Mid-Semester Test

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Course : EEE G522/Advanced Satellite Communication DATE: Oct. 12th, 2017. Test duration: 90 Mins. Max. points: 30.

Part I: Answer the following. Show key steps. Highlight final answers in rectangular boxes. Avoid overwriting. Simplify your answer to the extent possible.

Q. 1. Uplink (UL) and Downlink (DL) Budget [7 points]

Consider the uplink (UL) and the downlink (DL) of a satellite communication system. Using the data given in the table, compute the following.

TABLE I: Data pertaining to satellite link budget- Problem 1.

Quantity	Value
UL EIRP	120 dBm
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	1000 KHz
DL loss	190 dB
DL receiver $\frac{G}{T^\circ}$	50 dB
DL receiver bandwidth	1000 KHz
Boltzmann's constant	$1.38 \times 10^{-23}\ J/^\circ K$

(i). Uplink CNR (CNR_{UL}) in dB. (2 points) (ii). Downlink CNR (CNR_{DL}) in dB. (2 points)

(iii). Effective CNR at the earth station receiver in dB. (1 point)

(iv). Approximate average bit error rate (BER) when quadrature phase shift keying (QPSK) is used (assume coherent reception). (1 point)

(v). Approximate average BER when implementation margin of 1.8 dB is required (1 point).

Q. 2. Different orbit satellites and round trip time (RTT) delays [7 points]

Based on the altitude from Earth's surface, satellite orbits are classified as the following: LEO (low earth orbit, $99.42 - 1242.74$ miles), MEO (medium earth orbit, $1242.74 - 12427.43$ miles), and GEO (geostationary earth orbit, 22236.39 miles).

a). Compute the RTT of information transmitted between a satellite and the Earth for LEO, MEO, and GEO satellites. Assume that the speed of light is 3×10^8 m/s. [3 points]

b). If the maximum acceptable RTT for a voice transmission system is 29 ms, which of these satellite communication systems would be acceptable for two-way voice communication? [1 point]

Note: Give all calculations and answers up to two decimal places.

c). With respect to the following quantities, differentiate LEO, MEO, and, GEO satellites using a table.

i). Orbital period ii). Propagation loss iii). Coverage on Earth [3 points]

Q. 3. Time Division Multiple Access [6 points]

Consider a TDMA network that consists of 9 earth stations. The TDMA network shares a single transponder equally and employs QPSK modulation. The frame duration is 9 ms, the preamble time per station is 18 μs, and guard intervals of 9 μs are used between bursts. Transmission burst rate is 90 million symbols per second. Compute the following:

a). Data burst duration for each burst station in microsecond. [1 point]

b). Transmitted bit rate in each burst? [1 point]

c). Data rate of each earth station in bits per second (bps) [1 point]

d). Number of 64 Kbps voice channels that each TDMA earth station can transmit. [1 point]

e). If the earth stations transmitted without guard intervals and preambles, what is the maximum number of speech channels per station? [1 point]

f). Define efficiency of TDMA as '(message bits sent / maximum number of bits that could be sent) $\times 100\%$.' What is the efficiency of the TDMA system? [1 point]

Q. 4. Mission to the planet Saturn [3 points]

The distance from Earth to the planet Saturn is 1.2×10^9 km at the time a NASA space probe communicates back to an earth station using a 28 GHz carrier. The minimum received power is -135 dB. Suppose that the satellite's transmit amplifier maximum output power is 500 W and the earth station's receiver dish antenna is 20 times larger than the transmitter antenna, write the link budget equation and compute the minimum gain of the satellite dish antenna. [1 + 2 points]

Q. 5. Orbit Characteristics [3 points]

A satellite is in an elliptical orbit with a perigee of 1000 KM and an apogee of 9000 KM. Assume earth radius as 6400 KM. Note that when the satellite is at perigee, the eccentric anomaly is zero. Compute the following:

a). Orbital period. b). Mean daily motion. c). Eccentricity.

Part-II: True or False (4 points)

Note: Each question carries 1 point. Indicate 'T/F' ('T' for True statement; 'F' for false statement.). Give proper justification in one or two sentences.

1) Frequency hopping spread spectrum technique is used in DS-CDMA.
2) Intermodulation (IM) noise occurs in FDMA.
3) Beam-width of a circular aperture antenna is inversely proportional to $\frac{D}{\lambda}$, where 'D' is diameter and λ is operating wavelength.
4) The degree to which the transmitter output is decreased below its peak output is called backoff.

□ END OF QUESTION PAPER □

Answers

Part I

Q. 1. ans. (i). $\text{CNR}_{\text{UL}} = \frac{P_{\text{us}}}{P_{\text{un}}}$. 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.

If $\frac{G}{T^{\circ}}$ is taken as the Figure of merit, we get $\text{CNR}_{\text{UL}} = 18.9$ dB.

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

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

Alternate answer: 15.74 dB

(iv) $Q(\sqrt{10^{1.82}}) \approx 10^{-16}$.

(v) $Q(\sqrt{10^{1.64}}) \approx 10^{-11}$.

Q. 2. ans. a). GEO: RTT $= \frac{2\times 35786\times 10^3}{c} = 0.2386$ sec. or 238.6 millisecond.

MEO: $\text{RTT}_{\min} = 0.0133$ sec. or 13.3 millisecond.

LEO: $\text{RTT}_{\min} = 0.0011$ sec. or 1.1 millisecond.

b). LEO satellites has delay 1.1 millisecond $<$ 29 millisecond. So, LEO satellite communication systems would be acceptable for two-way voice communication. However, MEO satellite with altitude less than 4300 Km may also be used.

c). Comparison table is shown below.

Orbit	Orbital Period	Propagation Loss	Coverage on Earth
GEO	23 hrs 56 mins 4 sec	Very High	3 satellites
MEO	6-12 hrs	Medium	10-15 satellites
LEO	90 mins	Low	48 satellites

Q.3. ans. (a) 973 μs b). 180 Mbps c). 19.46 Mbps d). 304 channels e). 312 channels f). 97.3%.

Q.4. ans. For link budget equation, refer to class notes. Gain $G_t = 64$ dB.

Q.5. ans. semi-major axis, $a = 11400$ KM.

a) 201.8892 minutes or 3.3648 hours b). 7 revolutions per day

c). Eccentricity $e = 0.35$.

Part II

1. F. DS-CDMA uses direct sequence spread spectrum technique, not frequency hopping.

2. T. Intermodulation noise occurs due to the intermodulation products generated by a non-linear power amplifier. This occurs in FDMA.

3. T. Recall that gain is inversely proportional to beam-width and also directly promotional to $\frac{D}{\lambda}$.

4. T. Backoff is required to operate the HPA in linear region.