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

Show your work. Write a **Documentation** line at the end (**None** if you did not collaborate).

1. **Morse timing.** A dit lasts one unit of $1.2/W$ seconds at W words per minute. A dah lasts 3 units, and the key stays up for 1 unit inside a letter, 3 between letters, and 7 between words. SOS is `... --- ...`.

   (a) Find the length of a dit, a dah, and the gap between words at 15 WPM.

   dit: _____

   dah: _____

   word gap: _____

   (b) Count the units in SOS, including the 7-unit gap after it, and find how long it takes to send at 15 WPM.

   units: _____

   time: _____

   (c) A beacon sends its three-letter identifier at 7 WPM. In words, explain why the standard word PARIS lets us state its speed without knowing which letters it sends.

2. **Decoding marks and spaces.** The L12 decoder is set to 15 WPM, so one unit is 80 ms. It calls a mark under 2 units a dit and a longer one a dah, ends a letter when a space reaches 2 units, ends a word when it reaches 5, and ignores any change that lasts less than 0.3 unit. A human operator sends the following, in milliseconds, starting with a mark:

Mark	230		255		245		240		75		250
Space		85		70		260		95		80	

and then the key stays up for 700 ms.

(a) Find the decoder's boundaries in milliseconds, and decode the text.

(b) The operator pauses, and the 260 ms space stretches to 420 ms. What does the decoder print now?

(c) During the 700 ms space, a noise burst holds the key down for 15 ms. Explain what the decoder does with it, and what it would do with a 60 ms burst.

3. **Key clicks.** The CW Keyer Explorer on the Lesson 12 page has a readout, "1 kHz away, vs hard," that compares the shaped spectrum with hard keying 1 kHz from the carrier. At 20 WPM a cadet drags the edge time and reads -10 dB at 1 ms, -24 dB at 2 ms, -40 dB at 5 ms, and -53 dB at 10 ms.

   (a) A club station must keep its keying at least 30 dB below hard keying, 1 kHz from the carrier. Which of the four edge times meet that, and which is the shortest that does?

   (b) An operator wants 10 ms edges at 60 WPM. Find the dit length, and how much of each dit stays at full power. Each edge takes the full edge time, half of it before the nominal edge and half after.

   dit:

   full:

   (c) In words, explain which receivers a hard-keyed transmitter interferes with, and why, and why the operator in part (b) should choose a shorter edge.

4. **The product detector and the CW filter.** The L12 receiver moves the tuned frequency to 0 Hz, multiplies by a 700 Hz BFO, and keeps the real part. Its CW filter is a band-pass centered on 700 Hz.

   (a) A cadet tunes the receiver 120 Hz above the carrier. What pitch does the tone have, and does it pass a 150 Hz CW filter? A 1 kHz filter?

   tone:

   150 Hz:

   1 kHz:

   (b) At a noise amplitude of 8 with the 200 Hz filter, the envelope plot shows a space level of about 0.40 and a mark level of about 0.72, and the text is mostly wrong. The cadet narrows the CW filter to 50 Hz, and the space level drops to about 0.20 while the mark level stays near 0.65. Where should `thr` go now?

   thr:

   (c) Explain in words why the 50 Hz filter in part (b) lowered the space level and not the mark level, and what limits its use.

5. **Setting the threshold.** In the L12 receiver the Threshold block switches the key on when the envelope rises above $1.2\times$ `thr` and off when it falls below $0.8\times$ `thr`. On a noisy link, the envelope plot shows a space level of about 0.30 and a mark level of about 0.70.

   (a) Choose `thr`, and find the two levels at which the key switches.

   thr: ____

   on / off: ____

   (b) A teammate leaves `thr` at 0.3, the value that worked with little noise. Explain what the key and the decoded text do.

   (c) Another teammate sets `thr` to 0.8. Explain what happens, and why the hysteresis does not help.

Documentation: _____