

Slide 1 – Title Slide

Hello and welcome to Week 10, part 2 of EGM310: Active Sensors. In this lesson, we will discuss active remote sensing – that is, sensors that supply their own source of electromagnetic radiation.

Slide 2 – Recall

Recall that remote sensing typically involves measuring electromagnetic radiation. In order to measure electromagnetic radiation, we need some kind of source of electromagnetic radiation. This can be the Sun, as it is for most forms of optical remote sensing; this can also be the object itself – remember that if something has a temperature above 0K, it will emit electromagnetic radiation that can be measured. When we record electromagnetic radiation that is reflected by the sun or emitted by the object itself, it is called passive remote sensing, and we'll talk more about these examples in the next lesson. If the source of electromagnetic radiation is the sensor itself, however, it's what is known as active remote sensing.

Slide 3 – Radar

You have probably all heard of radar before. It originally stood for radio detection and ranging, though it has since entered the English language as an actual word. Radar involves making observations in the radio or microwave portion of the electromagnetic spectrum; we're going to focus on microwaves here, which is the portion of the electromagnetic spectrum corresponding to wavelengths between about 1 mm to 1 m in length.

The original purpose of radar was to “detect” objects and find out how far away they are and how fast they are moving (find the “range” to the object). To do this, we first send out a signal like the one shown here, and then we measure how long it takes for the signal to reflect off the object and come back to our receiver. This gives us the travel time to the object; if we know the speed of the signal, then we know how far away it is – it's just the speed times the time it takes for the signal to come back, divided by two. In doing this, we can also measure the signal strength – how much energy is reflected back to our receiver. This gives us some information about the object – perhaps how big it is or properties of the surface; using a polarized signal, we can find out even more about the object. We can also measure the phase, or partial wavelength of the signal that returns – this can tell us even more about the properties of the object. The frequency of the returning signal can also tell us something about how fast the object is moving. Recall that the atmosphere is largely transparent in the microwave portion of the spectrum, which means that we can make observations regardless of the time of day, time of year – especially useful in polar regions – and even somewhat independently of the weather.

Slide 4 – Radar Altimeters

One widely-used application of radar in remote sensing is using what are known as altimeters. As the name might suggest, an altimeter measures the distance between the satellite and the Earth's surface, which tells us about the altitude of the surface. Radar altimeters can achieve very high accuracy – down

to as little as 3 centimeters difference, which is rather impressive given that we're making these measurements from around 700 km away! The large footprint of the altimeter signal, however, means that we're limited to measuring the height of large, relatively "flat" surfaces such as the ocean or the interior of the ice sheets.

Slide 5 – Synthetic Aperture Radar

Another widely-used application of radar is what's known as synthetic aperture radar, or SAR. It turns out that the resolution of a radar, or the ability to differentiate between different objects, mostly depends on the size of the receiving antenna and the wavelength of the signal. This means that for a commonly-used radar signal, known as C-band, with a wavelength of ~5 cm, we would need an antenna nearly 4,250 meters long in order to have a spatial resolution of 10 m. Fortunately, we have a bit of a work-around – the way that a SAR system sends and receives signals is designed to imitate a much larger antenna. The details of this are outside of the scope of this course, but there are some links below that go into more detail.

SAR is probably the most common form of microwave sensing used, with a wide range of applications. The images that we get from a SAR sensor are quite a bit different than the kind of images you might be used to – one example is shown here on the slide. Looking at this, you might be able to guess that this is an image of some mountains somewhere, but I imagine that picking out different features might be a challenge. This is because the characteristics of the signal that we receive depend heavily on the wavelength of the signal and its polarity; the surface characteristics – for example, its structure or moisture content; and the geometry of the surface – mountainsides oriented toward the sensor will look quite a bit different than mountainsides oriented away from the sensor. SAR is a very powerful tool, but it does take some getting used to.

Slide 6 – (Some) applications of SAR

Depending on the properties of the surface and the wavelength, a SAR signal will actually measure beneath the surface. This means that by using signals with different wavelengths, we can get information about different layers within the surface – for example, we can learn about the structure of forests. We can also track and measure surface moisture. When combined with the fact that clouds are mostly transparent to SAR signals, this makes SAR a particularly potent tool for monitoring and studying floods, as shown in the example here. We can also use SAR to measure surface topography and surface motion, using a technique called Interferometric SAR, or InSAR. This can help us study things like ground subsidence in areas where groundwater is being depleted, as shown in the figure on the left, or areas where volcanic activity may be causing the ground to uplift by very small amounts, as shown in the figure on the right here.

Slide 7 – LiDAR

Similar to radar, LiDAR stands for Light detection and ranging. Rather than using radio signals, we use lasers in visible or infrared wavelengths. LiDAR works on a similar principle to radar – the sensor

sends out a signal, waits for it to return, and measures the travel time and signal properties, which tell us information about the surface that we're observing. Depending on the application, we may use a laser with a wavelength corresponding to visible green light, approximately 600 nm, or up to around 1000 nm, in the near-infrared portion of the electromagnetic spectrum. Depending on the wavelength used, LiDAR can give us information about topography – a common application of LiDAR is for mapping elevations, as the elevation data returned are both dense and highly accurate. It can also tell us about vegetation structure – similar to radar, the sensor gets returns from different portions of vegetation cover, and can even be used to 'remove' vegetation from elevation data. If you remember to the example I showed last week from Aguada Fénix, this is how archaeologists working in southern Mexico were able to map monuments and cities through dense forest cover. With lower wavelengths, such as green light, LiDAR can even be used to map bathymetry in shallow areas – the example profile here is from ICESat-2, a satellite that uses a green laser to map elevation across the globe.

Slide 8 – Summary

In this lesson, we have learned about how we use active sensors to produce a signal, and then measure the response of an object.

One type of active sensor, called an altimeter, can be used to map surface heights very precisely, at least on relatively flat surfaces.

Imaging sensors such as synthetic aperture radars provide an “image” of an area, though the image may look quite different to what we're used to.

Depending on the signal wavelength, active sensors can be mostly weather-independent, and can even make observations when there's no sunlight to reflect.

Finally, we've seen that active sensors can be useful for many different applications.

Slide 9 – Additional Resources

Once again, you can read more about the concepts we've covered in this lesson in the textbooks, Chapter 6 of Lillesand, Kiefer & Chipman; and Chapters 7 and 8 of Campbell & Wynne. You can also read further on the The Natural Resources Canada Remote Sensing Tutorials. Finally, I've linked to two videos that go into more detail about synthetic aperture radar and LiDAR, respectively. That's all for this lesson – I hope you found it interesting, and if you have any questions, please don't hesitate to e-mail me or post in the discussion forum on blackboard. Bye!