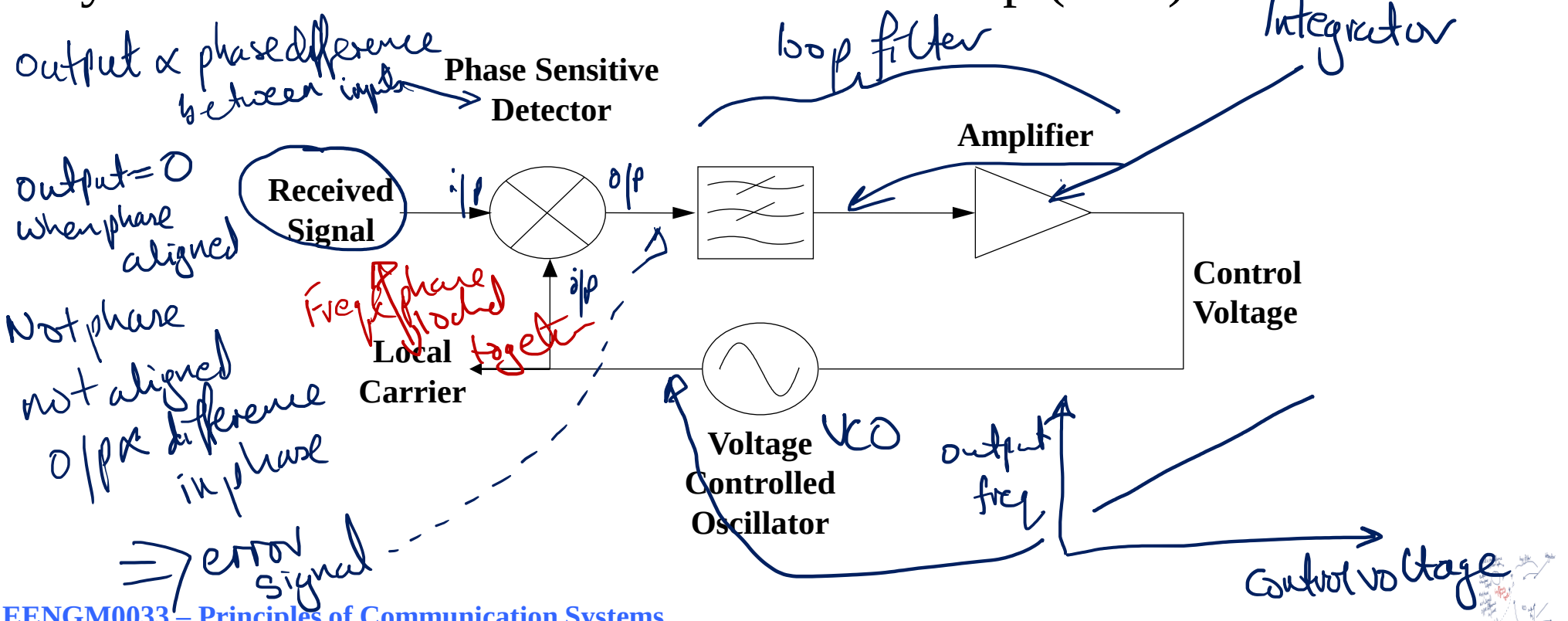
University of BRISTOL

Phase Locked Loop (PLL)

Phase Locked Loops (1)

- One of the most useful building blocks in a communication system tool box is the Phase Locked Loop (PLL).



Phase Locked Loops (2)

- The PLL has 3 essential blocks.
- The phase comparator
  - This compares the phase of the input signal, with the phase of the signal generated in the VCO.
- The loop filter.
  - With the amplifier, this sets the transient performance of the loop.
- The Voltage Controlled Oscillator.
  - This generates a signal, which, when the PLL is locked, has a frequency exactly equal to the frequency of the incoming signal.

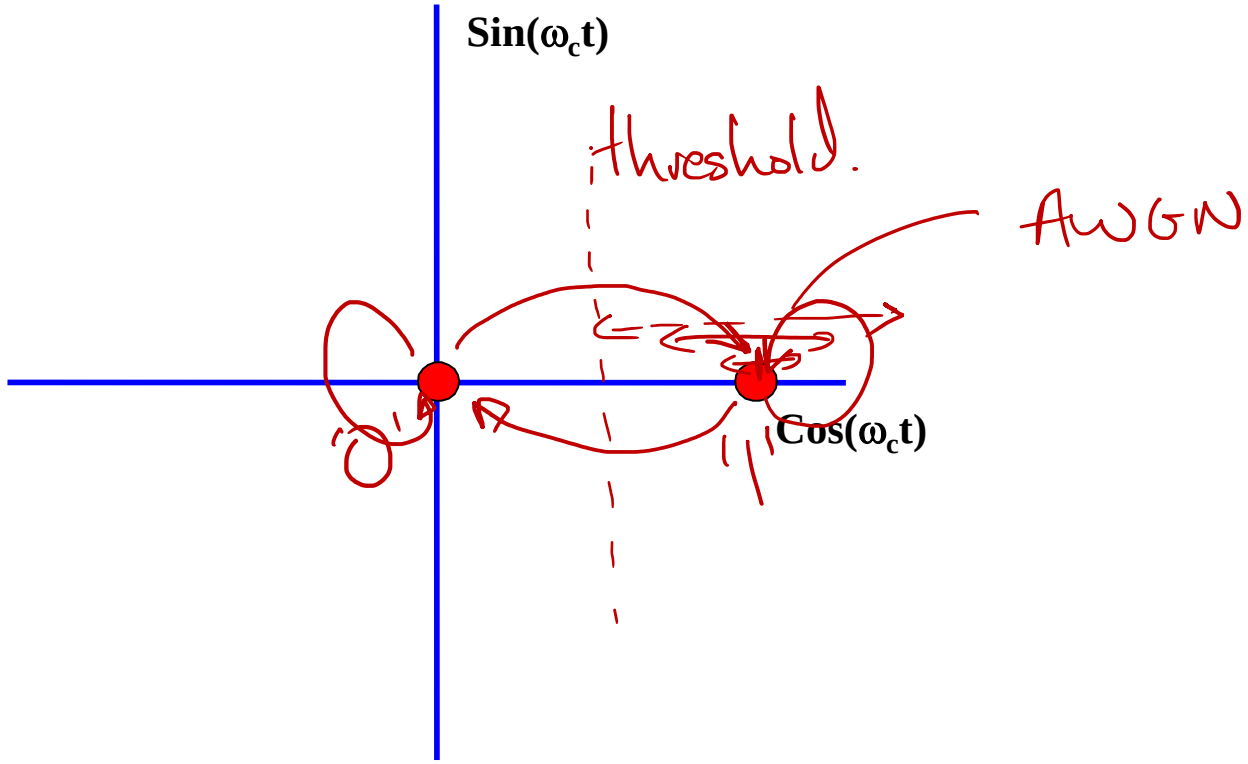
+ phase

Constellation Diagrams

- A constellation diagram is a method of representing the signal states of the amplitude and phase of the signal in a diagram.
- The horizontal axis displays the components of the signal that are in phase with the carrier signal *(cos(ω_c.t)). (real part)*
- The vertical axis shows the components that are in phase with the quadrature component of the carrier signal *(sin(ω_c.t)). (imaginary part)*

Constellation Diagram for Binary OOK ASK

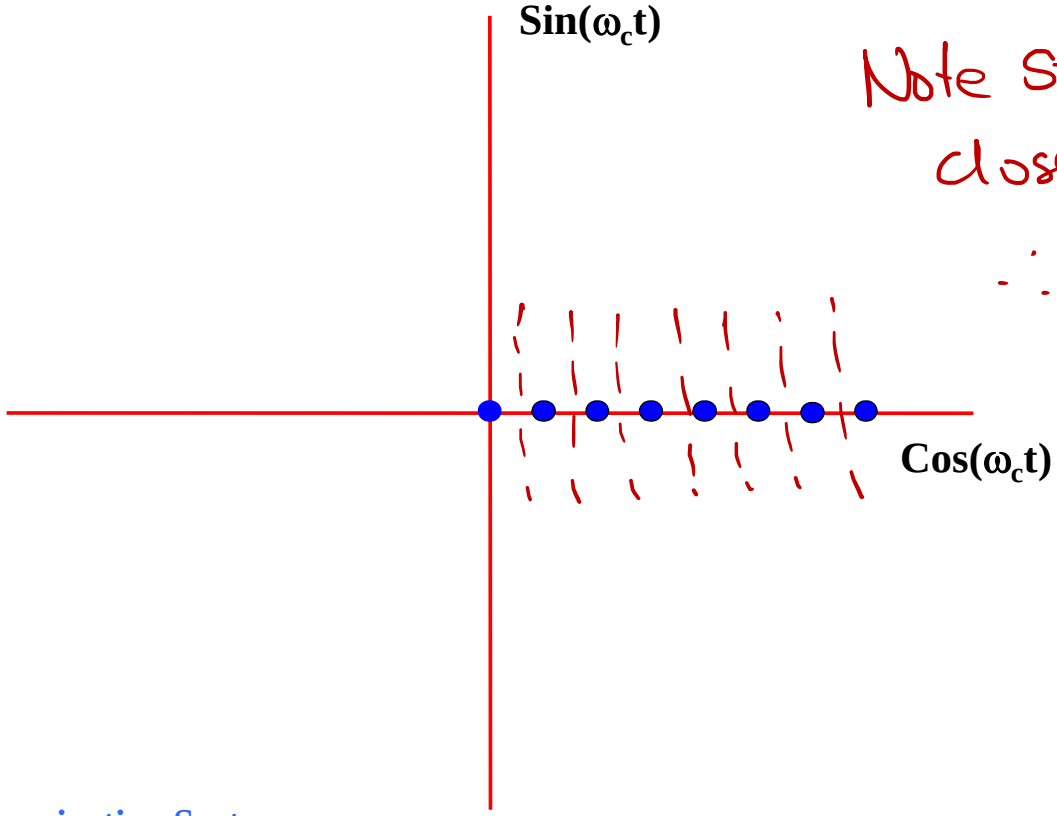
- A constellation diagram of binary OOK ASK is shown below.



Constellation Diagram: 8-ary ASK

- A constellation diagram of 8-ary ASK is shown below.

3 bits/symbol

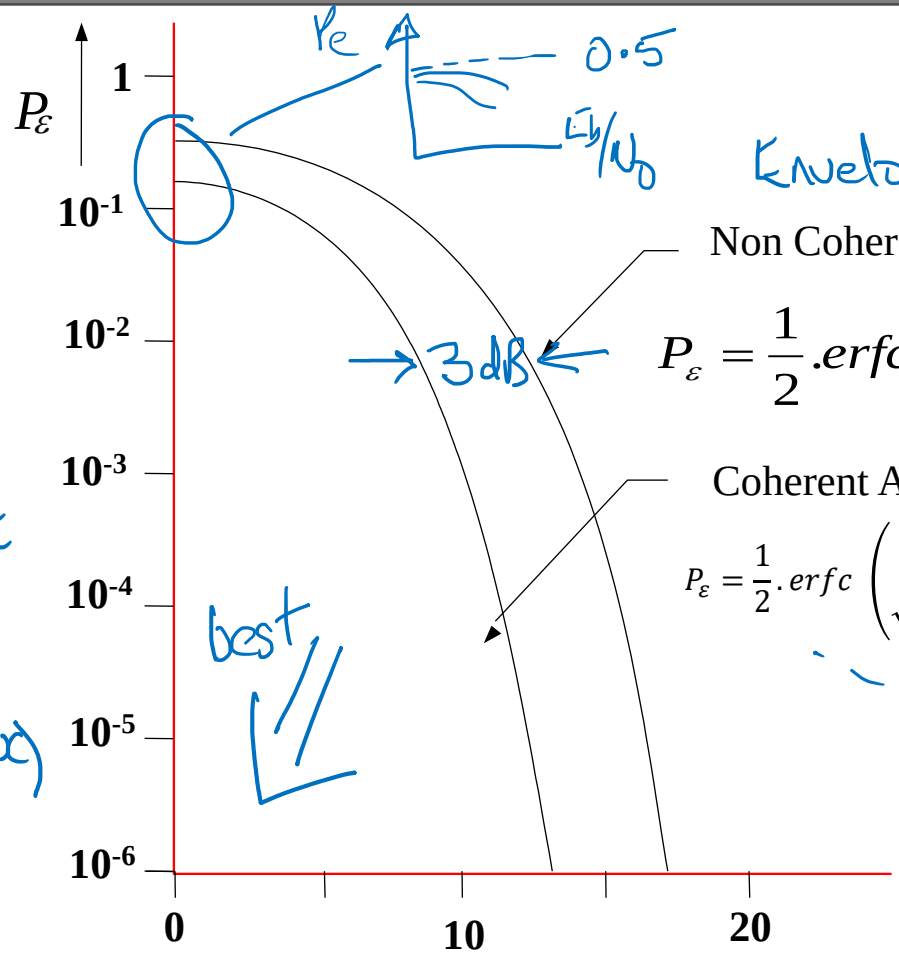


Note states are closer together

∴ more sensitive to AWGN

⇒ poorer noise performance than ASK (binary)

Bit Error Rate (BER) Performance of OOK ASK



$$P_\varepsilon = \frac{1}{2}.erfc\left(\sqrt{\frac{E_b}{2.N_0}}\right) + \frac{1}{2}\exp\left(\frac{-E_b}{4.N_0}\right)$$

$$P_\varepsilon = \frac{1}{2}.erfc\left(\sqrt{\frac{E_b}{2N_0}}\right)$$

$$erf(x) = \frac{2}{\pi}\int_0^x e^{t^2}dt$$

$$erfc(x) = 1 - erf(x)$$

Probability of an error

Envelope detector detects both in phase & quadrature noise

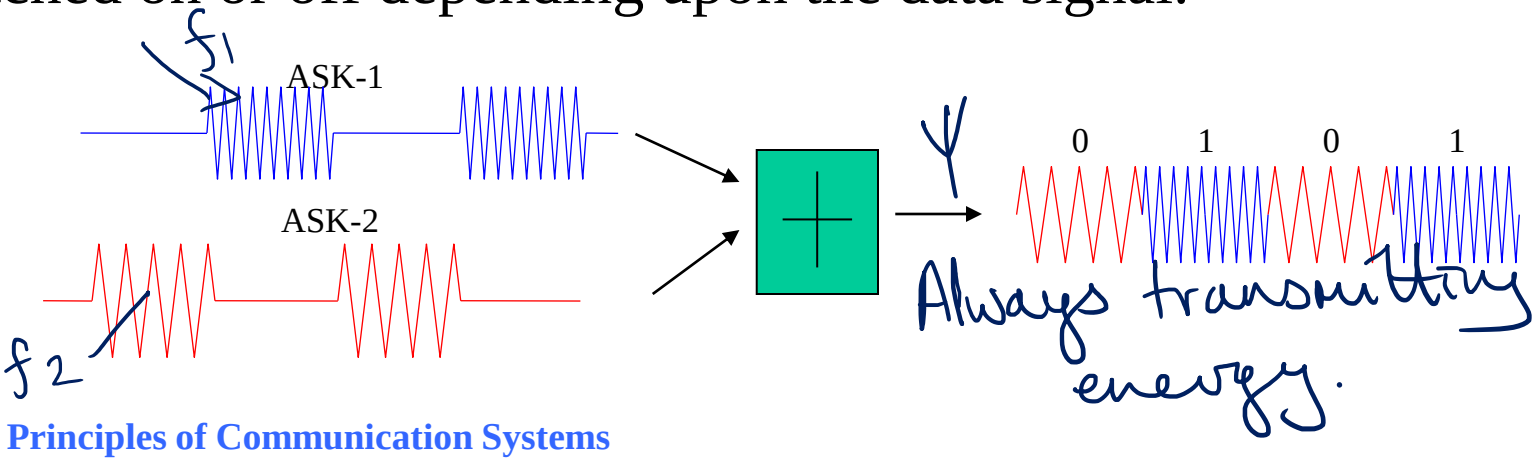
detects in phase only

uni-polar signalling.

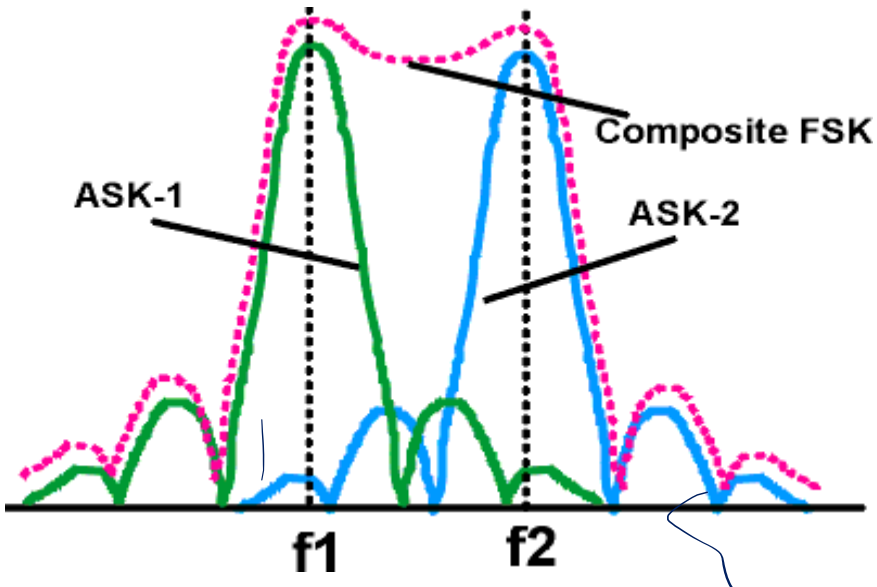
Frequency Shift Keying (FSK)

Frequency Shift Keying (FSK)

- Binary FSK uses 2 distinct frequencies to represent the different data bits. Thus, $s(t) = A\cos(\omega(t)t+\theta)$
- The amplitude of the signal is thus to some degree unimportant, and amplitude limiting can be used. This is a good, since FSK is thus robust to fading in the channel.
- An FSK signal can be viewed as two ASK signals with one or the other switched on or off depending upon the data signal.



FSK Spectrum

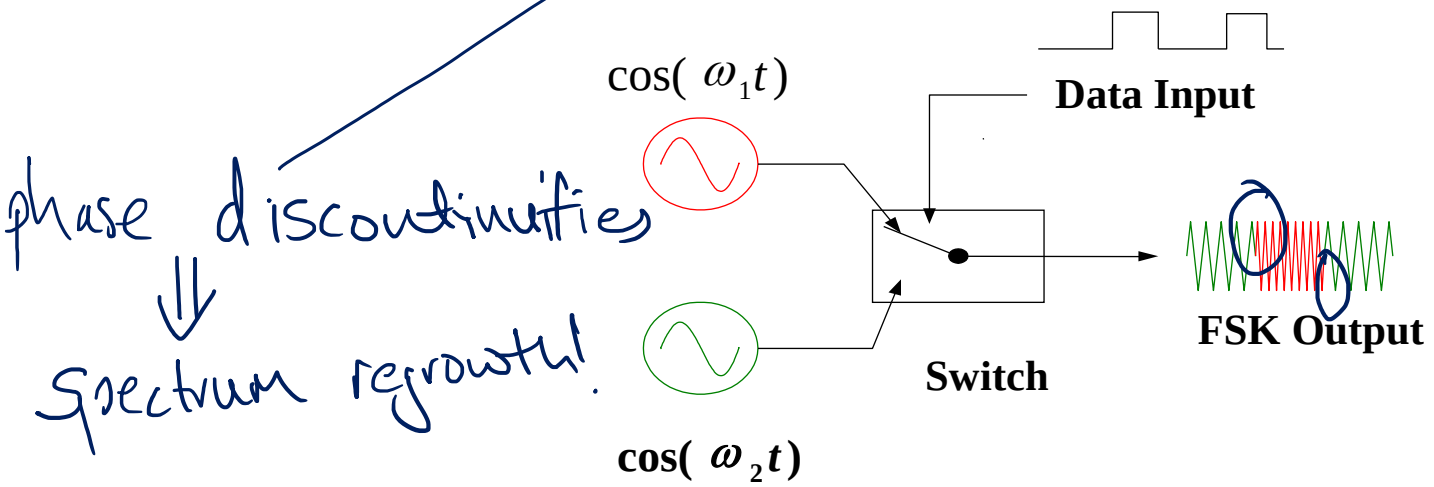


- It is not easy to determine the spectrum of an FSK signal analytically. However, it can be determined graphically as the composite of two appropriately spaced ASK spectra.
- Clearly, the FSK spectrum and bandwidth depend upon the spacing of the two centre frequencies

bandwidth depends on frequency separation

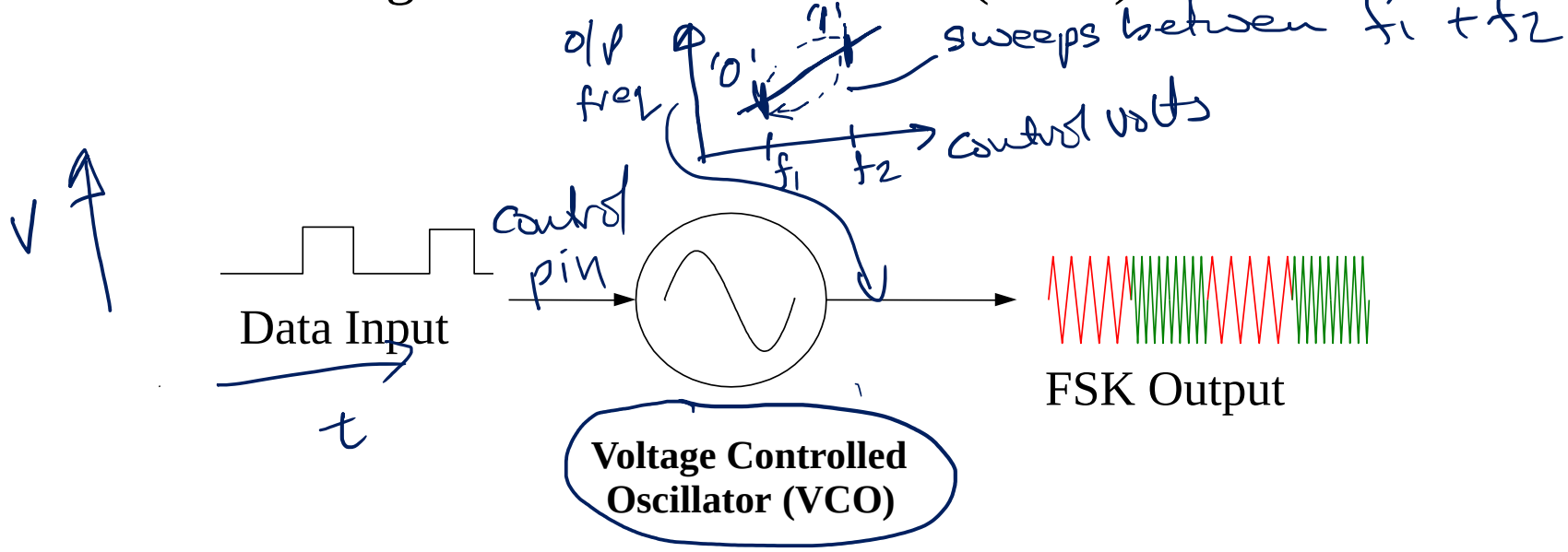
FSK Generation (1)

- FSK can be generated by switching between distinct frequency sources as shown. It is likely that the phase transition in this switching process won't be smooth, and there will be phase jumps.
- Also it is not possible to apply pulse shaping before the switch. As we have seen, filtering at RF is impractical.



FSK Generation

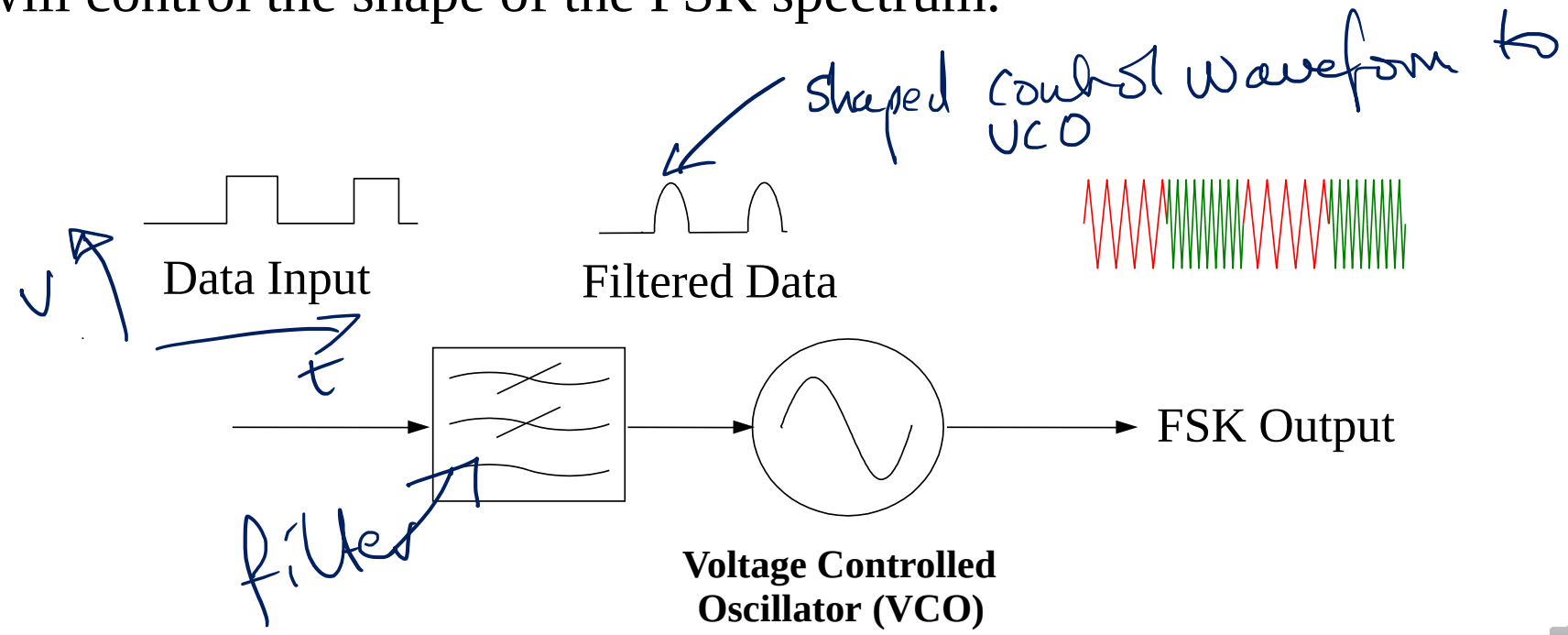
- The alternative method of FSK generation is to use the data input to control a Voltage Controlled Oscillator (VCO).



- This achieves Continuous Phase FSK (CPFSK)

FSK Generation via VCO

- Has the advantage of giving smooth phase transitions.
- Data input can be low pass filtered before the VCO.
- This will control the shape of the FSK spectrum.



Minimum Shift Keying

How to space the frequencies / tones for FSK

- If the two frequencies are spaced at a multiple of 1/2 of the symbol rate, they will be orthogonal.
- Thus the minimum spacing between the two frequencies required to ensure that they are orthogonal is half the symbol rate.

$$a_m(t) = \cos\left(2\pi t\left(f_0 + \frac{m}{2T_S}\right)\right) \qquad m = 0,1$$

- When this minimum spacing is used, the modulation is termed Minimum Shift Keying (MSK). Spectral efficiency can approach 2bits/s/Hz.

baseband case for binary data

FSK Band Limiting

- A common pulse shaping filter used for FSK (or MSK) is the Gaussian shape.
- This filter ensures that the spectrum of the FSK signal rolls off rapidly outside of the main lobe.
- This is termed Gaussian FSK (GFSK) or Gaussian MSK (GMSK)
- GMSK is used as modulation for the GSM cellular radio system.
- GFSK is used as the modulation scheme for Bluetooth

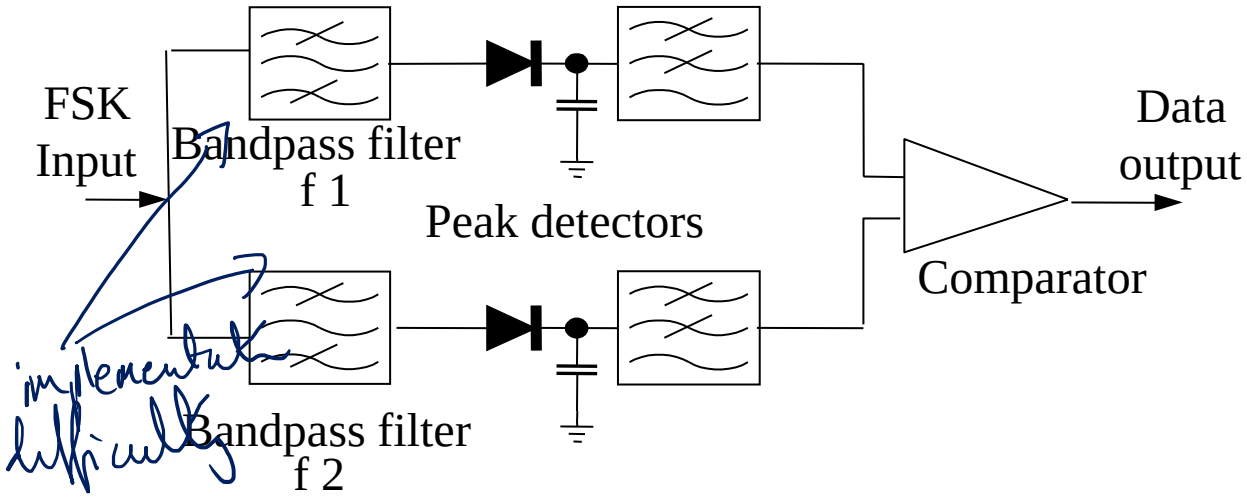
2nd Gen Digital.

Frequency Shift Keying (FSK) Detection

FSK Detection

- As with ASK, FSK can be detected coherently or non coherently.
- This is based around having filters tuned to the signal frequencies.
- The output of the filters is measured with a peak detector.
- The filters with the greatest output is assumed to correspond to correspond to the signal frequency.
- This is measured in a comparator circuit.

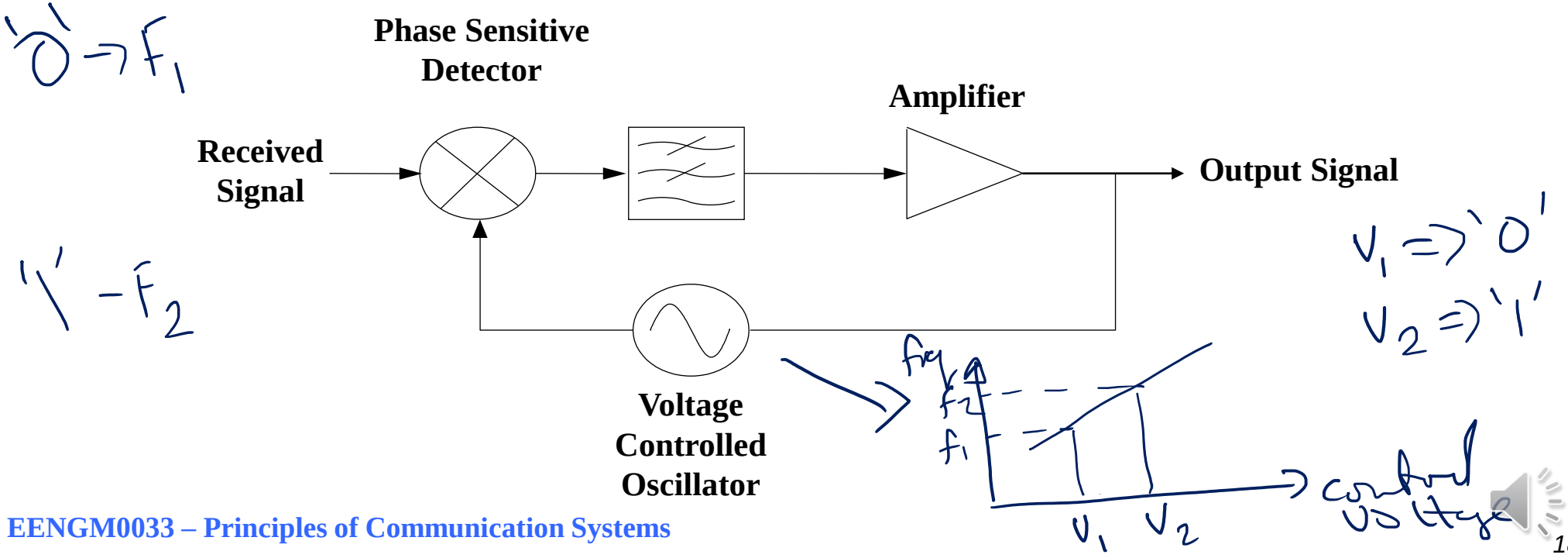
pair of envelope detectors for each frequency



implementation difficulty

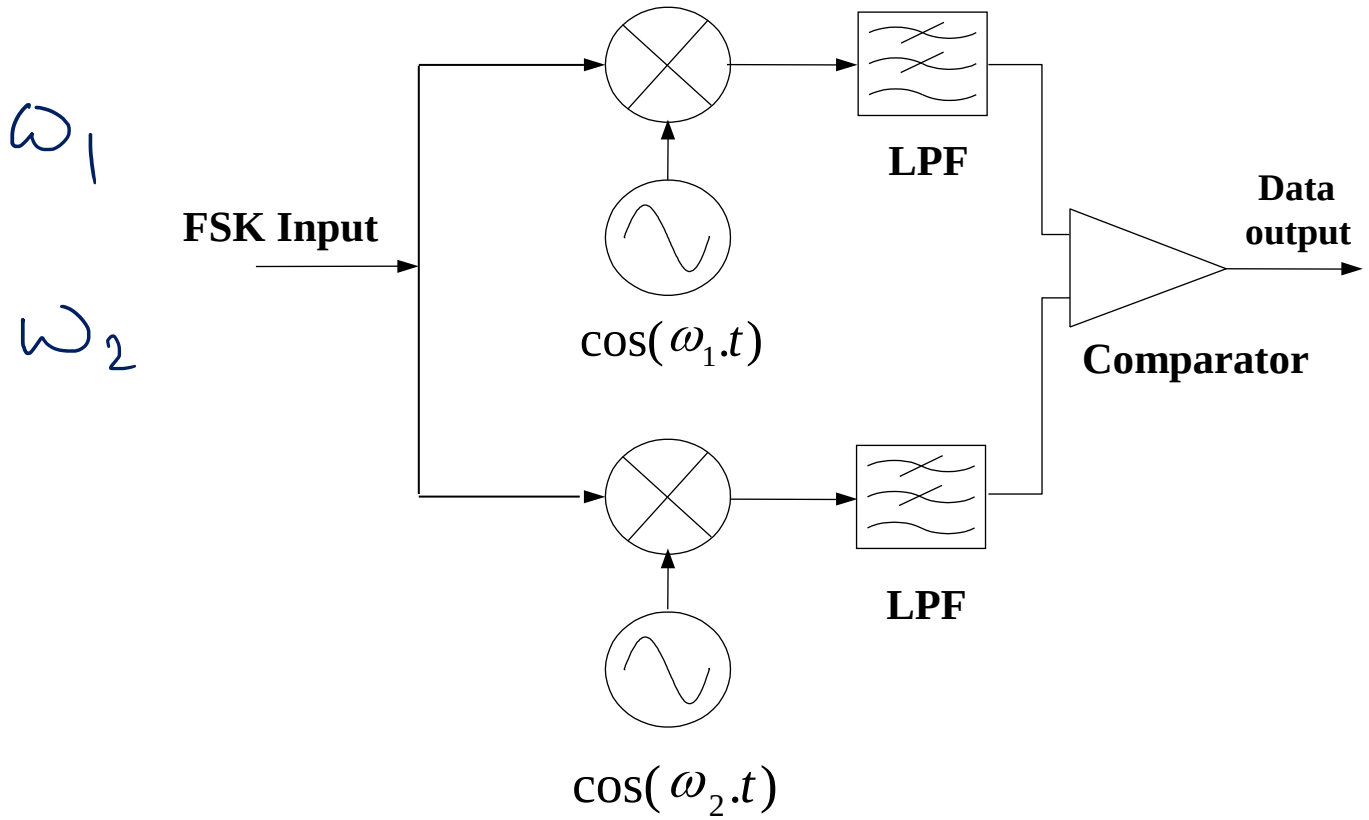
FSK Detection - PLL Method

- An alternative detection method for FSK is based on the PLL.
- The output signal is determined by the difference between the local carrier and the received signal.



Coherent FSK Detection

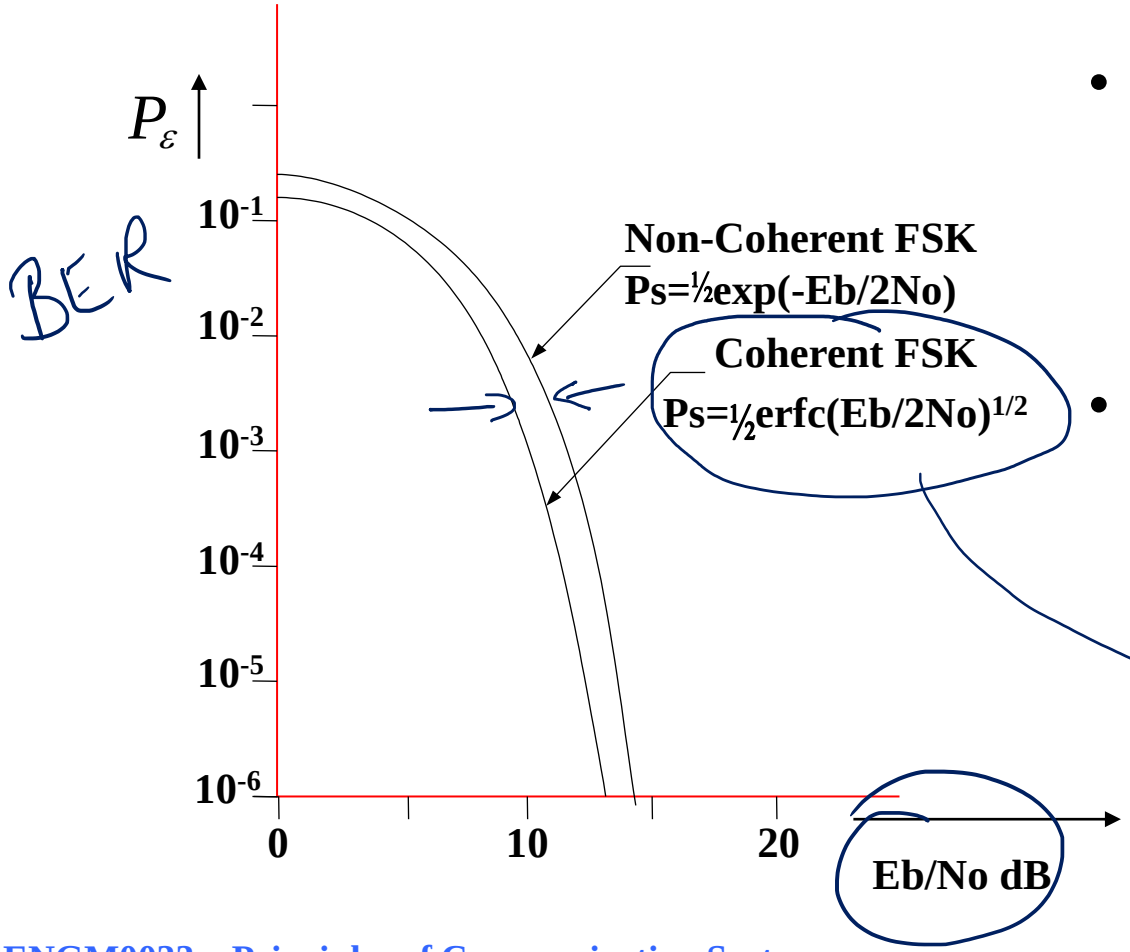
- A typical coherent FSK detector is shown below.



Coherent FSK Detection

- The two carrier frequencies required for binary FSK are generated at the receiver.
- Each detector only responds to the signal frequency it is set to demodulate.
- With binary FSK, one signal frequency should cause a detector to respond. The other signal frequency should provoke no response from the detector. This occurs when the frequencies of the signals are orthogonal. The product of the carrier with the incorrect signal frequency, over the symbol period, will integrate to zero.

BER Performance of FSK



- It can be seen that only about a 1dB advantage accrues from using coherent detectors at low BERs.
- For this reason it is very often acceptable to use non coherent FSK detectors.

Coherent ASK

$$P_e = \frac{1}{2}\,\mathrm{erfc}\sqrt{\frac{E_b}{2N_0}}$$

SAME

Advantages of FSK

- Detection can be based on the relative frequency changes between the states and thus does not require absolute frequency accuracy at the receiver. FSK is relatively tolerant to local oscillator drift and Doppler shift.
- Constant modulation envelope means this modulation method is insensitive to amplitude variations of the channel.
- This factor also has an advantage in mobile radio.
  - The power drain of the radio is largely determined by the power drain of the final power stage.
  - In general, the more non linear power stage, the more efficient that stage is.
  - Using a modulation that doesn't rely on amplitude being correct, is thus an advantage in this situation.

Disadvantages of FSK

- Slightly less bandwidth efficient than either ASK or PSK. (Not true for MSK)
- Bit/symbol error rate worse than PSK