

## Experiment 5 - Amplitude modulation

### Preliminary discussion

In an amplitude modulation (AM) communications system, speech and music are converted into an electrical signal using a device such as a microphone. This electrical signal is called the *message* or *baseband* signal. The message signal is then used to electrically vary the amplitude of a pure sinewave called the *carrier*. The carrier usually has a frequency that is much higher than the message's frequency.

Figure 1 below shows a simple message signal and an unmodulated carrier. It also shows the result of amplitude modulating the carrier with the message. Notice that the modulated carrier's amplitude varies above and below its unmodulated amplitude.

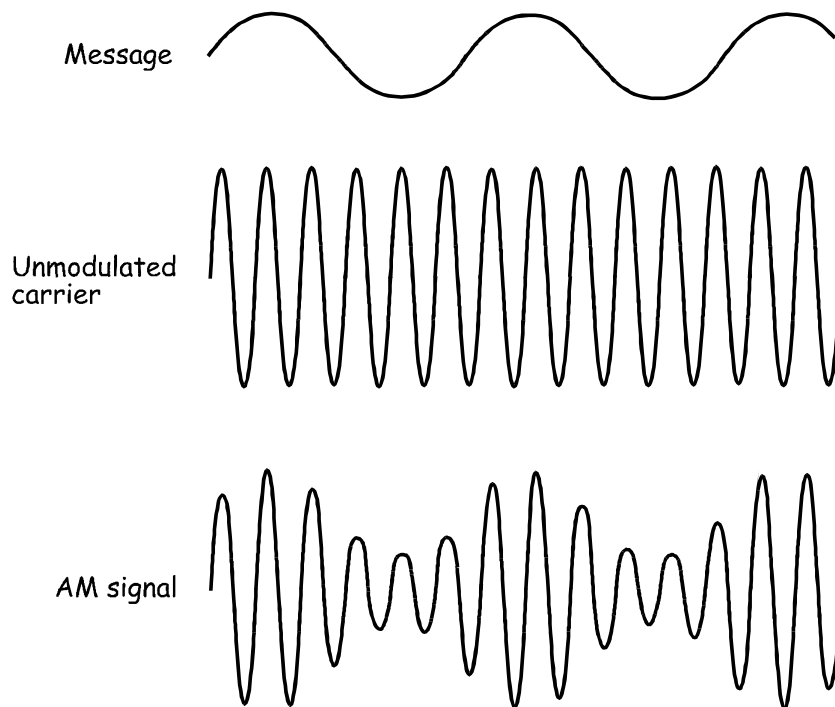


Figure 1

Figure 2 below shows the AM signal at the bottom of Figure 1 but with a dotted line added to track the modulated carrier's positive peaks and negative peaks. These dotted lines are known in the industry as the signal's *envelopes*. If you look at the envelopes closely you'll notice that the upper envelope is the same shape as the message. The lower envelope is also the same shape but upside-down (inverted).

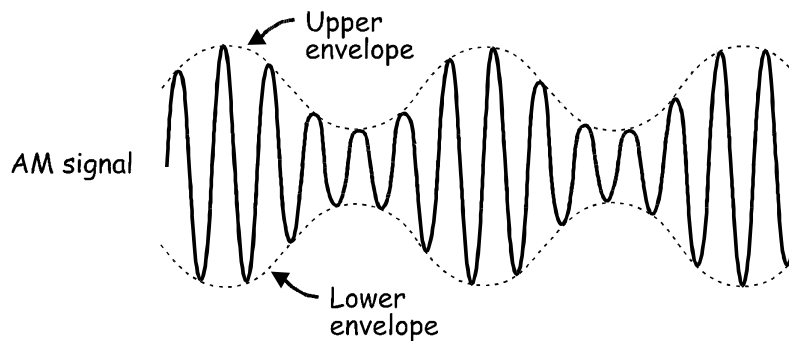


Figure 2

In telecommunications theory, the mathematical model that defines the AM signal is:

$$AM = (DC + message) \times \text{the carrier}$$

When the message is a simple sinewave (like in Figure 1) the equation's solution (which necessarily involves some trigonometry that is not shown here) tells us that the AM signal consists of three sinewaves:

- One at the carrier frequency
- One with a frequency equal to the sum of the carrier and message frequencies
- One with a frequency equal to the difference between the carrier and message frequencies

In other words, for every sinewave in the message, the AM signal includes a pair of sinewaves – one above and one below the carrier's frequency. Complex message signals such as speech and music are made up of thousands sinewaves and so the AM signal includes thousands of pairs of sinewaves straddling carrier. These two groups of sinewaves are called the *sidebands* and so AM is known as *double-sideband, full carrier* (DSBFC).

Importantly, it's clear from this discussion that the AM signal doesn't consist of any signals at the message frequency. This is despite the fact that the AM signal's envelopes are the same shape as the message.

### **The experiment**

In this experiment you'll use the Emona DATEx to generate a real AM signal by implementing its mathematical model. This means that you'll add a DC component to a pure sinewave to create a message signal then multiply it with another sinewave at a higher frequency (the carrier). You'll examine the AM signal using the scope and compare it to the original message. You'll do the same with speech for the message instead of a simple sinewave.

Following this, you'll vary the message signal's amplitude and observe how it affects the modulated carrier. You'll also observe the effects of modulating the carrier too much. Finally, you'll measure the AM signal's depth of modulation using a scope.

It should take you about 1 hour to complete this experiment.

### **Equipment**

- Personal computer with appropriate software installed
- NI ELVIS plus connecting leads
- NI Data Acquisition unit such as the USB-6251 (or a 20MHz dual channel oscilloscope)
- Emona DATEx experimental add-in module
- two BNC to 2mm banana-plug leads
- assorted 2mm banana-plug patch leads

## Procedure

### Part A - Generating an AM signal using a simple message

1. Ensure that the NI ELVIS power switch at the back of the unit is off.
2. Carefully plug the Emona DATEx experimental add-in module into the NI ELVIS.
3. Set the *Control Mode* switch on the DATEx module (top right corner) to *PC Control*.
4. Check that the NI Data Acquisition unit is turned off.
5. Connect the NI ELVIS to the NI Data Acquisition unit (DAQ) and connect that to the personal computer (PC).
6. Turn on the NI ELVIS power switch at the back then turn on its *Prototyping Board Power* switch at the front.
7. Turn on the PC and let it boot-up.
8. Once the boot process is complete, turn on the DAQ then look or listen for the indication that the PC recognises it.
9. Launch the NI ELVIS software.
10. Launch the DATEx soft front-panel (SFP).
11. Check you now have soft control over the DATEx by activating the PCM Encoder module's **soft PDM/TDM** control on the DATEx SFP.

**Note:** If your set-up is working correctly, the PCM Decoder module's LED on the DATEx board should turn on and off.



Ask the instructor to check your work before continuing.

12. Slide the NI ELVIS Variable Power Supplies' negative output *Control Mode* switch so that it's no-longer in the *Manual* position.
13. Launch the Variable Power Supplies VI.
14. Turn the Variable Power Supplies negative output soft *Voltage* control to about the middle of its travel.
15. You'll not need to adjust the Variable Power Supplies VI again so minimise it (but don't close it as this will end the VI's control of the device).
16. Locate the Adder module on the DATEx SFP and turn its soft *G* and *g* controls fully anti-clockwise.
17. Connect the set-up shown in Figure 3 below.

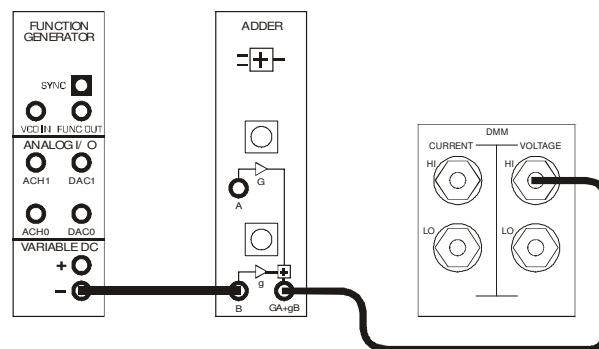


Figure 3

18. Launch the NI ELVIS DMM VI.
 

**Note:** Ignore the message about maximum accuracy and simply click the OK button.
19. Set up the DMM for measuring DC voltages.
20. Adjust the Adder module's soft *g* control to obtain a 1V DC output.
21. Close the DMM VI - you'll not need it again (unless you accidentally change the Adder module's soft *g* control).

22. Connect the set-up shown in Figure 4 below.

**Note:** Insert the black plugs of the oscilloscope leads into a ground (*GND*) socket.

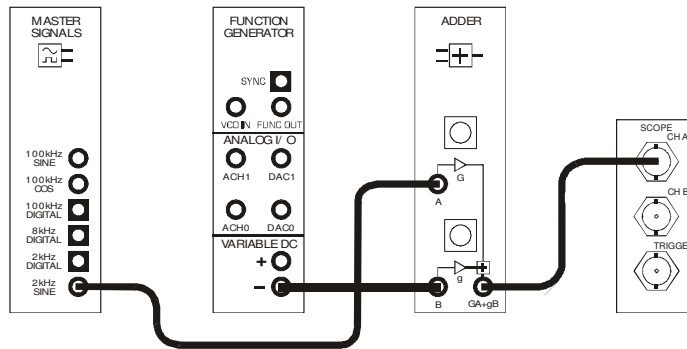


Figure 4

This set-up can be represented by the block diagram in Figure 5 below. It implements the highlighted part of the equation:  $AM = (DC + message) \times the\ carrier$ .

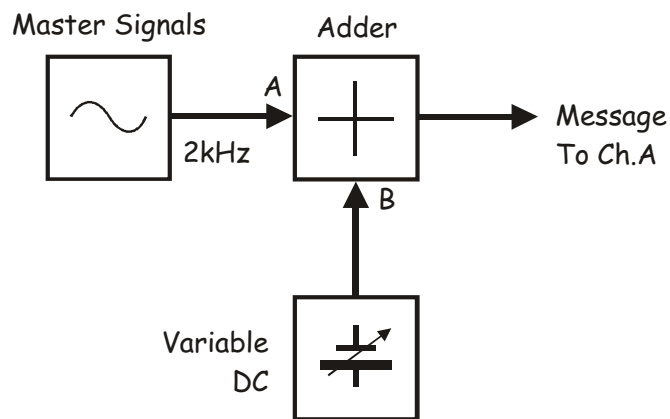


Figure 5

23. Launch the NI ELVIS Oscilloscope VI.
24. Set up the scope per the procedure in Experiment 1 (page 1-13) with the following changes:
  - *Trigger Source* control to *Immediate* instead of *CH A*
  - *Channel A Coupling* control to the *DC* position instead of *AC*
  - *Channel A Scale* control to the *500mV/div* position instead of *1V/div*

At the moment, the scope should just be showing a flat trace that is two divisions up from the centre line because the Adder module's output is 1V DC.

25. While watching the Adder module's output on the scope, turn its soft *G* control clockwise to obtain a 1Vp-p sinewave.

**Tip:** Remember that you can use the keyboard's *TAB* and arrow keys for fine adjustment of the DATEx SFP's controls.

The Adder module's output can now be described mathematically as:

$$AM = (1VDC + 1Vp-p\ 2kHz\ sine) \times \text{the carrier}$$

#### Question 1

In what way is the Adder module's output now different to the signal out of the Master Signals module's *2kHz SINE* output?

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Ask the instructor to check your work before continuing.

26. Set the scope's *Trigger Source* control to *CH A* and set its *Trigger Level* control to 1V.

27. Modify the set-up as shown in Figure 6 below.

### Before you do...

The set-up in Figure 6 builds on Figure 4 so don't pull it apart. Existing wiring is shown as dotted lines to highlight the patch leads that you need to add.

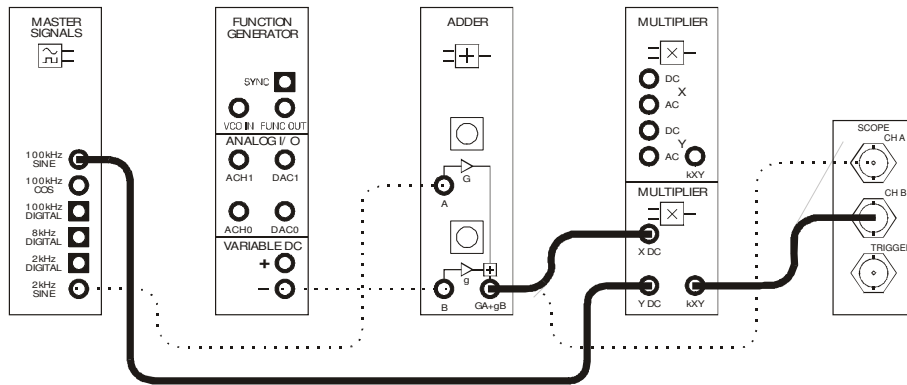


Figure 6

This set-up can be represented by the block diagram in Figure 7 below. The additions that you've made to the original set-up implement the highlighted part of the equation:  
 $AM = (DC + \text{message}) \times \text{the carrier}$ .

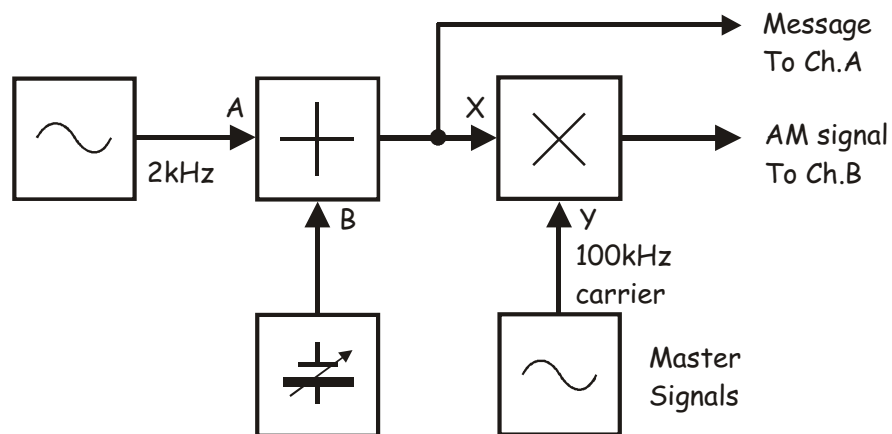


Figure 7

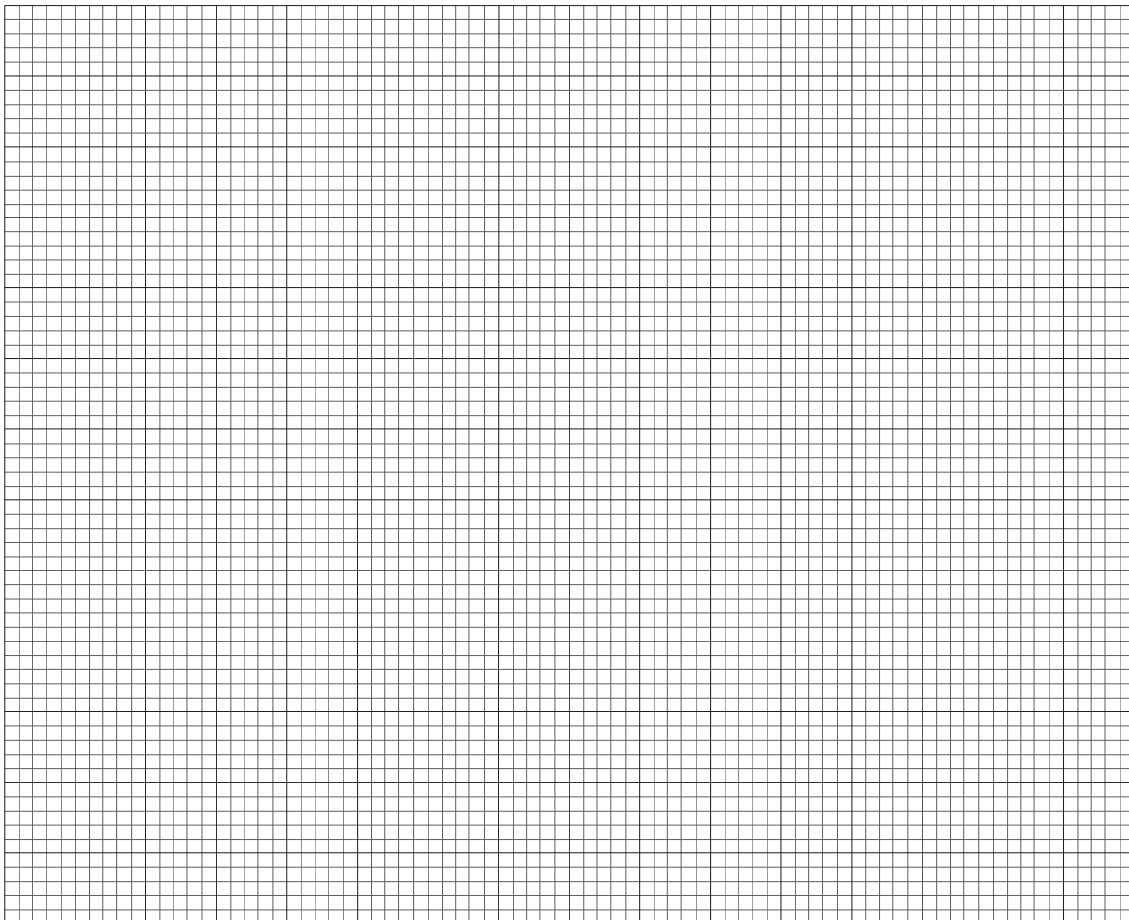


With values, the equation on the previous page becomes:

$$AM = (1VDC + 1Vp-p \text{ 2kHz sine}) \times 4Vp-p \text{ 100kHz sine.}$$

28. Adjust the scope's *Timebase* control to view only two or so cycles of the message signal.
29. Activate the scope's Channel B input by pressing the Channel B *Display* control's *ON/OFF* button to view the Multiplier module's output as well as the message signal.
30. Draw the two waveforms to scale on the graph provided below.

**Tip:** Draw the message signal in the upper half of the graph and the AM signal in the lower half.





Ask the instructor to check your work before continuing.

31. Use the scope's Channel A *Position* control to overlay the message with the AM signal's upper envelope then lower envelope to compare them.

**Tip:** If you haven't do so already, press the Channel B *Autoscale* button.

**Question 2**

What feature of the Multiplier module's output suggests that it's an AM signal? **Tip:** If you're not sure about the answer to the questions, see the preliminary discussion.

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**Question 3**

The AM signal is a complex waveform consisting of more than one signal. Is one of the signals a 2kHz sinewave? Explain your answer.

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**Question 4**

For the given inputs to the Multiplier module, how many sinewaves does the AM signal consist of, and what are their frequencies?

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Ask the instructor to check your work before continuing.

### Part B - Generating an AM signal using speech

This experiment has generated an AM signal using a sinewave for the message. However, the message in commercial communications systems is much more likely to be speech and music. The next part of the experiment lets you see what an AM signal looks like when modulated by speech.

32. Disconnect the plug on the Master Signals module's 2kHz SINE output that connects to the Adder module's A input.
33. Connect it to the Speech module's output as shown in Figure 8 below.

**Remember:** Dotted lines show leads already in place.

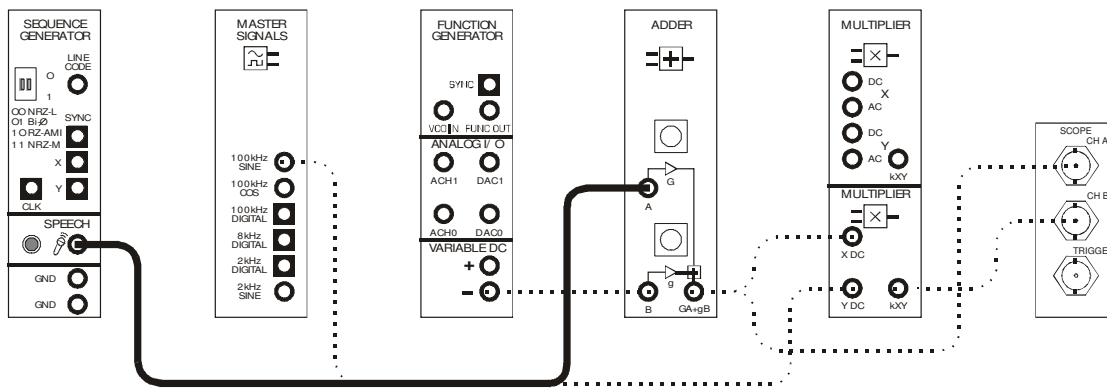


Figure 8

34. Set the scope's *Timebase* control to the *1ms/div* position.
35. Hum and talk into the microphone while watching the scope's display.

#### Question 5

Why is there still a signal out of the Multiplier module even when you're not humming (or talking, etc)?

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Ask the instructor to check your work before continuing.

### Part C - Investigating depth of modulation

It's possible to modulate the carrier by different amounts. This part of the experiment let's you investigate this.

36. Return the scope's *Timebase* control to the  $100\mu\text{s}/\text{div}$  position.
37. Disconnect the plug to the *Speech* module's output and reconnect it to the *Master Signals* module's  $2\text{kHz SINE}$  output.

**Note:** The scope's display should now look like your drawings on the graph paper on page 5-10.

38. Vary the message signal's amplitude a little by turning *Adder* module's soft  $G$  control left and right and notice the effect on the *AM* signal.

### Question 6

What is the relationship between the message's amplitude and the amount of the carrier's modulation?

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Ask the instructor to check your work before continuing.

You probably noticed that the size of the message signal and the modulation of the carrier are proportional. That is, as the message's amplitude goes up, the amount of the carrier's modulation goes up.

The extent that a message modulates a carrier is known in the industry as the *modulation index* ( $m$ ). Modulation index is an important characteristic of an AM signal for several reasons including calculating the distribution of the signal's power between the carrier and sidebands.

Figure 9 below shows two key dimensions of an amplitude modulated carrier. These two dimensions allow a carrier's modulation index to be calculated.

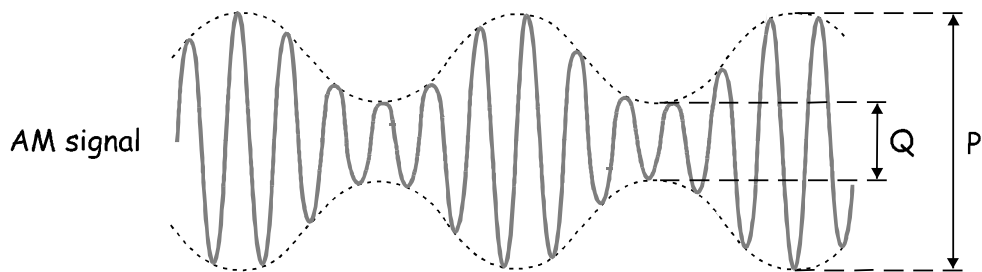


Figure 9

The next part of the experiment lets you practise measuring these dimensions to calculate a carrier's modulation index.

39. Adjust the Adder module's soft  $G$  control to return the message signal's amplitude to 1Vp-p.
40. Measure and record the AM signal's  $P$  dimension. Record your measurement in Table 1 below.
41. Measure and record the AM signal's  $Q$  dimension.
42. Calculate and record the AM signal's depth of modulation using the equation below.

$$m = \frac{P - Q}{P + Q}$$

Table 1

P dimension	Q dimension	m



Ask the instructor to check your work before continuing.

A problem that is important to avoid in AM transmission is *over-modulation*. When the carrier is over-modulated, it can upset the receiver's operation. The next part of the experiment gives you a chance to observe the effect of over-modulation.

43. Increase the message signal's amplitude to maximum by turning the Adder module's soft  $\mathcal{G}$  control to about half its travel then fully clockwise and notice the effect on the AM signal.
44. Press the scope's *Autoscale* controls for both channels resize the signals on the display.
45. Use the scope's Channel A *Position* control to overlay the message with the AM signal's envelopes and compare them.

#### Question 7

What is the problem with the AM signal when it is over-modulated?

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#### Question 8

What do you think is a carrier's maximum modulation index without over-modulation?

- A minus number
- 0
- 1
- Greater than 1



Ask the instructor to check your work before continuing.

46. Draw the two waveforms to scale in the space provided below.



Ask the instructor to check your work before finishing.

Name: \_\_\_\_\_

Class: \_\_\_\_\_

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## 6 - DSBSC modulation

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