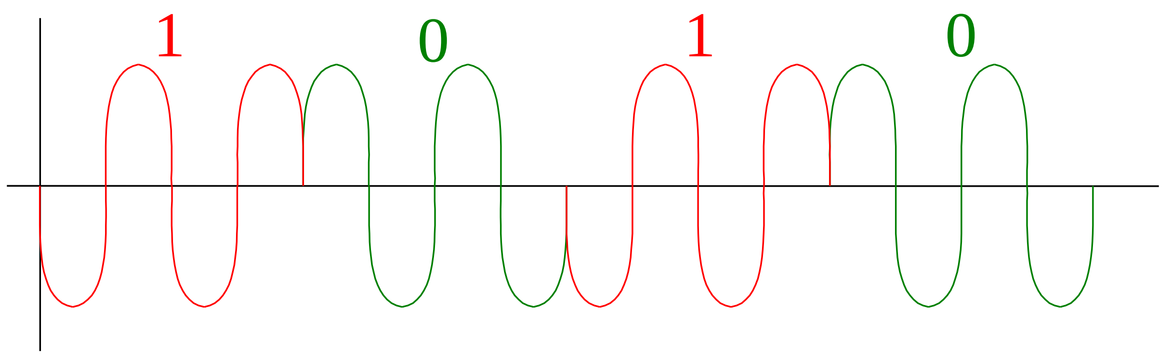
Phase Shift Keying (PSK)

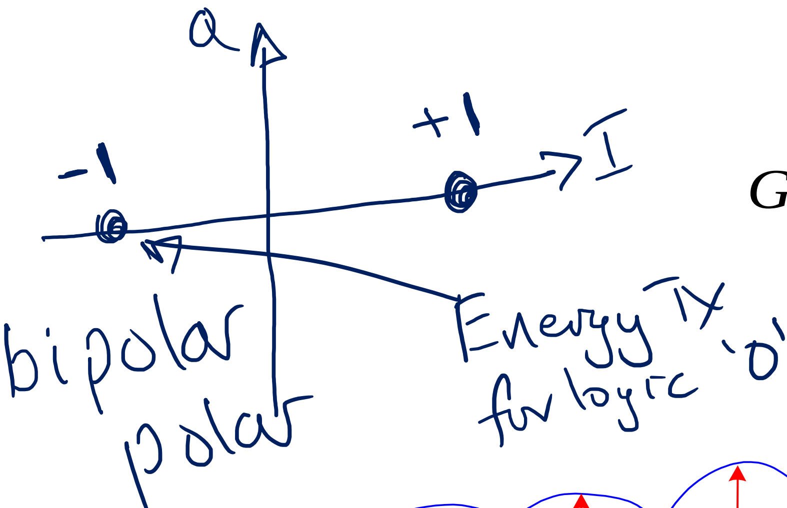
Phase Shift Keying (PSK)

- PSK modulates the phase of the signal, $s(t)=A\cos(\omega t+\theta(t))$
- The phase can be measured relative to a fixed carrier.
  - This is known as coherent PSK.
- Alternatively the information can be sent as a phase change between consecutive symbols.
  - This is known as differentially coherent PSK . DPSK
- There is no incoherent PSK

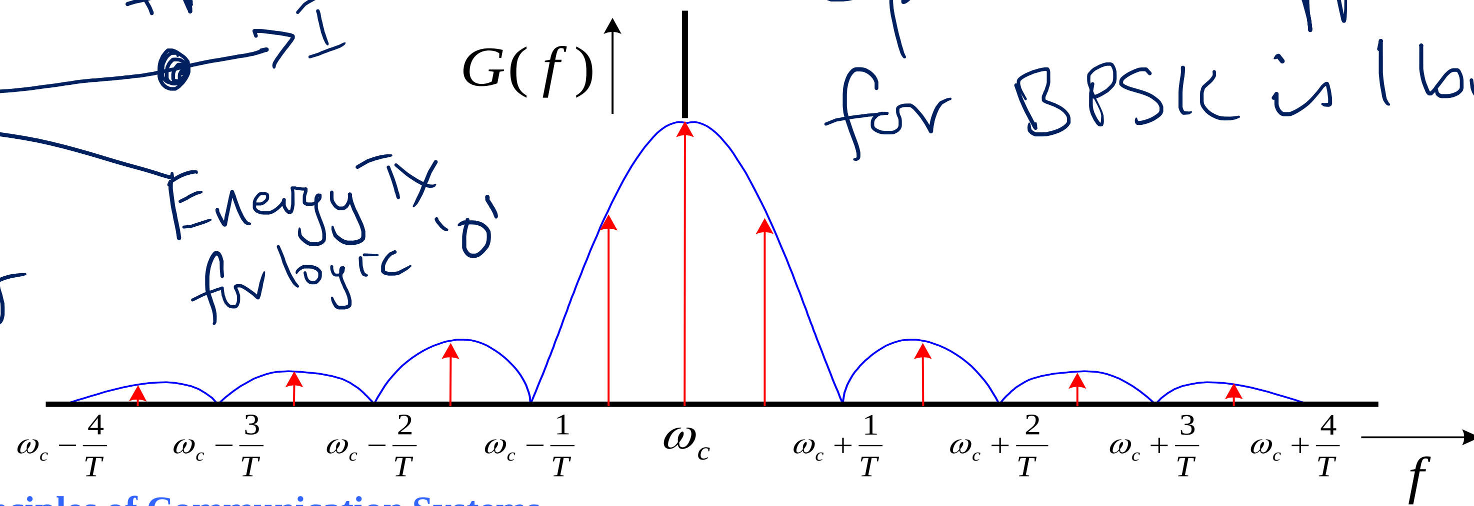


Spectral Occupancy of PSK

- The spectrum of binary PSK is identical to that of binary ASK.
- A binary PSK signal can be regarded as an ASK signal that has been modulated with a signal of +/- 1 (rather than 0 and 1). This is Polar ASK!

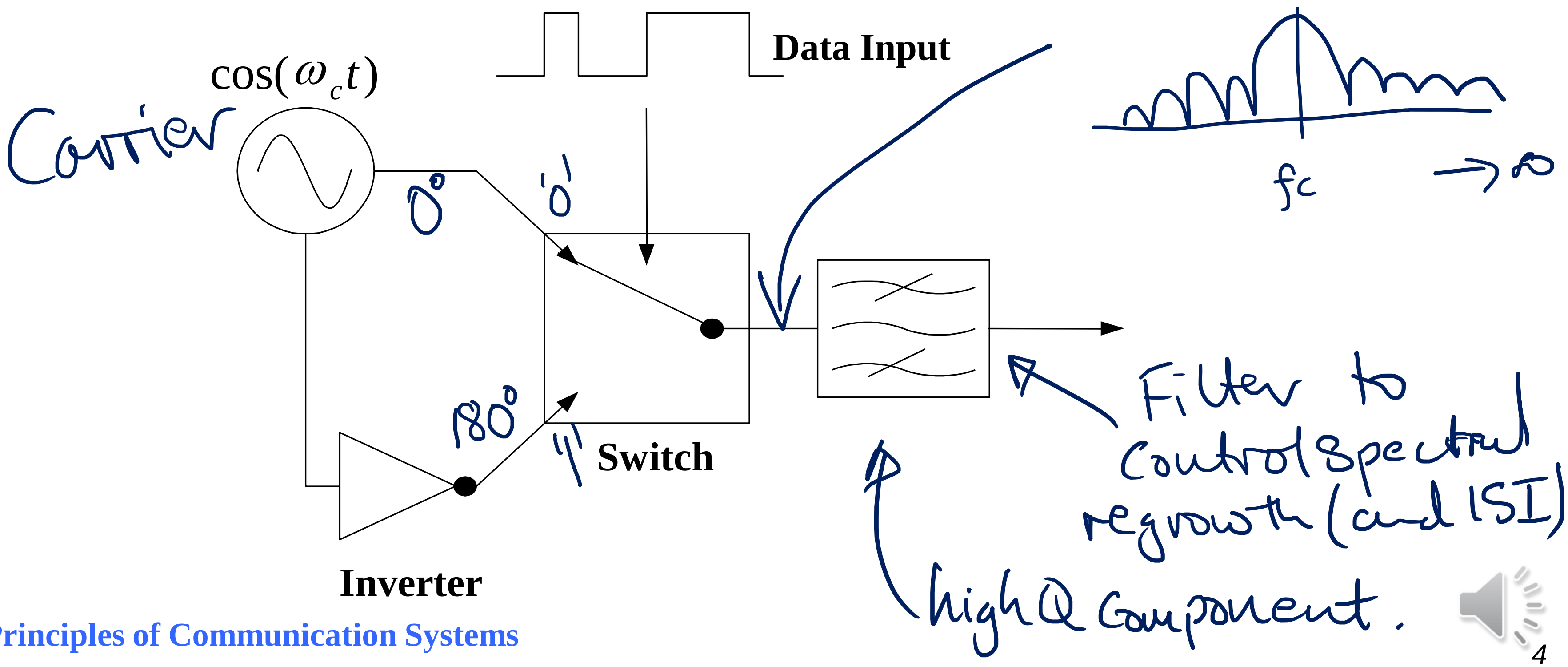


Spectrum efficiency for BPSK is 1 bit/s/Hz



Generation of Binary PSK (1)

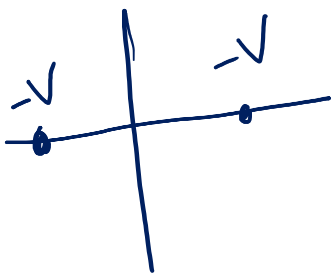
- One method of generating PSK is shown below
- It uses a switch to switch between a signal of 0 and 180 degree phase shift.

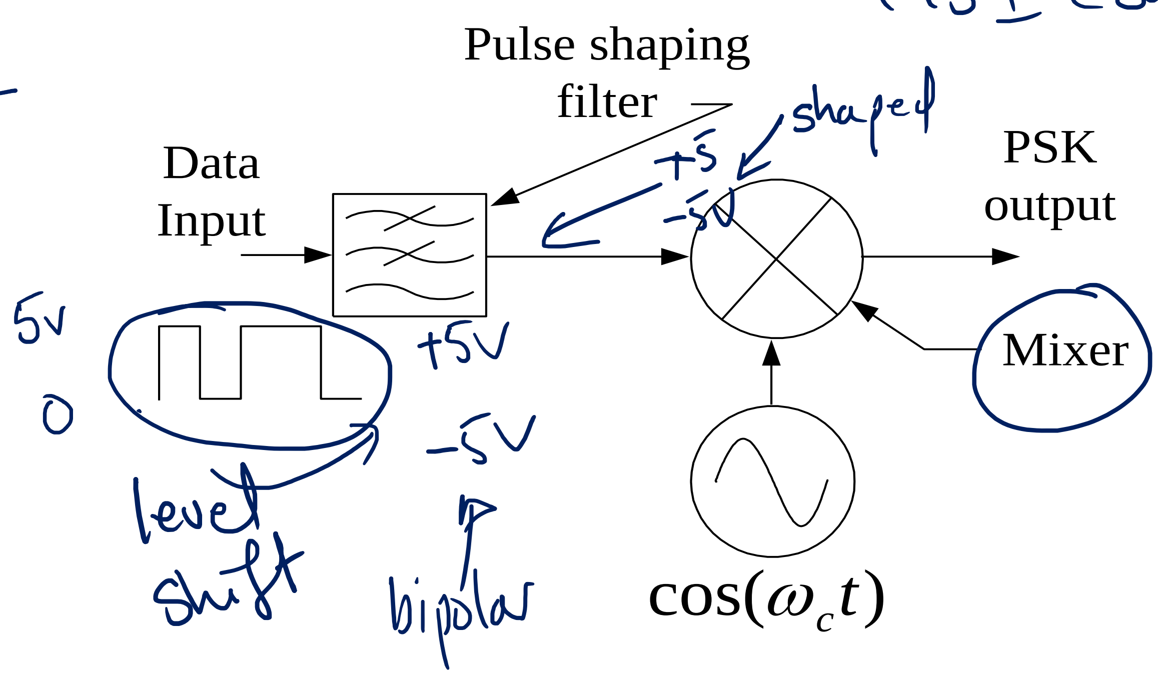


Generation of Binary PSK (2)

- Alternative method uses a linear multiplier to change the phase of the signals.

RRC → bandwidth control + ISI control



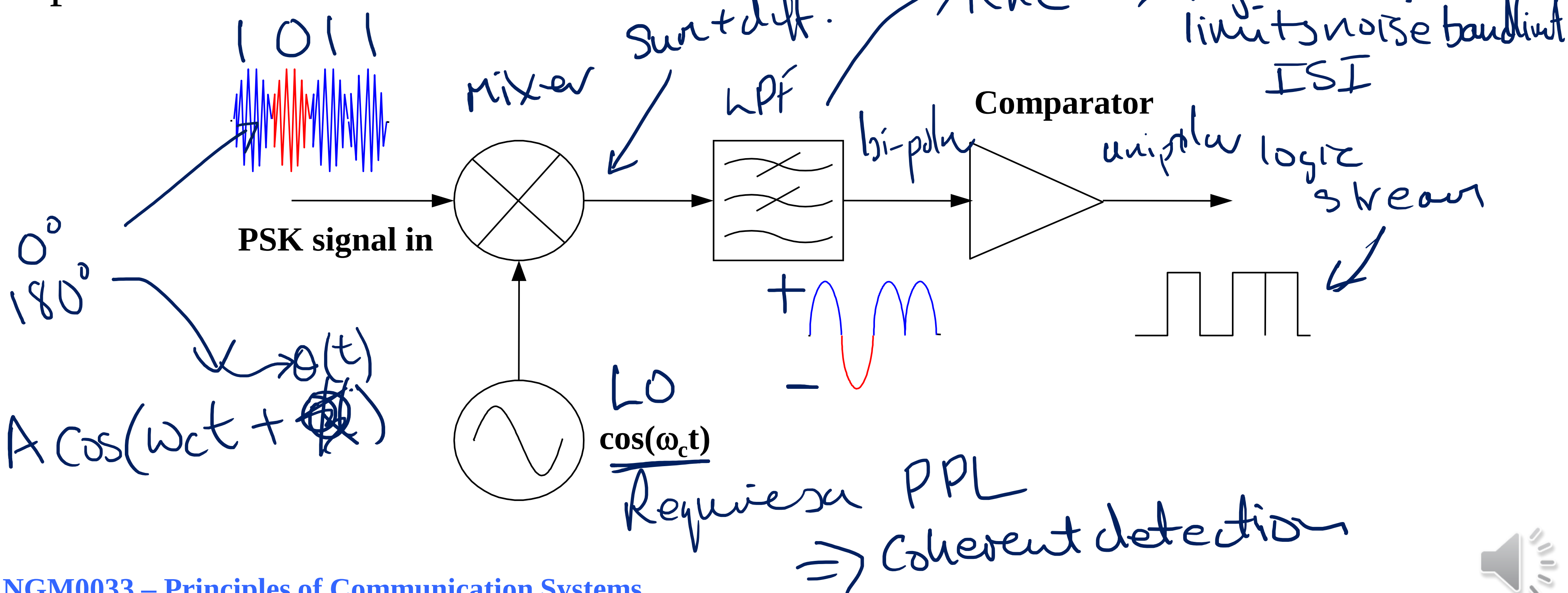


logic 1 → 0° Tx

logic 0 → 180° Tx

Detection of PSK

- There is no non-coherent method of detecting PSK.
- The method shown below requires a signal of exactly known phase to be present at the receiver.



Carrier Recovery

Carrier recovery for PSK.

LO

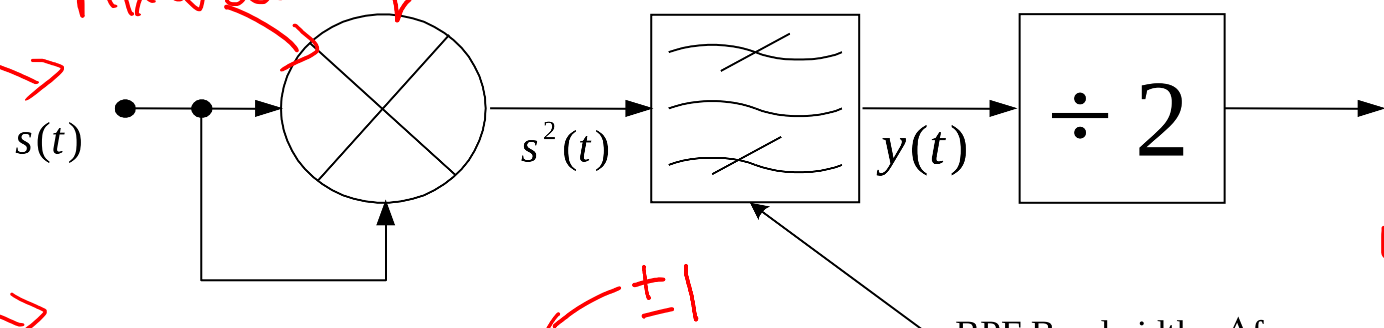
- The PLL can be use to generate the necessary local carrier signal.
- However, there is ambiguity in the phase of the signal. 0°, 180°
- It is possible that a regenerated carrier will interpret the ones as zeros and the zeros as ones.
- To overcome this problem, it is necessary to send a training sequence in which the position at which the ones and the zeros appear in the training sequence are known.
- Or, remove the data modulation before hand at the Rx (Squaring Loop
- Or, use Differential PSK.

Coherent Detection Using a Squaring Circuit

- A squaring loop circuit is shown below.

Mixer as a Squarer

Rx'd



fc with no data modulation

±1

$$s(t) = A_C.\cos(2.\pi.f_C.t).m(t)$$

$$s(t)^2 = \frac{A_c^2}{2}.m(t)^2.\left(1+\cos\left(2.2.\pi f_c.t\right)\right)$$

=1

$$y(t) = \frac{A_c^2}{2}.E.\Delta f.\left(\cos(4\pi f_c.t)\right)$$

(E = power spectral density of the message signal)

2fc with no data modulation

Coherent Detection Using a Squaring Circuit

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- Assuming that the input signal is given by:

$s(t) = A_C.\cos(2.\pi.f_C.t).m(t)$ ← ± 1

- After this is applied to the squarer we get the following signal.

$y(t) = s(t)^2 = A_C{}^2.\cos^2(2.\pi.f_C.t).m^2(t)$ $= 1$

$= (A_C{}^2/2).m(t)^2.[1+\cos(4.\pi.f_C.t)]$

Coherent Detection Using a Squaring Circuit

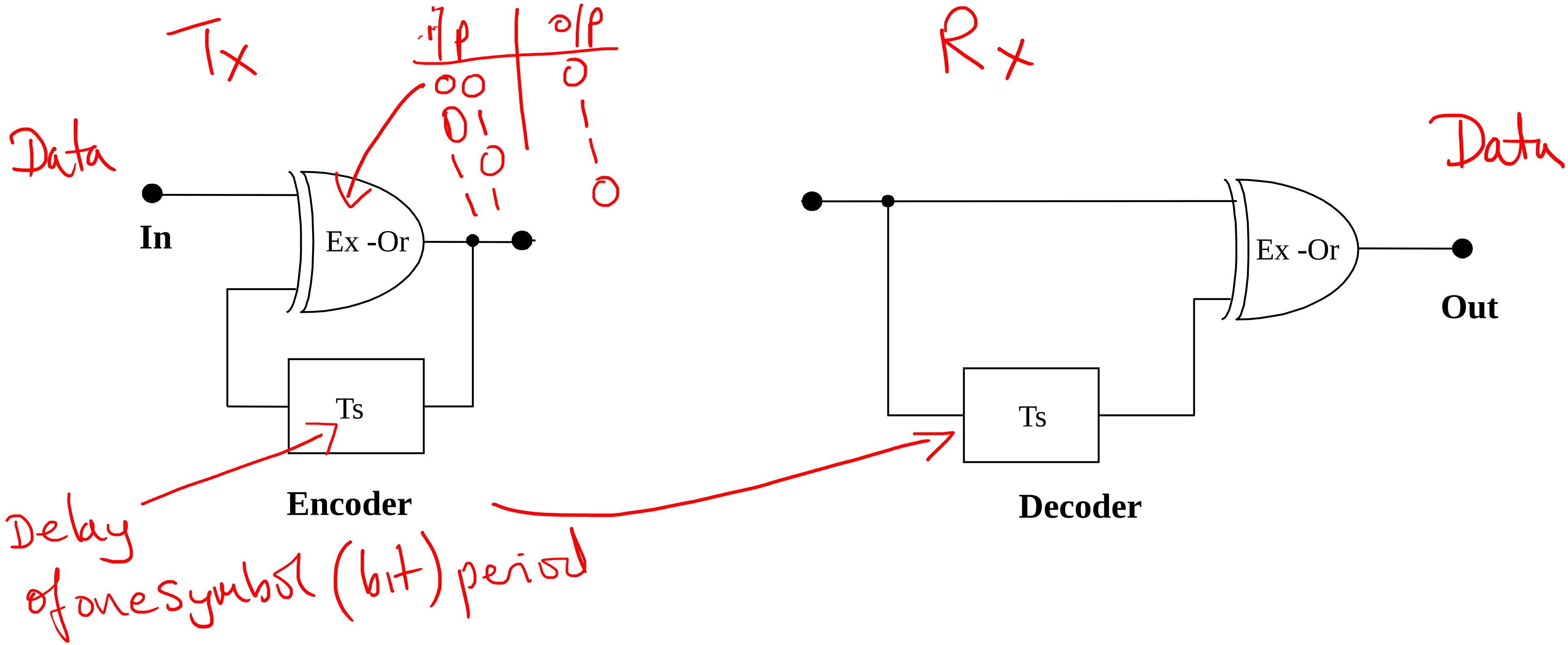
- If the bandwidth of the message is small enough for the spectrum of y(t) to be essentially constant over this bandwidth we can write:
- $v(t) = (A_C{}^2/2).E.\Delta f.\cos(4\pi f_C t)$

  where E is the energy of the message signal m(t)
- The resultant signal with twice the carrier frequency is tracked by the phase locked loop.
- This can now be divided down to the carrier frequency, by a simple flip flop.

Differentially Encoded Phase Shift Keying (DPSK)

Differentially Encoded PSK (DPSK)

- Differential encoder and decoder are shown below.



DPSK (2)

Baseband → logic levels

- Note that the output of the receiver (decoder) is the same as the input data stream to the encoder.

→ time

Ts

At the transmitter										
Input data stream	1	1	1	0	0	1	0	1	0	1
Delayed Data stream	1	0	1	0	0	0	1	1	0	0
Exclusive Or	0	1	0	0	0	1	1	0	0	1
At the receiver										
Input to receiver	0	1	0	0	0	1	1	0	0	1
Delayed Data	1	0	1	0	0	0	1	1	0	0
Output	1	1	1	0	0	1	0	1	0	1

Arbitary starting bit

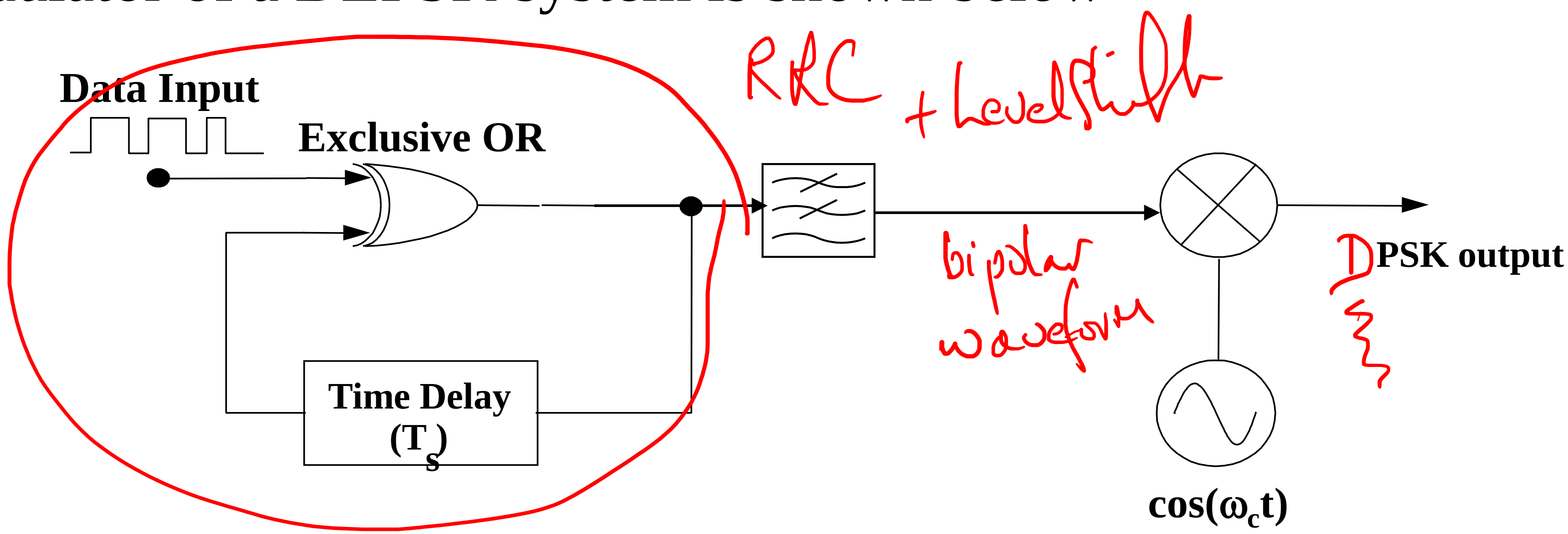
Output from transmitter

Tx encoded
↳ BPSK Tx
⇒ DPSK

previous data bit is used as reference for next data bit

DPSK Modulation

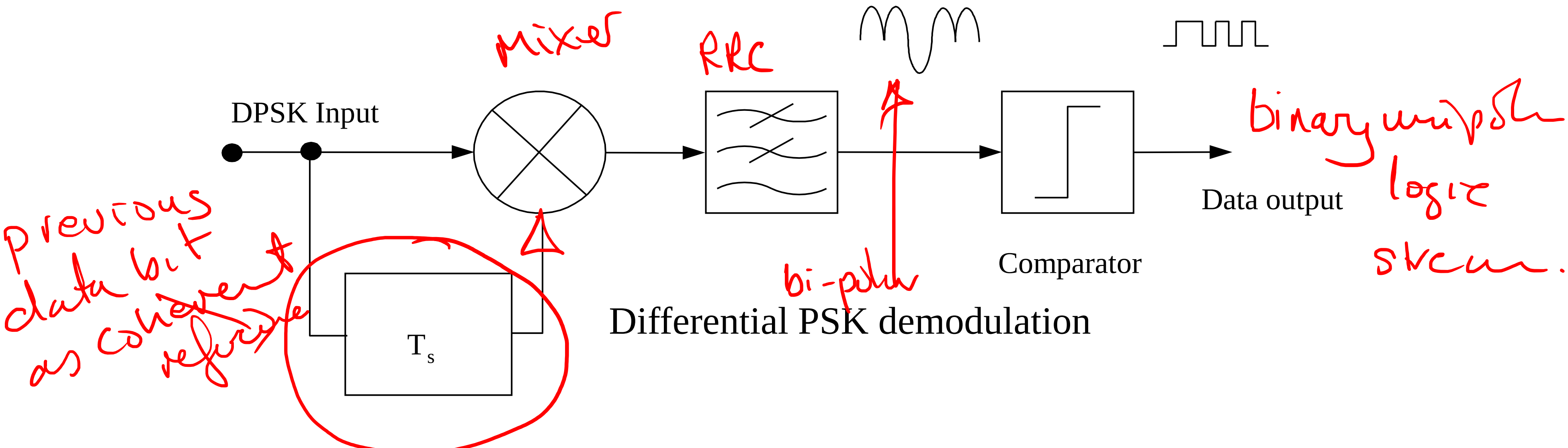
- The modulator of a DEPSK system is shown below



Differential PSK generator

DPSK Demodulation

- The circuit diagram for a DPSK demodulator is shown below.



Differential PSK demodulation

- Hybrid of Coherent Detection and Differential Detection
- Phase of the the previous bit acts as a reference for the succeeding bit

Disadvantages of Differentially Encoded PSK

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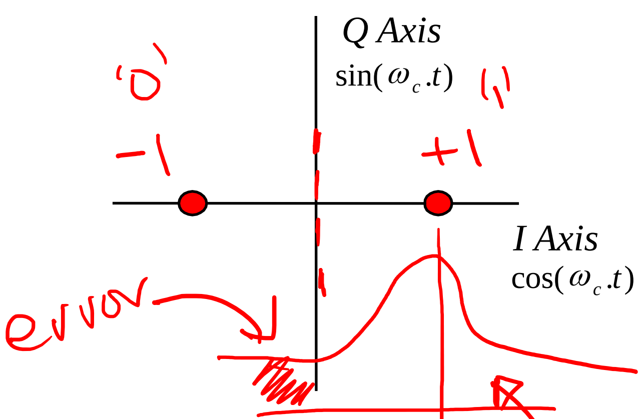
- Note that the noise immunity of DPSK is poorer than conventional PSK because the the phase reference for PSK comes directly from the ~~line~~ channel and is not as stable as a phase reference generated by other means.
- Also, there is potential for error propagation. Since each bit is 'decoded' relative to the previous one, if one symbol is in error then the next is also likely to be decoded in error.

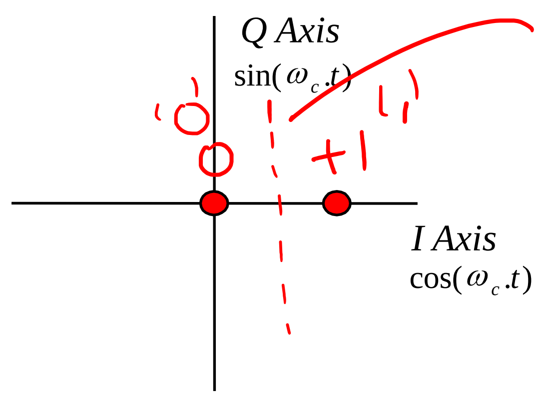
PSK Constellation Diagram (1)

- The constellation diagram of a PSK signal is shown below.



PSK Constellation Diagram

Pdf of AWGN



OOK ASK Constellation Diagram

logic threshold is $\frac{1}{2}$ of BPSK

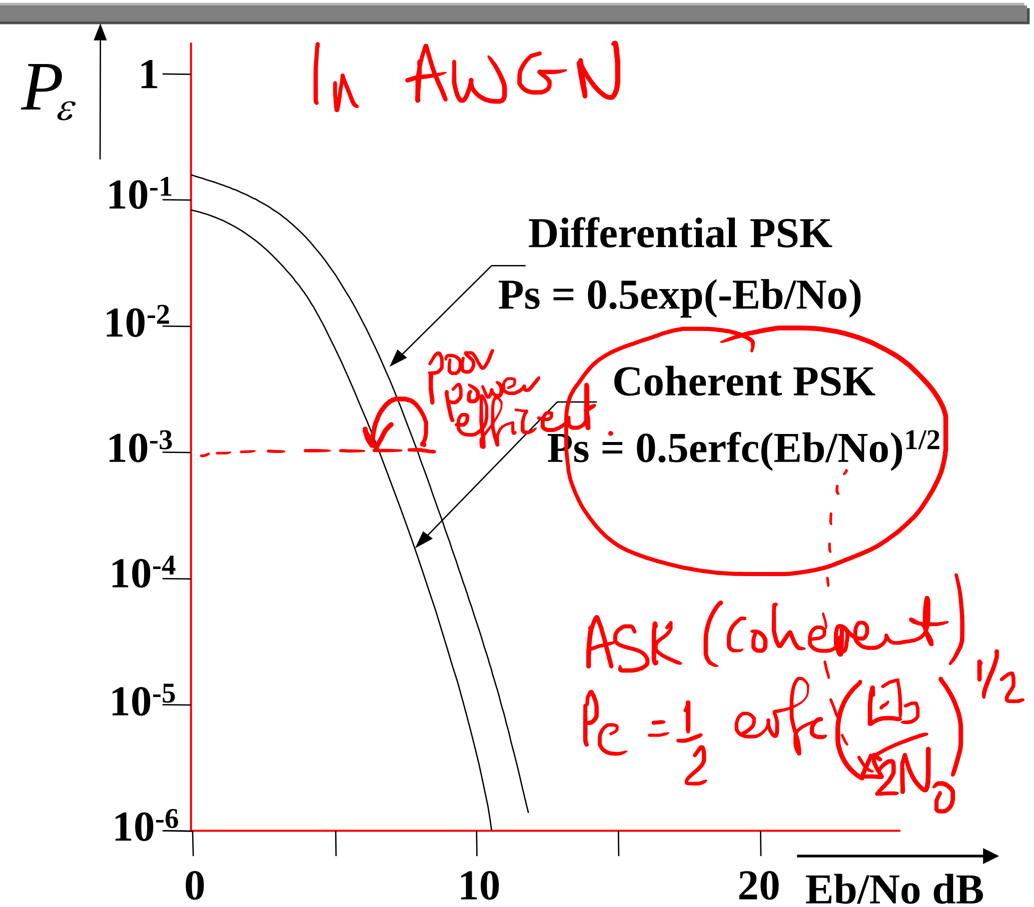
PSK Constellation Diagram (2)

- This type of constellation diagram is referred to as “antipodal” (as in antipodes).
- This means that the symbols are equal and opposite to each other in constellation space.
- Antipodal signals are seen as giving good noise immunity.
- Noise immunity is a function of the separation of the signal states.

BER versus E_b/N_0 for Binary PSK (1)

- As anticipated Differential PSK has a slightly worse performance compared with Coherent PSK.

due to error propagation



BER versus E_b/N_0 for Binary PSK (2)

- Note that the expression for the probability of error for the coherent PSK is similar to that for OOK ASK.
- The only difference is lack of a "2" in the denominator of the "erfc" function.
- This is a reflection of the separation of the signal states, and indicates that Coherent PSK is 3dB better than Coherent ASK.
- This is to be expected. As we showed earlier Binary PSK is equivalent to Binary Polar ASK. We already know that for baseband signals Polar signals offer 3dB advantage over On-Off signals.

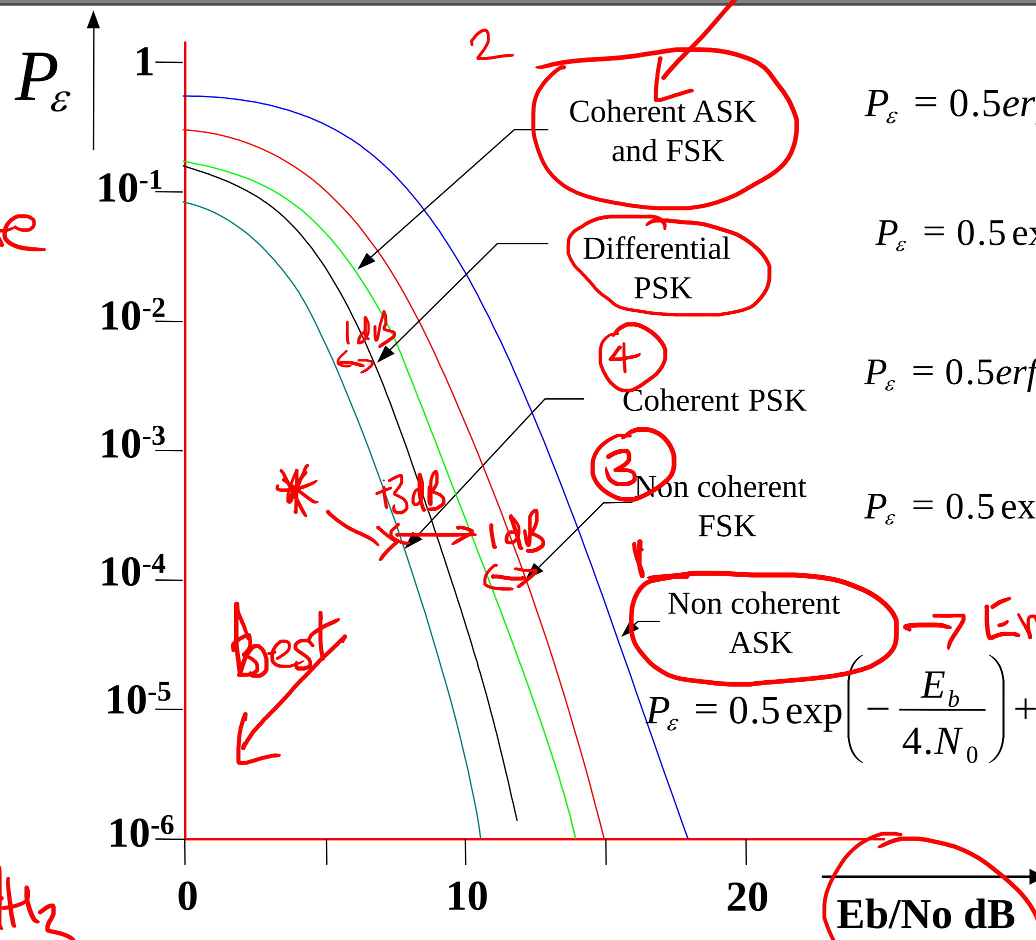
BER versus E_b/N_0 for Binary Bandpass Signalling (1)

Reject quadrature ~~inphase~~ noise

Bit Error Rate

Bandwidth efficiency is 1bit/s/Hz

Expect for MFSK
↳ ~2bit/s/Hz



$$P_\varepsilon = 0.5 erfc\left(\sqrt{\frac{E_b}{2.N_0}}\right)$$

$$P_\varepsilon = 0.5\exp\left(-\frac{E_b}{N_0}\right)$$

$$P_\varepsilon = 0.5 erfc\left(\sqrt{\frac{E_b}{N_0}}\right)$$

$$P_\varepsilon = 0.5\exp\left(-\frac{E_b}{2.N_0}\right)$$

$$P_\varepsilon = 0.5\exp\left(-\frac{E_b}{4.N_0}\right) + 0.5 erfc\left(\sqrt{\frac{E_b}{2.N_0}}\right)$$

→ Envelope detector → both I+Q noise

BER versus E_b/N_0 for Binary Bandpass Signalling (2)

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- Of all the binary modulation schemes, Coherent PSK is the most robust to additive noise.

- Non-coherent FSK performs less well but places lower demands on hardware. It is thus typically easier and cheaper to implement. When implemented as MSK it is also the most spectrally efficient.

- ASK offers a poor compromise between SNR requirements and spectral efficiency and is thus rarely used in practical applications.

- Thus, for binary modulation, the choice of modulation scheme is often between the cheaper simpler non-coherent FSK and the more robust coherent PSK. + DPSK for mobile applications