COMPREHENSIVE EXAMINATION

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Course: Advanced Satellite Communication (EEE G522)

DATE: Dec. 9^{th} 2017 (AN)   MAX. POINTS: 40   MAX. TIME: 3 hrs.

Important instructions:

- This is an open book test. Two textbooks, class notes/lecture slides, calculator, and, Q function table are allowed.
- You can answer questions in any order. But, provide answers to all subparts within a question at one place.
- Show all key steps. Give all your answers with proper units. Highlight final answer in rectangular box.
- In all sketches/illustrations, please include labels and figure caption. Incomplete figures will not get full credit.
- Over-written answers will not be re-checked.

Q. 1. [Satellite Receiver's Figure of Merit] [7 points]

Consider a 12.0 GHz satellite receiver (Rx). It consists of an RF front end with gain 30 dB and noise temperature 18 K, a mixer with gain 10 dB, and noise temperature 360 K. Furthermore, it has an IF amplifier stage with gain 18 dB and noise temperature 900 K. Assume that the reference temperature is equal to 290 K.

Compute the following.

i). Noise factor of RF stage (F_1), Mixer (F_2), and, IF amplifier (F_3). [3 points]

ii). Overall noise factor and overall noise figure. [2 points]

iii). Compute the equivalent noise temperature in dBK. [1 point]

iv). If the antenna gain is 45 dB, what is the figure of merit of the Rx. [1 point]

Q. 2. [Effective SNR] [7 points]

Consider an ADC in a navigation receiver. Recall that ADC process comprises of sampling, quantization, and encoding. Let SNR_q represent SNR resulting from the quantization noise. Further, let SNR_n represent SNR resulting from the thermal noise.

i). Derive an expression for the effective SNR, denoted by SNR_{eff}, in terms of SNR_q and SNR_n. Show all key steps. Give your remarks on the final expression. [4 points]

ii). If $\text{SNR}_n = -20\ dB$ and $3-$bit uniform quantization is employed, compute SNR_{eff}. [2 points]

iii). Comment on the SNR degradation. [1 point]

Q. 3. [GPS: Dilution of Precision (DOP)] [5 points]

DOP parameters provide a quantitative contribution of the user-satellite geometry on the error. Three DOPs exist. They are position dilution of precision (PDOP), time dilution of precision (TDOP), and, geometric dilution of precision (GDOP). The relationship among the three DOPs is given by $\text{GDOP}^2 = \text{TDOP}^2 + \text{PDOP}^2$. Furthermore, $\text{PDOP}^2 = \text{HDOP}^2 + \text{VDOP}^2$, where, HDOP and VDOP are horizontal and vertical DOPs, respectively. Consider the error budget shown in the table. Assume that the errors are independent of each other. Effectual error is defined as the square root of sum of squared values of the errors.

Error	Value
Ephemeris error	1.5 m
Clock error	1.5 m
Ionospheric error	5.0 m
Tropospheric error	1.5 m
Receiver noise	1.5 m
Multipath etc.	$\sqrt{2}$ m

Compute the following:

(i) Effectual error in meters. [2 points]

(ii). Suppose that HDOP is equal to 3 and VDOP is equal to 4, determine the error in position estimate which is the product of PDOP and effectual error. [2 points]

iii). If TDOP is 12 , determine GDOP. [1 point]

Q. 4. Answer the following. [8 points]

i). Discuss on the variation of bit error rate (BER) of a satellite link with respect to key satellite link parameters. [2 points]

ii). Consider a digital satellite transmission system. In it, the average received power is 10 dBm when binary phase shift keying (BPSK) is used. The bit duration is 100 μs. Furthermore, the noise power spectral density N_0 is 0.1 μJ. If optimum filtering is used, compute the BER. (Note: Use Q function table.) [2 points]

iii). In a satellite downlink (DL), the transmission rate is 61 Mbps, and the required $\frac{E_b}{N_0}$ at the ground station receiver is 39.5 dBm. Compute the required $\frac{C}{N_0}$. [2 points]

iv). A digital satellite link which uses BPSK modulation is required to operate with a BER of no more than 10^{-5}. Furthermore, the implementation margin is 2.0 dB. Compute the required effective $\frac{E_b}{N_0}$ in dB. Figure 1 plots BER as a function of bit energy-to-noise spectral density ratio. [2 points]

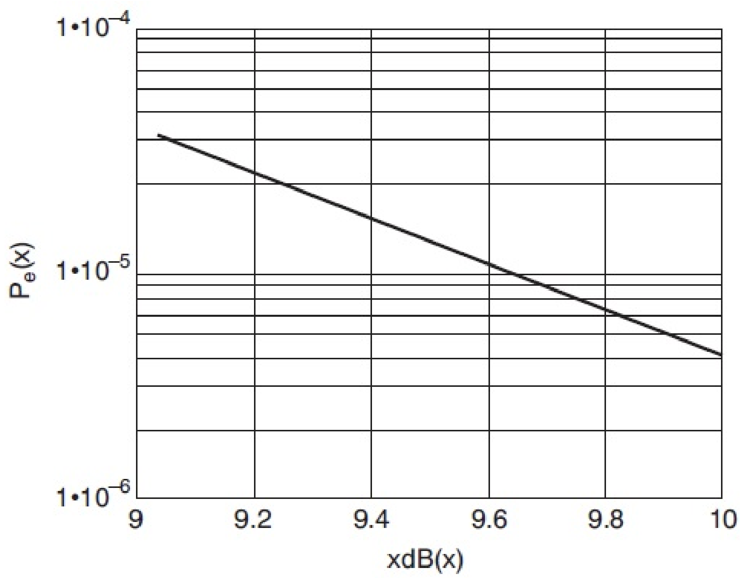

Fig. 1: Plot for Q.4.(iv).

Q. 5. Using an illustration, describe the following in just TWO meaningful and complete sentences. [8 points]

a). Pre-emphasis (PE) and de-emphasis (DE). Application of PE and DE in analog satellite communication systems.

b). Processing gain in direct sequence spread spectrum CDMA (DS-CDMA) and DS-CDMA applications in satellite systems.

c). Code concatenation and its importance in satellite communications.

d). Application of carrier sense multiple access with collision detection (CSMA/CD) in GEO satellite data networks.

Q. 6. TRUE or FALSE [5 points]

Note: Each question carries 1 point. Indicate ‘T/F’ (‘T’ for True statement; ‘F’ for false statement.). Justify with just one or two sentences.

(a) Software defined radio (SDR) based global navigation satellite system eliminates the need for hardware replacement. It is an ideal platform for development, test of algorithms, and integration with other devices.

(b) Consider the Loo’s statistical channel model. In it, if attenuation due to shadowing is kept constant, we get Rayleigh distribution.

(c) Cooperative and cognitive satellite systems can not only improve spectrum utilization but also enhances coverage.

(d) Pico/nano satellite have larger life span than Geo-synchronous satellites.

(e) Optical satellite link works reliably in clear-air conditions. Otherwise, the link will no longer be reliable.

□ END OF QUESTION PAPER □

Answers

1. i). $F_1 = 1.0621$, $F_2 = 2.2414$, $F_3 = 4.1034$.

ii). Noise factor = 1.0637 $\Rightarrow$ noise figure = 0.2680 dB.

iii). $T_e = 18.4730$ K $\Rightarrow T_e(dB/K) = 12.6654$ K.

iv). FOM = 33.3346 dBK

2. i). $\text{SNR}_{\text{eff}} = \left(\text{SNR}_n{}^{-1} + \text{SNR}_q{}^{-1}\right)^{-1}$. Depending on the values of the two SNRs, we can decide which one dominates more, i.e., thermal noise or quantization noise.

ii). For $3-$ bit quantization, we have $\text{SNR}_q = 6.02n + 1.76 = 19.82$ dB = 95.9401. So, $\text{SNR}_{\text{eff}} = -20.0005$.

iii). Degradation due to fewer quantization bits is negligible.

3. i). Effectual error = 6 m.

ii). PDOP = 5. So, position error estimate = 30 m.

iii). GDOP = 13.

4. i). BER depends on $\frac{E_b}{N_0}$ which is a function of effective CNR and noise bandwidth. Furthermore, effective CNR depends on uplink and downlink CNR plus other degrading effects such as intermodulation (IM) noise if FDMA is used.

ii). $E_b = 10^{-6}$ J and BER = 3.9×10^{-6}.

iii). $\frac{C}{N_0} = 87.35$ dBHz.

iv). Effective $\frac{E_b}{N_0} = 11.65$ dB.

5. a). FM was popular in analog satellite communications. In frequency modulation (FM), pre-emphasis, which is performed before modulator, boosts high frequency signal components, and, de-emphasis, which is performed after demodulator, reduce excessive noise at high frequencies so as to improve SNR.

b). Processing gain in direct sequence spread spectrum (DSSS) is the ratio of chip rate to the data rate or the ratio of data bit duration to the chip duration. DSSS modulation is used in DS-CDMA which has applications in MSAT, GPS.

c). Code concatenation is used for error control in satellite communication systems (e.g. deep space). In it, two different codes, namely, Reed-Solomon code and convolutional code, are used with interleaving.

d). CSMA cannot be applied in satellite data networks because it is not possible for earth stations to do carrier sense on the up-link due to the point to point nature of the link. A carrier sense at the down-link informs the earth stations about potential collisions that may have occurred 270 ms ago (for GEO), and such delays are not practical for implementing CSMA/CD protocols.

For illustrations refer to lecture slides/course text book.

6. i). TRUE ii). FALSE iii). TRUE iv). FALSE v). TRUE

Refer to course seminars' slides for justification.