Radar and Microwave Remote Sensing

• Microwave sensing encompasses both active and passive forms of remote sensing.

• The microwave portion of the spectrum covers the range from approximately 1cm to 1m in wavelength.

• Because of their long wavelengths, compared to the visible and infrared, microwaves have special properties that are important for remote sensing.

• Longer wavelength microwave radiation can penetrate through cloud cover, haze, dust, and etc.

Passive Remote Sensing

Passive remote sensing systems record electromagnetic energy that was:

- reflected (e.g., blue, green, red, and near-infrared light)

- emitted (e.g., thermal infrared energy) from the surface of the Earth.

Active Remote Sensing

There are also active remote sensing systems that are dependent on the Sun’s electromagnetic energy or the thermal properties of the Earth. Active remote sensors create their own electromagnetic energy that:

- detects microwave energy under almost all weather and environmental conditions so that data can be collected at any time.

- shorter wavelengths are not susceptible to atmospheric scattering which optical wavelengths.

- reflected (e.g., blue, green, red, and near-infrared light) off Earth's surface.

- emitted (e.g., thermal infrared energy) from Earth's surface.
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,
3. is recorded by the remote sensor’s receiver.

**Active Remote Sensing**

The most widely used active remote sensing systems include:

- **active microwave (RADAR)** which is based on the transmission of long-wavelength microwaves (e.g., 3 – 25 cm) through the atmosphere and then recording the amount of energy back-scattered from the terrain;

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

- **SONAR**, which is based on the transmission of sound waves through a water column and then recording the amount of energy back-scattered from the bottom or from objects within the water column (very long wave, low Hz)

**Sending and Receiving a Pulse of Microwave EMR**

**Side-looking airborne radar (SLAR)**

رادر هوایی نگاه از پهلو (SLAR)

- The discussion is based initially on the system components and functions of a real aperture side-looking airborne radar (SLAR).

**Synthetic aperture radars (SAR)**

رادارهای شکافی؟ (دیوان مسیر هدایت شونده؟)

- The discussion then expands to include synthetic aperture radars (SAR) that have improved capabilities.

The **pulse** of electromagnetic radiation sent out by the transmitter through the antenna is of a specific wavelength and duration (i.e., it has a pulse length measured in microseconds).

Pal بالسپاه امواج الکترونومیتریکی توسط ارسال کننده امواج از طریق آن انتخاب طول موج و به فعالیت زمانی مشخص ارسال می‌گردد (به درادار طول یک پالس بر حسب میکروثانیه است).

- The wavelengths are much longer than visible, near infrared, mid-infrared, or thermal infrared energy used in other remote sensing systems. microwave energy is usually measured in centimeters rather than micrometers.
The unusual names associated with the radar wavelengths (e.g., K, Ka, Ku, X, C, S, L, and P) are an artifact of the original secret work on radar remote sensing when it was customary to use the alphabetic descriptor instead of the actual wavelength or frequency.

Primary Advantages of RADAR Remote Sensing

• Active microwave energy penetrates clouds and can be an all weather remote sensing system.

• Synoptic views of large areas, for mapping at 1:25,000 to 1:400,000; cloud-shrouded countries may be imaged.

• Coverage can be obtained at user-specified times, even at night.

• Senses in wavelengths outside the visible and infrared regions of the electromagnetic spectrum, providing information on surface roughness, and moisture content.

Secondary Advantages of RADAR Remote Sensing

• May penetrate vegetation, sand, and surface layers of snow.

• Partial penetration of soil and vegetation canopy providing subsurface as well as surface information.

• Has its own illumination, and the angle of illumination can be controlled.

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Secondary Advantages of RADAR Remote Sensing

• May penetrate vegetation, sand, and surface layers of snow.

• Partial penetration of soil and vegetation canopy providing subsurface as well as surface information.

• Has its own illumination, and the angle of illumination can be controlled.
• Enables resolution to be independent of distance to the object, with the size of a resolution cell being as small as 1 x 1 m.

• Images can be produced from different types of polarized energy (HH, HV, VV, VH).

• Sensitivity to geometric shape, surface roughness, and moisture content

• May operate simultaneously in several wavelengths (frequencies) and thus has multi-frequency potential.

• Can measure ocean wave properties, even from orbital altitudes.

• Supports interferometric operation using two antennas for 3-D mapping, and analysis of incident-angle signatures of objects.

Disadvantages of RADAR Remote Sensing

• Data Processing
• Large Antenna
• Active Microwave systems tents to be the heaviest, largest and most power consuming
• Noise
• Low resolution (passive)
• Passive microwave sensing is similar in concept to thermal remote sensing
• All objects emit microwave energy of some magnitude, but the amounts are generally very small.

• A passive microwave sensor detects the naturally emitted microwave energy within its field of view. This emitted energy is related to the temperature and moisture properties of the emitting object or surface.

• Passive microwave sensors are typically radiometers or scanners.

• Passive microwave has an antenna to detect and record the microwave energy.

The microwave energy recorded by a passive sensor can be emitted by:

1) The atmosphere,
2) Reflected from the surface,
3) Emitted from the surface,
4) Transmitted from the subsurface

The wavelengths are so long, the energy available is quite small compared to optical wavelengths.

• The fields of view must be large to detect enough energy to record a signal.

• Most passive microwave sensors are therefore characterized by low spatial resolution.

• Applications of passive microwave remote sensing include meteorology, hydrology and oceanography.

Meteorologists can use passive microwaves to measure atmospheric profiles and to determine water and ozone content in the atmosphere. (Depending on the wavelength)
Hydrologists use passive microwaves to measure soil moisture since microwave emission is influenced by moisture content.

Oceanographic applications include mapping sea ice, currents, and surface winds as well as detection of pollutants, such as a soil slicks.

Active microwave sensors provide their own source of microwave radiation to illuminate the target.

Active microwave sensors are generally divided into two distinct Categories: imaging and non-imaging.

The most common form of imaging active microwave sensors is RADAR.

RADAR is an acronym for Radio Detection and Ranging.

RADAR essentially characterizes the function and operation of a radar sensor.

The sensor transmits a microwave (radio) signal towards the target Signal and detects the backscattered portion of the signal.

1. The strength of the backscattered signal is measured to discriminate between different targets

2. The time delay between the transmitted and reflected signals determines the distance (or range) to the target.
Types of Microwave remote sensing

انواع سیستم‌های سنجش از دور مايکروویوی

Microwave remote sensing
سنجدش از دور مايکروویوی

Passive
غیر فعال

Active
فعال

Sensing microwave radiation
آشکارسازی پرتوهای مايکروویو
emitted from the earth
ساعت شده از زمین

Illuminators the artificially and receives after interaction with the target

<table>
<thead>
<tr>
<th>Radiometer</th>
<th>Imaging</th>
<th>Non-Imaging</th>
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<th>Altimeters</th>
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• A well known example of a non-imaging system is a Doppler radar system
یک مثال بارز از سیستم‌های غیر تصویری، سیستم رادار داپل است.

• These systems are used (for example) to measure vehicle speeds by measuring the frequency, or Doppler shift between transmitted and return signals.
این سیستم‌ها (عنوان مثال) برای اندازه‌گیری سرعت اتوموبیل از طریق اندازه‌گیری فرکانس بین فرکانس ارسالی و بازگشت از آن است.

• Non-imaging microwave sensors include altimeters and scatter meters.
حسگرهای غیر تصویری مايکروویوی شامل ارتفاع سنج و سنجدش امواج پارکشی است.

• In most cases these are profiling devices which take Measurements in one linear dimension, as opposed to the two dimensional representation of imaging sensors.
حسگر این سیستم‌ها در بسیاری از موارد بر خلاف سیستم‌های دو بعدی نشان دهنده تصویری، دستگاه‌های تهیه مقطع از طریق اندازه‌گیری گیرنده که به وسیله فلزی تهیه می‌شود.

• Radar altimeters transmit short microwave pulses and measure the round trip time delay to targets to determine their distance from the sensor.
رادار ارتفاع سنج با ارسال پرتوهای کوتاه مايکروویوی، اندازه‌گیری زمان رفت و برگشت آنها از هدف فاصله خود را تا حسگر مشخص می‌نمایند.

• Altimeters look straight down at nadir below the platform and thus measure height or elevation (if the altitude of the platform is accurately known).
A radar image is quite different from and has special properties unlike images acquired in the visible and infrared portions of the spectrum.

**Radar altimetry** is used on aircraft for altitude determination.

**Radar altimetry** is used on aircraft and satellites for topographic mapping and sea surface height estimation.

**Scatter meters** are also generally non-imaging sensors and are used to make precise quantitative measurements of the amount of energy backscattered from targets.

The amount of energy backscattered is dependent on the surface properties (roughness) and the angle at which the microwave energy strikes the target.

Scatter meters measurements over ocean surfaces can be used to estimate wind speeds based on the sea surface roughness.

Ground-based scatter meters are used extensively to accurately measure the backscatter from various targets in order to characterize different materials and surface types.

(This is analogous to the concept of spectral reflectance curves in the optical spectrum.)

**Imaging Radars RADAR ( = RA dio D etection R anging)**

**Radar Imaging** is an active remote sensing system which bounces microwave energy from a target and records the energy that returns to the sensor.

A major advantage of radar is the capability of the radiation to penetrate through cloud cover and most weather conditions.

Radar is an active sensor; it can also be used to image the surface at any time, day or night.

**Advantages of RADAR Imaging**

- **All-weather Operation:** the transmitted and reflected microwave energy penetrates through cloud cover, dust, haze, and rain.
- **Day or Night Operation:** Radar sensors can operate both day and night since they do not require an external energy source
- **A radar image is quite different from and has special properties unlike images acquired in the visible and infrared portions of the spectrum.**
In the 1950s, advances in air reconnaissance and surveillance aircraft was imaged during flight. Because of the fundamentally different way in which active radar operates compared to the passive sensors.

Because of these differences, radar and optical data can be complementary to one another as they offer different perspectives of the Earth's surface providing different information content.

In the 1920s and 1930s, experimental aircrafts and ships were used during World War which were used for detection and positioning of military terrain.

After World War II, Side-Looking Airborne Radar (SLAR) was developed for military terrain reconnaissance and surveillance where a strip of the ground parallel to and offset to the side of the aircraft was imaged during flight. Because of the fundamentally different way in which active radar operates compared to the passive sensors.

Two imaging radar systems

- Real aperture radar (RAR)
  - Aperture means antenna
  - A fixed length (for example: 1 - 15m)
- Synthetic aperture radar (SAR)
  - 1m (11m) antenna can be synthesized electronically into a 600m (15 km) synthetic length.
- Most (air-, space-borne) radar systems now use SAR.

History of imaging radar

The first demonstration of the transmission of radio microwaves and reflection from various objects was achieved by H.R. Hertz in 1886.

The first rudimentary radar was developed for ship detection. In the 1900s, the first rudimentary radar was developed for ship detection.

In the 1920s and 1930s, experimental ground-based pulsed radars were developed for detecting objects at a distance.

The first imaging radars used during World War which were used for detection and positioning of aircrafts and ships. The first imaging radars used during World War which were used for detection and positioning of aircrafts and ships.

After World War II, Side-Looking Airborne Radar (SLAR) was developed for military terrain reconnaissance and surveillance where a strip of the ground parallel to and offset to the side of the aircraft was imaged during flight.
• In the 1960s these radars were declassified and began to bemused for civilian mapping applications.

Example:
• Aircraft platforms
  – Canada Centre for Remote Sensing Convair 580,
  – NASA Jet Propulsion Laboratory AirSAR
• Satellite platforms
  – SEASAT,
  – SIR-A, SIR-B, SIR-C,
  – ERS-1, ERS-2,
  – ALMAZ,
  – JERS-1,
  – RADARSAT

• Plan Position Indicator (PPI) Radar is a precursor to airborne and satellite imaging systems and is utilized for navigation and target location using a rotating antenna with images produced on a circular view screen.

• PPI is also called as radar screen.

• PPI Radar continues to be used for aircraft and ship navigation as well as for weather applications.

• These radars use a circular display screen to indicate objects surrounding the rotating antenna.

• Since this time, the development of several airborne and space borne radar systems for mapping and monitoring applications use has flourished.

• The period from the 1970s to the early 1990s saw the development of experimental synthetic aperture radar (SAR) systems for civilian purposes.

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- The spatial resolution of the view map of the area under surveillance is too coarse to be used in remote sensing applications.

Radar imaging systems used in remote sensing applications consist of an air or space borne antenna. These antennas transmit and/or receive radar signals in order to produce imagery at a fine enough resolution for image interpreters to identify physical features on the Earth's surface.

Over the 1980s and early 1990s, several research and commercial airborne radar systems have collected vast amounts of imagery throughout the world demonstrating the utility of radar data for a variety of applications.

Example of using Radar:

- In 1991 launch of European Space Agency (ESA) space borne radar.
  - European Space Agency (ESA) توسط موسسه (Toros Moodo) به فضا پرتاب شد.
- In 1992 launch of Japan’s J-ERS satellite.
  - J-ERS به فضا پرتاب شد.
- In 1995 Canada's advanced RADARSAT satellite.
  - RADARSAT به فضا پرتاب شد.

- In 1991 Canada initially became involved in radar remote sensing themid-1970s.
  - در دهه سالهای 1970 کانادا پژوهشی استفاده سنجش از دور راداری را شروع کرد.
- It was recognized that radar may be particularly well-suited for surveillance of our vast northern expanse.
  - توصیه شده بود که ممکن است رادار وسیله مناسبی برای پایش نواحی شمالی باشد.
- North of Canada is often cloud-covered and shrouded in darkness during the Arctic winter.
  - شمال کانادا غالباً پوشیده از ابر و در زمان زمستان قطبی ناحیه ای پیشتر تاریک است.
- Radar remote sensing is used for monitoring and mapping our natural resources.
  - سنجش از دور راداری برای پایش و تهیه نقشه های منابع طبیعی مورد استفاده است.