REMOTE SENSING FOR NATURAL HAZARD STUDIES

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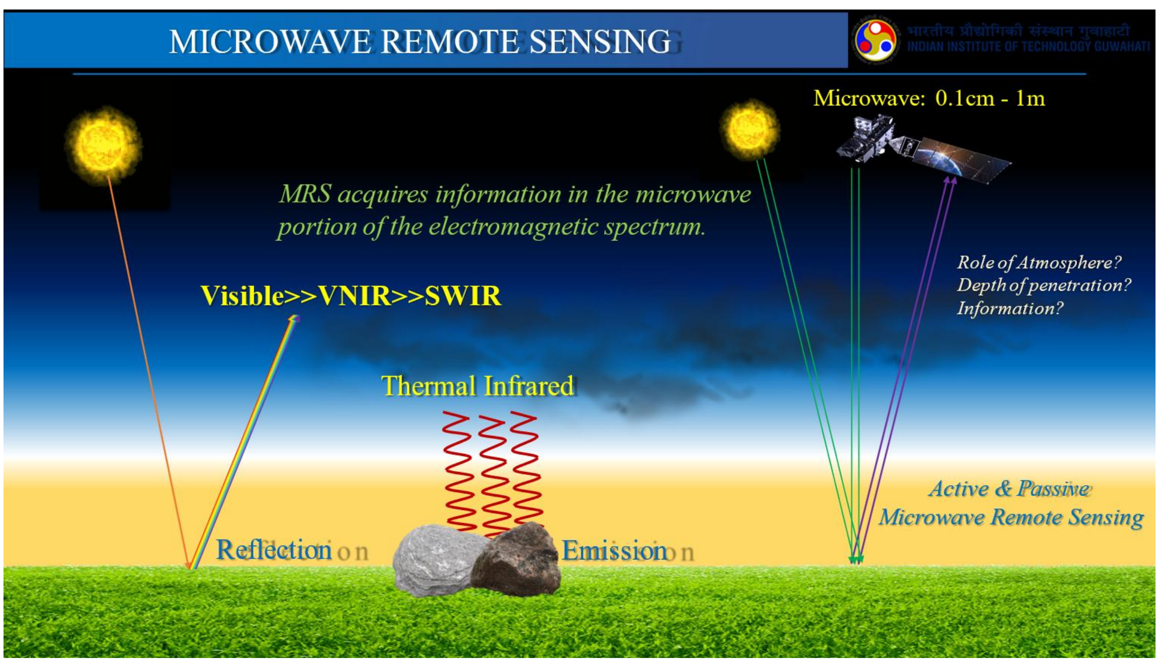
Lecture 5a: Microwave Remote Sensing-I Part A

Hello everyone, today we are going to start Lecture 5, which is on Microwave Remote Sensing – 1. So, like previous lectures, this lecture is also divided into two parts. This is the second lecture of the second module and the fifth lecture of this particular course. So, you remember this slide where we mentioned different domains of remote sensing: reflection, emission, and then microwave. So, what do we measure here? Here, we measure the backscattered energy. And you see here we have incoming radiation from the sun as well as incoming radiation from the sensor. So, it is possible that we can have active as well as passive microwave remote sensing for any given target. So, this is active and passive; this is just an example. Now, we have to think about the role of the atmosphere here, what kind of depth of penetration we will have, and then what information we will have that is not possible with the reflective and emissive domains. So, the role of the atmosphere is important since we are talking about scattering and absorption. Remember, the scattering is more influential at shorter wavelengths because we are talking about the size of the scatter and the wavelength.



If the size of the scatter is equal to the wavelength, we have scattering; if the molecule is larger than the wavelength, it is experiencing the scattering phenomenon. But since we are talking about this microwave, which is 0.1 centimeter to 1 meter, this is the longer wavelength region. So, in the longer wavelength region, the scattering effect will be very, very low or negligible, that is the reason we can use microwave remote sensing. When we have cloudy days when the atmosphere has aerosols and dust particles, in such situations, you will also have microwave remote sensing data. So, if this is the situation for the higher altitude areas, where the sky is almost always cloudy. So, in such a situation, microwave remote sensing is more useful. And remember, I talked about the depth of penetration in visible NIR and the thermal infrared, and I mentioned that the depth of penetration is equal to the wavelength. So, here we are talking about the microwave, which is 0.1 centimeter to 1 meter. So, the depth of penetration will be greater here compared to your optical remote sensing because these two are known as optical remote sensing; this is microwave. In microwave remote sensing, you have more depth of penetration, whereas the emission does not follow the depth of penetration of light; it is a volumetric property, now what different information will we have from microwave remote sensing? Since we have a better depth of penetration here than in optical remote sensing or the reflective domain, we will have the subsurface information correct; that is point number 1. The second point is that here we will have very little information about the composition of the target. Whereas we will have more information about the structure of the target. So, this particular slide is made to explain or to remind you about Rayleigh scattering, Mie scattering, and non-selective scattering.

Now here you see that in non-selective cases, the size of the scatterer is greater than the wavelength. Here in Mie scattering, it is as good as your wavelength, and when we have Rayleigh scattering, we have wavelengths larger than the size of the scatterer. If you look here, the advantages of microwave remote sensing are that microwave radiation can penetrate through cloud cover, haze, dust, and all but the heaviest rainfall. Not vulnerable to atmospheric scattering like shorter optical wavelengths, as I have already explained, since we are talking about the size of the scatterer, which is equal to, less than, or greater than the wavelength. This microwave remote sensing ranges from 0.1 centimeter to 1 meter and will not have much problem because of this scattering. So, the atmosphere is clear for us, at least for this longer wavelength, and because of this, we can do remote sensing in the cloud cover, haze, dust, and all but the heaviest rainfall because, at that time, the signal or the energy that is backscattered from the surface will be interacting with your water. So, because of that, it is very difficult. Now the disadvantages, as the disadvantage says, is that it is a very costly instrument setup. So, here, compared to optical remote sensing, this is costlier.

Then the output of microwave remote sensing is complex and hard to interpret because earlier we talked about the optical remote sensing output where we had only the pixel; the pixel will have x, y, and z values: x is your latitude, y is your longitude, and z is your DN value. These DN values were further converted to radiance and then to reflectance. But here, when we talk about the microwave remote sensing output, it is in the complex form (a+ib). So, this is not the simple DN value; we will understand this in subsequent slides. Very little information related to the composition of the material that I already mentioned is that in microwave remote sensing, we have different types of information rather than only looking for the composition. If you are interested in composition, you should go for optical remote sensing. But if you are concerned about subsurface information or soil moisture data, then you should use this microwave remote sensing data. This particular slide will explain active microwave remote sensing, where the sensor itself has a source of light in the microwave domain, which ranges from 0.1 centimeters to 1 meter. So, in this domain, we have a source that is available with this particular satellite, and this is illuminating the surface. You can see how the pulses are sent, and then they are reaching the ground. So, once it interacts with the ground, what will happen? The reflection will take place in the backscattering, and then this backscattering will slowly reach the sensor, and then we will capture how much time it has taken and what the backscattering value is.

So, these two things will be measured and recorded for a particular pixel. In this slide, you can see that there is one microwave remote sensing instrument available with this particular airborne flight, and it is illuminating the surface. Now, see it very carefully. Here, the pulses are sent; now the pulses will interact with different targets available in this field of view. Now, this particular tree has interacted first, you see, it has interacted first. So, what will happen? This will provide the backscattering value before this house, here. So, you see this has started to give the backscattering signal. So, it is slowly reaching this particular sensor. And then next, this backscattering signal from this house will reach this sensor. So, what is happening with this particular object, in this case, it is a tree.

So, this tree will provide the backscattering signal before this. So, there will be less time for this, and here it will show the time delay. Based on that, the objects will be identified: which is near, which is close, which is high, which is low. That kind of information can be measured with this data. In the case of passive remote sensing. So, here the sun is our source, illuminating the whole area, and then the signal goes back to space, where it is measured by the passive microwave sensors, So, this is called active or backscattering radar; this is called passive. Here, we are using the radiation or the passive radiometers. So, if you see here, this particular graph shows the wavelength versus percent transmission in one way. So, this is transmission in our atmosphere when we have water clouds or ice clouds; the percent transmission is almost very good, when we have wavelength and the percent transmission, here again in the percent, you can see how it is behaving. So, when we increase the wavelength, this percent transmission is also increasing, which means that the moment we increase the wavelength, transmission is increasing. So, because of that, the water cloud or ice clouds are not the biggest problem during this measurement.

Microwave Remote Sensing

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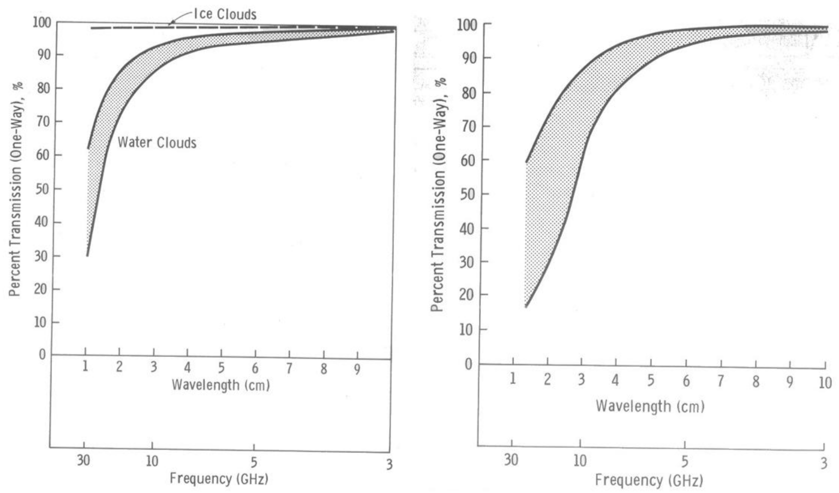
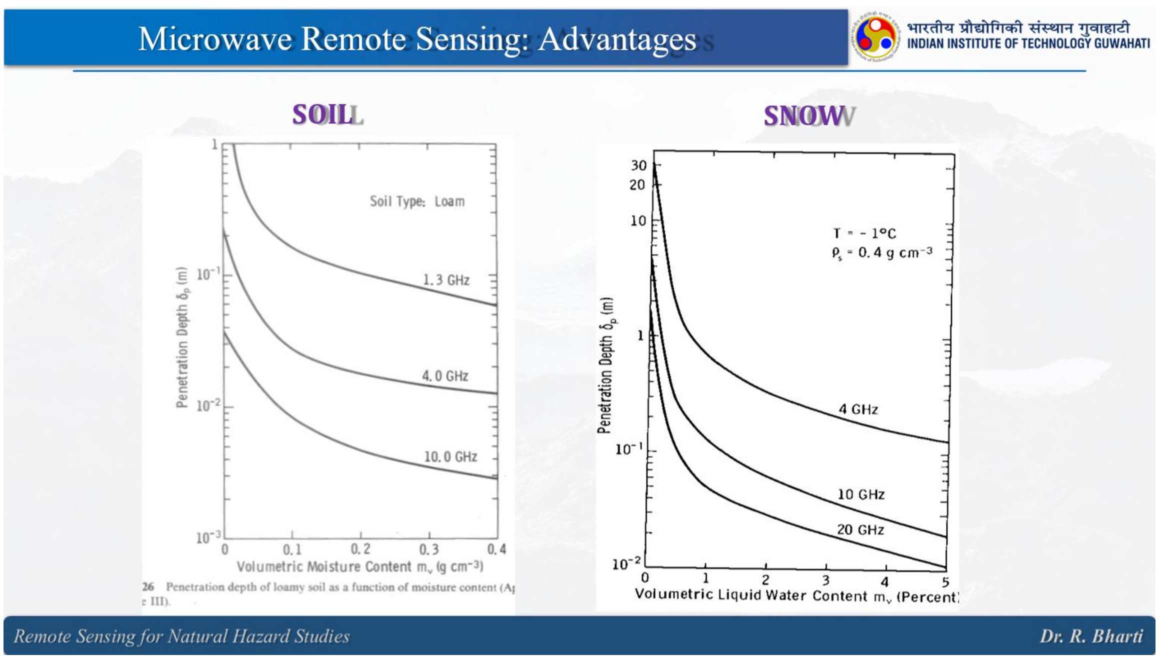


Remote Sensing for Natural Hazard Studies **Dr. R. Bharti**

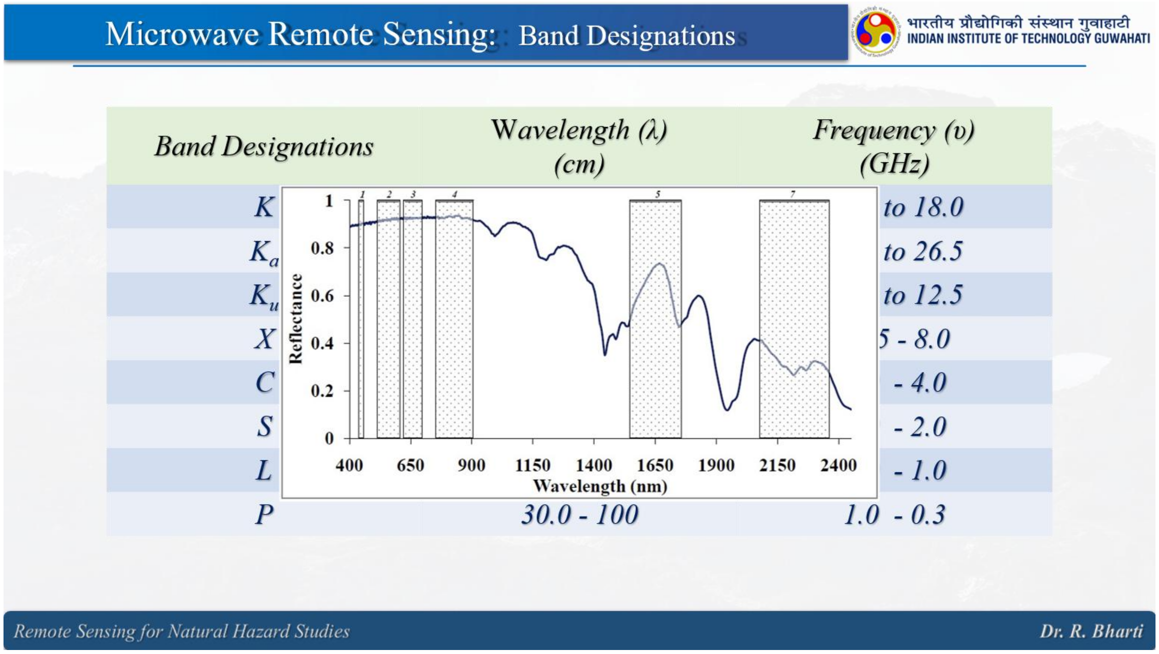
So, that is why microwave remote sensing is very suitable for higher altitude areas where there is more cloud cover throughout the year. The amount of intensity of emitted, reflected, or transmitted microwave energies is very small. Which is generally insufficient for the passive microwave sensor or detector. So, remember this E=hc/lambda. So, what is the relation here? This is energy E, and this is the wavelength. So, if the wavelength is low, energy is high, and if the wavelength is longer, energy will be low. Since we are talking about the wavelength in the order of 0.1 centimeter to 1 meter, the wavelength is too high. So, energy will be very very less. The amount of intensity of the emitted microwave energy is related to the temperature and moisture properties because we are talking about this wavelength, which is absorbed by the surface that has moisture conditions. So, microwave energies are absorbed, or they will be absorbed by the surface if it has a high moisture content. So, in this situation, what will happen? This will be controlled by the surface properties. Since the microwave wavelengths are long, the energy available to passive sensors is very low when we rely on the sun as our source of light. So, naturally, this is illuminating this particular target, and it is being reflected. So, in that condition, we are following this fundamental, and here the longer the wavelength, the lower the energy is because of that, the energy which is released from the surface will be very little to be resolved by our sensor. So, what do we do when we increase the spatial resolution or the size? Then you have bigger pixels. So, that is why these passive microwave sensors are characterized by low spatial resolution. I hope this is clear: the energy and wavelength relation that is being used here to decide which particular size will be suitable for microwave remote sensing. Now we will talk about the applications of passive microwave remote sensing. The application of passive microwave remote sensing includes metrology, hydrology, and oceanography. So, in these areas, microwave remote sensing data sets are widely used.

Meteorologists can use passive microwaves to measure atmospheric profiles and to determine water and ozone content in the atmosphere. Hydrologists use passive microwaves to measure soil moisture since microwave emission is significantly influenced by moisture content. So, what happens? If you have a surface that is moist or has moisture content, the dielectric property of this particular surface will control how much energy is absorbed in the microwave domain. So, that is why microwave remote sensing can be used and is widely used for moisture-related studies. Oceanographic applications include mapping sea ice, currents, and surface wind, as well as the detection of pollutants such as oil slicks in the ocean. These are some of the applications where microwave remote sensing is widely used. Active microwave sensors provide their own source of microwave radiation to illuminate the targets. Remember the previous slide where I showed you two examples: one where the sun is the source of light and another where the sensor itself has the source of radiation. The active microwave sensors are generally divided into two distinct categories. The first one is imaging, and the other one is non-imaging. So, this is also true for the other remote sensing. So, either we can generate an image or we can have only point measurements with the help of ground instruments, which are looking at a particular area, and for this particular pixel only, you are getting all these values. So, similarly in the microwave domain, we also have imaging and non-imaging; for non-imaging, some examples are altimeters and scatterometers. The most common form of imaging active microwave sensors is radar. This is very very popular, Radar is an acronym for radio detection and ranging, which essentially characterizes the function and operation of a radar sensor. The sensor transmits a microwave radio signal toward the target and detects the backscattered portion of the signal. So, here suppose this is a source; the sensor will emit the light, and then it will reach the target, and the backscattered portion of the signal will be recorded here. The strength of the backscattering signal is measured to discriminate between different targets and the time delay between the transmitted and reflected signals, which determines the distance to the target. Remember I told you that this is the microwave sensor that is illuminating this particular area, and here you have one small object and one tall object. So, which one will interact first, this taller one, and once it interacts, what happens is it will start sending the signal, and this will interact later, and then this will also provide the information. So, this way we have 2 pieces of information: the first one is time, how much time it took to travel; the second is the backscattering signal. So, now we will see what the different advantages of microwave remote sensing are.

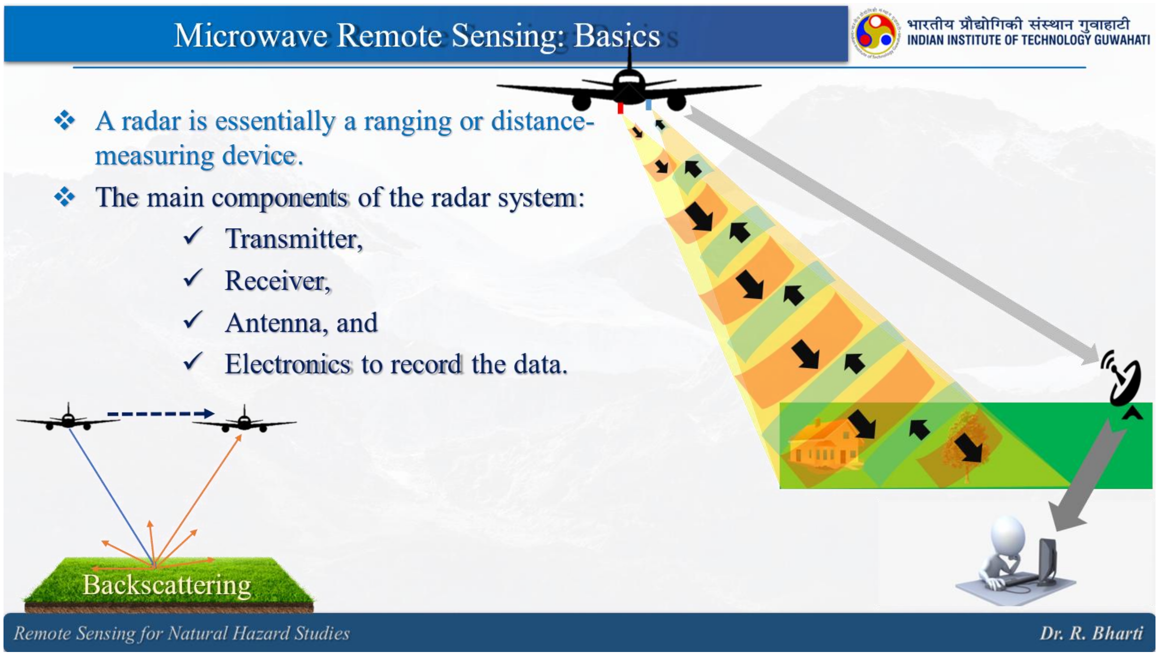
So, it has all-weather capability because it can measure through cloud cover and hazy atmosphere, and it also has day-night ability because we have active microwave sensors. So, this can also work at night, but when we have the passive one, when we go for passive microwave remote sensing, then here the sun is our source of light. So, we are restricted to doing this microwave remote sensing only during the day. Penetration through a medium occurs because you have a longer wavelength, and the surface can be penetrated with this particular wavelength that is equal to your wavelength,   Information through microwave is different from optical data because here we are talking about the longer wavelength region, and in the longer wavelength region, what happens is that the backscattering is measured, The back scattering is not a surficial property; it also has subsurface information. So, this is not related to the composition. So, this is more because of the surface roughness; what is the geometry of the target? So those things will control the moisture condition that will affect this backscattering signal. Information about the geometric properties of the various features that will be possible through microwave remote sensing, whereas in optical, the geometric information is limited. Only when we go for the panchromatic image do we have the geometry of the target   because the spatial resolution is very, very high. When we talk about the penetration depth.



In the soil, you see the volumetric moisture content. When we have more moisture content, the depth of penetration will be less, when we have this snow here, you also see volumetric liquid water content, and this is the penetration depth. So, when we talk about the less liquid water content here, the depth of penetration is high. When we have more volumetric liquid water content, the penetration is less. Similarly, the penetration depth is high when the moisture content is low. So, that means it is significantly influenced by the dielectric properties of the target. Now referring back to optical remote sensing, we had the full domain starting from 400 to 16,000 nanometers. Optical remote sensing includes both the reflective and emissive domains.



Here we were not restricted to using a specific wavelength; we only have to check what the atmospheric constituents are, what their different absorption positions are, and based on that, we have to check the atmospheric window. In those atmospheric windows, we can design a specific detector that is sensitive, maybe let us say, to 400 to 500 nanometers or 420 to 440 nanometers, So, we were free to use that, but when we talk about microwave remote sensing, our bands are fixed because we have more concern about the frequency, So, if you see here the band designation, the K band, the first band, it is from 1.18 to 1.67 centimeters, Likewise, Ka, Ku, X, C, S, L, and P bands, and here, according to their wavelengths, we have the frequencies . So, these are the fixed bands for microwave remote sensing. So, if you refer to any of the sensors that are operating in the microwave domain, they will define whether they are sensitive in C band, S band, L band, or P band. So, here this is 30 to 100 centimeters, this is 15 to 30 centimeters, 7.5 to 15 centimeters, C is 3.8 to 7.5 centimeters. So, you will find most of the sensors working or operating in this particular wavelength, and corresponding to that, you have the frequencies. Now, one thing that you will find is this word at various places, which is called wave number. So, sometimes we define the wavelength in terms of meters, centimeters, micrometers, or nanometers. But some of the papers or some of the books will be referring to this wave number. So, what is the wave number? The wave number is 1 over lambda. So you do not get confused with the wave number; if you have it, you simply do 1 over lambda, and then you can convert it to meters, centimeters, micrometers, or nanometers. So, generally in physics, people use more wave numbers, but in remote sensing, when we talk about the wavelength, we generally refer to meters, centimeters, micrometers, or nanometer. Now, there are two major types of radar. So the first one is the pulse radar; the distance between the transmitter and the object can be measured. Speed can also be measured by constantly tracking the object, and that is a change in the range from pulse to pulse, In the second one, which is the continuous wave radar, we have Doppler radar and the frequency modulated continuous wave radar, so FMCW, Pulleys often use continuous wave radar to measure the speed of cars. These are also being used for the aircraft altimeter, but they are not suitable for long-distance range measurement. So, remember these are precise. And with that, you can measure the speed of the car, and people are using it at the traffic signal. You will find many such cameras that are placed, and based on that, only your speed will be calculated, and people are charged a penalty.



These are also used by aircraft. So, their altimeter works with this continuous wave radar, and these are very, very precise. So, you will find out at what altitude your aircraft is flying. A radar is essentially a ranging or distance-measuring device. So, the main components of the radar system are the transmitter, receiver, antenna, and electronics to record the data correctly. So, you see here this particular surface, which is illuminated by the microwave signal, and then backscattering is happening, and then it is going back to space or the atmosphere, and then your aircraft or the sensor that is attached to a spacecraft or aircraft will be measuring it. So, this is the basic principle of microwave remote sensing. Now, here if you see the signals are sent. The house is interacting first with this signal. So it will start sending the pulses first, , and then it will be recorded here, and then what will happen is that this signal, which is recorded here, will be stored, and then it will be sent to the ground station when it comes in the proximity of the ground station, and then it will be circulated to the users, So, the backscattering is, you can say, this is also a reflection, But only since we are talking about the longer wavelength to discriminate it, the portion of the incident radar signal redirected directly back to the antenna through the target is known as backscatter. So, here the target is known as backscatter, and the energy is known as backscattering energy. So, here again referring to the basics of microwave remote sensing, the transmitter generates successive pulses of microwave A at regular intervals, which are focused by the antenna into beam B. So, here A is being sent successive pulses; the beam radar illuminates the surface at a right angle to the motion of the platform.

So, this is the motion of the platform. The antenna receives a portion of the transmitted energy reflected or backscattered from various objects within the illuminated beam that is C. Now, it is going back to the sensor. Subsequently, the electronic system stores this data in the form of a two-dimensional image of the surface because we have time and backscattering data, and then it will be sent to the ground station where it will be distributed. Thank you. We will continue this with the second part in the next lecture. Thank you.