Diversity

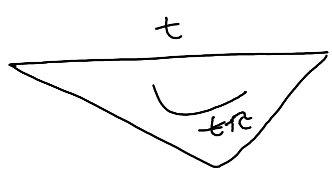
Exercise 1: Which of these might lead to a reduction in system efficiency by requiring more time or bandwidth? Which of these would require additional or more complex antennas?

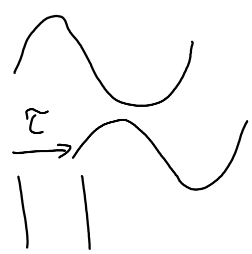
	more time	more bandwidth	more antennas
• locations (space diversity)			✓
• frequencies (frequency diversity)		✓	
• times (time diversity)	✓		
• antenna polarizations (polarization diversity)			✓

Exercise 2: What spacing is required for 10λ separation at 900 MHz?

$$\lambda = \frac{c}{f} = \frac{300\times10^6}{900\times10^6} = 33\text{ cm} \qquad 10\lambda = 3.3\text{ m.}$$

Exercise 3: What frequencies would see complete cancellation due to multipath if there are two equal-gain paths with a delay difference of τ? If the path length differences are 300 m? 3 m?





300m → $\tau = 1\,\mu s$

→ nulls every 1 MHz

3 m → $\tau = 10$ ns

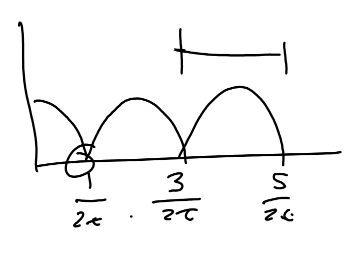
→ nulls ≈ 100MHz apart

$$\theta = 2\pi f\tau = \pm\pi \pm 2n\pi$$

$$2f\tau = 2n+1$$

$$f = \frac{2n+1}{2\tau} = \frac{2n}{2\tau} + \frac{1}{2\tau}$$

complete cancellation at multiples of $\frac{1}{\tau}$



Exercise 4: Would time diversity be more or less effective as the receiver's speed increased? What would happen if the receiver was stopped (such as a traffic light)?

- more effective (shorter fades) as speed increases.
- if stopped, need to rely on motion of scatterers.

Exercise 5: Assuming maximal-ratio combining, what would be the resulting SNR if the branch SNRs were +10 dB and +20 dB? If they were both +10 dB?

SNR = 10 dB $\quad \frac{S}{N} = 10 \quad$ if $N=1$ $S=10$ $V_1 = \sqrt{10}$

20 dB $\quad \frac{S}{N} = 100 \quad$ $N=1$ $S=100$. $V_2 = 10$

scale by $\frac{V}{N}$: $\sqrt{10}$ & 100

signal power = $(\sqrt{10}+10)^2 \approx 173$

noise power = $1+1 \approx 2$

$\frac{S}{N} = 86 \approx 19.4$

???

for 10 & 10 dB $\quad V = \sqrt{10}$

$S = (2\sqrt{10})^2 = 4 \cdot 10$

$N = 2 = 2$

$= 20 = 13$ dB.

Exercise 6: Assuming independent Rayleigh fading, the same SNRs as in the previous exercise and that the signal is considered "faded" if the SNR is below 0 dB, what fraction of time would be signal be faded with and without two-branch selection diversity?

10, 20   0 dB. $P \approx 0.1,\ 0.01$

10, 10 $P \approx 0.1$

for SNRs of 10 & 20 : $P_{faded} = (0.1)(0.01) = 10^{-3}$

10 & 10 $(0.1)^2 = 10^{-2}$

Exercise 7: What type of diversity would you expect to be implemented in an (inexpensive) WLAN card? In a cellular base station?

- inexpensive: switching
- expensive: maximal ratio.