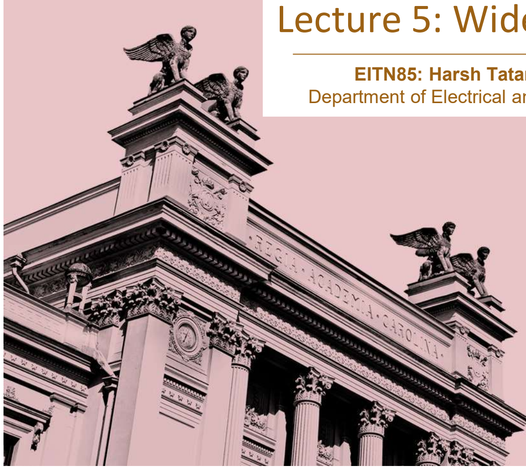

Wireless Communications Channels
Lecture 5: Wideband Characterization

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What have we covered thus far?

- ❑ **Recap:** Considered the effect of multipath propagation on the received amplitude and phase, as well as 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.
- ❑ Desirable to describe channel variations over a larger bandwidth range – the topic for the current lecture.
  - ❑ **Wideband characterization** of channels and real world examples.

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Propagation Impact on Wideband Systems

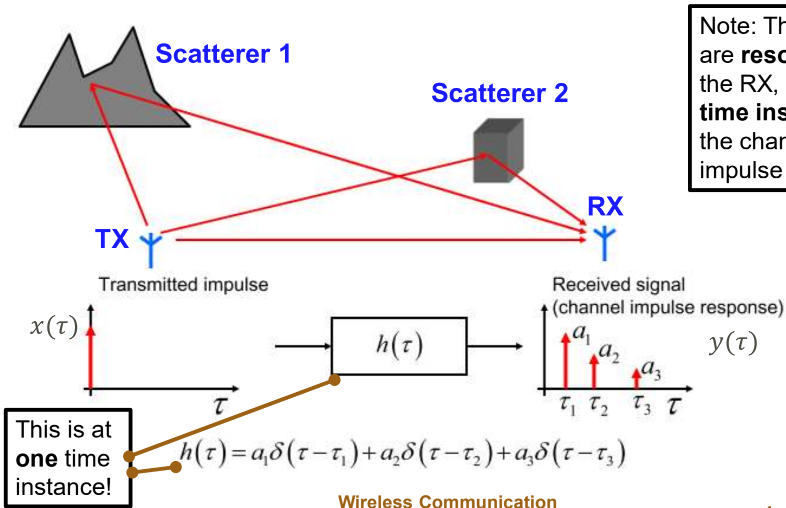
Impact interpreted in **two** different ways:

- ❑ 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).

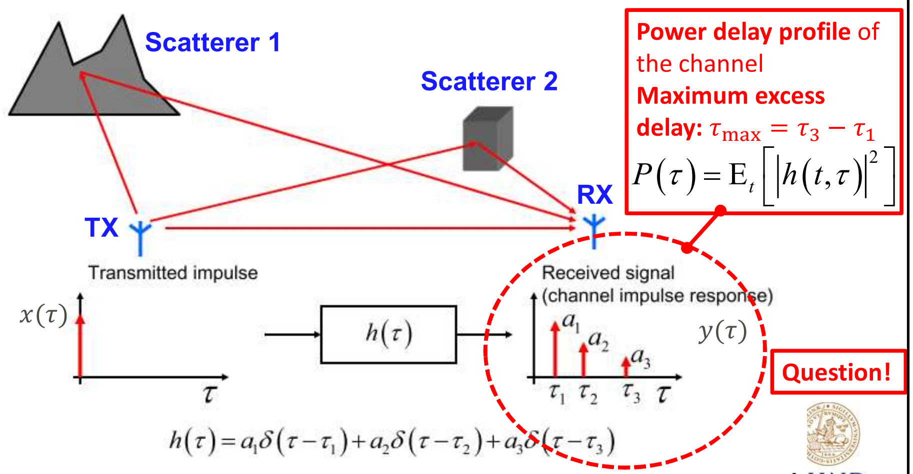
Question: What is the relationship between the above?

Delay Dispersion: A Simple Case



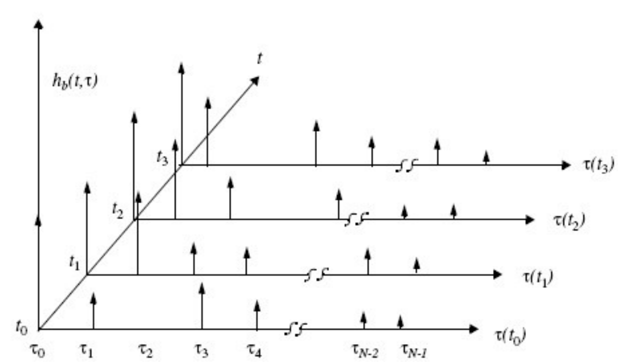
Note: The delays are **resolvable** at the RX, at a **given time instance** of the channel impulse response.

Delay Dispersion: A Simple Case

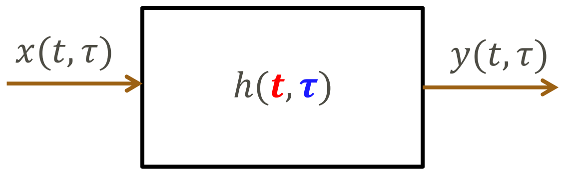


Power delay profile **over time**

The General Description

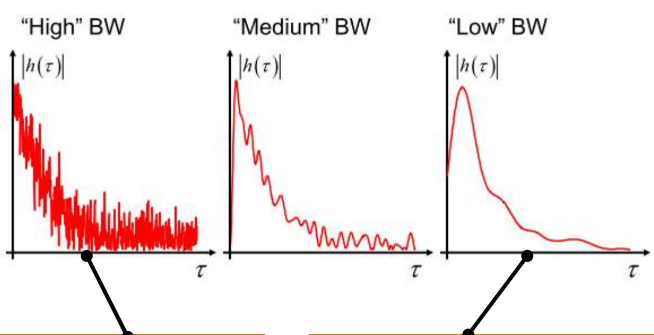


Consequence of Wideband Channels



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

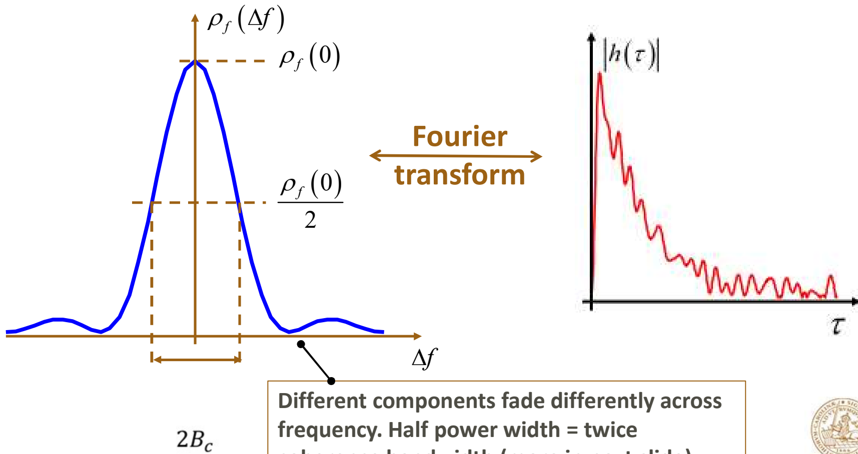
Narrowband vs. Wideband Channels Bandwidth Dependency



Much better resolvability of multipath components

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

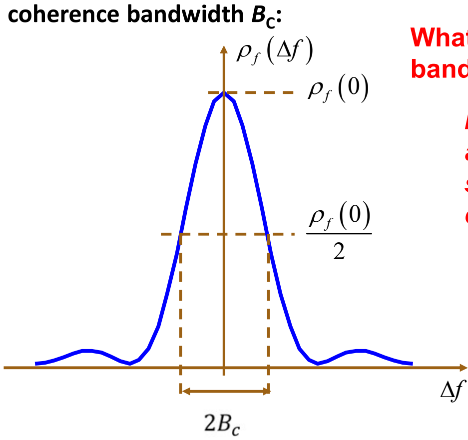
Power delay profile vs. frequency correlation function



Different components fade differently across frequency. Half power width = twice coherence bandwidth (more in next slide)

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):

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

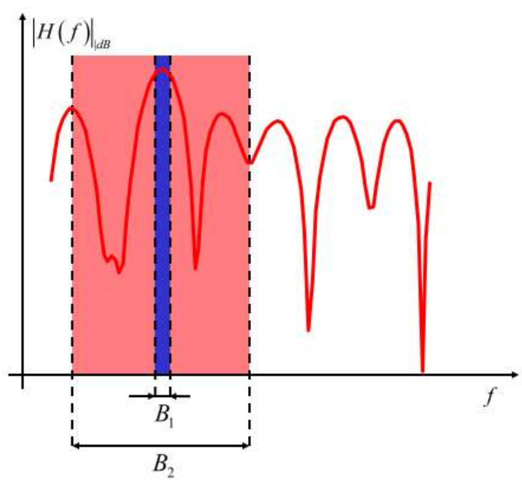
Average mean delay (first moment of the PDP)

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

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"

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

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

time over which the time correlation function is above 0.5

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

less restrictive and widely used

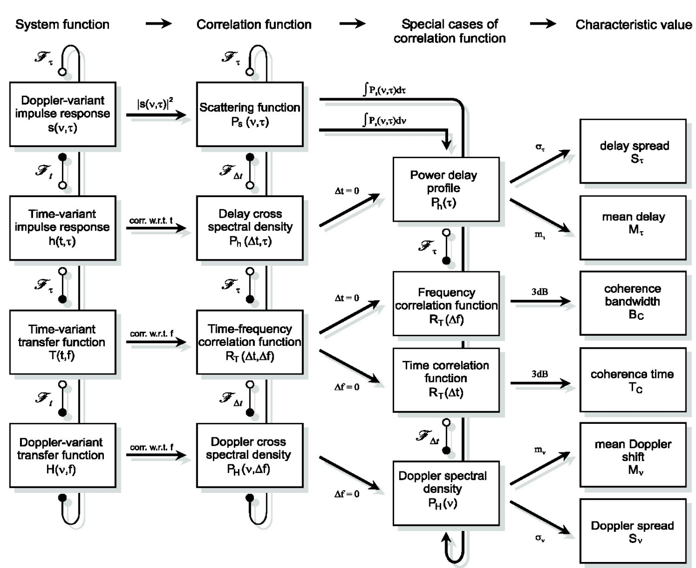
$$Bc \approx \frac{1}{S_\tau}$$

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

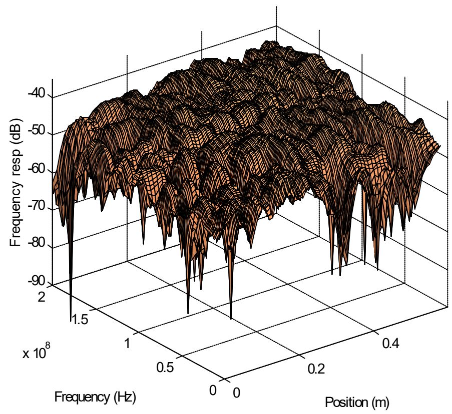
band over which the frequency correlation function is above 0.5

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

band over which the frequency correlation function is above 0.9



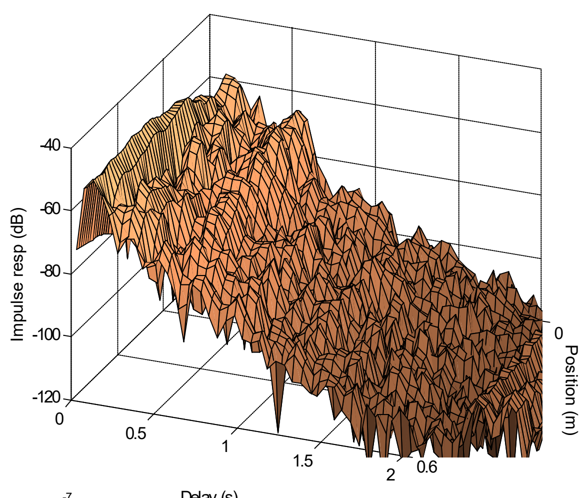
Time variant channel **transfer function**



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**

Time variant channel **impulse response**

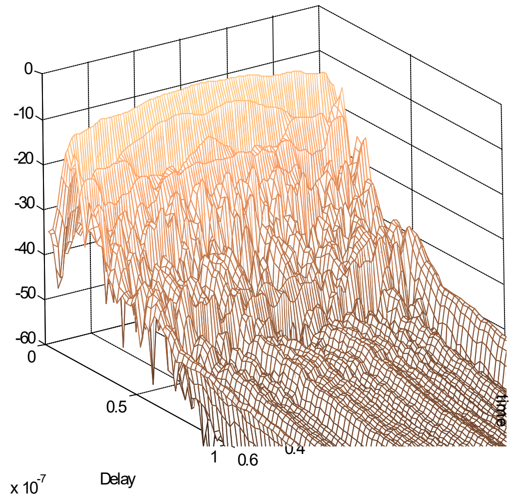


What are the delays?

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?

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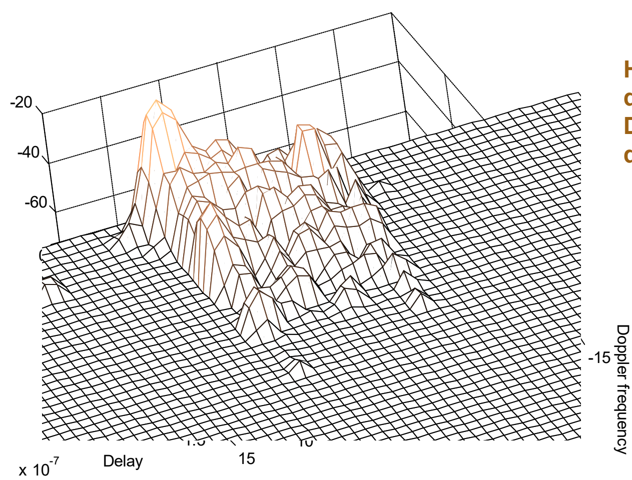
Spreading function of the channel



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

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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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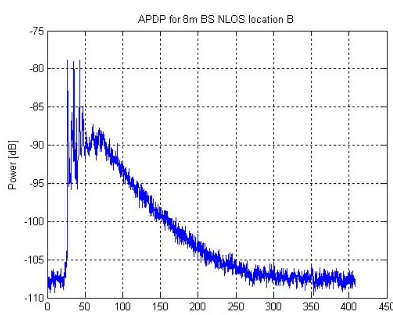
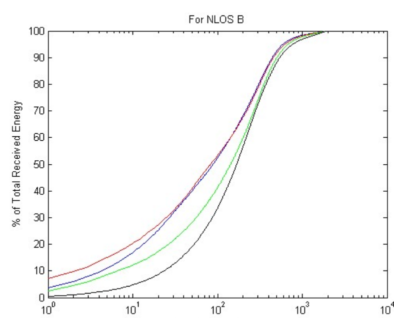
UWB channels – PDP





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

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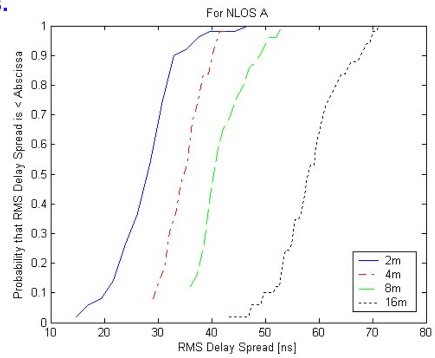
UWB channels

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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