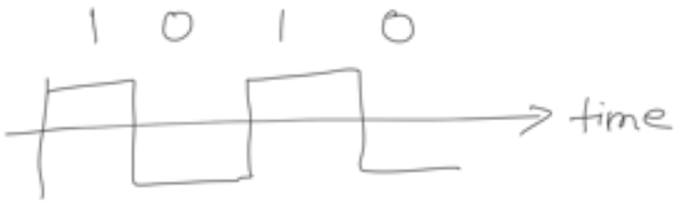
Analog / Digital signals → Wireless / RF

Analog / Digital Data → Height, Weight, Number of objects



$s(t) = A \sin 2\pi f t$ freq $= f$, $T = \frac{1}{f}$

Attenuated / distorted

freq $= f$, $T = \frac{1}{f}$

$s_1(t) = A\left(\sin 2\pi f t + \frac{1}{3}\sin 2\pi(3f)t\right)$

BW $= 2f$

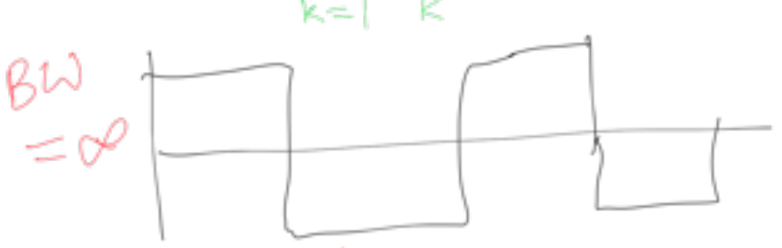
fundamental freq $= f$

$s_2(t) = A\left(\sin 2\pi f t + \frac{1}{3}\sin 2\pi 3 f t + \frac{1}{5}\sin 2\pi 5 f t\right)$

BW $= 4f$

freq $= f$, $T = \frac{1}{f}$

$s_\infty(t) = \sum A \sin 2\pi k f t$



Bandwidth

$s_1(t)$ = $f = 1MHz$ $bw = 2f$ 2MHz

BW 2MHz $T = \frac{1}{f} = 1\mu s$ 2bits/μs = 2Mbps

$f = 2MHz$

BW 4MHz $T = \frac{1}{f} = 0.5\mu s$ 2bits/0.5μs = 4Mbps

$s_2(t)$ $BW = 4f$

$f = 1MHz$ $t = \frac{1}{f} = 1\mu s$ 2bits/μs 2Mbps

$BW = 4MHz$ error prob. is lower

Signal to Noise Ratio

$SNR = \frac{P_r}{N}$ → Noise

SINR (Signal to Interference + Noise Ratio)

P_r

$= \frac{P_r}{I+N}$

Bels

$SNR_{dB} = 10 \log_{10} SNR$

SNR ⟶

Power ~~W~~ dBm dBW ⟶ $10 \lg_{10} \frac{X}{1W}$

$100W = 20 dBW$

$100W = 10 \lg_{10} \frac{100W}{1mW}$

$= 50 dBm$

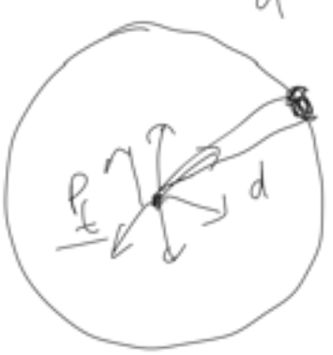
$P_r = 20 dBm$

$N = 2 dBm$

$SNR_{dB} = 18 dB$

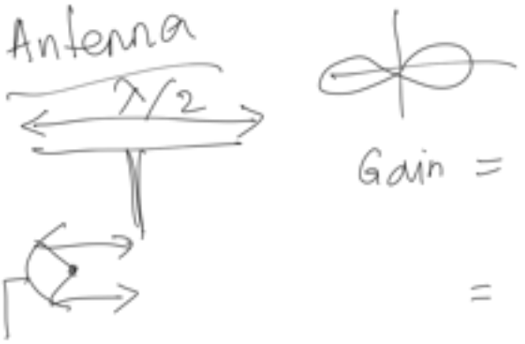
Claude Shannon

$C = B \lg_2 (1 + SNR)$



$4\pi d^2$

$P_r \sim \frac{P_t}{d^2}$



$$\text{Gain} = \frac{4\pi f^2 A_e}{c^2}$$

$$= \frac{4\pi A_e}{\lambda^2}$$

G

$$P_r = \frac{P_t}{d^2} \cdot G_t G_r$$

$$= \frac{P_t}{d^2} \frac{(4\pi)^2 f^4 A_t A_r \lambda^2}{c^4}$$

$$= \frac{P_t}{d^2} \frac{(4\pi)^2 f^2 A_t A_r}{c^2}$$

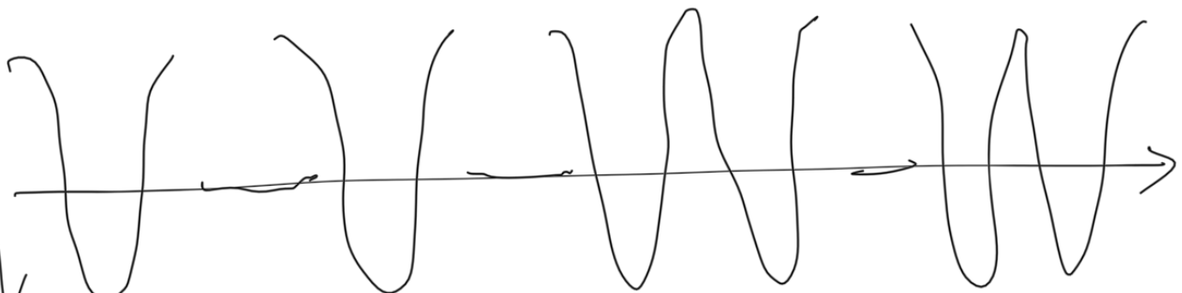
$$P_r \sim f^2$$

Modulation / Demodulation

1 0 1 0 1 1 0 1 1

Amplitude Shift Keying (ASK)

$$s(t) = \begin{cases} A\cos(2\pi f_c t) & 1 \\ 0 & 0 \end{cases}$$

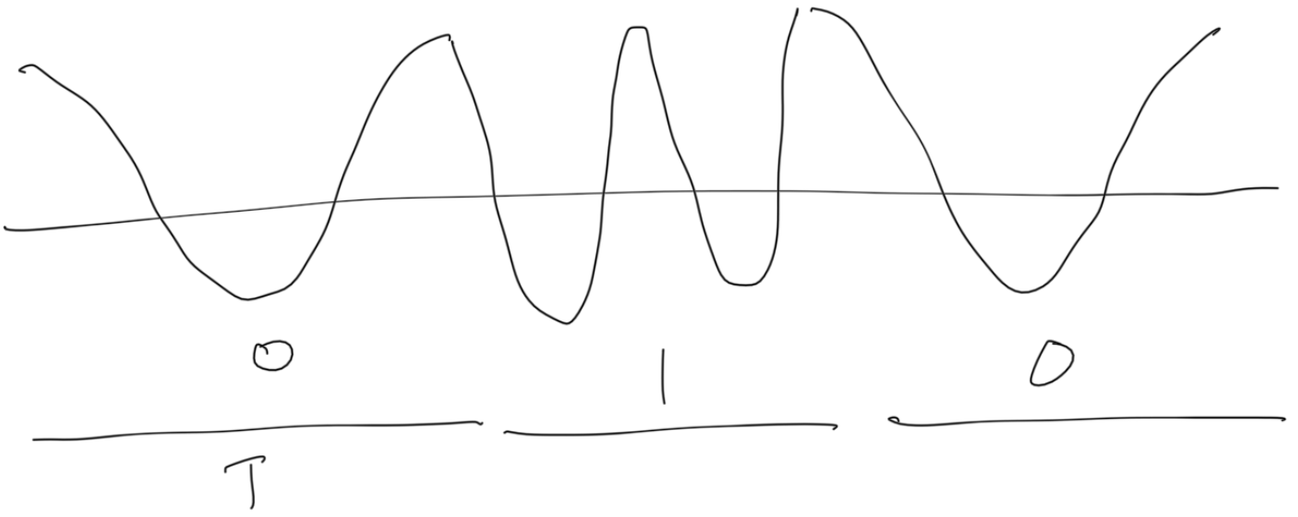


BINARY

Frequency Shift Keying (FSK)

$$s(t) = \begin{cases} A\cos 2\pi f_1(t) & 1 \\ A\cos 2\pi f_2(t) & 0 \end{cases}$$

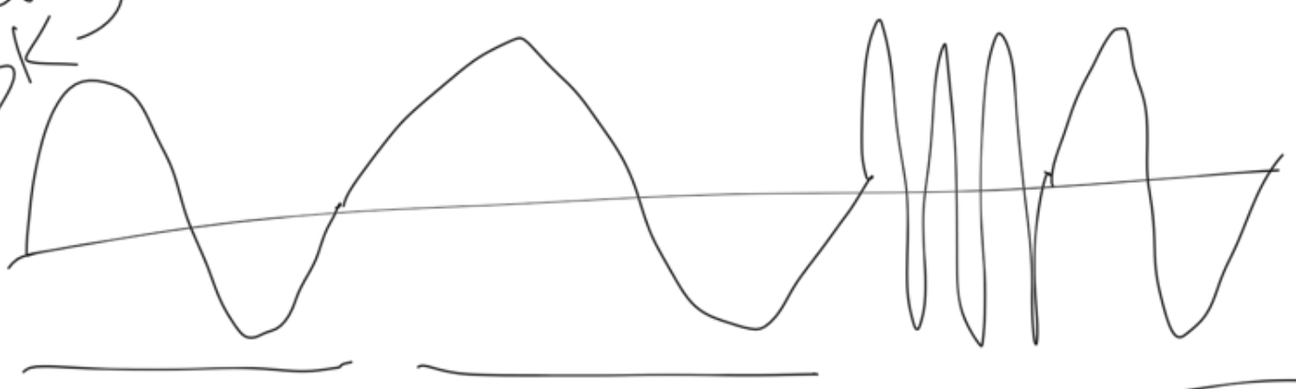
$A \cos 2\pi f_0(t)$



Y

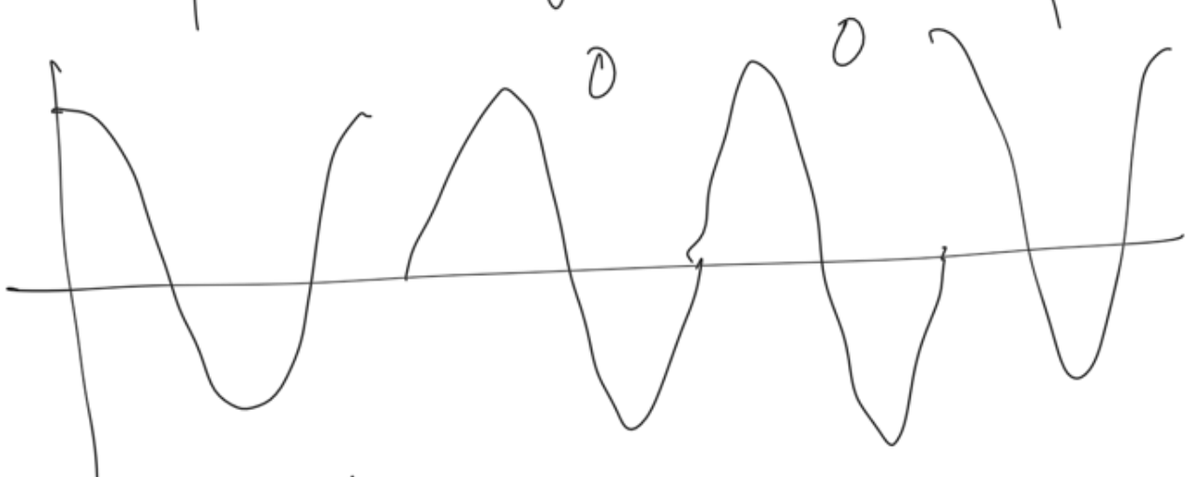
$$s(t) = \begin{cases} A\cos f_1 t & 00 \\ f_2 t & 10 \\ f_3 t & 11 \\ f_4 t & 01 \end{cases}$$

M-ary FSK



Phase Shift Keying

$$s(t) = \begin{cases} A\cos 2\pi f t) = 1 \\ A(\cos 2\pi f t + \pi) = 0 \end{cases}$$



Amplitude
frequency
Phase

PHASE

0000 → f_1, $3\pi/4$, A_1

0001 → f_1, $\pi/4$, A_2

0010

0011

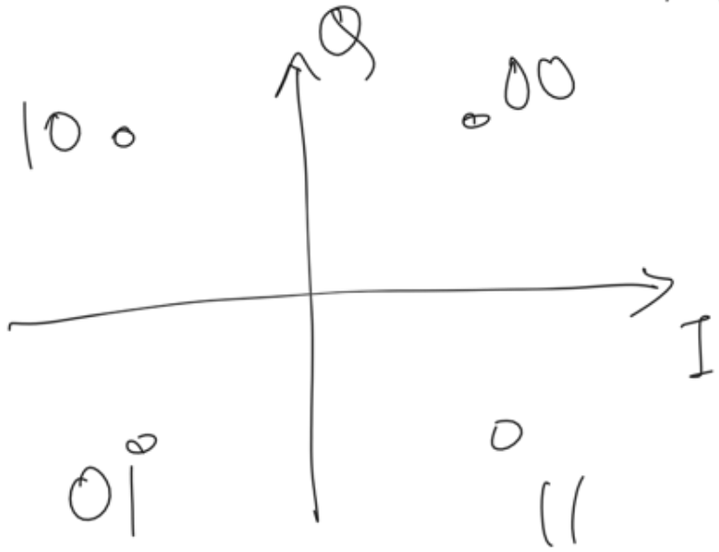
0100

0101

QAM

Quadrature Amplitude Modulation

Amplitude, Phase



Constellation diagram

4-QAM

↓

QPSK

Quadrature Phase SK

2-PSK

BPSK