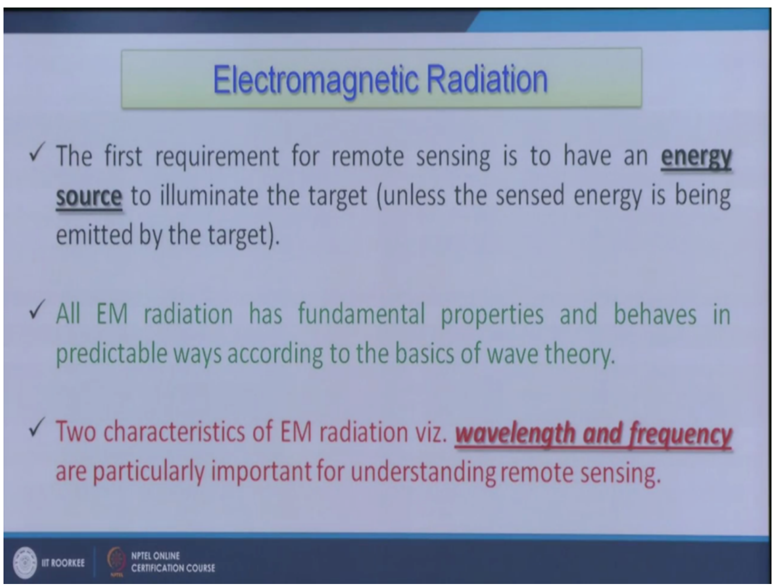
Introduction to Remote Sensing
Dr. Arun K Saraf
Department of Earth Sciences
Indian Institute of Technology Roorkee
Lecture 04
Electromagnetic Spectrum, solar reflection & thermal emission

Hello everyone! This is the fourth lecture of introduction to remote sensing course and in this particular lecture we will be covering topics of electromagnetic spectrum which is very important to understand the entire gamete of remote sensing and solar reflection which will include of course this passive part that is solar reflection and then emission that is thermal emission as well. So we will be looking in detail different portions of EM spectrum.

(Refer Slide Time: 1:00)



Now as you know the first requirement for remote sensing is to have energy source and that might be external energy source or internal energy source to illuminate the target unless the suns energy is being emitted by the target. So two ways, one is either the solar energy you have or natural heat being emitted by the earth's object but it has to have energy source. In case if radar remote sensing or active remote sensing the energy is coming through the satellite.

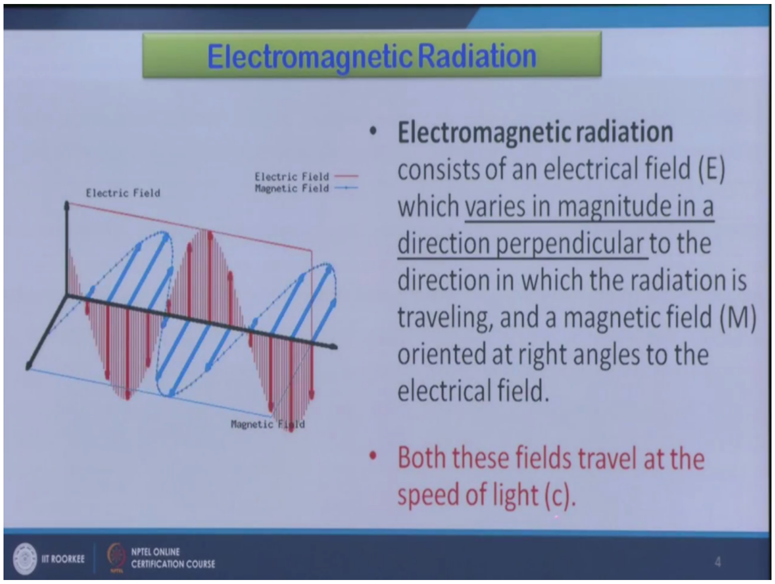
So there also you have external energy. One needs to have in case of remote sensing some form of energy source to illuminate the target and to get the signatures of any object that are present on the earth through these sensors so that is very must. And all EM radiation has fundamental properties and behaves in predictable ways according to the basics of wave theory.

We will not go into wave theory part because altogether it is a different topic but we will be covering different portions of EM spectrum specially those which are having more applications or direct applications in current remote sensing and electromagnetic radiations. So therefore there are two characteristics of EM radiation, first is the wavelength and frequency particularly important for understanding remote sensing. Sometimes people us one term another or simultaneously but it is not possible to use interchanging.

(Refer Slide Time: 2:40)

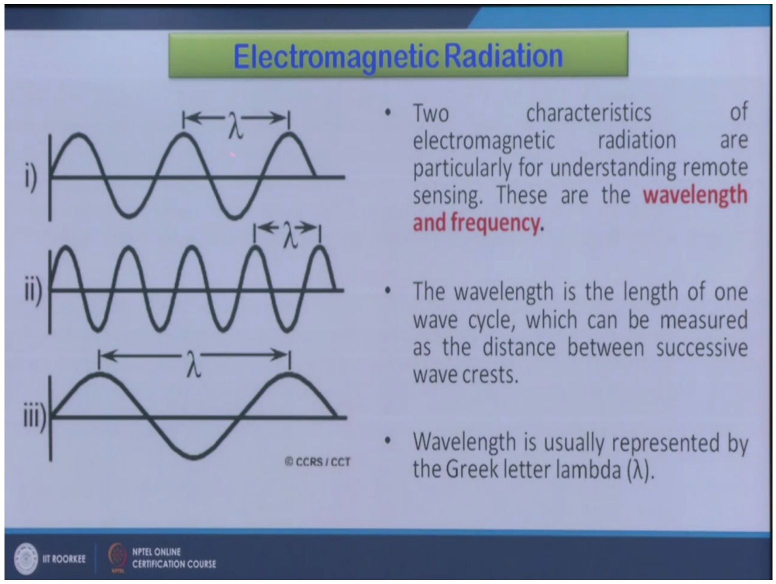
Because it is electromagnetic radiation so you are having the way you have waves which are in magnet, we put them in magnetic waves we call them and then electric waves are there which are having relationship which are perpendicular to each other. Suppose this is the direction of movement of the wave then in this particular example the magnetic waves are in this pink color and the electric waves which are perpendicular to magnetic waves are travelling in yellow color. This distance between two peaks makes the wavelength which we will see in a bit.

(Refer Slide Time: 3:15)



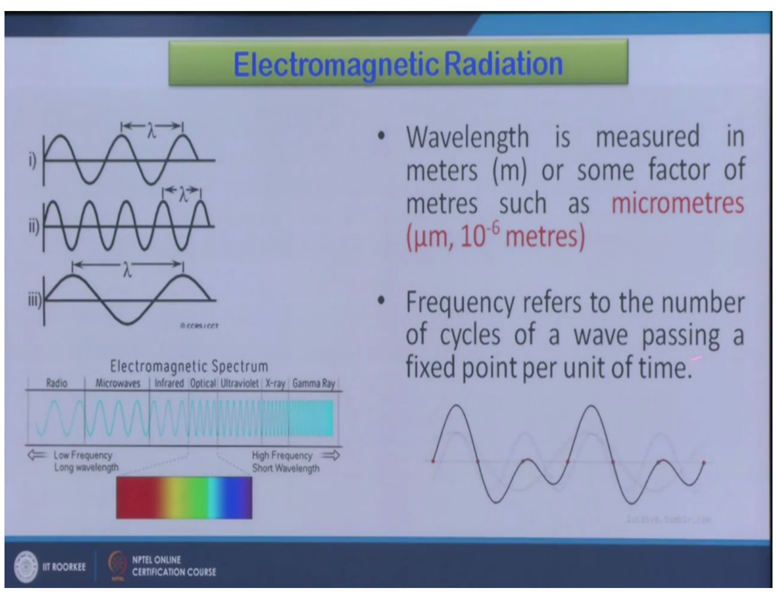
This is how in a simulation I can show that how electric and magnetic fields are having relationship and this is how they travel. This is the magnetic field here, this is electric field, two types of electromagnetic waves are travelling and this is line of propagation, direction of propagation so electromagnetic radiation consists of two electrical fields that is E which varies in magnitude in direction of perpendicular to the direction in which the radiation is travelling and a magnetic field M which is oriented at right angle to the electrical field and this is how they keep travelling. Both these fields travel at speed of light, so that’s one thing one has to remember that they travel at speed same and at speed of light, equivalent to speed of light.

(Refer Slide Time: 4:27)



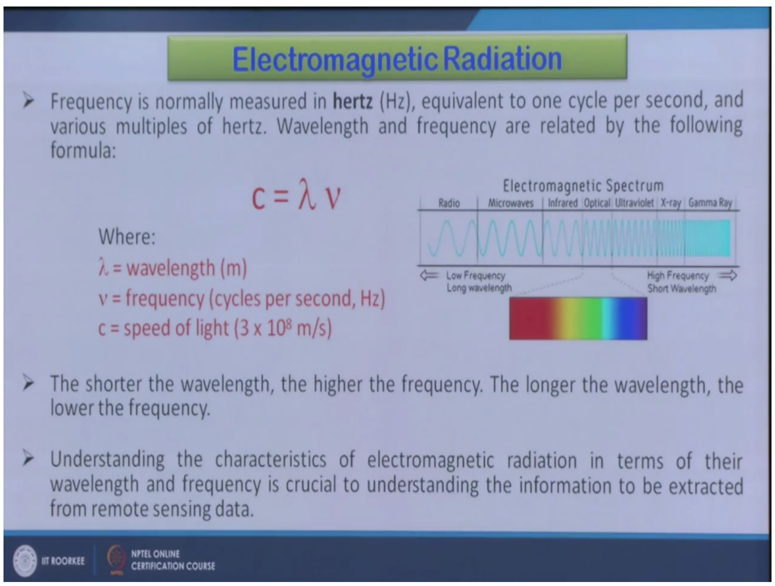
Now two characteristics of electromagnetic radiation are particularly wavelength and frequency which you can see that different wavelengths are shown and their frequencies. Wavelength is the length of one wave cycle as you can see and denoted by lamda and which is measured at distance between successive wave crest. These two parts in this case, lamda is much longer and here it is shorter so wavelength is usually represented by Greek letter lamda.

(Refer Slide Time: 4:57)



Wavelength is measured in meters or some factors of meters. Sometimes we call as micrometer, some people may prefer to call nanometer or meters depending but we always put meters or some factors of meters whenever we talk about wavelength. Whereas the frequency refers to number of cycles of wave passing through fixed point for unit of a time. This is the major difference and between these two electromagnetic here the radio based are having much more wavelength and wavelength is much higher whereas gamma rays the frequency is higher, wavelength is less so there is an inverse relation which we will see later.

(Refer Slide Time: 5:46)

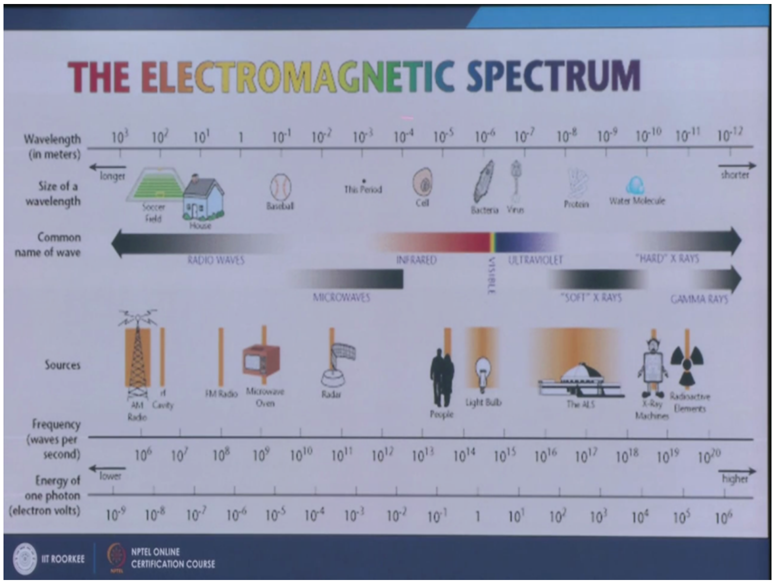


So frequency is measured in hertz whereas wavelength is measured in meters or factor of meters equivalent to one cycle per second and in various multiples of hertz wavelength and frequency are related by the following formula that is C equals to lamda V where our lamda is the wavelength which we measure in meters or factors of meters, V is the frequency cycle per second in hertz and C is speed of light and this relationship tells us that the shorter the wavelength, the higher the frequency and you have also seen that here the wavelength in case of gamma rays is very short but having high frequency.

In case of radio waves in this particular example having longer wavelength but less frequency, so the longer the wavelength the lower the frequency is there. Now these characteristics or understanding these about electromagnetic radiation in terms of their wavelength and frequency is crucial to understanding the information which we try to extract from remote sensing data.

One has to remember in which part of visible spectrum we are working or near infrared, infrared, thermal infrared and other things are there.

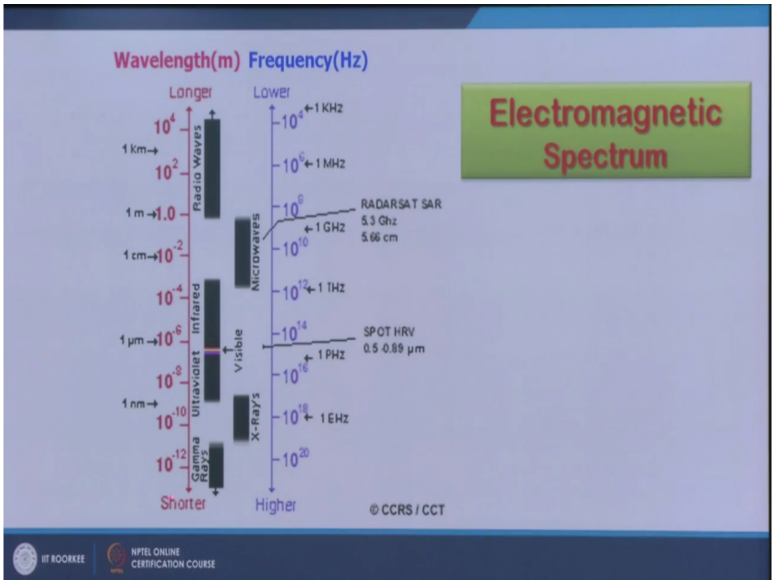
(Refer Slide Time: 7:11)



So this is what whole spectrum is shown here. Here is the longer wavelength, shorter wavelength are shown in meters and water molecules of very small size but they do affect and there are different names given like longer wavelength we call them as radio waves and for reference the set of wavelength or the size of objects are also shown, then infrared, then visible, then ultraviolet maybe x-rays and other things so here remote sensing doesn't work till ultraviolet because atmosphere energy is absorbed so basically it starts from visible to thermal infrared or even radar.

Now sources of energy can vary starting from radio frequencies then you have solar energy, light bulbs and so on so forth and this energy and frequency. Here the wavelength when it is shorted the frequency is going to be higher because there's inverse relation. When the wavelength is longer the frequency is going to be lower.

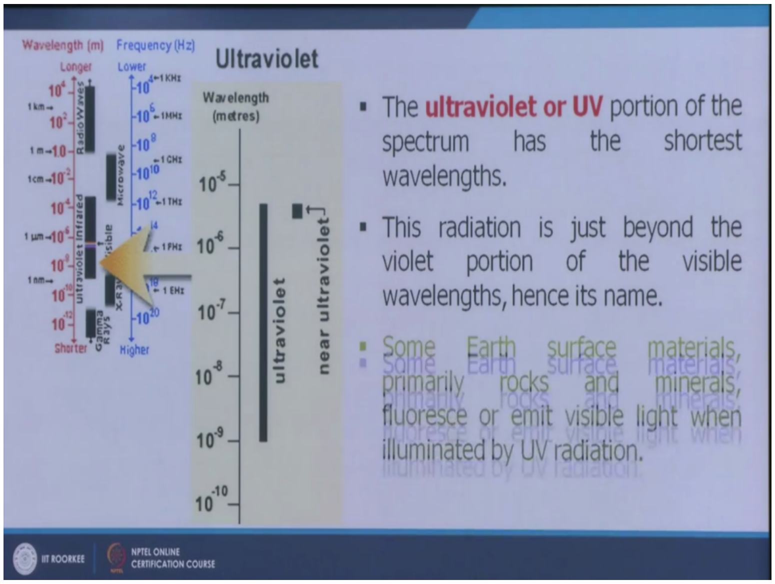
(Refer Slide Time: 8:39)



Now different parts of electromagnetic spectrum like here, radio waves are shown in this part then you have microwave, infrared, visible and here. In these figures what we are trying to show, very distinctly these parts. These are very transitional, if we look at visible part of EM spectrum what we will find is that the colors change is very smoothly but for our own convenience we divide and we put SAR boundaries between one color to another or one band to another.

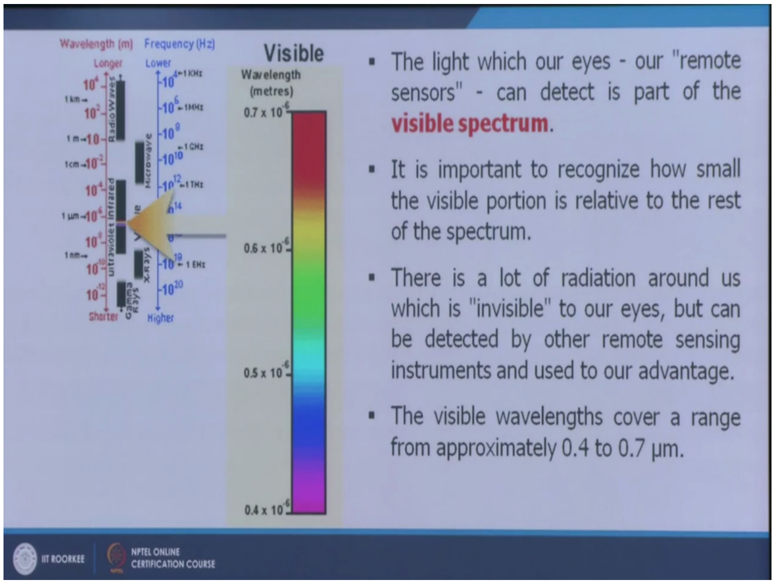
So one has to remember and that is why here these boundaries are not deliberately shown very sharper. They gradient changing of this transition is there. So radar remote sensing is basically covering this part of EM spectrum starting from 1 meter to few centimeters that is microwave, radar SAR synthetic aperture radar remote sensing then visible of course many satellites including SPOT or Landsat AVHRR, NOAA and so on, and then of course ultraviolet x-ray remote sensing is not possible.

(Refer Slide Time: 9:52)



Now ultraviolet part which is here in EM spectrum and which covers wavelength but the problem is the ultraviolet portion of the spectrum has the shortest wavelength and the radiation is just beyond the violet portion of the visible length and that is what we call ultraviolet but except some earth materials like certain rocks or minerals, they emit the energy and the fluorescence and which we can detect in ultraviolet light otherwise once the energy has to pass through the atmosphere, the ultraviolet in this part of EM spectrum, the energy is absorbed and we cannot have a sensor, satellite based sensor but on left conditions people will use ultra violet lights to detect certain minerals like fluoride or others because of having fluorescence capabilities.

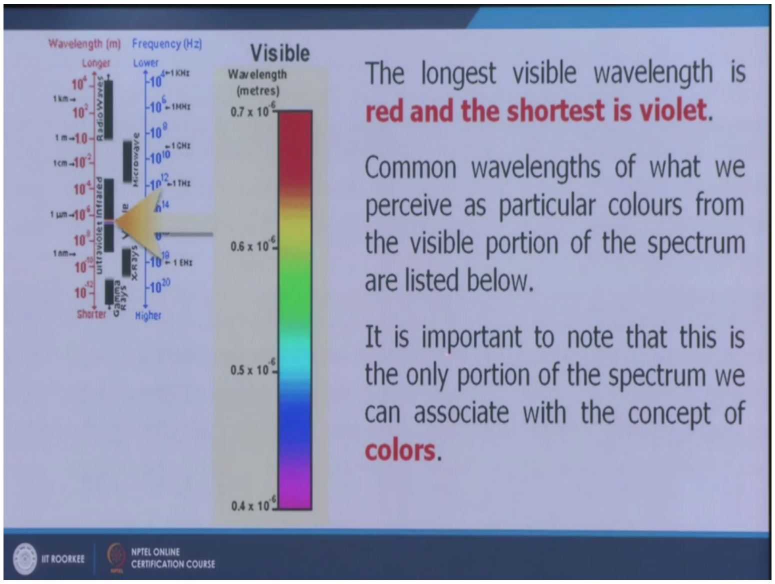
(Refer Slide Time: 11:03)



Visible is the most popular one as I was mentioning here though we sometimes call red band, blue band, green band but if you see the colors are changing very smoothly, very smooth transition. Gradually things change but we can put the SAR boundaries slice down so the light which our eyes are also sensitive and we call it as visible spectrum can detect which we can see different colors. It is important to recognize how small the visible portion is. So if you look at the entire EM spectrum, a very tiny portion of EM spectrum where our eyes are sensitive where visible channels are present but most of the remote sensing is concentrated mainly in this part so this is very important thing.

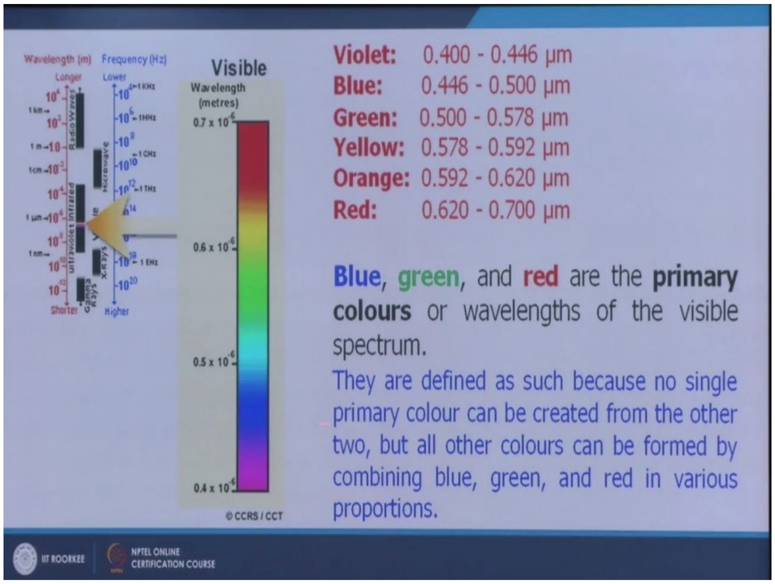
There is lot of radiation around is which is invisible to our eyes especially in infrared, thermal infrared but can be detected by other remote sensing instruments and used to our advantage. Our eyes are not capable but their sensors onwards satellites are capable of looking beyond visible channels or visible part of EM spectrum. So visible wavelength covers a very small portion of EM spectrum, only 0.4 micrometer to 0.7 micrometer. That’s the only part which is available for us and for remote sensing. But lot of remote sensing has been done in this part.

(Refer Slide Time: 12:37)



This is the longest wavelength or visible wavelength is the red which is here and the shortest is the violet and common wavelength what we perceive as particular colors from visible portion of the spectrum are here. It is important to know that this is the only portion of the spectrum we can associate the concept of colors basically otherwise the white color is made from this vibgyor so there we use the word color or colors otherwise in any other parts of EM spectrum we cannott use the word color.

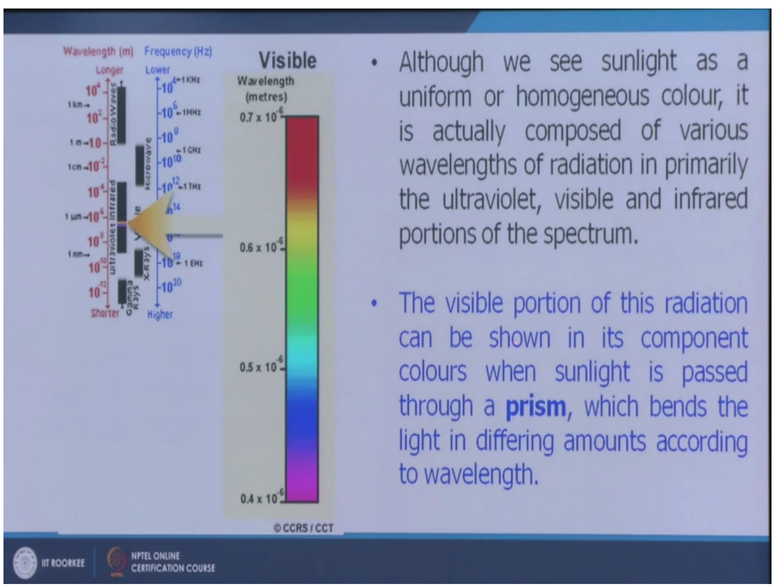
(Refer Slide Time: 13:01)



So violet which is having the shorter wavelength is 0.4 to 2.446, no remote sensing sensors are there. It starts with blue 0.44 and 2.5 if you remember when I was showing about the Landsat MSS, or IRS, LISS 1 or LISS 3 sensors their first channel started from 0.45, 2.5 something like that. So then blue after blue you come to the green part of visible spectrum, 0.5 to 0.78. Then yellow part of visible spectrum, 0.5 to 9 which is not covered then orange then red part is covered, specially infrared part also people go there.

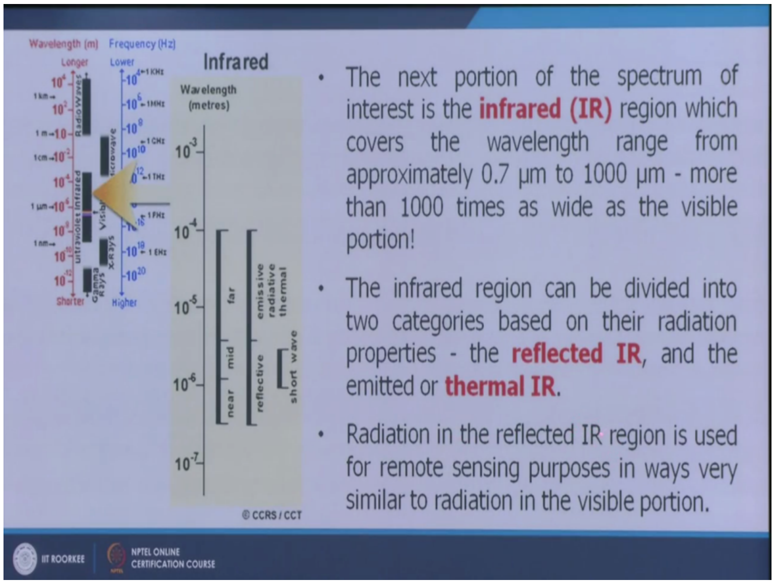
So blue, green and red are primary colors and wavelength of visible length. These are the colors which most of the devices used edited color scheme uses. Our eyes are also sensitive, many sensors are there in this part but it's a very tiny part of EM spectrum which is available without much problems. These colors are defined as no single primary color can be created from other two but all other colors can be formed combining blue, green and red in various portions. That is why they are called primary colors.

(Refer Slide Time: 14:38)



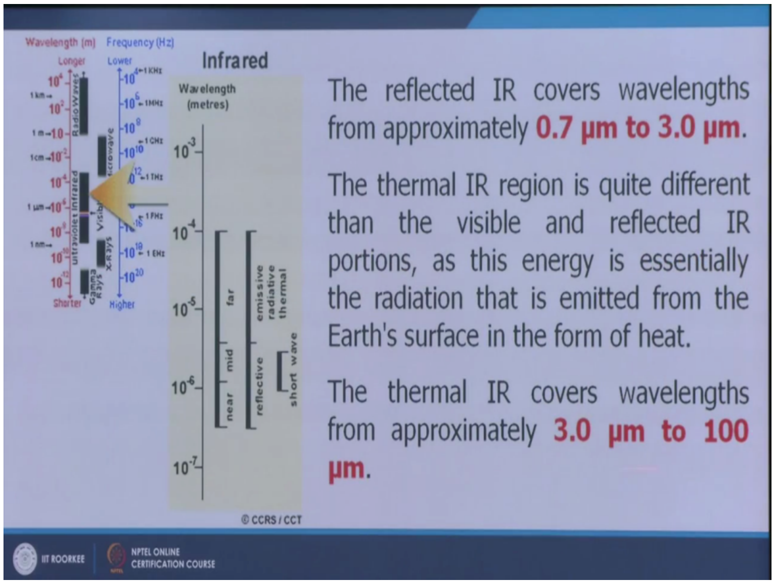
Although we can see sunlight as a uniform or homogenous color, it is composed of various wavelengths of variation in primary with violet visible infrared portion of spectrum and they as you know the visible portion of radiation can be shown in the components of colors and sunlight is passed through a prism and then all components of white light will come as a vibgyor.

(Refer Slide Time: 15:05)



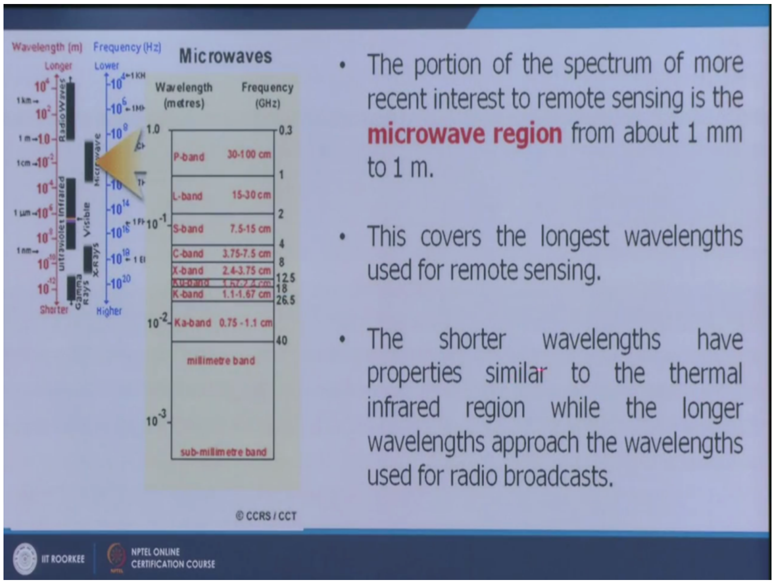
So the next portion which is again important is the infrared and there are sensors which work in infrared part of EM spectrum so IR region which covers the wavelength range from 0.7 to 1000 micrometer or 1 meter and more than 1000 times as wide as visible portion. Visible portion was very narrow but many channels are there, many sensors are there. Now this infrared region can be divided into two main categories. One is reflected infrared; another one is thermal infrared which is the emitted energy whereas the reflected is the solar energy. Then radiation is reflected this infrared region is used for remote sensing purposes is very similar to ratio of visible portion.

(Refer Slide Time: 16:07)



Whereas the emitted one is used differently and the reflected IR covers wavelength approximately 0.7 micrometer to 3 micrometer and this thermal IR region is quiet different than the visible reflected IR portions and this energy is essentially the radiation which is emitted from the earth surface in the form of heat. Thermal sensor IR covers the wavelength from 3 micrometer to 100 micrometer and there are channels in various satellites like Landsat TM, it has thermal sensors. ETM is having thermal sensors, ETM plus, NOAA AVHRR sensors they are all equipped with thermal channels having wavelength between 3 micrometer to 100 micrometer.

(Refer Slide Time: 16:59)



Now we come to this microwave and here the longer wavelength we are discussing, the portion of spectrum of more recent remote sensing is microwave region from above 1 mm to 1 meter. That region is especially because of SAR interferometry, it has become very useful and popular and this covers the longest wavelength used for remote sensing. Shorter wavelengths have properties similar to thermal infrared region while the longer wavelength region approach the wavelength used for radio broadcast so this brings to the end of this different part of EM spectrum.

We started with visible, of course ultraviolet their sensors cannot work because of presence of atmosphere then infrared, near infrared, thermal infrared and then finally the micro ignitions. So thank you very much.