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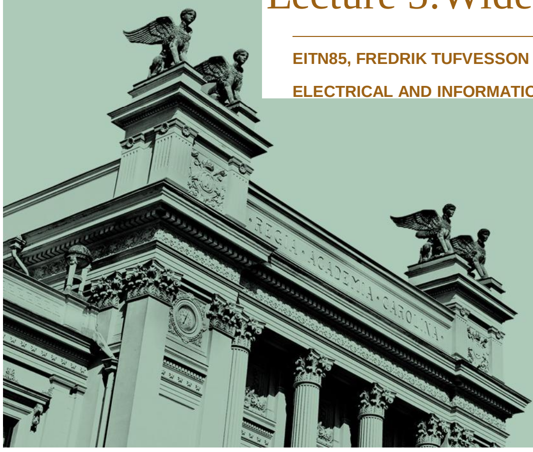
Wireless Communication Channels
Lecture 5:Wideband characterization

EITN85, FREDRIK TUFVESSON

ELECTRICAL AND INFORMATION TECHNOLOGY



Contents

- Channel measures
  - Transfer function, impulse response, delay cross spectral density, scattering funtion, PDP, Doppler spectrum
  - Transfer function, time frequency correlation function, time correlation function, frequency correlation function
- Measurement examples
  - Peer-to-peer
  - Ultra wideband
  - Vehicle-to-vehicle

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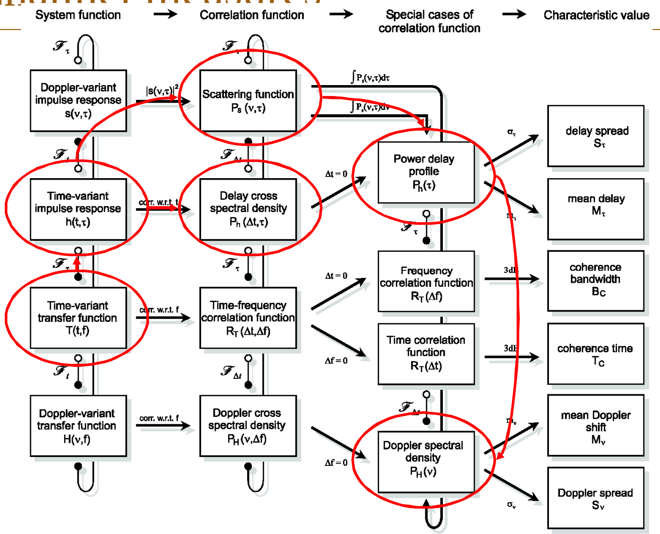
Channel measures



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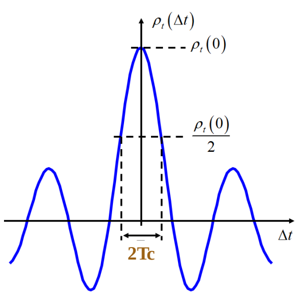
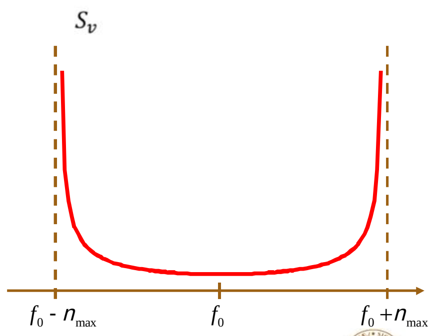
Doppler spectrum vs. the time correlation function

Doppler spectrum and the time correlation of the signal are related to each other by Fourier transformation



Fourier transforms



time correlation function

Doppler power spectrum

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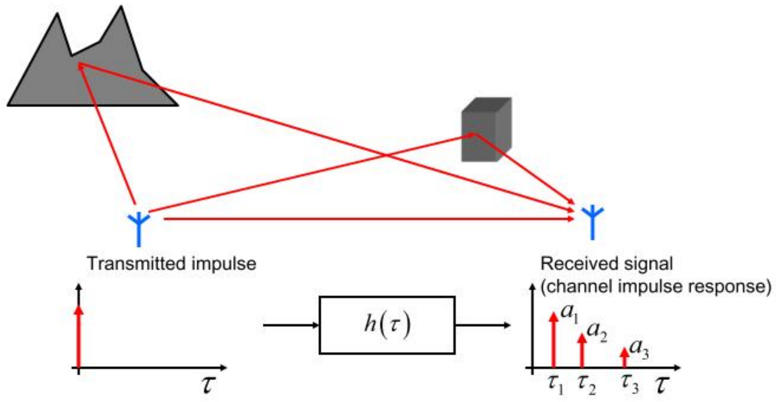
Delay dispersion (a simple case)



$$h(\tau) = a_1\delta(\tau-\tau_1) + a_2\delta(\tau-\tau_2) + a_3\delta(\tau-\tau_3)$$

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The WSSUS model
Assumptions

A very common wide-band channel model is the WSSUS-model.

Recalling that the channel is composed of a number of different contributions (incoming waves), the following is assumed:

The channel is Wide-Sense Stationary (WSS), meaning that the time correlation of the channel is invariant over time. (Contributions with different Doppler frequency are uncorrelated.)

The channel is built up by Uncorrelated Scatterers (US), meaning that the frequency correlation of the channels is invariant over frequency. (Contributions with different delays are uncorrelated.)

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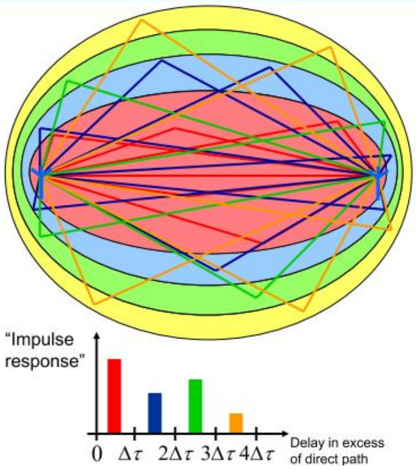
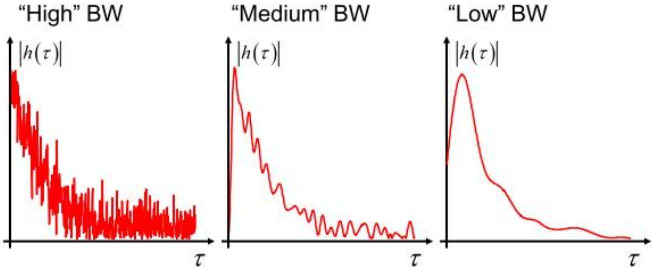
Delay dispersion (many paths)



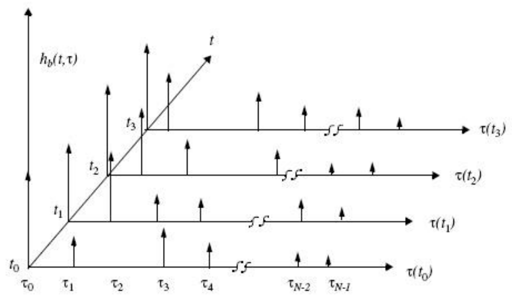
Narrow versus wide-band channel impulse response



Power-delay profile

One interesting channel property is the power-delay profile (PDP), which is the expected value of the received power at a certain delay:

$$P(\tau)=E_t\left[\left|h(t,\tau)\right|^2\right]$$



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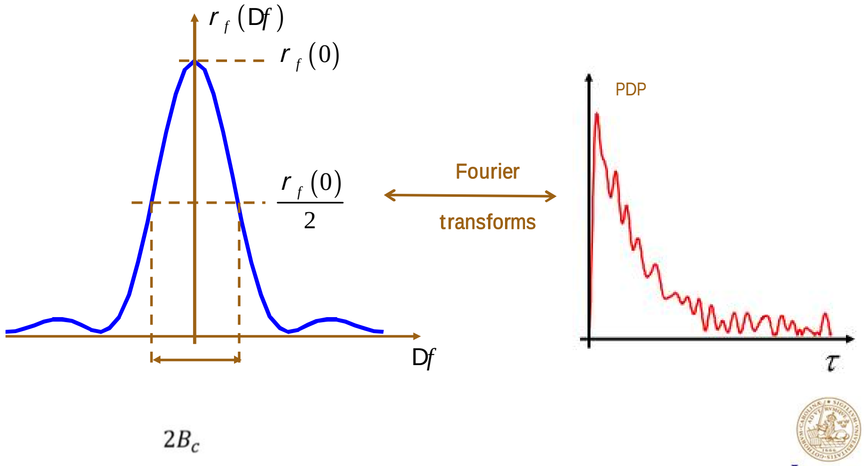
Power Delay Profile vs. the frequency correlation function



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Condensed parameters
Power-delay profile (cont.)

We can "reduce" the PDP into more compact descriptions of the channel:

Total power (time integrated):

$$P_m = \int_{-\infty}^{\infty} P(\tau)\,d\tau$$

Average mean delay:

$$T_m = \frac{\int_{-\infty}^{\infty} \tau P(\tau)\,d\tau}{P_m}$$

Average rms delay spread:

$$\sigma_\tau = \sqrt{\frac{\int_{-\infty}^{\infty} \tau^2 P(\tau)\,d\tau}{P_m} - T_m^2}$$

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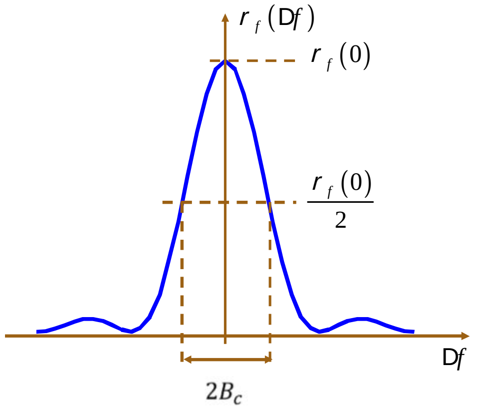
Condensed parameters
Coherence bandwidth

Given the frequency correlation of a channel, we can define the coherence bandwidth B_C:



What does the coherence bandwidth tell us?

It shows us over how large a bandwidth we can assume that the channel is fairly constant.

Radio systems using a bandwidth much smaller than B_C will not notice the frequency selectivity of the channel.

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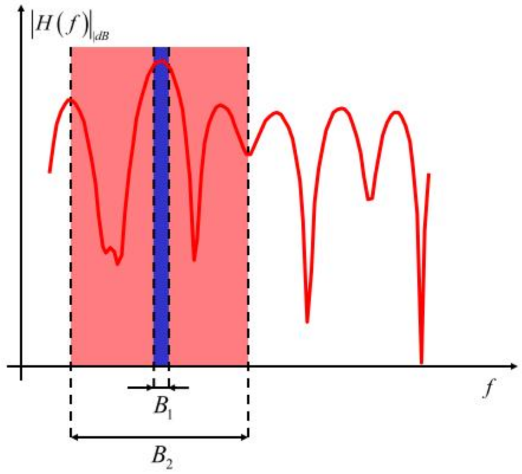
Narrow versus wide-band channel frequency response



Widely used approximations

$$Tc \approx \frac{1}{D_s}$$

$$Bc \approx \frac{1}{S_\tau}$$

$$Tc = \frac{9}{16\pi D_s}$$

time over which the time correlation function is above 0.5

$$Bc = \frac{1}{5S_\tau}$$

band over which the frequency correlation function is above 0.5

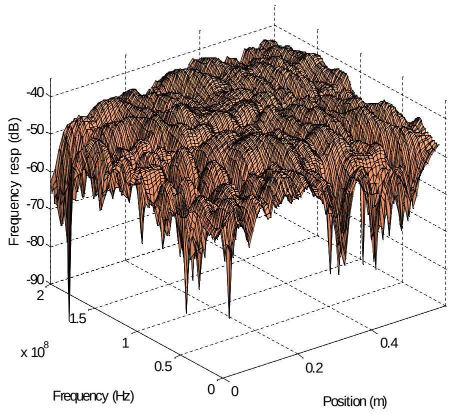
$$T_c = \frac{0.423}{D_s}$$

less restrictive and widely used

$$Bc = \frac{1}{50S_\tau}$$

band over which the frequency correlation function is above 0.9

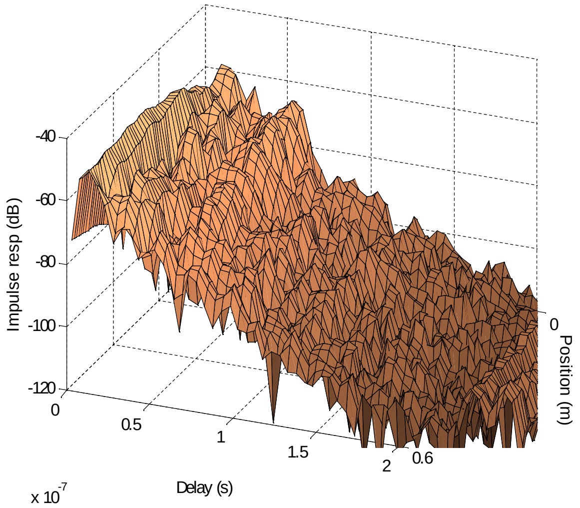
Time variant transfer function



Measurement in the lab with a vector network analyzer

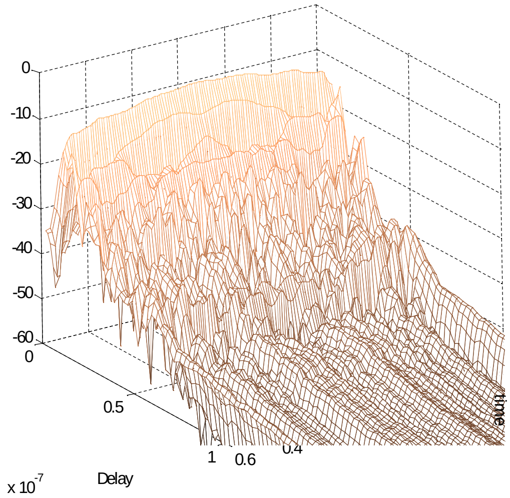
- Center frequency 3.2 GHz
- Measurement bandwidth 200 MHz, 201 frequency points
- 60 measurement positions, spaced 1 cm apart

Time variant impulse response



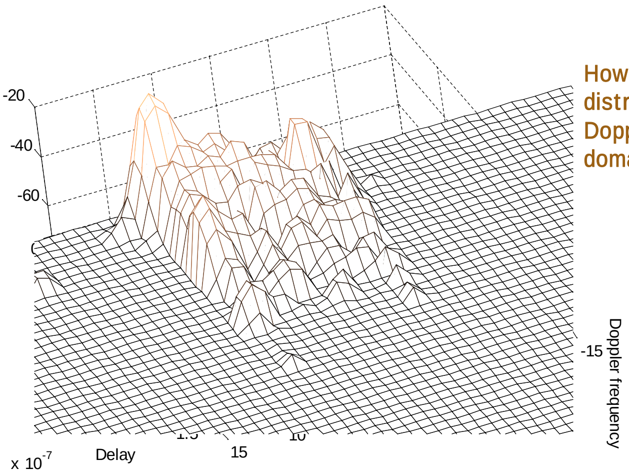
What are the delays? How is the signal affected for different delays? How does it change with time?

Delay cross spectral density



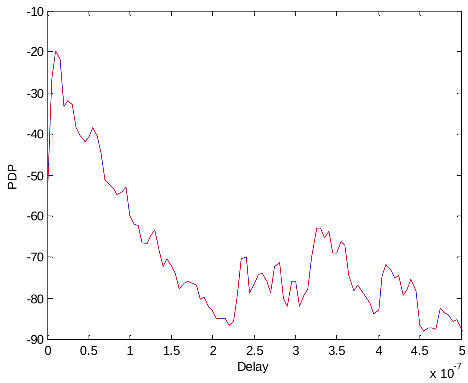
How is the power for different delays correlated in time?

Scattering function



How is the power distributed in the Doppler and delay domains?

Integrating the scattering function over the Doppler – the power delay profile



How is the power distributed in the delay domain?

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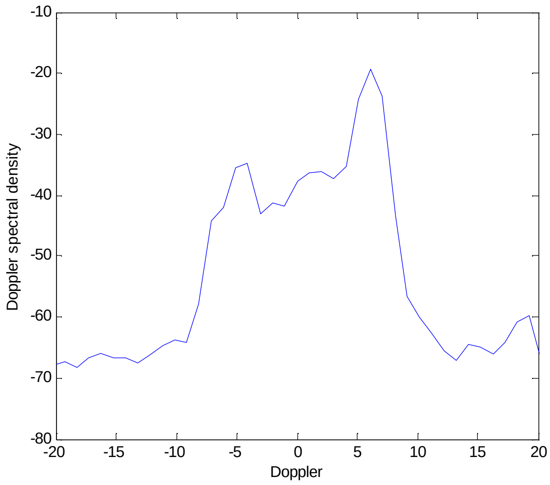
Integrating the scattering function over the delay – the Doppler spectral density



How is the power distributed in the Doppler domain?

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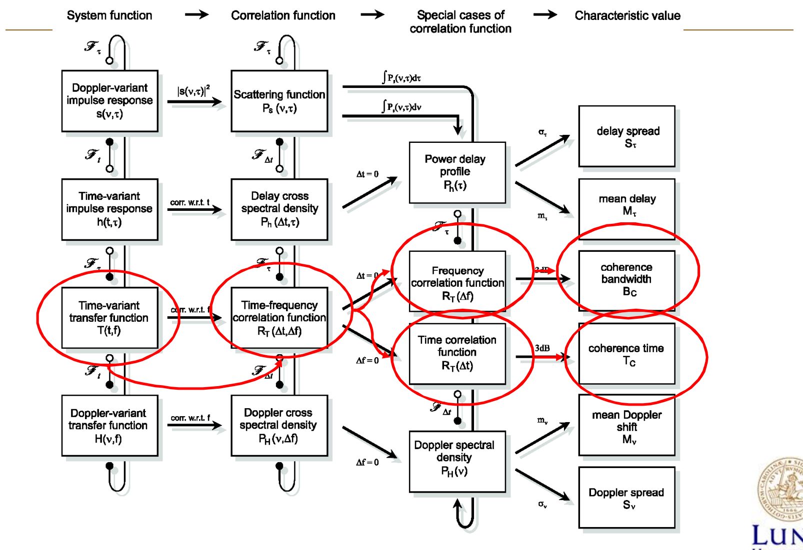
Channel measures



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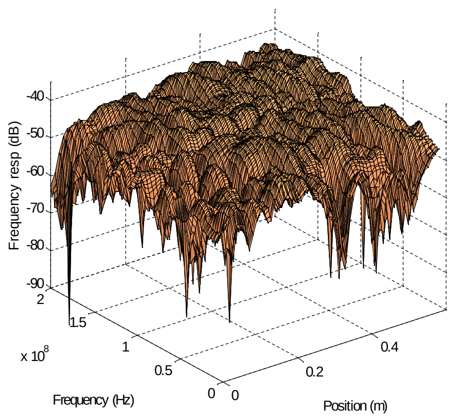
Time variant transfer function



Measurement in the lab with a vector network analyzer

- Center frequency 3.2 GHz
- Measurement bandwidth 200 MHz, 201 frequency points
- 60 measurement positions, spaced 1 cm apart

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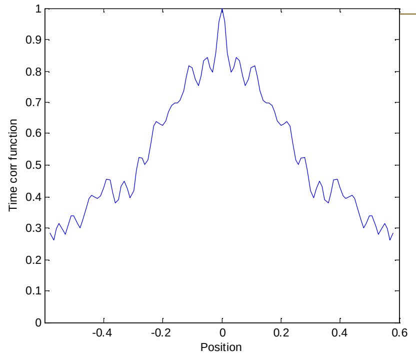
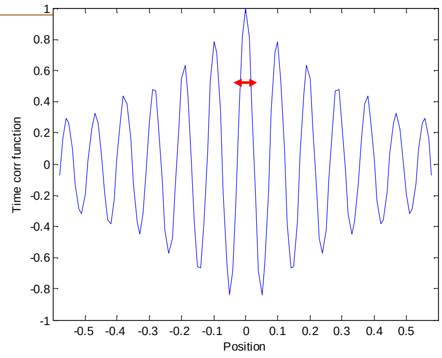
Time correlation function



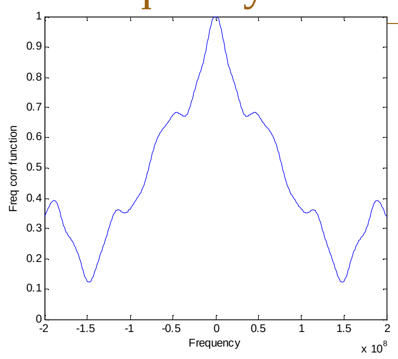


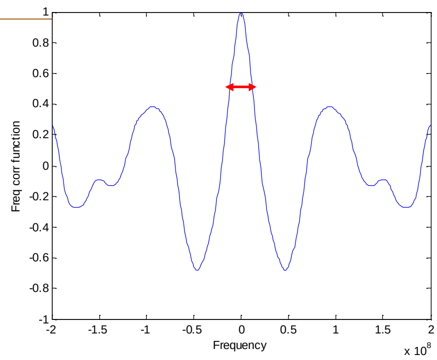
Absolute value

Real part

Coherence time 0.04 s

Frequency correlation function





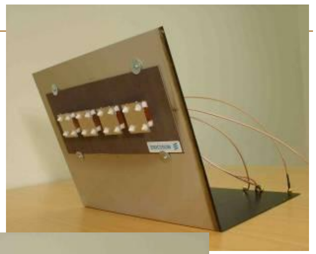
Absolute value

Real part

Coherence bandwidth 20 MHz

2.6 GHz antennas

2 port
hand held



PC

4 port
hand held

fixed
device

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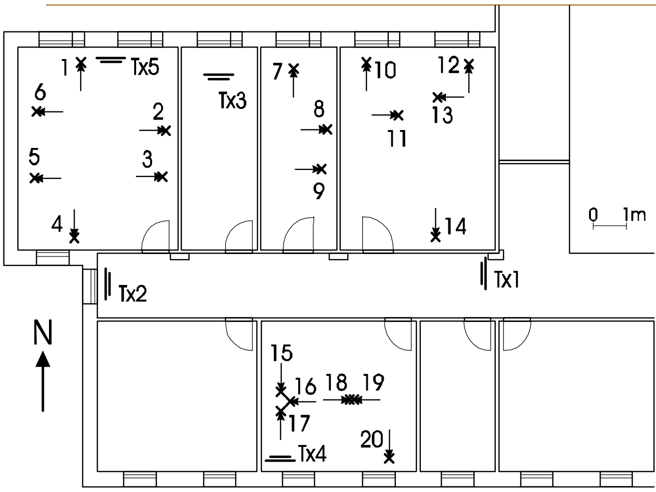
Measurements performed at typical work positions



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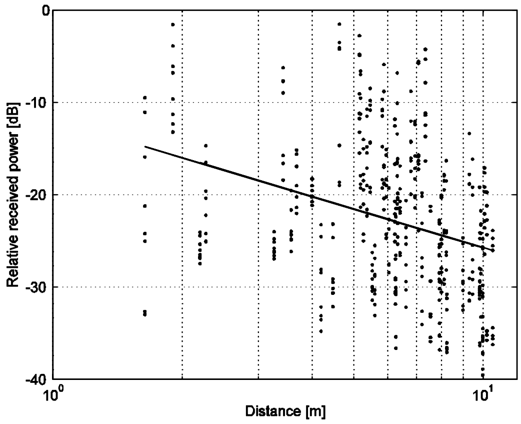
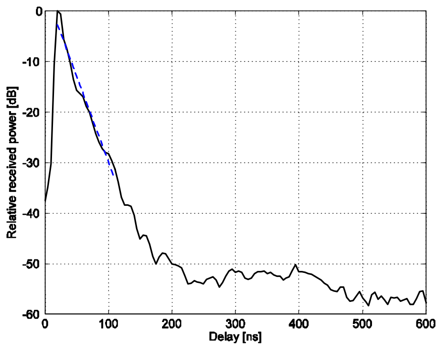
Total power



Fixed device – PC
NLOS
co-polarized

Only one cluster is seen in the PDP



- exponential decay

$$P(t) = |b|^2 e^{-t/g}$$

- Gaussian distributed decay constants
- mean 10 - 13 ns
- standard deviation 1.2 - 2.1 ns

Condensed parameters
Power-delay profile (cont.)

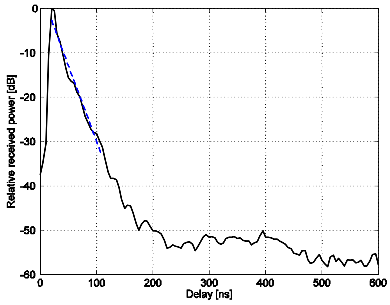
We can "reduce" the PDP into more compact descriptions of the channel:

Total power (time integrated):

$$P_m = \int_{-\infty}^{\infty} P(\tau)\,d\tau$$

Average rms delay spread:

$$S = \sqrt{\frac{\int_{-\infty}^{\infty} \tau^2 P(\tau)\,d\tau}{P_m} - T_m^2}$$



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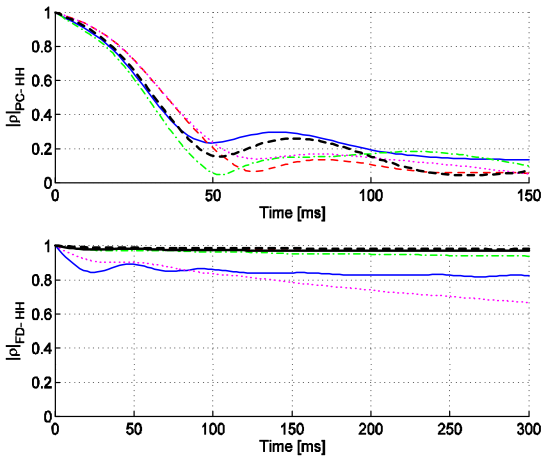
The coherence time is large



PC-HH

moving receiver

FD-HH

person moving in corridor

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Measurements in an industrial UWB channel

4.9 GHz bandwidth
49 TX-RX positions 49
7*7 Virtual MIMO system
Antenna array elements
separation 5cm
TX-RX Separations 3,6,10,12m

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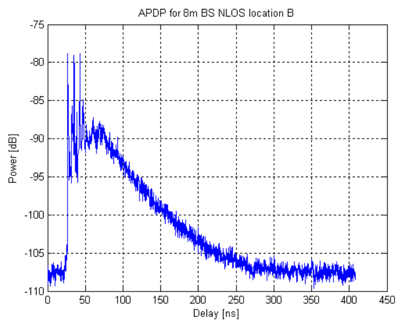
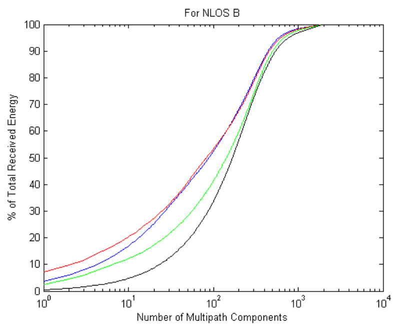
UWB channels – PDP





Huge bandwidth – possible to identify single multipath componenets
Need a large number of fingers in a so called RAKE receiver

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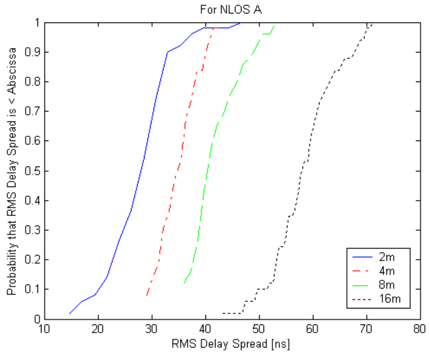
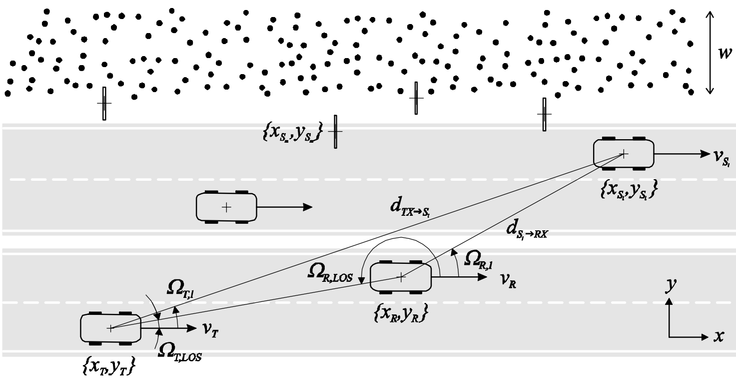
UWB channels

Delay spread is mainly dependent on distance to the scatterers, not on the bandwidth

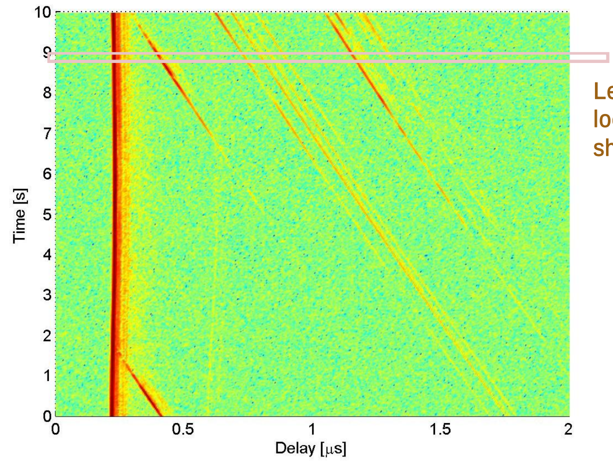


Car to car communication

Cars driving in same direction with a distance of 50 m, 70 km/h, rural area

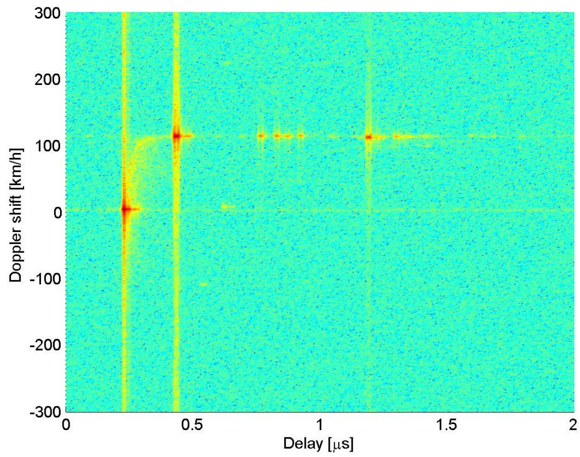


Time variant impulse response



Let's take a closer look at the Doppler shifts here

Scattering function, t=8.5-8.65 s



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