# Daffodil International University
## Department of Electrical and Electronic Engineering
### EEE 316: Communications Engineering Laboratory

**EXPERIMENT NO: 01**

**NAME OF THE EXPERIMENT: Study of Amplitude Modulation (AM)**

## Objective and Theory

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 2 shows the AM signal at the bottom of Figure 1but 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). In telecommunications theory, the mathematical model that defines the AM signal is:

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

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.

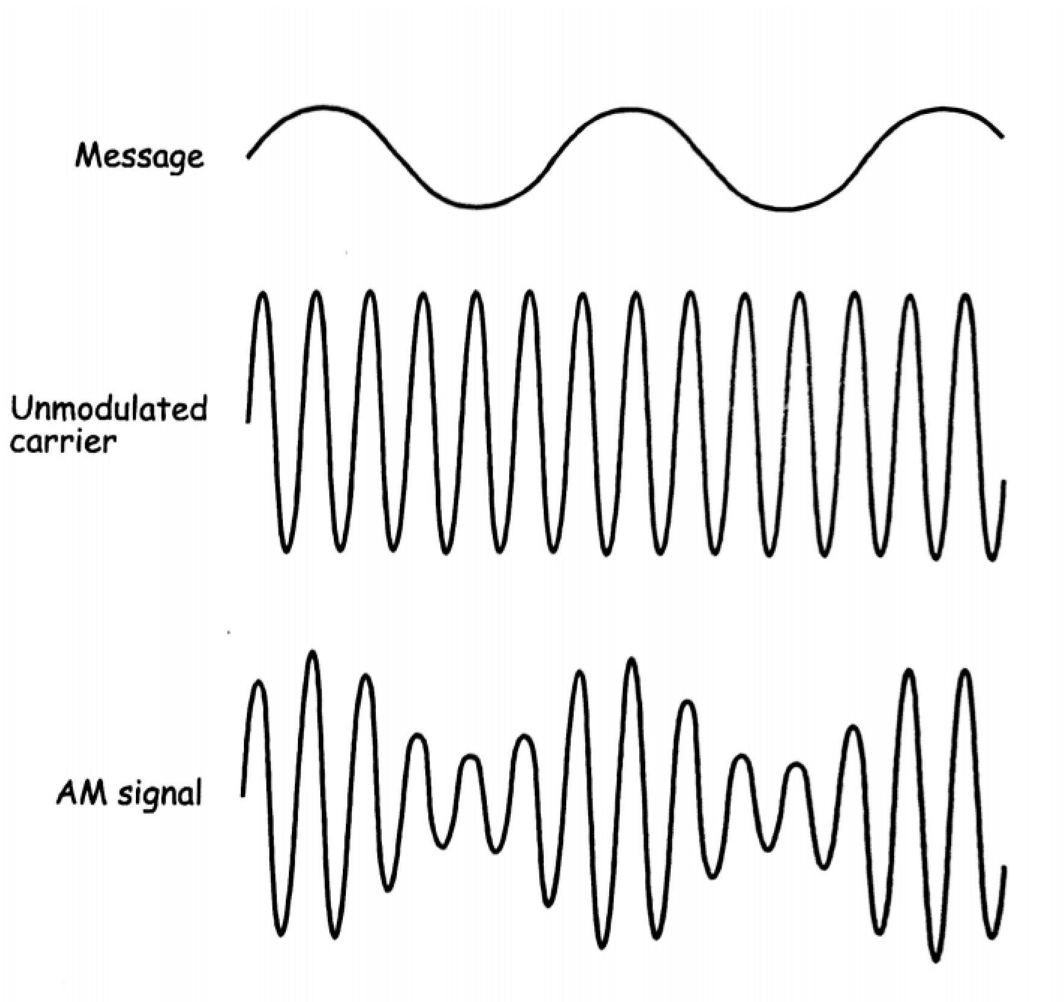


Figure: 01

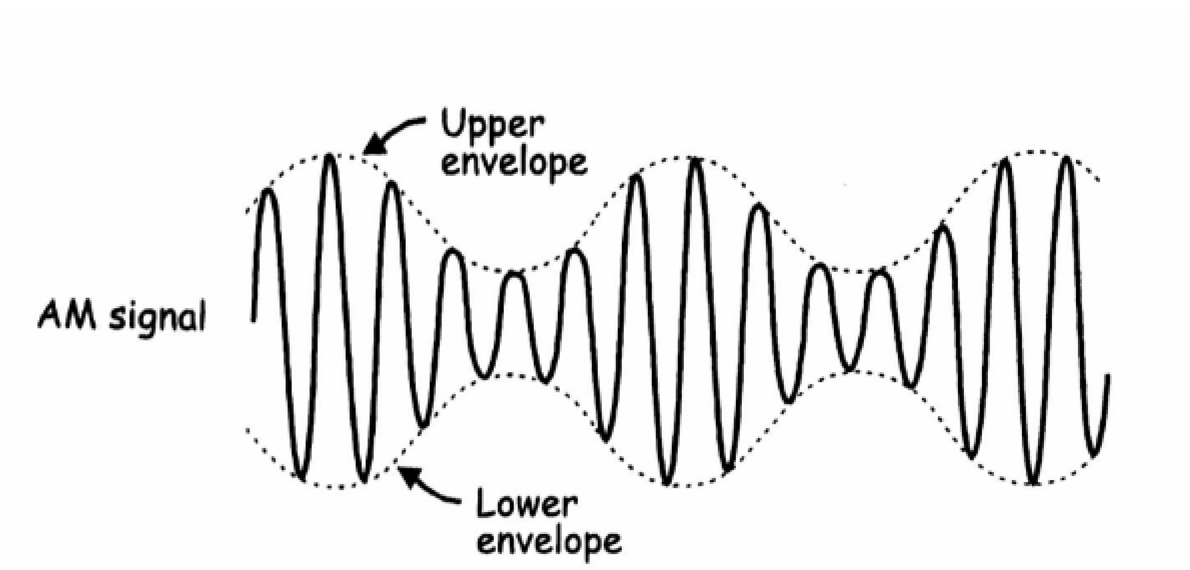


Figure: 02

## The experiment

In this experiment you'll use Emona Telecoms- Trainer 101 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:

- Emona Telecoms-Trainer 101 (plus power-pack)
- Dual channel 20MHz oscilloscope
- Two Emona Telecoms- Trainer 101 oscilloscope leads
- Assorted Emona Telecoms- Trainer 101 patch leads

## Procedure:

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

1. Gather a set of the equipment listed on the previous page.

2. Set up the scope per the instructions in Experiment 1. Ensure that :
   - the Trigger Source control is set to the CH1 (or INT) position.
   - the Mode control is set to the CH1 position.

3. Set the scope's Channel l Input Coupling control to the DC position.

4. Locate the Adder module and turn its G and g controls fully anti-clockwise.

5. Locate the Variable DCV module and turn its DC Voltage control almost fully anti-clockwise.

6. Connect the set-up shown in Figure 3 below.

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

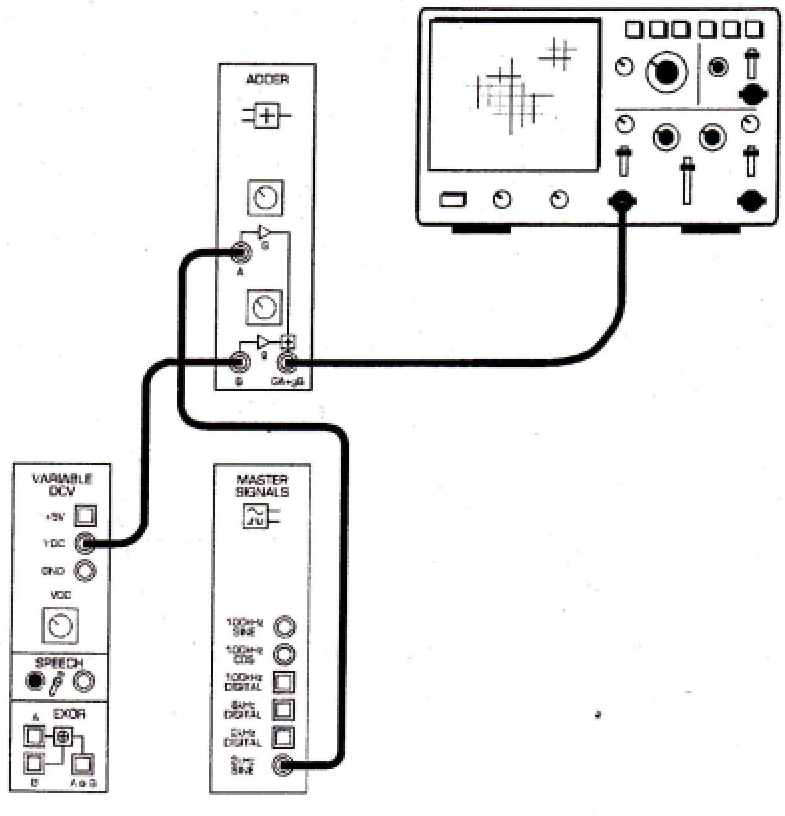


Figure: 03

The set-up in Figure 3 can be represented by the block diagram in Figure 4 below. It implements the highlighted part of the equation: $AM = (DC + message) \times the\ carrier$

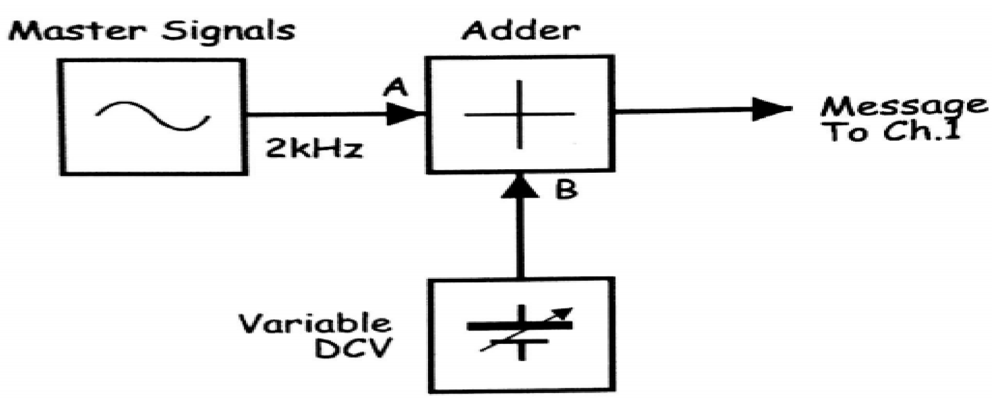


Figure: 04

At the moment, the scope should just be showing a flat trace because the Adder module's output is 0V. Once you've completed steps 7 to 10 below, the equation will have the following values:

$$AM = (1\,VDC + 1\,Vp-p\;2kHz\;sine) \times the\;carrier\,.$$

7. Set the scope's Channel l Vertical Attenuation control to the 0.5V/div position.

8. Use the scope's Channel 1 Vertical Position control to move the trace so that it lines up with the horizontal line in the middle of the scope's screen.

9. While watching the Adder module's output on the scope, turn its g control clockwise until the DC level is 1V.

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

**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?

The set-up in Figure 5 can be represented by the block diagram in Figure 6 below. The additions that you've made to the original set-up implement the highlighted part of the equation:

$$AM = (DC + message) \times the\;carrier$$

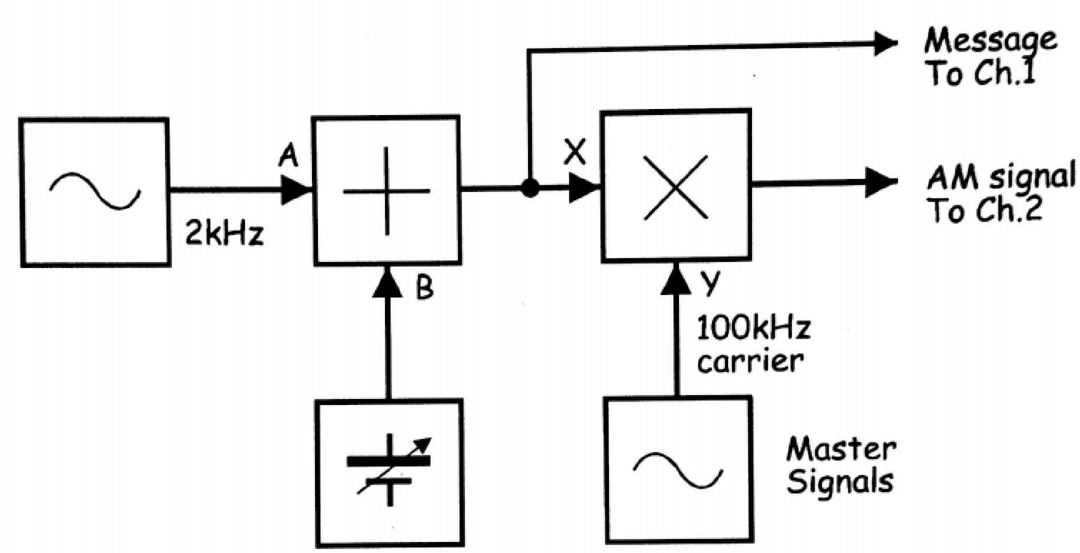


Figure: 05

With values, the equation is:

$$AM = (1\,V\,DC + 1\,V\,p-p\;2kHz\;sine)\;x\;4Vp-p\;100kHz\;sine.$$

11. Set the scope's Mode control to the DUAL position.

12. Set the scope's Channel 2 Vertical Attenuation control .to the 1V/div position.

13. Draw the two waveforms to scale.

14. Use the scope’s Channel 1 vertical position control to overlay the message with the AM signal envelopes and compare them.

**Question 2**

What features 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.

**Question 3**

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

**Question 4**

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

**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.

15. Disconnect the plug on the Master Signals module's 2kHz SINE output that connects to the Adder module's A input.

16. Connect it to the Speech module's output as shown in Figure 7 below.

Remember: Dotted lines show leads already in place.

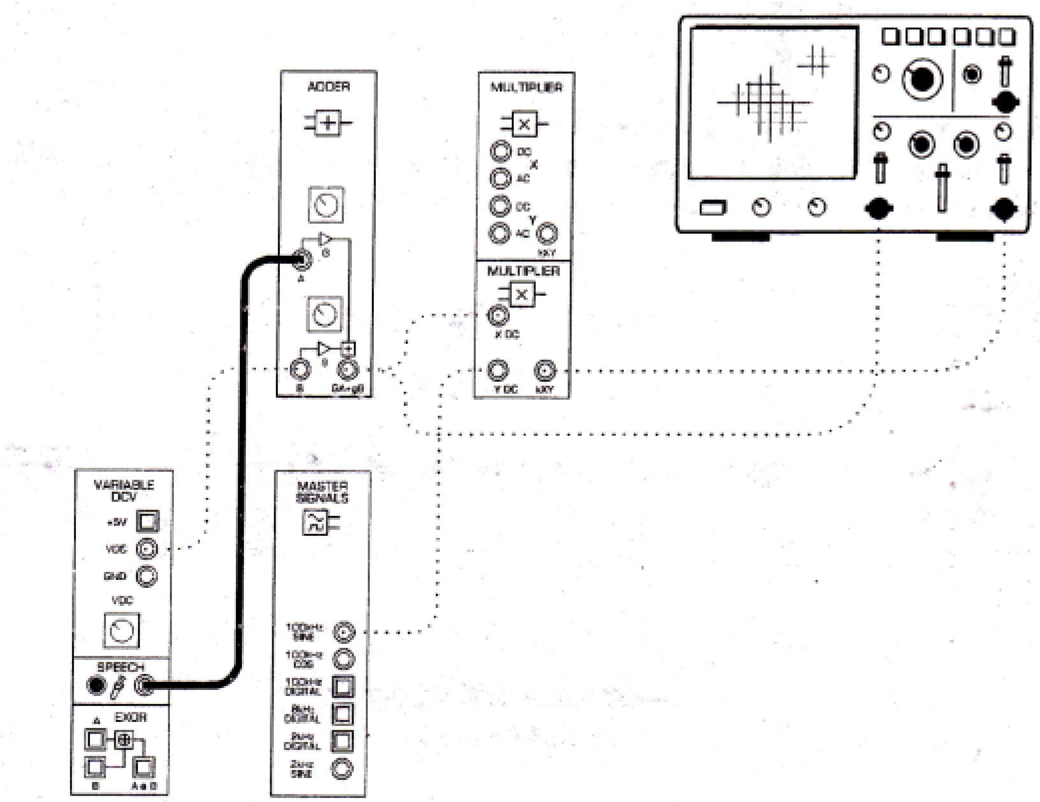


Figure: 06

17. Set the scope's Timebase control to the 2ms/div position.

18. Talk, sing or hum while watching the scope's display.

**Question 5**

Why is there still a signal out of the Multiplier module when you are not  talking, whistling etc.?

**Part C - Investigating depth of modulation**

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

19. Return the scope's Timebase control to the 0.1ms/div position.

20. Disconnect the plug on the Speech module's output .

21. Reconnect the Adder module's A input to the Master Signals module's 2kHz SINE output.

22. Vary the message signal's amplitude a little by turning Adder module's 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?

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

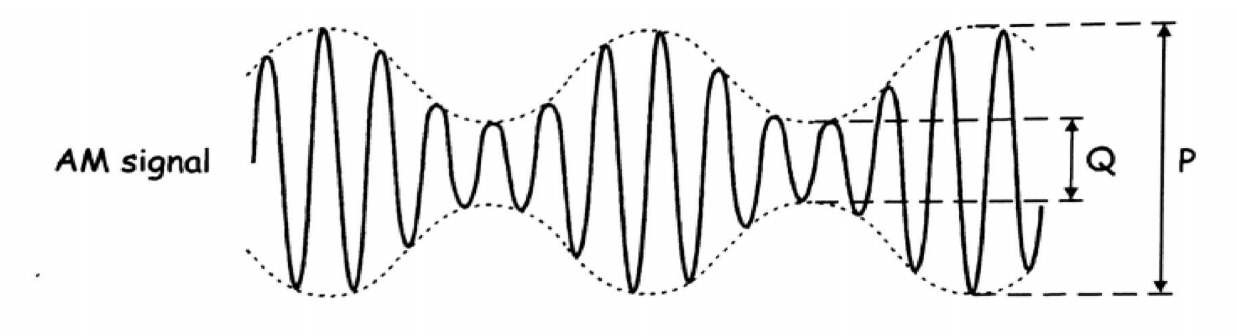


Figure: 08

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

23. Adjust the Adder module's G control to return the message signal's amplitude to l V p-p.

24. Measure and record the AM signal's P dimension. Record your measurement in Table 1 below.

25. Measure and record the AM signal's Q dimension.

26. 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 |
|---|---|---|
| | | |

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.

27. Increase the message signal's amplitude to maximum by turning the Adder module's G control fully clockwise and notice the effect on the AM signal.

28. Use the scope's Channel l Vertical 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?

**Question 8**

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