University of New Mexico

Electrical and Computer Engineering Department

ECE535 Satellite Communications

Summer 2025, Exam II Version A

July 26, 2025, Time: 120 minutes

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- **This exam is open book open notes.**
- **Show all your steps and write the proper equations and units.**
- **If you are using MATLAB provide the code labeled with the problem number.**
- **No cooperation among classmates is allowed.**

Academic dishonesty is a violation of the UNM Student Code of Conduct. Students suspected of academic dishonesty will be dismissed from the exam and referred to disciplinary action in accordance with university procedures.

Problems Number	Possible Points	Actual Points
1- Solar arrays and Production of power during eclipses	10	
2- DBS satellite service and the overall gain for cascaded amplifiers	10	
3- Carrier-to-noise ratio for FDMA system and frequency reuse	10	
4- Carrier-to-noise ratio with system noise temperature and CDMA concepts	10	
5- Uplink and downlink frequencies and the combined C/N_0 ratio	10	
Total	50	

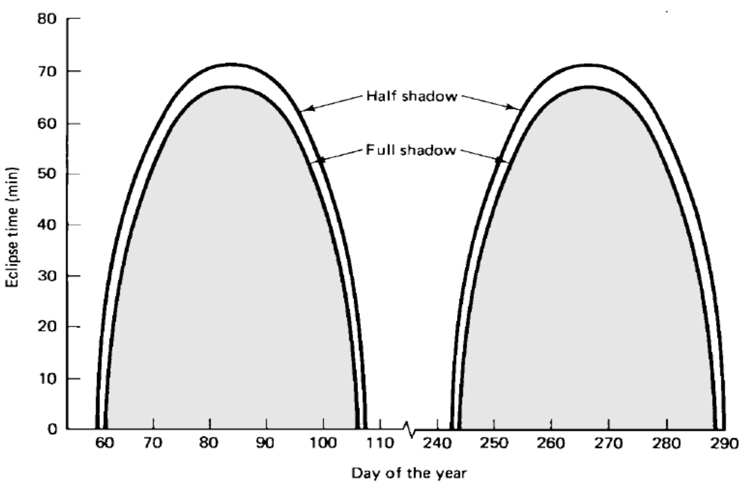
<u>Professor: Tarief Elshafiey</u>

Problem 1 (10 Points)

(A) Explain why some satellites employ cylindrical solar arrays, whereas others employ solar-sail arrays to produce primary power. State the typical power output to be expected from each type. Why is it necessary for satellites to carry batteries in addition to solar-cell arrays?

Some satellites use cylindrical solar arrays because they're compact and provide continuous power as the satellite spins, making them ideal for spin-stabilized systems. These arrays typically produce lower power, around 100–500 watts. In contrast, solar-sail or panel arrays can be pointed directly at the Sun, making them more efficient for 3-axis stabilized satellites and capable of generating 1–20 kilowatts or more. Despite using solar cells, satellites also carry batteries to supply power during eclipse periods when they pass through Earth's shadow and can't generate electricity from sunlight.

(B) Explain the following figure. How to overcome the eclipses in driving satellite energy?

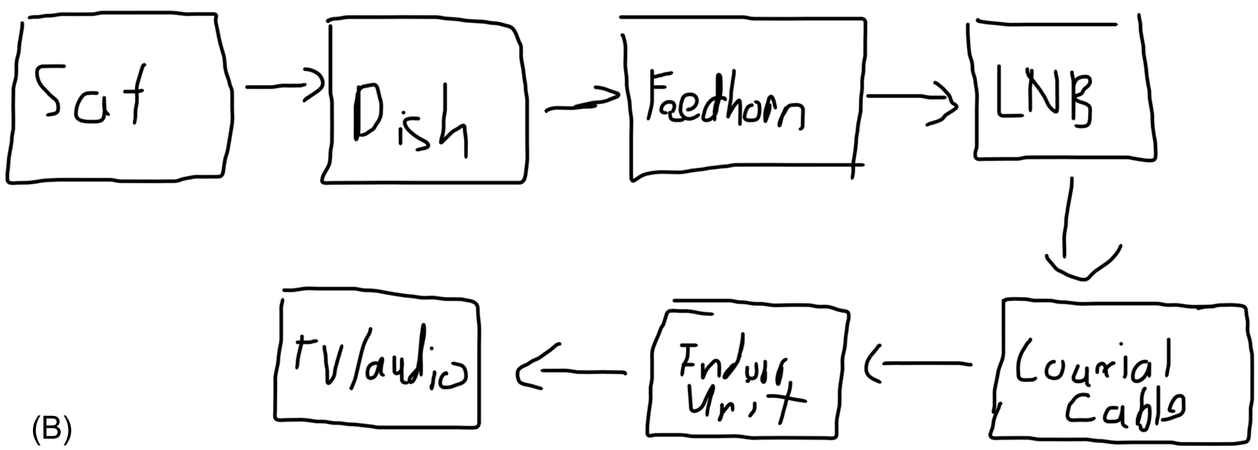


The figure shows how eclipse time for a satellite change throughout the year, with two peaks around the equinoxes. During these times, the satellite passes into Earth's shadow during each orbit, experiencing either full or partial loss of sunlight. This results in reduced or no power generation from the solar panels. The duration of these eclipses can reach over an hour, depending on the time of year. To maintain continuous operation, satellites rely on rechargeable batteries that store energy while the panels are exposed to sunlight. These batteries supply power during eclipse periods to keep essential systems running.

Problem 2 (10 points)

(A) Explain what is meant by DBS service. Hand sketch the block diagram showing a home terminal for DBS TV/FM reception. What are the frequency bands assigned to America.

Direct Broadcast Satellite (DBS) service is a system that delivers TV and radio signals directly from a satellite to users at home using a small parabolic dish. It operates mainly in the Ku-band, with downlink frequencies from 12.2 to 12.7 GHz and uplink from 17.3 to 17.8 GHz in the U.S. A typical home setup includes a dish, a low-noise block converter (LNB), and an indoor receiver connected to a TV. The LNB amplifies and converts the high-frequency signal to a lower one for processing. DBS systems also use circular polarization to reduce interference and often compress digital signals for efficient use of bandwidth.



(B)

(I) For three cascaded amplifiers with gains G_1, G_2, and G_3 and effective noise temperatures T_{e1}, T_{e2}, and T_{e3}, derive a system noise temperature referred to input, $T_{s,i}$.

$$T_{s,i} = T_{e1} + \frac{T_{e2}}{G_1} + \frac{T_{e3}}{G_1\, G_2}$$

(II) Two amplifiers are connected in cascade, each having a gain of 15 dB and a noise temperature of 190 K. Calculate (a) the overall gain and (b) the effective noise temperature referred to input.

$$G_1 = G_2 = 10^{\frac{15}{10}} = 31.62$$

$$G_{\text{total(dB)}} = 15 + 15 = 30 \text{ dB}$$

$$G_{\text{total}} = G_1 \times G_2 = 31.62 \times 31.62 = 1000$$

$$T_{s,i} = T_{e1} + \frac{T_{e2}}{G_1}$$

$$T_{s,i} = 190 + \frac{190}{31.62} = 190 + 6.01 = 196.01 \text{ K}$$

Problem 3 (10 points)

(A) A satellite transponder has a bandwidth of 36 MHz and a saturation EIRP of 25 dBW. The earth station receiver has a G/T ratio of 30 dB/K, and the total link losses are 196 dB. The transponder is accessed by FDMA carriers with 3-MHz bandwidth, and 6-dB output backoff is employed. Calculate the downlink carrier-to-noise ratio for single-carrier operation and the number of carriers which can be accommodated in the FDMA system. Compare this with the number which could be accommodated if no backoff were needed. The carrier-to-noise ratio determined for single-carrier operation may be taken as the reference value, and it may be assumed that the uplink noise and intermodulation noise are negligible.

$$\mathrm{EIRP}_{\mathrm{actual}} = 25 - 6 = 19\,\mathrm{dBW}$$
$$10\ \log_{10}(k) = -228.6\,\mathrm{dB}$$
$$10\ \log_{10}(3 \times 10^{6}) = 64.77\,\mathrm{dB}$$
$$C/N = 19 - 196 + 30 + 228.6 - 64.77 = 16.83\,\mathrm{dB}$$
$$N_{\text{no backoff}} = \frac{36}{3} = 12$$
$$\text{Power ratio} = 10^{-6/10} = \frac{1}{4}$$
$$N_{\text{with backoff}} = 12 \times \frac{1}{4} = 3$$

(B) Explain what is meant by frequency reuse and briefly describe two methods by which this can be achieved.

Frequency reuse is a technique used in satellite communications to efficiently use limited spectrum by transmitting the same frequency in different ways without causing interference. One method is spatial separation using spot beams, where the satellite focuses its transmission into multiple narrow beams aimed at different geographic regions. Since these beams don’t significantly overlap, the same frequencies can be used in separate areas. Another method is polarization reuse, where the satellite transmits signals with different polarizations—such as vertical and horizontal or left-hand and right-hand circular—on the same frequency. Because the receiver can distinguish between these polarizations, interference is minimized, allowing for increased capacity within the same bandwidth.

Problem 4 (10 points)

(A) In CDMA (code-division multiple access), individual carriers may be present simultaneously with the same frequency, but each carrier carries a unique code waveform that allows it to be separated from all others at the receiver. Assume you have two users: user 1 data is 00 and code 0101 and user 2 data are 10 and code 0011. (a) Calculate user 1 and user 2 spread messages. (b) Create the composite waveform that each user receives. (c) Show how to retrieve user 1 and user 2 data.

$$EIRP_{\text{actual}} = 25 - 6 = 19 \text{ dBW}$$

$$10 \log_{10}(k) = -228.6 \text{ dB}$$

$$10 \log_{10}(3 \times 10^6) = 64.77 \text{ dB}$$

$$C/N = 19 - 196 + 30 + 228.6 - 64.77$$

$$C/N = 16.83 \text{ dB}$$

$$N_{\text{no backoff}} = \frac{36}{3} = 12$$

$$\text{Power ratio for backoff} = 10^{-6/10} = \frac{1}{4}$$

$$N_{\text{with backoff}} = 12 \times \frac{1}{4} = 3$$

(B) Explain what is meant by carrier-to-noise ratio. At the input to a receiver the received carrier power is 400 pW and the system noise temperature is 450 K. Calculate the carrier-to-noise ratio in dBHz. Given that the bandwidth is 36 MHz, calculate the carrier-to-noise ratio in decibels.

The carrier-to-noise ratio, or C/N, describes how strong a received signal is compared to the background noise in a communication system. It's an important way to judge how clearly a signal can be received and decoded. A higher C/N means better signal quality and fewer errors.

$$P_c = 400 \times 10^{-12} = 4.00 \times 10^{-10} \text{ W}$$
$$k = 1.38 \times 10^{-23} \text{ J/K}$$
$$T = 450 \text{ K}$$
$$C/N_0 = \frac{P_c}{k\,T}$$
$$C/N_0 = \frac{4.00 \times 10^{-10}}{1.38 \times 10^{-23} \times 450} = 6.44 \times 10^{10}$$
$$C/N_0 \text{ (dBHz)} = 10 \log_{10}(6.44 \times 10^{10}) = 108.09 \text{ dBHz}$$
$$B = 36 \times 10^6 \text{ Hz}$$
$$C/N = C/N_0 - 10 \log_{10}(B)$$
$$C/N = 108.09 - 10 \log_{10}(36 \times 10^6) = 108.09 - 75.56 = 32.53 \text{ dB}$$

Problem 5 (10 points)

(A) Explain why the uplink and downlink frequencies are different. What are the differences between satellite and mobile communications in terms of uplink and downlink frequencies? Justify your answers with equations and figures as needed.

Uplink and downlink frequencies are different to avoid interference between strong signals sent from Earth and weaker signals returned from the satellite. Uplinks use higher frequencies since ground stations can transmit more power, while downlinks use lower frequencies to reduce loss for receivers. This is supported by the free-space path loss formula:

$$L = 20 \log_{10}\left(\frac{4\pi d f}{c} \right)$$

As frequency f increases, path loss L also increases. So, it's more efficient to use higher frequencies for uplinks and lower ones for downlinks. This same idea applies in mobile systems, though with smaller frequency gaps.

(B) In a link budget calculation at 12 GHz, the free-space loss is 206 dB, the antenna pointing loss is 1 dB, and the atmospheric absorption is 2 dB. The receiver G/T ratio is 19.5 dB/K, and the receiver feeder losses are 1 dB. The ERIB is 45 dBW. Calculate the carrier-to-noise spectral density ratio.

$$L_{\text{total}} = 206 + 1 + 2 + 1 = 210 \text{ dB}$$
$$C/N_0 = EIRP - L_{\text{total}} + G/T - 10 \log_{10}(k)$$
$$C/N_0 = 45 - 210 + 19.5 - (-228.6)$$
$$C/N_0 = 83.1 \text{ dBHz}$$