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

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

1. **The hop synthesizer.** A hopper like the L16 transmitter runs at $f_s = 128$ kHz. A Vector Source lists the hop frequencies, a Repeat block holds each one for one hop, and a VCO (complex) with sensitivity 2π turns each value, in hertz, into a tone. The hopper uses 6 channels spaced 12 kHz apart and centered on 0 Hz, and each hop lasts 125 ms.

   (a) Find the frequency of each channel, $k = 0$ to 5.

   (b) Find the Repeat block's interpolation, and the time for one cycle that visits every channel once.

   Repeat:

   cycle:

   (c) The FSK signal on each hop is about 4 kHz wide. In words, explain why a channel spacing of 3 kHz would not work, and what the receiver's low-pass filter after de-hopping does with the other channels at 12 kHz.

2. **Hop timing.** A hopper sends one packet per hop, as the L16 link does: 2 guard bytes, the 12-byte access code and header, the payload, and 2 more guard bytes. It runs at $R_s = 2000$ baud, with 16 channels.

   (a) For a 26-byte payload, find the bits per hop, the time on one hop, and the hop rate.

   bits: ____

   hop: ____

   rate: ____

   (b) Find the time for one cycle of the 16 channels, and the share of each hop that carries the payload.

   cycle: ____

   payload: ____

   (c) How long is each guard, in milliseconds?

   ____

   (d) In words, explain why the hopper makes each packet exactly one hop long instead of letting packets run across hop boundaries.

3. **The FCC dwell rule.** Among its limits on power and bandwidth, FCC Part 15.247 lets a narrowband hopper at 915 MHz transmit without a license only if it hops over at least 50 channels, uses every channel equally, and keeps its average time on any one channel to no more than 0.4 s within a 20 s period. The L16 link hops over 8 channels with 240 ms hops, each channel once per cycle.

   (a) Find how long the L16 link spends on one channel in 20 s.

   (b) A link like L16's hops over 50 channels instead, with the same 240 ms hops, each channel once per cycle. Find its average time on one channel in 20 s.

   (c) The rule also limits each single visit: a hop longer than 0.4 s breaks it even with 50 channels. In words, explain why a permutation sequence, like the L16 link's, makes the equal-use rule easy to meet, and what a sequence drawn independently at random each hop would do instead.

4. **Jamming.** The L16 link hops over 8 channels, channel k at 10 kHz $\times\ (k - 3.5)$, in the order 7, 2, 0, 6, 4, 1, 3, 5. A jammer tone sits at $+5$ kHz, on channel 4. On each hop, Hop Sync multiplies the band by a tone at minus that hop's channel frequency, and the low-pass filter after it keeps ± 2 kHz.

   (a) Find where the jammer appears after Hop Sync on the hop to channel 7, and on the hop to channel 4.

   ch 7: ____

   ch 4: ____

   (b) On which hops of the cycle does the jammer get through the low-pass filter?

   ____

   (c) A cadet turns the jammer amplitude up from 1 to 10, and the Packets label stays near 88%. Explain in words why the extra power takes no more packets.

   (d) Bluetooth's adaptive frequency hopping lets the receiver mark channels that keep losing packets as bad and drop them from the sequence. A hopper with 20 channels has 3 of them jammed. In words, explain what happens to the packets delivered when it drops the 3 jammed channels, and why the jammer cannot simply follow.

5. **Synchronization.** The L16 link hops over 8 channels with key 448, in the order 7, 2, 0, 6, 4, 1, 3, 5, with 240 ms hops and 16 guard bits, 16 ms, at each end of every hop. Its receiver parks on the sync channel, channel 7, until hop 0 arrives there.

   (a) A receiver with the right timing tunes one hop behind the transmitter. List the transmitter's and the receiver's channels for hops 1 to 4, and find how many packets arrive in a full cycle.

   (b) A receiver starts and parks on channel 7 at 0.70 s after the start of a hop 0. How long does it wait before it locks?

   (c) After locking, the receiver changes channel 10 ms late on every hop. A teammate's receiver changes channel 20 ms early. Explain what each one misses and whether its packets arrive.

   (d) In words, explain why parking on one channel tells the receiver which hop the transmitter is on, and what would go wrong if the sequence visited channel 7 twice in each cycle.

Documentation: _____