Experiment 19 – Binary Phase Shift Keying

Preliminary discussion

Experiments 17 and 18 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.
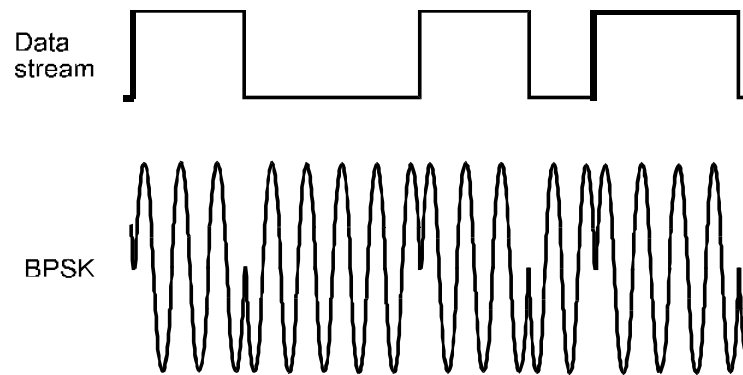

Figure 1

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 6 and 9 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 DATEx 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

- Personal computer with appropriate software installed

- NI ELVIS plus connecting leads

- NI Data Acquisition unit such as the USB-6251 (or a 20MHz dual channel oscilloscope)

- Emona DATEx experimental add-in module

- two BNC to 2mm banana-plug leads

- assorted 2mm banana-plug patch leads

Procedure

Part A – Generating a BPSK signal
A BPSK signal will be generated by implementing the mathematical model for DSBSC modulation. For more information on this, refer to the preliminary discussion of Experiment 6.

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

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

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

4. Check that the NI Data Acquisition unit is turned off.

5. Connect the NI ELVIS to the NI Data Acquisition unit (DAQ) and connect that to the personal computer (PC).

6. Turn on the NI ELVIS power switch at the back then turn on its *Prototyping Board Power* switch at the front.

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

8. Once the boot process is complete, turn on the DAQ then look or listen for the indication that the PC recognises it.

9. Launch the NI ELVIS software.

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

11. Locate the Sequence Generator module on the DATEx SFP and set its soft dip-switches to 00.

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

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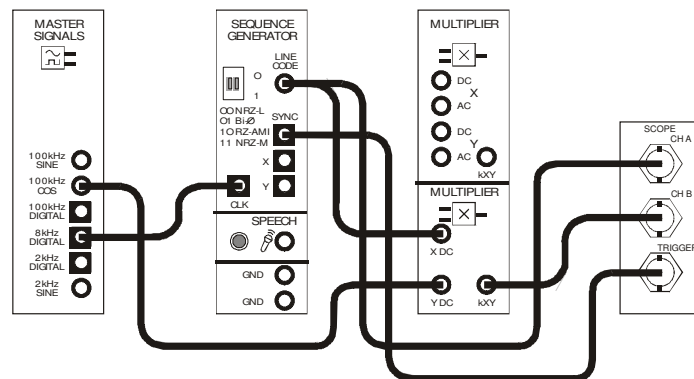

Figure 2

This set-up can be represented by the block diagram in Figure 3 on the next page. 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.
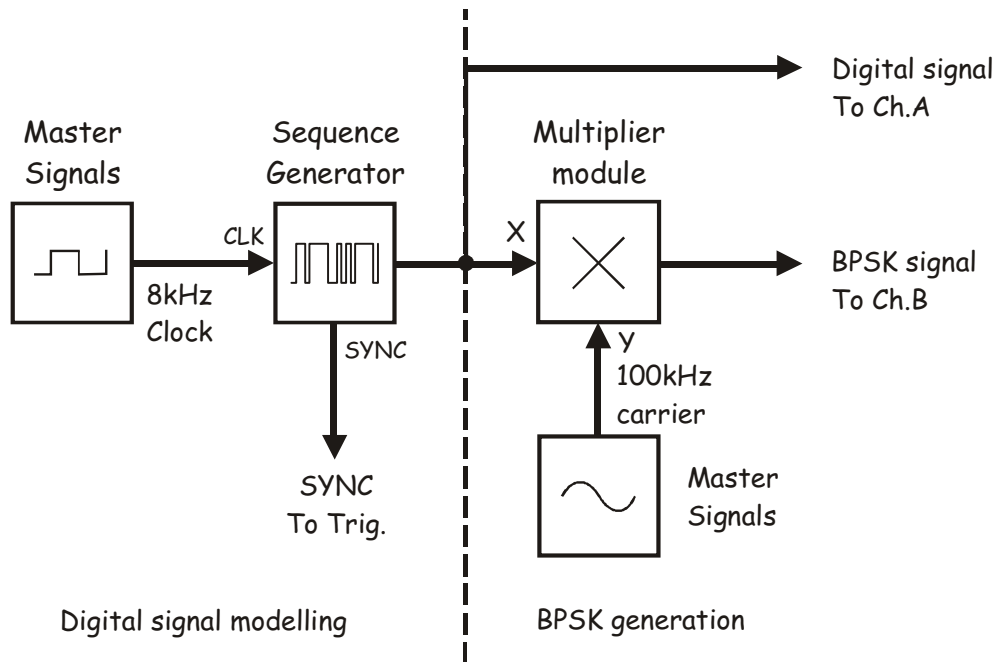
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Figure 3

13. Set up the scope per the procedure in Experiment 1 with the following changes:

   - *Scale* control for Channel B to *2V/div* instead of *1V/div*
   - *Input Coupling* controls for both channels to *DC* instead of *AC*
   - *Timebase* control to *100µs/div* instead of *500µs/div*
   - *Trigger Source* control to *TRIGGER* instead of *CH A*

14. Activate the scope's Channel B input to observe the Sequence Generator module's output and the BPSK signal out of the Multiplier module.

15. Compare the signals.

Question 1
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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It's clear that something happens when the Sequence Generator' module's output changes logic level but it's difficult to see exactly what it is at this resolution. The next few steps allow you to get a better look.

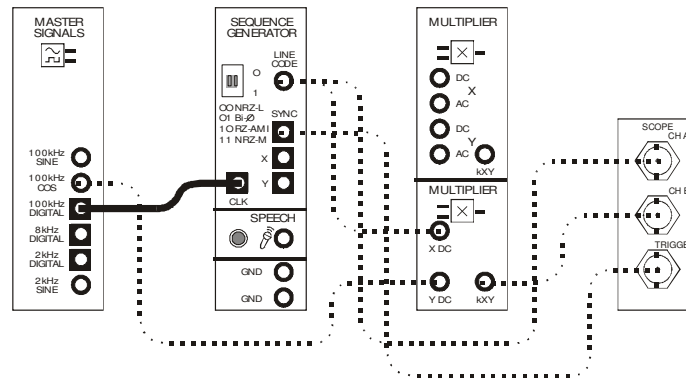16.   Modify the set-up as shown in Figure 4 below.

Figure 4

17.   Set the scope's *Timebase* control to the *10µs/div* position.

Note: The NI Data Acquisition unit is being operated at close to the limits of its specifications and so the Master Signals module's *100kHz COS* output looks a little triangular. However, the display is sufficient to see what occurs when the Sequence Generator module's output changes logic level.

Question 2
What happens to the BPSK signal on the data stream's logic transitions?

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┌───┐
│   ✓   Ask the instructor to check   │
│   your work before continuing.   │
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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.

18. Return the Sequence Generator module's *CLK* input to the Master Signals module's *8kHz Digital* output.

19. Set the scope's *Timebase* control to the *200μs/div* position.

20. Locate the Tuneable Low-pass Filter module on the DATEx SFP and turn its soft *Cut-off Frequency Adjust* control fully clockwise.

21. Set the Tuneable Low-pass Filter module's soft *Gain* control to about the middle of its travel.

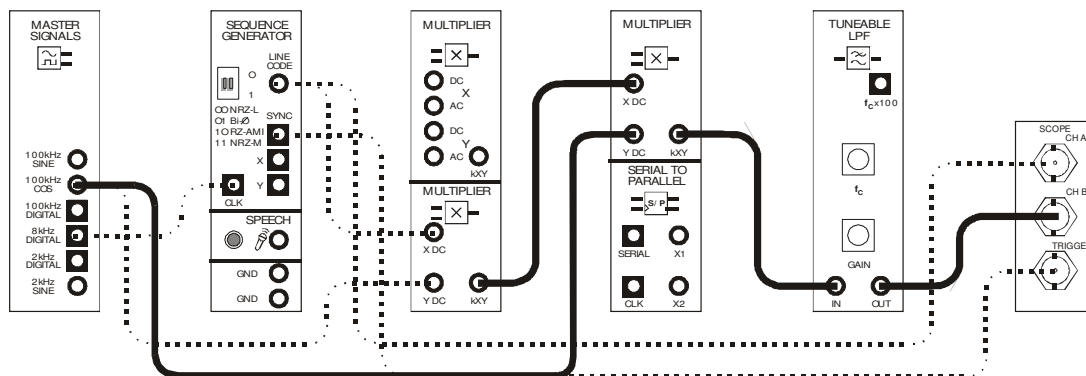22. Modify the set-up as shown in Figure 5 below.

Figure 5

The BPSK generation and demodulation parts of the set-up can be represented by the block diagram in Figure 6 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.
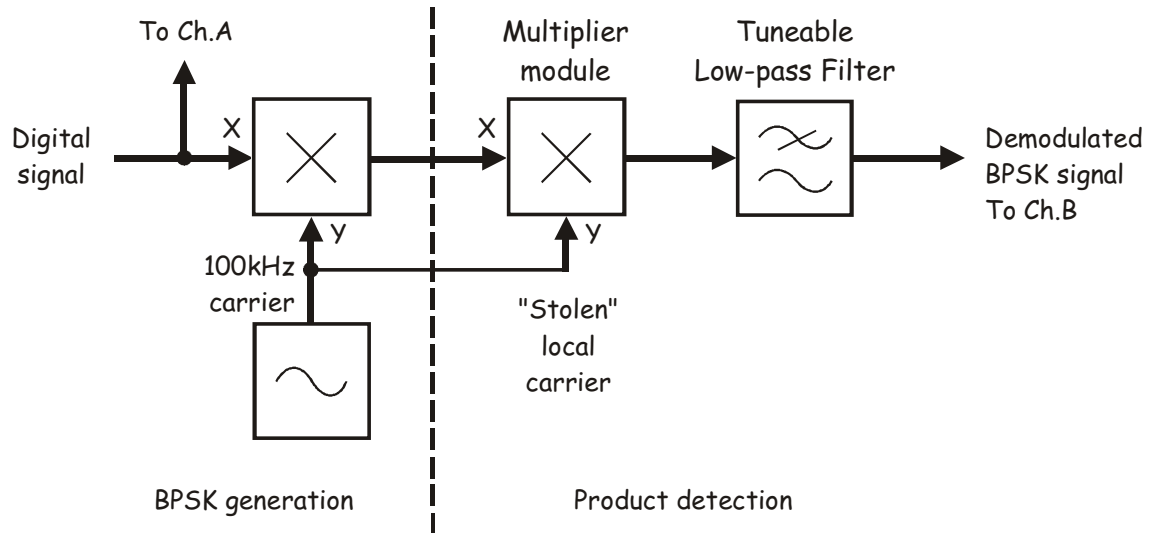
Figure 6

23. 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 16 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.

24. Slide the NI ELVIS Variable Power Supplies' positive output *Control Mode* switch so that it's no-longer in the *Manual* position.

25. Launch the Variable Power Supplies VI.

26. Set the Variable Power Supplies' positive output to 0V by pressing its *RESET* button.
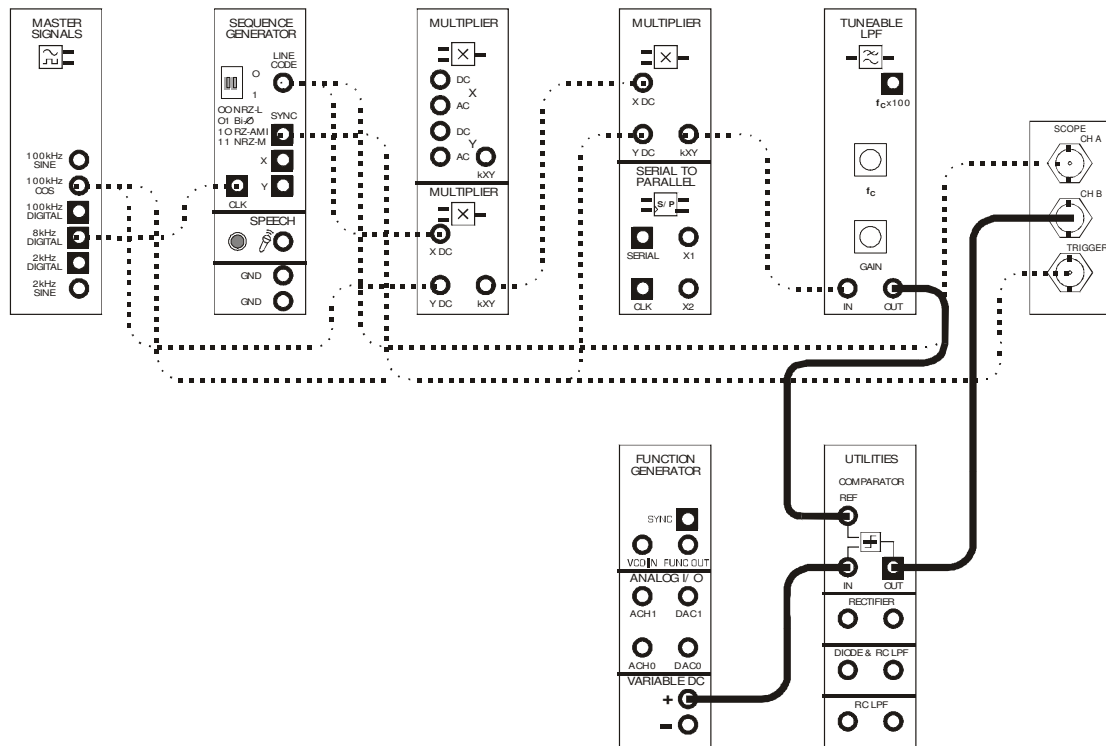
27. Modify the set-up as shown in Figure 7 below.

Figure 7

The BPSK generation, demodulation and digital signal restoration parts of the set-up can be represented by the block diagram in Figure 8 below.
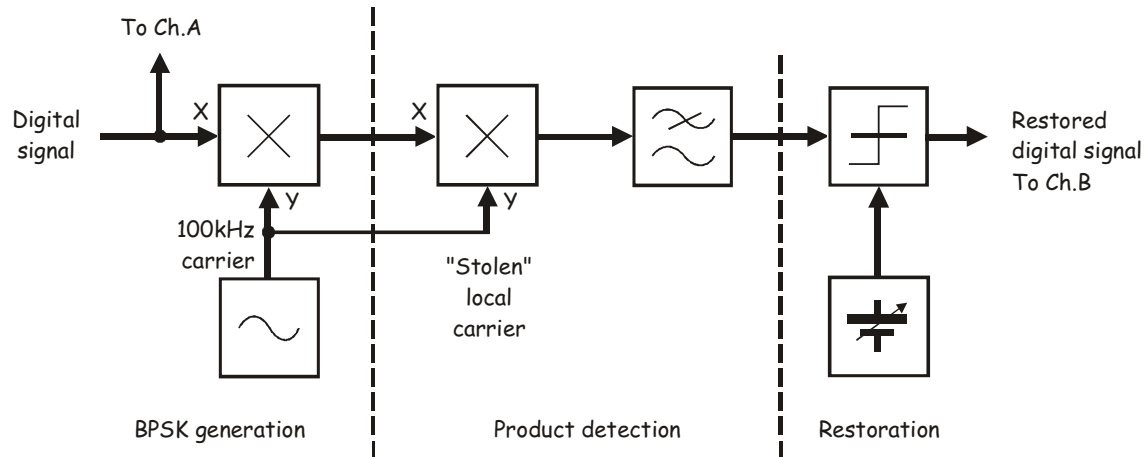

Figure 8

28. Compare the signals. If they're not the same, adjust the Variable Power Supplies positive output soft *Voltage* control until they are.

> Ask the instructor to check
> your work before finishing.

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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 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 large (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 DATEx. 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.
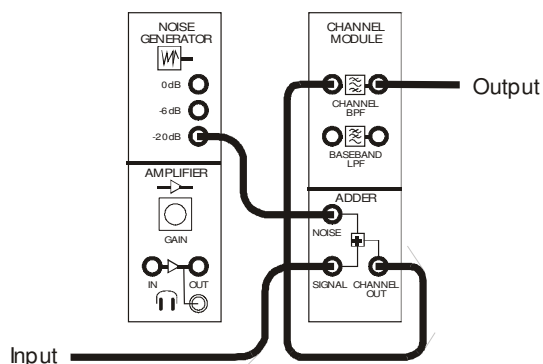

Figure 1

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).

Adder   Channel BPF

Channel input   Signal   Channel output
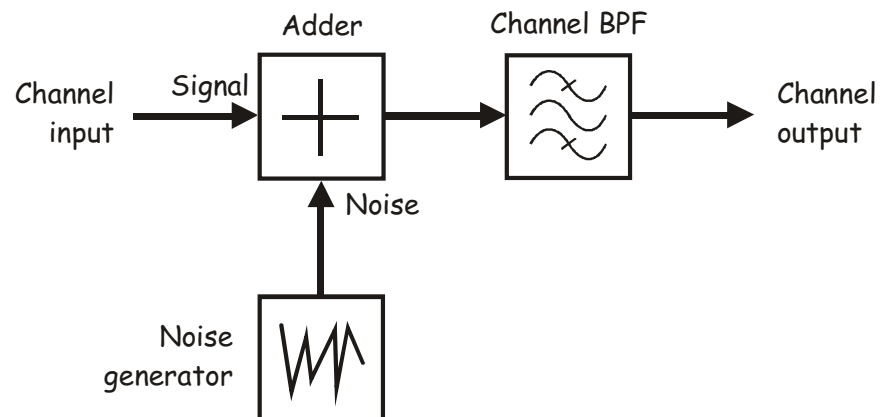
Noise

Noise generator

Figure 2

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

3.   Connect the noisy channel's output to the input of the Multiplier module in the lower-half of the DATEx.

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, adjust the Variable Power Supplies positive output soft *Voltage* control until they are.

5.   Unplug the scope's Channel B 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 B input to the comparator's output.

9.   Compare the original and recovered data. If they're not the same, adjust the Variable Power Supplies positive output soft *Voltage* control until they are.

10.   Repeat for the Noise Generator module's *0dB* output.

Note: It may be impossible to recover the data.