

Lab Manual:  
Communications Principles  
  
Using the EMONA Communications board for NI ELVIS III



Lab 4: Amplitude Modulation (AM)

List of Updates

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# Lab 4: Amplitude modulation

In this Lab you will Create an amplitude modulated signal from a variety of message sources, calculate the modulation index and confirm the frequency spectrum of this signal type.

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 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: Amplitude Modulated signal

Figure 2 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 : Message envelopes

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

AM = (DC + message) × 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:

1. One at the carrier frequency
2. One with a frequency equal to the sum of the carrier and message frequencies
3. 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 of 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 also 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.

## Section 1: Amplitude Modulation

For this experiment you’ll use the Emona board 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.

## Learning Objectives

After completing this lab, you should be able to complete the following activities.

1. Generate a real AM signal
2. Examine a real AM signal with scope and compare it to its original message
3. Use multiple message sources in your AM examination
4. Describe the term “depth of modulation”

## Prerequisites

You should have completed Labs 1 & 2 and be familiar with the equipment, its use and the handling precautions for the equipment.

## Required Tools and Technology

|  |  |
| --- | --- |
| Platform: NI ELVIS III Instruments used in this lab:   * Oscilloscope-Time * Oscilloscope-FFT * Function Generator | * Install Instruments: [http://www.ni.com/documentation/en/ni-elvis-iii/latest/getting-started/installing-the-soft-front-panel/](http://www-preview.ni.com/documentation/en/ni-elvis-iii/1.0/getting-started/installing-the-soft-front-panel/) * Access instruments <https://measurementslive.ni.com> * View User Manual <http://www.ni.com/en-us/support/model.ni-elvis-iii.html>   View tutorials <https://www.youtube.com/playlist?list=PLvcPIuVaUMIWm8ziaSxv0gwtshBA2dh_M> |
| Hardware: Emona Communications Board Components used in this lab:   * Four BNC to 2mm banana-plug leads * Assorted 2mm banana-plug patch leads * Set of headphones or earbuds | * View User Manual <http://www.ni.com/en-us/support/model.emona-communications-board-for-ni-elvis-iii.html> |
| Software: NI ELVIS III Function Generator File used in this lab (available in lab folder):   * ECB\_positive1V\_DC.csv | * Access instrument <https://measurementslive.ni.com> |

## Expected Deliverables

In this lab, you will collect the following deliverables:

* Calculations
* Data from measurements
* Observations

Your instructor may expect you complete a lab report. Refer to your instructor for specific requirements or templates.

## 1.1 Implement: Generating Amplitude modulation (AM)

**Powering up the ELVIS III + EMONA Communications Board**

|  |  |
| --- | --- |
| 1. | Ensure that the NI ELVIS III Application Board power button at the top left corner of the unit is OFF (not illuminated). |

|  |  |
| --- | --- |
| 2. | Carefully plug the Emona Communications board into the NI ELVIS III ensuring that it is fully engaged both front and back. |

|  |  |
| --- | --- |
| 3. | Ensure that you have connected the NI ELVIS III to the PC using the USB cable and that the PC is turned on. |

|  |  |
| --- | --- |
| 4. | Turn on the Application Board *Power* button by pressing it once and confirm that it is illuminated. The LEDs on the board should also be illuminated. If they are not, then switch the unit off immediately and check for connection or insertion errors. |

|  |  |
| --- | --- |
| 5. | Open the Instrument Launcher software in your browser and select the required instruments. |

Table 3 Scope Configuration

|  |  |
| --- | --- |
| Channel Voltage range | 2 V/div |
| Horizontal Timebase | 50us/div |
| Trigger | Analog Edge, Chan 1, Rising |
| Probe Attenuation | 1x |

|  |  |
| --- | --- |
| 6. | Use the ELVIS III Function Generator output Channel 2 to create a DC voltage of about 1V by loading the Custom waveform file “ECB\_positive1V\_DC.csv”. |

|  |  |
| --- | --- |
| 7. | Connect the set-up shown in Figure 3. |

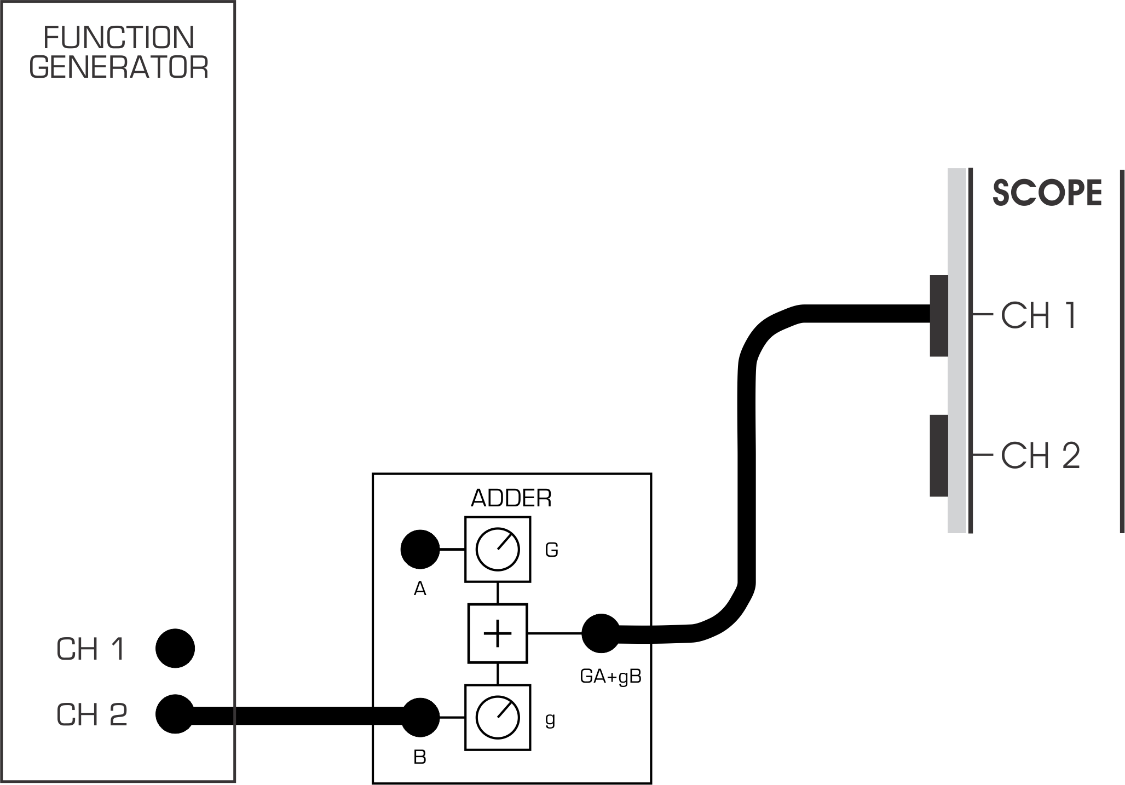


Figure 3: Create DC voltage

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| --- | --- |
| 8. | Locate the Adder module on the board and turn its *G* control fully anti-clockwise. |

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| --- | --- |
| 9. | Adjust the Adder module’s *g* control to obtain a 1V DC output (as measured by the Scope). |

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| --- | --- |
| 10. | Connect the set-up shown in Figure 4.  **Note:** Insert the black plugs of the oscilloscope lead into a ground (*GND*) socket. |

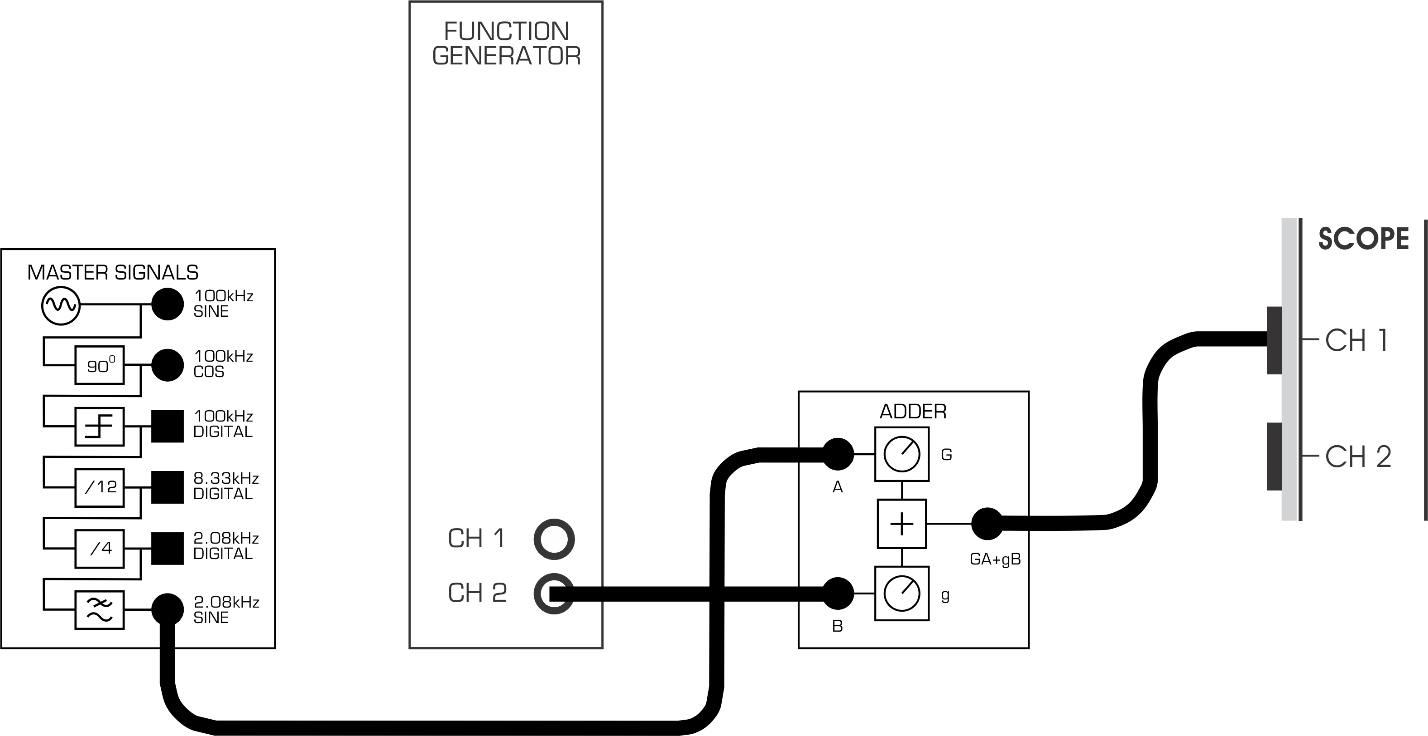


Figure 4: Add DC to the message

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

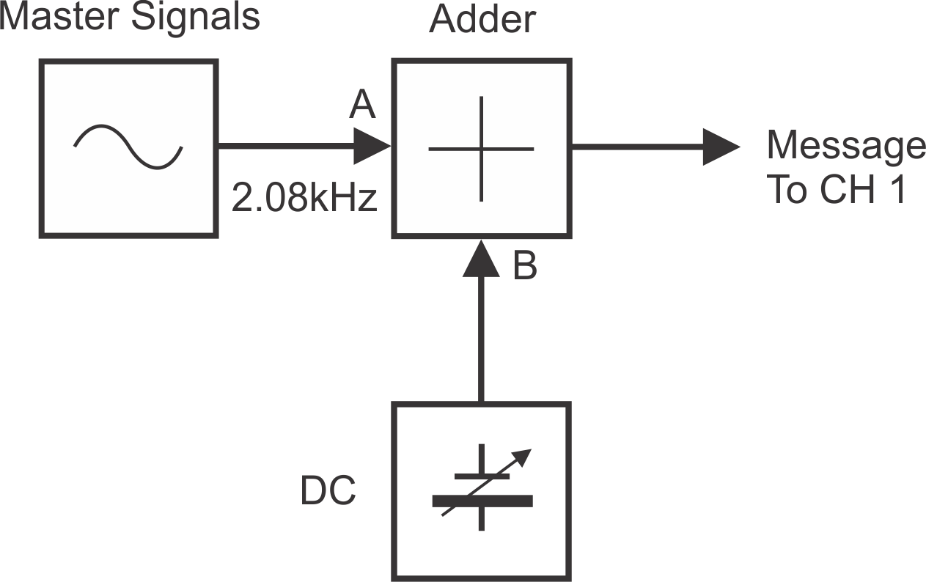


Figure 5: Block diagram for addition

|  |  |
| --- | --- |
| 11. | Set up the scope with the following settings:   1. Channel 1*Coupling* control to the *DC* position 2. Channel 1*Scale* control to the *500mV/div* position 3. *Trigger Level* control to the *1V* position instead of *0V* |

Adjust the Trigger level and Source to have a stable signal to view.

|  |  |
| --- | --- |
| 12. | While watching the Adder module’s output on the scope, turn its *G* control clockwise to obtain a 1Vp-p sinewave. |

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

AM = (1VDC + 1Vp-p 2.08kHz sine) × the carrier

* 1. In what way is the Adder module’s output now different to the signal out of the Master Signals module’s *2.08kHz SINE* output?

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| 13. | Modify the set-up as shown in Figure 6. |

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| --- | --- | --- | --- | --- |
|  |  |  | |  |
|  | 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. | | |  |
|  |  | |  |  |

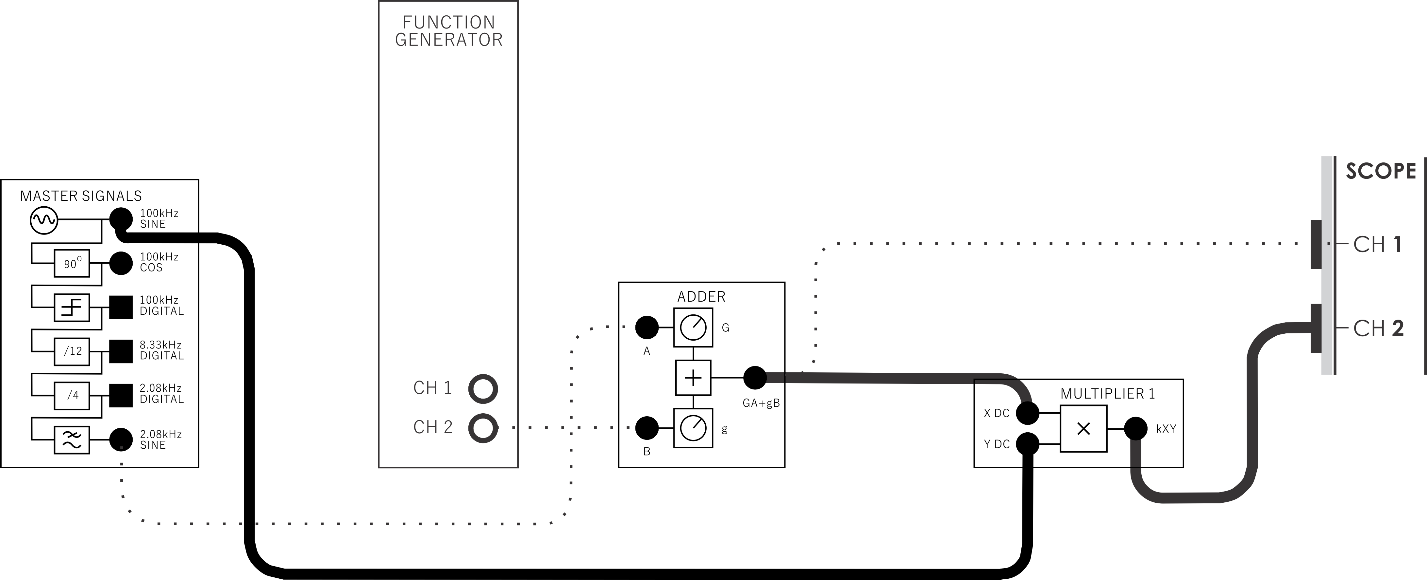


Figure 6: Multiply the baseband message by the carrier

This set-up can be represented by the block diagram in Figure 7. The additions that you’ve made to the original set-up implement the highlighted part of the equation:

AM = (DC + message) **× the carrier**.

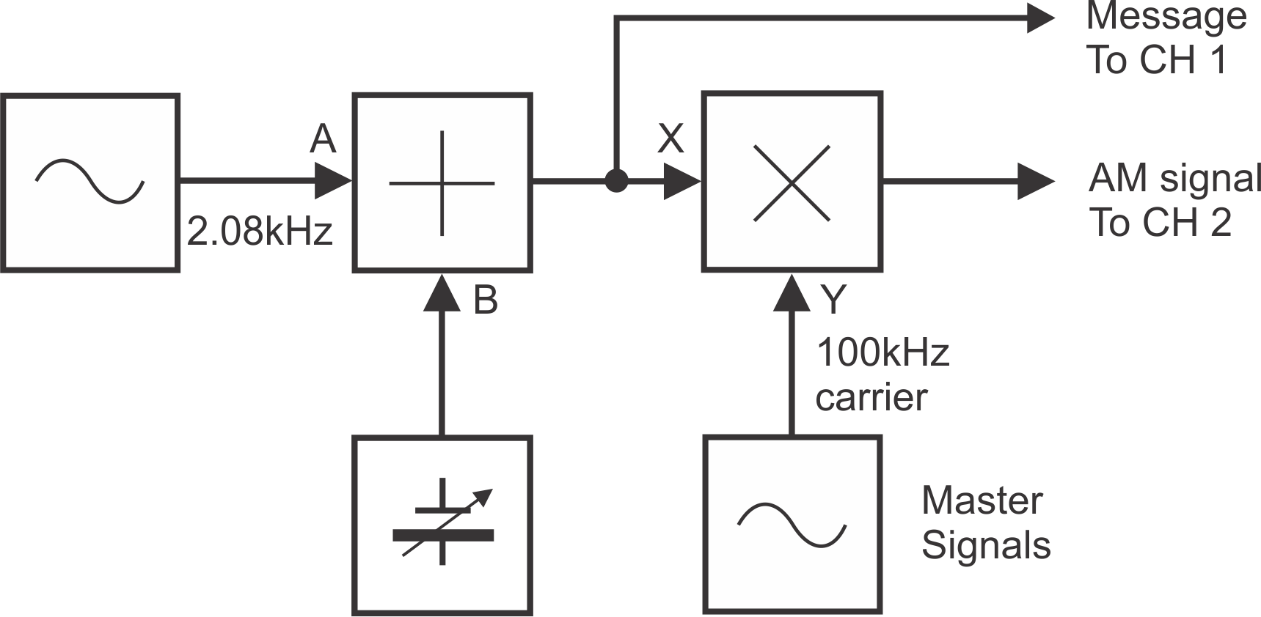


Figure 7: Block diagram for AM

With values, the equation on the previous page becomes:

AM = (1VDC + 1Vp-p 2kHz sine) × 4Vp-p 100kHz sine.

|  |  |
| --- | --- |
| 14. | Adjust the scope’s *Timebase* control to view only two or so cycles of the message signal i.e.: 100us/div or even 50us/div for one cycle. Change the Volts per division control for Channel 2 to 2 V. |

|  |  |
| --- | --- |
| 15. | Activate the scope’s Channel 2 input to view the Multiplier module’s output as well as the offset message signal. |

|  |  |
| --- | --- |
| 16. | Capture a screenshot of the scope and append to your report. Annotate your report appropriately so as to identify the waveforms captured. Use the cursors to highlight important levels and transition points in the waveform if necessary. |

|  |  |
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| 17. | Use the scope’s Channel 1 *Position* control to overlay the message with the AM signal’s upper envelope then lower envelope to compare them. |

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| --- | --- |
| 18. | Capture a screenshot of the scope and append to your report. Annotate your report appropriately so as to identify the waveforms captured. Use the cursors to highlight important levels and transition points in the waveform if necessary. |

* 1. 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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* 1. The AM signal is a complex waveform consisting of more than one signal. Is one of the signals a 2.08kHz sinewave? Explain your answer.

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* 1. 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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## 1.2 Implement: 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.

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| --- | --- |
| 1. | Disconnect the plug on the Master Signals module’s *2.08kHz SINE* output that connects to the Adder module’s *A* input. |

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| 2. | Connect it to the Speech module’s output as shown in Figure 8.  **Remember:** Dotted lines show leads already in place. |

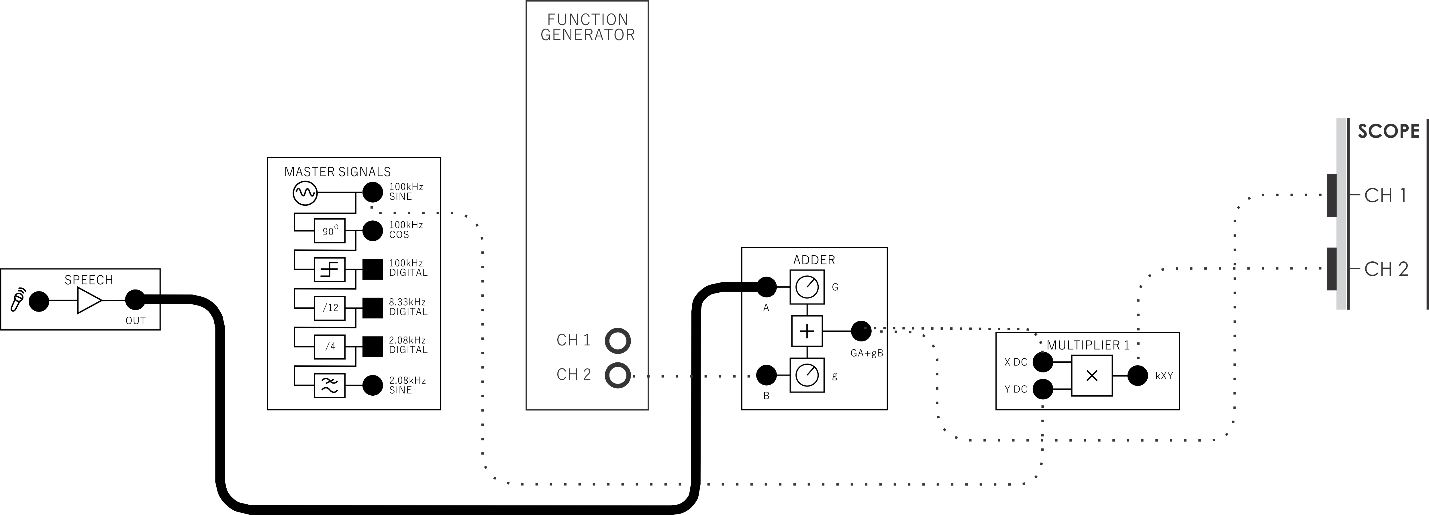


Figure 8: Using speech as a message

|  |  |
| --- | --- |
| 3. | Set the scope’s *Timebase* control to the *1ms/div* position. |

|  |  |
| --- | --- |
| 4. | Hum and talk into the microphone while watching the scope’s display. |

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

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## 1.3 Implement: Investigating depth of modulation

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

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| --- | --- |
| 1. | Return the scope’s *Timebase* control to the *100µs/div* position. |

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| --- | --- |
| 2. | Disconnect the plug to the Speech module’s output and reconnect it to the Master Signals module’s *2.08kHz SINE* output.  **Note:** The scope’s display should now look like the screen captures done previously in this Lab. |

|  |  |
| --- | --- |
| 3. | 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. |

* 1. What is the relationship between the message’s amplitude and the amount of the carrier’s modulation?

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



Figure 9: Modulation index dimensions

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

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| 4. | Adjust the Adder module’s *G* control to return the message signal’s amplitude to 1Vp-p. |

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| --- | --- |
| 5. | Measure and record the AM signal’s *P* dimension. Record your measurement in Table 1. |

|  |  |
| --- | --- |
| 6. | Measure and record the AM signal’s *Q* dimension. |

|  |  |
| --- | --- |
| 7. | Calculate and record the AM signal’s depth of modulation using the equation below. |



|  |  |  |
| --- | --- | --- |
| **P dimension** | **Q dimension** | **m** |
|  |  |  |

Table 1: Modulation index measurements

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.

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| 8. | Increase the message signal’s amplitude to maximum by turning the Adder module’s *G* control to about half its travel then fully clockwise and notice the effect on the AM signal. |

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| 9. | Set the scope’s Channel 1 *Scale* control to *1V/div* and the Channel 2 *Scale* control to *2V/div*. |

|  |  |
| --- | --- |
| 10. | Use the scope’s Channel 1 *Position* control to overlay the message with the AM signal’s envelopes and compare them. |

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

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1-8 What do you think is a carrier’s maximum modulation index without over-modulation?

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| --- | --- |
| 11. | Capture a screenshot of the scope and append to your report. Annotate your report appropriately so as to identify the waveforms captured. Use the cursors to highlight important levels and transition points in the waveform if necessary. |

## 1.4 Implement: Investigating the Frequency Spectrum of AM

It’s possible to modulate the carrier by different amounts. As you discovered in the previous section, this affects the relative levels of sideband to carrier in the signal. This part of the experiment lets you investigate this.

|  |  |
| --- | --- |
| 1. | Maintain the setup from the previous section with a 2.08kHz message. |

|  |  |
| --- | --- |
| 2. | Enable the FFT mode of the Oscilloscope instrument. Change the scope’s timebase to 1ms/div. This increases the resolution of the FFT display. |

|  |  |
| --- | --- |
| 3. | Set the frequency span for the FFT displayed from say 90kHz to 110kHz for a closeup of the frequency domain of interest. |
| 4. | Set the modulation index of your signal to m = 1 and examine the spectrum. |

|  |  |
| --- | --- |
| 5. | Set to modulation index to various values including m = 0 and m > 1. |

|  |  |
| --- | --- |
| 6. | Capture a screenshot of the FFT and append to your report. Annotate your report appropriately so as to identify the waveforms captured. Use the cursors to highlight important levels and transition points in the waveform if necessary. |
| 7. | Confirm that the levels of carrier versus sideband correspond correctly to the levels you would expect based on the equation for AM and the level of modulation index, “m” you have set up. |

1-9 For m= 1, what does theory predict the ratio of carrier to sidebands to be? What have you measured? Explain any differences.

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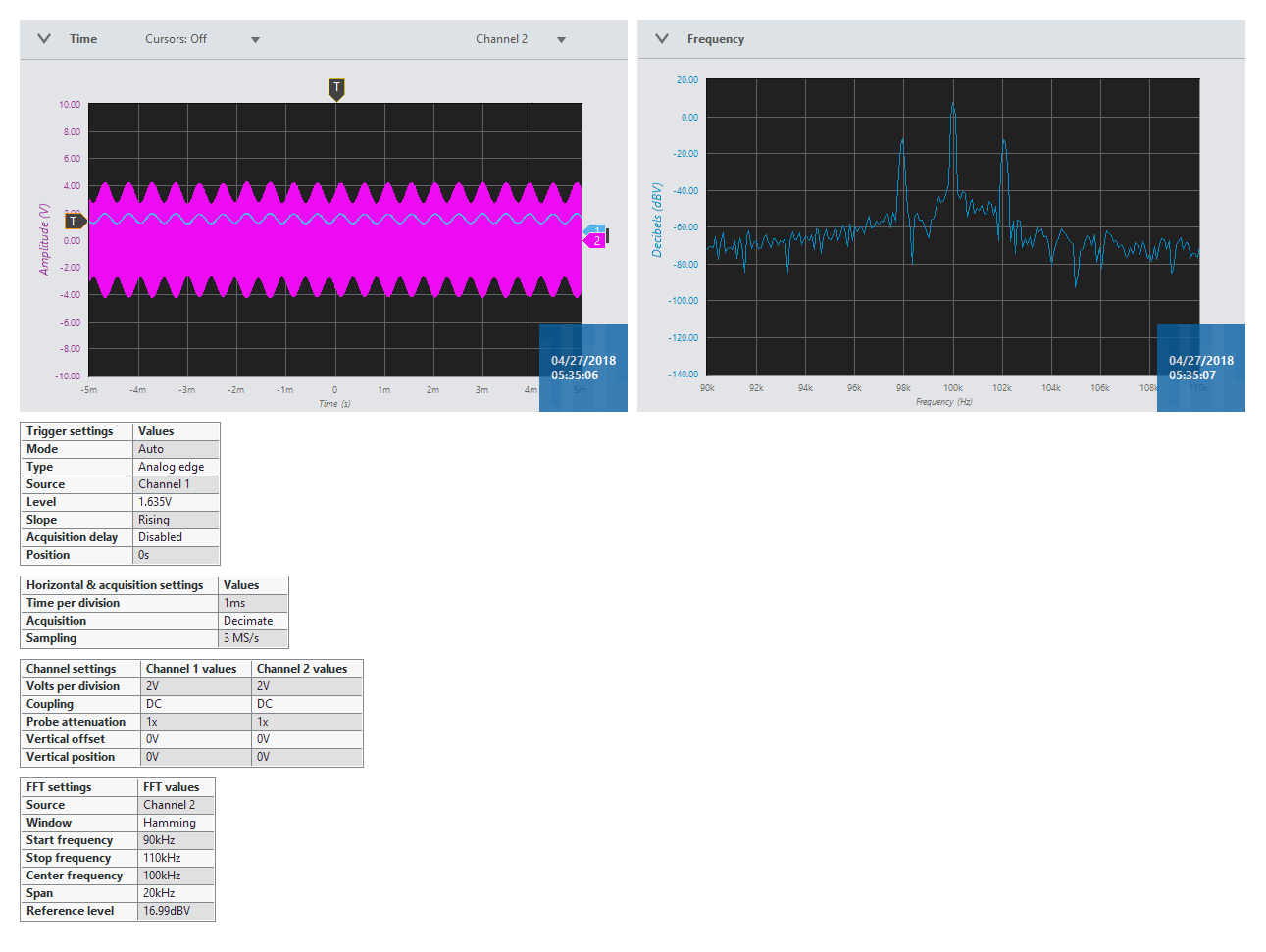


Figure 10: Example of FFT display settings for AM