Active and Passive Microwave Remote Sensing

Passive remote sensing system record EMR that was reflected (e.g., blue, green, red, and near IR) or emitted (e.g., thermal IR) from the surface of the Earth.

**Atmospheric blinds:** The wavelength which are Blocked by the atmosphere.

**Atmospheric windows:** The wavelength which can pass through the atmosphere.
Active and Passive Microwave Remote Sensing

Active remote sensing systems are not dependent on the Sun's EMR or the thermal properties of the Earth. Active remote sensors create their own electromagnetic energy that:

1. is transmitted from the sensor toward the terrain (and is largely unaffected by the atmosphere),
2. interacts with the terrain producing a backscatter of energy, and
3. is recorded by the remote sensor's receiver.

The most widely used active remote sensing systems include:

*Active microwave* (RADAR = **RA**dio **D**etection and **R**anging), which is based on the transmission of long-wavelength microwave (e.g., 3-25 cm) through the atmosphere and then recording the amount of energy backscattered from the terrain.

The beginning of the RADAR technology was using radio waves. Although radar systems now use microwave wavelength energy almost exclusively instead of radio wave, the acronym was never changed.
**LIDAR (LIght Detection And Ranging),**

which is based on the transmission of relatively short-wavelength laser light (e.g., 0.90 µm) and then recording the amount of light backscattered from the terrain;

**SONAR (SOund NAvigation Ranging),**

which is based on the transmission of sound waves through a water column and then recording the amount of energy backscattered from the bottom or from objects within the water column.
RADAR (RAdio Detection and Ranging)

The "ranging capability is achieved by measuring the time delay from the time a signal is transmitted to the terrain until its echo is received.

Radar is capable of detecting frequency and polarization shifts.

Because the sensor transmitted a signal of known wavelength, it is possible to compare the received signal with the transmitted signal.

From such comparisons imaging radar detects changes in frequency that form the basis of capabilities not possible with other sensors.
Brief History of RADAR

- 1922, Taylor and Young tested radio transmission across the Anacostia River near Washington D.C.
- 1935, Young and Taylor combined the antenna transmitter and receiver in the same instrument.
- Late 1936, Experimental RADAR were working in the U.S., Great Britain, Germany, and the Soviet Union.
- 1940, Plane-The circularly scanning Doppler radar (that we watch everyday during TV weather updates to identify the geographic locations of storms)
- 1950s, Military began using side-looking airborne radar (SLAR or SLR)
- 1960s, synthetic aperture radar (SAR)
- 1970s and 1980s, NASA launched SARs, SEASAT, Shuttle-Imaging Radar (SIR)
- 1990s, RADARSAT …
Advantages:

Pass through cloud, precipitation, tree canopy, dry surface deposits, snow …

All weather, day-and-night imaging capacity

<table>
<thead>
<tr>
<th>Band Designation</th>
<th>Wavelength Range (cm)</th>
<th>Common Wavelengths for Imaging Radars (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_s$</td>
<td>0.8–1.1</td>
<td>0.86</td>
</tr>
<tr>
<td>$K$</td>
<td>1.1–1.7</td>
<td></td>
</tr>
<tr>
<td>$K_w$</td>
<td>1.7–2.4</td>
<td></td>
</tr>
<tr>
<td>$X$</td>
<td>2.4–3.8</td>
<td>3.0, 3.2</td>
</tr>
<tr>
<td>$C$</td>
<td>3.8–7.5</td>
<td>6.0</td>
</tr>
<tr>
<td>$S$</td>
<td>7.5–15.0</td>
<td></td>
</tr>
<tr>
<td>$L$</td>
<td>15.0–30.0</td>
<td>23.5, 24.0, 25.0</td>
</tr>
<tr>
<td>$P$</td>
<td>30.0–100.0</td>
<td>68.0</td>
</tr>
</tbody>
</table>
Side-Looking (Airborne) Radar (SLAR or SLR)

The disadvantage of real-aperture radar is that its resolution is limited by antenna length.

SAR produce a very long antenna synthetically or artificially by using the forward motion of the platform to carry a relatively short real antenna to successive position along the flight line. These successive portions are treated electronically as an individual elements of the same antenna. Therefore the resolution is improved.
Radar Measurements

Smooth Surface

Rough Surface

Radar Measurements

Double-bounce

Vegetation Layer
Wavelength and Penetration of Canopy

The longer the microwave wavelength, the greater the penetration of vegetation canopy.
SIR-C/X-SAR images of a portion of Rondonia, Brazil, obtained on April 10, 1994. a) X-band image with VV polarization. b) C-band image is HV. c) L-band image is HV. A heavy rain in the lower center of the image appears as a black “cloud” in the X-band image, more faintly in the C-band image, and is invisible in the L-band image. L-band, at 24 cm (9 in) wavelength, is relatively unaffected by such rain cells. Also, the L-band image differentiates the pristine rain forest (bright) from the darker clear-cut areas because it penetrates farther into the canopy, experiencing greater volume scattering. Water, of course, is dark in all three bands. A color composite of the three images is found in Color Plate 9-2 (courtesy NASA Jet Propulsion Lab).

Example of radar penetration of dry soil along the Nile River, Sudan. a) Black-and-white version of a color-infrared photograph acquired by Space Shuttle Columbia crew in November 1995; b-d) SIR-C/X-SAR images acquired by the Space Shuttle Endeavor in April 1994. Subtle, different information is recorded in each of the three radar images. Each reveals an ancient, previously unknown channel of the Nile. Radar brightness values are inverted in these examples (courtesy NASA Jet Propulsion Laboratory).
Imaging Radar Applications

Environmental Monitoring
- Vegetation mapping
- Monitoring vegetation regrowth, timber yields
- Detecting flooding underneath canopy, flood plain mapping
- Assessing environmental damage to vegetation

Hydrology
- Soil moisture maps and vegetation water content monitoring
- Snow cover and wetness maps
- Measuring rain-fall rates in tropical storms

Oceanography
- Monitoring and routing ship traffic
- Detection oil slicks (natural and man-made)
- Measuring surface current speeds
- Sea ice type and monitoring for directing ice-breakers

LIDAR (LIght Detection And Ranging)

LiDAR is a rapidly emerging technology for collecting high resolution elevation data through active remote sensing. determining the shape of the ground surface plus natural and man-made features.

Buildings, trees and power lines are individually discernible features. This data is digital and is directly processed to produce detailed bare earth DEMs at vertical accuracies of 0.15 meters to 1 meter.

Derived products include contour maps, slope/aspect, three-dimensional topographic images, virtual reality visualizations and more.
**LiDAR: The Basics**

- Distance Measured by Time Difference
- Records > 200k Points Per Second
- Ability to Collect Multiple Returns for Each Pulse

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**LiDAR Point Clouds: The Value of Multiple Returns**

- **First Return**: Highest feature on landscape
- **Middle Returns**: Vegetation structure
- **Last Return**: Generally bare earth
Evaluation Data: Source Matters

• Data accuracy/resolution important

Gesch, 2009

Christopher Damon
Evaluation Data: Digital Elevation Models

Source: USGS 30m (~98ft)  Source: LiDAR 0.6m (~2ft)

Terminology: DSM vs. DEM
2011 LiDAR: A Common Foundation

- Northeast LiDAR Initiative
  - USGS initiative to improve NED
  - ARRA Funds with state plus-up
  - RI Environmental Monitoring Collaborative
  - PhotoScience awarded contract
  - Winter 2010 – Spring 2011

Data Collection Specifications

- Horizontal
  - Nominal Post Spacing (NPS) ≤ 1 meters
  - NAD83 UTM 19N

- Vertical
  - Root Mean Square Error (RMSEz) 15cm
  - NAVD88 (GEOID99)

- Fundamental vertical accuracy
  - 29.4cm @ 95% C.L. in open terrain
  - 2-Foot contours (NSSDA Standards)
Exploring the Data: Point Clouds

- LAS File Information
  - Elevation
  - Intensity
  - Return #
  - # of Returns
  - Classification

Orthophoto RGB

Quick Terrain Modeler Visualization
LiDAR

LiDAR data can be integrated with other data sets, including orthophotos, multispectral, hyperspectral and panchromatic imagery.

LiDAR is combined with GIS data and other surveying information to generate complex geomorphic-structure mapping products, building renderings, advanced three dimensional modeling/earthworks and many more high quality mapping products.