QAM and QPSK:

Aim:

Review of Quadrature Amplitude Modulator (QAM) in digital communication system, generation of Quadrature Phase Shift Keyed (QPSK or 4-PSK) signal and demodulation.

Introduction:

The QAM principle:

The QAM modulator is of the type shown in Figure 1 below. The two paths to the adder are typically referred to as the 'I' (inphase), and 'Q' (quadrature), arms.

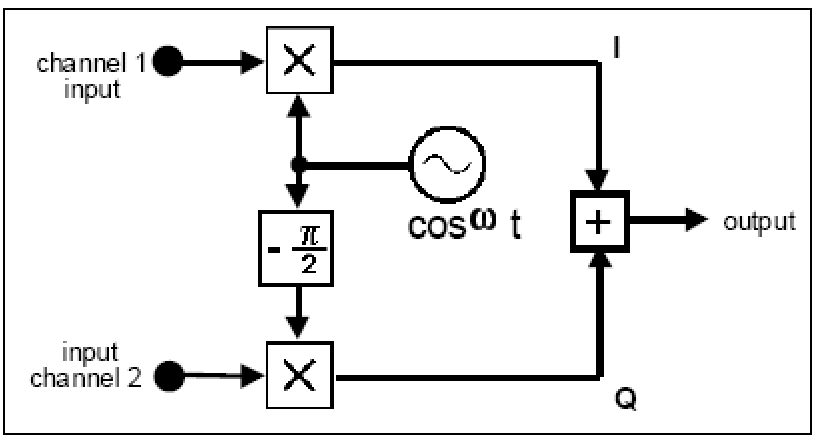

Figure 1: a quadrature modulator

Not shown in Figure 1 is any bandlimiting. In a practical situation this would be implemented either at message level - at the input to each multiplier - and/or at the output of the adder. Probably both !

The motivation for QAM comes from the fact that a DSBSC signal occupies twice the bandwidth of the message from which it is derived. This is considered wasteful of resources. QAM restores the balance by placing two independent DSBSC, derived from message #1 and message #2, in the same spectrum space as one DSBSC. The bandwidth imbalance is removed.

In digital communications this arrangement is popular. It is used because of its bandwidth conserving (and other) properties.

It is not used for multiplexing two independent messages. Given an input binary sequence (message) at the rate of n bit/s, two sequences may be obtained by splitting the bit stream into two paths, each of n/2 bit/s. This is akin to a serial-to-parallel conversion.

The two streams become the channel 1 and channel 2 messages of Figure 1.

Because of the halved rate the bits in the I and Q paths are stretched to twice the input sequence bit clock period. The two messages are recombined at the receiver, which uses a QAM-type demodulator. The two bit streams would typically be band limited and/or pulse shaped before reaching the modulator. A block diagram of such a system is shown in Figure 2 below.

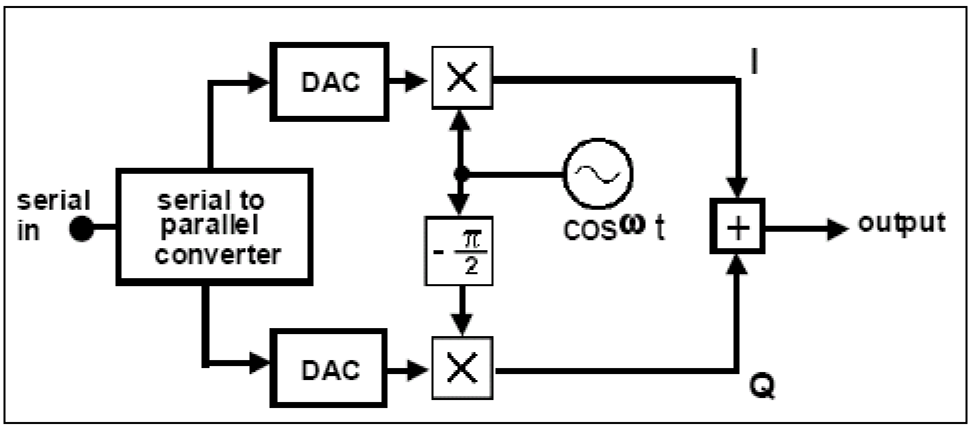

Figure 2: a QPSK modulator

QAM becomes QPSK:

The QAM modulator is so named because, in analog applications, the messages do in fact vary the amplitude of each of the DSBSC signals.

In QPSK the same modulator is used, but with binary messages in both the I and Q channels, as describe above.

Each message has only two levels, ±V volt. For a non-bandlimited message this does not vary the amplitude of the output DSBSC. As the message changes polarity this is interpreted as a 180^0 phase shift, given to the DSBSC.

Thus the signal in each arm is said to be undergoing a 1800 phase shift, or phase shift keying - or PSK. Because there are two PSK signals combined, in quadrature, the two-channel modulator gives rise to a quadrature phase shift keyed - QPSK - signal.

Constellation:

Viewed as a phasor diagram (and for a non-bandlimited message to each channel), the signal is seen to occupy any one of four point locations on the complex plane. These are at the corner of a square (a square lattice), at angles π/4, 3π/4, 5π/4 and 7π/4 to the real axis.

M-PSK and M-QAM:

The above has described digital-QAM or QPSK. This signal is also called 4-PSK or 4-QAM. More generally signals can be generated which are described as M-QAM or M-PSK. Here $M = 2^{\mathbf{L}}$, where **L** = the number of levels in each of the I and Q arms. For the present experiment **L** = 2, and so M = 4. The 'M' defines the number of points in the signal constellation. For the cases M > 4 then M-PSK is not the same as M-QAM.

The QAM Receiver:

The QAM receiver follows the similar principles to those at the transmitter, and is illustrated in idealised from in the block diagram of Figure 3. It is idealised because it assumes the incoming signal has its two DSBSC precisely in phase quadrature. Thus only one phase adjustment is required.

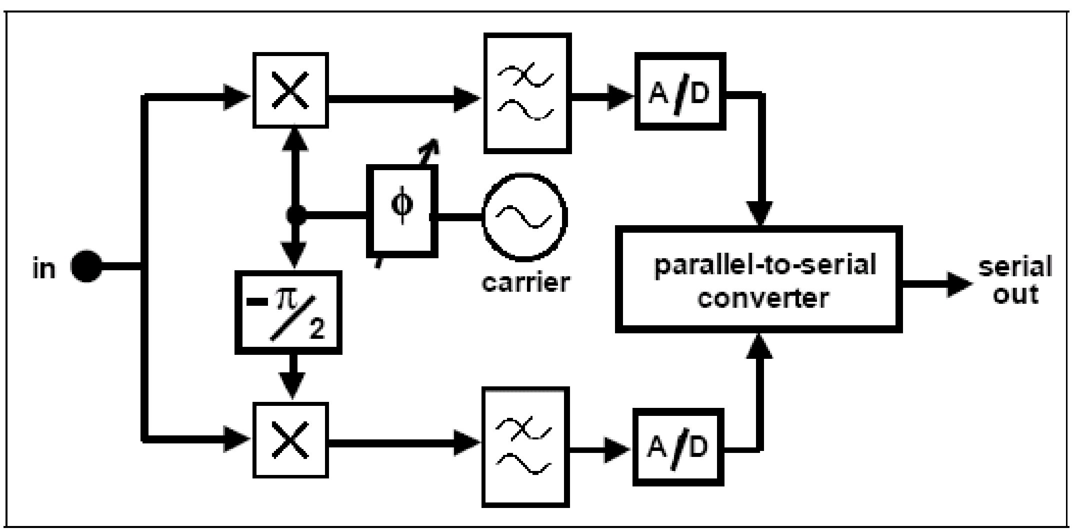

Figure 3: the QAM demodulator for QPSK

The parallel-to-serial converter block performs the following operations:

1. regenerates the bit clock from the incoming data.
2. regenerates a digital waveform from both the analog outputs of the I and Q arms.
3. re-combines the I and Q signals, and outputs a serial data stream.

Not shown is the method of carrier acquisition. This ensures that the oscillator, which supplies the local carrier signal, is synchronized to the received (input) signal in both frequency *and* phase. In this experiment we will use a stole carrier to ensure that carrier signal in the transmitter and receiver are in synchronism with each other. (Please read about Costas Receiver to understand more about carrier acquisition).

In this experiment, two independent data sequences will be used at the input to the modulator, rather than having digital circuitry to split one data stream into two (the serial-to-parallel converter). Two such independent data sequences, sharing a common bit clock (2.083 kHz), are available from a single SEQUENCE GENERATOR module. The data stream from which these two channels are considered to have been derived would have been at a rate of twice this - 4.167 kHz.

Lowpass filter bandlimiting and pulse shaping is not a subject of enquiry in this experiment. So a single bandpass filter at the ADDER (summer) output will suffice, providing it is of adequate bandwidth. A 100 kHz CHANNEL FILTERS module is acceptable (filter #3).

<u>Experimental Procedure:</u>

<u>The QPSK transmitter:</u>

A model of the generator of Figure 1 is shown in Figure 4.

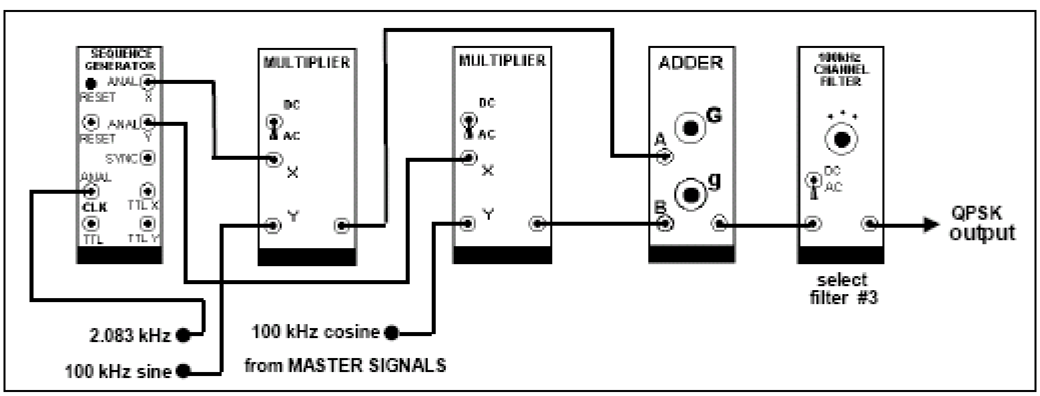

Figure 4: the QAM modulator for QPSK

The QAM modulator involves analog circuitry. Overload must be avoided, to prevent crosstalk between channels when they share a common path - the ADDER and output filter. In practice there would probably be a filter in the message path to each multiplier. Although these filters would be included for pulse shaping and/or band limiting, a secondary purpose is to eliminate as many unwanted components at the multiplier (modulator) input as possible.

T1 *patch up the modulator according to Figure 4. Set the on-board switch SW1 of the PHASE SHIFTER to HI. Select channel #3 of the 100 kHz CHANNEL FILTERS module (this is a bandpass filter of adequate bandwidth).*

T2 *there are no critical adjustments to be made. Set the signals from each input of the ADDER to be, say, 1 volt peak at the ADDER output.*

T3 *for interest predict the waveforms (amplitude and shape) at all interfaces, then confirm by inspection.*

Constellation:

You can display the four-point constellation for QPSK:

T4 *set the oscilloscope in X-Y mode. With no input, select equal gains per channel. Locate the 'spot' in the centre of the screen; then connect the two data streams entering the QAM to the scope X and Y inputs.*

The Demodulator:

Modelling of the demodulator of Figure 3 is straightforward. But it consumes a lot of modules. Consequently only one of the two arms is shown in Figure 5.

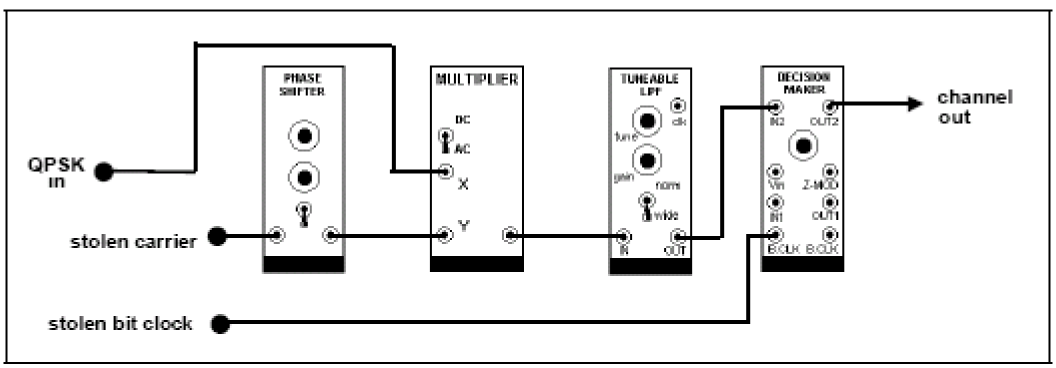

Figure 5: one channel of the demodulator

The PHASE SHIFTER can be used to select either channel from the QAM signal. If both channels required simultaneously, as in practice, then a second, identical demodulator must be provided.

T5 *patch up the single channel demodulator of Figure 5, including the z-mod facility of the DECISION MAKER.*

T6 *while watching the 'I' channel at the transmitter, use the PHASE SHIFTER to match the demodulator output with it.*

T7 *while watching the 'Q' channel at the transmitter, use the PHASE SHIFTER to match the demodulator output with it.*

Tutorial Questions:

1) Explain how a QAM system conserves bandwidth.

2) The modulator used the quadrature 100 kHz outputs from the MASTER SIGNALS module. Did it matter if these were not **precisely** in quadrature ? Explain.

3) Name one advantage of making the bit rate a sub-multiple of the carrier frequency.

4) Why is there a need to eliminate as many unwanted components as possible into the modulator ?