Summary of Baseband Transmission

Line Coding

- On-Off
- NRZ
- RZ
- Manchester

M-ary baseband signals

- $r_b = \frac{1}{T_b}$
- γ bits/symbol (binary case $\gamma = 1$)
- $T_s = \gamma * T_b$
- $r_s = \frac{1}{T_s}$ = symbol rate
- $B_0 = \frac{r_s}{2}$ = minimum baseband bandwidth

Symbol detection

- Minimum distance decision algorithm
- Integrate & dump is the same as filter & sample
- Decision based on the output of the Integrate & dump (or filter & sample)
- One symbol error can cause multiple bit errors

ISI

- Pulse shaping
- Criteria for no ISI, $p(0) = 1$ (constant) and $\sum_{\substack{k=-\infty \\ k\neq 0}}^{\infty} p(t - \mathrm{k}T_s) = 0$
- Raised cosine pulse shaping,
- $B_T = B_0(1+\alpha)$ = baseband bandwidth with pulse shaping
- Eye-diagram

Analog-to-Digital (A/D) conversion

- PAM
- PCM
- $(S/N)_Q \approx 6\gamma$ (dB)

Summary of Time Division Multiplexing

Time frame

Time slot & number of time slots/frame

Number of bits/time slot

Bit rate = $\frac{\sharp\text{ bits/frame}}{\text{Frame Time}}$

TDMA

TDD

Uplink and downlink

Frame synchronization

TDM/PAM

Minimum baseband bandwidth= $\frac{r_s}{2}$ with no pulse shaping (with raised cosine pulse shaping, multiply by 1+α)

TDM/PCM

Minimum baseband bandwidth= $\frac{r_b}{2}$ with no pulse shaping (with raised cosine pulse shaping, multiply by 1+α)

Summary of DSB-SC

$x_{DSB-SC}(t) = A_c\, x_{bb}(t) \cos(2\,\pi f_c t)$

$B_{RF} = 2\, B_{bb}$

Spectrum of DSB-SC signals

In general requires a synchronous (coherent) receiver, carrier recovery is needed

DSB-SC is a linear modulation

ASK is a digital modulation using DSB-SC with a specific digital baseband signal, $x_{ON-Off}(t)$

- $B_{RF} = r_b$
- Spectral efficiency = (1b/s)/Hz

BPSK is a digital modulation using DSB-SC with a specific digital baseband signal, $x_{NRZ}(t)$

- $B_{RF} = r_b$
- Spectral efficiency = (1b/s)/Hz

Power in the DSB-SC signal, $A_c x(t)\cos(2\,\pi f_c t)$, is $P_{DSB-SC} = \frac{A_c^2 P_x}{2}$

Summary of Quadrature Modulation and Multiplexing

Quadrature Multiplexing allows two signals to use (share) the same RF spectrum, one signal on the I-channel and one on the Q-channel

Carrier recovery is required to demodulate quadrature modulated signals

Quadrature modulation is used to transmit digital signals

- One baseband digital signal (NRZ or M-ary) transmitted on the I-channel and one on the Q-channel
- Constellation (signal-space) diagrams
- Minimum distance detection of transmitted symbols-in two dimensions
- Transmitter block diagram
- Receiver block diagram
- Relationships:
  - γ bits/symbol
  - Symbol time $T_s = \gamma T_b$
  - QPSK 2 bits/symbols, γ=2
  - M-QAM; M= 2^{γ}
  - M-ary PSK; M= 2^{γ}
  - Maximum spectral efficiency = γ (b/s)/Hz

Modulation Type	Maximum Spectral Efficency (b / s) / Hz
ASK	1
BPSK	1
QPSK	2
8 – ary PSK	3
16 – QAM	4
64 – QAM	6
256 – QAM	8
1024 – QAM	10

Representations of RF Signals

$y_l(t) = y_c(t) + j y_s(t)$

$\mathrm{Re}(y_l(t) e^{j2\pi f_c t})$

$V(t) \cos(2\pi f_c t + \Theta(t))$

$y_c(t) \cos(j2\pi f_c t) - y_s(t) \sin(j2\pi f_c t)$

Summary of Frequency Division Multiplexing (FDM) and Orthogonal Frequency Division Multiplexing (OFDM)

FDM enables sharing of spectrum

Guard bands are placed between the channels to prevent adjacent channel interference.

FDM can support independent transmitters and receivers, i.e., the broadcast case.

Composite baseband signals can be constructed using FDM then modulated to RF.

Bandwidth of FDM signals.

FDD

FDMA

Combined TDMA and FDMA

OFDM

- No explicit sidebands
- $\frac{1}{T_s}$ =Δf (subcarriers are orthogonal)
- N=Number of subcarriers
- $B_{RF} \approx (N+1)\Delta f$ (Not a function of the QAM modulation on each subcarrier)
- $r_b = N * \Delta f * \gamma$ (γ=#bits/symbol, assumes same QAM on all N subcarriers)
- Transmitter/receiver use IDFT/DFT

OFDM combined with TDMA

- Time/Frequence Resource Grid
- T_f=Frame time = Number of slots * (Number of OFDM symbols/time slot) * T_s
- $r_b = \frac{\text{Number of bits in a } T_f}{T_f}$