

REMOTE SENSING FOR NATURAL HAZARD STUDIES

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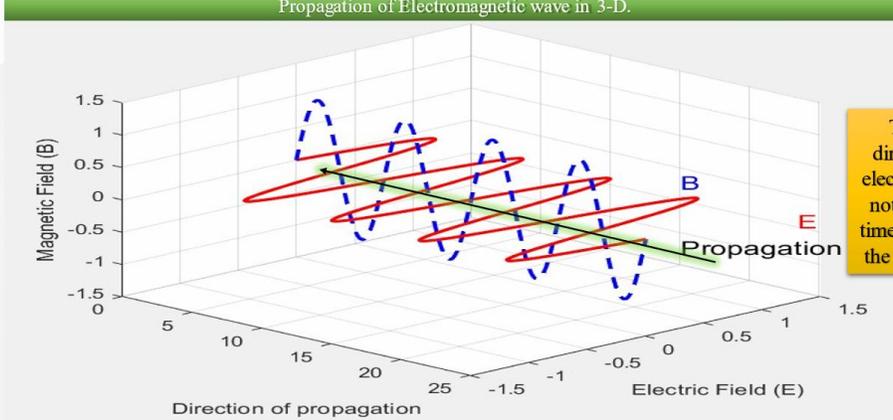
Lecture 5b: Microwave Remote Sensing-I Part B

Hello everyone, welcome back to Lecture 5. This is the second lecture of module 2 and the fifth lecture of this particular course. So, here we are referring back to the basic properties of the electromagnetic wave. So, here you can see that the fundamental properties of an electromagnetic wave, including its sinusoidal nature, perpendicular fields, wavelength, and direction of propagation, are explained in this particular image, the overall direction of the electric field does not change with time. So, it only shifts the wave in time. So, it will be very clear from this animation if you see how the electric and magnetic fields are present here and how the waves are moving from one place to another, and this electric field does not change with time; it only shifts the wave in time. So, that is very, very important. So, it is basically the Maxwell equations that describe the generation of time-varying electric and magnetic fields and the propagation of light as electromagnetic waves. So, this is the basics of remote sensing, and particularly for microwave remote sensing, you need to understand how the waves are generated, what the different fields are, and how we are utilizing them in microwave remote sensing.

Electromagnetic Wave

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Propagation of Electromagnetic wave in 3-D.



Magnetic Field (B)

Direction of propagation

Electric Field (E)



The overall direction of the electric field does not change with time; it only shifts the wave in time.

Wave theory of light (Maxwell's equations) describes the generation of time-varying electric and magnetic fields and the propagation of light as electromagnetic waves.

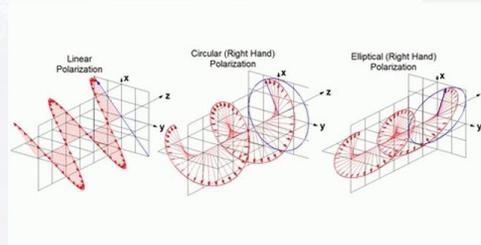
Remote Sensing for Natural Hazard Studies

Dr. R. Bharti

Starting with the polarimetry, "polar" means polarization, and "metry" means measure. So, basically, we are measuring the polarization, that is polarimetry. Polarimetry deals with the vector nature of electromagnetic waves. So, this vector nature is very, very important. Polarization is the orientation of the electric field vector as the wave propagates perpendicular to the mutually orthogonal electric and magnetic fields. If you remember the video, polarimetry is a technique that is widely used in various scientific and technological fields.

From material science to astrophysics, to study the polarization properties of the wave, including light. Polarization is a fundamental characteristic of waves; this is the fundamental property of right polarization. So, it describes the oscillation of the electric field vector in a specific direction perpendicular to the direction of wave propagation. Understanding the polarization of light is crucial for a wide range of applications such as laser cutting efficiency, optical manipulation of particles, and defect detection in composite materials. So, this polarization, or polarimetry, is widely used in different communities, and they are using it for different objectives.

Light can be described as a transverse electromagnetic wave with oscillations of the electric and magnetic fields perpendicular to the direction of propagation. So that was very clear from the diagrams. The polarization of light refers to the specific orientation of the electric field vector, which can be linear, circular, or elliptical. Now, here we are referring to the electric field vector and it can be linear, circular, and elliptical. Linear polarization occurs when the electric field oscillates in a single direction, while circular polarization involves the electric field rotating around the direction of propagation. Now, elliptical polarization is a combination of linear and circular polarizations. So, this is where the electric field traces an elliptical path. So, this is an elliptical path, but this is a combination of linear and circular polarization. Several methods can be used to generate polarized light, including the use of polarizing filters that are very common in our microscope, birefringent materials, and the inherent polarization properties of certain light sources, such as lasers.



So, these are used to obtain the polarization of the light, and now we will understand how it is being used in microwave remote sensing. So, in this particular slide, you can see how the wave is propagating. Now, once you put the filter. So, this is the axis of the polarizer parallel to horizontal; this is h . So, what will happen as a result will be like this? So, you are removing one field. So, this is the horizontal component, this is the propagation direction, and this is the vertical component. So, this is what I was mentioning: linear, circular, and elliptical. Here you can see the linear polarization, how it is behaving compared to the circular one and the elliptical one in the x , y , and z directions. Based on the parameter describing the polarization state of a wave, there are three canonical polarization states. Here you can see the different properties of linear, circular, and elliptical polarization and this table has the parameters of right-handed circular polarization and left-handed circular polarization, and how they are different from each other. So, in microwave remote sensing, the polarization of the radiation is also important. So, those were the basics of polarization.

Based on the parameters describing the polarization state of the wave there are three canonical polarization states: (1) Linear (2) Circular and (3) Elliptical Polarization



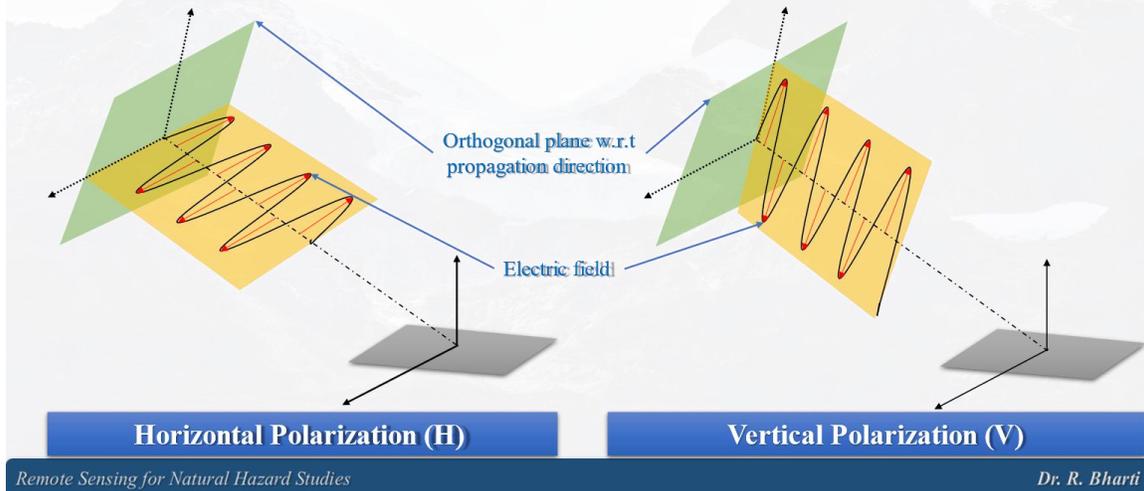
- > Horizontal Polarization (H)
 > $\phi = 0^\circ$
 > $\tau = 0^\circ$
- > Vertical Polarization (V)
 > $\phi = 0^\circ$
 > $\tau = \pi/2$
- > Linear $\pi/4$
 > $\phi = 0^\circ$
 > $\tau = \pi/4$
- > Linear $3\pi/4$
 > $\phi = 0^\circ$
 > $\tau = 3\pi/4$

Parameters	Right-handed Circular Polarization	Left-handed Circular Polarization
ϕ	$[-\pi/2, \pi/2]$	$[-\pi/2, \pi/2]$
τ	$= -\pi/4$	$= \pi/2$

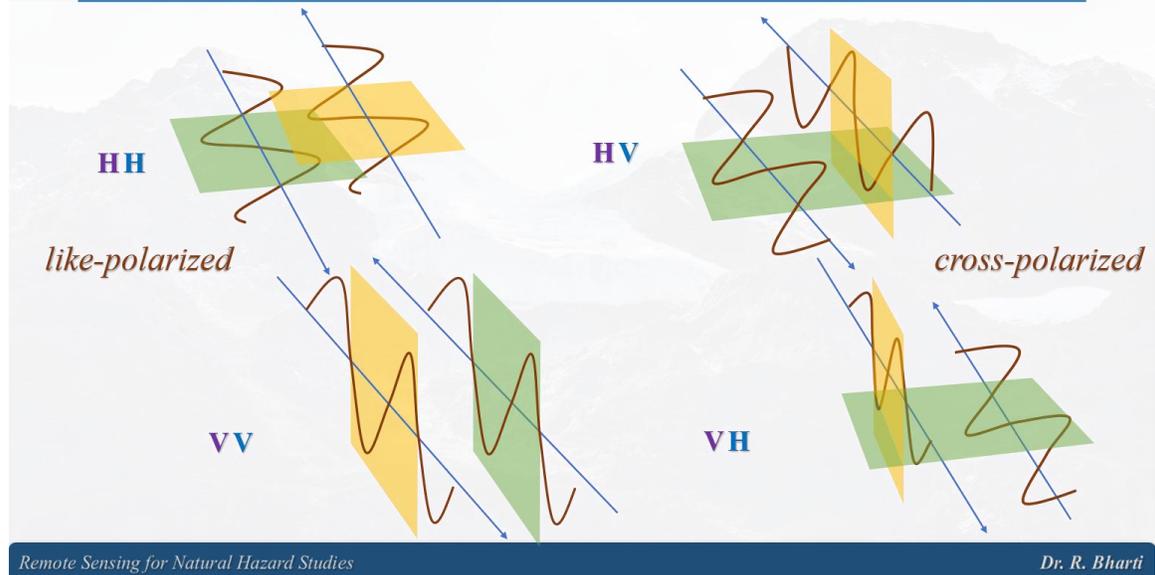
So that you will understand how a wave is behaving and how we have a filter to polarize the light, or the polarizer we are using to polarize or use a specific field of light. Radiation refers to the orientation of the electric field. Most radars are designed to transmit microwave radiation that is either horizontally polarized or vertically polarized. So, here we will be using H, or here we will be using V. So, here you can see this one is horizontal and another one is vertical. So, this kind of orientation of the electric field is used in microwave remote sensing. The combination of polarizations is also used in microwave remote sensing. HH, which is horizontal transmit and horizontal receive, VV, the vertical transmits and vertical receive, HV, horizontal transmit and vertical receive, and the last one, which is the combination of VH, the vertical transmits and horizontal receive. So, you will see these details in the subsequent figures, and you will be able to understand what I mean by HH, VV, HV, and VH. So, here you divide these words: HH, VV, HV, VH.

So, the first letter of this defines the transmitter; this is the receiver. So, this is the transmitter. And on the right-hand side, it is the receiver. So, horizontal transmit and horizontal receive. The last two combinations, HV and VH, are referred to as cross-polarized because the transmitted or received polarizations are opposite to one another.

“Polarimetry is the science of acquiring, processing and analyzing the polarization state of an electromagnetic field”



So, here you can see that these are the planes orthogonal to the propagation direction, and this is the electric field right here and here, and these are the axes so that you will have the perception of 3D. So, this is H horizontally polarized; this is vertically polarized. Polarimetry is the science of acquiring, processing, and analyzing the polarization state of an electromagnetic field. Here, HH means the first one is the transmitter and this one is the receiver. So, here HV is sent horizontally and measured in the vertical direction. This is VV and this is VH; here, you have vertically polarized light being sent, and the horizontally polarized light is received. So, this is called polarized HH and VV, and this is called cross-polarized; you have HV and VH. So, cross means both are sent in different directions. This is an example of polarization. So, this is HH, this is VV, and this is HV, and this is the combination or the color composite of these three. So, here you see if we have HH, VV, or HV, what different information we have for the topography. Now here you can see in this particular HV that this particular area does not have any information; it looks completely black, when we refer to VV, this particular area is showing the topography. , you can see the details here. When we refer to HH again, we have this information. So, depending on what the objective of our observation is and what the objective of that space mission is, you have to select the wavelength and the polarization.

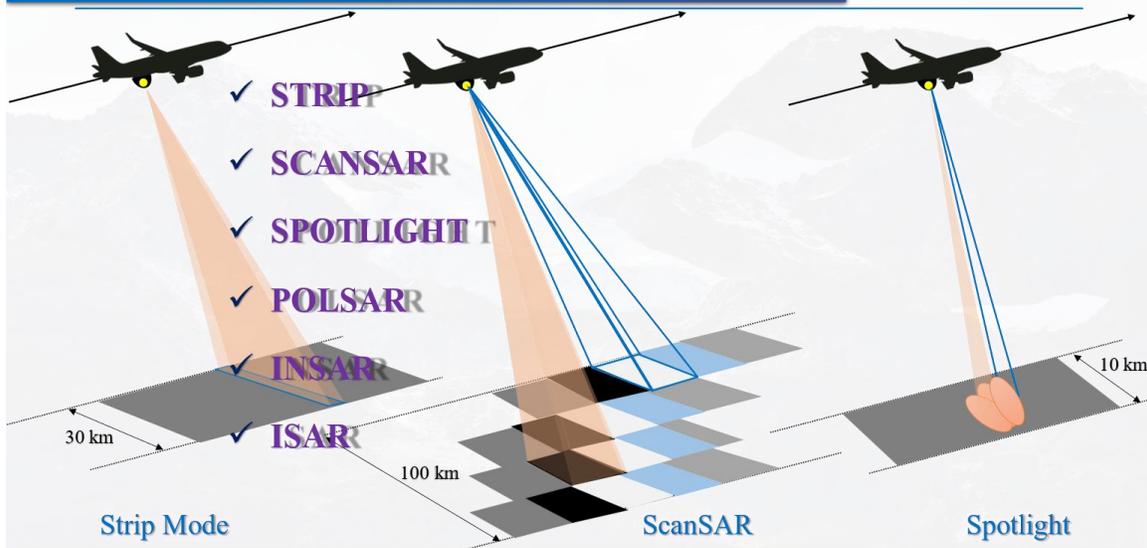


Because the polarization will be mentioned in which wavelength it is measuring and whether it is HV, VV, or VH. So, that information is available on your space agency's website that you can refer to; this is just one example. Here you can see the CSAT satellite; this was launched in June 1978. The frequency is 1.275, the wavelength is 23.5, the resolution is 25 meters, and the swath is 100 kilometer. The swath is the width of the photograph. So, this is a swath. The look angle is 23 degrees, the polarization is HH, and the look is 4. We will discuss this look in the subsequent slides. When we go with the ERS, JERS, Radarsat, SIRSI, ENVISAT, or Radarsat-2, you will find how this polarization is changing. So, depending on your objective, you have to select wisely which particular satellite image or which particular sensor is more applicable to your study.

Parameters	Seasat	ERS-1,2	JERS-1	Radarsat	SIR-C	ENVISAT	Radarsat -2
Launch	June 1978	July 91 & Apr 95	Feb. 92	Nov. 95	Apr & Oct. 1994	March 1, 2002	Dec. 14, 2007
Frequency (GHz)	1.275	5.3	1.275	5.3	1.2, 5.3, 9.8	5.3	5.3
Wavelength (cm)	23.5	5.6	23.5	5.6	23.5,5.6,3.1	5.6	5.6
Resolution(m)	25	30	18	10 - 100	25	30	10-100
Swath (km)	100	100	75	35 - 500	15 - 90	150-1km	35 - 500
Look angle	23	23	35	20 - 50	20 - 55	20 - 50	20 -50
Polarization	HH	VV	HH	HH	HH,VV,HV	HH,VV	HH,VV
Looks	4	4	3	1- 4-14	1, 4		

So, these are the different modes of imaging. So, here in the microwave, you will either have the strip. Or you will have a SCANSAR, SPOTLIGHT, POLSAR, INSAR, or ISAR. This kind of measurement or the imaging modes is available. So, depending on the modes, you will have different information. So, here you have a Strip Mode. this is SCANSAR. And this is Spotlight. I hope the figure itself is sufficient to explain what we mean by strip mode, what we mean by SCANSAR, and what spotlight is. Now we will talk about the operation of the side-looking radar system.

Microwave Remote Sensing: Imaging Modes



So, here we have a sensor that is operating in this particular area with microwave remote sensing sensors, illuminating the area with radar pulses, and it is onboard this particular aircraft. So, the signal is being sent. Now you see the house is interacting first because this is a side-looking radar system. So, this does not necessarily depend upon the height of the object; this is the position of the sensor and how it is looking at the ground. So, now you see that this particular house has started giving back the backscattering signal.

Now this has interacted, now this will start sending the signal. So, here we have two pieces of information: one is time, and the other is back scattering. Now we have two different types of imaging radars. So, the side-looking airborne radar we have is real aperture radar. So, real aperture radar and synthetic aperture radar are the two different types of imaging radar systems. The real aperture radar, which is RAR, means that "aperture" refers to the antenna, and "real" means real or fixed length of the antenna. For example, 1 to 15 meters of the length of the antenna itself. Synthetic aperture radar; the name itself is synthetic aperture, which means the synthesized length of the antenna. So, a 1 meter antenna can be synthesized electronically into a 600-meter synthetic length.

Microwave Remote Sensing



- ❖ The distance between the transmitter and reflecting objects can be estimated using the measured signal echoes.
- ❖ Since the energy propagates with the velocity of light (c), the Slant Range (SR) to any object can be:

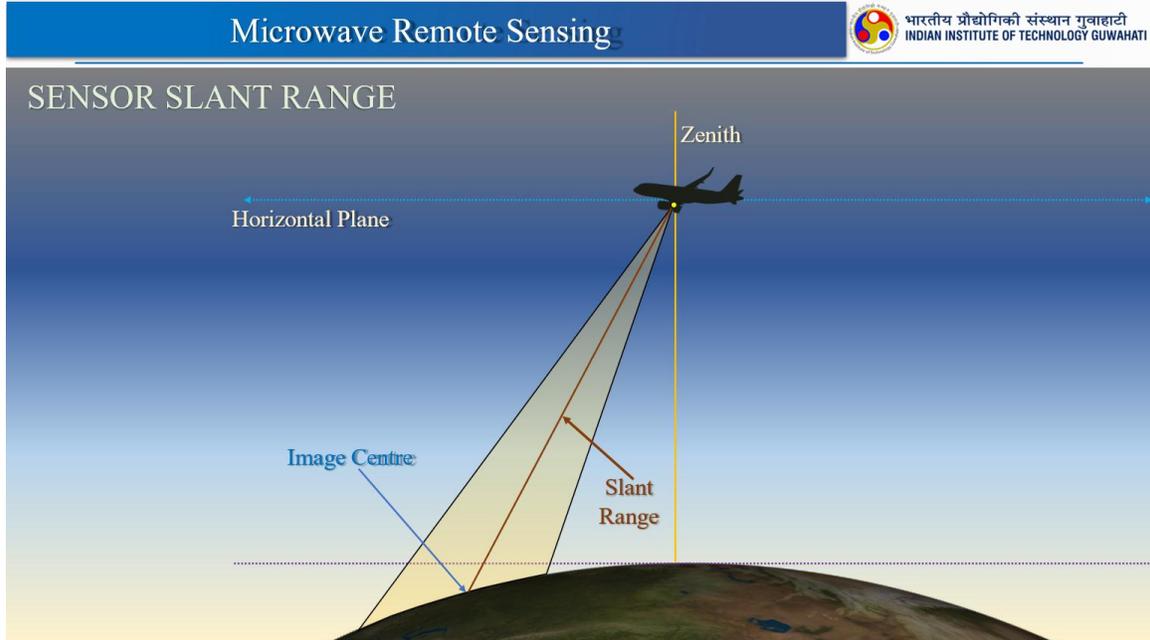
$$SR = \frac{ct}{2}$$

Since the time incorporated in the equation (time measured for the pulse to travel both the distance to and from the target), factor 2 is used in the equation.

Range term is used for the distance.

Commonly used in airborne and spaceborne radar systems, because if you keep 15-meter, or let's say if you have 11-meter of fixed antenna length, that will work as a 15-kilometer antenna length. So, that much is not feasible to send into space. So, what we do is use the synthetic aperture radar technique to synthesize the length of the antenna and measure the backscattering information. The distance between the transmitter and the reflecting object can be estimated using the measured signal echoes. Since the energy propagates at the velocity of light (c), the slant range (SR) to any object can be identified or measured using this ct divided by 2, where the time incorporated in the equation is divided by 2. Here you

can see the time is divided by 2 because the time measures for the pulse to travel both the distance to and from the target; therefore, a factor of 2 is used in the equation. So, the range that is used for the distance in microwave remote sensing will always have the range resolution or range in many places.



So, whenever range comes, it is basically the distance, So, the sensor's slant range. You see, this is the aircraft; here you have the sensor, and perpendicular to the ground, this is the nadir, this is the flight direction, this is the horizontal plane, and this is the zenith, this is looking at this particular area from a certain angle. So, this is called slant range, and this will be the image center because your image will be generated for this particular area. This will be your image center. Now we will talk about the viewing geometry. So, with this, I will end this lecture. We will continue this topic in the next lecture. Thank you. Thank you very much.