Experiment 88 - Modulation/Demodulation Techniques
ELEC273

December 17, 2021

Abstract

This report shows solutions for this experiment with corresponding comments.

Contents

1 Part I: Amplitude modulation

1.1 Experiment A

1. Queation 1: Why is a DC signal added to the message?

   The DC signal is added to move the entire modulation signal above the time axis. Otherwise, the modulation signal will be distorted.

2. The waveforms are shown in Figure 1.

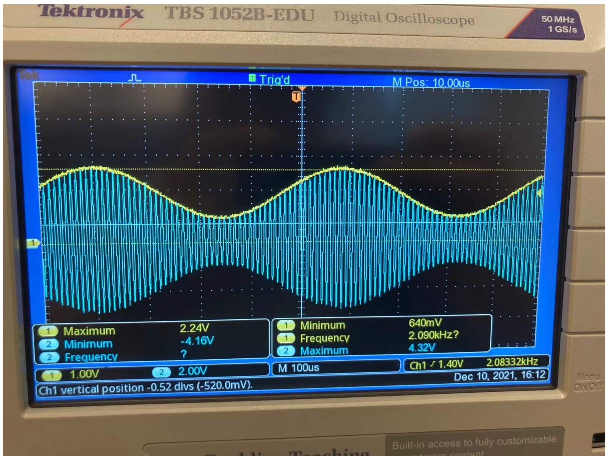

Figure 1: The two waveforms of Experiment A

3. Question 2: What is the key characteristic of the envelope of this AM signal?

   The upper envelope is same as the message signal. The lower envelope also has the same shape but upside-down

4. Question 3: For the given inputs to the multiplier module, how many sinewaves does the AM signal consist of and what are their frequencies?

   The signal consist of three sinewaves.

   - One at carrier frequencies (2kHz).
   - The second one is equal to the sum of the message and carrier frequencies (102kHz).
   - The third one is equal to the difference between the meaasge and carrier frequencies (98kHz).

5. Question 4: Why is there still a signal out of the multiplier module even when you are not talking, whistling, etc?

   When we are not talking or whisting, there is still have background noise in the lab room. Therefore, we can still see the signal output.

1.2 Experiment B

1. Question 5: What is the relationship between the message amplitude and the amount of the carrier modulation?

$$y(t) = 2\pi f_c t + A \times m(t) \tag{1}$$

f_c is the carrier frequency and $m(t)$ is the message amplitude with the respect of time. A is an constant.

2. Calculate and record the AM signal modulation index using the equation below:

$$m = \frac{(P - Q)}{(P + Q)} = \frac{(8.56 - 2.88)}{(8.56 + 2.88)} \approx 0.4965 \tag{2}$$

3. The two waveforms are shown in Figure 2.

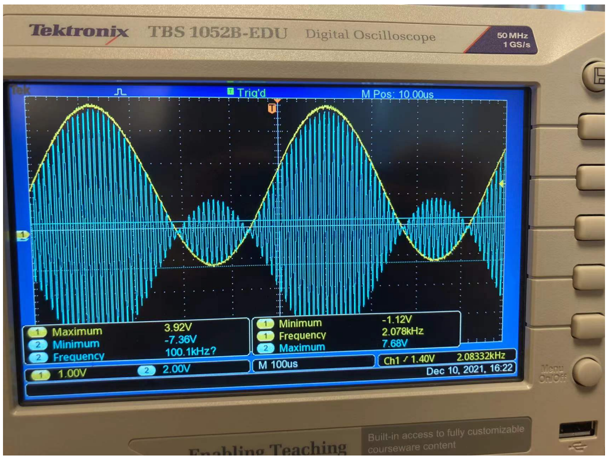

Figure 2: The two waveforms of Experiment B

4. Question 6: What is the problem with the AM signal when it is over-modulated?

   If the signal is overmodulated, the maximum magnitude of modulating signal is larger than the maximum magnitude of the carrier signal. The carrier phase has a 180 degrees reversal, which causes additional sidebands. Therefore, the signal becomes distorted.

5. Question 7: What is a carrier maximum modulation index without over-modulation?

   The maximum modulation index should be 1.

2 Part II: DSBSC modulation

2.1 Experiment A

1. The two waveforms are shown in Figure 3.

2. Question 8: What is the key characteristic of the envelope of this DSBSC signal?

   The maximum value for the envelope is quite close to 4V, which is the product of the maximum amplitude of message signal and carrier signal. The mimimum value is about to 0. The modulation index is close to 1.

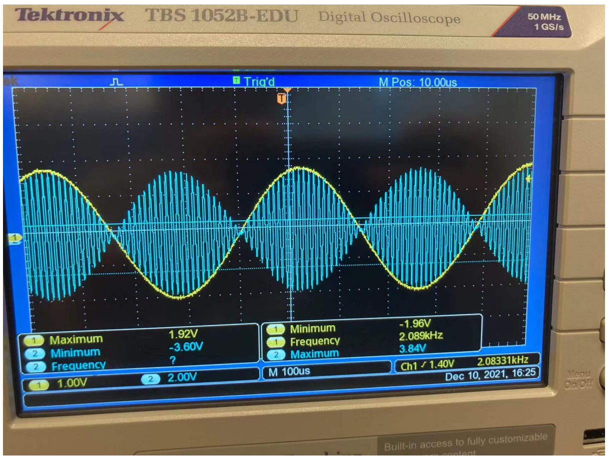

Figure 3: The two waveforms of Experiment A

3. Question 9: For the given inputs to the multiplier module, how many sinewaves does the DSBSC signal consist of and what are their frequencies?

   There will be two sinewaves. The frequency of the first one is 102kHz, while the second one is 98kHz.

4. Question 10: Why does this make DSBSC signals better for transmission than AM signals?

   In the DSBSC modulation, the wave carrier is not transmitted. Hence, DSBSC has better effiecncy and requires less power for transmission compared to AM signal. Thus, DSBSC is better than AM.

5. Question 11: What is the difference between the speech signal modulation here in DSBSC and the one in AM modulation?

   For DSBSC, the carrier will be suppressed, which means no carrier will be transmitted. For AM, the carrier signal will also be transmitted.

2.2 Experiment B

1. Question 12: Based on your observations, what is the effect of the message amplitude on the signal dimensions P and Q?

   When the magnitude of message signal becomes larger, the P will becomes larger. When the magnitude of message signal continue to increase, the magnitude of P will not change and remain at a certain value. Q will not change.

2. Set the Buffer module gain control to about half of its travel and notice the effect on the DSBSC signal. Draw the new DSBSC signal in the space provided.

   The waveforms are shown in Figure 4.

3. What is the name of this type of distortion? Why?

   Amplitude distortion. From the results, only the amplitude does not follow the theory. Other characteristics such as frequency, period follows the rules. Thus, it is called amplitude distortion.

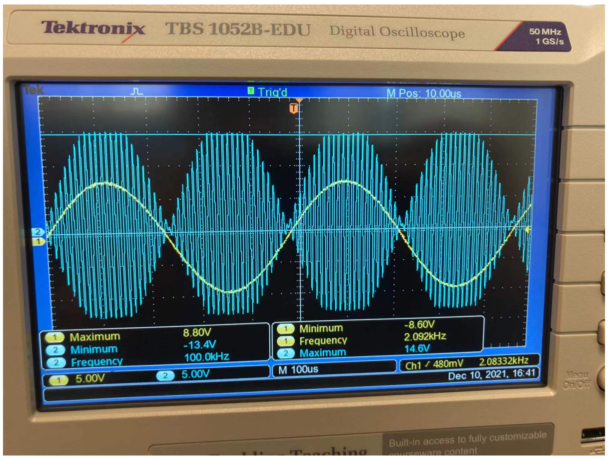

Figure 4: The DSBSC signal of Experiment B

3 Part III: AM demodulation

3.1 Experiment A

Measure the AM signal modulation index. m = 0.495

3.2 Experiment B

1. The waveforms are shown in Figure 5 and Figure 6.

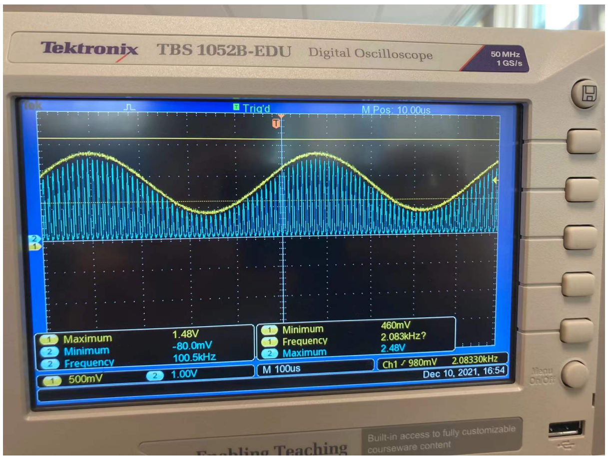

Figure 5: The waveforms of Experiment B

2. Question 14: Is there any difference between the original message signal and the recovered message? Why?

   The amplitude of recovered signal is about half of the origional signal. The message signal was modulated and received by the demodulation and passed through a filter. Thus, the amplitude will be attenuated. What is more, there is also a phase shifting between the two signals. That is caused by the cut-off frequency of the low pass filter.

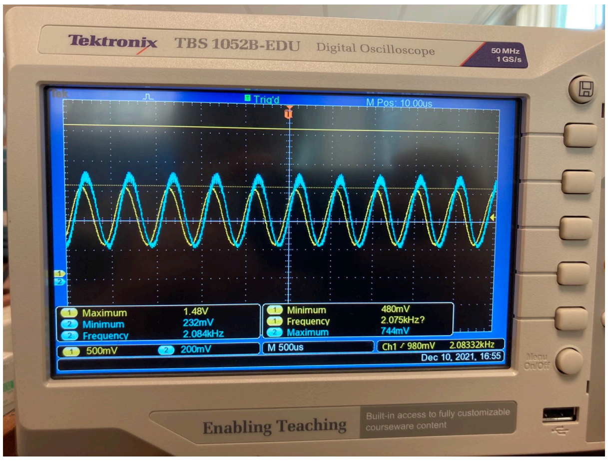

Figure 6: The waveforms of Experiment B

3.3 Experiment C

1. Question 15: Is there a difference between the amplitude of the two message signals? Why?

   Decrease the ampitude of the message, there is no change. Slight increases in the signal amplitude does not have any affect. Continue to increase the magnitude of signal, the signal will be distorted. Incrase the magnitude of the signal will make the magnitude beyond the maximum amplitude of the unmodulated wave. Thus, the signal will be clipped and a distorted signal can be seen.

2. Question 16: What causes the heavy distortion in the demodulated signal?

   If the magnitude of the message signal is larger than the carrier wave amplitude, the phase will be reversed. Thus, the demodulator will receive the incorrect envelope of the wave and output the distorted signal.

3.4 Experiment E

1. Question 17: How many sinewaves are present in the Multiplier module output?

   6.

2. What are their frequencies?

   200k, 0, 2k, 198k, 202k, 2k.

4 Part IV: DSBSC demodulation

4.1 Experiment A

1. The waveforms are shown in Figure 7 and Figure 8

2. Question 18: Why must a product detector be used to recover the message instead of an envelope detector?

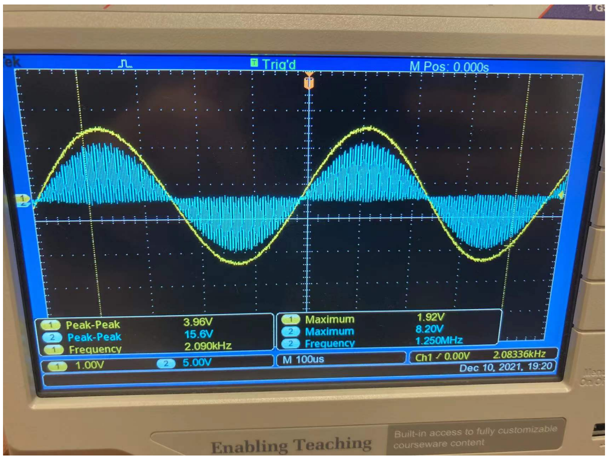

Figure 7: The waveforms of Experiment A

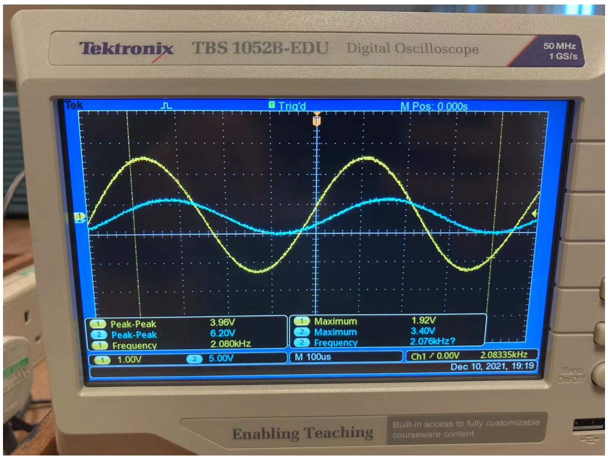

Figure 8: The waveforms of Experiment A

The product detector will not be influenced by the modulation index. If the modulation index is larger than 1, the envelope detector will produce an overmodulated signal. The output will become distorted. Thus, the product detector is used to avoid distortion.

4.2 Experiment B

1. Question 19:What is the difference between the amplitude of the two message signals (the original and the recovered)? Why?

   The amplitude of the recovered signal is larger than the original signal. The differnece is about 2V. Because a buffer is added to change the magnitude of the signal. What is more, the phase difference will also influence the magnitude of the signal.

2. Question 20: What causes the distortion in the demodulated signal?

   The phase of the carrier signal and variations in frequency cause the distortion.

4.3 Experiment D

1. Question 21: Given the size of the recovered message amplitude, what is the likely phase error between the two carriers?

   About 39.2 degree.

2. Question 22: Given the size of the recovered message new amplitude, what is the likely phase error between the two carriers?

   About -142.5 degree.

5 Part V: Frequency modulation

5.1 Experiment A

1. Question 23: How many sinewaves are at the output of the VCO module?

   Two

2. Question 24: Why do the sinewaves have different frequencies?

   Because during the FM process, the frequncy will changes in accordance with the modulating signal. The higher the amplitude of the message signal, the greater the frequency changes.

3. Question 25: Which sinewave corresponds with the squarewave upper peak? (the one with the lower frequency or the higher frequency?)

   The one with higher frequency.

4. Question 26: Do either of these sinewaves have the same frequency as the VCO module rest frequency? Why?

   Yes. The lower frequency is quite close to message signal.

   $$f_i(t) = f_c + k_f m(t) \tag{3}$$

   According to the equation, when the magnitude of the message signal is closer to 0. The output signal will be similar to rest frequency.

Table 1: FM modulating a square wave

	Period (s)	Frequency (kHz)
Low frequency sinewave	1.015×10^{-4}	9.852
High frequency sinewave	5.701×10^{-5}	17.54

5. Question 27: What do the FM signal two sinewaves tell you about the message signal?

   Two sinewaves indicates there are two different kinds of amplitude in the original message signal.

5.2 Experiment B

Question 28: What happens to the VCO module output as you talk louder? Why?

Increase the amplitude will increase the frequency the output. The equation is shown below:

$$f_i(t) = f_c + k_f m(t) \tag{4}$$

m_t is the message signal, k_f is frequency sensitivity of the modulator. f_c is the carrier frequency.

6 Part VI: FM demodulation

1. Question 29: Why does the FM signal have one frequency only in this case?

   The modulator produces a output frequency in proportion to the input voltage applied. Thus, it is a single frequency in correspondence to the voltage Vdc.

2. Question 30: What type of a waveform does the comparator output?

   Square wave.

3. Question 31: What does this tell you about the DC component of the comparator output?

   If the input is smaller than DC, the output will be negative. If it is equal to DC, the output will be 0. If it is larger than DC, the output is positive.

4. Question 32: What type of waveform does the ZCD output?

   A train of pulses.

5. Question 33: As the FM signal changes frequency so does the ZCD output, what aspect of the signal changes to achieve this?

   Both the signal mark and space

6. Question 34: What does this tell you about the DC component of the ZCD output?

   DC component falls with time. Therefore, the gain will increase.

7. Question 35: If the original message is a sinewave instead of a variable DC voltage, what would you expect the output of the baseband LPF be?

   It depends on the frequency of the signal. If frequency is larger than the low pass filter frequency, the output will be a sine wave. If smaller, the output is 0.