Active Spaceborne Sensing

Bryan Huneycutt
NASA

Space provides an ideal vantage point from which to study the Earth. Spaceborne earth-orbiting active sensors are used to remotely study the Earth’s land, ocean surface and atmosphere. They can be used to detect and monitor natural disasters such as hurricanes, floods, fires, and mudslides and provide valuable information for response and recovery efforts.

These spaceborne active sensors obtain information by transmitting radio waves and then receiving their reflected (backscattered) energy. Fourteen frequency bands, spanning from 432 MHz to 238 GHz, are allocated to the Earth exploration-satellite service (EESS) (active) for use by spaceborne active sensors. These frequency allocations were obtained by working through the ITU-R and World Radiocommunication Conferences (WRCs).

The ITU-R performs sharing studies to ensure that proposed new systems will not introduce harmful Radio Frequency Interference (RFI) into frequency bands currently in use. RFI signals can corrupt the active sensor’s backscattered signal, which usually returns at a very low level just above the receiver noise. For instance, the possible introduction of wireless access systems including radio local area networks (WAS/RLANs) into the frequency range 5350-5470 MHz, currently allocated on a primary basis for spaceborne active sensors, is an active area of study within the ITU-R for WRC-19.

Five Key Active Spaceborne Sensor Types

The active spaceborne sensor types studied in the ITU-R as part of the EESS (active) are: synthetic aperture radars (SARs), altimeters, scatterometers, precipitation radars (PR), and cloud profile radars (CPR).

Synthetic Aperture Radars Provide Images and Topographical Maps

Due to their all weather, day-and-night imaging capability and sensitivity to changes as small as a few centimeters, synthetic aperture radars (SARs) have been successfully used worldwide to respond to disasters including oil spills and earthquakes. The Shuttle Radar Topography Mission (SRTM) used a JPL/NASA 5-GHz SAR to obtain high-resolution digital elevation maps of the Earth’s surface. Figure 1 shows the SRTM SAR image taken in 2000 of the Crater Highlands along the East African Rift in Tanzania.

---

1 **Active** sensors use both a transmitter and a receiver. They transmit a signal in the direction of the target to be investigated. Then they detect and measure the backscatter signal. Passive sensors do not have a transmitter. They are pure receivers that detect naturally occurring radiation (e.g., sunlight) that is reflected from the observed object.

2 **WRC-19 Agenda Item 1.16** concerns, in part, the possible introduction of WAS/RLANs into the frequency range 5350-5470 MHz. As of yet, ITU-R studies have not identified an effective mitigation technique for preventing harmful RFI to spaceborne active sensors from WAS/RLANs.

3 **Synthetic aperture** is created by recording the backscatter signal along the radar flightpath. The data is processed by the SAR algorithm into an image, thereby synthesizing a virtual aperture much longer than the physical antenna length.
SAR sensors look to one side of the nadir\(^4\) track, collecting a phase and time history of the coherent radar echo. From this information a fine resolution radar image or interferometric topographical map of the Earth’s surface is produced.

**Altimeters Provide Altitudes and Sea Level Heights**

The Jason-3 altimeter uses dual frequencies in the EESS (active) allocations around 13.6 GHz and 5.3 GHz to image the sea level height. Figure 2 shows a May 2018 image taken as Jason-3 traveled eastward through the tropical Pacific Ocean. The Kelvin wave (red) shown at the equator is often a precursor to an El Niño\(^5\) event. By understanding the patterns and effects of climate cycles such as El Niño, it may be possible to predict and mitigate the disastrous effects of floods and drought.

---

\(^4\) Nadir is the point on the celestial sphere directly below a given position or observer. It is opposite the zenith.

\(^5\) El Niño Southern Oscillation (ENSO) refers to the cycle of warm and cold temperatures, as measured by sea surface temperature of the tropical central and eastern Pacific Ocean. El Niño is the warm phase of ENSO and La Niña is the cool phase. Both El Niño and La Niña, cause global changes of both temperatures and rainfall.
The altimeter sensors look in the nadir direction, measuring the precise time between a transmit and receive event to extract the precise height of the sea level.

**Scatterometers Provide Ocean Surface Wind Speeds and Direction**

The 13 GHz SeaWinds scatterometer onboard NASA’s QuikSCAT satellite collected the data used to create an image of hurricane Frances as it approached Cuba in September 2004. Figure 3 uses pseudo-color to show the near-surface wind speeds and black barbs to indicate wind speed and direction.

Scatterometer sensors look at various aspects to the sides of the nadir track, measuring the return echo power variation with aspect angle to determine the wind direction and speed on the Earth’s ocean surface.

**Precipitation Radars Provide Rainfall Rates in the Tropics**
The Global Precipitation Measurement (GPM) Dual-Frequency Precipitation Radar (DPR) uses the 13.6 GHz and 35.5 GHz frequency bands to create a 3-D view of the rainfall rates and structure of the precipitation. Figure 4 shows 3-D view of super typhoon MANGKHUT structure as it headed towards the Philippines in September 2018. This GPM DPR’s 3-D cross-section shows the heights of storm tops and the intensity of downpours in MANGKHUT's eye wall and other rain bands.

Figure 4 (Precipitation Radar) NASA’s GPM image of Super Typhoon MANGKHUT
Precipitation radar sensors scan perpendicular to nadir track, measuring the radar echo from rainfall to determine the rainfall rate over the Earth’s surface, typically concentrating on the tropics.

Cloud Profile Radars Provide Three-Dimensional Cloud Reflectivity Profiles
The JPL/NASA CloudSat satellite supports a 94 GHz radar to profile clouds across the Earth’s surface, including profiles of hurricanes and severe storms. Figure 5 shows a vertical profile through the deep clouds of Severe Tropical Storm Kammuri measured by CloudSat’s radar in August 2008.
Figure 5 (Cloud Profiling Radar) Severe Tropical Storm Kammuri
The CloudSat image shows a curtain-view of what the clouds along the red line in the top image from NASA’s Aqua satellite looked like.
Cloud profile radar sensors look in the nadir direction, measuring the radar echo return from clouds to determine the three-dimension cloud reflectivity profile over the Earth’s surface.

Summary

Spaceborne earth-orbiting active sensors serve an important role in our understanding of our home planet. These sensors have revolutionized our ability to measure and observe the Earth, are enabling a better understanding of the Earth as a complete system, and will help us predict disasters and improve quality of life in the future.