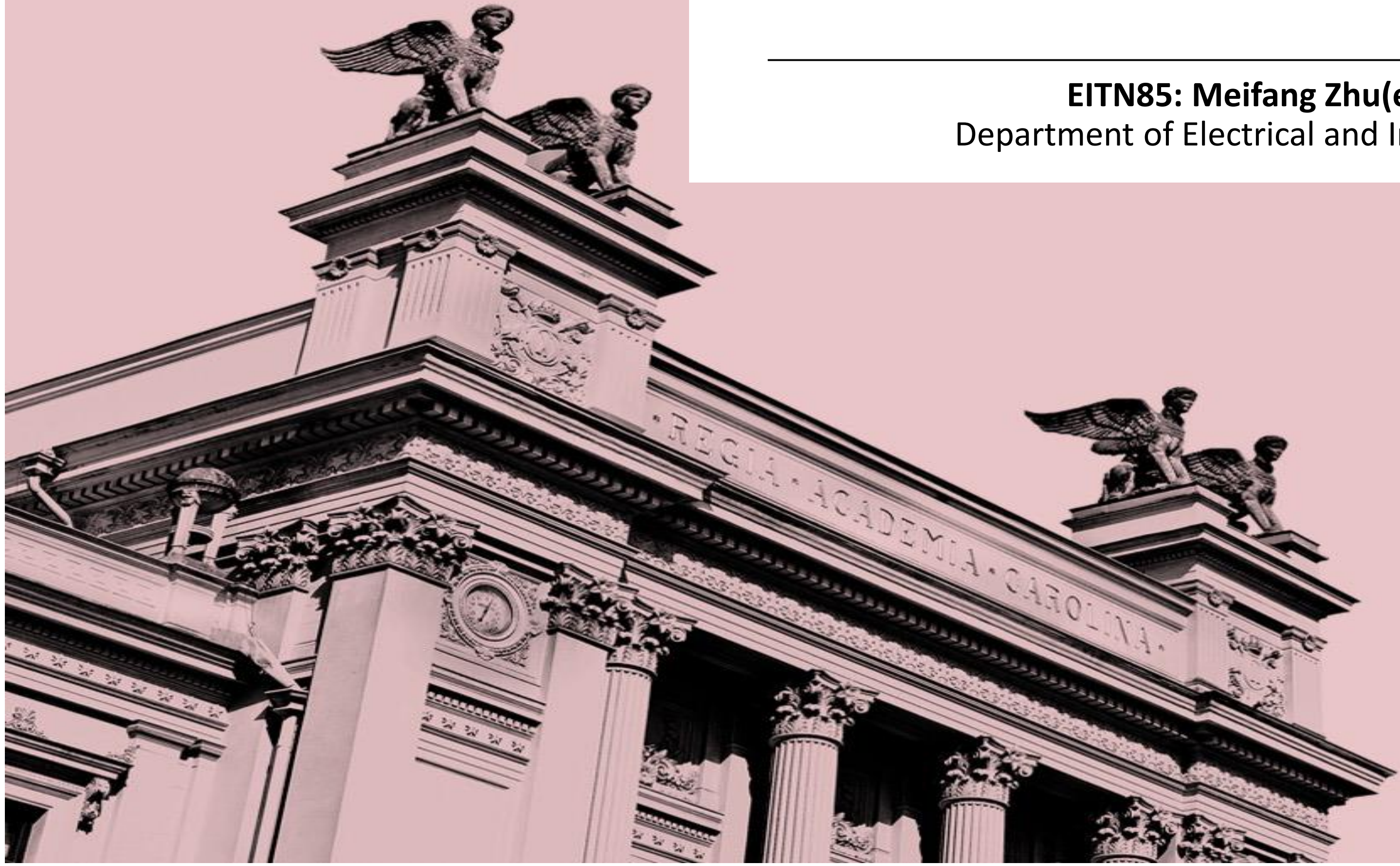
Wireless Communications Channels
Lecture 4: Wideband Characterization

EITN85: Meifang Zhu(e-mail: meifang.zhu@eit.lth.se)
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:

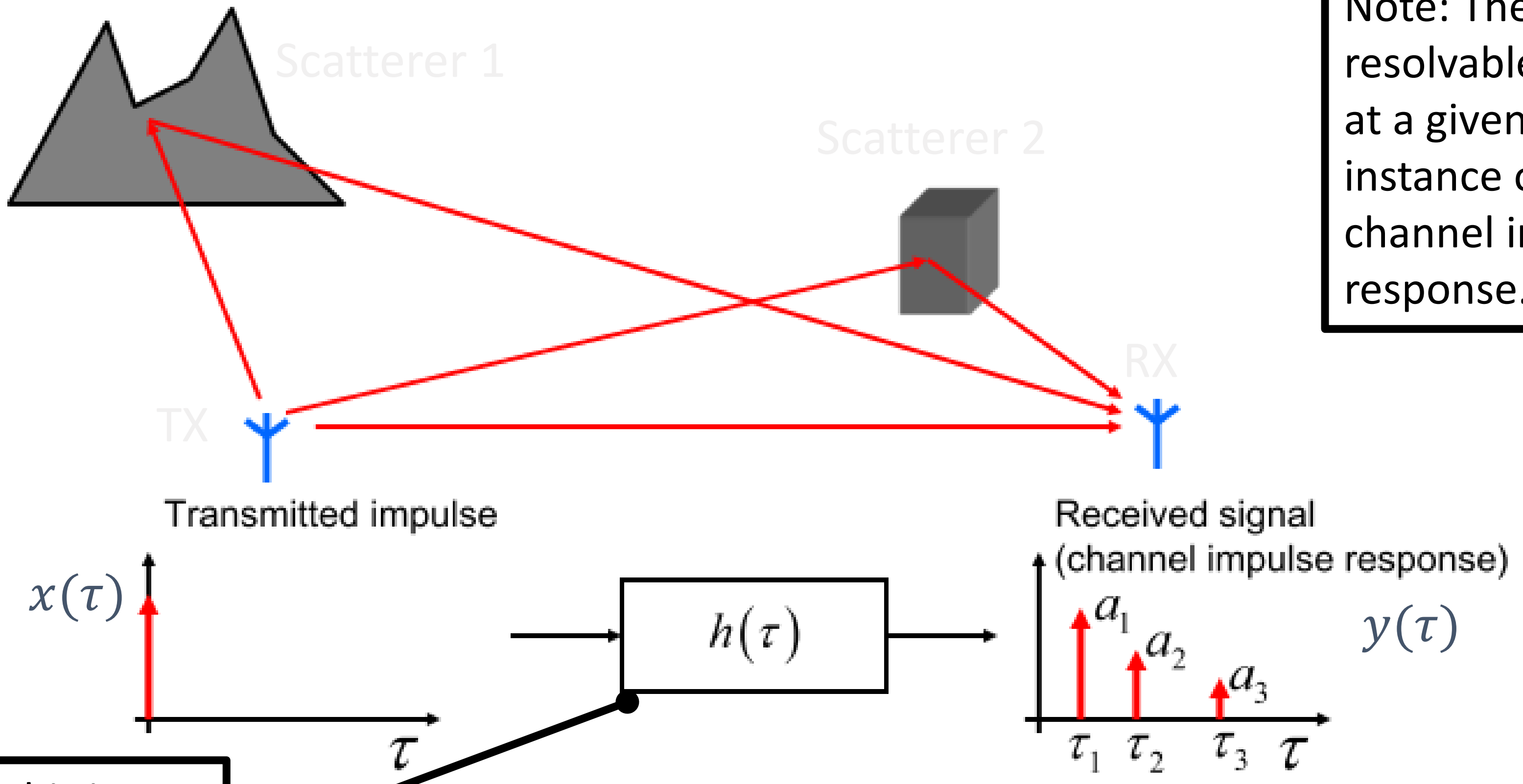
- ❑ The transfer function of the channel **varies** over the **bandwidth** of interest (a.k.a. the **frequency selectivity** of the channel).

- ❑ 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

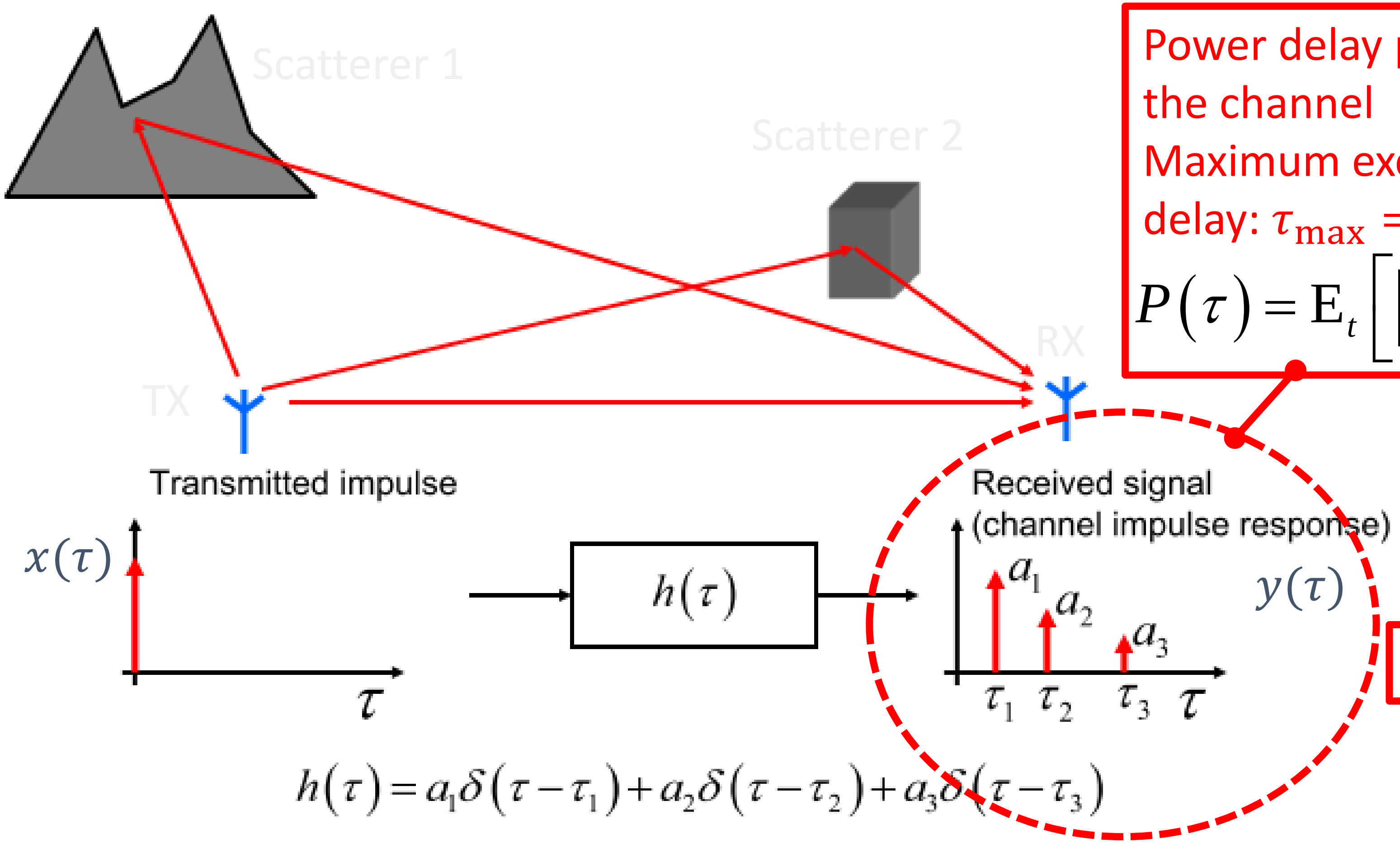
Note: The delays are resolvable at the RX, at a given time instance of the channel impulse response.



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

This is at one time instance!

Delay Dispersion: A Simple Case



Power delay profile of the channel

Maximum excess delay: $\tau_{\max} = \tau_3 - \tau_1$

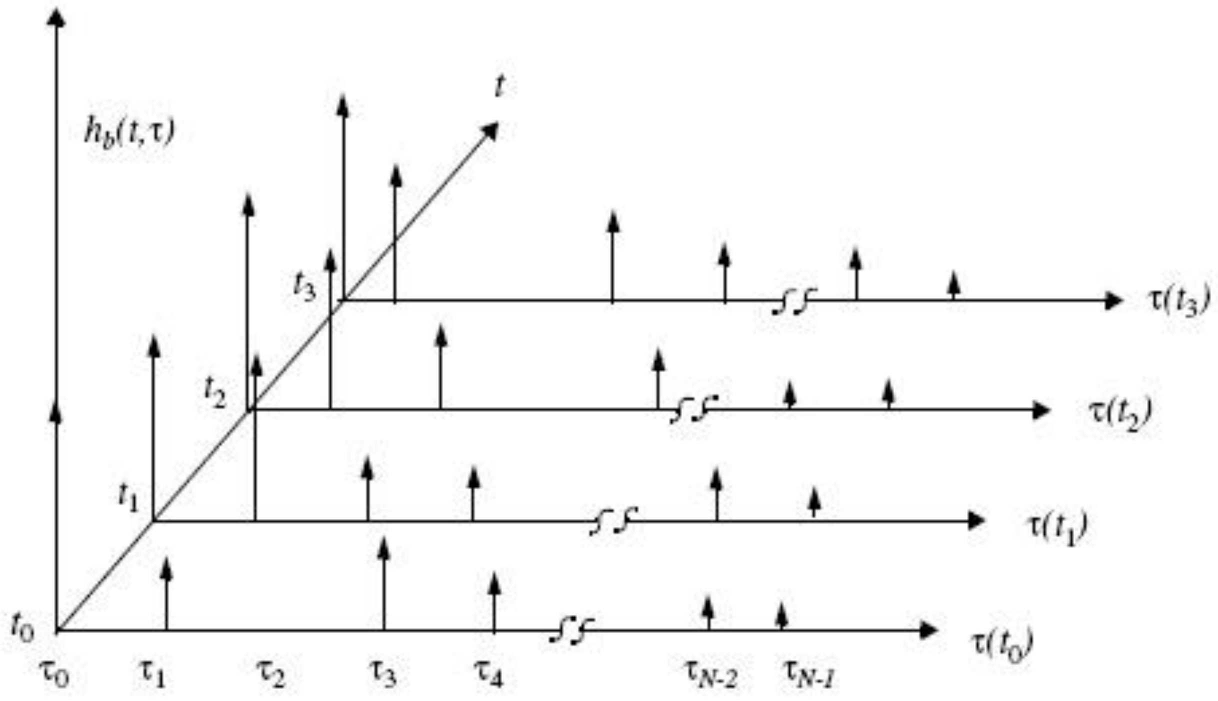
$$P(\tau) = \mathrm{E}_t\left[\left|h(t,\tau)\right|^2\right]$$

Question!

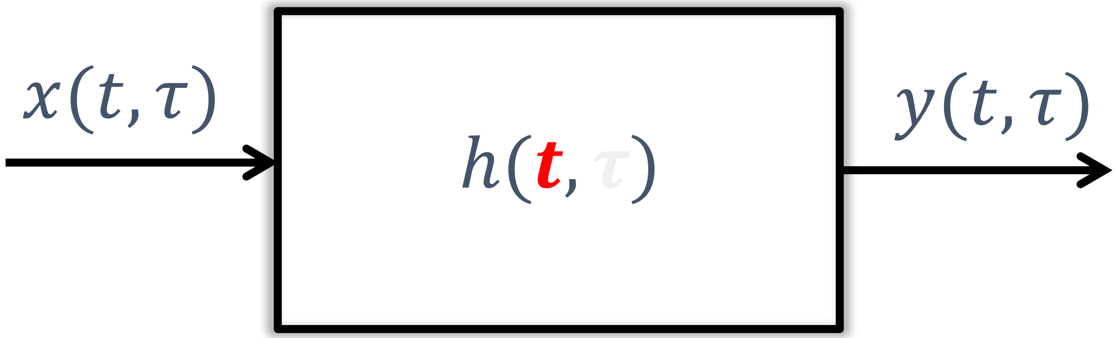
$$h(\tau) = a_1\delta(\tau-\tau_1) + a_2\delta(\tau-\tau_2) + a_3\delta(\tau-\tau_3)$$

Power delay profile over time

The General Description

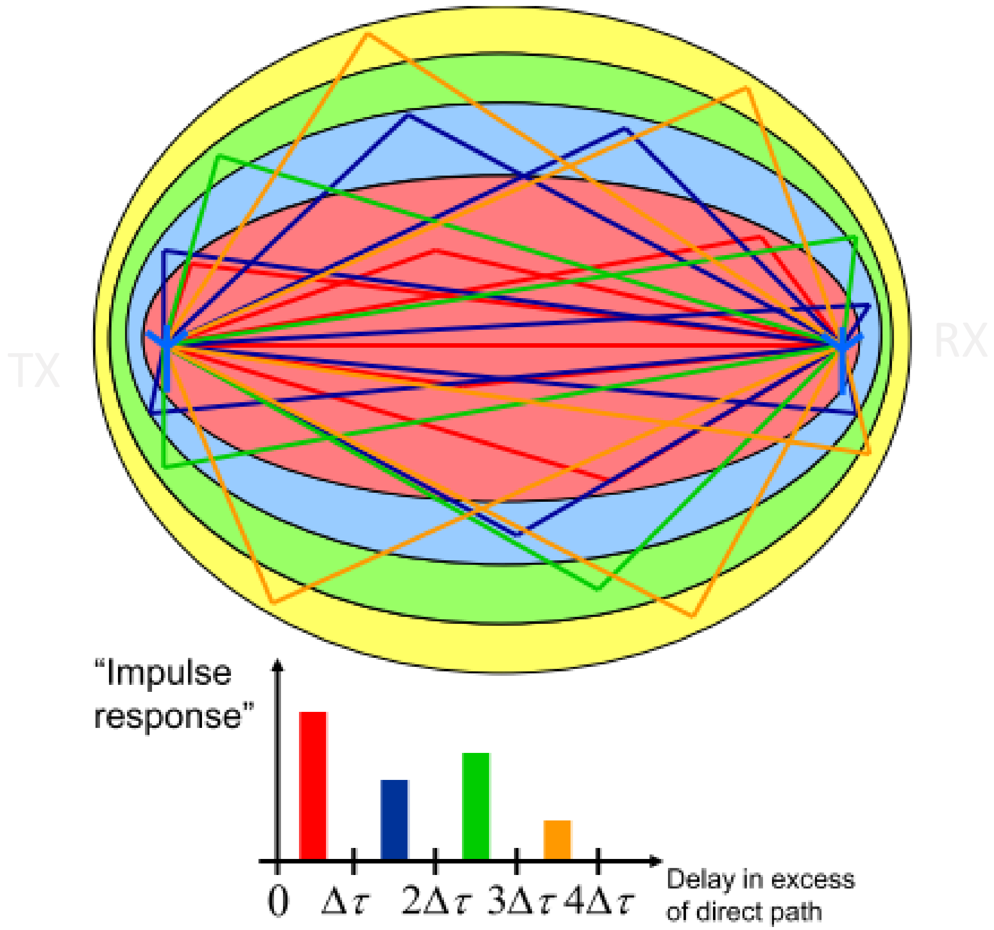


Consequence of Wideband Channels



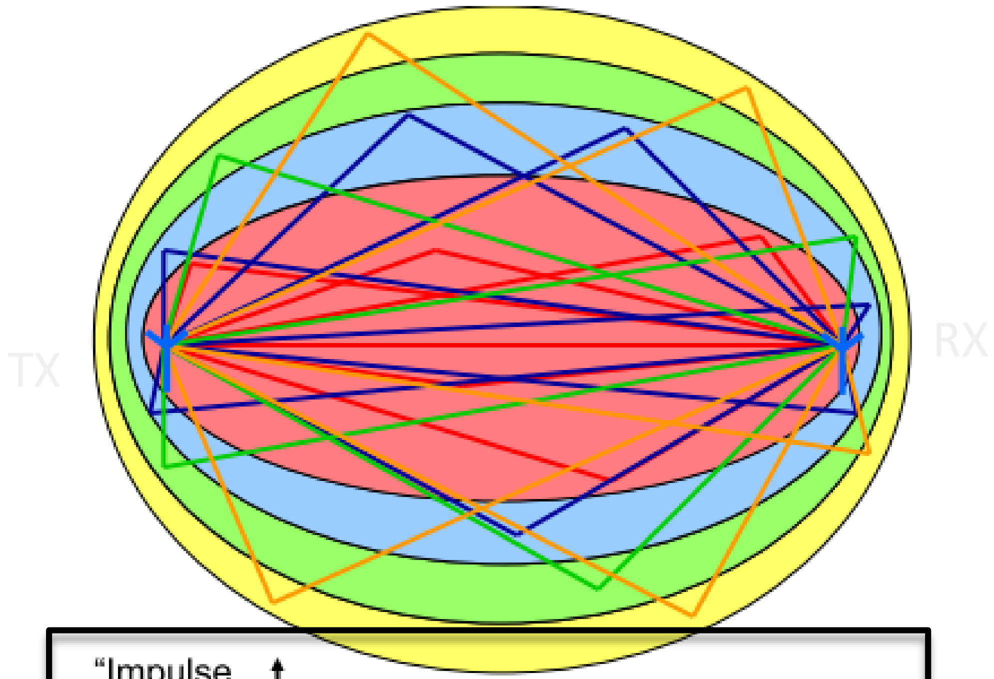
So, what about this?
What can we infer from a system view point?

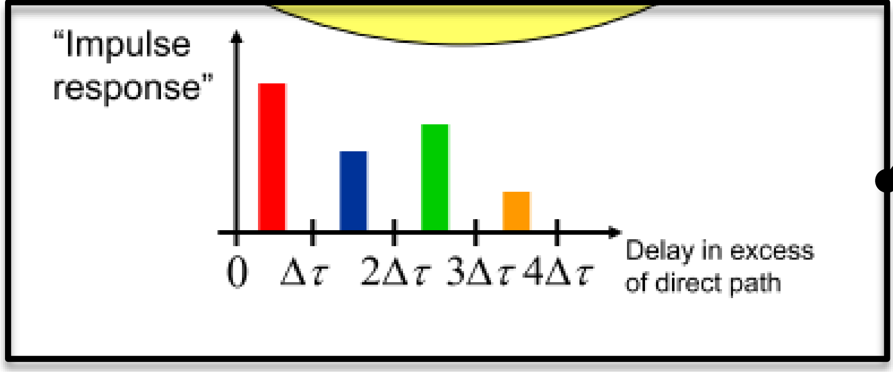
Delay dispersion: Many paths, a model



- ❑ Scatterers/Interacting objects placed anywhere along the plane
- ❑ Elipse 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

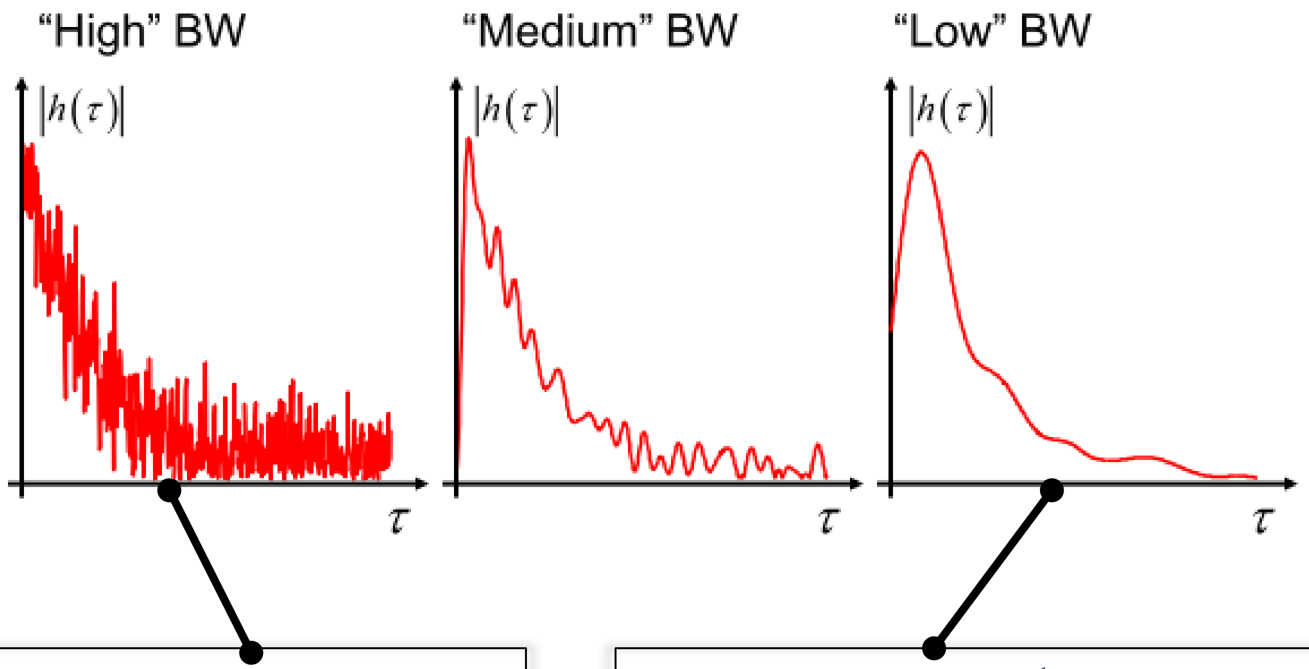
Delay dispersion: Many paths, a model





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.

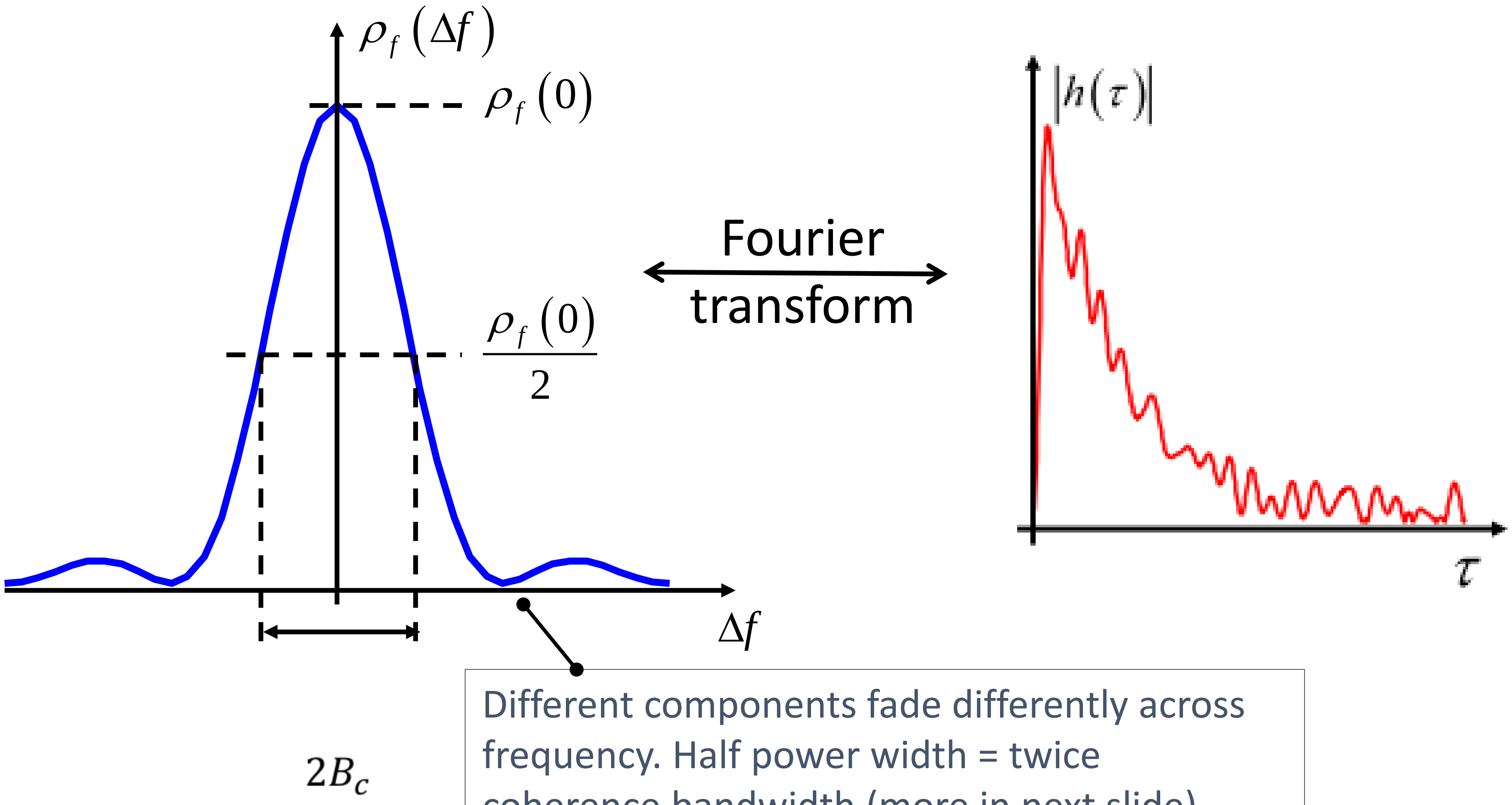
Narrowband vs. Wideband Channels Bandwidth Dependency



Much better resolvability of multipath components

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

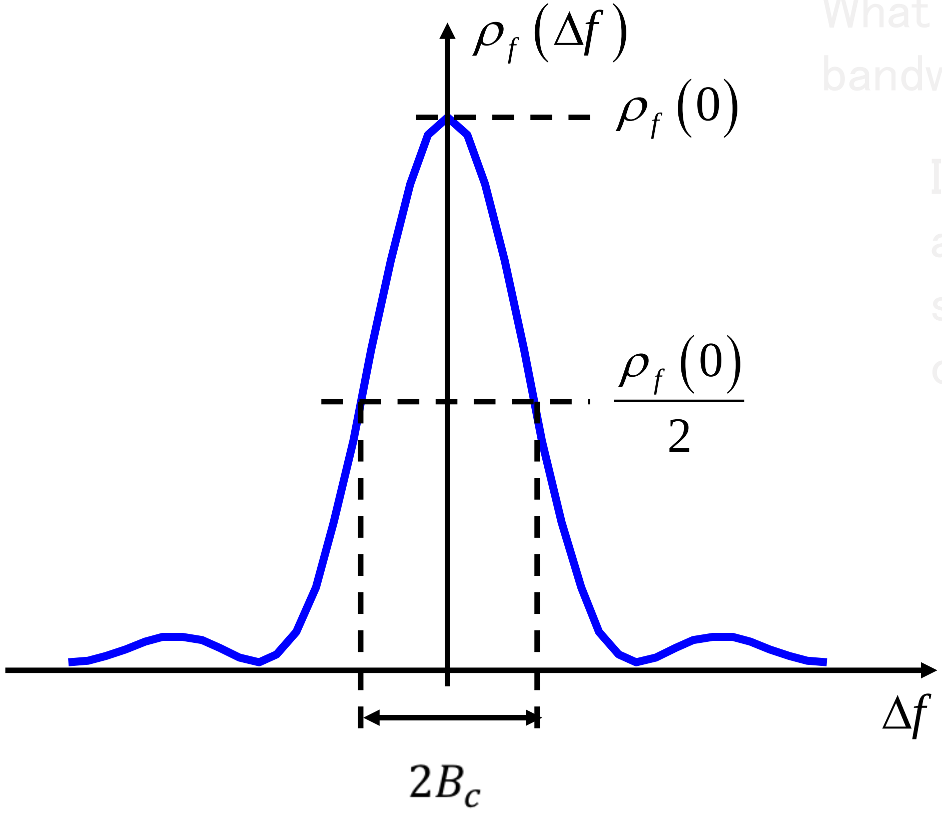
Power delay profile vs. frequency correlation function



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