Name: ____________________

Class: ____________________

17 - Binary phase shift keying

Experiment 17 - Binary Phase Shift Keying

Preliminary discussion

Experiments 15 and 16 show that the AM and FM modulation schemes can be used to transmit digital signals and this allows for the channel to be shared. As digital data forms the message instead of speech and music, it is preferred that these two systems are called ASK and FSK instead.

Recall that ASK uses the digital data's 1s and 0s to switch a carrier between two amplitudes. FSK uses the 1s and 0s to switch a carrier between two frequencies. An alternative to these two methods is to use the data stream's 1s and 0s to switch the carrier between two phases. This is called *Binary Phase Shift Keying* (BPSK). Figure 1 below shows what a BPSK signal looks like time-coincident with the digital signal that has been used to generate it.

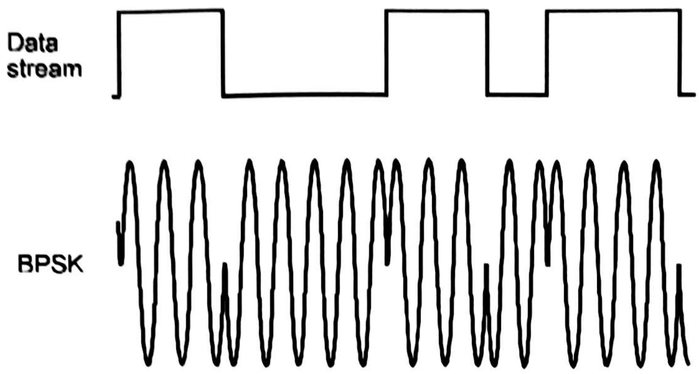

Figure 1

Notice that, when the change in logic level causes the BPSK signal's phase to change, it does so by 180°. For example, where the signal is travelling towards a positive peak the change in logic level causes it to reverse direction and head back toward the negative peak (and vice versa).

You may find it difficult to see at first but look closely and you'll notice that alternating halves of the BPSK signal's envelopes have the same shape as the message. This indicates that BPSK is actually *double-sideband suppressed carrier* (DSBSC) modulation. That being the case, BPSK generation and the recovery of the data can be handled by conventional DSBSC modulation and demodulation techniques (explained in Experiments 5 and 7 respectively).

With a choice of ASK, FSK and BPSK you might be wondering about which system you'll most likely see. All other things being equal, BPSK is the best performing system in terms of its ability to ignore noise and so it produces the fewest errors at the receiver. FM is the next best and AM is the worst. On that basis, you'd expect that BPSK is the preferred system. However, it's not necessarily the easiest to implement and so in some situations FSK or ASK might be used as they are cheaper to implement. In fact, FSK was used for cheaper dial-up modems.

The experiment

In this experiment you'll use the Emona Telecoms-Trainer 101 to generate a BPSK signal using the Multiplier module to implement its mathematical model. Digital data for the message is modelled by the Sequence Generator module. You'll then recover the data using another Multiplier module and observe its distortion. Finally, you'll use a comparator to restore the data.

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

Equipment

- Emona Telecoms-Trainer 101 (plus power-pack)
- Dual channel 20MHz oscilloscope
- three Emona Telecoms-Trainer 101 oscilloscope leads
- assorted Emona Telecoms-Trainer 101 patch leads

Procedure

Part A – Generating a BPSK signal

A BPSK signal will be generated by implementing its mathematical model. For more information on this, refer to the preliminary discussion of Experiment 5.

1. Gather a set of the equipment listed above.

2. Set up the scope per the instructions in Experiment 1.

3. Set the scope's *Trigger Source* control to the *EXT* position.

4. Set the scope's *Trigger Source Coupling* control to the *HF REJ* position.

5. Set the scope's Channel 1 and Channel 2 *Input Coupling* controls to the *DC* position.

6. Set the scope's *Timebase* control to the *0.1ms/div* position.

7. Locate the Sequence Generator module and set its dip-switches to 00.

   Tip: To do this, push both switches up.

8. Connect the set-up shown in Figure 2 on the next page.

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

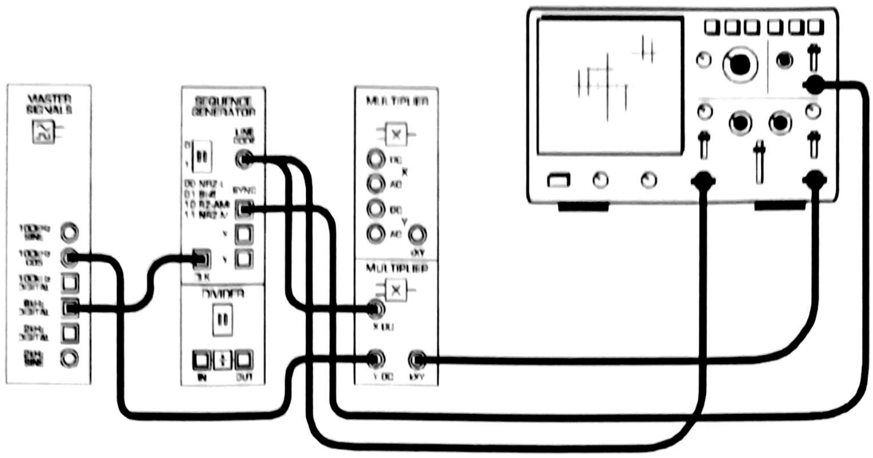

Figure 2

This set-up can be represented by the block diagram in Figure 3 below. The Sequence Generator module is used to model a digital signal and its SYNC output is used to trigger the scope to provide a stable display. The Multiplier module is used to generate the BPSK signal by implementing its mathematical model.

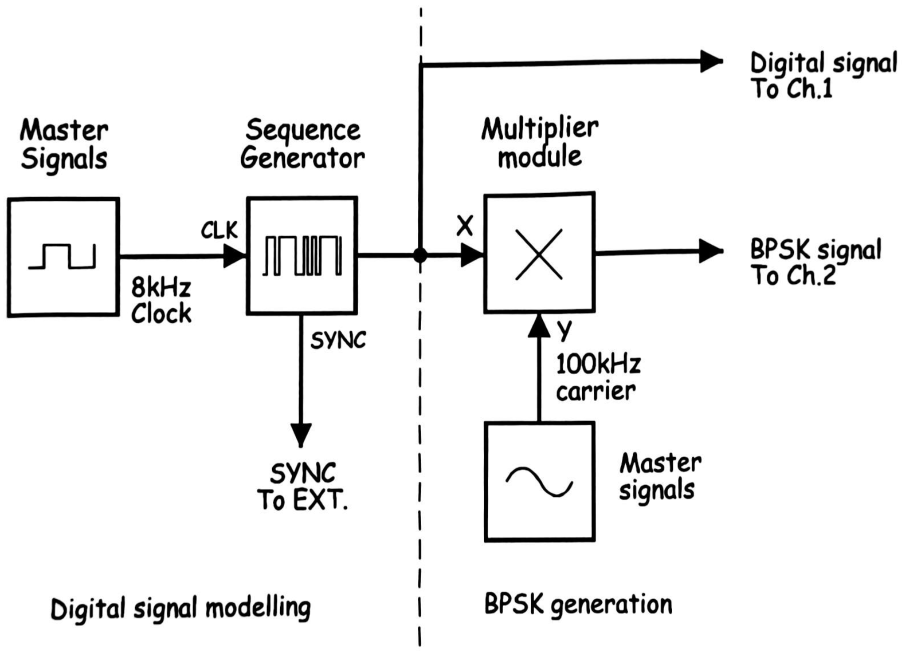

Figure 3

9. Set the scope's *Mode* control to the *DUAL* position to view the Sequence Generator module's output and the BPSK signal out of the Multiplier module.

10. Activate the scope's *Sweep Magnification* control.

    Tip: This control is located in different places on different scopes. If you can't find it or if you're not sure you have the right control, ask the instructor for assistance.

11. Compare the signals.

12. If necessary, use the scope's *Horizontal position* control to view at least one transition of the digital signal.

Question 1
What happens to the BPSK signal on the data stream's logic transitions?

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13. Deactivate the scope's *Sweep Magnification* control.

14. Use the scope's Channel 1 *Vertical Position* control to overlay the digital signal with the BPSK signal's envelopes and compare them.

Question 2
What feature of the BPSK signal suggests that it's a DSBSC signal? **Tip:** If you're not sure, see the preliminary discussion.

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Ask the instructor to check
your work before continuing.

Part B - Demodulating a BPSK signal using a product detector

As BPSK is really just DSBSC (with a digital message instead of speech or music), it can be recovered using any of the DSBSC demodulation schemes. The next part of the experiment lets you do so using a product detector.

15. Locate the Tuneable LPF module and turn its *Cut-off Frequency Adjust* control fully clockwise.

16. Set the Tuneable LPF module's *Gain* control to about the middle of its travel.

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

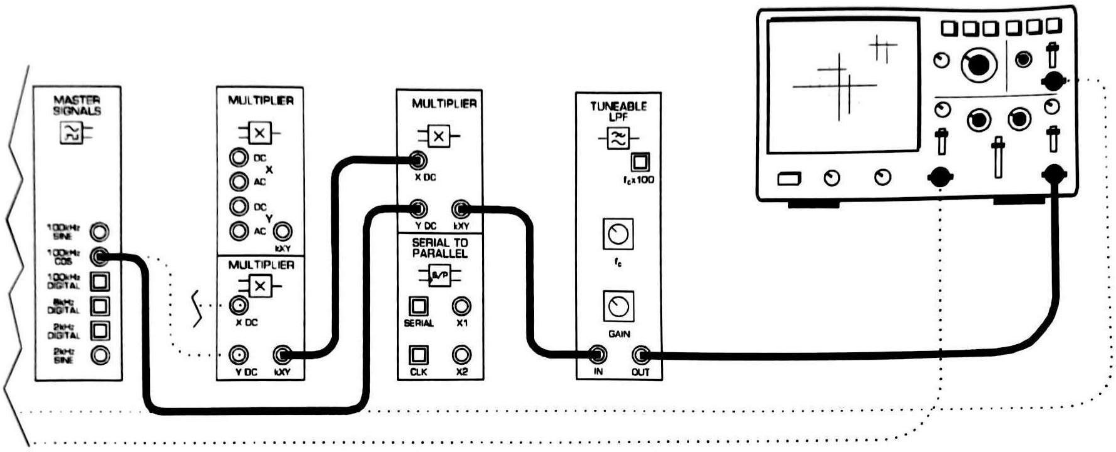

Figure 4

The BPSK generation and demodulation parts of the set-up can be represented by the block diagram in Figure 5 on the next page. The second Multiplier and the Tuneable Low-pass filter module are used to implement a product detector to recover the digital data from the BPSK signal.

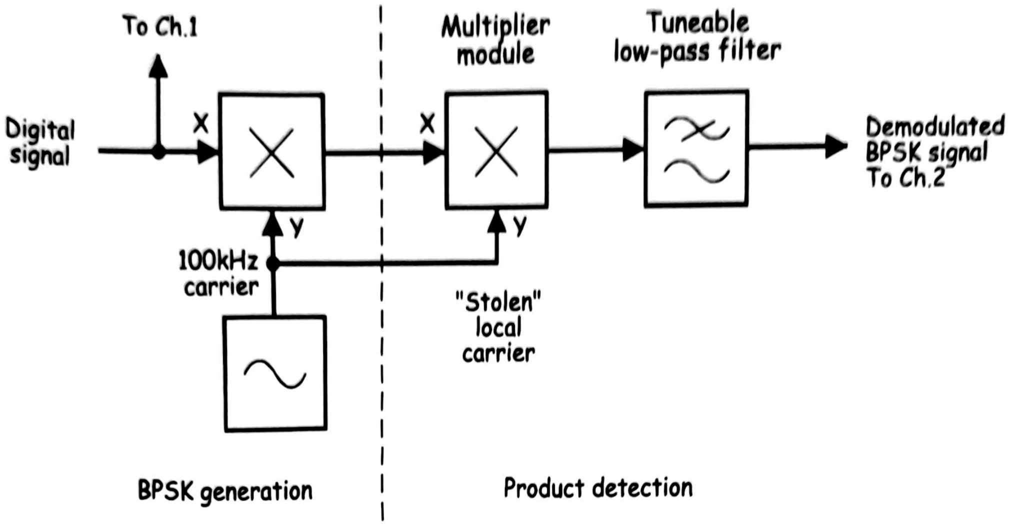

Figure 5

18. Compare the digital signal with the recovered digital signal.

Question 3
Why is the recovered digital signal not a perfect copy of the original?

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Question 4
What can be used to "clean-up" the recovered digital signal?

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☑ Ask the instructor to check your work before continuing.

Part C - Restoring the recovered data using a comparator

Experiment 14 shows that the comparator is a useful circuit for restoring distorted digital signals. The next part of the experiment lets you use a comparator to clean-up the demodulated BPSK signal.

19. Modify the set-up as shown in Figure 6 below.

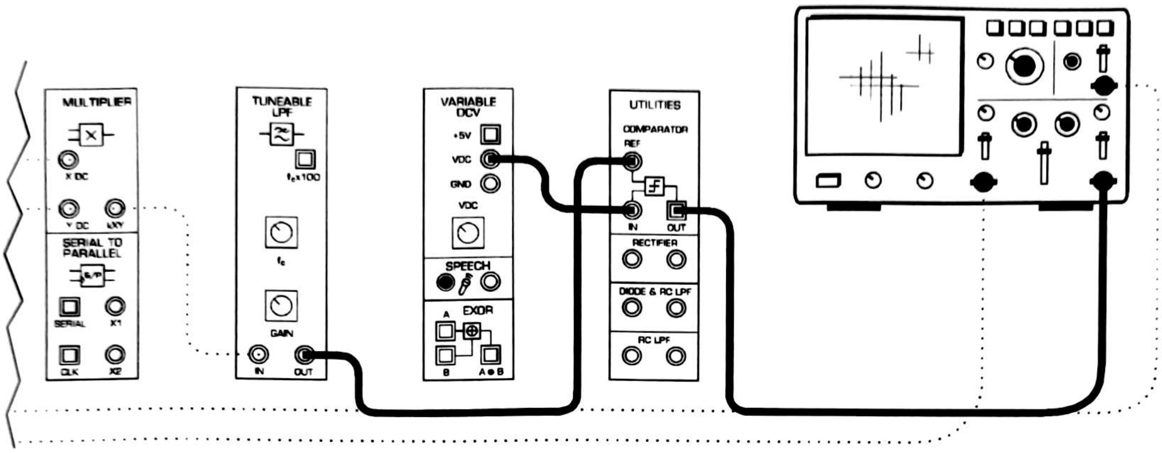

Figure 6

The BPSK generation, demodulation and digital signal restoration parts of the set-up can be represented by the block diagram in Figure 7 below.

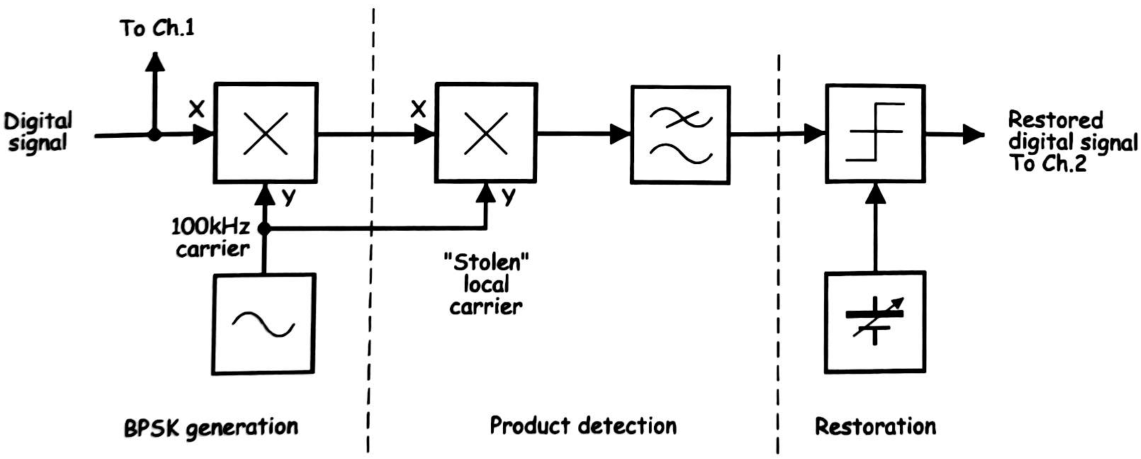

Figure 7

20. Set the Variable DCV module's *Variable DC* control to about the middle of its travel.

21. Compare the signals. If they're not the same vary the Variable DCV module's Variable DC control until they are (ignoring phase shift).

Question 5
Why does varying the DC voltage on the comparator's input change the shape of the digital signal?

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☑ Ask the instructor to check your work before finishing.

Noise

It's common for radio frequency communications systems to be upset by unwanted electromagnetic radiation called *noise*. Some of this radiation occurs naturally and is generated by the Sun and atmospheric activity such as lightning. Much of the radiation is also human-made - either unintentionally (the electromagnetic radiation given off by electrical machines and electronics equipment) or intentionally (other peoples' communication transmissions that we don't want to receive).

Most noise gets added to signals while they're in the channel. This changes the signals' shape which in turn changes how the signal sounds when demodulated by the receiver. If the noise is sufficiently big (relative to the size of the signal) the signal can be changed so much that it cannot be demodulated.

It's possible to model noise being added to a signal in the channel of a communications system using the Emona Telecoms-Trainer 101. If the instructor allows, this activity gets you to do so.

1. Connect the set-up shown in Figure 1 below but **don't** disconnect any of your existing wiring.

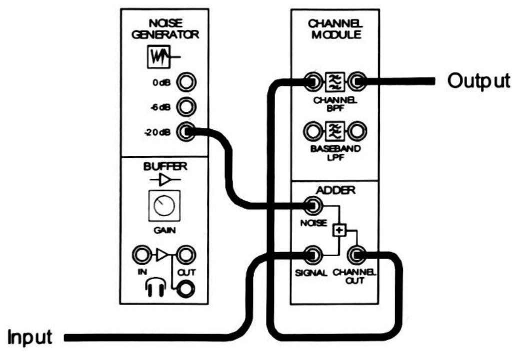

Figure 1

This set-up can be represented by the block diagram in Figure 2 on the next page. It models the behaviour of a real channel by adding noise to communications signals such as BPSK.

Usefully, the amount of noise can be varied by selecting either the *-20dB* output (noise is about one-tenth the size of the signal), the *-6dB* output (noise is about half the size of the signal) or the *0dB* output (noise is about the same size as the signal).

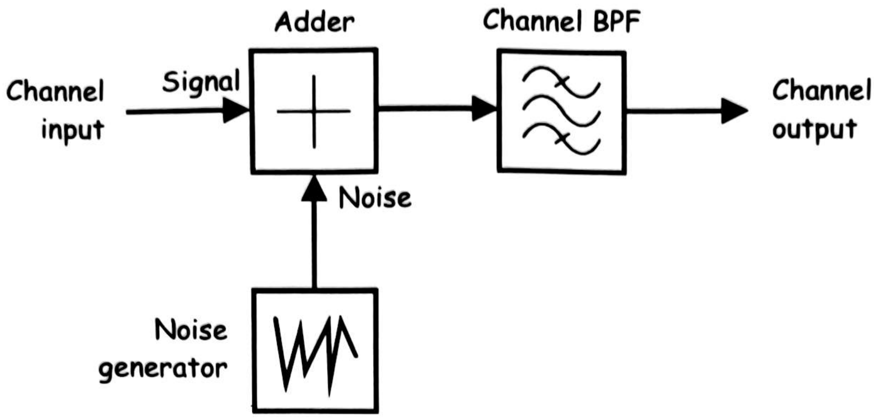

Figure 2

2. Unplug the patch lead to the output of the Multiplier module on the upper-half of the trainer and connect the noisy channel's input to it.

3. Unplug the patch lead to the output of the Multiplier module in the lower-half of the trainer and connect the noisy channel's output to it.

   Note: Once done, the transmitter's signal (the upper Multiplier module's output) travels to the receiver's input (the lower Multiplier module's input) via the model of a noisy channel.

4. Compare the original and recovered data. If they're not the same, vary the Variable DCV module's *Variable DC* control until they are.

5. Unplug the scope's Channel-2 input from the comparator's output and connect it to the Adder module's output to observe the noisy BPSK signal.

6. Connect the Adder module's *Noise* input to the Noise Generator module's -6dB output to increase the noise in the channel.

7. Observe the effect that this has on the BPSK signal.

8. Reconnect the scope's Channel-2 input to the comparator's output.

9. Compare the original and recovered data. If they're not the same, vary the Variable DCV module's Variable DC control until they are.

10. Repeat for the Noise Generator module's *OdB* output.