Antennas – Part B
Design & Technology Issues

- **Size**
  - Typical “small” antenna is at least $\sim \lambda/4$ (this is 8 cm @ 915 MHz)
  - As antennas become smaller their efficiency goes down
- **Bandwidth**
  - Impedance Bandwidth – frequency range over which the input impedance is close to 50 Ω
  - Pattern Bandwidth – frequency range over which radiation pattern is acceptable (usually not as difficult to achieve as impedance bandwidth)
- **Packaging** – conformal antennas are desirable but difficult to design
Size / Bandwidth / Efficiency

- Bandwidth is proportional to $1/Q$, where $Q$ is the quality factor (energy stored over energy dissipated) $\implies$ if $Q$ goes up then bandwidth goes down
- A theoretical limit for the lowest $Q$-factor for an antenna is:

$$Q_{lb} = \eta_r \left( \left( \frac{1}{ka} \right)^3 + \left( \frac{1}{ka} \right) \right)$$

$\eta_r =$ efficiency

$k = \frac{2\pi}{\lambda}$

$a =$ radius of volume enclosing antenna

$\implies$ The more efficiently an antenna fills the volume of space surrounding the antenna the higher its radiation efficiency will be! Small, flat, 2-D antennas are not very efficient.
Wire Antennas

• Common:
  – Short Dipole
    • $Z_{in} \sim 80\pi^2(l/\lambda)^2$ @ resonance
    • $D_o \sim 1.8$ dB
  – Half-wavelength Dipole
    • $Z_{in} \sim 73$ Ohms @ resonance
    • $D_o \sim 2.2$ dB
  – Quarter-wavelength Monopole
    • $Z_{in} \sim 36.5$ Ohms @ resonance
    • $D_o \sim 2.2$ dB
Planar 2-D Antennas

- **Common:**
  - Microstrip (patch)
    - $Z_{in}$ ~ varies
    - Bandwidth ~ narrow
    - $D_o$ ~ 6 dB
  - Slot
    - $Z_{in}$ ~ 500 Ohms @ resonance
    - Bandwidth ~ medium
    - $D_o$ ~ 2.2 dB
  - Spiral
    - $Z_{in}$ ~ 100 Ohms
    - Bandwidth ~ large
    - $D_o$ ~ 3 dB
Array Antennas

• “gain” for an antenna is similar to “magnification” for a microscope – the larger the lens (aperture) the higher the magnification (gain)
• In array antennas many individual antenna elements are separated in space to form a large aperture
• The signal to each elements is controlled (magnitude and phase) allowing the direction of radiation to be varied
Impact on Sensor Network Design

- Antennas with high gain will increase communications range
- Higher gain antennas require more careful alignment with distant receiver/transmitter

→ High gain antennas typically used only for fixed installations
→ Sensor nodes typically use low gain antennas in order to receive/transmit effectively in all (or most) directions
Antennas – Conclusions

• Antennas lie at the boundary between electromagnetic and circuit design
• They control the direction, concentration and polarization of the electromagnetic wave transmitted between two wireless devices
• They are often the size-limiting aspect of “small devices” and performance generally degrades as they are made smaller