Terminology

- **CODEC**
  - Short for Coder/Decoder (Compressor/Decompressor)
  - Describes baseband processing of a digital signal
- **MODEM**
  - Short for Modulator/Demodulator
  - Describes transmission of a digital or analog signal
- The previous set of slides briefly described the principles behind digital video CODECs
- This talk describes wireless MODEMs for transmitting CODEC information
**Keying: Digital on Discrete Symbols**

- Digital data of 1 or more bits are encoded on a finite “alphabet” of symbols
  - Differently-shaped symbols
  - Similar symbols with different amplitudes
- This signal then modulated onto an RF carrier

```
1 0 1 0
```

Unipolar Signal

```
1 0 1 0
```

Bipolar Signal

---

**Spectral Content of Pulses**

- **Box Function**
  - \( u(\frac{T}{2} - |t|) \)
- **Sinc Function**
  - \( T \sin(Tf) \)

Sinc Function ↔ Box Function
What About a Random Process?

- Random on-off binary pulses
- Power-Spectral Density (PSD) will, for long sequences, take the shape of a pulse spectrum
- What about binary sequence (50% 1, 50% 0)?
- $S_x(f)$ is PSD, $P(f)$ is pulse spectrum:

$$S_x(f) = |P(f)|^2 + \frac{1}{4} |P(0)|^2 \delta(f)$$

Example PSD

$$S_x(f) = T^2 \text{sn}^2(Tf) + \frac{T^2}{4} \delta(f)$$

Units of Power/Hz
Nyquist Criterion for Overlapped Pulses

- Adjacent pulses must cross zero in integer multiples of the symbol period \((nT_s)\)
- Can be non-zero for other times
- Requires Matched-Filter receiver

\[ T_s \]

Sinc-Function Pulse Spectrum
Half-Sinc Pulse?

Shifted and Truncated Pulse
**Shifted and Truncated Pulse**

![Graph of a shifted and truncated pulse]

**Raised Cosine Pulse and Spectrum**

- **Raised Cosine Pulse**
  \[
  \text{Raised Cosine Pulse} = \frac{2f_0 \sin(2f_0 t) \cos(2\pi \kappa f_0 t)}{1 - (4\kappa f_0 t)^2}
  \]

- **Spectrum**
  \[
  \cos^2\left(\frac{\pi|f-f_0|}{4\kappa f_0} + \frac{\pi}{4}\right)
  \]
Matched Filtering

- Goal of the matched filter:
  - Provide the best estimate of a signal value at a specific point in time.
  - Does not reproduce the best possible signal shape.
- Mathematically, the best way to produce a symbol estimate at AWGN channel.

![Diagram of matched filtering process]

How a Matched Filter Works

- Symbol Amplitude Estimate
- Baseband Signal + Noise
- $h(T; t)$
- $H(f)\exp(-j2\pi Tf)$
- Period

![Diagram showing how matched filtering works]
Example of Matched Filter in Action

Original Data

Noise Added

Matched Filter Output

Decisions based on Output

Amplitude Shift Keying (ASK)

In-Phase

Oscillator

Modulated RF Signal

90° Phase Shifter

Quadrature
**On-Off/Binary Phase Shift Keying**

OOK Signal Constellation

BPSK Signal Constellation

**Quadrature Phase Shift Keying**

Voltage

Test Sequence 1000111

Quadrature
\(4\)-QPSK

In-Phase

Voltage

- 01
- 00
- 10
- 11

Test Sequence

1000111

Quadrature

Differential QPSK (DQPSK)

01
00
11
10

Resistant to Frequency/Phase Rotation errors in the carrier reception