$$\Delta = \frac{2m_p}{L} \quad N_q = \frac{m_p^2}{3L^2} \quad SQNR = \frac{S_o}{N_q} = \frac{3S_oL^2}{m_p^2}$$

$$BW_{min} = \frac{Rate}{2}$$

$$S_y(f) = |P(f)|^2 S_x(f) = \frac{|P(f)|^2}{T_b} \sum_{n=}^{\infty}$$

$$= \frac{|P(f)|^2}{T_b}\left(R_0 + 2\sum_{n=1}^{\infty} R_n \cos 2\pi n f T_b\right)$$

Polar Coding:

BW	2Rb($\frac{1}{2}$-wid 4x BWmin) or Rb(1-wid, 2x BWmin)
Power	Most efficient
DC	Not zero (but can be made zero w/ Manchester)

ON-OFF coding:

BW	Same as Polar
Power	2x Power of Polar (or 4x Energy)
DC	Not zero

Bipolar (single bit error)

BW	Rb (No half-width pulse)
Power	2x Power (3dB)
DC	DC Null

Nyquist 1st Criteria ISI

sinc gives Rb/2 BW but falls off at 1/t, other functions have faster roll-off but (1+r)Rb/2 BW. Raised cos when r = 1,falls off at 1/t^3.

Controlled ISI

ZFE

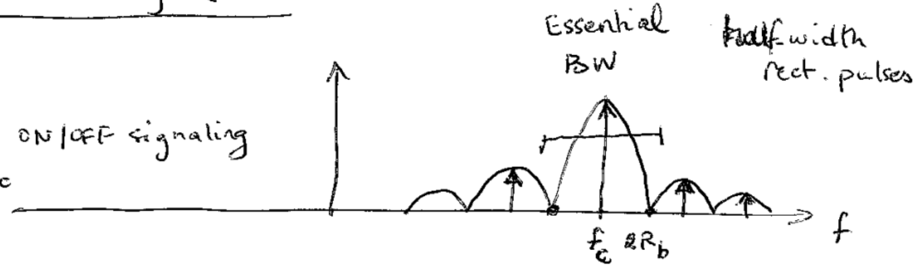
$$P_o(kT_b) = \sum_{n=-N}^{N} c_n P_r(kT_b - nT_b)$$

	Multiamplitude	Orthogonal
Rate	$\log_2 M$	$\log_2 M$
BW	Independent of M	M
SNR (power)	M^2	Independent of M

Power spectral density (PSD

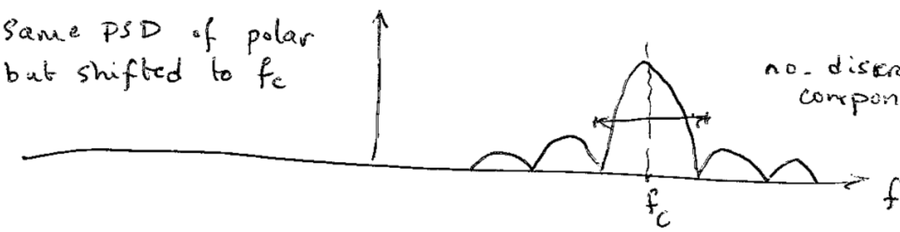
ASK

Same PSD of ON/OFF signaling but shifted to f_c



PSK

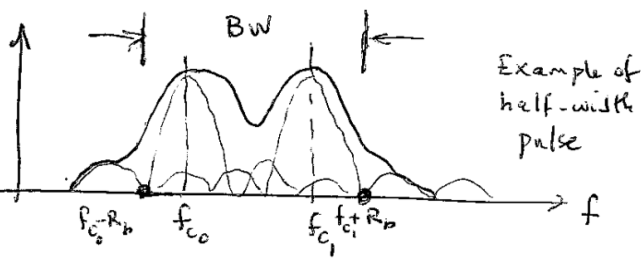
Same PSD of polar but shifted to f_c



FSK

$BW \simeq 2R_b + \Delta f$

$\Delta f = f_{c_1} - f_{c_0}$



PSK requires 3dB less power than ASK(on/off). BW(FSK) > BW(ASK or PSK). Can't use coherent demodulation for PSK but can for DPSK. DPSK 1 is same as previous bit and 0 is opposite.

FSK m-array, power const but BW increases with M linearly

The least $\delta f = \dfrac{1}{2T_s}$ Hz

PSK

$$\boxed{\theta_m = \theta_0 + \frac{2\pi}{M}(m-1)}$$

If BW was B_s Hz, then FHSS will use (occupy) a BW $B_c = LB$ L: spreading factor

T_s : symbol duration

T_c : Chip duration

$R_s = \frac{1}{T_s}$ symbol rate

$R_c = \frac{1}{T_c}$ Chip rate

If $T_c \gg T_s \rightarrow$ FH is slow hopping

If $T_c < T_s \rightarrow$ FH is fast hopping (multiple ~~symbols (hops)~~ hops over the duration of a symbol)

* Suppose a jamming source has level of jamming power P_J
* Narrow band (NB) signal $BW = B_s$, Jammer also has $BW = B_s$

Interference level $= \frac{P_J}{B_s} = I$

Signal-to-interference ratio $= \left(\frac{E_b}{I}\right)_{NB} = \boxed{\frac{E_b B_s}{P_J}}$

SIR_{NB}

* FHSS has $BW = B_c = LB_s$. Jamming source will divide its power $\Rightarrow$ $I = \frac{P_J}{B_c} = \frac{P_J}{LB_s} \Rightarrow \boxed{SIR_{FH} = \frac{E_b L B_s}{P_J}}$

$SIR_{FH} = L\, SIR_{NB}$

BW after spreading is L times broader than the original signal.

$$B_c = \underbrace{LB_s + B_s}_{\text{convolution of spectra of } s_{QAM} \text{ and } c(t)} = (L+1)B_s \simeq LB_s$$

Let P_i be the total power of interference.

Interference spectral level before despreading $= \frac{P_i}{B_s}$, $f_c - \frac{B_s}{2} \leq f \leq f_c + \frac{B_s}{2}$

After despreading, the interf. spectral level $= \frac{P_i}{(L+1)B_s}$, $f_c - \frac{B_c}{2} \leq f \leq f_c + \frac{B_c}{2}$

$$\frac{\text{SIR before}}{\text{SIR after}} = \frac{\frac{E_b B_s}{P_i}}{\frac{E_b (L+1) B_s}{P_i}} = \frac{1}{L+1}$$

SIR improves by a factor of $(L+1) \simeq L$ which is the spreading factor.

DSSS is very effective against narrowband jamming signals

TABLE 3.2
Properties of Fourier Transform Operations

Operation	$g(t)$	$G(f)$
Linearity	$\alpha_1 g_1(t) + \alpha_2 g_2(t)$	$\alpha_1 G_1(f) + \alpha_2 G_2(f)$
Duality	$G(t)$	$g(-f)$
Time scaling	$g(at)$	$\frac{1}{\lvert a\rvert} G\left(\frac{f}{a}\right)$
Time shifting	$g(t-t_0)$	$G(f)e^{-j2\pi f t_0}$
Frequency shifting	$g(t)e^{j2\pi f_0 t}$	$G(f-f_0)$
Time convolution	$g_1(t) * g_2(t)$	$G_1(f)G_2(f)$
Frequency convolution	$g_1(t)g_2(t)$	$G_1(f) * G_2(f)$
Time differentiation	$\frac{d^n g(t)}{dt^n}$	$(j2\pi f)^n G(f)$
Time integration	$\int_{-\infty}^{t} g(x)\,dx$	$\frac{G(f)}{j2\pi f} + \frac{1}{2}G(0)\delta(f)$

2	$e^{at}u(-t)$	$\frac{1}{a - j2\pi f}$
3	$e^{-a\lvert t\rvert}$	$\frac{2a}{a^2 + (2\pi f)^2}$
4	$te^{-at}u(t)$	$\frac{1}{(a+j2\pi f)^2}$
5	$t^n e^{-at}u(t)$	$\frac{n!}{(a+j2\pi f)^{n+1}}$
6	$\delta(t)$	1
7	1	$\delta(f)$
8	$e^{j2\pi f_0 t}$	$\delta(f-f_0)$
9	$\cos 2\pi f_0 t$	$0.5[\delta(f+f_0) + \delta(f-f_0)]$
10	$\sin 2\pi f_0 t$	$j0.5[\delta(f+f_0) - \delta(f-f_0)]$
11	$u(t)$	$\frac{1}{2}\delta(f) + \frac{1}{j2\pi f}$
12	$\operatorname{sgn} t$	$\frac{2}{j2\pi f}$
13	$\cos 2\pi f_0 t\, u(t)$	$\frac{1}{4}[\delta(f-f_0) + \delta(f+f_0)] + \frac{j2\pi f}{(2\pi f_0)^2 - (2\pi f)^2}$
14	$\sin 2\pi f_0 t\, u(t)$	$\frac{1}{4j}[\delta(f-f_0) - \delta(f+f_0)] + \frac{2\pi f_0}{(2\pi f_0)^2 - (2\pi f)^2}$
15	$e^{-at}\sin 2\pi f_0 t\, u(t)$	$\frac{2\pi f_0}{(a+j2\pi f)^2 + 4\pi^2 f_0^2}$
16	$e^{-at}\cos 2\pi f_0 t\, u(t)$	$\frac{a+j2\pi f}{(a+j2\pi f)^2 + 4\pi^2 f_0^2}$
17	$\Pi\left(\frac{t}{\tau}\right)$	$\tau\,\mathrm{sinc}\,(\pi f \tau)$
18	$2B\,\mathrm{sinc}\,(2\pi B t)$	$\Pi\left(\frac{f}{2B}\right)$
19	$\Delta\left(\frac{t}{\tau}\right)$	$\frac{\tau}{2}\,\mathrm{sinc}^2\left(\frac{\pi f \tau}{2}\right)$
20	$B\,\mathrm{sinc}^2\,(\pi B t)$	$\Delta\left(\frac{f}{2B}\right)$

	$g(t)$	$G(f)$	**Condition**
1	$e^{-at}u(t)$	$\frac{1}{a+j2\pi f}$	$a > 0$
2	$e^{at}u(-t)$	$\frac{1}{a-j2\pi f}$	$a > 0$
3	$e^{-a\lvert t\rvert}$	$\frac{2a}{a^2+(2\pi f)^2}$	$a > 0$
4	$te^{-at}u(t)$	$\frac{1}{(a+j2\pi f)^2}$	$a > 0$
		$n!$	