CS 598 WSI, Lecture 4

- → Rate adaptation
- → Frequency and bandwidth
- → Narrowband vs. wideband
- → OFDM: Motivation.

Rate Adaptation

mobility

→ Loss
→ SNR
→ Probe
→ success
→ smooth

Symbol rate: → 10MHz → 10^7 symbols per second
↳ hardware/ protocol/

Modulation

bits → symbols (complex- valued)

error increase

2 bits → 1 symbol → 2×10^7 bits/s
4 bits → 1 symbol → 4×10^7 bits/s
8 bits → 1 symbol 8×10^7 bits/s
80 Mbps

data rate improves

really low datarate → losing throughput

" high " → lose throughput

~~Cod~~ modulation and | coding.

MCS (Modulation and coding scheme)

0 → BPSK (1bit/s) 1/2 → datarate
1
2
3
4
5

2

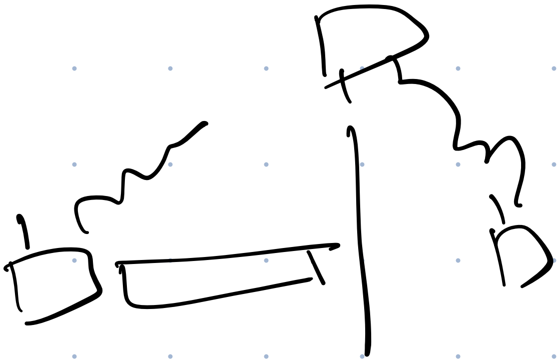
Q. How do you know your datarate is too high?

losses/ no acks.

Q. - - - - too low?

too much success, try something better

Losses ⟹ reduce datarate { SNR-based increase or reduction.



(Probing to increase datarate)

False

Sample Rate

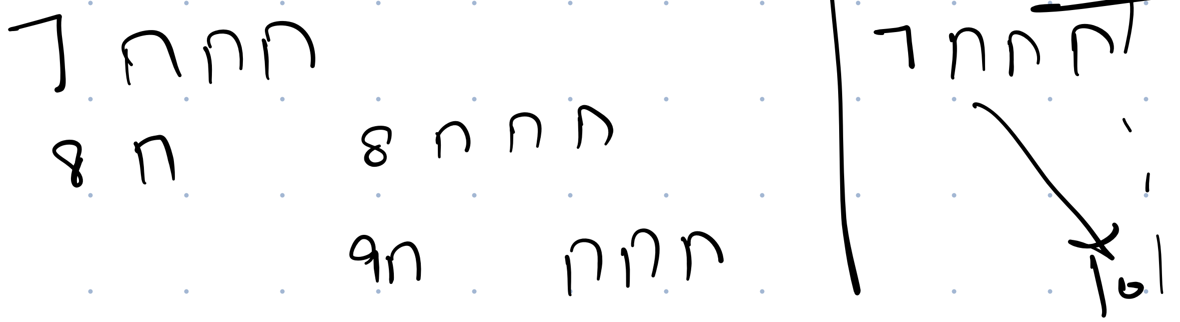
MCS	success rate table
6	→ 99.5%
7	→ ~~95%~~ 99%
8	→ 90%
9	→ 85%

99.5% × 10Mbps
= 9.95 Mbps

8.5% × 40Mbps
= 34Mbps

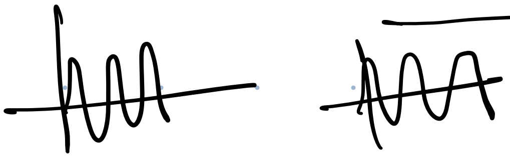
Naive vs Sample rate

Sample rat



Frequency vs Bandwidth

Wi-Fi operates at 2.4GHz
5GHz



bandwidth → how many samples/symbols can I send per second.

20MHz → 20×10^6 symbols/s

40MHz → 40×10^6 symbols/s

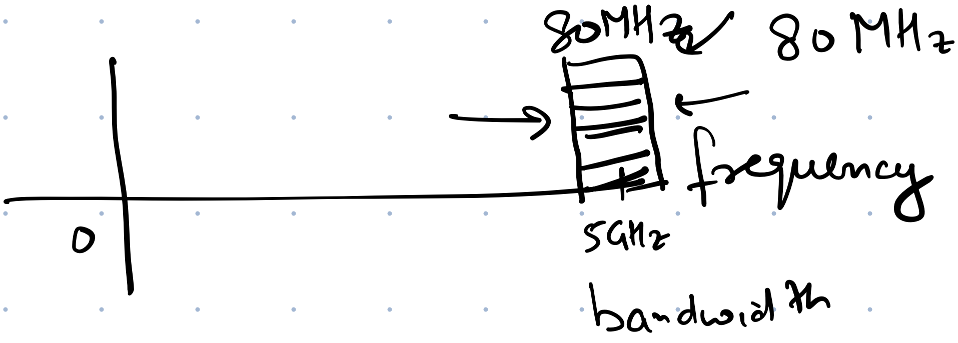
80 MHz → 80×10^6 symbols/s

(160/320)

80 MHz bandwidth at ~~2~~ 5GHz.

5GHz - 40MHz, 5GHz + 40MHz

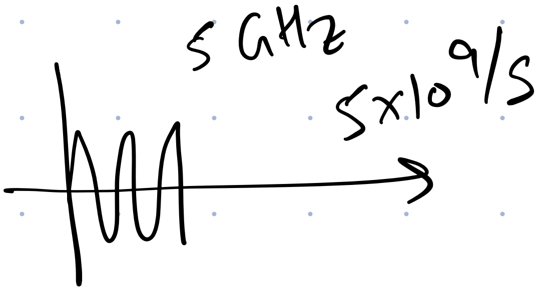
is occupied by this signal.



Q. Why choose 20MHz or 80MHz?

20×10^6 symbols/s → 80×10^6 symbols/s

4 times more data

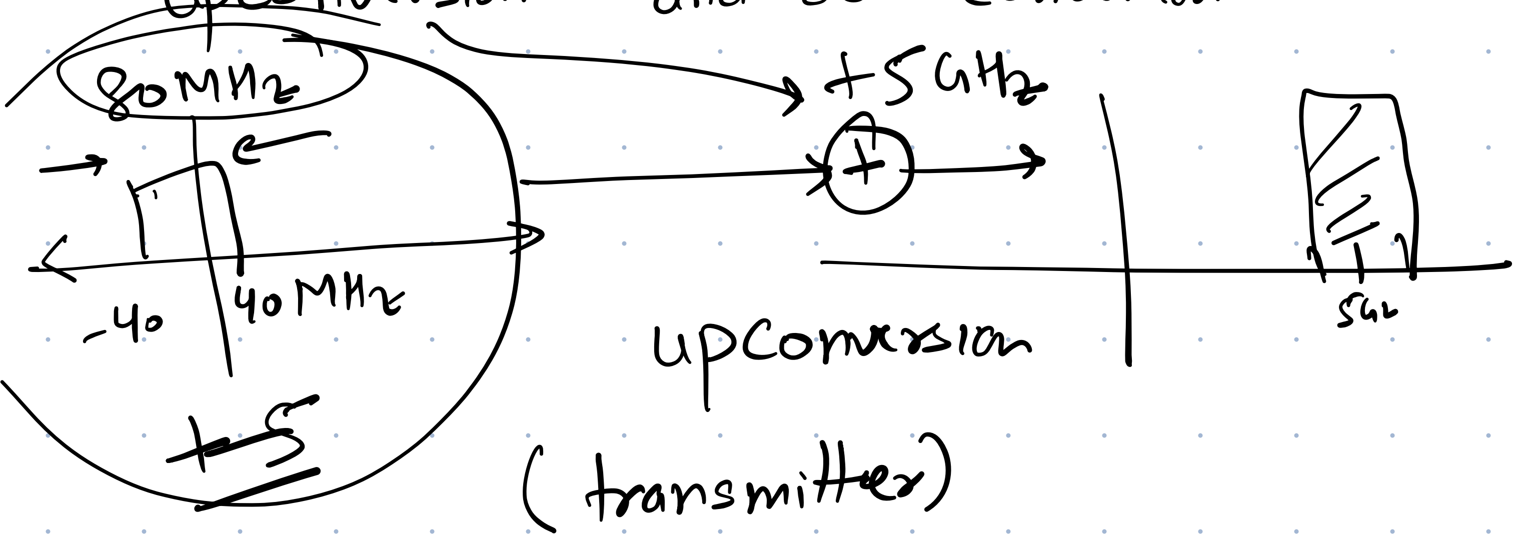


hardwar that samples my signal at 5×10^9/s.

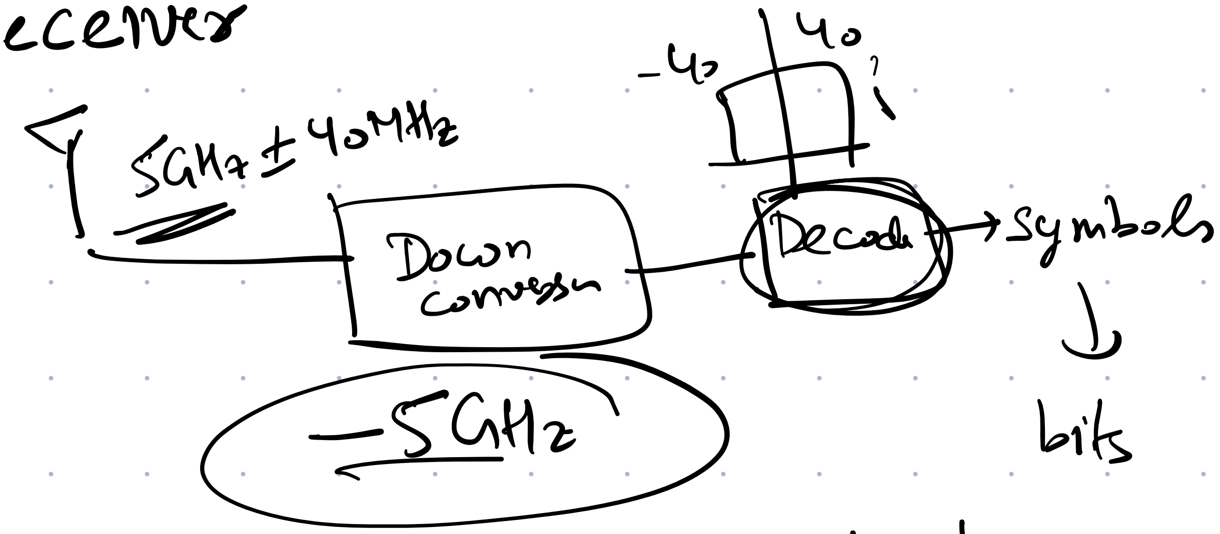
→ powar-hungry.

→ expensiv

upconversion and downconversion



Receiver



Transmit and receive directly at

80MHz?

spectrum?

channels 5 GHz, ~~5+80~~ 5G+80MHz

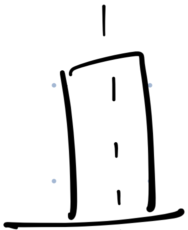
5GHz +40MHz

5GHz+120

Antenna ~ wavelength

$$80MHz = \frac{3\times 10^{8}}{80\times \cancel{10^{6}}} = \frac{300}{80} \approx 4m.$$

5GHz = 6cm



$B' \approx 80 MHz$

$f_c \approx 5 GHz$

got 0.0001 MHz $\overset{f_c}{5 GHz} + 1kHz = 10^3 Hz$

$f_c - B/2$ to $f_c + B/2$

Receiver $= (-f_c')$ $-B/2$ to $B/2$

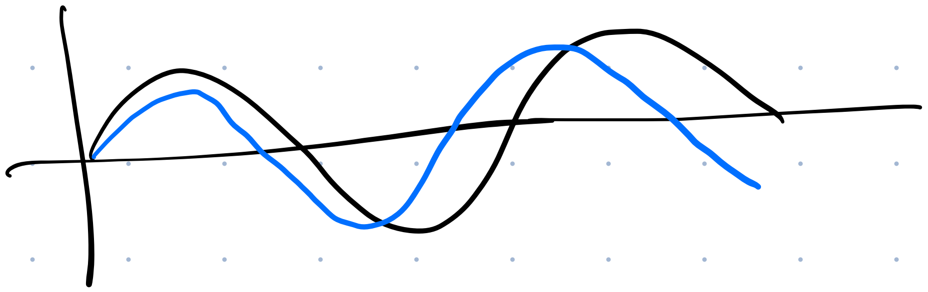
$\overset{f_c'}{5 GHz} - 1kHz$

$f_c - f_c'$ = Carrier frequency offset (CFO)

carrier frequency

$B \approx$ sampling frequency

B B' sampling frequency offset (SFO)



Recap: Wireless Channel

- $x_1, x_2, x_3, x_4 \ldots x_N$

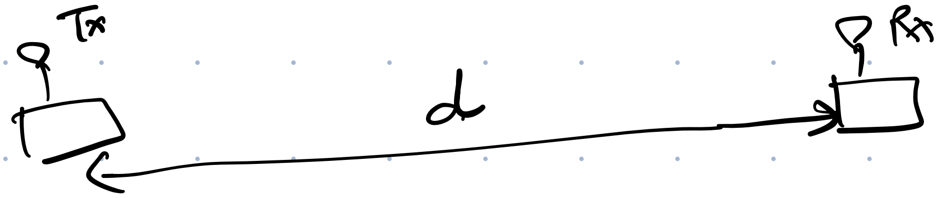
$y_1, y_2, \ldots y_N$

$$y_i = h x_i + n_i$$

→ wireless channel

(impact of the environment)

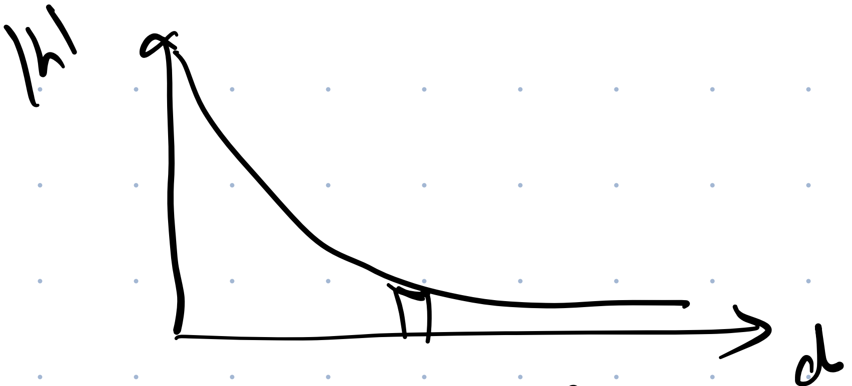
- What does h tell us about the environment?

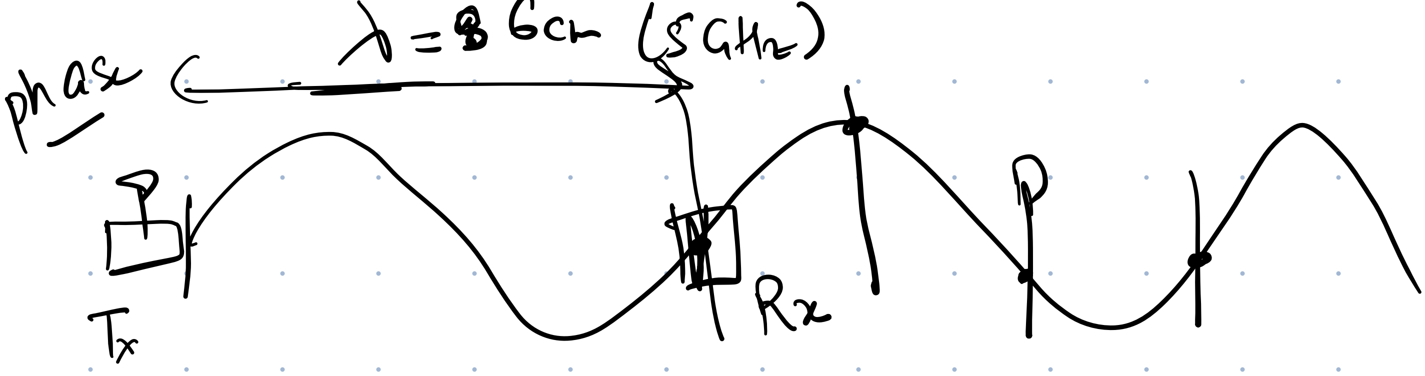


h is a complex number.

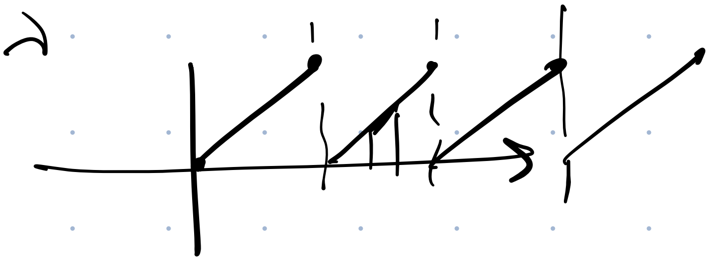
amplitude = strong or weak?

$$\rightarrow |h| \propto \frac{1}{d}$$

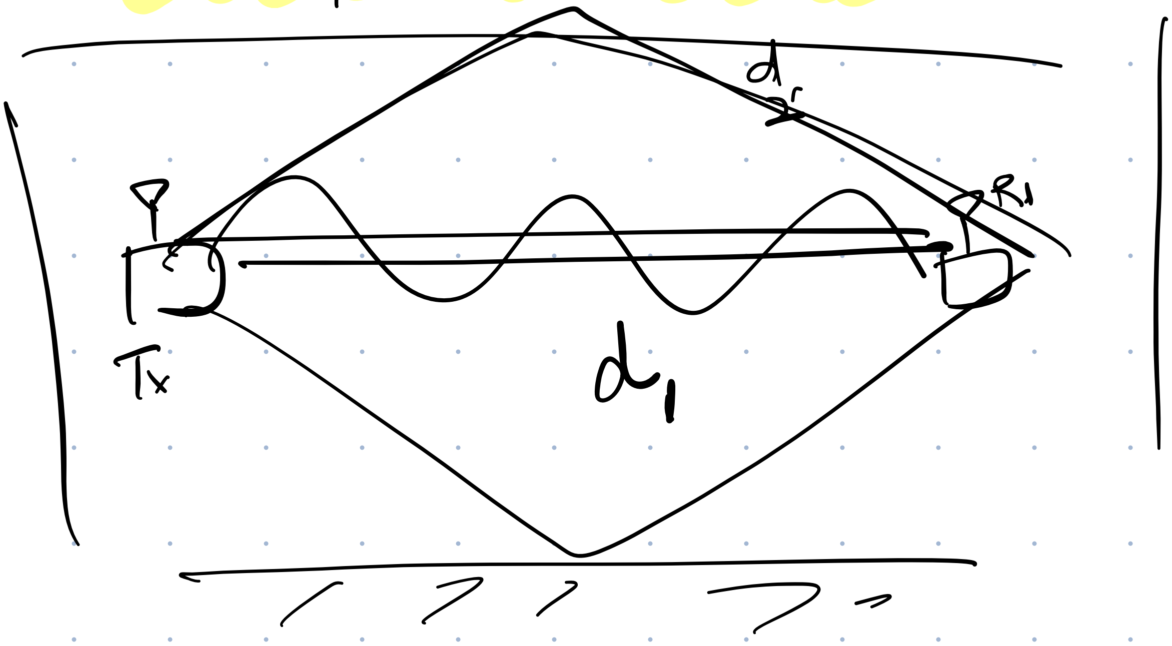




$$\angle h = \frac{2\pi}{\lambda} d \mod 2\pi$$



Multipath Channel



2 copies of the signal

d_1 , d_2

→ attenuation is nearly the same.

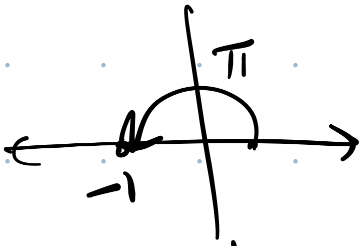
$$y_1 = h(d_1)\, x_1 + h(d_2)\, x_1$$

$$= \boxed{\underbrace{a\, e^{j\frac{2\pi}{\lambda} d_1}}_{\text{amplitude}}}\, x_1 + a\, e^{j\frac{2\pi}{\lambda} d_2}\, x_1$$

$a e^{j\phi}$

$$= a\, e^{j\frac{2\pi}{\lambda} d_1} x_1 \underbrace{\left(1 + e^{j\frac{2\pi}{\lambda}(d_2 - d_1)}\right)}$$

$$1+\underbrace{e^{j\frac{2\pi}{\lambda}\cancel{(d_2-d_1)}_{0}}}_{1}$$



$d_2 = d_1$

$= \boxed{2}\, a\, e^{j\frac{2\pi}{\lambda} d_1 x_1}$

[3cm] 5GHz

$$\boxed{d_2 - d_1 \approx \lambda/2}$$

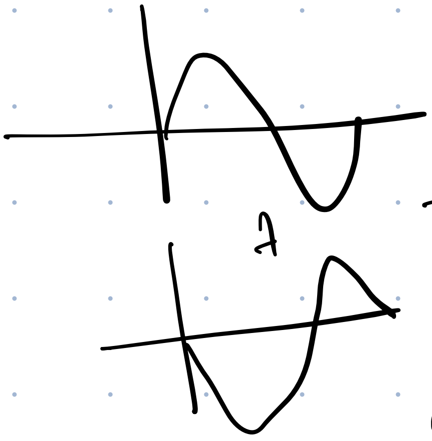
$1 + e^{j\frac{\cancel{2}\pi}{\cancel{\lambda}}(\cancel{\lambda}/\cancel{2})}$

$= 1 + e^{j\pi}$

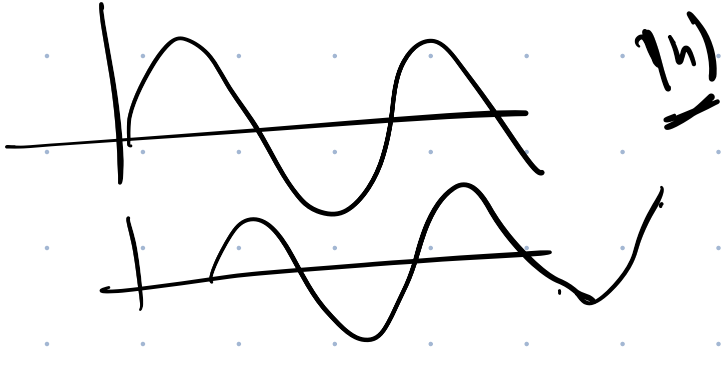
$= 1 + (-1)$

$= 0$

$= 0$



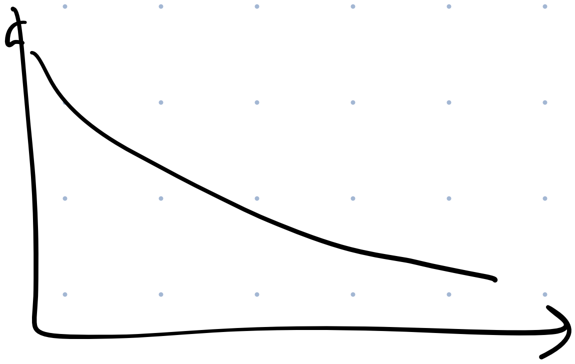
$= 0$



$$d_2 - d_1 = \lambda_1/2$$

$$\underline{\lambda_2} = \cancel{2\lambda_1}\ \lambda_1/2$$

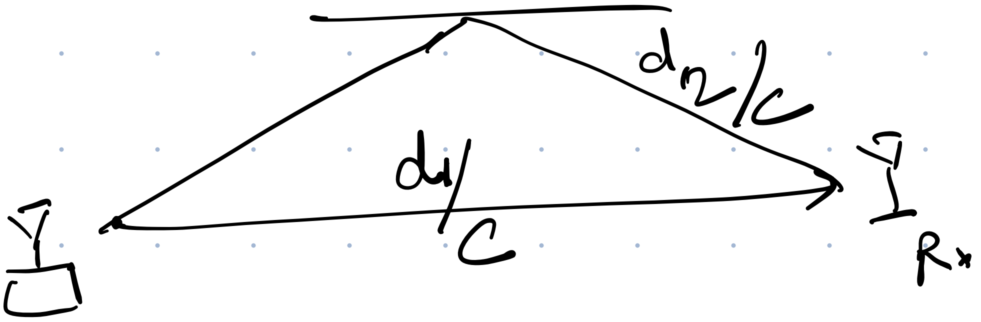
$$d_2 - d_1 = \cancel{\frac{2\lambda_1}{2} = \lambda}\ \lambda_2$$



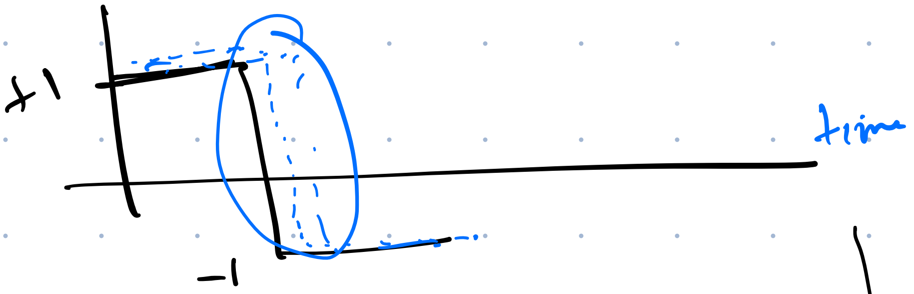
Bandwidth → Inter-symbol Interference

(ISI)

delay

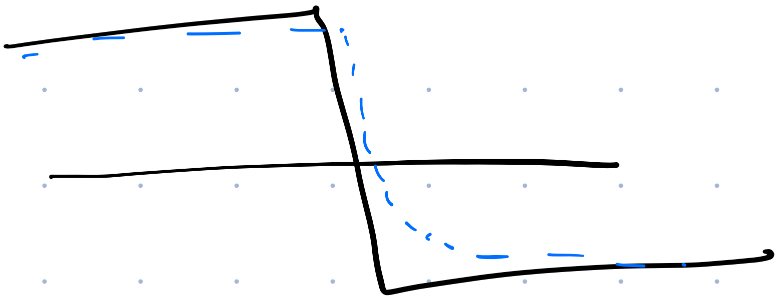


$x_1, x_2, x_3, x_4 \ldots$



~~to~~ low bandwidth

1kHz → 1ms



100MHz

→ 10^{-8}s

→ 10ns

Narrowband vs. Wideband

ISI

OFDM: Motivation