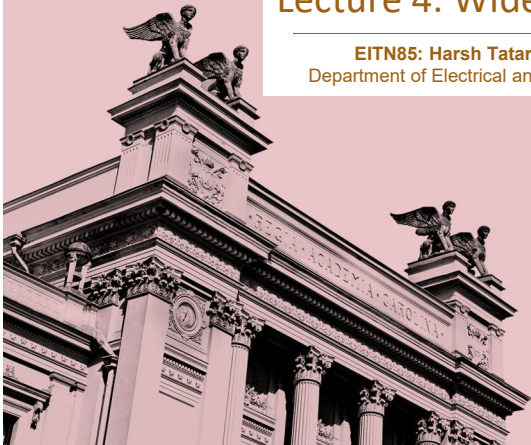



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Wireless Communications Channels Lecture 4: Wideband Characterization

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Department of Electrical and Information Technology, Lund University

What have we covered thus far?

- Recap:** Considered the effect of multipath propagation on the received field strength and its temporal variations.
- Key assumption:** Small system bandwidth (narrowband systems only). As a consequence, multiple directions can not be **resolved** by the RX and seem that they arrive almost at the same time.
- Most current and future systems however will leverage large bandwidths – why?**
- Desirable to describe channel variations over a larger bandwidth range – the topic for the current lecture.
 - Wideband characterization** of channels and real world examples.

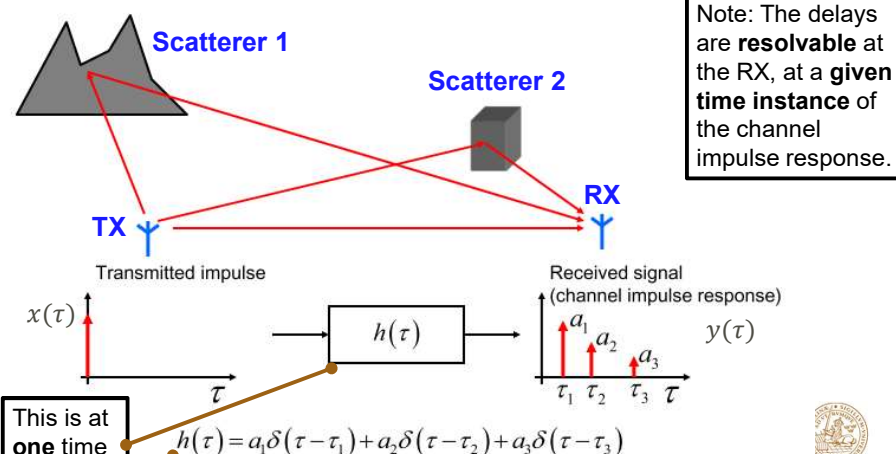
Propagation Impact on Wideband Systems

Impact interpreted in **two** different ways:

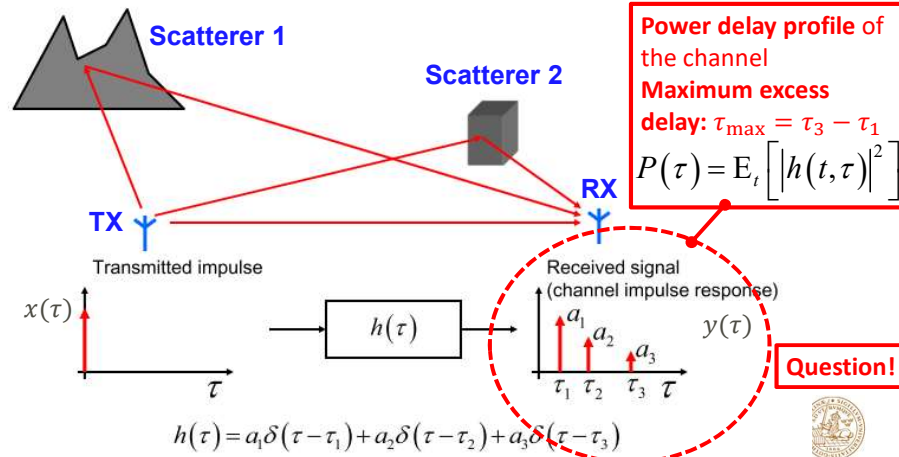
- ❑ The transfer function of the channel **varies** over the **bandwidth** of interest (a.k.a. the **frequency selectivity** of the channel).
- ❑ Impulse response of the channel is **not** a Delta function; the arriving signal has a **longer run time** than the transmitted signal (a.k.a. delay dispersion).

Question: What is the relationship between the above?

Delay Dispersion: A Simple Case



Delay Dispersion: A Simple Case



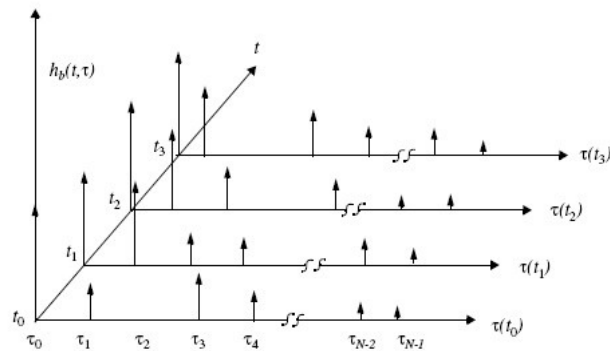
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Power delay profile over time

The General Description

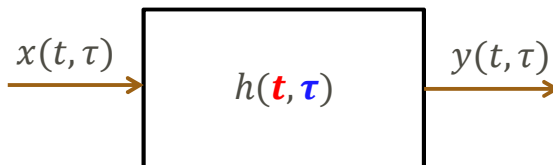


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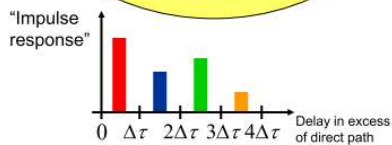
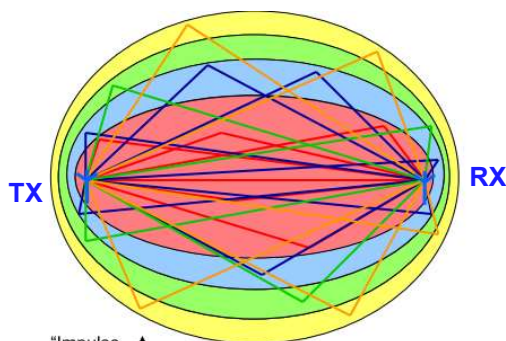


Consequence of Wideband Channels



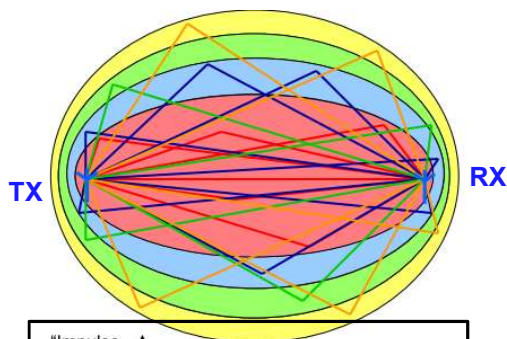
So, what about this?
 What can we infer from a system view point?

Delay dispersion: Many paths, a model

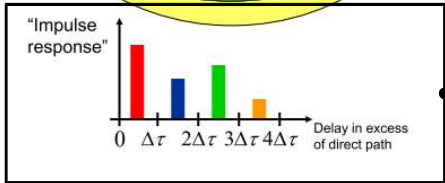


- ❑ Scatterers/Interacting objects placed anywhere along the plane
- ❑ Ellipse which is characterized by its focal points, i.e., TX and RX locations, as well as the eccentricity determining the run time of multipath components
- ❑ Single interaction on ellipse → arrive at the RX at the same time. Interaction on different ellipses → arrive at different times

Delay dispersion: Many paths, a model

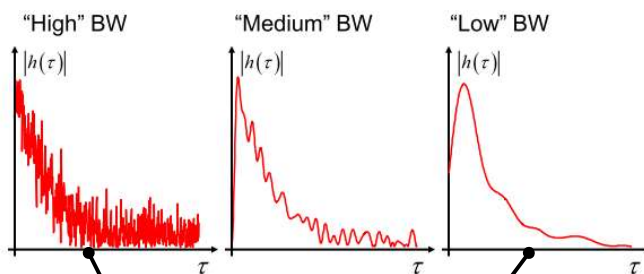


Discrete time-domain approximation to the impulse response of a wideband channel obtained by: dividing the impulse response into **different time intervals (each containing multiple delays)** and **summing** over the number of multipath components within **each bin**.



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Narrowband vs. Wideband Channels Bandwidth Dependency

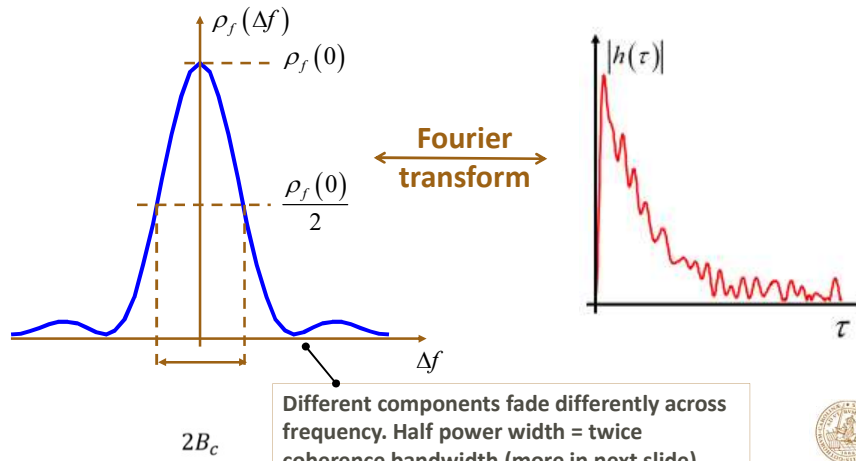


Much better resolvability of multipath components

Narrowband if $\frac{1}{B} \gg \tau_{max}$

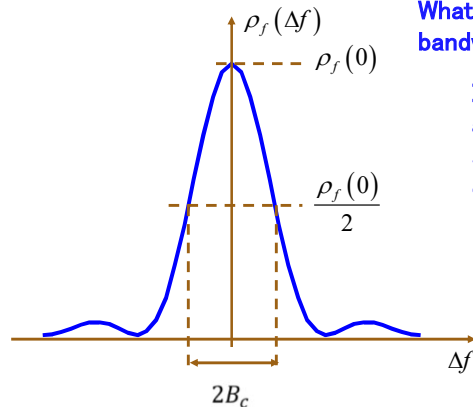
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Power delay profile vs. frequency correlation function



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 so 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.



Condensed parameters Power delay profile (cont.)

We can infer many useful parameters from the power delay profile

Total power (time integrated):

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

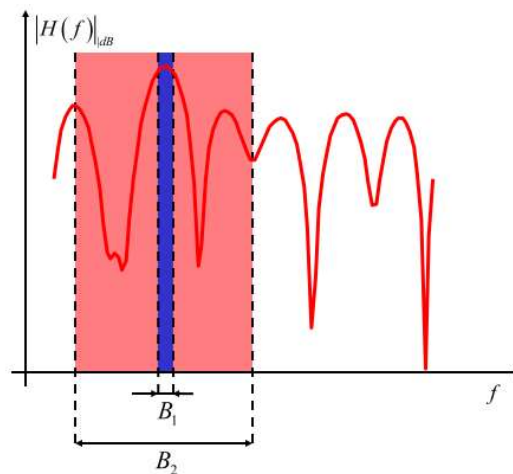
Average mean delay (first moment of the PDP)

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

Average RMS delay spread (second moment of the PDP)

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

Narrow vs. wideband frequency response



Widely used "rules-of-thumb"

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

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

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

time over which the time correlation function is above 0.5

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

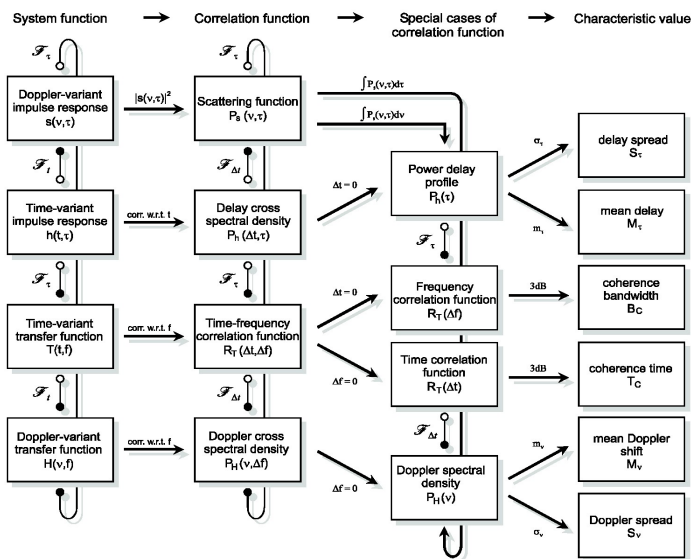
band over which the frequency correlation function is above 0.5

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

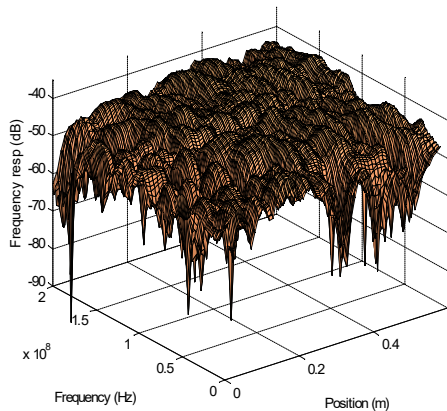
less restrictive and widely used

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

band over which the frequency correlation function is above 0.9



Time variant channel transfer function



Measurement in the lab with a vector network analyzer

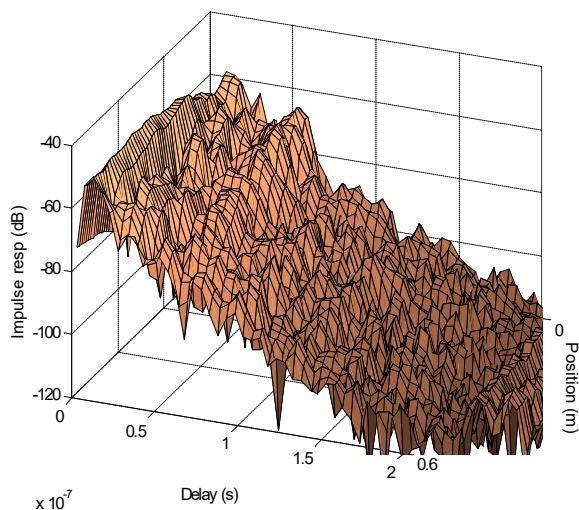
- Center frequency 3.2 GHz
- Measurement bandwidth 200 MHz, 201 frequency points
- 60 measurement positions, spaced 1 cm apart

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Time variant channel impulse response



What are the delays?

How is the signal affected for different delays?

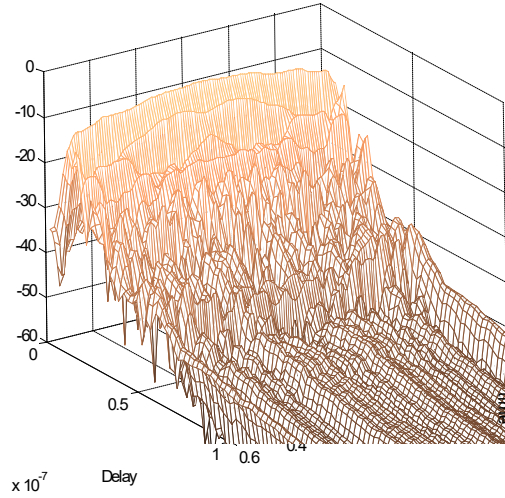
How does it change with time?

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Delay cross spectral density



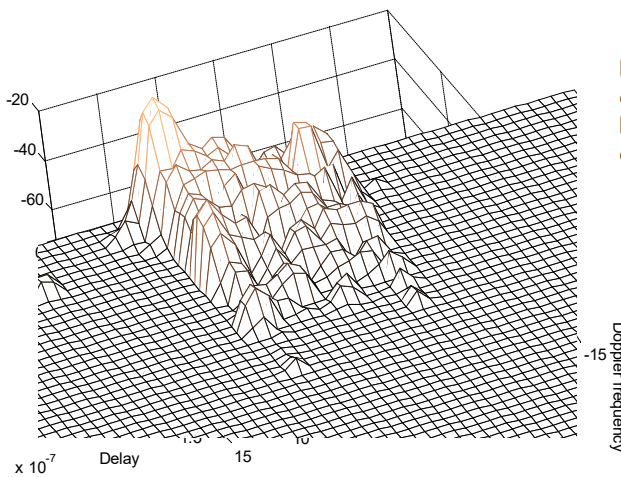
How is the power for different delays correlated in time?

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Spreading function of the channel



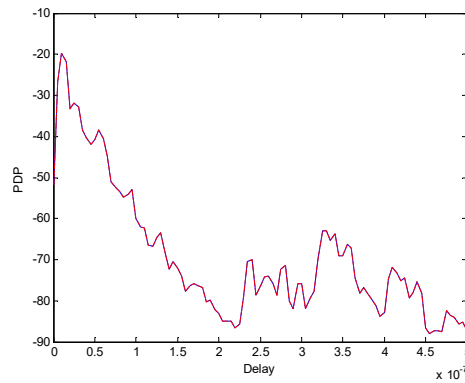
How is the power distributed in the Doppler and delay domains?

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Integrating the spreading function over the Doppler – the delay domain



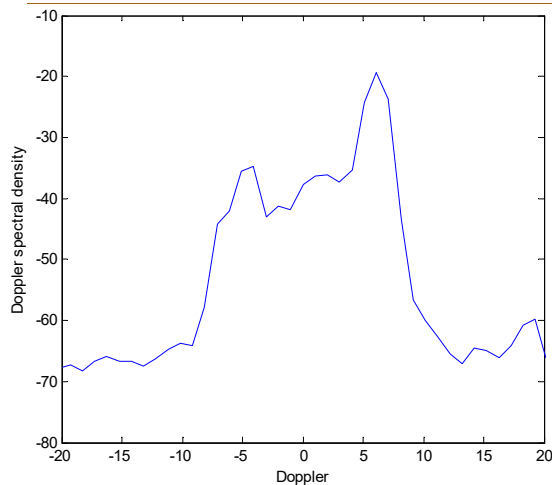
How is the power distributed in the delay domain?

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



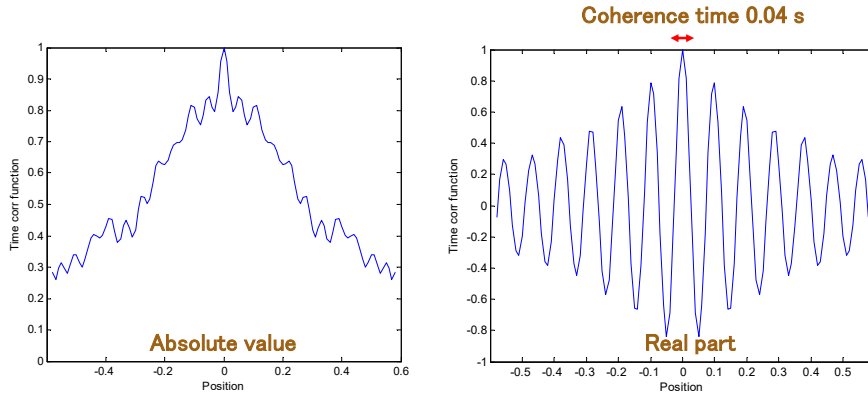
How is the power distributed in the Doppler domain?

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Measured time correlation function

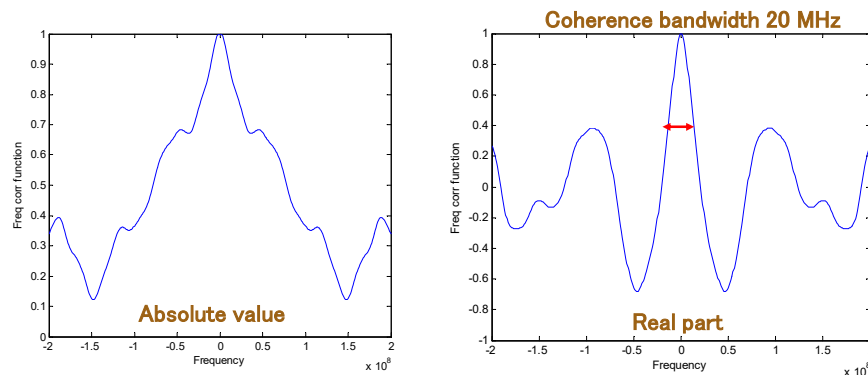


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Measured Frequency correlation function

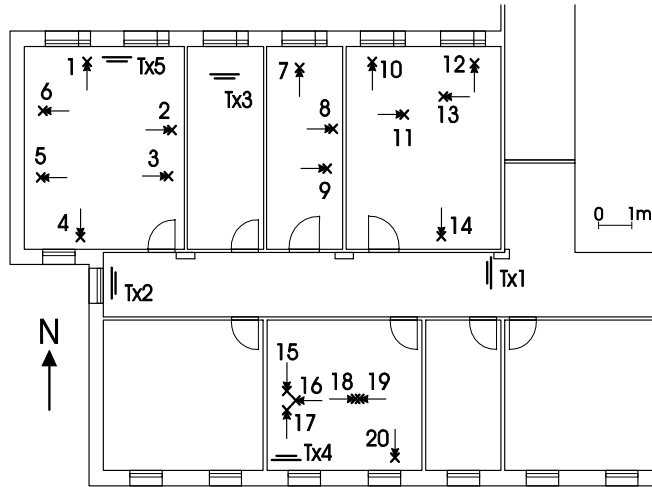


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Measurements performed at typical work positions

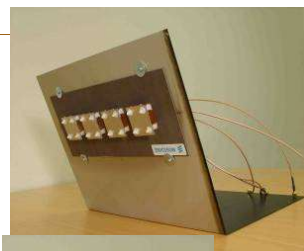


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2.6 GHz antennas



2 port hand held



PC



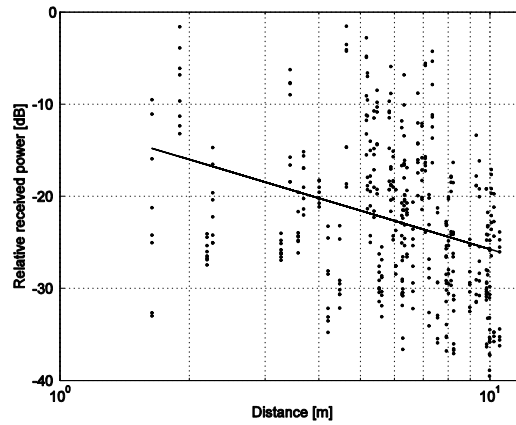
4 port hand held



Fixed device

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Total received power vs. link distance

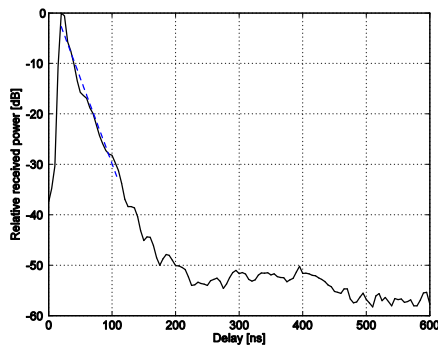


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Power delay profile



- exponential decay

$$P(\tau) = |\beta|^2 e^{-\tau/\gamma}$$

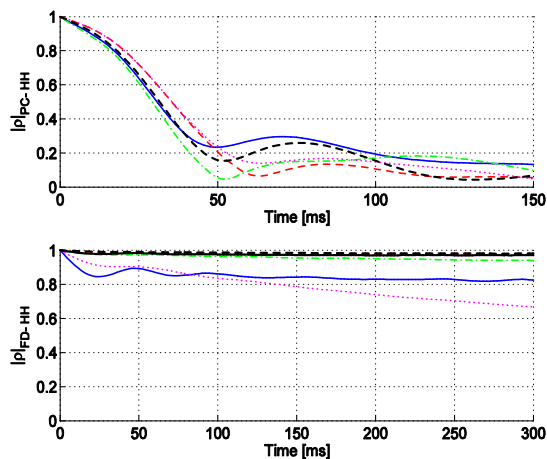
- mean 10 - 13 ns
- standard deviation 1.2 - 2.1 ns

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Variation of coherence time vs. measured environment



PC-HH
moving receiver

FD-HH
person moving in corridor

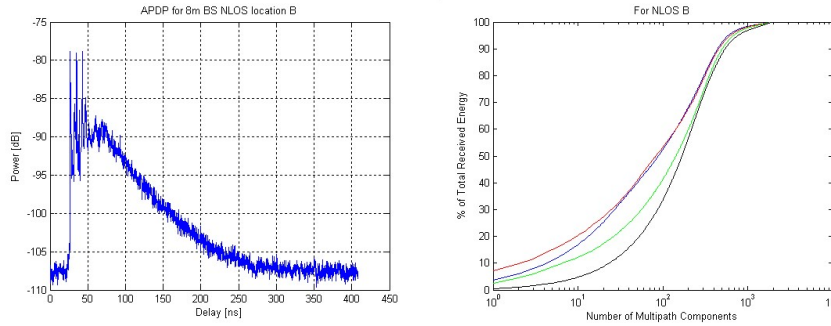


Measurements in an industrial UWB channel

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



UWB channels – PDP



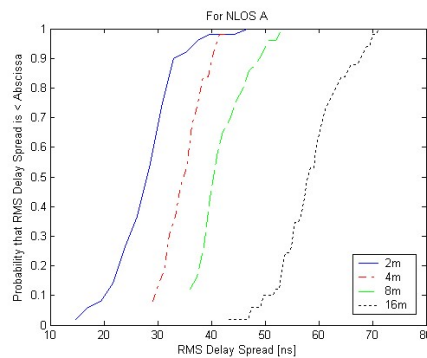
Huge bandwidth – possible to identify single multipath components
 Need a large number of fingers in a special type of receiver (so called RAKE receiver)



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UWB channels

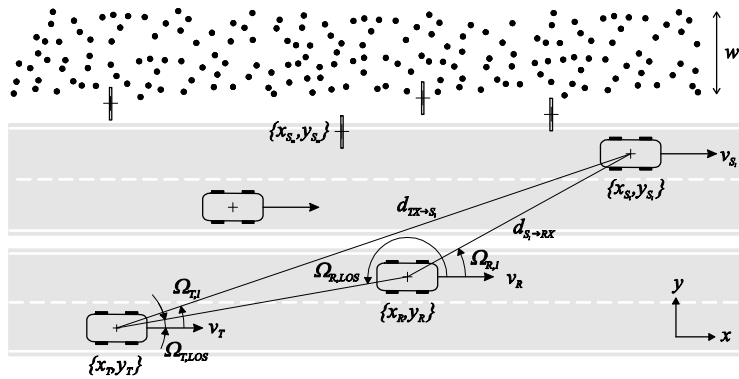
Delay spread is mainly dependent on distance to the scatterers, since it influences the resolvability of the system to identify potential multipath components.



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Car to car communication

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

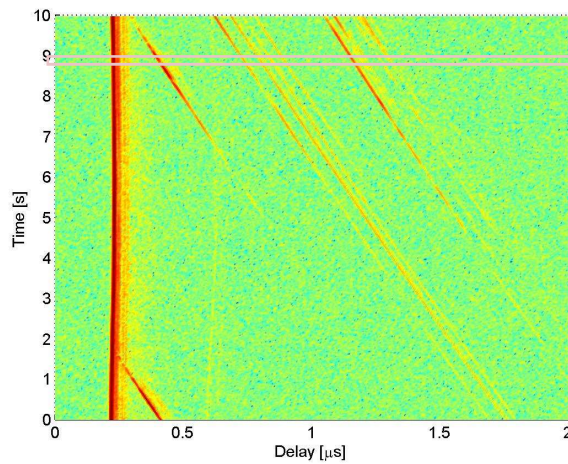


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Time variant impulse response



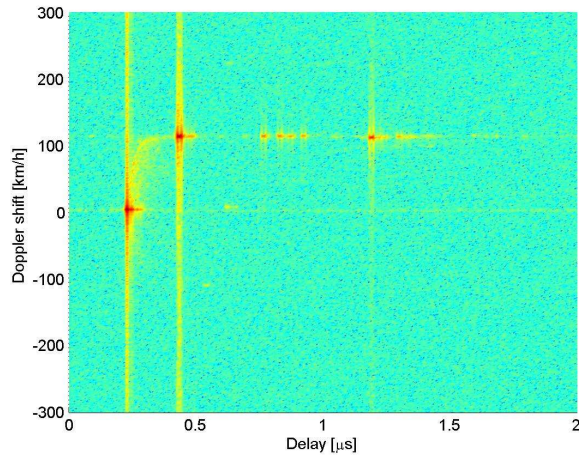
Let's take a closer look at the Doppler shifts here

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Scattering function, $t=8.5-8.65$ s



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