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# ELECENG 3TR4: Communication Systems
# Lab 2: Amplitude Modulation

2024-02-13

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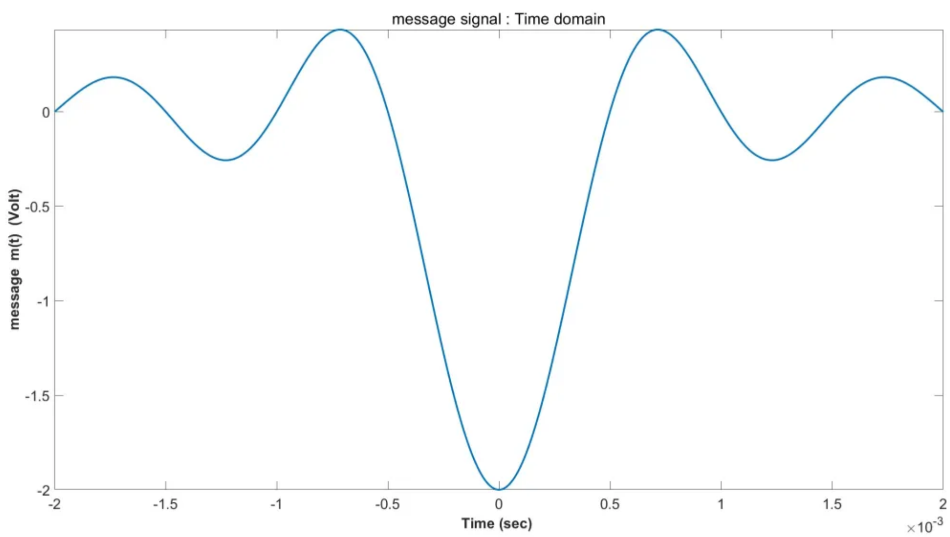
1. **Message Signal:**

Analytical Calculations:

$$T_m = 0.0005sec$$
$$m(t) \leftrightarrow M(f)$$
$$sinc(t) \leftrightarrow rect(f)$$
$$\sin\left(\frac{t}{T_m}\right) \leftrightarrow T_m rect(T_m f)$$
$$-2sinc\left(\frac{t}{T_m}\right) \leftrightarrow -2T_m rect(T_m f)$$
$$m(t) = -2sinc\left(\frac{t}{T_m}\right) \leftrightarrow M(f) = -2T_m rect(T_m f)$$
$$Bandwidth\ B = \frac{1}{T_m} = \frac{1}{0.0005} = 2000\ Hz$$

Experimental Results:



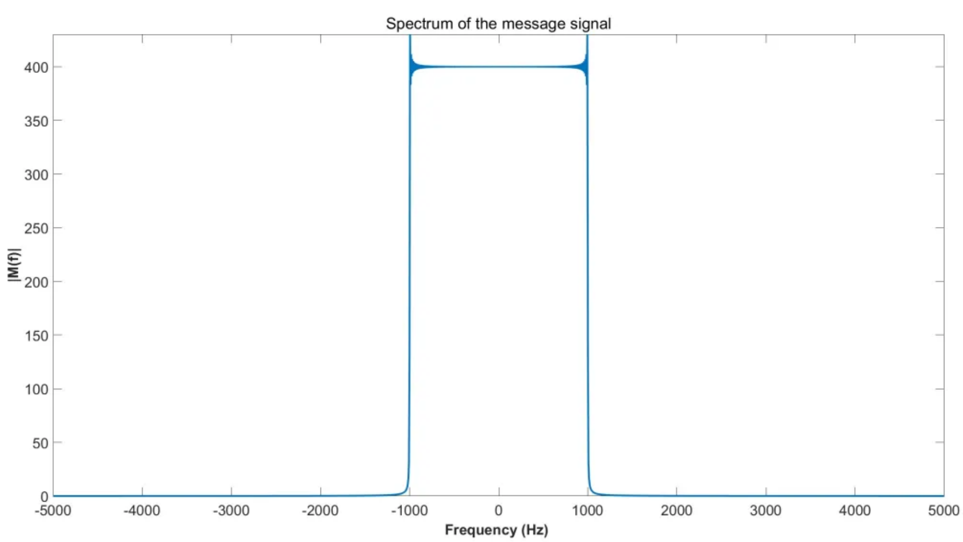



Figure 1. Message Signal in Time and Frequency Domain

The analytical results for the highest frequency match the experimental results, which closely range from -1000 Hz to 1000 Hz.

```
%carrier
fc=20e3;
Ac = 1;
ct=Ac*cos(2*pi*fc*tt);

%message signal
Am=1;
fm = 1e3;
Tm = 0.0005;
mt = -2*sinc(tt/Tm);

%max of absolute of m(t)
maxmt = Am;
%For 40% modulation
ka=0.4/maxmt;

%AM signal
st = (1+ka*mt).*ct;
```

Figure 2. Part 1 Matlab Partial Code

2. **Modulated Signal in Time and Frequency Domain:**
   The two below graphs illustrate the modulated signal in time and frequency domain on the magnitude spectrum with 50% modulation. The first graph in Figure 3 displays the carrier frequency and its sidebands introduced during modulated in the frequency domain, while the amplitude modulation of the carrier wave is controlled by the information signal.

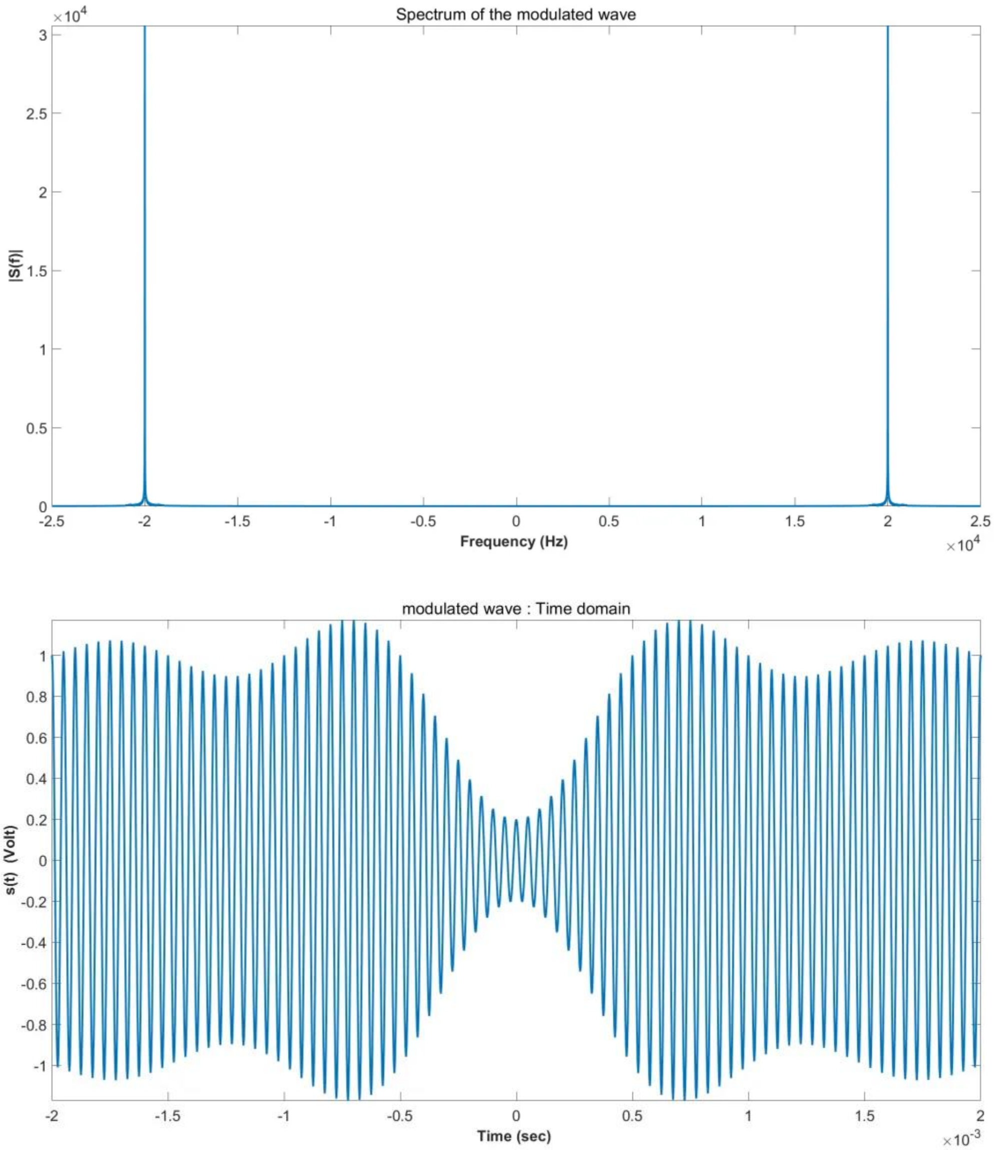



Figure 3. Modulated Signal in Time and Frequency Domain

```
%max of absolute of m(t)
maxmt = max(abs(mt));
%For 50% modulation
ka=0.5/maxmt;

%AM signal
st = (1+ka*mt).*ct;
```

Figure 4. Partial Code for 50% Modulation

(i). Output time constant $R_L C = \frac{1}{fc}$

The amplitude envelope of the signal follows the shape of the original information signal despite the presence of ripples introduced during the envelope detection process. These ripples are caused by an improper choice of the time constant. The DC removal process cleanses the signal, eliminating the DC offset to resemble the original information signal more closely. However, the presence of ripples in the signal indicates that the demodulation process has not completely eliminated high-frequency oscillations, leading to compromised signal quality.

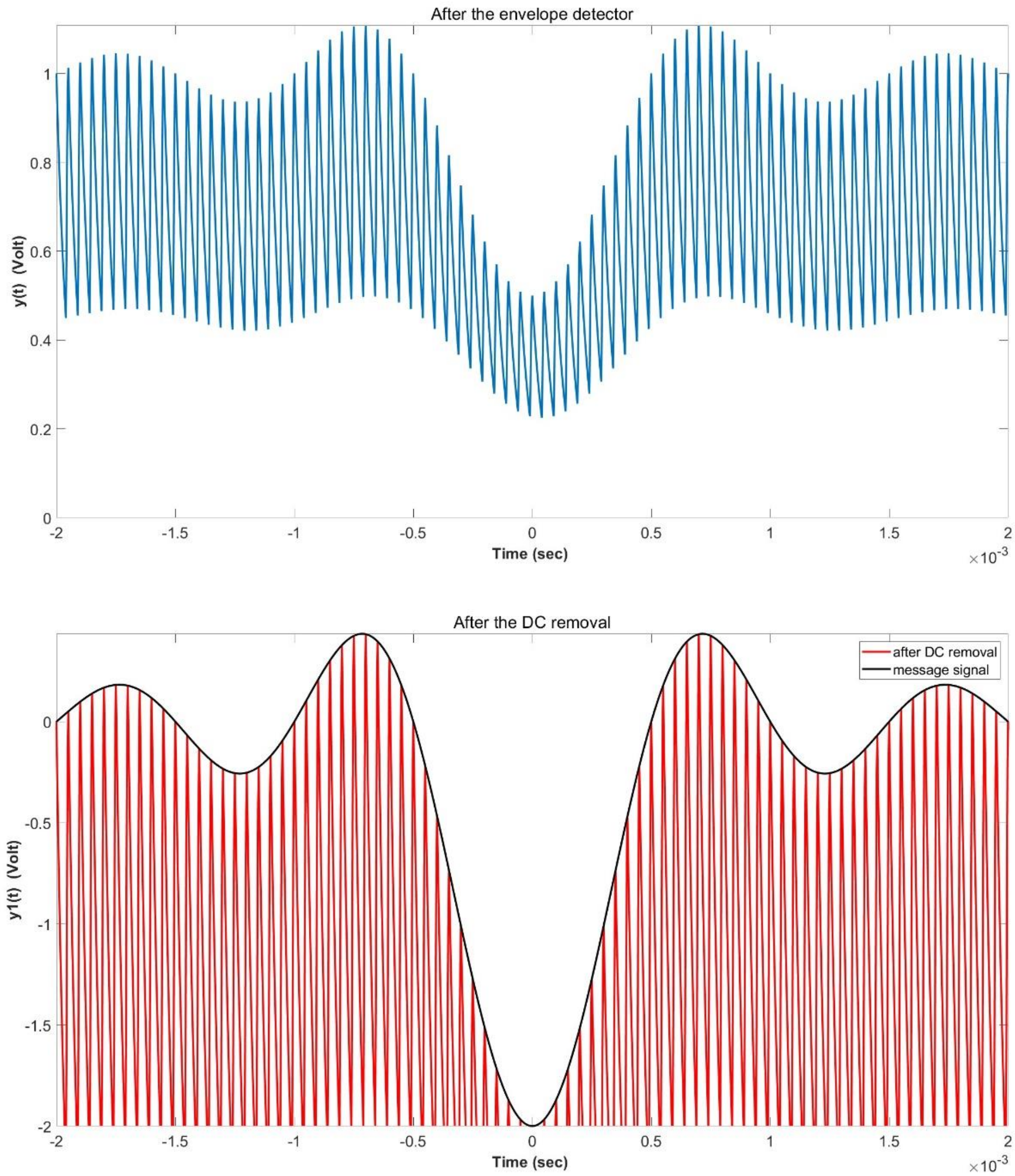


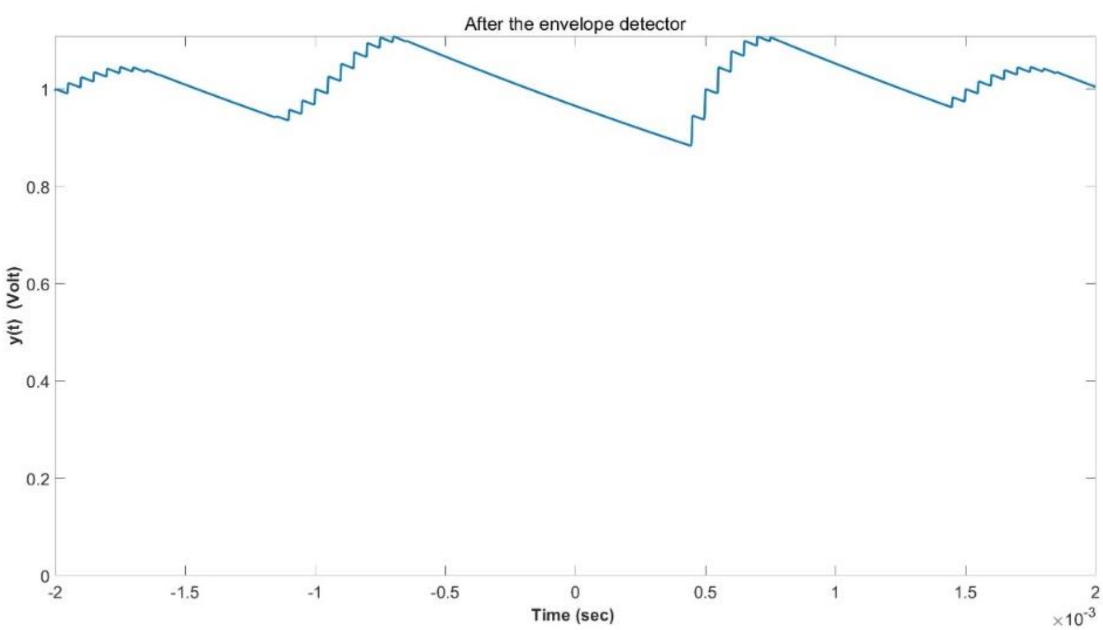

Figure 5. Output of Envelope Detector and DC Removal with $R_L C = 1/f_c$

```
%% Demodulation

%time constant RC
%This should be optimized to avoid envelope distortion
%RC = 0.5*(1/fc + 1/fm);
%Q2(i)
RC = 1/fc;
```

Figure 6. Partial Code for Question 2 (i)

(ii). Output time constant $R_L C = 10\, T_m$
The output of the envelope detector might not be perfectly tracking the peaks of the modulated signal with noticeable steps, which is causes by the chosen time constant not effectively smoothing the signal. The envelope detector has a slow response to changes in the input signal, which would cause a delay in following the input signal's amplitude precisely, particularly when the signal falls. The Dc removal graph shows the output after DC removal does not perfectly trace the message signal, leading the possibility of lost information during the demodulation process.



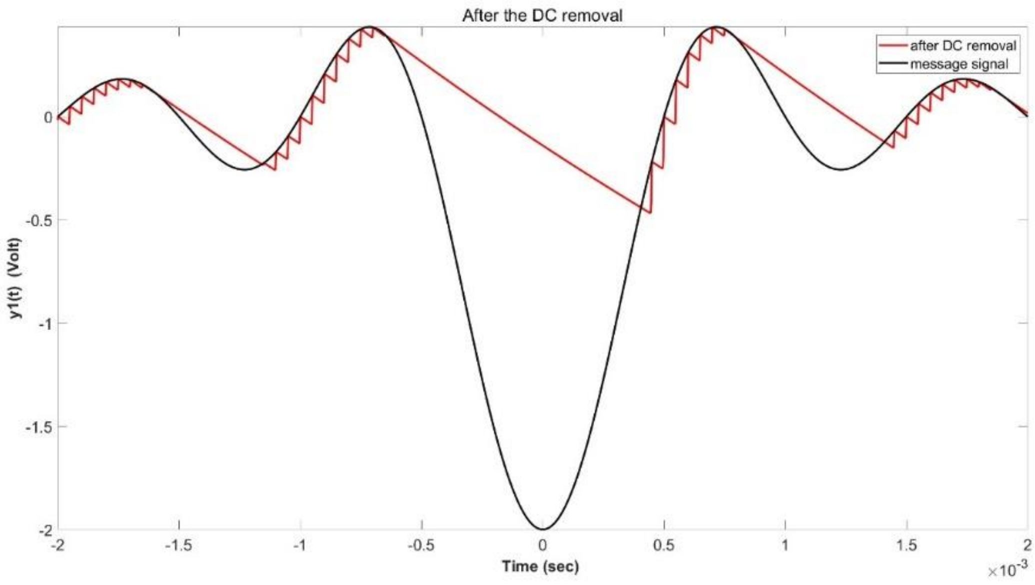



Figure 7. Output of Envelope Detector and DC Removal with $R_L C = 10T_m$

(iii). Output time constant $R_L C$ = Optimum Value
Based on the previous values, the optimum value of time constant is between $10T_m$ and $1/f_c$. The time constant $T_m$ is related to the modulating signal, and $1/f_c$ corresponds to the carrier frequency's period. The optimum value can be the combination of these two values to respond modulating signal and smooth out the rapid fluctuations.

The output signal exhibits a smooth, gradual change in amplitude over time, which is characteristic of the output from an envelope detector. On the DC removal graph, the red and black waveforms appear to have a close match in frequency and amplitude, which suggests that the DC removal process has been effective.

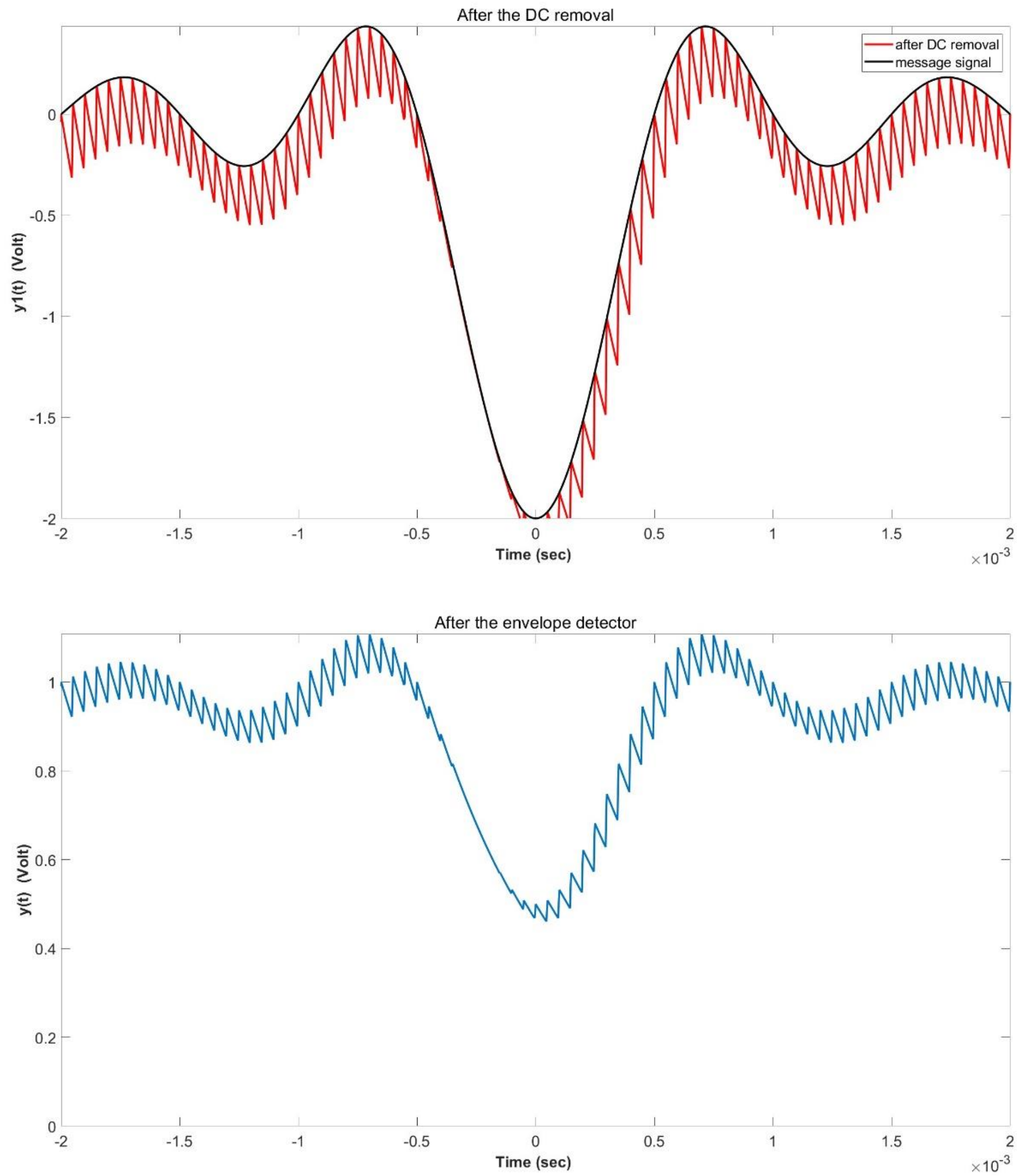



Figure 8. Output of Envelope Detector and DC Removal with optimum values

## 3. 200% Modulation

When the modulation depth exceeds 100%, it indicates overmodulation that the envelope of the modulated signal dips below zero, causing distortion in time domain plot. In the frequency domain, overmodulation can create additional frequency components that would not be present in standard amplitude modulation.

The envelope detector cannot resemble the original message signal distortions where the carrier dips below zero. Furthermore, the output still shows signs of distortion due to the overmodulation, although the process of DC removal is aimed at centering the signal around zero. The overmodulation has caused the envelope detector's output to deviate from the original message signal significantly.

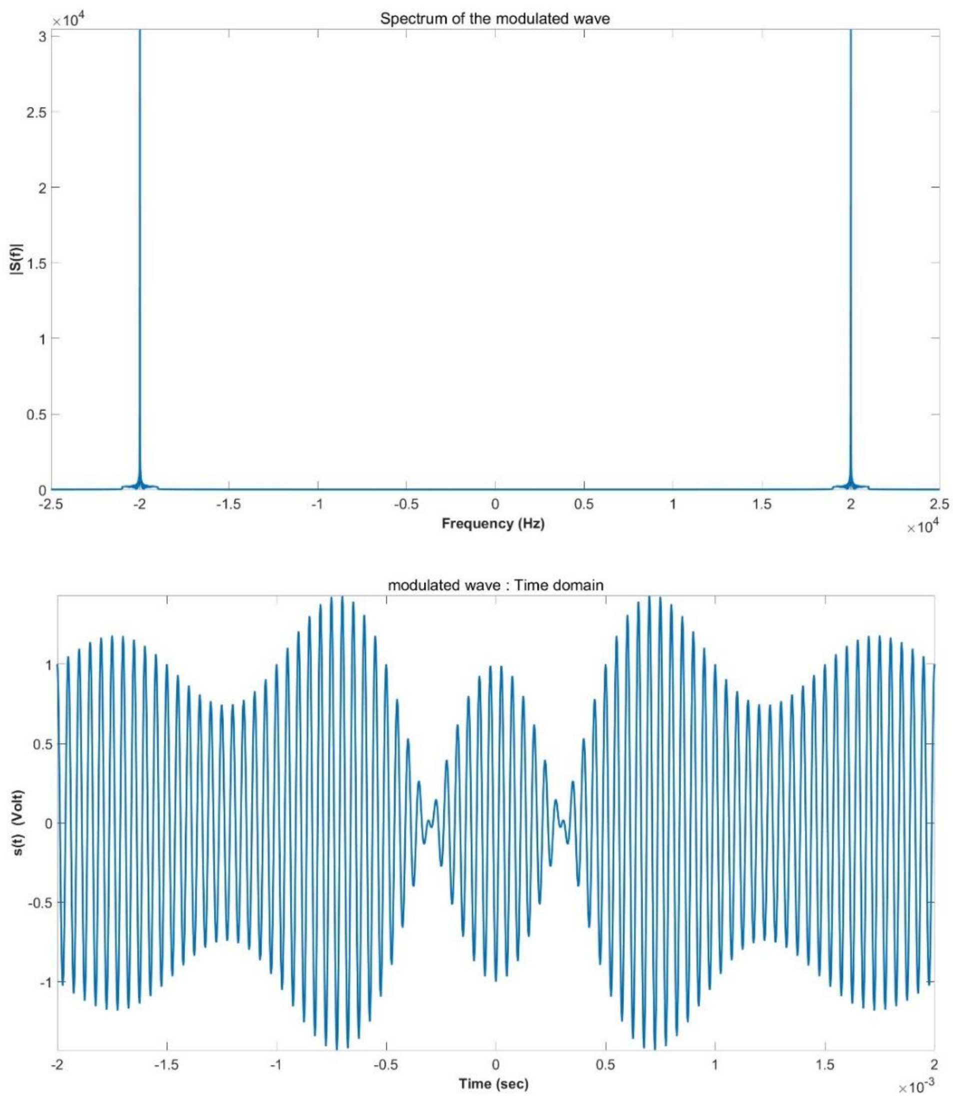



Figure 9. Modulated Signal in Time and Frequency Domain with 200% modulation

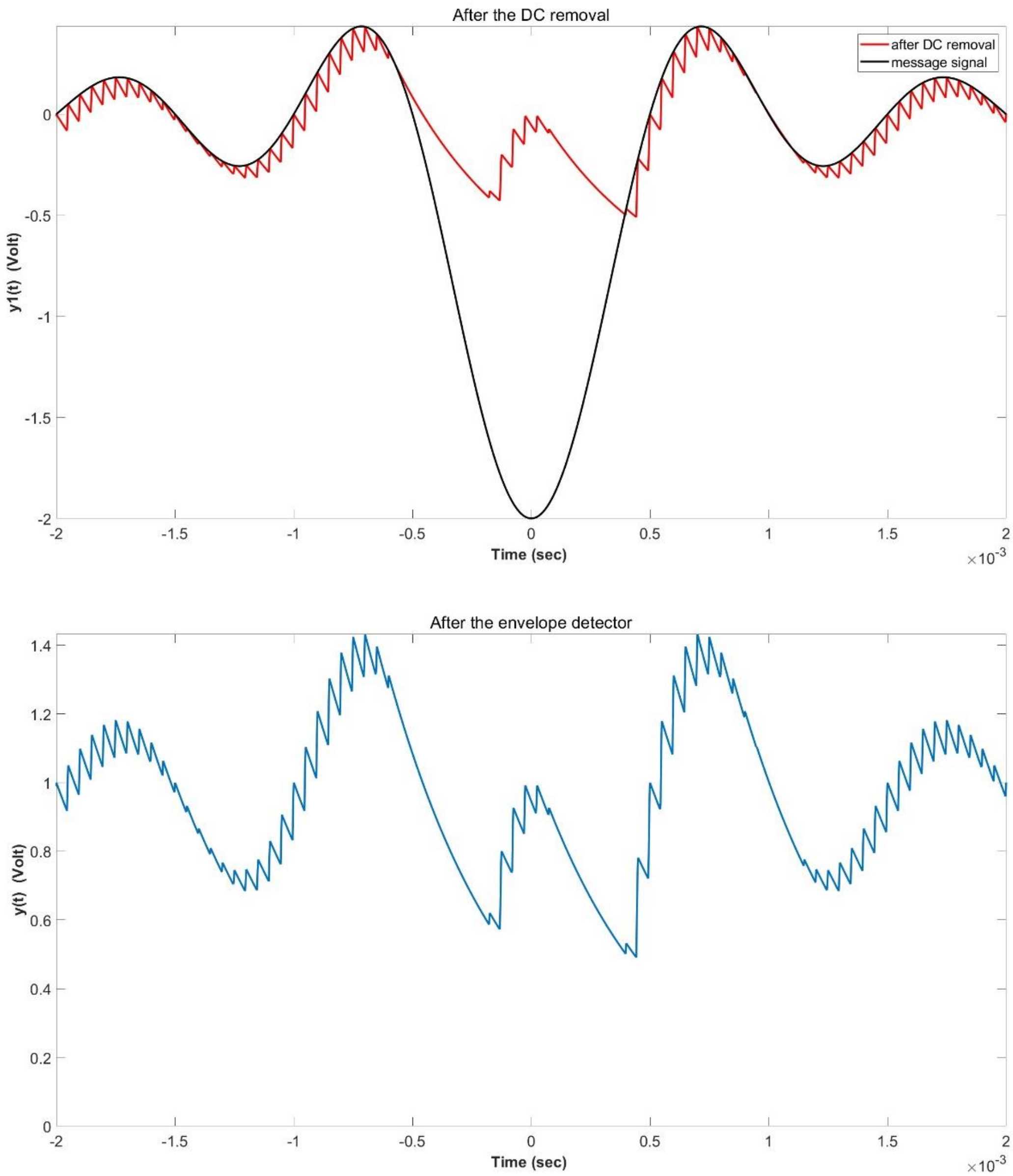



Figure 10. Output of Envelope Detector and DC Removal with 200% modulation