Project	**IEEE 802.20 Working Group on Mobile Broadband Wireless Access** <**http://grouper.ieee.org/groups/802/20/**>	
Title	**Channel Models and Performance Implications for OFDM-based MBWA**	
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Re:	IEEE 802.20 Session#1 Call for Contributions	
Abstract	To present channel models and their implications for OFDM-based MBWA systems	
Purpose	For informational purposes only	
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Channel Models and Performance Implications for OFDM-based MBWA

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Outline

- *Proposed channel model ensemble:* UTRA (UMTS Terrestrial Radio Access).
- Overview of UTRA test environments and channel models.
- Effects of channel characteristics on OFDM PHY layer parameters.
- Typical range of OFDM PHY parameters that arise from adopting UTRA models.

Model Choice: Overview

- UTRA *Test Configurations* [1].
- Subset of full ITU-R M.1034 channel set.
- Defines three basic test environments, with two delay profile variations (“A” and “B”) on each:
  - *Indoor Office*
  - *Outdoor-to-Indoor and Pedestrian*
  - *Vehicular*
- Also includes non-specific “mixed” environment, combinations of the basic 3 types.

Channel model provisions

- Mean loss model and parameters (deterministic):
  - $L = F(R,\ f, \ldots)$
- Shadow fading model and parameters (statistical):
  - *Distr. model:* log-normal *Parameter:* $s_{lognorm}$
  - *Pos'l corr. model:* $R(\Delta x) = e^{\ln 2|\Delta x|/d_{cor}}$ *Parameter:* d_{cor}
- Delay spread model
  - Ray specifications (delay, loss)
  - Doppler spectrum model
  - *No numerical values specified for mobility rates*.

Indoor: General characteristics

- Base stations and users located indoors
- Small cells
- Low transmit power
- Doppler set by walking speeds

Indoor: Path loss

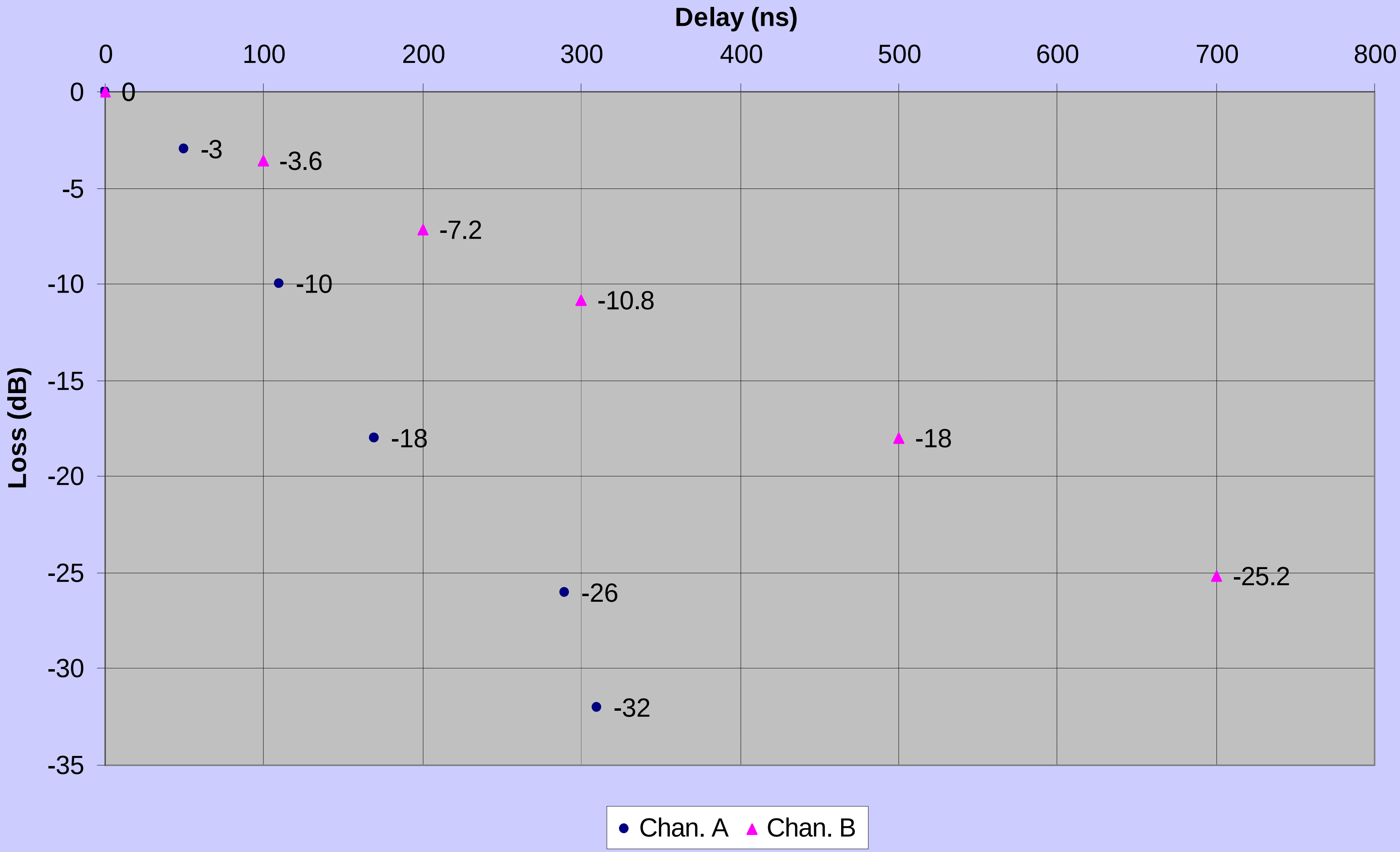
$$L = 37 + 30\log_{10} R + 18.3n^{((n+2)/(n+1)-0.46)}$$

L	Path loss (dB)
R	Tx-Rx distance (m)
n	Number of floors in path

- Shadowing: $\sigma_{lognorm}$ = 12 dB

Indoor: Delay profile

(Doppler spectrum: *flat*)



Pedestrian: General characteristics

- BSs with low antenna heights located outdoors; users located on streets or inside buildings/residences.
- Small cells
- Low transmit power
- Doppler set by walking speeds, with occasional higher rates due to vehicular reflections.

Pedestrian: Path loss

$$L = 40\log_{10} R + 30\log_{10} f + 49$$

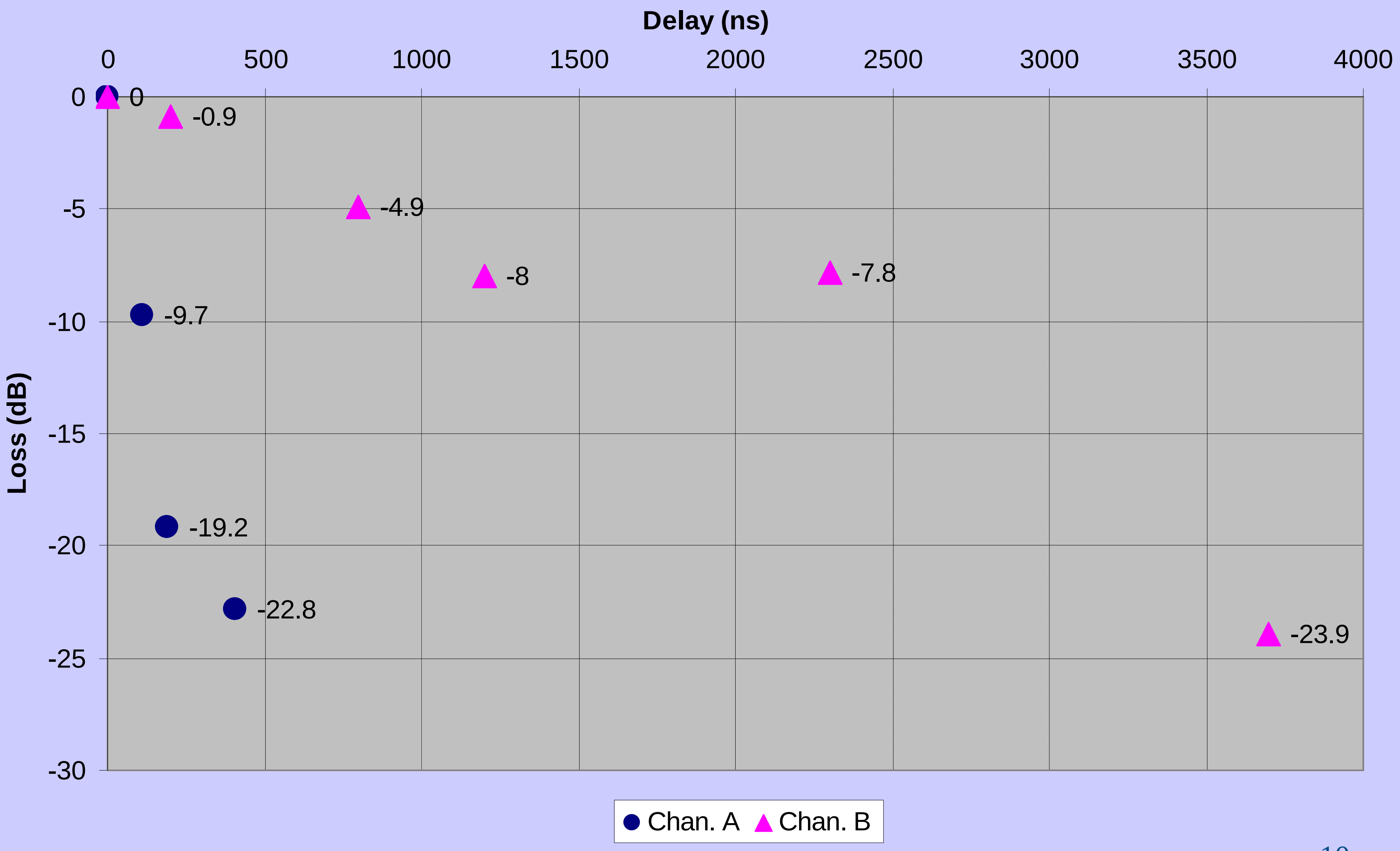
L	Path loss (dB)
R	Tx-Rx distance (m)
f	Carrier frequency (MHz)

- Shadowing:
  $\sigma_{lognorm}$ = 12 dB indoor
  $\sigma_{lognorm}$ = 10 dB outdoor

- Building penetration loss:
  μ = 12 dB, σ = 8 dB

Pedestrian: Delay profile

(Doppler spectrum: *classic (Jakes)*)



Vehicular: General characteristics

- Base stations with roof antennas; users are in vehicles, walking, or stationary.
- “Larger” cells
- “Higher” transmit power
- Maximum Doppler rate set by vehicular speeds; lower values for walking and stationary users.

Vehicular: Path loss

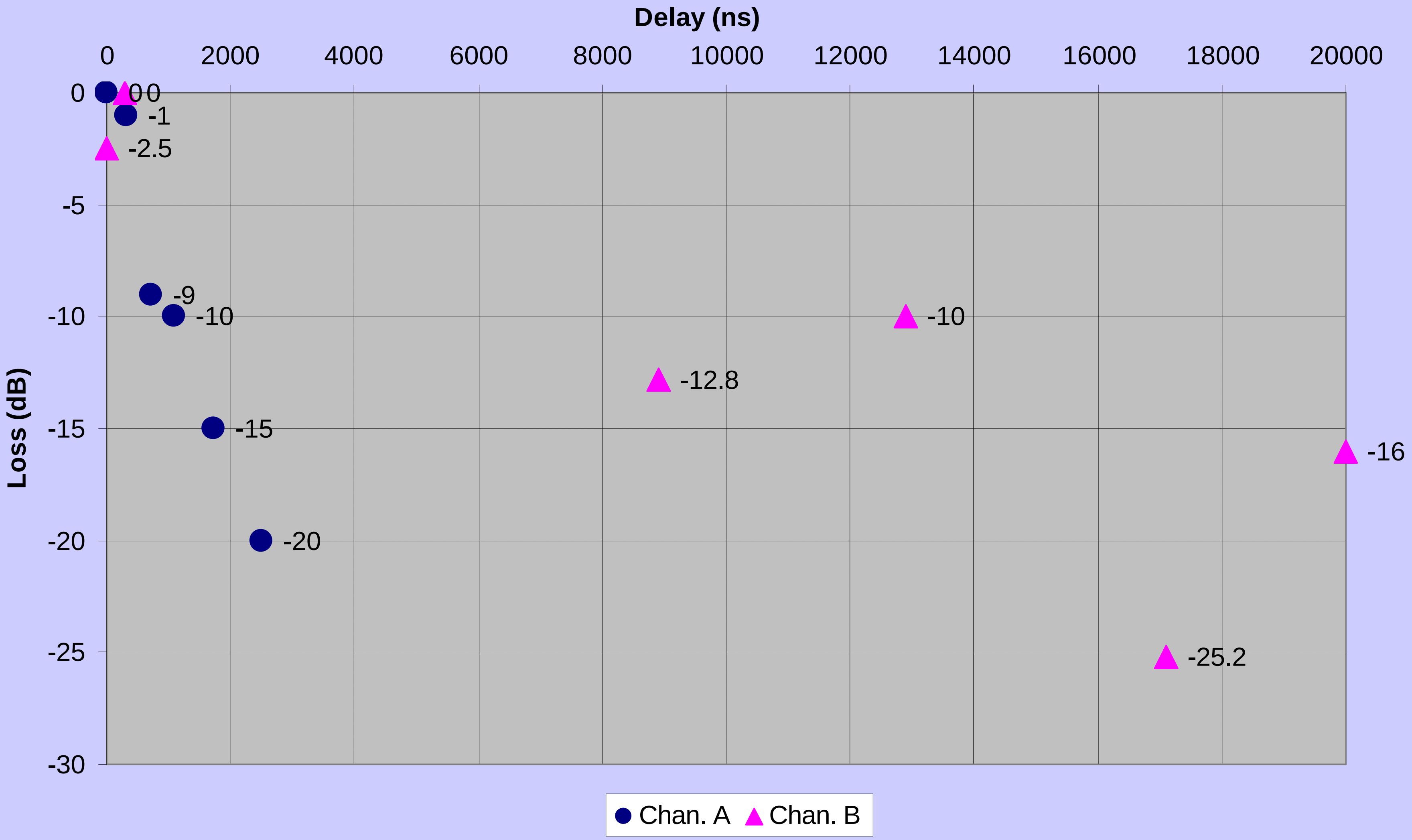
$$L = 40(1 - 4 \cdot 10^{-3} \Delta h_b) \log_{10} R - 18 \log_{10}(\Delta h_b) + 21 \log_{10} f + 80$$

L	Path loss (dB)
R	Tx-Rx distance (km)
Δh_b	BS ant. height (m above avg. rooftop level)

- Valid for $0 < \Delta h_b < 50$ m
- Shadowing: $\sigma_{lognorm} = 10$ dB

Vehicular: Delay profile

(Doppler spectrum: *classic (Jakes)*)

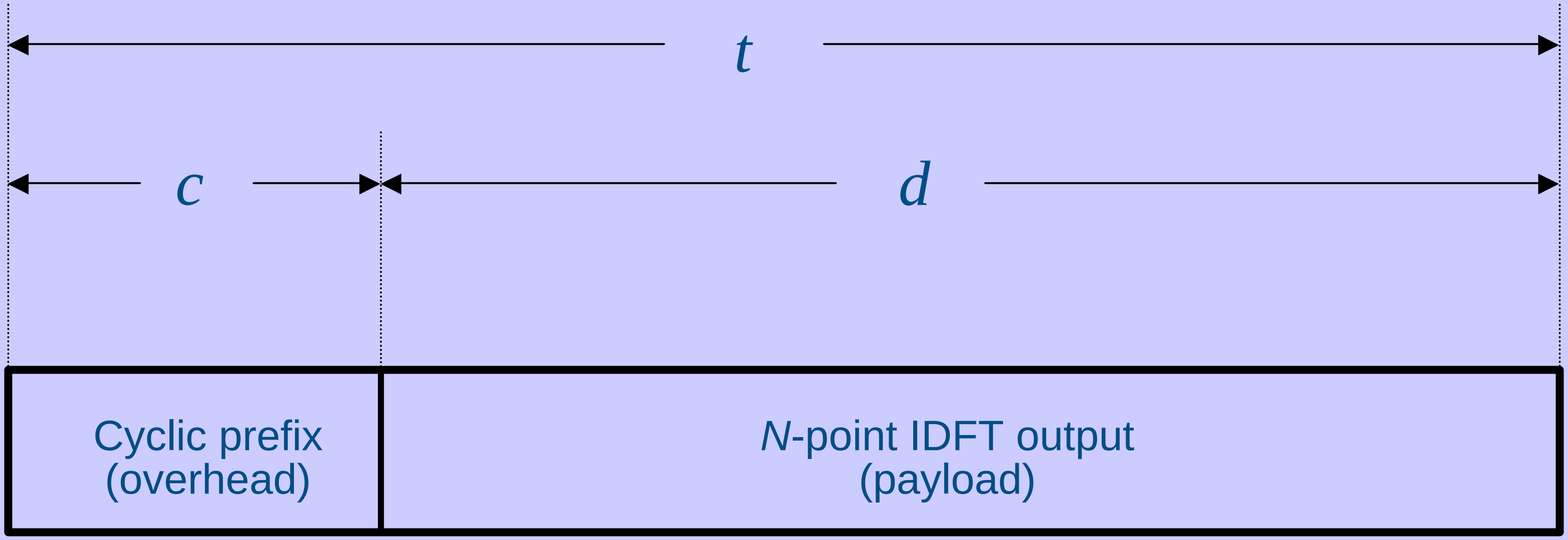


Proposed mobility rates

- Indoor: 3 km/h
- Pedestrian: 3, 30 km/h
- Vehicular: 0, 120, 250 km/h

Channel Characteristics -> OFDM PHY Parameters

Time-domain view



t

c

d

Cyclic prefix
(overhead)

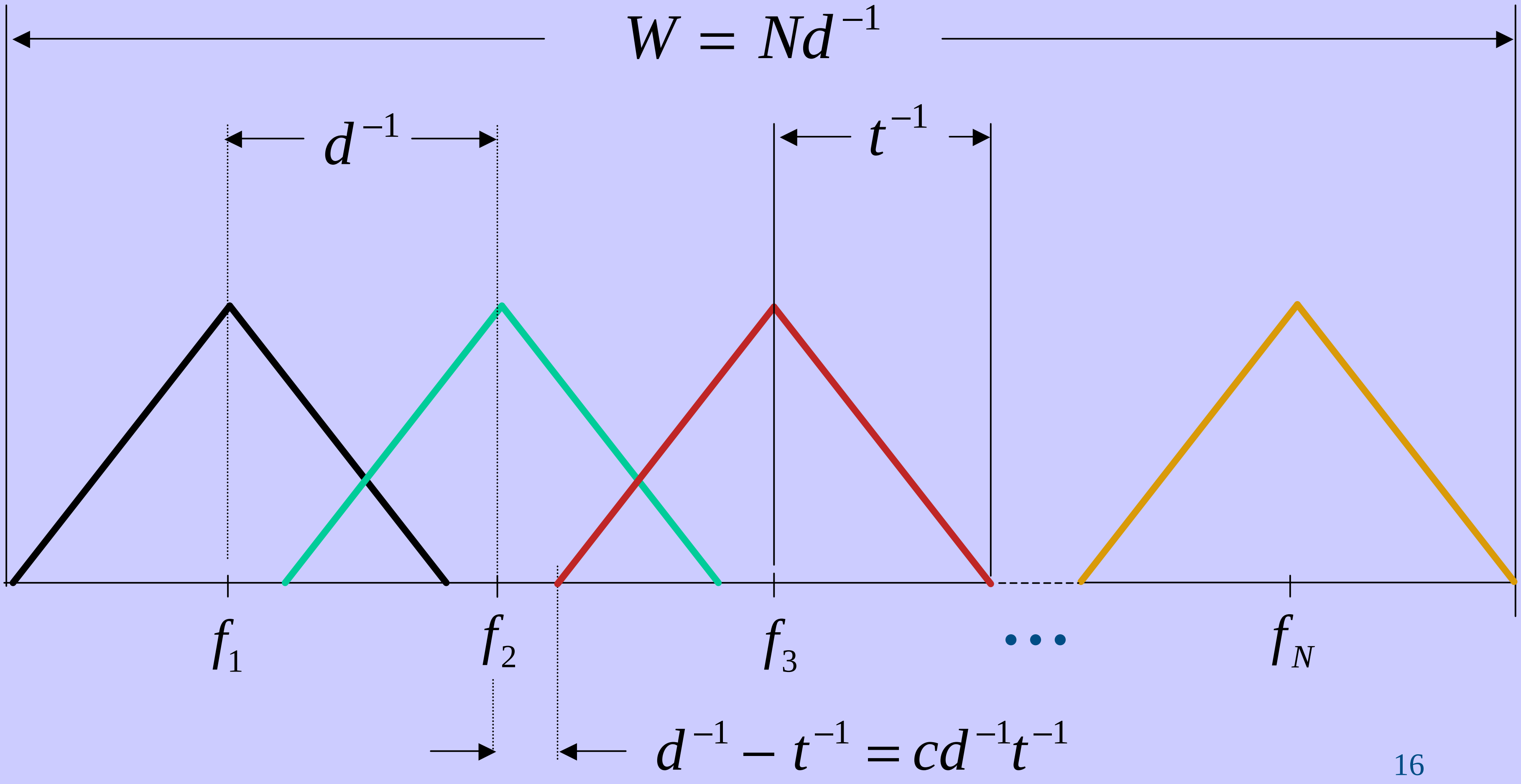
N-point IDFT output
(payload)

t	OFDM symbol duration (µs)
c	Cyclic prefix (“CP”) length (µs)
d	IDFT duration
N	IDFT/DFT order

Channel Characteristics -> OFDM PHY Parameters

Frequency domain view (schematic)

(Triangles represent main lobes of subcarrier freq-domain sinc functions)



$$d^{-1} - t^{-1} = cd^{-1}t^{-1}$$

Channel Characteristics $\Longrightarrow$ OFDM PHY Parameters

Cyclic prefix constraint imposed by delay spread:

$$c: \quad \int_0^c |h(t)|^2 dt \; > \; (1-a_c)\int_0^\infty |h(t)|^2 dt$$

$h(t)$ Channel impulse response

a_c ISI distortion threshold $0 < a_c < 1$

Typical range (SIR dependent): [2] $0.02 \le a_c \le 0.25$

Channel Characteristics $\Longrightarrow$ OFDM PHY Parameters

IDFT duration constraint imposed by Doppler rate:

$$d: \qquad d < a_d t_{chan}$$

t_{chan} Channel coherence time

a_d Quasi-stationarity threshold $0 < a_d < 1$

Typical range (SIR dependent): [3] $a_d \leq 10\%$

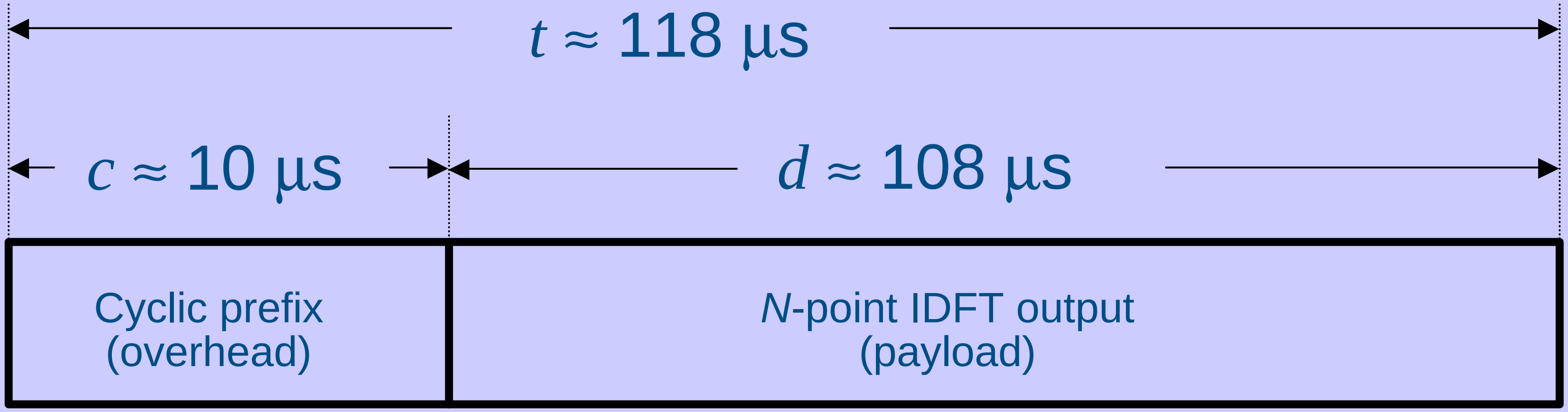
UTRA Channel $\Longrightarrow$ OFDM PHY Parameters

Hypothetical MBWA system: Channel bandwidth W = 1.25 MHz, operating frequency 2 GHz, supporting mobility rate of 250 km/h.

Desired per-subcarrier SINR ≈ 7 - 10 dB.

- Set $a_c = 0.1$ [10 dB SIR]. To capture $(1 - a_c) = 90\%$ of impulse energy of worst-case delay spread UTRA channel (Vehicular B) requires $c \approx 10\ \mu\mathrm{s}$
- Set $a_d = 5\%$. Mobility rate of 250 kph at 2 GHz gives $D_{\mathrm{max}} \approx 463$ Hz, $t_{chan} \approx 2160\ \mu\mathrm{s}$, $d = a_d t_{chan} \approx 108\ \mu\mathrm{s}$.

UTRA Channel $\Longrightarrow$ OFDM PHY Parameters



$t \approx 118$ μs

$c \approx 10$ μs

$d \approx 108$ μs

Cyclic prefix
(overhead)

N-point IDFT output
(payload)

Channel-imposed constraints thus give

tone spacing: $d^{-1} \approx (108\ \mu s)^{-1} \approx 9.2$ kHz

number of tones: $N = Wd \approx 135$

References

[1] ETSI TR 101 112, UMTS 30.03, V3.1.0 Annex B, sections 1.2.3, 1.3, 1.4.

[2] W. Henkel, et. Al., *The Cyclic Prefix of OFDM/DMT - An Analysis*, IEEE 2002 Int'l Zurich Seminar on Broadband Communication, Feb. 19-21, ETH Zurich, Switzerland.

[3] F. Tufvesson, T. Maseng, *Optimization of Sub-channel Bandwidth for Mobile OFDM Systems*, MMT '97, Melbourne, Austrialia, Dec. 1997.