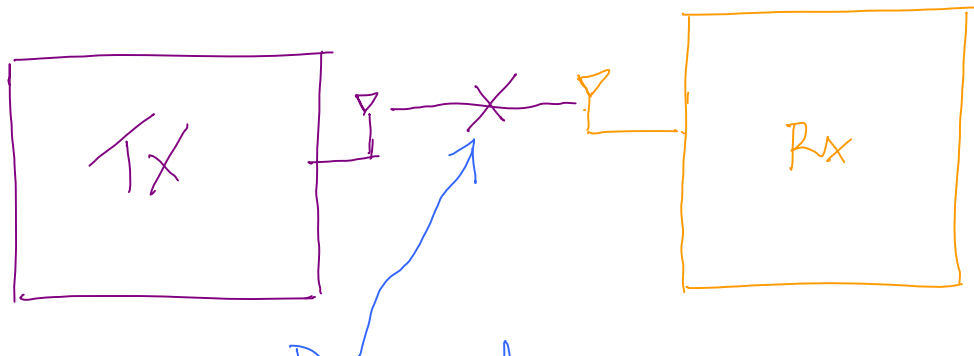
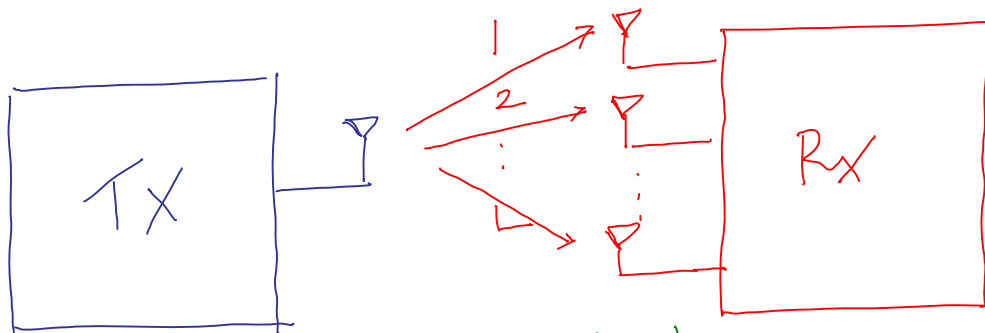




Deep Fade

$$\text{Prob of Deep Fade} \propto \frac{1}{\text{SNR}}$$



There are L links

E_i denote the event that link i is in a deep fade.

$$P(E_i) = \frac{1}{\text{SNR}}$$

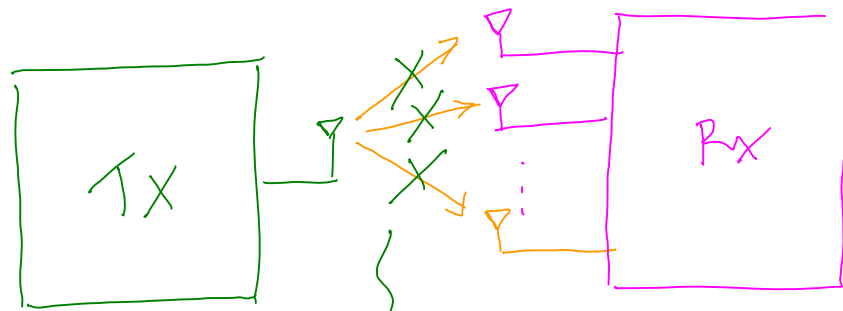
$$P(E_0) = \frac{1}{\text{SNR}}$$

$$P(E_1) = \frac{1}{\text{SNR}}$$

⋮

$$P(E_L) = \frac{1}{\text{SNR}}$$

For system to be in Deepfade,
all links have to be in Deepfade.



All L links have to
be in deepfade.

$$\underline{E_1 \cap E_2 \cap \dots \cap E_L}$$

↑
intersection of all events E_i

Prob (Deep Fade with L antennas)

Since $E_1, E_2, \dots, E_L$ are INDEPENDENT

$$\Pr(E_1 \cap E_2 \cap E_3 \dots \cap E_L) = \Pr(E_1) \times \Pr(E_2) \times \dots \times \Pr(E_L)$$

$$Pr(E_i) = \frac{1}{SNR}$$

Therefore,

$$Pr(E_1 \cap E_2 \cap \dots \cap E_L)$$

$$= Pr(E_1) \times Pr(E_2) \times \dots \times Pr(E_L)$$

$$= \left(\frac{1}{SNR}\right) \times \left(\frac{1}{SNR}\right) \times \dots \times \left(\frac{1}{SNR}\right)$$

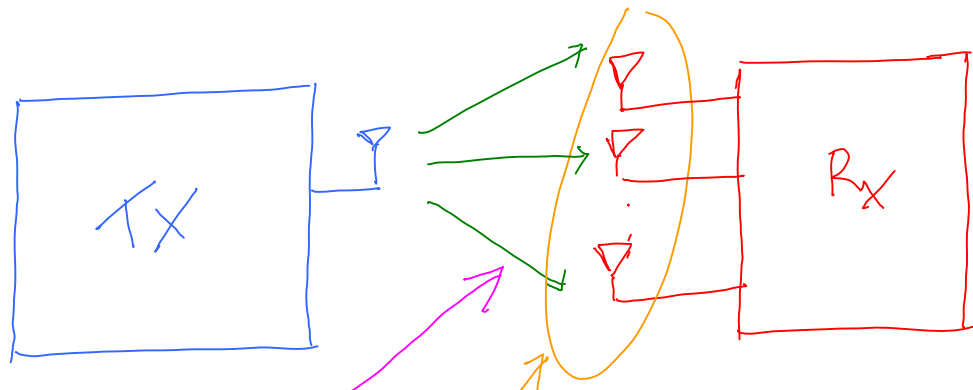
$$= \left(\frac{1}{SNR}\right)^L$$

Prob(Deep Fade with
L antennas)

$$= \frac{1}{\text{SNR}^L} .$$

This is arising due to multiple independent fading channels.

Prob of Deepfade decreases as $\frac{1}{\text{SNR}^L}$



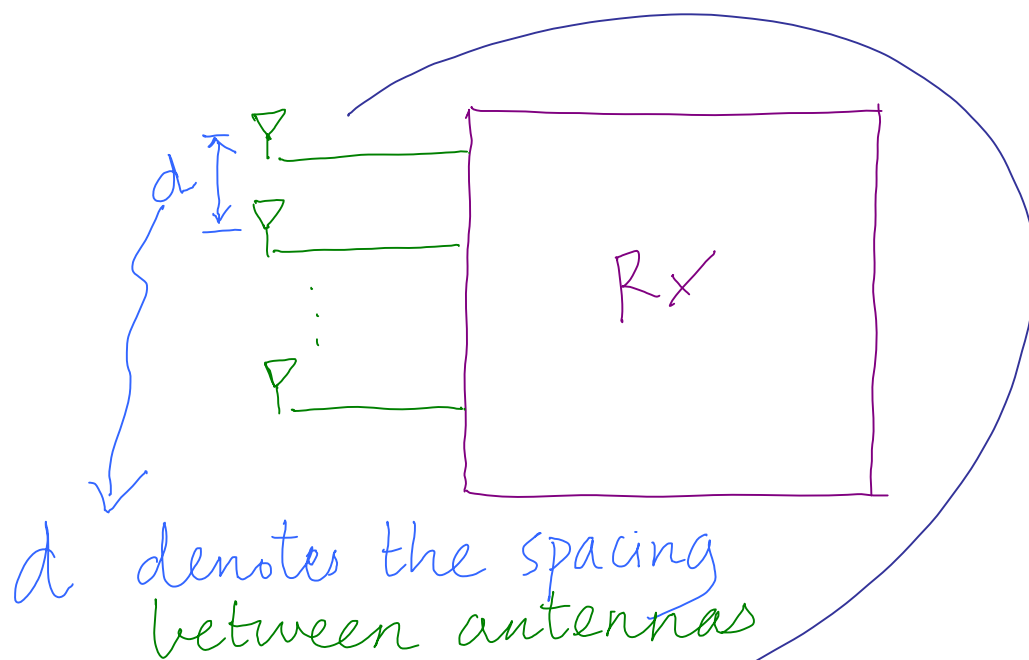
Multiple antennas
distributed in Space

Therefore, also known as
SPATIAL DIVERSITY.

One key assumption
is all coefficients $h_1, h_2, \dots, h_L$
are INDEPENDENTLY fading.

✓ For this to hold, antennas
have to be placed sufficiently
far apart.

How far?



d denotes the spacing
between antennas

Antennas are uniformly
spaced with distance d .

For independent fading,

$$\min d = \frac{\lambda}{2}$$

min separation
between antennas.

λ = wavelength
of carrier

$$\lambda = \frac{C}{F_c}$$

Frequency of
Carrier

C = velocity of light
or EM wave

$$= 3 \times 10^8 \text{ m/s.}$$

Example: Consider a GSM
system with $f_c = 900 \text{ MHz}$
 $= 900 \times 10^6 / \text{s}$

What is min d for
independent fading?

$$d = \frac{\lambda}{2}$$

$$\begin{aligned} \lambda &= \frac{c}{f} \\ \text{wavelength} &= \frac{3 \times 10^8 \text{ m/s}}{900 \times 10^6 / \text{s}} \\ &= 0.3333 \text{ m} \\ &= 33.33 \text{ cm} . \end{aligned}$$

$$d = \frac{\lambda}{2} = \frac{33.33 \text{ cm}}{2}$$

distance
for independent
fading

$$= 16.66 \text{ cm}$$

$$= 6.55 \text{ inches}$$

possible in
a router
or Base
Station

NOT possible in a regular
phone.

Consider a $36/46$ system
with $f_c = 2.36 \text{ Hz}$.

$$\begin{aligned}\lambda &= \frac{c}{f_c} \\ &= \frac{3 \times 10^8 \text{ m/s}}{2.3 \times 10^9 / \text{s}} \\ &= 0.1304 \text{ m} \\ &= 13.04 \text{ cm}\end{aligned}$$

$$\min d = \frac{\lambda}{2}$$

$$2.3 \text{ GHz} = \frac{13.04}{2} = 6.5 \text{ cm}$$

$$\boxed{\min d = 2.56 \text{ in}}$$

Possible on a phone
3G/4G