Name: ______________________________

Class: ______________________________

6 - DSBSC modulation

Experiment 6 – DSBSC modulation

Preliminary discussion

DSBSC is a modulation system similar but different to AM (which was explored in Experiment 5).

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 below shows a simple message signal and an unmodulated carrier. It also shows the result of modulating the carrier with the message using DSBSC.

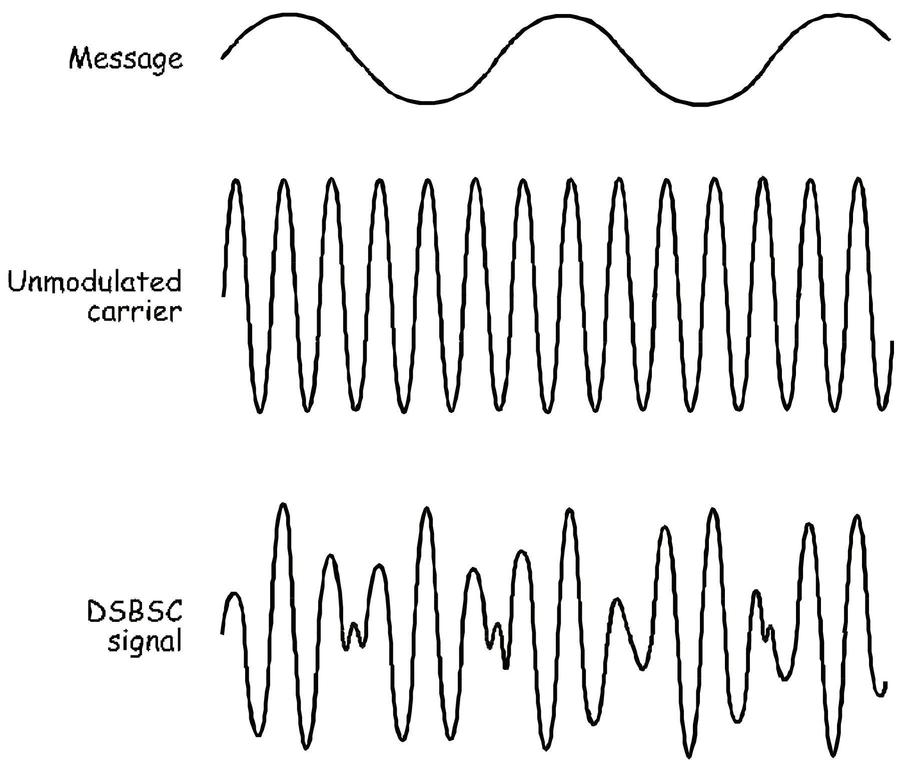


Figure 1

So far, there doesn't appear to be much difference between AM and DSBSC. However, consider Figure 2 below. 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 5 page 5-3 for an example).

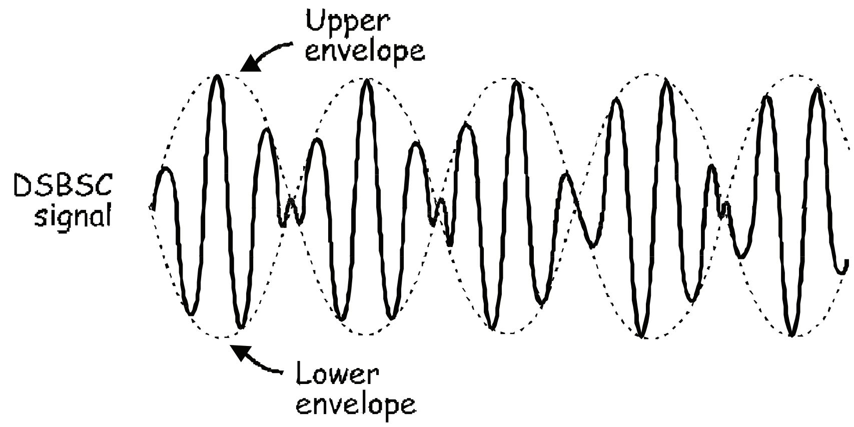


Figure 2

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

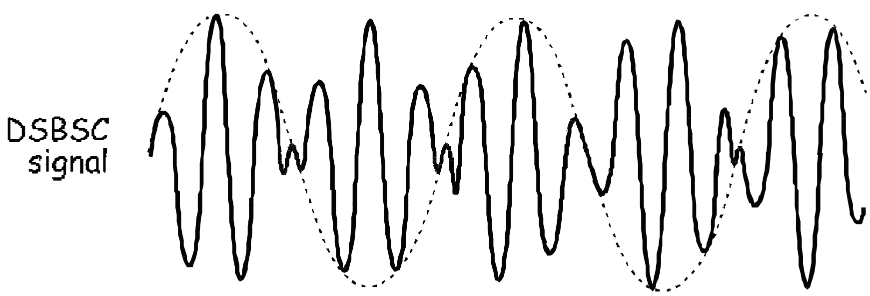


Figure 3

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

$$\text{DSBSC} = \text{the message} \times \text{the carrier}$$

Do you see the difference between the equations for AM and DSBSC? If not, look at the AM equation in Experiment 5 (page 5-3).

When the message is a simple sinewave (like in Figure 1) the equation's solution (which necessarily involves some trigonometry) tells us that the DSBSC signal consists of two sinewaves:

- 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

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.

The experiment

For this experiment you'll use the Emona DATEx to generate a real DSBSC signal by implementing its mathematical model. This means that you'll take a pure sinewave (the message) that contains absolutely no DC and multiply it with another sinewave at a higher frequency (the carrier). You'll examine the DSBSC 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 carrier's depth of modulation. You'll also observe the effects of modulating the carrier too much.

It should take you about 50 minutes to complete this experiment.

Equipment

- Personal computer with appropriate software installed
- NI ELVIS II plus USB cable and power pack
- Emona DATEx experimental add-in module
- Two BNC to 2mm banana-plug leads
- Assorted 2mm banana-plug patch leads

Procedure

Part A - Generating a DSBSC signal using a simple message

1. Ensure that the NI ELVIS II power switch at the back of the unit is off.

2. Carefully plug the Emona DATEx experimental add-in module into the NI ELVIS II.

3. Set the *Control Mode* switch on the DATEx module (top right corner) to *PC Control*.

4. Connect the NI ELVIS II to the PC using the USB cable.

   Note: This may already have been done for you.

5. Turn on the NI ELVIS II power switch at the rear of the unit then turn on its *Prototyping Board Power* switch at the top right corner near the power indicator.

6. Turn on the PC and let it boot-up.

7. Launch the NI ELVISmx software.

8. Launch and run the NI ELVIS II Oscilloscope virtual instrument (VI).

9. Set up the scope per the procedure in Experiment 1 (page 1-12) ensuring that the *Trigger Source* control is set to *CH 0*.

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 you're set-up is working correctly, the PCM Decoder module's LED on the DATEx board should turn on and off.

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

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

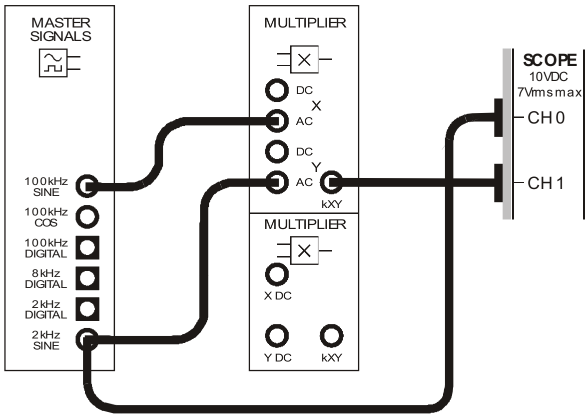


Figure 4

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

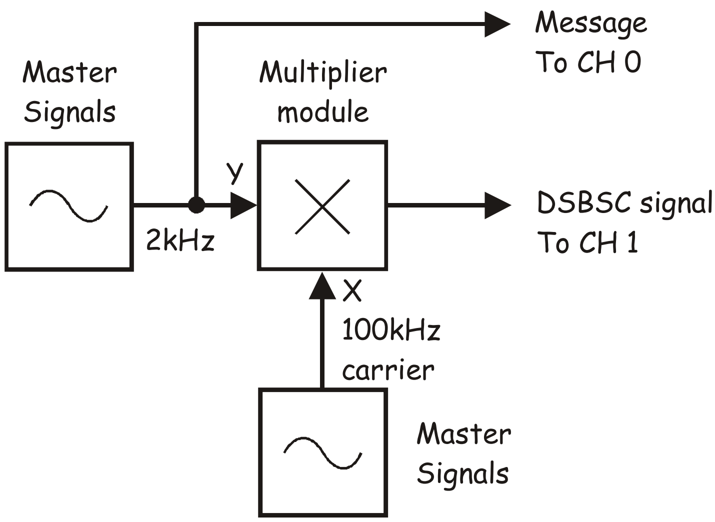


Figure 5

With values, the equation on the previous page becomes:

DSBSC = 4Vp-p 2kHz sine × 4Vp-p 100kHz sine.

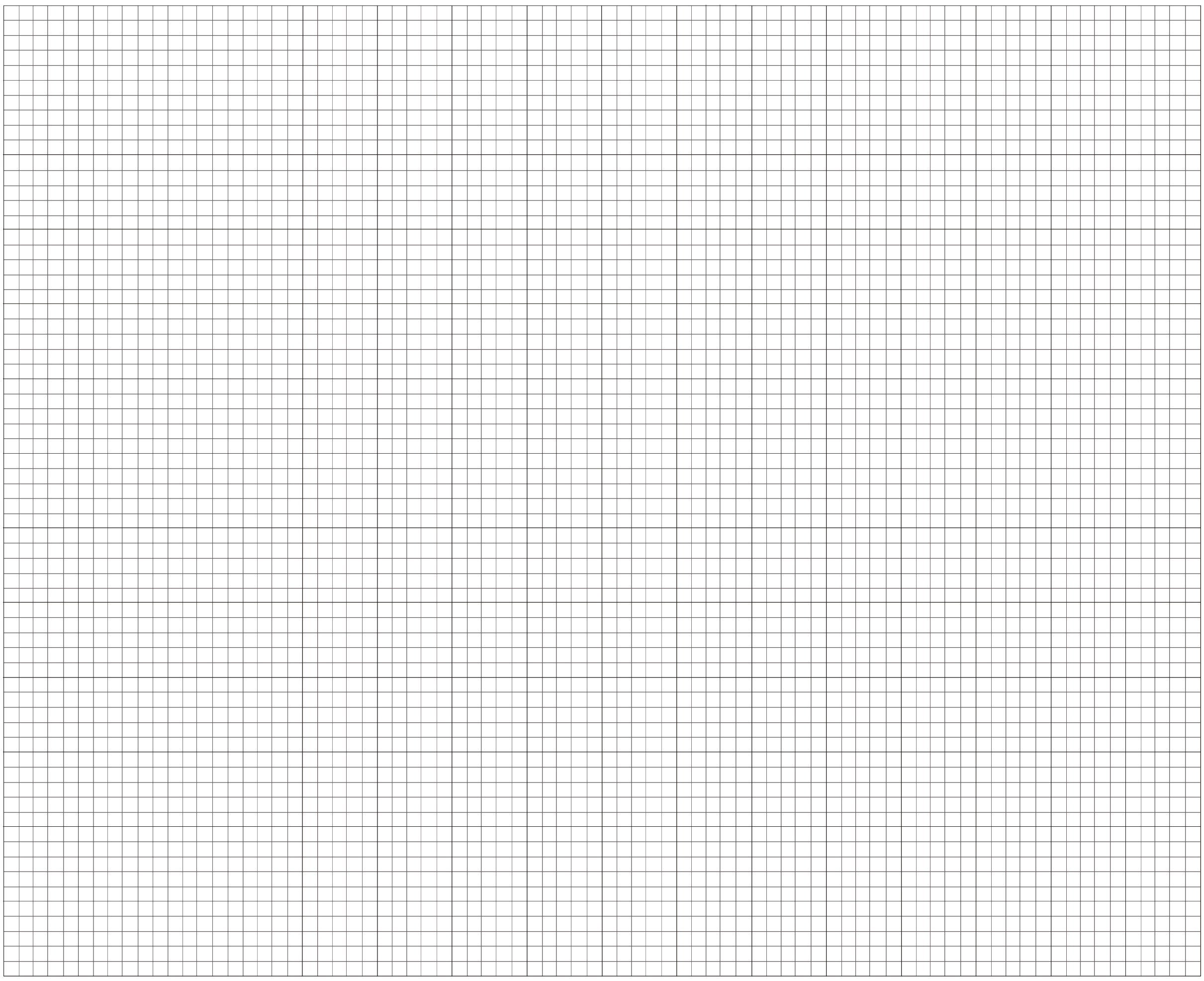
13. Adjust the scope's *Timebase* control to view two or so cycles of the Master Signals module's *2kHz SINE* output.

14. Activate the scope's Channel 1 input (by checking the Channel 1 *Enabled* box) to view the DSBSC signal out of the Multiplier module as well as the message signal.

15. Set the scope's Channel 0 *Scale* control to the *500mV/div* position and the Channel 1 *Scale* control to the *1V/div* position (if it's not already).

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

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



Ask the instructor to check your work before continuing.

17. If they're not already, overlay the message with the DSBSC signal's envelopes to compare them using the scope's Channel 0 *Position* control.

Question 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.

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

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

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

Ask the instructor to check your work before continuing.

Part B - 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.

18. Disconnect the plugs to the Master Signals module's *2kHz SINE* output.

19. Connect them to the Speech module's output as shown in Figure 6 below.

    Remember: Dotted lines show leads already in place.

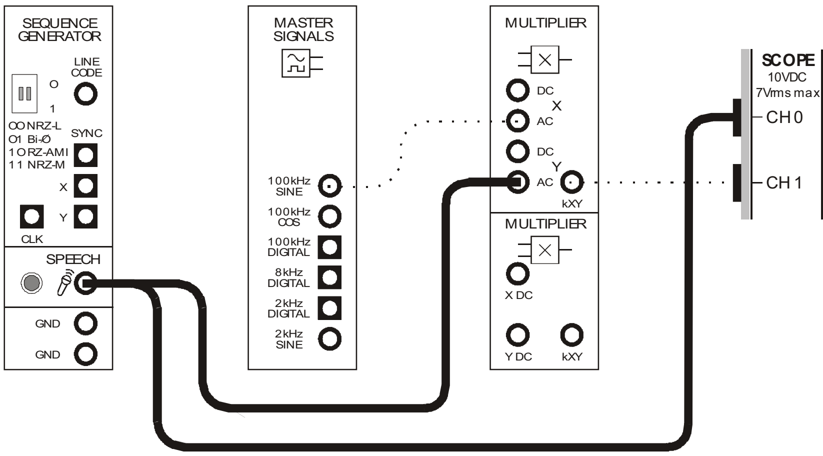


Figure 6

20. Set the scope's *Timebase* control to the *1ms/div* position.

21. Hum and talk into the microphone while watching the scope's display.

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

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.

22. Return the scope's *Timebase* control to the *100µs/div* position.

23. Locate the Amplifier module on the DATEx SFP and set its soft *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).

24. Modify the set-up as shown in Figure 7 below.

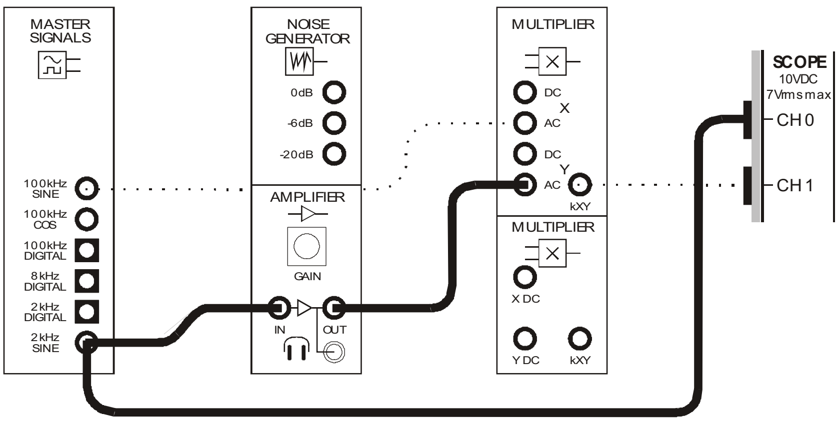


Figure 7

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

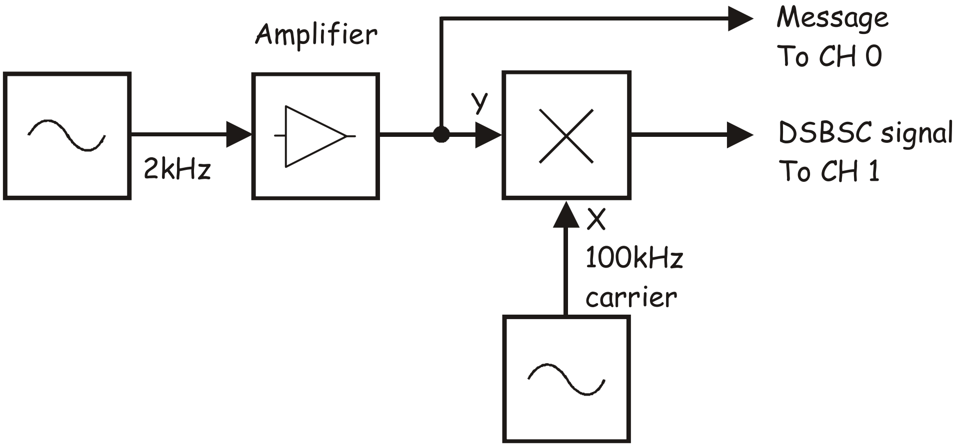


Figure 8

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

Recall from Experiment 5 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 at the top of page 5-14 before going on to the next step.

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

Question 6
Based on your observations in Step 25, when the message's amplitude is varied

☐ neither dimensions *P* or *Q* are affected.

☐ only dimension *Q* is affected.

☐ only dimension *P* is affected.

☐ both dimensions *P* and *Q* are affected.

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 signals *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. So 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.

26. Set the Amplifier module's soft *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.

27. Draw the new DSBSC signal to scale in the space provided below.

Question 7
What is the name of this type of distortion?

Ask the instructor to check
your work before finishing.

Name: ______________________________

Class: ______________________________

9 - DSBSC demodulation

Experiment 9 – DSBSC demodulation

Preliminary discussion

Experiment 8 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 1 below. Other names for this type of demodulation include a *synchronous detector* and *switching detector*.

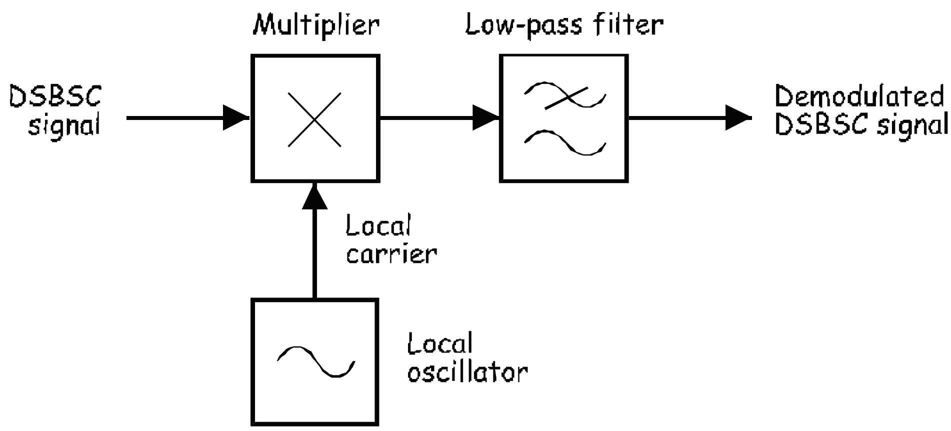


Figure 1

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 (the preliminary discussion in Experiment 6 summarises DSBSC generation). 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:

- Carrier + (carrier + message)
- Carrier + (carrier - message)
- Carrier - (carrier + message) which simplifies to just the message
- 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.

The experiment

For this experiment you'll use the Emona DATEx to generate a DSBSC signal by implementing its mathematical model. Then you'll set-up a product detector by implementing its mathematical model also.

Once done, you'll connect the DSBSC signal to the product detector's input and compare the demodulated output to the original message and the DSBSC signal's envelopes. You'll also observe the effect that a distorted DSBSC signal due to overloading has on the product detector's output.

Finally, if time permits, you'll investigate the effect on the product detector's performance of an unsynchronised local carrier.

It should take you about 1 hour to complete the whole experiment.

Equipment

- Personal computer with appropriate software installed
- NI ELVIS II plus USB cable and power pack
- Emona DATEx experimental add-in module
- Two BNC to 2mm banana-plug leads
- Assorted 2mm banana-plug patch leads
- One set of headphones (stereo)

Procedure

Part A – Setting up the DSBSC modulator
To experiment with DSBSC demodulation you need a DSBSC signal. The first part of the experiment gets you to set one up.

1. Ensure that the NI ELVIS II power switch at the back of the unit is off.

2. Carefully plug the Emona DATEx experimental add-in module into the NI ELVIS II.

3. Set the *Control Mode* switch on the DATEx module (top right corner) to *PC Control*.

4. Connect the NI ELVIS II to the PC using the USB cable.

   Note: This may already have been done for you.

5. Turn on the NI ELVIS II power switch at the rear of the unit then turn on its *Prototyping Board Power* switch at the top right corner near the power indicator.

6. Turn on the PC and let it boot-up.

7. Launch the NI ELVISmx software.

8. Launch and run the NI ELVIS II Oscilloscope VI.

9. Set up the scope per the procedure in Experiment 1 ensuring that the *Trigger Source* control is set to *CH 0*.

10. Connect the set-up shown in Figure 2 below.

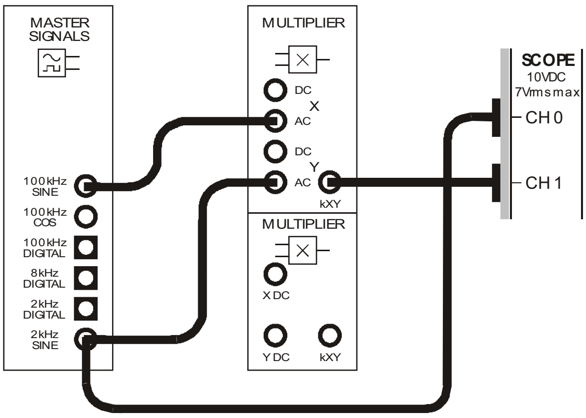


Figure 2

This set-up can be represented by the block diagram in Figure 3 below. It generates a 100kHz carrier that is DSBSC modulated by a 2kHz sinewave message.

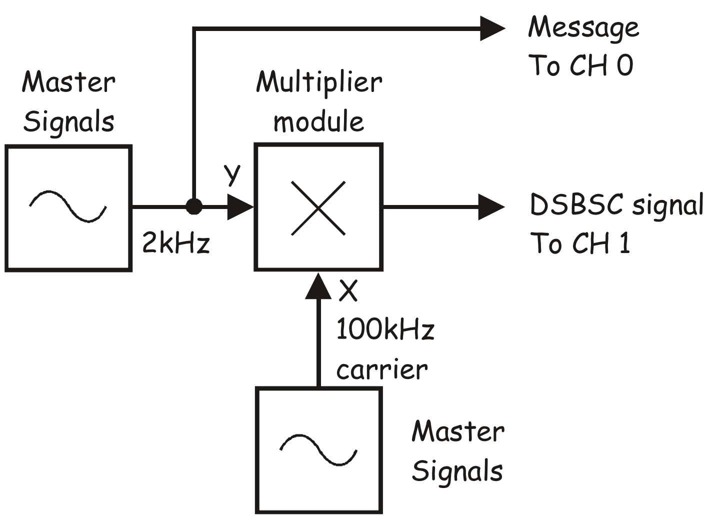


Figure 3

11. Adjust the scope's *Timebase* control to view two or so cycles of the Master Signals module's *2kHz SINE* output.

12. Activate the scope's Channel 1 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.

13. Set the scope's Channel 0 *Scale* control to the *1V/div* position and the Channel 1 *Scale* control to the *2V/div* position.

14. Draw the two waveforms to scale in the space provided on the next page leaving room to draw a third waveform.

    Tip: Draw the message signal in the upper third of the graph and the DSBSC signal in the middle third.

Ask the instructor to check
your work before continuing.

Part B – Recovering the message using a product detector

15. Launch the DATEx soft front-panel (SFP) and check that you have soft control over the DATEx board.

16. Locate the Tuneable Low-pass Filter module on the DATEx SFP and set its soft *Gain* control to about the middle of its travel.

17. Turn the Tuneable Low-pass Filter module's soft *Cut-off Frequency Adjust* control fully clockwise.

18. Modify the set-up as shown in Figure 4 below.

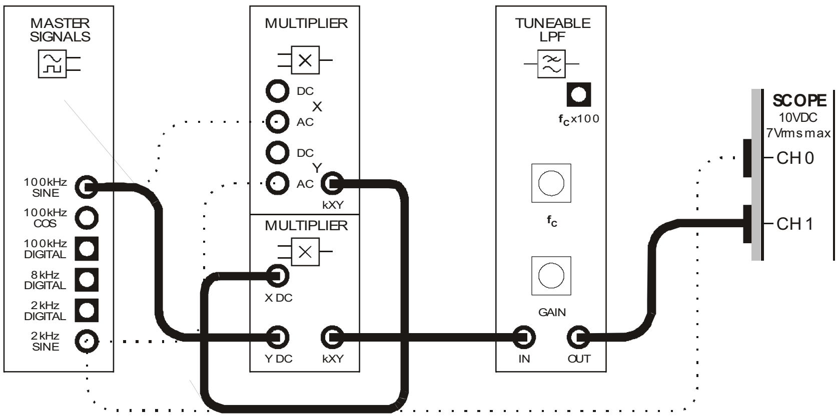


Figure 4

The additions to the set-up can be represented by the block diagram in Figure 5 on the next page. The Multiplier and Tuneable Low-pass Filter modules are used to implement a product detector which demodulates the original message from the DSBSC signal.

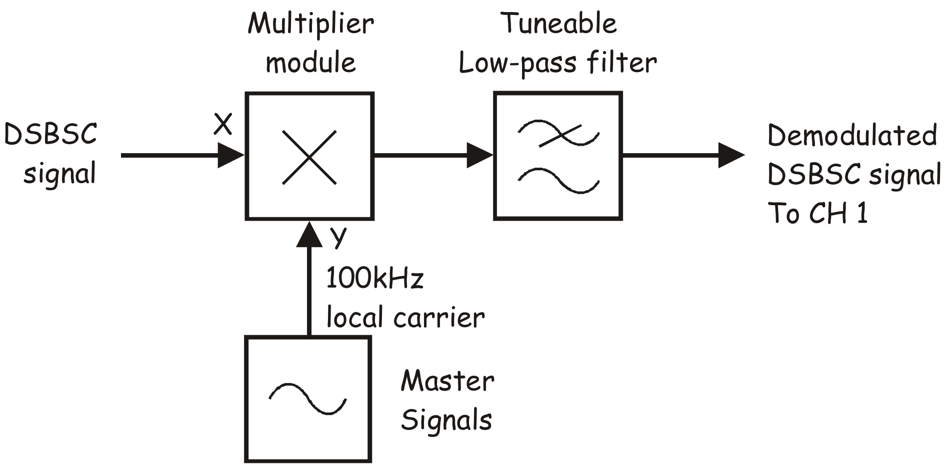


Figure 5

The entire set-up is represented by the block diagram in Figure 6 below. 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.

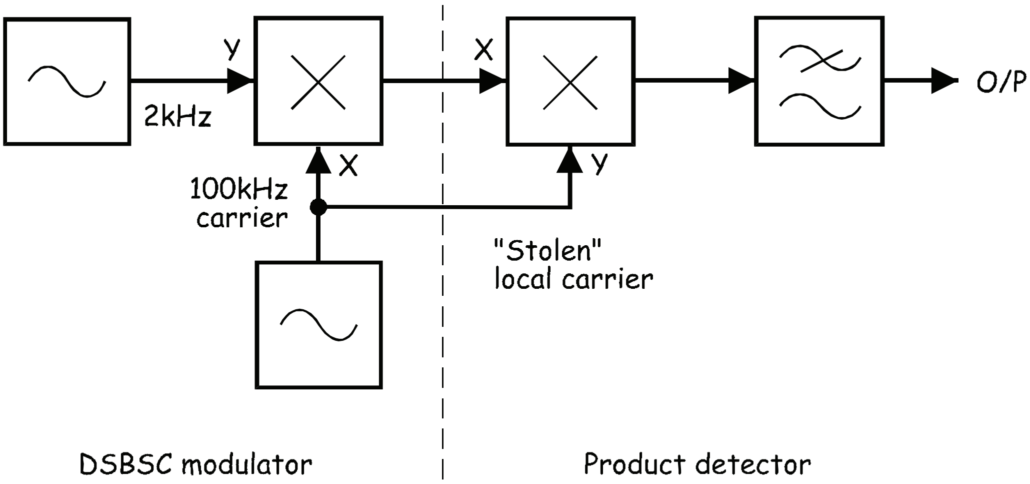


Figure 6

19. Draw the demodulated DSBSC signal to scale in the space that you left on the graph paper.

Question 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.

Ask the instructor to check your work before continuing.

Part C – Investigating the message's amplitude on the recovered message

20. Locate the Amplifier module on the DATEx SFP and turn its soft *Gain* control to about a quarter of its travel.

21. Disconnect the plugs to the Master Signals module's *2kHz SINE* output.

22. Use the Amplifier module to modify the set-up as shown in Figure 7 below.

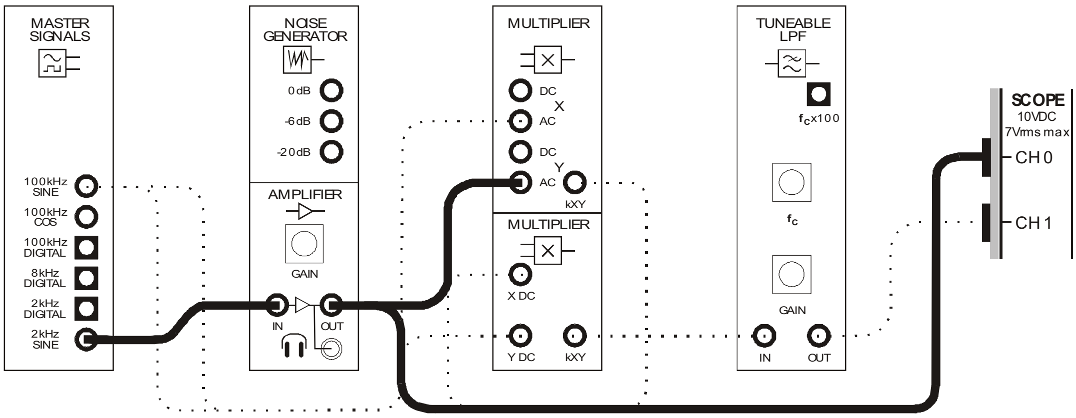


Figure 7

The addition to the set-up can be represented by the block diagram in Figure 8 below. The amplifier's variable gain allows the message's amplitude to be adjustable.

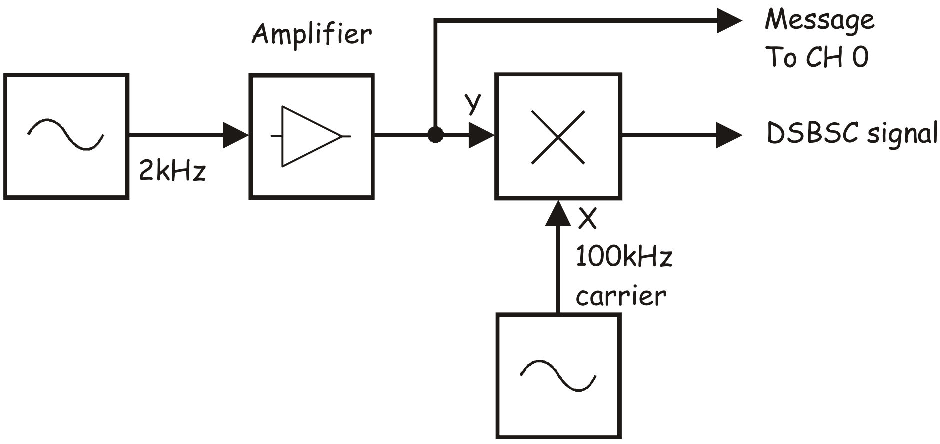


Figure 8

23. Vary the message signal's amplitude up and down a little (by turning the Amplifier module's soft *Gain* control left and right a little) while watching the demodulated signal.

    Remember: You can use the keyboard's TAB and arrow keys for fine adjustments of DATEx controls.

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

    ___

    ___

24. Slowly increase the message signal's amplitude to maximum until the demodulated signal begins to distort.

    Question 3
    What do you think causes the distortion of the demodulated signal? **Tip:** If you're not sure, connect the scope's Channel 0 input to the DSBSC modulator's output and set its *Trigger Source* control to the *CH 1* position.

    ___

Ask the instructor to check
your work before continuing.

Part D – Transmitting and recovering speech using DSBSC

This experiment has set up a DSBSC communication system to "transmit" a 2kHz sinewave. The next part of the experiment lets you use it to modulate, transmit, demodulate and listen to speech.

25. If you moved the scope's Channel 0 input and adjusted its *Trigger Source* control to help answer Question 3, return them to their previous positions.

26. Disconnect the leads to the Amplifier module and modify the set-up as shown in Figure 9 below.

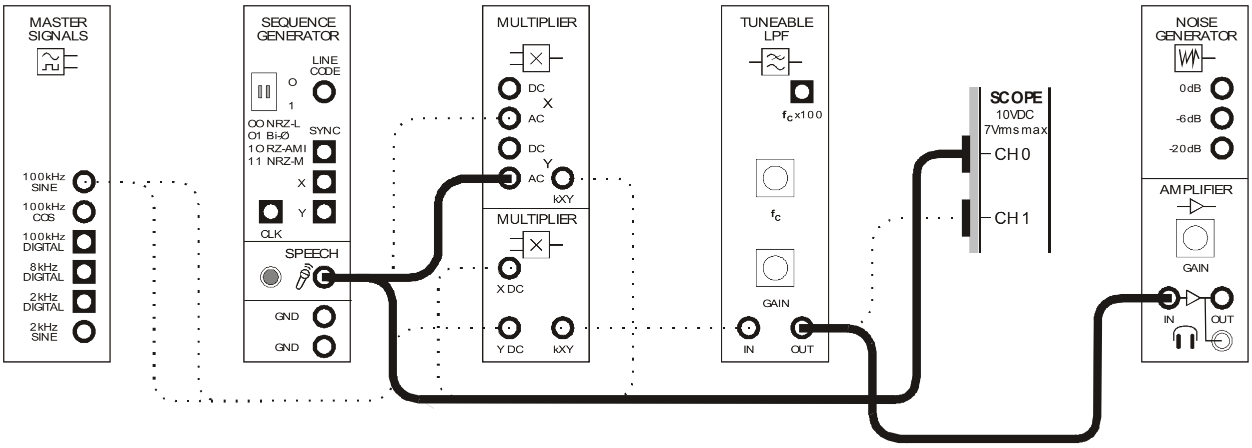


Figure 9

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

28. Turn the Amplifier module's soft *Gain* control fully anti-clockwise.

29. Without wearing the headphones, plug them into the Amplifier module's headphone socket.

30. Put the headphones on.

31. As you perform the next step, set the Amplifier module's soft *Gain* control to a comfortable sound level.

32. Hum and talk into the microphone while watching the scope's display and listening on the headphones.

Ask the instructor to check
your work before continuing.

Part E – Carrier synchronisation

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.

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.

33. Turn the Amplifier module's soft *Gain* control fully anti-clockwise again.

34. Return the scope's *Timebase* control to about the *100μs/div* position.

35. Locate the Phase Shifter module on the DATEx SFP and set its soft *Phase Change* control to the *180°* position.

36. Set the Phase Shifter module's soft *Phase Adjust* control to about the middle of its travel.

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

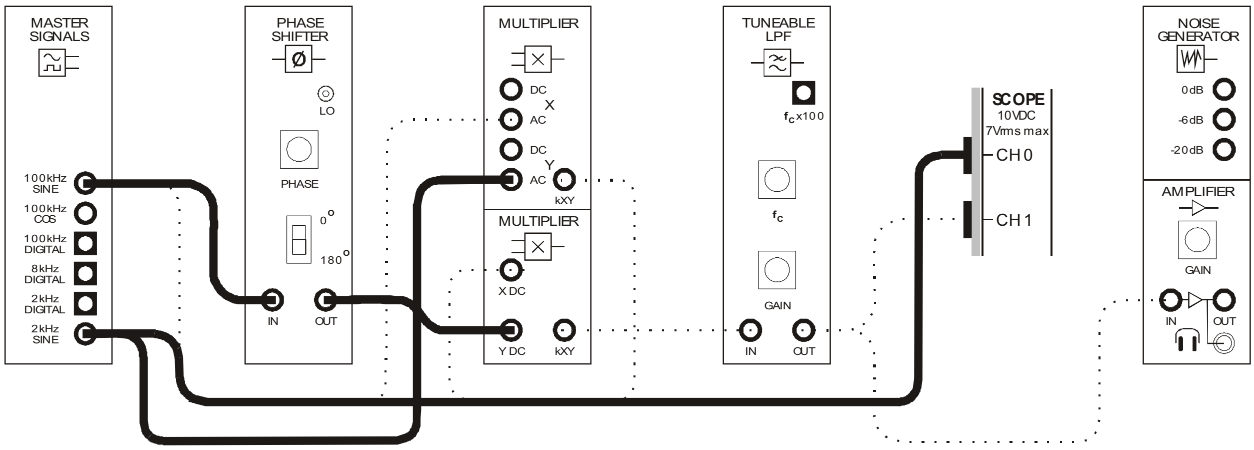


Figure 10

The set-up in Figure 10 on the previous page can be represented by the block diagram in Figure 11 below. The Phase Shifter module allows a phase error between the DSBSC modulator's carrier and the product detector's local carrier to be introduced.

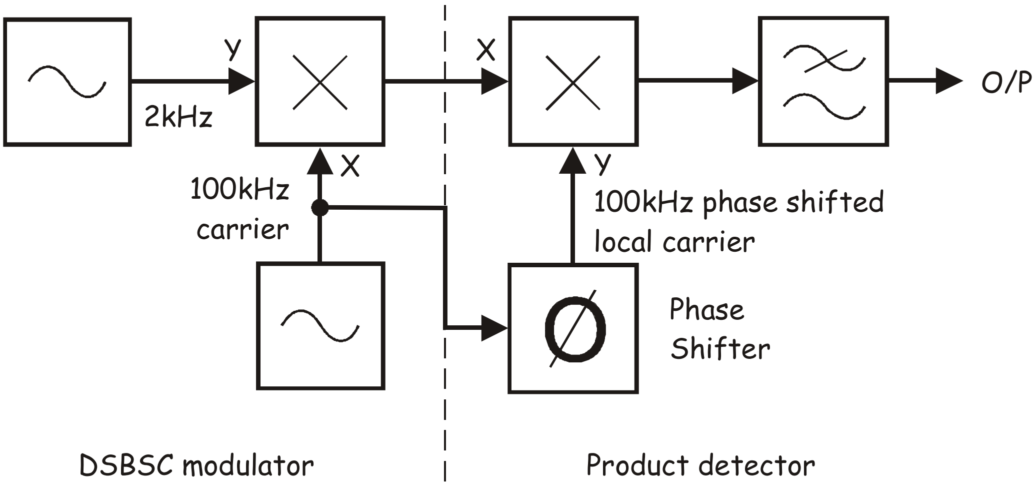


Figure 11

38. Slowly increase the Amplifier's module's gain until you can comfortably hear the demodulated 2kHz tone.

39. Vary the Phase Shifter module's soft *Phase Adjust* control left and right while watching and listening to the effect on the recovered message.

40. Use the keyboard's *TAB* and left arrow keys to turn the Phase Shifter module's soft *Phase Adjust* control anti-clockwise until the recovered message is smallest.

Question 4
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 on page 9-13.

41. Verify your answer to Question 4 by connecting the scope's Channel 0 input to the Master Signals module's *100kHz SINE* output, its Channel 1 input to the Phase Shifter module's output and setting its *Timebase* control to the *5μs/div* setting.

42. Use the keyboard's *TAB* and left arrow keys to adjust the Phase Shifter module's soft *Phase Adjust* control until the two signals are in phase.

Question 5
Given the two carriers are in phase, what should the amplitude of the recovered message be?

43. Verify your answer to Question 5 by reconnecting the scope's Channel 0 input to the Master Signals module's *2kHz SINE* output, reconnecting its Channel 1 input to the Tuneable Low-pass Filter module's output and setting its *Timebase* control back to the *100μs/div* setting.

Ask the instructor to check
your work before continuing.

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.

44. Launch and run the NI ELVIS II Function Generator VI.

45. Adjust the function generator's soft controls for an output with the following specifications:

- Waveshape: Sine
- Frequency: 100kHz exactly
- Amplitude: 4Vpp
- DC Offset: 0V

46. Disconnect the leads to the Phase Shifter module and modify the set-up as shown in Figure 12 below.

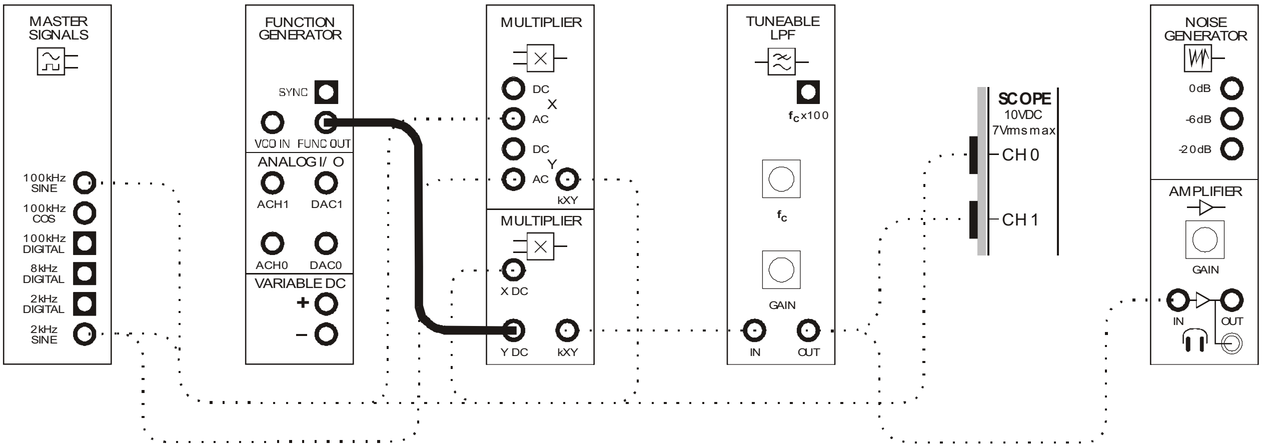


Figure 12

The entire set-up can be represented by the block diagram in Figure 13 below. The function generator allows the local oscillator to be completely frequency (and phase) independent of the DSBSC modulator.

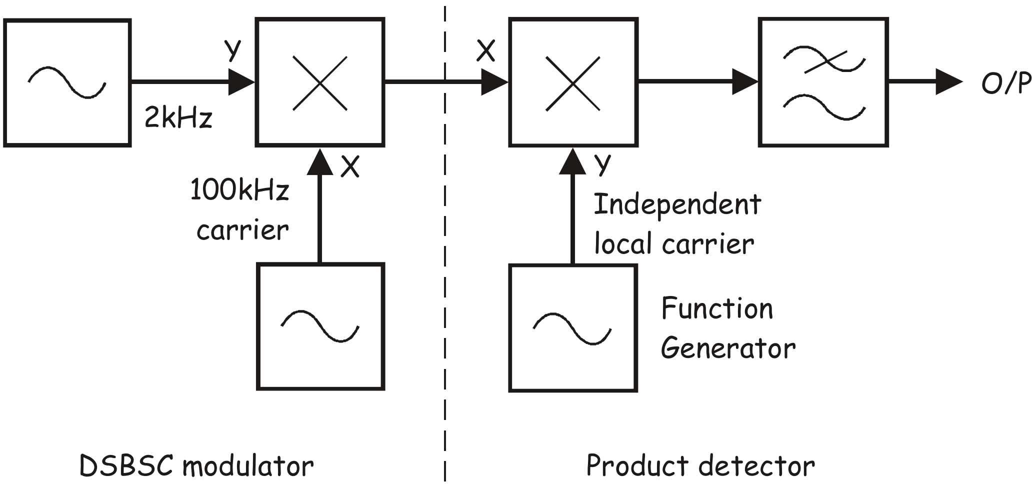


Figure 13

47. If you're not doing so already, listen to the recovered message using the headphones.

48. 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.

49. Reduce the function generator's output frequency to 99.8kHz.

50. 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 2kHz sounds like, set function generator's output to 100kHz for a moment then return it to 99.8kHz.

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

52. Return the function generator's output to 100kHz.

53. Disconnect the plugs to the Master Signals module's *2kHz SINE* output and connect them to the Speech module's output.

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

55. Vary the function generator's frequency again and listen to the effect of an unsynchronised local carrier on speech.

Ask the instructor to check your work before finishing.

