SCOPE

- The course will be divided up into a number of broad sections
  - Signals and Modulation
  - Active Sensor Basics (Radar, Laser & Sonar)
  - Interaction with the Environment
  - High Resolution Techniques
  - Target Tracking
  - Radiometers & Image Processing
  - 3D Imaging & Tomography
Introduction

thanks to Eli Brookner
Definition of a Sensor and a Transducer

- Biological sensors are those that equip us with our five senses – sight, hearing, smell, taste and touch.

- Our definition of what constitutes a sensor is slightly different:
  - A transducer is a device that converts input energy into output energy, the latter usually differing in kind but bearing a known relationship to the input.
  - A sensor is a transducer that receives an input stimulus and responds with an electrical signal bearing a known relationship to the input.

- Many measuring and sensing devices including loudspeakers, thermocouples, microphones and phonograph pickups, may be termed transducers.
Sensor Systems

- Sensors seldom operate in isolation
- They are generally part of a larger system that includes transducers, a signal processor and actuators to produce a useful tool

![Diagram of Sensor Systems]

Sensors used in an Autonomous Vacuum Cleaner

Why do we need additional sensors?

- Our sensors require contact, or at best operate at short range
  - Examination of the sensory homunculus indicates that we rely mostly on touch (lips, fingers & tongue)
  - Our eyes are sensitive to a very small band in the EM spectrum
  - Our ears are sensitive to a small range of vibration frequencies
- We use additional sensors to extend both the frequency sensitivity and dynamic range of our existing senses

![Frequency Chart]

<table>
<thead>
<tr>
<th>Infrasound</th>
<th>Audio</th>
<th>Ultrasound</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{-3}$</td>
<td>$10^3$</td>
<td>$10^4$</td>
</tr>
<tr>
<td>$10^4$</td>
<td>$10^8$</td>
<td>$10^9$</td>
</tr>
<tr>
<td>$10^9$</td>
<td>$10^{10}$</td>
<td>$10^{10}$</td>
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</tbody>
</table>

Frequency (Hz)
Why our Eyes are Sensitive between 400 and 700nm

Note that there are no atmospheric absorption bands within the visible spectrum.

What we see is not always what we get
Different EM frequencies have different penetration abilities
Using the Electromagnetic Spectrum

1 eV = 1.6x10^{-19} J
Some EM Applications

<table>
<thead>
<tr>
<th>Band</th>
<th>Frequency</th>
<th>Wavelength</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>VHF</td>
<td>30-300MHz</td>
<td>1-10m</td>
<td>Over the horizon radar</td>
</tr>
<tr>
<td>UHF</td>
<td>300-1000MHz</td>
<td>30-100cm</td>
<td>Ground penetrating</td>
</tr>
<tr>
<td>L</td>
<td>1-2GHz</td>
<td>15-30cm</td>
<td>Ground based surveillance, astronomy</td>
</tr>
<tr>
<td>S</td>
<td>2-4GHz</td>
<td>75-150mm</td>
<td>Ground based surveillance, Air traffic control</td>
</tr>
<tr>
<td>C</td>
<td>4-8GHz</td>
<td>37.5-75mm</td>
<td>Space based SAR</td>
</tr>
<tr>
<td>X</td>
<td>8-12.5GHz</td>
<td>24-37.5mm</td>
<td>Fire control radar, microwave proximity, Airborne SAR</td>
</tr>
<tr>
<td>Ku</td>
<td>12.5-18GHz</td>
<td>16.7-24mm</td>
<td>Collision avoidance, speed traps</td>
</tr>
<tr>
<td>K</td>
<td>18-38.5GHz</td>
<td>11.3-16.7mm</td>
<td>Fire control radar</td>
</tr>
<tr>
<td>Ka</td>
<td>26.5-40GHz</td>
<td>7.5-11.3mm</td>
<td>Fire control radar for low angle tracking, surveillance</td>
</tr>
<tr>
<td>Millimetre</td>
<td>30-300GHz</td>
<td>1-10mm</td>
<td>Imaging, terminal guidance, astronomy, collision avoidance</td>
</tr>
<tr>
<td>Terahertz</td>
<td>50μm-1mm</td>
<td></td>
<td>Astronomy</td>
</tr>
<tr>
<td>Far infrared</td>
<td>14-50μm</td>
<td>Molecular properties</td>
<td></td>
</tr>
<tr>
<td>Longwave IR</td>
<td>8-14μm</td>
<td>Laser radar, forward looking infrared</td>
<td></td>
</tr>
<tr>
<td>Near IR</td>
<td>1-3μm</td>
<td>Personnel detection</td>
<td></td>
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<tr>
<td>Very near IR</td>
<td>760-1000nm</td>
<td>Imaging, laser ranging (industrial)</td>
<td></td>
</tr>
<tr>
<td>Visible</td>
<td>380-760nm</td>
<td>Imaging, astronomy</td>
<td></td>
</tr>
<tr>
<td>Ultraviolet</td>
<td>100-380nm</td>
<td>Missile plume detection, gas fire detection, corona detection</td>
<td></td>
</tr>
</tbody>
</table>

Using the Acoustic Spectrum

- Weather
- Earthquakes
- Communications
- Medical imaging
- Seismic prospecting
- Ranging
- Underwater Sonar
- Acoustic Microscopy

Infrasound | Audio | Ultrasound

Frequency (Hz)
Passive Sensors

- Passive sensors directly generate an electric signal in response to a stimulus.
- They do not emit radiation.
- Cannot be detected (covert)
- Rely on a locally generated or natural source of radiation (sunlight) or a field (gravity).
- Can operate from ELF (<$3 \times 10^3$ Hz) to gamma rays (>3x10$^{19}$ Hz).
- Prone to feature ambiguity and errors of scale
- Availability is not guaranteed (contrast, light levels etc.)
- Good reliability due to simplicity
Earthquake

Vision over 360°
Night Vision

Active Sensors

- Active sensors require the application of external power for their operation. This excitation signal is modified by the sensor to produce an output.
- Often matched to the target characteristics – this makes them efficient
- Restricted to frequencies that can be generated and radiated fairly easily. This excludes part of the far IR, the UV and gamma ray spectra.
- Ambiguity constrained by range and angle
- Easy to detect because they radiate (not covert)
- Generally more complex than passive sensors so are less reliable
GPR - Land Mine Detection

Goalkeeper: Close-in Weapon System
4D Ultrasound: Checking on the Merchandise

How it works
- The Voluson 730D machine will improve the rate of early detection of abnormalities.
- It will allow the study of foetal behaviour and movement.
- It will cost between $300,000 and $350,000—about the same as a top of the range 2-D machine.
- Nepean Hospital and the Brisbane Ultrasound for Women are the first hospitals to use it.

Target Characteristics: How to tell the difference between a Tank and a Tow-Truck using Radar
Laser Scanners: Cloning King David

PET Scans: Examining your dog?
RFID: Big Brother is Watching!

CT Scans: Looking for the Inner Man
Radar Altimetry: Looking for Tsunamis