

## Objective

Simulate and understand how a coaxial cable introduces dispersive distortion to a Wi-Fi-band signal. Use and compare two independent numerical approaches:

- **Method A:** Fourier-series / per-harmonic phase method. Decompose the input waveform into discrete frequency bins, apply the dispersive phase delay  $e^{j\phi(\omega)}$  to each bin, then reconstruct by inverse DFT.
- **Method B:** Frequency-domain filtering. Define a dispersive transfer function  $H(\omega) = A(\omega)e^{j\phi(\omega)}$  for the cable, multiply the input spectrum by  $H(\omega)$ , and inverse DFT.

## Problem Statement

### 1. Medium: Coaxial cable.

- Length:  $L = 100$  m.
- Nominal characteristic impedance:  $Z_0 = 50 \Omega$ .
- Phase velocity model:

$$v_p(\omega) = \frac{c}{\sqrt{\epsilon_r}} \left( 1 + \frac{\kappa}{\omega^2} \right),$$

where  $c$  is the speed of light,  $\epsilon_r \approx 2.1$  (typical dielectric), and  $\kappa$  is a small dispersion constant.

- Phase shift:  $\phi(\omega) = -\frac{\omega L}{v_p(\omega)}$ .
- Optionally include attenuation:  $A(\omega) = e^{-\alpha(\omega)L/2}$  (5% extra Mark)

## Input Waveforms

Two different input test signals must be used to study dispersive effects:

### (a) Gaussian-modulated pulse:

- Center frequency  $f_c = 2.4$  GHz.
- Gaussian envelope:

$$x_a(t) = \cos(2\pi f_c t) e^{-\frac{t^2}{2\sigma_t^2}},$$

where  $\sigma_t$  is chosen such that the  $-3$  dB bandwidth  $\Delta f \approx 20$  MHz.

- Purpose: Observe pulse broadening, group-delay dispersion, and peak reduction after propagation through the coaxial cable.

### (b) NRZ modulated sequence:

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- Bit sequence (random 0/1 stream) mapped to  $\{-1, +1\}$  polarity.
  - Bit rate:  $R_b = 10$  Mbps (corresponding bandwidth  $\sim 10$  MHz).
  - Carrier upconversion:

$$x_b(t) = \left( \sum_k b_k \cdot \text{rect}\left(\frac{t - kT_b}{T_b}\right) \right) \cos(2\pi f_c t),$$

where  $T_b = 1/R_b$  is the bit duration.

- Purpose: Observe inter-symbol interference (ISI), eye diagram distortion, and amplitude reduction after dispersive propagation.

## 2. Tasks:

- (a) Implement Method A and Method B for the chosen cable model.
- (b) Plot and compare:
  - Input vs. output in time domain (real and envelope).
  - Input vs. output spectra (magnitude and phase).
  - Group delay  $\tau_g(\omega) = -\frac{d\phi}{d\omega}$ .
- (c) Quantify:
  - Pulse broadening (RMS and FWHM).
  - Peak amplitude reduction.
  - Difference between Method A and Method B outputs (error norms).

## 3. Parameter sweeps:

- Vary dispersion strength  $\kappa$  (e.g. 0,  $10^{-19}$ ,  $10^{-18}$  s<sup>2</sup>).
- Vary cable length  $L$  (10 m, 50 m, 100 m).
- Vary signal bandwidth (5 MHz, 20 MHz, 40 MHz).

## 4. Analysis questions:

- Do the two methods produce identical results? Under what conditions might they differ?
- How does group-delay variation across the band affect Wi-Fi symbols?
- Which method is more efficient and numerically stable?
- What practical implications arise for Wi-Fi transmission through long coaxial cables (e.g. indoor distribution networks)?

## 5. An additional 10% marks will be awarded for any critical and important analysis results beyond the analysis questions provided