USAF ACADEMY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
LESSON 16 LAB - FREQUENCY HOPPING
**Lab Packet**
Spring 2027

**Name:** _____ **Section:** _____ **Date:** _____

**Learning Objective 6.5:** I can implement FHSS transmission and reception, including hop-sequence synchronization.

This packet is the L16 Lab, in three parts, and you turn it in once, complete, before Lesson 17. Do **Part 1** on your own before the lab period: run the link flowgraph and work out the settings the bench uses. **Part 2** is what you build and observe, recorded in class: Questions 3 to 5 on your own laptop, and Question 6 at a PlutoSDR station with your team. Do **Part 3** on your own after the lab: explain, in words, what changed and why.

**Grading.** You submit the packet once, we grade it against Objective 6.5 on the course's 1 / 0 scale, and you may revise it under course policy. Paste screenshots where a question asks for one.

**Transmitting.** In class we transmit only into a cable, into a shielded enclosure, or at very low power in an ISM band, and only when the lesson says to. Questions 1 to 5 run on your laptop and transmit nothing. Question 6 transmits from a PlutoSDR's TX port, through a cable with an inline 30 dB SMA attenuator, to the same Pluto's RX port, at 915 MHz. Connect the cable and attenuator before you run the flowgraph, and never connect an antenna in this lab. Never set TX attenuation below 30 dB or change the slider's range; the RX input is rated to only a few dBm. We have run the PlutoSDR flowgraph only in simulation, so Question 6 is its first run on hardware.

The flowgraphs are on the L16 lesson page, `L16-fhss-tx.grc` and `L16-fhss-link.grc`, and on the L16 Lab page, `L16-fhss-pluto.grc`. Every number below assumes their settings: Lesson 8's FSK at 1000 baud, sampled at 128 kHz; one packet per hop, made of `guard` guard bytes, the 12-byte access code and header, the 14-byte payload `USAFA ECE 448` with its newline, and `guard` more guard bytes; $N$ channels 10 kHz apart; and key 448, whose sync channel for $N = 8$ is channel 7.

## Part 1: Pre-Lab (individual, before the lab period)

1. **Run the link.** Open `L16-fhss-link.grc` in GRC and run it with every slider at its default.

   (a) Once the Receiver label reads "locked," wait 30 s and record the Receiver and Packets labels.

   (b) Paste a screenshot of the running flowgraph's window.

**2. Settings.** Work out the numbers the flowgraphs use.

(a) Set `guard` to 4 bytes. Find the bits in one hop, the time on one hop, the hop rate, the time for one cycle of 8 channels, and the samples in one hop at 128 kHz.

| | Bits per hop | Hop time | Hop rate | Cycle | Samples |
|---|---|---|---|---|---|
| `guard` = 4 | | | | | |

(b) With `guard` = 4, how long does each guard last?

(c) For the hopper you build in Question 3, choose your own order of the 8 channels, using each once, and write the hop frequencies in that order. With `dwell` = 32,000 samples at 128 kHz, find the time on one hop and the time for one cycle.

## **Part 2: Measurements** (in class)

3. **Build a hopper and a de-hopper.** Start GRC with an empty canvas. Do not open `L16-fhss-tx.grc`: build the hopper and the de-hopper yourself as the lab page lists, with your order from Question 2(c).

    (a) Paste a screenshot of your running flowgraph's window with no Delay block. Mark where the jammer appears on each waterfall.

    (b) Paste a screenshot with the Delay block set to `dwell`. Explain what the De-hopped waterfall shows.

    (c) Describe the De-hopped waterfall with the delay at 2000 samples.

**4. Jamming.** Follow the lab page's steps for `L16-fhss-link.grc`. Record the Packets label after 30 s at each setting, as correct of sent, and as a percent.

(a) Fill in the table.

| `nch` | 8 | 1 | 8 | 2 | 4 |
|---|---|---|---|---|---|
| Jammer | 2, ch 4 | 0.7 | 0.7, ch 4 | 2, ch 1 | 2, ch 1 |
| Delivered | | | | | |

(b) Compare the two results at jammer amplitude 0.7, and explain in words why the hopping link lost so many fewer packets.

(c) Explain in words why 2 channels lost about half the packets and 4 channels about a quarter.

(d) Record the Receiver and Packets labels with the jammer at 3 on channel 7 turned on after the receiver locked, and again set as the slider defaults before the run.

**5. Sync.** Follow the lab page's steps.

(a) Record the Packets label with the hop offset at $+1$ and at $-1$.

(b) With `guard` = 4, fill in the table, and compare the edges with the guard time from Question 2(b).

| Timing (ms) | $-24$ | $+24$ | $-30$ | $+30$ | $-36$ | $+36$ |
|---|---|---|---|---|---|---|
| Delivered | | | | | | |

(c) Record the three times from moving the path delay to the first correct packet.

6. **Frequency hopping on a PlutoSDR.** At a PlutoSDR station, with your team, follow the lab page's steps: connect the Pluto's TX port to its RX port through the 30 dB attenuator, check the Pluto with `iio_info -s`, and run `L16-fhss-pluto.grc`. When you finish, stop the flowgraph and unplug the Pluto before you disconnect the cable.

   (a) Once `USAFA ECE 448` decodes, paste a screenshot that shows both waterfalls and the Receiver, Packets, and Received labels.

   (b) Record the Packets label with the jammer at 2 on channel 4.

   (c) Record the Receiver and Packets labels at each TX attenuation, and explain what limits the link as the attenuation rises.

| TX attenuation (dB) | 60 | 70 | 80 | 89 |
|---|---|---|---|---|
| Receiver | | | | |
| Delivered | | | | |

## **Part 3: Writeup** (individual, after the lab)

**7. Analysis.**

(a) Describe how the packets delivered changed as you changed the number of channels and the jammer's amplitude. Use your De-hopped waterfall from Question 3(a) to explain why a jammer stronger than the signal takes only the hops on its own channel, and why raising its power further does not take more.

(b) Compare the timing errors the link tolerated with 2 guard bytes, from the lesson's Timing Error frame, and with 4, from Question 5(b). Explain in words what the extra guard bytes take from each hop, and when they are worth it.

(c) From Question 4(d), explain why one jammed channel can keep a receiver from ever locking although it takes only 1 hop in 8 from a locked receiver, and propose a change to Hop Sync or to the packet that removes that weakness.

**Documentation:** _____