USAF ACADEMY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
LESSON 15 LAB - mPSK
Lab Packet
Spring 2027

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

Learning Objective 6.4: I can implement an mPSK modulator and demodulator (BPSK, QPSK, 8PSK) and recover carrier and symbol timing.

This packet is the L15 Lab, in three parts, and you turn it in once, complete, before Lesson 16. Do **Part 1** on your own before the lab period: run the link flowgraph and work out the settings you will need at the bench. **Part 2** is your own measurements, recorded in class: Questions 3 to 6 on your own laptop, and Question 7 at a PlutoSDR station with your team. Do **Part 3** on your own after the lab: explain what you saw and answer the analysis questions.

Grading. You submit the packet once, we grade it against Objective 6.4 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 6 run on your laptop and transmit nothing. Question 7 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 7 is its first run on hardware.

The flowgraphs are on the L15 lesson page, `L15-psk-tx.grc` and `L15-psk-link.grc`, and on the L15 Lab page, `L15-psk-pluto.grc`. Every number below assumes their settings: 4,000 symbols per second, RRC pulses with $\alpha = 0.35$ at 8 samples per symbol, Gray-coded points, a Costas Loop bandwidth of 0.02, a default noise amplitude of 0.5, and the default message.

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

1. **Run the link.** Open `L15-psk-link.grc` in GRC and run it with every slider at its default.

   (a) After about 15 s, record the Received label and the Lines label.

   (b) Type 50 into the frequency offset box, wait about 5 s, and paste a screenshot of the running flowgraph's window.

2. Settings. You will need each of these at the bench.

(a) Question 3 builds an 8PSK flowgraph whose Chunks to Symbols block needs the eight points on a circle of radius 1. Using the lesson's 8PSK map, list the angle of each point in degrees, by phase index.

Index	0	1	2	3	4	5	6	7
Angle								

(b) The Costas Loop's frequency output is in radians per symbol. Find the constant of the Multiply Const that turns it into hertz at 4,000 symbols per second.

(c) Your Question 3 flowgraph adds a 20 Hz frequency offset at 4,000 symbols per second. How far does it turn the constellation each symbol, and how many symbols does one full turn take?

Part 2: Measurements (in class)

3. **Build a carrier-recovery loop.** Start GRC with an empty canvas. Do not open the lesson's flowgraphs: build the 8PSK carrier-recovery flowgraph yourself as the lab page lists, with a 20 Hz frequency offset.

   (a) Paste a screenshot of your flowgraph on the GRC canvas. Every connection must be black, not red.

   (b) Paste a screenshot of the running window, and record the loop's frequency reading at offsets of 20 Hz and -60 Hz.

   20 Hz: _____

   -60 Hz: _____

   (c) Change the Costas Loop's order from 8 to 2 and run it again. Describe the output and the frequency reading, and explain why the loop needs the right order.

4. Noise. Follow the lab page's steps for `L15-psk-link.grc`, with `diff` = 1, no frequency offset, and the channel phase at 0. For each constellation, raise the noise amplitude by 0.1 at a time from 0.5, wait about 20 s at each step, and watch the Costas Loop's output and the Lines label.

(a) Record the noise amplitude at which about half the lines received are correct, and describe the Costas output there.

	BPSK	QPSK	8PSK
Noise amplitude			

(b) At each constellation's limit, describe the Lines label and the Received label: how many lines arrive, and what the wrong characters look like. Do the three limits look different?

(c) Paste a screenshot of the window for 8PSK at its limit, and mark one wrong character in the Received label.

5. **Carrier recovery.** Follow the lab page's steps at the default noise amplitude of 0.5, with differential coding on. Before each offset, start from a loop locked at 0 Hz, as the lab page describes, and then type the new offset in one jump. Watch the frequency estimate for up to 20 s.

   (a) For QPSK, record whether the loop locks, about how long it takes, and the frequency it settles at.

Offset (Hz)	250	350	400
Locks?			
Time			
Settles at (Hz)			

   (b) Set `M` to 8 and run the flowgraph again. Record the same for 8PSK, and find its pull-in range.

Offset (Hz)	100	150	200	250
Locks?				
Time				

6. Phase ambiguity. Follow the lab page's steps: set `diff` to 0 and run the flowgraph again, so that the loop locks with no frequency offset and the channel phase at 0, and leave the noise amplitude at 0.5. For each channel phase, start from a loop locked at 0 degrees, as the lab page describes, and then type the phase in one jump. Mark each setting at which the Lines count keeps rising.

(a) Mark the settings that deliver text, and count them.

Phase	0	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340
QPSK																		
8PSK																		

(b) Set `diff` to 1, run the flowgraph again, and repeat three settings that failed. Record what happens. Then, for QPSK with differential coding off, explain what changes if you step the phase by 20 degrees at a time without returning to 0.

7. QPSK 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 `L15-psk-pluto.grc`. When you finish, stop the flowgraph and unplug the Pluto before you disconnect the cable.

(a) Once lines arrive, paste a screenshot that shows both constellations, the frequency estimate, and the Lines label.

(b) With `diff` = 1, stop and start the flowgraph three times. Then set `diff` to 0 and do it eight more times. Record which runs deliver text.

Run	1	2	3	1	2	3	4	5	6	7	8
Differential	on	on	on	off	off	off	off	off	off	off	off
Text?											

(c) With `diff` = 1, wait 30 s at each TX attenuation and record the Lines label. Explain what changes as the attenuation rises.

TX attenuation (dB)	70	80	89
Lines correct of received			

Part 3: Writeup (individual, after the lab)

8. Analysis.

(a) Compare the noise limits in Question 4 for the three constellations. Explain in words why they come in that order, and what that means for a radio that must carry more bits per symbol.

(b) Compare the 8PSK pull-in range with QPSK's, explain the difference, and say what a link between two different Plutos, each accurate to 25 ppm at 915 MHz, would need before its Costas Loop.

(c) Compare Question 6 with Question 7(b). Explain why the working settings were where they were, why the Pluto runs behaved as they did, and why a real mPSK link uses differential coding even though one wrong symbol then corrupts two.

Documentation: _____