UNIVERSITY OF
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Digital Transmission

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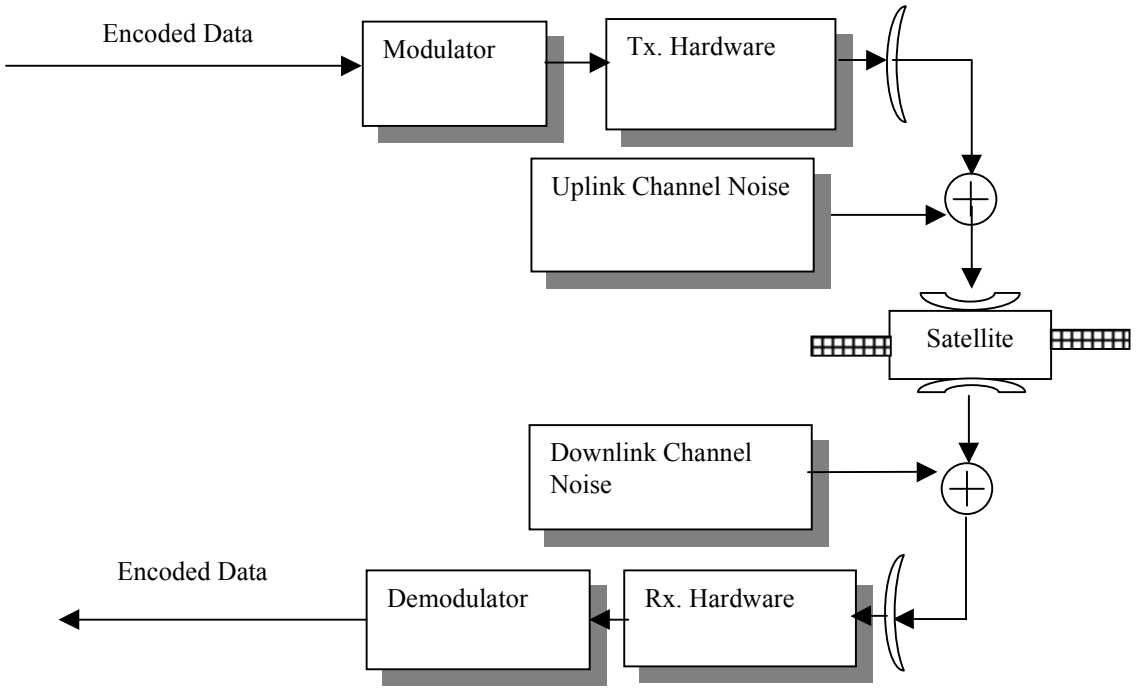
Tx/RX Chain


Encoded Data
Modulator
Tx. Hardware
Uplink Channel Noise
Satellite
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Encoded Data
Demodulator
Rx. Hardware

Digital Modulation

- Phase modulation is virtually the only means of modulating a signal in satellite communications
- This is known as Phase Shift Keying (PSK)
  - Two-state PSK is known as BPSK
  - Four-state PSK is known as QPSK
- Satellite operators tend to limit operation to BPSK and QPSK

PSK

- Phase of carrier is changed in accordance with the baseband digital streams
- General form is given bt

$$V(t) = A\cos(\omega_0 t + \varphi_m)$$

- Where:

φ_m is the phase angle varied in accordance with the information signal

- φ_m is defined as

$\varphi_m = (2m+1)\pi/M$, where m is of value 0 to (M-1)

BPSK

- It is possible to group several bits of information as a symbol
- When combining N information bits there is the possibility of $M = 2^N$ states
- When $N = 1$, $M = 2$

  m takes values of 0 and 1

  $\varphi_m = \pi/2$ and $3\pi/2$
- Carrier phase is changed by 180^0 for each bit. This is BPSK

QPSK

- When two bits are combined as a symbol, there are 4 possible phase states corresponding to:

  0^0, 90^0, 180^0 and 270^0

- This is known as QPSK (Q is for Quadrature)
- In general, when N baseband bits are combined to give M carrier states, such a scheme is known as M-ary PSK

Symbol and Bit Rate

- For PSK, the relationship between symbol rate R_s bauds and baseband bit rate R_b is given by

  $R_s = R_b/(\log_2 M)$ bauds

- E.G. for BPSK

  $R_s = R_b$ $\quad (\text{Log}_2 2 = 1)$

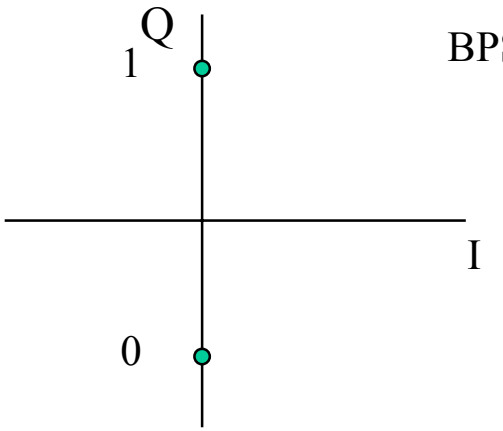
- and for QPSK

  $R_s = R_b/2$ $\quad (\log_2 4 = 2)$

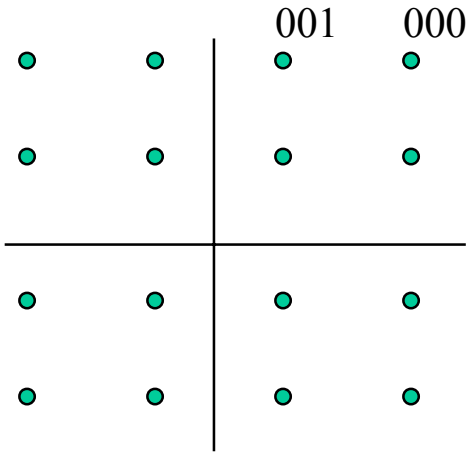
Quadrature Amplitude Modulation

- It is possible to vary amplitude as well as phase
- This is known as Quadrature Amplitude Modulation
- Information is carried in both phase and amplitude components of the carrier
- Not yet considered suitable for satellite due to sensitivity to amplitude fluctuations

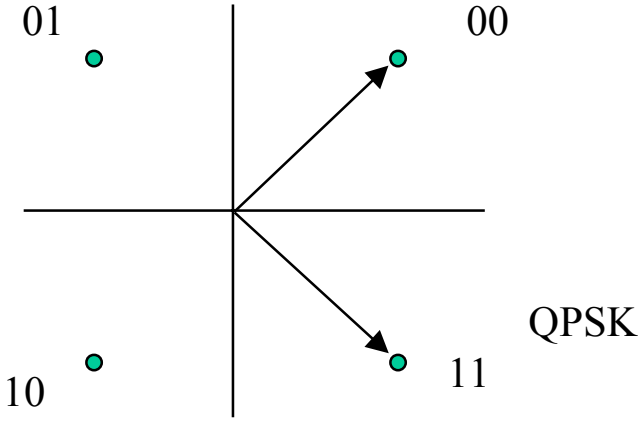
Phase Diagrams



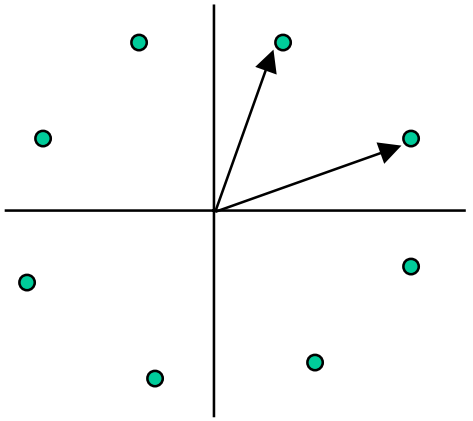
BPSK



16-QAM



QPSK

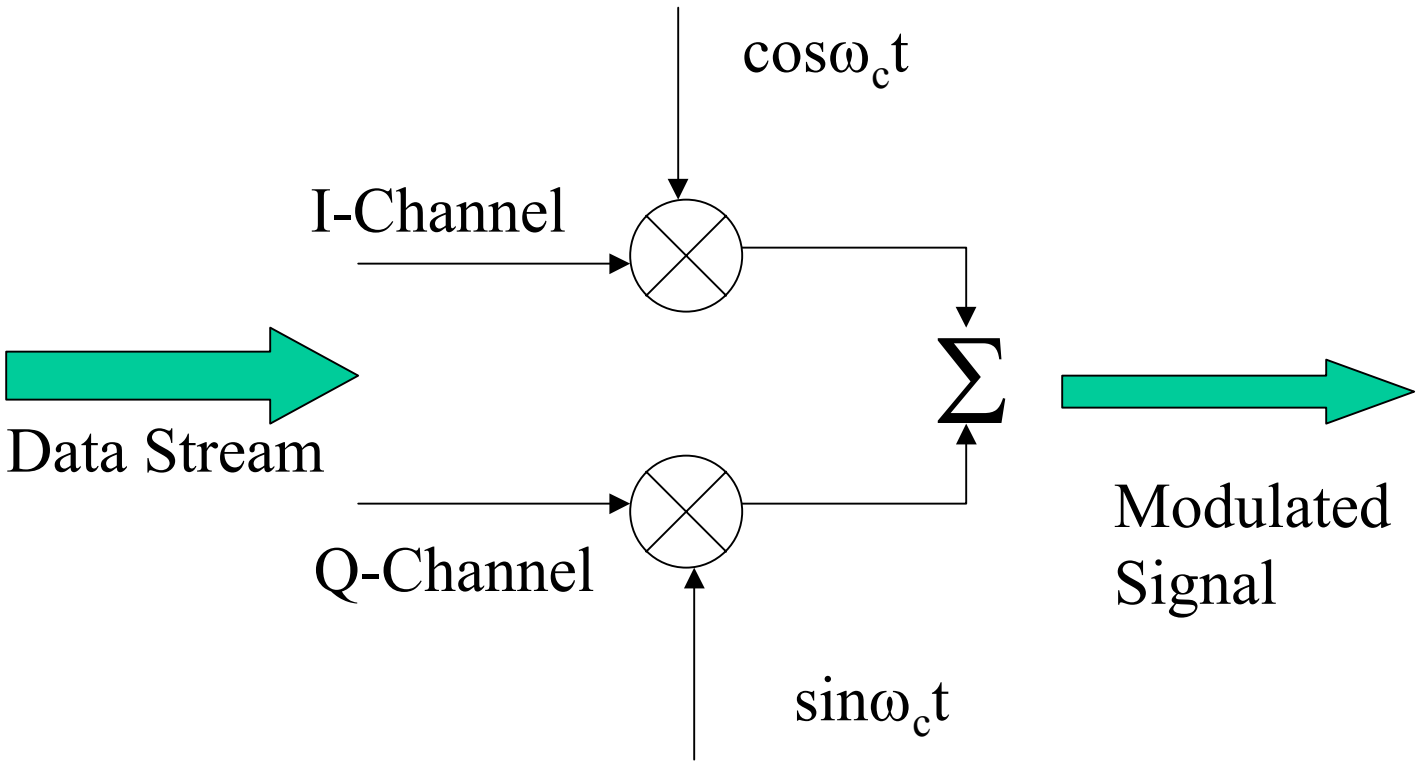


8-phase PSK

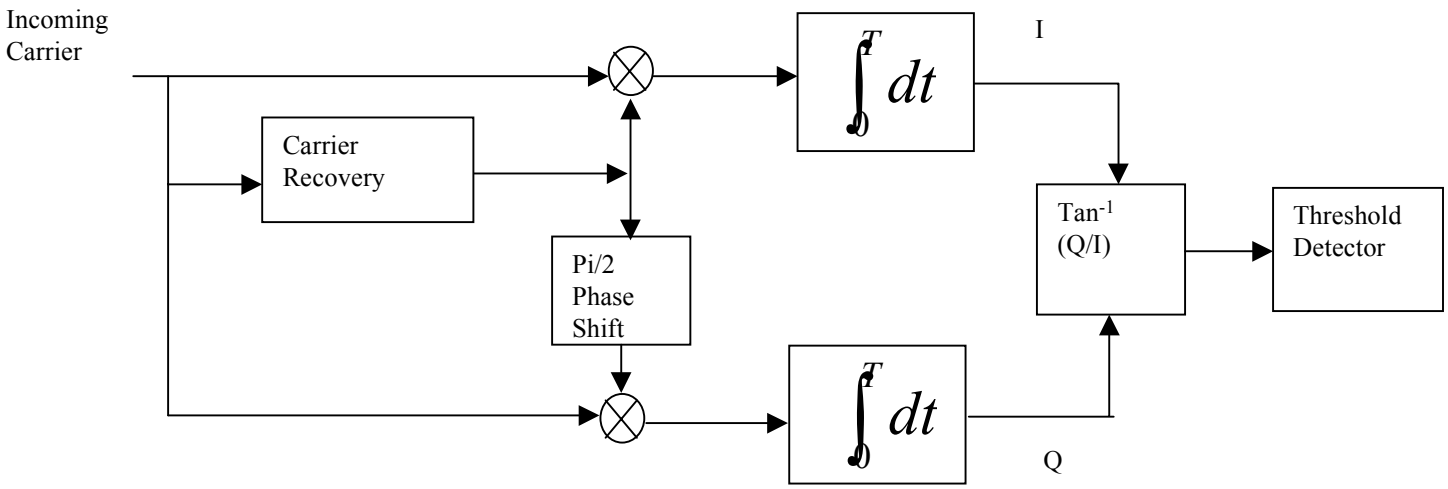
PSK Modulation and Demodulation

- Modulation is achieved using balanced amplitude modulators
- Demodulation is achieved by coherent detection
- Read up on these techniques

QPSK Modulator



QPSK Demodulator



Offset - QPSK

- In QPSK, a 180^{o} phase change occurs when the I and Q bits change simultaneously
- Offset -QPSK is used to reduce the amplitude variation caused by 180^{o} phase change
- In O-QPSK the maximum phase change is limited to 90^{o}
- Achieved by delaying Q with respect to the I channel by a half-bit period

BPSK and QPSK Bit Error Rate

- The bit error rate for BPSK and QPSK is given by

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

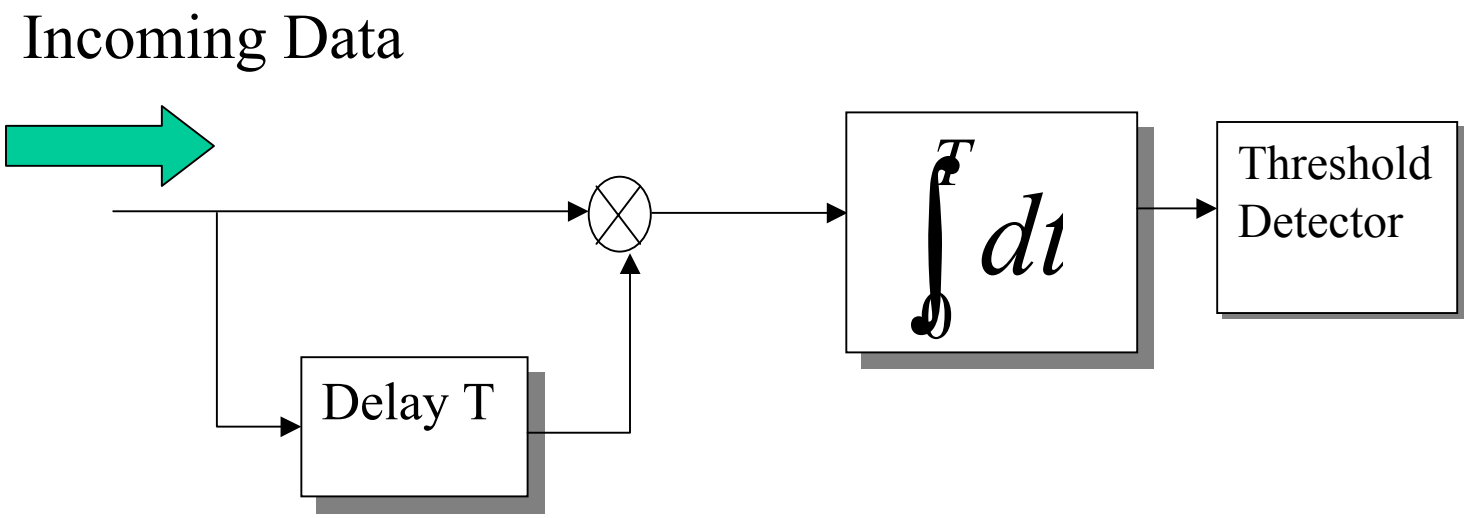
Symbol Error Rate

- For M-ary PSK (M > 2) error rate should be specified in terms of symbol error rate
- Symbol error rate of QPSK is given by

$$P_{es} = \frac{1}{2} erfc\left(\sqrt{\frac{E_s}{2N_0}}\right)$$

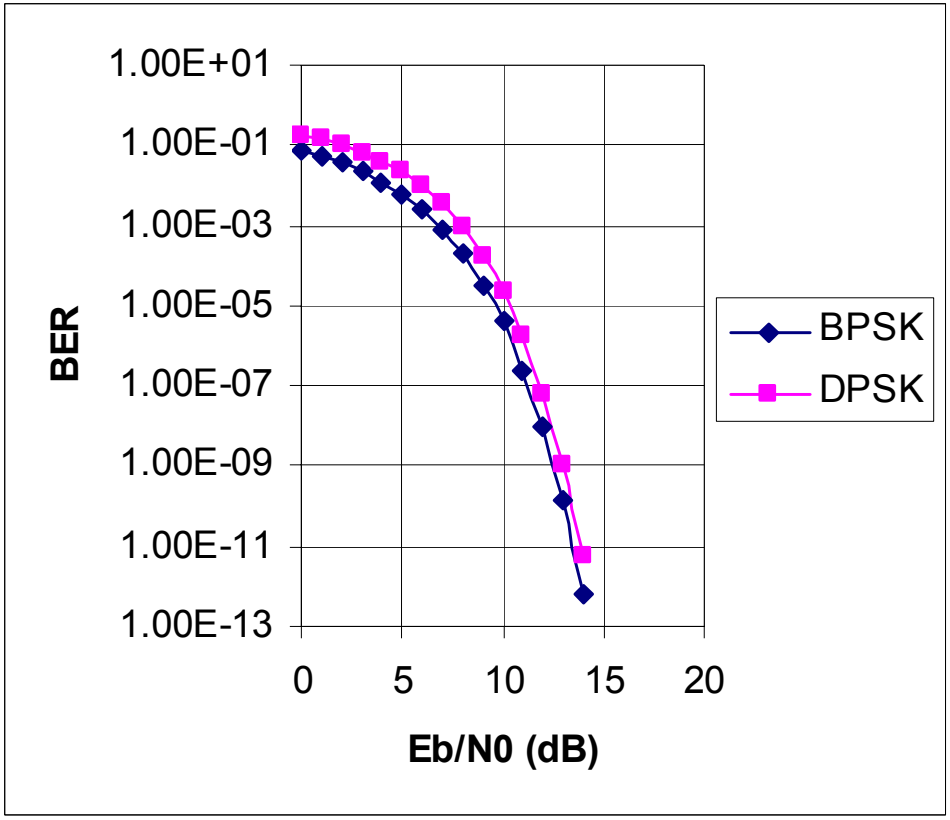
- When bit rate, RF bandwidth and satellite EIRP are the same, QPSK has a higher error rate than BPSK. However, it has twice the capacity

DPSK Modulator



Used to remove sign ambiguity at the receiver

BPSK & DPSK Performance



Directed Reading

- Chapter 5, Mobile Satellite Communication Networks, Sheriff & Hu
- Blackboard multiple choice revision questions