

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



Lab 7: SSB Modulation & Demodulation

List of Updates

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# Lab 7: SSB modulation & demodulation

## 

## Learning Objectives

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

1. Generate a real SSB signal
2. Examine a real SSB signal with a scope
3. Discuss the differences between SSB and DSBSC
4. Demodulate an SSB signal

## Prerequisites

You should have completed Lab 1 and Lab 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:   * Two 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> |

## 

## 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.

## Section 1: SSB modulation

## 1.1 Theory and Background

Comparing the two communications systems considered earlier in this manual, DSBSC offers considerable power savings over AM (at least 66%) because a carrier is not transmitted. However, both systems generate and transmit *sum and difference* frequencies (the upper and lower sidebands) and so they have the same bandwidth for the same message signal.

As its name implies, the *Single Sideband Suppressed Carrier* (SSBSC or just SSB) system transmits only one sideband. In other words, SSB transmits either the sum **or** the difference frequencies but not both. Importantly, it doesn’t matter which sideband is used because they both contain all of the information in the original message.

In transmitting only one sideband, SSB requires only half the bandwidth of DSBSC and AM which is a significant advantage.

Figure 1 shows a simple message signal and an unmodulated carrier. It also shows the result of modulating the carrier with the message using SSBSC. If you look closely, you’ll notice that the modulated carrier is not the same frequency as either the message or the carrier.



Figure 1: SSB signals

A common method of generating SSB simply involves generating a DSBSC signal then using a filter to pick out and transmit only one of the sidebands. This is known as the *filter method*. However, the two sidebands in a DSBSC signal are close together in frequency and so specialised filters must be used. This means that the filters for non-mainstream communications systems can be expensive.

Another way of generating SSB that is becoming increasingly popular is called the *phasing method*. This uses a technique called *phase discrimination* to cancel out one of the sidebands at the generation stage (instead of filtering it out afterwards).

In telecommunications theory, the mathematical model that defines this process is:

SSB = (message × carrier) + (message with 90° of phase shift × carrier with 90° of phase shift)

If you look closely at the equation you’ll notice that it’s the sum of two multiplications. When the message is a simple sinewave the solution of the two multiplications tells us that four sinewaves are generated. Depending on whether the message’s phase shift is +90° or -90° their frequencies and phase differences are:

|  |  |
| --- | --- |
| These… | Or these… |
| 1. Carrier + message 2. Carrier - message 3. Carrier + message 4. Carrier - message (180° phase shifted) | 1. Carrier + message 2. Carrier - message 3. Carrier + message (180° phase shifted) 4. Carrier – message |

Regardless of whether the message’s phase shift is +90° or -90°, when the four sinewaves are added together, two of them are in phase and add together to produce one sinewave (either *carrier + message* or *carrier – message*) and two of the sinewaves are phase inverted and completely cancel. In other words, the process produces only a sum or difference signal (that is, just one sideband).

The block diagram that implements the phasing type of SSB modulator is shown in Figure 2.

Fig 10-2

Figure 2: Block diagram for SSB generation

As SSB signals don’t contain a carrier, they must be demodulated using product detection in the same way as DSBSC signals (the product detector’s operation is summarised in the preliminary discussion of Lab 6).

## 1.2 Implement: Generate a SSB signal

For this experiment you’ll use the EMONA Communications board to generate a SSB signal by implementing the mathematical model for the phasing method. You’ll then use a product detector (with a stolen carrier) to reproduce the message.

Importantly, you’ll only do so for a sinewave message (that is, you’ll not SSB modulate then demodulate speech). There’s a practical reason for this. The phase shift introduced by the Phase Shifter module is frequency dependent (that is, for any given setting, the phase shift is different at different frequencies). A wideband phase shifting circuit is necessary to provide 90° of phase shift for all of the sinewaves in a complex message like speech.

It should take you about 40 minutes to complete this experiment.

**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(ECB) 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 ECB 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 |

Table 4 Function Generator Configuration

|  |  |
| --- | --- |
| Channel 1 | Sine |
| Frequency | 10kHz |
| Amplitude | 2Vpp |
| DC offset | 0V |

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

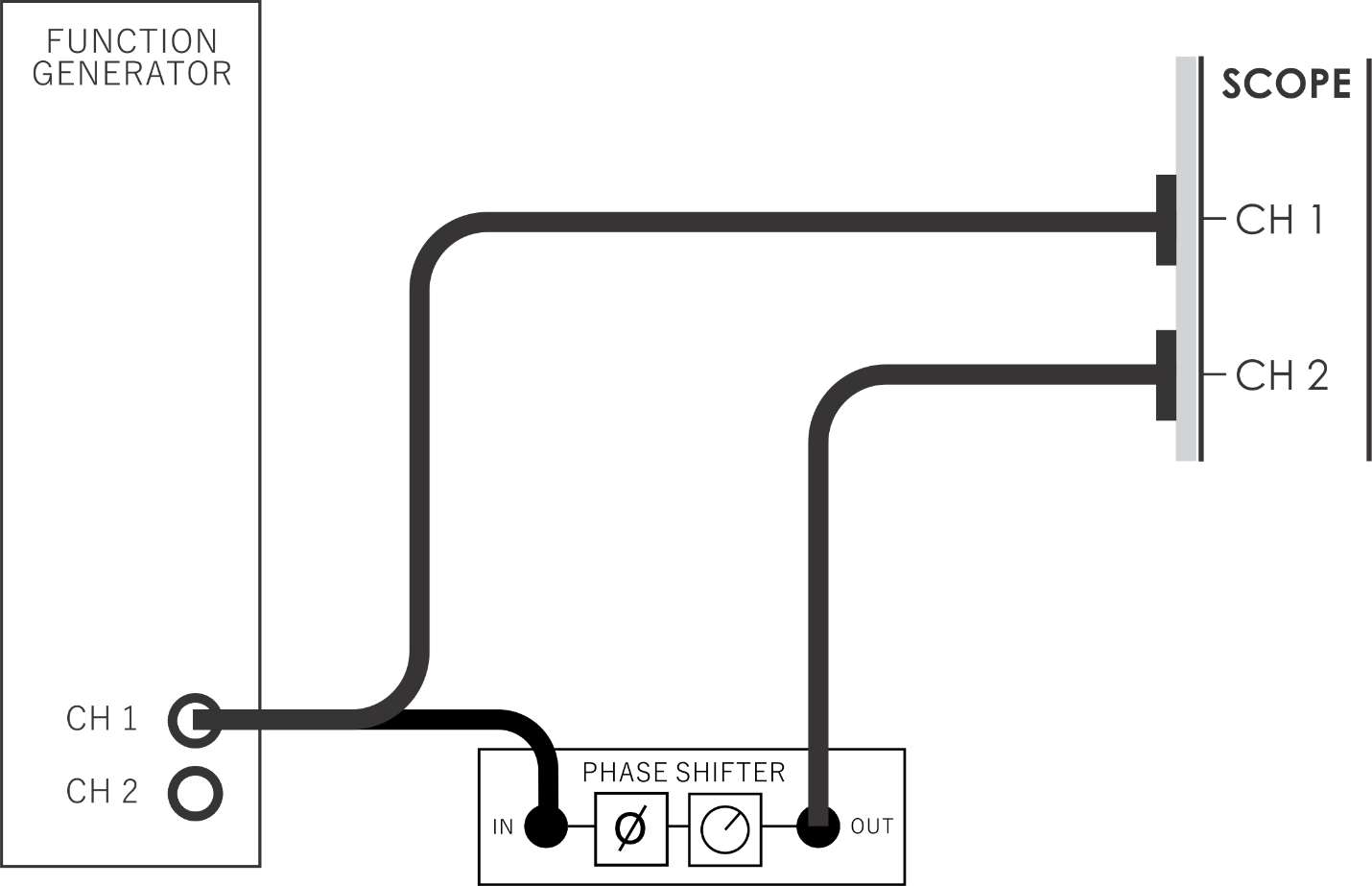


Figure 3: Patching for phasing setup

This set-up can be represented by the block diagram in Figure 4. It is used to set up two message signals that are out of phase with each other.

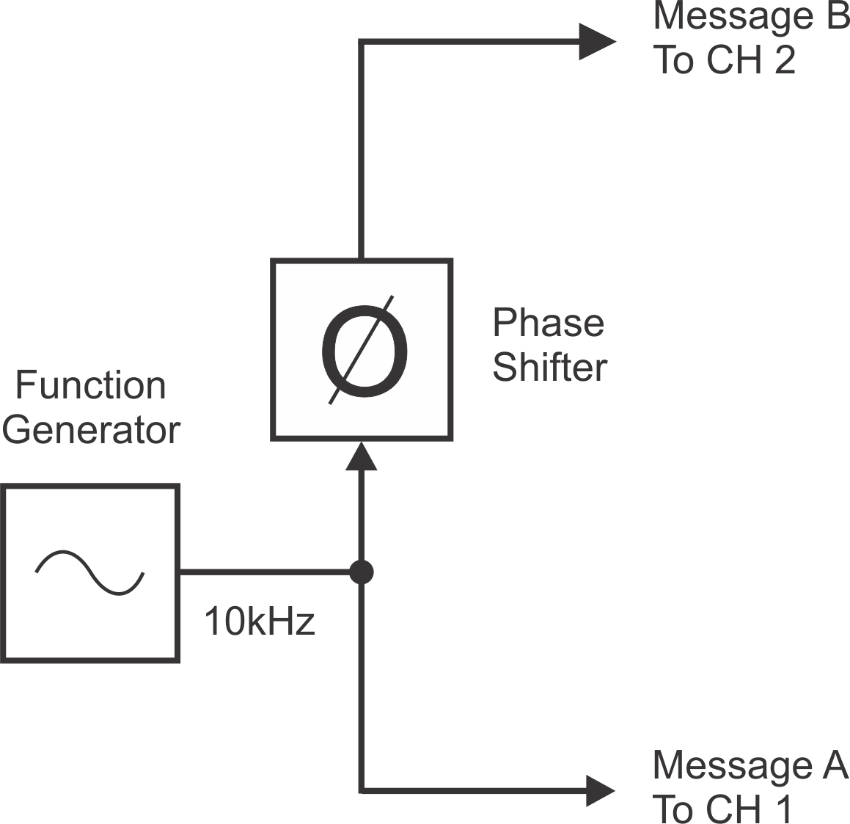


Figure 4: Block diagram for phasing setup

|  |  |
| --- | --- |
| 7. | Locate the Phase Shifter module on the board and set its *Phase Change* control to the *0°* position. |

|  |  |
| --- | --- |
| 8. | Set the Phase Shifter module’s *Phase Adjust* control to about the middle of its travel. |

|  |  |
| --- | --- |
| 9. | Set the scope *Trigger Source* control to *Channel 1*. |

|  |  |
| --- | --- |
| 10. | Adjust the scope’s *Timebase* control to view two or so cycles of the function generator’s output. |

|  |  |
| --- | --- |
| 11. | Activate the scope’s Channel 2. |

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| --- | --- |
| 12. | Check that the two message signals are out of phase with each other.  **Note:** At this stage, it doesn’t matter what the phase difference is. |

|  |  |
| --- | --- |
| 14. | Modify the set-up as shown in Figure 5. |

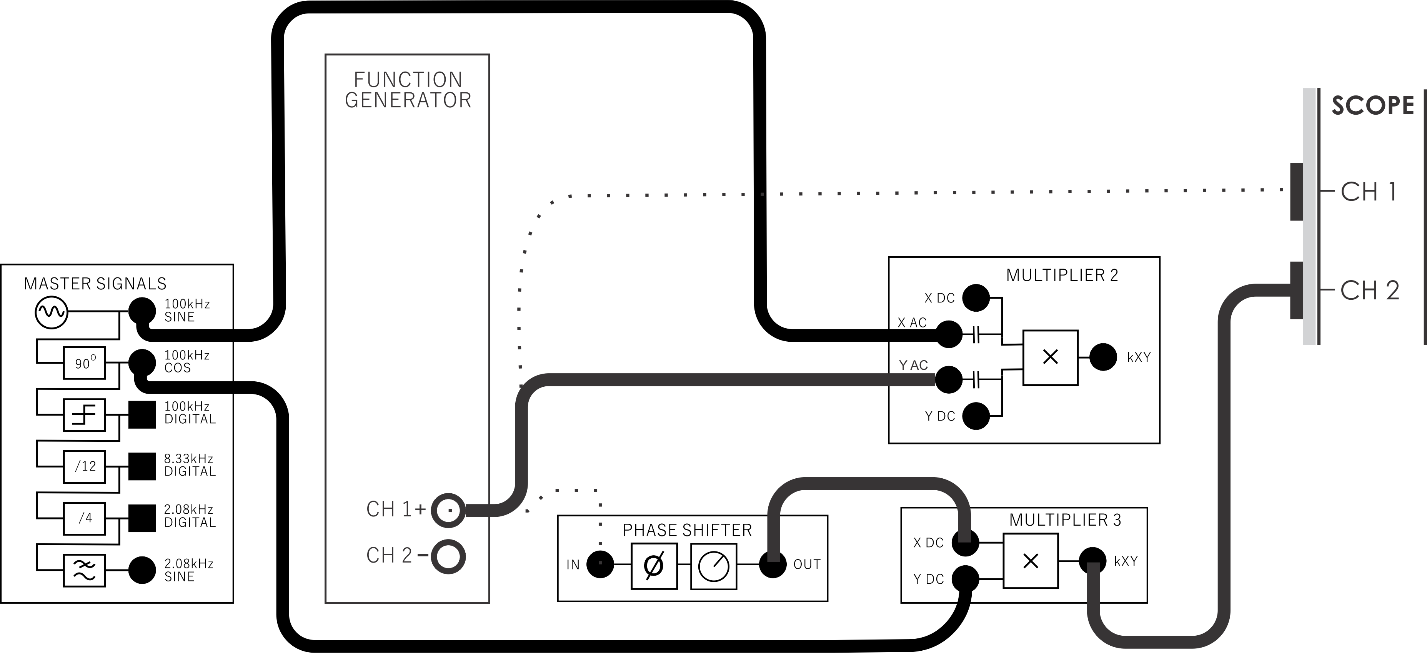


Figure 5: Partial patching for SSB

This set-up can be represented by the block diagram in Figure 6. It is used to multiply the two message signals with two 100kHz sinewaves (the carriers) that are exactly 90° out of phase with each other.

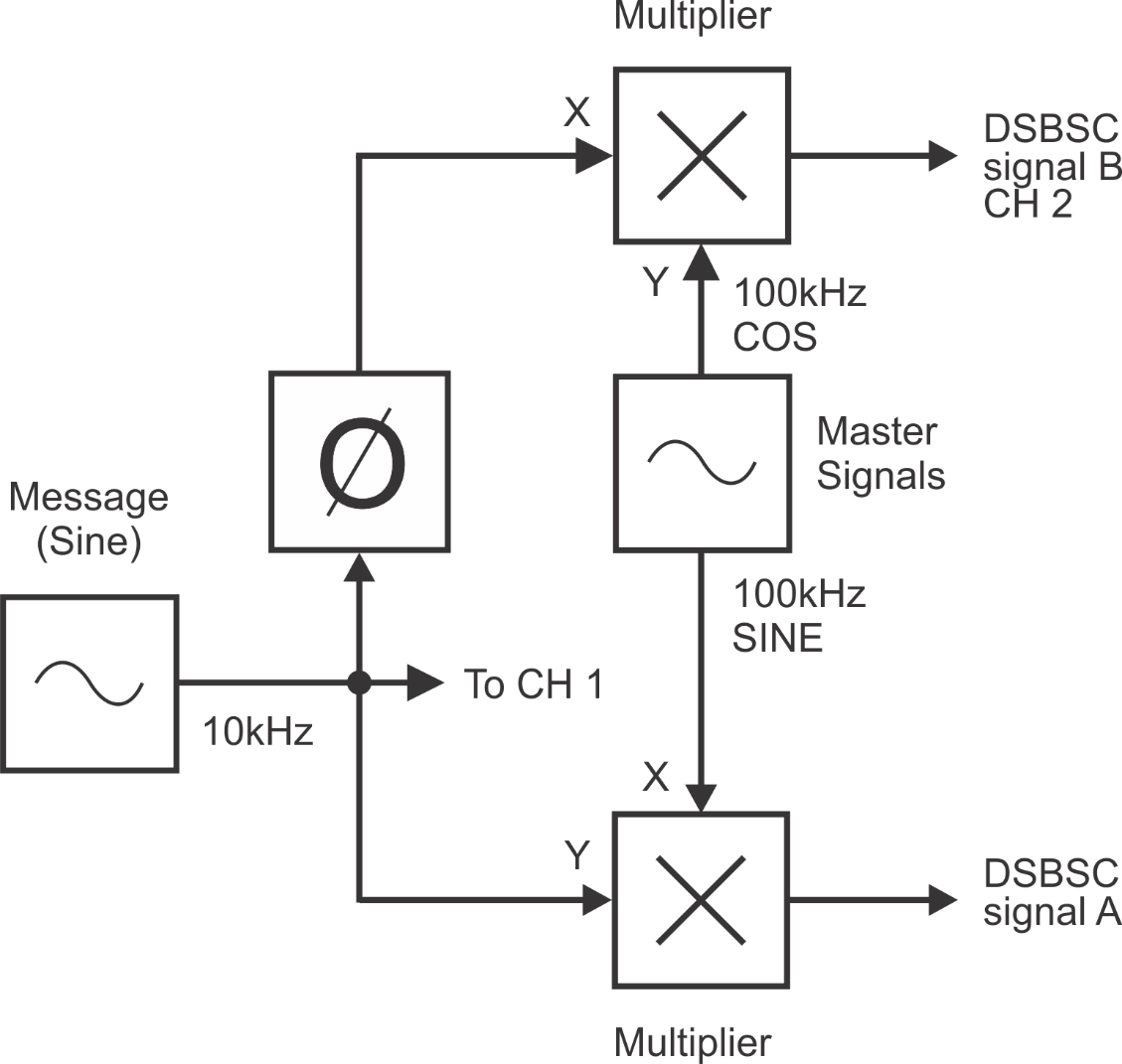


Figure 6: Block diagram for partial SSB generation

|  |  |
| --- | --- |
| 16. | Use the scope to check that the lower Multiplier module’s output is a DSBSC signal.  **Tip:** Temporarily set the scope’s Channel 2 *Scale* control to the *2V/div* position to do this. |

|  |  |
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| 17. | Disconnect the scope’s Channel 2 input from the lower Multiplier module’s output and connect it to the upper Multiplier module’s output. |

|  |  |
| --- | --- |
| 18. | Check that the upper Multiplier module’s output is a DSBSC signal as well. |

|  |  |
| --- | --- |
| 19. | Locate the Adder module and set BOTH its *G* and *g* controls to about the middle of their travel. This is about unity gain. |

|  |  |
| --- | --- |
| 20. | Modify the set-up as shown in Figure 7. |

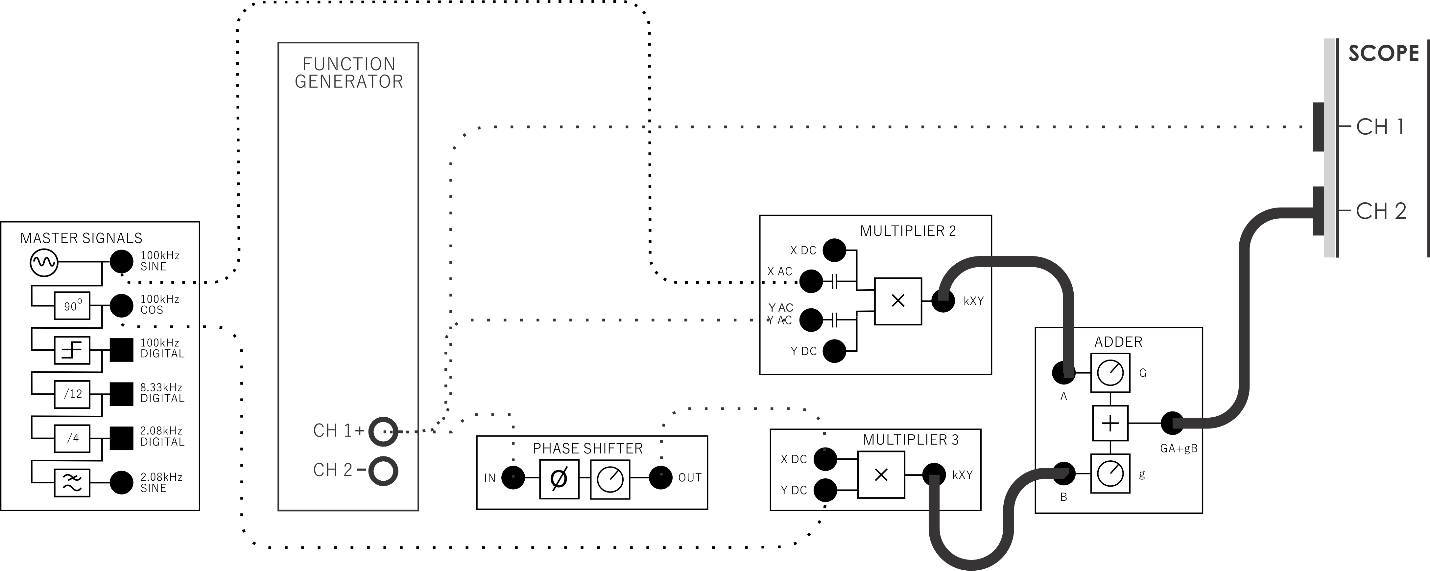


Figure 7: Patching for SSB generation

This set-up can be represented by the block diagram in Figure 8. The Adder module is used to add the two DSBSC signals together. The phase relationships between the sinewaves in the DSBSC signals means that two of them (one in each sideband) reinforce each other and the other two cancel each other out.

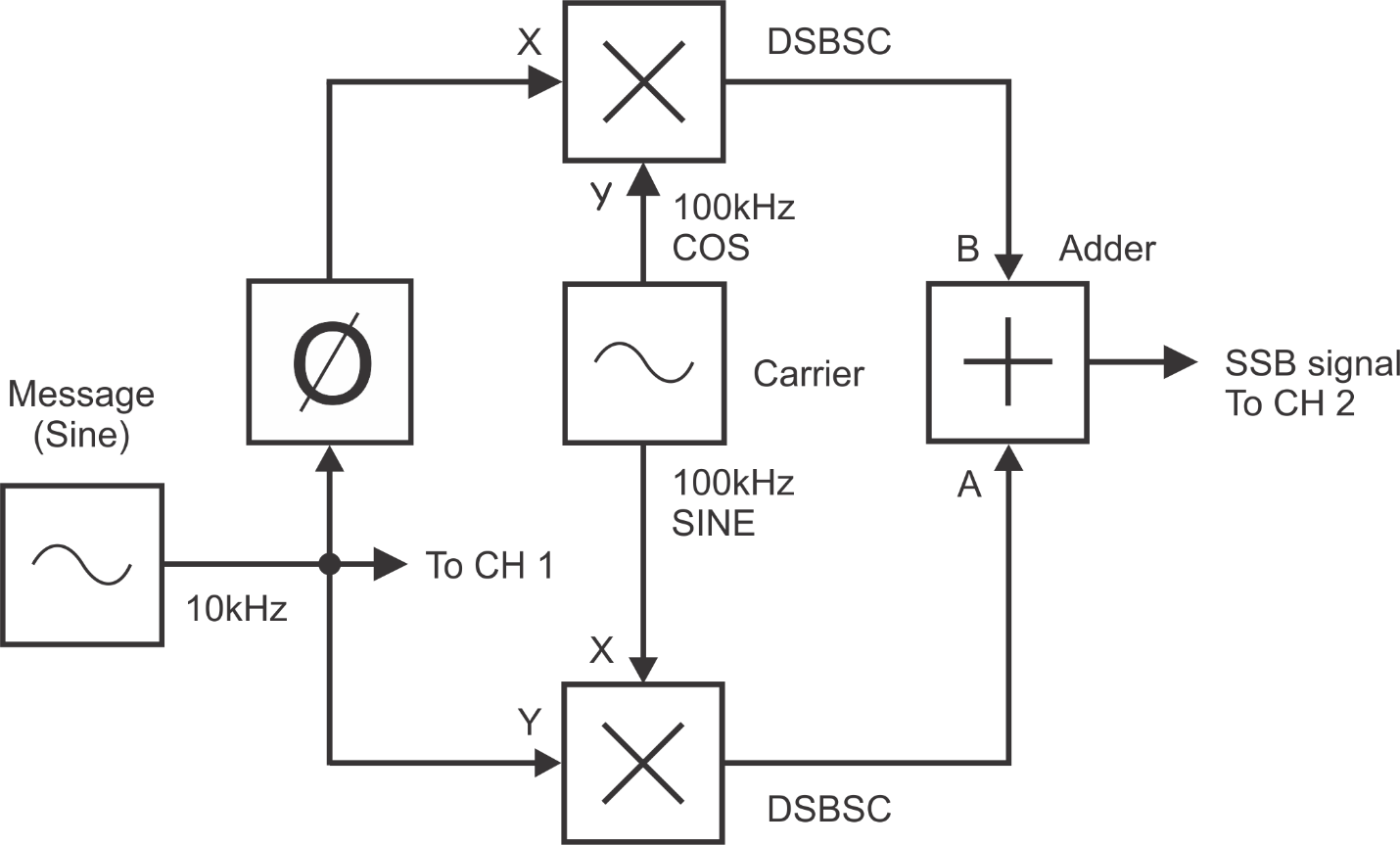


Figure 8: Block diagram for SSB

* 1. The signal out of the Adder module is highly unlikely to be an SSB signal at this stage. What are two reasons for this? **Tip:** If you’re not sure, one of them can be worked out by reading the preliminary discussion.

|  |
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The next part of the experiment gets you to make the fine adjustments necessary to turn the set-up into a true SSB modulator.

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| --- | --- |
| 21. | Deactivate the scope’s Channel 1 input. |

|  |  |
| --- | --- |
| 22. | Disconnect the patch lead to the Adder module’s *B* input.  **Note:** This removes the signal on the Adder module’s *B* input from the set-up’s output. |

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| 23. | Adjust the Adder module’s *G* control to obtain a 4Vp-p output. |

|  |  |
| --- | --- |
| 24. | Reconnect the Adder module’s *B* input and disconnect the patch lead to its *A* input.  **Note:** This removes the signal on the Adder module’s *A* input from the set-up’s output. |

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| --- | --- |
| 25. | Adjust the Adder module’s *g* control to obtain a 4Vp-p output. |

|  |  |
| --- | --- |
| 26. | Reconnect the patch lead to the Adder module’s *A* input. |

The gains of the Adder module’s two inputs are now nearly the same. Next, the correct phase difference between the messages must be achieved.

|  |  |
| --- | --- |
| 27. | Slowly vary the Phase Shifter module’s *Phase Adjust* control left and right and observe the effect on the envelopes of the set-up’s output.  **Note:** For most of the *Phase Adjust* control’s travel, you’ll get an output that looks like a DSBSC signal. However, if you adjust the control carefully, you’ll find that you’re able to flatten-out the output signal’s envelope. |

|  |  |
| --- | --- |
| 28. | Set the scope’s Channel 2 *Scale* control to the *500mV/div* position. |

|  |  |
| --- | --- |
| 29. | Adjust the Phase Shifter module’s *Phase Adjust* control to make the envelopes as “flat” as possible. |

The phase difference between the two messages is now nearly 90°.

|  |  |
| --- | --- |
| 30. | Tweak the Adder module’s *G* control to see if you can make the output’s envelopes flatter. |

|  |  |
| --- | --- |
| 31. | Tweak the Phase Shifter module’s *Phase Adjust* control to see if you can make the output’s envelopes flatter still. |

Once the envelopes are as flat as you can get, the gains of the Adder module’s two inputs are very close to each other and the phase difference between the two messages are very close to 90°. That being the case, the signal out of the Adder module is now SSBSC.

1-2 How many sinewaves does this SSB signal consist of? **Tip:** If you’re not sure, see the preliminary discussion.

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* 1. For the given inputs to the SSB modulator, what two frequencies can this signal be?

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| 32. | Keep all settings the same as for the flattest envelope i.e.: the best SSB signal possible, for this next step. |

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| --- | --- |
| 33. | To further confirm the reinforcing and cancellation effect between the two DSBSC signals, view each DSBSC signal on Channel 1 and Channel 2 respectively. You will notice that they are similar in form but not aligned. |
| 34. | Turn on the MATH function of the Oscilloscope and display the sum of channels 1 & 2 i.e.: MATH channel = Ch1 + Ch2. It should be a signal with a flat envelope. Confirm for yourself visually that you understand how this signal comes about. |

|  |  |
| --- | --- |
| 35. | Connect Channel 3 of the Oscilloscope to the actual SSB signal on the board at the output of the ADDER module. Now you can view 4 signals on the scope: 3 real and 1 calculated. The calculated signal and the real SSB signal should be the same. |

|  |  |
| --- | --- |
| 36. | 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. |

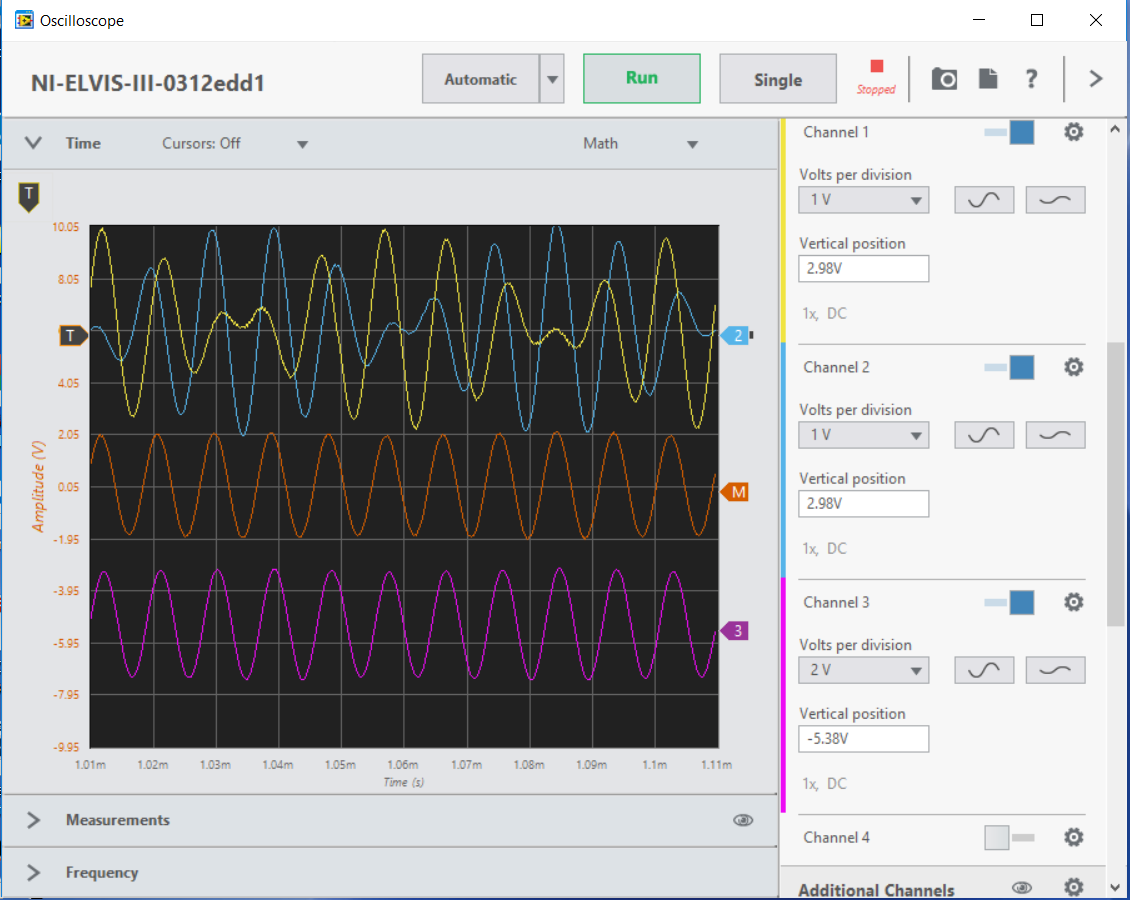


Figure 9: Example of addition of DSBSC signals to form SSB

## 1.3 Implement: Spectrum analysis of an SSB signal

The next part of this experiment let’s you analyse the frequency domain representation of the SSB signal to see if its spectral composition matches your answers to Questions 1-2 and 1-3.

|  |  |
| --- | --- |
| 1. | Launch the NI ELVIS III FFT mode on the Oscilloscope. |

|  |  |
| --- | --- |
| 2. | Use the cursors to measure the frequency of the visible sideband. |

* 1. Based on your measurement for the step above, which sideband does your SSB modulator generate?

|  |
| --- |
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|  |  |
| --- | --- |
| 3. | Align cursors with some of the other significant sinewaves close to this sideband and note their frequencies.  **Note:** You should find that there’s a sinewave at the carrier frequency and another at the frequency for the other sideband. Importantly, despite appearances, these signals are very small relative to the significant sideband (the scale used for the Y-axis is decibels which is not a linear unit of measurement). |

* 1. Give two reasons for the presence of a small amount of the other sideband.

|  |
| --- |
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| 4. | Tweak the Phase Shifter module’s *Phase Adjust* control and note the effect on the size of the carrier and other sideband.  **Note:** Give the signal analyzer’s display time to update after each adjustment. |

* 1. Why doesn’t varying the Phase Shift module’s *Phase Adjust* control affect the size of the carrier in the SSBSC signal?

|  |
| --- |
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| --- | --- |
| 5. | Adjust the two controls to obtain the smallest size for the insignificant sideband. |
|  |  |
| 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. | Close the FFT mode and view the oscilloscope. |

|  |  |
| --- | --- |
| 8. | Note whether there is any improvement in the SSB signal’s envelope (that is, note whether the envelope is any flatter). |

## Section 2: Using the product detector to recover the message

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| --- | --- |
| 9. | Reactivate the scope’s Channel 1 input and return the Channel 2 *Scale* control to the *1V/div* position. |

|  |  |
| --- | --- |
| 10. | Locate the Tuneable Low-pass Filter module on the board and set its *Gain* control to about the middle of its travel. |

|  |  |
| --- | --- |
| 11. | Turn the Tuneable Low-pass Filter module’s *Cut-off Frequency Adjust* control fully clockwise. |

|  |  |
| --- | --- |
| 12. | Modify the set-up as shown in Figure 9. |

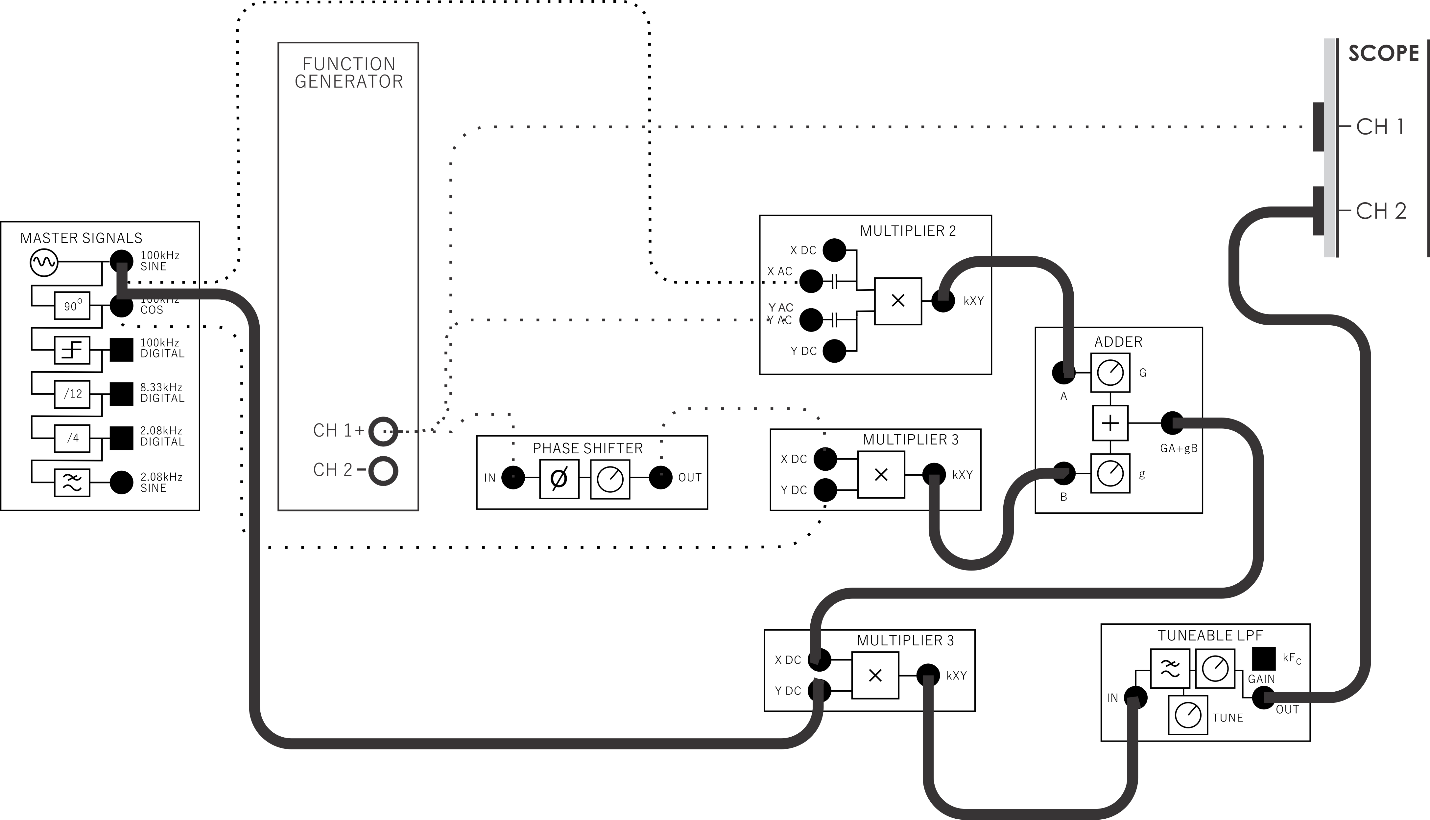


Figure 10: Product demodulation of SSB

The additions to the set-up shown in Figure 10 can be represented by the block diagram in Figure 11. The Multiplier and Tuneable Low-pass Filter modules are used to implement a product detector which demodulates the original message from the SSB signal.

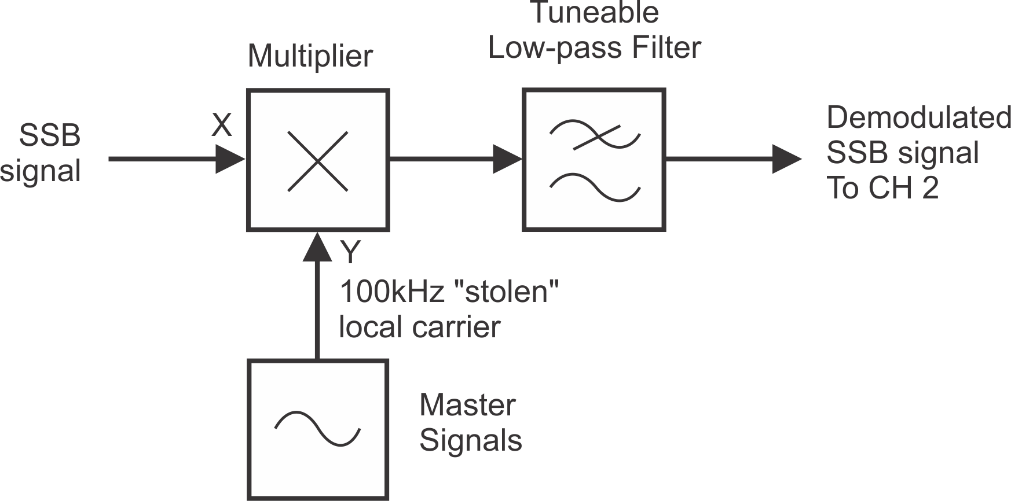


Figure 11: Block diagram for product demodulation

|  |  |
| --- | --- |
| 13. | Use the scope to compare the original message with the recovered message. |

* 1. What is the relationship between the original message and the recovered message?

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| --- |
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|  |