Wireless Spectrum Continued

Name	Band	Application
ELF, SLF, VLF LF	Up to 30 kHz 30—300 kHz	Military, navigation
MF	300 KHz—3 MHz	AM radio
HF	3—30 MHz	Shortwave radio, amateur radio
VHF	30—300 MHz	FM radio, TV, point-to-point comm
UHF	300 MHz—3 GHz	TV, cellphones, ISM bands
SHF EHF	3—30 GHz 30—300 GHz	ISM, Satellites, high-capacity links

- Each slice of the wireless spectrum is licensed for a specific task, and by law cannot be used for any other purpose
- E.g. radio stations are licensed to the station using them by the government, and by law can only be used by that station for approved purposes
- An exception is the "ISM band" (ISM = Industrial, Scientific, Medical) – these are unlicensed bands which may be used for any purpose (subject to power restrictions)
- There are several in various parts of the wireless spectrum, but the most popular is from 2.4-2.5 GHz; used for WiFi, Bluetooth, Zigbee, etc.

Path Loss

- Wireless signals decay with distance from the transmitter
- In free space, the decay is proportional to the size of the wave front (conservation of energy)

(Fig. 1)

- in empty three-dimensional space, the surface area of a sphere is proportional to r^2 (more precisely it's $4\pi r^2$), so this is how fast signals decay
- If signal decay is proportional to r^d, then d is called the *path loss exponent*
- Real-world signals can bounce off the ground, buildings, etc., so in practice d can be between 2 and 4
- On the other hand, if the signal is guided (e.g. by a tunnel), d can be less than 2 (doesn't happen often).

(Fig. 2)

- example: 1 W signal, 100m from tx to rx, if rx power is 0.1 μW with d=2, assuming same constant of proportionality, what is rx power with d=3 and d=4?
- Answer: 1 μW, 0.01 μW

More on signal propagation

- Main effects on radio signals other than attenuation: scattering, shadowing, diffraction, reflection

(Fig. 3)

Antenna Design

- Antennas have an antenna pattern, the relative signal strength (either transmit or receive) from all directions
- Some examples: isotropic, dipole, sector

(Fig. 4)

- A directional antenna is designed by creating physical reflectors/blockers (e.g., dish) or by combining many antenna elements (e.g., array)
- Project signal where wanted, reject interference from unwanted sources, eliminate extra paths

The Mobile Radio Environment: Multipath Fading

- As mentioned, wireless signals can follow many paths from transmitter to receiver (reflection, scattering, etc.)
- These signals have different lengths and therefore different phases

(Fig. 5)

- For a sinusoid with frequency f_c, phase at the rx is

(Eq. 1)

- Say you have two paths, one with distance d_1, the other with distance d_2. They combine at the receiver to form

(Eq. 2)

- Trig identity: $\sin a + \sin b = 2 \sin((a+b)/2) \cos((a-b)/2)$

(Eq. 3)

- since sin is always between -1 and 1, the effect of the fading is to diminish the signal amplitude, possibly to nothing!