

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



Lab 6: Double Sideband Modulation and Demodulation (DSBSC)

List of Updates

|  |  |
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# Lab 6: DSBSC modulation & demodulation

In this experiment you will create a DSBSC signal and gain insight into the meaning of “Suppressed Carrier”. As well you will again use product demodulation to recover the message and examine the effect of phase and frequency errors on the recovery process.

DSBSC is an acronym for Double Sideband-Suppressed Carrier. It is the most basic form of modulation composing of a simple multiplication of two sinusoids: one being the message and the other the carrier. The relevance of the ‘suppressed carrier” term should be evident if you have completed the earlier lab on Amplitude Modulation.

## Learning Objectives

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

1. Generate a real DSBSC signal
2. Examine a real DSBSC signal with scope and compare it to its original message
3. Use multiple message sources in your DSBSC examination
4. Describe the term “depth of modulation”
5. Describe the effects and meaning of over and under modulation of the carrier
6. Compare original and demodulated signals
7. Describe distortion in the recovered signal
8. Identify the effect of phase and frequency errors on the demodulation process
9. Explain the term “product modulation”

## Prerequisites

You should have completed Lab 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> |

## 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: DSBSC modulation

## 1.1 Theory and Background

Like AM, DSBSC uses a microphone or some other transducer to convert speech and music to an electrical signal called the *message* or *baseband* signal. The message signal is then used to electrically vary the amplitude of a pure sinewave called the *carrier*. And like AM, 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 modulating the carrier with the message using DSBSC.

.



Figure 1: DSBSC signals

So far, there doesn’t appear to be much difference between AM and DSBSC. However, consider Figure 2. It is the DSBSC signal at the bottom of Figure 1 but with dotted lines added to track the signal’s envelopes (that is, its positive peaks and negative peaks). If you look at the envelopes closely you’ll notice that they’re not the same shape as the message as is the case with AM (see Experiment 4, Figure 2 for an example).



Figure 2: DSBSC envelopes

Instead, alternating halves of the envelopes form the same shape as the message as shown in Figure 3.



Figure 3: DSBSC message

Another way that DSBSC is different to AM can be understood by considering the mathematical model that defines the DSBSC signal:

DSBSC = the message × the carrier

Do you see the difference between the equations for AM and DSBSC? If not, look at the AM equation in Lab 4.

When the message is a simple sinewave (such as in Figure 2) the equation’s solution (which necessarily involves some trigonometry) tells us that the DSBSC signal consists of two sinewaves:

1. One with a frequency equal to the sum of the carrier and message frequencies
2. One with a frequency equal to the difference between the carrier and message frequencies

Importantly, the DSBSC signal doesn’t contain a sinewave at the carrier frequency. This is an important difference between DSBSC and AM.

That said, as the solution to the equation shows, DSBSC is the same as AM in that a pair of sinewaves is generated for every sinewave in the message. And, like AM, one is higher than the unmodulated carrier’s frequency and the other is lower. As message signals such as speech and music are made up of thousands of sinewaves, thousands of pairs of sinewaves are generated in the DSBSC signal that sit on either side of the carrier frequency. These two groups are called the *sidebands*.

So, the presence of both sidebands but the absence of the carrier gives us the name of this modulation method - ***d****ouble-****s****ide****b****and,* ***s****uppressed* ***c****arrier* (DSBSC).

The carrier in AM makes up at least 66% of the signal’s power but it doesn’t contain any part of the original message and is only needed for tuning. So by not sending the carrier, DSBSC offers a substantial power saving over AM and is its main advantage.

## 1.2 Implement: DSBSC modulation

You will now build a model of the system being studied and explore its performance.

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

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

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

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| 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. |

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| --- | --- |
| 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 |

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| --- | --- |
| 6. | Connect the setup shown in Figure 4. |

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

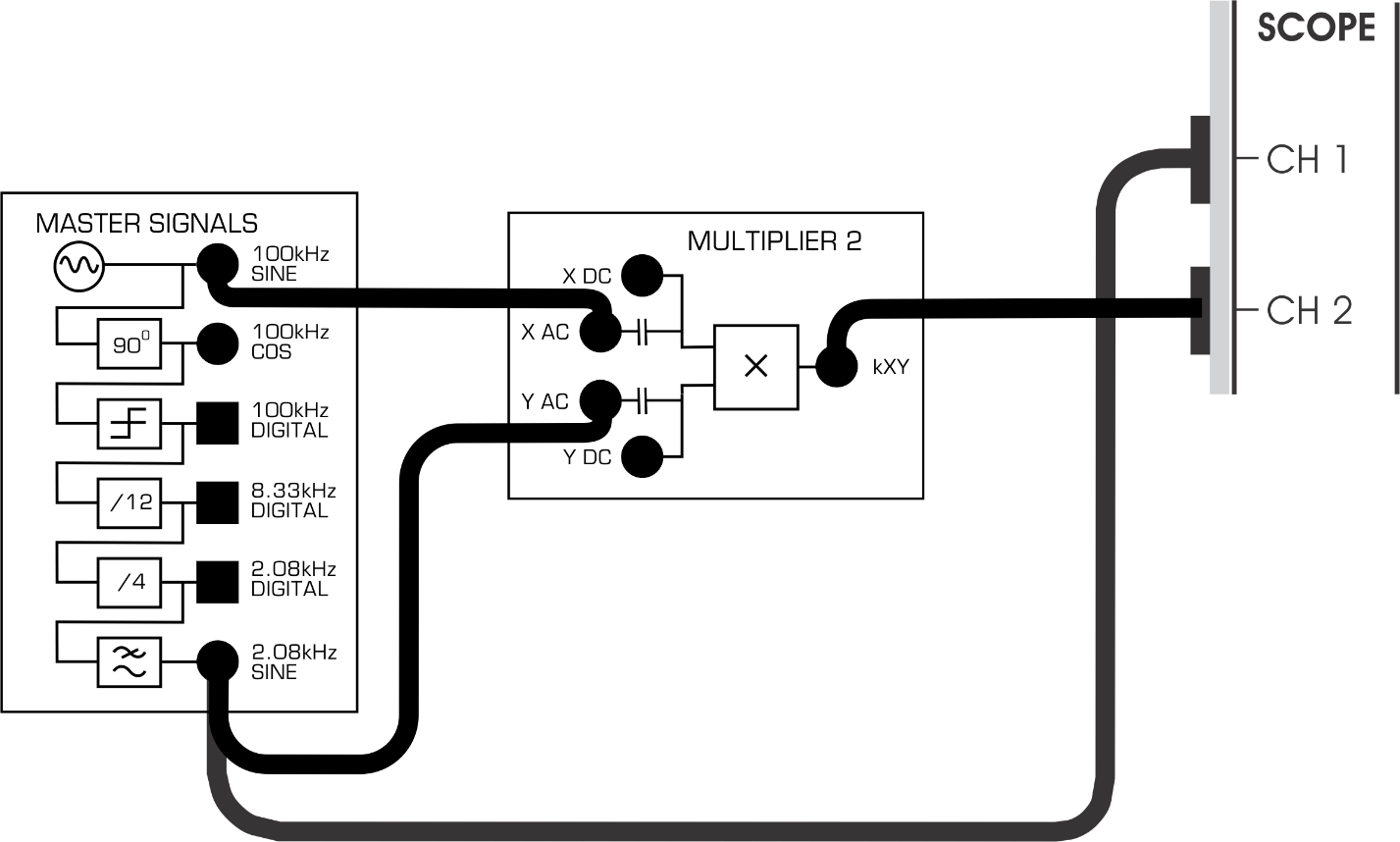


Figure 4: Patching for DSBSC

This set-up can be represented by the block diagram in Figure 5. It implements the entire equation: DSBSC = the message × the carrier.

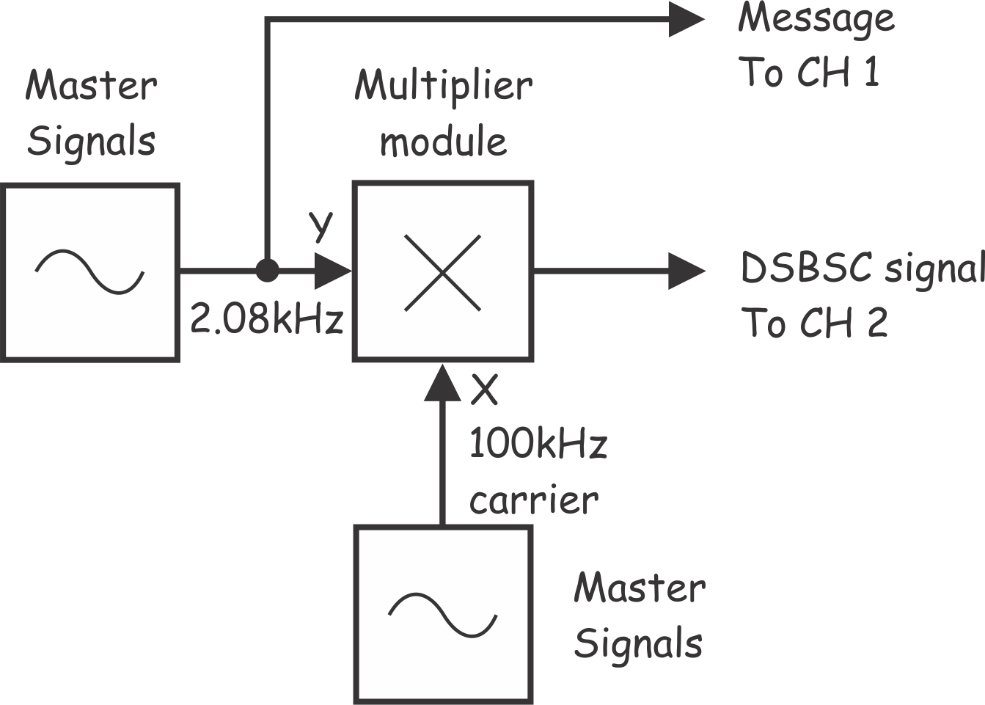


Figure 5: Block diagram for DSBSC

With values, the equation on the previous page becomes:

DSBSC = 4Vp-p 2.08kHz sine × 4Vp-p 100kHz sine.

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| --- | --- |
| 7. | Adjust the scope’s *Timebase* control to view two or so cycles of the Master Signals module’s *2.08kHz SINE* output. |
| 8. | Activate the scope’s Channel 2 input to view the DSBSC signal out of the Multiplier module as well as the message signal. |
| 9. | Set the scope’s Channel 1*Scale* control to the *1V/div* position and the Channel 2 *Scale* control to the *2V/div* position (if it’s not already). |
| 10. | 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. |

#### Display layout tips:

* Position the message signal in the upper half of the display and the DSBSC signal in the lower half.

|  |  |
| --- | --- |
| 11. | If they’re not already, overlay the message with the DSBSC signal’s envelopes to compare them using the scope’s Channel 1 *Position* control. |
| 12. | Set the scope’s Channel 1 *Scale* control to the *1V/div* position and the Channel 2 *Scale* control to the *2V/div* position (if it’s not already). |

1-1 What feature of the Multiplier module’s output suggests that it’s a DSBSC signal? **Tip:** If you’re not sure about the answer to the questions, see the preliminary discussion.

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1-2 The DSBSC 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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1-3 For the given inputs to the Multiplier module, how many sinewaves does the DSBSC signal consist of, and what are their frequencies?

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1-4 Why does this make DSBSC signals better for transmission than AM signals?

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## 1.3 Implement: Generating a DSBSC signal using speech

This experiment has generated a DSBSC 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 a DSBSC signal looks like when modulated by speech.

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| --- | --- |
| 1. | Disconnect the plugs to the Master Signals module’s *2.08kHz SINE* output. |

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| 2. | Connect them to the Speech module’s output as shown in Figure 6.  **Remember:** Dotted lines show leads already in place. |

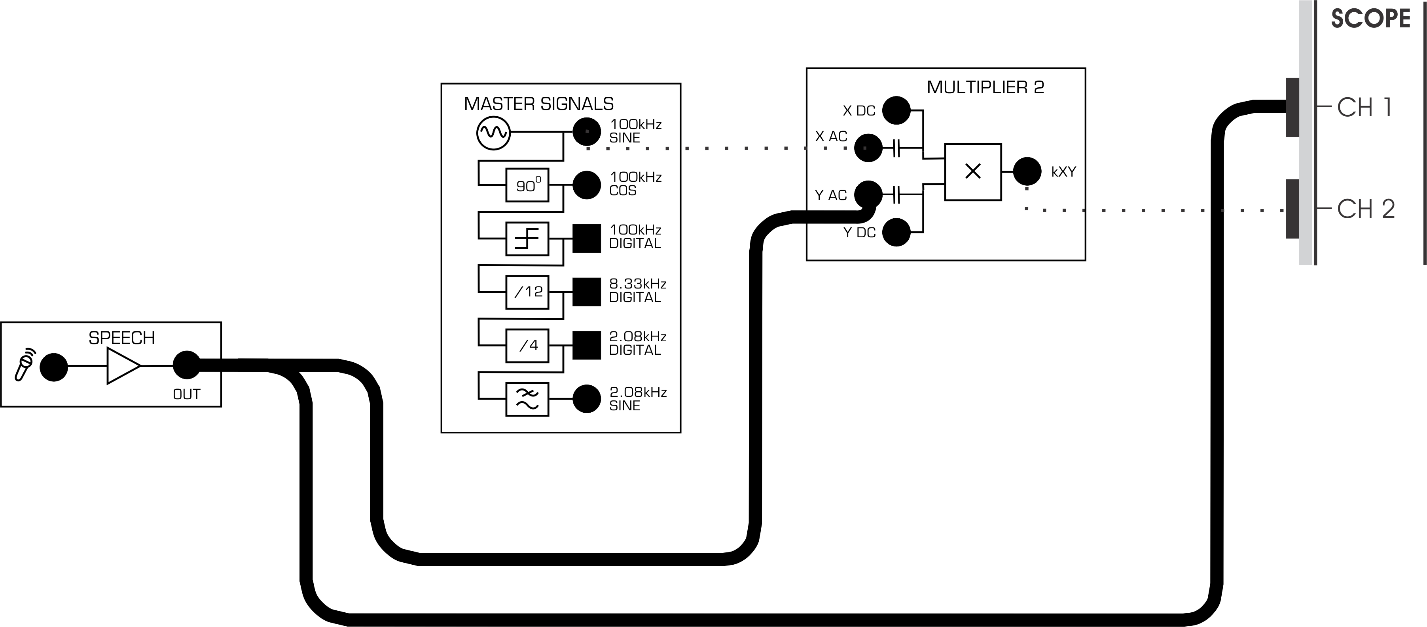


Figure 6: DSBSC using speech as a message

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

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

1-5 Why isn’t there any signal out of the Multiplier module when you’re not humming or talking?

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## 1.4 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. | Locate the Amplifier module on the board and set its *Gain* control to about a quarter of its travel (the control’s line should be pointing to where the number nine is on a clock’s face). |

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| 3. | Modify the set-up as shown in Figure 7. |

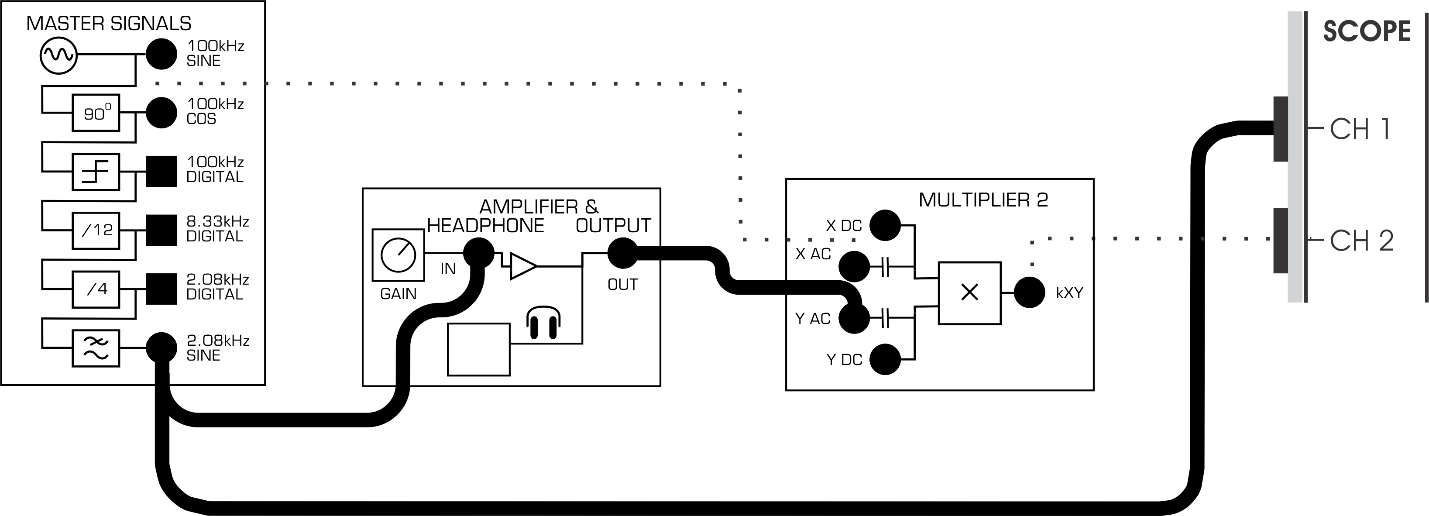


Figure 7: Patching for DSBSC with 2.08kHz message

The set-up in Figure 7 can be represented by the block diagram in Figure 8. The Amplifier allows the message signal’s amplitude to be adjustable.

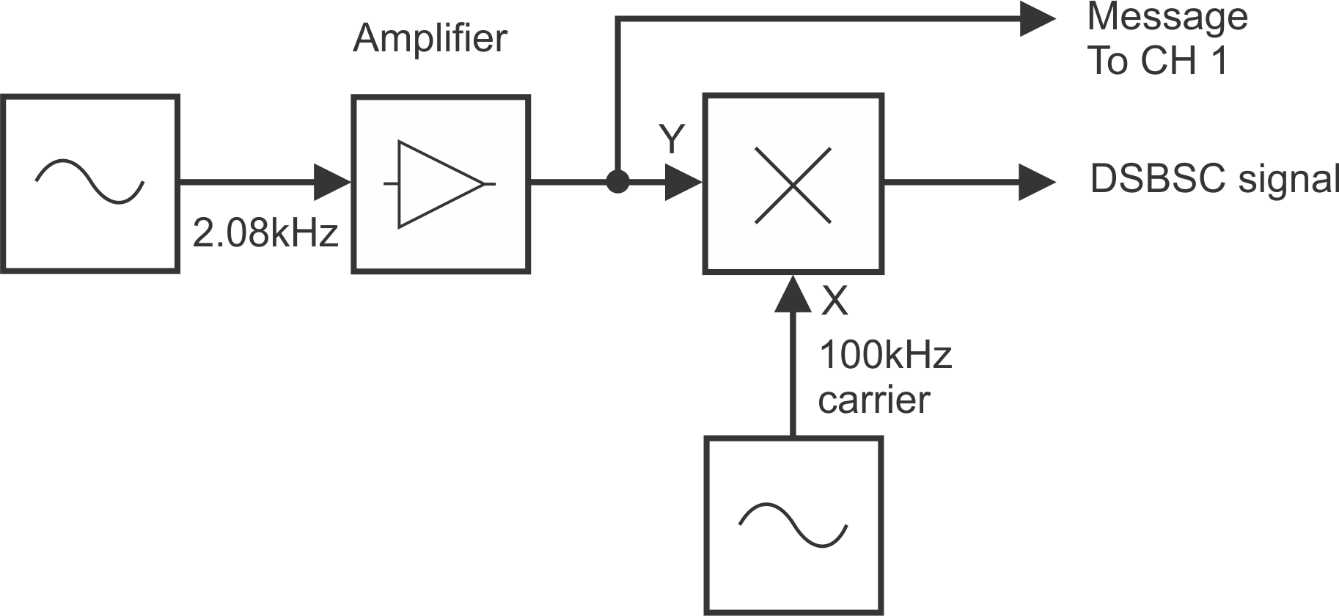


Figure 8: Block diagram for DSBSC with 2.08kHz message

**Note:** At this stage, the Multiplier module’s output should be the normal DSBSC signal that you sketched earlier.

Recall from Experiment 4 that an AM signal has two dimensions that can be measured and used to calculated modulation index (m). The dimensions are denoted *P* and *Q*. If you’ve forgotten which one is which, take a minute to read over the notes in that previous lab before going on to the next step.

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| --- | --- |
| 4. | Vary the message signal’s amplitude a little by turning the Amplifier module’s *Gain* control left and right a little. Notice the effect that this has on the DSBSC signal’s *P* and *Q* dimensions. |

1-6 Based on your observations in Step 4 above, when the message’s amplitude is varied, which dimensions are affected?

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On the face of it, determining the depth of modulation of a DSBSC signal is a problem. The modulation index is always the same number regardless of the message signal’s amplitude. This is because the DSBSC signal’s *Q* dimension is always zero.

However, this isn’t the problem that it seems. One of the main reasons for calculating an AM signal’s modulation index is so that the distribution of power between the signal’s carrier and its sidebands can be calculated. However, DSBSC signals don’t have a carrier (remember, it’s suppressed). This means that all of the DSBSC signal’s power is distributed between its sidebands evenly. As such, there’s no need to calculate a DSBSC signal’s modulation index.

The fact that you can’t calculate a DSBSC signal’s modulation index might imply that you can make either the message or the carrier as large as you like without worrying about over-modulation. This isn’t true. Making either of these two signals too large can still *overload* the modulator resulting in a type of distortion that you’ve seen before. The next part of the experiment lets you observe what happens when you overload a DSBSC modulator.

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| 5. | Set the Amplifier module’s *Gain* control to about half its travel and notice the effect on the DSBSC signal.  **Note 1:** Resize the display as necessary using the scope’s Channel 1 S*cale* control.  **Note 2:** If doing this has no effect, turn up the gain control a little more. |

|  |  |
| --- | --- |
| 6. | 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 is the name of this type of distortion?

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## Section 2: DSBSC Demodulation

## 2.1 Theory and Background

Lab 5 shows how the envelope detector can be used to recover the original message from an AM signal (that is, demodulate it). Unfortunately, the envelope detector cannot be used to demodulate a DSBSC signal.

To understand why, recall that the envelope detector outputs a signal that is a copy of its input’s envelope. This works well for demodulating AM because the signal’s envelopes are the same shape as the message that produced it in the first place (that is, as long as it’s not over-modulated). However, recall that a DSBSC signal’s envelopes are not the same shape as the message.

Instead, DSBSC signals are demodulated using a circuit called a *product detector* (though *product demodulator* is a more appropriate name) and its basic block diagram is shown in Figure 9. Other names for this type of demodulation include a *synchronous detector* and *switching detector*.

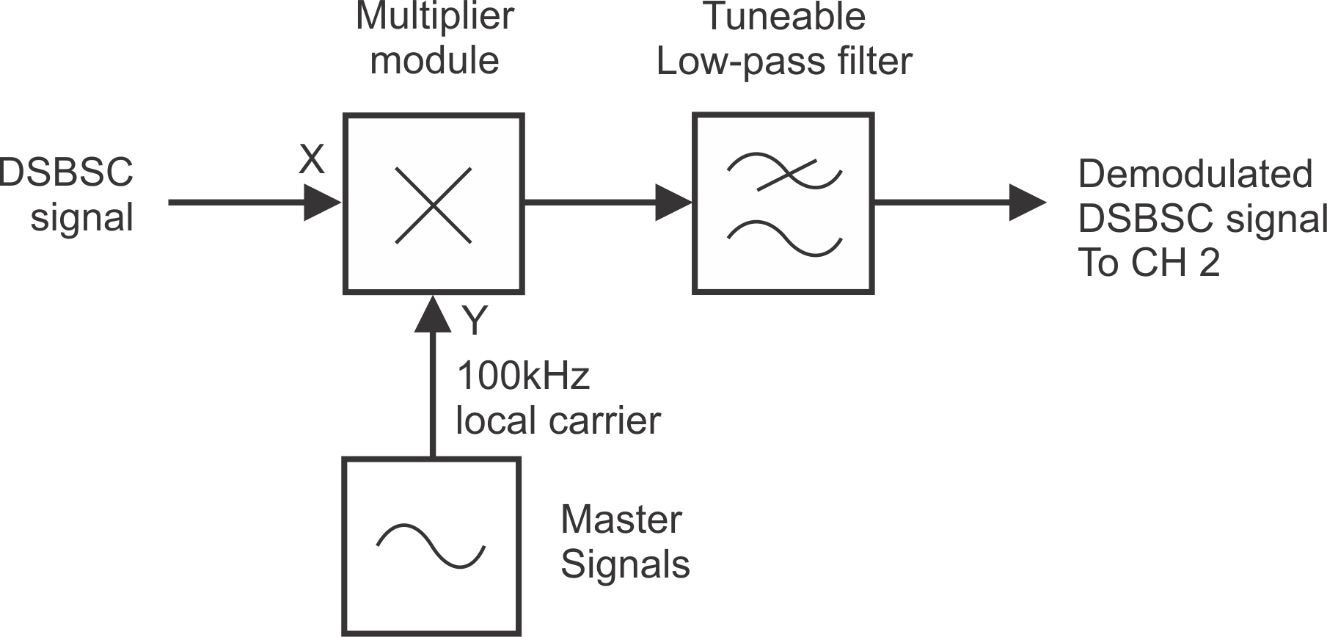


Figure 9: Block diagram for DSBSC demodulation

As its name implies, the product detector uses multiplication and so mathematics are necessary to explain its operation. The incoming DSBSC signal is multiplied by a pure sinewave that must be the same frequency as the DSBSC signal’s suppressed carrier. This sinewave is generated by the receiver and is known as the *local carrier*.

To see why this process recovers the message, let’s describe product detection mathematically:

DSBSC demodulator’s output = the DSBSC signal × the local carrier

Importantly, recall that DSBSC generation involves the multiplication of the message with the carrier which produces sum and difference frequencies. That being the case, this information can be substituted for the DSBSC signal and the equation rewritten as:

DSBSC demodulator’s output = [(carrier + message) + (carrier – message)] × carrier

When the equation is solved, we get four sinewaves with the following frequencies:

1. Carrier + (carrier + message)
2. Carrier + (carrier - message)
3. Carrier - (carrier + message) which simplifies to just the message
4. Carrier - (carrier - message) which also simplifies to just the message

(If you’re not sure why these sinewaves are produced, it’s important to remember that whenever two pure sinewaves are multiplied together, two completely new sinewaves are generated. One has a frequency equal to the sum of the original sinewaves’ frequencies and the other has a frequency equal to their difference.)

Importantly, notice that two of the products are sinewaves at the message frequency. In other words, the message has been recovered. As the two message signals are in phase, they simply add together to make one larger message.

Notice also that two of the products are non-message sinewaves. These sinewaves are unwanted and so a low-pass filter is used to reject them while keeping the message.

## 2.2 Implement: DSBSC Demodulation

To experiment with DSBSC demodulation you need a DSBSC signal. The first part of this experiment gets you to set one up. This procedure is identical to that in Implementation 1 above.

1. Ensure that the NI ELVIS III power switch at the back of the unit is off.
2. Carefully plug the Emona Communications application board into the NI ELVIS III.
3. Power up the ELVIS III and connect to the PC.
4. Power up the application board using the Application Board power button at the top left corner of the ELVIS III.
5. Run the NI launcher software and open the instruments you need.
6. Configure the scope using the configuration below:

Table 3 Scope Configuration

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

1. Connect the set-up shown in Figure 10.

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

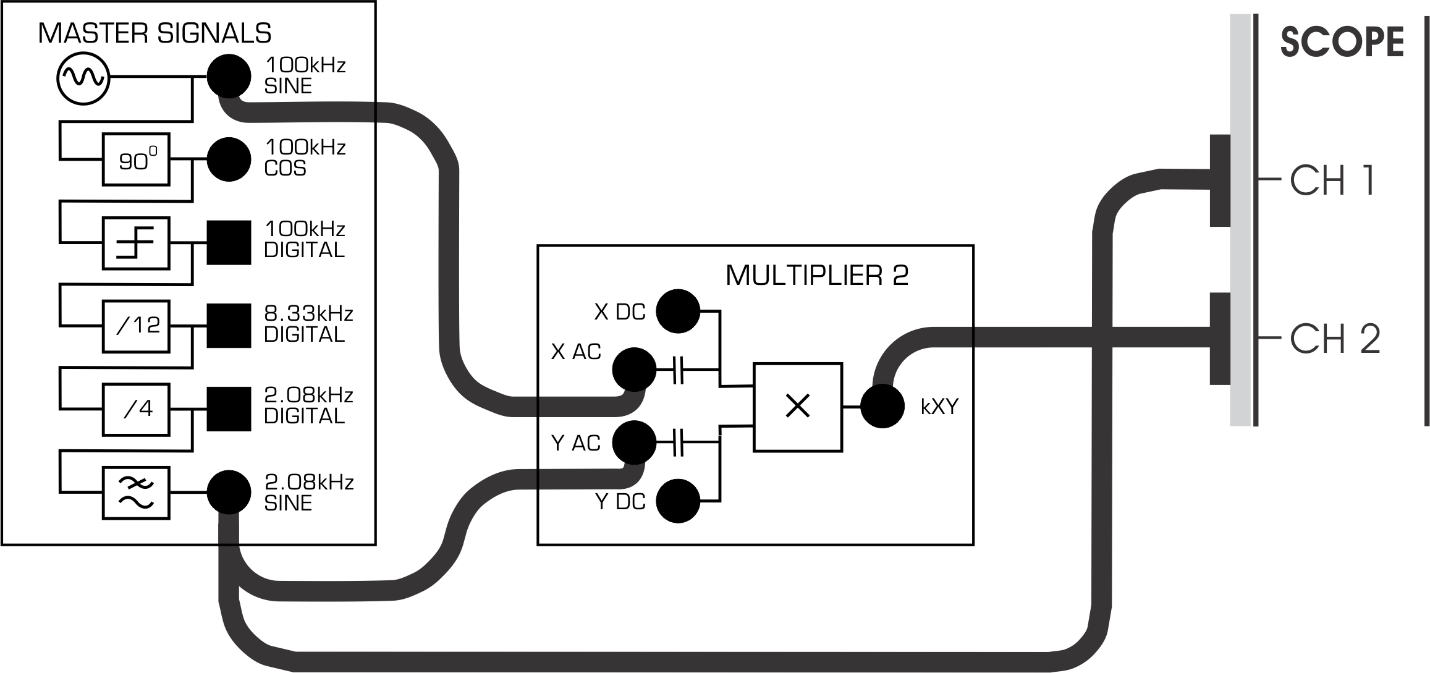


Figure 10: Patching for DSBSC signal

This set-up can be represented by the block diagram in Figure 11. It generates a 100kHz carrier that is DSBSC modulated by a 2.08kHz sinewave message.

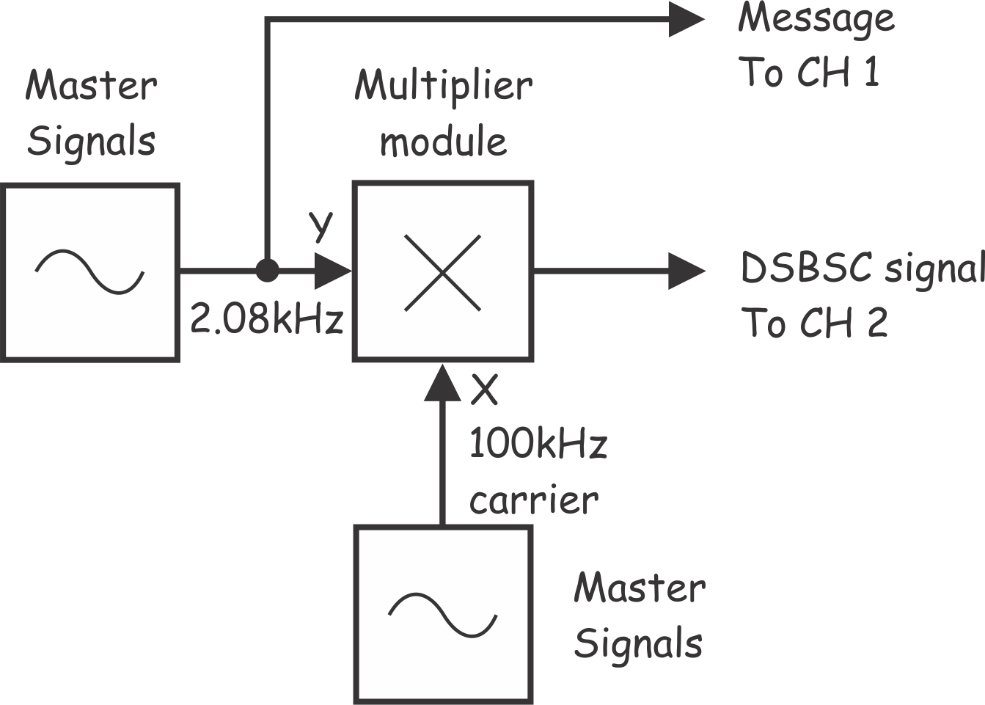


Figure 11: Block diagram for DSBSC

|  |  |
| --- | --- |
| 8. | Adjust the scope’s *Timebase* control to view two or so cycles of the Master Signals module’s *2.08kHz SINE* output. |

|  |  |
| --- | --- |
| 9. | Activate the scope’s Channel 2 input to view the DSBSC signal out of the Multiplier module as well as the message signal.  **Note:** If the Multiplier module’s output is not a DSBSC signal, check your wiring. |

|  |  |
| --- | --- |
| 10. | Set the scope’s Channel 1 *Scale* control to the *1V/div* position and the Channel 2 *Scale* control to the *2V/div* position. |

## 2.3 Implement: Recovering the message using a product detector

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| --- | --- |
| 1. | Locate the Tuneable Low-pass Filter module on the board and set its *Gain* control to about the middle of its travel. |

|  |  |
| --- | --- |
| 2. | Turn the Tuneable Low-pass Filter module’s Frequency Adjust control fully clockwise. |

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| --- | --- |
| 3. | Modify the set-up as shown in Figure 12. |

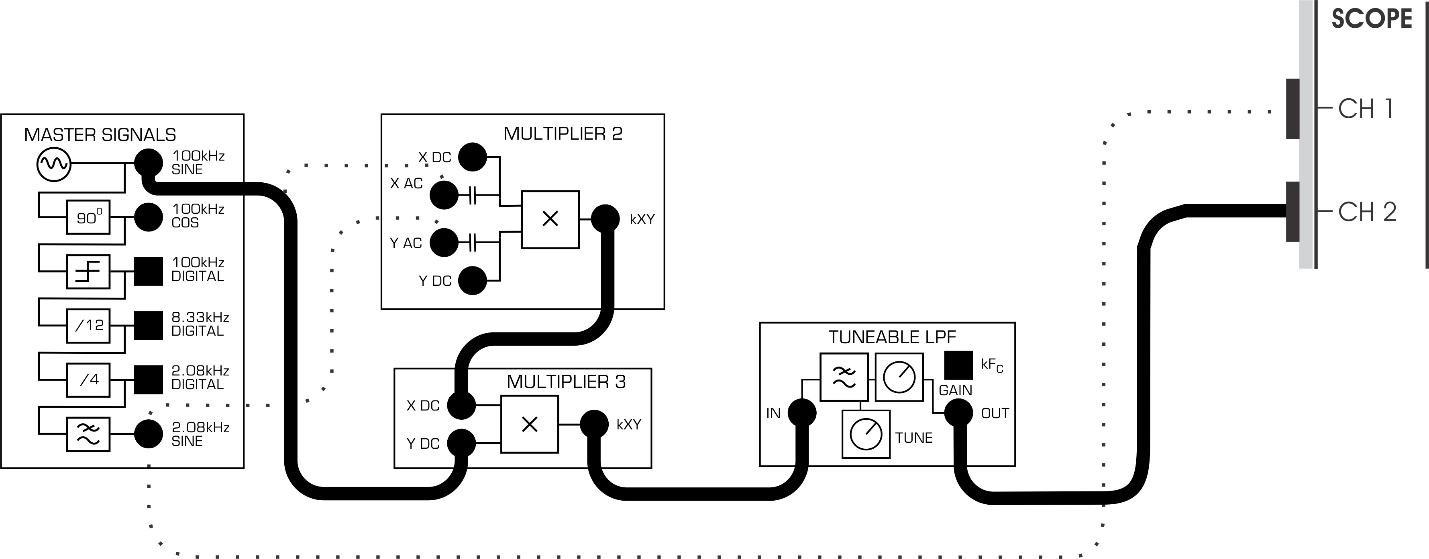


Figure 12: Patching for product demodulation

The additions to the set-up can be represented by the block diagram in Figure 13. The Multiplier and Tuneable Low-pass Filter modules are used to implement a product detector which demodulates the original message from the DSBSC signal.

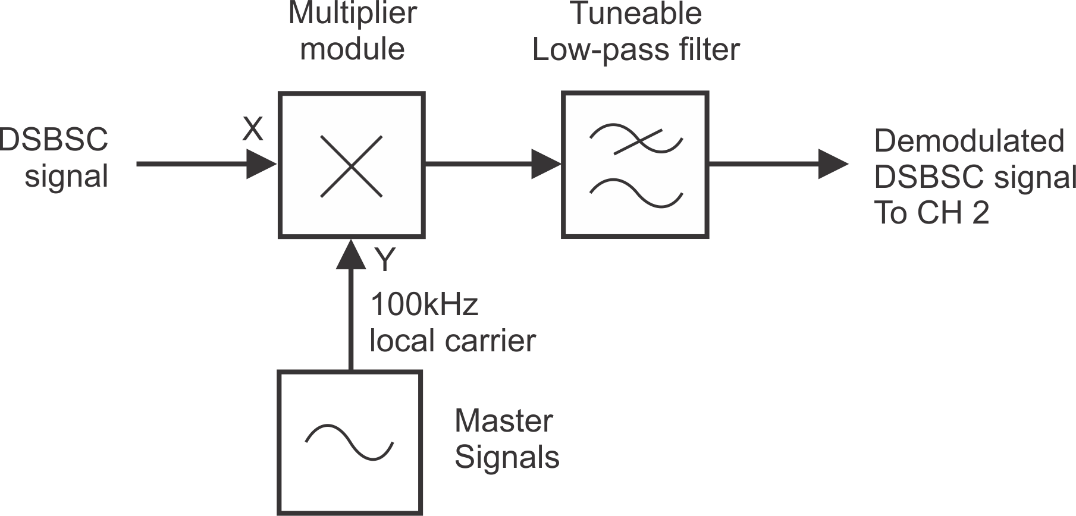


Figure 13: Block diagram for product demodulation

The entire setup is represented by the block diagram in Figure 14. It highlights the fact that the modulator’s carrier is “stolen” to provide the product detector’s local carrier. This means that the two carriers are synchronised which is a necessary condition for DSBSC communications.

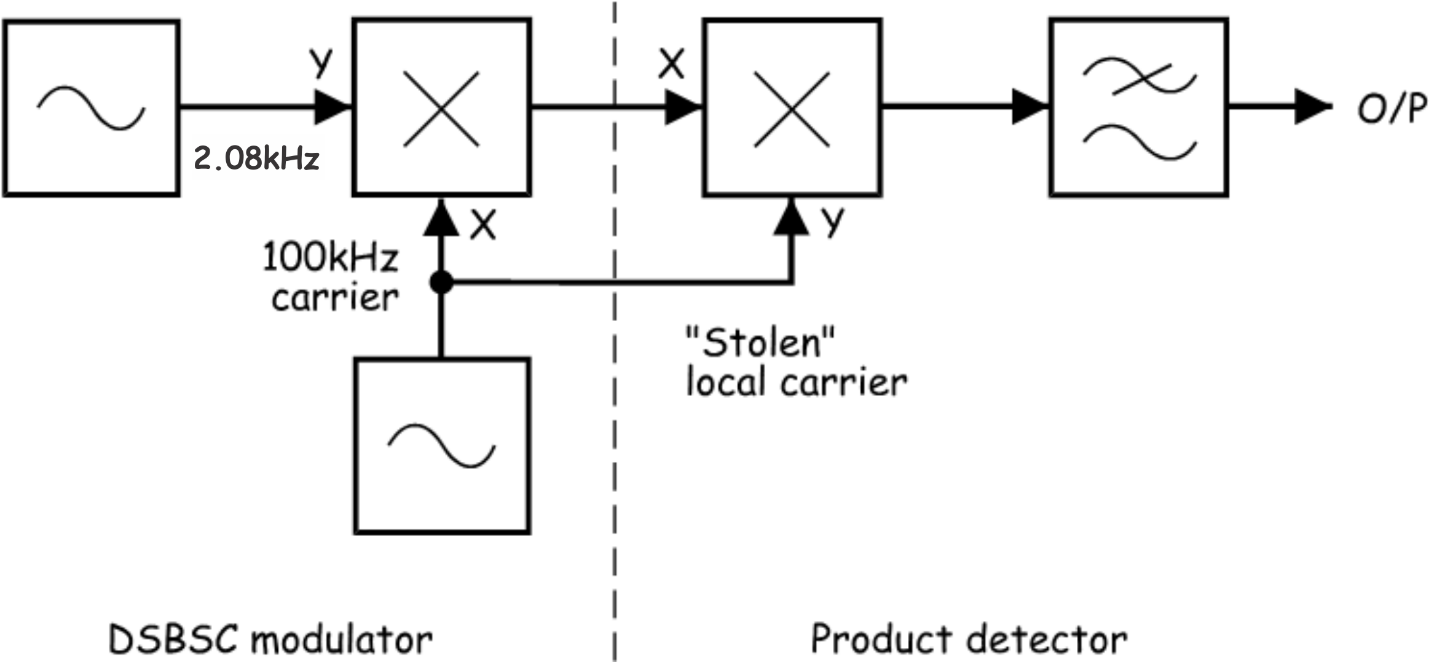


Figure 14: Block diagram for complete system

|  |  |
| --- | --- |
| 4. | 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. |
|  | **Tip**: Position the message signal in the upper half of the graph and the DSBSC signal in the lower half. |

2-1 Why must a product detector be used to recover the message instead of an envelope detector? **Tip:** If you’re not sure, refer to the preliminary discussion

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## 2.4 Implement: Investigating the message’s amplitude on the recovered message

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| --- | --- |
| 1. | Locate the Amplifier module on the board and turn its *Gain* control to about a quarter of its travel. |

|  |  |
| --- | --- |
| 2. | Disconnect the plugs to the Master Signals module’s *2.08kHz SINE* output. |

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| --- | --- |
| 3. | Use the Amplifier module to modify the set-up as shown in Figure 15. |

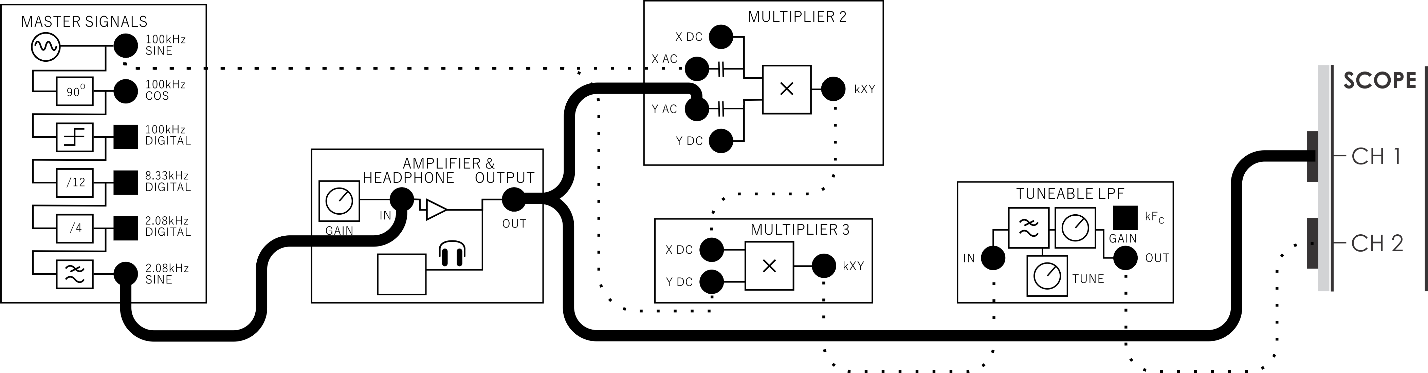


Figure 15: Patching for the complete system

The addition to the set-up can be represented by the block diagram in Figure 16. The amplifier’s variable gain allows the message’s amplitude to be adjustable.

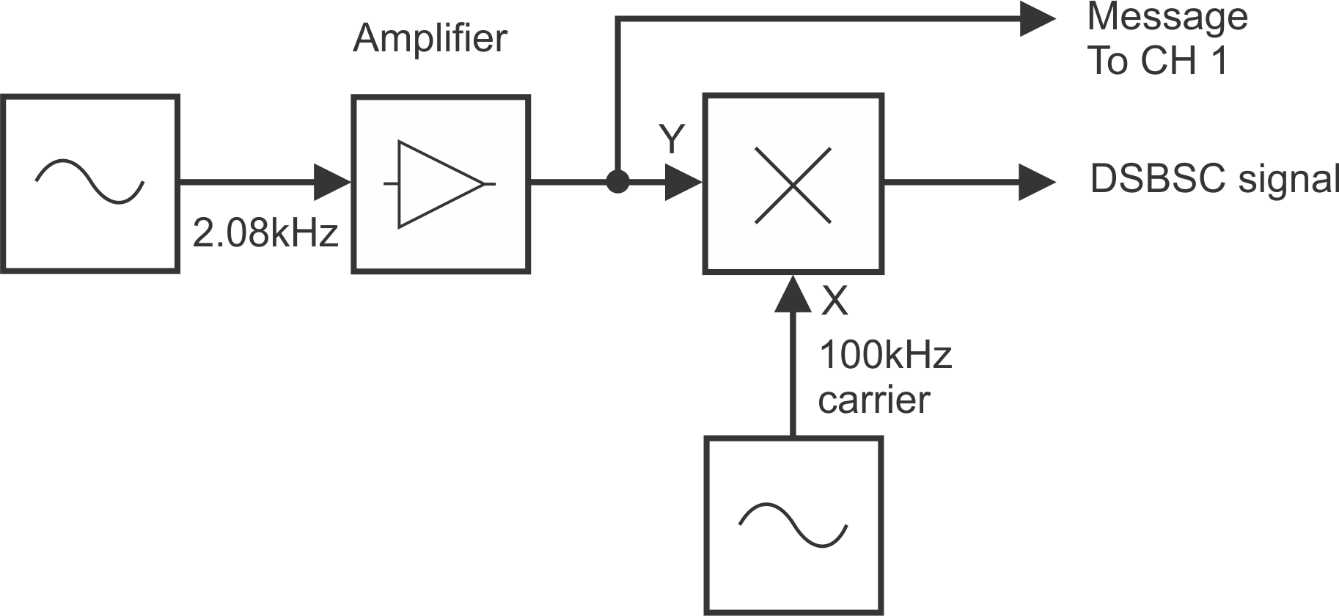


Figure 16: Block diagram for amplitude adjustment

|  |  |
| --- | --- |
| 4. | Vary the message signal’s amplitude up and down a little (by turning the Amplifier module’s *Gain* control left and right a little) while watching the demodulated signal. |

2-2 What is the relationship between the amplitude of the two message signals?

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| 5. | Slowly increase the message signal’s amplitude to maximum until the demodulated signal begins to distort. |

2-3 What do you think causes the distortion of the demodulated signal? **Tip:** If you’re not sure, connect the scope’s Channel 1 input to the DSBSC modulator’s output and set the *Trigger Source* to Channel 2.

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## Section 3: Transmitting and recovering speech using DSBSC

This experiment has set up a DSBSC communication system to “transmit” a 2.08kHz sinewave. The next part of the experiment lets you use it to modulate, transmit, demodulate and listen to speech.

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| 1. | If you moved the scope’s Channel 1 input and adjusted its *Trigger Source* control to help answer Question 2-3, return them to their previous positions. |

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| 2. | Disconnect the leads to the Amplifier module and modify the set-up as shown in Figure 17. |

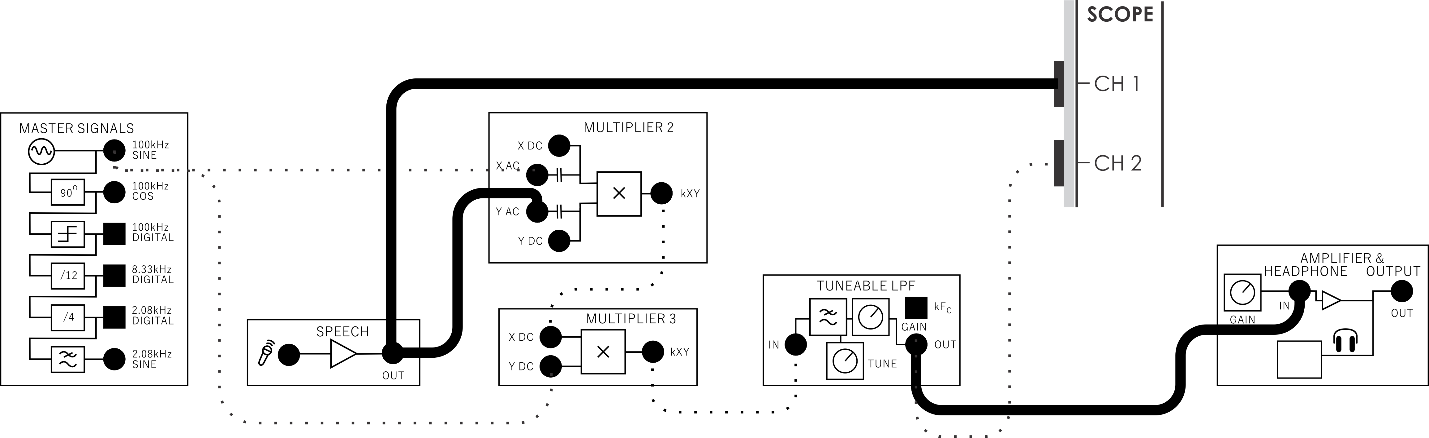


Figure 17: Patching for DSBSC with speech as message

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| --- | --- |
| 3. | Set the scope’s *Timebase* control to the *2ms/div* position. |

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| 4. | Turn the Amplifier module’s *Gain* control fully anti-clockwise (minimum gain). |

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| 5. | Without wearing the headphones, plug them into the Amplifier module’s headphone socket. |

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| 6. | Put the headphones on. |

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| 7. | As you perform the next step, set the Amplifier module’s *Gain* control to a comfortable sound level. |

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| --- | --- |
| 8. | Hum and talk into the microphone while watching the scope’s display and listening on the headphones. |

## Section 4: Carrier synchronisation - phase and frequency errors

Crucial to the correct operation of a DSBSC communications system is the synchronisation between the modulator’s carrier signal and the product detector’s local carrier. Any phase or frequency difference between the two signals adversely affects the system’s performance.

## 4.1 Implement: The effect of phase errors

Recall that the product detector generates two copies of the message. Recall also that they’re in phase with each other and so they simply add together to form one bigger message. However, if there’s a phase error between the carriers, the product detector’s two messages have a phase error also. One of them has the sum of the phase errors and the other the difference. In other words, the two messages are out of phase with each other.

If the carriers’ phase error is small (say about 10°) the two messages still add together to form one bigger signal but not as big as when the carriers are in phase. As the carriers’ phase error increases, the recovered message gets smaller. Once the phase error exceeds 45° the two messages begin to subtract from each other. When the carriers’ phase error is 90° the two messages end up 180° out of phase and completely cancel each other out.

The next part of the experiment lets you observe the effects of carrier phase error.

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| 1. | Turn the Amplifier module’s *Gain* control fully anti-clockwise again. |

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| 2. | Return the scope’s *Timebase* control to about the *100µs/div* position. |

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| 3. | Locate the Phase Shifter module on the board. |

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| 4. | Set the Phase Shifter module’s *Phase Adjust* control to about the middle of its travel. |

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| 5. | Disconnect the leads to the Speech output and modify the set-up as shown in Figure 10 below. |

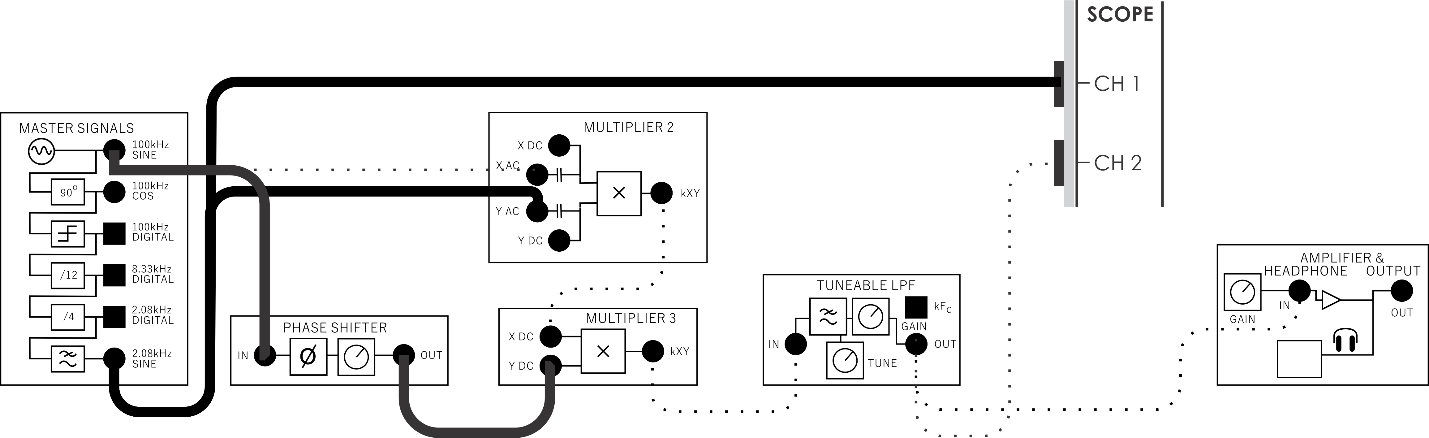


Figure 18: Patching for phase adjustment

The set-up in Figure 18 can be represented by the block diagram in Figure 19. The Phase Shifter module allows a phase error between the DSBSC modulator’s carrier and the product detector’s local carrier to be introduced.

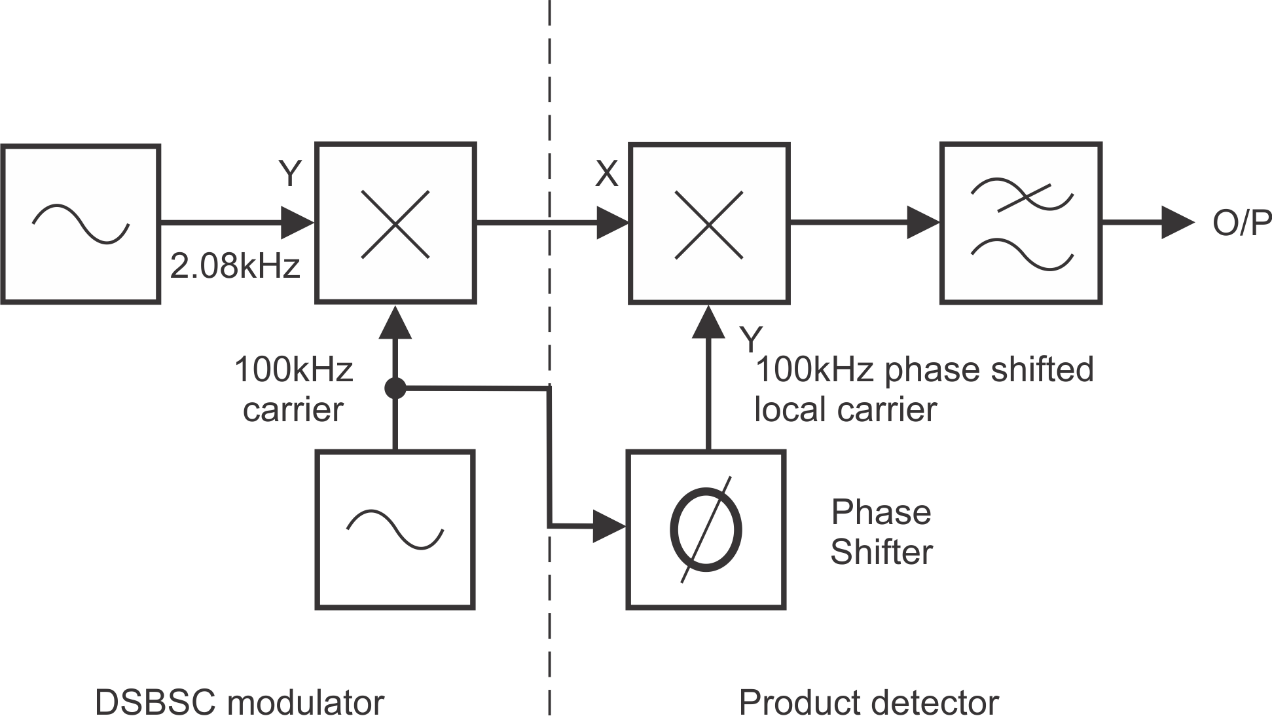


Figure 19: Block diagram for phase adjustment

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| 6. | Slowly increase the Amplifier’s module’s gain until you can comfortably hear the demodulated 2.08kHz tone. |

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| 7. | Vary the Phase Shifter module’s *Phase Adjust* control left and right while watching and listening to the effect on the recovered message. |

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| 8. | Turn the Phase Shifter module’s *Phase Adjust* control until the recovered message is smallest. |

4-1 Given the size of the recovered message’s amplitude, what is the likely phase error between the two carriers? **Tip:** If you’re not sure about the answer to this question (and the next one), reread the notes.

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| 9. | Verify your answer to Question 4-1 by connecting the scope’s Channel 1 input to the Master Signals module’s *100kHz SINE* output, its Channel 2 input to the Phase Shifter module’s output and setting its *Timebase* control to the *5µs/div* setting. |

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| 10. | Adjust the Phase Shifter module’s soft *Phase Adjust* control until the two signals are in phase. |

4-2 Given the two carriers are in phase, what should the amplitude of the recovered message be?

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| 11. | Verify your answer to Question 4-2 by reconnecting the scope’s Channel 1 input to the Master Signals module’s *2.08kHz SINE* output, reconnecting its Channel 2 input to the Tuneable Low-pass Filter module’s output and setting its *Timebase* control back to the *100µs/div* setting. |

## 4.2 Implement: The effect of frequency errors

When there’s a frequency error between the DSBSC signal’s carrier and the product detector’s local carrier, there is a corresponding frequency error in the two products that usually coincide. One is at the message frequency minus the error and the other is at the error frequency plus the error.

If the error is small (say 0.1Hz) the two signals will alternately reinforce and cancel each other which can render the message periodically inaudible but otherwise intelligible. If the frequency error is larger (say 5Hz) the message is reasonably intelligible but fidelity is poor. When frequency errors are large, intelligibility is seriously affected.

The next part of the experiment lets you observe the effects of carrier frequency error.

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| 1. | Launch and run the NI ELVIS III Function Generator Instrument. |

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| 2. | Adjust the function generator’s soft controls for an output with the following specifications:   1. Waveshape: Sine 2. Frequency: 100kHz exactly 3. Amplitude: 4Vpp 4. DC Offset: 0V |

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| 3. | Disconnect the leads to the Phase Shifter module and modify the set-up as shown in Figure 20. |

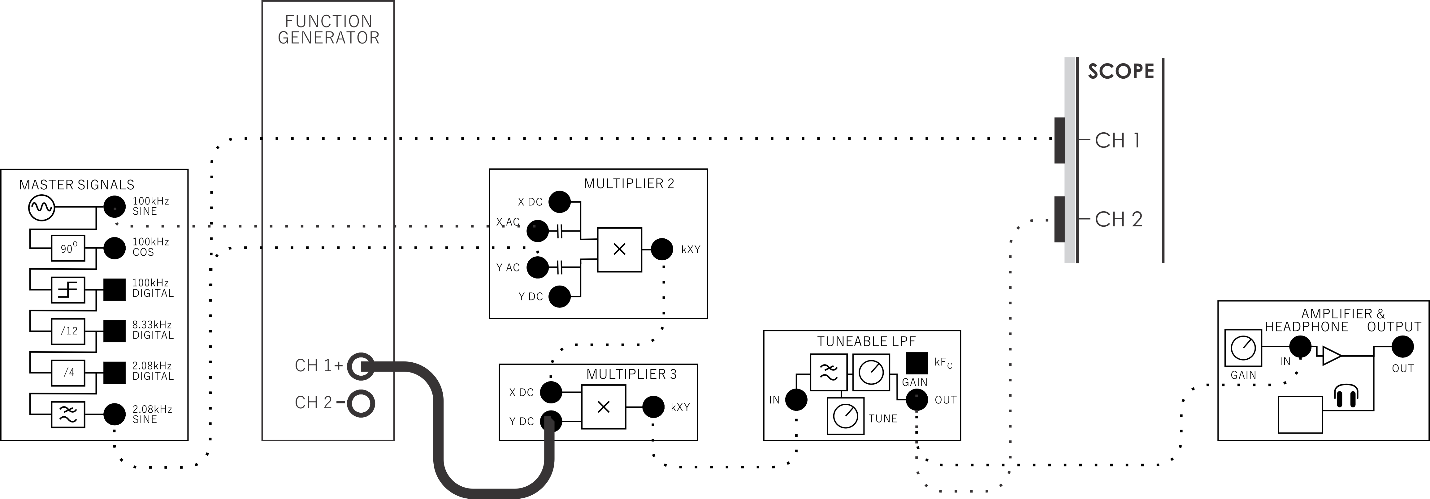


Figure 20: Patching for frequency error

The entire set-up can be represented by the block diagram in Figure 21. The function generator allows the local oscillator to be completely frequency (and phase) independent of the DSBSC modulator.

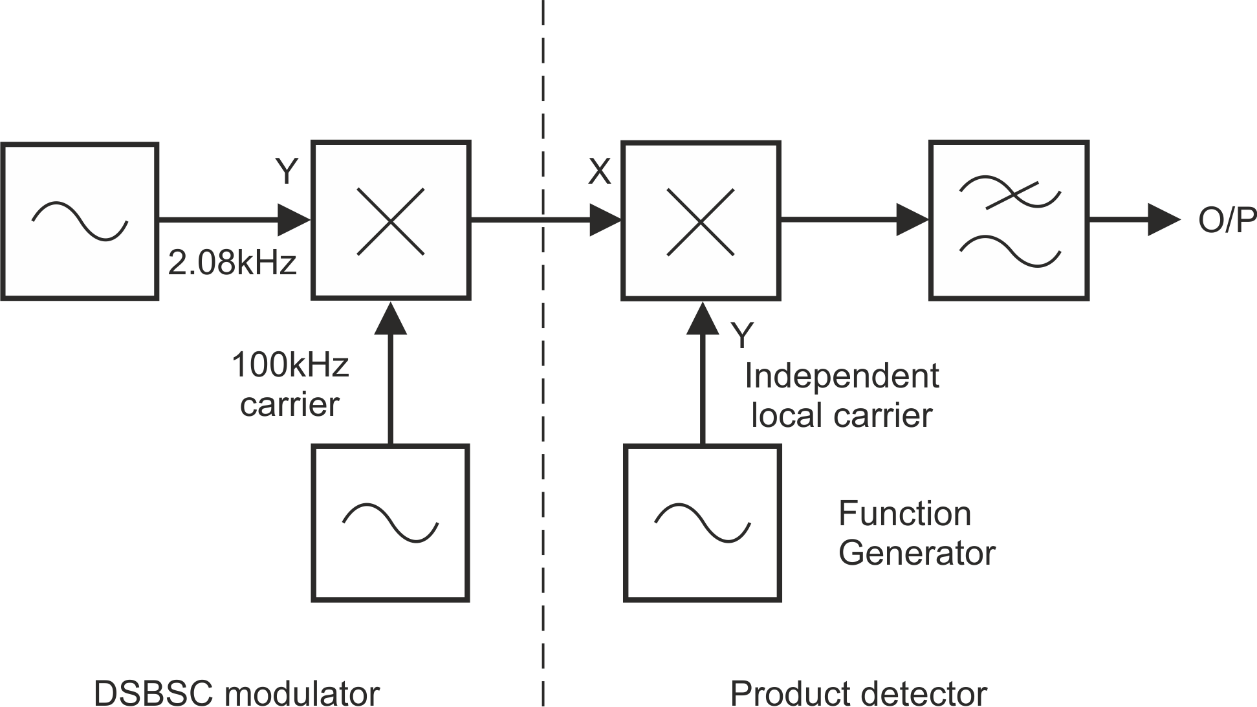


Figure 21: Block diagram for frequency error

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| 4. | If you’re not doing so already, listen to the recovered message using the headphones. |

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| 5. | Compare the scope’s frequency measurements for the original message and the recovered message.  **Note 1:** You should find that they’re very close in frequency.  **Note 2:** You’ll notice that the volume of the recovered messages varies. This is due to the phase error between the two carriers and should be ignored for the following steps. |

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| 6. | Reduce the function generator’s output frequency to 99.8kHz. |

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| 7. | Give the function generator a moment to achieve the correct frequency and note the change in the tone of recovered message.  **Tip:** If you can’t remember what 2.08kHz sounds like, set function generator’s output to 100kHz for a moment then return it to 99.8kHz. |

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| 8. | Experiment with other local carrier frequencies around 100kHz and listen to the effect on the recovered message. |

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| 9. | Return the function generator’s output to 100kHz. |

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| 10. | Disconnect the plugs to the Master Signals module’s *2.08kHz SINE* output and connect them to the Speech module’s output. |

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| 11. | Hum and talk into the microphone to check that the whole set-up is still working correctly. |

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| 12. | Vary the function generator’s frequency again and listen to the effect of an unsynchronised local carrier on speech. |