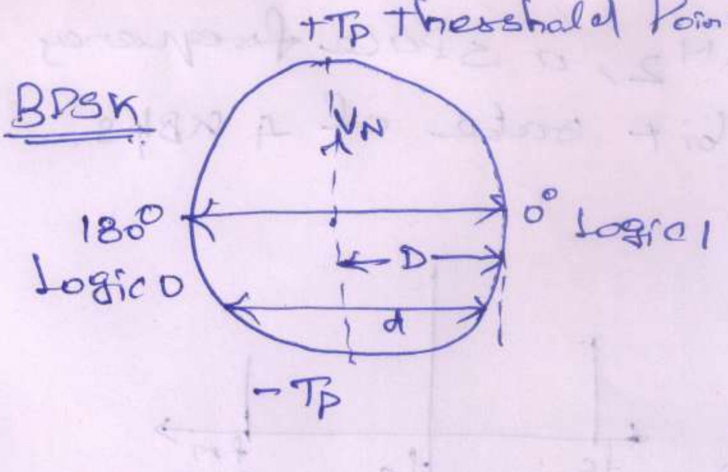
1. PSK error Performance



$T_P = \pm \frac{\pi}{M}$

M = no. of signal states

$P(e) = \frac{1}{\log_2 M} \text{erf}(z)$

$z = \sin\left(\frac{\pi}{M}\right)\left(\sqrt{\log_2 M}\right)\sqrt{E_b/N_0}$.

2. QAM - Quadrature Amplitude modulation.

* Both Amplitude and Phase changes.

* $d = \frac{\sqrt{2}}{L-1} \times D$ 'L' - no. of levels on each axis.

* $P(e) = \frac{1}{\log_2 L}\left(\frac{L-1}{L}\right) \text{erf}(z)$.

$\text{erf}(z) = z = \frac{\sqrt{\log_2 L}}{L-1}\sqrt{\frac{E_b}{N_0}}$

3. FSK error Performance

$P(e) = \frac{1}{2}\exp\left(-\frac{E_b}{2N_0}\right)$ → non-Coherent FSK.

$P(e) = \text{erf}\,z\sqrt{\frac{E_b}{N_0}}$ → coherent FSK.

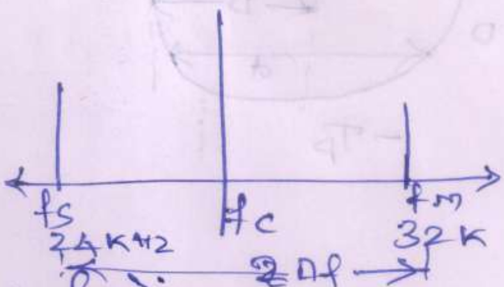
1. Determine the Bandwidth and Baud for an FSK signal with a mark frequency of 32 kHz, a space frequency of 24 kHz and a bit rate of 4 KBps.

Given: $f_m = 32\,kHz$

$f_s = 24\,kHz$

$f_b = 4\,kpbs$

$BW = ?$ Baud = ?



for FSK, $BW = 2(\Delta f + f_b)$

$2\Delta f = |32k - 24k|$
$= 8k$
$\Delta f = 4k$

$BW = 2(4000 + 4000)$
$= 16000\,Hz$

4000

$\therefore$ Baud $= \frac{f_b}{N} = \frac{4000}{1} = 4000$

$= 4000$ Baud.

2. Determine the maximum bit rate for an FSK signal with a mark frequency of 48 kHz, a space frequency of 52 kHz, and a available Bandwidth of 10 kHz.

Given: $f_b = ?$ $BW = 10\,kHz$

$f_m = 48\,kHz$ $f_s = 52\,kHz$

$\Delta f = \frac{|48 - 52|}{2} = \frac{4}{2} = 2\,kHz$

$\frac{BW - 2\Delta f}{2} = f_b$

$f_b = \frac{BW - 2 \times \Delta f}{2} = \frac{10000 - 4000}{2} = 3000$ bitsPS.

3. Determine the bandwidth and baud for an FSK signal with a mark frequency of 99 kHz, a space frequency of 101 kHz and a bit rate of 10 kbps.

Given: $f_m = 99000$ Hz

$f_s = 101000$ Hz

$f_b = 10000$ bps

$\Delta f = \left|\frac{99000 - 101000}{2}\right|$

$= 1$ kHz

$= 1000$ Hz

$BW = 2(\Delta f + f_b)$

$BW = 2(10{,}000 + 10{,}000)$

$= 22{,}000$ Hz

$= 22$ kHz.

$\text{Baud} = f_b/N = 10000/1 = 10$ kHz.

4. Determine the maximum bit rate for an FSK signal with a mark frequency of 102 kHz and a space frequency of 104 kHz and an available bandwidth of 8 kHz.

Given: $BW = 8000$ Hz

$f_m = 102$ kHz

$f_s = 104$ kHz.

$\Delta f = \left|\frac{f_m - f_s}{2}\right|$

$= \left|\frac{102k - 104k}{2}\right|$

$= 1k.$

$f_b = \frac{BW - 2\Delta f}{2} = \frac{8k - 1k}{2} =$

$= 3.5$ kbs.

3/

5. Determine the bandwidth efficiency of the following modulators.

a. QPSK, $f_b = 10$ mbps

b. 8 PSK, $f_b = 21$ mbps

c. 16 QAM, $f_b = 20$ mbps.

Bandwidth efficiency $= \frac{\text{bits}}{\text{cycle}}$.

a) QPSK, $f_b = 10$ mbps

for QPSK $\Rightarrow$ $2^2 = \underline{4.}$

2 bit,

$\text{Baud} = \frac{10 \text{mbps}}{2} = 5 \text{ Mbs}$ $\left(\frac{f_b}{N}\right)$

for QPSK.

$\text{Bandwidth} = \frac{f_b}{N} = 5 \text{ Mbs}$

$\therefore$ Bandwidth efficiency $B\omega_{\eta} = \frac{10 \text{mbs}}{5 \text{mbs}} = \underline{2}$ bit/cycle

b) 8 PSK, $f_b = 21$ mbs

for 8 PSK $\Rightarrow$ $2^3 = 8$; $N = 3$. bit.

$\therefore$ $\text{Baud} = \frac{21 \text{mbs}}{3} = 7 \text{ mbs}$

$B\omega = \frac{f_b}{N} = \frac{21 \text{mbs}}{3} = 7 \text{ MHz}$

$B\omega_{\eta} = \frac{21 \text{ Mbs}}{7 \text{ mHz}} = 3$ bits/cycle.

c) 16 QAM, $f_b = 20$ mbs

for 16 QAM, $2^4 = \underline{16}$; $N = 4$ bit

$\rightarrow \text{Baud} = f_b/4 = \frac{20 \text{mbs}}{4} = 5$ mbps

$\rightarrow B\cdot\omega = f_b/4 = \frac{20 \text{mbs}}{4} = 5$ mHz

$\rightarrow B\cdot\omega_{\eta} = \frac{20 \text{mbs}}{5 \text{ MHz}} = \underline{4}$ bits/cycle.

b) For a QPSK system and the given parameters, determine,

$C = 10^{-13}\,W \qquad f_b = 30\text{ kbs}$

$N_T = 0.06\times10^{-15}\,W \quad B = 60\text{ kHz}$

a) Carrier Power in dBm

$$C_{dBm} = 10\log\frac{10^{-13}}{0.001} = -100\text{ dBm}$$

b) Noise Power in dBm,

$$N_{T\,dBm} = 10\log\frac{0.06\times10^{-15}}{0.001} = -132.21\text{ dBm}$$

c) The Noise Power density,

$$N_0 = N_{T\,dBm} - 10\log B$$

$$= -132.21 - 10\log 60{,}000\text{ Hz}$$

$$= -180\text{ dBm}$$

d) Energy per bit, dB, $E_b = 10\log\frac{C}{f_b}$

$$E_b = 10\log\frac{10^{-13}}{30{,}000\text{ Hz}} = -174.77\text{ dBJ}$$

e) Carrier to noise Power ratio in dB,

$$\frac{C}{N} = 10\log\frac{10^{-13}}{0.06\times10^{-15}} = 19.2\text{ dB}$$

f) Energy bit to noise density ratio is,

$$\frac{E_b}{N_0} = C/N + 10\log\frac{B}{f_b}$$

$$= 19.2\text{ dB} + 10\log\frac{60000}{30000} = 22.2\text{ dB}$$

7) Determine the minimum bandwidth and baud for a BPSK modulator with a carrier frequency of 40 MHz and an input bit rate of 500 kbs. Sketch the output spectrum.

5 MHz
5 M baud.

Given: BPSK, $f_b = 500$ kbs

$f_c = 40$ MHz. $\quad f_a = \frac{f_b}{2} = 250$ kbs

$$BPSK = \frac{1}{2}\cos 2\pi(f_c - f_a)t - \frac{1}{2}\cos 2\pi(f_c + f_a)t$$

$$= \frac{1}{2}\cos 2\pi(40\,MHz - 250\,kbs) - \frac{1}{2}\cos(2\pi(40\,MHz + 250\,kbs))$$

$$= \frac{1}{2}\cos 2\pi(39.75\,MHz) - \frac{1}{2}\cos(2\pi(40.25\,MHz))$$

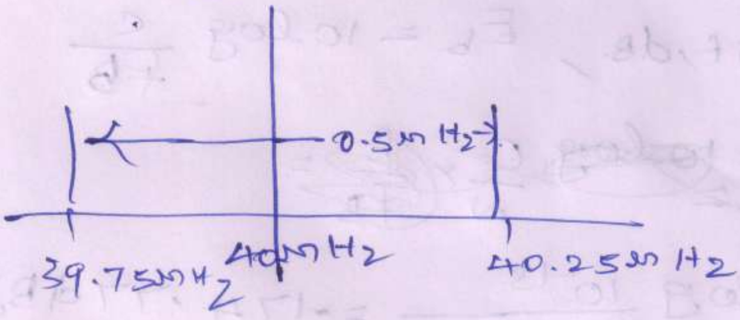
40×10^{6}
250 kbs
0.250 Mbs.
40

$$Bw = (f_c + f_a) - (f_c - f_a) = 2f_a$$

$\therefore$ Bandwidth $= 40.25\,MHz - 39.75\,MHz$

$= 0.5\,MHz.$

$2f_a = 2\times 0.25\,MHz = 0.5\,MHz.$



Baud $= 0.5\,MHz$.