Remote Sensing: Principles and Applications
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Lecture-02
Introduction to EMR

Hello everyone, welcome to the second lecture of this course Remote sensing principles and applications. In this particular lecture, we are going to get introduced to the concept of electromagnetic radiation. In the last lecture while I discussed about the remote sensing system I told you about some medium that carries the signal that we need.

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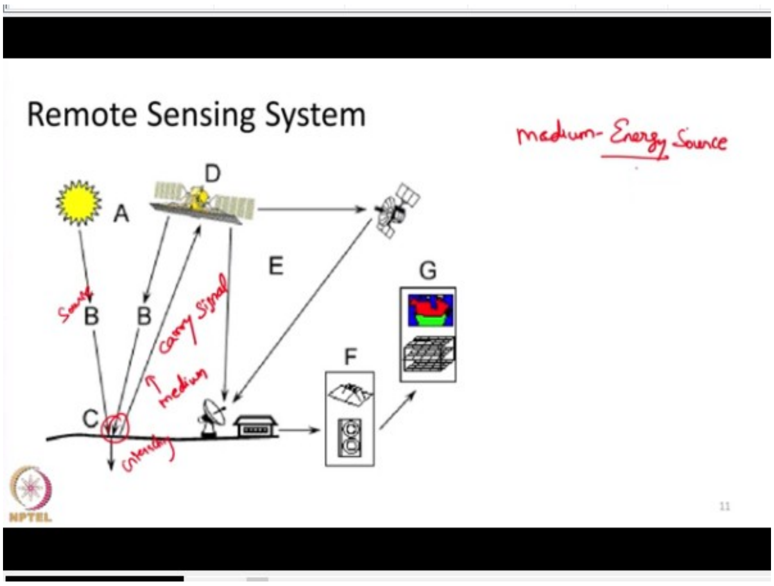

So, that is whatever the source of energy is giving will be interacting with the object of interest and then this particular energy will carry the signal that we need. This signal will contain useful information about the object of interest which we will record in the sensor and then we will use it for various applications. So, this in the last lecture I termed it as medium okay.

So, this particular medium is nothing but some energy source that collects information about the object of interest and carries it towards the sensor. So, in this particular lecture we are going to see what this energy is and what are the properties of this particular energy.

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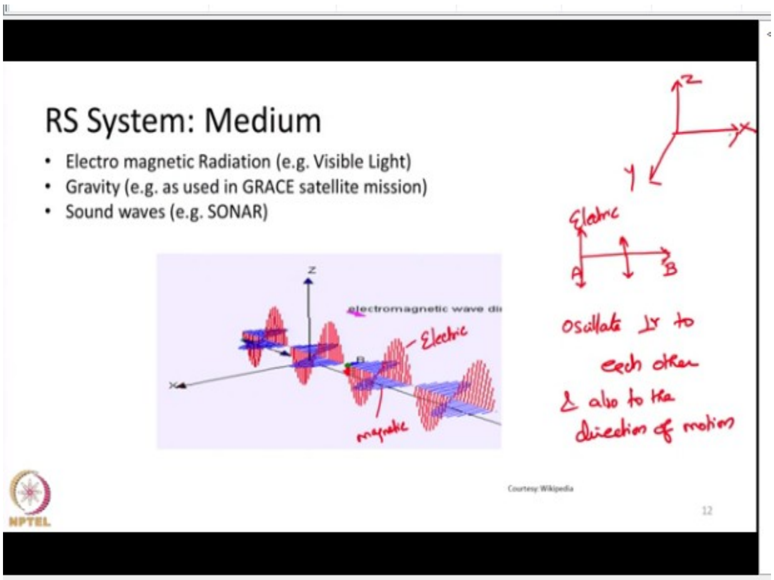

So, in normal remote sensing whatever we do with our regular satellites we use electromagnetic radiation as the primary source of energy. What electromagnetic radiation is? The best example of electromagnetic radiation is the visible light that we are seeing. What it contains? There are 2 different postulates of studying this electromagnetic radiation. Wave theory and Quantum theory.

So, we will use the concepts of wave theory to understand or to know more about this electromagnetic radiation. So, electromagnetic radiation is nothing but a particular way in which energy transmits itself. That is some energy is produced in point A, then it has to reach point B which means that particular energy will transmit itself as electromagnetic radiation to reach point B.

So, this is one particular way of energy transmission and this particular energy transmission can happen even in vacuum that is even in outer space where no atmosphere is present actually nothing is present. So, this sort of energy transmission can occur even in vacuum. So, electromagnetic radiation is one particular form of energy transmission from one point to another point.

What this electromagnetic radiation contains? If we look at electromagnetic radiation as wave then it contains 2 components, as the name suggests it has an electric component and then it also has a magnetic component. What is it? Basically speaking whenever electric charge is oscillated within a magnetic field it produces electromagnetic radiation or when electric field changes within a particular area it produces electromagnetic radiation.

So, electric field will produce magnetic field, magnetic field will produce electric field and vice versa, each of them will be sustaining each other. So, it is a combination of 2 components one is electric field another one is magnetic field and by looking from the concept of wave theory they travel from one point to another point in form of a wave.

That wave consists of 2 components as I said. So, the red one is the electric field, the blue one is the magnetic field, if you look at this particular slide say the energy is travelling in this particular direction, point A to point B that is marked as from left to right in this particular screen. So, electric field and magnetic field will oscillate in a direction perpendicular to each other and also to the direction of motion.

That is if the wave is travelling from point A to point B from left to right in this particular screen, electric field may be vibrating in this particular plane that is top to bottom and the magnetic field may be vibrating within a plane going in and out of this particular slide. So, each and every component will be perpendicular to each other. Say if electric field is in like Z direction and if the wave is traversing in X direction then magnetic field will be vibrating in Y direction. Each and every one of them will be perpendicular to each other and also to the direction of motion. So, again just to repeat electromagnetic radiation is a way in which energy transmits itself from point A to point B. It is an energy transfer mechanism that is all. So, this is the primary source that we use for our remote sensing purposes.

So, whatever the sun is producing and giving us, the visible light is a very good example of electromagnetic radiation. Apart from visible light sun is also producing other parts of energy that we will see in the subsequent slide. But apart from electromagnetic radiation we can also use sound waves for remote sensing purposes like some of you might have heard a term called sonar which is like surveying using sound.

Like if you want to understand the depth of water bodies, we will be carrying a sonar instrument on a boat, we will be sending sound waves towards the bottom of the lake, it will be reflected back by the bottom. Based on the time taken we will be calculating what is the depth of that particular lake. So, that is we call sonar service. So, there we use sound waves as the medium to collect data.

Bats use sound as a medium to collect data. Similarly the earth's own gravity field is now being used to collect some information about change in earth's mass. That is the satellite called grace and grace follow on. Now grace is not there grace follow on is there which collects different or minute changes in earth's gravity field. Using that, scientists are collecting information about where is like change in groundwater, where is change in glacier ice mass. All this sort of information people are collecting by understanding gravity field. So, gravity is nothing but a force field, sound is nothing but a form of energy. Electromagnetic radiation is similarly a form of energy. So, essentially, we are using some energy as a medium to collect information about the object of interest. In this particular course we will be discussing in detail about the remote sensing we carry out using electromagnetic radiation. I said we will first consider the electromagnetic radiation as waves.

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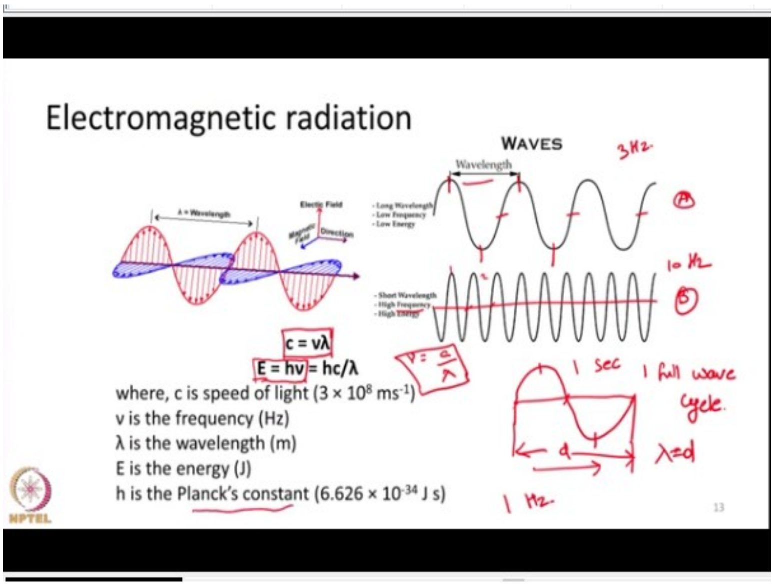

So, when we consider that as wave, we can associate certain properties with that particular wave, some of the properties are first thing is wavelength**,** then comes frequency, then the energy associated with the wave. So, what exactly a wavelength is? A wavelength is defined as the distance travelled by a wave between 2 consecutive crest or 2 consecutive troughs or to be more precise the distance travelled by a wave for it to complete one full cycle.

So, this we call one full wave cycle. So, this is the point where wave starts from 0 th position, it reaches a peak, it falls down again to 0 position, the amplitude reaches a negative value, then again it comes to a 0 position. So, this is how the amplitude of the wave will change and while the amplitude changes, the wave will progress in one particular direction. So, the distance covered by the wave before it finishes one particular full cycle is called the wavelength.

So, what frequency is? Frequency is defined as the number of cycles a wave does in 1 second. Say in this particular example, if the wave completes this one full cycle in one second then I call this wave has a frequency of 1 hertz. Most of the waves will have like higher frequency. Here in this example I label it as figure B, if we calculate the number of full cycles, this is full cycle 1, this is full cycle 2 and so on. Let us assume this particular wave may be having a frequency of say 10 hertz, if everything is completed within 1 second, whereas this wave on the top I label it as wave A has 3 full cycles within it. So, if this entire 3 cycle is completed in one second I will call it as the frequency as 3 hertz. So, essentially frequency is the number of cycles completed per second.

Wavelength is the distance travelled by the wave to complete 1 full cycle and then what is the velocity at which this wave will travel? I said this wave will travel from point A to point B, but with what velocity, with what speed? The speed of electromagnetic radiation in vacuum is equal to the speed of light. We all studied this in our school physics classes. Speed of light is roughly can be taken as 3 lakh kilometer per second or 3×10^{8} m/s.

So, that is the speed of electromagnetic radiation and light is a part of electromagnetic spectrum. So, light is nothing but a part of electromagnetic spectrum. So, electromagnetic radiation travels at speed of light that is 3×10^{8} m/s. So, what is the relationship between the velocity, frequency and wavelength? That is given here, velocity c is equal to frequency times lambda.

$$c = \nu \lambda$$

$$\nu = c / \lambda$$

So, essentially the wavelength and frequency are inversely related with each other. If the frequency is more wavelength will be less or otherwise if the wavelength is more frequency will be less. So, essentially a high frequency wave will have a shorter wavelength. And also if we look at the quantum nature of radiation that is energy transfers not in form of wave but as packets of energy that is another high postulate that also we should have come across in our school physics classes.

The energy of a wave is given by,

$$E = h\nu$$

that is E is equal to h times frequency where h is the Planck's constant. So, what this says? The energy content of a wave is directly proportional to the frequency. So, higher the frequency higher the energy content of the wave or longer the wavelength which will implies lower the frequency that means lesser the energy content of the wave. So, energy content, wavelength and frequency are all related with each other.

Then we are coming to the most important topic electromagnetic spectrum.

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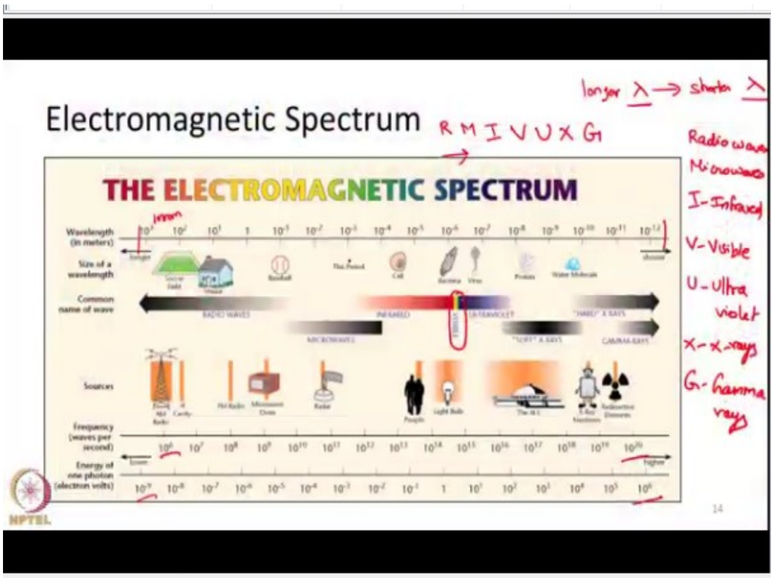

So, I said the visible light that we get from sun is only a small part of electromagnetic spectrum, what exactly electromagnetic spectrum is? An electromagnetic spectrum is the continuum of different wavelengths or different frequencies in which energy manifest itself or in which energy transmit itself, that is some source is producing an energy, that energy has to travel from one point to another point, it travels in form of EMR.

But at which wavelength it will travel, at which frequency it will travel, that depends on the object properties, object temperature and so on. But essentially most of the naturally occurring objects be the sun, be the earth surface, be it our own body or whatever object surrounding us will emit electromagnetic radiation in some form. And that particular electromagnetic radiation will not travel in one particular wavelength or one particular frequency it will travel in different, different wavelengths or different, different frequencies.

So, it will contain multiple waves a mixture of waves each having different wavelength different frequencies. So, if we can take all these different wavelengths or different frequencies together from almost all possible objects and plot them in one particular scale from very short wavelength to very long wavelength or very short frequency to very high frequency, that will give us electromagnetic spectrum.

So, electromagnetic spectrum is nothing but a continuum of energy which can transmit itself from one point to another point. So, just for our convenience for us to understand better we have divided this electromagnetic spectrum into different portions and for each portion we have given a name. So, based on the wavelength or based on the frequency this entire spectrum is divided into several portions.

So, what are they? Let us move from longer wavelength to shorter wavelength. Lambda λ is the symbol we conventionally use to denote wavelength. So, this symbol λ if we use any time in this course this will indicate we are referring to wavelength. So, I will write it as R M I V U X G from longer wavelength to shorter wavelength in this particular order.

So, what is R? R is named as radio waves, M is the microwaves, I is known as the infrared, V is the visible light, U is the ultraviolet, X is x-rays and G is gamma rays. So, this is classification of electromagnetic spectrum. In this particular figure you can see radio waves in this particular end of spectrum, gamma rays is in this particular end of spectrum. The wavelength range, if you look at the figure the wavelength ranges from 10^3m roughly 1000 meters and up to 10^{-12}m which is even less than 1 nanometer.

So, much shorter wavelengths, energy can transmit itself in this entire spectrum, any different wavelength energy can take based on the energy source from which it is coming and most of the natural energy source will produce a mix of wavelength not one single wavelength. There are sources like laser bulbs which produce a uniform monochromatic light. But almost all naturally occurring substances will produce EMR in a continuum of spectrum. It will be a mix of wavelengths or mix of frequencies.

From the previous slide what we learnt is longer the wavelength lesser will be the frequency, shorter the wavelength higher will be the frequency. Similarly higher the frequency higher will be the energy content of the wave, lower the frequency lower will be the energy content of the wave.

And we all know that some of the high energy wave is the gamma radiation which is produced in nuclear reactors. Why atomic bomb produces such deathly devastation? because of the high energy content within it which produces gamma waves and when gamma radiation interacts with objects it has the capacity to destroy the cells within our bodies.

That is what will cause cancer and all those things, higher energy content higher will be the interaction. The interaction will be deadly in case of gamma radiation. If you take the lower end of spectrum radio waves which we use for communication or microwave which we use for cooking again for communication and all those things, those waves are relatively harmless. We are using it that particular portion of energy for applications like communications.

If you look in this particular slide you can see a very small portion of electromagnetic spectrum is marked as visible and our eyes can see only this small portion of energy that is coming in from the sun. Sun produces a continuum of energy but our eyes can see only the small portion. So, from this slide what we can observe is electromagnetic spectrum spans a quite huge and very long range of wavelength spectrum.

Our eyes can see only a minute part of it. So, remote sensing helps us to see the other portions of this huge spectrum with which we can collect lot of information about the object of our interest. So, whatever I said in the previous slide, the classification of electromagnetic spectrum I have listed as in form of table here is for deeper understanding.

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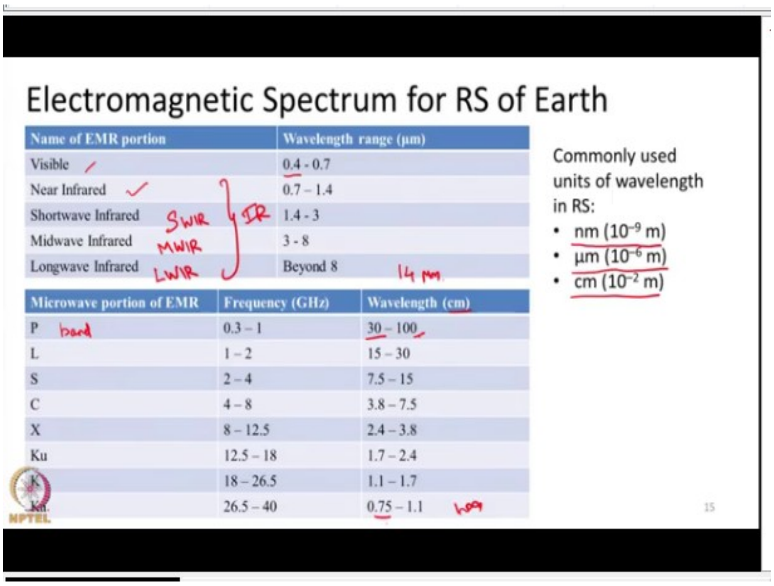

So, electromagnetic spectrum is classified as radio waves to gamma waves, but for normal remote sensing purposes especially remote sensing of earth surface we will be restricting ourselves to the visible portion, infrared portion and the microwave portion of the electromagnetic spectrum. So, if you look at the wavelength, the wavelength for the visible portion will start at 0.4 micrometers. For normal remote sensing, we will be talking up to 14 micrometers, then there will be a huge gap, we will start from 0.75 centimeters to 100 centimeters. So, essentially this is the range of wavelengths from 0.4 micrometers to 14 micrometers and then 0.75 centimeters to 100 centimeters used for remote sensing purposes.

So, before proceeding I just want to give you an idea of what is the units of wavelength that we will use. Most conventionally the units of wavelength that we will use in remote sensing class or remote sensing parlance will not be meter like the normal standard unit of distances. Wavelength is nothing but a distance. But for our convenience we will not use meter as the unit in this class. Instead we will be using units such as nanometers 10^{-9}m, micrometers 10^{-6}m or centimeters 10^{-2}m. And one more thing I want to highlight is say each portion has a certain bandwidth that I have given in this particular table if the wavelength ranges from this end to this end like 0.4 to 0.7, I call it as visible portion.

This range is slightly arbitrary nature, arbitrary in the sense there is not a clear cut distinction between this wavelength range. If you look at different textbooks or different sources there will be a slight variation in the range given here, maybe instead of giving 0.75 to 1.1 they might have given 1 to 1.5, as there are no clear cut differences between the different portions of the spectrum.

And one more thing you have to remember is the names of each band. As we progress through this particular course I will be just telling you the visible portion of spectrum, infrared portion of spectrum, microwave portion of spectrum. So, you should be essentially in a position to understand what is the wavelength range of that particular portion of spectrum. If I say visible you should recall visible spans between 0.4 to 0.7 micrometers.

If I say near infrared you should be able to tell, near infrared spans between 0.7 to 1.4 micrometers. So, that sort of knowledge you should develop at the end of this lecture. And also infrared portion itself is further divided into various sub categories called near infrared, short wave infrared we will call it as SWIR band, mid wave infrared, we will call it as MWIR and then long wave infrared LWIR. This is like different, different portions of infrared. Everything taken together we call IR infrared, but IR itself was subdivided into 4 different thing. Similarly the microwave portion of spectrum spanning from 0.75 centimeters to 1 meter is divided into several portions such as P band, L band, S band, C, X, Ku, K and Ka bands.

For our own understanding, we have divided the electromagnetic spectrum into different portions and using it. Also the objects in the earth's surface will behave differently to different parts of energy. Any particular object which will behave in a certain way in visible will behave differently in NIR portion, it will behave differently in microwave portion and in order to make it easier for us to study the objects of our interest this classification will help us.

So, how the object will behave at visible band, how the object will behave at P band of microwave, how the object will behave at near infrared portion of the spectrum, all these detailed analysis we will be able to do by this classification.

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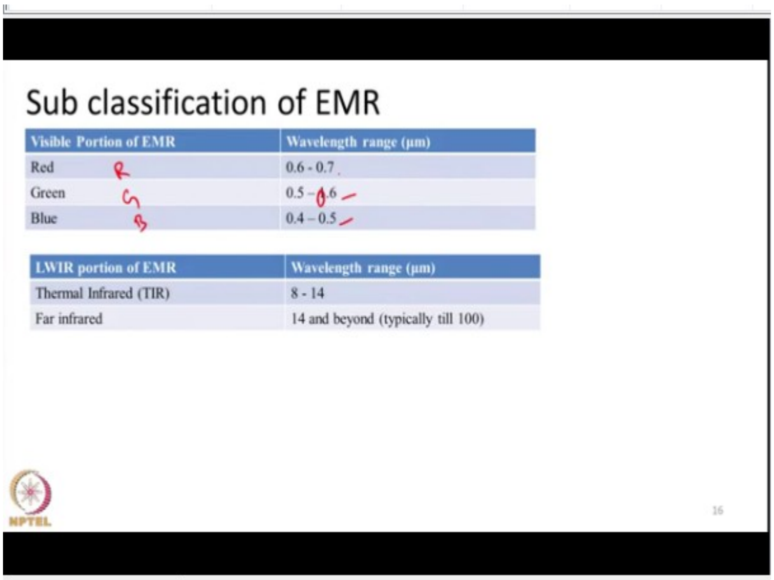

And this is further subdivision, the white light we get from the sun, the visible portion from 0.4 to 0.7 has 3 primary colors within it R, G, B, we all know that the three primary colors produces white light. Again there is a subdivision of wavelength, blue is 0.4 to 0.5, green is 0.5 to 0.6, red should be 0.6 to 0.7 and so on. So, this is like further sub classification of electromagnetic spectrum.

So, just to summarize what we have learnt in this particular lecture, we have learnt what electromagnetic radiation is and how to characterize an electromagnetic wave with wavelength, frequency and its energy content. And also, what electromagnetic spectrum is and how we classify the entire electromagnetic spectrum and we have seen the wavelength ranges.

So, I suggest you to look at the lecture and understand what electromagnetic spectrum is and to know more about the different wavelength ranges and the names given to it. So, in later classes it will be a lot benefit to you, if you can recall quickly what is meant by visible portion? What is meant by near infrared portion? So, please go through the lecture slides and make it clear to yourself that which wavelength range corresponds to which electromagnetic band. So, with this lecture we can conclude.

Thank you very much.