**SDR Receiver Project Research**

Quadrature Mixers, IQ Demodulation, and the Tayloe Detector

Reference: <https://www.youtube.com/watch?v=JuuKF1RFvBM>

**MIXER DESIGN:** When we talk about mixers, we are usually implying we are talking about multiplying mixers.

+/- IF

RF

LO

Essentially, the local oscillator acts as a theoretical “switch” that turns on and off. In order to tell if we are at the +IF or the –IF, we need a reference frequency. And that’s when we need a phase parameter as our reference. Thus, we need waves 90 degrees out of phase with each other out of the output (the I and Q signals). We essentially need to take our input signal (RF) and break it down into two smaller components (I and Q).

If we have a signal positive with respect to the local oscillator, then we have this equation:

where is the I signal, and is the Q signal.

The I wave is leading and the Q wave is lagging.

If we have a signal negative with respect to the local oscillator, then we have this equation:

where is the I signal, and is the Q signal.

The Q wave is leading, and the I wave is lagging.

So, when we talk about I and Q, we mean that the I signal is the “in phase” or our “reference” signal which is static (as indicated by the equation where the cosine term is unchanged in the equations. And the Q signal is the quadrature signal. It is essentially flipped 180 degrees so that it appears like it is either leading or lagging the I signal by 90 degrees. If it is lagging, then it is above our local oscillator frequency, whereas if it is leading, then it is below the local oscillator frequency.

*Using a Tayloe Mixer:* utilizes 4 to 1 multiplexer IC. Called Dan tayloe mixers after the guy who popularized them. Only need one multiplexer, they are very cheap (about 50 cents apiece), they require very low local oscillator drive levels (don’t need a lot of power out of your local oscillator), have high 3rd order intercept (so immune to being overloaded by strong levels), and have very low insertion loss (about 1dB). How they work: they have select lines s0 and s1, where the I signal of the local oscillator connects to s0 and the Q signal of the local oscillator connects to s1. Since the I and Q signals are 90 degrees out of phase, we essentially see this as an input to the tayloe mixer select lines:

00 01 11 10 00 01 11 10 00 01 11 10

So the input signal into the multiplexer will be the RF signal, and the output will be a combination of 0, 90, 180, and 270 degree signals. Each one \*starts sampling at the corresponding degree. Thus, we have each of the four signals out of phase with the next.

Note, we need capacitors on the outputs of the tayloe mixer multiplexer. The purpose of these capacitors is to sample and hold the voltage that they see. They will track whatever voltage they see while the RF signal is connected to them.

For instance – when the RF and LO signals are the same, we will see that the 0 deg will be the peak voltage value, the 90 deg will be at 0V, and the 180 deg at the minimum voltage value, and the 270 deg will again be at 0V. BUT, if the RF and LO are at slightly different frequencies, then instead of seeing the maximum, minimum and 0V, we will instead start to see this phase shift at the frequency difference over time. Thus, we have our down-converted signal, but in four parts instead of just two. These are our quadrature outputs. Where 0 deg is complimentary to 180 deg, and 90 deg is complimentary to 270 deg. So, these complimentary outputs are put into a summing amp so that we aren’t throwing away any signals. Classically, we use the FST3253, which is a dual 4 to 1 multiplexer. Typically, the RF signal is actually applied to both of the inputs on the dual multiplixer – and this is just done to lower the resistance that the chip provides to the signal. The typical resistance is 4 ohms, but if you use two inputs, then it lowers it to 2 ohms. The corresponding outputs are also tied together for the same reason.

The way you select the sample capacitors is to set the low pass cut off frequency that you want. This essentially becomes a low pass filter when examined in conjunction with the 50 ohm impedence of the input signal. But it’s important to note that the input resistance is split between 4 outputs, so each output only sees ¼ of the input resistance, which is 50/4 = 12.5 ohms. But then we also need to add in the resistance from the multiplexer.

jX = 1/(jwC) => 12.5 = 1/(2\*pi\*f\*C). If we choose a cut off frequency, then we can calculate the capacitance for this low pass filter.

**BANDPASS FILTER DESIGN:**

**CRYSTAL AND CLOCK GENERATOR FOR LOCAL OSCILLATOR:**

**SUMMING AMPS AND LOW PASS FILTER DESIGN:**