–•–• ––•– –•• • •••– • ––••• –• ••• •–•

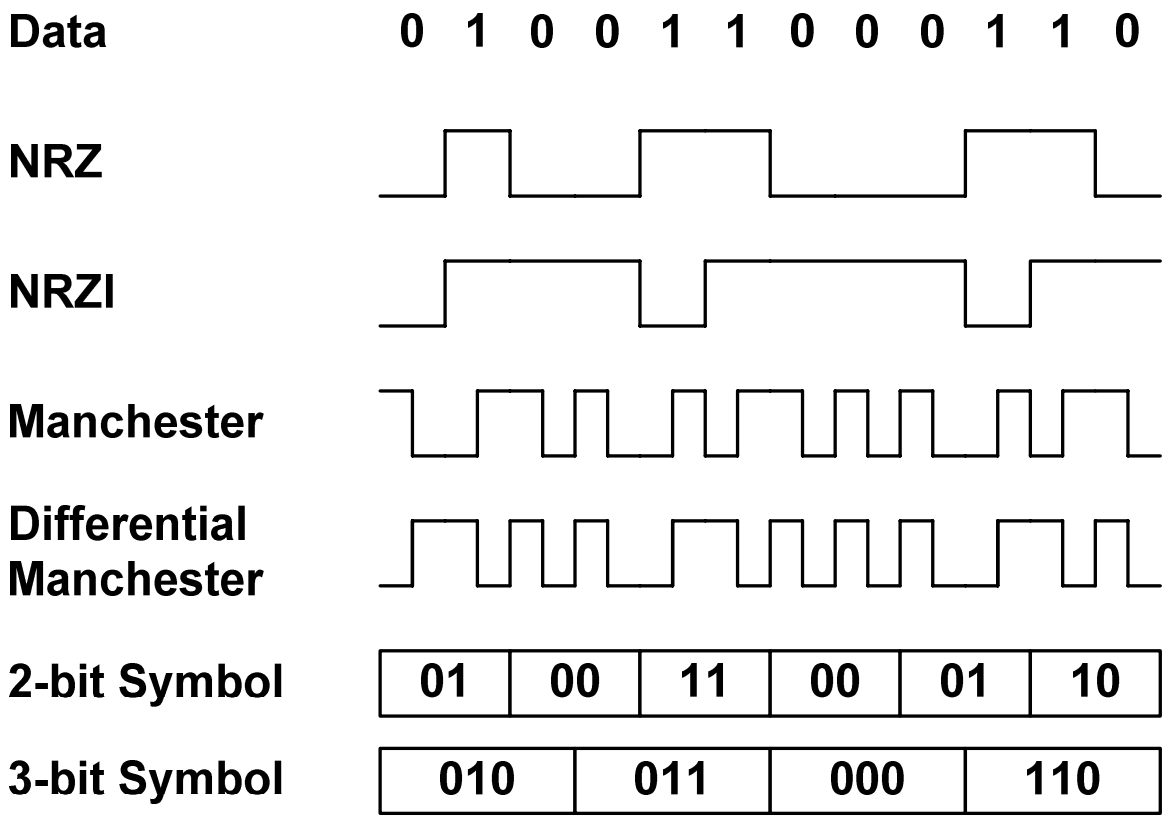
Digital Modulation

Nick Massey

VA7NRM

Encoding

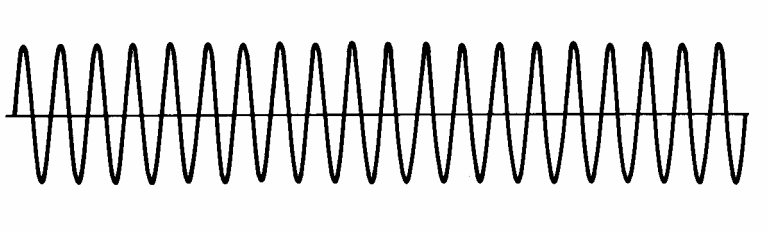
- • - • - - • - - •• • • • • - • - - • •• - • • • • • - •


Data
0 1 0 0 1 1 0 0 0 1 1 0
NRZ
NRZI
Manchester
Differential Manchester
2-bit Symbol
01 00 11 00 01 10
3-bit Symbol
010 011 000 110

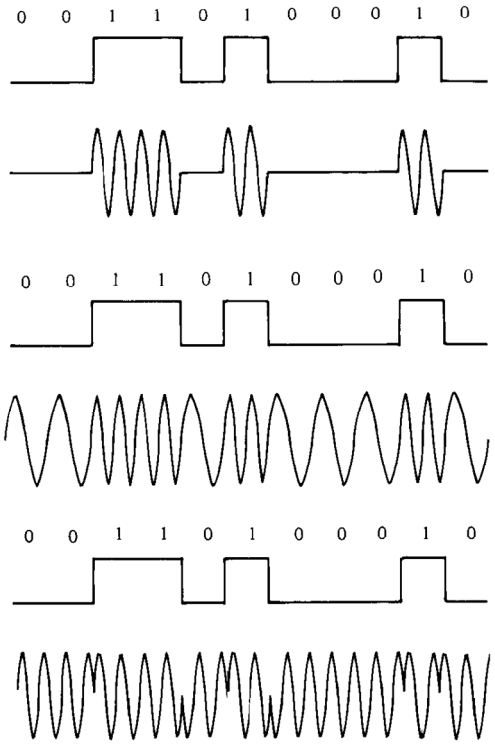
Modulation

- • - • - - • - - •• • • • • - • - - • • • - • • • • • - •

- What aspects of the RF carrier can we "modulate" to convey the information?



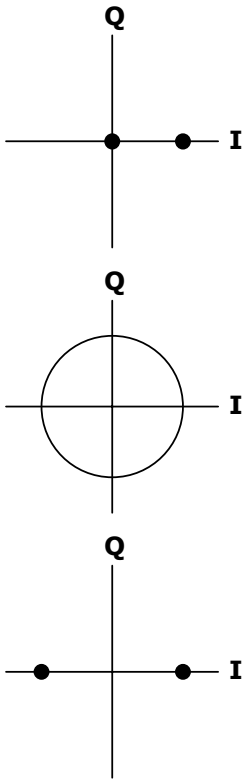
ASK, FSK & PSK



ASK
Amplitude Shift Keying

FSK
Frequency Shift Keying

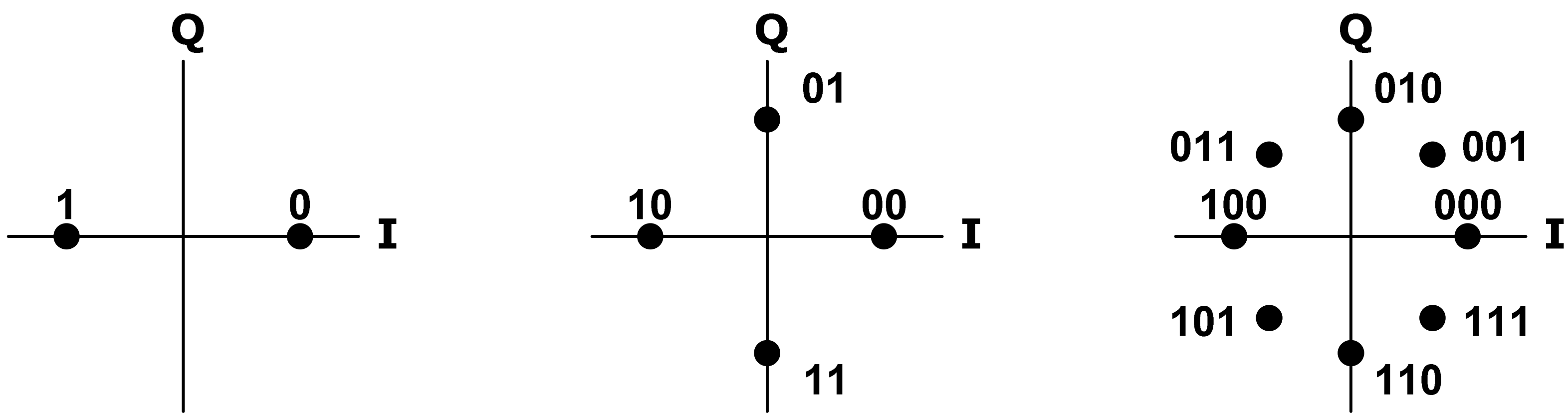
PSK
Phase Shift Keying



m-ary Modulation

- • - •   - - • -   - • •   •   • • • -   •   - - • • •   - •   • • •   • - •

- Conveys more than one bit of data per symbol



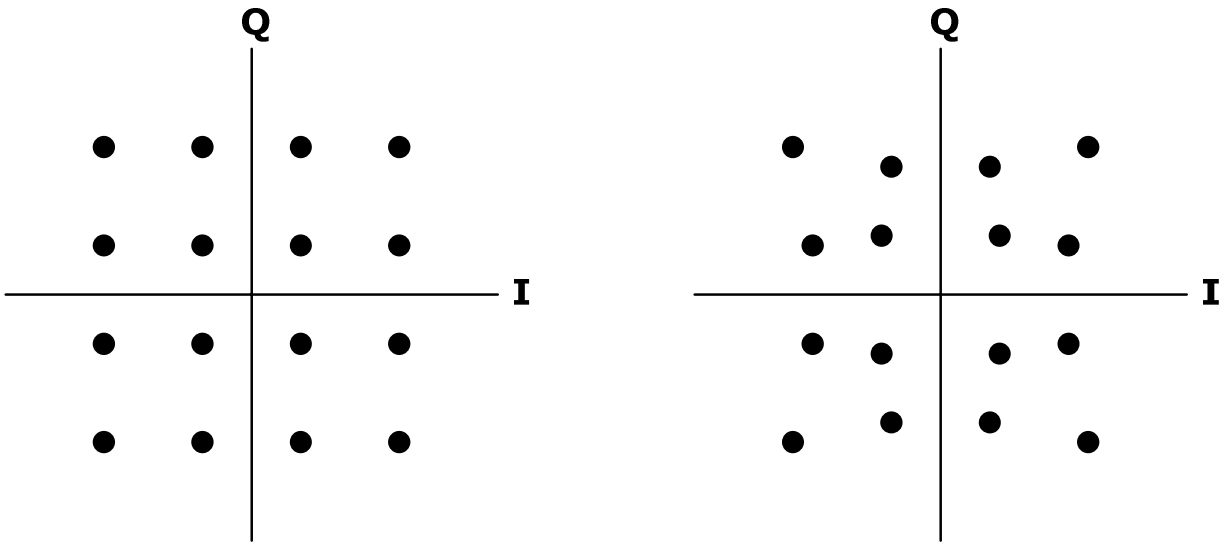
BPSK
Binary PSK

QPSK
Quadrature PSK

8PSK
8-ary PSK

Complex Modulation

- . - . - - . - - - . . . . - . . . - . - - . . - . . . . . - .

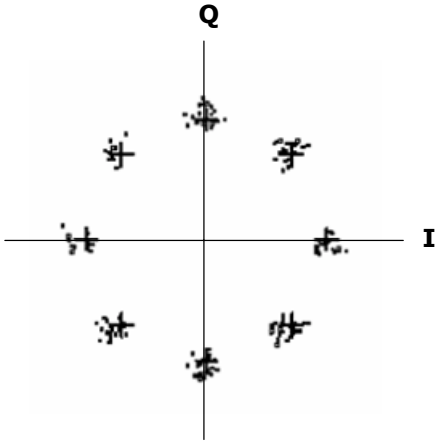


16-QAM
4-bit Symbols

Noise and Interference

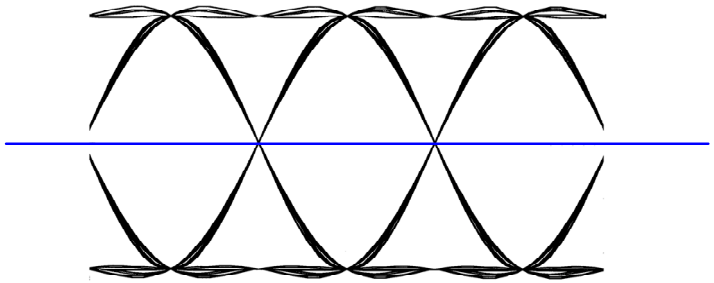
- - - • - • - - • - - • • • • - • - - • • • - • • • • - • • • • - -

- The signal that is received is usually “contaminated” by Noise and Interference
  - Noise
    - Galactic Noise
    - Atmospheric Noise
    - Man-made Noise
  - Interference
    - Other Users, Radars, ISM
    - “License Free” systems use ISM bands

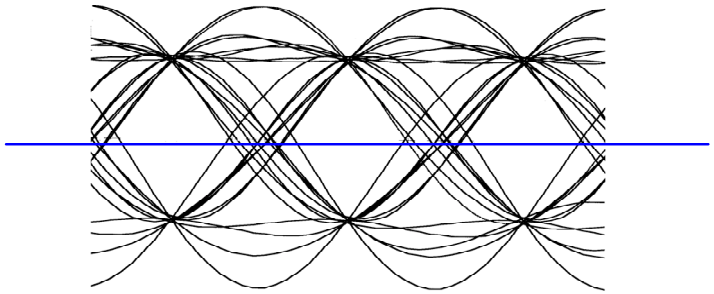


"Eye" Pattern

- • - • - - • - - •• • • • • - • - - • • •• - • • •• • - •



Good Signal /Noise



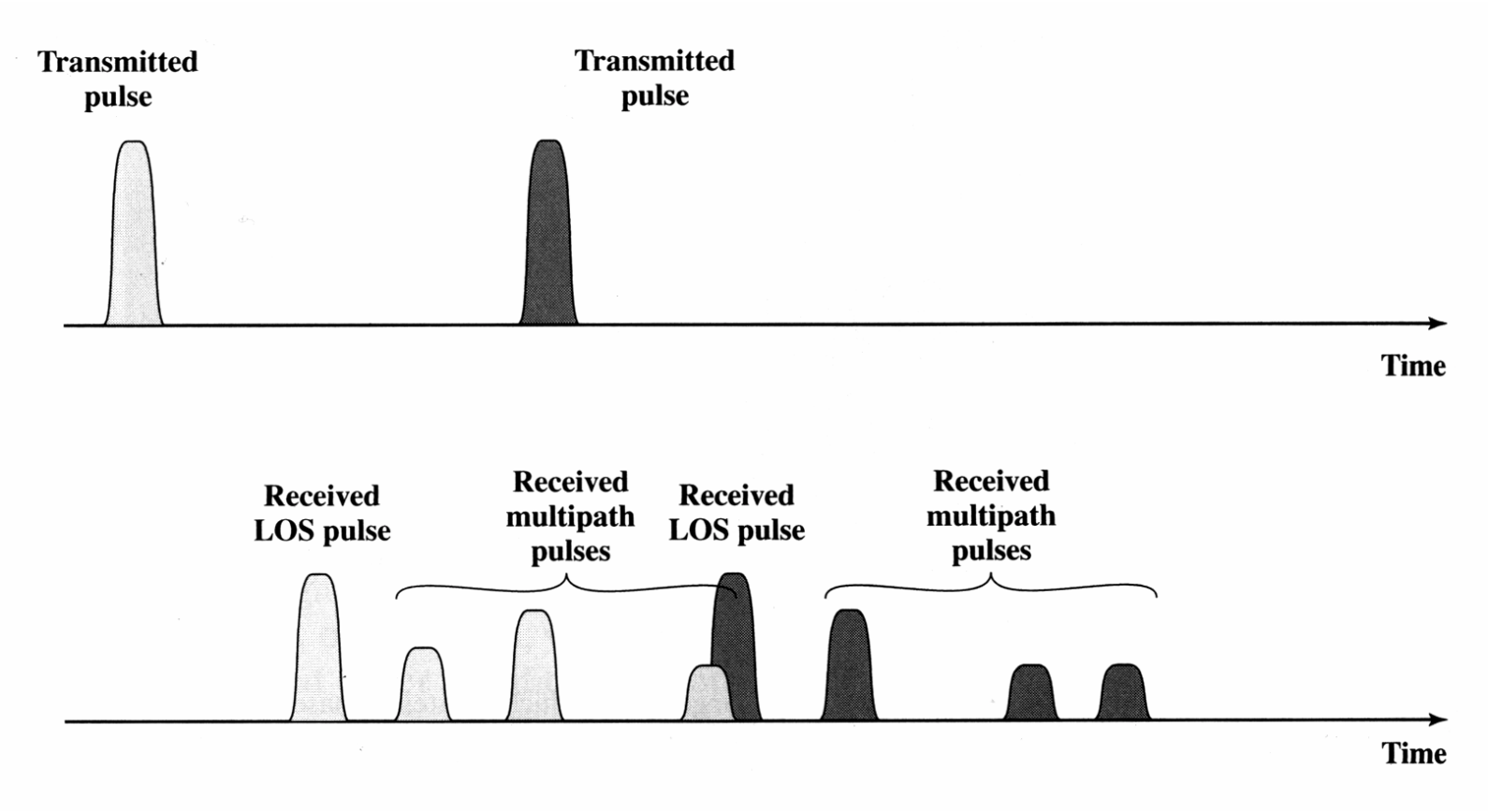
Poor(er) Signal /Noise

Distortion

- The signal that is received is not very often the same as the signal that was transmitted!
  - Fading
    - Narrowband - Multiple paths, signal cancels
    - Fading varies as paths change (radios or obstacles move)
  - Frequency Shift and Frequency Spread (Doppler)
    - Mobile Applications
  - Time Dispersion and Delay Spread
    - Multiple paths, signals arrive with different delays
    - Paths change

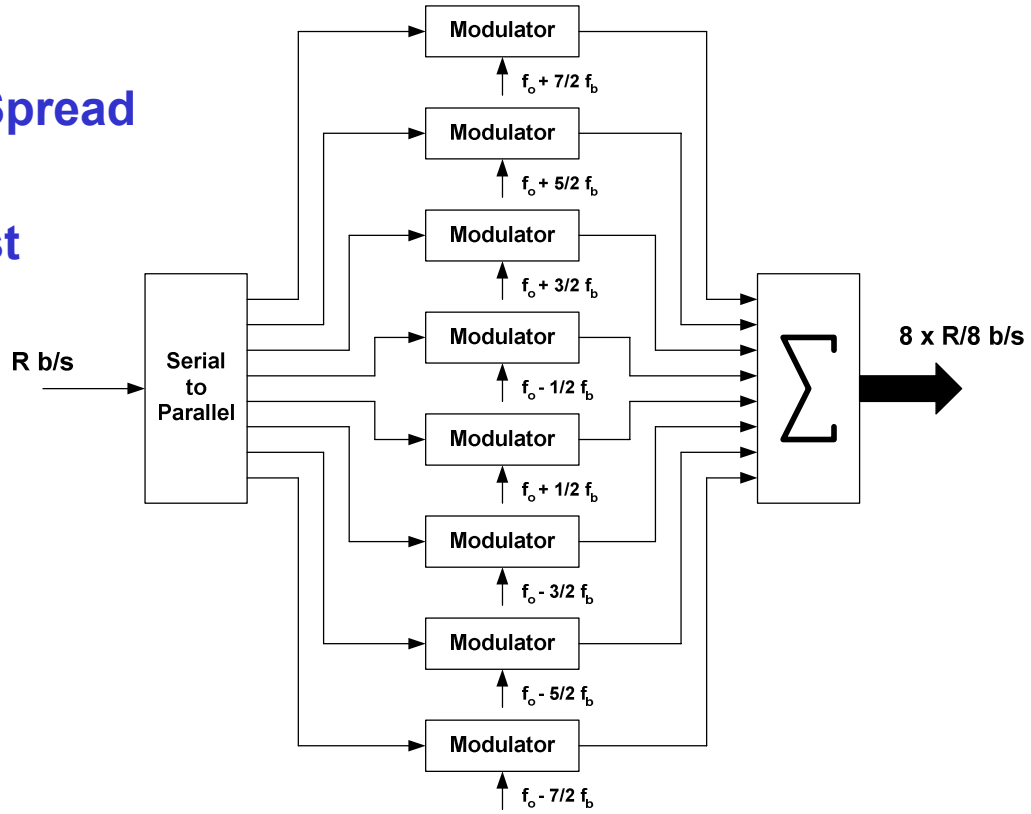
Multipath
Inter-symbol Interference

- • - • - - • - - • • • • - • - - • • • - • • • • - • • • - • -



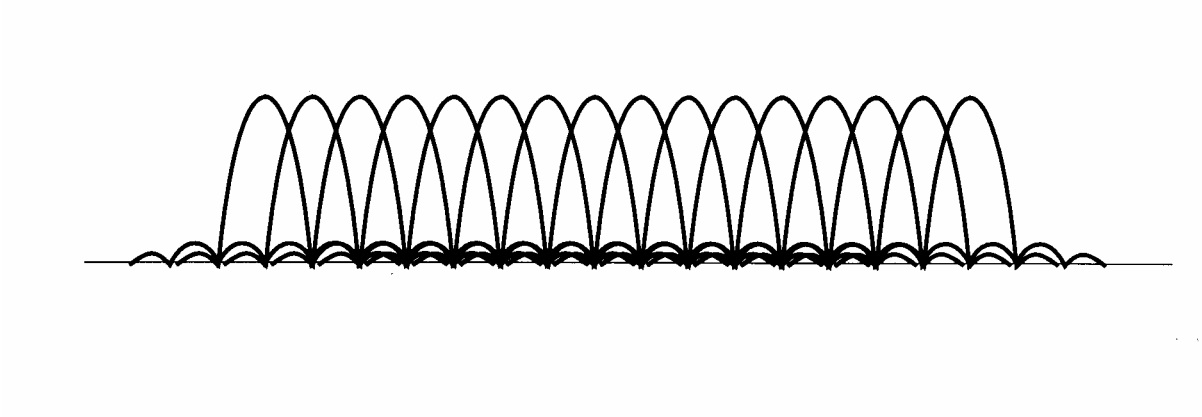
Parallel Modems (OFDM)

- Combat Inter-Symbol Interference
  - Many parallel signals
  - Symbol > Multipath Spread
- Combat Fading
  - Few sub-channels lost
- Modulation
  - Usually m-QAM
- Coding
  - FEC
  - Interleaving



OFDM (16 sub-carriers)

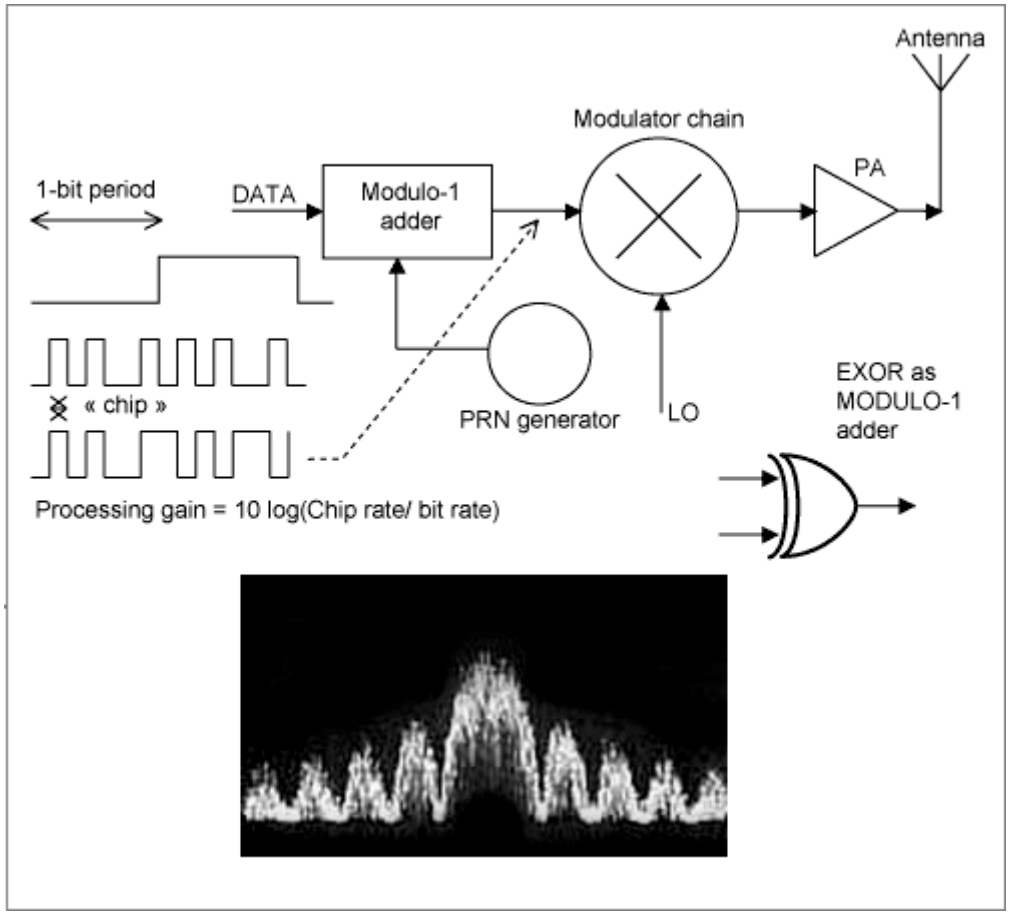
- • - • - - • - - •• • • • • - • - - • • • - • • • • • - •



Spread Spectrum

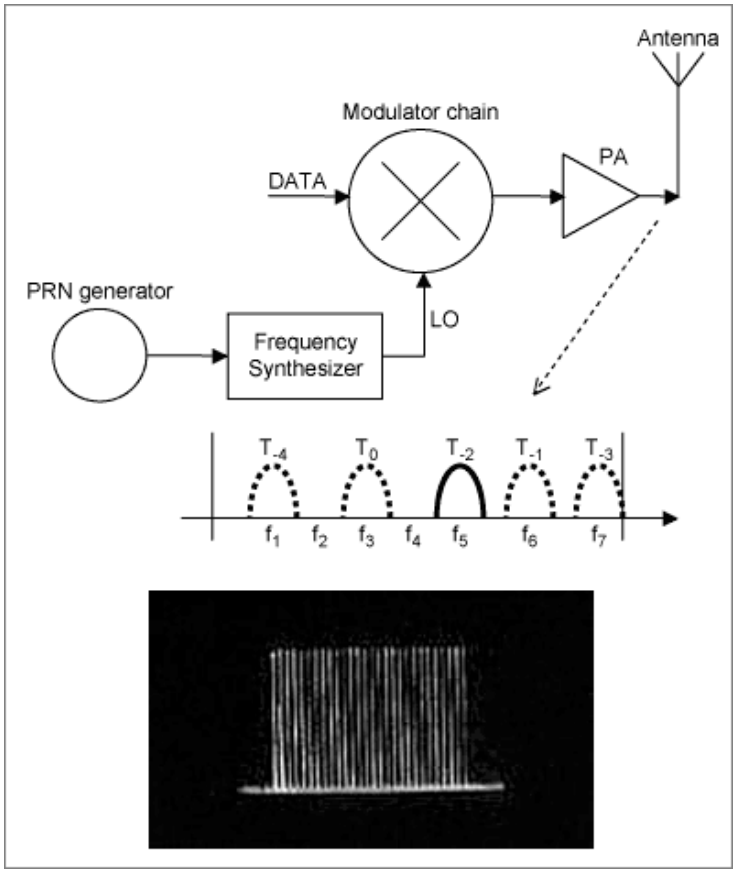
- **Spread Spectrum**
  - Signal Bandwidth is much greater than Information Bandwidth
  - A code, other than the data (message) to be transmitted, determines the actual on-air bandwidth
- **Advantages**
  - LPI, Anti-DF and Anti-Jam in a Tactical Environment
  - Spectrum Sharing
  - Resilient against multipath
  - "Whitens" noise and interference

Direct Sequence



- High-speed code spreads the signal
- "Near-Far" problem
- CDMA Cellular, GPS Navigation, Wi-Fi
- De-spreading spreads (weakens) other non-correlated signals

Frequency Hopping



- Code controls instantaneous frequency of transmission
- "Graceful Degradation"
- GSM Cellular, Bluetooth
- Resilient against Fading
- Bit-Rate Hopping resilient against Inter-symbol Interference