Surveying
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Module - 3
Lecture - 3

Linear Measurements

Well, we are again in another video lecture of basic surveying and this is lecture number 3 of module 3.

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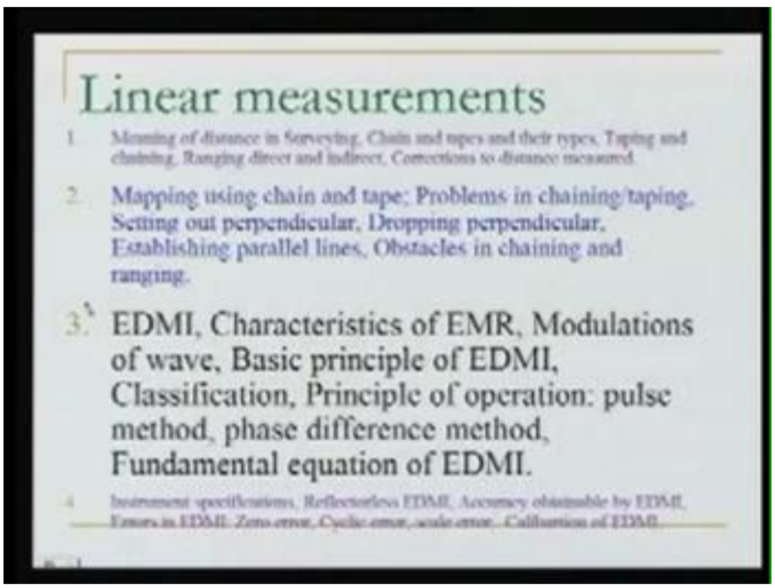

Now, in module 3, we are talking about the linear measurements, and what we have done so far, particularly in the lecture which was the last lecture - the lecture number 2 of module 3 - we talked about how we can do mapping using chain and tape. Now, we took a ground; we made a ground on our drawing sheet, and we thought: well, if this is the ground, what should be done in order to make a map using chain and tape? So, we used various principles of surveying in order to make the map. Now, there, when we are doing that, we saw that there could be many problems which might occur, particularly in finding the offsets, because we need the offsets - we need the chainage, we need the offsets - and using these we can make the maps. So, we saw some of the techniques by which we can erect the perpendiculars, we can drop the perpendiculars; we saw some instruments also. Also, many times, you need to establish parallel lines, and we have seen also some methods in order to do that.

Now, whatever we have discussed in our last lecture, that is not the end of it; I will appeal to you, I will request you to please go through your textbooks, whatever the textbook you have, and read more on that. As well as, when you are in the field all these things which are in the textbook are not the limit; rather, in the field you have enough scope to innovate, because there, in the field, the problem which is in front of you it is entirely different; every time, it is a new problem, and you try to find a solution for that particular problem. The solution may not be there in the textbook; you will have to device that solution. So always, whenever we are talking of the basic surveying, we must keep this in mind, that we have to find a solution which is practical. 'Practical' means, which we can implement in the field; which we can do in the field. Second, it should satisfy our requirement. Whatever the requirements are; what you want to do; what kind of accuracies you want to achieve - all those requirements should be met.

Well, having said that, today, we are going to a new area. Again, this is about the linear measurement. We want to measure the distances; we want to measure the lengths and the 'new area' I am saying because we will be using an instrument that is called 'EDMI'. We will see it stands for Electronic Distance Measuring Instrument. So, how we are making use of the modern electronics to measure the linear distances? We will - see of course, very briefly - the characteristics of the EMR, the modulations of the wave, then we will see how this EDMI works - the basic principles. Then there are various EDMI's; how to classify them? So we will see the classification of that. Then, the principle of operation, the pulse method, the phase difference method, and finally, we will look at the fundamental equations of the EDMI. So, this is what we will cover today.

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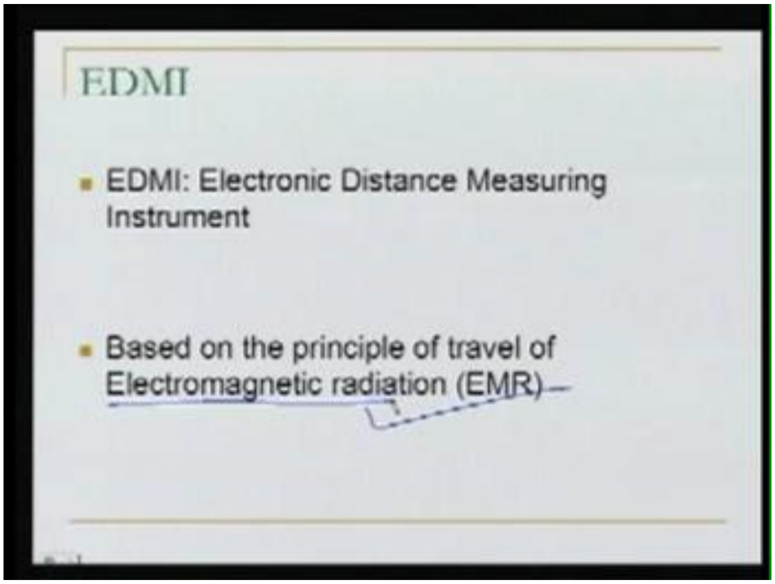

The EDMI - as you can see here, it stands for Electronic Distance Measuring Instrument. For the distances that we measured so far, we were making use of physical things - maybe chain or maybe paces - when we walk, by walking we can measure the distance, or maybe tape or physical item was there - and using that physical thing, instrument, we are measuring the distance. Now here, in this case, we want to make use of the electromagnetic radiation, the light waves, the microwaves, and using those, we want to measure the distance. So basically, we will go into this, and first we will discuss a little bit about the electromagnetic radiation, because this is what we will be making use of.

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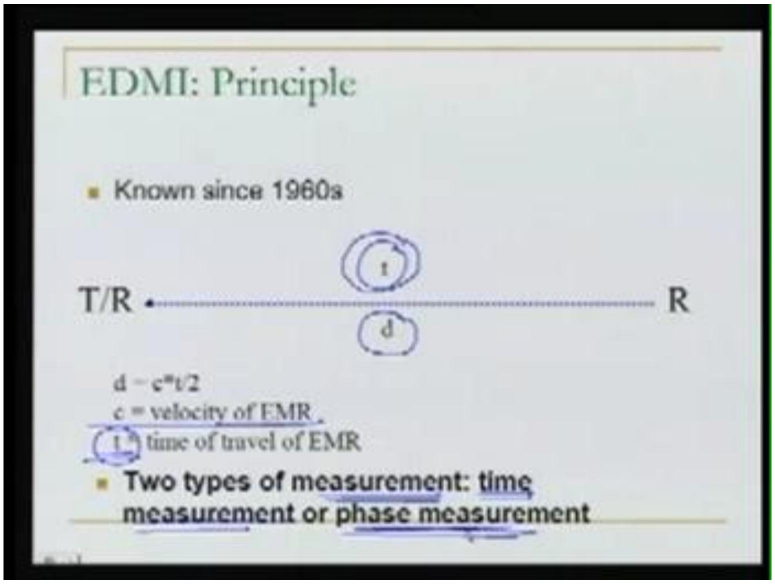

Well, we will briefly - we will look into detail about this, very briefly - what is the principle? This principle of measuring - using lasers, particularly, because this date is for lasers (Refer Slide Time 04:36); is known since 1960's, and that is the time when people started making use of light waves or the lasers to measure the distances. The principle is, as I am writing here, there is one 'T' and an 'R'; now T stands for transmitter, and this R stands for receiver (Refer Slide Time 04:52). So, we have an instrument here (Refer Slide Time 05:04), and this instrument is a transmitter and as well as a receiver. What it will do? At certain distance from this transmitter and receiver is another part, another instrument, which we can say is 'reflector' (Refer Slide Time 05:19). Now, this may be an instrument, or this may be just anything - a wall, a tree, a pole, or anything. Well, our job is, we want to measure the distance between these 2 points (Refer Slide Time 05:36) - the transmitter and the reflector. The principle is - first of all, an electromagnetic radiation, whatever the radiation is - we are not talking about that particular wavelength right now, but it starts from the transmitter, because it is fired from the transmitter, and it goes to the reflector. From the reflector, it will reflect back, and again, it will reach the receiver. So, the receiver will pick it up. After picking it up, receiver will somehow - I am writing somehow here - measure the time of travel. So, by measuring this time of travel, we know the basic equation; we know the velocity of light or velocity of electromagnetic radiation, and if we can measure this time of travel - as we are assuming here, right now, that yes, we can measure this time of travel - so we can determine this distance D between these 2 points. So, that is the basic principle of EDMI - how the electronic distance measuring instruments, they work. Now, over here, I am writing (Refer Slide Time 06:49) that there are 2 types of measurements possible: one is the time measurement, and the other is the phase measurement. Basically, in order to find this value of T, either we can measure it directly by the time measurement principle, or we can measure it indirectly using this phase measurement principle. We will look into these later on.

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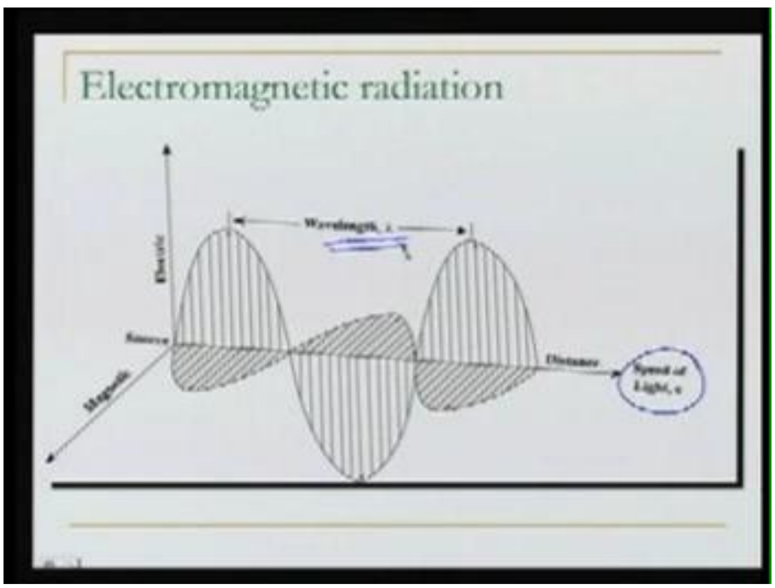

We know about this electromagnetic radiation; you know that it travels at the speed of light from a source (Refer Slide Time 07:18), and you know about the wavelength, you know about the frequency - we know all those things; the characteristics of the electromagnetic radiation. We are going to make use of this.

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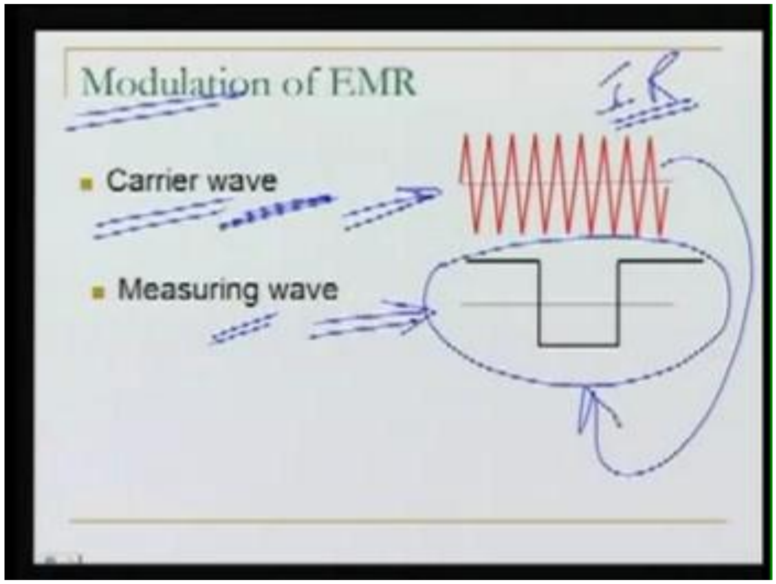

Some more things about it - because here, in the case of the EDMI, we do not use the wavelength or the carrier wave directly for making the measurements. What is the meaning of that? If we are measuring the distance between 2 points, we do not make use of any, for example, the infrared, directly, no; or maybe the blue wavelength directly, no - rather, we need to modulate these waves. Now, what is the meaning of modulation? You might have done the modulations somewhere in your physics classes. The modulations which we will make use of here - we will talk about that, but before that, let us say this is the carrier wave (Refer Slide Time 08:14) - carrier wave means this is the infrared. You know the wavelength, and so, this the infrared wave. I am just making a very rough sinusoidal wave here, and this is the measuring wave. Measuring wave means, we want to have a wave, which we say measuring wave, which is of a particular frequency, of a particular wavelength, and it is different than the carrier wave. Carrier wave is the actual wave in our electromagnetic spectrum - one of those wavelengths - while the measuring wave is a suitably chosen wavelength which we will make use of for measuring our distances. So, we are interested in measuring wave, but this is not available; this not available in the spectrum. So, what we do, we modulate our carrier wave as per the measuring wave. Now, how this modulation is done?

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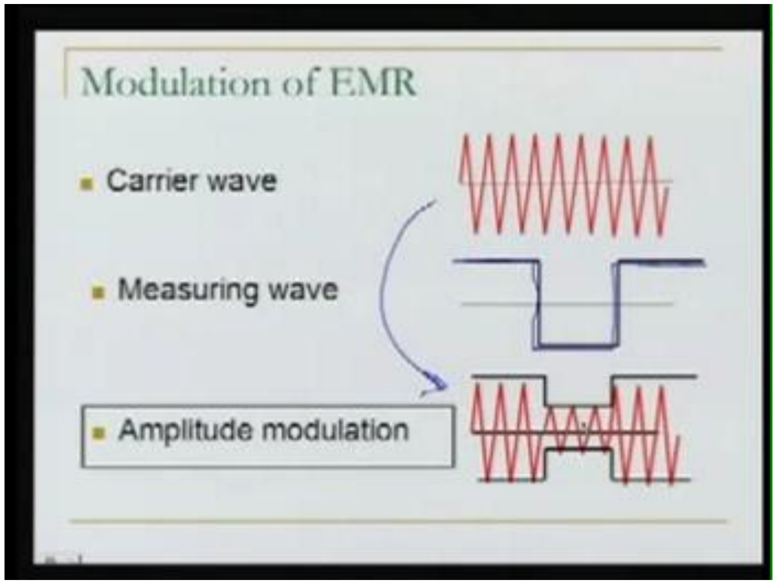

The very first modulation is ‘amplitude modulation’. In the case of the measuring wave, as you can see here, this is the wave (Refer Slide Time 09:19), so it has its signal like this (Refer Slide Time 09:21), so we modulate the carrier wave in such a way that the carrier wave carries the signal of the measuring wave, as you can see here in a very rough diagram (Refer Slide Time 09:27). So here, the carrier wave has been modulated.

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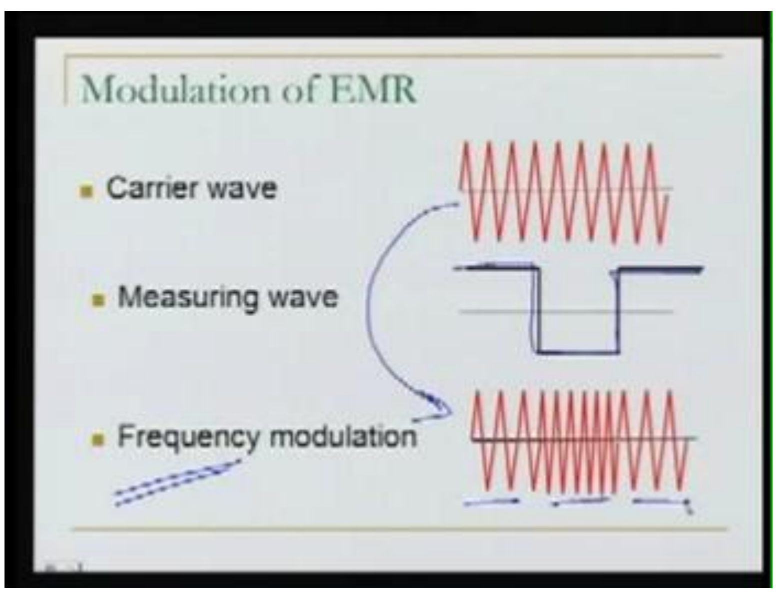

Similarly, there could be another modulation - this modulation is the amplitude modulation, the another one could be ‘frequency modulation’. What we are doing? The signal which you want to send as the measuring wave (Refer Slide Time 09:51) is being sent by modulating our carrier wave in frequency. As you can see, the frequency is changing here (Refer Slide Time 09:59), and this change in the frequency is carrying the signal of the measuring wave.

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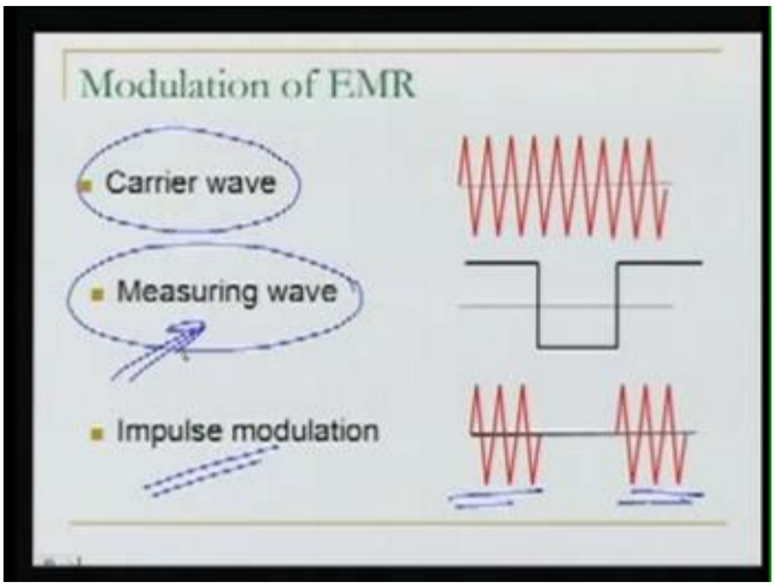

There is one more method, and in that method, we can modulate using the ‘impulse modulation’. This particular signal - this step signal - is being represented here by waves and no waves (Refer Slide Time 10:15). So, a step kind of signal is being transmitted. What we are doing? Using this, we are making use of the carrier wave in order to transmit the signal which is required to be transmitted by measuring wave. So, this is why the modulation of the wave is required. If we are going further, we would like to see the classification of EDMI. There will be some terms right now which are not explained so far, but as we progress in this lecture, we will explain these terms one by one.

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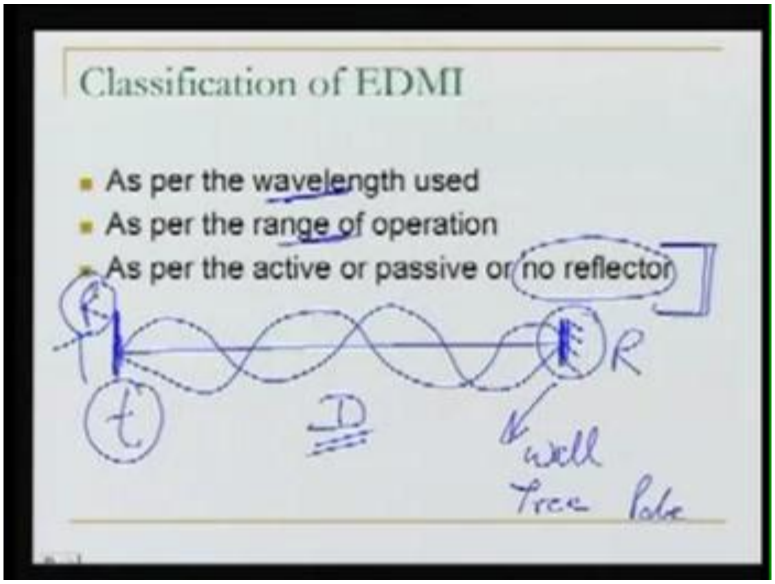

Now, we can classify the EDMI's which are available in market in these three broad categories. We can classify them by the wavelength which they use; or maybe the range of the operation - how long they can measure; or whether they are active, passive or no reflector type. I will start talking about this from this bottom one - this classification is whether the EDMI is active, passive or having no reflector. What is the meaning of that? Well, if I draw a diagram now, here, you saw we fired the EMR - electromagnetic radiation - and it returns back, and once it returns back, we measure, somehow, the time of travel (Refer Slide Time 11:34). Now, in order for this EMR or this pulse to return from the reflector, there are various possibilities. The meaning of 'no reflector' is, this reflector (Refer Slide Time 12:08) is no instrument, rather, it is any natural thing. For example, it could be the wall, it could be a tree, it could be a pole, it could be anything - anything which is naturally occurring, because we know any electromagnetic radiation will get reflected from a naturally occurring surface. So, we make use of these kinds of EDMI; we do not use the reflectors. And this is true, more when we are working in very short ranges. So, without using any reflector, we can measure the distances, because our natural objects are acting as a reflector. However, if this distance - for example, I am writing this distance as 'D' - if this distance is very large - what will happen if it is very large? The signal, once it starts from the transmitter T (Refer Slide Time 13:09), it goes to the reflector, and if this distance D is very large, the signal will lose its energy; it will diminish, and what happens in the process is, while it gets reflected also from the reflector, by the time it reaches the receiver again - R - it is very weak, and if the signal is very weak, we cannot really make use of that to measure the distances.

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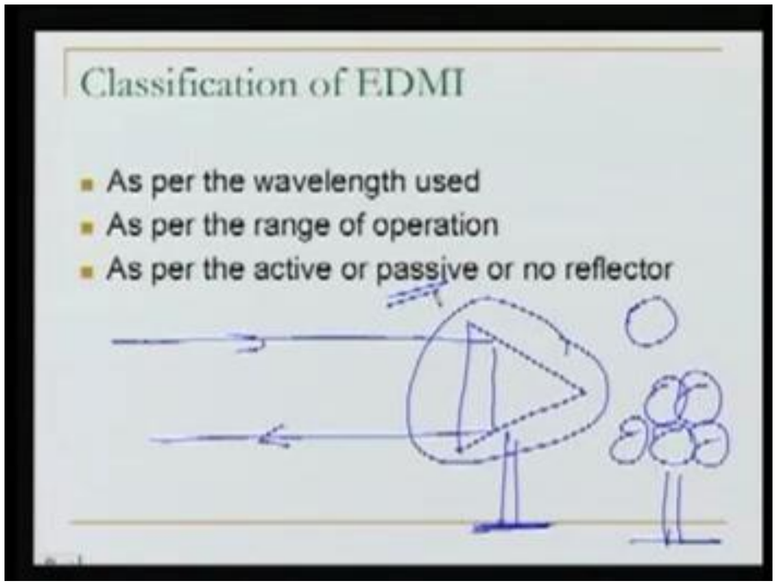

So, in those cases - what we can do in those cases, instead of having our wall, our tree, or any natural thing as the reflector, what we can do, we can make use of an artificial prism (Refer Slide Time 13:54). So here is our stand - let us say this is something - a rod - on that rod is a prism, and the radiation is travelling from here and it gets reflected from the prism (Refer Slide Time 13:57). So, this is a very, you know, a kind of ideal reflector. Because we have an ideal reflector here, so whatever is the radiation reaching here, most of it will be reflected back. This kind of thing where our reflector is a simple prism or maybe an assembly of them - we have one prism or maybe one, two, three, four, five (Refer Slide Time 14:31) - that kind of reflector, so all these are called the 'passive'; they are just simple prisms.

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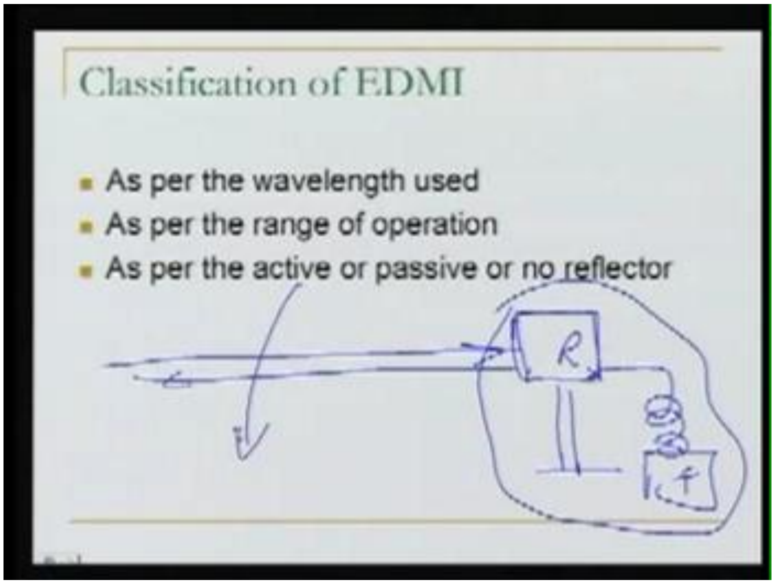

Now, what is the meaning of 'active'? The meaning of active is, now, our electromagnetic radiation reaches here (Refer Slide Time 14:51). There is an instrument now - it is not - we are not making use of simple wall or natural surfaces, we are not making use of any passive prism also; rather, we are making use of some instrument which is supported by a battery, a power, and the electromagnetic radiation which reaches here will be captured by this reflector (Refer Slide Time 15:16), and then this reflector will fire the radiation. So what it is doing? We have an active system here; active system which means the power. So generally, these are heavy in weight, large in size, and they are generally used - these active ones - when the ranges are very, very large.

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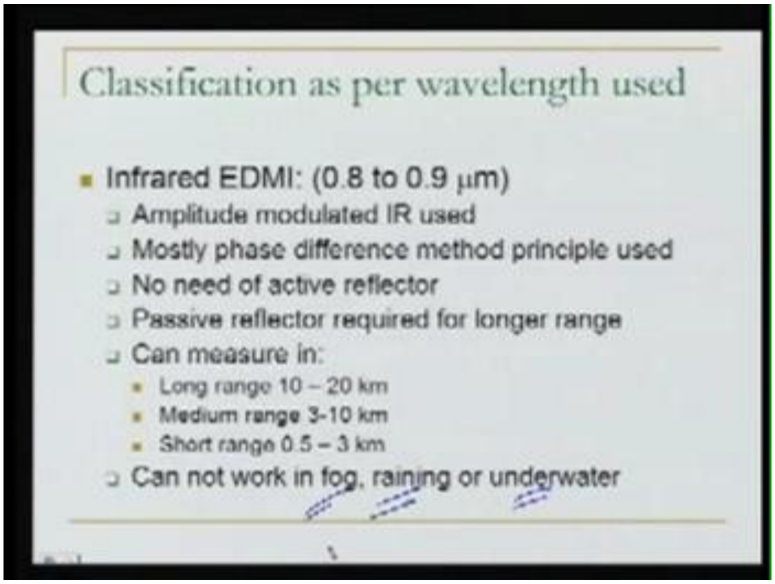

Now, the second classification is as per the wavelength used. What wavelength we are making use of in order to measure the distances using EDMI? Now, the first category is 'infrared EDMI'. You know the infrared will be from 0.8 to 0.9 micrometre. For example, mostly, these are amplitude modulated infrared, and also mostly, we go for phase difference method - we will talk about this method in a moment; what is the phase difference. Then, we do not need active reflector in this case, rather, we just need, sometimes, the passive reflectors. Passive means, a set of prisms or simple wall or natural surfaces or any tree or any anything, any naturally occurring surface can work as a reflector in this case. So, for longer distances only we need the passive reflectors. These infrared EDMI's, they come in various ranges; they can measure in 10 to 20 kilometre range, 3 to 10 kilometre, or maybe half a kilometre to 3 kilometre - so, all these ranges, they can take the measurements in. There is one problem about this infrared EDMI; that is, because infrared gets absorbed in water - so in case of the raining, underwater or maybe in foggy condition, these infrared EDMI's cannot be used.

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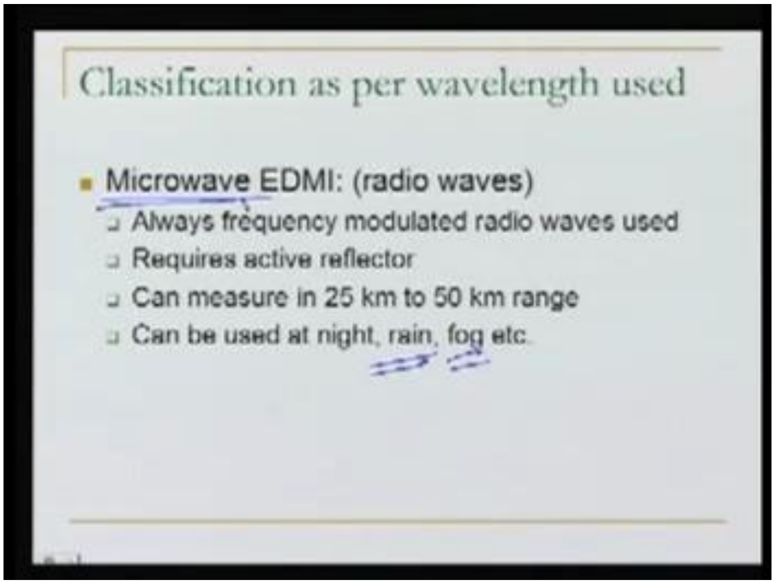

The other category is the microwave EDMI. They basically make use of radio waves. Now, with the radio waves - it is mostly frequency modulated - there is one problem: the radio waves are weak in energy, and because they are weak in energy, so we need an active reflector, but these are used generally for very large ranges - 25 kilometres to 50 kilometres. There is one more advantage of these microwave EDMI's - now, that advantage is, they can be used in case of rain, fog or in high-moisture areas. For example, over a water body, the moisture is - a lot of moisture is there, but these microwaves, they will not be affected because of these; it will penetrate the fog, it will penetrate the cloud. In all these circumstances, wherever the moisture is there and we cannot use the infrared EDMI and the ranges are very large, we will go for microwave EDMI.

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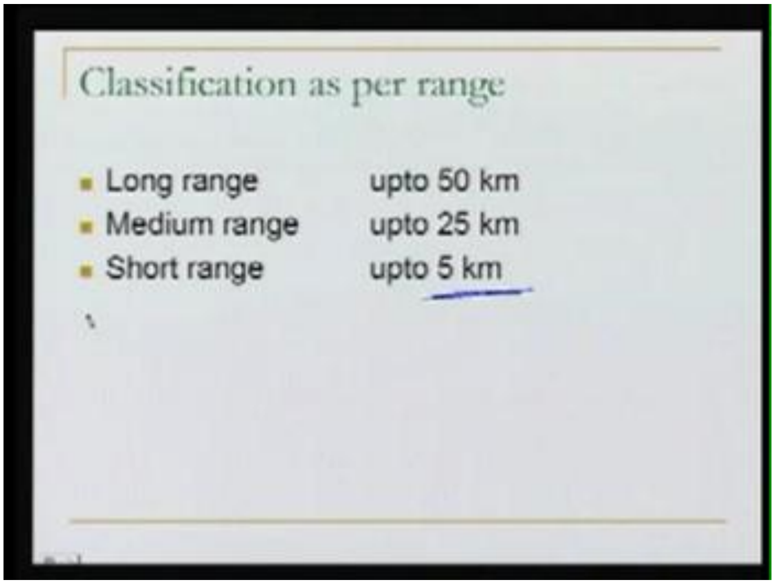

Okay, another classification: if you go to the market and you will find, in the market, the EDMI's are being sold by the range also. What range? Up to 50 kilometre, 25 kilometre and up to 5 kilometre - that kind of ranges are also referred to, and they are called long-range, medium-range and short-range.

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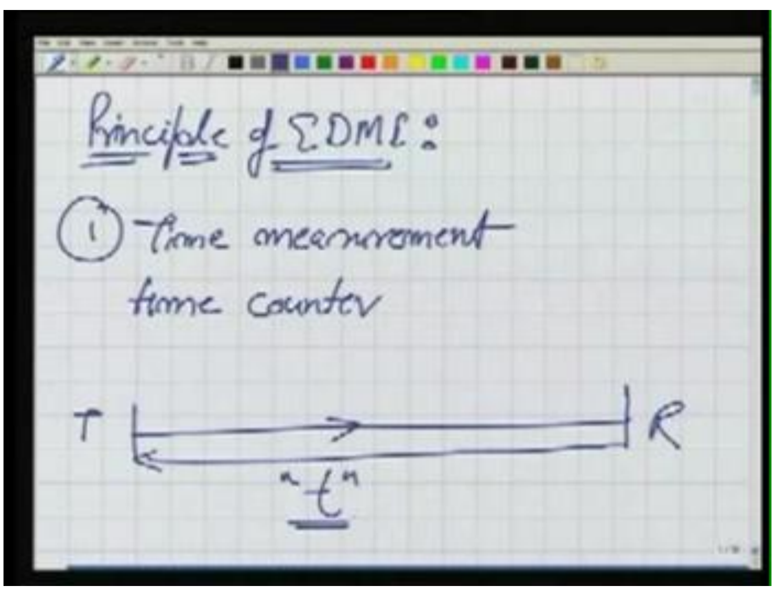

Now we will talk about the principle of EDMI. How do they measure the distances? We have seen only very briefly the principle, but here, we will look into the details. Number one method which we are talking about was by time measurement. Now, what is this? In the case of the time measurement, there is a time counter. Generally, this is called the time counter, and what is happening there? From our transmitter, a pulse is fired, and this pulse travels to the reflector (Refer Slide Time 19:34). So, this is our transmitter and reflector - now again, the reflector could be anything; it could be the natural objects or it could be a passive reflector consisting of the prism. So, the pulse travels to the reflector and then from there, it comes back. Now, somehow, this time travel is measured. How it is measured? There are various devices - basically it is a CCD-based device - Charged Couple-based Devices are there; or photo - diode-based.

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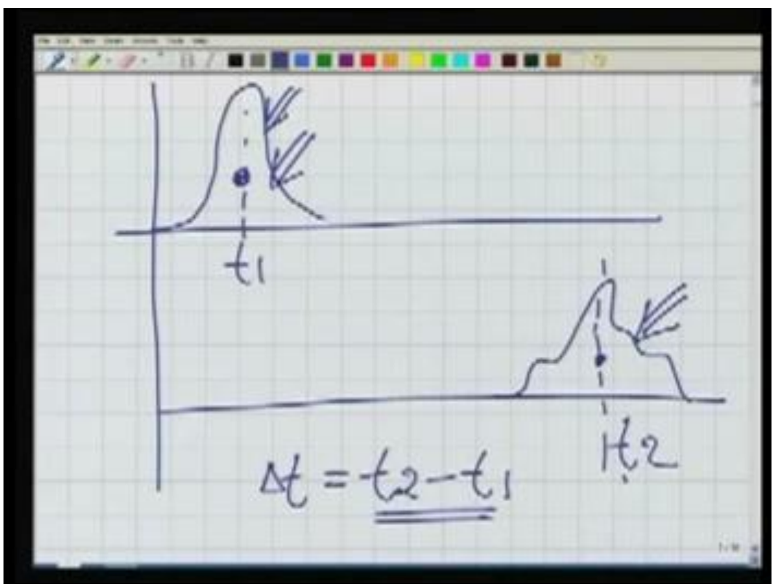

Now, what happens in this case? The reflection which was sent or the pulse which was fired is fired at a time - let us say t_1 (Refer Slide Time 20:36) - and here, in this case, we are making use of the centroid of the pulse (Refer Slide Time 20:46) for taking the measurement. Now, this pulse comes backs to us after some time, and that is the centroid of this pulse (Refer Slide Time 20:55), and let us say the time at that moment is t_2. So, the time taken for this pulse to start from the transmitter, go to the reflector and come back again is t_2 minus t_1 - that is the time taken. Now, how these times are measured? Actually, there is electronic circuitry inside the instrument and it makes use of that circuitry; it basically captures the return waveform. The moment the one pulse is fired, it captures when this pulse was fired, then it waits for the return pulse, so when the return pulse comes back to the instrument, it captures the return waveform. The return waveform could be like this (Refer Slide Time 21:47). The waveform which was fired is a Gaussian waveform, but the return waveform may have any shape; it will depend upon what kind of reflector is there, what kind of surface is there. Anyway, whatever it is, in this case, as we are seeing, we are making use of the centroids of the pulses. So, by measuring this return waveform, as you can see here, we determine its centroid. We already know the centroid of this, and by measuring these two times; by recording these two times, we can measure the time of travel.

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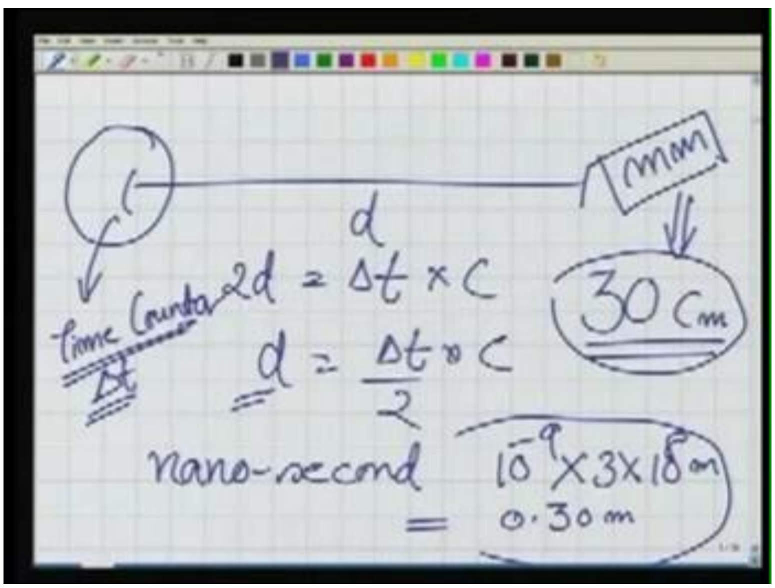

So, having known this time of travel, the distance between these two points - if the distance is ‘D’ (Refer Slide Time 22:28) - we know 2D now, so delta t multiplied by C - this is how you can determine the D. So, we can know our D here. Now, there is some problem - we will see that what is the problem here. The time measurement or the resolution of time measurement has to be very, very good here - why it is so? Let us say, if we are talking of nanosecond, now, there in the instrument, you have a time counter (Refer Slide Time 23:04), as we said, and this time counter is measuring the delta t - t_2 and t_1. Now, what should be the least count of this time counter? Let us say, if the least count is in nanoseconds, how much will be the error? If it is so, we know the velocity of light is 3 into … metre (Refer Slide Time 23:25). If you find it, if you solve it, then this comes out to be 0.30 metre, or we can say, 30 centimetre. What is the meaning of this? Even if our time counter is very precise, it is measuring, or its least count is, in nanoseconds; we are committing an error of the order of 30 centimetres in our measurement - you can do this computation, you can find the values. Now, 30 centimetre error in our computation, or - sorry, in distance measurement - is too large, because we are making use of EDMI in order to measure in millimetre level; our aim is to measure in millimetre, so thirty centimetre is really too large.

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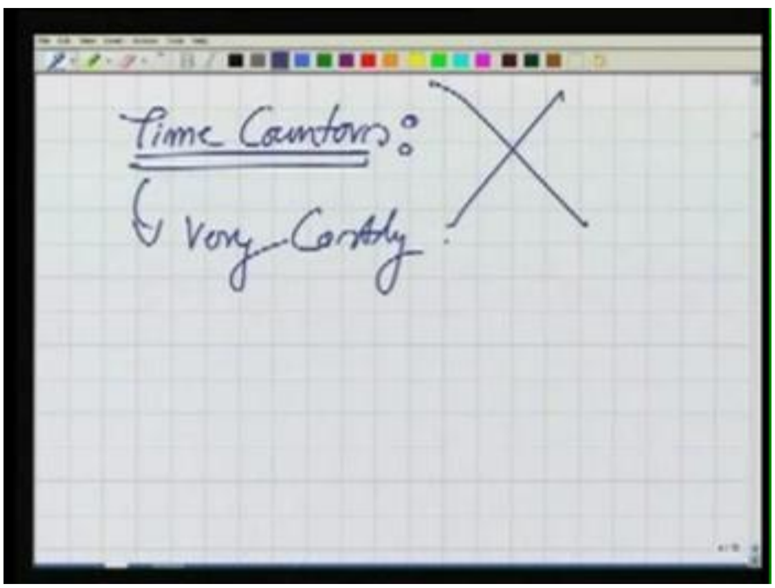

So generally, the instruments or the time counters which are used for measuring accurately are very costly. Because their cost is high, we cannot use them for cheaper instruments. I need an EDMI which I can use in this room, which I can use there, outside, which I can use to measure any distance. If the EDMI is too big because of all that electronic circuitry, if it is too costly because of this precision of the time counter, I cannot use it in the field; it cannot be cheaper. So, generally, we have instruments which work on this time counter principle but they are - these are the instruments which are very costly and mostly, they are used in airborne survey, not for the land survey. Here, in the land survey, we are looking for instrument which is cheaper; which can be handled by many people - you know, if the cost is less, you can take it to the field; the size of the instrument should be small. So, because of these reasons, generally, the EDMI's which work with this time counter principle or time measurement are not used in land surveying, rather, we use the another principle which is the phase measurement.

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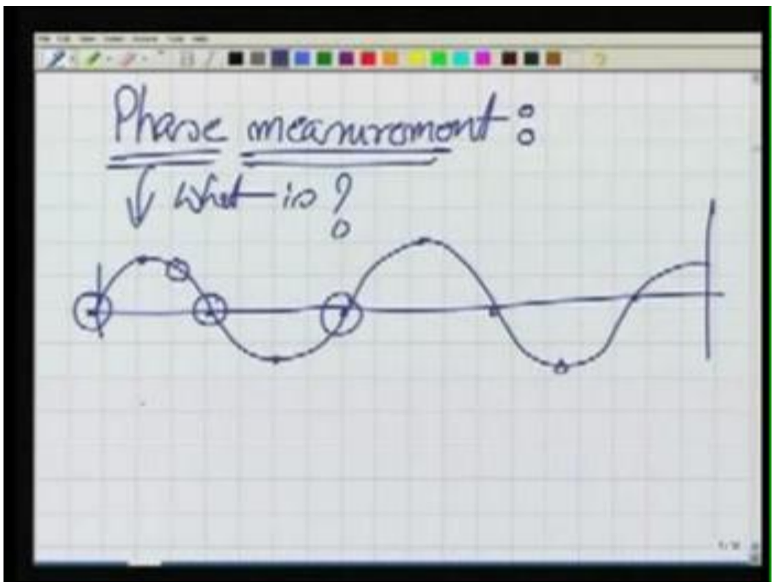

Now, what is this phase measurement? What is happening there? Before we go into that, we would like to see what is the phase. You have done in your physics classes - you can measure the phase of a wave. What does the phase indicate? If a wave is travelling from a point to the another point - let us say, like this (Refer Slide Time 26:28), at any moment - it is a sinusoidal curve - at any moment it corresponds to a particular angle value. Whether it is this point here (Refer Slide Time 26:46), there will be a certain value of the angle. For example, here, the angle value is 0. Over here, it is 180 degrees or pi; it is 2 pi here (Refer Slide Time 26:58). So, these angle values, speaking very simply, we term or we refer as the' phase' of the wave. So, that is the phase. Now, phase measurement means, we can measure the phase.

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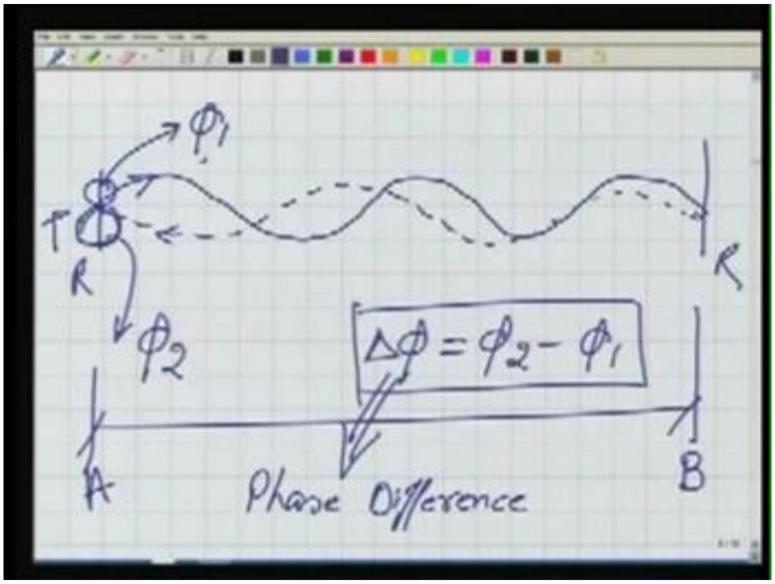

I am going to draw one more diagram here. Let us say, a wave starts travelling from here, and travels like this (Refer Slide Time 27:25). Now, from here - this is our transmitter, and that is the reflector - now, from the reflector, it gets reflected back, and let us say I draw the reflected part like this (Refer Slide Time 27:41). So, that is the one which is going there, and this is the reflected one. Now, we can measure the phase of the wave at any moment - for example, once this wave is leaving the transmitter here, we can measure the phase as 'phi 1'. Once this wave is reaching again the receiver - receiver is R - we can measure again the phase of the wave as 'phi 2'.Now, one very important concept: if the distance between these two points (Refer Slide Time 28:20) is constant; is not changing, then the phase difference 'delta phi', which will be 'phi 2' minus 'phi 1', will be constant. Whatever is the value of phi 1, the phase at which the wave is leaving this transmitter, at the same time, the wave which is coming back to the receiver - whatever its phase; the value of phi 2 - the difference of these two will be always constant, because the distance between these 2 points - let us say A and B - is not changing. So, this phi value will be always constant, and this, we say as ‘phase difference’.

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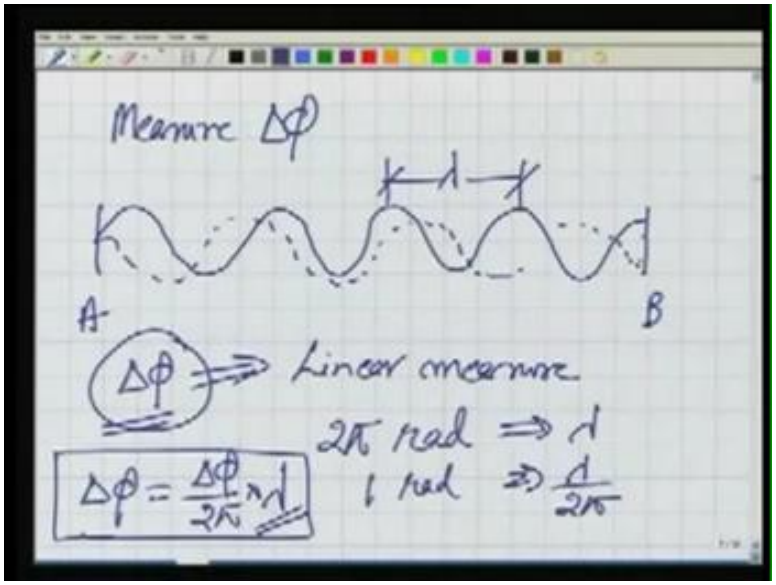

Well, what we try to do, we try to measure this phase difference. Now again, I am going to draw a figure here. This is point A and point B (Refer Slide Time 29:30). We want to measure the distance between these two points. So what we do, we again fire the laser pulse or any electromagnetic radiation which travels like this (Refer Slide Time 29:41), and then it will come back, and we are measuring the phase difference delta phi. Let us say you are able to measure the delta phi - what will be the distance corresponding to this delta phi? The linear measurement. We know, in a wave - that is the wavelength ‘lambda’ (Refer Slide Time 30:20); this lambda corresponds to 2 pi radian, so this corresponds to lambda. So, our one radian in phase will correspond to lambda by 2 pi, and our delta phi phase will correspond to delta phi by 2 pi into lambda (Refer Slide Time 30:27). What I am saying here, what I am trying to indicate? Well, I am - let us take it for granted right now that there are some instruments which can measure delta phi or the phase difference. So, if you can measure the phase difference - because our aim is not to measure the phase difference; our aim is to measure the distance between 2 points - but what we are measuring, we are measuring the phase difference of the wave which is outgoing, and the wave which is coming. So, whatever is the phase difference at any instant, we are measuring that one, and we know, if the distance between 2 points is constant, this phase difference will be constant. So, if you can - let us take it for granted now that we can measure this phase difference. If we can measure the phase difference, what is the corresponding length? So, we can find this corresponding length here in terms of the lambda, as we have seen here. Now, is that enough?

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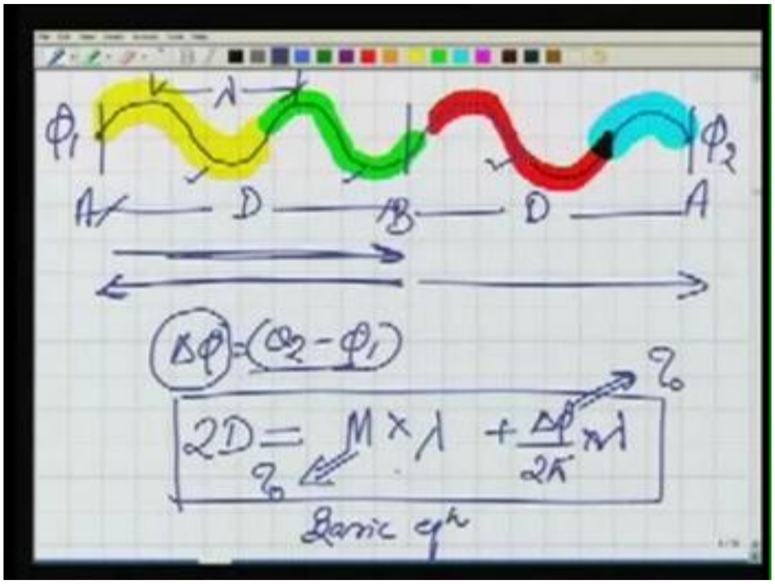
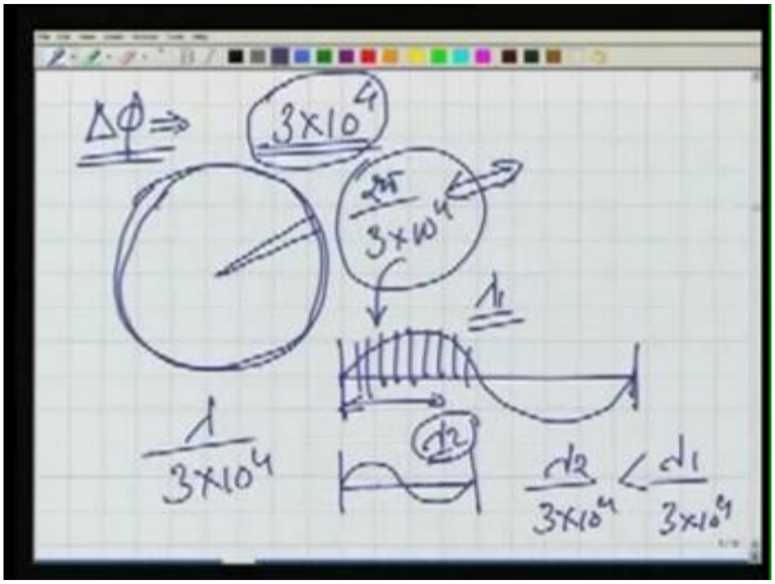


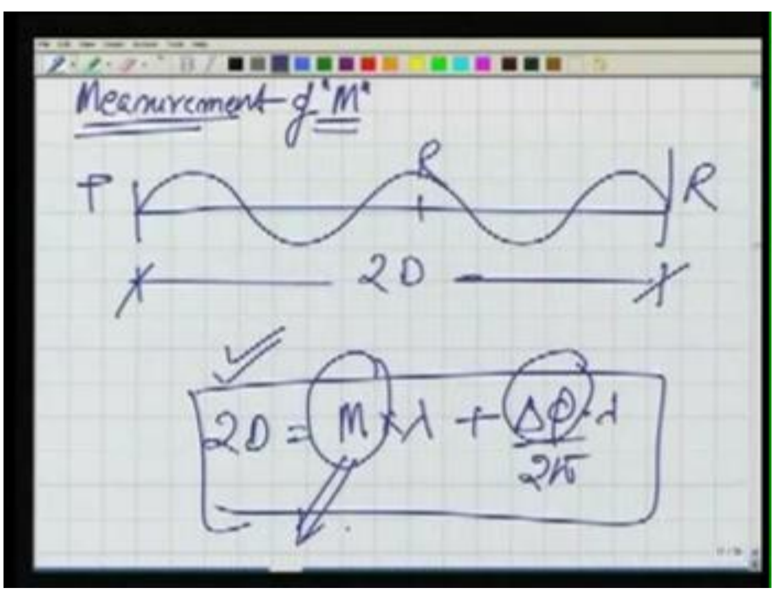
What I am going to do now, I am going to draw another figure here. Well, let us say this is point A and point B, and between these 2 points, we have to measure the distance. As usual, what we do, we fire our electromagnetic radiation - the continuous wave we are firing - and this continuous wave will reflect from B and will come back again to A. Let me open this, or rather, I take this A as here again (Refer Slide Time 32:26) now. What I am trying to do? The wave will actually go here, reflect, and go to A. So, instead of showing it this way, I am trying to show it now this way (Refer Slide Time 32:41). What will happen now? The wave will travel further and will reach A, so the phase at here is phi 1, and the phase here is phi 2 (Refer Slide Time 32:50), and we are measuring delta phi, which is phi 2 minus phi 1, by - sorry, just phi 2 minus phi 1. That is the phase. Well, our interest is, as I was saying, that we want to measure this distance D. I am trying to write the equation now. Somehow, I am again - somehow we are able to measure this delta phi. What will be the equation for the distance? We can write the equation for the distance as 2D - 2D means, the D here and the D here (Refer Slide Time 33:34) - of course, because the wave is going to the reflector, getting reflected back, so the wave travels a total distance of 2D. So, this 2D will be equal to - we are measuring this delta phi divided by 2 phi into lambda. Lambda is the wavelength which we are making use of - that is lambda (Refer Slide Time 34:00) - but is that - is that the distance? Now, you will very easily guess that this is not the distance; rather, we need to write something more here. What we need to write? We need to know, as we see in this figure now, how many complete wavelengths are there. If I highlight here - look at this figure -in this figure itself, there is one full wavelength (Refer Slide Time 34:31). Then - I highlight this by another colour (Refer Slide Time 34:40), then there is one more full wavelength here, then, there is one more full wavelength here, and finally, this is the partial wavelength (Refer Slide Time 34:53); the phase difference which we are measuring is for this partial wavelength. So, we do not know anything so far about how many of these full wavelengths. So, what we can do, we can write: if there are M number of full wavelengths, so the distance can be written as M into lambda (Refer Slide Time 35:18) - of course, because the lambda is the wavelength, so M into lambda plus whatever the distance we are getting because of the phase difference - so that is the basic equation. Now in this equation, there are questions - questions are: one, how to get this value of M, and as well as, how to measure this delta phi (Refer Slide Time 35:38), though so far, we have taken it for granted. So, what we will do now, we will see how to get these two: M - number of those wavelengths, and delta phi - the phase difference.

(Refer Slide Time: 36:03)



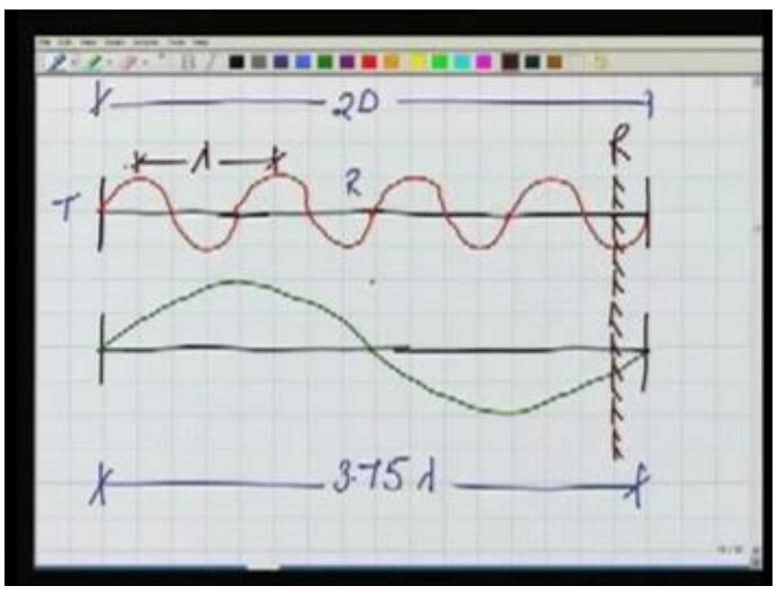
We will start with how to measure delta phi or the phase difference. Now, there are instrument in market which can measure this delta phi with a least count of 3 into 10 to the power 4 (Refer Slide Time 36:15). Let me explain this - what is the meaning of this? If we are making use of - because the phase is angle, I can show the 2 pi angle like this (Refer Slide Time 36:24), and within this 2 pi angle or 2 pi phase, I can measure the phase difference with a least count which will give me 2 pi by 3 into 10 to the power (Refer Slide Time 36:42) … that kind of least count. So, there are instruments in market which can measure the phase difference with this kind of accuracy. Now, what is - what we can say in terms of the corresponding wavelength? Let us have a wavelength here - any wavelength - what is the meaning? The meaning is, if that is my lambda 1 (Refer Slide Time 37:11), I can measure now, because by measuring the phase difference, what we are doing, we are measuring - or rather, we are getting the value of the distance - isn't it? Whatever is the distance which we can determine corresponding to the phase difference, we can determine that; we have seen that. So, what will be the corresponding value in terms of the distance, if we can measure our phase difference with this kind of least count? Over here, with this kind of a least count (Refer Slide Time 37:40), if we can measure the phase difference, what we can do in terms of the lambda? The meaning is, this entire lambda can be divided into so many parts, or we can say, when we are measuring the lambda, we can have our least counts equal to lambda divided by 3 into 10 to the power 4 (Refer Slide Time 38:02). Now, I can have another lambda which is smaller (Refer Slide Time 38:09). This is again, another important concept here - lambda 2. Now, you can guess very well in which case - in case of lambda 1, which is large, or lambda 2, which is small - the least count of distance measurement, because of the phase difference measurement will be better; will be finer. In case of the lambda 2, you know the lambda 2 divided by 3 into 10 to the power of 4 will be smaller than lambda 1 divided by 3 into 10 to power of 4 (Refer Slide Time 38:37). So, that means the least count in case of lambda 2 is finer; our resolution of distance measurement is better. So, what we have seen? We have seen that we can make use of the phase difference measuring instruments; they can measure with certain accuracy. It does not matter what is the value of lambda because they are measuring the phases. Phase is something like this: here, in the angle value, whatever is the value of lambda - small or large - the phase difference can be measured always with the same least count as far as phase is concerned. This same least count, when converted to the wave, turns out to be: in case of the smaller wavelength, the resolution of distance measurement will be better; in case of the large wavelength, the resolution of the distance measurement will be poorer. Having said that, now let us go to measurement of M.

(Refer Slide Time: 39:51)



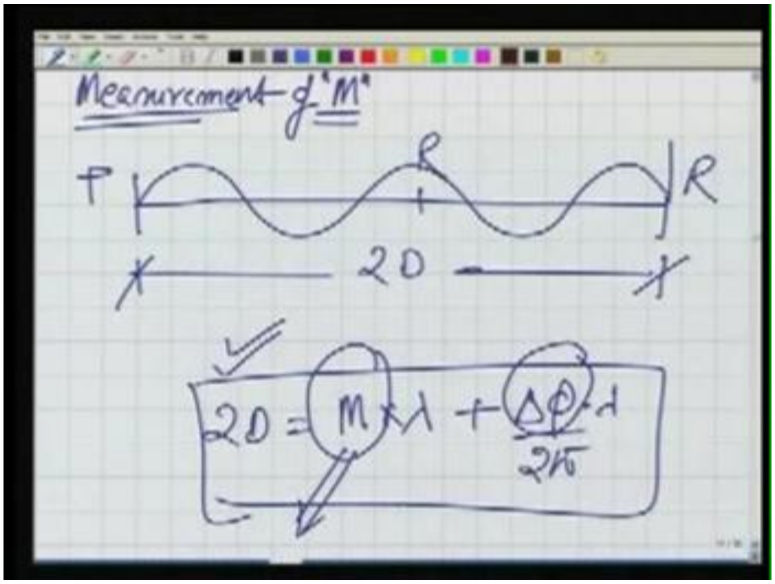
For measuring M, let us see what the M is. You have seen it before - you are writing this: if it is 2D distance - 2D means we are unfolding it (Refer Slide Time 39:55). If that is my transmitter, that is the reflector, the wave will start from the transmitter, goes to the reflector, and then it again goes to the receiver - so this distance is D, the distance what is travelled by the wave is 2D. What I am doing, in a moment, I am writing this as entire distance 2D, I am taking this reflector somewhere here (Refer Slide Time 40:20), so D and D makes 2D, so this is why I am writing here 2D, as explained earlier also. So that is transmitter, and somewhere in between is the reflector, and here it is receiver (Refer Slide Time 40:34). We have seen this 2D is M, and stands for number of complete waves. How many complete waves are there? M into lambda plus delta phi into lambda divided by 2 pi (Refer Slide Time 40:53) - that is our equation. Now, we have seen already how we can measure this phi, and we are trying to see what to do to determine this M - M is number of complete wavelengths.

(Refer Slide Time: 41:19)



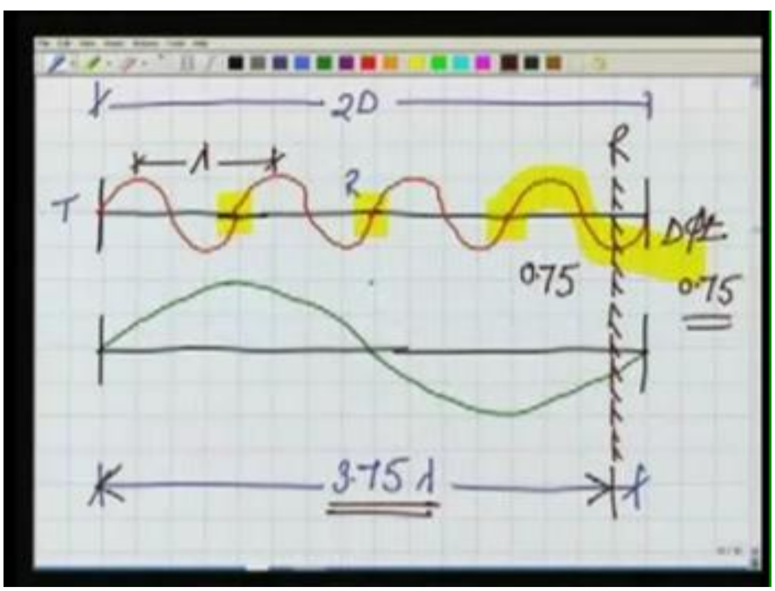
Now, in order to do that, we will go to this diagram. Again, in this case, this is the distance 2D (Refer Slide Time 41:28), a wave, as seen here by the red colour, is fired from our transmitter. It goes to the reflector somewhere here (Refer Slide Time 41:44), and then finally to the receiver- let us say the receiver is here (Refer Slide Time 41:58). I will explain all these figures: that is, my receiver is not at this point, rather, here (Refer Slide Time 42:11).

(Refer Slide Time: 42:29)



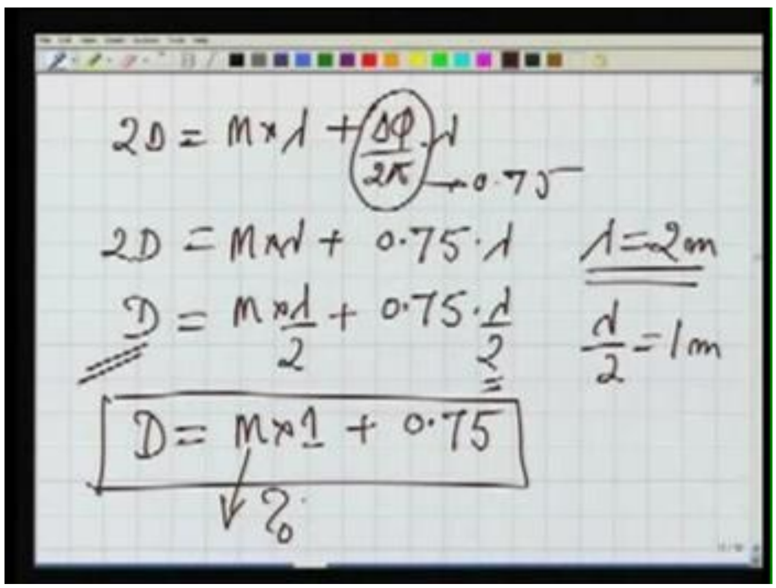
Now, if it is so, we can see our one wavelength is lambda, and as usual, we will write the equation of this measurement as we have seen here: this 2D is M into lambda plus phase difference and corresponding distance because of wavelength.

(Refer Slide Time 42:46)



Now, let us take this distance up to here as 3.75 times lambda. I am trying to explain that how to measure M, that is, our distance. If it is so, the phase difference, delta phi, will be measured as 0.75. This particular part here, as you can see here, you know the one wavelength is completed if I highlight (Refer Slide Time 43:22): this is where the first wavelength will be completed, the second one, and the third one, and now, in the rest, for this particular part (Refer Slide Time 43:29), this is leading to the measurement of, or measurement of the delta phi; the phase difference. So, the phase difference, as in this case, you can see, will be 0.75, in terms of the wavelength.

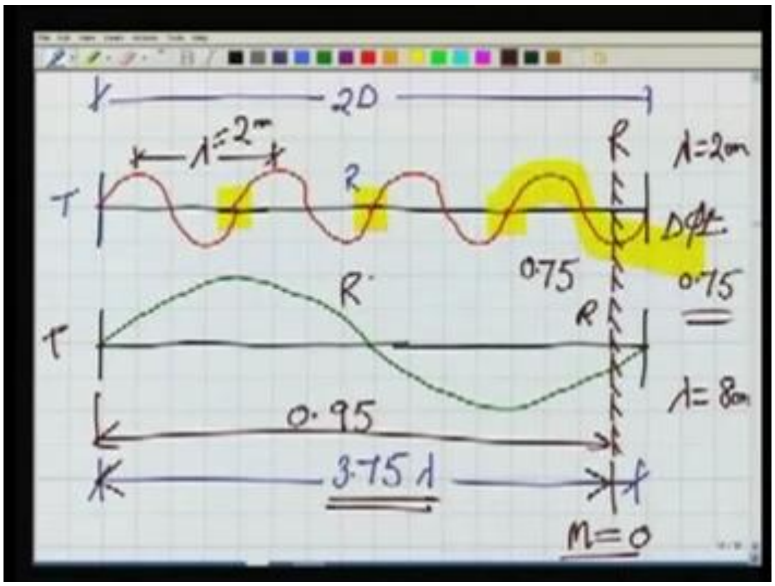
(Refer Slide Time: 43:56)



So, from the first diagram - the top one (Refer Slide Time 43:52) - what we know, we can write that our 2D is M - we do not know the value of M - into lambda - lambda is the wavelength which we are using - plus delta phi by 2 pi into lambda, and this particular value is 0.75 (Refer Slide Time 43:57). So, we can write it as M into lambda plus 0.75 times lambda. We do not know, in this case, the value of M; we do know the value of M, but this is what our equation will say. If, for example, let us say we take this lambda as 2 metre. This equation terms are to be: D is M into lambda by 2 plus 0.75 times lambda by 2 (Refer Slide Time 44:43). Very often - very often, we will find this lambda by 2 -

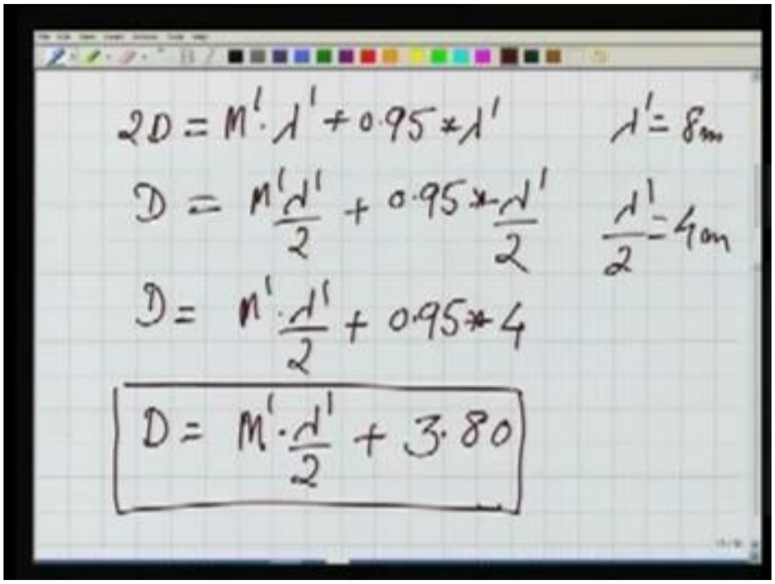
because for this D, we are measuring it in terms of lambda by 2 - this is why this lambda by 2 is, many times, called the 'unit length'. Now here, the lambda by 2 will be 1 metre, in this example. So, you can write our D as M into 1 plus, again, 0.75 - so that is our distance (Refer Slide Time 45:16). Now, we do not know the value of M here; this is still a big question. In order to find this value of M, what we do, we fire another wavelength.

(Refer Slide Time: 45:43)



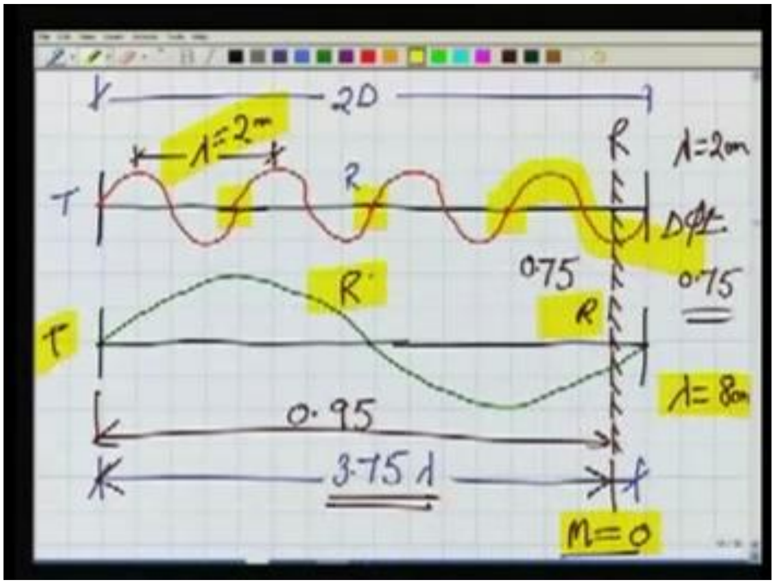
Let us say we fire another wavelength here. Here in this case, the lambda was 2 metre (Refer Slide Time 45:46). We fire another wavelength, and as you can see here, in this case, the lambda is 8 metre (45:55). This is 4 times this one (Refer Slide Time 45:59) - 8 metre. If it is so, looking at this figure also, it will become clear to you that in this case, in this figure, the value of M is 0; for this distance, the value of M is 0. What distance? 3.75 lambda. M is 0 because - why is it 0? From transmitter to reflector and again to receiver, the entire distance is covered by one wavelength or part of one wavelength. There are no multiple waves in between, so this is why M is 0. In this case, because you are making this example; we can see here in the figure - that is why we are saying M is 0. But we will try to determine the value of M; it is really not known. Well, if this is the case here, the phase difference here in this case will be starting from here to there (Refer Slide Time 47:05), 0.95.

(Refer Slide Time: 47:21)



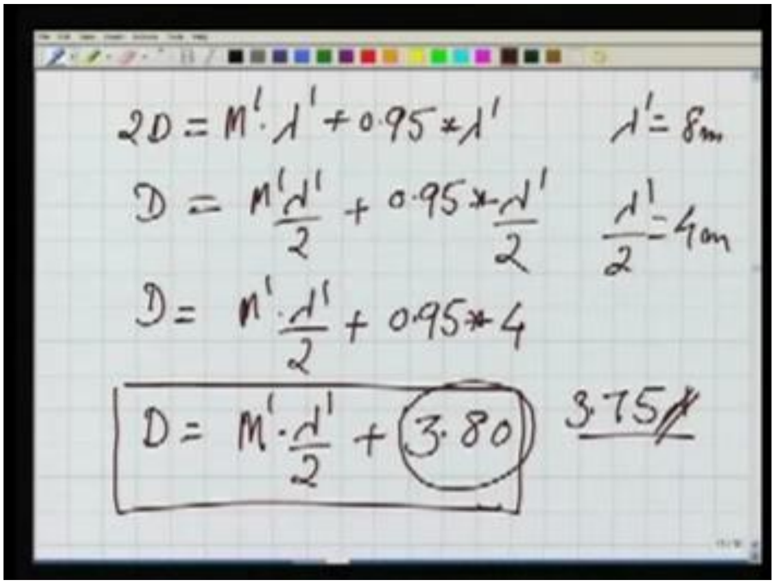
So, we can write the equation this case as, again: 2D will be - let us say I am writing M dash - I do not know the value of M - lambda dash - lambda dash is 8 metre plus 0.95 times lambda dash. So, we can write this equation further as D is M dash lambda dash by 2 plus 0.95 into lambda dash by 2 (Refer Slide Time 47:43). So, lambda dash by 2 is 4 metre. Well, you can compute now: D will be M dash into lambda dash by 2 plus 0.95 into - over here, the value is 4. If you compute it further - M dash into lambda dash by 2 plus - this comes out to be 3.80. Now, this is the important point here (Refer Slide Time 48:30)- let us look at that.

(Refer Slide Time: 48:38)



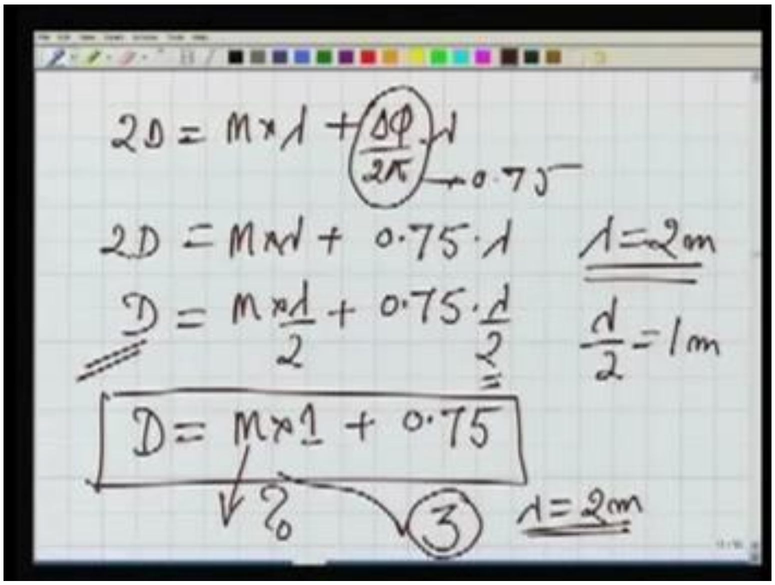
Now here, in the figure also, here in this figure, I had increased - we started with a lambda of 2 metre; as you can see here, we started with a lambda of 2 metre. Then, I took a lambda which was 4 times that one, and this lambda, if it occupies, in one full wavelength, the entire distance starting from transmitter to the reflector and again back to the receiver, if this entire distance is covered in less than one full wavelength of this lambda, then, in that case, our M has to be 0.

(Refer Slide Time: 49:20)



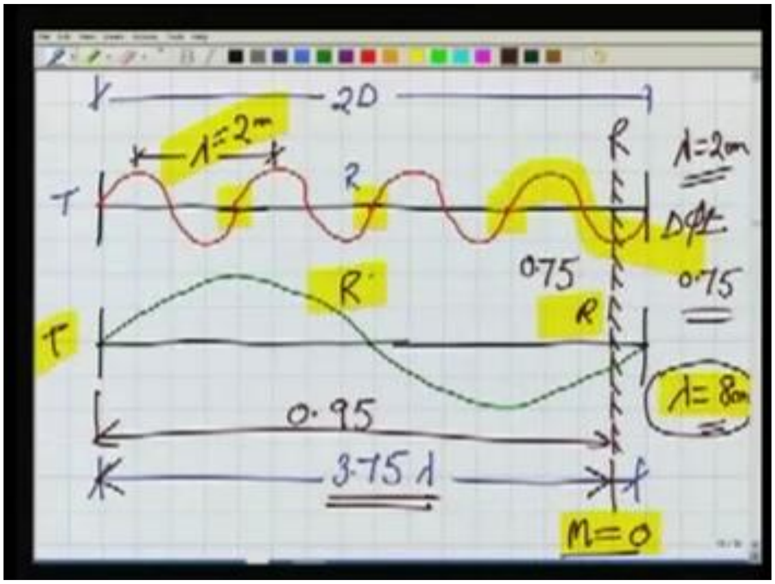
Now, this is very much reflected from this equation, because in this equation, our distance - as we saw - was 3.75 lambda or 3.75, we can say, if the lambda is unit, if you take the lambda away, that was the distance - 3.75 (Refer Slide Time 49:28) - and this whatever is measured by the phase difference is 3.80.

(Refer Slide Time 49:50)



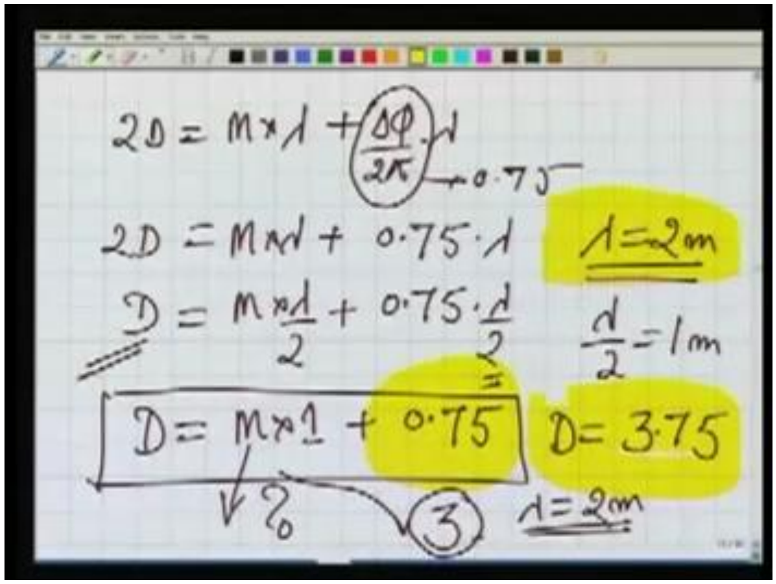
What does is it tell us? It tells us, in the previous case - here in this equation, it tells us that the value of M should be 3 - in which case? In the case when lambda was 2 metre.

(Refer Slide Time: 50:08)



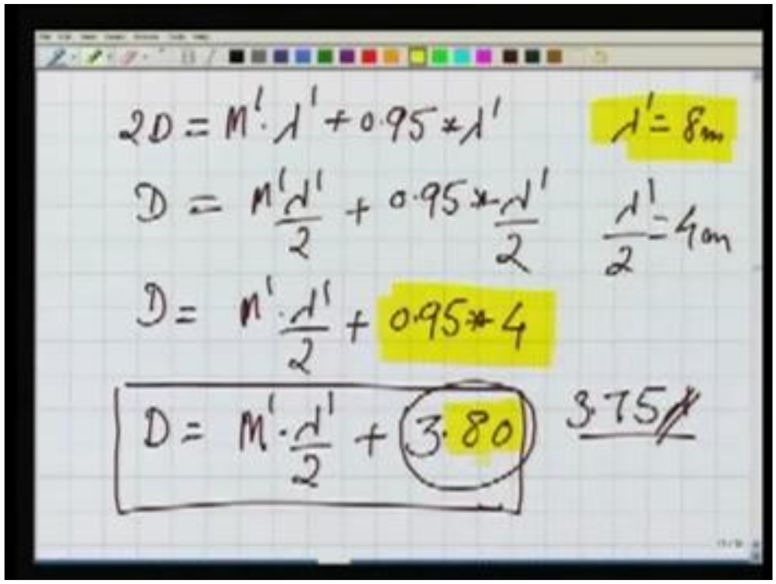
Also, another thing: because it maybe confusion, how we are, you know, selecting this value of 8 metre; how we are deciding that it should be 8 metre. 8 metre onwards, any wavelength that you select, the phase difference will increase monotonically. For any other wavelength which is less than that, the phase difference will sometimes be less, sometimes be more - it will be - it will have a distribution, a different kind of distribution; it will not increase monotonically. But here, in this case, it will have a monotonic difference - constant, you know, increasing all through. So, using that - using that clue, you determine, beyond this there is no need to increase the wavelength. This is the wavelength which covers one - the entire distance from transmitter to the reflector and then to the receiver again, so entire is covered by one wavelength. So this wavelength - the largest one - gives you an idea that, in case of this smaller wavelength - as here, lambda is equal to 2 (Refer Slide Time 51:13) - how many M's should be there.

(Refer Slide Time: 51:19)



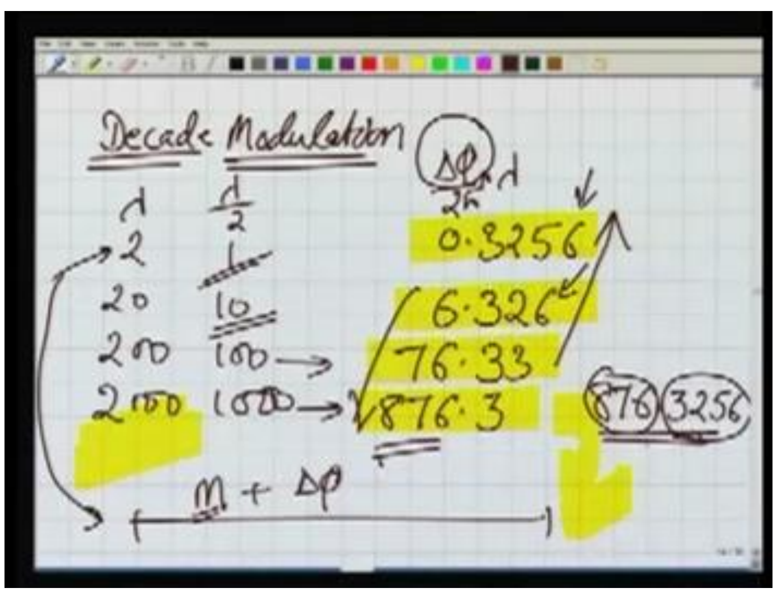
So, using this, we have seen that our M's should be 3 in case of lambda is equal to 2. If M's are 3, we can write this distance D as 3.75 (Refer Slide Time 51:26). Now, this is again, important here: we are using this 7.5 (Refer Slide Time 51:37) from lambda is equal to 2 - why? Because we have seen already that the phase difference can be measured with a certain least count, and this least count or this resolution is better if the lambda is smaller. So, because of that reason, this 7.5 is measured more accurately, more precisely than in the case of when lambda was 8. Now here, because the lambda is smaller - lambda is 2 metre - so the part which is being measured by the phase difference is more precise, rather than in the case when the lambda dash is 8 metre (Refer Slide Time 52:20).

(Refer Slide Time 52:19)



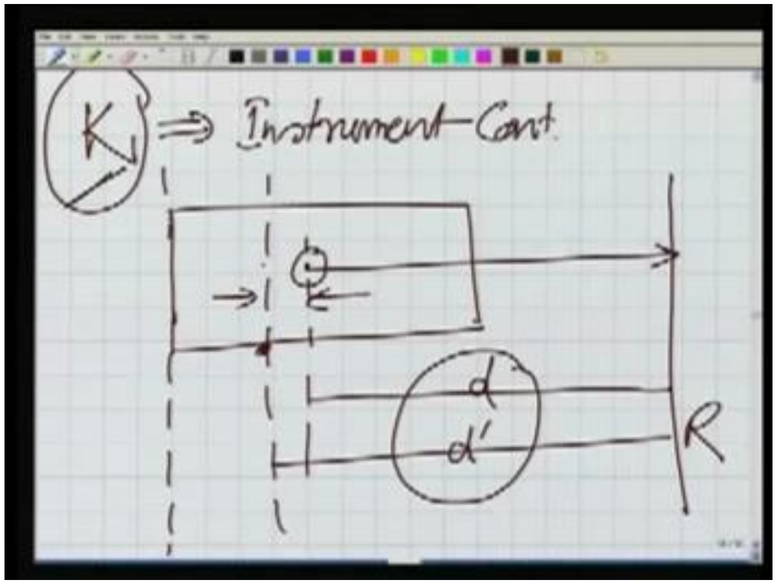
So, in the case of the lambda dash, this particular part which is being measured by the phase difference (Refer Slide Time 52:24) is less precise, and because of this reason, we are taking this 8.0 - we are not taking the 8.0; rather, we are taking this 0.75 from here (Refer Slide Time 52:39), and we are saying our distance is 3.75.

(Refer Slide Time: 52:52)



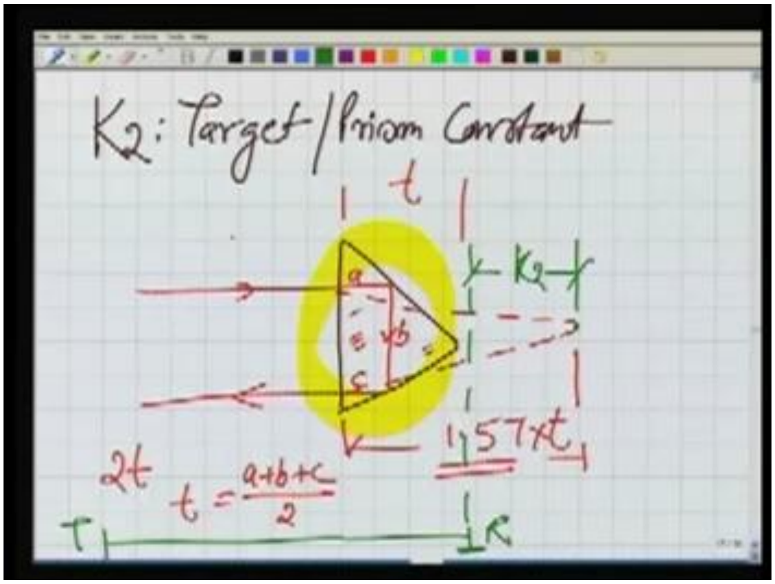
Now, one more thing to explain this - we say this particular process to be ‘decade modulation’. In decade modulation, what we do, we start with our lambda as 2 metre, 20 metre, 200and 2000. The unit length of the measuring unit will be 1 metre, 10, 100, 1000 (Refer Slide Time 53:15). Now, we are measuring a distance using these - we started with our first wavelength which was 2 metre; now see the same process that we have just seen. What it will do if we are using lambda equal to 2 metre for which the unit distance is 1 metre? What we will measure? We will measure some numbers of M's plus a phase difference. Let us say this particular thing - phi by 2 pi into lambda (Refer Slide Time 53:53) - in this case, this gives a value of 0.3256. Now, we do not know anything else; we only can get this particular value. Where this value is coming from? This value is coming from the phase measurement. We do not know anything about the M here. Similarly, as I am showing here in the chart, once we are using lambda is equal to 20 (Refer Slide Time 54:24), the corresponding phase difference will be measured and we will write this distance, which the corresponding one to be 6 point - let us say, 6.326. Now, you will notice here that the least count in this case (Refer Slide Time 54:44) is higher, or rather, we can say, finer least count. Here, in this case, it is poor (Refer Slide Time 54:50), as you know the reason. Similarly, using this as 100, we can write the distance as 76.33 (Refer Slide Time 54:56) - again, our least count has widened. Using it as 1000, you can write it as 876.3. Now, all these measurements - all these measurements what I am writing here, we are getting because of the measurement of the phase only. Now, here on (Refer Slide Time 55:31), if you increase your value of lambda, you notice that there is no change in this distance, or very minute change in this distance - it will not change as it is changing so far. So, that is the point where we stop, and here, we can say easily that yes, our distance should be - I will write the full distance - it should be 876.3256. Now, how we are writing this distance? We are taking these (Refer Slide Time 56:10) from the larger wavelengths from this side (Refer Slide Time 56:13), while these terms after the decimal, you are taking from a smaller wavelengths, because we know we can get these values (Refer Slide Time 56:22) only from the larger wavelengths, while those towards the better least count, we can get only from smaller wavelengths. So, this is how the distance can be written.

(Refer Slide Time: 57:26)



Now, next thing: again, I would like to give you the basic equation; the equation is - we have seen - M lambda by 2 plus delta phi by 2 pi. That is the basic equation, but we need to write something more here; we write this as also K_1 plus K_2. I will explain this - this is the fundamental equation of EDMI measurement. We know about all these terms, but these terms which I am adding - what they are? I will explain the K_1 first. The K_1 is called 'instrument constant' - what is the meaning of that? Let us say our EDMI is here (Refer Slide Time 57:26); the EDMI, the actual laser, is being fired from here - that is the point (Refer Slide Time 57:33). However, we are measuring the distances from here (Refer Slide Time 57:37), or maybe, if you are measuring the distances from the back of the EDMI, for us the centre of the instrument is this; the physical centre of instrument is here (Refer Slide Time 57:48) - we are measuring the distances from here. So, if that is our reflector (Refer Slide Time 57:52), actually, the wavelengths are being transmitted from this distance. So, the distance which we measure is actually this (Refer Slide Time 57:59), but the distance which we need is this (Refer Slide Time 58:04). So, because of this difference, we need to apply a correction, and this is what the K_1 is - instrument constant, and this constant is generally known from the manufacturer. They know about the instrument; that what is this difference in the point from where the laser is being fired, and the instrument centre, which we say, ‘Okay, we measure the distance from here’. So, what is the value of K_1? This is known from the manufacturer.

(Refer Slide Time: 58:36)



The second one is K_2 - this is called ‘target or prism constant’. Now, what is this? I am going to draw a passive target here, that is, the prism (Refer Slide Time 58:53); the laser or the EMR comes here (Refer Slide Time 59:03), reflects and goes back. Now, what is happening? If this total distance is ‘t’ (Refer Slide Time 59:14), the distance travelled by this laser or this EMR in between is 2t, because this ‘a’ - if I am writing it a, b and c (Refer Slide Time 59:29) - so, a plus b plus c divided by 2 will be t. Now, there is a little problem - what it is? This is our target - target means, in which the prisms are there. This is the glass (Refer Slide Time 59:49), and for this glass, the refractive index is different than that in the air. So, in air, our EMR is travelling at a certain velocity, while in this glass material the velocity will change, and because of the change in the velocity, what is happening? We need to apply correction for that. So if the glass is not there, it is equivalent to that this wave might have travelled from here to a distance which we can say, 1.57 times t (Refer Slide Time 1:00:18) - I am making use of the refractive index of the material here. So, if this glass would not have been there, this wave or this EMR would have travelled up to here in the time in which it is travelling within this glass

(Refer Slide Time 1:00:47). Now, in our instrument, we have a centre; the instrument is stationing on the centre line (Refer Slide Time 1:00:56), so once I am holding this target, I say the point in the ground is here (Refer Slide Time 1:01:09) - this is the prism, the point on the ground is here. So, what is happening? I am actually measuring the distance starting from this point to my transmitter (Refer Slide Time 1:01:18). I am seeing the reflector is here, but actually, the reflector should have been here (Refer Slide Time 1:01:22); this particular point should have been here. So, we are introducing an error here equal to this amount (1:01:31), and this is what is the prism constant. So, we need to know about this prism constant and we need to apply correction for this. This prism constant is also known from the company where from we buy this instrument.

So, what we have seen today? We saw the principle of EDMI, how they work, what are their types; what they are - you know, wavelength-dependent or maybe the range or maybe the different kind of reflector. Then, we saw their basic principles: they can make use of the time of travel - they measure the time, but they are costly. The EDMI's mostly which we use in our land surveying make use of phase measurement or the phase difference. Now, in the case of the phase difference, we saw that how we can determine the value of the phase difference. Also, we saw that not only making phase difference measurement is enough; we need to know also the value of M - the total number of multiple wavelengths, full wavelengths, in our distance. We saw a method - how to determine that by using multiple wavelengths. We start, for example, let us say, with lambda is equal to 2 metre, then 20 metre, 200 metre, 2000 metre and we keep getting the value which is being measured by the phase difference. So, at some wavelength, we come to know: now the distances are not increasing. So, from there, we get the value of M. So this M, then we replace in those measurements which we got using the smaller wavelengths, because the smaller wavelengths are giving better precision. So, this is how we make our total measurement. Then finally, we saw the K_1 and K_2 - these two constants. One is because of the discrepancy in the point of the instrument - the centre point of the instrument - and where from the laser has been fired. The second one is about the prism, because prism is basically a rod having some prisms there. So this rod has a centre there in the ground; I say, that is my point, because the rod is pointing there, but once the laser is travelling, it is travelling into the prism - the refractive index is different here; we need to apply correction for this - if this prism is not there, it should have been come here and then gone (Refer Slide Time 1:03:41). So basically, I should measure from this point (Refer Slide Time 1:03:52), not from this point, but my rod is saying, no, this is the point. So, this difference is K_2, the another constant.

So, we end our this lecture here - thank you.