Learning Objective 6.8: I can receive and decode AIS messages from marine vessels.

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

1. **Slots.** Each AIS channel divides every minute into 2,250 slots, and sends 9600 b/s.

   (a) Find the length of one slot in milliseconds and in bits.

   $$\frac{60\text{ s}}{2250} = 26.67\text{ ms}, \qquad 9600 \times \frac{60}{2250} = 256\text{ bits}$$

   ms: 26.67

   bits: 256

   (b) A burst carries an 8-bit ramp, 24 training bits, two 8-bit flags, the message, and a 16-bit CRC. How many slots does a 168-bit position report need, and how many does a 424-bit name and voyage report need, before stuffed bits?

   The overhead is $8 + 24 + 8 + 16 + 8 = 64$ bits. A position report is $64 + 168 = 232$ bits, which fits in one slot of 256 with room for stuffed bits. A name and voyage report is $64 + 424 = 488$ bits, so it needs two slots.

   position: 1

   name: 2

2. **Stuffing and NRZI by hand.** The data bits `011111111100` are about to be sent. The transmitter stuffs a 0 after every five 1s in a row, then applies NRZI: a 0 changes the level and a 1 keeps it. The level before the first bit is high (H).

   (a) Write the bits after stuffing.

   After the first five 1s a 0 goes in; the count then restarts, and the four 1s that remain are fewer than five: `0111110111100`, 13 bits.

   `0111110111100`

   (b) Write the level, H or L, of each of the 13 transmitted bits.

   The first 0 changes H to L, the five 1s keep L, the stuffed 0 changes to H, the four 1s keep H, and the last two 0s change to L and back to H: `LLLLLLHHHHHLH`.

   LLLLLLHHHHHLH

   (c) In words, explain why the receiver does not need to know which FM frequency, up or down, stands for H.

   Under NRZI the bit is in whether the level changed, not in which level it is. If the receiver swapped H and L, every change would still be a change and every repeat a repeat, so the bits come out the same.

3. **Receiver settings.** A classmate brings back a SigMF recording whose `.sigmf-meta` file says `cf32_le`, a sample rate of 250000, and a center frequency of 162000000.

   (a) Set the Frequency Xlating FIR Filter's center frequency for channel A and for channel B.

   Channel A is $161.975 - 162.000 = -0.025$ MHz, or -25 kHz; channel B is $162.025 - 162.000 = +25$ kHz.

   A: -25 kHz

   B: $+25$ kHz

   (b) Choose `decim` so that the rate after the filter is about 48 kS/s, and find the samples per bit that Symbol Sync needs.

   $250/48 \approx 5.2$, so `decim` $= 5$, which gives 50 kS/s and $50000/9600 = 5.21$ samples per bit. Symbol Sync accepts a fractional value.

   decim: 5

   sps: 5.21

   (c) The Quadrature Demod's gain is the rate after decimation divided by $2\pi \times 2400$, so that a 2.4 kHz shift comes out as 1. Find it.

   $$\frac{50000}{2\pi \times 2400} = 3.32$$

   3.32

4. **An NMEA sentence.** A decoder prints

```
!AIVDM,2,1,7,B,55NQj<02D1o9L@gGG788iDF0PE8tp0000000000t:0I8840Ht>0CSPD3k2Dh,0*14
!AIVDM,2,2,7,B,00000000000,2*20
```

(a) Which channel carried it, and into how many sentences was it split?

Channel B, in 2 sentences; the 7 is the sequence number that ties them together.

B, 2

(b) Each character carries 6 bits: subtract 48 from its ASCII code (and 8 more if the result is above 39). The first character is `5`, ASCII 53. Find the message ID and say what kind of message it is.

$53 - 48 = 5$: message 5, the static and voyage report with the ship's name, callsign, type, size, and destination.

5, name and voyage

(c) Explain why this message needed two sentences when a position report needs one.

A message 5 is 424 bits, which takes 71 characters at 6 bits each, more than one sentence holds; a position report is 168 bits, 28 characters, and fits in one. The same message filled two slots on the air.

5. **Noise and the squelch.** You run `L19-ais-rx.grc` on the lesson's recording.

   (a) You raise the Added noise slider until channel B's trace in the time plot swings wildly between bursts and frames start failing the CRC. Explain what has happened, and which slider you move to fix it.

   The noise between bursts is now above the squelch threshold, so the Power Squelch stays open and passes noise to the FM demodulator. Symbol Sync then chases that noise between bursts and starts each burst out of step, so bits come out wrong and the CRC fails. Raising the Squelch slider above the noise closes it between bursts again.

   (b) Explain what goes wrong if you raise the Squelch slider too far.

   The squelch then shuts out the weaker ships' bursts as well as the noise, so their frames never reach the decoder and they drop out of the table.

   (c) AIS uses a Gaussian filter with BT = 0.4. In words, say what a smaller BT would gain and what it would cost.

   A smaller BT rounds the steps more, so the spectrum gets narrower and less power spills into the next channel. It also smears each bit into its neighbors, so a single bit's frequency swing falls short of ± 2.4 kHz and noise pushes it across the slicer's threshold more easily.