W3USR Activity 3: Satellite Communication

EE 451: Communications Systems

OPTIONAL EXTRA CREDIT ACTIVITY

Name: ______________________________ **Date:** ________________

Objectives

1. Understand satellite orbit types and their communication characteristics
2. Calculate Doppler shift for LEO satellite passes
3. Observe or participate in amateur satellite communication
4. Analyze satellite link budgets
5. Connect satellite communication to course concepts

Part 1: Satellite Fundamentals (20 points)

Task 1.1: Orbit Type Comparison

Complete the comparison table:

Orbit Type	Altitude (km)	Period	Latency	Coverage	Example Satellites
LEO	200-2000				
MEO	2000-35786				
GEO	35786				
HEO					

Task 1.2: Amateur Satellite Resources

Visit https://amsat.org/status and identify active amateur satellites:

Satellite	Uplink Freq	Downlink Freq	Mode	Status
ISS				
SO-50				
AO-91				
RS-44				

Question 1.1 (10 points)

a) Why do LEO satellites require tracking antennas while GEO satellites use fixed dishes?

b) What is the maximum line-of-sight distance for a LEO satellite at 400 km altitude when directly overhead? When at 10° elevation?

c) Why is the ISS orbit inclined at 51.6° rather than being equatorial?

Your Answer:

[Write your answer here]

Part 2: Doppler Shift Calculation (25 points)

Background

For a satellite moving at velocity v, the Doppler shift is:

$$\Delta f = f_0 \cdot \frac{v_r}{c}$$

where v_r is the radial velocity component toward the observer.

Maximum Doppler occurs when satellite is at horizon, minimum (zero) at closest approach.

Task 2.1: Calculate Doppler for ISS

The ISS orbits at approximately: - Altitude: 420 km - Orbital velocity: 7.66 km/s - Downlink frequency: 145.80 MHz

Calculate:

1. Maximum radial velocity (at horizon): ___________ km/s
2. Maximum Doppler shift: ___________ Hz
3. Total Doppler swing (AOS to LOS): ___________ Hz

Task 2.2: Doppler Compensation

During a pass, the receiver must compensate for Doppler. Plot the expected Doppler curve:

Time from AOS	Elevation	Doppler Shift (Hz)
0 min (AOS)	~0°	
2 min	~20°	
4 min (TCA)	~60°	
6 min	~20°	
8 min (LOS)	~0°	

Sketch the Doppler curve:

```
        +3000 |
              |
Doppler  0 Hz |--------------------
(Hz)          |
        -3000 |
              +------------------------
               AOS    TCA    LOS
                  Time →
```

Question 2.1 (15 points)

a) If you don't correct for Doppler on a 145 MHz FM satellite, what happens to the received audio?

b) Why is Doppler correction more critical for higher frequencies?

c) A satellite downlink is at 2.4 GHz. What is the maximum Doppler shift for a LEO satellite? Why is this problematic for data communications?

d) How do digital modes like FT8 handle Doppler shift on satellite passes?

Your Answer:

[Write your answer here]

Part 3: Satellite Pass Observation (25 points)

Task 3.1: Predict Satellite Pass

Use a tracking tool (N2YO.com, Heavens-Above, GPREDICT, or phone app) to find upcoming passes:

Satellite: ______________________________

Pass Details:

Parameter	Value
Date/Time (Local)	
AOS Time	
AOS Azimuth	
Maximum Elevation	
TCA Time	
LOS Time	
LOS Azimuth	
Pass Duration	

Screenshot 3.1: Pass prediction from tracking software.

[Insert screenshot]

Task 3.2: Observe/Listen to Pass

If live observation is possible, record your observations:

Time	Azimuth	Elevation	Signal Strength	Notes

Time	Azimuth	Elevation	Signal Strength	Notes

Audio recording made? Yes / No

Stations heard (if FM repeater):

[List callsigns/activity heard]

Task 3.3: Compare to Prediction

How did the actual pass compare to the prediction?

Parameter	Predicted	Observed	Difference
AOS Time			
Max Elevation			
Signal Strength		N/A	

Question 3.1 (10 points)

a) Why do low-elevation passes have weaker signals than high-elevation passes?

b) What causes QSB (signal fading) during a satellite pass?

c) Why is FM commonly used for LEO amateur satellites rather than SSB?

Your Answer:

[Write your answer here]

Part 4: Link Budget Analysis (20 points)

Task 4.1: Satellite Link Budget

Calculate the link budget for a LEO satellite downlink:

Given parameters: - Frequency: 435 MHz - Satellite altitude: 800 km (slant range at 30° elevation 1500 km) - Satellite transmit power: 1 W (30 dBm) - Satellite antenna gain: 0 dBi (omnidirectional) - Ground station antenna gain: 10 dBi - Receiver noise figure: 2 dB - Receiver bandwidth: 15 kHz

Calculate:

1. **Free Space Path Loss:**

$$FSPL = 20\log_{10}(d) + 20\log_{10}(f) + 32.44$$

   FSPL = __________ dB

2. **EIRP (Satellite):** EIRP = P_tx + G_tx = __________ dBm

3. **Received Power:** P_rx = EIRP - FSPL + G_rx = __________ dBm
4. **Noise Power:** N = kTB = -174 + 10 · log (B) + NF = __________ dBm
5. **SNR:** SNR = P_rx - N = __________ dB
6. **Is link viable?** (Need >10 dB SNR for FM) Yes / No

Task 4.2: Link Budget Sensitivity

What happens if:

Change	Effect on SNR
Double the slant range	
Double the frequency	
Use 20 dBi antenna	
Satellite at 3 W power	

Question 4.1 (10 points)

a) Why do GEO satellites require much higher transmit power than LEO satellites?

b) Calculate the one-way latency for GEO (35,786 km) vs. LEO (400 km) satellites.

c) Starlink operates at 12 GHz. How does this affect the link budget compared to 435 MHz amateur satellites?

Your Answer:

[Write your answer here]

Part 5: Advanced Topics (10 points)

Question 5.1 (10 points)

a) What is "linear transponder" mode vs. "FM repeater" mode on amateur satellites? What are the advantages of each?

b) Explain the concept of "full duplex" satellite operation. Why do you need separate receive and transmit antennas?

c) Some amateur satellites use "store and forward" for digital messages. How does this work, and why is it useful for limited pass times?

d) The ISS uses packet radio (APRS) on 145.825 MHz. What modulation does APRS use, and how does the digipeater function?

Your Answer:

[Write your answer here]

Lab Summary

Key Concepts

1. **Orbit Characteristics**: LEO (low latency, Doppler), GEO (high latency, fixed pointing)
2. **Doppler Effect**: $\Delta f/f = v\_r/c$, critical for tracking and communication
3. **Link Budget**: EIRP - Path Loss + Rx Gain - Noise = SNR
4. **Pass Geometry**: Elevation affects path loss, duration, and Doppler rate

Numerical Results Summary

Parameter	Calculated Value
Max Doppler (145 MHz)	
Path Loss (435 MHz, 1500 km)	
Received Power	
Required SNR for FM	

Connections to Course Material

Course Topic	Satellite Application
Doppler Effect	
Link Budget	
Path Loss	
FM Modulation	
Digital Modes	

Personal Reflection

Describe your experience observing or thinking about satellite communication. How does this connect to commercial satellite systems (Starlink, GPS, etc.)?

[Write your reflection here]

Submission Checklist

- ☐ All calculation tables completed
- ☐ Doppler shift calculations shown
- ☐ Pass prediction screenshot included
- ☐ Link budget calculated
- ☐ All questions answered
- ☐ Reflection completed

Submit to Brightspace by due date.