Today

- Recap: Rate Adaptation
- Upconversion / Downconversion
- Narrowband vs. Wideband
- OFDM
- Cyclic Prefix.

Rate Adaptation: Recap

Rate is too high ⟹ losses

" " " low ⟹ bad datarate (inefficiency).

losses

- → bad SNR → reduce datarate
- → interference → ~~reduce datarate~~

⇑ → reduce datarate

⇓ → increase datarate.

RTS/CTS → collision
or
→ bad SNR

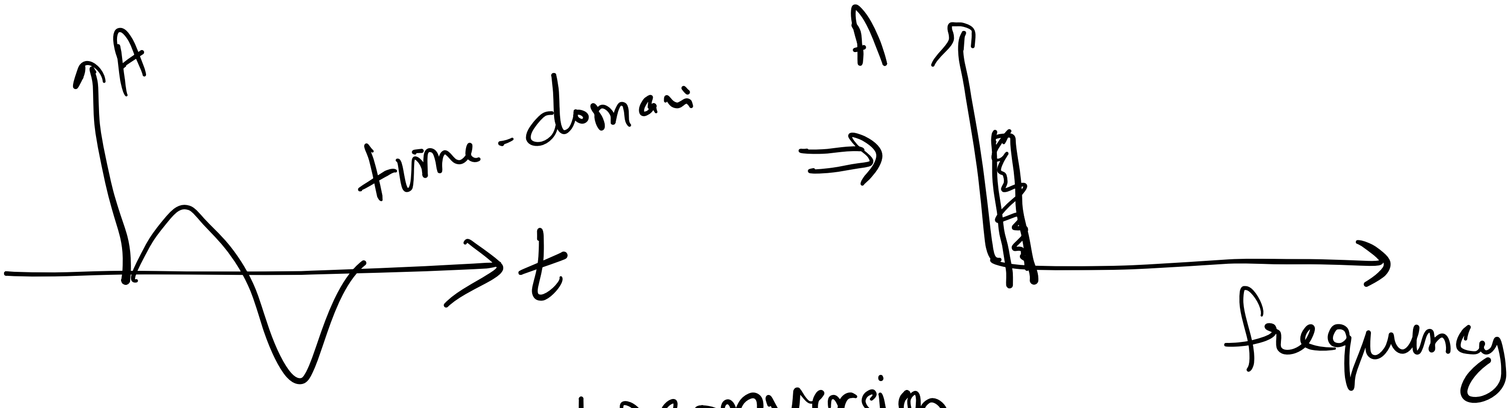
MCS - table

Modulation → Coding → Scheme.

Coding
↳ each bit twice

0 → MCS → datarate
1 →
.
.
16
..
32

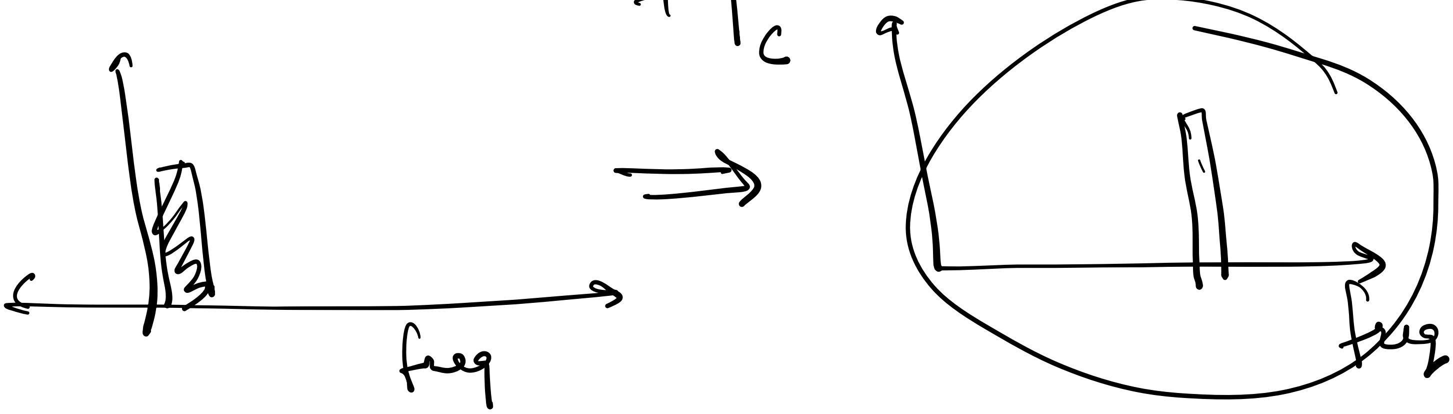
Upconversion / DownConversion



upconversion

Sender

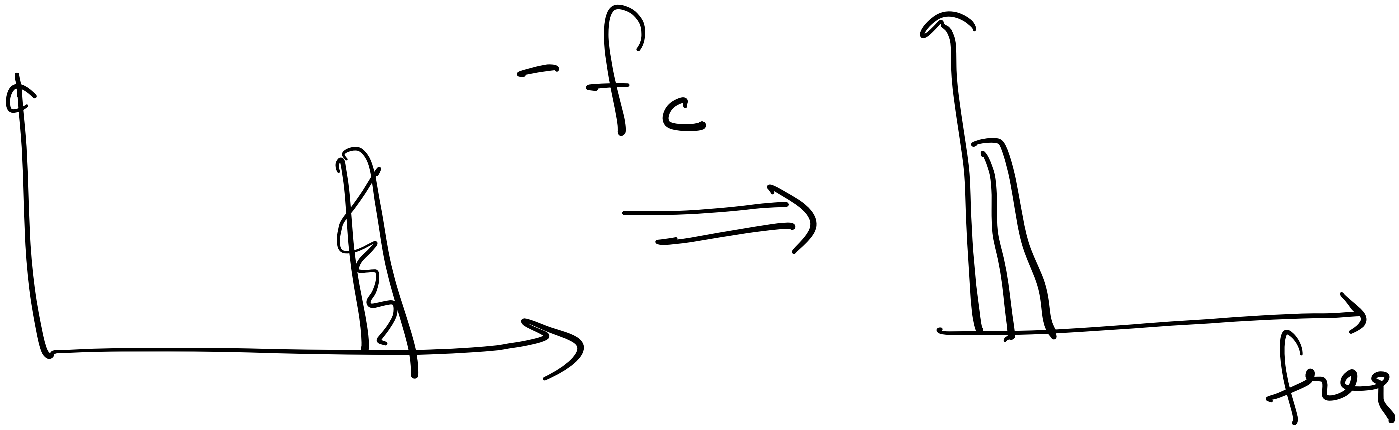
$+ f_c$



Receiver

Downconversion

$- f_c$



Why not use low freq.
for transmission?

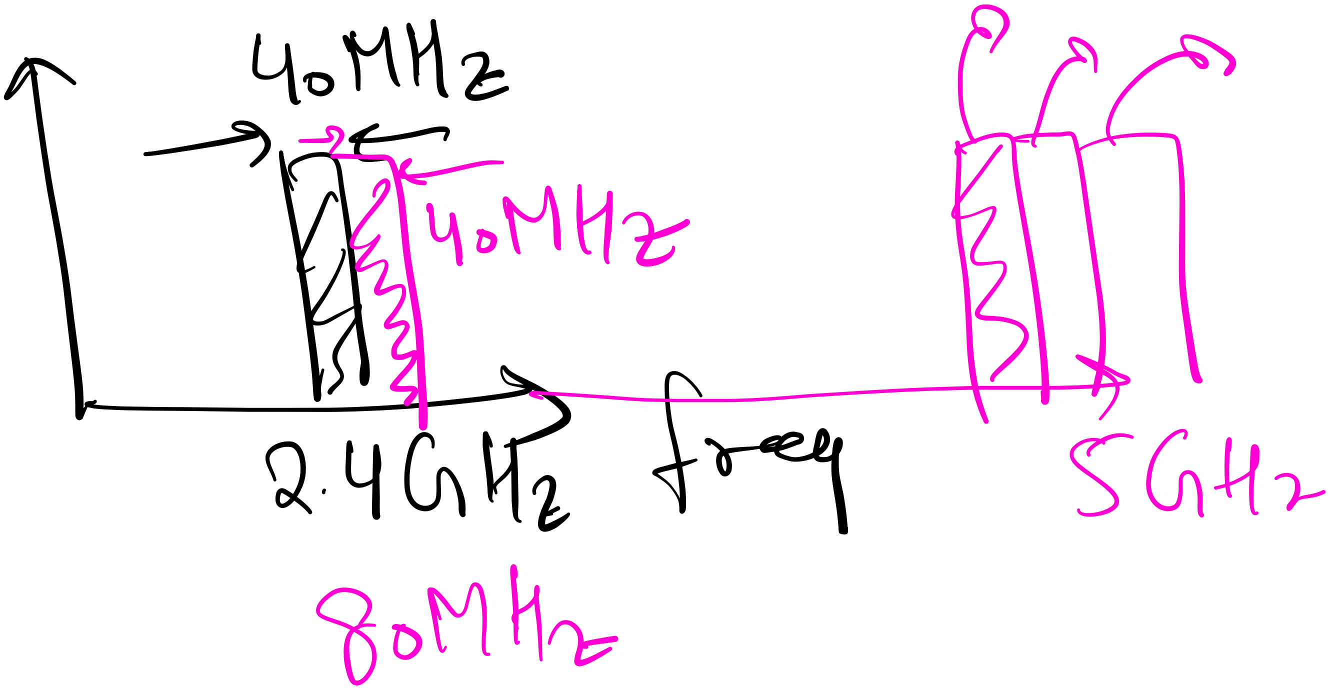
↳ Antenna length
∝ wavelength

low freq ⟹ wavelength is high.

↳ spectrum usage.

0 - 40MHz

Wi-Fi bandwidth: 40MHz
f_c : 2.4GHz



Q. Why not do everything at high freq.?

2.4GHz → sample at high freq.

Q. What sampling freq. should I use?

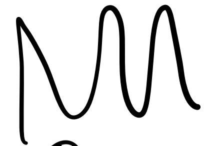
↳ Nyquist : 2B ← sampling freq. to capture all the information

2B ↓ signal bandwidth

Wi-Fi b/w 40 MHz → 80 MHz sampling rate.

Q. How does this relate to modulation?

symbols

11011 → x_0, x_1, x_3 → DAC →  ← modulation?

↑ mod.

how fast are you generating symbols?

f_c ← carrier wave

$4 \times 40 \times 10^6$ b/s

40×10^6 S/s → 40×10^6 b/s

→ $40 \times 10^6 \times 2$ b/s (3)

how does my bandwidth correspond to data rate?

Narrowband vs Wideband Channel

Channel

$\underline{x_1}, x_2, x_3$ $\quad\quad\quad\quad$ $y_1, y_2 \cdot y_3$

$$y_i = h\, x_i + n$$

n ← noise

h ↳ channel ← complex

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

d ← distance

$a e^{j\phi}$

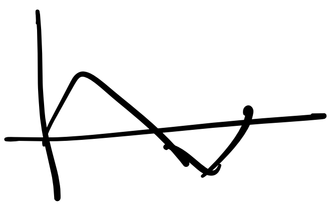
ϕ ← phase

a ↳ amplitude

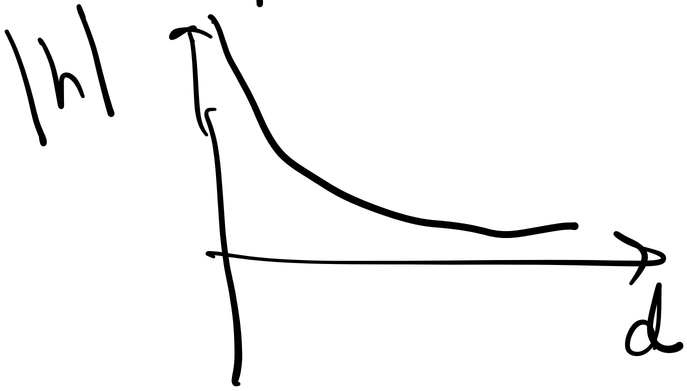
$$\text{phase } \angle h \approx \frac{2\pi}{\lambda} \times d$$

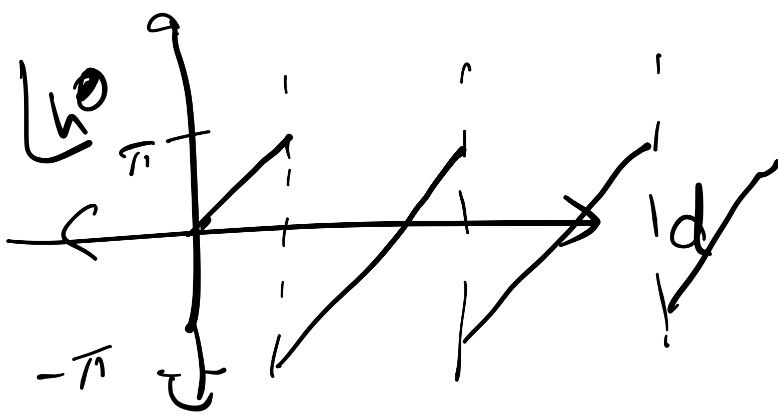
d ← distance

λ ← wavelength



$$\frac{2\pi}{\lambda} \times d \mod 2\pi$$





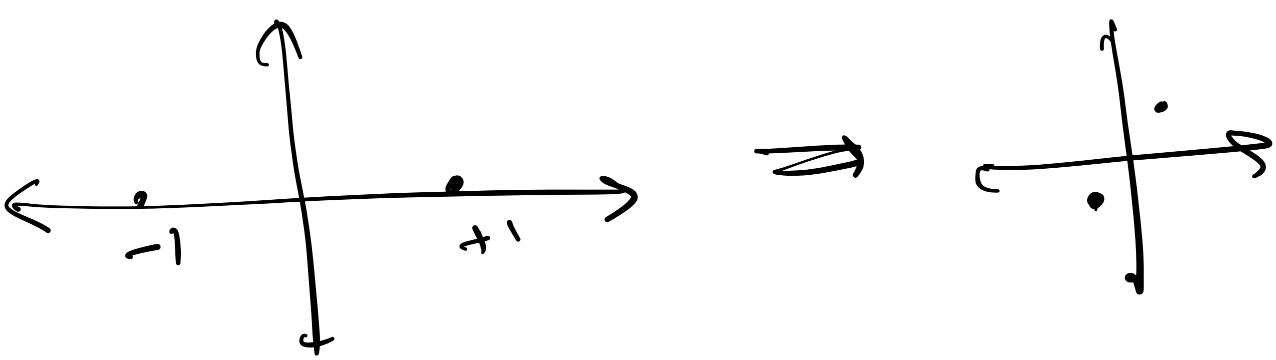
$$y = \frac{\alpha}{d} e^{j\frac{2\pi}{\lambda}d} \times x + n.$$

At time t, $x(t)$ $\quad \tau = d/c$

$$y(t) = \frac{\alpha}{d} e^{j\frac{2\pi}{\lambda}d} \, x(t-\tau)$$

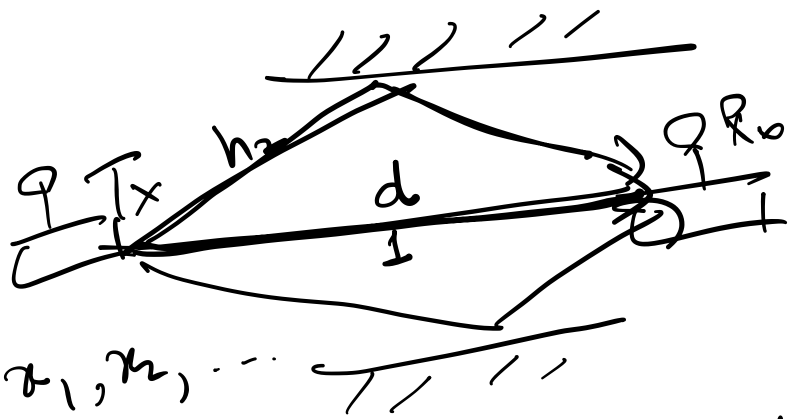
$$y(t) = h \, x(t-\tau)$$

h
- → amplitude becomes smaller (α/d)
- → phase shift
- → delay



Multipath Channel

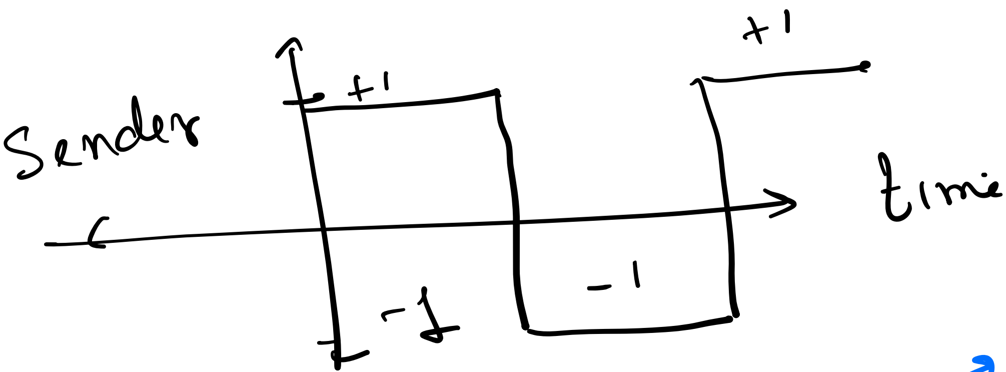
→ ISI
→ Fading

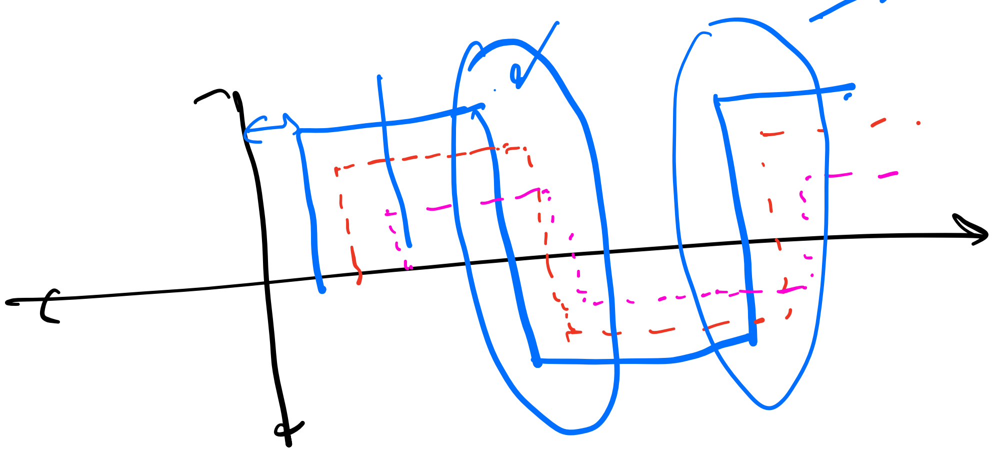


$$h \propto \frac{1}{d} e^{j\frac{2\pi}{\lambda}d}$$

$$y(t) = h_1 x(t-\tau_1) + h_2 x(t-\tau_2) + h_3 x(t-\tau_3) \ldots$$

ISI → Inter Symbol Interference.

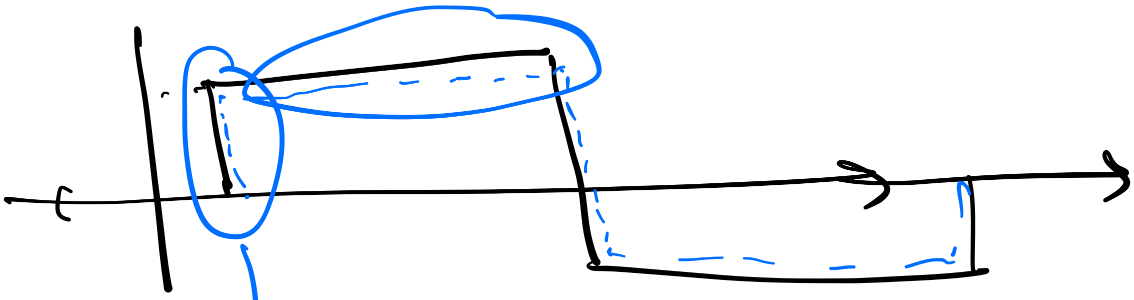


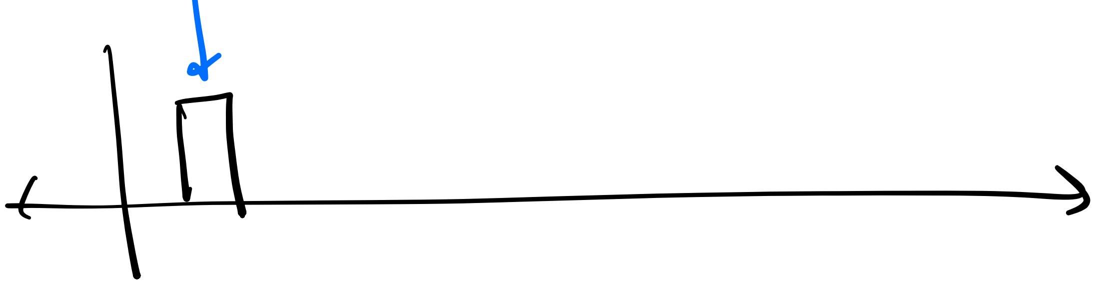


→ Inter-symbol interference.

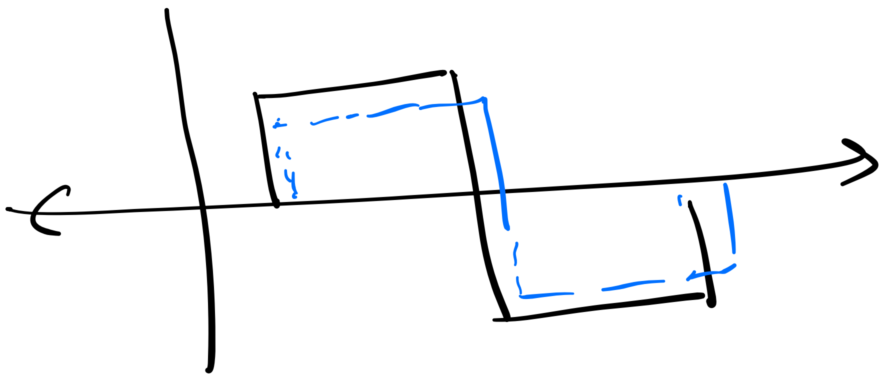
symbol rate is low — narrowband (low bandwidth)

1 symbol per s





high bandwidth (ISI)



$$y = h_1 x + h_2 x$$

$$= \frac{\alpha}{d_1} e^{j\frac{2\pi d_1}{\lambda}} x + \frac{\alpha}{d_2} e^{j\frac{2\pi d_2}{\lambda}} x$$

$$\frac{\alpha}{d_1} \approx \frac{\alpha}{d_2}$$

$$= \frac{\alpha}{d_1} x \left[e^{j\frac{2\pi}{\lambda}d_1} + e^{j\frac{2\pi}{\lambda}d_2} \right]$$

$$= \frac{\alpha}{d_1} x \, e^{j\frac{2\pi}{\lambda}d_1} \left[1 + e^{j\frac{2\pi}{\lambda}(d_2 - d_1)} \right]$$

$d_2 \approx d_1$ → 2

$d_2 - d_1 \approx \lambda/2$

$d_2 - d_1 \approx \lambda/2$] 3 cm

$\frac{2\pi}{\lambda} \cdot \frac{\lambda}{2} = e^{j\pi} = -1$ ⇓ 0

multipath.

"fading"

move a little bit

$d_2 - d_1 \approx \lambda/2$ → change λ.

Multipath fading is frequency- (wavelength) selective

$$\left[1 + e^{j\frac{2\pi}{\lambda}(d_2 - d_1)}\right]$$

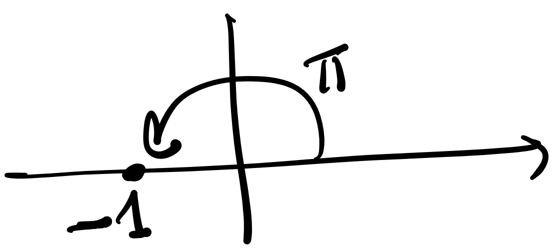
$\lambda = \frac{c}{f} = \frac{3\times10^8}{5\times10^9} =$ 6 cm.

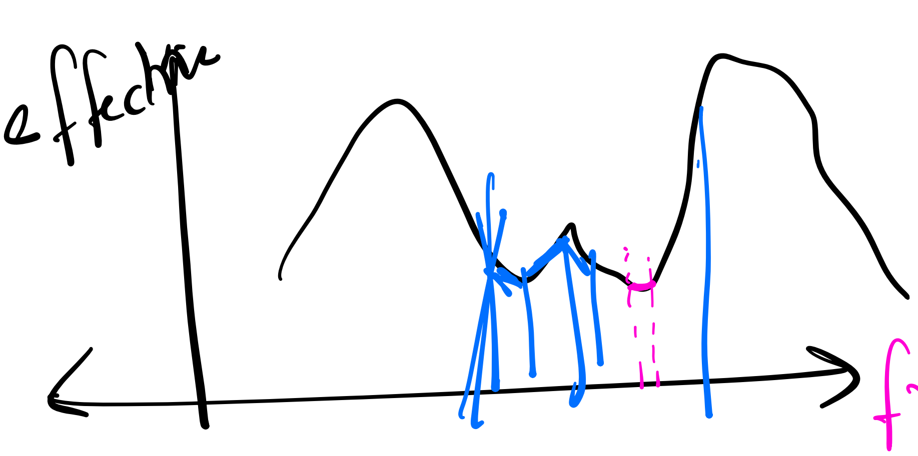
$[1 + (-1)]$
$= 0$

$d_2 - d_1 = \lambda/2 = \underline{3\,cm}$

$e^{j2\pi/\lambda\,(d_2 - d_1)} = e^{j\frac{2\pi}{\lambda}\cdot\frac{\lambda}{2}}$

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





frequency-selective fading.

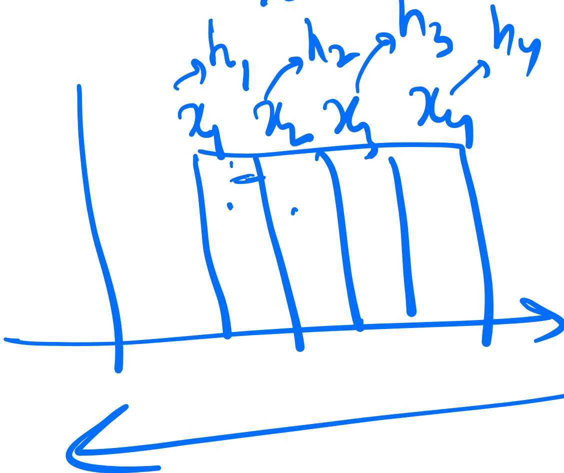
$y = hx + n$.

divide wideband channels into many narrowband channels.

10 40MSps $\approx$ 40MHz

$x_1, x_2, x_3, x_4 \ldots x_{100}$

x_1 x_5
x_2 x_6
x_3 x_7
x_4 x_8



OFDM

Orthogonal Freq. Division Multiplexing

OFDM: Basic Idea

10 chunks

vs.

100 chunks. → each of the bands become smaller.

128

OFDM: Cyclic Prefix