Radio tuning, selecting a particular signal with software using the Softrock IQ analog receiver.

The Softrock receiver is designed to receive radio frequency (RF) signals at frequencies f_c in the range $f_{LO} \pm f_s / 2$ MHz, where f_{LO} is the local oscillator (LO) frequency set to about 10.125 MHz and f_s is the sampling rate of the soundcard. If $f_s = 48$ KHz, then the frequency range is 10.101-10.149 MHz.

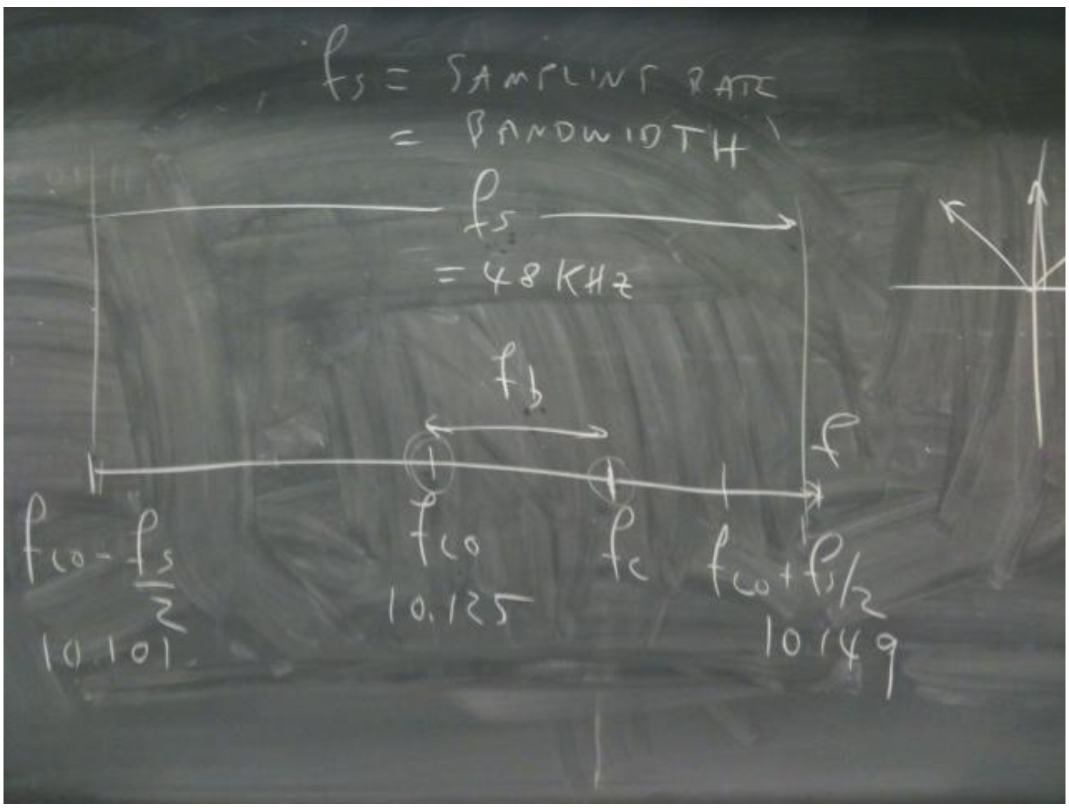
The Softrock receiver operates by generating two local oscillator signals at f_{LO} and mixing (multiplying) it with a desired radio frequency (RF) carrier wave $\hat{r}(t) = e^{j2\pi f_c t}$ at f_c to yield a complex baseband signal $\tilde{r}(t) = I(t) + jQ(t)$ at the difference frequency $f_b = f_c - f_{LO}$

$$\hat{r}(t)e^{-j2\pi f_{LO}t} = e^{j2\pi f_c t}e^{-j2\pi f_{LO}t} = e^{j2\pi f_b t} = \cos 2\pi f_b t + jsin2\pi f_b t = I(t) + jQ(t)$$

$I(t)$ and $Q(t)$ can be sampled by the sound card and processed by the computer, provided that f_c is close enough to f_{LO}, i.e. the difference is less than half the sampling rate, $| f_c - f_{LO} |< f_s / 2$ or

$$f_{LO} - f_s / 2 < f_c < f_{LO} + f_s / 2$$

The difference frequency $f_b = f_c - f_{LO}$, where $| f_b |< f_s / 2$



The Softrock receiver function is to shift a 48 KHz wide slice of spectrum from 10.101 to 10.149 MHz centered at $f_{LO} = 10.125$ MHz down to -0.024 to +0.024 MHz (positive and negative frequencies centered around zero Hz). The complex baseband signal $\tilde{r}(t) = e^{j2\pi f_b t}$ can represent positive and negative frequencies, since f_b can be positive or negative. The 48 KHz slice of spectrum may contain many different signals at various frequencies within the 48 KHz range (recall waterfall plot in lab 0).

If the RF carrier wave is turned on and off to transmit information in e.g. Morse code, or shifted slightly in frequency according to the information as in e.g. the WSPR code in lab 0, then we wish to listen to (or digitally decode) the complex baseband signal $\tilde{r}(t) = \cos 2\pi f_b t + \mathrm{j} \sin 2\pi f_b t$ and no other signals.

If f_b is outside the audio range we want to listen to, or f_b is not the frequency expected at the WSPR decoder input, around 1,500 Hz, then we multiply $\tilde{r}(t)$ by a complex exponential $e^{-j2\pi f_d t}$ at frequency f_d to obtain another complex baseband signal $\tilde{r}_2(t) = e^{j2\pi f_b t} e^{-2\pi f_d t} = e^{j2\pi(f_b - f_d)t} = e^{2\pi f_E t}$ at frequency $f_E = f_b - f_d =$ 1,500 Hz. We then add a low pass filter with cutoff 1,500 Hz to filter out any other signals.

In effect, we have shifted the spectrum twice, once by f_{LO} using analog circuits and a second time by f_d using software to get the exact frequency we want for the WSPR decoder.

More generally, if the RF signal contains information encoded in its amplitude and phase, then the RF signal $\hat{r}(t) = a(t)e^{j\phi(t)}e^{j2\pi f_c t}$ is multiplied by the complex local oscillator

$$e^{-j2\pi f_{LO} t|} = \cos 2\pi f_{LO} t - j sin 2\pi f_{LO} t$$

to yield

$$\hat{r}(t)e^{-j2\pi f_{LO} t} = [a(t)e^{j\phi(t)}e^{j2\pi f_c t}]e^{-j2\pi f_{LO} t} = a(t)e^{j\phi(t)}e^{j2\pi f_b t} = I(t) + jQ(t)$$

where the received complex baseband signal is

$$\tilde{r}(t) = I(t) + jQ(t) = a(t)\cos\phi(t) cos 2\pi f_b t + \mathrm{j}\ a(t)\sin\ \phi(t) sin 2\pi f_b t$$

If we want to receive the information contained in $a(t), \phi(t)$ then we multiply $\tilde{r}(t)$ by a complex exponential $e^{-j2\pi f_b t}$ at exactly $-f_b$ to obtain $\tilde{r}(t)e^{-j2\pi f_b t} = a(t)e^{j\phi(t)}e^{-j2\pi f_b t} = a(t)e^{j\phi(t)}$ centered at 0 Hz, followed by a low pass filter to filter out any other signals. We have shifted the spectrum twice, once by f_{LO} using analog circuits and a second time by f_b using software to receive the desired signal.