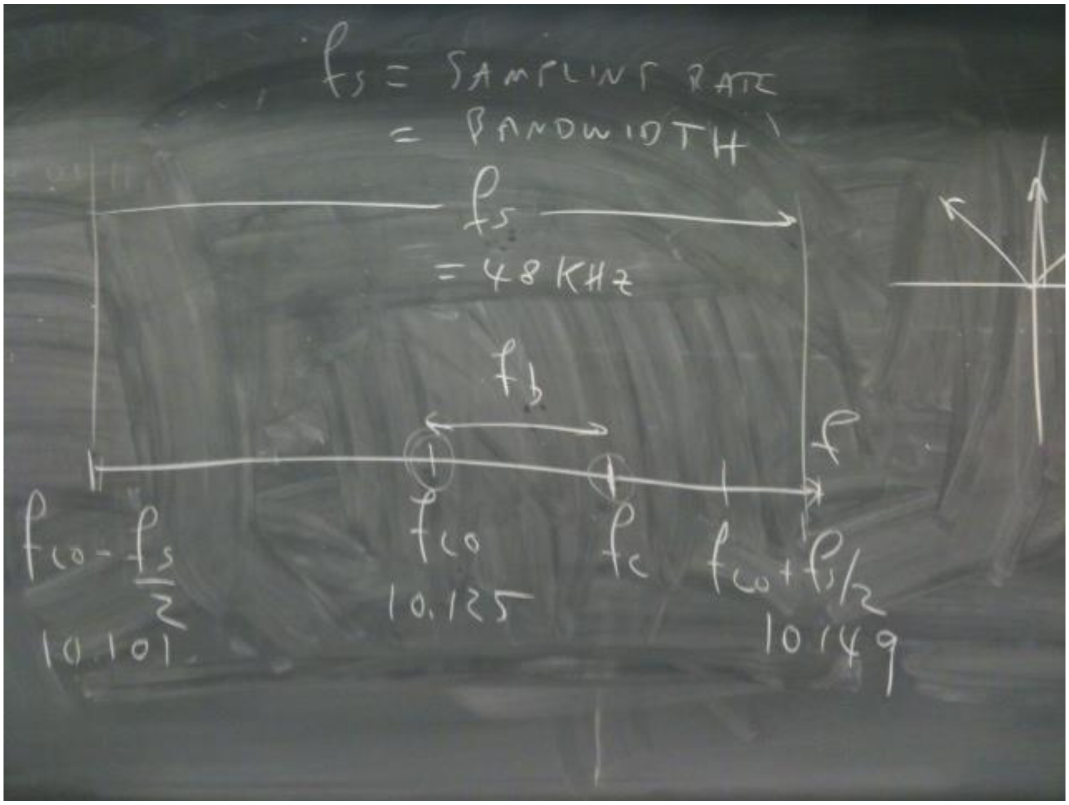
Radio tuning, selecting a particular signal (channel) with software using a digital IQ receiver.

The USRP receiver is designed to receive radio frequency (RF) signals at any frequency f_c in the range $f_{LO} \pm f_s / 2$ MHz, where f_{LO} is the local oscillator (LO) frequency set to 710 KHz and f_s is the sampling rate of the soundcard. If $f_s = 256$ KHz, then the frequency range is Selecting a signal (channel) at a particular frequency f_c is called "tuning" the radio.

The USRP 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 $f_b = f_c - f_{LO}$, where we write

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

$I(t)$ and $Q(t)$ contains all signals (channels) for which 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 $|f_b| < f_s / 2$



In this figure, 10.101 should be 582, 10.125 should be 710, 10.149 should be 838, f_s=256 KHz

The USRP receiver function is to shift a 256 KHz wide slice of spectrum from 710-128 = 582 KHz to 710+128 = 838 KHz centered at $f_{LO} = 710$ KHz down to -128 to +128 KHz (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 and $|f_b| < 128$ KHz.. The 256 KHz slice of spectrum may contain many different signals (channels) at various carrier frequencies within the 256 KHz span.

Table of frequencies used above

f_s sampling rate of computer sound card

f_{LO} local oscillator frequency (fixed frequency crystal analog oscillator near 14 MHz)

f_c carrier frequency of desired signal at radio frequency near 14 MHz (passband)

$(f_{LO} - f_s/2) < f_c < (f_{LO} + f_s/2)$ passband frequency range

$f_b = f_c - f_{LO}$ desired signal obtained by converting to baseband

$(-f_s/2) < f_b < (f_s/2)$ baseband frequency range (centered at 0 Hz)

Conversion (spectrum shifting) is done by complex multiply

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

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 $e^{-j2\pi f_{LO}t|} = \cos 2\pi f_{LO}t - jsin2\pi f_{LO}t$ 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

$$\tilde{r}(t) = I(t) + jQ(t) = a(t)\cos\phi(t) cos2\pi f_b t + \text{j } a(t)\sin \phi(t) sin2\pi f_b t$$

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 (DC) followed by a low pass filter to filter out any other signals. We have shifted the spectrum twice, once by f_{LO} by the USRP to obtain $\tilde{r}(t) = I(t) + jQ(t)$ containing multiple signals (channels) and a second time by f_b using GNURadio software to receive the desired signal (i.e. select the desired channel).