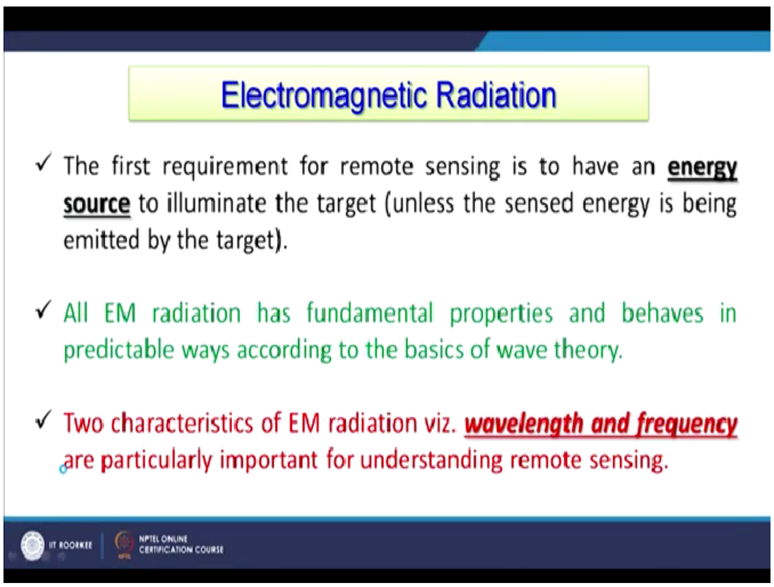
Remote Sensing Essentials
Prof. Arun K. Saraf
Department of Earth Sciences
Indian Institute of Technology-Roorkee

Lecture-03
Electromagnetic Spectrum, Solar Reflection and Thermal Emission Remote Sensing

Hello everyone and welcome to remote sensing essential course and this discussion we are going to have on electromagnetic spectrum that is in short I would be calling as EM spectrum and we will be also discussing about solar reflection emission and thermal emission is basically. So, these 3 things which we going to discuss in this lecture.

(Refer Slide Time: 00:51)



First is electromagnetic spectrum that is the first requirement for any remote sensing instrument or sensors and that is basically energy source. In the previous lecture also I discussed this part that energy source can come either from the Sun especially in daytime to illuminate the part of earth or surface of earth or maybe moon or Mars. And another source can also be that is emission because any object which is above absolute 0 emit energy and that energy by the target can also be received or detected by the sensors which are on board of different satellites.

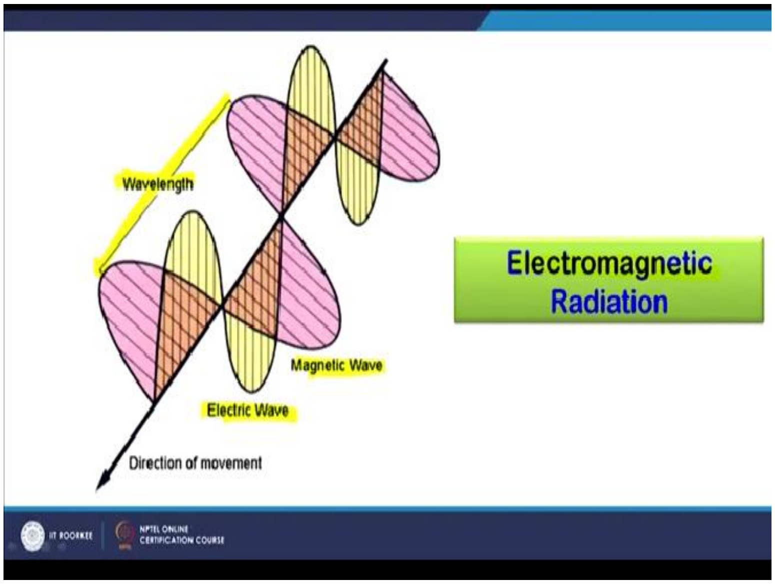
So, there has to be the source of energy without which the remote sensing will not work, because there are as also discussed yesterday or in previous lecture that 2 types of remote sensing is there, one is passive remote sensing and another one is active remote. So, in case of passive remote sensing you need to have energy source and once that is there then these sensors will work. However, in case of active remote sensing the sensor itself generates energy through informal pulses.

And then it is a completely different remote sensing and generally we put in the category of microwave remote sensing, but in microwave also a natural microwave emission is also possible and that comes in the category of passive microwave. So, there are 2 types of microwave one is active microwave, another one is passive microwave, and later in this course we will be also covering passive micro-1, but for time being this the first requirement as said for remote sensing is to have an energy source.

And that can be either sun or maybe the natural emission of the objects and all EM radiation has fundamental properties and behaves in predictable ways according to the basics of wave theory, and very little, very briefly we will be also discussing wave theory as well. So, this is another important thing, 2 main characteristics of EM radiation or EM spectrum and that is wavelength and frequency. And so, we can use any terms separately also or together many times **to** in order to address a certain part of EM spectrum.

Because very soon we will be seeing that it is a very broad spectrum and certain part of EM spectrum are used in passive remote sensing. So, there are 2 things wavelength and frequency and which are very important for understanding of EM spectrum and especially with reference to remote sensing.

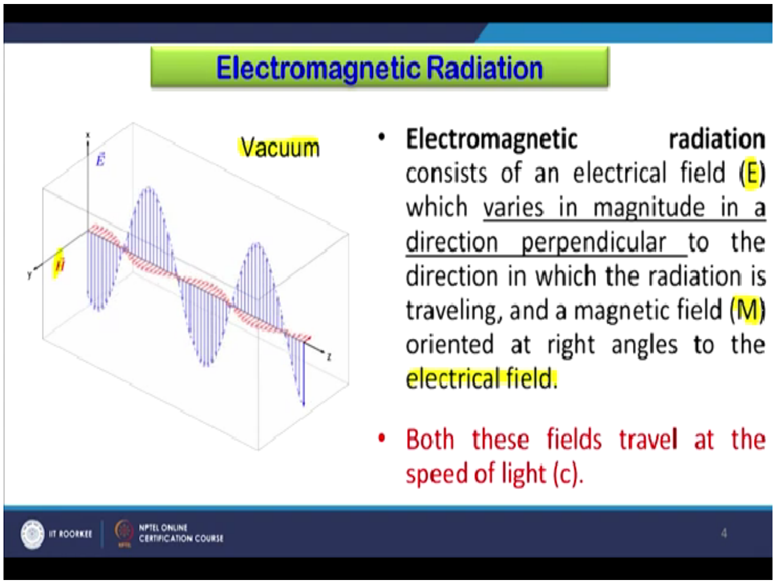
(Refer Slide Time: 03:57)



Here what we are seeing that this is the direction of wave propagation. And very soon I am going to show you also through animation and there because there are 2 types of wave that is why they are called electromagnetic waves. So, in one plane you are having the magnetic field or magnetic waves or perpendicular to that you are having electric field and you are having electric waves and in combination these waves becomes the EM waves or electromagnetic waves.

And so this is in the direction of propagation and between 2 peaks or thresholds of any wave that the distance between that becomes the wavelength. So, this is how and the frequency we will be discussing that from one point and how frequently the wave passes that will fix the frequency of that particular way.

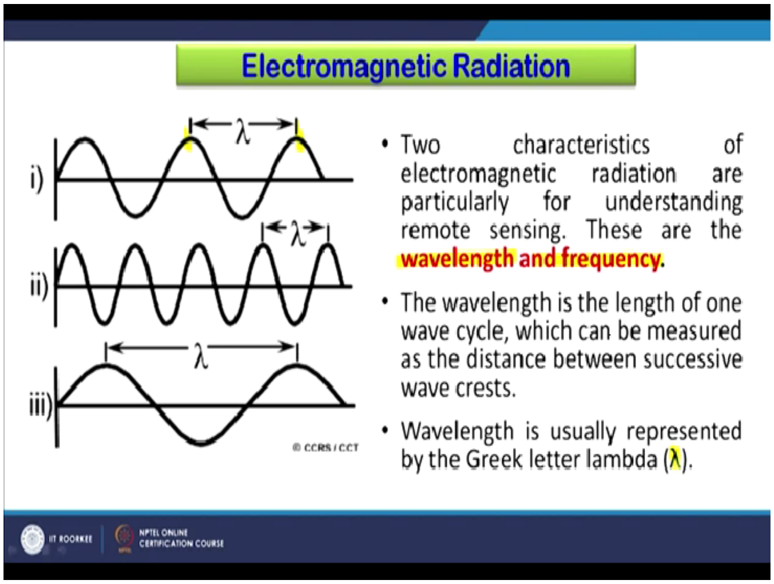
(Refer Slide Time: 05:01)



So, here is the example in the vacuum and both waves electric waves and magnetic waves which are denoted here with H in red color they are moving and this is what in nature this is how they move and they are perpendicular to each other and this is a situation particularly in the vacuum. However in a natural conditions there might be some other issues related with the scattering or absorptions which we will be discussing also later on.

So, electromagnetic radiation that is which consists of electrical field which we denote generally with E and which varies in magnitude in direction perpendicular to the direction in which the radiation is traveling. And the magnetic field M are here it is also noted as the H, oriented at right angle, right angle or perpendicular to each other to the electrical field and this is what this animation is showing to us. So, both these fields electric and magnetic travel at the speed of light.

(Refer Slide Time: 06:11)

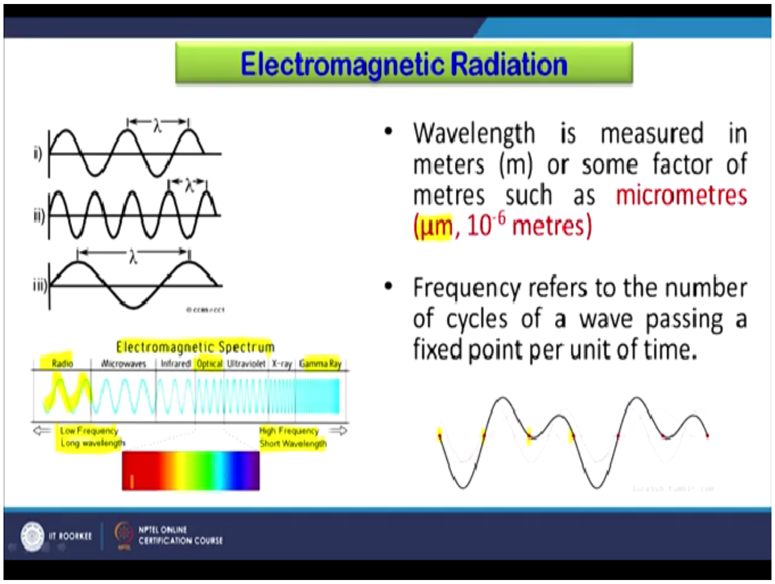


Now, here this wavelength issue will come and the 2 characteristics of electromagnetic radiation are particularly for understanding remote sensing and these are as mention the wave length and the frequency. So, here what we see that the 3 examples are shown lambda is denoted for wavelength, so 2 peaks or threshold of a single wave, if you measure the distance between that, that the wavelength as you can see that the bottom one is having very long wavelength.

But in terms of frequency, it would have definitely a low frequency. Whereas, the second one it is having very less wavelength relatively, but it will have high frequency because from single point in the direction of propagation and the wave will pass more frequently as compared to example 3. So, the wavelength is the length of one wave cycle as shown here, which can be measured at a distance between successive wave crest.

So, if you want to measure then just use these 2 talks and the distance will tell us the wavelength and the wavelength is usually represented as I have already told you with a Greek letter lambda.

(Refer Slide Time: 07:26)

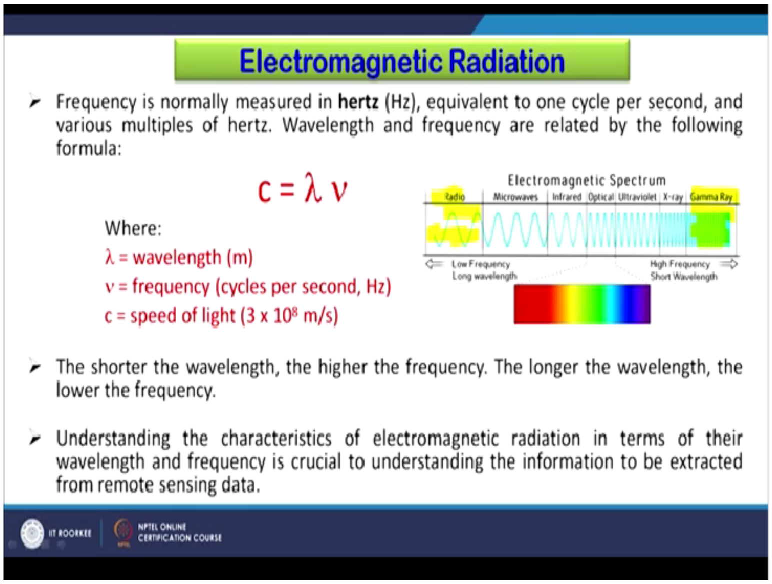


Now, here the same example we have kept here and but what are the units so, wavelength is measured in meters or for in some factor of meters also, sometime we also use micro meters, micro meter address in case of remote sensing is very common. And there are also in hyperspectral remote sensing because of our bands are becoming narrower and narrower. So, instead of micro meter, we also use term nanometer. And this the frequency basically as also indicated earlier, refers to the number of cycles of wave passing a fixed point per unit of time.

And this is what it is being shown through this animation, that a single wave is passing through all these points. So, there are 3 examples in one is blue color, red color and black color are shown here, which you can see here also a part of EM spectrum on the left side is shown that is here. So, we start with the radio waves, wavelength is large, but frequency is less compared to this the gamma rays, here the frequency is more, but wavelength is less.

So, these are we consider as a low frequency and long wavelength, these are high frequency but short wavelength, of course, the visible part which we are our eyes work and this is that visible spectrum. So, we start from here ultraviolet and go up to red.

(Refer Slide Time: 09:07)

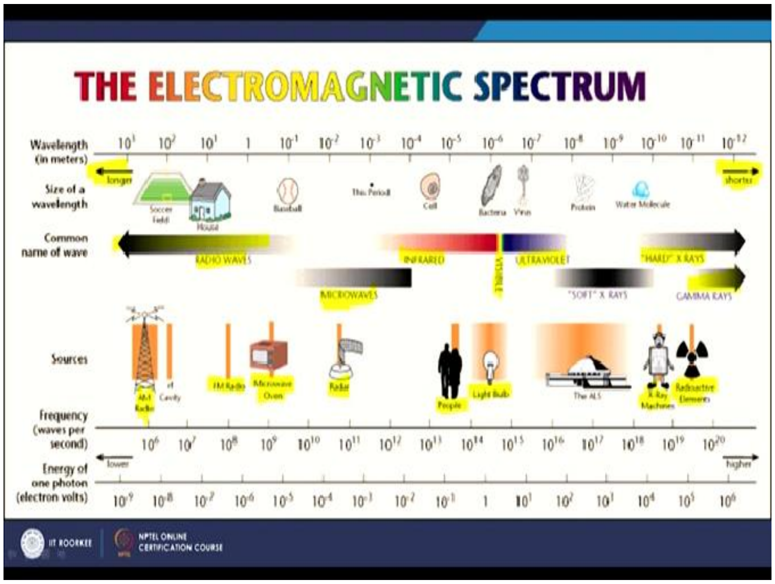


So, the frequency as wavelength is measured in lambda, frequency generally is denoted in hertz and which is equivalent to one cycle per second. And various multiples of hertz also are like mega hertz and others and wavelength and frequency are related to the very simple formula that is C lambda v and where lambda is you know the wavelength which is measured in meters or micro meters or fraction of meters, v is the frequency that is the cycle per second which is measured in hertz and c is of course, the speed of light.

So, when we multiply we get these things, so if 2 values are known the third one can be determined. And this is also important to remember that the shorter the wavelength, like here in the in case of gamma rays, here is relatively the wavelengths are shorter. So, the frequency is higher and in case of radio waves in this particular example, longer the wavelength, lower the frequency.

So, there is a sort of inverse relation and understanding the characteristics of electromagnetic radiation in terms of their wavelength and frequency is crucial to understanding the information to be extracted from remote sensing data. Because in normal remote sensing understanding and practice, when we use different bands we have to remember that which wave band of EM spectrum they are representing and what is the wavelength or frequency.

(Refer Slide Time: 10:53)

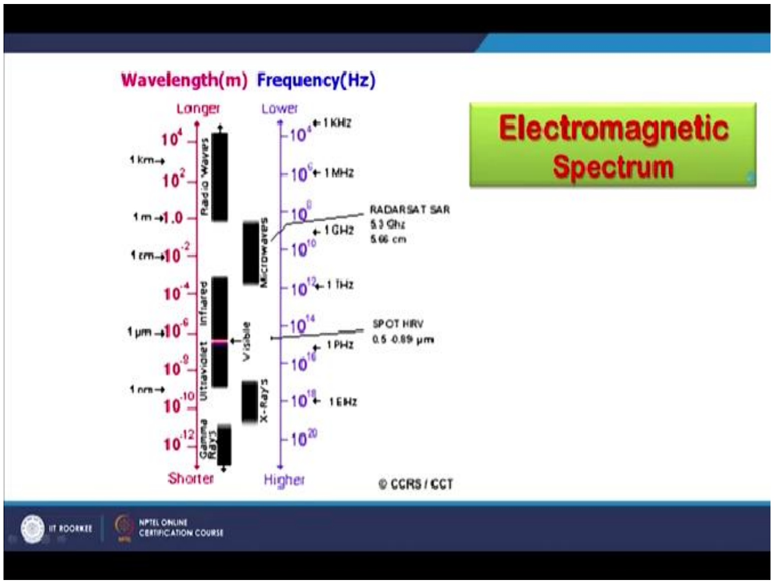


And this is a almost the entire EM spectrum known today and here we see that the example I was giving and that you are having gamma rays here as shown here very shorter wavelength and compared to those, then you are having radio waves which are moving in this direction and very longer wavelength and in between you are having various wavelengths, where they fall depending on the size. And of course, this visible part is also mentioned before that you are having ultraviolet than infrared.

And of course, in between you are also having microwaves and different equipments and different areas where different types of wavelengths are used like when you go for hard X-rays are also there. So, these are the radioactive waves X-ray machines work in this part of EM spectrum, then light walls which is of course in the visible part. People also fall in this visible wall category, then you are having radar which works in microwave region.

Then microwave oven which works in a different way when compared to normal microwaves and these microwave ovens works in this part of the EM spectrum, then you are having FM radio, AM radio not many common now and these stations but nonetheless, this is what the entire EM spectrum starting from shorter wavelength to longer wavelength, higher frequency to lower frequency.

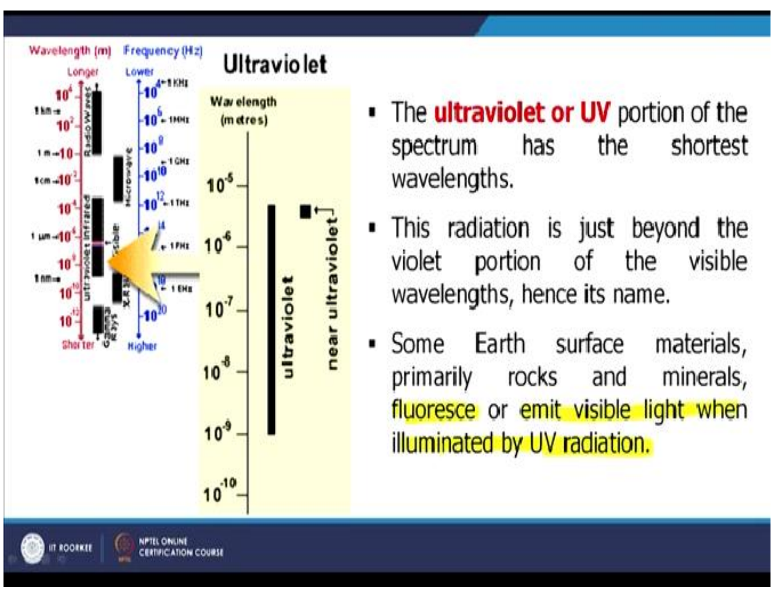
(Refer Slide Time: 12:38)



And one by one we will be seeing now are discussing different part of EM spectrum and especially focusing mainly with remote sensing. So, as you can see here, that both longer wavelengths are shown here like here the shorter wavelength starting from gamma to radio waves of course, microwave visible and X-rays are there and they are frequencies also shown and against these the Radarsat. So, the one of the satellites the sensor is SAR synthetic aperture radar name of the satellite is Radarsat which works in microwaves.

So, that is also shown here, these are the frequencies 5.3 and 5.66 centimeter and similarly, that is the wavelength 5.66 SPOT HRV and that is in French satellite which works in the visible part of EM spectrum or used to work. So that is no more there but this is what the EM spectrum is covered.

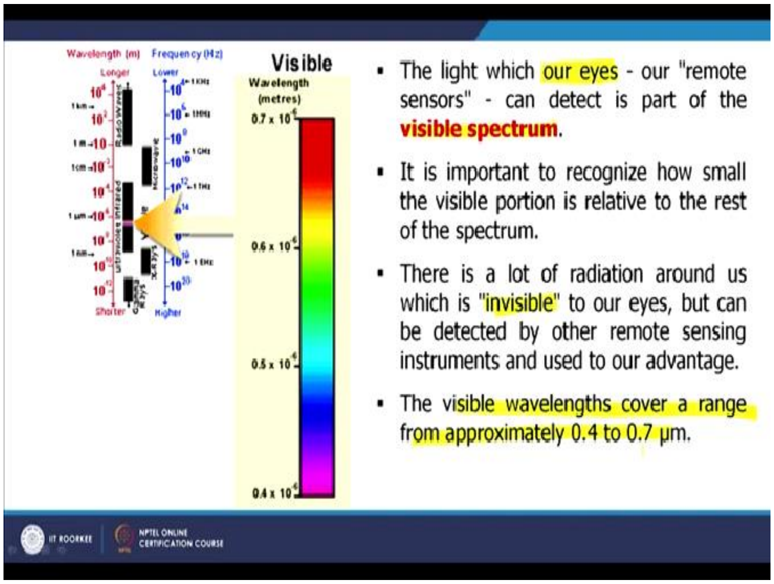
(Refer Slide Time: 13:43)



And of course there is no satellites in the ultraviolet or UV portion of the spectrum. And because whatever the energy which is there in this part of EM spectrum is absorbed completely by the atmosphere. So, it does not reaches to the satellites and therefore no sensors can be designed. So, radiation is just beyond violet portion of the visible wavelength which we call is ultraviolet. And some earth surface materials, there are certain minerals, rocks, which are having this fluorescence characteristics.

And they emit light in the visible part, you know when we illuminate these minerals by ultraviolet radiation like fluoride and other minerals.

(Refer Slide Time: 14:34)



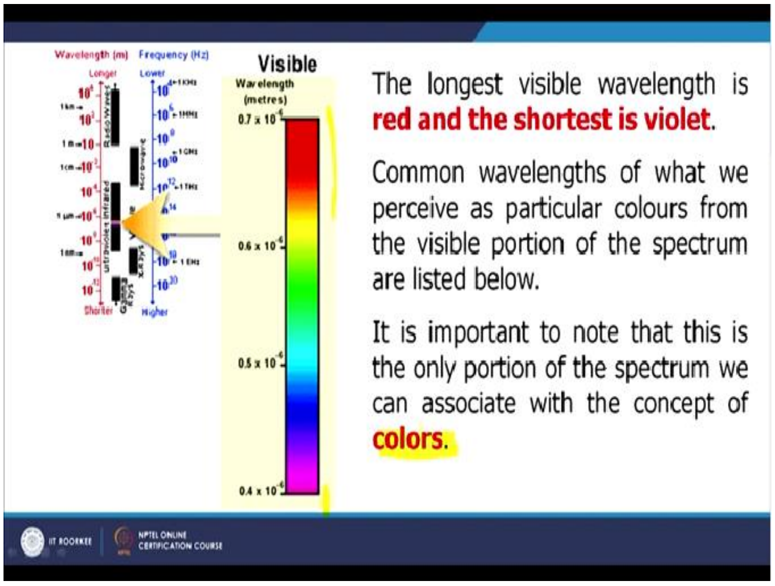
So, that is what ultraviolet part of EM spectrum which is the one end of the visible spectrum. Now, when we discuss the visible spectrum, many, many satellites and in previous lectures when I touched about a different types of platforms, many such platforms have been working or are working invisible part of EM spectrum especially the landsat and others, they had the visible channels of course they had the near infrared channels and IR channels.

And later on like a landsat team sensor and they had also thermal channels but many channels we are devoted mainly visible part of a spectrum. So, visible part is very important from remote sensing point of view and as discussed already that our eyes also work as sensors in the only in the visible part. Our eyes are not sensitive in infrared or thermal infrared or microwave vision. But our eyes are mainly sensitive to visible part of the EM spectrum which is what it is shown here. And it is important to recognize how small compared to the available EM spectrum, how small portion of EM spectrum is having the visible.

But they are the most development has taken place and there is a lot of radiation around us which is invisible. Like infrared or thermal infrared, which our eyes cannot detect, but human or our eyes had designed instruments, which can provide data or images of those part of EM spectrum, where our eyes cannot work. So, that is a very big advantage with remote sensing. Visible wavelength, as you know that it covers between 0.4 to 0.7 micro meter.

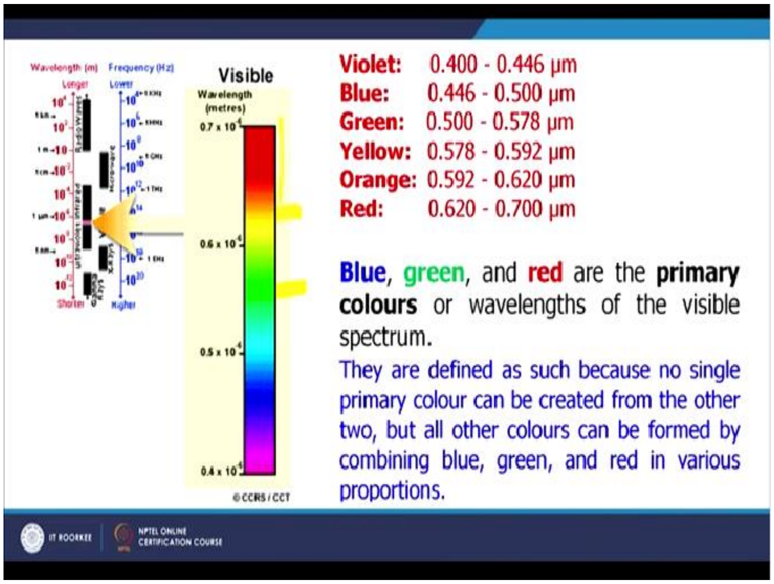
This is the most common and as a spectral resolution has improved. So, now, very thin bands are also coming between 0.4 to 0.7 and earlier in landsat-1 when we had this MSS scanner and there we are 2 or 3 **3** channels where there in this part of EM spectrum.

(Refer Slide Time: 16:47)



Now, this is the rest is when we come to this starting from ultraviolet then blue, then green and then red part. Red part which we are discussing this one which is the wavelength is red and the shortest is the of course the violet which is in the beginning and common wavelength of what we perceived as particular colors from the visible portion of the spectrum are here and that is it is important to note that this is the only portion of a spectrum, we can associate with the concept of colors, that is the visible part of EM spectrum.

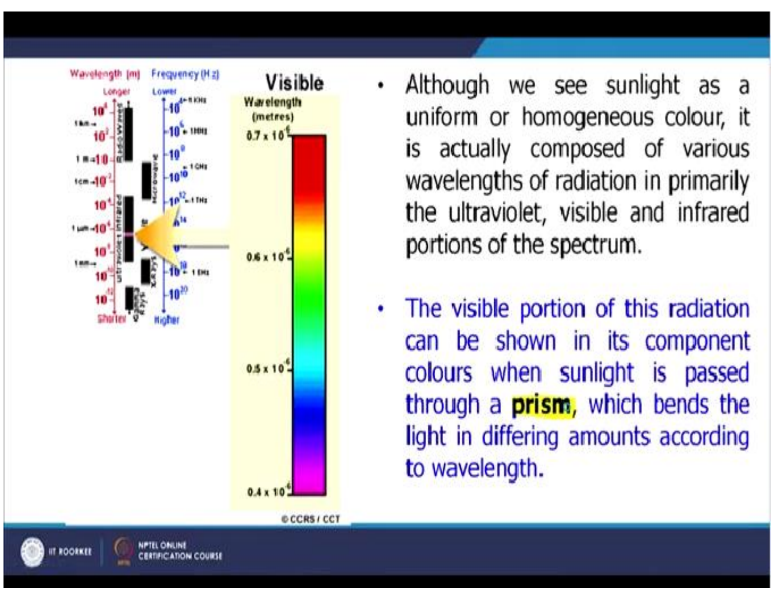
(Refer Slide Time: 17:29)



Also, the different wavelengths are shown like violet is 0.4 to 0.44 is a very thin band and then blue is there 0.446 to 5. Then of course, comes the green band which you are seeing here, a 0.5 to 0.78 0.578 and then yellow band 0.578 to 0.592 and then of course the orange band which you are seeing here. Orange band 0.592 620 and then red band, which is quite big compared to other bands, which is 0.622 0.7 and this blue green and red as he also you know that these are additive colors also called primary colors of wavelength of visible spectrum which are very, very important in case of remote sensing.

And these are defined as such because no single primary color can be created from other 2, but all other colors can be formed by combining blue, green and red in various proportions. So, that is why they are called primary colors.

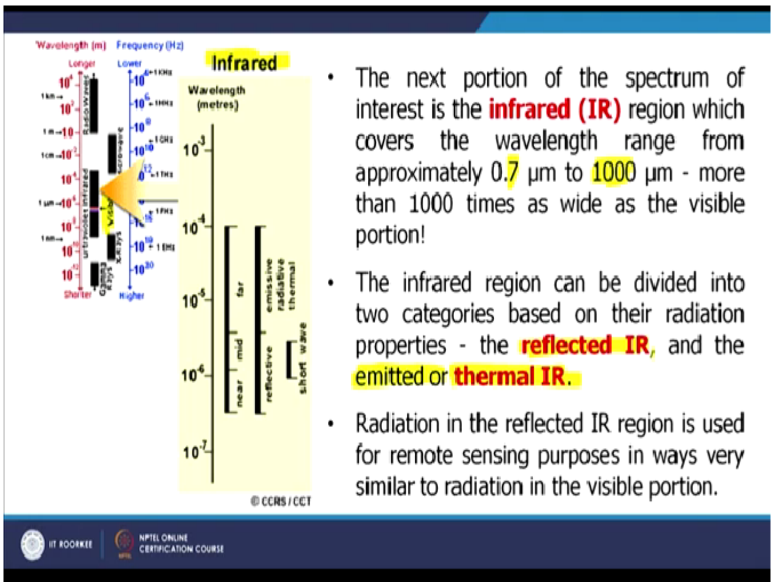
(Refer Slide Time: 18:44)



Although we see sunlight as a uniform or homogeneous colors, but as you know in a very primary level physics that this white light is having you know, BIGRO colors or seven color. So, it is actually composed of various wavelengths of radiation in primary ultraviolet, visible infrared portion of EM spectrum. And the visible portion of the radiation can be shown in its component colors when sunlight is passed through a prism.

And these experiments we have done, but at that time probably we never thought that these concepts which we are doing short of practical or trying to understand the theory part, now, will be used in directly into remote sensing. So, which events the light in different amounts according to wavelength.

(Refer Slide Time: 19:43)



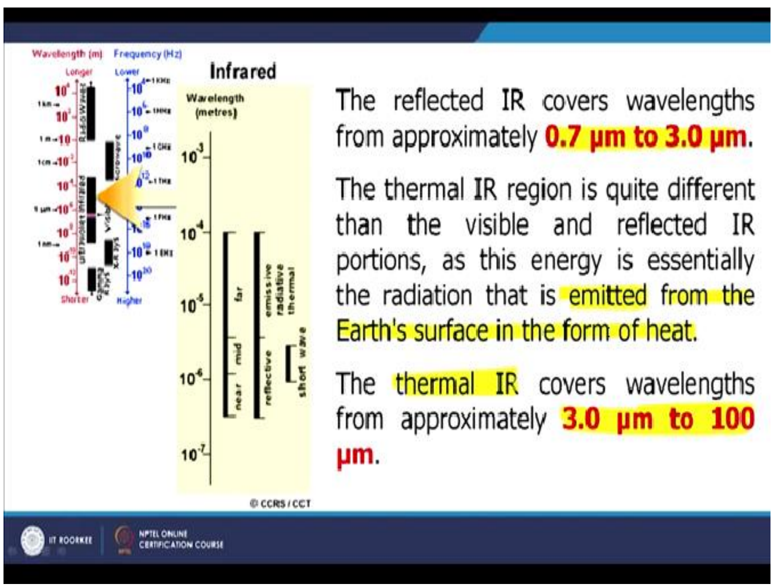
Now, we come to this infrared part of EM spectrum, which is next to visible part of EM spectrum as you can see the visible part is shown here. And next is upward in the towards the longer wavelength we get the infrared. So, the next portion of the spectrum of interest from remote sensing point of views infrared region, which covers the wavelength range from approximately 0.7 micro meter to 1000 micro, say see quite relatively quite broadband.

And more than 1000 times as wide as visible portion and there are sensors, there are bands in different sensors starting from MS to MSS like the landsat-1 to TM sensors or ETM + sensors in landsat-8 they are having few channels, 1 or 2 channels devoted for infrared. And so infrared region of course can be divided into 2 main categories. One is the reflected infrared, which is the beginning part of EM and this infrared band and then of course the thermal infrared also, which is the emitted part.

So naturally for this you do not require any energy source from the sun, but this for reflected IR that means say reflected IR channel will work only in daytime whereas the thermal infrared channel will work also in the nighttime also they will work in the daytime. And this is a very common in case of NOAA AVHRR satellite and sensor NOAA satellite AVHRR sensor and so reflected infrared channel of course works in daytime.

And thermal infrared works in daytime as well as in nighttime. In nighttime reflected infrared, and does not work because you do not have the solar illumination. So, radiation in the reflected infrared region is used for many remote sensing purposes ways very similar to radiation in the visible portion. We handled such data or images of infrared part of EM spectrum almost the same way as we handle in case of visible channels.

(Refer Slide Time: 22:10)



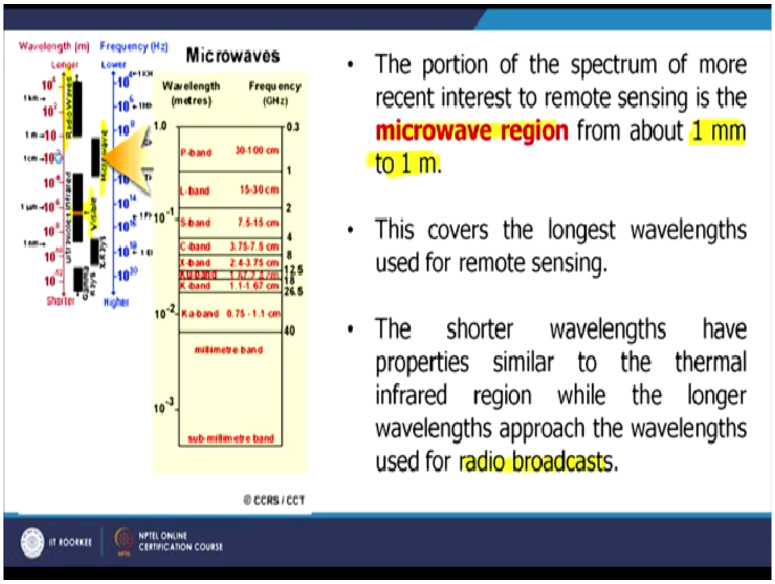
They say the reflected infrared as mentioned is covered between 0.7 micrometer to 3 micrometer is still related to your visible part it is quite divided, whereas, the thermal reason is quite different than visible reflected infrared portion is this energy is essentially the radiation that is emitted from the earth's surface in form of heat. So, that heat is detected and this is what that covers the theme and the thermal infrared the IR portion of EM spectrum falls beyond the infrared that is a starting from 3 micrometer to 100 micrometer.

This is a quite big band, but the emitted energy is relatively very small and that makes it a little difficult for sensors to gather that or sense that variation and that radiation that too at 800 roughly 840 + - 10 kilometer of having distance between surface of the earth that is in space. So, that is why though this discussion will also come later on in much detail, but, timing because we are discussing the thermal infrared part of EM spectrum. So, that the energy is so less.

That is why if you compare like landsat team the TIR band that is the thermal band and will have say in that case had the resolution of 60 meter whereas visible channels are having resolution of 30 meter. Similarly, in case of landsat, ETM+ or landsat-8, and the similar difference in resolution is there. So visible channels can have higher spatial resolution, but thermal infrared channel, because energy which is reaching to the sensor from the surface of earth is very little.

Therefore, high resolution thermal infrared channels may cannot be made available and though like NOAA AVHRR we are having 1 kilometer resolution thermal infrared images or thermal images whereas in case of landsat ETM+ in OLI series of lens at 8 we are having 60 meter and but there are 30 meter also possible, but there are limitations of spatial resolution. That is the point here. Now, the other part of EM spectrum which is exploited and very much nowadays in microwave region.

(Refer Slide Time: 24:52)



In micro region starts from 1 millimeter to 1 meter. Again, this is a very compared to visible channel or visible bands, and this is quite thick and quite broad of EM spectrum discovers the longest wavelength used for remote sensing and the shorter wavelengths have properties of micro similar to the like thermal infrared region, TIR region and while the longer wavelength approach the wavelength used for radio broadcast.

They go in that particular direction because next waves are radio waves from here. So, this brings to the end of this discussion about EM spectrum, different part of EM spectrums and in which way and how they are used in different sensors. Those sensors specific discussion will definitely will be coming in future lectures, but for time being thank you very much.