

Amplitude Shift Keying & Frequency Shift Keying

Aim: To generate and demodulate an amplitude shift keyed (ASK) signal and a binary FSK signal.

Intro to Generation of ASK

Amplitude shift keying - ASK - in the context of digital communications is a modulation process, which imparts to a sinusoid two or more discrete amplitude levels. These are related to the number of levels adopted by the digital message.

For a binary message sequence there are two levels, one of which is typically zero.

Thus the modulated waveform consists of bursts of a sinusoid.

Figure 1 illustrates a binary ASK signal (lower), together with the binary sequence which initiated it (upper). Neither signal has been bandlimited.

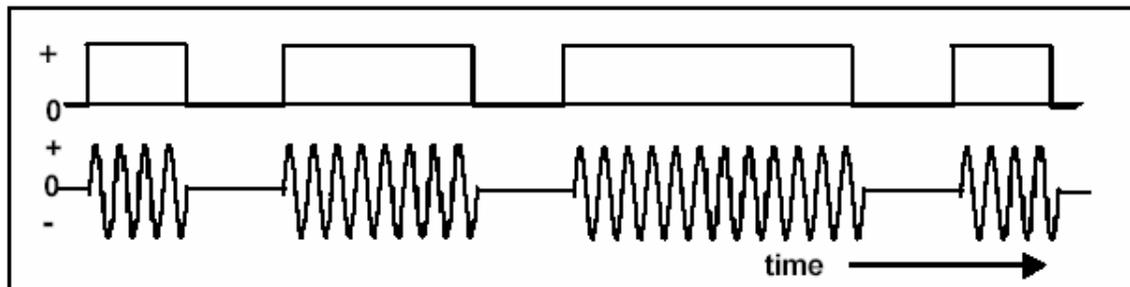


Figure 1: an ASK signal (below) and the message (above)

There are sharp discontinuities shown at the transition points. These result in the signal having an unnecessarily wide bandwidth. Bandlimiting is generally introduced before transmission, in which case these discontinuities would be 'rounded off'. The bandlimiting may be applied to the digital message, or the modulated signal itself.

The data rate is often made a sub-multiple of the carrier frequency. This has been done in the waveform of Figure 1.

One of the disadvantages of ASK, compared with FSK and PSK, for example, is that it has not got a constant envelope. This makes its processing (eg, power amplification) more difficult, since linearity becomes an important factor. However, it does make for ease of demodulation with an envelope detector.

Intro to Bandwidth Modification

As already indicated, the sharp discontinuities in the ASK waveform of Figure 1 imply a wide bandwidth. A significant reduction can be accepted before errors at the receiver increase unacceptably. This can be brought about by bandlimiting (pulse shaping) the message *before* modulation, or bandlimiting the ASK signal itself *after* generation.

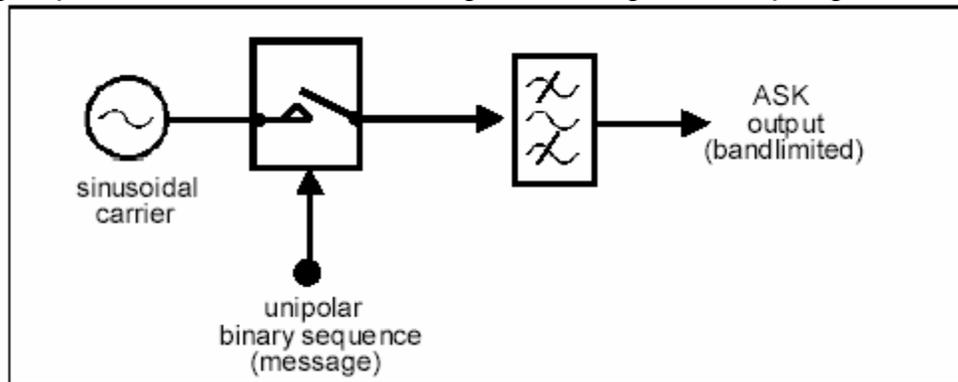


Figure 2: ASK generation method

Figure 3 shows the signals present in a model of Figure 2, where the message has been bandlimited. The shape, after bandlimiting, depends naturally enough upon the amplitude and phase characteristics of the bandlimiting filter.

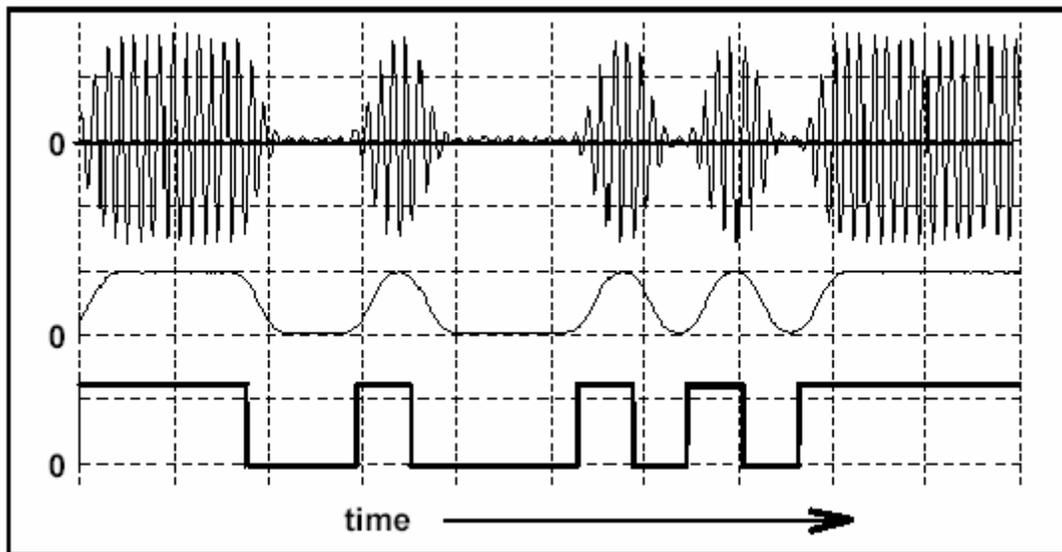


Figure 3: original TTL message (lower), bandlimited message (center), and ASK (above)

Intro to Demodulation

It is apparent from Figures 1 and 4 that the ASK signal has a well defined envelope. Thus it is amenable to demodulation by an envelope detector.

With bandlimiting of the transmitted ASK neither of these demodulation methods (envelope detection or synchronous demodulation) would recover the original binary

sequence; instead, their outputs would be a bandlimited version. Thus further processing - by some sort of decision-making circuitry for example - would be necessary.

Thus demodulation is a two-stage process:

1. recovery of the bandlimited bit stream
2. regeneration of the binary bit stream

Figure 4 illustrates.

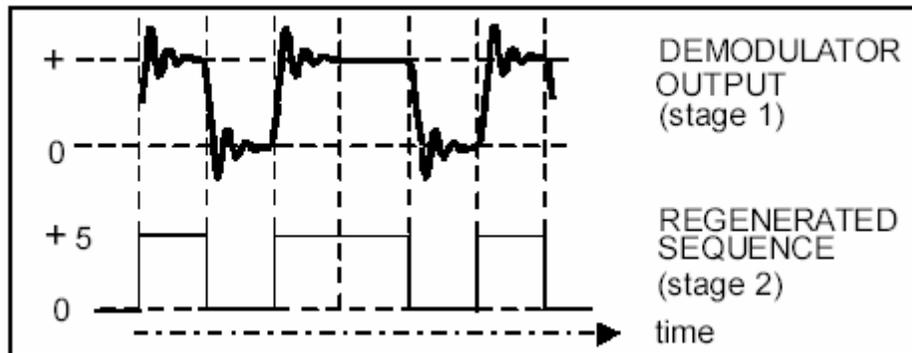


Figure 4: the two stages of the demodulation process

Modeling an ASK Generator

It is possible to model the rather basic generator shown in Figure 2.

The switch can be modeled by one half of a DUAL ANALOG SWITCH module. Being an *analog* switch, the carrier frequency would need to be in the audio range. The TTL output from the SEQUENCE GENERATOR is connected directly to the CONTROL input of the DUAL ANALOG SWITCH. For a synchronous carrier and message use the 8.333 kHz TTL sample clock (filtered by a TUNEABLE LPF) and the 2.083 kHz sinusoidal message from the MASTER SIGNALS module.

If you need the TUNEABLE LPF for bandlimiting of the ASK, use the sinusoidal output from an AUDIO OSCILLATOR as the carrier. For a synchronized message as above, tune the oscillator close to 8.333 kHz, and lock it there with the sample clock connected to its SYNCH input.

This arrangement is shown modeled in Figure 5.

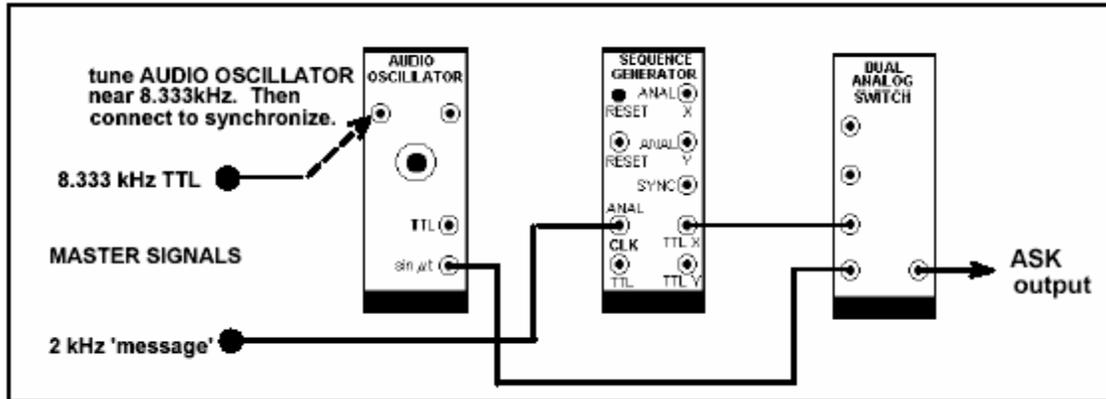


Figure 5: modeling ASK with the arrangement of Figure 2

Demodulation of an ASK signal

Having a very definite envelope, an envelope detector can be used as the first step in recovering the original sequence. Further processing can be employed to regenerate the true binary waveform.

Figure 6 is a model for envelope recovery from a baseband ASK signal.

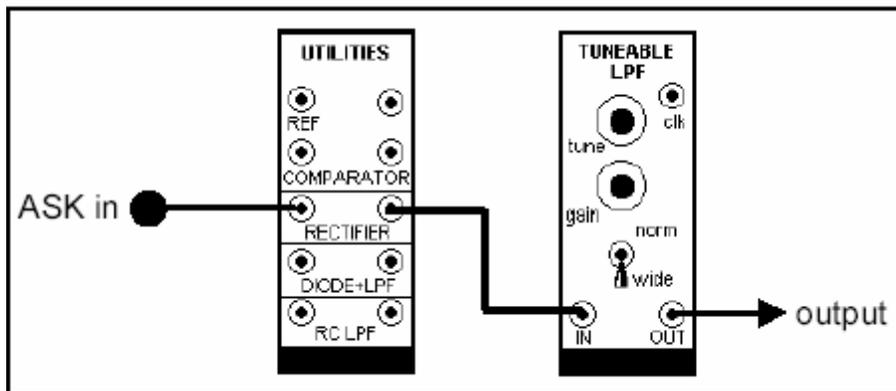


Figure 6: envelope demodulation of baseband ASK

The output from the above demodulators will not be a copy of the binary sequence TTL waveform. Bandlimiting will have shaped it, as (for example) illustrated in Figure 3.

If the ASK has been bandlimited before or during transmission (or even by the receiver itself) then the recovered message, in the demodulator, will need restoration ('cleaning up') to its original bi-polar format.

Some sort of decision device is then required to regenerate the original binary sequence. This could be done with a COMPARATOR.

Introduction to Part II:

FSK Generation:

As its name suggests, a frequency shift keyed transmitter has its frequency shifted by the message.

Although there could be more than two frequencies involved in an FSK signal, in this experiment the message will be a binary bit stream, and so only two frequencies will be involved.

The word 'keyed' suggests that the message is of the 'on-off' (mark-space) variety, such as one (historically) generated by a morse key, or more likely in the present context, a binary sequence. The output from such a generator is illustrated in Figure 1 below.

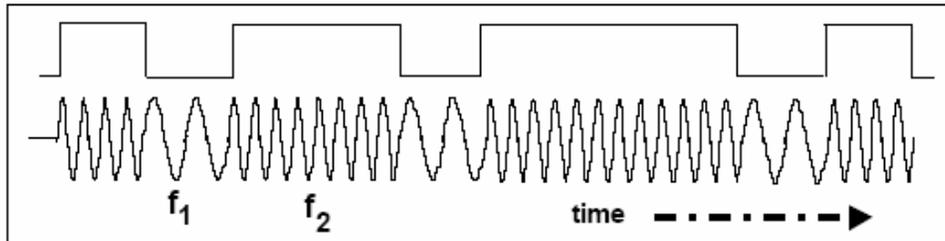


Figure 1: an FSK waveform, derived from a binary message

Conceptually, and in fact, the transmitter could consist of two oscillators (on frequencies f_1 and f_2), with only one being connected to the output at any one time. This is shown in block diagram form in Figure 2 below.

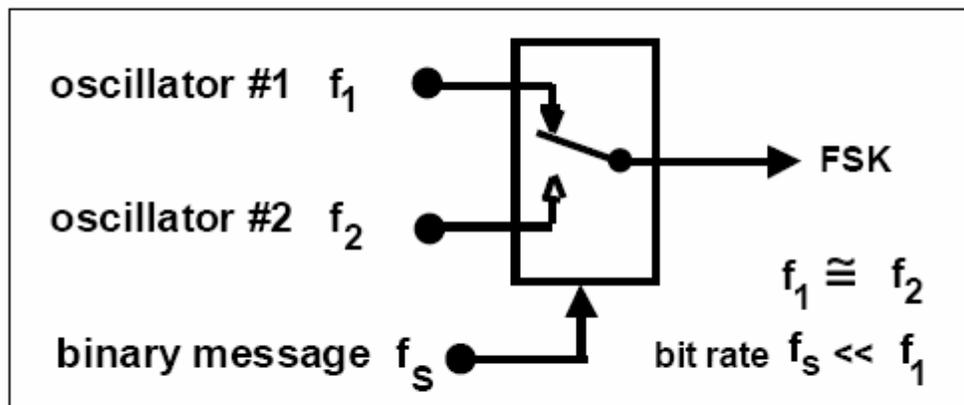


Figure 2: an FSK transmitter

Unless there are special relationships between the two oscillator frequencies and the bit clock there will be abrupt phase discontinuities of the output waveform during transitions of the message.

Bandwidth:

Practice is for the tones f_1 and f_2 to bear special inter-relationships, and to be integer multiples of the bit rate. This leads to the possibility of continuous phase, which offers advantages, especially with respect to bandwidth control.

Alternatively the frequency of a single oscillator (VCO) can be switched between two values, thus guaranteeing continuous phase - CPFSK.

The continuous phase advantage of the VCO is not accompanied by an ability to ensure that f_1 and f_2 are integer multiples of the bit rate. This would be difficult (impossible ?) to implement with a VCO.

FSK signals can be generated at baseband, and transmitted over telephone lines (for example). In this case, both f_1 and f_2 (of Figure 2) would be audio frequencies. Alternatively, this signal could be translated to a higher frequency. Yet again, it may be generated directly at 'carrier' frequencies.

Demodulation:

There are different methods of demodulating FSK. A natural classification is into synchronous (coherent) or asynchronous (non-coherent).

Representative demodulators of these two types are the following:

Asynchronous Demodulator:

A close look at the waveform of Figure 1 reveals that it is the sum of two amplitude shift keyed (ASK) signals.

The receiver of Figure 3 takes advantage of this. The FSK signal has been separated into two parts by bandpass filters (BPF) tuned to the MARK and SPACE frequencies.

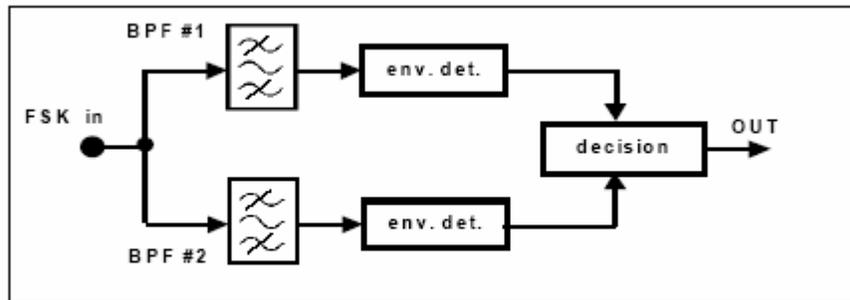


Figure 3: demodulation by conversion-to-ASK

The output from each BPF looks like an amplitude shift keyed (ASK) signal. These can be demodulated asynchronously, using the envelope.

The decision circuit, to which the outputs of the envelope detectors are presented, selects the output which is the most likely one of the two inputs. It also re-shapes the waveform from a bandlimited to a rectangular form.

This is, in effect, a two channel receiver. The bandwidth of each is dependent on the message bit rate. There will be a minimum frequency separation required of the two tones.

Hint:

You are advised to read ahead, before attempting the experiment, to consider the modelling of this demodulator. Unlike most TMS models, you are not free to choose parameters - particularly frequencies. If they are to be tuned to different frequencies, then one of these frequencies must be 2.083 kHz (defined as the MARK frequency). This is a restriction imposed by the BIT CLOCK REGEN module, of which the BPF are sub-systems. As a result of this, most other frequencies involved are predetermined. Make sure you appreciate why this is so, then decide upon:

- bit clock rate
- SPACE frequency
- envelope detector LPF characteristics

Synchronous Demodulator:

In the block diagram of Figure 4 two local carriers, on each of the two frequencies of the binary FSK signal, are used in two synchronous demodulators. A decision circuit examines the two outputs, and decides which is the most likely.

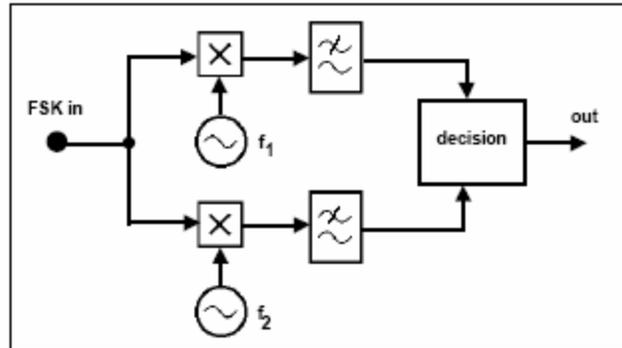


Figure 4: synchronous demodulation

This is, in effect, a two channel receiver. The bandwidth of each is dependent on the message bit rate. There will be a minimum frequency separation required of the two tones. This demodulator is more complex than most asynchronous demodulators.

Phase Locked Loop:

A phase locked loop is a well known method of demodulating an FM signal. It is thus capable of demodulating an FSK signal. It is shown, in block diagram form, in Figure 5 below.

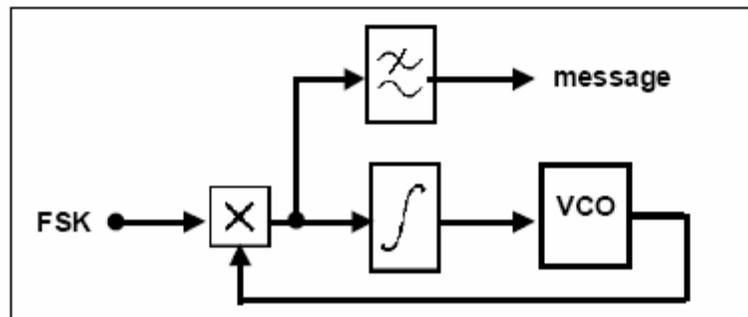


Figure 5: phase locked loop demodulator

The control signal, which forces the lock, is a bandlimited copy of the message sequence. Depending upon the bandwidth of the loop integrator, a separate LPF will probably be required (as shown) to recover the message.

Experimental Procedure:

Generation:

Scheme # 1:

A VCO module is ideally suited for the generation of a continuous phase FSK signal, as shown in Figure 6.

In FSK mode the VCO is keyed by the message TTL sequence. Internal circuitry results in a TTL HI switching the VCO to frequency f_1 , while a TTL LO switches it to frequency f_2 . These two frequencies may be in the audio range (front panel toggle switch LO), or in the 100 kHz range (front panel toggle switch HI).

The frequencies f_1 and f_2 are set by the on-board variable resistors RV8 and RV7 respectively, while a continuous TTL HI or a TTL LO is connected to the DATA input socket.

In FSK mode neither of the front panel rotary controls of the VCO is in operation.

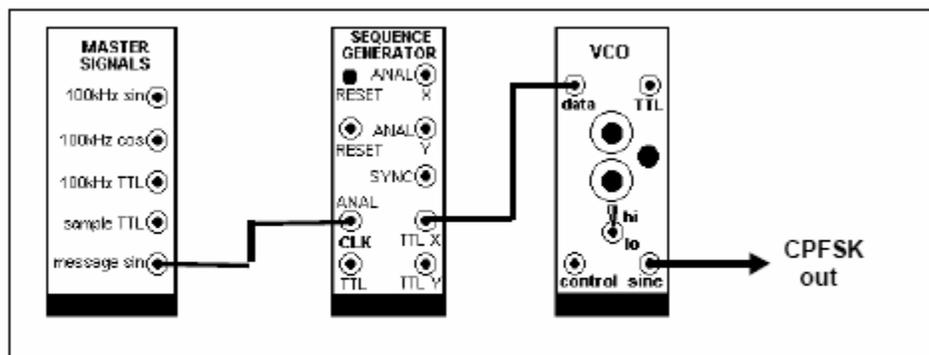


Figure 6: CPFSK

Scheme # 2:

Figure 7 shows a model of the arrangement of Figure 2. It switches either one of two tones to the output, in response to the message sequence.

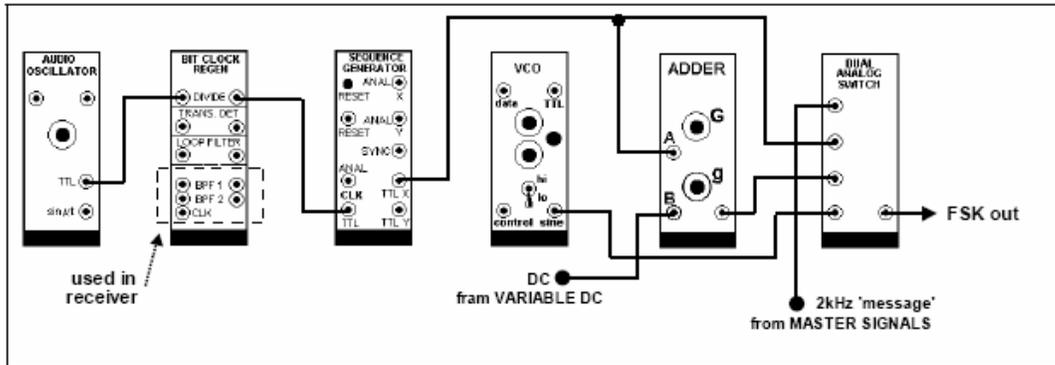


Figure 7: a model of the arrangement of Figure 2

The binary sequence is shown clocked by a divided-by-8 version of the output of an AUDIO OSCILLATOR. This oscillator cannot itself be tuned to this relatively low (for TIMS) frequency. The DIVIDE-BY-8 sub-system is in the BIT CLOCK REGEN module (set the on-board switch SW2 with both toggles DOWN).

The signals at f_1 and f_2 are provided by the 2.083 kHz MESSAGE from the MASTER SIGNALS module, and a VCO, respectively. The DUAL AUDIO SWITCH module is used to switch between them.

- one of the two ANALOG SWITCHES is driven directly by the TTL binary message sequence.
- the other ANALOG SWITCH is driven by the same TTL sequence, reversed in polarity, and then DC shifted by +5 volts. The reversal and DC shift is performed by the ADDER, with a maximum -ve output from the VARIABLE DC module. Although 5 volt signals exceed the TIMS ANALOG REFERENCE LEVEL the ADDER design is such that it will not be overloaded.

Demodulator:

An example of this is the demodulator of Figure 3, shown modelled in Figure 8.

The demodulator requires two bandpass (BPF) filters, tuned to the MARK and SPACE frequencies. Suitable filters exist as sub-systems in the BIT CLOCK REGEN module.

To prepare the filters it is necessary to set the on-board switch SW1. Put the left hand toggle UP, and right hand toggle DOWN. This tunes BPF1 to 2.083 kHz, and BPF2 anywhere in the range $1 < f_0 < 5$ kHz, depending on the VCO (the filter centre frequency will be 1/50 of the VCO frequency).

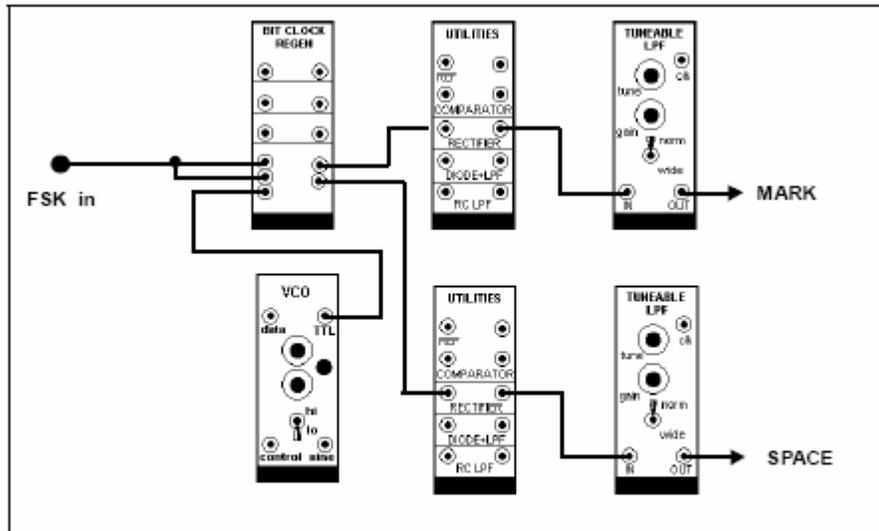


Figure 8: a model of the receiver of Figure 3

If you do not have extra UTILITIES and TUNEABLE LPF modules, then complete just one arm of the demodulator.

Alignment requires the BPFs to be tuned to the MARK and SPACE frequencies. The first is already done (2.083 kHz is already pre-set with SW1); the other is set with the VCO (already pre-set with SW2).

Note that the specified bit rate is, by TMS standards, rather low. The average oscilloscope display can be a little flickery. Use a short sequence, and the SYNC signal from the SEQUENCE GENERATOR to ext. trig.

Phase Locked Loop:

A phase locked loop is shown in block diagram form in Figure 5, and modelled in Figure 9.

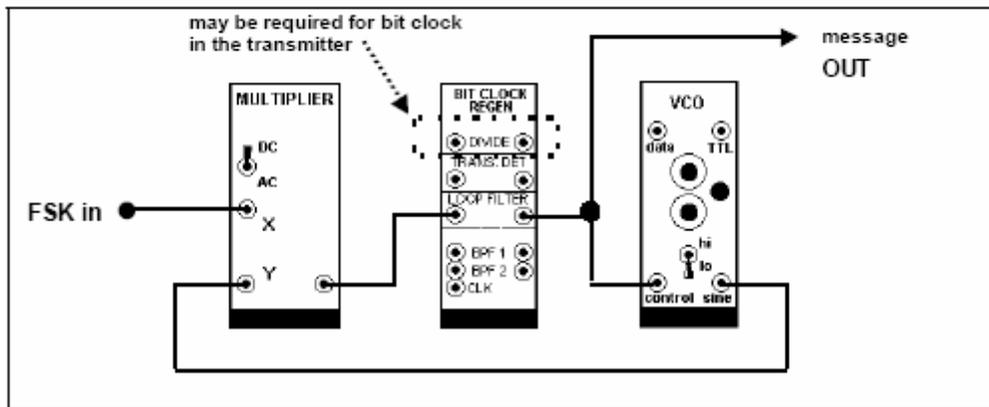


Figure 9: PLL demodulator - the model of Figure 5

For the present experiment the integrator (of Figure 5) is modelled with the LOOP FILTER in the BIT CLOCK REGEN module. This module contains four independent sub-systems. The DIVIDE-BY-8 sub system may already be in use at the transmitter.

Discussion Questions:

- 1) Suggest an advantage of making the data rate a sub-multiple of the carrier rate in ASK
- 2) What will you observe in the spectrum of ASK signal if the binary message frequency is of alternate ones and zeros?