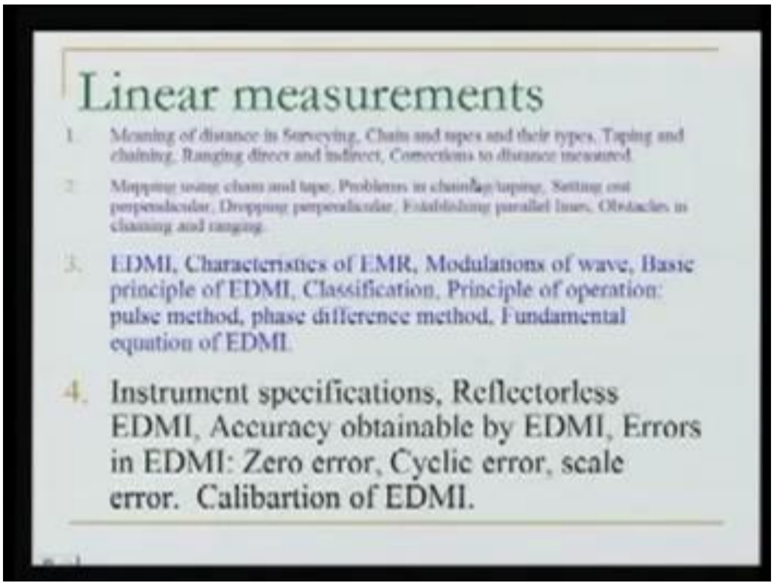
Surveying
Prof. Bharat Lohani
Department of Civil Engineering
Indian Institute of Technology, Kanpur

Module - 3
Lecture - 4

Linear Measurements

Welcome again to this another video lecture on basic surveying. This is lecture number 4 of module 3 in which we are talking about the linear measurements.

(Refer Slide Time: 00:33)



And the linear measurements - what we did so far, in our last lecture? We talked about the EDMI - what it is. It is based on the electromagnetic radiation, so we talked about the characteristics of the electromagnetic radiation also little bit. Then, the modulation of the wave. We talked about also the basic principle of EDMI; how does it work; what are the various categories in which we can put it; then, the principles of operation, which are the pulse method and the phase difference method. Before we go further, let us talk about one very important thing - why we need EDMI? We have the chain, we have the tape, so the answer should come to you automatically. If you think of going to the field, measuring using a chain or tape, it is a very cumbersome exercise; very, very time-consuming - number one. Number two, you cannot do in any kind of weather. Number three, you have to go and occupy the ground physically; you have to be there - then only you can perform this kind of survey with the chain and tape, if you want to measure the distances. Then, accuracy is always dependent; you have to be very, very precise while you are working in the field; very, very careful. You need to apply all the corrections, then only the accuracy could be good, and there is also limitation - it cannot be more accurate than certain limit. So, because of these reasons, the EDMI has got many advantages - it eliminates all these disadvantages of the conventional systems. And this is why we need EDMI, and EDMI has gained lot of popularity in surveying industry, in doing the surveying for measuring the distances.

Well, we were looking about these principles of the EDMI - we talked about the pulse method. In the pulse method, a laser pulse fired from the transmitter goes to the reflector and it comes back; we measure the time of travel. So, we saw that if it - if there is a little error in time measurement, it will lead to the error in distance measurement also. In order to eliminate this error in time measurement, we have to go for some costly equipment. So, the instrument size will become big; the cost of the instrument will become more. Because of these reasons, mostly, in surveying, we do not go for pulse method, rather, we go for the phase difference method. In the case of the phase difference method, the wave is travelling from transmitter - continuous wave - goes to the reflector, gets reflected back and being received again here. Now, because this distance is constant for a particular wave, the phase difference in the outgoing wave and the incoming will be constant, and we saw the basic equation also of the EDMI, and in that, we saw that we can measure this phase difference. Also, in the equation, if you remember, there was a term called ‘M’. M stands for number of complete waves in between this distance. So, if you know M, if you know the final phase difference, we can determine this distance. And we saw a method which was called the ‘decade modulation’, in which we send the waves of the order of - for example, let us say we will start with 2 metre, 20 metre, 200 metre, 2000 metre, 20,000 metre and so on. Now, once I am saying 2 metre, 20 metre, 200 metre - now, all these, we do not use the actual electromagnetic radiation waves there, rather, our carrier is one: infrared. This infrared, we modulate for making it a lambda of 2 metre, 20 metre, 200 metre, 20,000 metre. This is why we need the modulation. And by using these wavelengths, it is possible that we can determine the distance between these two points. We have seen that - because for our final lambda - for example, let us say 20,000 wavelength - what will happen after that? After that, if we use any more wavelength for a distance which is less than 10,000 metre - the value of phase difference - and when you convert it to the corresponding distance, the distance will not change anymore. We can use 20,000 kilometre - sorry, metre - of wavelength or maybe 200,000. So, the value of the distance which is being computed by the phase difference will not change anymore; only little change will be there - this is how we know what should be the largest wavelength which we need to use when we are doing this decade modulation. So here, at this moment, I would like to show you the EDMI, what the EDMI is.

(Refer Slide Time: 05:53)

Here is an EDMI with me and this is handheld EDMI (Refer Slide Time 05:37). It is a very small instrument, as you can see, and in this EDMI I will demonstrate also. You can see there are couple of buttons here (Refer Slide Time 05:48) - I can press, and I can start operating this. It runs on just pencil battery - it is a very convenient instrument, and you can measure distances very quickly with this. What you need to do here, you just need to switch it on, and here is the power switch (Refer Slide Time 06:05) - it gets switched on and then you point it. For example, I am pointing it to the wall here (Refer Slide Time 06:09). If I point it to the point where I need to measure the distance, then I ask for the distance. As you can see, the red dot here (Refer Slide Time 06:20)- this red dot means the laser pulse is being fired there, and it is reaching that particular point and it is being reflected from there. Again, after it is being reflected from there, it is coming to the instrument; the instrument is capturing it back and then it gives me the distance - it tells me the distance is 1.56 metres. I can measure any distance, for example, like this. I can measure the distance, for example, if the problem is, I need to find the volume of this room, to find the volume of this room what I will do, I will measure it from the ground keeping it like this, the height (Refer Slide Time 06:55). I will keep it on one wall of the room like this (Refer Slide Time 06:59), I measure the distance, so width of the room is there. I keep it on another wall like this (Refer Slide Time 07:08), and I measure this distance, so the length of the room is there. So, having all these three measurements, the instrument automatically multiplies them and gives me the volume. So now, finding the volume of this room becomes very fast; this instrument is really very, very fast, very quick. Right now, when I am using this instrument - for example, in this case, I am pointing there (Refer Slide Time 07:29). Now here, in this case, what is happening? The reflection is being coming - is coming from the wall, so our target is the natural target; we are not using any external target.

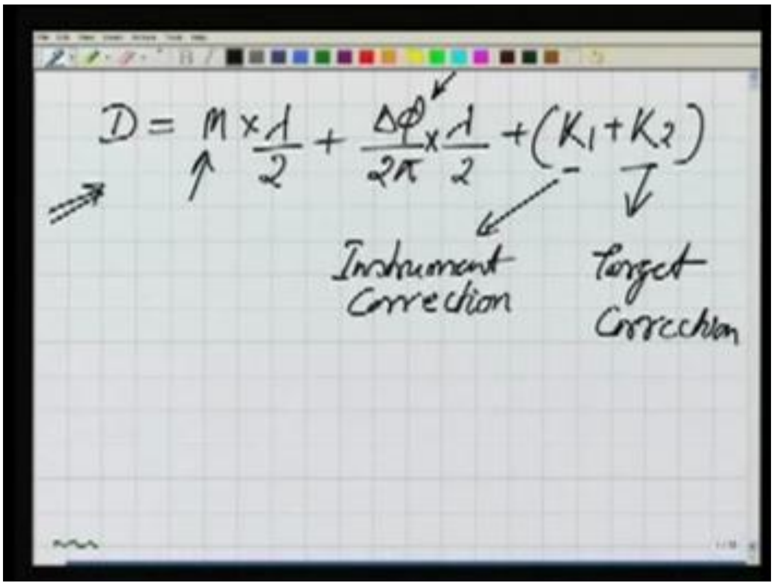
(Refer Slide Time: 07:47)

However, we can use some external targets also. For example, here, this is the material (Refer Slide Time 07:48) which we say ‘retro-reflective’. This will reflect the laser pulse in a better way. So, sometimes, when the distances are large, we use this as the target. Now, in this case, the target will become the passive target, as we are seeing yesterday in our last lecture - the passive reflectors. So the reflector will be the passive reflector.

(Refer Slide Time: 08:14)

We have one more passive reflector here, and I will show you there. This is another passive target (Refer Slide Time 08:16). Now here, in this target, what is there? As you can observe, now here we have a bipod, as you can see, down here (Refer Slide Time 08:24). I want to keep this target vertical, so by making use of the bipod, I press two knobs here (Refer Slide Time 08:32), and we have a bubble tube - a circular bubble - here (Refer Slide Time 08:35), and I find that this bubble should be in centre. So, by manipulating it, that bubble comes to the centre so my rod is vertical. Once we have made it vertical in this particular bipod or in this target, I can change the height also - I can un-knob it here (Refer Slide Time 08:54) and screw it, and I can raise it up or lower it down so that height can be also changed. The important thing: you are seeing these yellow paints (Refer Slide Time 09:04) - this is basically, if you are at a distance - 1 kilometre, 2 kilometre - and you want to locate your target using some telescope or using naked eye, because you want to bisect this target. So, in this case, these, they help to bisect the target. Now, the most important part of this, the core of it - the core of it is the prism. Over here, as you can see, is the simple prism (Refer Slide Time 09:30). The job of the prism is, whatever the radiation is coming, it will reflect it back. So here, in this case, if the distances are large and the energy of our infrared or energy of our wave gets reduced in the medium, it tries to help that; it tries to reflect the whatever amount of radiation is coming here by specular reflection, back to the EDMI. So, this is why we say this as passive; passive means it does not have - it is a reflector, but it does not have any battery or anything; no power system is there. Just because it is a prism, using its optics, it reflects the wave back to the EDMI and we can carry out the distance measurement.

(Refer Slide Time: 10:25)



We also discussed about the basic equation or the fundamental equation of the EDMI, and as I am writing here, this is the equation (Refer Slide Time 10:25), and in this equation, you know, we need to determine M. M stands for number of total wavelengths within the distance, and delta phi is the phase difference, while lambda is the wavelength which we are using - the modulated wave, and K_1 and K_2, they stand for instrument correction or constant, or target correction. Now here, in this case, again, to have an explanation of this K_1 and K_2, as we have discussed it already.

(Refer Slide Time: 11:11)

Now here, in this case of the EDMI, the wave is being fired like this (Refer Slide Time 11:17). Somewhere here inside is the instrument which is firing the laser pulse. Now, that is there somewhere inside, but when we measure the distance, I do not know where that point is; it is not marked here anywhere. What I do, I measure the distance about this face of the instrument (Refer Slide Time 11:35). So, my distances in the - physically, in the ground, are being measured from here, while actually, the laser is being fired from there (Refer Slide Time 11:44). Now, this distance is the instrument correction, because we need to know about it; we need to add this particular one to the measured distances - that is how I will know about my distances.

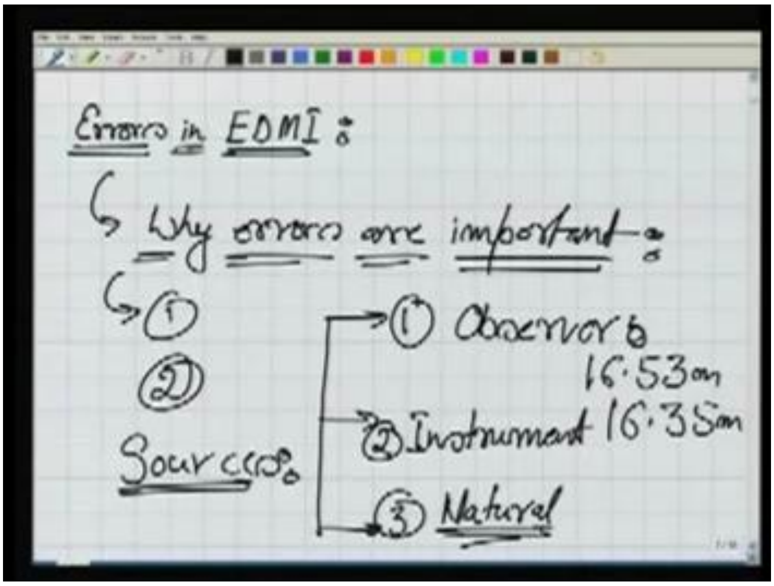
(Refer Slide Time: 12:40)

Then, if we look into the target - we will talk about the target correction. Here, in the case of the target, as we are seeing that the laser pulse or the electromagnetic radiation will come over here, will get into the prism and will get reflected (Refer Slide Time 12:11). Now, the refractive index of the medium here (Refer Slide Time 12:17) and the medium that is inside is different. What we are measuring? We are assuming that it is reflecting back, and all through in our computations we are using the refractive index of this medium (Refer Slide Time 12:27); we are not applying any correction so far, inside the target, but the refractive index of the glass material here is different. So, what happens if I rotate it like this (Refer Slide Time 12:39)? So, laser is actually coming over here like this (Refer Slide Time 12:42) and is being reflected from there. In fact, as we saw in our last lecture, if you take into account the RI of the glass material, that is equivalent to as if the laser pulse would have reflected from here - not from there, rather, from here (Refer Slide Time 13:00).

(Refer Slide Time: 13:16)

Now, there in the ground, I am measuring the distance from this point (Refer Slide Time 13:07), where this rod is or where the centre of the rod is. So, for this centre of the rod there in the ground, I want to measure the distance from that point (Refer Slide Time 13:15) there in the ground. But my laser is equivalent to be reflecting from here (Refer Slide Time 13:23), so there is a discrepancy. This discrepancy of around this amount (Refer Slide Time 13:26) - from the centre of this rod, which we can see there in the ground, where I have put it, to this point - we need to the apply correction again. Now, this correction we say, ‘target correction’.

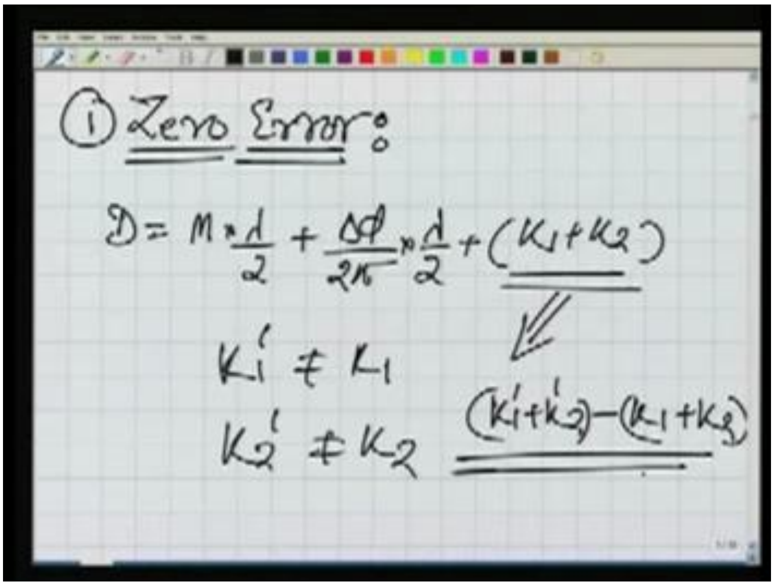
(Refer Slide Time: 13:49)



So today, we will start our discussion now, after this repetition or recapitulation of the things that we have done so far on errors in EDMI, or what kinds of errors may occur when we are carrying out measurements with electronic distance measuring instrument. Now, the important thing here: why errors are important. That is a big question. Not only in case of EDMI or whatever instrument we are using - why errors are important; why should we know about the errors? Well, there are couple of reasons. Number one: if we know about the errors, we can apply corrections in our observations. Then only we will get the right kind of measurements, because from the instrument, we expect an instrument to perform under some permissible limits of the accuracy. If it is not performing, the results which we are obtaining will be wrong, so we should know about the errors. Then, second thing - that was number one -number two is, if we know about the error, we know about the behaviour of the instrument; how the instrument is actually behaving in the field. So, because of these reasons, we should know about the errors. Now, when we talk about the errors, we should know what are the sources -what are the sources of error. In all the cases, whatever surveying or whatever equipment we are using, generally we classify these sources in three categories. Number one is the error which is because of the human being, the observer. What could be the error in case of EDMI by the human being? I was supposed to bisect from here (Refer Slide Time 15:35) - from the EDMI - to a target here (Refer Slide Time 15:37), but I am tired in the field, and I bisect something else;

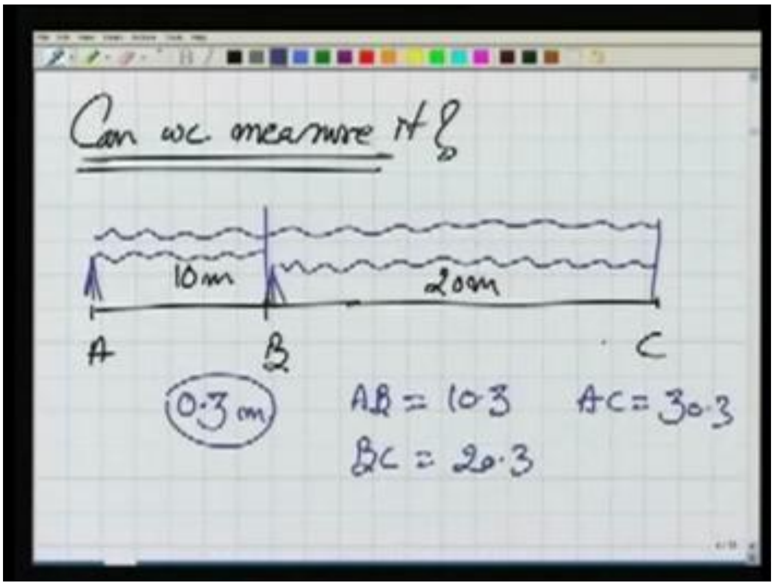
I do not bisect the target which I am supposed to bisect. So what is happening? It is a bisection error; it is an error because of the observer. Or maybe, he keys in some wrong keys in the EDMI, so the distance is coming out to be wrong. So, there are many errors which could be - they are by the observer. Or maybe, a distance which is given by the EDMI is 16.53. Let us say 16.53 metre is the distance which is given by the EDMI, but the observer writes it as 16.35 - that is an error because of the observer, the surveyor. Then, the second category - that is about the instrument; the errors which are because of the instrument. Instrument means, something goes wrong there inside - it is not measuring the phase correctly, it is not measuring the travel time of the laser pulse correctly. So, if those things are there, we categorize them as instrument error. Then, third thing - what could be that? It is the nature or error due to nature or the natural sources. For example, the atmosphere - our laser pulse is travelling from one point to the other point and is coming back. What we are assuming? We assume that it is travelling with the speed of light in vacuum, but it is not vacuum here. Well, if it is not a vacuum, we can apply corrections for the atmosphere, but do we know the atmosphere? We need to sample our atmosphere everywhere in between, which is the difficult exercise. So, because of the atmospheric perturbations, something which we could not measure, what will happen? There will be some error in our observations. So, they are sources which are the natural sources.

(Refer Slide Time: 17:46)



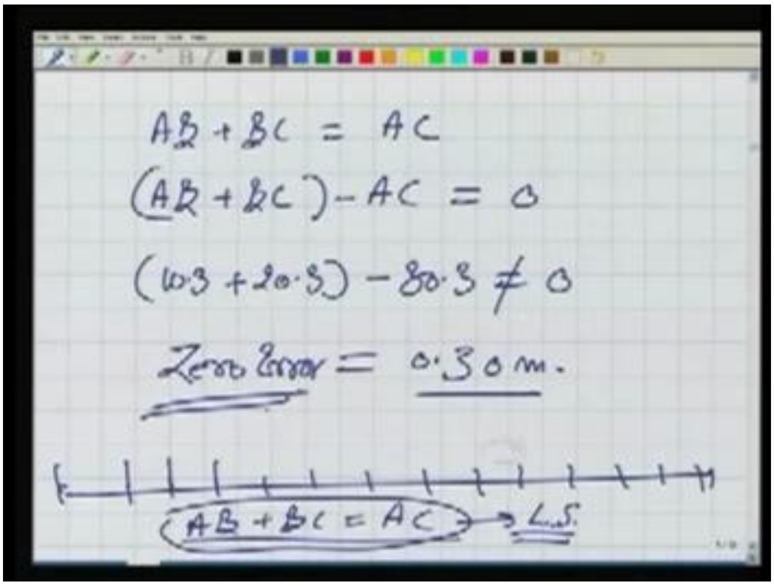
Now, having said that, we will talk about these errors now, one by one, which are there in the EDMI - these are the common errors or the most prominent errors. The very first one is called as ‘zero error’. Now, what is this zero error? We need to look into our basic equation again: D was M into lambda by 2 plus phase difference … again, lambda by 2 plus - we have seen K_1 plus K_2 (Refer Slide Time 18:04). Now, here in this case, this K_1 and K_2 - these are available to the observer by the company, by the vendor from whom we have purchased our instrument, but it might happen that those K_1 and K_2 values which were the initial values - you know why K_1 and K_2 are required - these are because of some configuration in the instrument. Now, with constant use of the instrument, it might happen that those settings of the instrument, they change. So, the actual K_1 and K_2 are not same as K_1 and K_2 - the actual ones which are there in the instrument - because with the time, with the wear and tear, they might have changed. Now, because of this reason, what happens? There is a constant error in the instrument which we can say as K_1 plus K_2 minus K_1 plus K_2 (Refer Slide Time 19:14), that will result in a constant error always, whatever measurement we carry out, and this kind of error we say as the zero error.

(Refer Slide Time: 19:35)



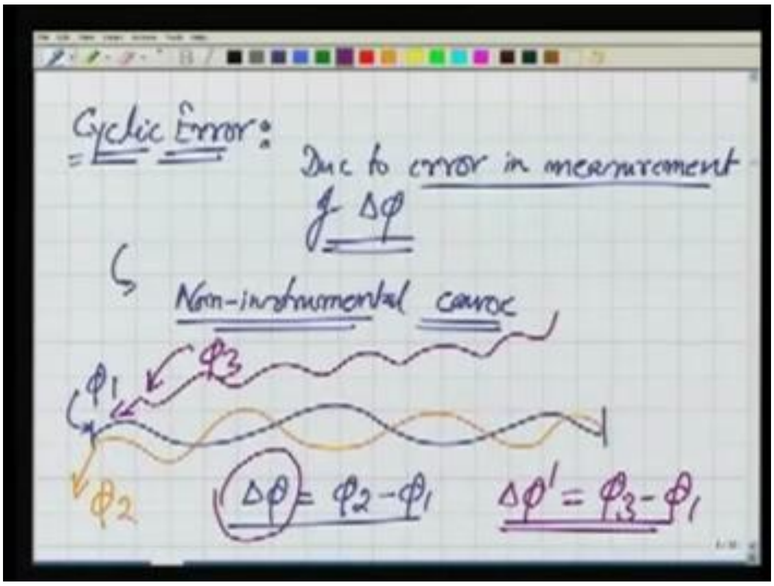
Now about this zero error: can we determine it? That is the question - can we determine the zero error? There is a way. What we do - let us say there is a distance, and this distance is A, B and C (Refer Slide Time 19:48). Let us say AB is 10 metre and this is 20 metre (Refer Slide Time 19:58). These distances are measured on a flat horizontal surface, very accurately. These three distances - we know that it is 10 metres; it has been measured very accurately with some very good instrument or the instrument which did not have any error. Well, what we do, we keep our EDMI over here, and we measure first this distance (Refer Slide Time 20:24). Then, we keep our target here, and again, we measure this distance. Also, we keep our EDMI here and we measure this distance (Refer Slide Time 20:37). Let us see the zero error. As we are talking about, the zero error is 0.3 metre on positive side, because the zero error will have always one direction and a constant value. If it is so, what will happen? The measurement AB will come out to be 10.3, BC will come out to be 20.3 and AC will come out to be 30.3 - obviously, because the error is constant in same direction. Now, using these measurements, can we determine the amount of the zero error? Right now, we are considering that it is 0.30 - 0.30 metre.

(Refer Slide Time: 21:42)



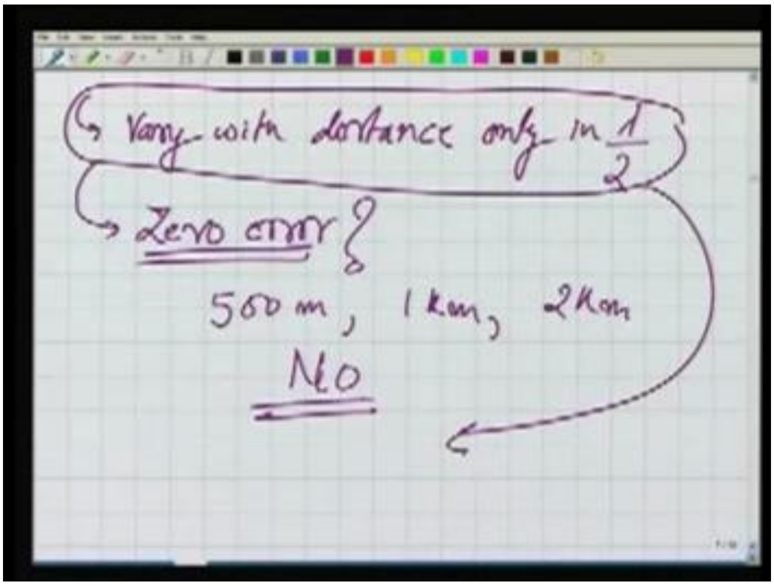
Well, what we do, we can write a simple equation. If you look at that, here we can see that AC is AB plus BC. So, AB plus BC is AC. If I write it further, AB plus BC minus AC - in ideal case, that should be 0, but will it be so if there is any zero error? As we can see in this case, 10.3 plus 20.3 minus 30.3 is not equal to 0 (Refer Slide Time 22:01); that is equal to 0.30 metre. So, just by using this basic equation, we could find the amount of the zero error. So, that is our zero error. Now here, in this case, I took just one observation; only one set of observation here. What we can do, we can repeat these observations - and we can repeat them, for example, that is our length (Refer Slide Time 22:36). We can make many bays (Refer Slide Time 22:39) and the combinations like AB plus BC is AC - many such combinations can be developed here; many such combinations. Now we can write all these equations together, we can solve them by least square and we can find the more true or nearer to the true value through zero error which is more promising. So, that is our error number one: the zero error.

(Refer Slide Time: 23:19)



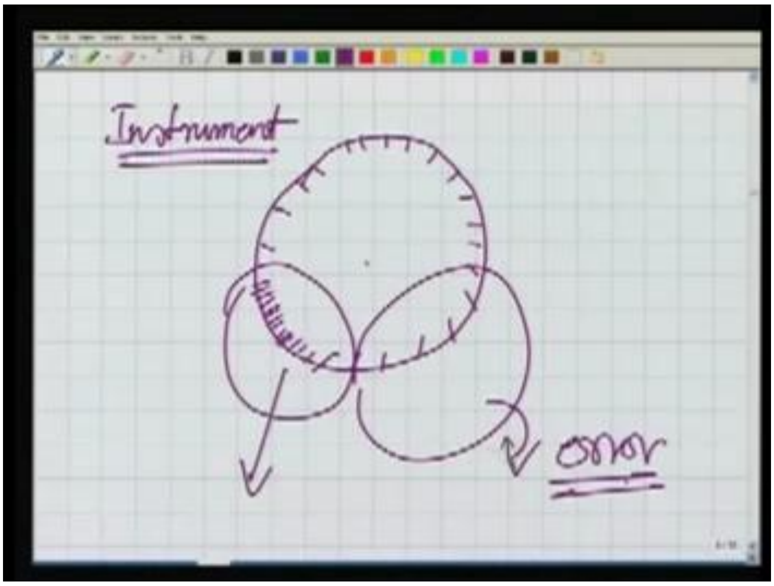
The another error is 'cyclic error'. Now, this cyclic error is because of error in measurement of phase difference. There is something which is there inside, because we need to measure the phase difference and if there is an error in that, it will lead to an error and we say that error as cyclic error. Now, what are the causes; what are the reasons for that? Number one reason is non-instrumental - which is not because of the instrument, but it could be because of some external factors. For example, if we are interested in measuring this distance - our signal will go and will come back - so, while it comes back, what we do, we measure these phases phi 2, and the first phase was phi 1(Refer Slide Time 23:48). So outgoing phase is phi 1 and incoming is phi 2, and what we do, we determine delta phi as phi 2 minus phi 1, and that is the phase difference. Now, this phase difference will give us the distance, but let us say there is some external factor; there is an extra radiation and this extra radiation - or this noise, we can say - it is being captured by the instrument, and it is reaching the instrument at phi 3 (Refer Slide Time 24:40), and this is strong enough to dominate this signal. So, because of that, what will happen? Instead of delta phi, we end up computing phi 3 minus phi 1. So, that is now such different value of the phase difference. So, what we are computing? We are not computing our actual phase difference as we should have - rather, we are computing a different value because of the some extra signal, some other signal, which reaching the instrument, and the instrument is capturing that; instrument is recording the phase of that one - phi 3. Now, what it does, it will lead to the error.

(Refer Slide Time: 25:33)



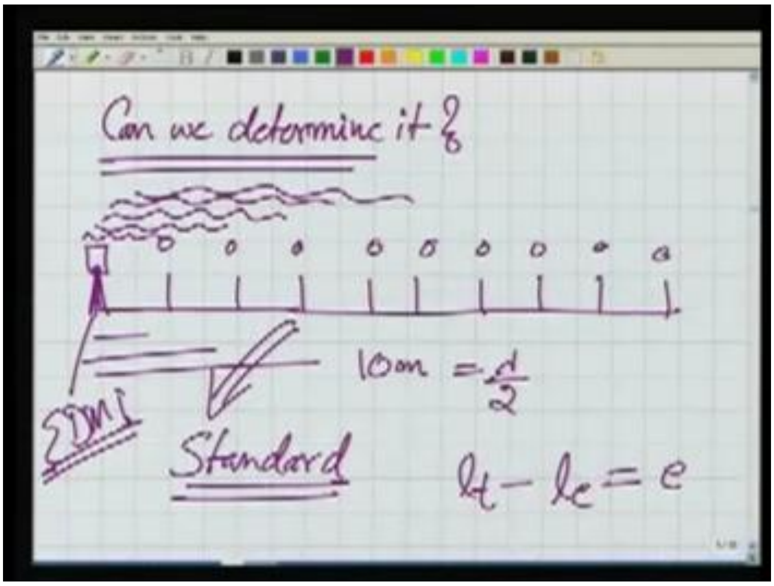
Now, this error, as you can feel, will be limited - it will vary with distance, but only in lambda by 2, because this is cyclic error, only within the lambda by 2 is an error because of the phase measurement. So, only within that one cycle, it will vary - it will not affect anything more in that. Now, it is important to note here, in case of zero error, does it vary with distance? If you are measuring, let us say, 500 metres once, then we are measuring 1 kilometre, then we are measuring 2 kilometres- will the zero error be different in all these cases? No, the zero error will be same because it was constant and having the same direction. Now, about the cyclic error: the cyclic error will vary with the distance, but only within this lambda by 2 - not beyond that.

(Refer Slide Time: 26:43)



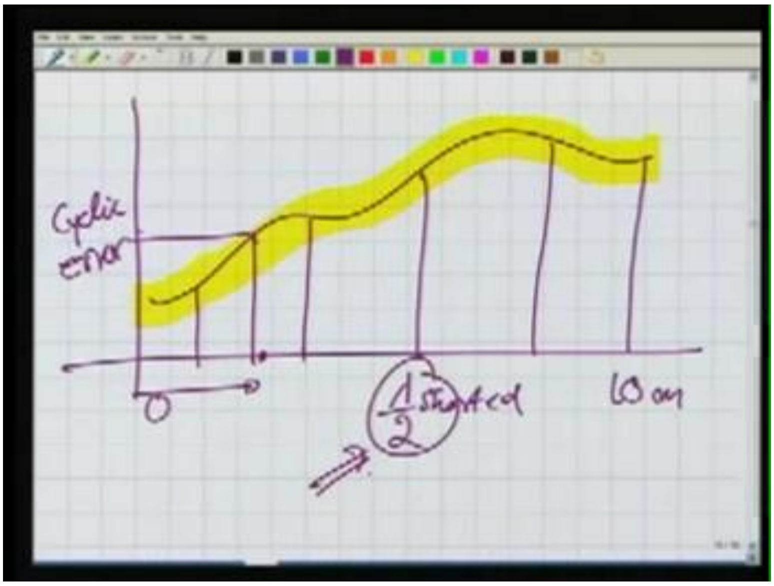
Now, some other reasons for the cyclic error: these are the reasons because of the instrument. Now, what could be that? Instrument is basically measuring the phase difference - the difference in the outgoing phase and the incoming phase - and let us say I am drawing a very rough diagram here just to understand the process; it is not the actual thing. Let us say the instrument uses this particular circle (Refer Slide Time 27:06) for measuring the phases, and these are the graduations (Refer Slide Time 27:09). There are so many graduations here - it is a kind of a scale, a linear scale, by which the phases are being measured. If, because of some problem, these graduations are - they do not follow the linearity - somewhere they are very close apart to each other, while at some other places they are very far apart - still the total number of graduations will be same, but they are non-linear in that 360 degree angle. So, because of this nonlinearity, again, whenever the phases are being measured in those parts where they are very close to each other or where they are very far to each other, when the phase is being measured there, it will lead to the error. So again, this is another way, another cause, of the cyclic error, which is because of the instrument.

(Refer Slide Time: 28:12)



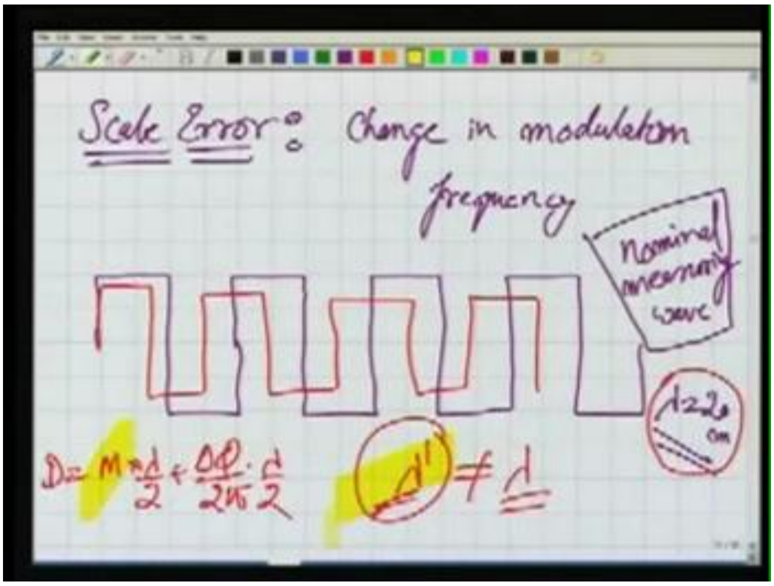
Now, can we determine it? Well, that is the question - can we really determine the cyclic error, or can we - after determination, can we apply the correction? What we do for this, we take a distance - let us say that is the distance (Refer Slide Time 28:31), and this distance is 10 metres, which is, in this case, the measuring unit, lambda by 2. Now, for this 10 metre, at every metre or less than that, what we do, we now keep our EDMI here (Refer Slide Time 28:57), and our targets at all these places (Refer Slide Time 28:59). So, basically, what we are doing, we are measuring all these distances using the EDMI (Refer Slide Time 29:05). Also, this is a standard - I will explain the meaning of this term standard. We can establish any standard in our laboratory. If there is a ground which is flat - horizontal ground - using some very accurate distance-measuring technique, we can establish a standard where there are points 10 meters apart, and at each 1 metre, or maybe within that, we have further these points are located, so this is something which is measured very accurately; it is not going to change with time. So, that is the standard. So, what we are doing, we are checking our EDMI against the standard, because we know all these distances; we know these distances from the standard, the true value. I will not show the true value, but the most probable value of these - we know this, and as well as, from the EDMI also we are measuring this distance. So, what we can say, for example, let us say there is any distance which is the - I am writing not true value, but l_t - let us say, which we know, while the one which was measured by the EDMI is l_e, so the difference of these two is the error.

(Refer Slide Time: 30:39)



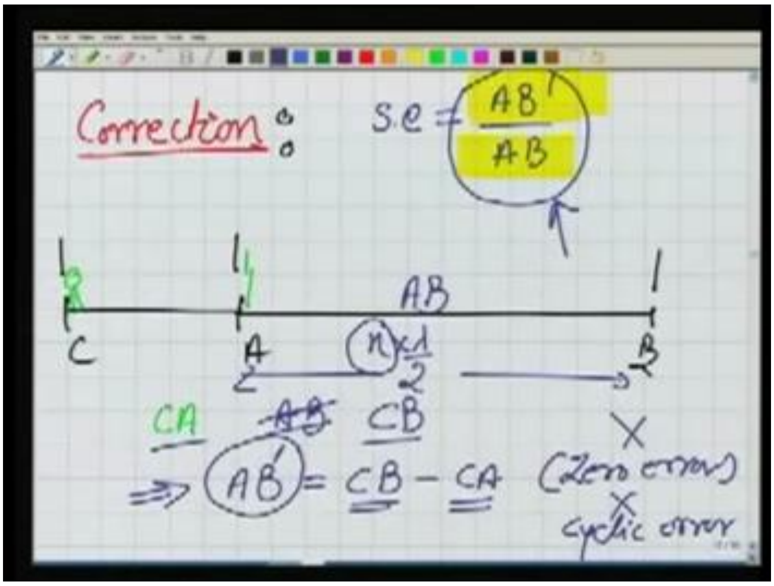
Now, this difference, we can plot: from 0 to 10 metre (Refer Slide Time 30:41) - the error value. It might vary like this (Refer Slide Time 30:52) - whatever. So, at any - and before we conduct this experiment, we should eliminate from our observations with zero error, so this is only the cyclic error. So, for this cyclic error, we can generate a calibration curve like this (Refer Slide Time 31:11) - so that is our calibration curve for the cyclic error. Now, we know that cyclic error will be in only one cycle. So, any distance that has been measured by EDMI, we can apply in that last lambda by 2. This is the lambda short, the shortest one (Refer Slide Time 31:26). In that, we can apply the correction - that is the value of the correction (Refer Slide Time 31:33) - we can apply that correction in the distance which we have measured. So, this is the cyclic error.

(Refer Slide Time: 31:49)



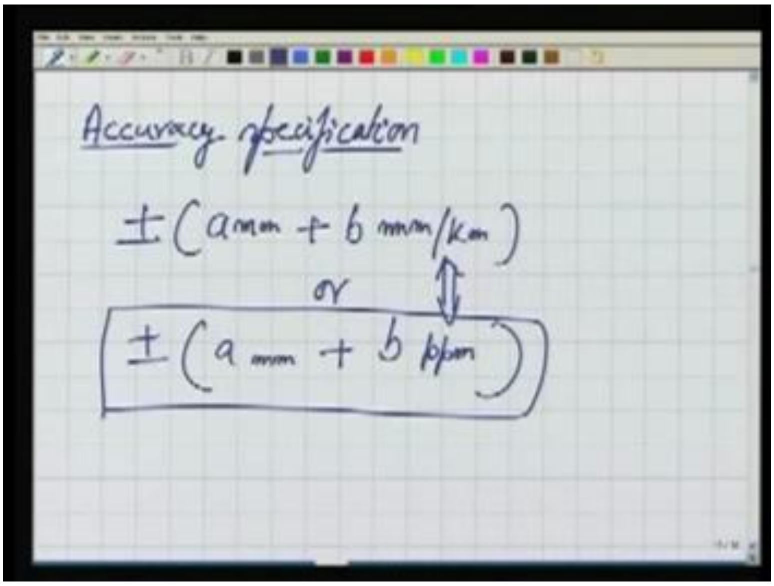
Now, the third error is scale error - what is the scale error? This is basically because of change in modulation frequency. I will explain this term - what is the meaning of this? In order to measure the distance, what we are doing? We are using a wave, and that carrier wave we are modulating, and this is how we want to measure the distance. So, that is my carrier wave (Refer Slide Time 32:16) - sorry, this is my the measuring wave. This is - I am giving a term here - nominal. Nominal measuring wave - nominal measuring wave means, something which the instrument knows. Instrument knows it is firing a lambda by - lambda of 20 metre, that is, instrument knows this thing. But actually, the instrument is firing something else. The actual thing what the instrument is firing different, it is different here. For example, we can say, like this (Refer Slide Time 33:08). It is a different one; it is not the same lambda, so this is lambda dash - it is not equal to lambda. Now, what will happen because of this? In our computations, we are using lambda because instrument knows, instrument thinks, I am firing this particular lambda is equal to 20 centimetre - 20 metre - but because of some instrument problems - this happens when the temperature is more, and the instrument develops some problem - the modulation frequency will change. In those cases, instrument is actually firing lambda dash. So, in our basic equation, when we write our basic equation - D is M lambda by 2 plus delta phi (Refer Slide Time 33:54) -if you are writing this basic equation now. In this basic equation, instead of using lambda, we should use lambda dash - number 1; and number 2 - this angle also changed (Refer Slide Time 34:12). So, what is happening here? Because of this different value of actually fired modulated wave, then what the instrument is thinking? There will be some error in the distance measured. Now, the question is, can we determine it; can we apply the correction?

(Refer Slide Time: 34:32)



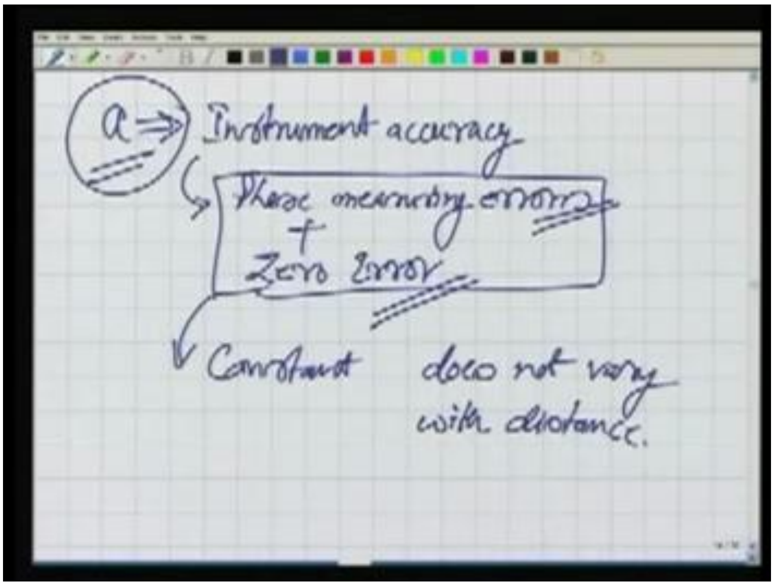
So, to determine it or to apply the correction, what we need to do? Now here, we will do one thing: let us take a distance (Refer Slide Time 35:49), and I am writing this as A, B and C. Now, we measure here using our EDMI. Let us say I keep the EDMI over here, and the target here (Refer Slide Time 35:06), and I measure CA, I also measure AB - sorry, rather, I will write it as CB. Having measured CA and CB, I can determine AB as CB minus CA. Now, what is there in this? I am determining AB using CB minus CA. Once I am doing this CB minus CA, I have eliminated the zero error. So, in this value of AB, there is no zero error. Let us say I write this as, right now, AB dash (Refer Slide Time 36:04). We will see why I am writing AB dash. This AB is also known from the measurement there in the field, or, again I am saying, this is a standard length; these two points AB are on a standard, so we know exactly this value of AB and this is generally equal to n times lambda by 2 (Refer Slide Time 36:26). We have taken these two points, n times lambda by 2, far apart. Now, why we are doing it? Because we know the cyclic error, it varies within lambda by 2, so if you are taking multiples of lambda by 2 or the integer multiples, the effect of the cyclic error will be minimized. So here, when we are carrying out the measurements, over here, the effect of the cyclic error is also minimized, so there is no zero error, no cyclic error, when we are measuring this AB; when we are determining this AB. So, there is no of these measurements. Well, this error, as we are saying that it is called scale error - the scale error, if I write as ‘se’ (Refer Slide Time 37:25), is then given as AB dash by AB (Refer Slide Time 37:29). This AB is known from the standard - we know its actual value - and while this (Refer Slide Time 37:38) is being known by the measurement. And a very special measurement - measurement means, in this particular measurement of AB, we do not have zero error and cyclic error - they are eliminated. So, this particular ratio is called the ‘scale error’ (Refer Slide Time 37:52). Now, one thing you will understand very quickly, as you are seeing here (Refer Slide Time 38:00), if our lambda dash is different than lambda, so in each multiple of the wavelength, in ideal case, we should have been measuring one lambda like this (Refer Slide Time 38:12), but because of this difference in the frequency modulation, our lambda is this much (Refer Slide Time 38:17). So, what is happening? In each bay, in each lambda, we are introducing some error, as we can see here also. So, this error varies with distance; it very much varies with distance - larger the distance, more this error will be, as you can see here.

(Refer Slide Time: 39:17)



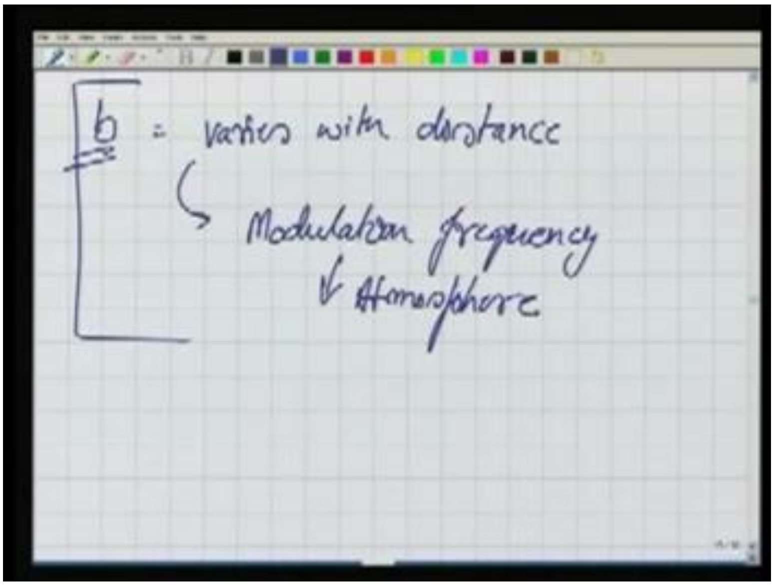
Having seen all these errors in the EDMI, now we will go to another important thing, and we should know about that in the EDMI, because whenever we are buying an EDMI from the market, this is very important. Or, whenever we are working with an EDMI - we have purchased an EDMI from a vendor and we are going to work with that - we should know what kind of accuracies can be achieved with that particular instrument. So, when you buy it from the vendor and when you talk to the vendor, the accuracy specifications of the EDMI are written as - so, we are talking first about this accuracy specification. How do we specify the accuracy of EDMI? The general way, the most general way of doing it as plus-minus 'a_{mm}' - millimetre - plus 'b millimetre per kilometre' (Refer Slide Time 39:33) or plus-minus - same thing here I am writing - 'a millimetre' plus 'b millimetre' (39:47) or rather, I will write it 'b ppm'. So both of these are same; either I write in ppm or in millimetre per kilometre or per part million - this ppm stands for per part million. Now, what these two things are? Mostly, we will find the EDMI accuracy is given by these. Now, what are these things? We will start talking about them one by one.

(Refer Slide Time: 40:35)



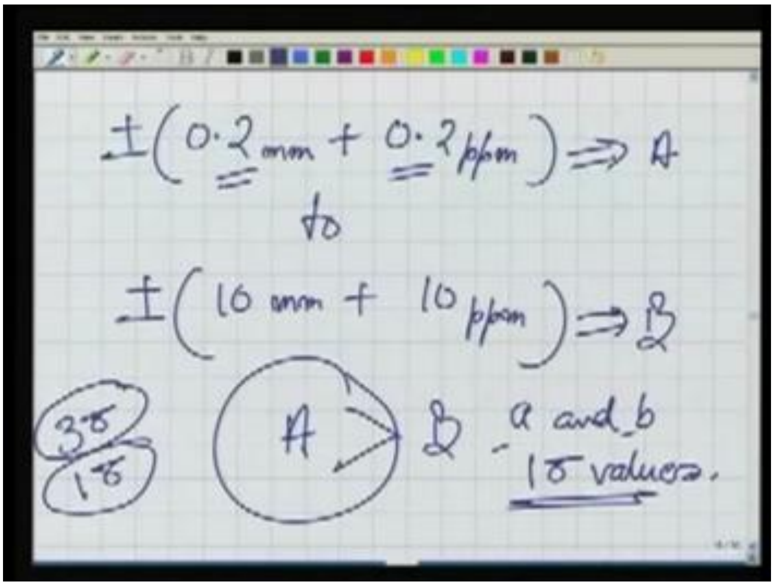
First, we will start talking about 'a'. This 'a' is called 'instrument accuracy or error'. The error in the instrument or accuracy of the instrument - what is the meaning of this? This is dependent upon the phase measuring errors and zero error. So basically, this will remain constant, or we can say otherwise: it does not vary with distance. You have seen it; zero error - it does not vary with the distance, and this phase measuring error only varies in 1 unit distance or the lambda by 2. So, they are basically constant. We take them as constant, and this entire thing is represented in ‘a’ - so we say this the instrument error - an error which is in the instrument; it does not have to do anything with the distance.

(Refer Slide Time: 42:07)



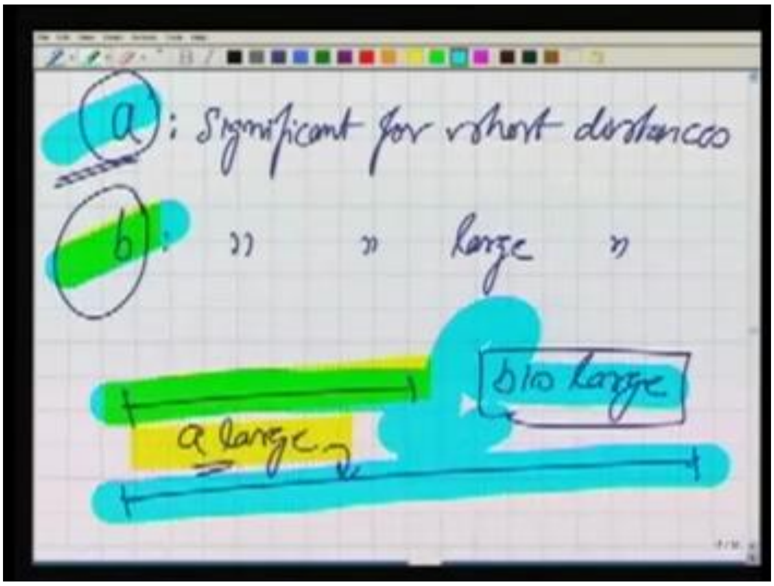
The another one - ‘b’. It is - it varies with distance. Now, this is interesting - we are representing the error in EDMI in two components. One is one which is constant; which is not varying, so this is ‘a’ - it is that error which is in the instrument, inbuilt in the instrument. But other one, ‘b’, is something which will vary with the distance - more the distance which we are measuring, more this error will be; lesser distance, less will be the ‘b’. So, this ‘b’, as you know now, is basically because of problem with the modulation frequency and sometimes, the atmosphere. Now generally, what are these values?

(Refer Slide Time: 43:12)



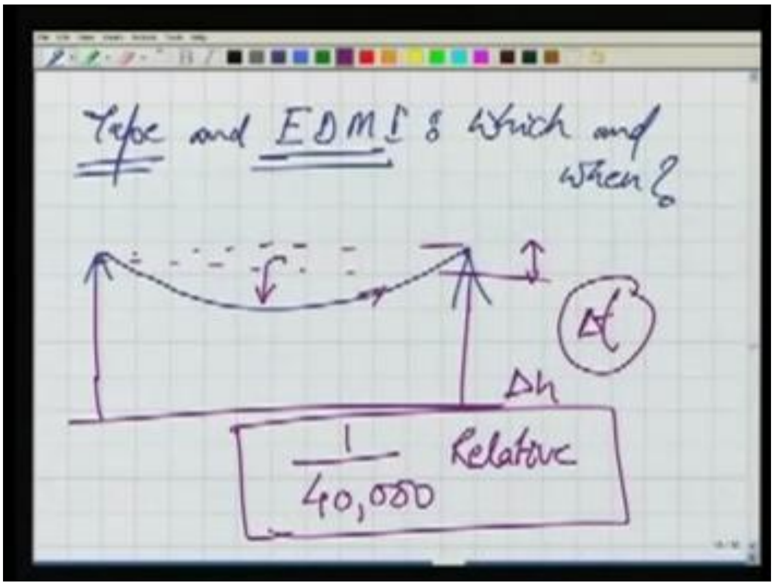
The EDMIs which we get in market - what kind of EDMIs we get? We get the EDMI's as 0.2 millimetre plus 0.2 ppm to 10 millimetre plus 10 ppm (Refer Slide Time 43:13). So, these are the common specifications which you get in market. Now, easily you can guess, out of these two instruments - let us say I write this as instrument A and this, instrument B (Refer Slide Time 43:36). A instrument is definitely better than B - it is better because the error which is there, inbuilt in the instrument, as well as, which is being introduced with the distance, is less here. Now, what are 'a' and 'b'? 'a' and 'b', they are basically the 1 sigma values. We have discussed this already when we are talking about the errors in surveying. We said that, many times, we use the extended deviation to talk about the error in the instrument. So, these are the 1 sigma values, or whenever you are purchasing an instrument; whenever you are talking to a vendor, it is important that we should know what 'a' and 'b' are - are they at 3 sigma, or are they at 1 sigma? So, we have to enquire these things, because by making our enquiry, we will come to know that what is the instrument; what this instrument can do for us; what kind of accuracies the instrument can give us.

(Refer Slide Time: 44:54)



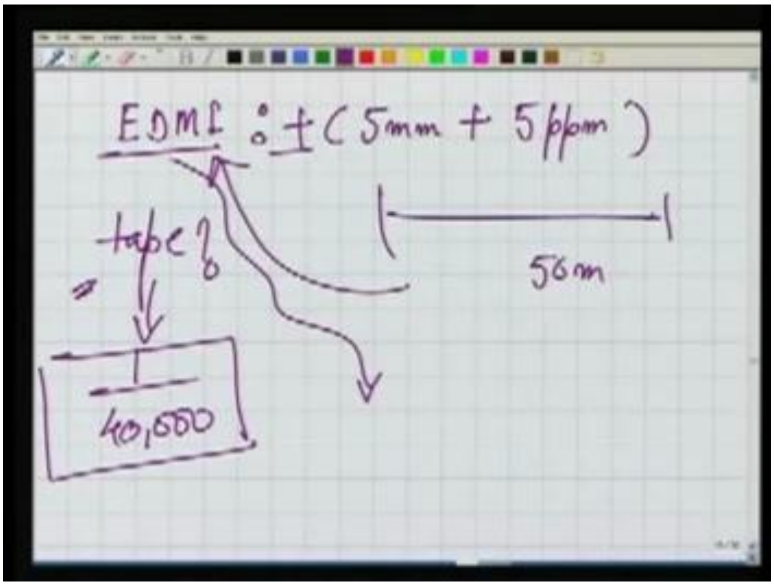
The another thing about the ‘a’ and ‘b’: ‘a’, it is significant for short distances - I will tell the meaning of this; ‘b’, it is significant for large distances. What is the meaning? If you are going for an EDMI and you want to use it for small distances - your job is not to work on large distances - then, you should look for an EDMI which has this small value, while if your job is to go for a measurement of large distances, then this value should be small, because as we have seen here also, we have seen that this ‘a’ - instrumental error - it is constant, and if we are taking a very small distance and our ‘a’ is large, even if the distance is small, this ‘a’ is not going to change. If the distance is very, very large, so this large ‘a’, its impact on this large distance will be less, while the impact of large ‘a’ on a small distance will be more. Similarly, for the ‘b’ - if ‘b’ is large: now in this case, if ‘b’ is large, the impact of ‘b’ - a large ‘b’ - on a short distance will be less, because ‘b’ varies with the distance, while this impact of ‘b’ on a long distance will be more, because more the distance, more will be effect of this ‘b’. So, whenever we are choosing EDMI, we need to know that how it will - the accuracy is given, what is the specification of the accuracy.

(Refer Slide Time: 47:02)



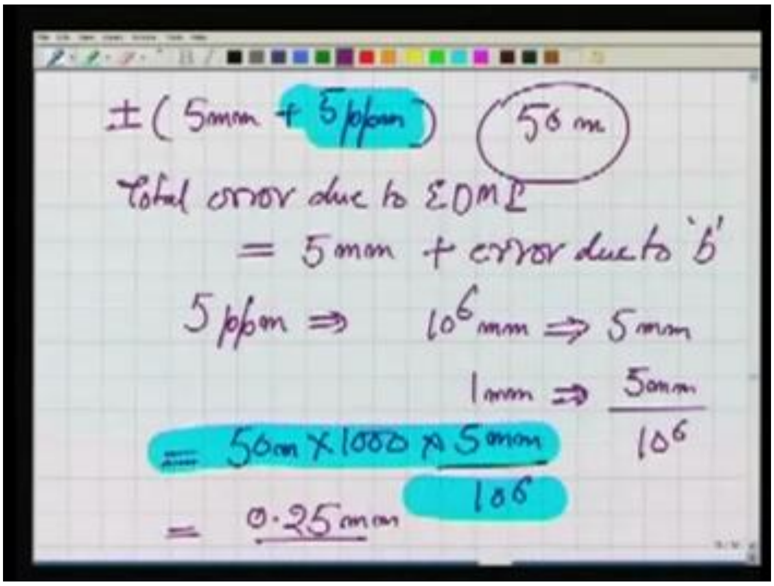
Now, one very important thing here: we are going to compare our EDMI with tape. Tape and EDMI - we are going to compare these two - which and when? If you know about the tape - we have discussed this thing - in the case of the tape, what we do, we carry out our measurements on a catenary (Refer Slide Time 47:25). Now here, we measure the difference in the elevation of these two points also (Refer Slide Time 47:37). So, we apply the correction for this difference in the elevation - whatever the difference in elevation, we apply the correction for that. We apply the correction for the pull, we apply the correction for the sag, we apply the correction for the difference in temperature. So, if we are applying all kinds of corrections in a tape, a tape can give us an accuracy of 1 by 40,000 - this is the relative accuracy or relative precision. This kind of accuracy is possible with the tape, provided we are taking all precautions; we are applying all corrections - for difference in height, for the pull, for the sag - everything.

(Refer Slide Time: 48:35)



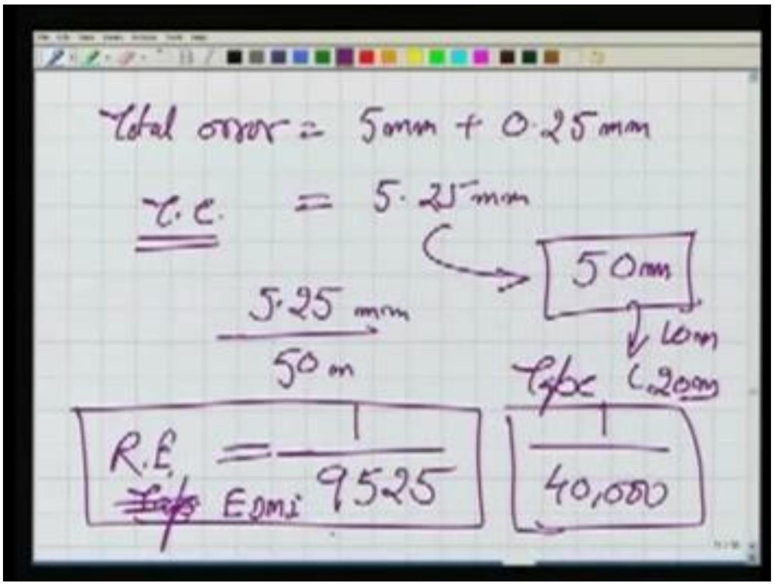
Well, in the case of an EDMI, let us say the EDMI is 5 mm - I should write it as plus-minus because these are the standard deviation values - and 5 ppm (Refer Slide Time 48:38). Let us say there is a distance, and this distance is 50 metre, and we want to measure this distance of 50 metre using this EDMI or using a tape. The question is, which should we use out of these two, tape or EDMI? So we can do a little analysis here, we can do some little, you know, computation, in order to arrive at a particular value. This tape, we know, gives a relative accuracy of 1 is to 40,000 -we know about it. What kind of relative accuracy can be given by EDMI? We will try to compute it.

(Refer Slide Time: 49:41)



Now, in order to compute this, as the EDMI is plus-minus 5 mm plus 5 ppm, and let us say the distance, as we are saying, is 50 metre - the distance which we are going to measure. Now, the total error - total error due to EDMI - what it will be? We are doing very rough computation: it will be 5 mm - 5 mm is always there because this is the error in the instrument; it is a constant error, so it is always there - plus, the error due to ‘b’. Now, what is ‘b’? ‘b’ is this 5 ppm. So, what will the amount of ‘b’? The meaning of 5 ppm is, in a distance of 10 to the power 6 millimetres, there is an error of 5 millimetre. So for 1 millimetre distance, the error is 5 millimetre divided by 10 to the power 6 - that is the error. If it is so, what will be the error in 50 metre? So, the error in 50 metre will be 50 metre - I am converting into the millimetre, so I am multiplying the 1000 - multiplied by 5 mm divided by 10 to the power 6 (Refer Slide Time 51:06). So, we will compute the value of this part (Refer Slide Time 51:23). This value, on computation, it comes out to be 0.25 millimetre. So, what is our total error?

(Refer Slide Time: 51:38)



The total error is - we know total error is 5 mm plus due to ‘b’ (Refer Slide Time 51:46), so 5 mm plus due to ‘b’ was 0.25 mm. 5.25 mm is the total error. Now, we convert it to the relative error, because the distance which we are measuring is 50 metre and this is the error in 50 metres. So, relative error is 5.25 millimetre divided by 50 metre - if you compute this particular value, this comes out to be approximately 1 by 9525. This is important; this is the relative error by tape - sorry, by EDMI; we are doing the computation for EDMI - while by tape, we know the relative error is 1 by 40,000. So, what is the meaning; what do we understand from this? In the case of the tape, in measuring 40,000 thousand metre, the probable error there is 1 metre, while in the case of the EDMI, in measuring around 9525 metre, the probable error is 1 metre. So, the EDMI is leading to more error when the distance measured is 50 metre. This is important here - we are doing all these computations for 50 metre - please mind it. If you go further below it - 10 metre or 20 metre - this will be further larger value (Refer Slide Time 53:49). So, what do we get out of this? We understand from here that if we are using tape for a short distance, it is a good decision, while using EDMI for a short distance is not a good decision. So, whenever there is a short distance, we want to measure it very accurately. Still, it is advisable that yes, we apply all the corrections and we measure the distance using tape, or if you are using the EDMI, we should try to apply all the possible corrections for everything, and our EDMI instrument has to be accurate. We should apply the corrections for this ‘b’ also. If you can apply those corrections, still with the EDMI, we can measure good, accurate, short distances but generally speaking, looking at the EDMI, the way it comes, with those errors ‘a’ and ‘b’, it is not as good as tape for short distances.

So, what we have seen today? We saw the targets or the reflectors - the passive ones - one was the retro-reflective paper, the other one was having a prism. Then, we saw what was the, you know, utility of that K_1 and K_2 - why they occur, K_1 and K_2. The value of K_1 in case of, if the reflector is natural reflector - just the wall; the value of - I am sorry - the value of K_2, rather. The value of K_2 in case of a wall will be 0, because there is no prism involved. This prism comes in picture when we are using the passive target. Then, we started talking about the errors in EDMI, where it is very important we should know about the errors - what are the sources? The errors could be because of the human being who is doing the survey; it could be because of the instrument - instrument has got something wrong; it could because of the nature - if the moisture is too much there, we have not taken the atmospheric measurement, so we are not able to apply the corrections for the actual velocity of light, so they are errors, these are the natural source of the errors; then we look into some common errors or mostly, you know, major kind of errors. These were the zero error, when the K_1 and K_2 values, which are given by the vendor or the company are no more valid, because instrument has got, you know, wear and tear, and this K_1 and K_2 - these things have changed. If you remember this target with the prism, many times, it happens: when you are working with this in the field - it will fall. If it falls, the arrangement of the prism and the target will change. So this is the target rod (Refer Slide Time 56:35); earlier, the prism was here (Refer Slide Time 56:37), now it has slightly changed its position. So, what will happen? It will change the value of K_2 - the target correction - so there will be a zero error. So, we should know about that zero error, and we have seen a way how we can determine it - using a standard. Then, we talked about the cyclic error. Cyclic error - the problem with the phase measurement - and we can determine this also; we can apply correction for this. Then finally, we have talked about the error which was the scale error, something which varies with the distance: larger the distance, more is the scale error. It was because of change in modulation frequency. Then finally, we looked into the specification of the instrument -how do we specify the accuracy of the instrument? When you go to a literature, literature provided by the vendor of the instrument - you see this is how the accuracies are specified for EDMI - what is the meaning of that? We discussed that. And finally, we saw that, for measuring a short distance - you know, 30 metre, 25 metre, 10 metres - a tape is better than the EDMI.

Thank you very much.