

Bandwidth = $f_{max} - f_{min} = \frac{N}{2}$ where $N = \text{bitrate} = \text{number of bits}$

Bitrate = Baudrate $\times \log_2(\text{level})$

Bitrate = $2 \times \text{Bandwidth} \times \log_2(\text{level})$

Bitrate = Bandwidth $\times (\log_2(1 + \text{SNR}))$

$\text{SNR} = \frac{\text{wanted}}{\text{unwanted}}$

$\text{SNR}_{dB} = 10 \log_{10}(\text{SNR})$

Information rate = $10 \log_{10}(P)$

Information rate = $10 \log_{10}(\frac{P_2}{P_1})$

noisy channel

line coding \rightarrow unipolar \rightarrow single level voltage

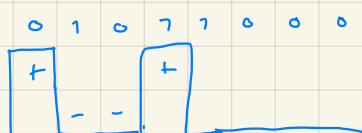
1 is high
0 is low



\rightarrow polar \rightarrow multiple voltage

\hookrightarrow polar NRZ-I (always inverse)

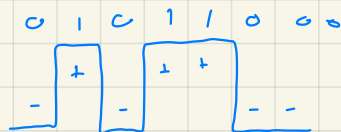
start high



clock and data

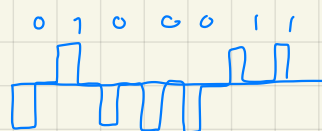
\hookrightarrow polar NRZ-L

1 = +
0 = -



\hookrightarrow polar RZ

1 = \uparrow
0 = \downarrow

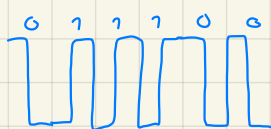


always returns to zero

alternating \rightarrow 0

\hookrightarrow manchester \rightarrow RZ + NRZ-L (if dif NRZ-I)

\uparrow = 1
 \downarrow = 0



band \uparrow , data rate

\rightarrow Bipolar

\hookrightarrow AMI \rightarrow 1 toggle

presb \rightarrow 0 toggle

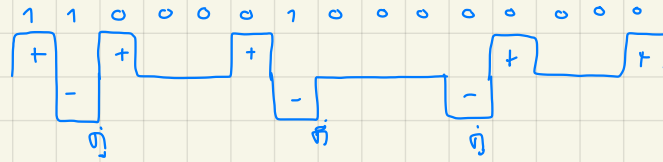
\hookrightarrow B8ZS \rightarrow 0 6 levels

level	
+	0 0 0 + - 0 - +
-	0 0 0 - + 0 + -

AMI

4DB3 → 6 bit 0 4 bit

last pulse	if Σ is odd	if Σ is even
+	000+	-00-
-	000-	+00+



→ MLT3 6 bit 1 ns = 100

→ 2B1Q

00	+1	-1
01	+3	-3
10	-1	+1
11	-3	+3

analog to digital conversion

↳ PCM

↳ Qbit = จำนวน bit ที่ใช้แทนสัญญาณ

Qlevel = จำนวน level ที่ใช้ = 2^{Qbit}

D = ความกว้างของ level = $\frac{V_{max} - V_{min}}{Qlevel}$

↖ 7 bit Qbit = 3

Qpartition = $-4D, [-3D, -2D, -1D, 0, D, 2D, 3D], 4D$ 6 bit level 1 bit

Qcodebook = Qpartition $\frac{1}{2}$ = $[-3.5D, -2.5D, -1.5D, -0.5D, 0.5D, 1.5D, 2.5D, 3.5D]$

normalized PAM = $\frac{V_{read}}{D}$

normalized quantize value (อ่าน) = PAM ที่อ่านมา

normalized error = normalized PAM - normalized quantize value

index 7 bit 0 bit 1 bit 2 bit 3 bit 4 bit 5 bit 6 bit

digital to analog conversion

↳ ASK

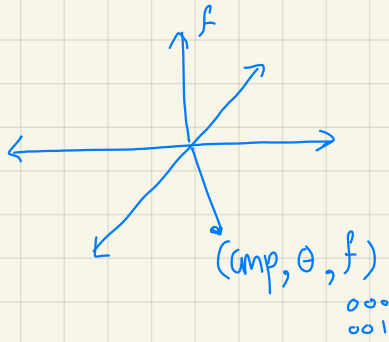
↳ $B = (1 + d) \text{ (bandrate)}$
odd 1

$$\frac{\text{cycle}}{\text{band}} = \frac{f_c}{\text{bandrate}}$$

↳ FSK

↳ $B = (1 + d) \text{ (bandrate)} + 2\Delta f$
also $(f_1 - f_0) + \text{bandrate}$

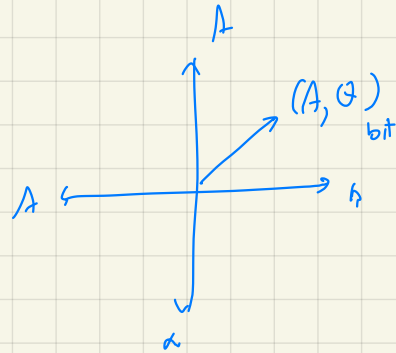
constellation diagram



θ ที่แสดงข้าง
บนแกนคือ amplitude

$$s(t) = A \sin(\omega t + \theta)$$

qes0



analog to analog modulation

↳ เทคนิคการมอดูเลต

↳ ค่า dc ของคลื่น

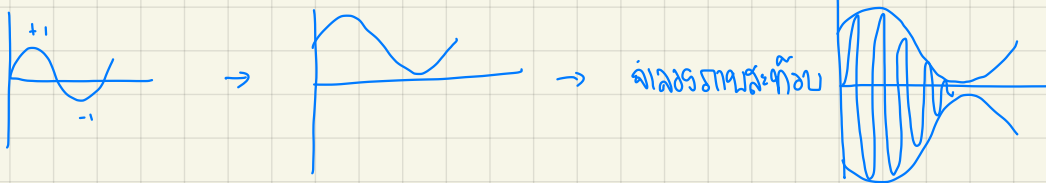
$$dc = v_{pp} \\ \downarrow \\ m=1$$

$$dc > v_{pp} \\ \downarrow \\ m < 1$$

$$dc < v_{pp} \\ \downarrow \\ m > 1$$

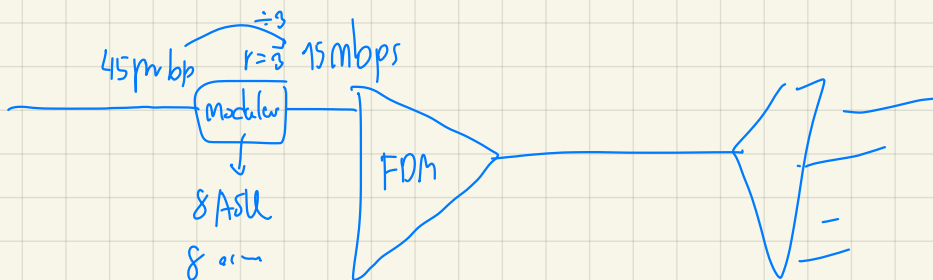
$$\text{modulus index} = \frac{p-n}{p+n}$$

↳ ระบบ การมอดูเลตแบบ AM



multiple access

↳ FDM → แบ่งสัญญาณออกเป็นช่อง → รวมเข้า channel → ส่ง → รับสัญญาณ F → demod



$$\text{bitrate} = \text{frame rate} \times \left[\frac{\text{bit}}{\text{frame}} \right] \rightarrow \text{ถ้า frame อยู่แค่ channel ก็คูณเข้าไป}$$