

Wideband Models. Multipath Intensity Profile. Doppler Spectrum.

Lecture Outline

- Wideband Channel Models
- Scattering Function
- Multipath Intensity Profile, Delay Spread, and Coherence Bandwidth
- Doppler Power Spectrum, Doppler Spread, and Coherence Time

1. Wideband Channel Models

- In wideband multipath channels the individual multipath components can be resolved by the receiver. True if $T_m > 1/B$.
- If the components can be resolved then they can be combined for diversity gain (e.g. using an equalizer).

2. Channel Scattering Function:

- For deterministic channels, the scattering function is defined as the Fourier transform of $c(\tau, t)$ with respect to t .
- Typically $c(\tau, t)$ is unknown, so it must be characterized statistically.
- Since underlying process $c(\tau, t)$ is Gaussian and WSS, only need to characterize its mean and correlation, which is independent of time. We assume $c(\tau, t)$ has mean zero.
- Autocorrelation of $c(\tau, t)$ is $A_c(\tau_1, \tau_2; \Delta t) = A_c(\tau_1, \tau_2; \Delta t)\delta(\tau_1 - \tau_2) = A_c(\tau; \Delta t)$ since we assume channel response associated with different scatterers is uncorrelated.
- Statistical scattering function defined as $S(\tau, \rho) = \mathcal{F}_{\Delta t}[A_c(\tau, \Delta t)]$. This function measures the average channel gain as a function of both delay τ and Doppler ρ .
- $S(\tau, \rho)$ easy to measure empirically and is used to get average delay spread T_M , rms delay spread σ_τ , and Doppler spread B_d for empirical channel measurements.

3. Multipath Intensity Profile and Delay Spread

- Multipath intensity profile (delay power spectrum) defined as $A_c(\tau; \Delta t = 0) = A_c(\tau)$, i.e. the autocorrelation relative to delay τ at a fixed time.
- The average delay T_m and rms delay spread σ_τ are defined relative to $A_c(\tau)$. These parameters approximate the maximum delay of nontrivial multipath components.

4. Coherence Bandwidth

- The coherence bandwidth is defined relative to the Fourier transform of $A_c(\tau)$, given by $A_C(\Delta f) = \mathcal{F}[A_c(\tau)]$. Note that $A_C(\Delta f) = A_C(\Delta f, \Delta t = 0)$.
- Since $A_C(\Delta f)$ is the autocorrelation of a Gaussian process, multipath components separated by Δf_0 are independent if $A_C(\Delta f_0) \approx 0$.
- By the Fourier transform relationship, the bandwidth over which $A_C(\Delta f)$ is nonzero is roughly $B_c \approx 1/T_m$ or $B_c \approx 1/\sigma_\tau$ (can also add constants to these denominators).

- B_c defines the coherence bandwidth of the channel, i.e. the bandwidth over which fading is correlated.
- A signal experiences *frequency selective fading* or *ISI* if its bandwidth exceeds the coherence bandwidth of the channel.

5. Doppler Power Spectrum, Doppler Spread, and Coherence Time:

- Doppler power spectrum defined as the Fourier transform of $A_c(\tau = 0; \Delta t) = A_c(\Delta t)$, which is the autocorrelation of $c(t, \tau)$ for a fixed delay over time Δt .
- Specifically, the doppler power spectrum is $S_c(\rho) = \mathcal{F}[A_c(\Delta f = 0, \Delta t)]$, which measures channel intensity as a function of Doppler frequency.
- The maximum value of ρ for which $|S_c(\rho)| > 0$ is called the channel Doppler spread, which is denoted by B_d .
- By the Fourier transform relationship, $A_c(\Delta t) \approx 0$ for $\Delta t > 1/B_d$. Thus, the channel becomes uncorrelated over a time of $1/B_d$ seconds.
- We define the channel coherence time as $T_c = 1/B_d$. If the coherence time greatly exceeds a bit time, the signal experiences *error bursts*

Main Points

- Wideband models characterized by scattering function, which measures average channel gain relative to delay and Doppler.
- Scattering function used to obtain key channel characteristics of rms delay spread and Doppler spread, which are important for system design.
- Multipath delay spread defines the maximum delay of significant multipath components. Its inverse is the channel coherence bandwidth. Signals separated in frequency by the coherence bandwidth have independent fading.
- Doppler spread defines the channel's maximum nonzero doppler. Its inverse is the channel coherence time. Signals separated in time by the coherence time have independent fading.