Lab 5 - DSB-SC

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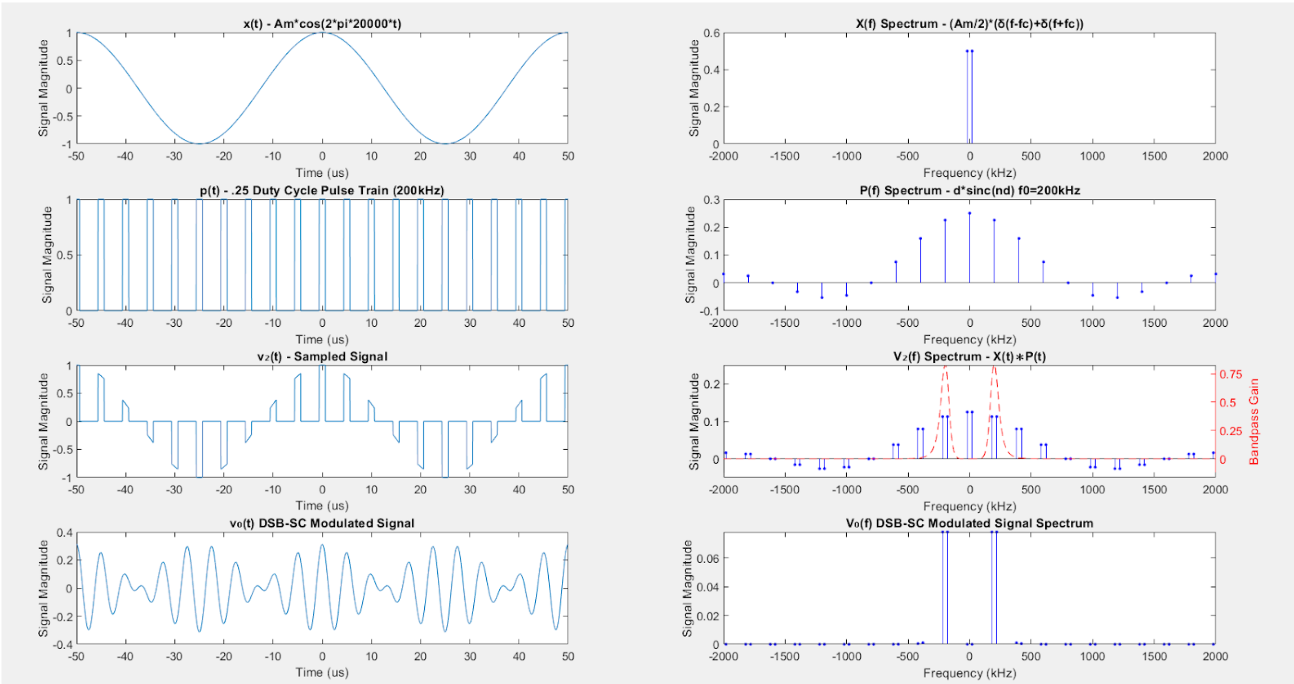
ECE 4705-L

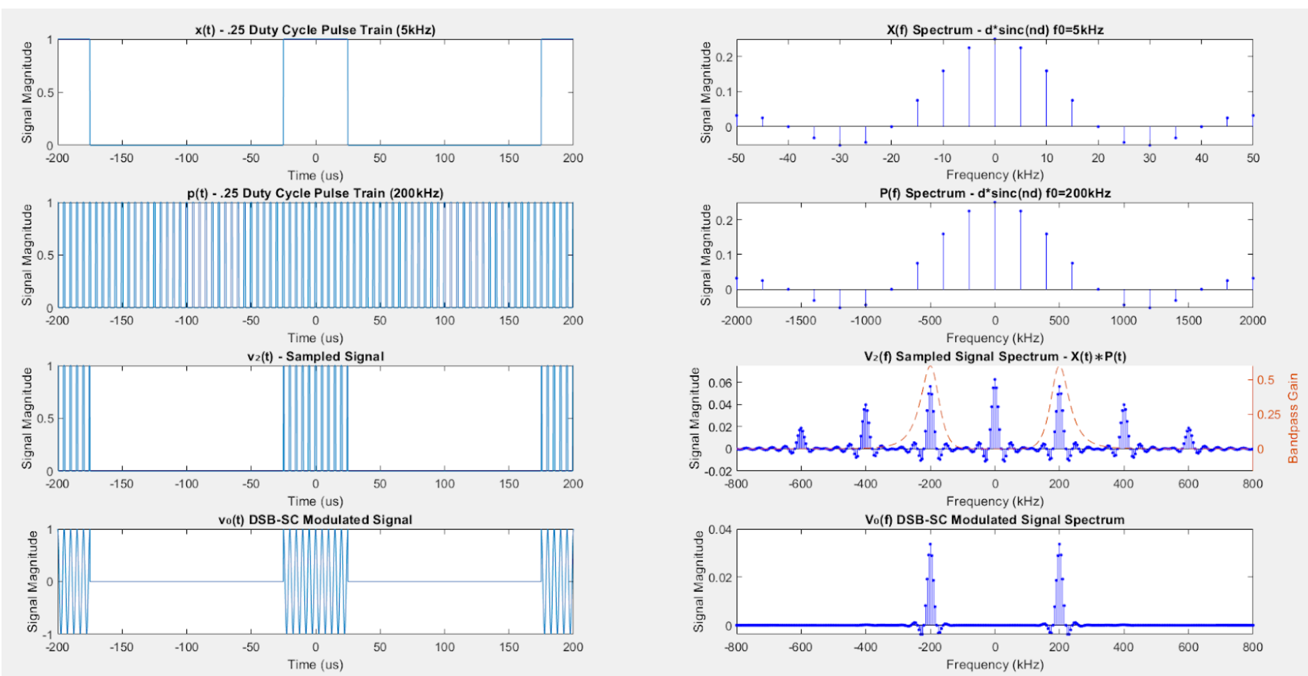
Introduction:

Background Theory

Double sideband-suppressed carrier (DSB-SC) modulation takes the original double sided spectrum of a message signal and shifts it to the positive and negative frequency of the carrier. Multiplying the message signal with a cosine wave of carrier frequency will effectively do just this, but the same results can be achieved with sampling and filtering. Sampling a signal with a rectangular pulse train will produce spectral copies of the original signal at every integer multiple of the pulse train's fundamental frequency, scaled by some sinc based value. With a bandpass filter, the spectral copy which is present at first integer multiple of the fundamental frequency could be passed while all other content is attenuated. What is left will be a spectral copy of the original signal placed at the sampling frequency scaled by some value. This filtered spectrum will yield our DSB-SC modulated signal. The information contained in the original signal is the same as the modulated signal, but now all is contained in higher frequencies making it suitable for transmission. The DSB-SC modulated signal simply has a copy of the message spectrum at the positive and negative sampling frequency. The frequency component of the sampling signal itself is not present and this is characteristic of DSB-SC.

Prelab


x(t) - Am*cos(2*pi*20000*t)
X(f) Spectrum - (Am/2)*(δ(f-fc)+δ(f+fc))
p(t) - .25 Duty Cycle Pulse Train (200kHz)
P(f) Spectrum - d*sinc(nd) f0=200kHz
v₂(t) - Sampled Signal
V₂(f) Spectrum - X(t)∗P(t)
v₀(t) DSB-SC Modulated Signal
V₀(f) DSB-SC Modulated Signal Spectrum
Signal Magnitude
Time (us)
Frequency (kHz)
Bandpass Gain


x(t) - .25 Duty Cycle Pulse Train (5kHz)
X(f) Spectrum - d*sinc(nd) f0=5kHz
p(t) - .25 Duty Cycle Pulse Train (200kHz)
P(f) Spectrum - d*sinc(nd) f0=200kHz
v₂(t) - Sampled Signal
V₂(f) Sampled Signal Spectrum - X(t)∗P(t)
v₀(t) DSB-SC Modulated Signal
V₀(f) DSB-SC Modulated Signal Spectrum
Signal Magnitude
Time (us)
Frequency (kHz)
Bandpass Gain

The prelab shows the process of DSB-SC modulation in both the time and frequency domain for two message signals. The first message signal is a pure 20kHz cosine wave and the other is a 5kHz .25 duty cycle pulse train . The sampling signal was a 200kHz .25 duty cycle pulse train. The prelab shows the expected results for our experiment. The sampled cosine wave will have double peaks at every 200kHz (sampling frequency), with each pair of peaks being separated by 40kHz. After the double peaks at the first integer multiple (200kHz) are filtered through the bandpass, the resulting time domain signal will resemble a beat frequency signal. For the sampled pulse train message signal, the spectrum will have sinc valued peaks at every 200kHz (sampling frequency). The distance between each peak will be 5kHz. In the lab, these peaks will blend together and give the impression of continuous sinc functions spaced by 200kHz. After bandpass filtering, the resulting time domain signal will resemble that of an OOK modulated signal where the signal only has non-zero amplitude when the original message is high.

Lab:

The experiment consisted of the same signals which were simulated in the prelab. These again were a 20kHz cosine wave and a 5kHz .25 duty cycle pulse train. The sampling signal was a 200kHz .75 duty cycle pulse train which sampled the circuit for 25% of a cycle, essentially producing the product of the message signal with a 200kHz .25 duty cycle pulse train. A 4th order Butterworth filter was used to filter the resulting signals.

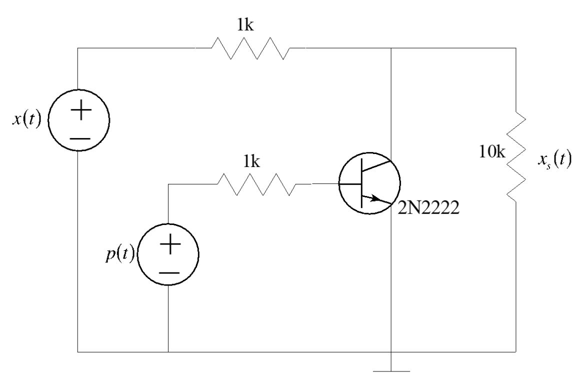


Figure 1 - Sampling Circuit

Results

Figure 2 - Sampled Cosine Wave

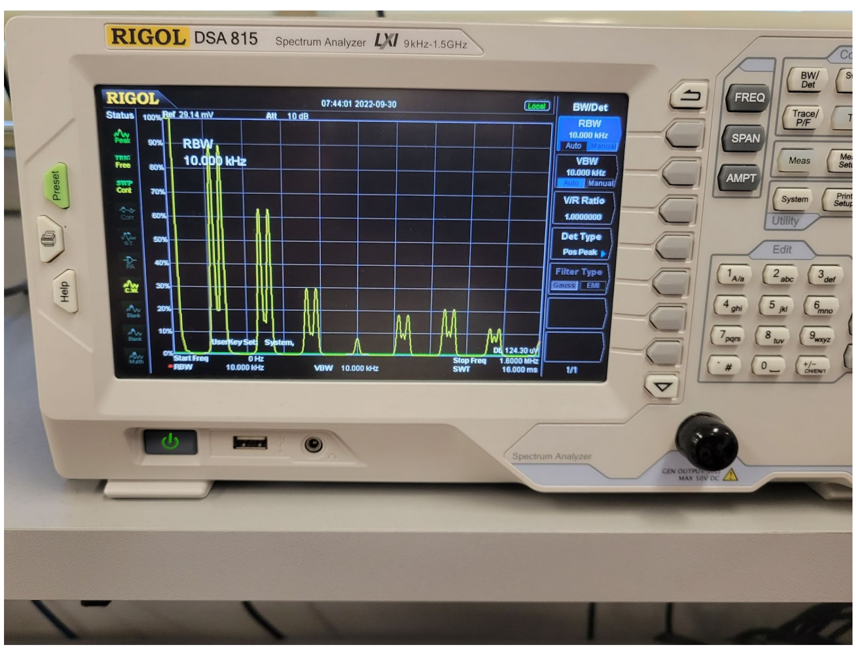


Figure 3 - Sampled Cosine Wave Spectrum

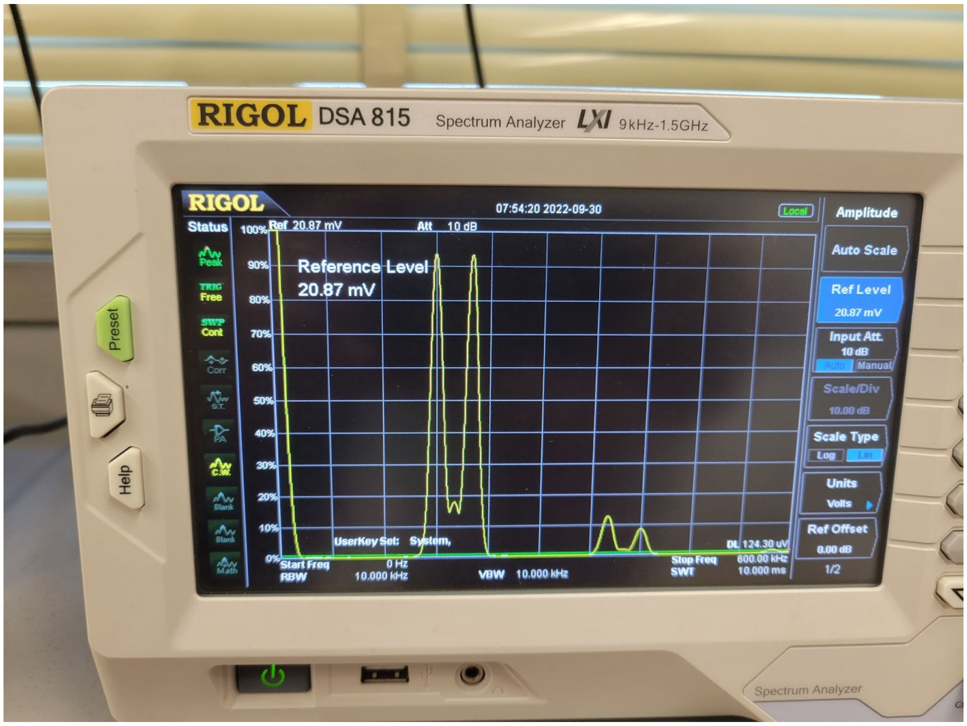


Figure 4 - Filtered Sampled Cosine Wave Spectrum

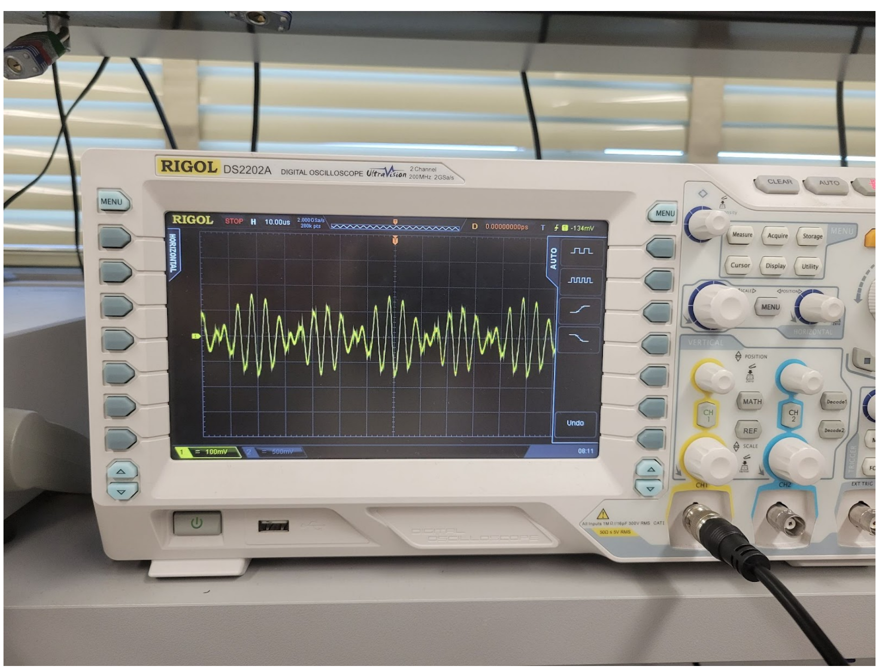


Figure 5 - Filtered Sampled Cosine Wave (DSB-SC Modulated Cosine Wave)

Figure 6 - Sampled Pulse Train

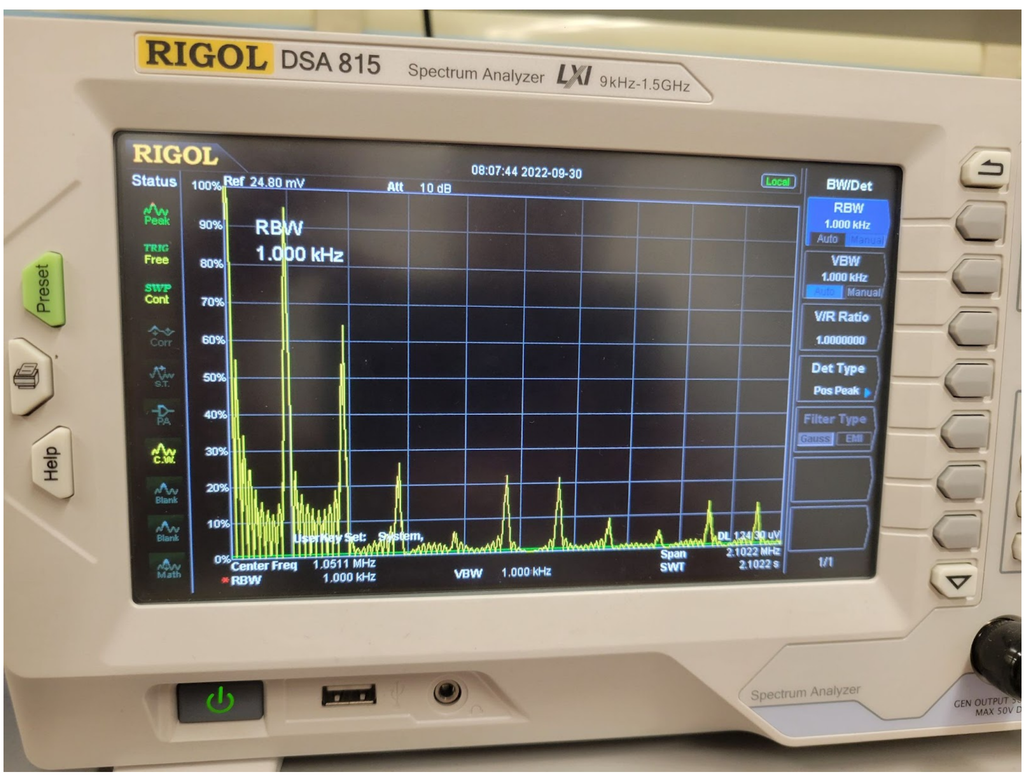


Figure 7 - Sampled Pulse Train Spectrum

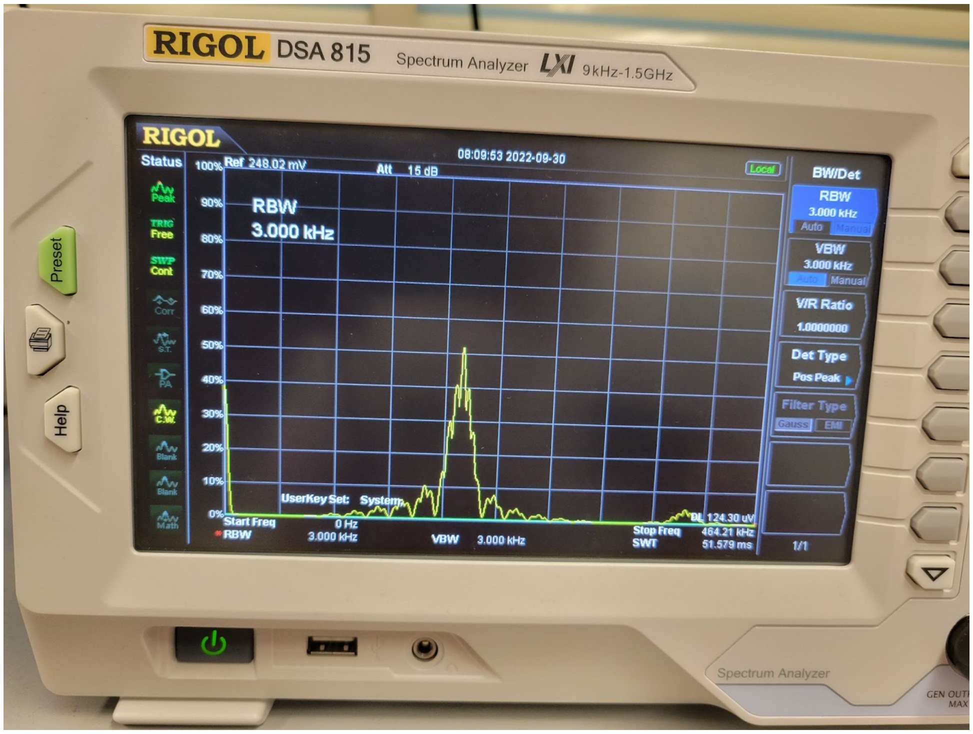


Figure 8- Filtered Sampled Pulse Train Spectrum

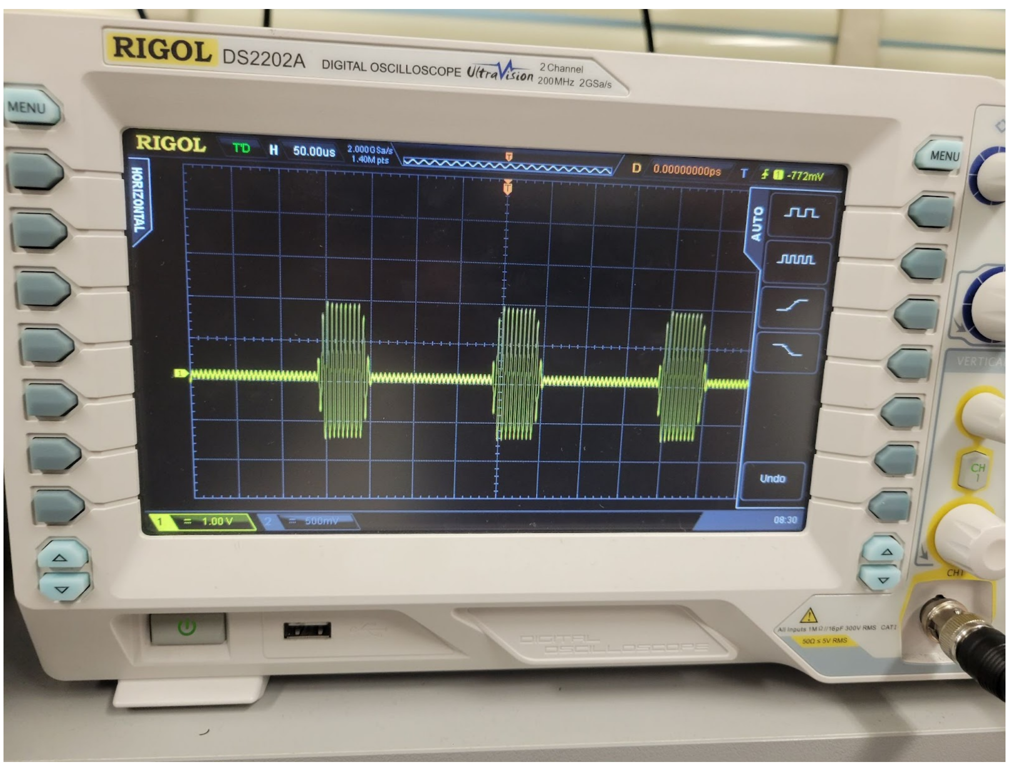


Figure 9 - Filtered Sampled Pulse Train (DSB-SC Modulated Signal)

Conclusion/Analysis:

Figure 2 shows the sampled sine wave. The spectrum of a pure cosine wave would be two peaks, at its positive and negative fundamental frequency. When sampled, this spectrum is copied at every integer multiple of the sampling frequency and scaled by some sinc factor. This is what is demonstrated in Figure 3. To perform DSB-SC modulation, only the spectral copy at the first integer multiple (sampling frequency itself) must be retained while the other spectral content is removed. Figure 4 demonstrates this bandpass filtered spectrum. The spectrum after filtering does contain the spectral copy at the first integer multiple, but there are also some remnants of the spectral copy at the second integer multiple. This is due to the bandwidth of the filter being too large to capture only a single copy. The oversized pass band of the filter is due to something called the quality factor of the filter or Q. The quality factor is a property of the filter and does not change. It describes the relationship between the center frequency of the filter and its bandwidth, that is $Q = \frac{\omega_0}{BW}$. As the center frequency increases, the bandwidth of the filter must also increase so that the quality factor remains constant. In the case of our modulated signal, the sampling frequency is too large to create a passband with small enough bandwidth to only pass one spectral copy. This is not too much of a problem as the second spectral copy is still attenuated and does not have large enough magnitude to completely corrupt the modulated signal. The filtered/modulated signal in the time domain is seen in Figure 5.

The sampled rectangular pulse is shown in Figure 6. In the time domain, the sampled rectangular pulse train is equivalent to the product of the sampling signal and the message signal. This means that in the frequency domain, their spectrums will be convoluted. Since the spectrum of the message and the sampling signal are both pulse trains the resulting frequency spectrum will be the convolution of two differently scaled sinc functions. This is what is shown in Figure 7. At every integer multiple of the f sampling frequency, there is a sinc spectrum scaled by some sinc based constant. The filtered spectrum is shown in Figure 8. Similar to the filtered cosine message signal, there is still frequency content at the second integer multiple of the sampling frequency. Again this is because of the large center frequency of the filter which causes a large filter bandwidth due to the constant quality factor of a 4th order Butterworth filter. Figure 9 shows the OOK resembling DSB-SC modulated signal.