Wireless Channel Simulation Report

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Contents

1 Introduction

Wireless communication systems are essential for modern connectivity. This report details the simulation of key aspects of wireless channels, including:

- Path loss analysis.
- Fading analysis (Rayleigh and Rician).
- Multipath propagation effects.
- Bit Error Rate (BER) performance analysis for BPSK and QPSK.

The MATLAB-based simulation provides insights into the behavior of wireless channels under realistic conditions.

2 Simulation Parameters

The following parameters were used in the simulation:

- Frequency: $f = 2.4$ GHz.
- Speed of light: $c = 3 \times 10^8$ m/s.
- Reference distance: $d_0 = 10$ m.
- Path loss exponent: $n = 3$.
- Shadowing standard deviation: $\sigma_{\text{shadow}} = 4$ dB.
- Transmission power: $P_{\text{tx}} = 0$ dBm.

3 Path Loss Analysis

Path loss quantifies signal attenuation as a function of distance. The total path loss is modeled as:

$$PL(d) = PL(d_0) + 10n \log_{10}\left(\frac{d}{d_0}\right) + X_\sigma, \tag{1}$$

where X_σ represents shadowing effects.

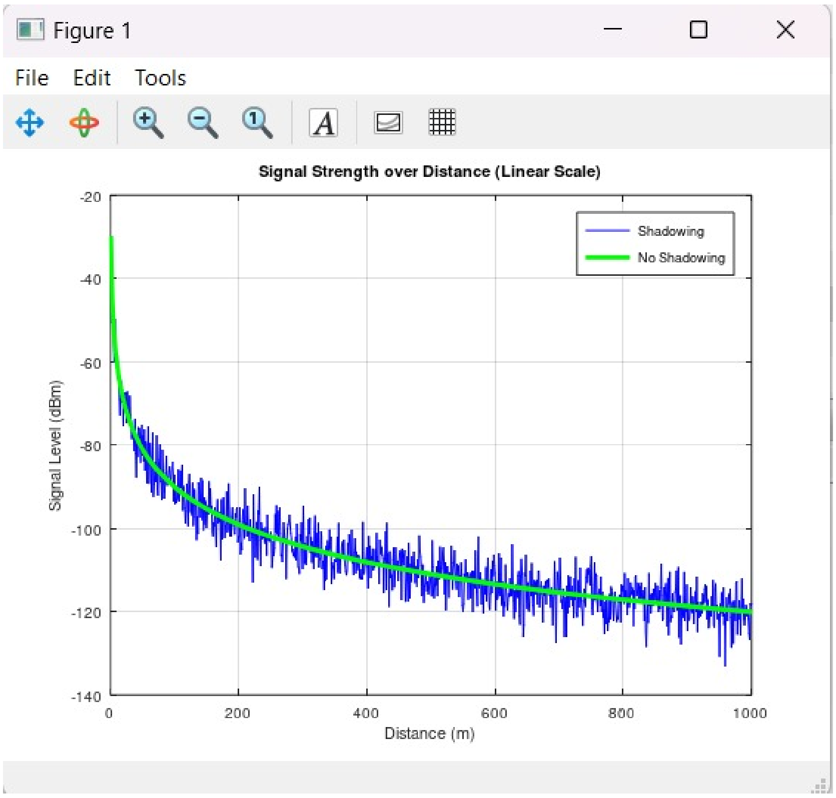

Figure 1: Signal Strength over Distance (Linear Scale)

4 Fading Analysis

Fading describes signal amplitude variations caused by multipath propagation.

4.1 Rayleigh Fading

Rayleigh fading occurs in environments with no dominant line-of-sight (LOS) component. Its probability density function (PDF) is:

$$f_R(r) = \frac{r}{\sigma^2} e^{-\frac{r^2}{2\sigma^2}}, \quad r \geq 0. \tag{2}$$

4.2 Rician Fading

Rician fading includes a dominant LOS component. Its PDF is:

$$f_R(r) = \frac{r}{\sigma^2} e^{-\frac{r^2+s^2}{2\sigma^2}} I_0\left(\frac{rs}{\sigma^2}\right), \quad r \geq 0, \tag{3}$$

where I_0 is the modified Bessel function of the first kind.

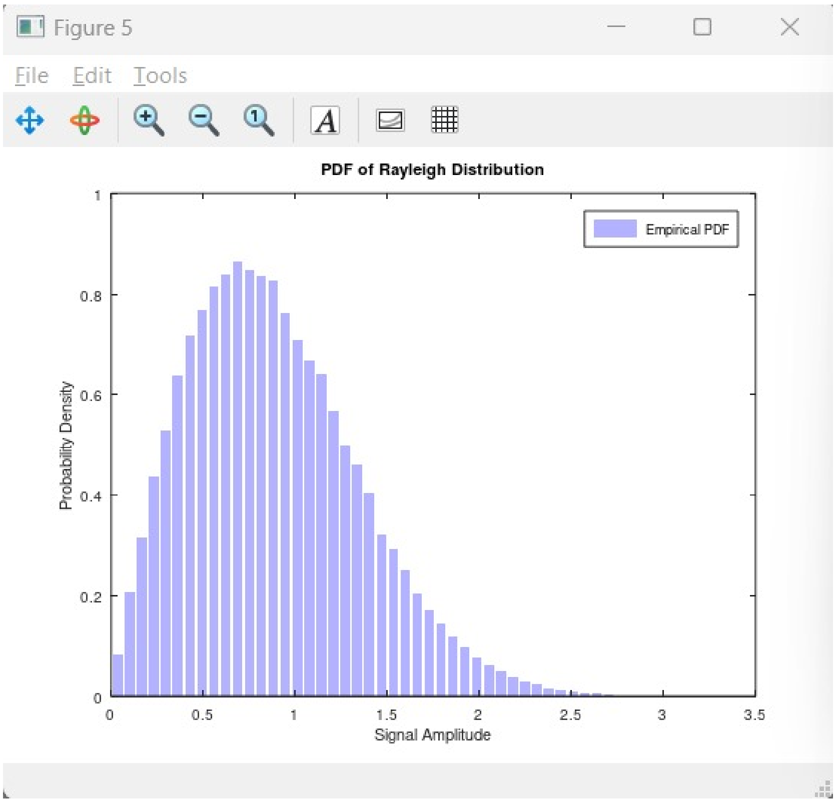

Figure 2: Rayleigh Fading Distribution

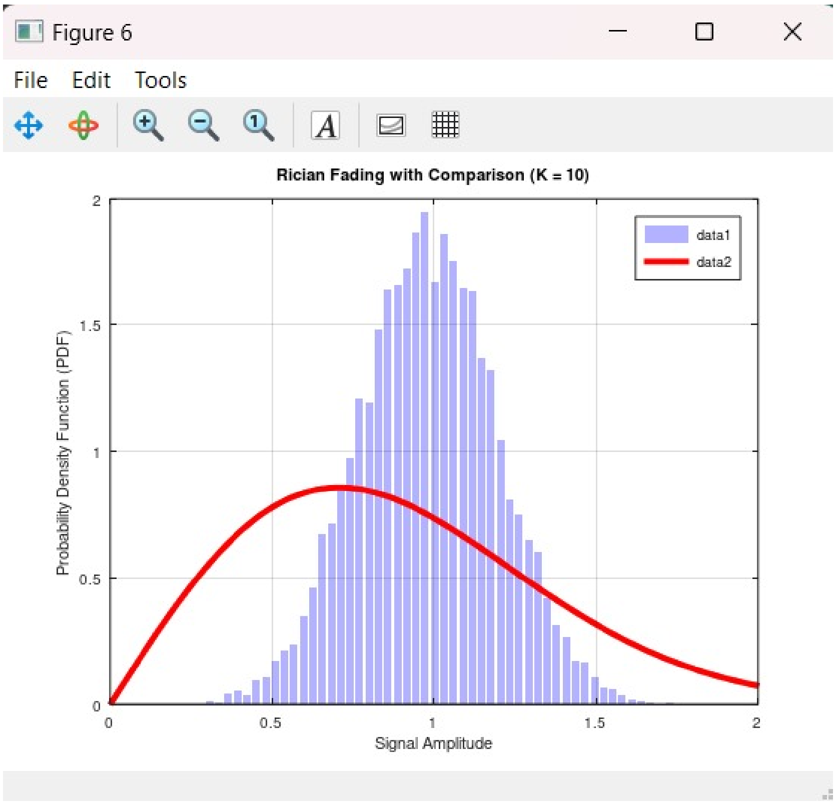

Figure 3: Rician Fading Distribution

5 Multipath Propagation

Multipath propagation involves signals arriving via multiple paths with different delays and amplitudes. The received signal is modeled as:

$$y(t) = \sum_{i=1}^{N} h_i x(t - \tau_i), \tag{4}$$

where h_i are fading coefficients, and τ_i are path delays.

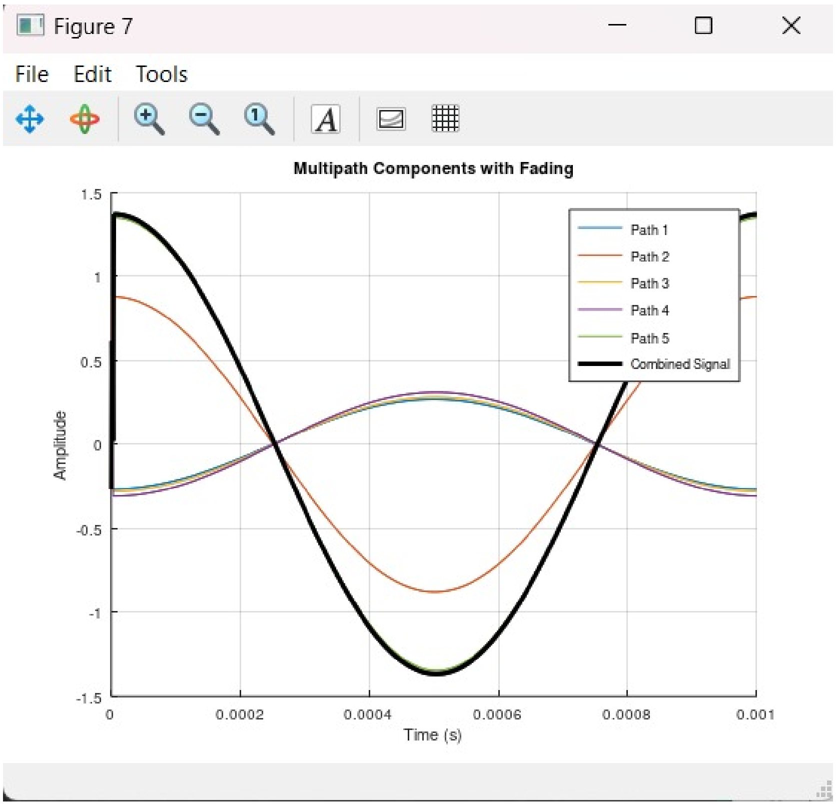

Figure 4: Multipath Components with Fading

6 Bit Error Rate Analysis

The BER evaluates the performance of modulation schemes under noise conditions.

6.1 BPSK

The BER for Binary Phase Shift Keying (BPSK) is given by:

$$P_b = Q\left(\sqrt{2\frac{E_b}{N_0}}\right), \tag{5}$$

where $Q(x)$ is the Q-function.

6.2 QPSK

The BER for Quadrature Phase Shift Keying (QPSK) is:

$$P_b = Q\left(\sqrt{\frac{E_b}{N_0}}\right) - \frac{1}{4}Q\left(\sqrt{\frac{E_b}{N_0}}\right)^2. \tag{6}$$

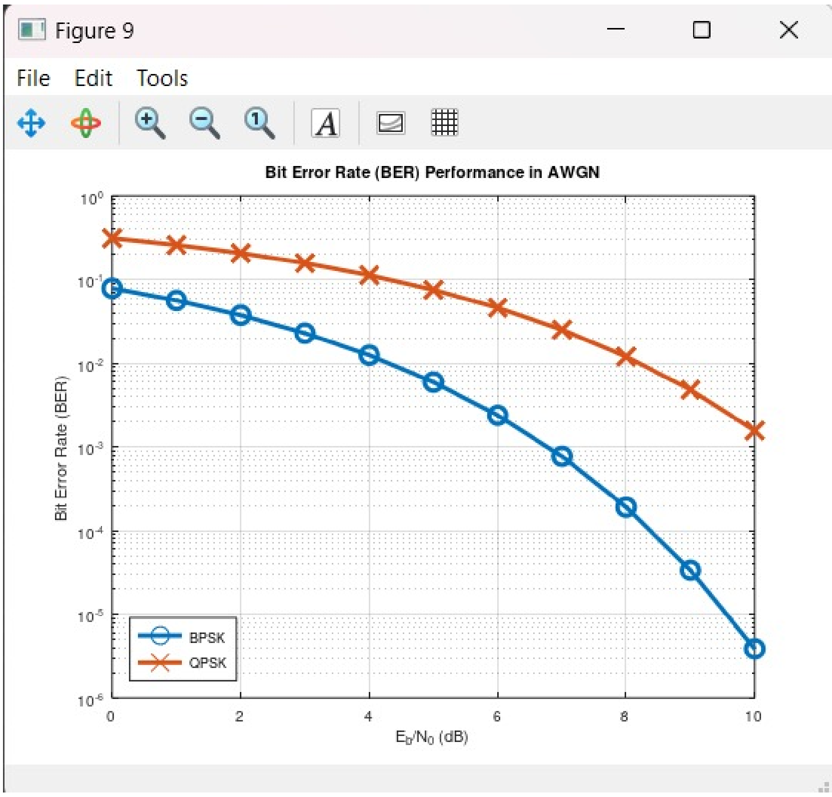

Figure 5: BER Performance for BPSK and QPSK

7 Results and Discussion

- Path loss results show significant attenuation with distance, amplified by shadowing and fading.
- Rayleigh fading demonstrates higher variability compared to Rician fading due to the absence of a LOS component.
- BER analysis confirms the superior noise performance of QPSK over BPSK at equivalent SNRs.

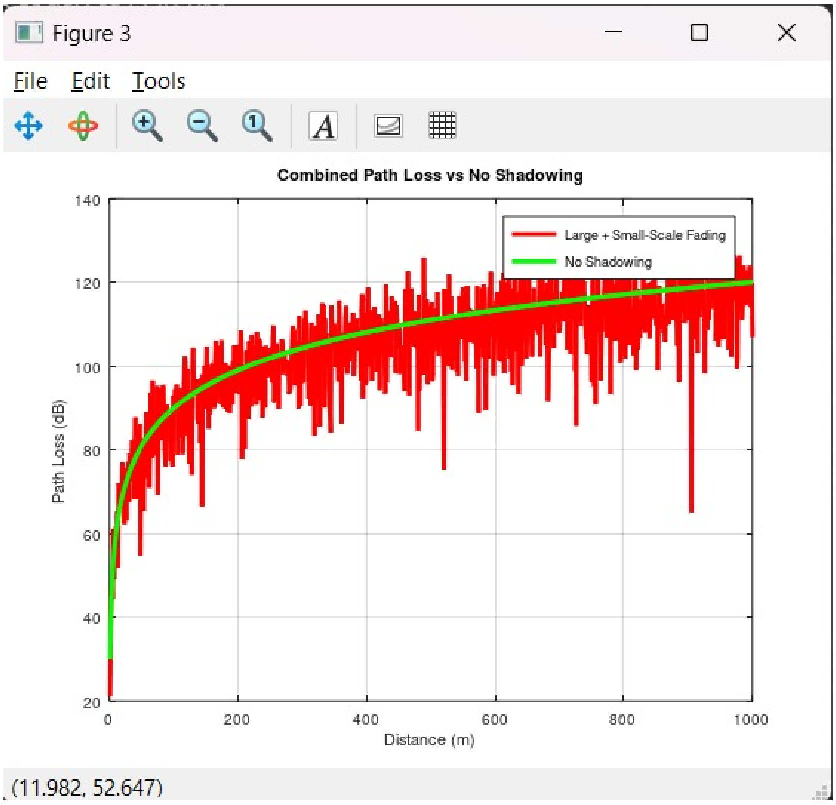

Figure 6: Combined Path Loss and Fading Effects

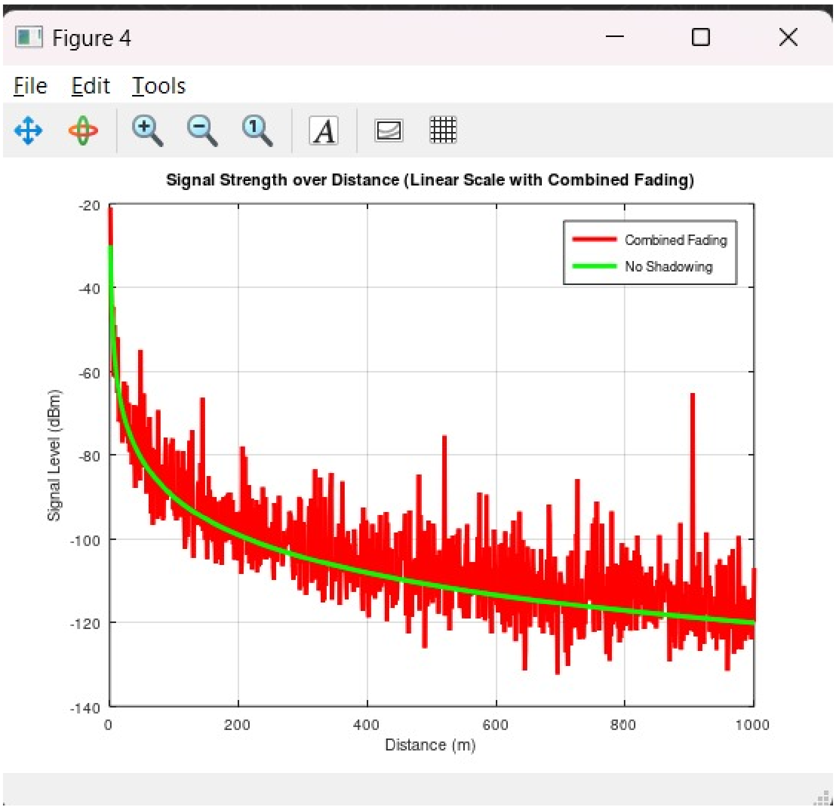

Figure 7: Original vs Received Signal

8 Conclusion

This report presented a comprehensive simulation of wireless channel effects, including path loss, fading, multipath propagation, and BER analysis. The results provide valuable insights into the challenges and performance of wireless communication systems.