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 cannot 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.
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

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

*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 of the channel
Maximum excess delay: \( \tau_{\text{max}} = \tau_3 - \tau_1 \)

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

Question!
Power delay profile over time
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.
Wireless Communication Channels

Narrowband vs. Wideband Channels

Bandwidth Dependency

- **Narrowband** if \(\frac{1}{B} \gg \tau_{\text{max}}\)
- Much better resolvability of multipath components

Diagram showing the differences in channel characteristics between narrowband and wideband channels.
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 $B_C$:

$$\rho_f(\Delta f)$$

What does the coherence bandwidth tell us?

It shows us over how large a bandwidth we can assume 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