REMOTE SENSING FOR NATURAL HAZARD STUDIES

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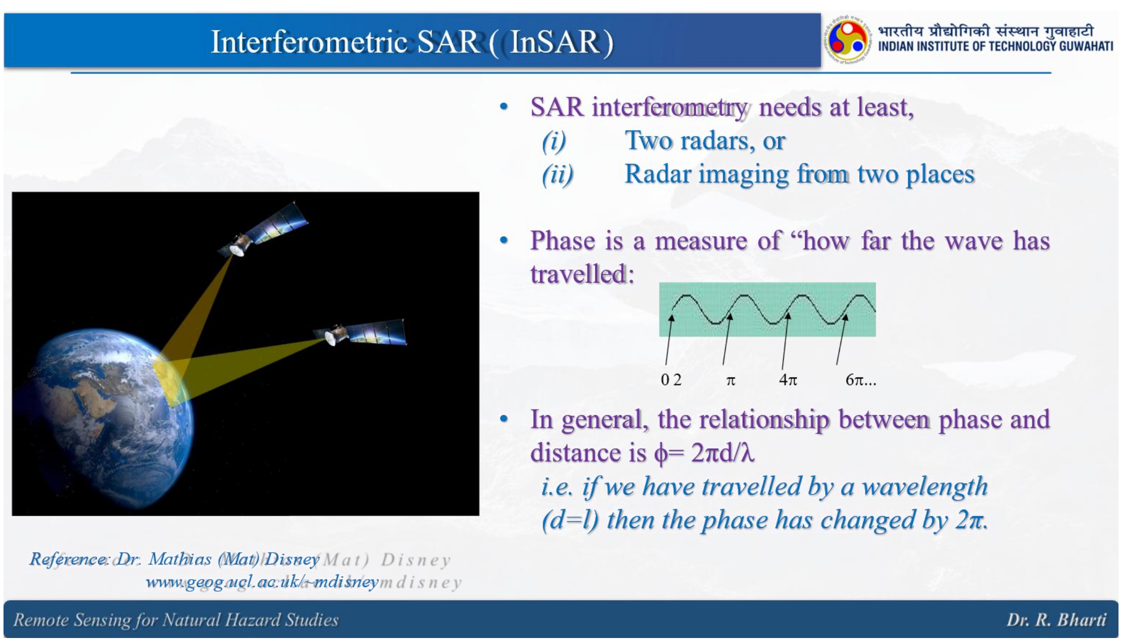
Lecture 6b: Microwave Remote Sensing-II Part B

Hello everyone, welcome back to Lecture 6, which is on Microwave Remote Sensing. In this particular lecture, we will continue with microwave remote sensing and we will also have a look at imaging spectroscopy. So, let us continue with this course. So, this is the interferometric SAR. So, the system commonly known as INSAR synthetic aperture radar (SAR) imaging system with interferometric configuration is known as interferometric SAR or INSAR. So, this INSAR it is very very popular.

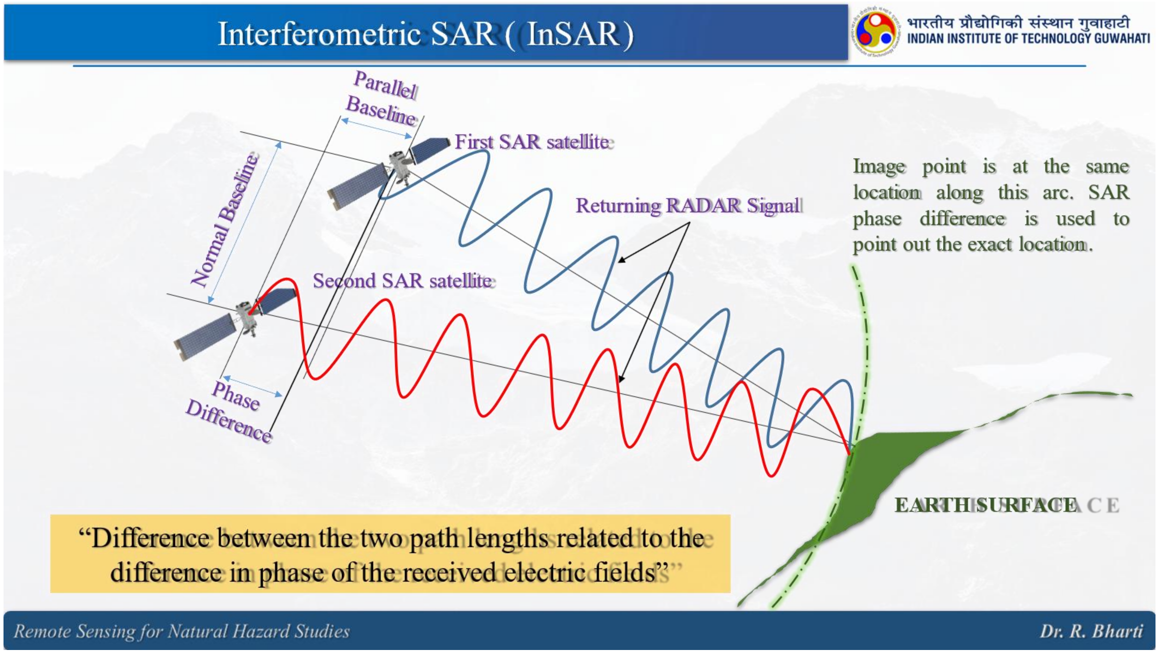
So, here what happens it allows accurate measurements of the radiation travel path because it is coherent. The measurement of the travel path variation with respect to the satellite position and time of acquisition allowed for the generation of a digital elevation model. And it can also provide centimeter-level information related to surface deformation; that is why this particular domain of microwave remote sensing, the INSAR, is widely used in surface deformation studies. High-resolution digital elevation model or surface change map due to earthquakes, land subsidence, glacial movement, volcanic activity, and land use land cover change.



These are the most common areas. INSAR is widely used in these particular areas. So, here you can see that this has an interferometric configuration. So, here basically you have 2 sensors that are looking at the same area, and they are generating the microwave images, The SAR interferometry needs at least 2 radars and radar imaging from 2 different places. So, remember we are having an interferometric configuration; that means we have a minimum requirement of 2 radars, and these 2 radars must be placed at different locations at the same time, and they should be looking at the same area. So, this is called an interferometric configuration. Phase is a measure of how far the wave has traveled, so whether it is 0, 2π, 4π, or 6π, that will provide you with how far the wave has traveled. In general, the relationship between phase and distance is 2 pi d over lambda; that is, if we have traveled a distance equal to one wavelength, then the phase has changed by 2 pi. If it is 2, then it will be 4 pi; if it is 3, then it will be 6 pi.

Phase information is effectively random noise in a single SAR image because the phases are randomized by all the scattering on the Earth's surface, So, here is one example of the phase image and how it appears on your screen. However, if we view it from another position very close to the first, then the differences in phase tell us about the difference in distance. I would like to take the example of our eye. Our eyes are two different sensors placed at two different locations, and we are looking at one particular object at the same time; because of that, we have depth perception. If you close your eyes for a longer duration, you may not feel it because our brains are trained in such a way if you close one of your eyes temporarily.

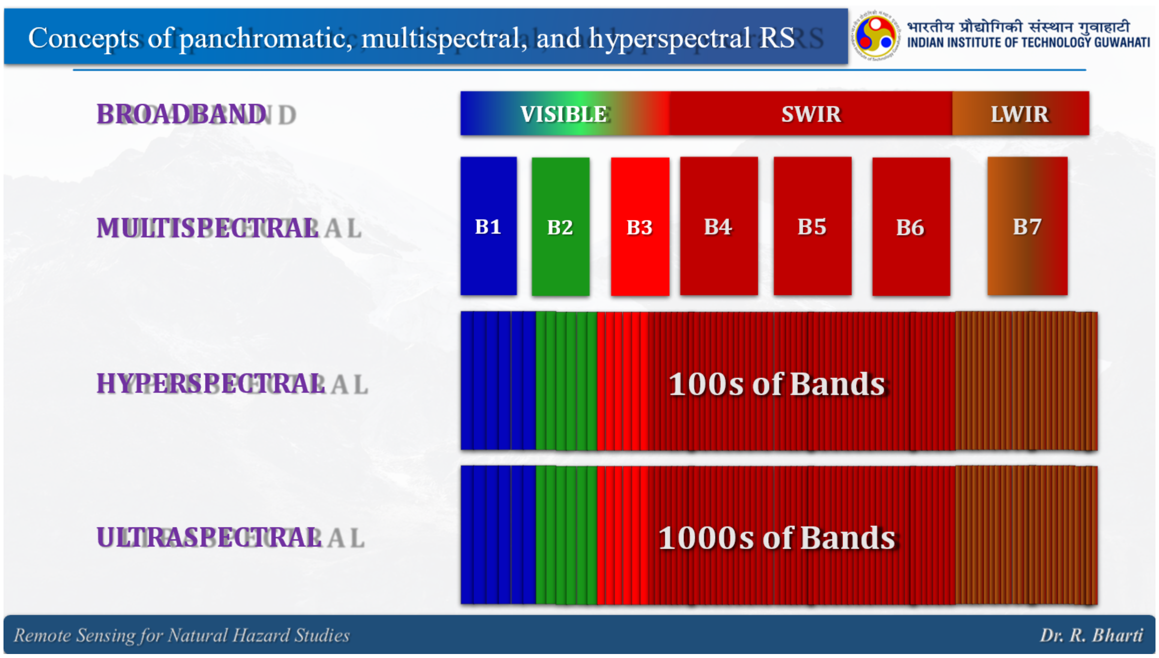
But if you close one eye for 1 month or 2 months when your brain loses the memory of depth perception, then with one eye you will not be able to see depth. So, the depth information comes when we view from 2 different positions. So, this is one example; here you can see that this is the normal baseline, which is the distance between these two satellites, and this is the phase difference and parallel baseline. So, this is from here to here; it is a parallel baseline, and this is the phase difference, then comes the returning radar signal, so here these two signals are reaching these two sensors, and they are targeting the same area at the same time; then this is the surface. So, the image point is at the same location along this arc; the SAR phase difference is used to pinpoint the exact location.



So, this is the phase difference that is used to point out the location of this particular object. And it will be very, very precise when we are using the interferometric configuration. So, the difference between the two path lengths is related to the difference in the phase of the received electric fields, Interferometry is used to generate two products. One is coherence; another one is phase image, The phase image is nothing but your interferogram, and you might have heard about the interferogram in many other courses. An entire image of the phase information is known as an interferogram. An image of the coherence that represents the correlation between the two images. So, the coherence the word itself means the correlation, how coherent these two are with each other. Coherence near one means the phase information is reliable, which means both images can be used together and the images have a high degree of correlation. When coherence is less than or equal to 0.3, it means the image has low correlation and is most probably noisy. In this case, the phase information is probably not useful. Before you use the interferometric SAR product, you have to check the coherence. If the coherence value is 1 or near 1, that means the images will provide you with very good information. If it is equal to or less than 0.3, you are not supposed to use them together for any kind of quantitative analysis.

With microwave remote sensing, the radar signal can penetrate vegetation cover and soil surfaces. Depth of penetration is significantly affected by moisture content, surface roughness, and the incident angle. Remember the geometry of microwave remote sensing. Maximum penetration is in the arid region with a longer wavelength signal. So, you remember the different wavelengths we have used, and we have designated letters representing the wavelengths, in microwave remote sensing? So, that is the longer wavelength region that we have to choose and the maximum depth of penetration we receive in arid regions is due to the water content.

So, here you have low water content, and you will have a low dielectric constant, so because of that depth of penetration will be more in such area. So if this is the surface, if you have a longer wavelength region, it will penetrate more; it will be as good as or equal to the wavelength of your microwave energy. Microwave remote sensing products are widely used in geology, hydrology, oceanography, and glaciology. So, you might have come across many literatures in which we are using microwave remote sensing for soil moisture mapping, vegetation mapping, soil temperature, snow cover, or snow water equivalent in glaciology, sea ice mapping, atmospheric temperature profiling, humidity profiling, and precipitation; all these areas are possible areas of research with microwave remote sensing data. So, these are some of the potential areas where microwave remote sensing is used widely.

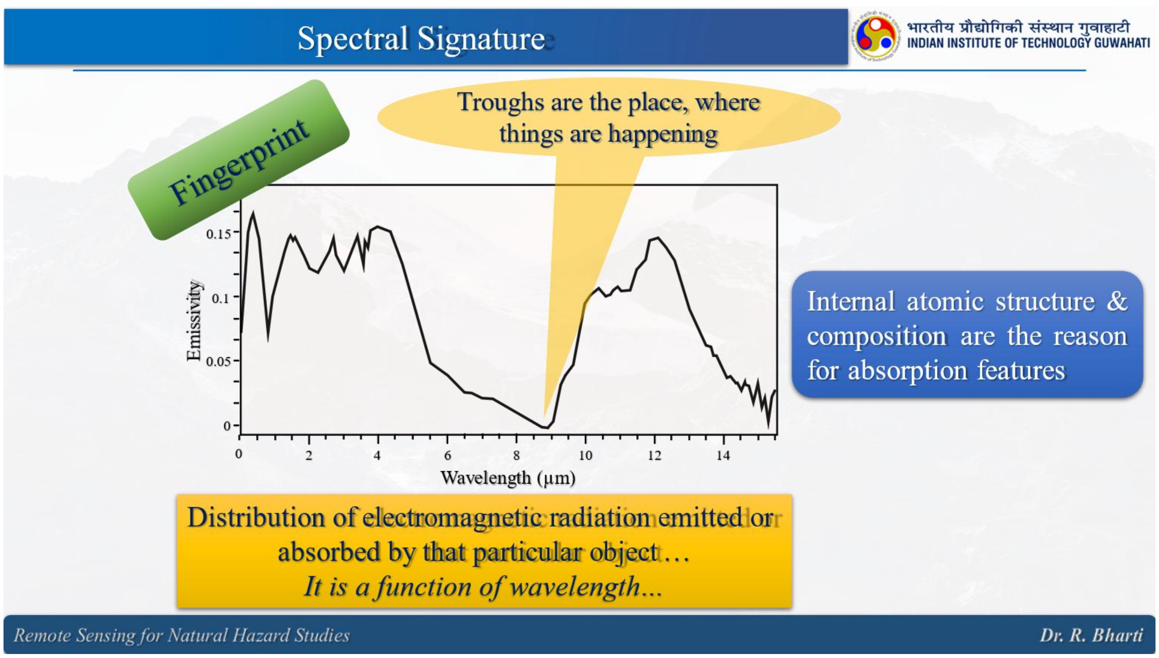


Now we will talk about the introduction to imaging spectroscopy, So, this is another important topic that we have to understand. So, let us go back to panchromatic, multispectral, and hyperspectral remote sensing, and here you remember this slide where broadband is using a very long wavelength range to generate a single image, When we talk about multispectral, we have several bands or images generated in this wavelength range, but in between, we can have some gaps where there are no measurements, When we talk about hyperspectral, the bandwidth is narrow. And the measurement is contiguous. So, there is no gap in between when we talk about ultra spectral; again, the measurement is contiguous, and the number of bands is in the order of thousands, So, here is one thing that we have to understand: how we are generating this image. So, if it is broadband, we have one pixel value, a second pixel value, a third, a fourth, and a fifth; then we have another set of pixels.

This is how we are completing this particular image, and when we extract these DN values, we get only one point in this x and y, which is lambda versus reflectance. But when we talk about the multispectral, we have several images available in different wavelength ranges, which are measured in this way. So, we have a few points in this particular graph that can be connected like this, but when we talk about hyperspectral, it is a contiguous measurement. So, we have our points arranged in this way so that we are not losing any information in between, which is missing in this particular setup, So, here we also have lambda, and this is reflectance. We will have further details here.

Data sets will be much more than your hyperspectral data, So, this will provide you more information about the target about their chemical composition internal atomic structure. Now, how we are generating this is by using one instrument that is looking at the ground, and then we are generating one pixel value. So, this is acting as a detector; one detector is capturing one pixel value in the case of broadband. Now, if we have this kind of setup, this kind of instrument, let us say, 5. So, then we will have 5-pixel values.

So, these 5-pixel values can be arranged. And we are having this 5-pixel image: 1, 2, 3, 4, and 5. Now, similarly, when we talk about multispectral, we have 5 bands or a minimum of 3 bands, So, each pixel will have three images. So, individually, if we refer to any of the images, then they have one set of values corresponding to each pixel. When we talk about multispectral, we have multiple values corresponding to each pixel, So, this concept explains the advantage of spectral resolution.

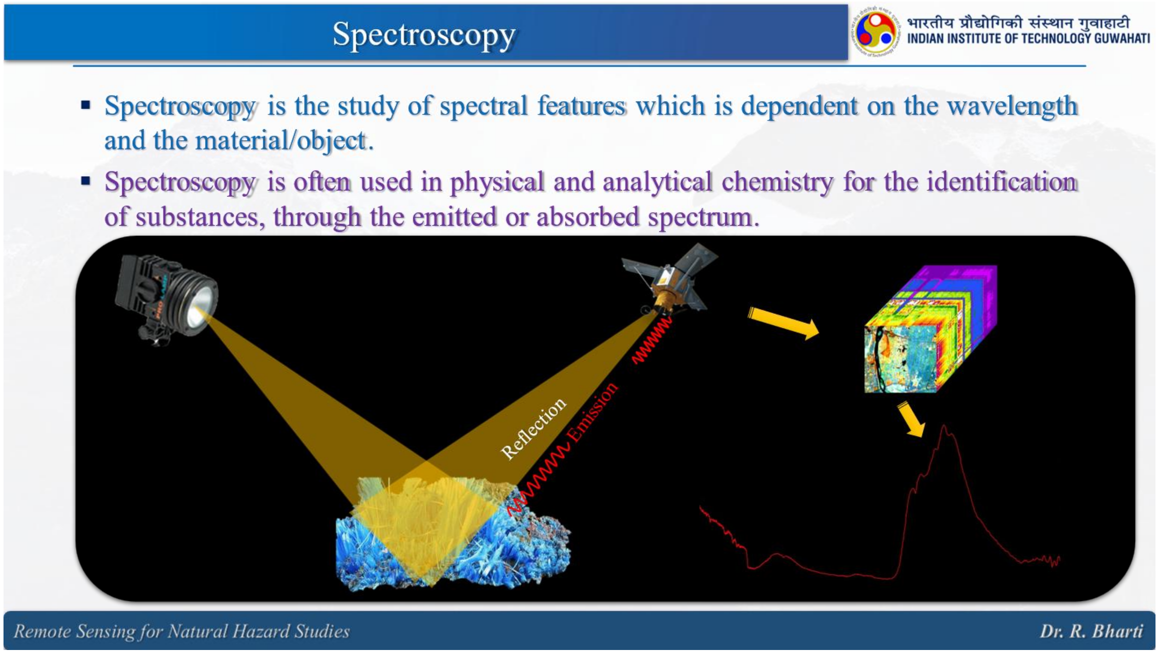


So, when we talk about hyperspectral remote sensing or imaging spectroscopy, the spectral resolution is high. So, this represents a particular pixel from this image. So, when we talk about the spectral signature, the high spectral resolution means it will provide you with all the information that was missing in multispectral. Let us say these points correspond to multispectral.

So, this is missing. So, what is happening here that is missing, which is available in hyperspectral remote sensing, is that corresponding to these absorption features, we are able to identify the material, whether it is x, y, or z. So, now you can just imagine how important it is to have these measurements. All these dots are from different images. Now, once we understand that every material has its own characteristic absorption feature, maybe a single absorption feature or maybe a set of absorption features, that can be used to identify them in remote sensing products. So, we can consider this spectral signature, or particularly this characteristic absorption feature, as the fingerprint of this material.

So, that is very important. So, that comes only when you have high spectral resolution. So, the internal atomic structure and composition are the reasons for the absorption features, and troughs are the places where things are happening. Remember I told you that if there is a tree, it appears green to us because the green color is reflected; other wavelengths are not reflected compared to this green. So, let us talk about this 400 to 700 nanometer range, and we find that it has reflectance in the green region, which is higher compared to blue and red. That means this particular target is not interested in the green wavelength, but it is interested in red and blue, and further, if we see the spectra of vegetation, So, here it is: green, red, and then in NIR you have this kind of spectral signature.

So, this is comparatively high. But since we are not able to see this particular region, it appears green to us. But if you see this particular wavelength, it is very interesting to note that this wavelength is absorbed by the vegetation. That means these troughs are the places where things are happening, not these, because these are simply reflected by the target. So, that is why the characteristic absorption features are helping us to identify their chemical composition or atomic structure and to better characterize them in the remote sensing products. So, the distribution of electromagnetic radiation emitted or absorbed by a particular object is a function of wavelength because these are the wavelengths, So, this is a function of wavelength that is very, very important to remember.



Now, when we talk about spectroscopy, it is the study of spectral features that depend on the wavelength and the material or object, Spectroscopy is often used in physical and analytical chemistry for the identification of substances through the emitted or absorbed spectra. So, let us take this example. So, this is the target, which is getting illuminated by our own source of light. Then what will happen? Some amount of energy will be absorbed, some will be reflected, and some will be transmitted. So, then we can have a different setup of instruments; we can put one instrument here to measure what the transmitted energy is.

If we put one sensor here to measure how much energy is reflected, So, we can have this kind of spectroscopy. So, here in this case, we have the reflectance, which is measured by this particular sensor; or if it is absorbing, it will emit, and this particular data goes to your sensor, then it is getting recorded. So, this is the hyperspectral setting. This hyperspectral data will provide you with a better representation of the target because you are able to capture all these absorption features, So, these absorption feature or set of absorption feature will help you to identify the material. So, spectroscopy is the study of spectral features that depend on the wavelength and the material or object, and indirectly, we are referring to the chemical composition and the atomic structure. To acquire spectroscopic information over a large area, we need sensors, and those sensors should have the capability of generating high spectral signatures. So, it has the power of both spectroscopy and imaging. So, you will have the power of both spectroscopy and imaging. So, in this case, what will happen is that you will be generating the hyperspectral remote sensing images, so that is also known as imaging spectroscopy.

With this, we will end this lecture. So today we have learned about microwave remote sensing and imaging spectroscopy. We will continue this topic in the next lecture, where we will learn more about hyperspectral remote sensing.