COMPREHENSIVE EXAMINATION

Instructor-in-charge: B. Sainath, 2210-A, Electrical and Electronics Eng. Dept., BITS Pilani.
Course No./Title : EEE F472/Satellite communications
DATE: Dec. 24^{th}, 2022. Test duration: 180 Mins. Max. Points: 40.

(*Note*: You may use standard results or formulae by stating them explicitly. Highlight final answers in boxes. Simplify your response to the extent possible. Use notation consistently. Provide key intermediate steps.)

Q. I. Various satellite uplink and downlink parameters/ quantities are presented in the following table.

Quantity	Value
UPLINK	
Frequency (GHz)	14
Ideal antenna gain (aperture $= 1\ m^2$)	?
Earth station EIRP (dBmW)	97.1
Path loss (dB)	208.5
Slant range (Km)	?
Transponder figure of merit (dB/K)	2.5
Noise PSD (dBW/Hz)	?

Quantity	Value
DOWNLINK	
Frequency (GHz)	12
EIRP (dBmW)	68
Path loss (dB)	206.6
Slant range (Km)	?
ES antenna efficiency	0.62
ES antenna gain (diameter 1.8 m)	?
Figure of merit (dB/K)	21
Noise PSD (dBW/Hz)	?

Answer the following: (Boltzmann's constant = 1.38×10^{-23} $(J/^{\circ}K)$.) (***Note:*** Round-off final answers to one decimal place. Provide all the answers in the form of a table differentiating the uplink and the downlink quantities.)

a). Determine the "**?**" quantities in the tables. [6 points]

b). i) Uplink carrier power-to-noise PSD ratio (dB-Hz). ii). Downlink carrier power-to-noise PSD ratio (dB-Hz). iii) If carrier power-to-interference plus intermodulation power density ratio is 81 dB, compute the (approximate) overall carrier power-to-noise PSD (dB-Hz). [3 points]

Q. II. Consider the following information about a TDMA frame:

1) TDMA frame length is 15 millisecond and burst rate 108 Mbps.
2) Consider 12 earth stations transmit two traffic bursts (i.e., a total of 24 traffic bursts) in the frame plus two reference bursts.
3) The length of the carrier and clock recovery sequence is 360 bits.
4) The length of the unique word and the order wire channel are 54 bits and 540 bits, respectively.
5) The management channel, the transmit timing channel, and the service channel have 270 bits, 360 bits, and 36 bits, respectively.
6) The Guard time duration is 0.889 microsecond. Note that this Guard time is required for each reference burst and traffic burst.

*Determine the "**?**". Redraw the complete table with all the final values.* [1 + 1 + 2 + 1 + 1 + 2 + 1 points]

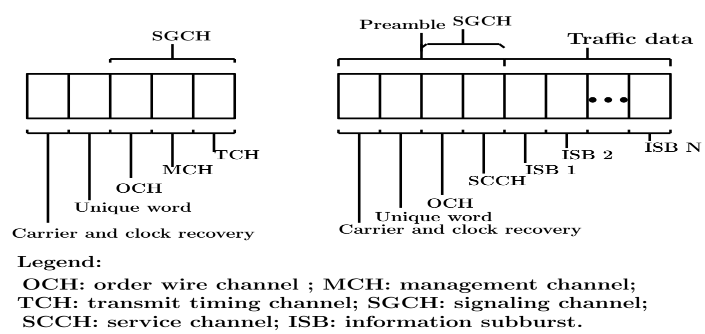

Fig. 1: Pertaining to Q. 2.TDMA burst structure: (Left) Reference burst; (Right) Traffic burst.

Quantity	Value
Number of bits in one reference burst preamble	?
Number of bits in one traffic burst preamble	?
Total number of overhead bits (per frame)	?
Total number of bytes in a frame	?
TDMA Frame efficiency	?
Number of bits in a 15−ms frame fora a voice subburst	?
Maximum no. of PCM voice channels carried in a frame	?

Fig. 2: Pertaining to Q. 2.

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Q. III. i). Consider the following data for a GPS:

a). Consider a GPS that uses a C/A code. The carrier-to-interference plus noise power ratio for one GPS C/A code signal with a finite number of interfering signals is -20.1 dB. Suppose that the signal power to noise power ratio of the correlated C/A signal is 10 dB. Assuming an ideal correlation, determine the number of stages in the linear feedback shift register. [1 point]

b). Compute the approximate i) RMS timing error, and ii) positioning error if the noise bandwidth is 10 MHz. Assume $c = 2.99792458 \times 10^8$ m/s. [2 points]

ii). Consider a C/A code GPS receiver at the geographic south pole, coordinates $(0, 0, -z_p)$, where z_p is positive (Km). Four GPS satellites are required for position estimation. Let the estimated diameter of the earth is approximately 12716 Km. Let the product of the clock offset, and the speed of light is equal to 1.4989624×10^4 Km. At the time instant that the measurement is made, the satellites have coordinates $\mathcal{S}_1 = (0, -d_y, -d_z)$, $\mathcal{S}_2 = (0, d_y, -d_z)$, $\mathcal{S}_3 = (d_y, 0, -d_z)$ $\mathcal{S}_4 = (0, 0, D_z)$. The corresponding measured time delays for the C/A code sequences from the satellites S_1, S_2, S_3 and S_4, are 0.12102731 second, 0.12102731 second, 0.12102731 second, 0.11738995 second, respectively. Compute d_y, d_z, D_z in Km. [6 points]

Q. IV. Consider a four-beam MSAT network that uses CDMA. Let $\frac{\mathcal{E}_b}{N_0}$ denote the bit energy to noise PSD ratio and let $\frac{\mathcal{E}_b}{\mathcal{N}_0}$ denote the bit energy to noise plus jamming PSD ratio. Consider the following: i) The bit rate to CDMA spread bandwidth ratio $= \frac{1}{127}$. ii) Multipath reflection and polarization interference factor $= 1.2$. iii) voice activity factor $= 0.375$. iv) Interbeam interference factor $= 1.1$. v) Multibeam frequency reuse factor $= 2$. vi) CDMA noise bandwidth $= 0.9B_s$. *Answer the following:*

a). Compute the CDMA MSAT network spectral efficiency when $\frac{\mathcal{E}_b}{\mathcal{N}_0} = 5$ dB and $\frac{\mathcal{E}_b}{\mathcal{N}_0} << \frac{\mathcal{E}_b}{N_0}$.

b). i). Compute the CDMA MSAT network spectral efficiency when $\frac{\mathcal{E}_b}{\mathcal{N}_0} = 5$ dB and $\frac{\mathcal{E}_b}{N_0} = 10$ dB.

ii). Determine the number of simultaneous users in the network. [2 + 2 + 1 points]

c). i). Consider the MSAT shadow fading scenario. Derive an analytical expression for the outage probability p_{out} of the path that undergoes shadow fading with probability 1. Assume threshold $\mathcal{P}_{\text{th}}$ (dB) and average received power is $\overline{P}_r$ (dB). *Note:* Express the final answer in terms of $Q-$function and complementary error function (erfc(.)).

[3 points]

ii). Note that the received power (in dB) of the shadowed path is Gaussian distributed, that is, $\mathcal{S}, \text{dB} \sim \mathcal{N}(0, \sigma^2_{\mathcal{S},\text{dB}})$. Compute p_{out} for shadow fading scenario when the threshold power is -10 dB, $\overline{P}_r = 0$ dB, and $\sigma_{\mathcal{S},\text{dB}} = 6$ dB. *Note:* Use the formula obtained in (c)(i).

[1 point]

Q. V. Valid or Invalid (4 points) *Note: Write down Valid/Invalid. Justify your response.*

1) Global positioning system (GPS) uses two types of codes, namely, C/A code and P code. However, both codes provide the same positioning accuracy.
2) Consider 1000-bit packets transmitted over a channel operating at a speed of 100 kbits/s. When one considers GSO satellite channels, the propagation delay is a relatively large multiple of the packet transmission time.
3) A Ku-band satellite uplink has a carrier frequency of 14.125 GHz and carries a symbol stream at 16 Msps. The transmitter and receiver have ideal RRC filters with a roll-off factor of 0.25. The frequency range of the transmitted signal is RF 14.115 GHz to 14.135 GHz.
4) A disadvantage of forward error correction (FEC) in satellite links is the requirement for more bandwidth in the satellite transponder.

ALL THE BEST!