Midterm Exam.

1. Consider a microcellular system where the channel is modeled as the simplified path loss model (K = 0 dB, path loss exponent = 3, reference distance d_0 = 1 m) and log-normal shadowing with σ = 8 dB. When the received power is lower than a minimum received power requirement $P_{\min}$, an outage event occurs. With the transmit power of 10 mW and $P_{\min}$ = -100 dBm, find the outage probability at 500 m.

2. Let a scattering function $S(\tau,\rho)$ be nonzero over $0 \le \tau \le 0.2$ ms and $-0.5 \le \rho \le 0.5$ Hz. Assume that the power of the scattering function is approximately uniform over the range where it is nonzero.
   (a) Calculate a coherence bandwidth, a coherence time.
   (b) Will this channel exhibit flat fading or frequency-selective fading for a typical voice channel with a 3 kHz? How about for a cellular channel with a 30 kHz bandwidth?

3. Assume that the receiver and transmitter know the channel side information. Also, when a received SNR is lower than γ_0, outage occurs.
   (a) Maximum outage capacity under truncated channel inversion policy
   (b) Optimal outage capacity with average power constraint

4. We explore the power penalty involved in going from BPSK to 16-PSK.
   (a) Find the minimum distance between constellation points in 16-PSK modulation as a function of signal energy E_s.
   (b) Find α_M and β_M such that the symbol error probability of 16-PSK in AWGN is approximately $P_s(\gamma_s) \approx \alpha_M Q\left(\sqrt{\beta_M \gamma_s}\right)$.
   (c) Find an approximation for the average symbol error probability of 16-PSK in Rayleigh fading in terms of $\overline{\gamma}_s$.
   (d) Convert the expressions for average symbol error probability of 16-PSK in Rayleigh fading to an expression for average bit error probability, assuming Gray coding.
   (e) Find the approximate value of $\overline{\gamma}_b$ required to obtain a BER of 10^{-3} in Rayleigh fading for BPSK and 16-PSK. What is the power penalty in going to the higher-level signal constellation at this BER?