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EE597

Lecture 1 May 18, 2016

Office hours: M W after class

RTH 410 W 10am-12pm

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What this course is about

- Physical Layer: modulation, coding, radio propagation, multipath fading, Delay/Doppler spread, MIMO, OFDM, CDMA, etc.

- Link Layer - Medium Access:
randomized access — ALOHA, CSMA
scheduled access - TDMA/FDMA
Graph Theory - Graph coloring algorithms

- Network Layer : Routing in multi-hop wireless networks such as wireless sensor networks / low power IoT networks or mesh networks
  - routing metric
  - mobile ad hoc networks
  - intermittently connected mobile networks

- Transport Layer : Congestion control
  - Utility based Network Optimization using Backpressure Scheduling.

- Application Layer : mobile browsing, publish-subscribe middleware

Examples of current standards & protocols.

Physical Layer.

Electromagnetic Waves

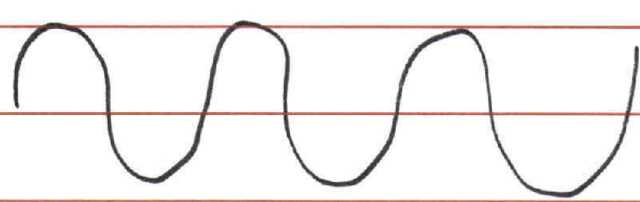
Radio Waves

RF

mm Wave

1 GHz ⟷ 6 GHz | 60 GHz ⟷ 100 GHz

Sinusoidal signal.

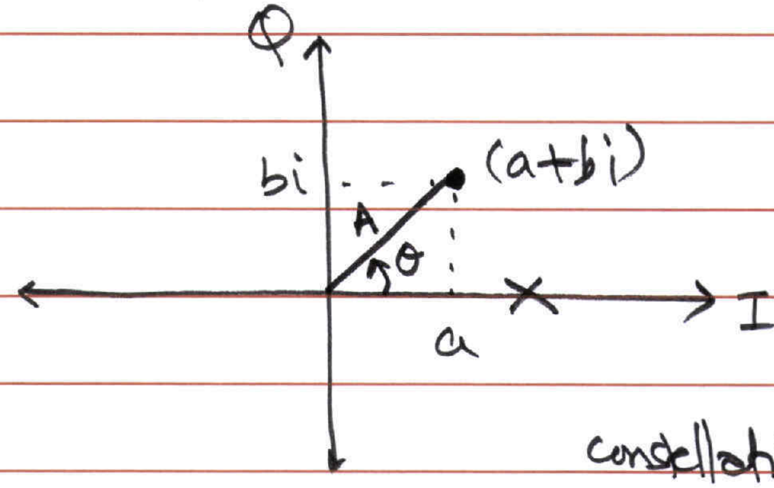


Carrier Wave.

$$A \sin(2\pi f_c t + \theta)$$

A ← amplitude, f_c ← freq, θ ← phase fix the carrier frequency f_c

can vary amplitude & phase



constellation Diagram

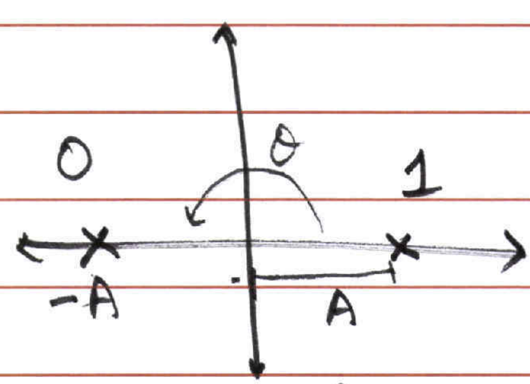
Complex Plane / Argand Plane.

$\underbrace{a}_{Re} + \underbrace{bi}_{im}$

A, θ

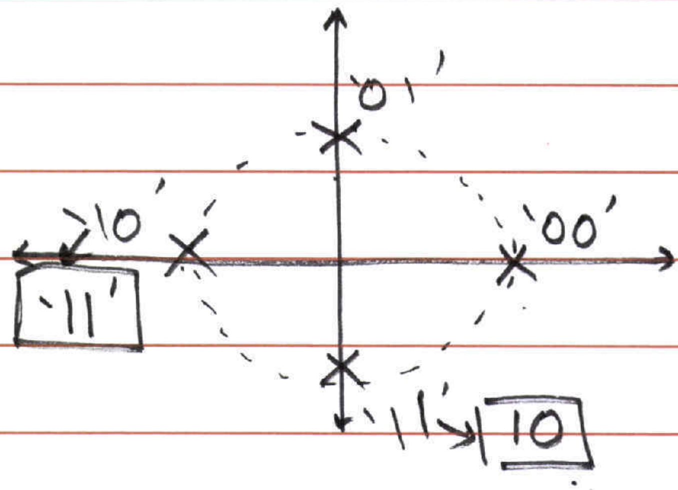
$A = \sqrt{a^2 + b^2}$

$\theta = \tan^{-1}\left(\frac{b}{a}\right)$



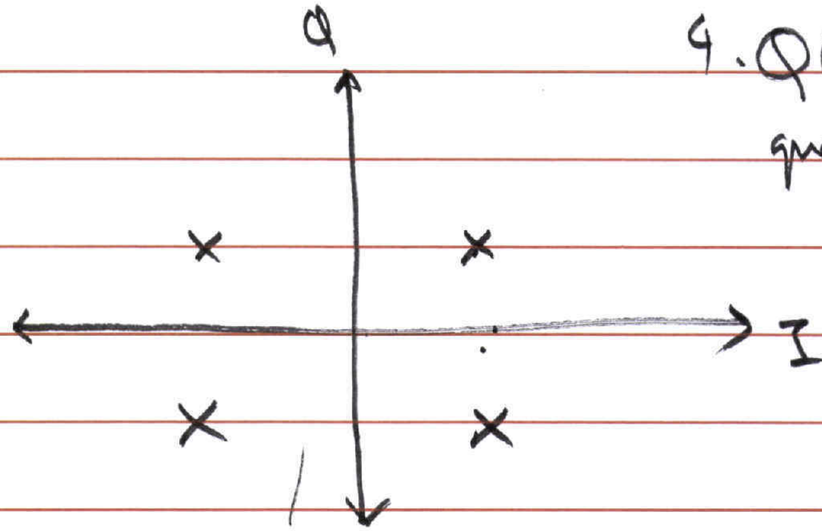
BPSK

Binary Phase Shift Keying

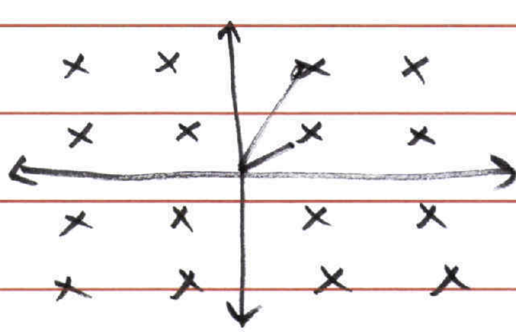


4 PSK
2 bits/symbol

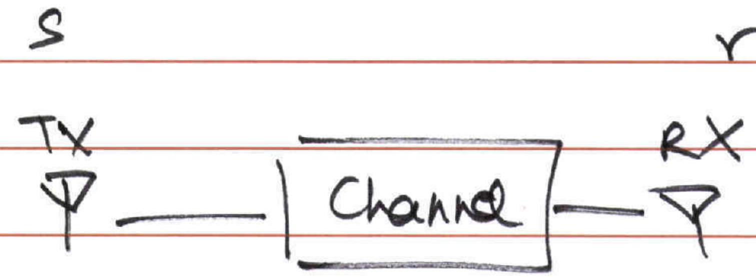
8 PSK
- 3 bits/symbol



4-QAM
quadrature
amplitude
modulation



16-QAM
4 b p symbol.

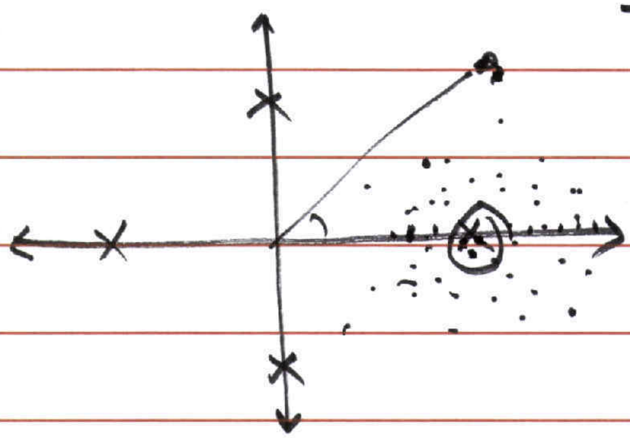


AWGN channel.

Additive white Gaussian Noise.

$$\underline{r} = s + w$$

- $\underline{r}$: complex valued received signal
- s: complex-valued signal
- w: random noise, a circularly symmetric complex Gaussian r.v.



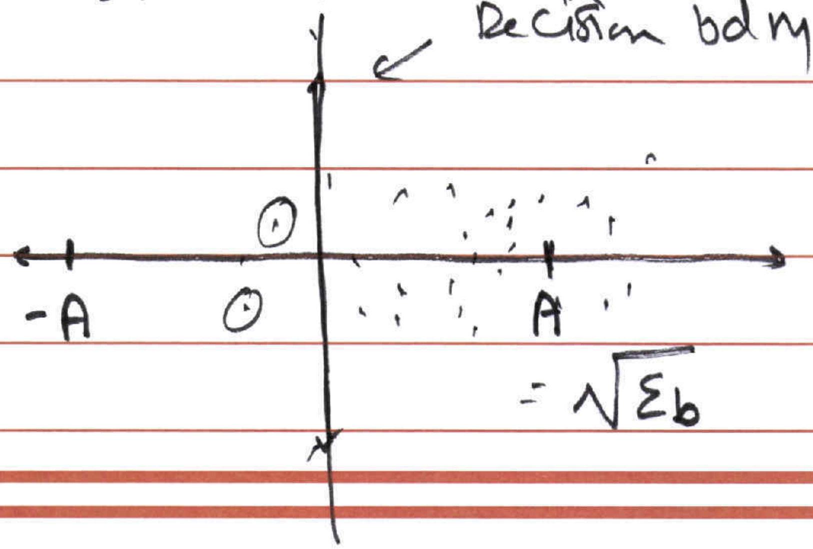
$\underline{w} = \underline{r} - \underline{s}$ is also complex.

$= \underline{w_{re}} + \underline{w_{im}} \cdot i$

w_{re} & w_{im} are both real Gaussian r.v. w/ zero mean & same variance, indep. of each other.

How do modulation schemes perform under AWGN?

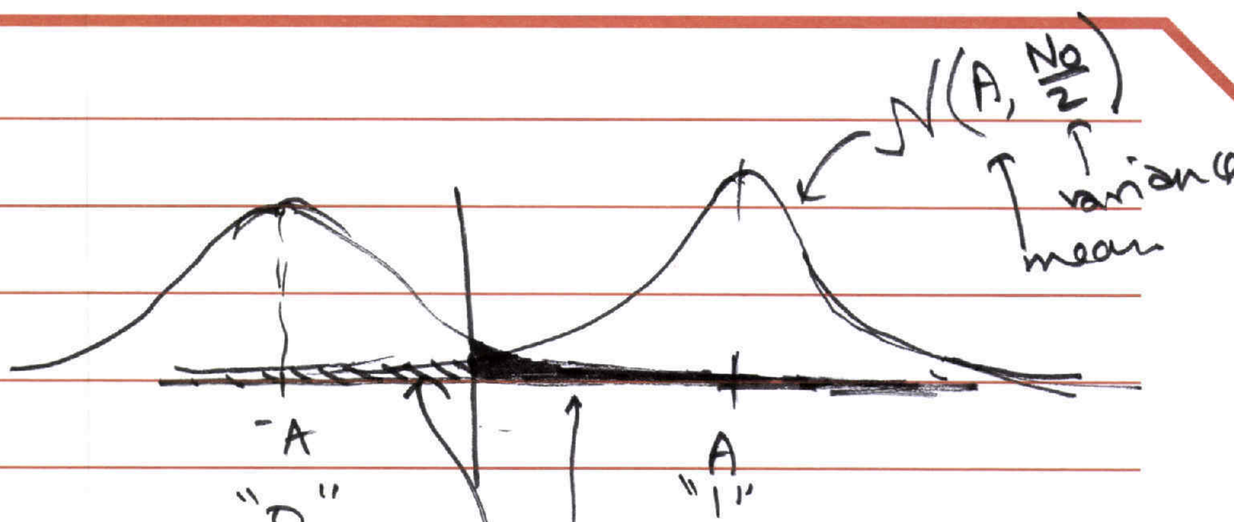
e.g. BPSK.



What is the prob. of error?

total noise variance of N_0

Var. for w_{re} = var w_{im} $= \frac{N_0}{2}$



Prob. of error when "1" is sent.

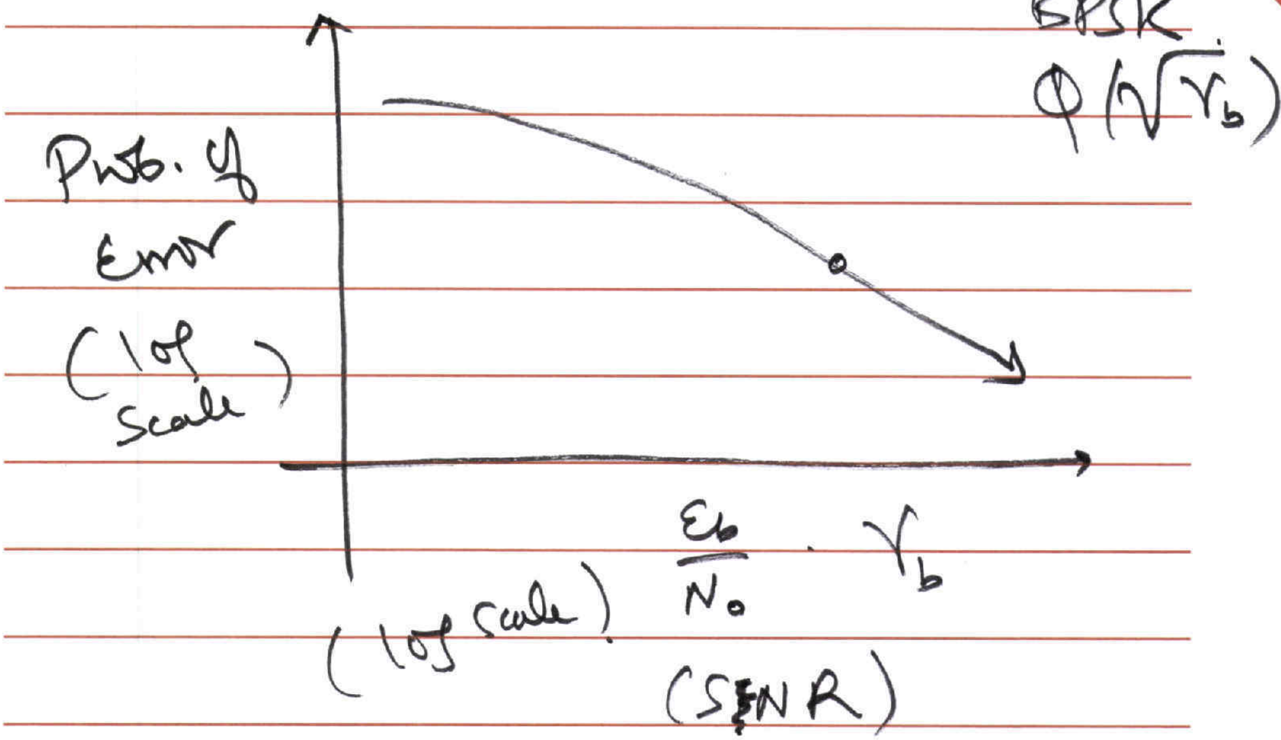
Prob. of error when "0" is sent

Q-function

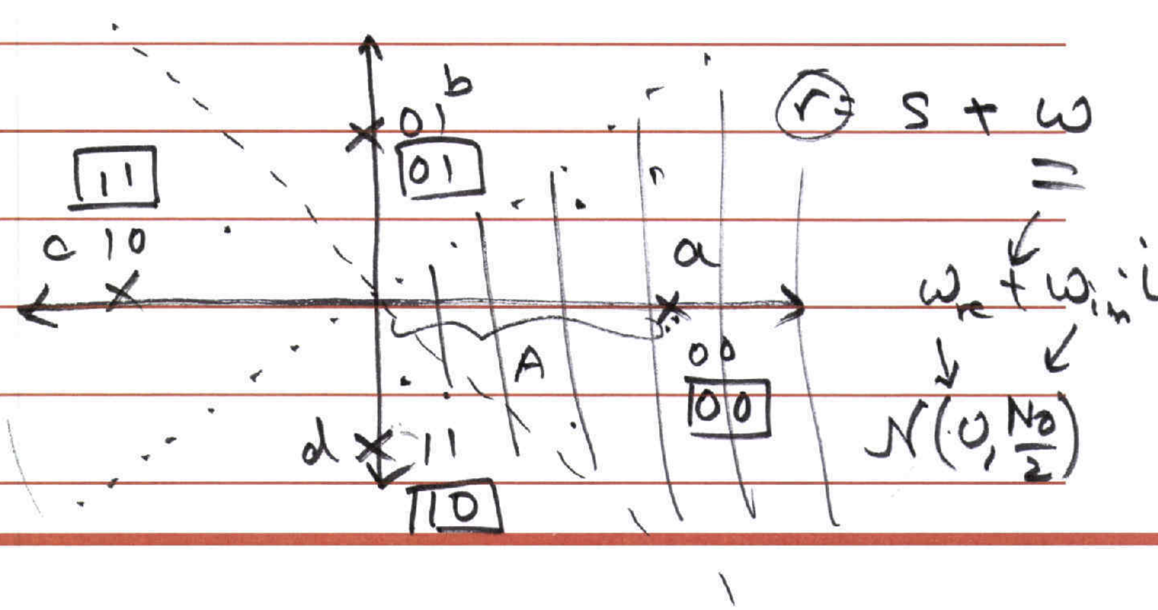
1 − cdf for Gaussian with mean 0 & std. dev. 1 (variance)

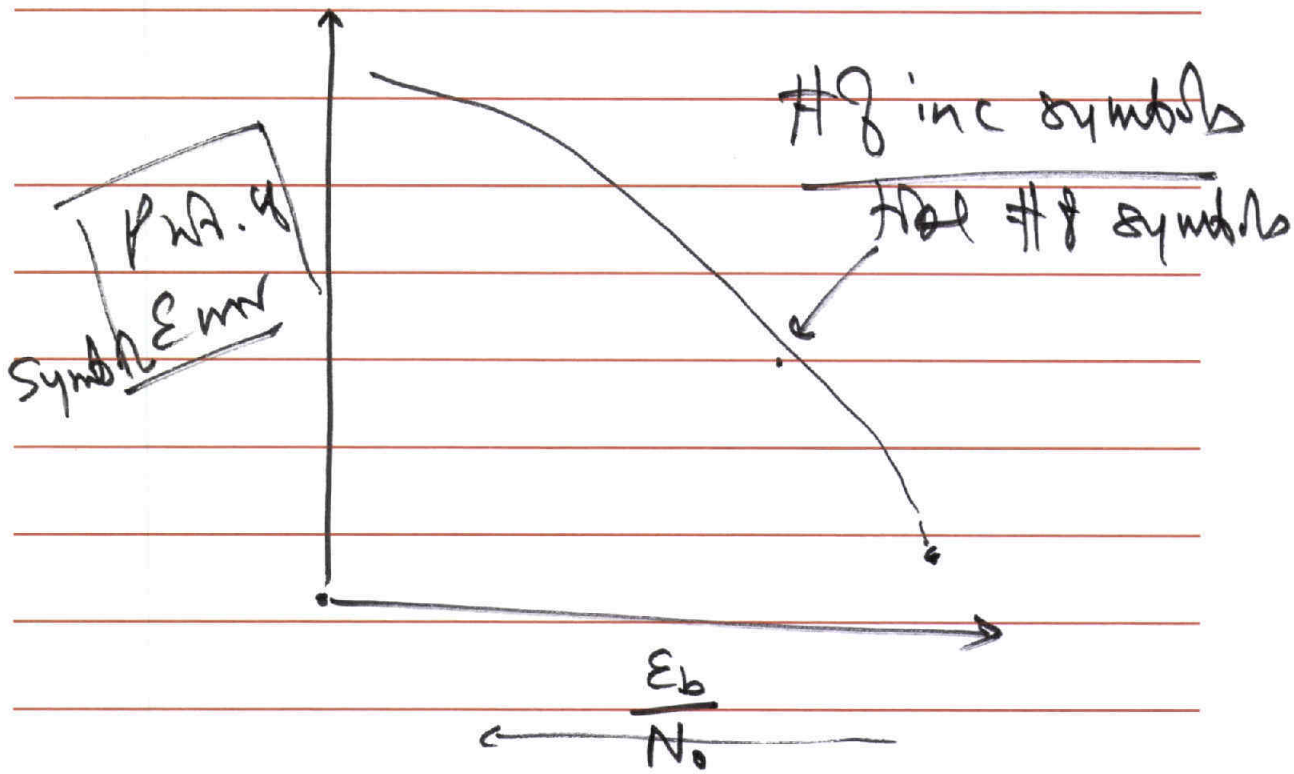
$$Q\left(\frac{A}{\text{std. dev.}}\right) = Q\left(\frac{\sqrt{\mathcal{E}_b}}{\sqrt{\frac{N_0}{2}}}\right)$$

$$= Q\left(\sqrt{\frac{2\mathcal{E}_b}{N_0}}\right) = Q\left(\sqrt{2\gamma_b}\right)$$



Compute numerically the prob. of error for 4-QPSK 4PSK

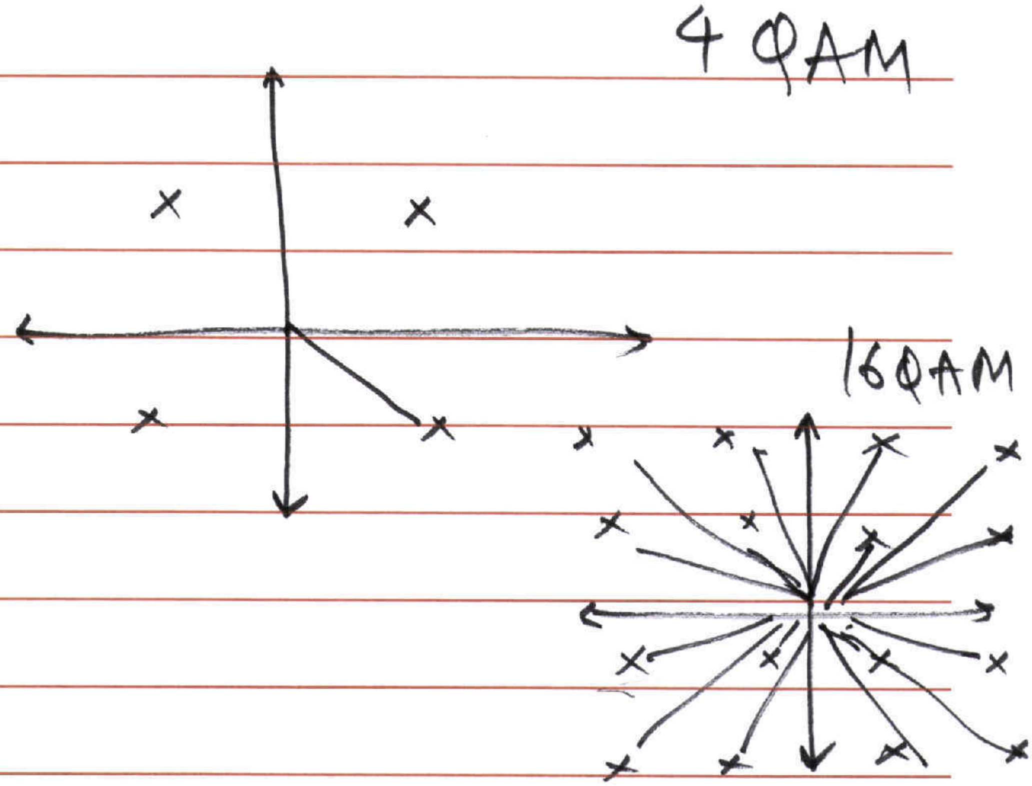




Try both encoding schemes (regular & Gray encoding) & see what happens to the Bit Error Rate (BER)

$$\frac{\text{\# of incorrect bits}}{\text{total \# of bits}}.$$

how many symbols to send?



Rate & error Rate tradeoff.

Higher constellation Rate ↑
for the same average energy, error Rate ↑

for the same error rate, can get a higher data rate by & using a larger constellation by doing ______.

2 bits × 4 bits

to go from 4QAM – 16QAM
& keep same error rate,
need ~ 4X the power
for 2x improvement
in rate.

need to scale power
exponentially to get
imp. in rate.

rate $\underset{\sim}{\propto}$ log (1+ power)
for fixed error rate.

$R = B \log_2 (1 + SNR)$.

Rate – Power – Error Rate

A fundamental tradeoff