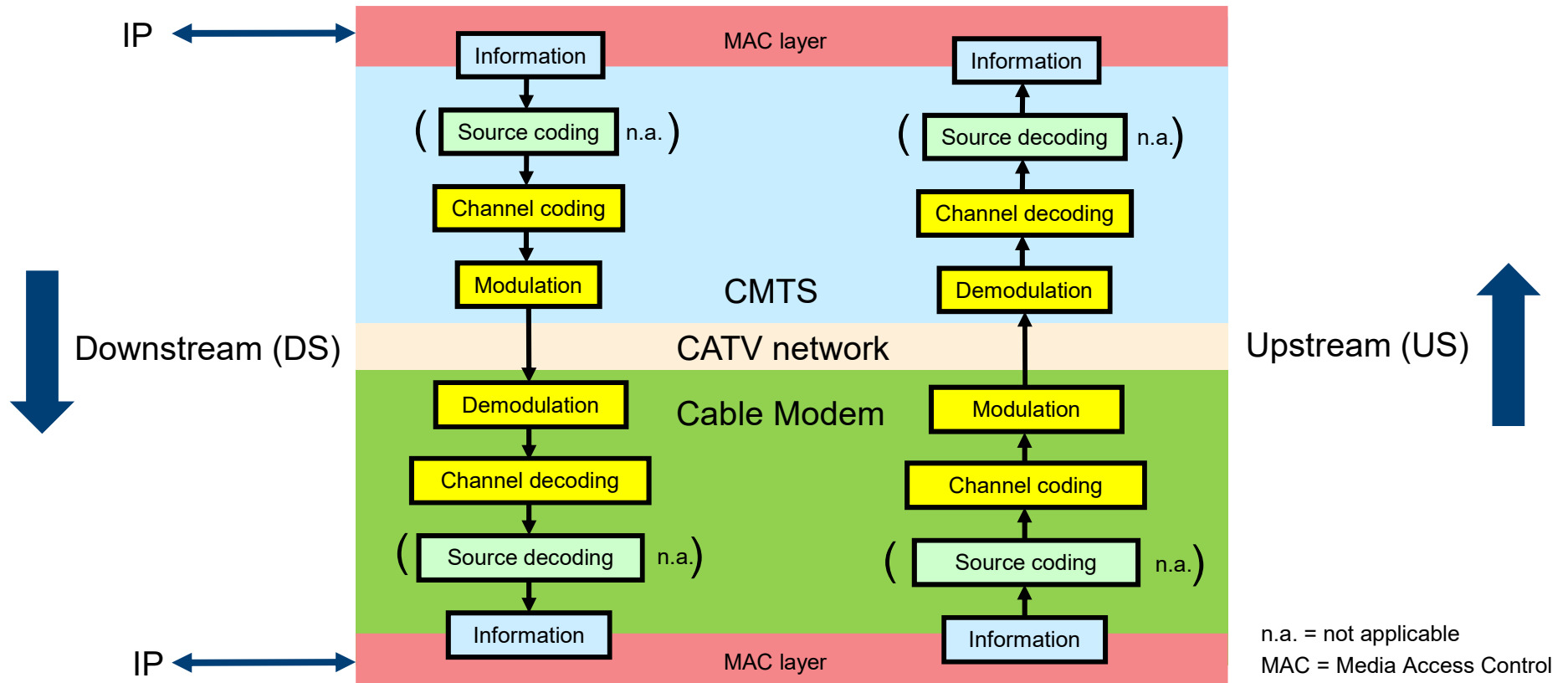
BROADBAND INTERNET & TELEPHONE VIA CATV



- 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

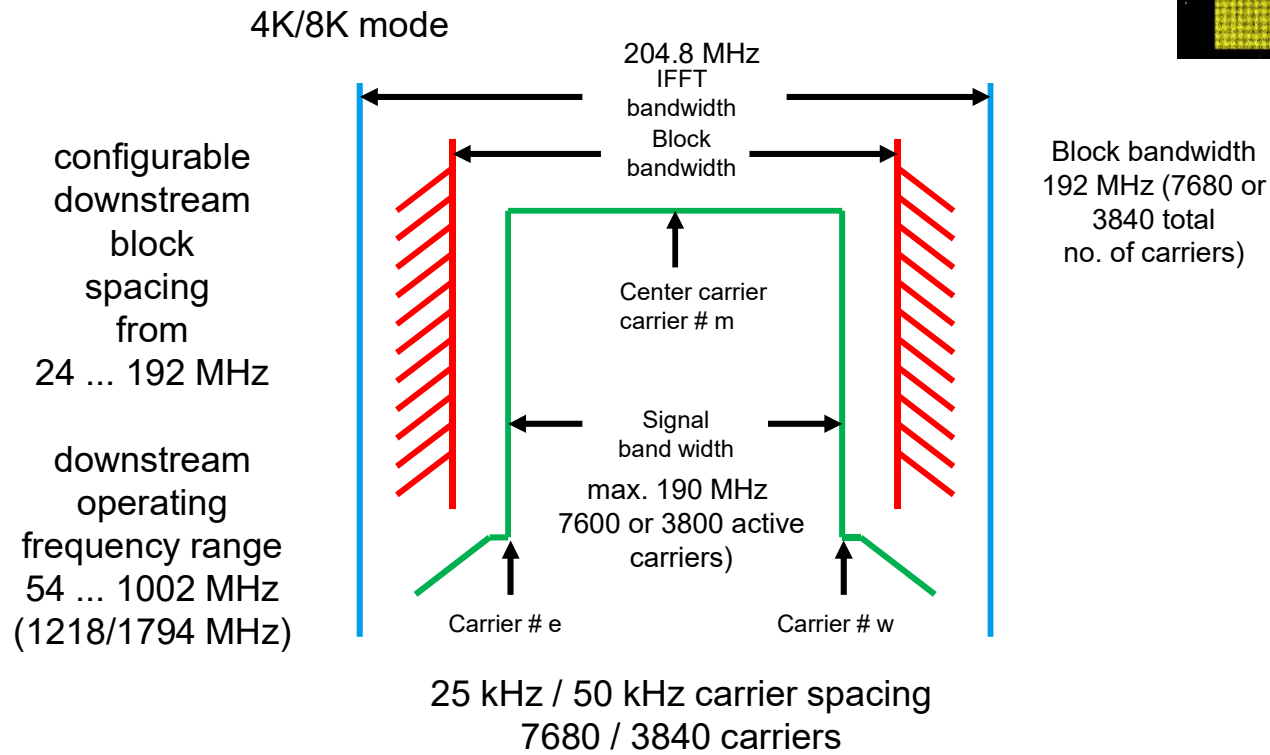
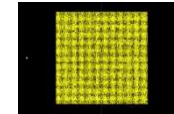
DOCSIS – Data-over-Cable Service Interface Specification

DOCSIS DOWNSTREAM AND UPSTREAM



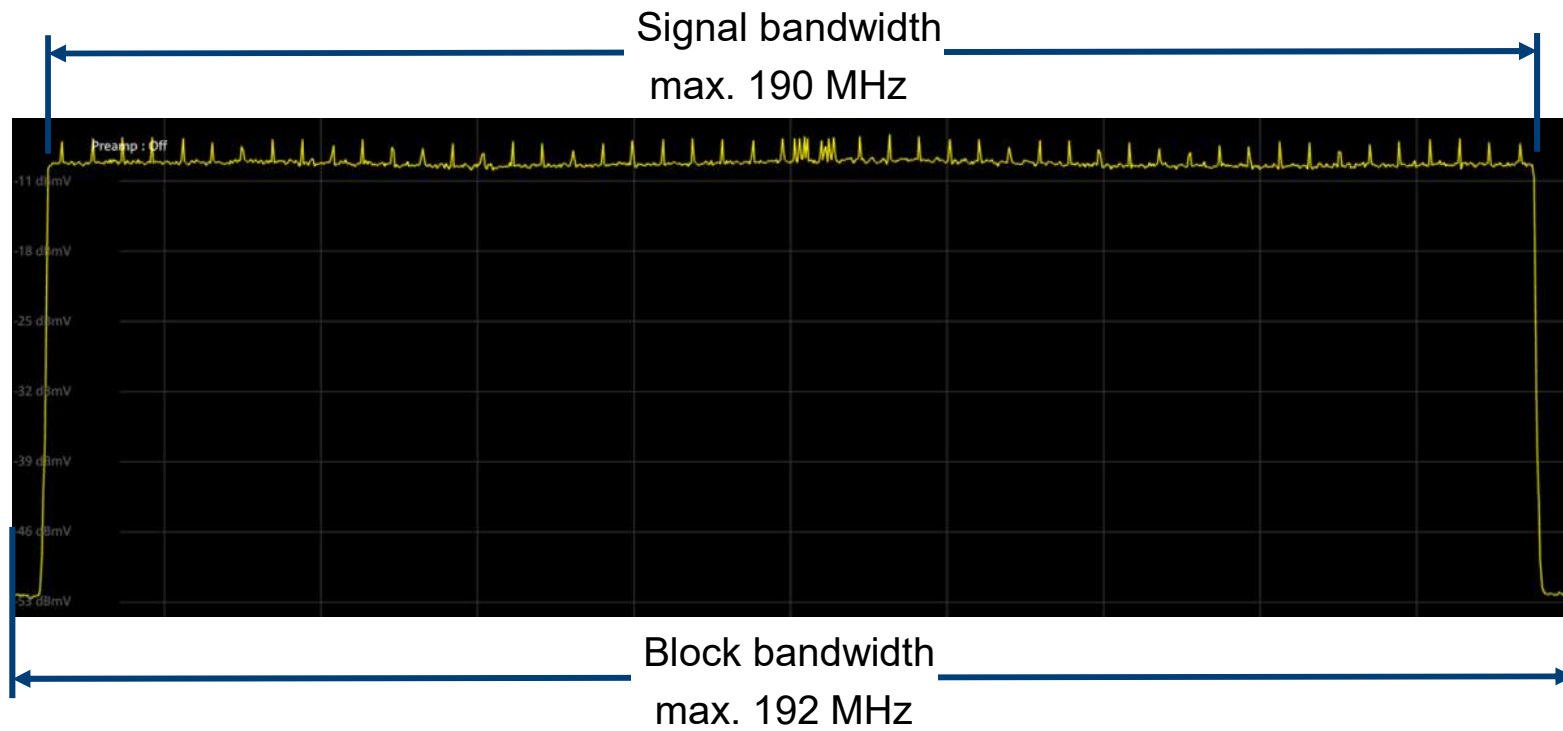
DOCSIS 3.1 DOWNSTREAM SPECTRUM

Up to 1024/4096/16384QAM



(... DOCSIS3.1 symbol duration ... 20 or 40 μ s ... OFDM, 1...5 μ s guard)

DOCSIS3.1 DOWNSTREAM SPECTRUM

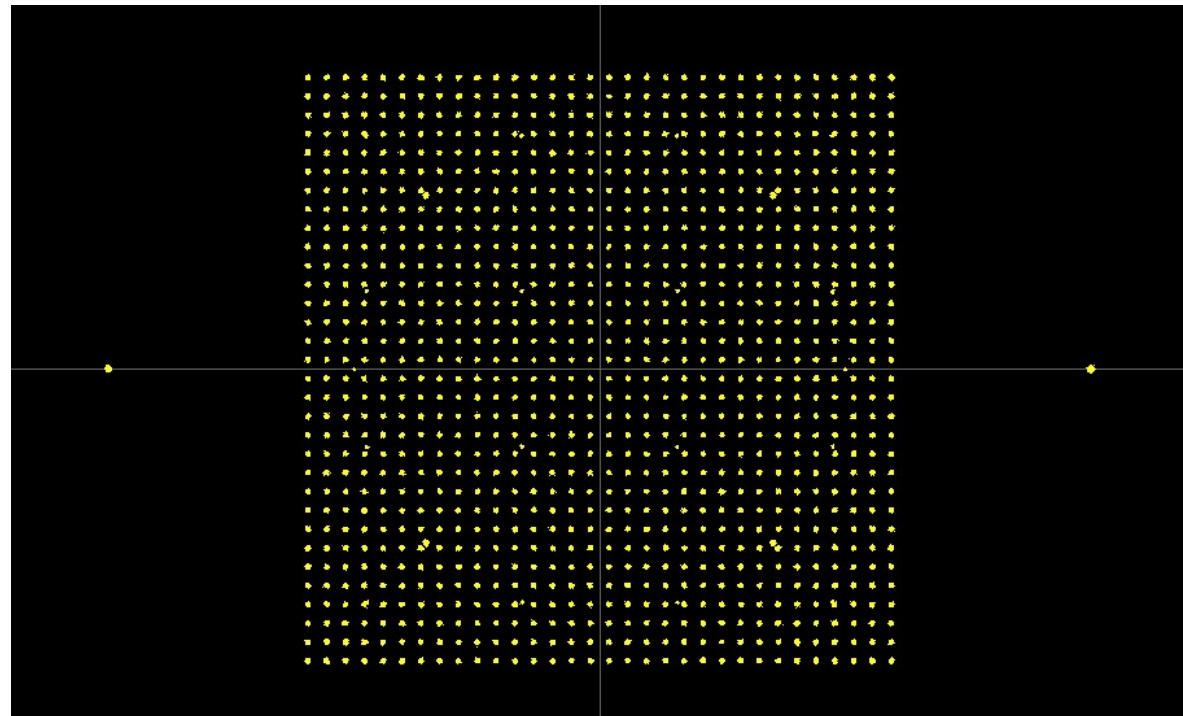


DOCSIS3.1 DOWNSTREAM BLOCK BANDWIDTH

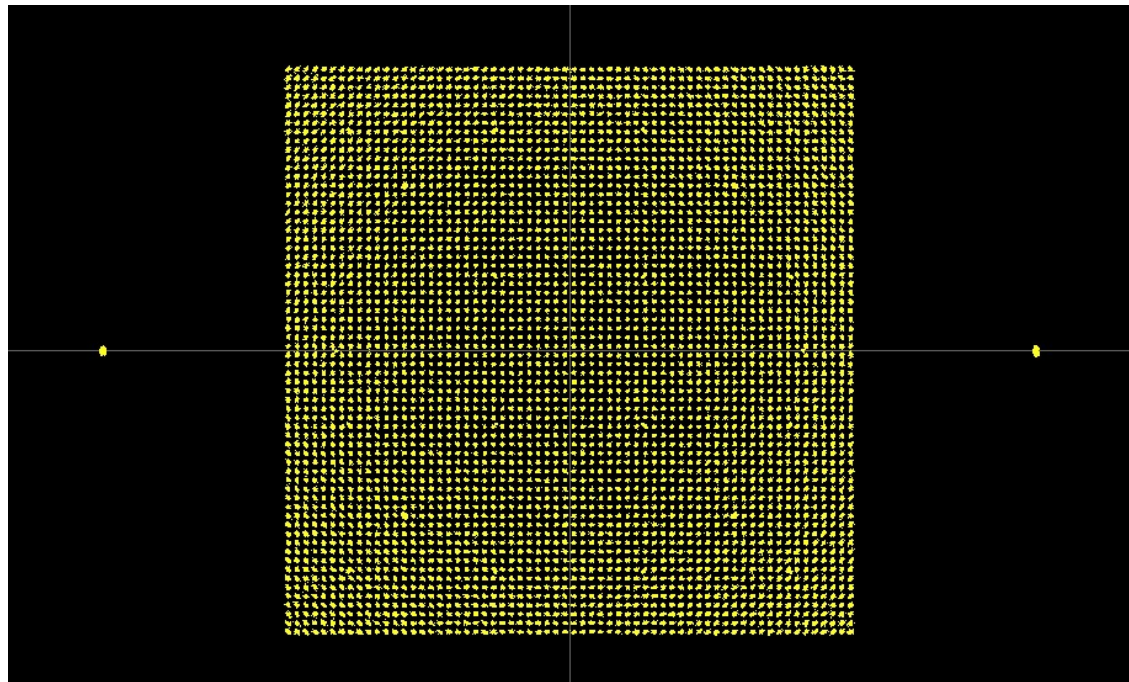


4K mode	$4096 \cdot 50 \text{ kHz} = 204.8 \text{ MHz} = \text{IFFT bandwidth}$
	$3800 \cdot 50 \text{ kHz} = 190 \text{ MHz} = \text{signal bandwidth}$
	$3840 \cdot 50 \text{ kHz} = 192 \text{ MHz} = \text{block bandwidth}$
8K mode	$8192 \cdot 25 \text{ kHz} = 204.8 \text{ MHz} = \text{IFFT bandwidth}$
	$7600 \cdot 25 \text{ kHz} = 190 \text{ MHz} = \text{signal bandwidth}$
	$7680 \cdot 25 \text{ kHz} = 192 \text{ MHz} = \text{block bandwidth}$

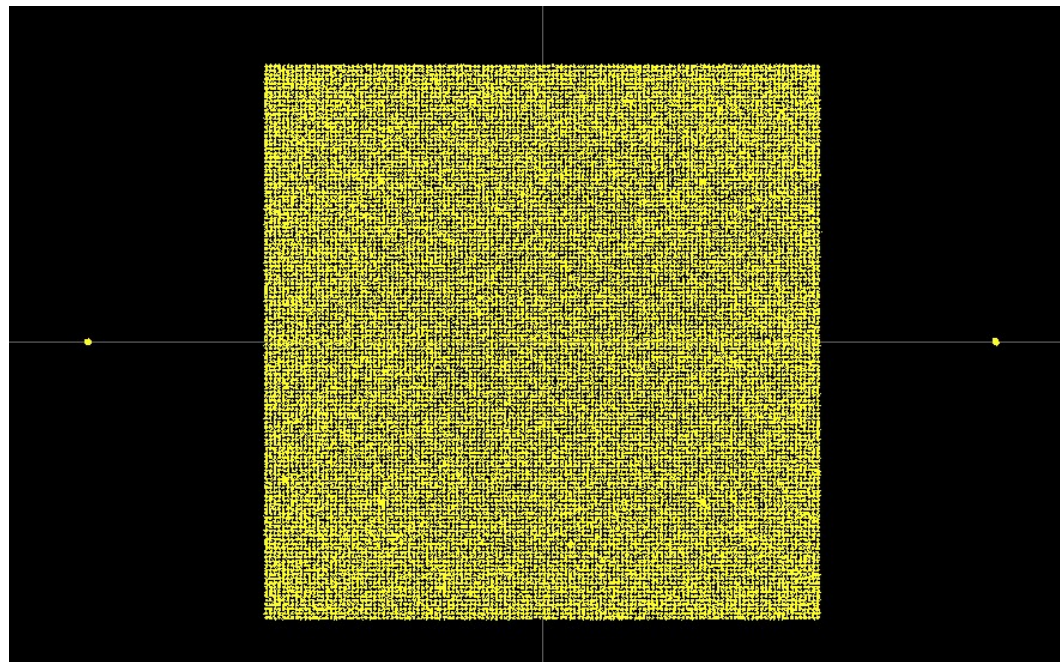
DOCSIS3.1 - 1024QAM DOWNSTREAM



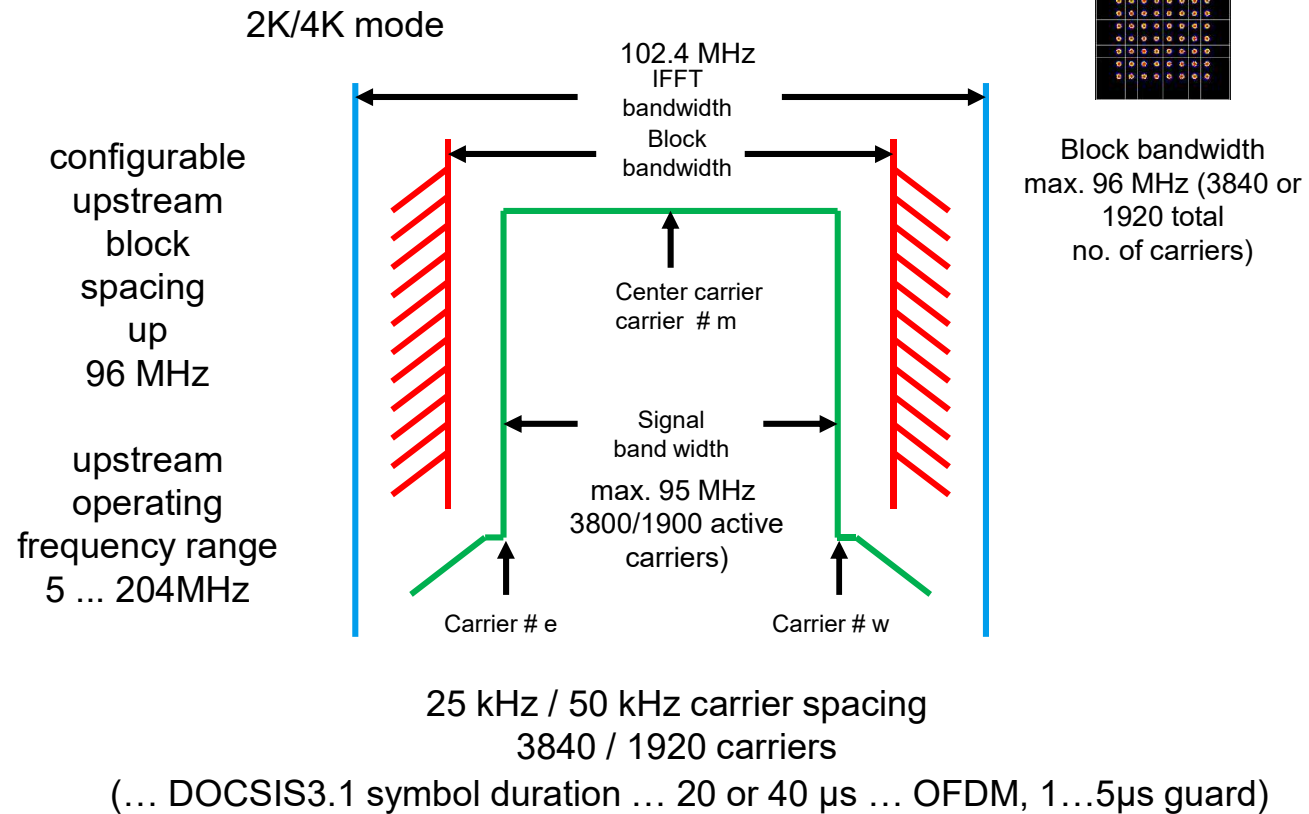
DOCSIS3.1 - 4096QAM DOWNSTREAM



DOCSIS3.1 - 16384QAM DOWNSTREAM



DOCSIS 3.1 UPSTREAM SPECTRUM



OFDM – PRINZIP ...

DOCSIS3.1 Overview

OFDM Principle

Guard Interval – Cyclical Prefix (CP) in OFDM

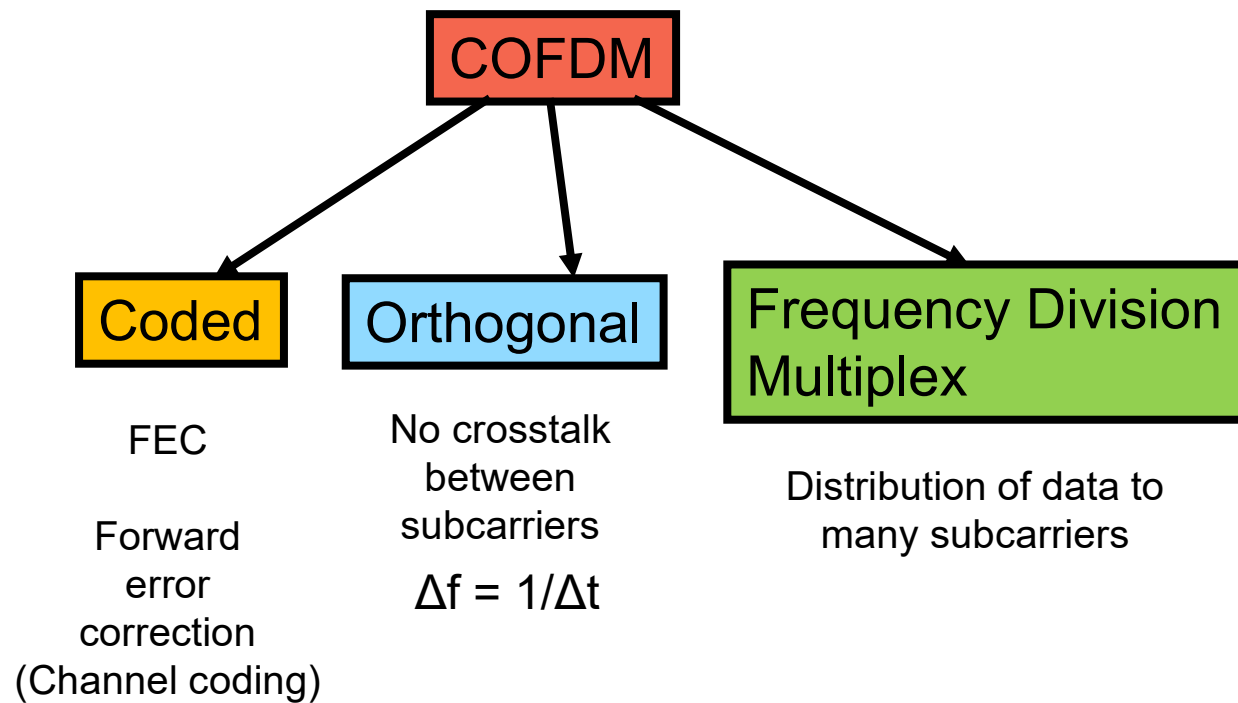
OFDM Spectrum and Shoulders

Principle of „Windowing“

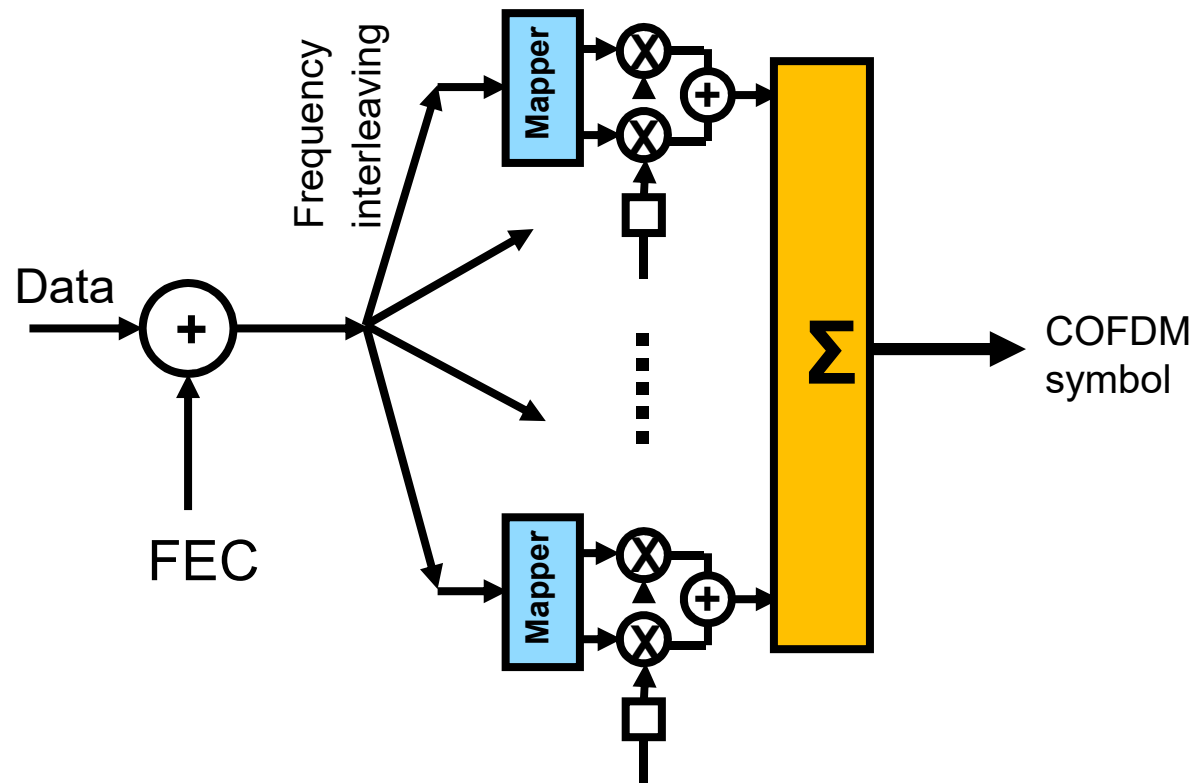
„Windowing“ in DOCSIS3.1

Summary

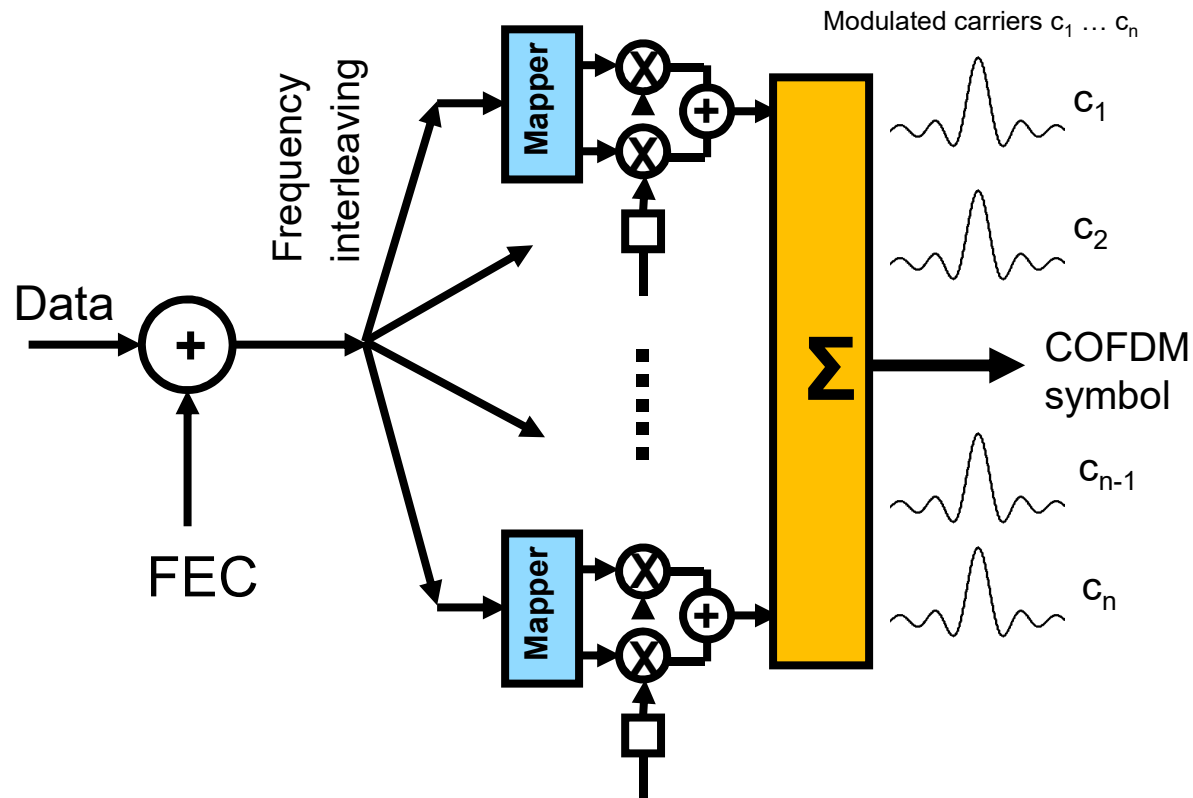
OFDM – ORTHOGONAL FREQUENCY DIVISION MULTIPLEX



(C)OFDM PRINCIPLE



(C)OFDM PRINCIPLE

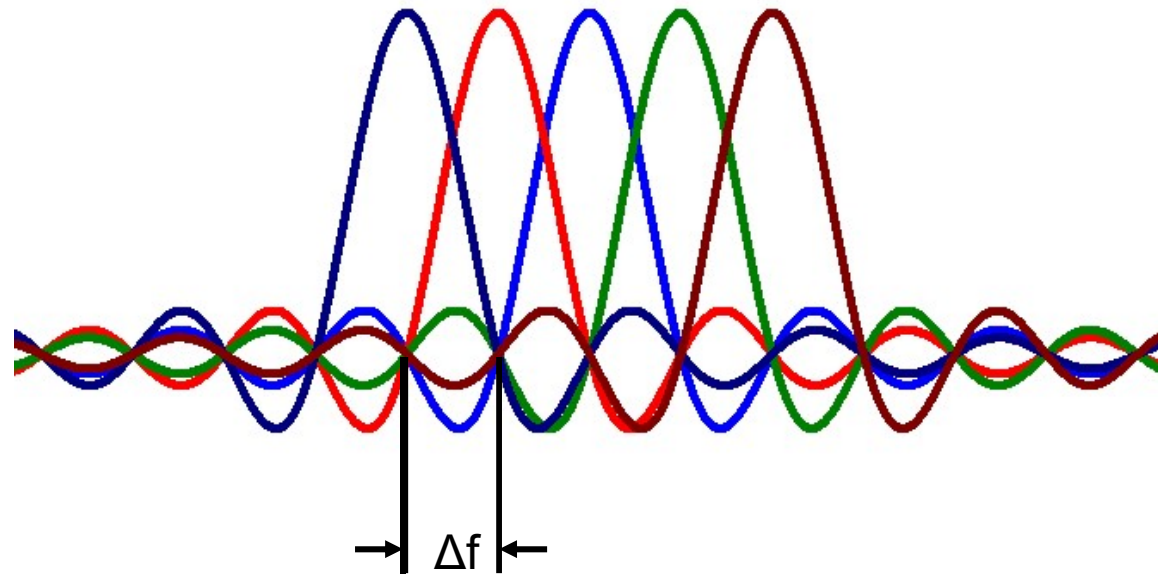


COFDM = FEC + OFDM

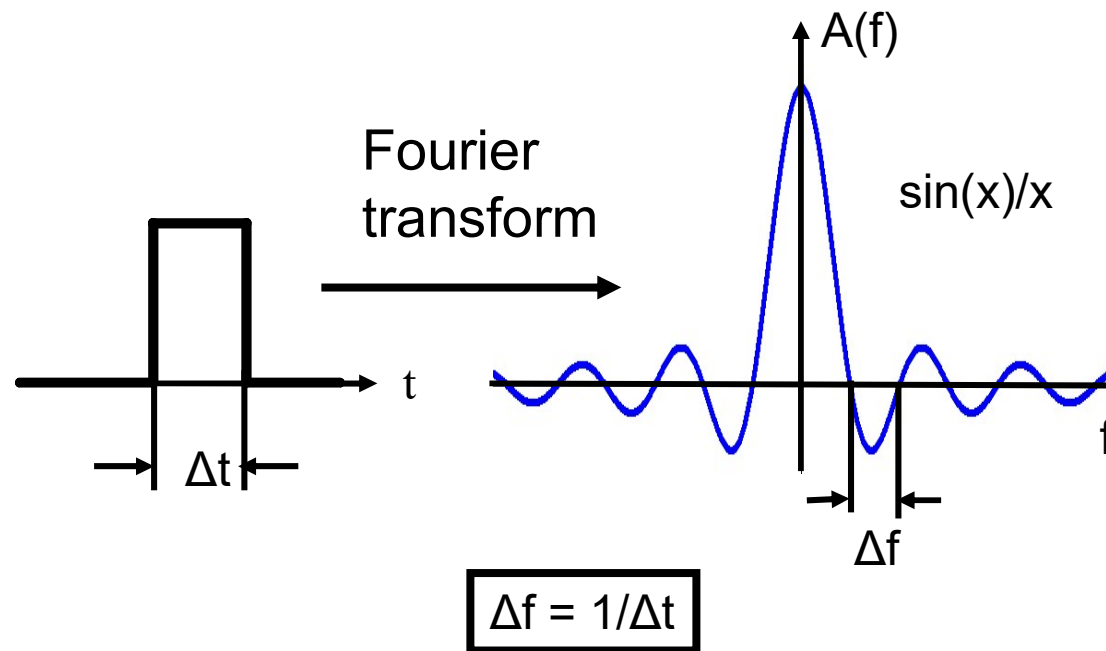
OFDM =

- multiple
- slowly clocked
- narrow-band channels.

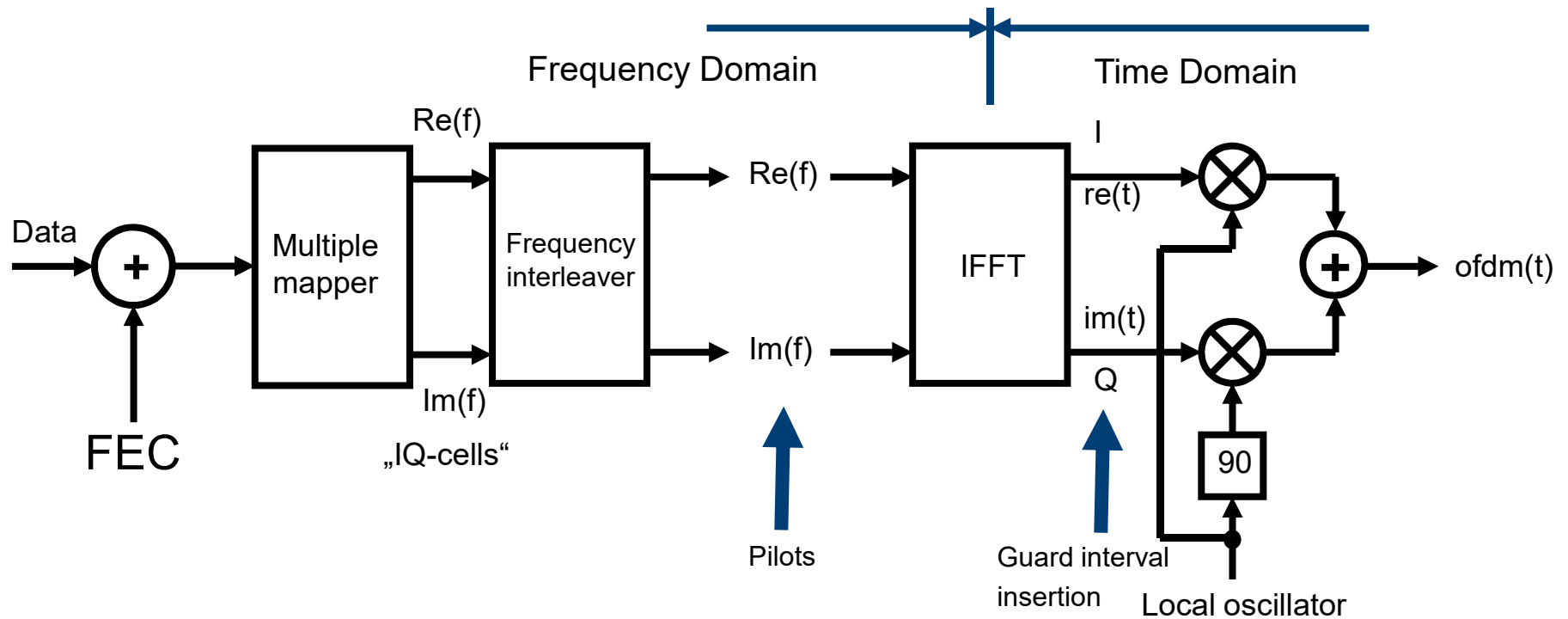
OFDM SPECTRUM



OFDM – TERM „ORTHOGONALITY“

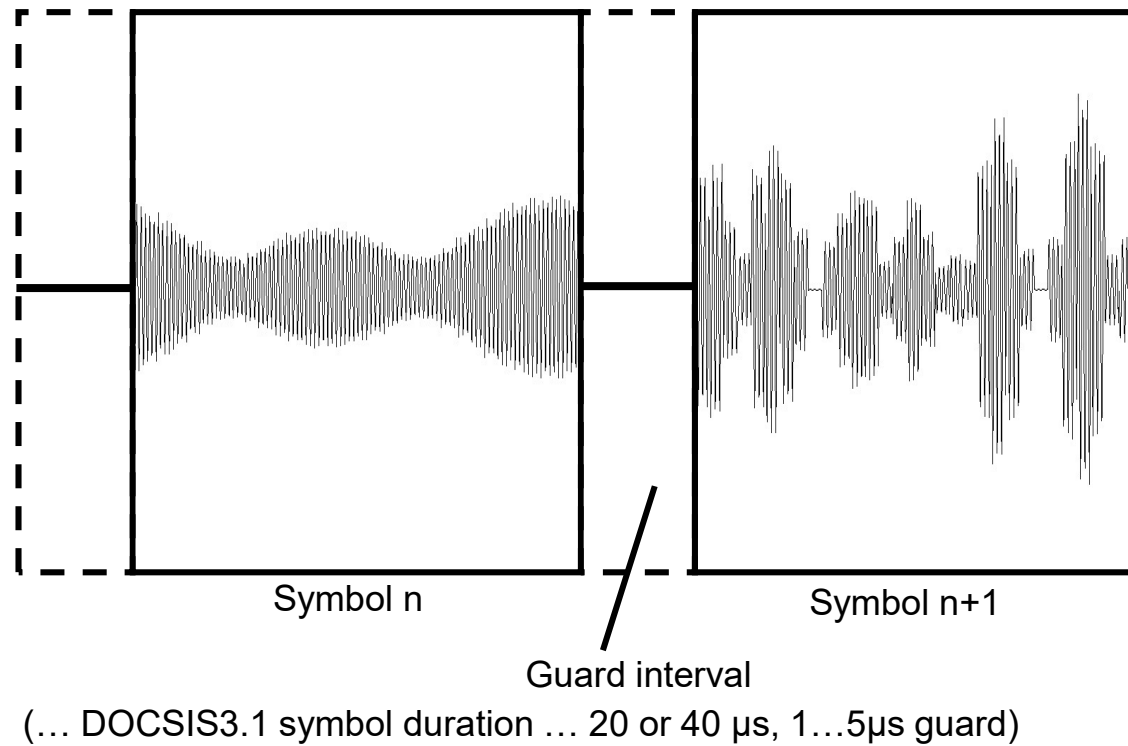


FUNCTIONAL BLOCK DIAGRAM OF AN OFDM MODULATOR



OFDM SYMBOLS WITH GUARD INTERVAL

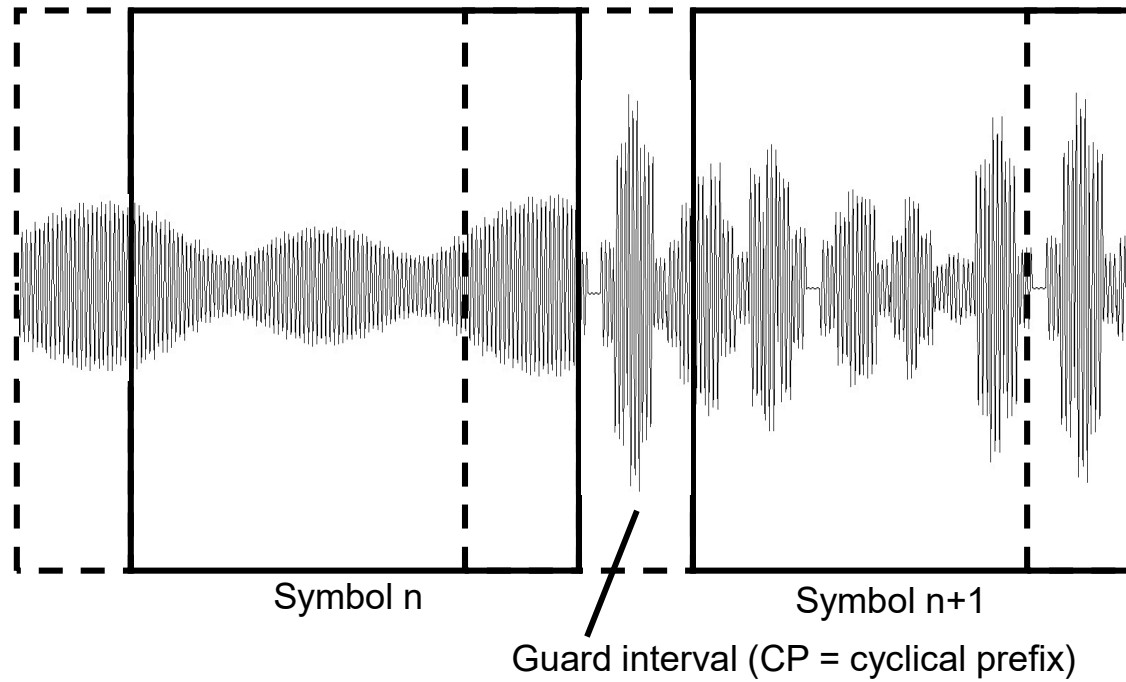
„Schutzintervall“



OFDM SYMBOLS WITH GUARD INTERVAL

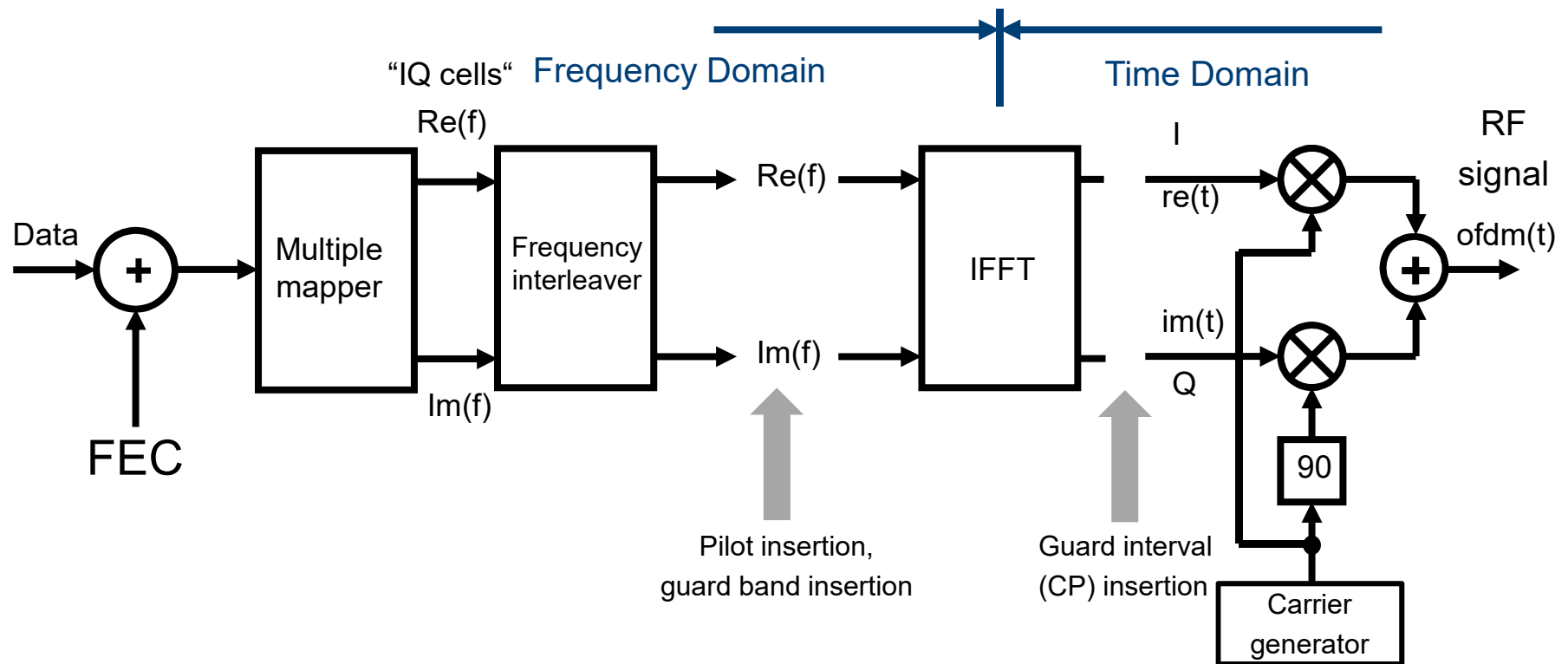
„Schutzintervall“
„Zyklischer Prefix“

„CP“

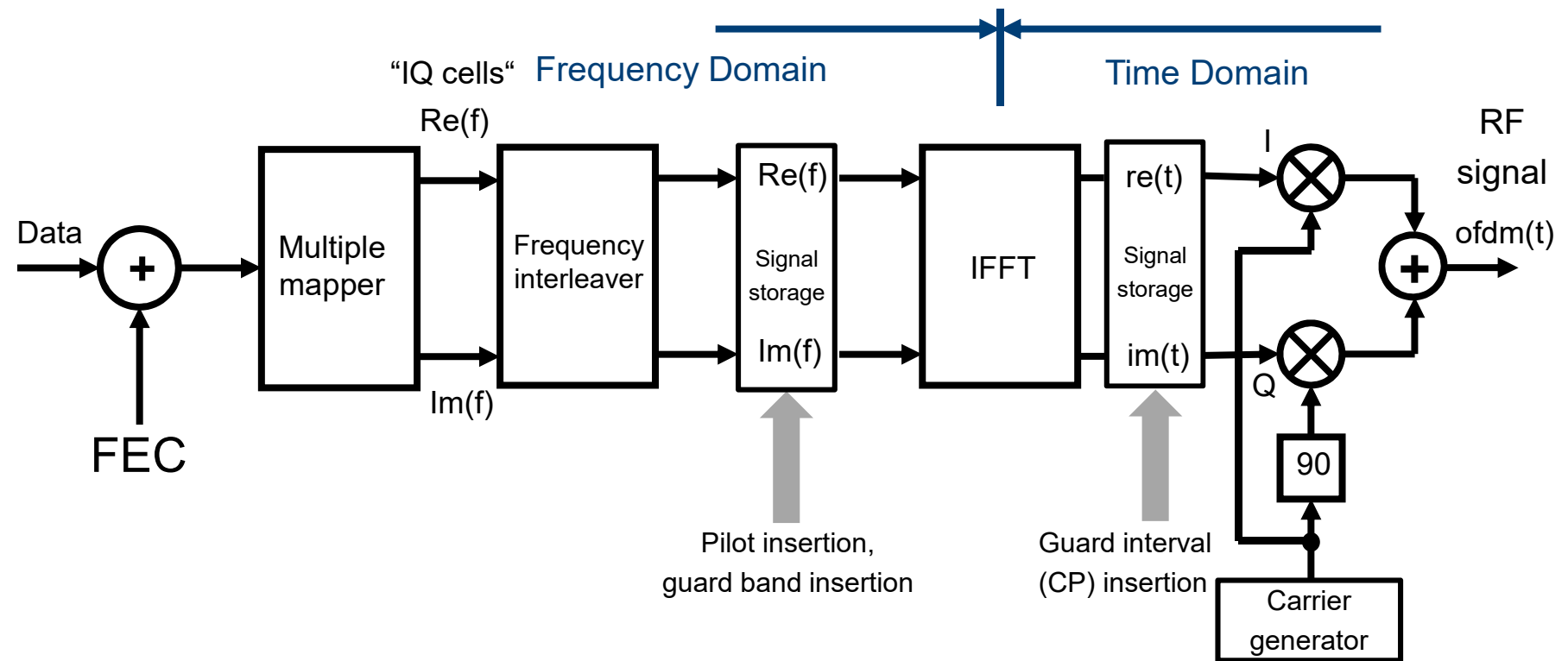


(... DOCSIS3.1 symbol duration ... 20 or 40 μ s, 1...5 μ s guard)

PRINCIPLE BLOCK DIAGRAM OF AN OFDM MODULATOR



PRINCIPLE BLOCK DIAGRAM OF AN OFDM MODULATOR



SCHUTZINTERVALL – CYCLICAL PREFIX (CP) BEI OFDM ...

DOCSIS3.1 Overview

ODFM Principle

Guard Interval – Cyclical Prefix (CP) in OFDM

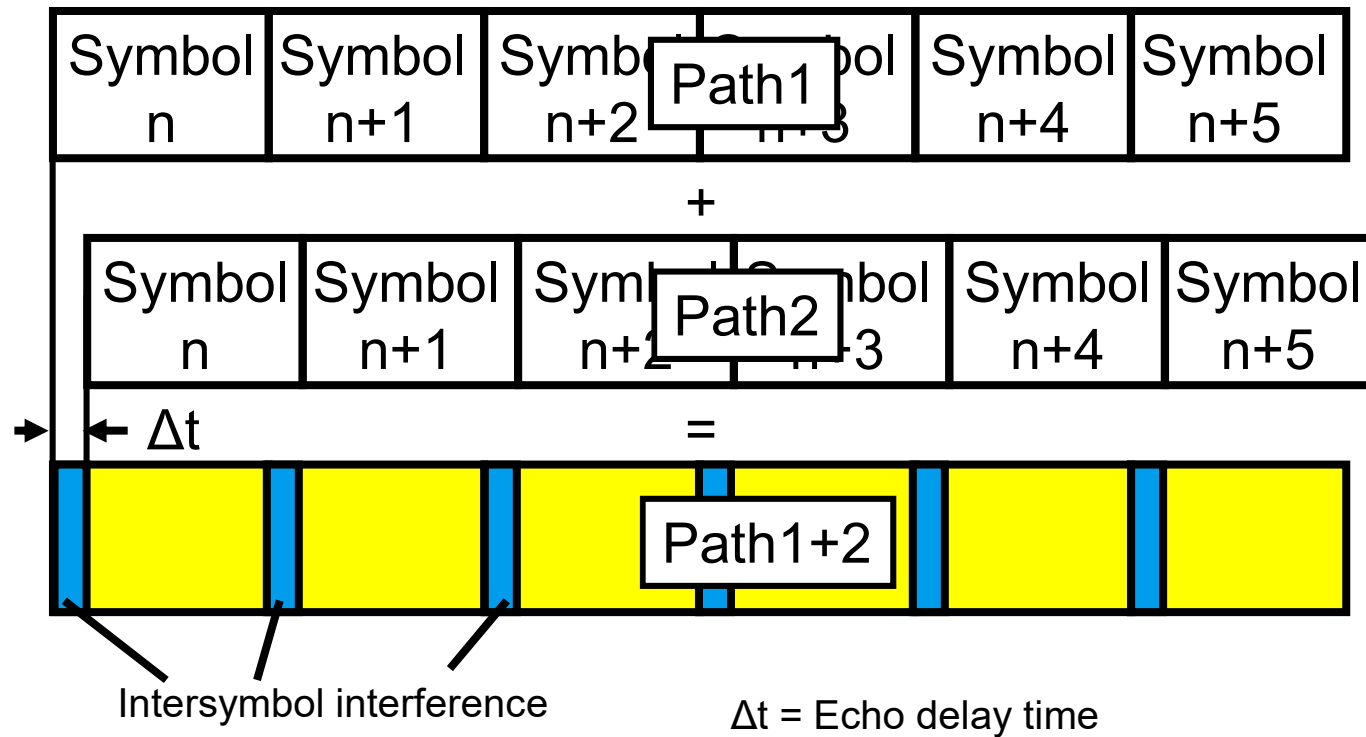
OFDM Spectrum and Shoulders

Principle of „Windowing“

„Windowing“ in DOCSIS3.1

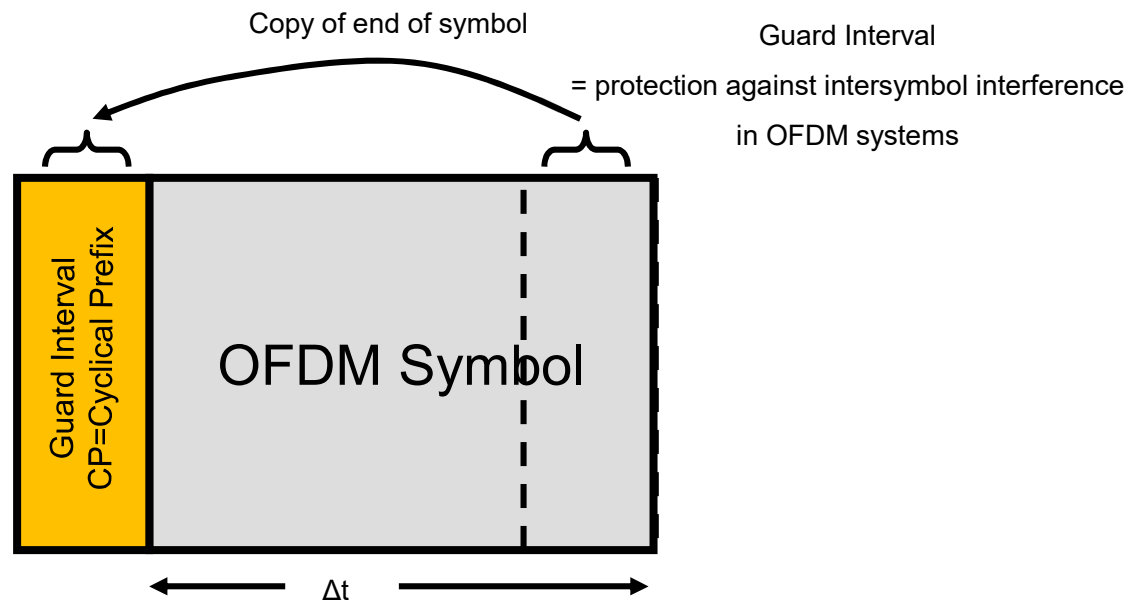
Summary

INTERSYMBOL INTERFERENCE (ISI)



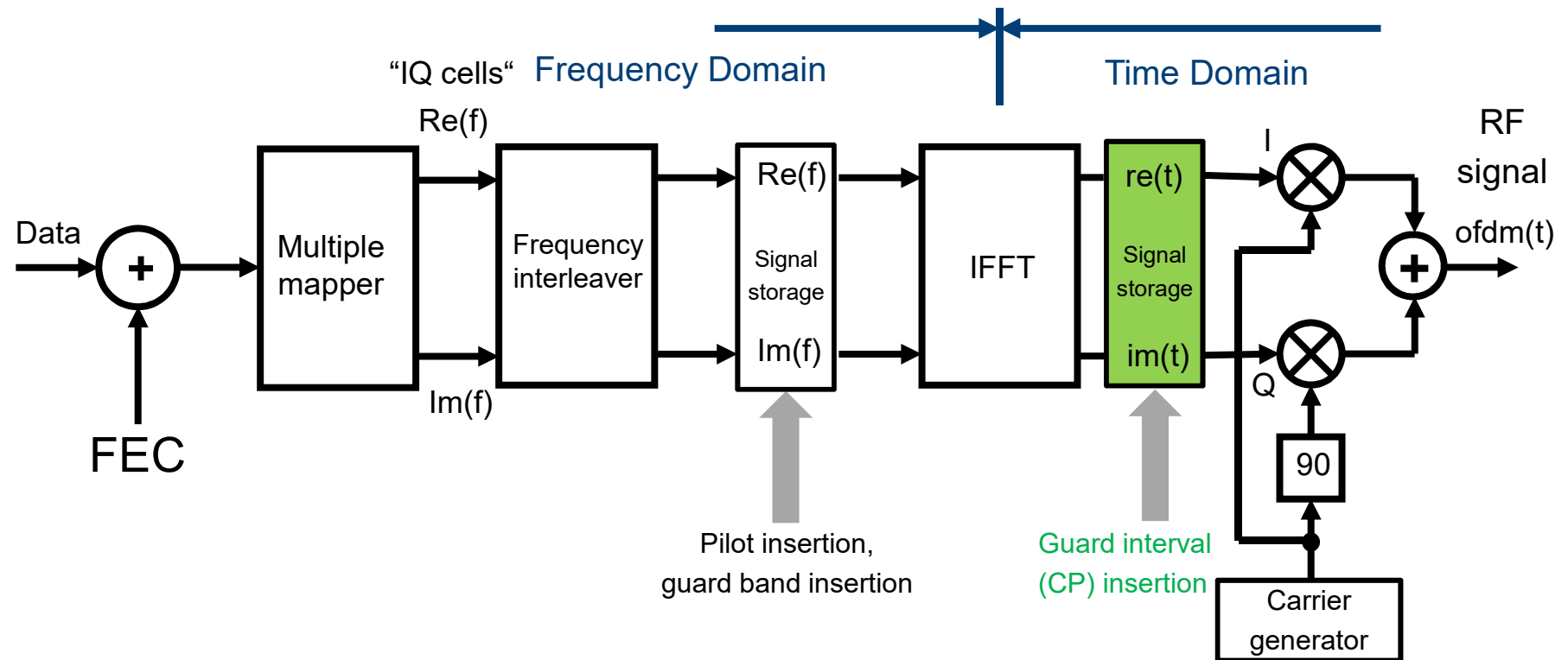
GUARD INTERVAL – CYCLICAL PREFIX

„Schutzintervall“
„Zyklischer Prefix“
„CP“

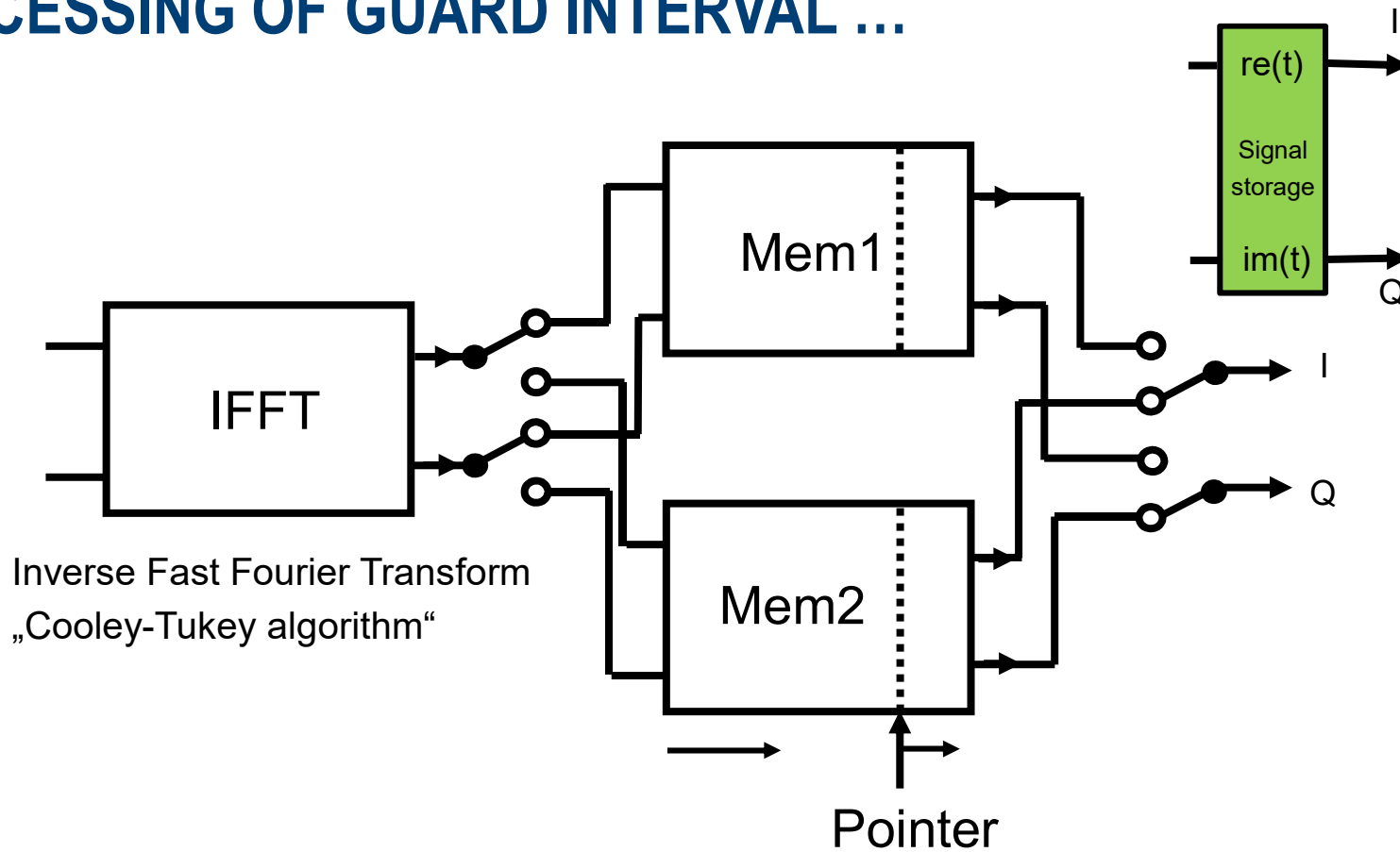


Guard interval = „quasi-break“ =
Mechanism against problems in time domain at multipath reception

PROCESSING OF GUARD INTERVAL



PROCESSING OF GUARD INTERVAL ...

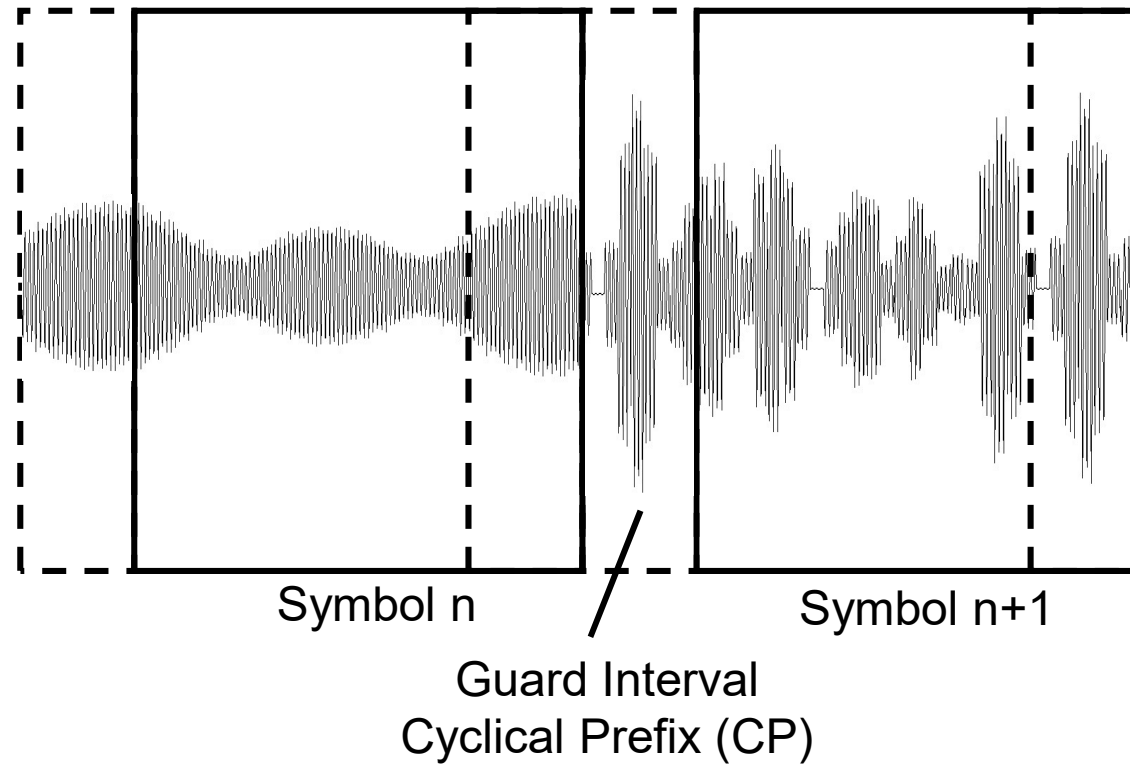


OFDM SYMBOLS WITH GUARD INTERVAL

„Schutzintervall“

„Zyklischer Prefix“

„CP“



OFDM-SPEKTRUM MIT SCHULTERN ...

DOCSIS3.1 Overview

ODFM Principle

Guard Interval – Cyclical Prefix (CP) in OFDM

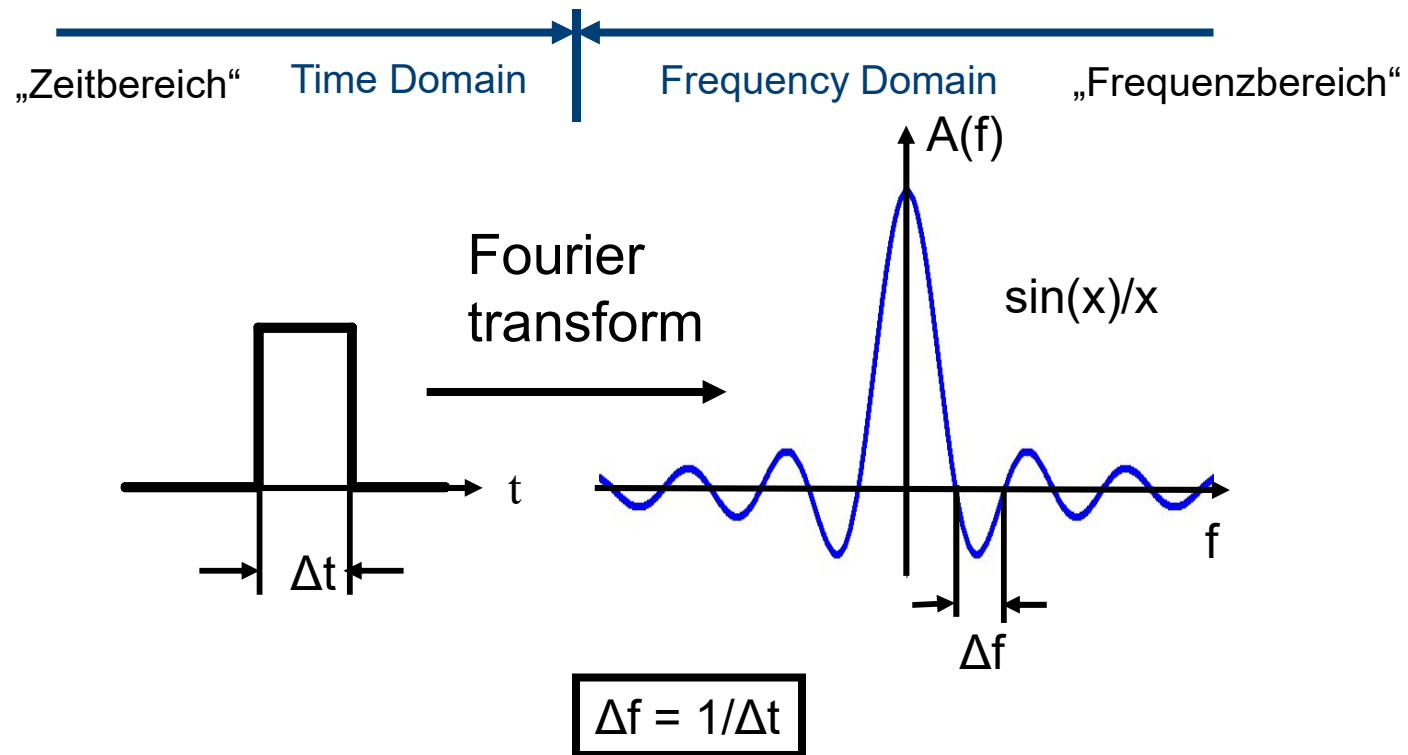
OFDM Spectrum and Shoulders

Principle of „Windowing“

„Windowing“ in DOCSIS3.1

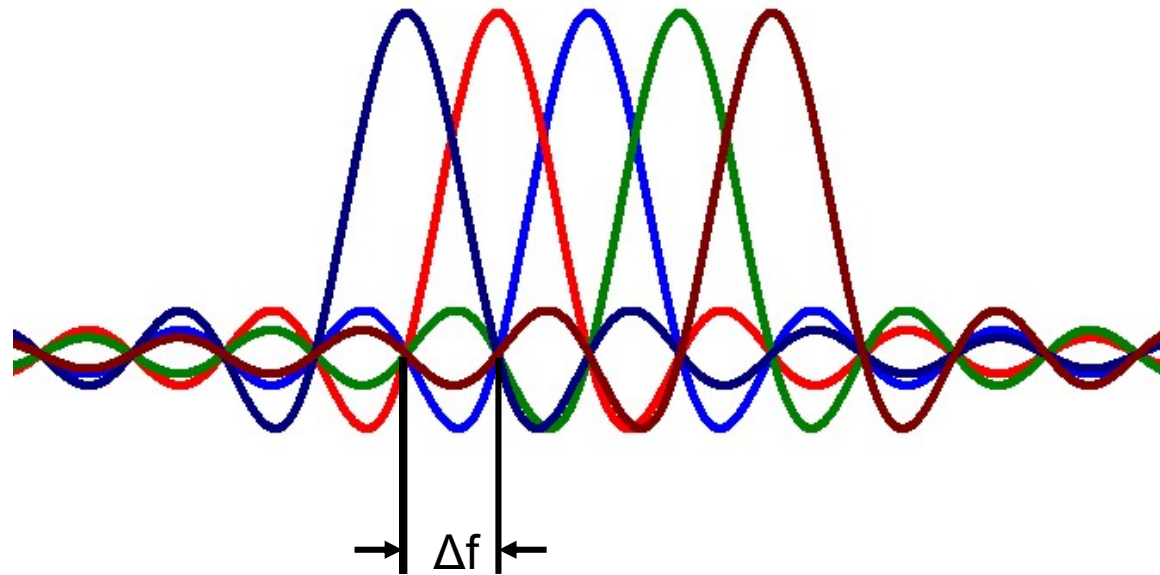
Summary

OFDM – SPECTRUM SHAPE

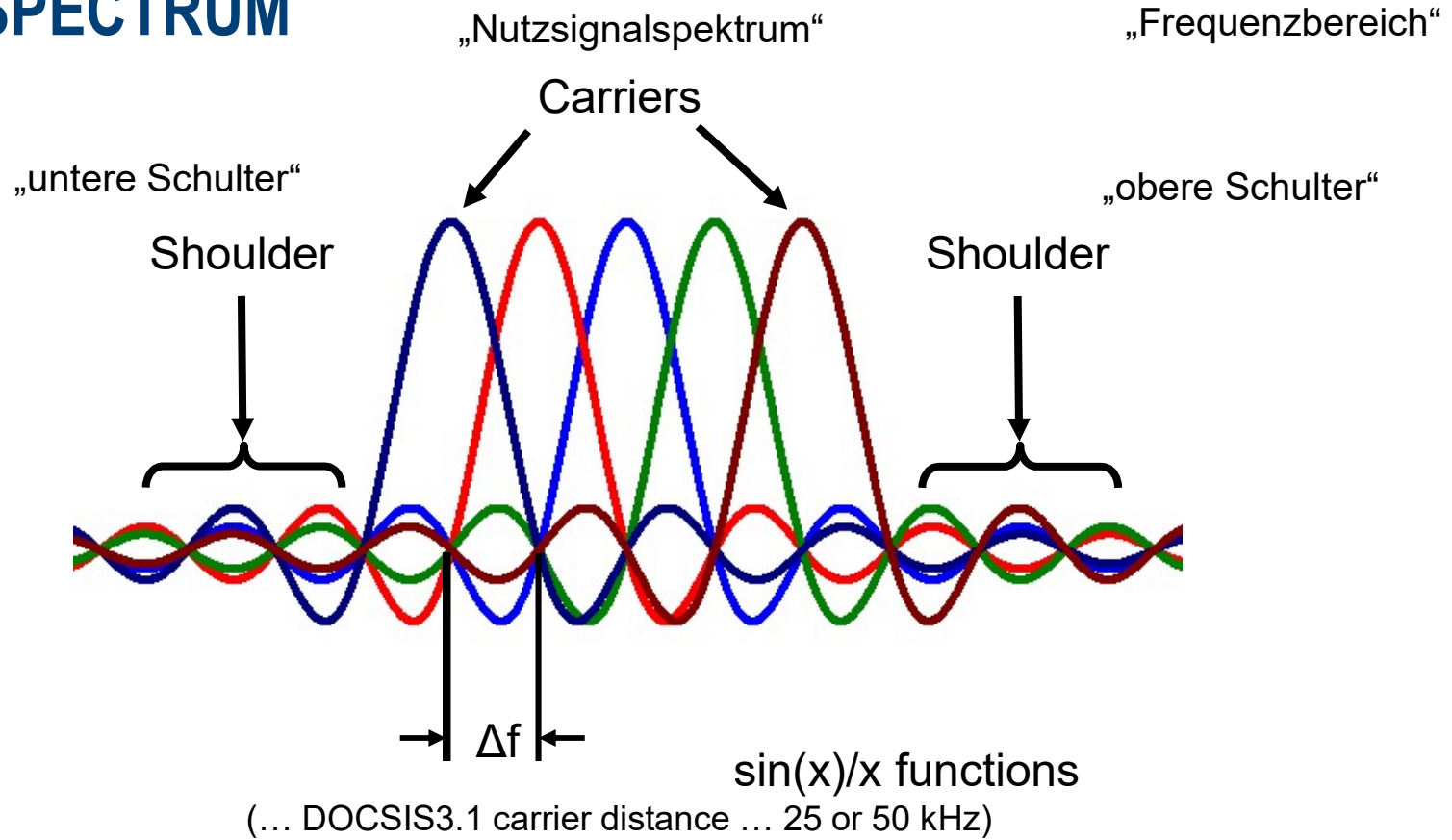


OFDM SPECTRUM

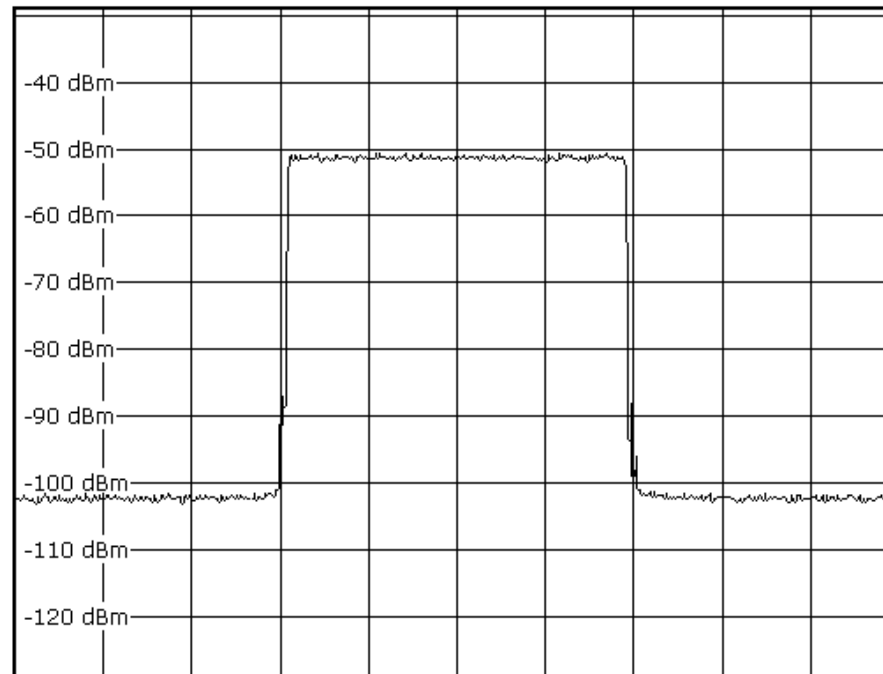
„Frequenzbereich“



OFDM SPECTRUM



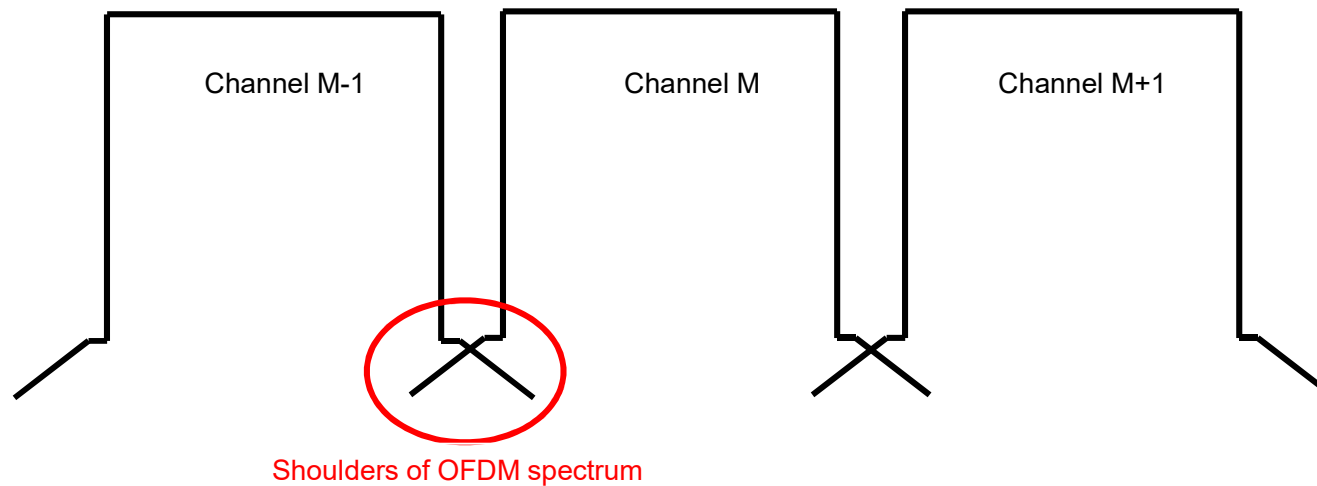
OFDM SPECTRUM



OFDM – EDGE CARRIERS SWITCHED OFF

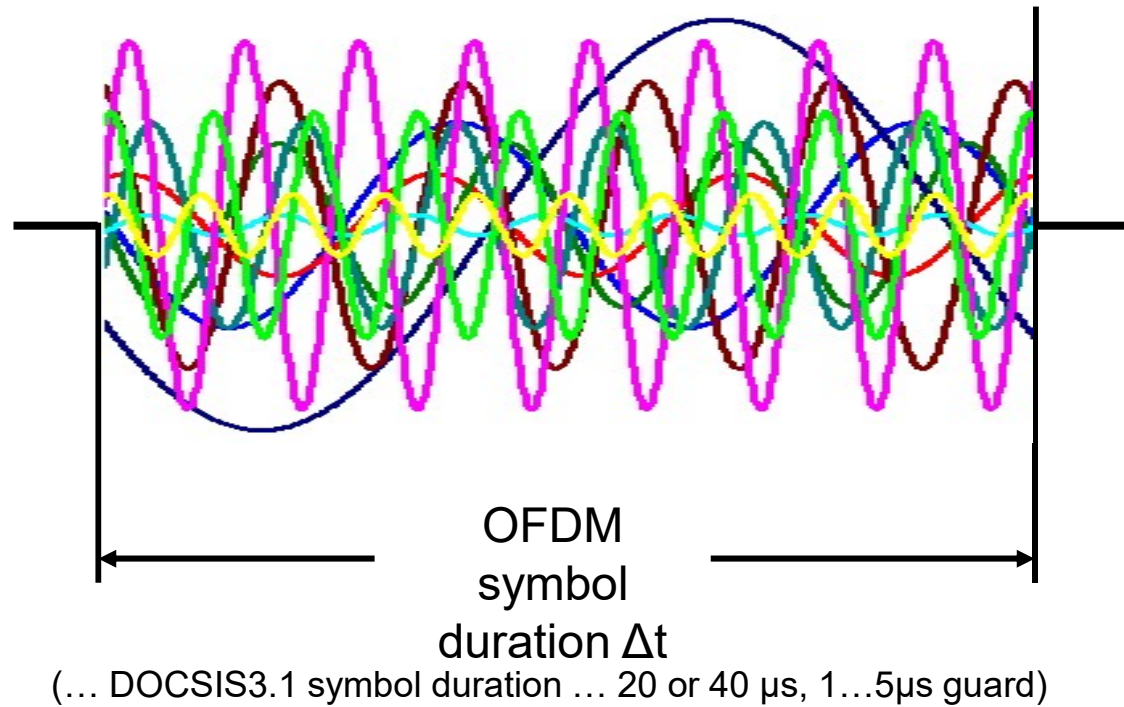
„Guard band“

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

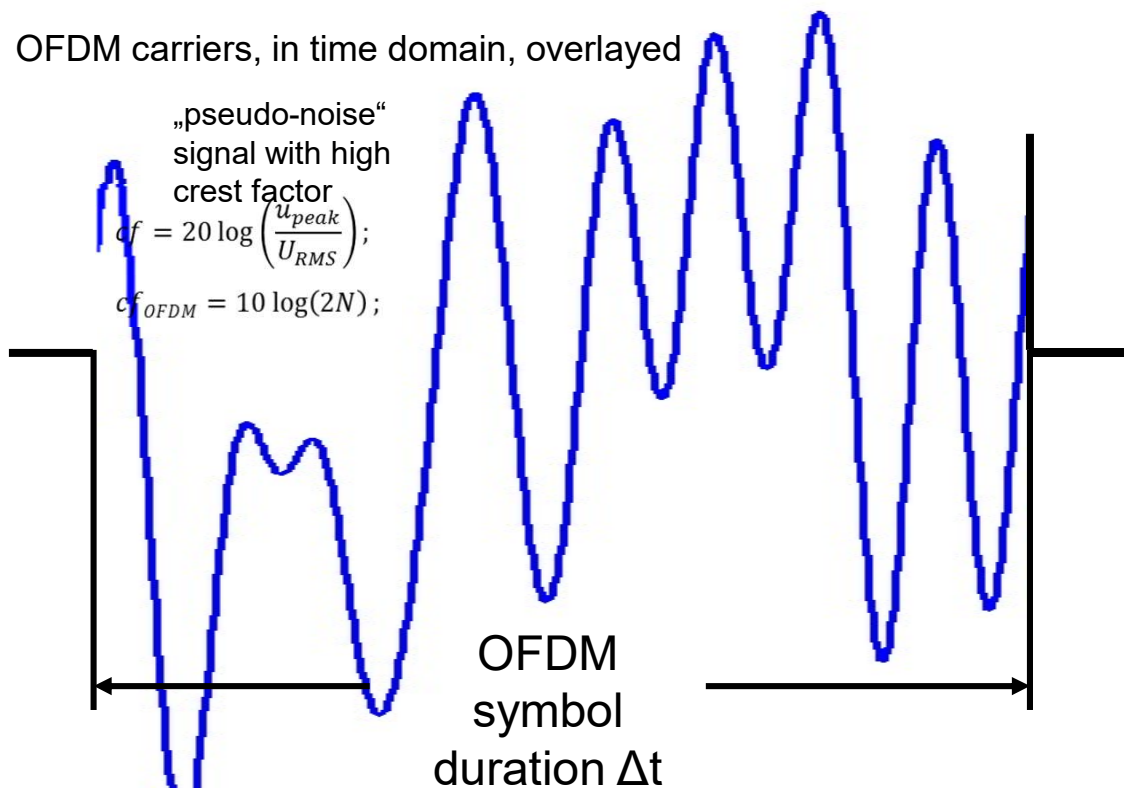


OFDM SYMBOL

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



OFDM SYMBOL



WINDOWING ... FENSTERUNG ... PRINZIP ...

DOCSIS3.1 Overview

OFDM Principle

Guard Interval – Cyclical Prefix (CP) in OFDM

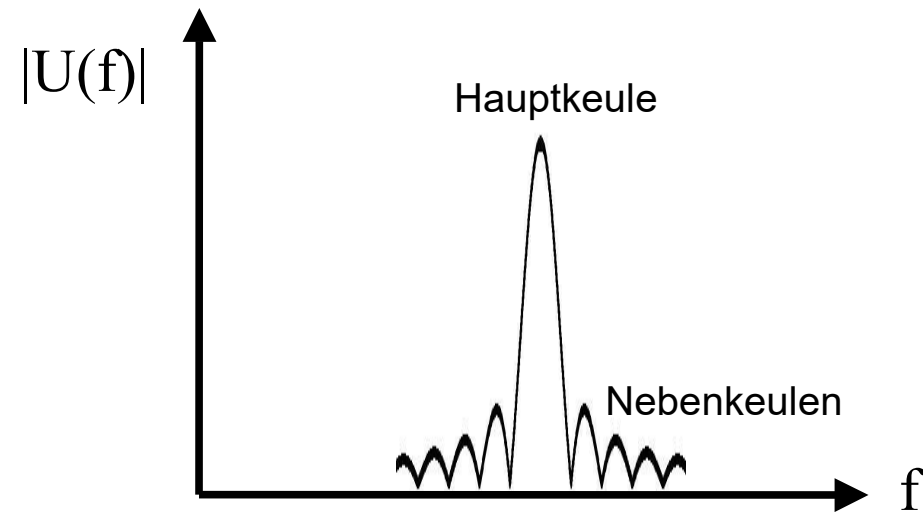
OFDM Spectrum and Shoulders

Principle of „Windowing“

„Windowing“ in DOCSIS3.1

Summary

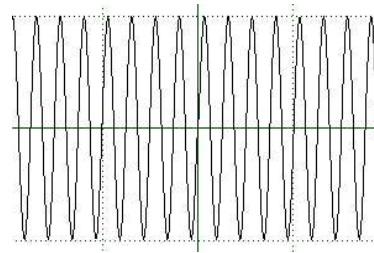
SPECTRUM WITH MAIN LOBE AND SIDE LOBES ...



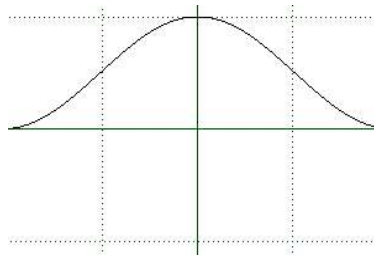
WINDOWING ...

„Fensterung“

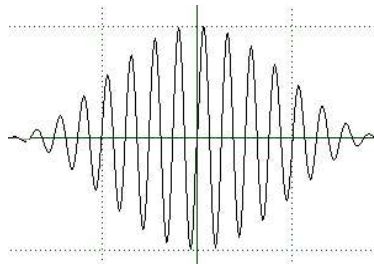
... see also „rolloff“
filtering ...



$u(t)$
Original time domain signal



$k(t)$
Windowing function
(e.g. Hanning)

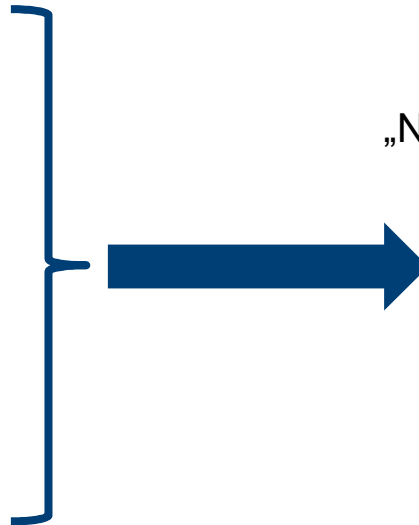


$u'(t) = k(t) * u(t)$;
windowed time
domain signal

TYPICAL WINDOWING FUNCTIONS ...

„Fensterfunktionen“

- Rectangular
- Hanning
- Hamming
- Triangular
- Tukey
- Kaiser-Bessel
- Gauß
- Blackman

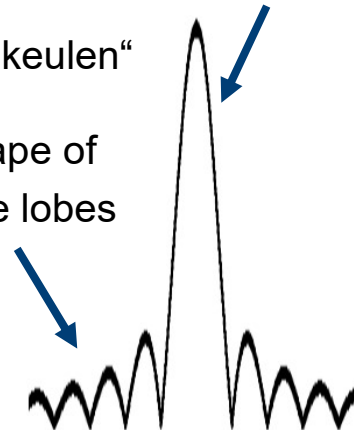


„Hauptkeule“

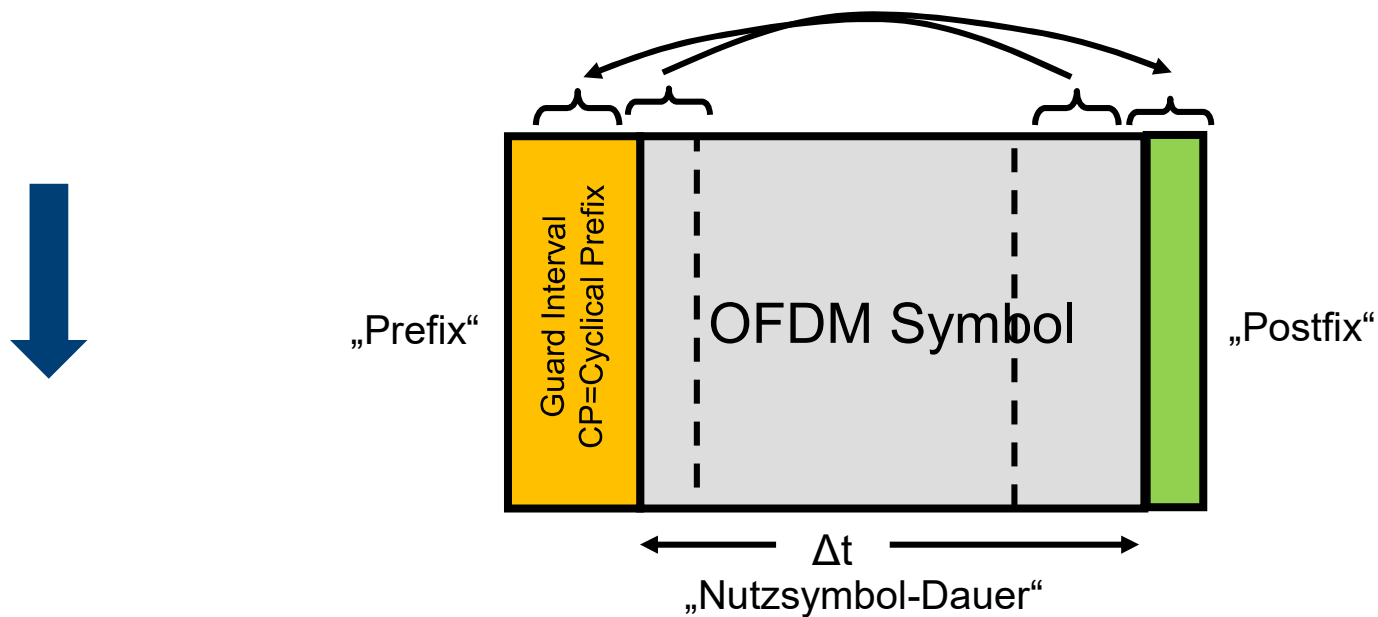
Shape of main lobe

„Nebenkeulen“

Shape of side lobes



GUARD INTERVAL / CP BEFORE AND BEHIND OF THE SYMBOL



(... DOCSIS3.1 symbol duration ... 20 or 40 μ s ... OFDM, 1...5 μ s guard)

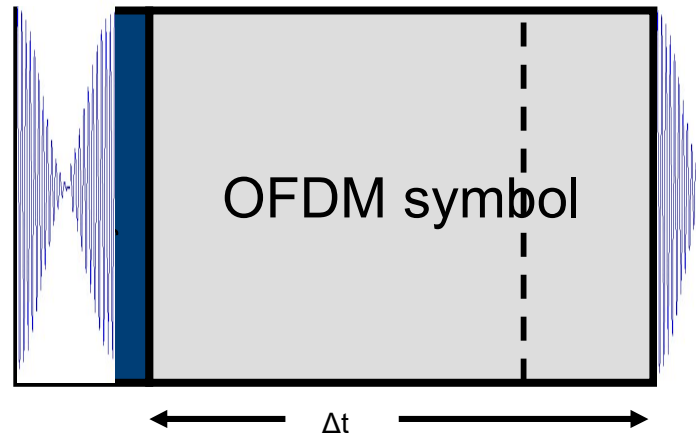
GUARD INTERVAL & WINDOWING

„Fensterung“

DOCSIS 3.1

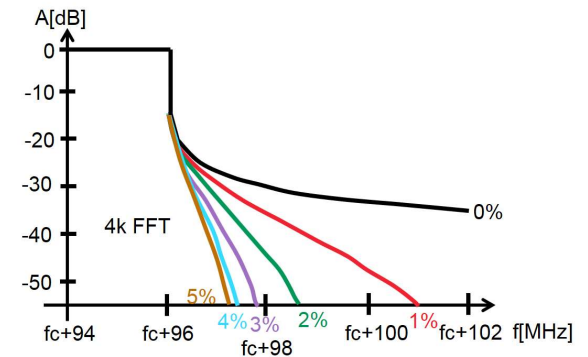


„Fensterung“



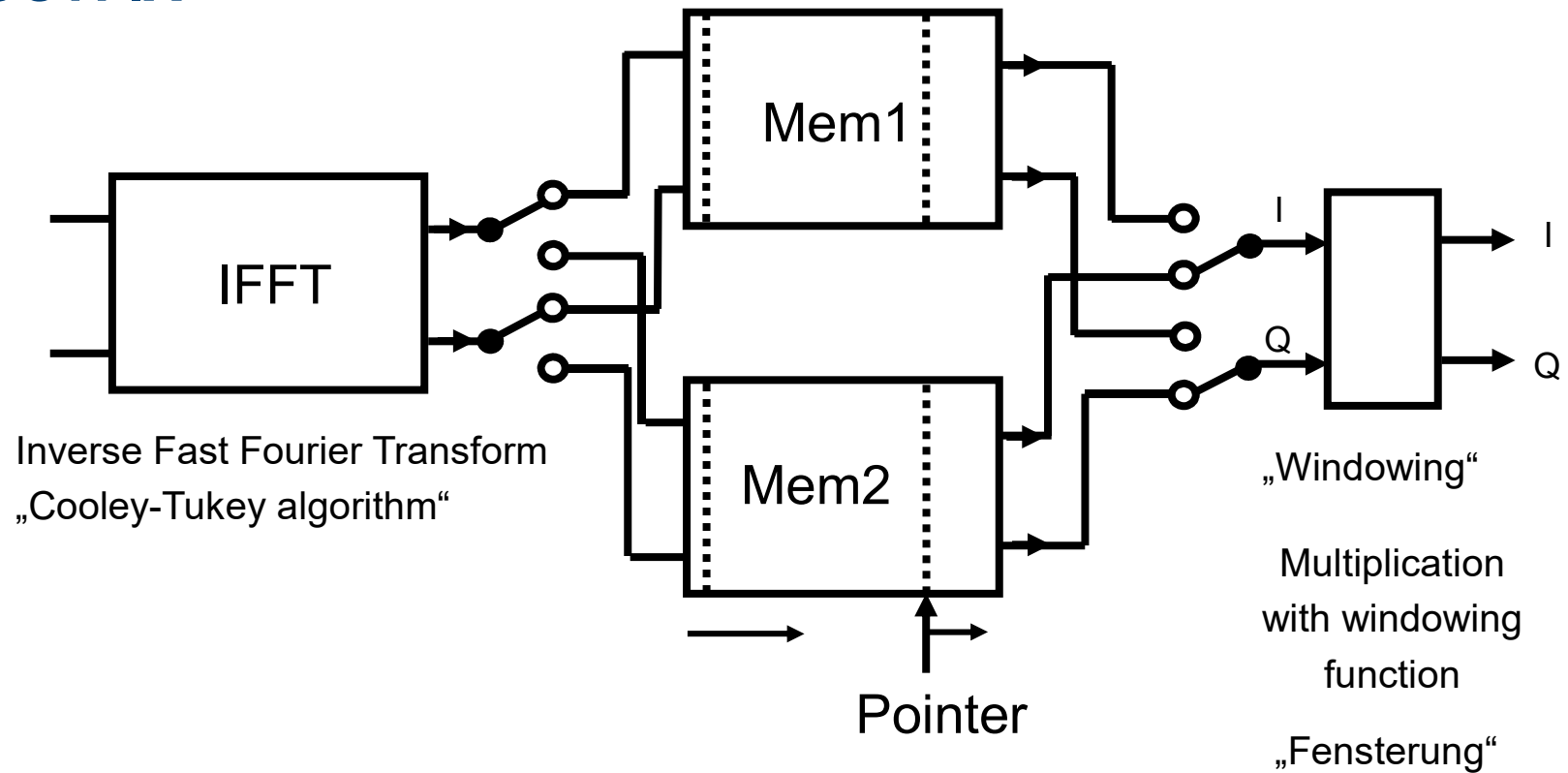
Tukey-raised cosine windowing
in DOCSIS 3.1

Tukey-raised cosine windowing,
embedded in the cyclic prefix



(... DOCSIS3.1 symbol duration ... 20 or 40 μ s ... OFDM, 1...5 μ s guard)

PROCESSING OF CYCLIC PREFIX AND POSTFIX



FENSTERUNG BEI DOCSIS3.1 ...

DOCSIS3.1 Overview

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„Windowing“ in DOCSIS3.1

Summary

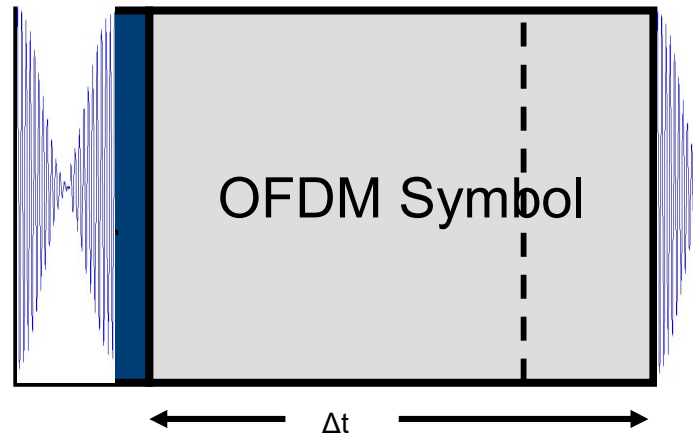
GUARD INTERVAL & WINDOWING

„Fensterung“



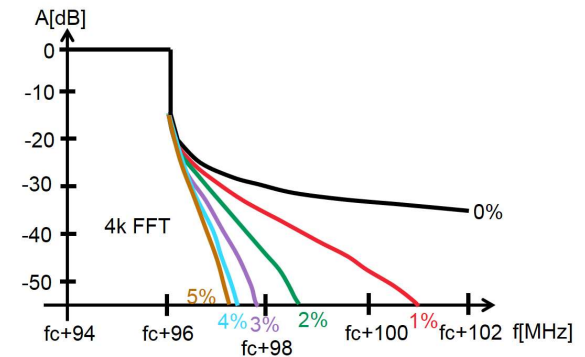
DOCSIS 3.1

„Fensterung“



Tukey-rised cosine windowing
in DOCSIS 3.1

Tukey-raised cosine windowing,
embedded in the cyclic prefix



(... DOCSIS3.1 symbol duration ... 20 or 40 μ s ... OFDM, 1...5 μ s guard)

CYCLIC PREFIX AND WINDOWING ROLL-OFF PERIODE



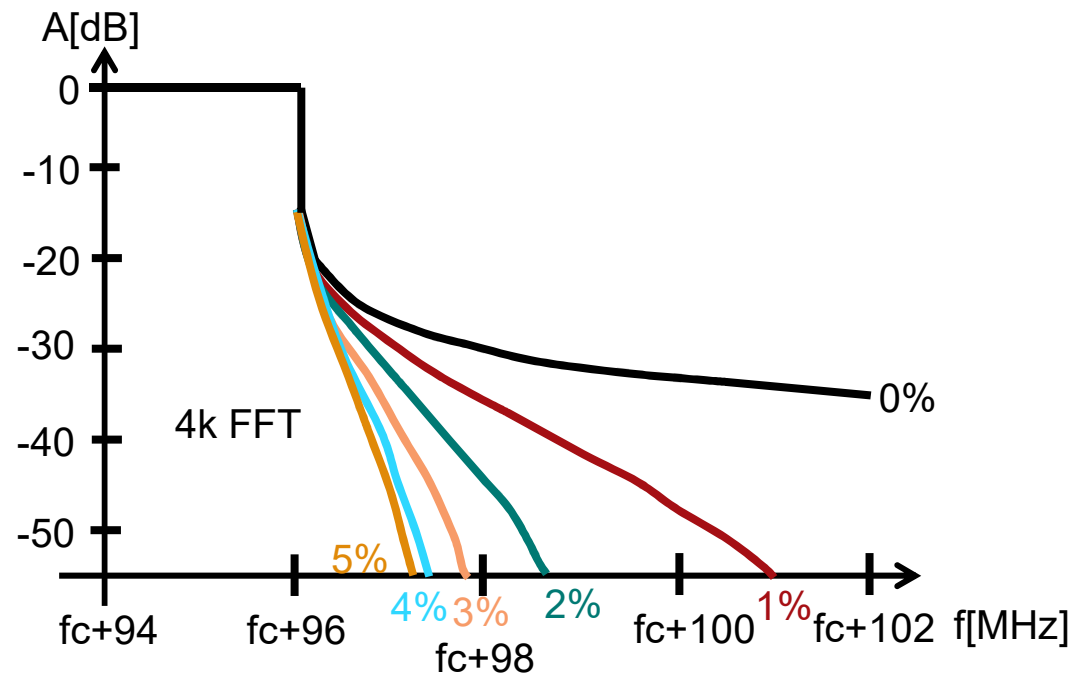
Cyclic prefix (μs)	Cyclic prefix samples
0.9375	$192 \cdot T_s$
1.25	$256 \cdot T_s$
2.5	$512 \cdot T_s$
3.75	$768 \cdot T_s$
5.0	$1024 \cdot T_s$

Roll-off periode (μs)	Roll-off periode samples
0	$0 \cdot T_s$
0.3125	$64 \cdot T_s$
0.625	$128 \cdot T_s$
0.9375	$192 \cdot T_s$
1.25	$256 \cdot T_s$

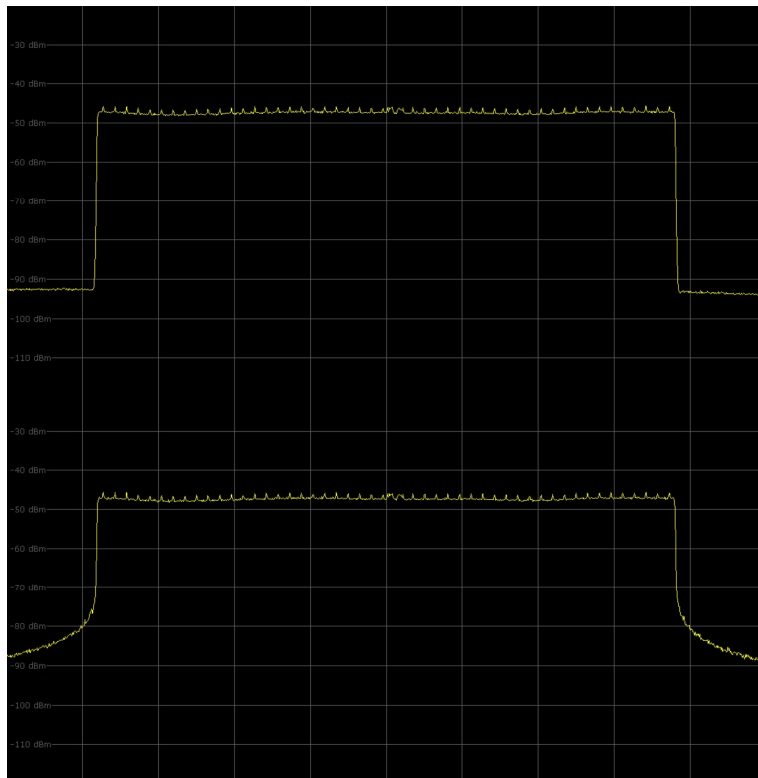
„Fensterung“

WINDOWING AND SPECTRUM SHAPE

„Fensterung“



WINDOWING FUNCTION AND SHOULDERS ...



„Fensterung“

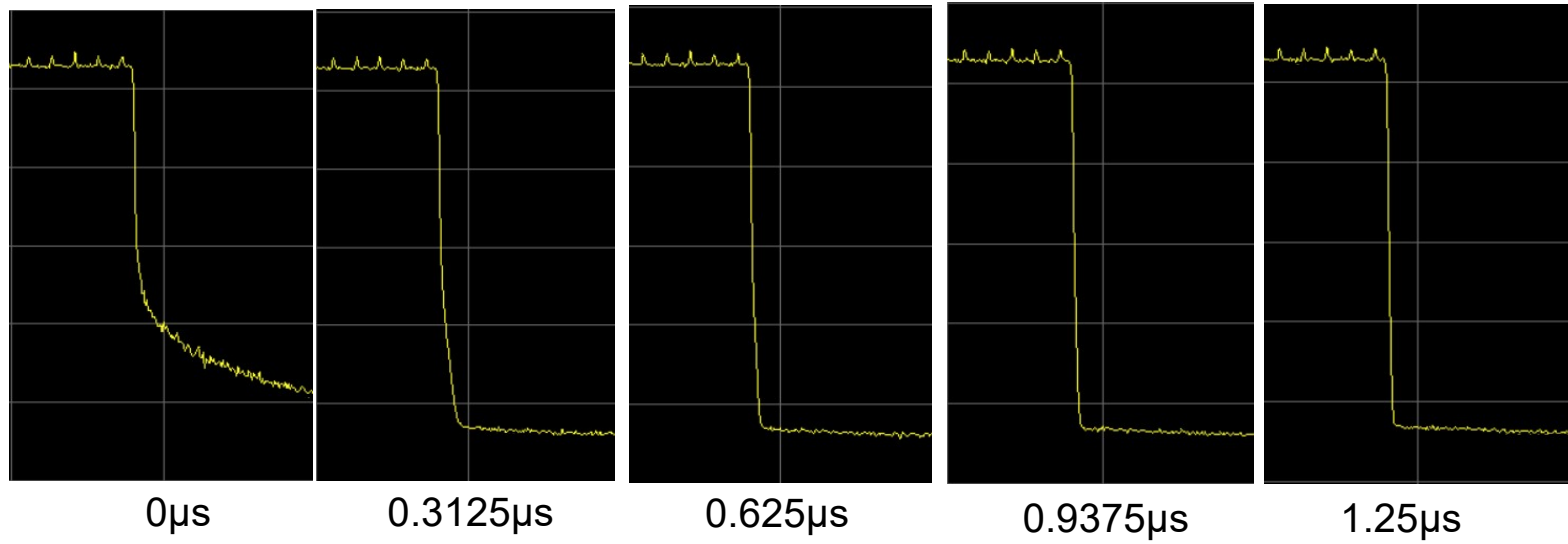
Windowing 1.25µs

Channel	Modulator State	Carrier Definition	Power (dBuV)	FFT Size	Windowing (us)	Cyclic Prefix (us)	Continuous Pilot Parameter	Interleaver Depth	Exclusion Band	
									Start Subcarrier	Width
1	ON	204MHz (CENTER) Subcarriers:3800	90.0	4K	0	5.0	#8	2	0	0
<input type="checkbox"/>	PLC Location	PLC Source	PLC Source Port	NCP Order	Profile ID	Profile Constellation	Profile Port	Profile Source	Profile FEC Code Shortening	Advanced Options
	2104	TEST	1001	QPSK	A B C D	QAM4096 QAM1024 QAM1024 QAM256	NONE 10200 NONE 10201 NONE 10202 NONE 10203	0 b/s 0 b/s 0 b/s 0 b/s	FILL FILL FILL FILL	1779 1779 1779 1779

Windowing 0µs

WINDOWING FUNCTION AND SHOULDER

„Fensterung“



ZUSAMMENFASSUNG ...

DOCSIS3.1 Overview

OFDM Principle

Guard Interval – Cyclical Prefix (CP) in OFDM

OFDM Spectrum and Shoulders

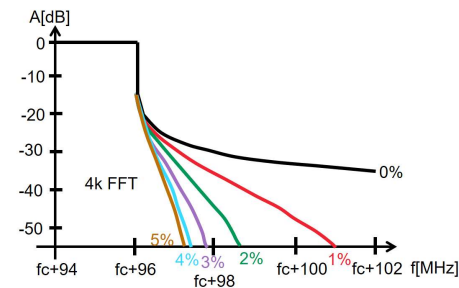
Principle of „Windowing“

„Windowing“ in DOCSIS3.1

Summary

SUMMARY

- DOCSIS3.1 is wideband OFDM based
- OFDM spectrum = rectangular shape with unwanted „shoulders“
- OFDM signals are using a „quasi-break“ between long symbols
- „quasi-break“ = „guard interval“ or „cyclical prefix“ („CP“)
- Standard OFDM uses a rectangular time windowing function
- DOCSIS3.1 uses a cyclical prefix and a cyclical postfix
- DOCSIS3.1 allows „smooth“ windowing at the beginning and the end of a symbol
- „Windowing“ attenuates the unwanted shoulders



CLGD ... SIMULATING MULTICHANNEL CATV LOAD

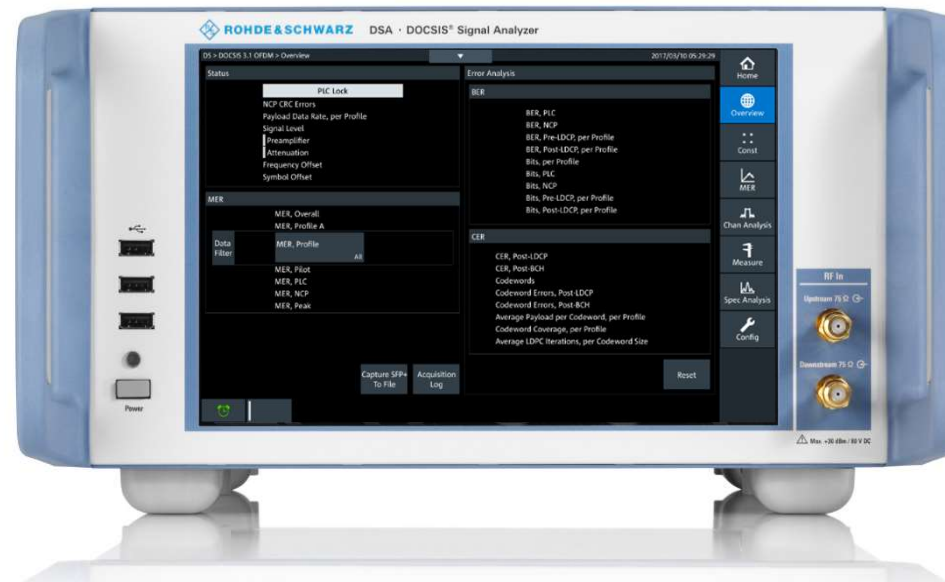
ATV
DVB-C
DOCSIS



SFD ... SINGLE CHANNEL DOCSIS 3.0/3.1/ARB GENERATOR



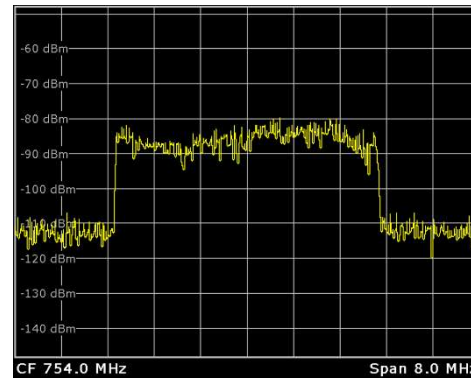
R&S DSA – DOCSIS SIGNAL ANALYZER

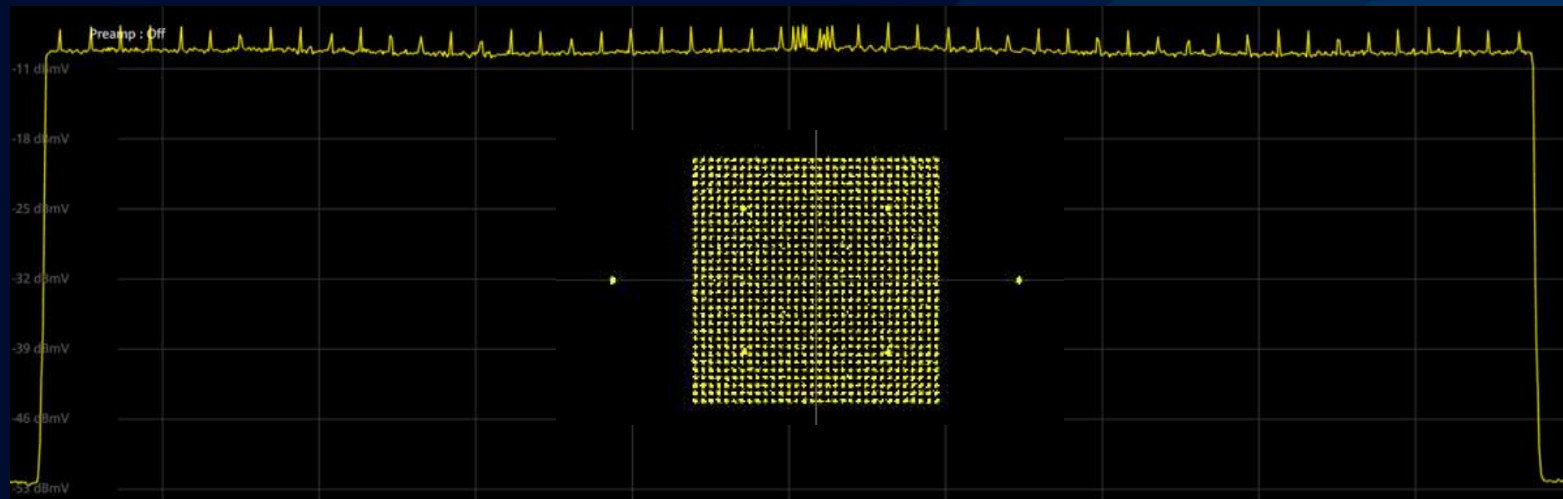


DVB-C
J83A, B, C
DOCSIS
EuroDOCSIS
DOCSIS3.1

“5G TODAY“ ... 5G/LTE BASED BROADCAST ...

„neues Thema ...“





Walter.Fischer@rohde-schwarz.com