# Wideband Fading Models Summary

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# Narrowband vs. Wideband Channels

Gist of the topic

- **Narrowband:**
  - Bandwidth small relative to delay spread
  - Multipath overlaps $\rightarrow$ flat fading, minimal ISI(*intersymbol interference*)
- **Wideband:**
  - Bandwidth large enough to resolve multipath
  - Causes frequency-selective fading and ISI

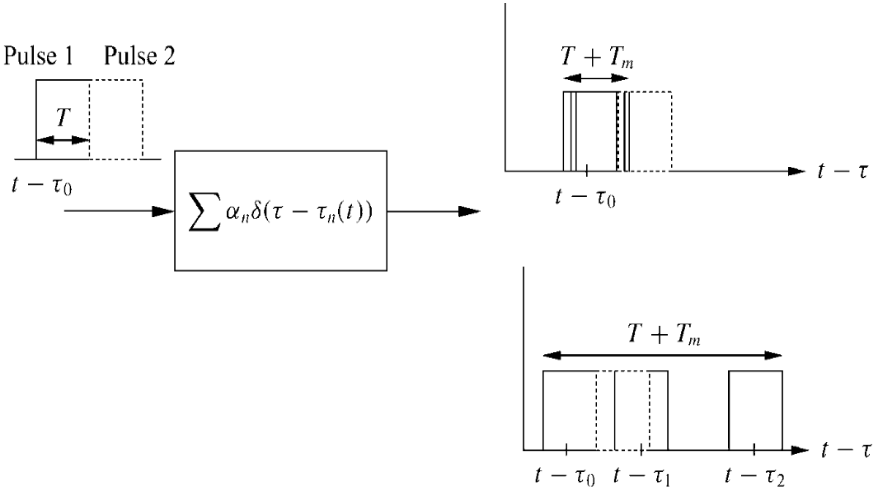


**Figure 3.11:** Multipath resolution.

## Time-Varying Channel Model

- Channel represented by impulse response $c(\tau, t)$
  - $\tau$: multipath delay
  - $t$: channel time variation
- Scattering function $S_c(\tau, \rho)$
  - $S_c(\tau, \rho)$ is fourier transform of impulse response with respect to $t$ called *deterministic scattering function*
  - Describes multipath energy over delay and Doppler

# WSSUS Channel Model

- **Wide-Sense Stationary (WSS)**:
  - Statistics depend only on time difference
  - $E[c(\tau, t)]$ is constant
  - $A_c(t_1, t_2)$ is only a function of $t_1 - t_2$
- **Uncorrelated Scattering (US)**:
  - Multipath components with different delays are uncorrelated
- Enables simplified channel analysis:
  - Power delay profile
  - Autocorrelation functions
  - Scattering function

# Power Delay Profile & Delay Spread

- Power delay profile $A_c(\tau)$: average power vs. delay
- it can be shown that $S_c(\tau, \rho) = \int A_c(\tau, \Delta t) e^{(-j2\pi\rho\Delta t)} d\Delta t$
- Metrics:
  - Mean delay spread $\mu_{T_m}$
  - RMS delay spread $\sigma_{T_m}$
- ISI becomes significant when:

$$T_s \lesssim \sigma_{T_m}$$

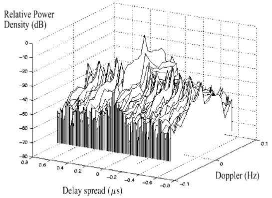


**Figure 3.12:** Scattering function.

# Coherence Bandwidth

- Coherence bandwidth:

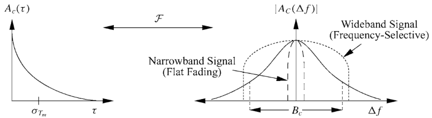


**Figure 3.13:** Power delay profile, rms delay spread, and coherence bandwidth.

- $A_C(\Delta f) = \int A_c(\tau) e^{-j2\pi\Delta f\tau} d\tau$

$$B_c \approx \frac{1}{\sigma_{T_m}}$$

- Describes frequency range with correlated fading
- If signal bandwidth:
  - $B \ll B_c \rightarrow$ flat fading
  - $B \gg B_c \rightarrow$ frequency-selective fading

# Doppler Spread & Coherence Time

- Caused by motion of transmitter/receiver
- Doppler spread $B_D$: max Doppler shift
- Coherence time:

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

- Higher speed $\rightarrow$ larger Doppler $\rightarrow$ smaller coherence time

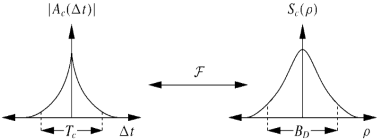


**Figure 3.14:** Doppler power spectrum, Doppler spread, and coherence time.

# Transform Relationships

- Delay–frequency duality via Fourier transforms
- Time correlation   Doppler spectrum
- Scattering function links:
  - Delay profile
  - Doppler spectrum
  - Frequency correlation
  - Time correlation

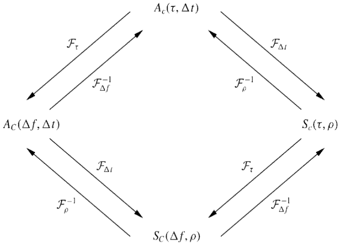


**Figure 3.15:** Fourier transform relationships.