Learning Objective 4.1: I can describe FSK modulation and implement an FSK transmitter and receiver in GNU Radio.

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

1. **Transmitter settings.** A flowgraph samples at $f_s = 48$ kHz and sends FSK at 1200 baud with a deviation of $\Delta f = 600$ Hz, one bit per symbol.

   (a) Find the samples per symbol to enter in the Repeat block.

   (b) Find the sensitivity to enter in the Frequency Mod block.

   (c) Find the modulation index and estimate the bandwidth with Carson's rule.

   h =

   B =

   (d) A classmate builds the same transmitter from two Signal Sources at $+600$ and -600 Hz and a selector that switches between them at each bit. Explain why Frequency Mod gives a more compact spectrum.

2. **Receiver settings.** The receiver for the link of Question 1 follows the L8 flowgraph: Low Pass Filter, Quadrature Demod, Moving Average, Symbol Sync, and Binary Slicer.

   (a) Find the Quadrature Demod gain that puts the two tones at $+1$ and -1.

   (b) Find the low-pass filter cutoff that passes the Carson bandwidth.

   (c) A classmate leaves the Quadrature Demod gain at 1. Find the levels the two tones produce, and explain whether the slicer still decides correctly.

   (d) The classmate also sets the filter cutoff to 8 kHz. Explain what changes on the eye diagram, and what happens to the noise voltage at which the text first breaks.

3. **Noise.** The link of Questions 1 and 2 ($f_s = 48$ kHz, 1200 baud, $\Delta f = 600$ Hz, cutoff 1800 Hz) runs through a Channel Model with a noise voltage slider. With the slider low, the eye is wide open and every line of text arrives.

   (a) The noise slider is raised a long way. Describe what you expect to see on the spectrum, on the eye diagram, and in the received text.

   (b) A spike crosses zero on the eye diagram, but away from the sampling instant. Explain whether it causes a bit error.

   (c) The link raises its symbol rate to 1600 baud and keeps $\Delta f = 600$ Hz. Find the new samples per symbol, bandwidth, and filter cutoff.

   sps =

   B =

   f_c =

   (d) Explain whether the 1600-baud link's text breaks at a higher or a lower noise setting than the 1200-baud link's.

   (e) On an FSK link the text goes from clean to almost no packets over a small range of the noise slider. Lesson 2 designs a link with margin. Explain, from that observation, why margin matters for FSK.

4. **An FSK remote on a spectrogram.** An RTL-SDR capture, viewed as a spectrogram in URH, shows a burst with two tracks, at 433.900 and 433.940 MHz. In the alternating preamble, the signal stays on each track for 0.417 ms.

   (a) Find the center frequency, the deviation, and the symbol rate.

   f_c =

   Δf =

   R_s =

   (b) The remote's crystal is accurate to 10 ppm. Find the largest frequency offset at 433.92 MHz.

   (c) An offset adds $f_{\text{off}}/\Delta f$ to both demodulator levels. Find the remote's two levels with a 4.3 kHz offset, and say whether the slicer still decides correctly. Then do the same for a 433.92 MHz link built with $\Delta f = 2$ kHz.

   (d) Name one change to the remote's receiver that would put its levels back at ± 1.

Documentation: _____