Mid-Semester Test

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Acronyms: AM: Amplitude modulation, FM: Frequency modulation, PCM: Pulse code modulation, QPSK: quadrature phase shift keying, SNR: signal-to-noise power ratio, SQNR: signal-to-quantization noise power ratio, SCPC: single channel per carrier, FDM: frequency division multiplexing, ISI: intersymbol interference, FEC: forward error correction, ARQ: automatic request for retransmission, RRC: root raised-cosine, AWGN: additive white Gaussian channel, UL: uplink, DL: downlink, EIRP: effective isotropic radiated power, QAM: quadrature amplitude modulation.

Part-I: Multiple choice questions (8 points)

Note: Each question carries 1 point. Write the right answer in your answer book.

1. Which of the following code is used in satellite communication systems?

A. Golay code B. Reed-Solomon code C. Hamming code D. Huffman code

2. A satellite is observed at an elevation angle of 30° by a vehicle moving at speed of 60 miles per hour. The Doppler shift at 1.1 GHz in the received carrier is approximately

A. 86 Hz B. 860 Hz C. 43 Hz D. 430 Hz

3. Consider a SCPC-FM-FDMA speech transmission system with peak frequency deviation of 9.1 KHz. The bandwidth of the system is given by

A. 15 KHz B. 25 KHz C. 35 KHz D. 40 KHz

4. Consider (n,k) linear block code. If R_b is the message bit rate at the input of the encoder, the coded bit rate at the output of the encoder is

A. $\frac{nR_b}{k}$ B. $\frac{kR_b}{n}$ C. nkR_b D. $(k+n) \times R_b$

5. An analog signal is uniformly sampled and quantized. Each sample is encoded and transmitted using PCM. The system has SQNR of 56 dB. The number of bits used for encoding is

A. 10 B. 9 C. 11 D. 8

6. Spectral efficiency is a measure of 'utilization of limited frequency spectrum (bandwidth)'. The unit of Spectral efficiency is

A. bits/Hz B. bits/sec/Hz C. baud/Hz D. bits/sec

7. A satellite link has an RF channel bandwidth of 1.5 MHz. Both transmitter and receiver use RRC filter with roll-off factor of 0.5. The bit rate of the link if 8-PSK is employed is

A. 1 Mbps B. 2 Mbps C. 4 Mbps D. 3 Mbps

8. Match the following:

(i). Raised-cosine filter	A. Channel capacity less than bandwidth
(ii). Power limited	B. Minimize ISI
(iii). Bandwidth limited	C. Redundant bits
(iv). Error detection/correction	D. Channel capacity greater than bandwidth

Part-II: True or False (2 points)

Note: Each question carries $\frac{1}{2}$ point. Just indicate 'T/F' ('T' for True statement; 'F' for false statement.).

1) For SNR improvement, pre-emphasis and de-emphasis are employed in FM systems.

TABLE I: Data pertaining to Part III - Problem 2.

Quantity	Value
UL EIRP	90 dB
UL loss	200 dB
UL sky temperature	300 K
Satellite gain	100 dB
Satellite noise figure	5 dB
Satellite $\frac{G}{T^\circ}$	-40 dB
Satellite bandwidth	1 MHz
DL loss	190 dB
DL receiver $\frac{G}{T^\circ}$	50 dB
DL receiver bandwidth	1 MHz
Boltzmann's constant	$1.38 \times 10^{-23}\ J/^\circ K$

2) Figure of merit (FOM) of an analog communication systems is the ratio of input SNR to output SNR.

3) FEC by Turbo codes enhance reliability of deep space communication.

4) Purpose of interleaving in satellite communication systems is to spread out burst errors.

Part III: Solve the following.

1. Consider a 1.8 KW HPA and a 21 m cassegrain reflector antenna whose gain is 60 dB at 14 GHz. The loss of the waveguide that connects the HPA to the feed is 1.8 dB. Compute the following:

a). Fraunhofer distance (the distance which provides the limit between near field and far field) ? [2 points]

b). Earth station EIRP in dBW. [2 points]

2. [UL-DL system]

Given the UL-DL satellite communication system. The carrier is transmitted to the satellite, amplified, and then retransmitted. Compute the following, using the data given in the table:

(i). CNR_{UL} in dB (2 points) (ii). CNR_{DL} in dB (2 points) (iii). Effective CNR at the receiver in dB (1 point) (iv). Approximate average BER when QPSK is used (assume coherent reception) (1 point) (v). Approximate average BER when implementation margin of 1.8 dB is required (1 point).

3. [Maximum bit-rate and spectral efficiency]

A satellite transponder has a bandwidth of 36 MHz. Earth stations use RRC filters with roll-off factor of 0.45. What is the maximum bit rate that can be sent through this transponder with

a). QPSK [1 point] b). 256-QAM [1 point] c). Compute spectral efficiency for both a) and b). [2 points]

4. Recall Shannon-Hartley's law for AWGN channel.

a). As bandwidth $B \to \infty$, channel capacity will approach finite value. What is that limiting capacity in terms of received SNR? [2 points] (Note that $\lim_{n\to 0}(1+n)^{\frac{1}{n}} = e$.)

b). For received SNR of 10 dB, what is the limiting capacity in bps? [1 point]

5. Describe the following in just one sentence. [2 points]

a). FEC b). ARQ c). Code concatenation d). Interleaving

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Answers

Part I

1. B 2. A 3. B 4. A 5. B 6. B 7. D 8. $(i) \to B$, $(ii) \to A$, $(iii) \to D$, $(iv) \to C$

Part II

1. T 2. F 3. T 4. T

Part III

1. (a). 41.16 KM.

(b). $10 * \log_{10}(1800) + 60 - 1.8$ = 90.75 dB.

2. (i) (Refer to class notes) $\text{CNR}_{\text{UL}} = \frac{P_{\text{us}}}{P_{\text{un}}}$. The noise power $P_{\text{un}} = KT_{eq}B = -138.93$ dB. P_{us} is nothing but EIRP of the uplink. Thus, $\text{CNR}_{\text{UL}} = 90 - 200 + 138.93 = 28.9$ dB.

(ii) $\text{CNR}_{\text{DL}} = 90 - 200 + 100 - 190 + 50 + 168.60 = 18.6$ dB.

(iii) $\text{CNR}_{\text{eff}} = 18.2$ dB.

(iv) $Q(\sqrt{18.2}) = Q(4.26) = 9.94 \times 10^{-7}$.

(v) $Q(\sqrt{16.4}) = Q(4.05) = 2.56 \times 10^{-5}$.

3. a). 49.65 Mbps.

b). 198.62 Mbps.

c). 1.38 bits/sec/Hz.

d). 5.52 bits/sec/Hz.

4. a). Let the received SNR is denoted by $\gamma = \frac{\mathcal{S}}{\mathcal{N}}$, where '$\mathcal{S}$' is the signal power and $\mathcal{N}$ is the noise power. The noise power is N_0B, where N_0 is one-sided noise PSD and B is the bandwidth.

Limiting capacity $C = 1.44\frac{S}{N_0} = 1.44\ \gamma B$ bps. (Note that $B \to \infty$, not equal to ∞.)

b). Limiting capacity $C = 14.4\ B$ bps.

(What is spectral efficiency?)

5. a). Forward error correction (FEC): Process of correcting errors in the received data using error correcting codes, such as block codes or convolutional codes.

b). Automatic retransmission request (ARQ): Protocol that sends retransmission request to the sender whenever errors are detected in the received data blocks.

c). Code concatenation: Placing two different error correcting codes in series.

d). Interleaving: Process of rearranging information such that data read-into a matrix row-wise, and read-out column-wise.