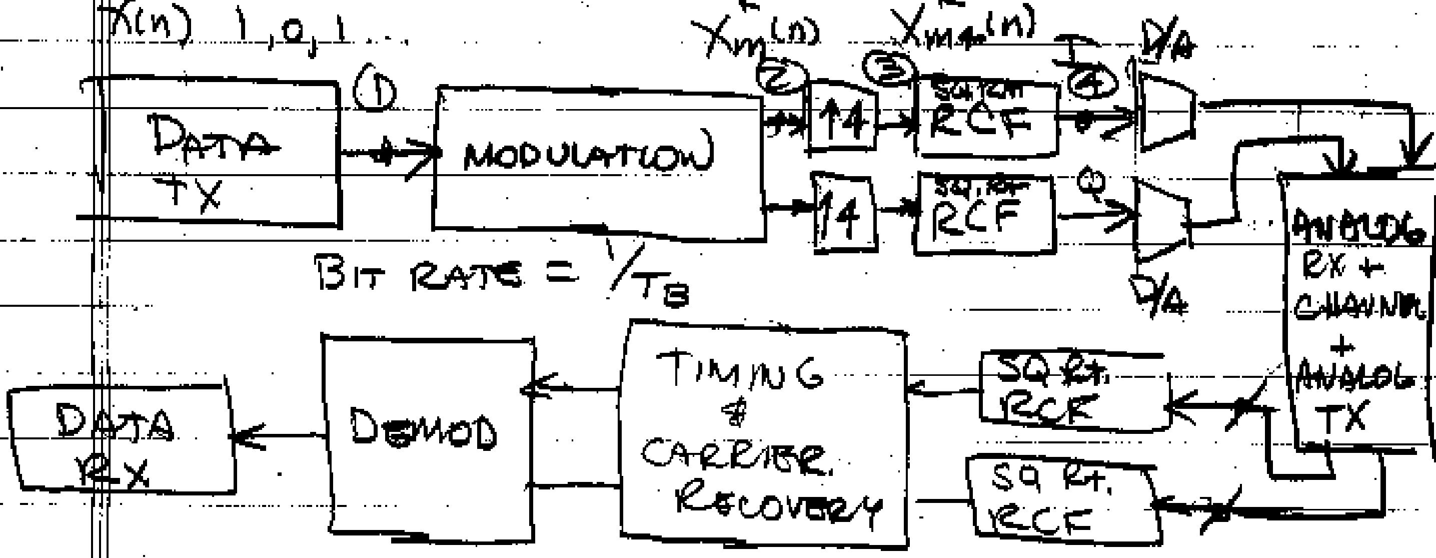
LEC 9

COMMUNICATIONS THEORY

- MODULATION & NOISE
- ANALOG IMPAIRMENTS

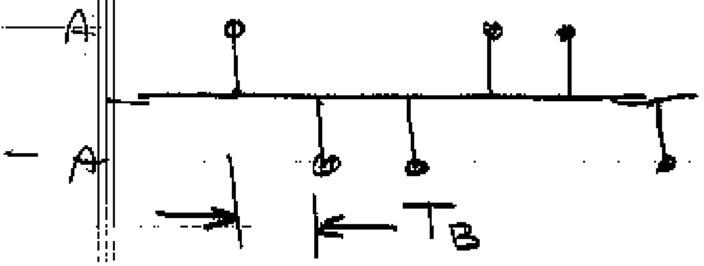
DIGITAL PARTS OF RECEIVER



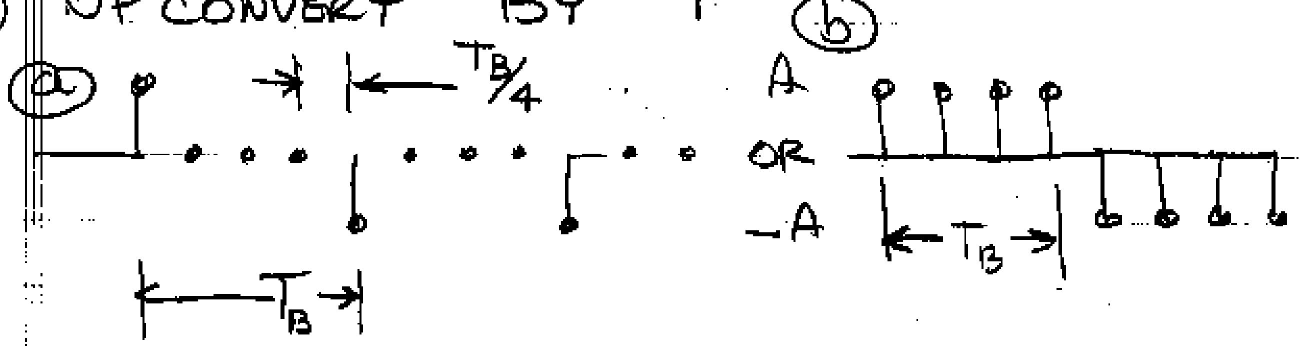
① $X_D(n) = 1,0,0,1,1,0$

② $X_M^R(n) = A,-A,-A,A\,A,-A$

PAM
PULSE AMPL. MODULATION



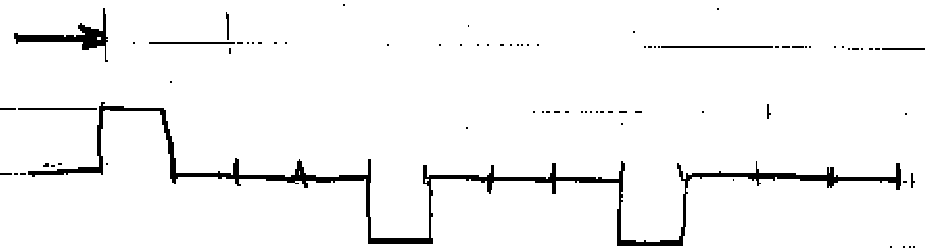
③ UPCONVERT BY 4



WE COULD CONVERT THESE TO ANALOG WAVEFORMS

③ - ANALOG (WITHOUT FILTER)

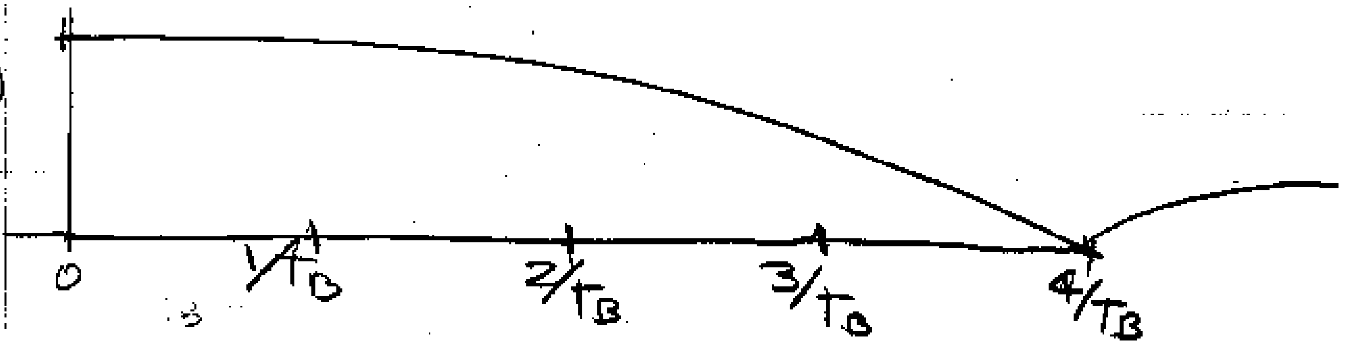
ⓐ



LETS SAY THE INITIAL SEQUENCE IS RANDOM WITH A FLAT FREQ. RESPONSE

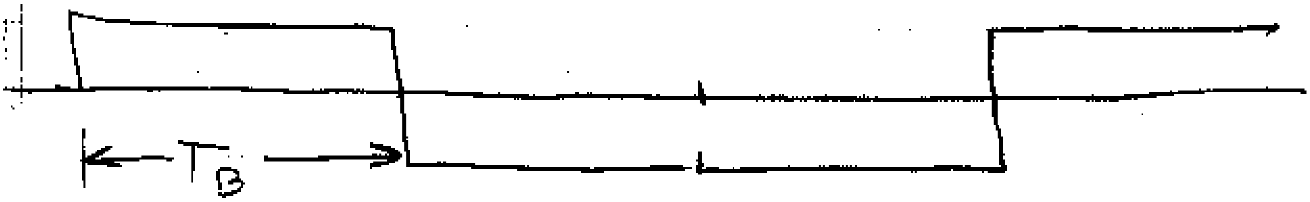
THEN THE FREQUENCY RESPONSE IS

ⓐ



FOR ~~THE~~ SAMPLE & HELD CASE

ⓑ



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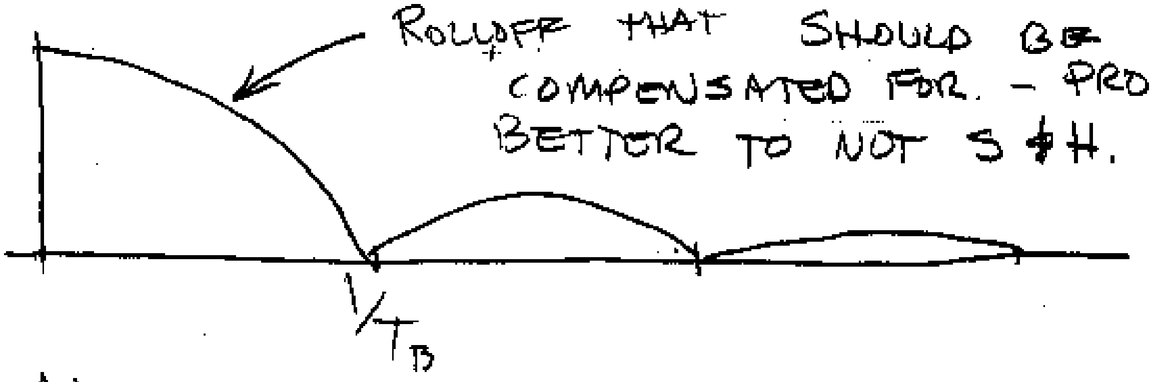


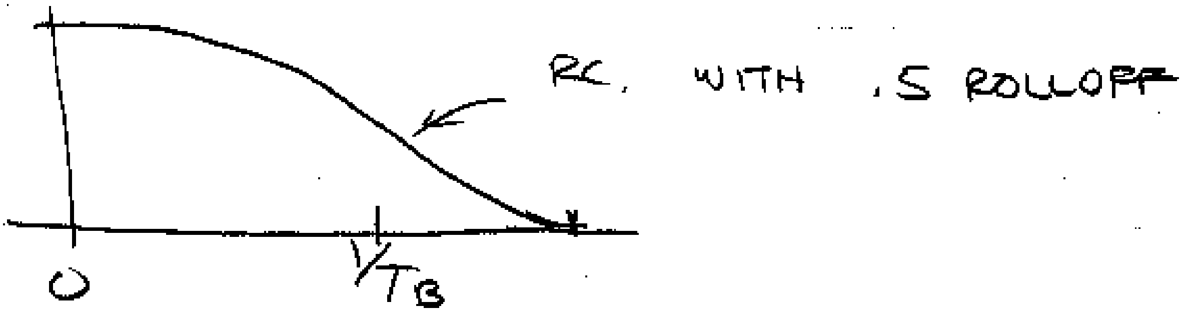
ROLLOFF THAT SHOULD BE COMPENSATED FOR. - PROBABLY BETTER TO NOT S & H.

NEED TO BANDLIMIT THE SIGNAL!

④ USE A RAISED COSINE FILTER TO BAND LIMIT THE SIGNAL WITHOUT ISI (HW. 1)

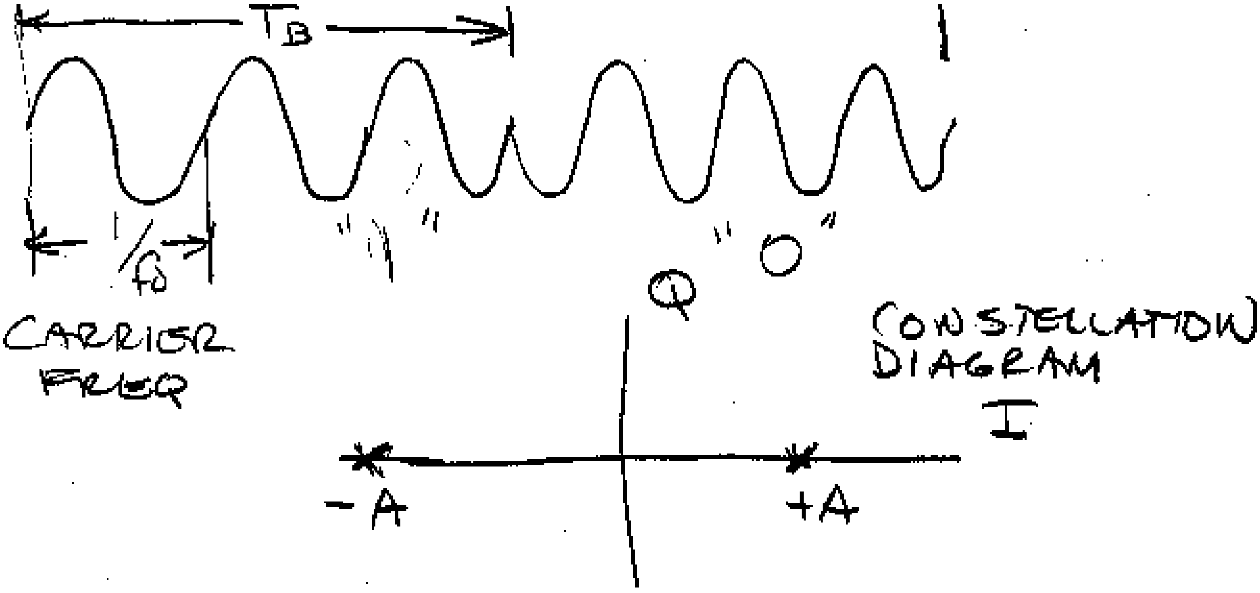
USE METHOD (a) FOR UPCONVERTING THEN BANDLIMIT USING FILTER

(a) FREQ RESPONSE - INPHASE CHANNEL

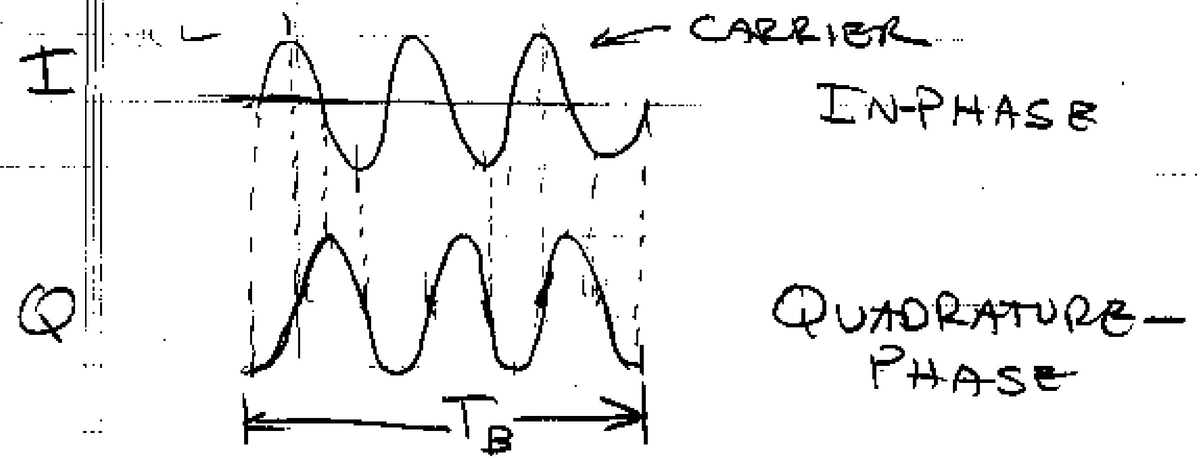


WHAT ABOUT Q CHANNEL, IT IS NEEDED TO DO PHASE MODULATION

CARRIER WITH ONLY PAM

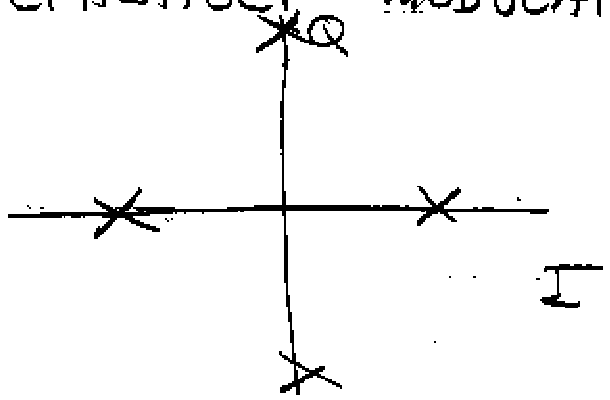


THE ANALOG CIRCUITS WILL TAKE THE Q CHANNEL (QUADRATURE) AND USE IT TO MODULATE A 90° PHASE SHIFTED VERSION OF ~~THE~~ CARRIER.



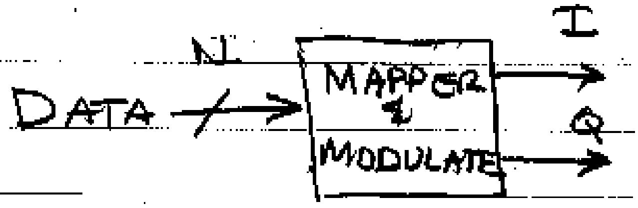
EQUAL I & Q GIVES A CARRIER PHASE SHIFT OF 45° (0° + 90°)

WE CAN ENCODE 2-BITS BY SEPARATELY MODULATING I & Q



10, 01, 10

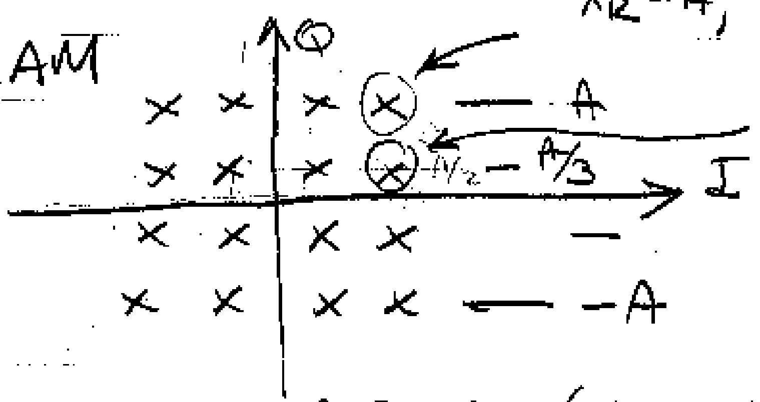
SYMBOL



N BITS/SYMBOL OR SYMBOL RATE

IS $NT_B = T_S$

16-QAM

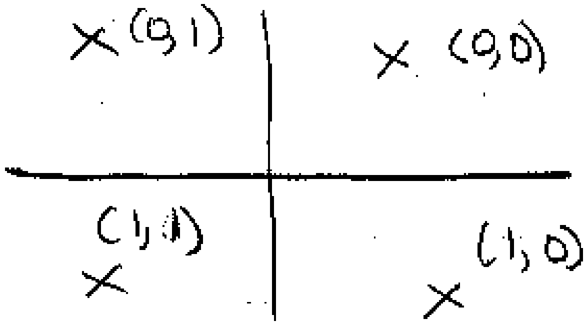


$X_R = A,\ X_Q = A$

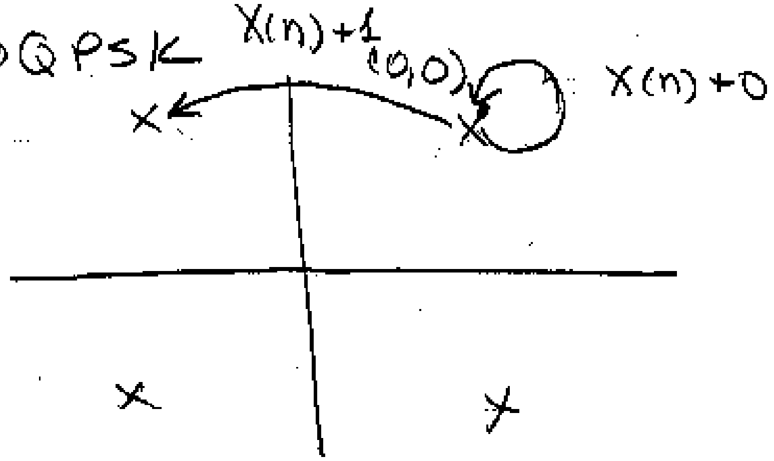
$X_R = A,\ X_I = A/3$

OR

- 4QAM OR QPSK (QUADRATURE PHASE SHIFT KEYED)

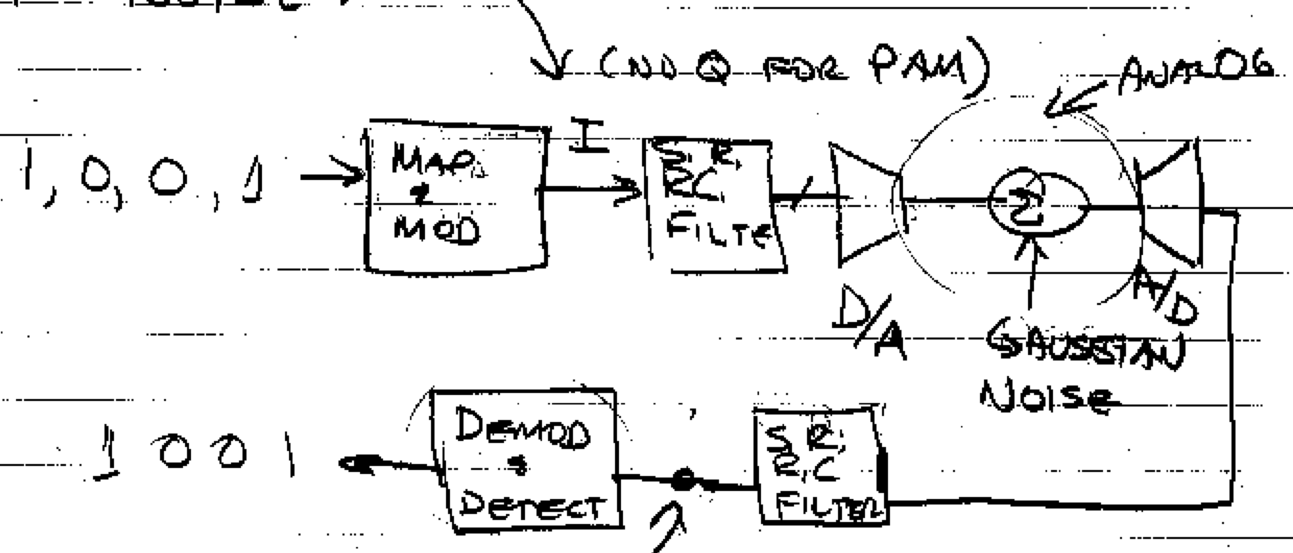


OR DQPSK

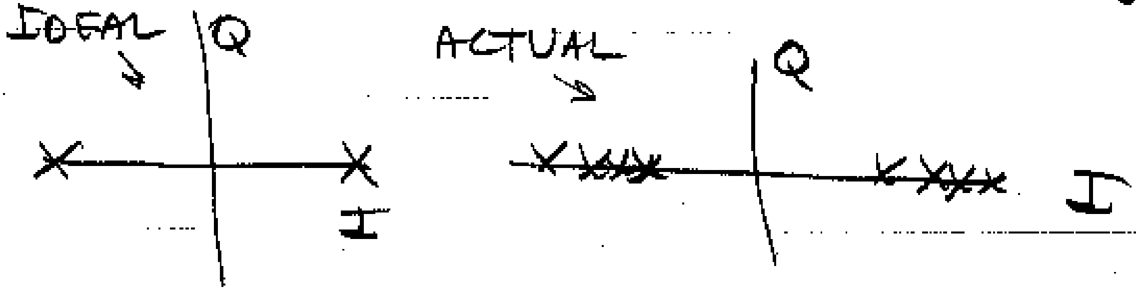


	ADD PHASE
(0,0)	0°
(0,1)	90°
(1,1)	180°
(0,1)	225°

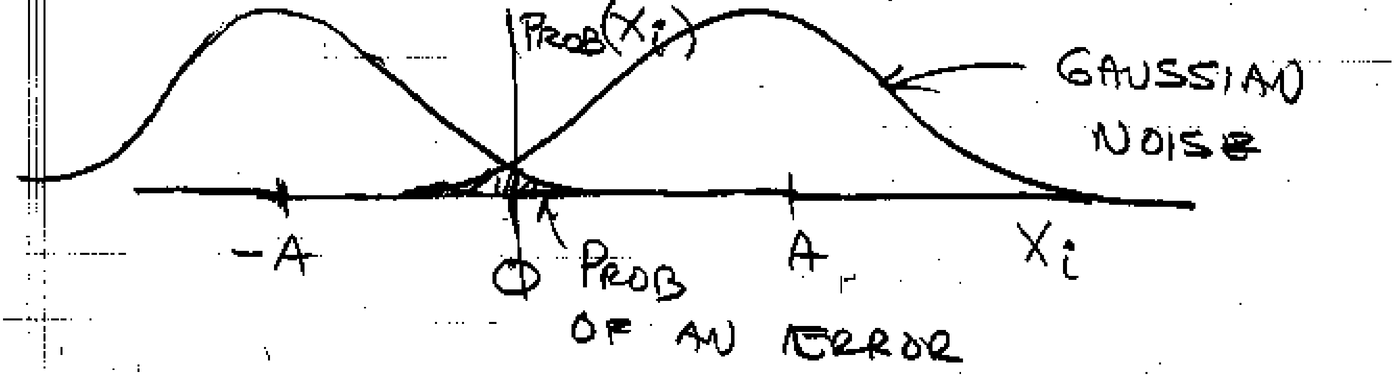
BACK TO **PAM** TO SEE EFFECT OF NOISE.



CONSTELLATION AT THIS POINT



PLOT OF PROBABILITY OF AN AMPLITUDE

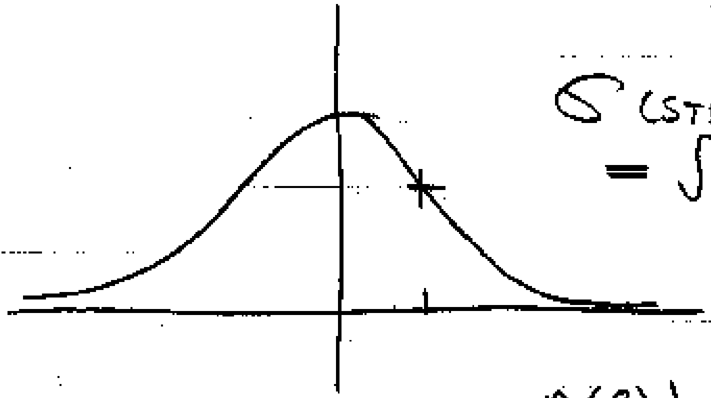


AWGN ≡ ADDITIVE WHITE GAUSSIAN NOISE

WHITE = FLAT FREQ RESPONSE

NOISE – AWGN

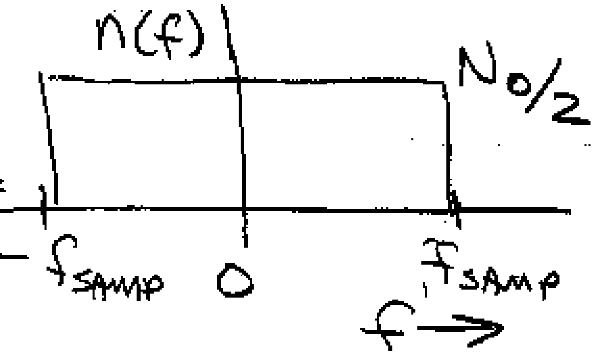
GAUSSIAN AMPLITUDE DISTRIBUTION



σ (STD. DEVIATION) $= \sqrt{N_0 T_B}$

FOR N_0

SINGLE SIDED NOISE SPECTRAL DENSITY



$$(N_{RMS})^2 = \int_{-f_{SAMP}}^{+f_{SAMP}} n(f)\,df = N_0 f_{SAMP}$$

(INDEP. OF SAMPLE RATE)

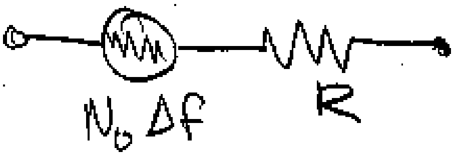
$$N_0 = \frac{VOLTS^2}{Hz}$$ = POWER SPECTRAL DENSITY

NOISE ON 50Ω RESISTOR

$N_0 = 4kTR$ $\left(\frac{V^2}{Hz}\right)$

$k = 1.38 \times 10^{-23}$ $\frac{WATT\text{-}SEC}{°K}$

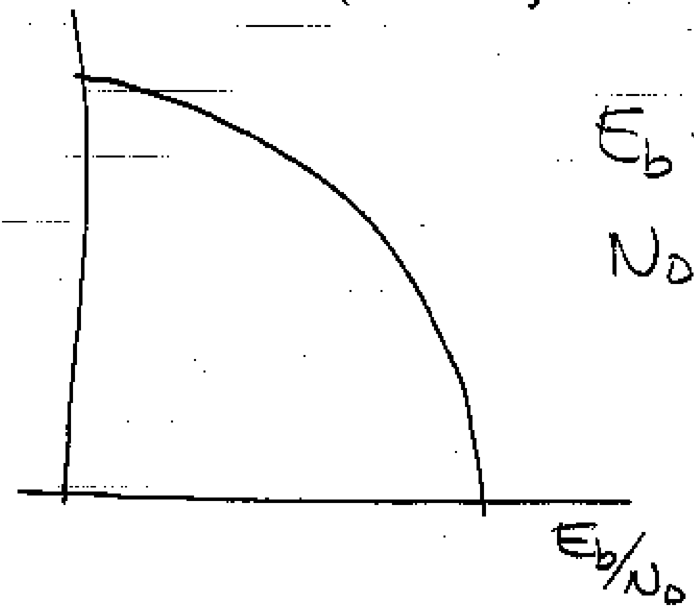
T = TEMP IN °K



PROBABILITY OF AN ERROR IS

$$P_B = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$$

Q IS A TABULATED FUNCTION



E_b = ENERGY/BIT

$N_0 = \frac{V^2}{Hz}$ NOISE

$\frac{E_b}{N_0}$ IS INDEPENDENT OF DATA RATE !

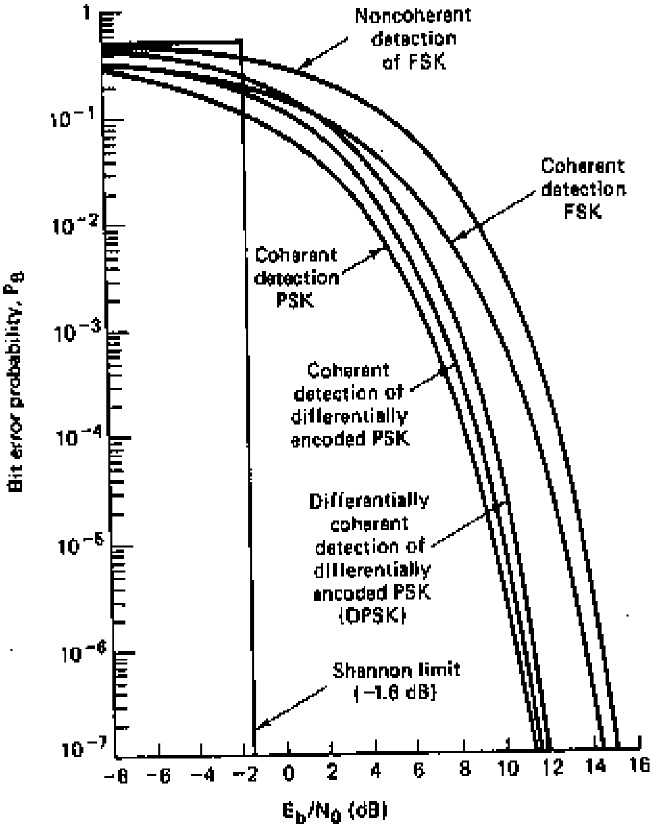
IT IS ACTUALLY ~~THE~~ SIGNAL/NOISE RATIO.

S = SIGNAL POWER $\sim A^2$
T_b = BIT TIME $= 1/R$ R = BIT RATE
W = SIGNAL BANDWIDTH
N = NOISE POWER $= N_0 W$

$$\frac{E_b}{N_0} = \frac{ST_b}{N_0} = \frac{S}{RN_0} = \frac{SW}{RN_0W} = \left(\frac{S}{N}\right)\left(\frac{W}{R}\right)$$

BIT ERROR RATE CURVES

⑨

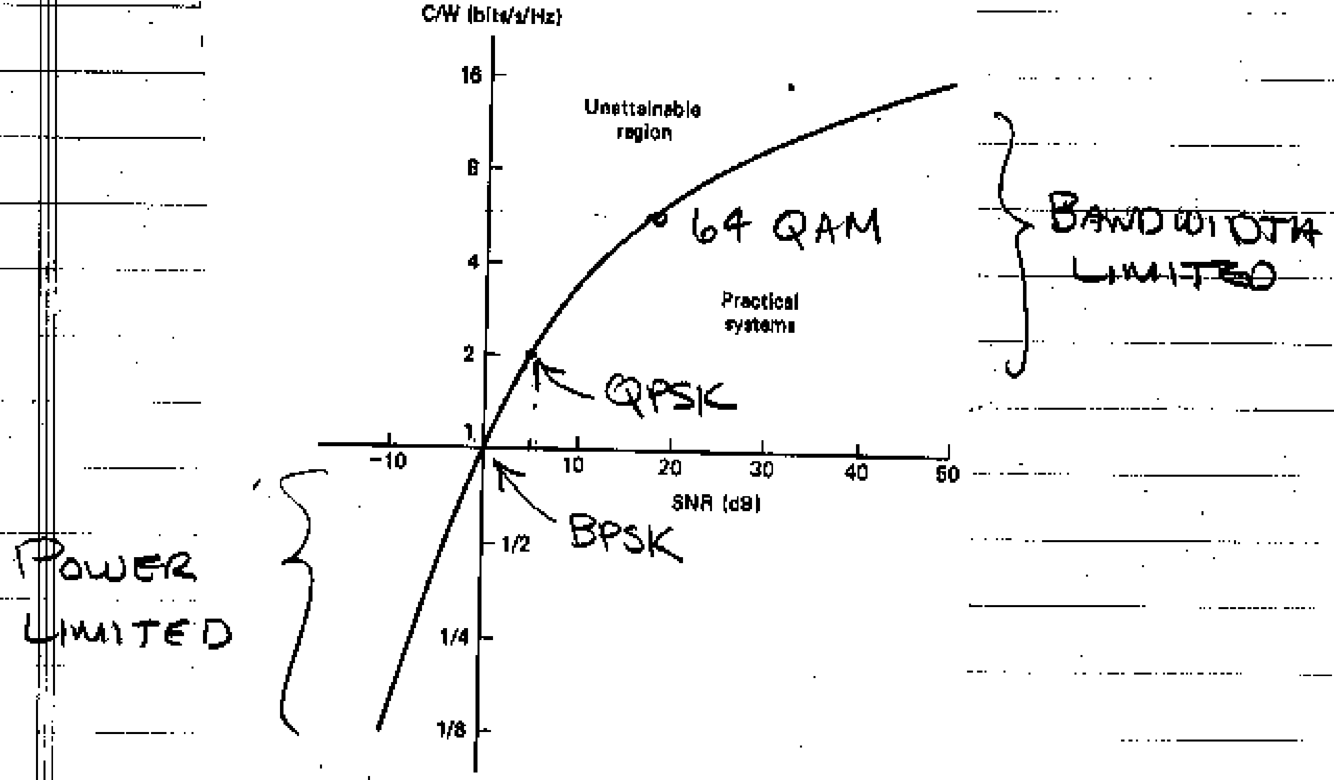


SHANNON SHOWED THAT S, N AND W SET A LIMIT ON THE AMOUNT OF DATA THAT CAN BE SENT WITHOUT ERROR.

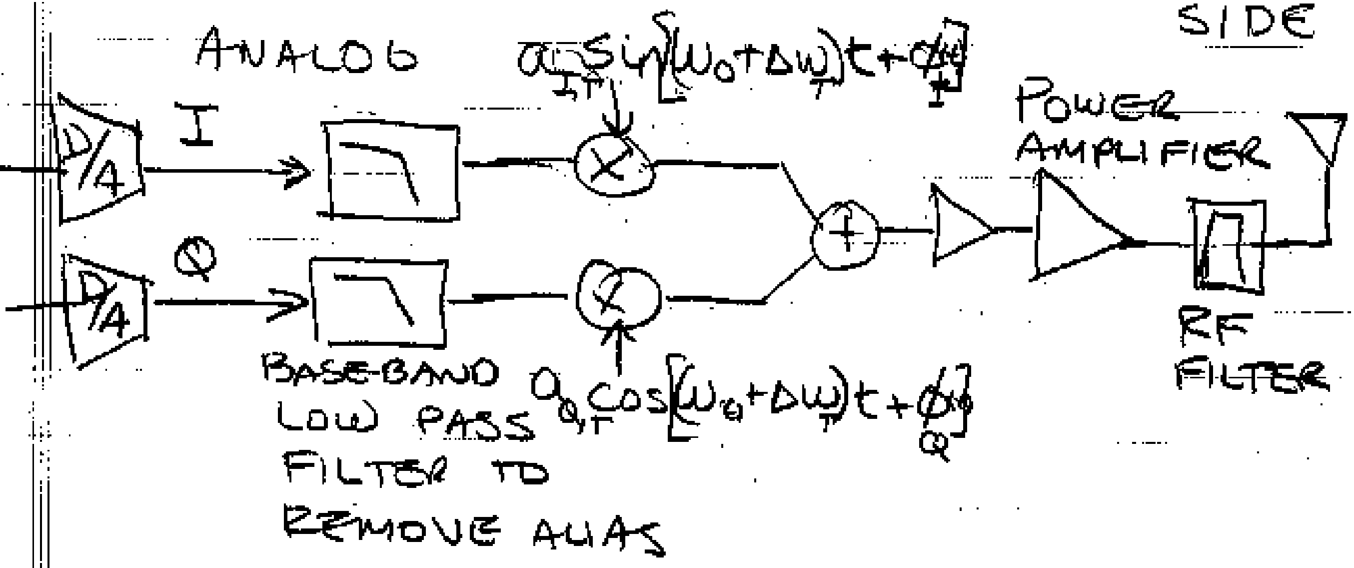
$$C = W \log_2\left(1 + \frac{S}{N}\right) = \left(\text{BITS}/\text{SEC}\right)$$

OR $$\frac{C}{W}\left(\frac{\text{BITS/SEC}}{\text{HZ}}\right) = \log_2\left(1 + \frac{E_b}{N_0}\left(\frac{C}{W}\right)\right)$$

PLOT OF SHANNON'S CAPACITY FORMULA



NOW BACK TO THE ANALOG / CHANNEL BLOCK - TRANSMIT SIDE



IMPAIRMENTS:

a) I Q MISMATCH

  a) DIFFERENT GAINS IN EACH PATH
  $a_I \neq a_Q$

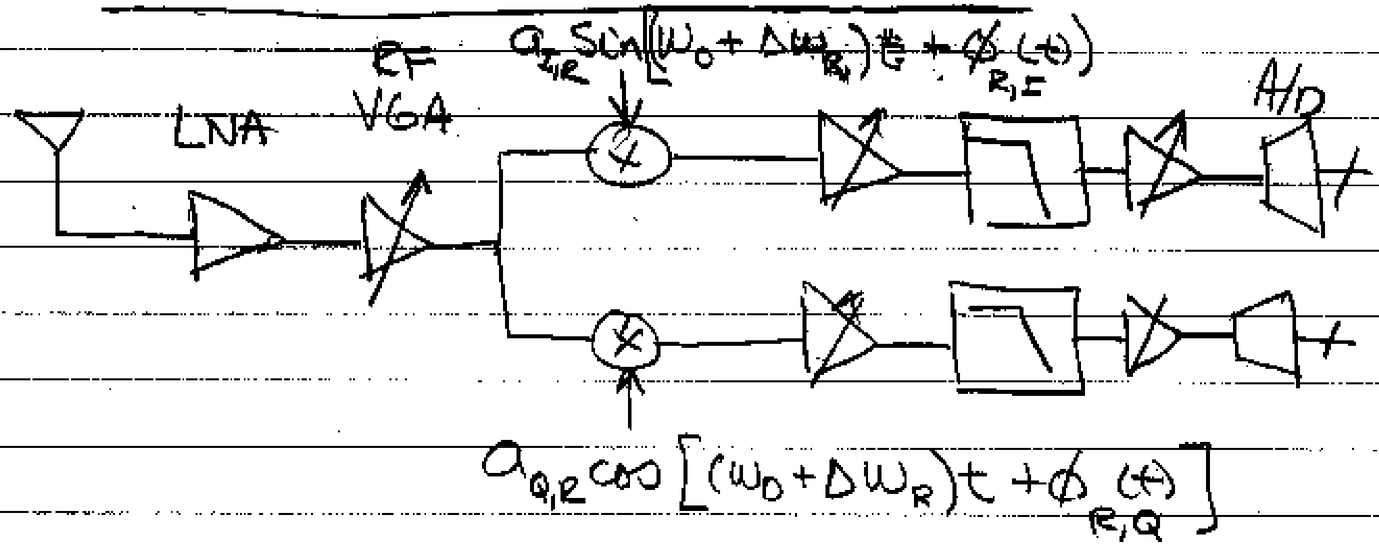
  b) PHASE SHIFT NOT EXACTLY 90°
  $\bar{\phi}_I \neq \bar{\phi}_Q$ (AVERAGE VALUES)

b) PHASE NOISE
  TIME VARIATION IN PHASE
  $\phi_I(t), \phi_Q(t)$

c) NON-LINEARITIES IN POWER AMPLIFIER

d) BASEBAND & RF FILTER RESPONSE

RECEIVE SIDE IMPAIRMENTS



IMPAIRMENTS

a) IQ MISMATCH - GAIN & PHASE
b) PHASE NOISE
c) AMPLIFIER NON-LINEARITIES
    i) HARMONICS
    ii) DISTORTION
d) GAIN VARIATIONS IN VGA'S
    (VARIABLE GAIN AMPLIFIER)

e) THERMAL NOISE
f) MIXER NONLINEARITIES, CONVERSION LOSS
g) DC OFFSET