University of Tehran, ECE
Wireless Communications, Spring 2020

Assignment Set #5

Adaptive Modulation and Coding

Problem 1 (problem 9.2 Goldsmith)

Consider a truncated channel inversion variable-power technique for Rayleigh fading with average SNR of $20\ dB$. What value of threshold corresponds to an outage probability of 0.1? What is the maximum size MQAM constellation that can be transmitted under this policy so that in non-outage, $P_b \approx 10^{-3}$?

Problem 2 (problem 9.4 Goldsmith)

Consider variable-rate $MQAM$ modulation scheme with just two constellations, $M = 4$ and $M = 16$. Assume a target P_b of approximately 10^{-3}. If the target cannot be met then no data is transmitted.

(a) Using the BER bound (9.7) find the range of γ values associated with the three possible transmission schemes (no transmission, $4QAM$, and $16QAM$) where the BER target is met. What is the cutoff γ_0 below which the channel is not used.
(b) Assuming Rayleigh fading with $\overline{\gamma} = 20\ dB$, find the average data rate of the variable-rate scheme.
(c) Suppose that instead of suspending transmission below γ_0, BPSK is transmitted for $0 \le \gamma \le \gamma_0$. Using the loose bound (9.6), find the average probability of error for this BPSK transmission.

Problem 3 (problem 9.7 Goldsmith)

In this problem we compare the spectral efficiency of non-adaptive techniques with that of adaptive techniques.

(a) Using the tight BER bound for $MQAM$ modulation given by (9.7), find an expression for the average probability of bit error in Rayleigh fading as a function of M and $\overline{\gamma}$.
(b) Based on the expression found in part (a), find the maximum constellation size that can be transmitted over a Rayleigh fading channel with a target average BER of 10^{-3}, assuming $\overline{\gamma} = 20\ dB$.
(c) Compare the spectral efficiency of part (b) with that of adaptive modulation shown in Figure 9.3 for the same parameters. What is the spectral efficiency difference between the adaptive and non-adaptive techniques?

Spectral efficiency = average

ظرفیت نمیذاریم چون فرض میکنیم که
ظرفیت برای کدینگ بهینه هس و ما
کدینگ بهینه نداریم و برای همین
spectral efficiency میگیم

Problem 4 (problem 9.9 Goldsmith)

Consider a discrete time-varying AWGN channel with four channel states. Assuming a fixed transmit power $\overline{P}$, the received SNR associated with each channel state is $\gamma_1 = 5\ dB$, $\gamma_2 = 10\ dB$, $\gamma_3 = 15\ dB$, and $\gamma_4 = 20\ dB$, respectively. The probabilities associated with the channel states are $p(\gamma 1) = .4$ and $p(\gamma 2) = p(\gamma 3) = p(\gamma 4) = 0.2$. Assume a target BER of 10^{-3}.

a) Find the optimal power and rate adaptation for continuous-rate adaptive MQAM on this channel.
b) Find the average spectral efficiency with this optimal adaptation.
c) Find the truncated channel inversion power control policy for this channel and the maximum data rate that can be supported with this policy.

Problem 5 (Adaptive coded modulation)

Consider a wireless communication system that uses 16-QAM modulation with 4 different available coding schemes with coding rates of r = 1 (uncoded), r = 3/4, r = 1/2, and r = 1/4. The coding scheme is chosen adaptively based on the CSI feedback that we receive from RX (assume a perfect CSI at TX). The channel fading is due to shadowing which has a log-normal distribution with average SNR of 10 dB and standard deviation of 8 dB if the TX power is 1Watt.

For a satisfactory data transmission we need a BER 10^{-4} for each of these coding schemes and their gap (at $P_b = 10^{-4}$) are 8, 4, 2, and 2 respectively. We do not send any data if we cannot meet the target BER.

Find the best strategy of transmission, average data rate, and probability of using each coding scheme for the following scenarios:

a) C**onstant TX power** of 1Watt with on-off capability.

b) C**ontinuous TX power** (as we like), **but** a limited average power of 1 Watt.

c) F**ixed TX power for each coding scheme** (as we like), **and** limited average power of 1 Watt.

Hint : Formulate the optimization problems using Q function,

$$\int_a^b f_x(x)dx = Q\left(\frac{a-m}{\sigma}\right) - Q\left(\frac{b-m}{\sigma}\right) \text{ ; where } f_x(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(x-m)^2}{2\sigma^2}}$$

$$\int_a^b e^{-\alpha x} f_x(x)dx = e^{-\alpha m + \frac{(\alpha\sigma)^2}{2}} \left(Q\left(\frac{a-m}{\sigma} + \alpha\sigma\right) - Q\left(\frac{b-m}{\sigma} + \alpha\sigma\right) \right)$$

and use constrained optimization functions of Matlab.