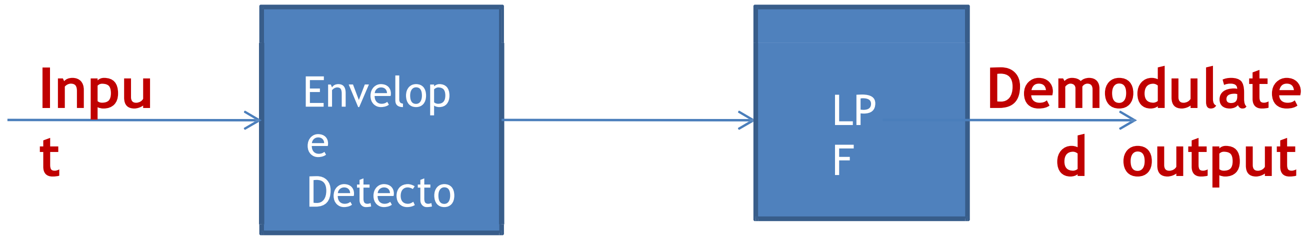
Digital Demodulation

Coherent vs Non coherent Detection

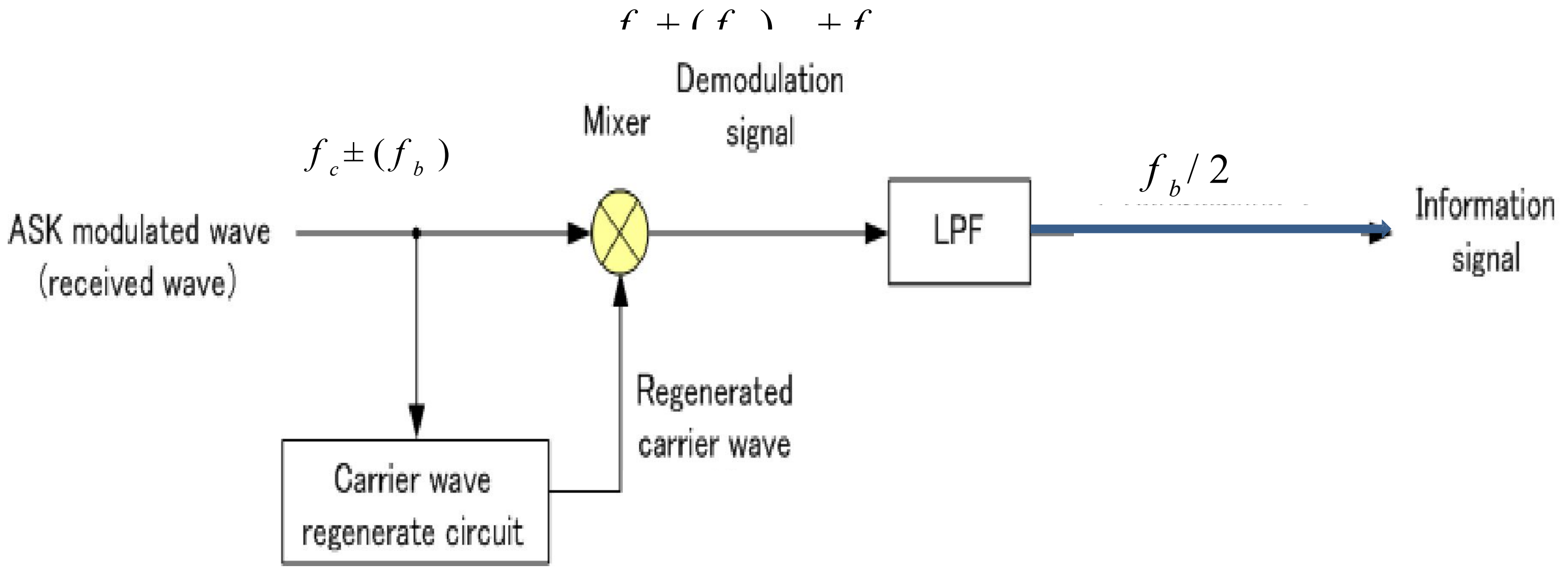
- In **coherent detection** the local carrier generated at the receiver is phase locked with the carrier used at the transmitter. Hence it is also called **synchronous detection**.

- In **non coherent detection** the local carrier generated at the receiver is not phase locked with the carrier used at the transmitter. Hence it is also called **Asynchronous detection**.

Asynchronous ASK Demodulator –Non coherent detection

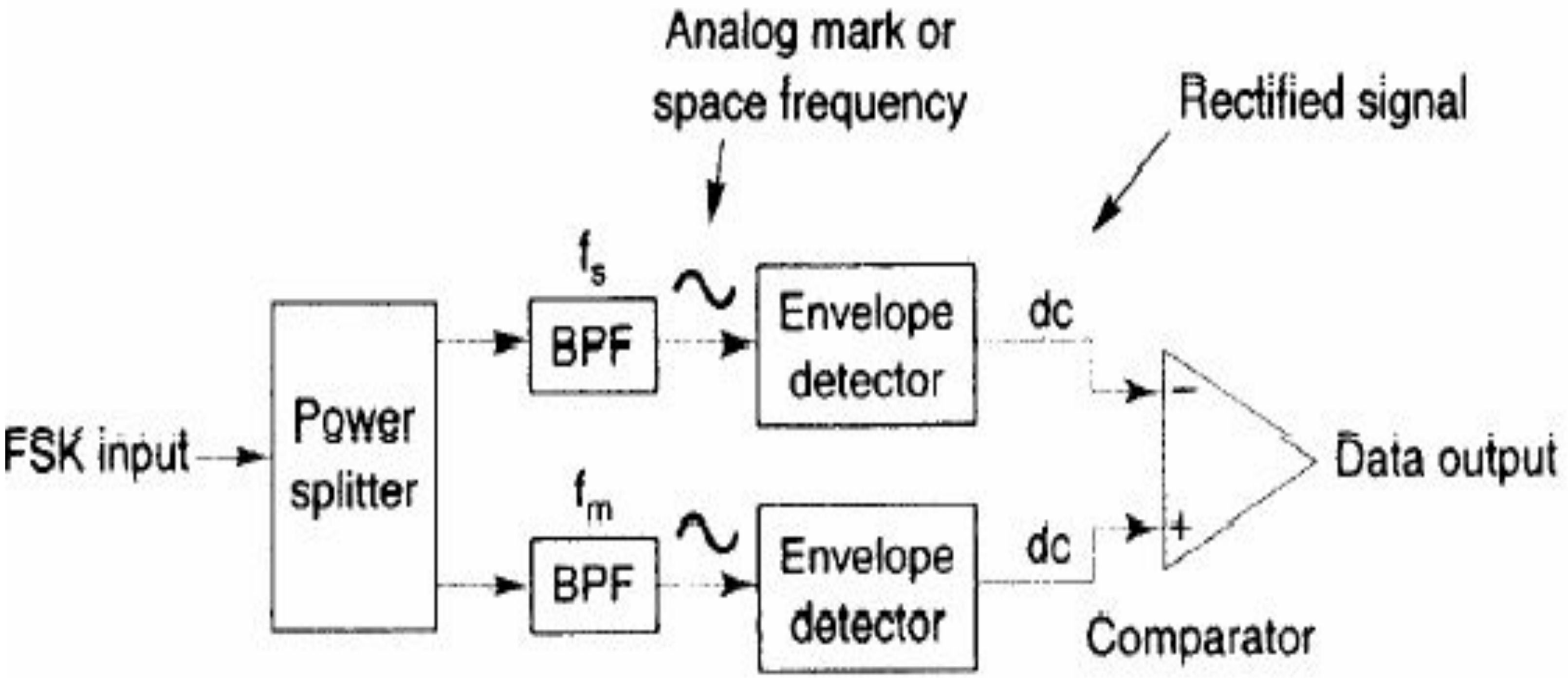


Synchronous ASK Demodulation- Coherent Detection

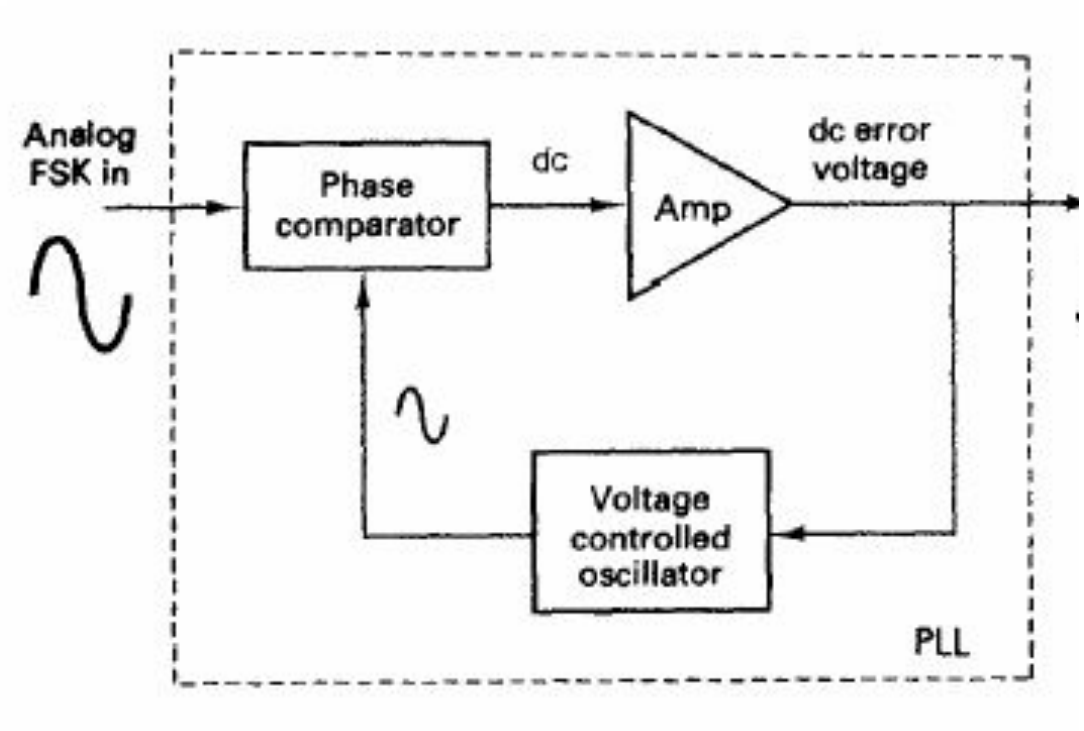


FSK Receiver

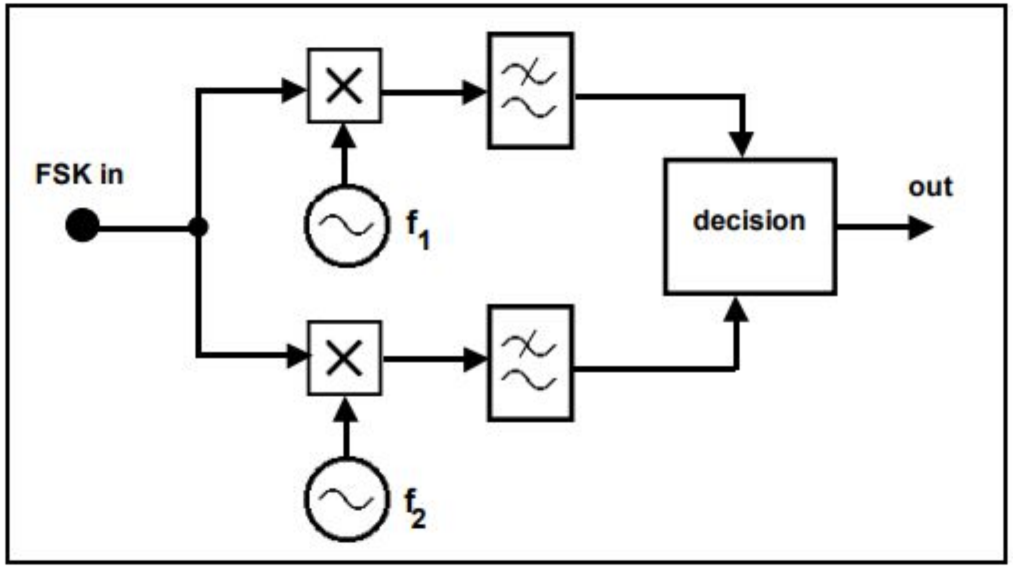
(a) Noncoherent FSK demodulator



(b) Coherent FSK demodulator



PLL-FSK demodulator

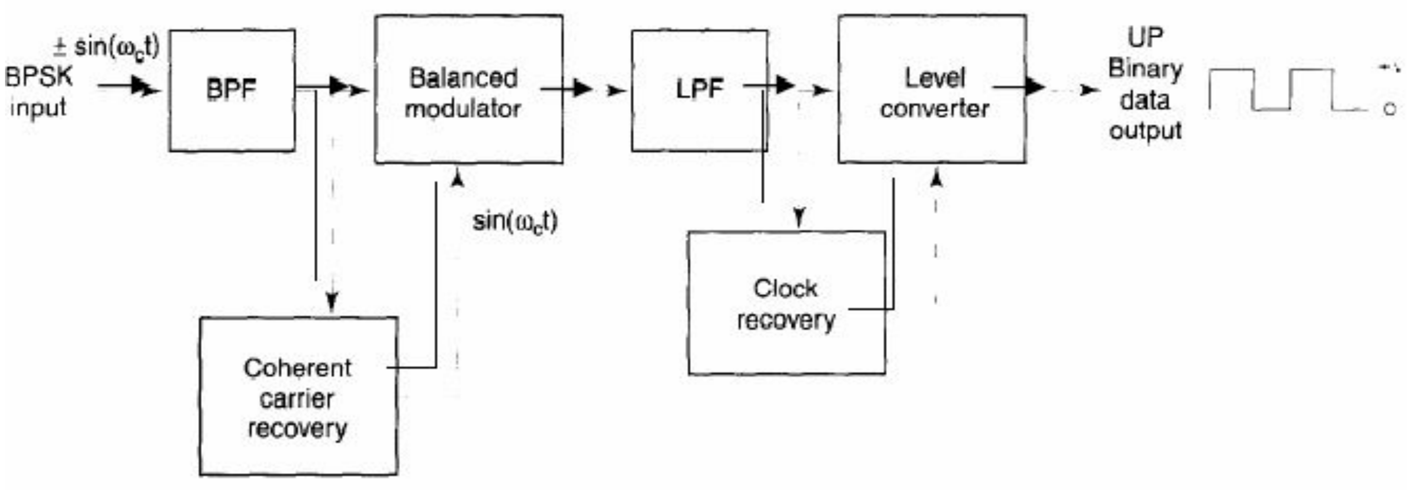


synchronous demodulation

PLL-FSK demodulator operation

- **As the input to the PLL shifts between the mark and space frequencies, the *dc error voltage at the output of the phase* comparator follows the frequency shift.**
- **Because there are only two input frequencies (mark and space), there are also only two output error**

BPSK receiver.



Demodulation

Mathematically, the demodulation process is as follows.

For a BPSK input signal of + sin $\omega_c t$ (logic 1), the output of the balanced modulator is

$$\text{output} = (\sin \omega_c t)(\sin \omega_c t) = \sin^2 \omega_c t \qquad (2.21)$$

or

$$\sin^2 \omega_c t = 0.5(1 - \cos 2\omega_c t) = 0.5 - 0.5\cos 2\omega_c t$$

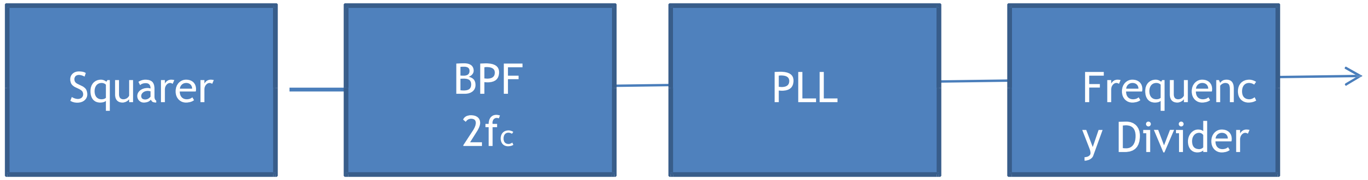
filtered out

leaving

$$\text{output} = +0.5 \text{ V} = \text{logic } 1$$

Carrier Recovery Circuit--Squaring Loop

- The incoming modulated signal is squared and band-pass filtered to extract the carrier component at 2 times its original frequency.
- This signal is then fed into a phase locked loop whose other input comes from a VCO.
- The error output of the phase locked loop is converted into a DC voltage which is fed back into the VCO to cause it to oscillate at a frequency which is almost same as the carrier frequency such that the error output reduces to nearly zero.
- This is then divided by two to give the in phase carrier frequency.



Input to squarer $= \pm \sin w_c t$ *(PSK input)*

Output of squarer

$= + \sin w_c$

${}^2 t$

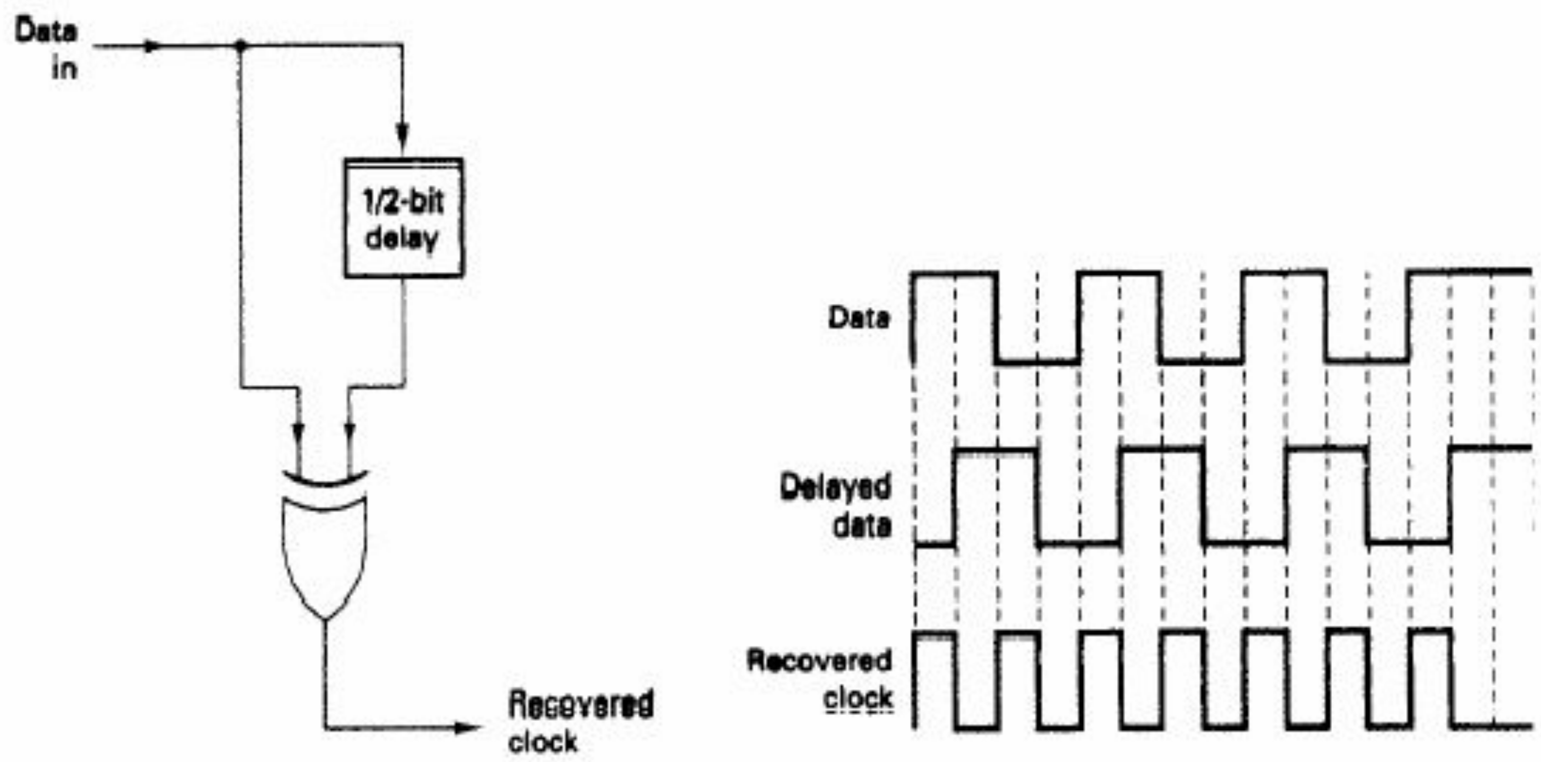
$= + \frac{1}{2}(1 - \cos 2w$

This is filtered to give

$= -\frac{1}{2} \cos 2w t$

This is divided by 2 to give in phase carrier frequency

Clock recovery and timing



COSTAS LOOP

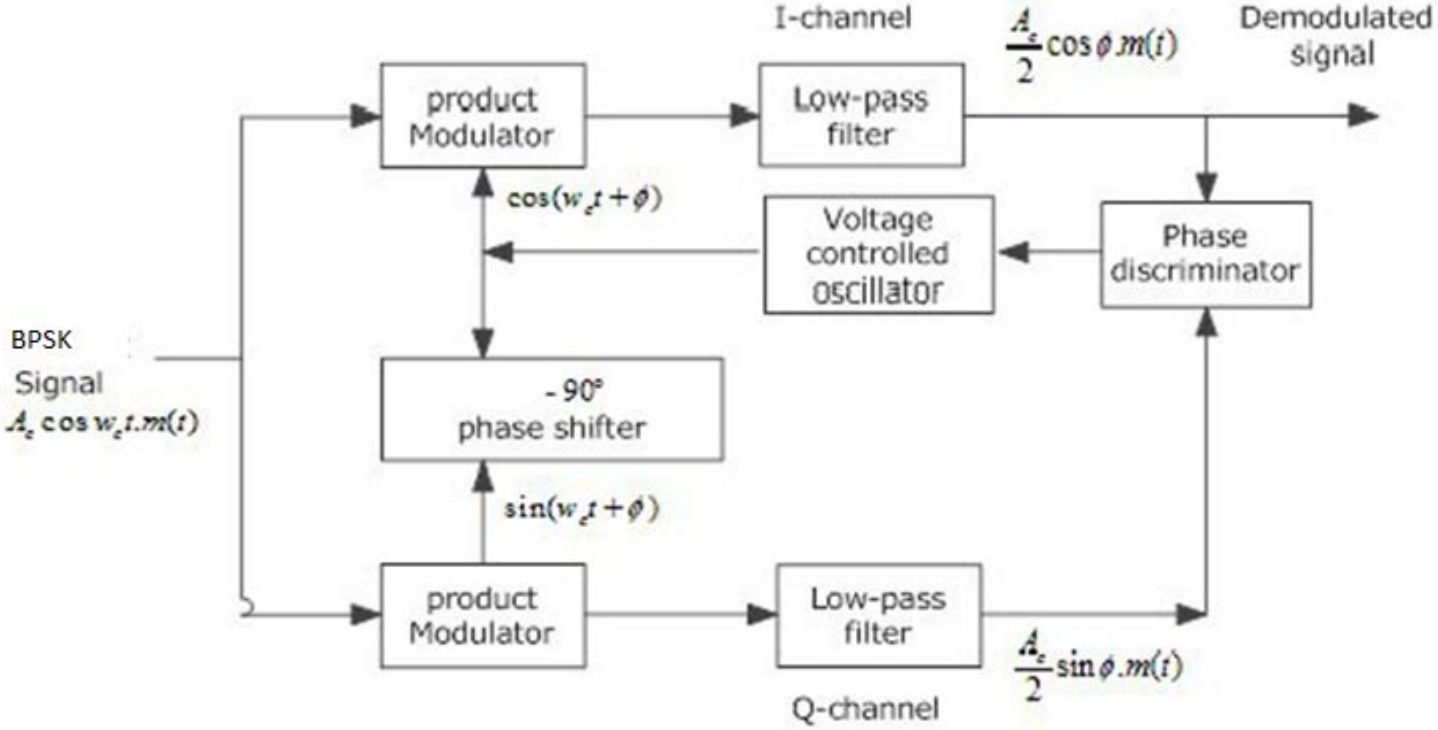


Figure: Costas receiver.

- It consists of two coherent detectors supplied with the same received PSK input
- Carrier is generated locally by using a VCO which is having a phase difference of φ for simplicity we assume that it has amplitude =1 volt.
- This carrier is given as it is to I product modulator
- Other product figure is applied the locally generated carrier with phase of 90° shift of as shown.
- Both the outputs of I and Q channel are passed through a LPF and are fed to a phase discriminator which is consisting of a multiplier followed by a low pass filter
- Output of the final LPF is error voltage which is proportional to sin2φ and it corrects VCO frequency

Output of I Modulator is

$$= A_c.\cos w_c t . m(t) \times \cos(w_c t + \varphi)$$

$$= \frac{A_c}{2} m(t) \{\cos(2 w_c t + \varphi) + \cos\varphi\}$$

After LPF it is $= \frac{A_c}{2} \to \to m(t)\cos\varphi$

Output of Q Modulator is

$$= A_c.\cos w_c t . m(t) \times \sin(w_c t + \varphi)$$

$$= \frac{A_c}{2} m(t) \{\sin(2 w_c t + \varphi) - \sin(-\varphi)\}$$

$$\frac{A_c}{2}$$

After LPF it is $= \frac{A_c}{2} m(t)\sin\varphi$

Output of phase discriminator is

$$= \frac{A_c}{2} m(t)\cos\varphi . \frac{A_c}{2} m(t) \left[\frac{A_c^2}{4} \cdot \frac{1}{2}\sin 2\varphi\right] m^2 \ ($$

as $\varphi \to 0$ *error voltage goes to* 0 *and it locks to carrier frequency.*

Differential Coding in BPSK

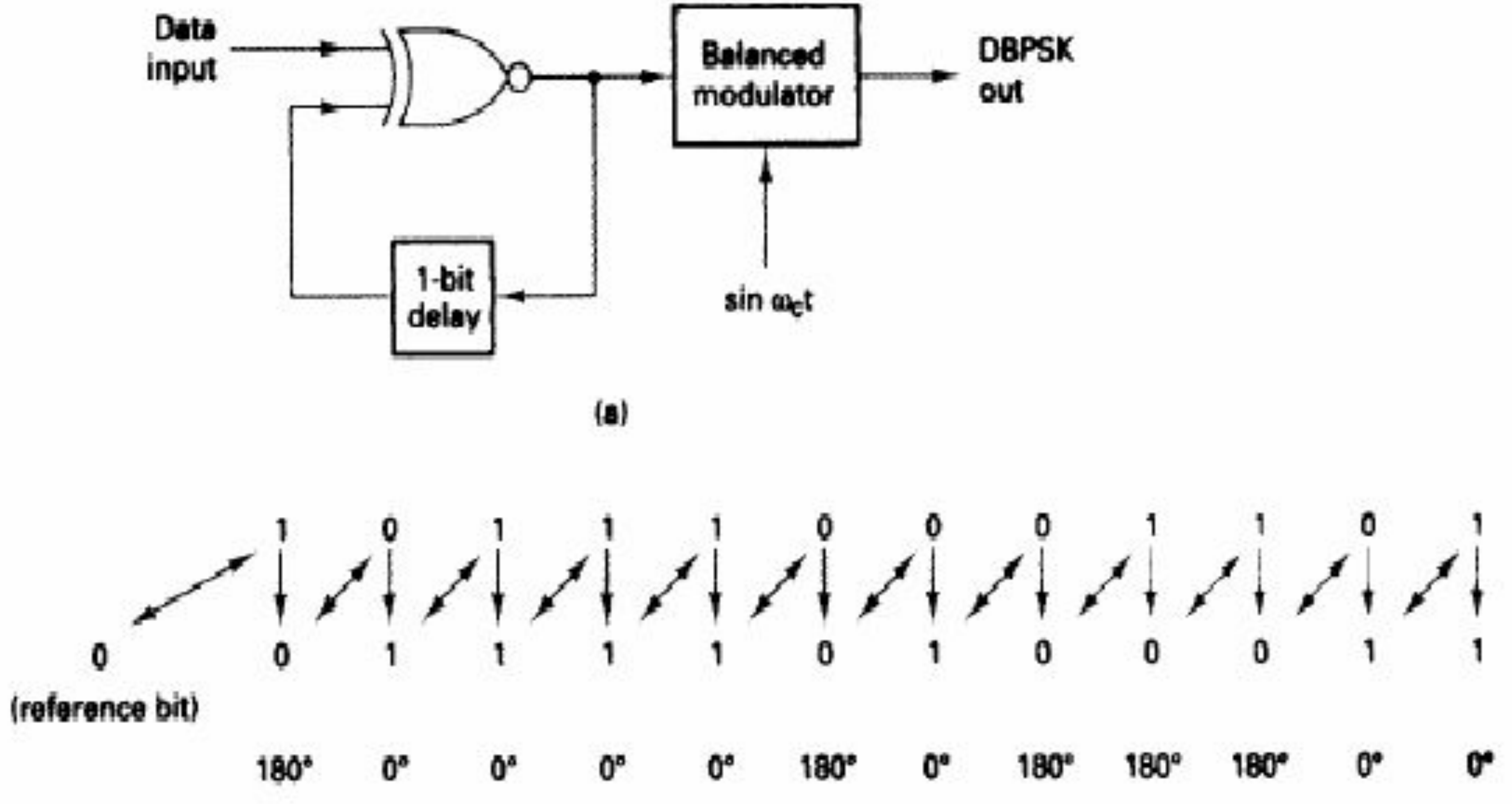
- BPSK demodulator outputs 0 and 1 for the input carrier phase of 0° and 180°.
- The input carrier phase is measured with respect to the recovered local carrier.
- If carrier is recovered using the 'multiply by 2 and divide by 2' technique, it removes the modulation and provides a carrier with fixed phase.

- However, the recovered carrier phase can be either in phase or 180 out of phase with the carrier used at modulator.

- To avoid phase ambiguity problem, modulator employs the differential coding technique.

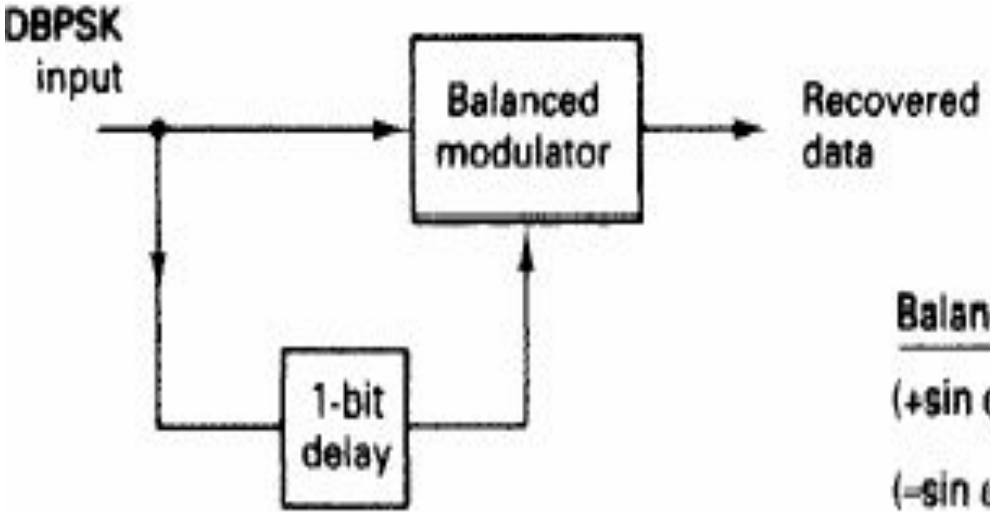
DIFFERENTIAL PHASE-SHIFT KEYING

Is an alternative for of digital modulation where binary the information is contained input in the difference between two successive signaling elements rather than the



(initial reference bit is assumed a logic 0, If the initial reference bit is assumed a logic 1, the output from the XNOR circuit is simply the complement of that shown)

DPSK Demodulation



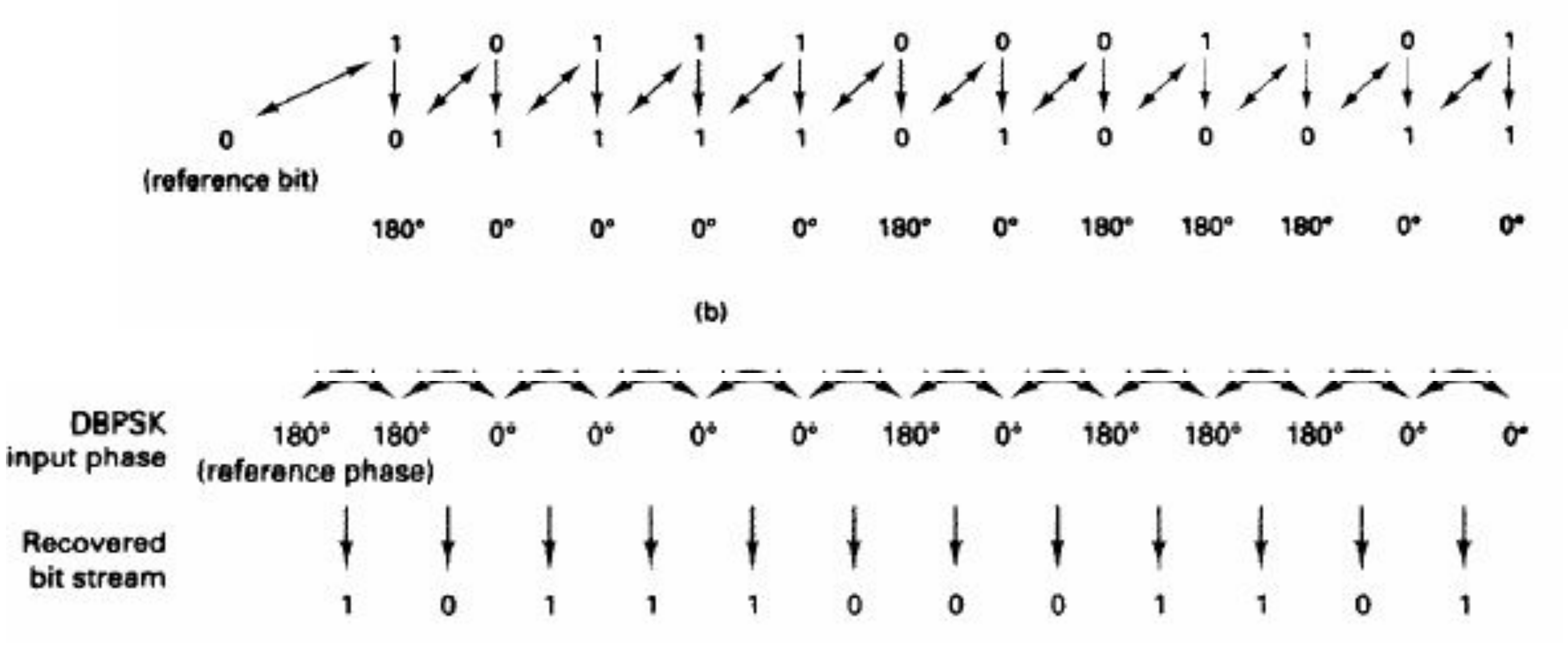
Balanced modulator output

$$(+\sin \omega_c t)(+\sin \omega_c t) = +\frac{1}{2} - \frac{1}{2}\cos 2\omega_c t$$

$$(-\sin \omega_c t)(-\sin \omega_c t) = +\frac{1}{2} - \frac{1}{2}\cos 2\omega_c t$$

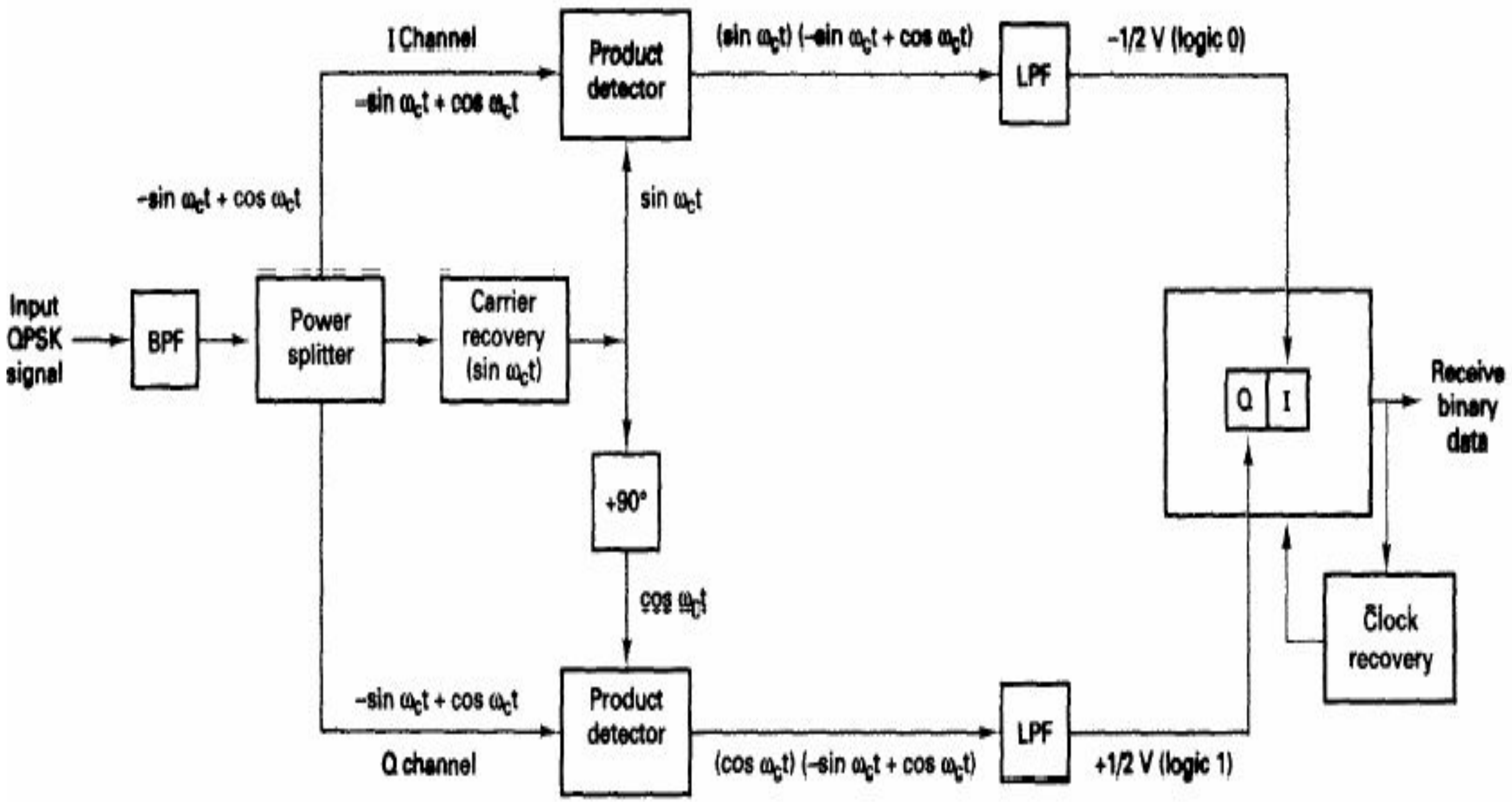
$$(-\sin \omega_c t)(+\sin \omega_c t) = -\frac{1}{2} + \frac{1}{2}\cos 2\omega_c t$$

DPSK Demodulation



Change of phase indicates 0, same phase indicates 1

QPSK receiver



Demodulation

(For input I=0 and Q=1

$$I = \underbrace{(-\sin\omega_c t + \cos\omega_c t)}_{\text{QPSK input signal}}\underbrace{(\sin\omega_c t)}_{\text{carrier}}$$

$$= (-\sin\omega_c t)(\sin\omega_c t) + (\cos\omega_c t)(\sin\omega_c t)$$

$$= -\sin^2\omega_c t + (\cos\omega_c t)(\sin\omega_c t)$$

$$= -\frac{1}{2}(1 - \cos 2\omega_c t) + \frac{1}{2}\sin(\omega_c + \omega_c)t + \frac{1}{2}\sin(\omega_c - \omega_c)t$$

$$I = -\frac{1}{2} + \underbrace{\frac{1}{2}\cos 2\omega_c t}_{\text{(filtered out)}} + \frac{1}{2}\sin 2\omega_c t + \underbrace{\frac{1}{2}\sin 0}_{\text{(equals 0)}}$$

$$= -\frac{1}{2}\text{V (logic 0)}$$

8-QAM receiver.

- An 8-QAM receiver is almost identical to the 8-PSK receiver