USAF ACADEMY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
LESSON 12 LAB - CW
Lab Packet
Spring 2027

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

Learning Objective 6.1: I can transmit and receive CW (Morse) using GNU Radio and decode a received CW stream.

This packet is the L12 Lab, in three parts, and you turn it in once, complete, before Lesson 13. Do **Part 1** on your own before the lab period: run the link flowgraph, watch what noise does to it, and work out the timing and settings the bench uses. **Part 2** is your own measurements, 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 what you saw in the analysis questions.

Grading. You submit the packet once, we grade it against Objective 6.1 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. Or, if your instructor says so, Question 6 goes over the air at 915 MHz at low power, with an antenna on each port in place of the cable. 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 L12 lesson page, `L12-cw-tx.grc` and `L12-cw-link.grc`, and on the L12 Lab page, `L12-cw-pluto.grc`. Every number below assumes their settings: the keyed carrier at 5 kHz in a 32 kHz band, a 700 Hz BFO, 5 ms edges, and the default message `USAFA ECE 448`.

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

1. **Run the link.** Open `L12-cw-link.grc` in GRC and run it with every slider at its default.

   (a) After about 30 s, record the Received label, and time one repeat of the message with a watch.

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

2. Timing, noise, and settings. The bench builds on each of these.

(a) Find the length of a dit, a dah, the gap between letters, and the gap between words at 13 WPM.

dit =

dah =

word gap =

(b) Write your initials, two or three letters, in Morse code. Then write them as a list with one 0 or 1 per unit: 1 for each unit the key is down, 0 for each unit it is up, ending with the 7-unit gap after the word. Count the units and find how long the pattern lasts at 13 WPM.

(c) In the running link, drag the noise amplitude slider slowly from 1 up to 7, with the other sliders at their defaults. Describe what happens to the waterfall, to the envelope's level between marks, and to the Received label, and say roughly where the text starts to break.

(d) The decoder is set to 20 WPM, so its unit is 60 ms. It calls a mark under 2 units a dit, ends a letter when a space reaches 2 units, and ends a word when a space reaches 5. Find those two boundaries in milliseconds.

2 units =

5 units =

(e) The CW filter is 200 Hz wide and centered on the 700 Hz tone. How far can you tune the receiver from the carrier before the tone leaves the filter?

Part 2: Measurements (in class)

3. **Build a hand keyer.** Start GRC with an empty canvas. Do not open `L12-cw-tx.grc`: build the keyer yourself as the lab page lists, with your list from Question 2(b) in the Vector Source.

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

   (b) Paste a screenshot of the time sink zoomed in on one dit, and compare its length with Question 2(a).

   (c) Read the highest peak of the hard and shaped spectra within 100 Hz of 1 kHz and of 2 kHz from 0 Hz, where the carrier would sit. How far below hard keying is your ramp at each? In words, what would a receiver tuned 1 kHz away hear from each?

	Hard (dB)	Ramp (dB)	Difference (dB)
1 kHz from the carrier			
2 kHz from the carrier			

4. The receiver in noise. Follow the lab page's steps for `L12-cw-link.grc`. At each setting, set the threshold halfway between the space and mark levels you read on the envelope plot, wait for three new repeats of the message, and count the wrong, missing, and extra characters among those 39.

(a) Fill in the table.

Noise	4.5	5.5	6.5	6.5	6.5
Filter width	200 Hz	200 Hz	200 Hz	1000 Hz	50 Hz
Space level					
Mark level					
Threshold					
Wrong of 39					

(b) Paste a screenshot at a noise amplitude of 6.5 with the 200 Hz filter, and mark one wrong character in the Received label.

5. Speed and tuning. Follow the lab page's steps, with the noise amplitude at 1, the 200 Hz filter, and the threshold at 0.3.

(a) With the decoder at 20 WPM, record whether each sender speed decodes correctly, and if not, what goes wrong.

Sender WPM	10	12	13	20	27	28	30
Decodes?							

(b) Record the pitch and whether the text decodes at each tuning.

Tuning (Hz)	5050	5080	5100	5150
Pitch				
Decodes?				

6. **CW 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 `L12-cw-pluto.grc`. The transmitter and receiver share the Pluto's clock, so the carrier should arrive close to +5 kHz. 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 the waterfall, the envelope with the threshold line halfway between the space and mark levels, and the Received label.

   (b) Record your teammate's message as decoded, and check it with them.

   (c) Record the mark and space levels and whether the text decodes at each TX attenuation. Explain why the mark level hardly changes while the received power falls by about 10 dB a step, and what does change.

TX attenuation (dB)	60	70	80	89
Mark level				
Space level				
Decodes?				

Part 3: Writeup (individual, after the lab)

7. Analysis.

(a) Using your noise table and what you saw in Question 2(c), describe what rising noise did to the envelope and to the decoded text with the 200 Hz filter, and explain in words why the threshold had to move as the noise rose.

(b) Compare the 1000, 200, and 50 Hz filters at a noise amplitude of 6.5. Explain why the narrowest filter did best, and use your tuning measurement to say what it gives up.

(c) Use your boundaries from Question 2(d) to say which window failed at each end of the sender speeds you tried, and propose a change to the decoder that would let it copy any sender's speed.

Documentation: _____