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

EXPERIMENT NO: 04

NAME OF THE EXPERIMENT: Study of DSBSC demodulation

Objective and Theory

If you've completed experiment 2 you've seen 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. 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.

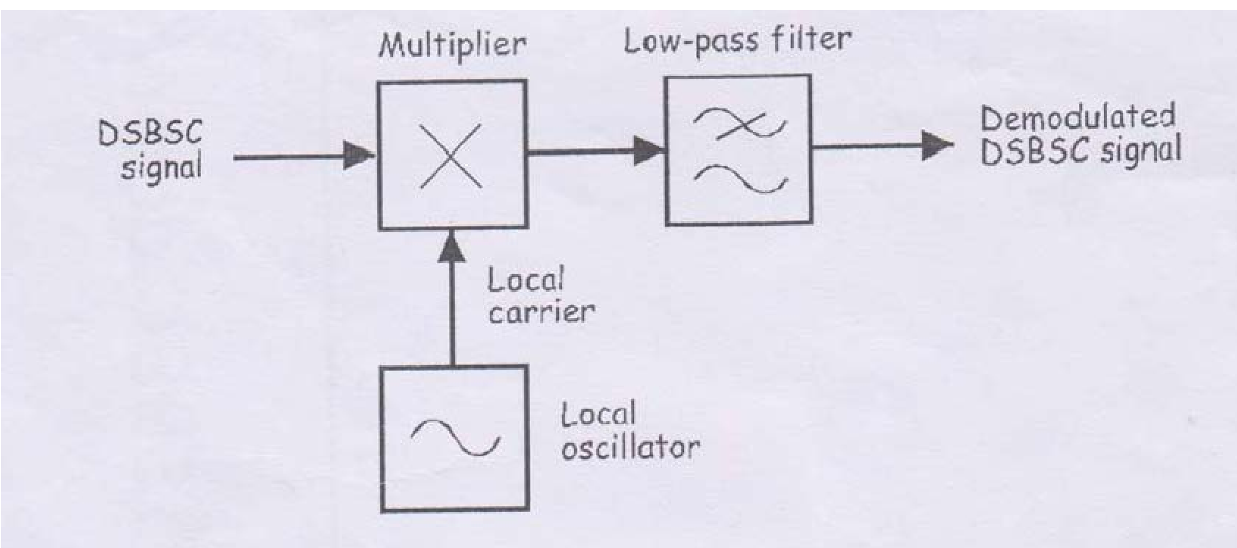

Figure: 01

As its name implies, the product detector uses multiplication and so mathematics is 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:

$$DSBSC\ demodulator's\ output\ =\ the\ DSBSC\ signal\ \times the\ local\ carrier$$

Importantly, recall that DSBSC generation involves the multiplication of the message with carrier which produces sum and difference frequencies (the preliminary discussion in Experiment 3 summarizes DSBSC generation). That being the case, this information can be substituted for the DSBSC signal and the equation rewritten as:

$$DSBSC\ demodulator's\ output = [(carrier + message) + (carrier - message)] \times carrier$$

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 for every pair of pure sinewaves that are multiplied together, two completely new sinewaves are generated. One has a frequency equal to the sum of the original sinewaves' frequencies and 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

In this experiment, you'll use the Emona Telecoms- Trainer 101 to generate a DSBSC signal by implementing its mathematical model. Then you'll set-up a product detector by implementing mathematical model too.

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 distortion of a DSBSC signal due to overloading has on the product detector's output.

Equipment

- Emona Telecoms- Trainer 101 (plus power-pack)
- Dual channel 20MHz oscilloscope
- Two Emona Telecoms- Trainer 101 oscilloscope leads
- Assorted Emona Telecoms- Trainer 101 patch leads
- 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. Gather a set of the equipment listed above.

2. Set up the scope per the instructions in Experiment 1. Ensure that:

• The Trigger Source control is set to the CHI (or IN7) position.

• The Mode control is set to the CHI position 3. Connect the set-up shown in Figure 2 below.

3. Connect the set-up in figure 2 below.

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

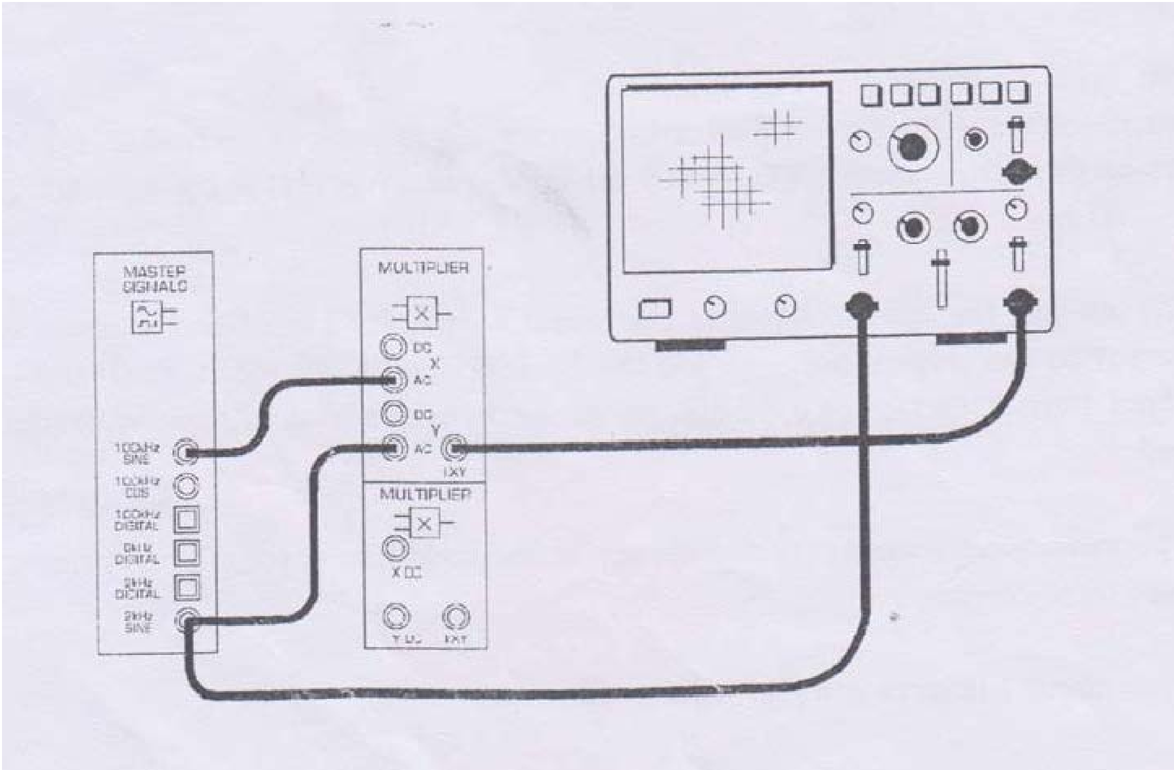

Figure: 02

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

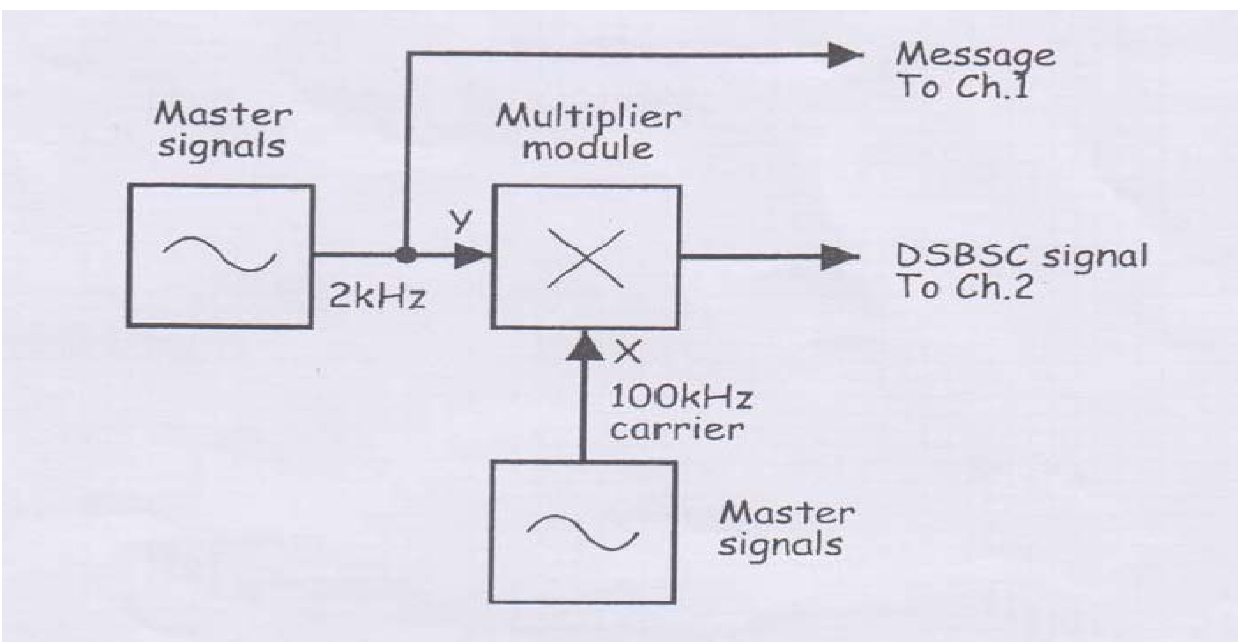

Figure: 03

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

5. Set the scope's Mode control to the DUAL position to view the DSBSC signal out of the Multiplier module as well as the message signal.

Note: If you have connected the set-up correctly, the Multiplier's output should be a carrier modulated by a sinewave to produce a DSBSC signal.

Tip: You may need to adjust the scope's two vertical Attenuation controls.

6. 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.

Part B - Recovering the message using a product detector

7. Locate the Tuneable Low-pass Filter module and set its Gain control to about the middle of its travel.

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

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

Remember: Dotted lines show leads already in place.

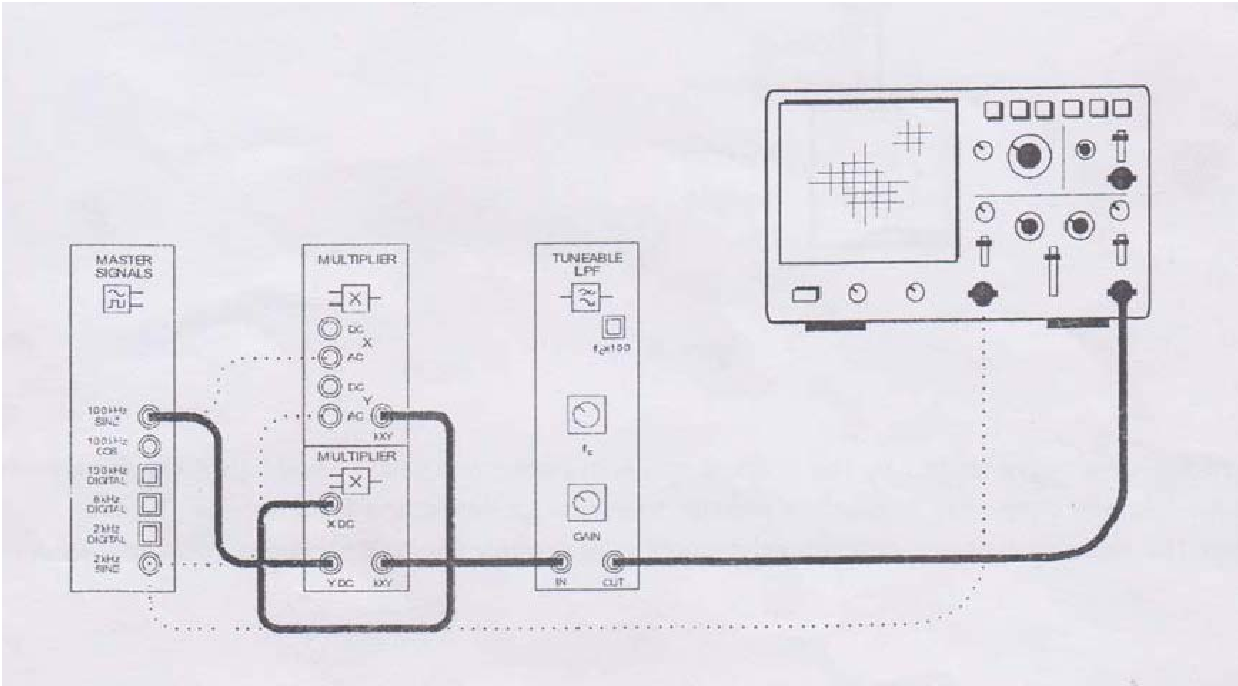

Figure: 04

The additions to the set-up in Figure 4 can be represented by the block diagram in Figure 5 below. The Multiplier module and the *RC Low-pass Filter* on the Utilities module are used to implement a product detector which demodulates the original message from the DSBSC signal.

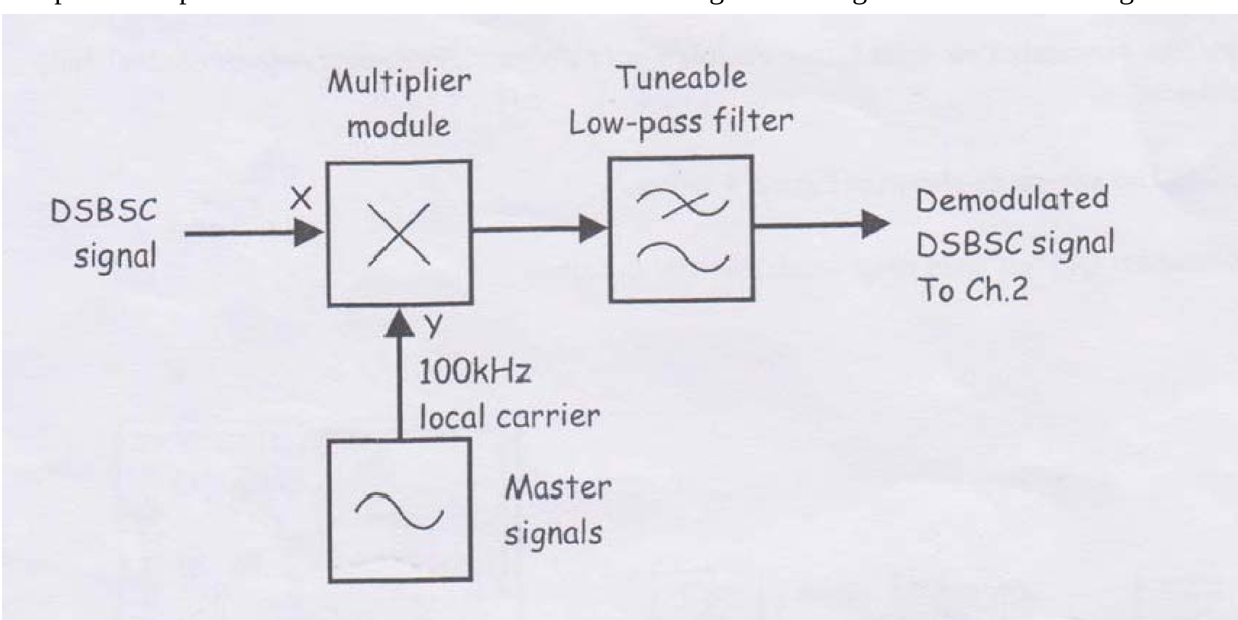

Figure: 05

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 focal carrier. This means that the two carriers are synchronized which is necessary for DSBSC communications to work.

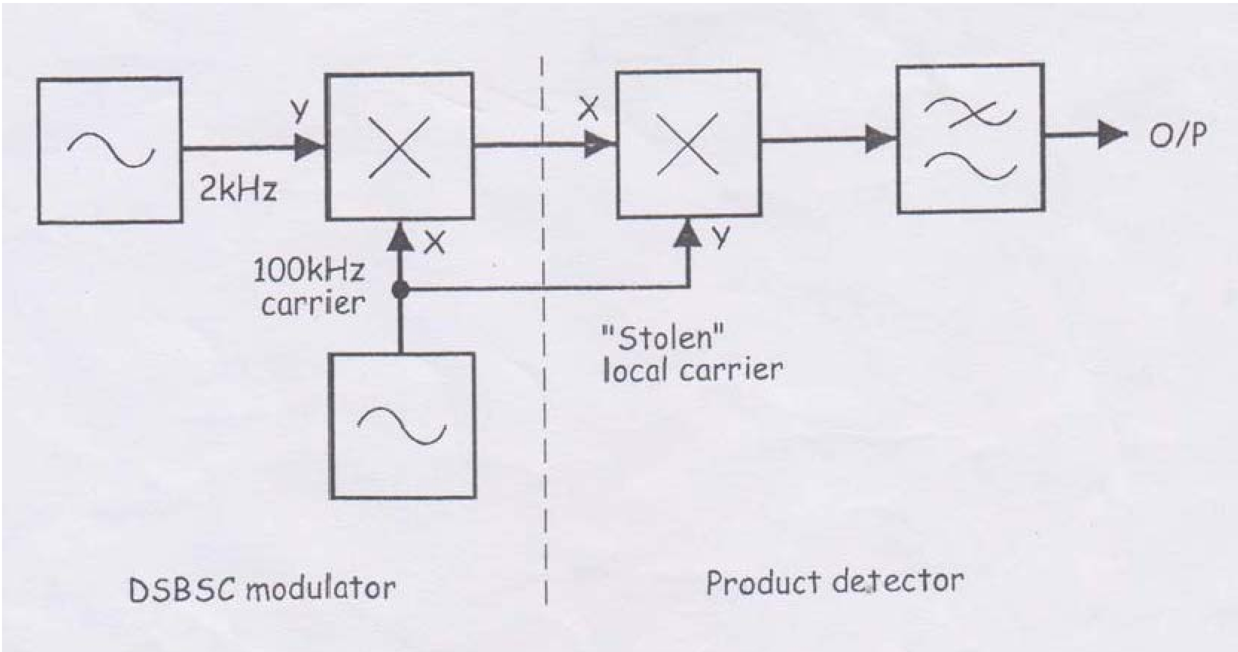

Figure: 06

10. 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, see the preliminary discussion.

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

11. Disconnect the plug to the Master Signals module's 2 kHz SINE output.

12. Locate the Buffer module and turn its Gain control to about a quarter of its travel.

13. Use the Buffer module to modify the set-up as shown in Figure 7 below.

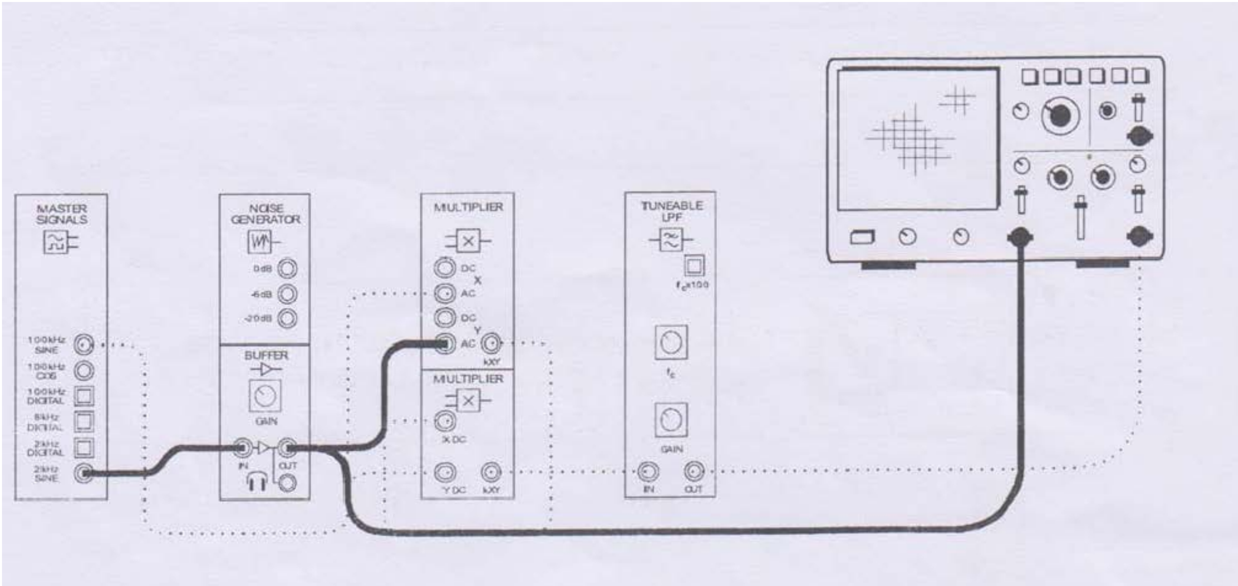

Figure :07

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.

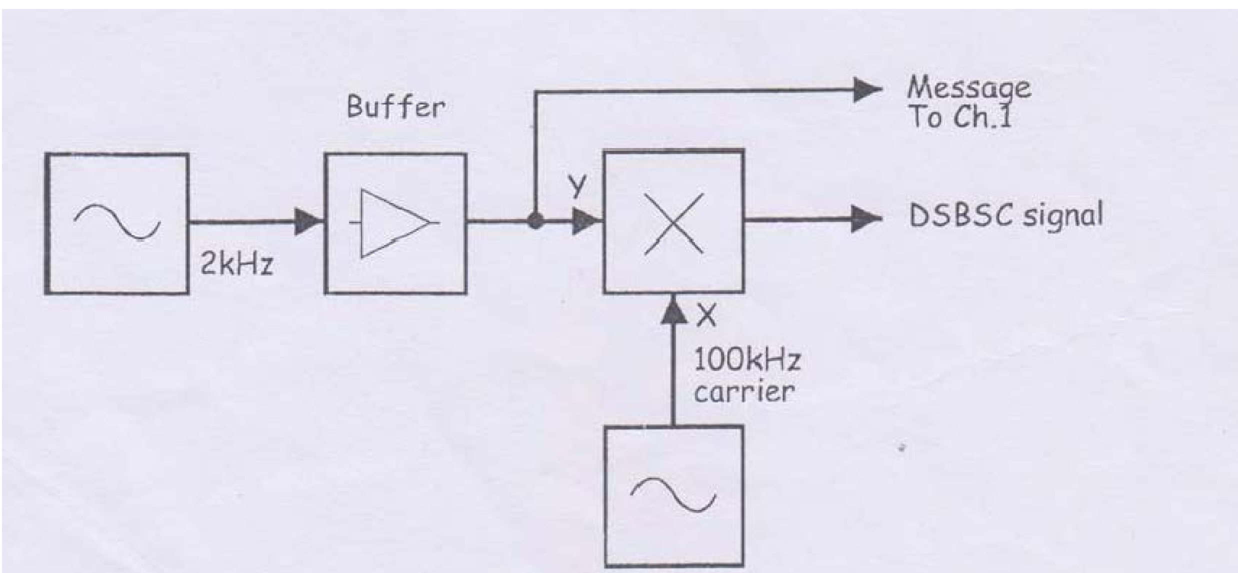

Figure: 08

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

Question 2

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

15. Slowly increase the message signal's amplitude 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 1 input to the DSBSC modulator's output and set its Trigger Source control to the CH2 position.

Part D - Transmitting and recovering speech using DSBSC

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

16. If you adjusted the scope's Trigger Source control to help answer Question 3, return it to the CH1 position.

17. Modify the set-up as shown in Figure 9 below.

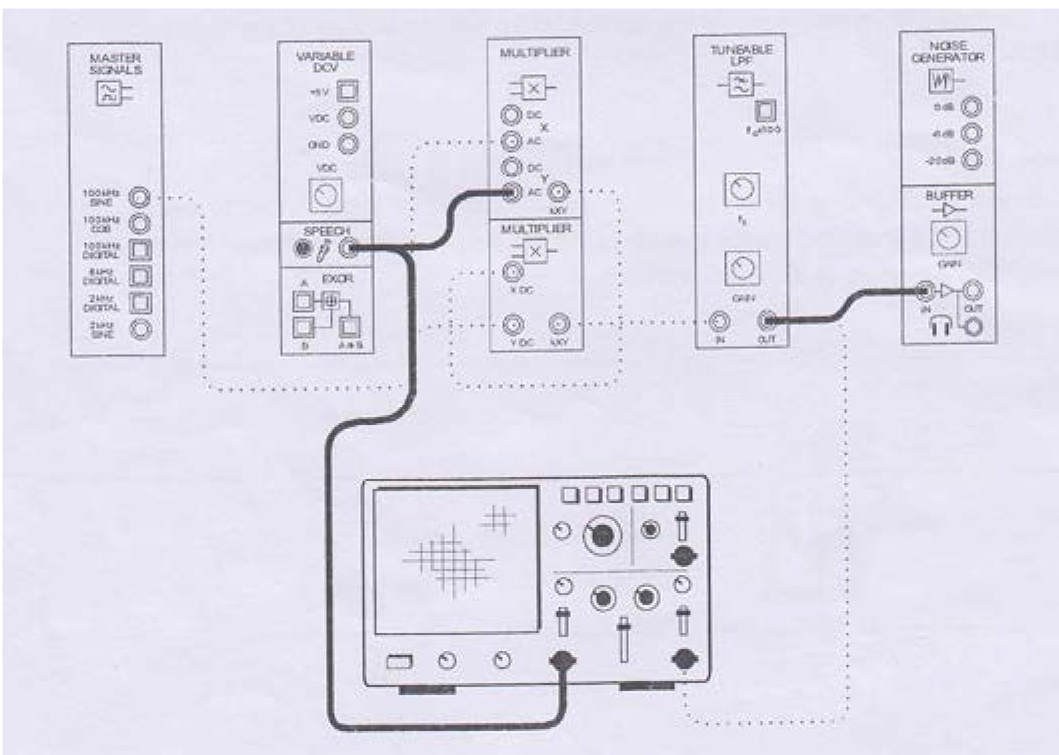

Figure: 09

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

19. Turn the Buffer module's Gain control fully anti-clockwise.

20. Without wearing the headphones, plug them into the Buffer module's headphone socket.

21. Put the headphones on.

22. As you perform the next step, set the Buffer module's Gain control to a comfortable sound level.

23. Talk, sing or hum while watching the scope's display and listening on the headphones

Part E - Carrier synchronization

Crucial to the correct operation of a DSBSC communications system is the synchronization 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.

24. Turn the Buffer module's Gain control fully anti-clockwise again.

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

26. Locate the Phase Shifter module and set its Phase Change control to the 180°position.

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

28. Modify the set-up as shown in Figure 10 below.

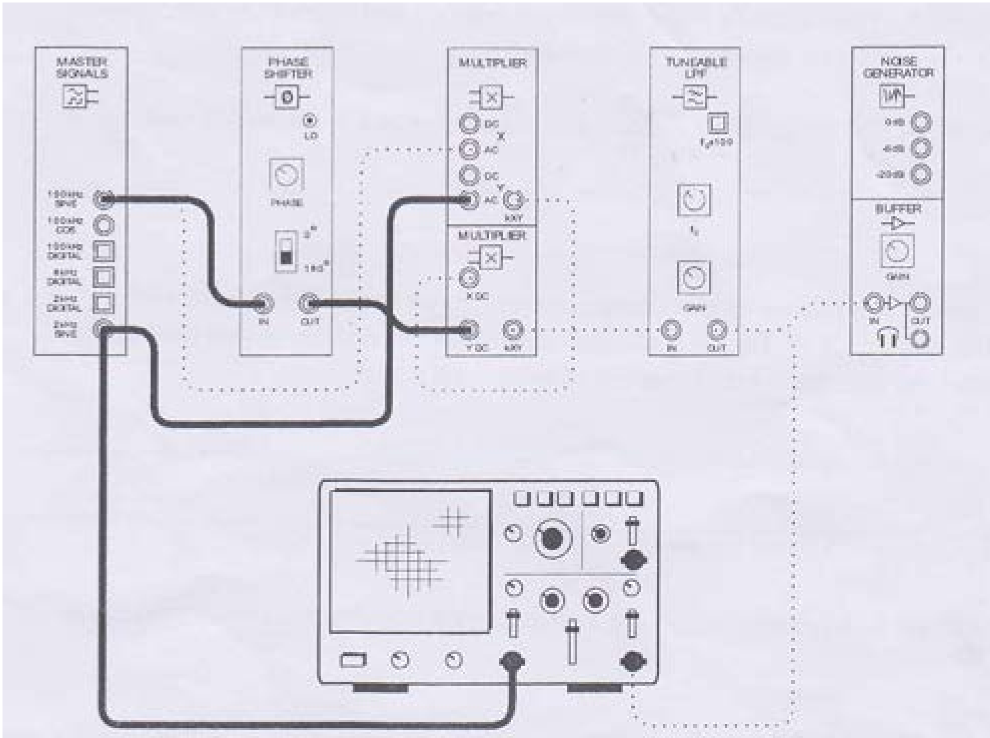

Figure: 10

The entire set-up 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.

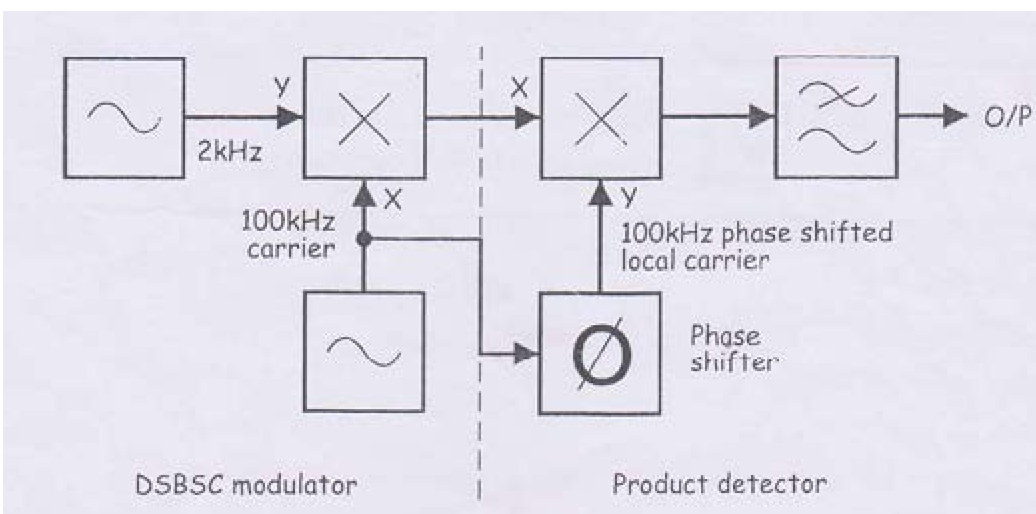

Figure:11

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

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

31. Adjust the Phase Shifter module's Phase Adjust control until the recovered message is biggest.

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 at top of page 7-13.

32. Adjust the Phase Shifter module's Phase Adjust control until the recovered message is smallest.

Question 5

Given the size of the recovered message's new amplitude, what is the likely phase error between the two carriers?

The effects 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 message frequency plus the error.

If the error is small (say 0.l Hz) 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.

33. Locate the VCO module and set its *Range* control to the Hi position.

34. Set the VCO module's *Frequency Adjust* control to about the middle of its travel.

35. Modify the set-up as shown in Figure 12 below.

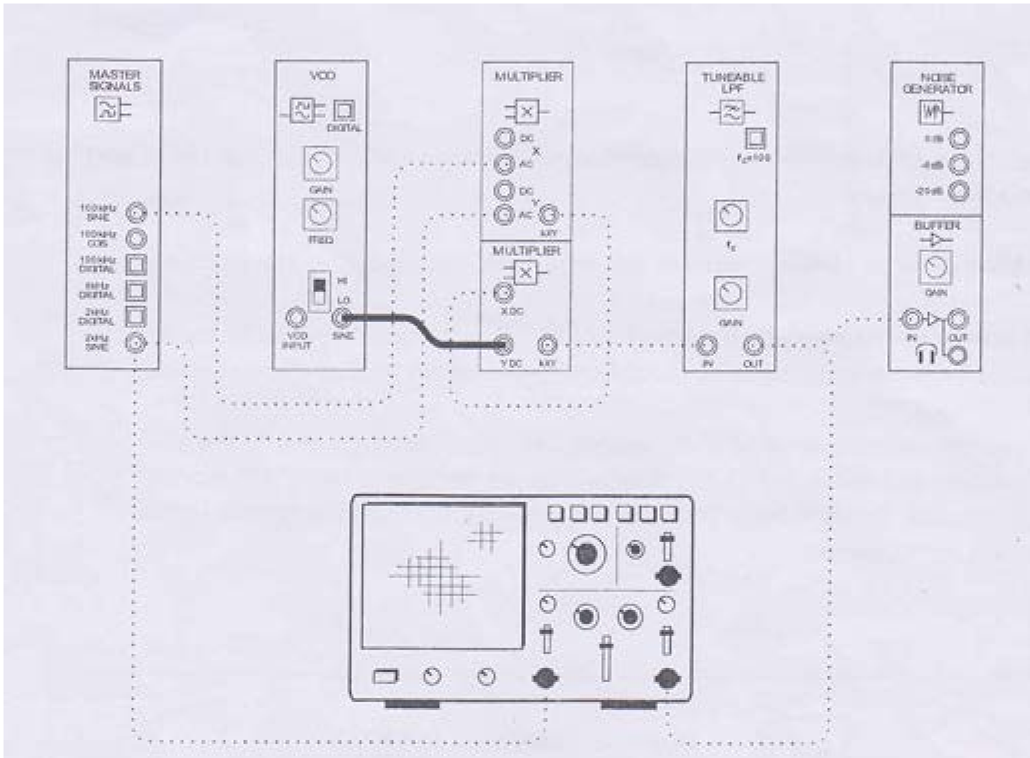

Figure:12

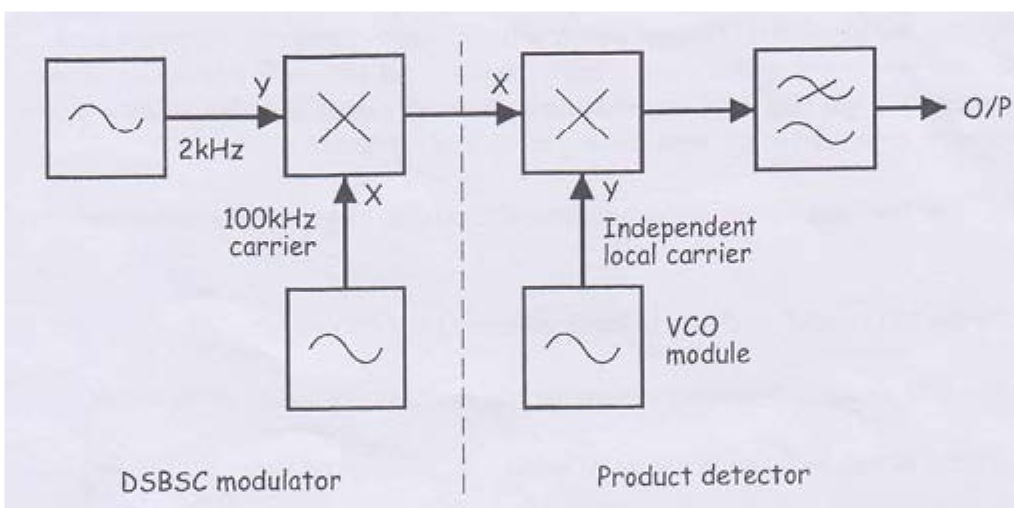

Figure:13

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

36. Vary the VCO module's frequency adjust control left and right and observe the effect on the recovered message.

37. If you are not doing so already, listen to the recovered message using headphones.

38. Use the display of the recovered message on the scope and your hearing to try to get

VCO module's frequency as close as possible to the transmitter's carrier frequency.

If you can't remember what 2kHz sounds like, disconnect the plug to the VCO module's output and connect it to the Master Signals modules 100kHz SINE output for a couple of seconds. This will mean that the two carriers are the same again and the message will be recovered.

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

40. Talk, sing etc. into the microphone while varying the VCO module's Frequency Adjust control and listen to the effect of an unsynchronized local carrier on speech.