Learning Objective 6.3: I can describe how HD Radio works and demodulate an HD Radio signal.

Show your work. Write a **Documentation** line at the end (**None** if you did not collaborate). From the lesson: a hybrid station's sidebands run from 129.4 to 198.4 kHz on each side of its center, subcarriers 356 to 546, spaced 363.4 Hz apart.

1. **Reading the display.** You tune `L14-hd-find.grc` to a station at 98.5 MHz.

   (a) Type 98.5 into the finder's Center, zoom in on the frequency sink, and read where each shelf starts and ends, in MHz.

   Upper: about 98.629 to 98.698 MHz. Lower: about 98.302 to 98.371 MHz. As a check, the lesson's offsets give 98.5 ± 0.1294 and 98.5 ± 0.1984 MHz.

upper	98.6294 to 98.6984
lower	98.3016 to 98.3706

   (b) On the waterfall, the station at 98.5 MHz shows a rounded band whose width changes from moment to moment, and two straight bands of constant width on either side. Which is the analog host, and which are the HD Radio sidebands? What makes each look the way it does?

   The rounded band of changing width is the analog FM host: its width follows the audio, because louder audio swings the frequency farther. The straight bands are the sidebands: every subcarrier carries the same power all the time and the subcarriers stop at fixed numbers, so the shelves are flat, sharp-edged, and constant in width.

   (c) A second station shows shelves that start much closer to its host than 129.4 kHz and end at 198.4 kHz. A third shows a rounded host and nothing beside it. Name the mode of each.

   The second is extended hybrid: it has added partitions on the inside edge of each sideband. The third is an analog-only station with no HD Radio.

2. **Reading the OFDM blocks.** Open `L14-hd-test-tx.grc`.

   (a) The OFDM Carrier Allocator's occupied carriers for the upper sideband are `list(range(356, 547))`. Which subcarrier numbers does that list hold, and where does each end of the list appear on the frequency sink?

   `range(356, 547)` holds 356 through 546; Python's range stops one short of its second number. Subcarrier 356 is the inner edge of the upper shelf, 129.4 kHz above the center, and 546 is its outer edge, 198.4 kHz above the center.

   (b) A Multiply Const after each OFDM Cyclic Prefixer sets that sideband's level. Halve the lower sideband's constant, rerun both flowgraphs, and record how far the lower shelf and the lower meter drop. What happens to the upper side?

   The lower shelf and the lower meter both drop by about 6 dB, and the Upper minus lower meter rises by the same amount. The upper shelf and the upper meter do not change.

   (c) You set the OFDM Cyclic Prefixer's rolloff from 112 to 0. What do you expect to see at the edges of the shelves, and why does it matter to a neighboring station?

   The rolloff smooths the change from one symbol to the next. Without it, each symbol starts and stops abruptly, which spreads power outside the sideband, so the shelves' edges slope down slowly instead of dropping sharply. That spread power lands in the neighboring channel.

3. **Setting the meter.** The sideband meter in `L14-hd-find.grc` uses a Frequency Xlating FFT Filter, Complex to Mag^2, a Moving Average of `avg_len` samples (0.2 s), Keep 1 in N, and Log10 for each band.

   (a) You shorten the Moving Average to 0.02 s. What changes in the readings, and what stays the same?

   The readings jump around more from one update to the next, because each one averages fewer samples of a noise-like signal. Their average value stays the same.

   (b) You type `sb_center` into the lower sideband's filter instead of `-sb_center`. What do the two readings show?

   Both meters then measure the upper sideband, so both read the upper sideband's level, and the lower sideband is not measured at all.

   (c) On an extended hybrid station, you leave Inner subcarrier at 356. Does the meter read high or low, and what do you do with the slider?

   Low: the filter leaves out the added partitions inside 356. Slide Inner subcarrier down until the readings stop rising; there the meter covers the whole sideband.

4. **What noise does.** In `L14-hd-test-tx.grc` you raise the Variable `noise_amp`, run it again, and play the new file in the sideband finder.

   (a) Describe what happens to the floor, the shelves, and the host on the frequency sink as `noise_amp` goes up.

   The floor rises. The host stays well above it, but the shelves, which are much weaker, sink toward the floor; their edges blur, and eventually the shelves disappear into it.

   (b) What happens to the two meter readings, and why?

   They read higher than the level the sidebands were built with. Each meter measures all the power in its band, and the noise in that band adds to the sideband's power, so the reading rises as the floor comes up to the shelves.

   (c) On a real station, what would you expect to hear from nrsc5, and from the analog station on Lesson 7's FM receiver, as the shelves sink into the floor?

   nrsc5's digital audio stops abruptly once the shelves sink too far, rather than getting gradually noisier. The analog station on Lesson 7's FM receiver, which is much stronger than the shelves, keeps playing, with more hiss as the floor rises.