Industrial Instrumentation
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Lecture - 25
Ultrasonic Sensors

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Welcome to the lesson 25 of industrial instrumentation. In this lesson, we will consider a ultrasonic sensors, ultrasonic sensors; ultrasonic measurements of flow velocity or the ultrasonic based flow velocity we have discussed sometimes back. But in this particular lessons, we will basically use the, we will discuss the basic principle of the sensors and the how the transmitters, what is the principle of transmitters? It is equivalent circuits. How the receiver works and the various applications of the ultrasonic sensors like level measurements, a crack detection as well as the biomedical applications, where the ultrasonic sensors plays a great role. So, to that part we will discuss in this particular lesson. Let us look at the contents of this lesson.

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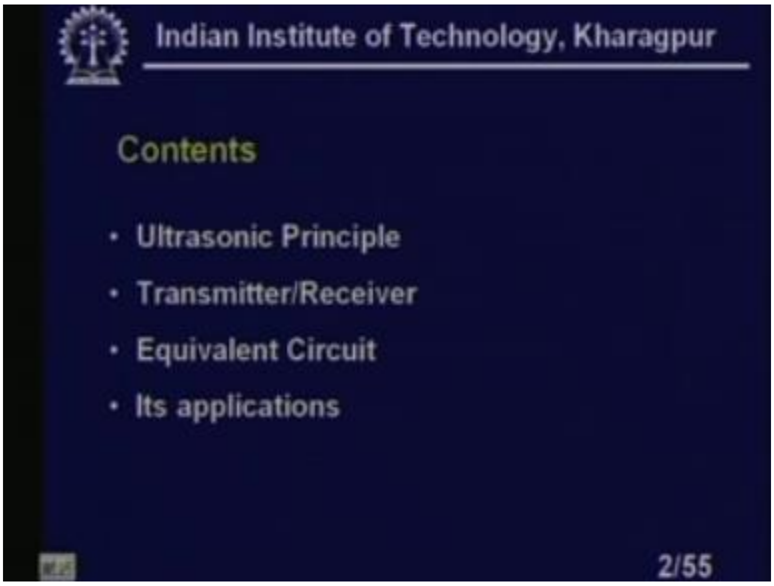

Contents looks like ultrasonic principle how the, what is the principle, how it works? That is actually we will discussed here, then transmitter receiver we will discuss in details. Then equivalent circuit of the ultrasonic sensors we will discuss then its applications both the level measurements crack detection as well as biomedical applications we will all discuss in this particular lesson.

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Ultrasonic sensors, if I look at the ultrasonic measurement system consist of an ultrasonic transmitter. The transmission medium and ultrasonic receiver whenever there is ultrasonic sensor there must be a transmission medium and ultrasonic we will see that later on that ultrasonic is a very poor transmission in air. So, medium there must be some medium, might be water, might be some steel, might be some alloy and so on and so forth. Especially the ultrasonic, I mean signals we will see that it is a great transmissions and the transmission extremely good in the case of. Because ultimately we need to we need some receiver the where the signal will be received either the same signal can be used as a same transducer can be used as a receiver. So, in all the cases there should be a good transmission; that means, transmission power should not be lost. Substantially,, so that we will not it is not possible to detect either by the separate I mean receiver or by the same receiver, which is transmitting signal some time back like that. The commonly used ultrasonic sensors are the piezoelectric sensing element. These are most commonly used.

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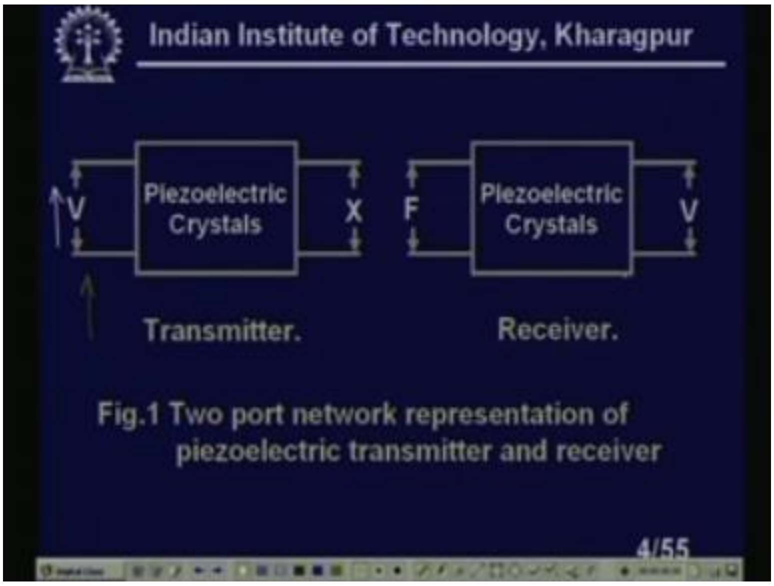

You see here in the figure we are showing the piezocrystals. We are applying here let us look at, you see here, if I you see here I am applying the signals. Let me take this one applying a voltage signal here, I am getting a force here, right. And it is reversible you can see that if I apply the force I will get a voltage. That is the typical principles of the ultrasonic sensors or the piezoelectric crystals I should say right. It is a typical I mean we are using that properties of the piezoelectric crystals to generate the ultrasonic signals, right.

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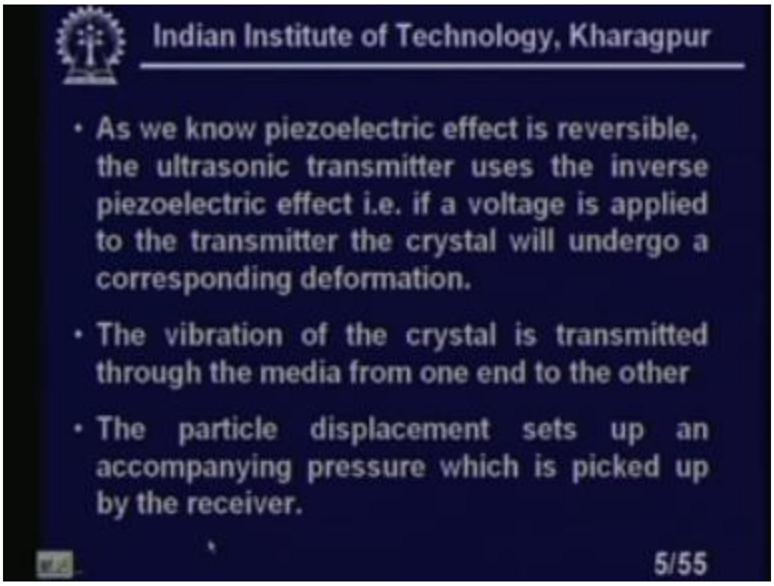

As we know piezoelectric effect is reversible. The ultrasonic transmitter uses the inverse piezoelectric effect as I just right now I told. That that is if a voltage is applied to the transmitter, the crystal will undergo a corresponding deformation, right. If I apply a voltage to a crystals, so there will be deformation of the crystal. So, how can I utilize? Let us look at you see I have I have a crystal here.

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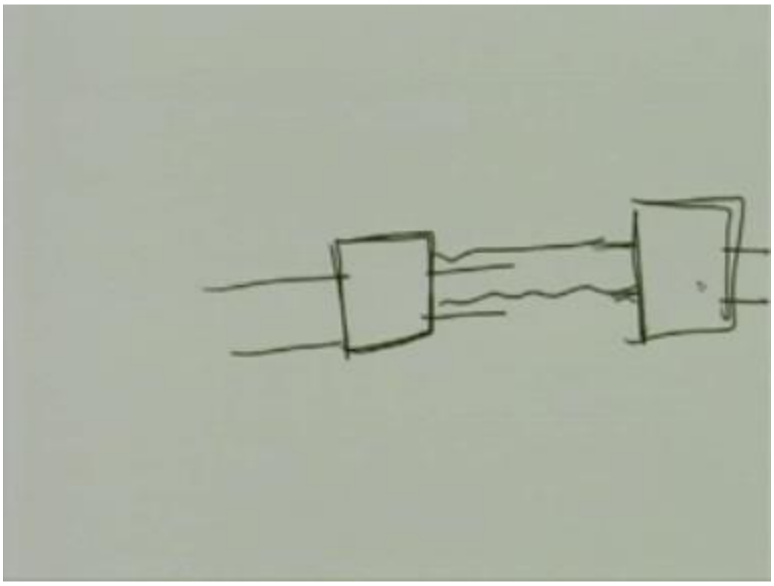

I am taking a different pen, crystal here. So, I have applied the voltage, right. If I applied the voltage; obviously, what will happen? I will get a vibrations on this side mechanical vibrations. So, these vibrations now if I applied AC; obviously, if I applied a high frequency AC here I will get a vibration on this side. So, these vibrations will be transmitted on a medium. Now, if I receive if I put when on the receiver on the other side. So, this will also will vibrate with the same frequency, because there is a movement of the particle movement of the medium. So, obviously, this will I mean this I should say the direct, I mean indirect method indirect way that; that means, if I am applying a voltage and I am getting a force. And now, the force is in imposing on this crystal which is the receiver and I am getting the output voltage.

This is basic principles of the ultrasonic transmitters and receiver though sometimes we will see that the same crystals are utilized for both transmission, and for receiving the signals, right. The vibration of the crystal is transmitted through the media from one end to the other which just I have shown that the there is a vibrations and the signal ultrasonic signals will move through that medium. Basic ideas I mean all these I am not discussing because already we have discussed. We have also we have I mean draw the I mean discussed the basic flow meters using ultrasonic sensors. Here actually I am going more on the sensor side; that means, how actually what is the equivalent circuits, what is the, what type of signals it will generate? What are the basic application?

I mean that though that type of things we will discuss in this particular lesson. The particle displacement sets up an accompanying pressure, which is picked up by the receiver, right. Just I shown that is it is a particle vibrations, like it will . So, this I have a receiver this will also vibrate, because wave will the ultrasonic wave will transmit through the medium. So, it is received by the that I mean that receiver and it will get the output signal. It might be the; however, it might happen in the separate also. Suppose I am giving as a transmitting a signals which is a burst of signals, a short waves I am transmitting. So, it is getting reflected during transmission it is working as a transmitter. So, one it is reflected and coming back here. So, I am if this I can use as a receiver, right.

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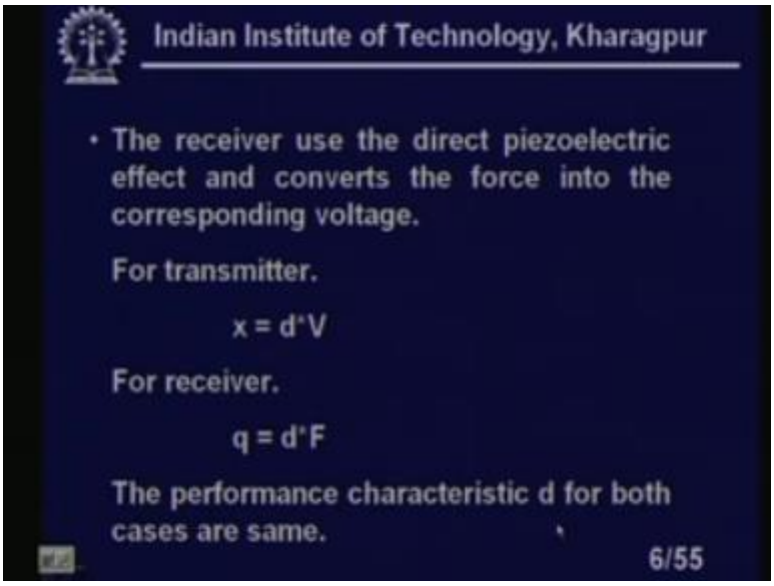

The receiver use the direct piezoelectric effect, because I mean if you I mean if I use the term that if the with the electric where with the electric voltage I am applying I am getting the force that is indirect. So, the receiver use the direct. So, the receiver will use the direct method, right. So, one is indirect another is direct it is nothing it is a reversible process that I want to mean, direct piezoelectric effect can converts the force into the corresponding voltage. For transmitter I use some notation x equal to d multiplied by V and for receiver q equal to d multiplied by F. The performance characteristic d for both the cases are same, right.

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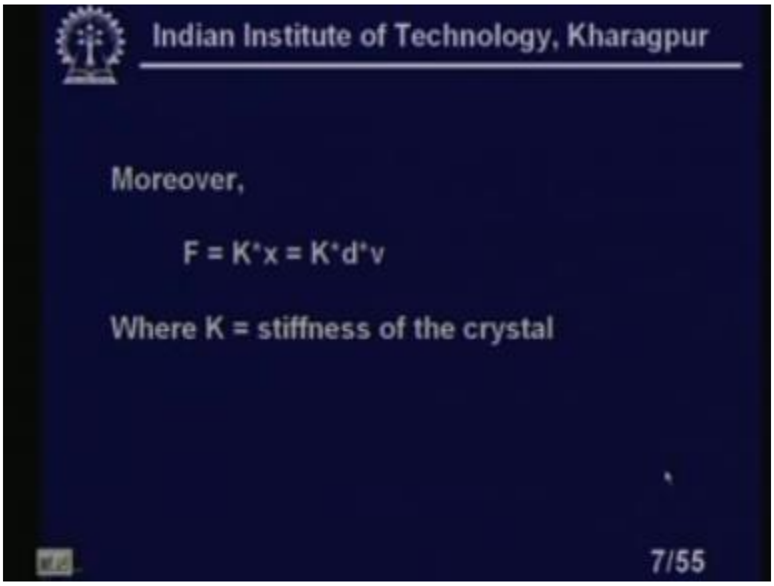

Moreover F we can write K multiplied by x K into x into d into v, where K is the stiffness constant of the crystal.

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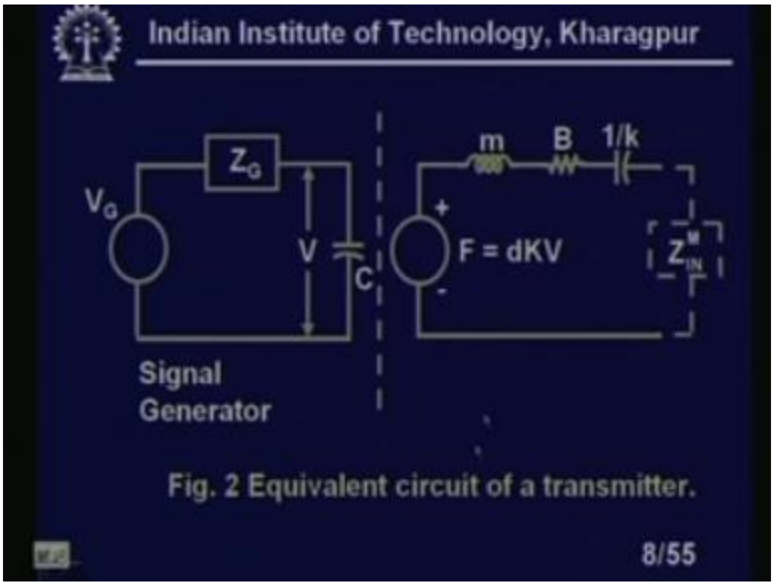

This is the equivalent circuit of a transmitter. I see we have a signal generators, on the other side we have m B 1 by K what are these regions will be shown in the next slide this is the equivalent circuit of a I mean piezoelectric transmitter, right which is actually we ultrasonic transmitter, I should say. So, its contrast in context with the, I mean piezoelectric crystals.

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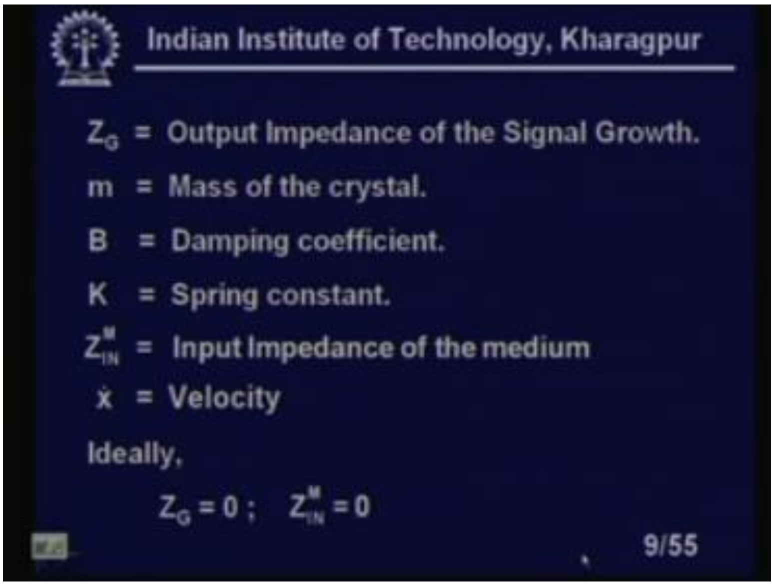

I am discussing all this where you see the ZG the output impedance of the signal. So, let me go back again ZG, ZG is here on the generator side, output impedance of the signal growth, mass of the crystals m, damping coefficient B, K the spring constant. ZMIN is the input impedance of the medium. X dot is a velocity and ideally we can assume always ZG equal to 0 and ZMIN. That means, output impedance of the signal growth is 0 and the input impedance of the medium is also 0.

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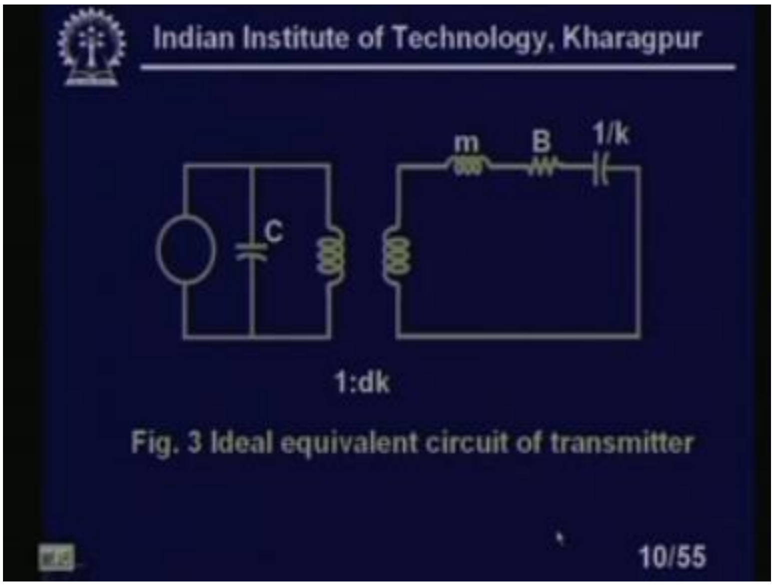

So, ideal equivalent circuit of the transmitter looks like this, right. So, taking account the other with what we have assumed.

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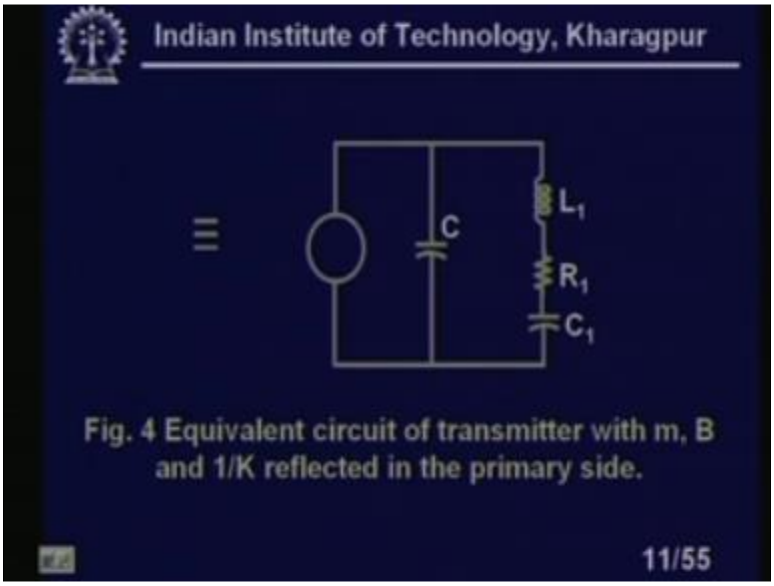

Now, this is the equivalent circuit, this is equivalent circuit of the transmitter with m B and 1 by K reflected in the primary side. If I reflect in the primary side; obviously, I will get L 1 R 1 C 1.

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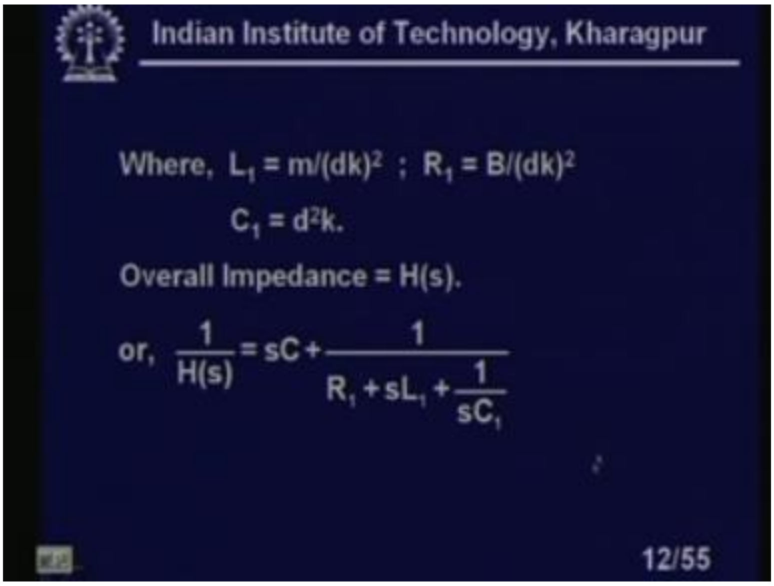

Where; obviously, when I reflect I mean the primary side, what is the relation between the I mean what we tried previously in the secondary side and what it has now in the primary side? That was been related by the, I mean I mean some coefficients which is decay. L 1 equal to m upon dk square R 1 equal to B upon dk square and C 1 equal to d square into k, right. Now, overall impedance I should say 1 by Hs or 1 by Hs SC plus 1 upon R 1 SL 1 plus 1 by SC 1.

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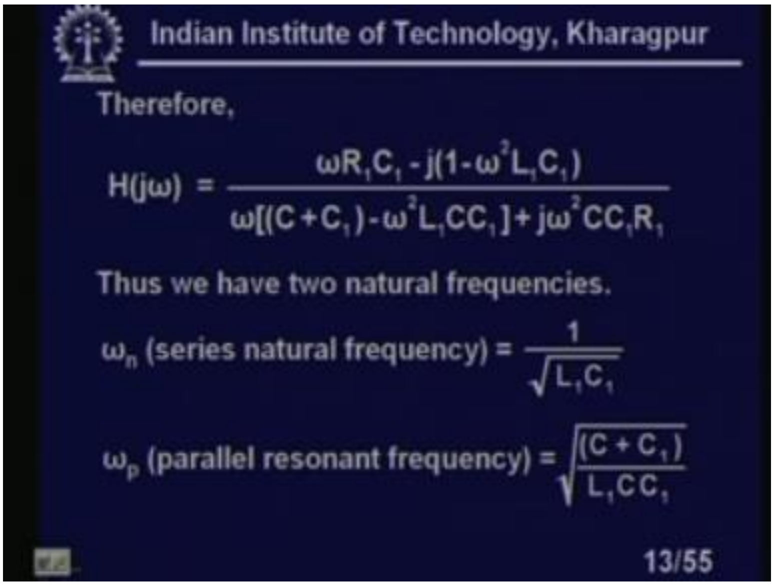

Therefore, I can say that H j omega if I write in the j omega domain. So, omega R 1 C 1 minus j all inside 1 minus omega square L 1 C 1, upon omega C plus C 1 minus omega square L 1 C C 1 plus j omega square C C 1 R 1. Thus we have 2 natural frequencies. series natural frequency which is 1 upon root over L 1 C 1. And the parallel resonant frequency omega p root over C plus C 1 upon L 1 C C 1 all another square root obviously.

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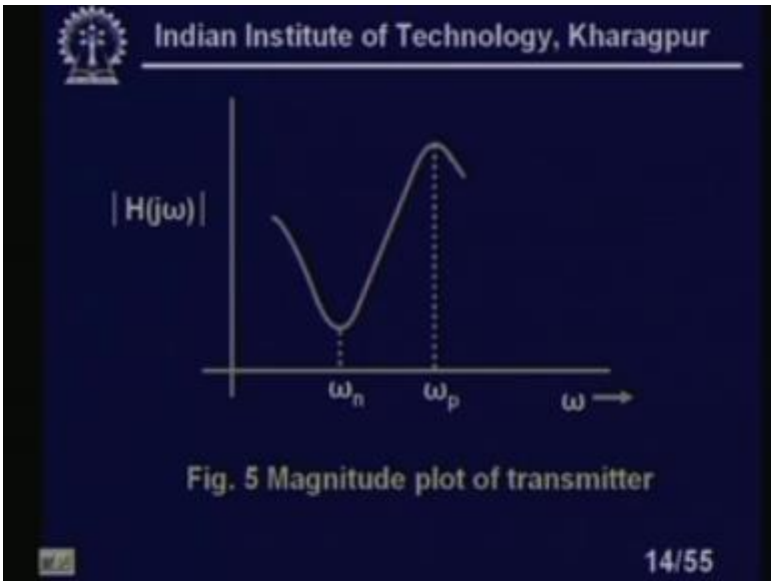

Now, you see the magnitude plot of this transmitter is like this one, right. It has significant I mean there is some significance of this plot which will be discussed later on.

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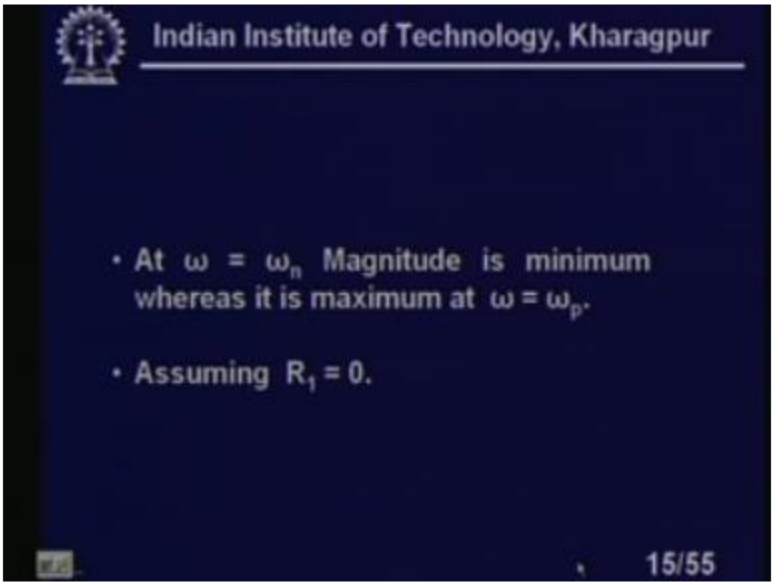

And the where at omega equal to omega omega n natural frequency magnitude is minimum whereas, it is maximum at omega equal to omega p assuming R 1 equal to 0.

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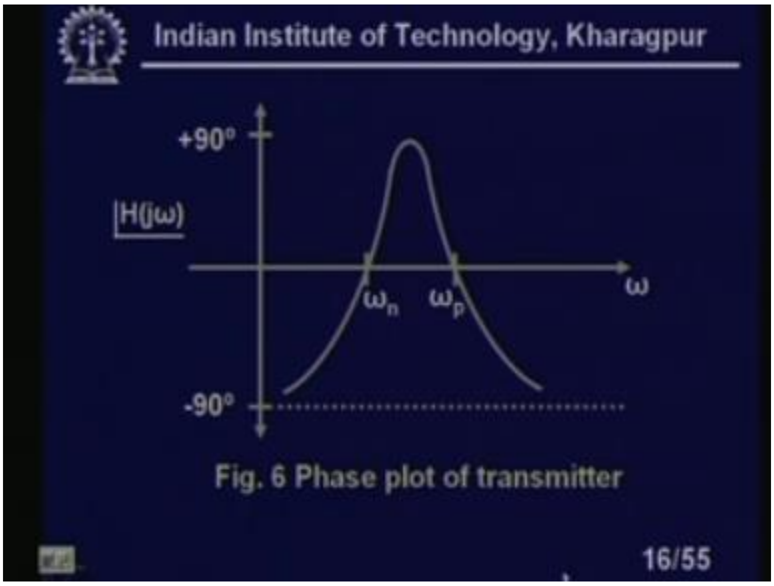

You see this is the phase plot of the transmitter. So, you can see within omega n omega p it is a 90 degree plus 90 degree phase shift, and outside that range it has a minus pi by 2 phase shift what does it mean?

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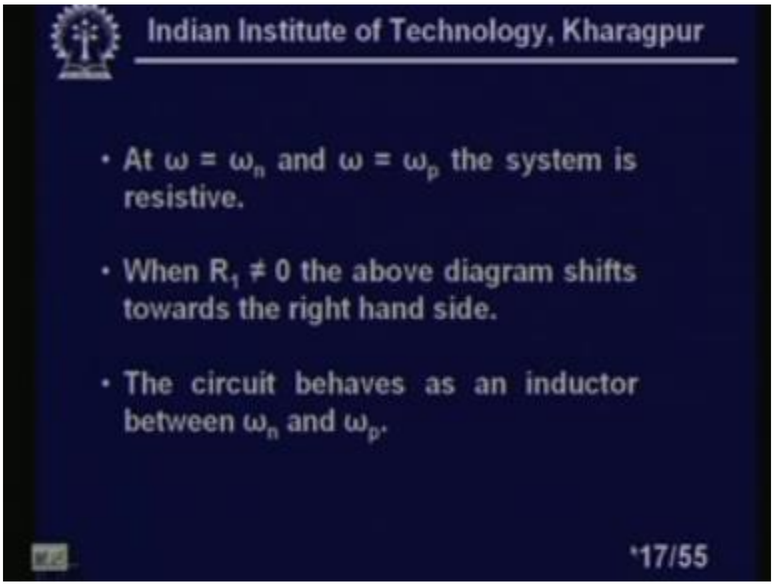

At omega equal to omega n omega equal to omega p the system is resistive this is most important. And when R 1 not equal to 0, the above diagram shifts towards the right hand side. So, this you see that is working is resistive sensors. At omega equal to omega p, the system is resistive and when R 1 equal to 0, the above diagram shifts towards the right hand side. The circuit behaves as an inductor between omega n and omega p, clear? In some part it is I mean resistive in some part it is inductive.

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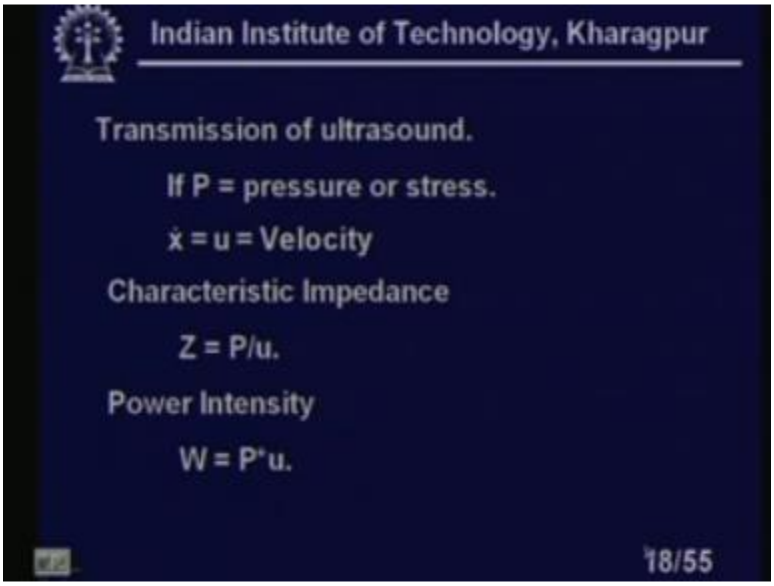

Transmissions of ultrasound; how will you transmit this ultrasound signal if P is the pressure or stress and X dot equal to u is the velocity, because X is the displacement. So, we have taking the derivative of that. So, the characteristic impedance Z equal to P by u. the power intensity W equal to P into u.

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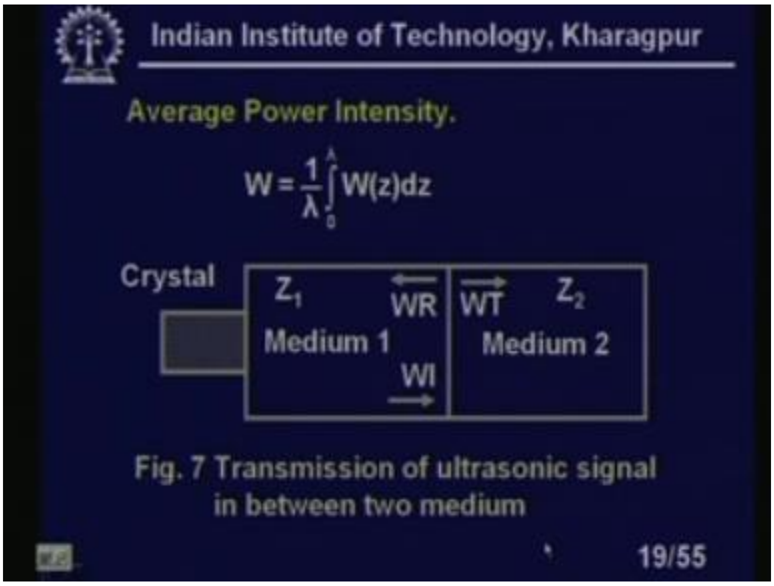

Average power intensity, is given by W equal to 1 by lambda integral omega z dz lambda over the integration of the limit lambda to 0. It looks like this you see the transmissions of ultrasound signal between 2 medium. You see the medium 1 and this is medium 2. This is crystals this is the reflected wave. We will see the regions what are the regions.

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Where Z 1 is the characteristic impedance of the medium 1.What is Z 1? This is Z 1. Z 2 is the characteristic impedance of medium 2, right. And WI is the incident power intensity and WR the reflected power intensity and WT is the transmitted power intensity.

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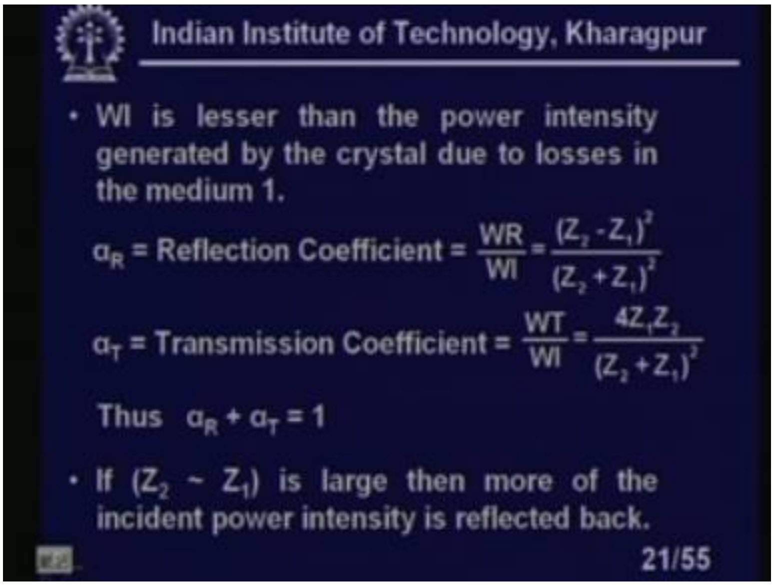

WI is the lesser, lesser than the power intensity generated by the crystal due to losses in the medium 1, right. Obviously, there will be some loss in the medium 1 and alpha R is the reflection coefficients which is given by WR by WI equal to Z 2 minus Zone the whole square upon Z 2 plus Z 1 square. Alpha T is the transmission coefficient WT by WI 4 Z 1 into Z 2 Z 2 upon Z 2 plus Z 1 the whole square and; obviously, alpha R plus alpha T reflected and transmission. I mean if you take this coefficient; obviously, this two will be one if there is no absorptions, right. If Z 2 in minus Z 1 is large than the more of the incident power is intensity is reflected back, right.

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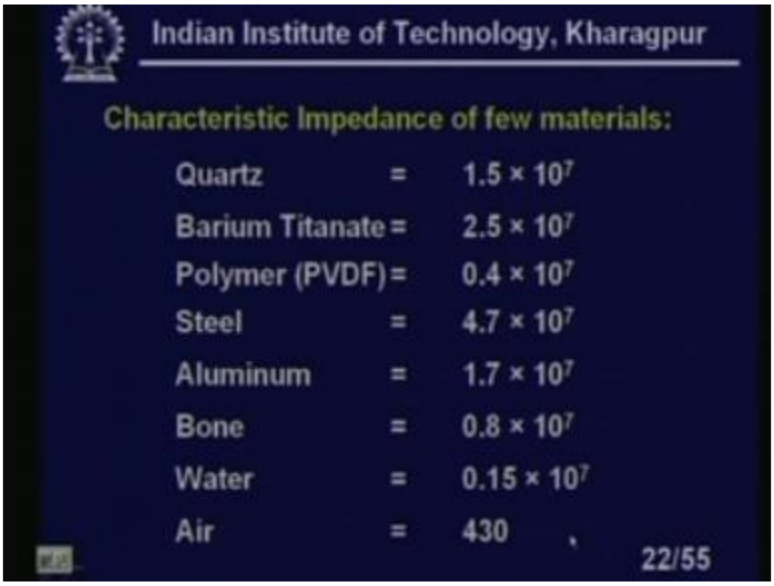

So, the characteristics impedance of the few this you see the very important while you will find you will see that while using this ultrasonic sensor for the level measurements, right. If Z 2 minus Z 1 is large then more of the incident power it will be reflected back from the mediums 2, right. Using this principle, we will make the level sensors, right. So, this is the typical property even though sometimes it is feels like that this is a bad quality. But this property will be utilized to make a very good sensors of the level measurements as well as crack detections in a metal, clear. Now, characteristic impedance of the few materials we will now drawn down some characteristic impedance of the few materials Quartz 1.5 into 10 to the power 7 and barium titanate 2.510 to the power 7. Then polymer PVDF we are using all sin notations please note 0.4 into 10 to the power 7, steel 4.7 into 10 to the power 7, the aluminum 1.7 into 10 to the power 7, bone 0.8 into 10 to the power 7, water 0.5 into 10 to the power 7, air 430 only, right. So, this property of the air will be utilized to meet the good level measurement of any liquid, most of the liquids.

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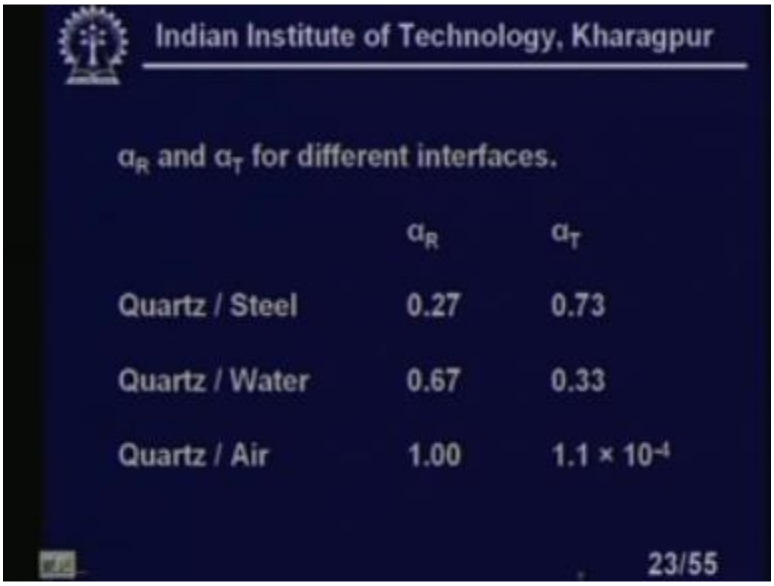

So, we will define I mean the liquid is good, but in the most of the cases I mean offering I mean transmit I mean characteristic impedance alpha R and alpha T for different interfaces. There are 2 interfaces of the 2 material media 1 and medium 2, alpha R and alpha T for the different mediums will be this will give you how you can interface 2 actually 2 different medium while you are transmitting the signal from medium 1 to medium 2, right. So, that is the reason the alpha R and alpha T is necessary. So, this is the 2 different we will take the combinations of the 2 materials, right. See, quartz steel;, so it is 0.27 0.3 quartz water 0.67 0.733; that means, if you want to transmit, right. So, this is reflected is the more than the, I mean transmittance and here you see the quartz the reflectance is less than the transmittance. And quartz air; obviously, extremely poor see 1 and 1.110 to the power minus 7 into 10 to the power minus 4.

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Thus we can say that the air is a poor choice for transmission of ultrasound waves, right. As a difference of the characteristic impedance of the air with others is very large, right PVDF is the polymer actually is used for biomedical applications.

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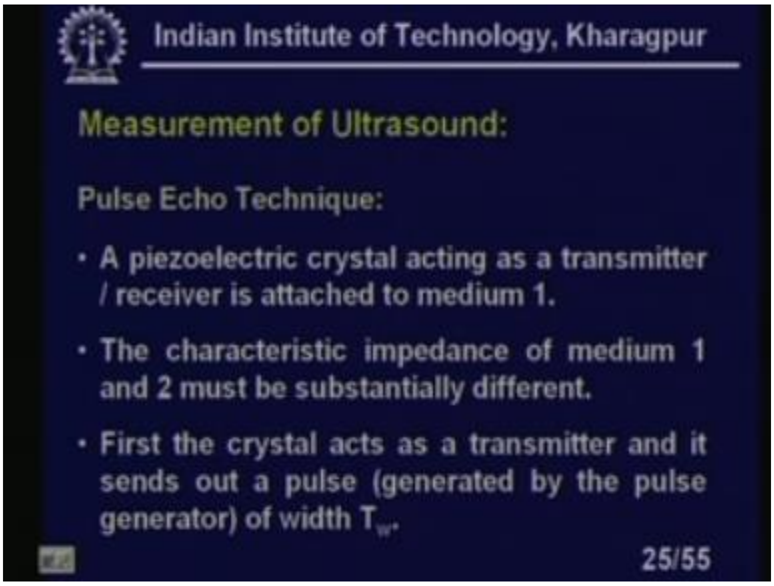

So, measurement of ultrasound. Pulse echo technique, is a piezoelectric crystal acting as a transmitter receiver is attached to the medium 1, we will show the diagram. The characteristic characteristics impedance of medium 1 and medium 2 must be substantially different, otherwise it cannot be reflected. First the crystal act as a transmitter and it send out a pulse. It is a burst of signal I mean burst of pulse I mean it is very short duration pulse. And it will remain silent for some time, until unless I will see all the signals all the reflected signals, right. You will find you will get a repeated reflected signals. We will take the first one either I mean received signals which has highest intensity other subsequent signals reflected signals we have low intensity, right generated by the pulse generator width Tw.

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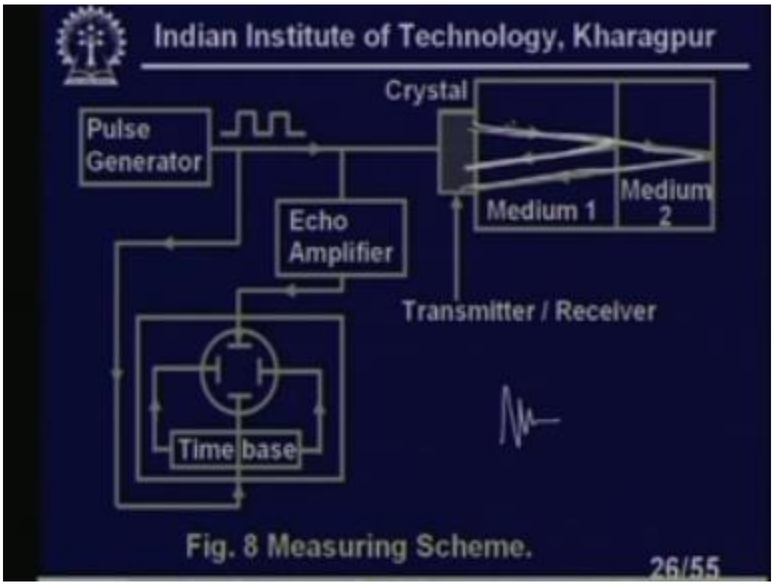

You see this is here we are measuring scheme of ultrasounds. We are showing one time base here it is same as the oscilloscope, oscilloscope as you know we have a time base there also. So, all together for there also we have I have 2 medium medium 1 and medium 2. We have just discussed these I mean alpha R and alpha T for the 2 different mediums. The 2 medium you see 1 reflected from this side, another 1 reflected for the medium. So; obviously, this will take more than time and; obviously, intensity. So, here you will find the intensity is much more. And if the first signal you see the signal will come. So, it will first go sorry. So, it will signal will go and reflected back, after I mean this signal again will come and reflected back. Obviously the first the shortest time will be this signal, right. Because ultrasounds will transmit and will silent for some time, right, until unless we will make all the measurements and next time again, we will transmit the signals.

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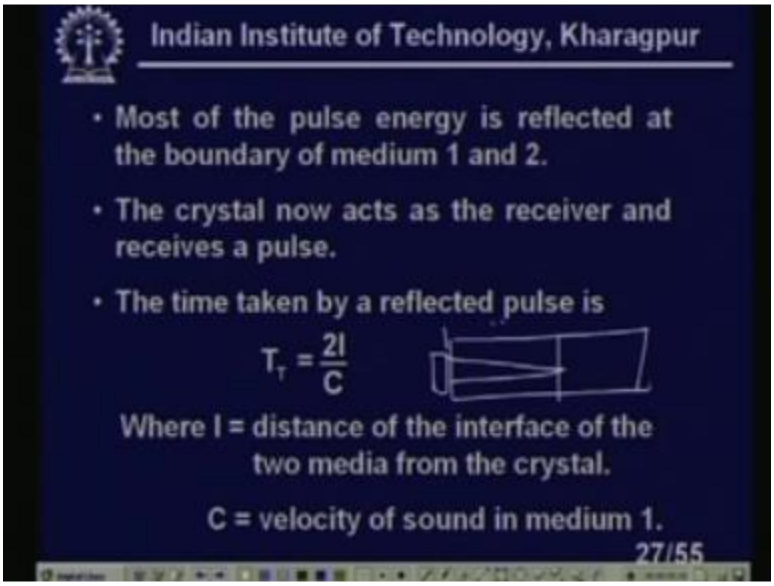

Most of the pulse energy what is this I mean the surprise what is echo amplifier echo amplifier is nothing, it is an amplifier. It is I mean operated only for the time when the first reflected signal will come. Because the signal you may need the amplification that is the reason I need an amplifier here. So, that is the echo signal; that means, the reflected back signal will be amplified and pushed here, hence we have pulse generators which will give you in the time base. It is in the vertical signals in the echo amplifier the signals. What is the signals which is coming at the vertical plate? That is the signal that is reflected ultrasonic waves are coming in the vertical path. Whereas, the time base we are giving in the horizontal path. Principle is same as they have seen in the oscilloscope, right. Most of the pulse energy is reflected at the boundary of medium 1 and 2, clear? What is that most of the pulse energy will be reflected here?

So, signal will come it will be reflected back and will come down here, right. The crystal now acts as a receiver and receive a pulse, right. Initially transmitted and remain silent. It will not transmit any signals, until unless the signal is coming back from the receiver from the reflected surface. That means, the junctions of the 2 surfaces 2 different medium will work as a reflector of the ultrasonic waves. The time taken by the reflected pulse is TT equal to 2 I upon C, right. What is y 2? Because it will go and it will reflected back. What is 2 l? If you say it is l small letter or 2 I whatever, it. So, it is the length of the medium 1, where I is the distance of the interface of the 2 medium from the crystals, right. What is that? Let us look at I have reflected like this 1. So, I have a 2 medium is here right. So, I am transmitting the signals. So, it is signal is coming reflected back this is our l I, right. And C is the velocity of sound in medium 1, clear?

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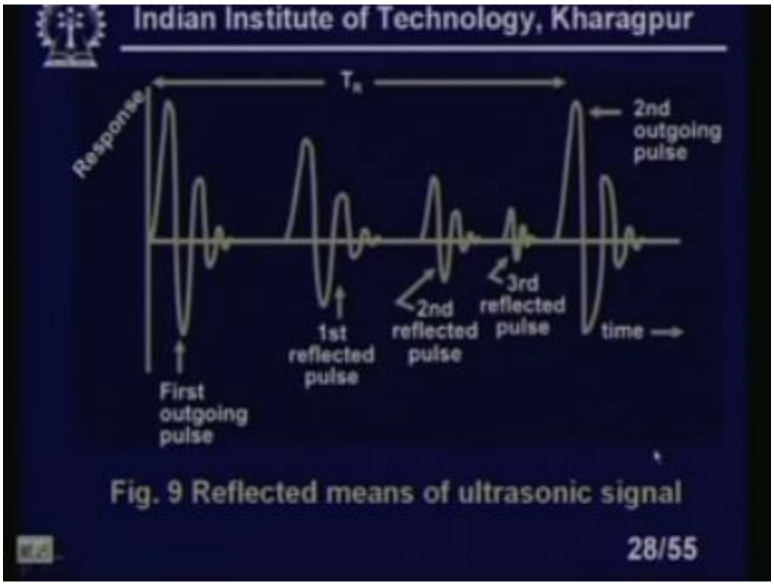

Now, you see the reflected means of the ultrasonic signals. There is a very nicely we have shown you see the first outgoing pulse will look like this 1. Obviously, because a part of the signal will be transmitted through the medium through the junction of the medium will go to the medium 2. So, the this is the first reflected wave it will come, then second reflected wave, then third reflected all of different magnitude. So, we will first the we will take this 1, and we will not send any signals until unless all the signals are died out. All the reflected signals are died out; we can calculate that part and accordingly my burst of signals which will go to the transmitter. Because there must be some electronic circuitry which will transmit the signal which will go the, because ultimately I have to impose some vibrations I can use some oscillators also there, right. Electronic oscillators which will start to make the vibrations of the ultrasonic crystals, right. So, I can obviously, I can program in such a way that the time taken time in between transmission of 2 signals will be such that all the reflected waves will be die out by during within that time.

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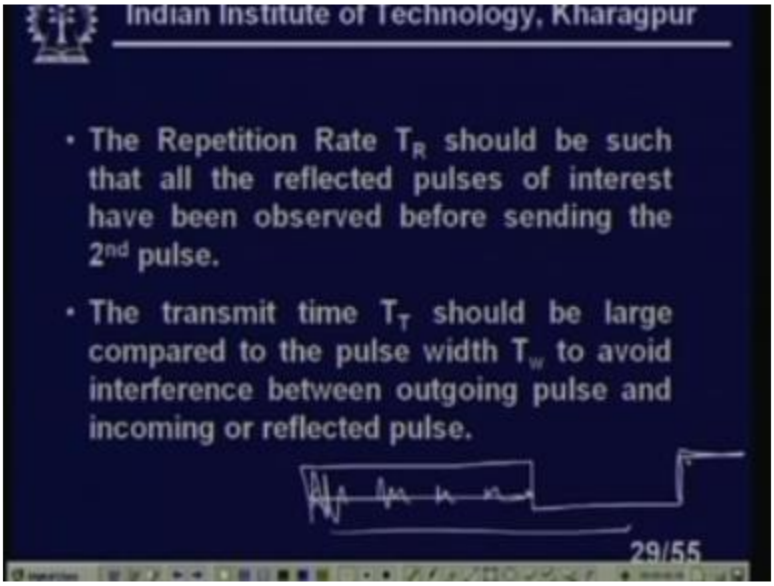

The repetition rate TR should be such that all the reflected pulses of the interest have been observed before sending the second pulse, right. The transmit time TT should be large compared to the pulse width Tw. To avoid interference between the outgoing pulse and the incoming or reflected wave, right. So, we have a width. So, we have decided I mean we are making transmitting time TT should be large compared to the pulse width to avoid the interference. So, we are making this large width. So; obviously, using that times we will transmit, right. What does it mean? It means you see I have a its looks like this that means I have a width like this one, right. Because this I can program. So, during that time this time all my signal reflected waves will be finished until unless. So, there is a sufficient amount of elapse time by next pulse will be transmitted again. So, this is the transmission width, right. So, this is the pulse width, Tw to avoid interference between the outgoing pulse and the incoming or reflected pulse this is all about, right.

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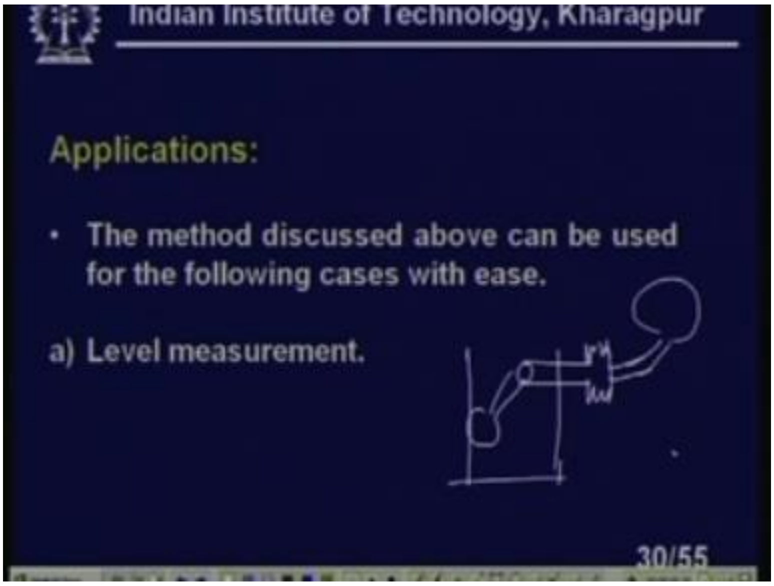

An application of this type of I mean ultrasonic signals let us look at. The method discussed can be used to the to make the level measurements. Especially the level measurements of a liquid I mean if I need a with precisions and fast measurements. Because you know the liquid there are various types of measurement of the level measurements. We have a steel tape and the and the ruler, that type of things are there scale and I mean steel tape which is used mostly in the our country. You will find many where in the municipality I mean tank, so huge tank. So, that it can be utilized for measurements; that means, it is other way. You see the scale will be when it is empty. I mean the tank is empty, the all the indicators will go up and when the tank is full the indicator will come down.

So, mechanical indicator which will which is connected by a counter width. So, that I mean it will whenever this level is up level the level is filled up. So, it will switch off there are many other there are a capacitive method of level measurements we have seen there are I mean method of so many other methods of I mean level measurements. We have pneumatic level measurements; that means,; that means, I mean it looks like this. You see I have a I mean a vessels. So, I will put a a pressure on this 1. So, there is a float, so this will. So, if it goes up, so it will put a pressure on the values right. So, this can be transmitted to indicate on a both the gauge or a I mean to show the pressure because. So, this pressure gauge will be calibrated in terms of in terms of I mean in terms of levels.

You cannot use both the cases; that means, you cannot use both the I mean both the gauges and the I mean and the C type both the. We have to use either either you use bellows because bellow will try to expand so that if you connect an indicator, it will show you the level or if you connected to some, the gauges. So, there is a deflections of the free end of the I mean tube. So, we will get the measurements and that pressure can be calibrated in terms of level. So, there is lot of lever you see the most of the cases this is most important that the ultrasonic method measurement you will find is very non invasive type of technique, right. You do not have to your sensor should not be in contact with the not necessary should be in contact with the liquids or any others I mean materials.

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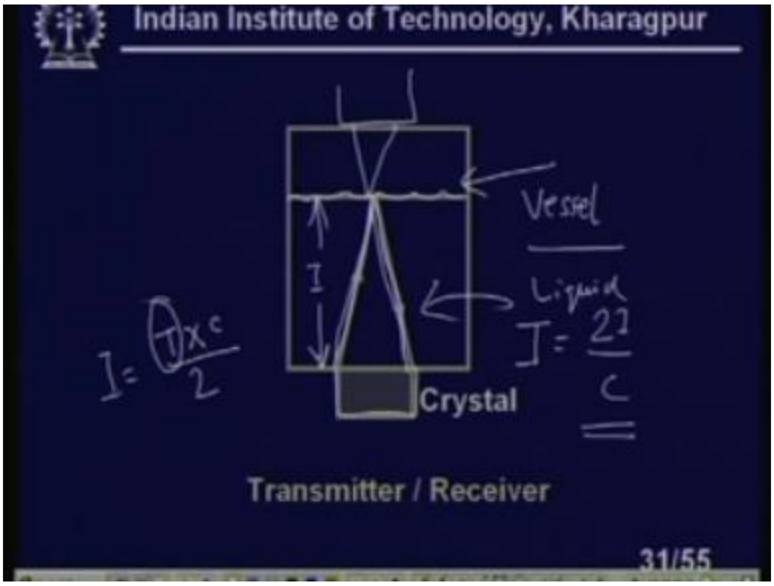

See this is the typical example, I mean of a level measurements. It looks like this. You see this is a liquid, this is our vessel in which I am interested to make the measurement, right. So, there is a ultrasonic signal. So, I am transmitting these signals and reflected back. As I told you the pulse width will be sufficient in large. So, that I mean I mean all the reflected waves will be collected here before I send the next pulse, right. So, this time will be measured. So, time will be what, so as the level goes high. So, as the level goes high it will ultrasonic waves will take more and more time to travel the distance, right. And will be deflected I will calculated the T as I told you. T equal to 2 I by C. So, if this is I right, so what is C? C is the velocity of ultrasonic waves in this particular liquid, right. So, I will get direct measurements, because how if I measure T? So; obviously, I will be what? I will be level.

So, I will be T multiplied by C divided by 2 is not it? But there is a precision of measurement because you see this I mean signal which go so fast the entire accuracy will lie on how accurately you can measure the T, that is most important, right. Even though it looks very simple I mean when you show like this one, but actual implementation is quiet taught in that sense, clear? Now, you see why I have installed the crystal at this side? I could have install that on this side also, I could have install the crystal on this side is not it? Either the ultrasonic wave also will come here and it is reflected back, but this is the liquid this is my liquid, right. So, let me take the new page. So, that will be better.

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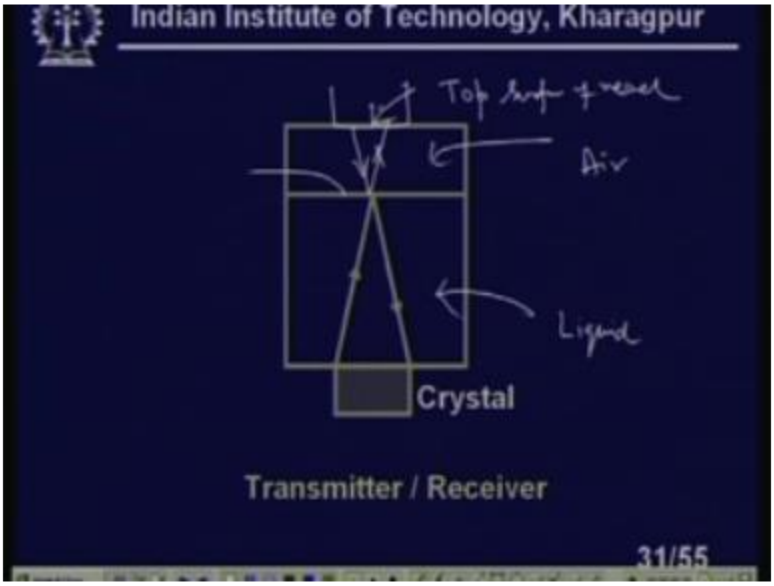

You see this is my liquid, and this is air. This is the top surface of the vessel, top surface and this is the top surface of the liquid. If I install the ultrasonic sensor here then what will happen? Either way it is same, because as the liquid goes up and up what will happen that again that this it will reflected back from this side. Because you see due to the difference of the characteristics impedance of the ultrasonic wave will be reflected. Here also the some will be reflected, but as I told you that it is very difficult to launch these ultrasonic waves in the air. So, that is the reasons we have put the crystal down. So, that it can be easy to transmit the signals through the liquid other than transmitting through the air, clear?

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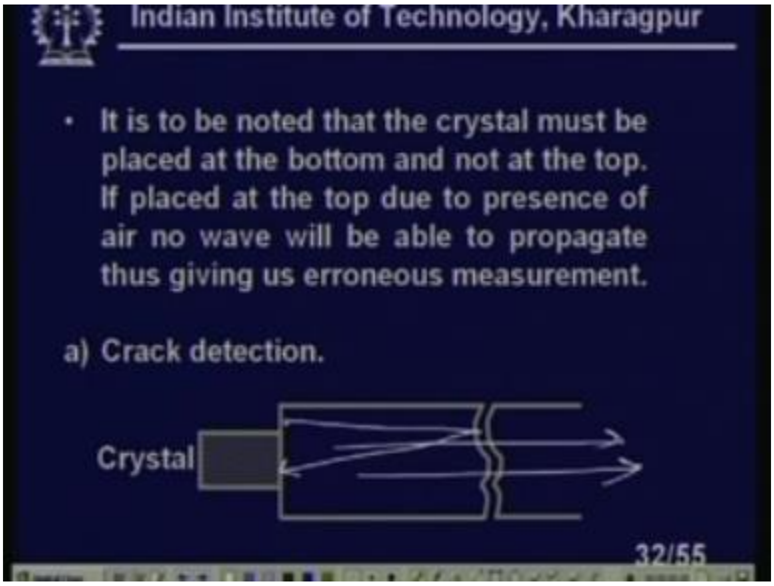

It is to be noted that the crystal must be placed at the bottom not at the top, just we have what we have discussed right now, right. It placed at the top due to presence of air no wave will be able to propagate thus giving us erroneous measurements, right. That is the reason we have installed at the bottom of our vessel. Now, ultrasonic waves as I told you earlier at the beginning of the lesson, it is also used for the crack detection. You see here what will happen the ultrasonic waves will come if it there is no crack. So, what will happen? The signal will transmitted like this one, if there is no crack. If there is a crack then what will happen. So, again there is a difference of the characteristic impedance here. So, what will happen? So, it will it will come it will reflected back through this one if I know that sorry if I know the time, sorry if I take a.

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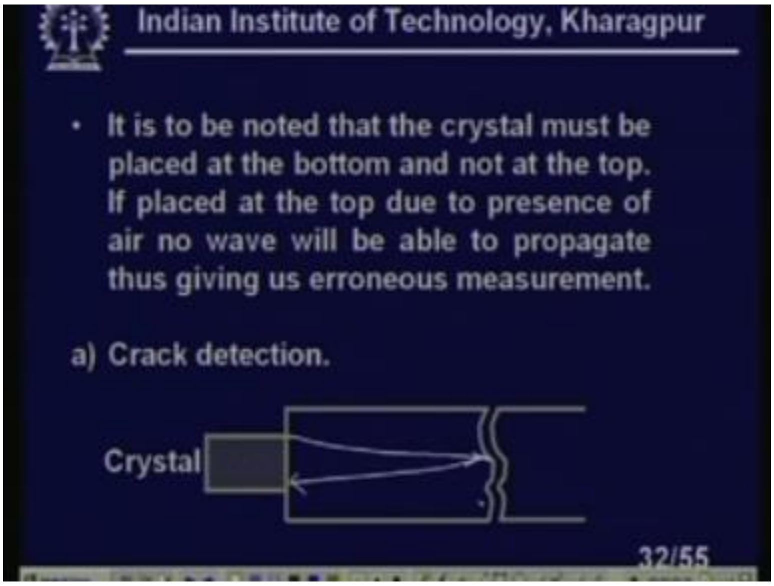

So, what will happen? it will go it cannot move through air. So, it will be reflected back. So, if I measure the time I can exactly locate the where the crack is even though if it is from outside it might be invisible if this the crack is inside, right. This is a very excellent technique I mean we have a different techniques of a crack detections. So, we have the detections of the we have the method of X ray and all those thing. But it is a very you know we have to I mean take an X ray and it is an high. We have to shield the people who are working there then I mean you need a place where to develop all those thing. But that is not necessary here in the case of ultrasonic signals if we use when it for crack detection.

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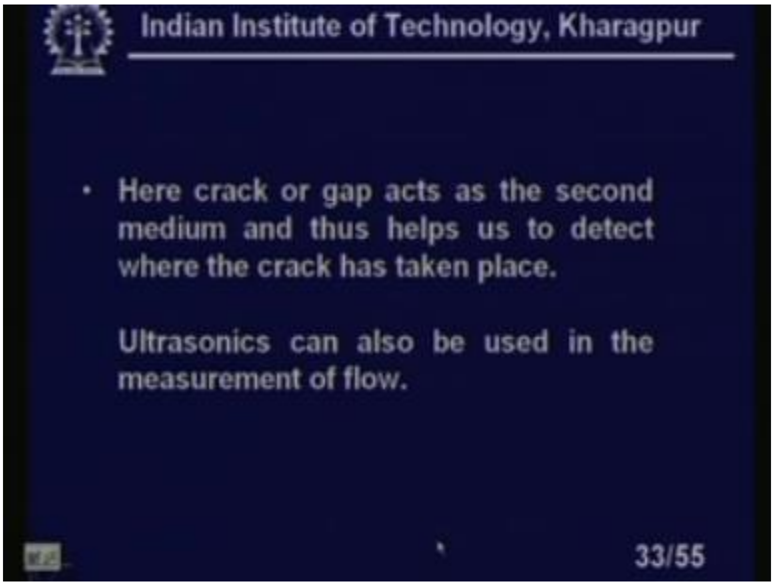

Here the crack or gap acts as a second medium, and thus help us to detect where the crack has taken place. Ultrasonic can also be used in the measurement of flow. You have already you have seen that the transit time ultrasonic flow meter Doppler shift ultrasonic flow meter those we have already discussed. Though we have not discussed the details of the transmitter and receiver that we actually we are discussing in the ultrasonic sensor itself. That is actually is the part of flow measurements and there is a little scope of discussing of all these sensor as such as a whole as a transducers flow, transducers. We have discussed the ultrasonic measurements of flow.

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Advantages; what are the different advantages? It is easy to direct and focus a beam of ultrasound as diffraction of these waves are small, due to short due to their short wavelength diffraction is small. Ultrasonic waves can easily pass through the metals that is a great advantage. This help in mounting the measurement system outside the system and it will not lead to the development. It will lead to the development of non invasive techniques of measurement or non invasive sensors. This is a terminal logic we are calling non invasive measurement. So, this is a non invasive measurement techniques, we are utilizing for ultrasonic waves. I mean making the ultrasonic measurement. Because I again install it outside I do not have to install anything inside you have seen in all the pressure all the level measurements except capacitance obviously. But capacitance is not a problem I am in shield shielding parasitic capacitance all these comes great problems in a measurements. We need very accurate LCR meters or the accurate bridge and all these this is not necessary in the case of ultrasonic measurement.

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Special application; an ultrasonic application there are special applications of this ultrasonic waves. Ultrasonic sensors have a wide applications in biomedical instrumentation, right. Measurements of blood flow; there are I will discuss 3 different major applications of ultrasonic waves in biomedical instrumentation. Measurements of blood flow in the artery, determination of the blood pressure and ultrasonography. Even though ultrasonography I have not discuss the typical ultrasonography that mean abdomen ultrasonography. All those things, we will discuss some part of the ultrasonography because it is a huge subjects and you can take reference choose any books I mean text books.

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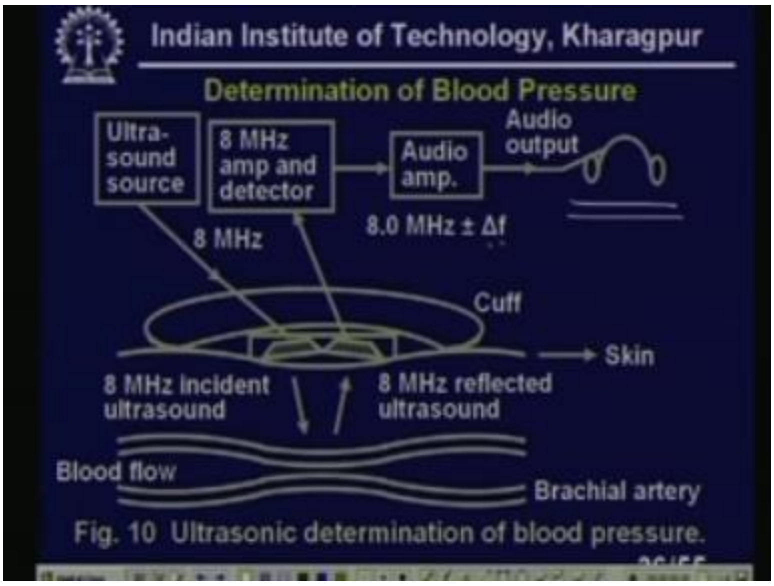

Determination of blood pressures; how the blood pressures will be used? You see this is the typical I mean typical diagram. So, ultrasonic determination of the blood pressure, so right. So, here you will find that I mean ultrasound sensor. And we have a ultrasound this is the blood flow and we have a ultrasound 8 megahertz detector also. This 8 megahertz signals and we have a 8 megahertz detector also, so amplifier and detectors. This is audio amplifier audio outputs it is going to a head phone. This is actually please note this is a head phone, right. This is a head phone, so we can I mean by listening to the sound I can tell what is the pressures.

This is how the and the blood is flowing through this artery. You see what will happen that 8 megahertz incident ultrasound will come and in the blood. So, they will be reflected. Now, what will happen? You see here I have a skin here, because we have to put outside the skin. So, it is a non invasive technique very much. So, we will look at the sound, we will listen to the sound during the opening and the closing of the valves. I will get the signals of the, during opening I will get a largest amplitude signals and during closing I will get a short I mean amplitude signals. So, by this I can detect the ultrasounds and measure the pressures. So, these frequencies this delta f is now convert it into the audio output. You see delta f will be different, right.

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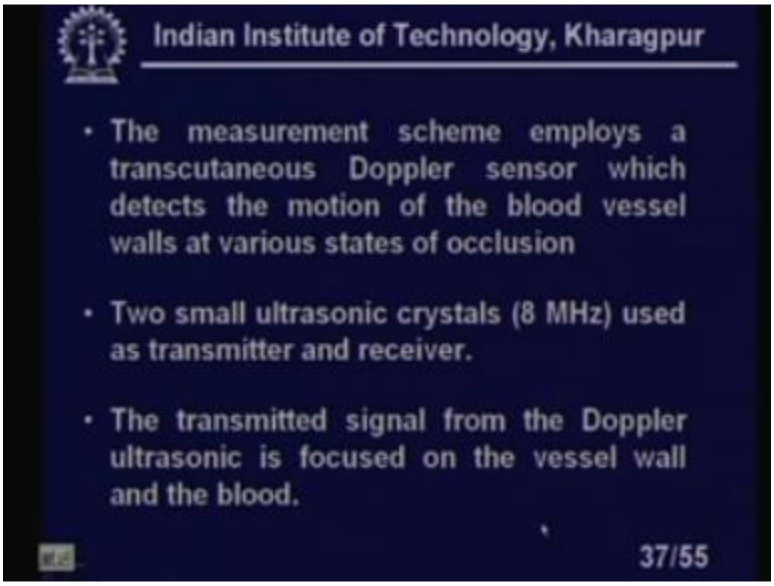

Now, measurement scheme employs a transcutaneous Doppler sensor which detects the motion of the blood vessel walls at various states of occlusion, right. Two small ultrasonic crystals 8 megahertz used as a transmitter as well as receiver. The transmitted signal from the Doppler ultrasonic is focused on the vessel wall and the blood.

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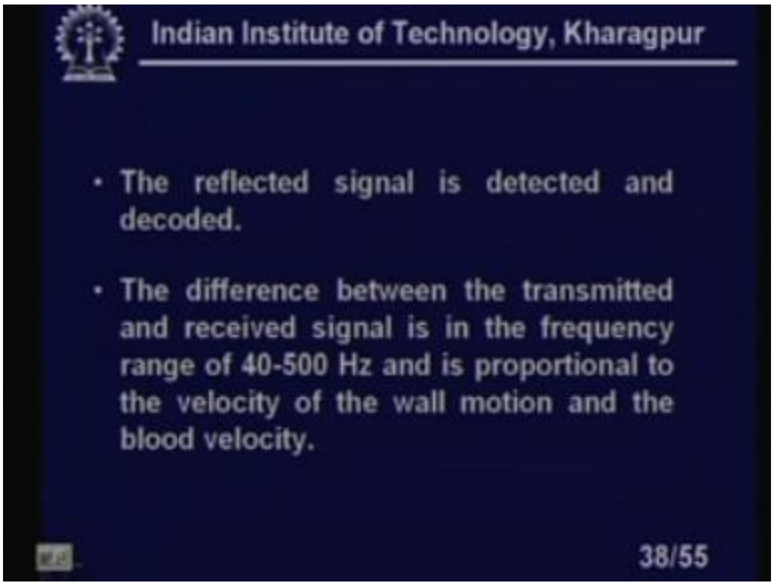

The reflected signal is detected and decoded, right. Decoding means; that means, I am decoding converting into the amplitudes and all those frequency depend I mean frequency voltage convert or that type of signal. Difference between the transmitted and received signal is in the frequency range of 40 to 500 hertz and is proportional to the velocity of the wall motion and the blood velocity, right.

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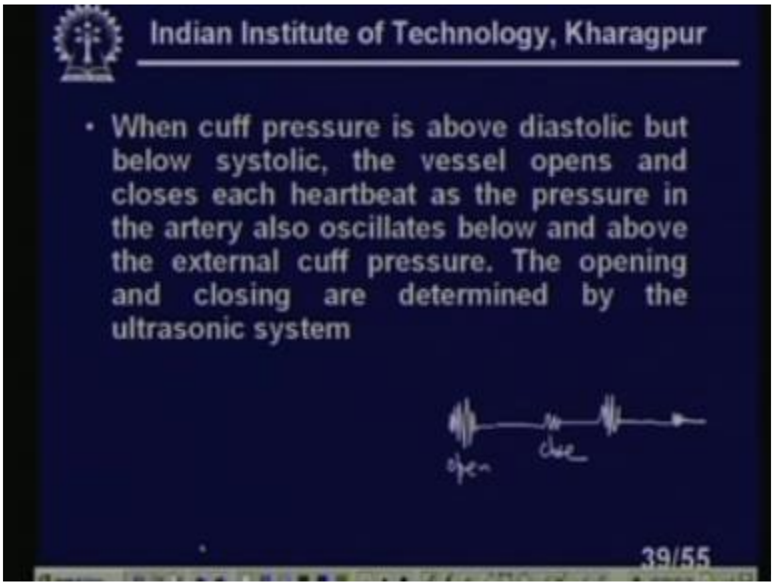

When cuff pressure is above the diastolic, but below systolic. The vessel opens and closes each heartbeat as the pressure in the artery also oscillates below and above the external cuff pressure. This opening and the closing are determined by the ultrasonic systems. That I have shown; that means, the 2 different ways during openings I will get a signal like this 1 sorry. So, I will get a signal which looks like during opening and during closing I will get a again during opening, so again close, right. So, this type of signal I will get.

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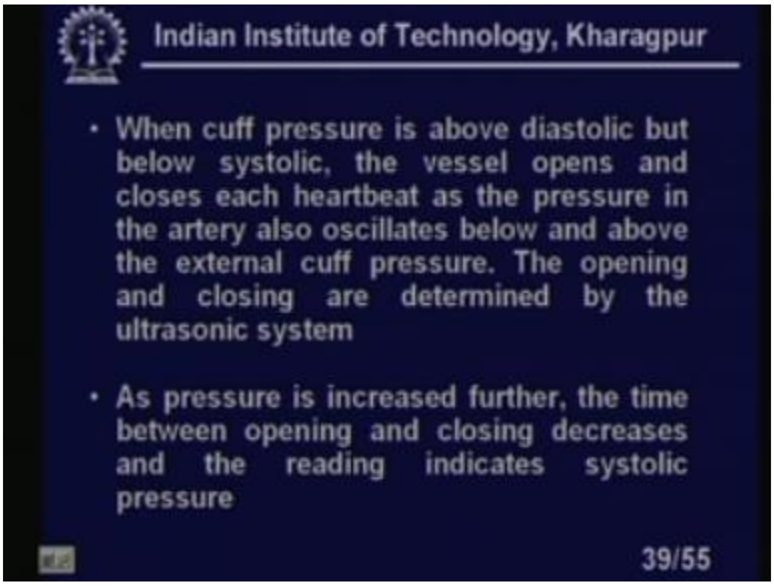

As pressure is increased further the time between the opening and closing decreases, and the reading indicates the systolic pressures, right.

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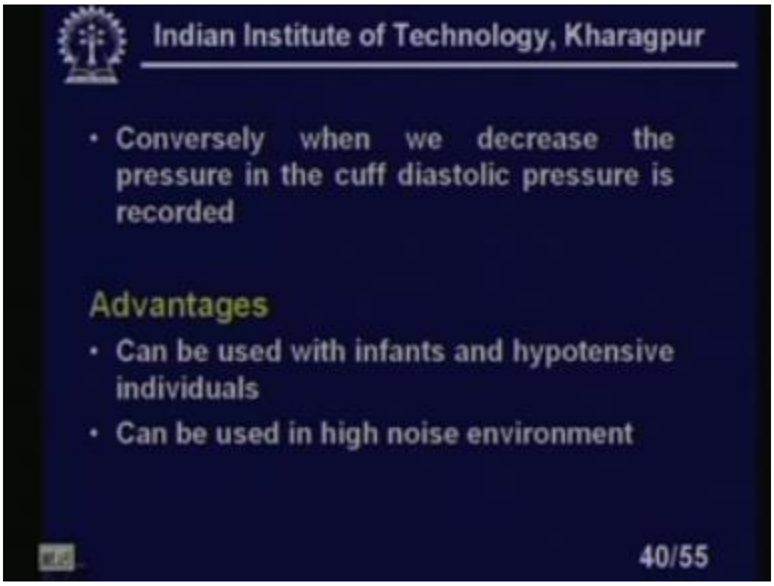

Conversely when we decrease the pressure in the cuff, the diastolic pressure is recorded, clear? The advantage what is the advantage of this system? There was some disadvantages also. Let us first look at the advantage it can be used with the infants and hypotensive individual; that means, pressures I mean persons with a high blood pressures as you know the medical for a healthy person the blood pressure should be within 80 to

120, right. So, but some people have very high blood pressures in for that type of patients we can use or also it can be used for infants can be used in the high noise environment.

Because you see all this I mean this other type of measurement techniques what they are used actually depends that the physician must locate the time when the valves are opening And must locate the pressures sorry the manometric pressures when the valves are opening, right. So, it is sometimes very difficult if it is a noisy environment. So, it is quite mute noise outside noise environmental noise which is very common in hospitals and all those things. So, it can be nicely utilized in that type of environment or that type of in that type of I mean places.

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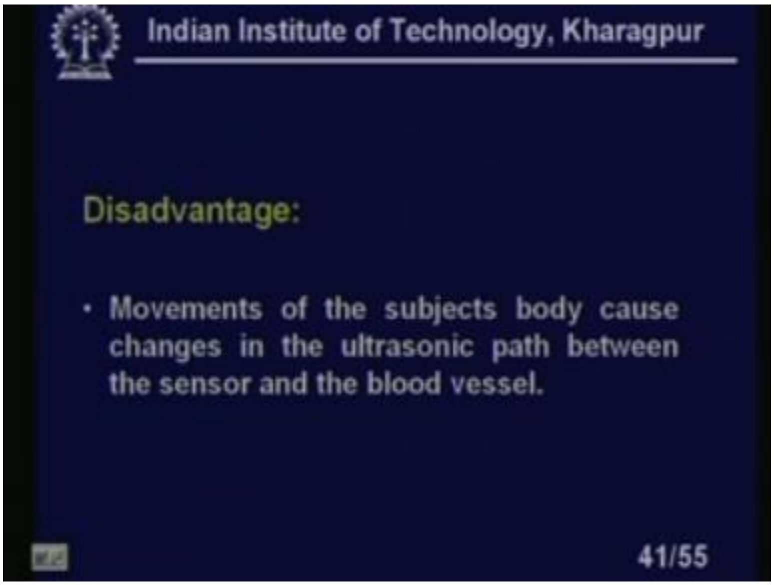

But what is the disadvantages? The movements of the subjects body cause the changes in the ultrasonic path, between the sensor and the blood vessels; obviously, everything will change. So, the patient should I mean some steady condition. So, you should not nice, so it is very difficult to; obviously, though we are saying that is very we are saying the infant we can use. But in some cases we can utilize this type of the measurement.

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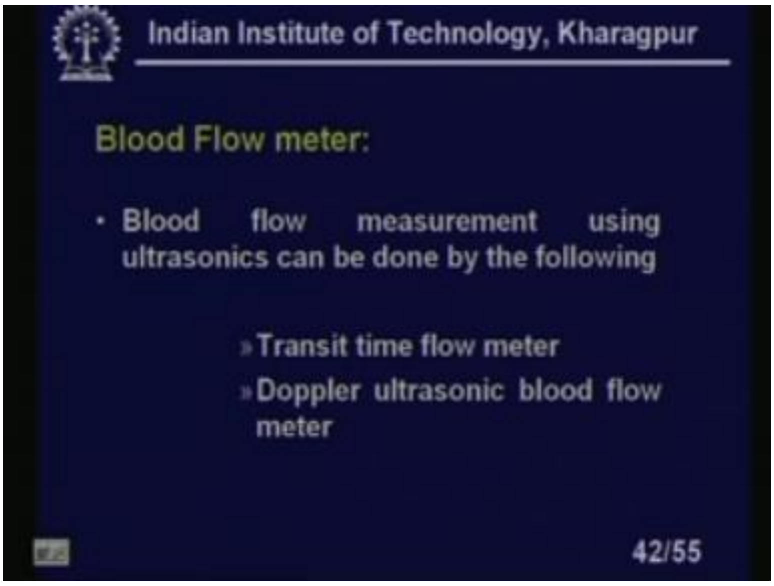

Now, blood flow meters, you know this flow meters it is basic principle is same transit time flow meters and the flow meters like Doppler shift flow meters. But the same principle also used for measurements of blood flow on the measurements of blood in the artery. Blood flow measurements using the ultrasonic can be done by the following. Transit time on the measurements flow meter, doppler ultrasonic flow meters. Doppler shift this we have discussed very details in our, I mean flow meter I mean lessons. So, I will not go too much details of this one. In context with the, I mean biomedical instrumentation I will discuss something nothing more than that.

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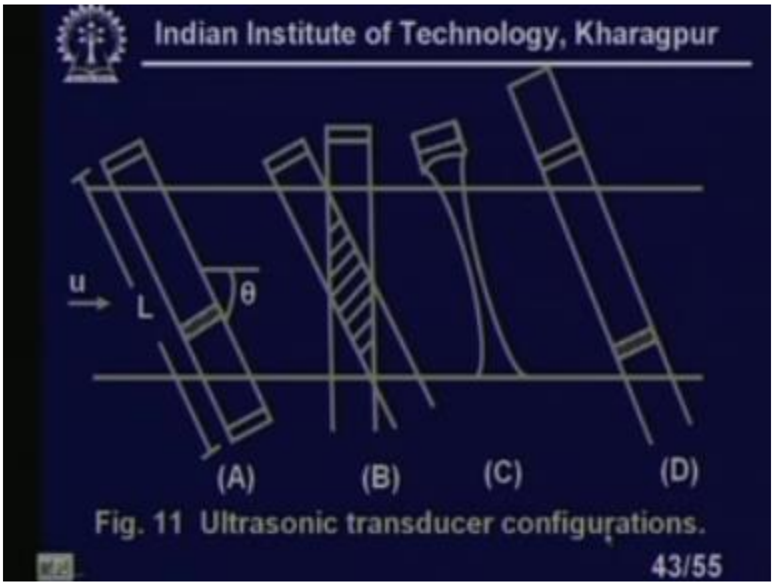

You see this is ultrasonic transducers configurations we are using different configurations. So, the ultrasonic uses I mean transducers A B C D, what is this?

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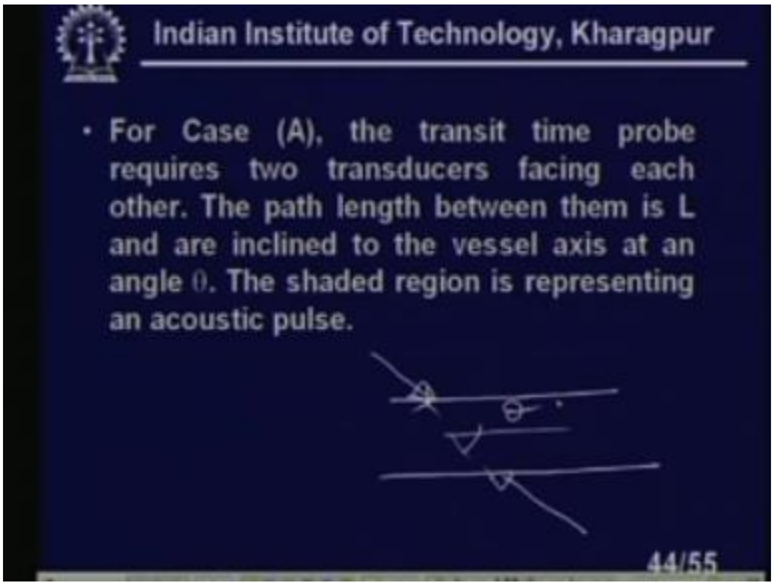

Let us look at Case A; the transit time probe requires two transducer facing each other. And the path length between them is L and are inclined to the vessel axis at an angle theta. We know if we recall go back to the ultrasonic I mean you see the transit time principle is something like this I have a vessel like this one. So, I have a signals always will be inclined I have a sensor here. So, it is a this make an angle of theta right. That is actually I am telling that means what I am telling here.

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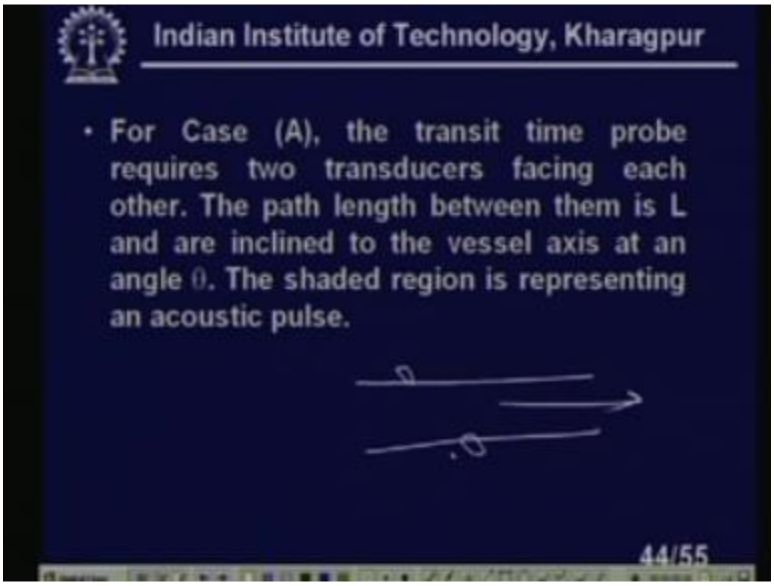

For case A, the transit time probe requires two transducers facing each other. Obviously you see that you remember in the, I have 2 sensors liquid is flowing through this and one sensor here and another sensor here right. So, facing each other clear?

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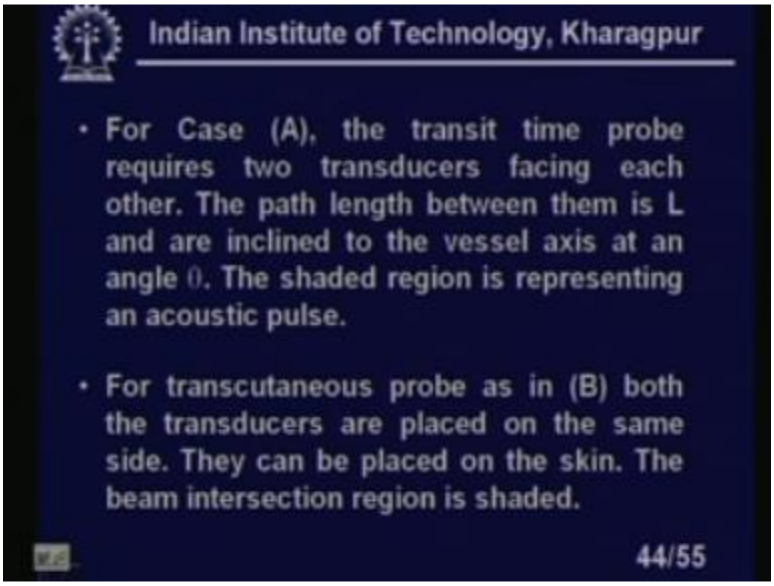

And the transit time probe requires two transducers facing each other and the path length between them is L and that inclined to the vessel axis at an angle theta. The shaded region is representing the an acoustic pulse right. What is that? Let us go back shaded region is acoustic pulse. For transcutaneous probe as in B both the transducers are placed on the same side. They can be placed on the skin and the beam intersection region is shaded. Let us go back this is a beam intersection region. So, two are placed. So, for transcutaneous probe as in the B both the transducers are placed on the same side and they can be placed on the skin. So, that we are utilizing the reflection from the blood I mean from the end of the artery like that the intersection region is the shaded right.

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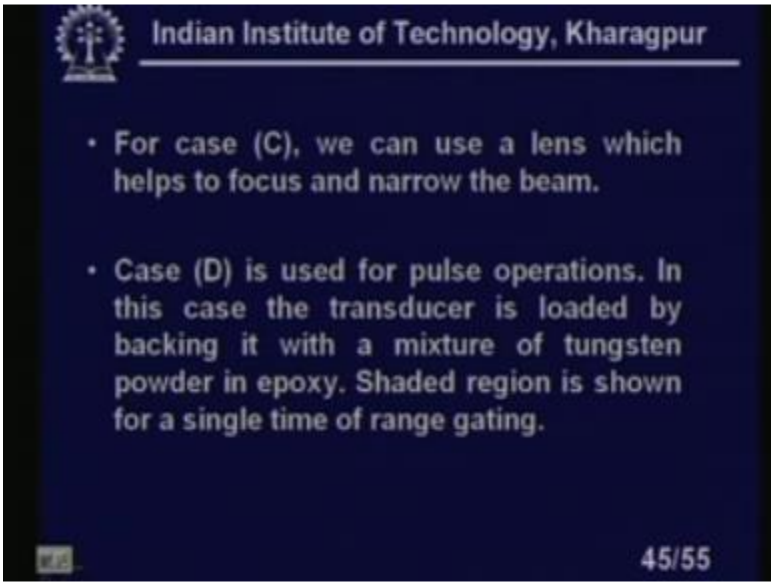

For case C, we can use a lens which helps to focus and narrow the beam. Sometimes we need to narrow the beam since it can be utilized to do there. Case D is used for pulse operations In this case the transducer is loaded by the backing it with a mixture of tungsten powder in epoxy and the shaded region is shown for a single time of range gating.

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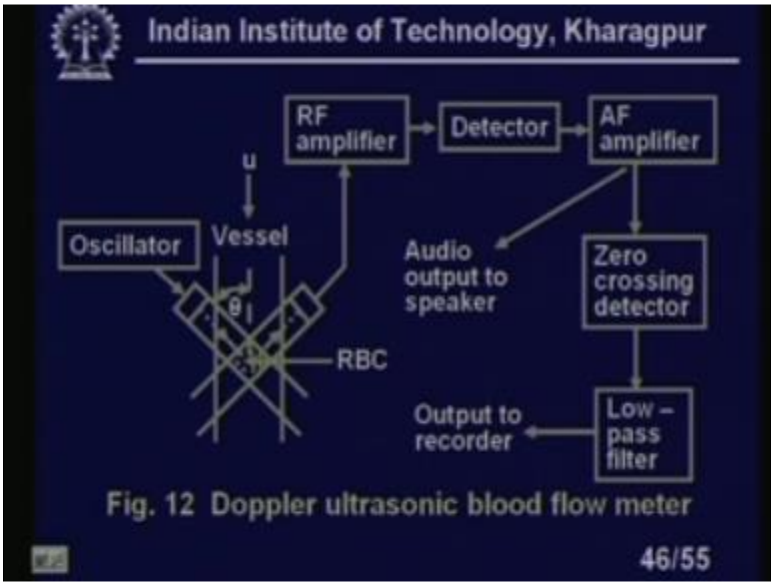

Now, this is a Doppler ultrasonic flow meters we see here we have an oscillators I mean I always encourage that the those who are I mean listening to this particular lesson they should go back to my the lesson on the flow measurements using ultrasonic principles. So, all the things will discussed in details there right. So, the this is the Doppler ultrasonic blood flow measurements the principle is same. There are 2 types of frequency will have we will get a 0 crossing detectors. We have an low pass filters and output detectors because the audio frequency will be related on the I mean difference of frequencies will be derived which is very small. So, that will be passed or all other frequencies will be stopped.

So, this is actually the entire scheme of our ultrasonic flow meters using ultrasonic measurements of blood flow using the Doppler shift method right. We can see here. So, we have a detector, so then after that frequency will be lowered. So, we have a audio frequency amplifier. Detector can be simply a so; obviously, what will happen that the output signals what we will get? The low frequency and obviously, I can use a audio frequency amplifier there. You see this is a audio frequency amplifier we have a audio frequency output of the speaker output also. And we have a 0 crossing detector then low pass filter then we can get the output recorder because this I will get a signal. This I am getting audio signals. This I am getting electrical signal again here which can be recorded, right.

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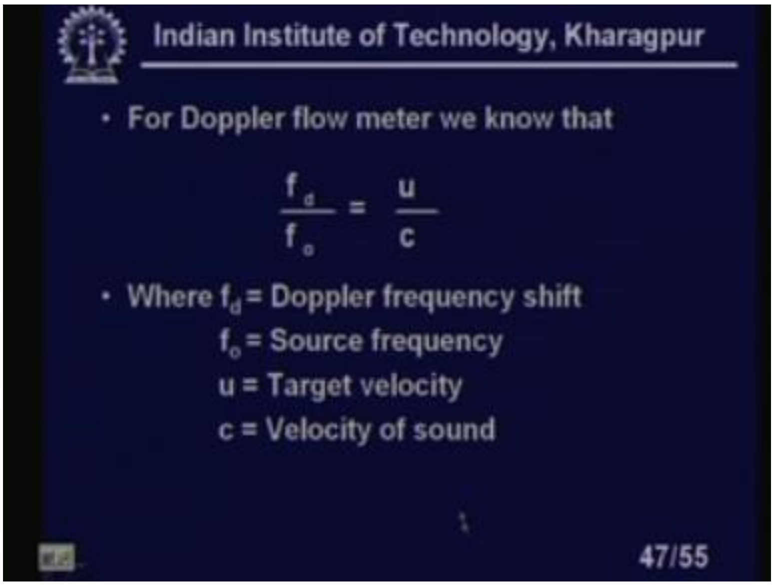

For Doppler flow meter we know that fd by fo equal to u by c where fd is the Doppler frequency shift. And fo is the source frequency which is basically ultrasonic frequency u is the target velocity and c is the velocity of sound sorry. It is source frequency not velocity. This f naught is the source frequency or the frequency of the ultrasonic sensor.

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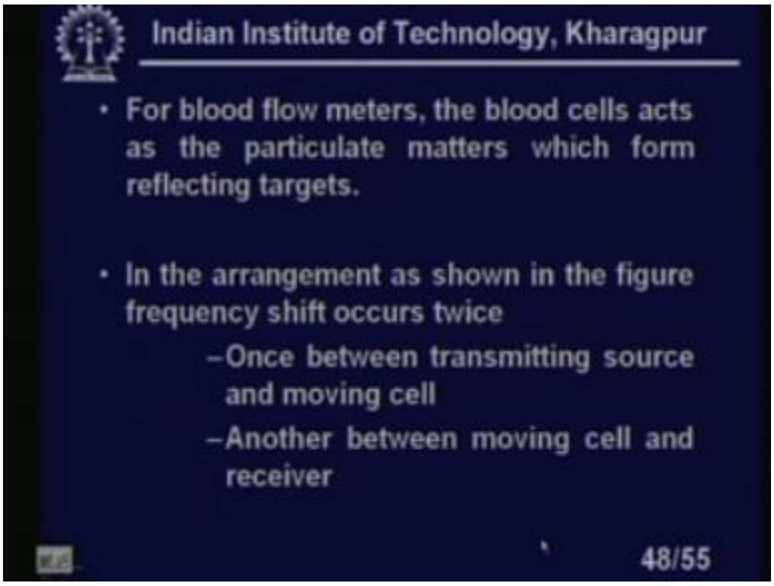

For blood flow meters the blood cells act as a particulate matters which form the reflecting targets right. Because as you know in the case of Doppler shift flow meters I mean in the case of transit time flow meters this is basically used in the case of clean liquid. Whereas, the Doppler shift flow meter will not work with that we have discussed in details that it will not work until unless there is some suspended particle there in the liquid itself. The liquid is flowing through the pipe there is some suspended particle whatever small it may be. But that particle will missing here in the case on the blood flow measurement. But the blood cells will act as a particulate matters which form the reflecting targets right. From that actually the ultrasonic will be reflected back it is excellent it is not it? There is sometimes with that time we have discussed that the 2 different flow meters because in we do not know what type of liquids flow we are measuring.

Sometimes the liquids are might be very clean suppose in the case of water or some other liquid, but in sometimes it it may have studies. It may have suspended particles, but if the liquid is extremely clean I cannot use the Doppler shift flow meters, but that I mean principles is purposely we are utilizing in the case of blood flow measurement right where the cells will act as a reflector of the signal ultrasonic signal which is transmitted from the transmitter. In the arrangement shown in the figure frequency shift occurs twice, once between the transmitting source and the moving cell correct. Second another between the moving cell and the receiver, right. One is the moving between the transmitter source and the moving cell. Moving cell means moving blood cell right. It is moving cell means moving blood cell because; obviously, when the there is a there is a continuous flow of blood through our artery, right. So, there is the cells are also be continuously moving through the artery. So, another between the moving cells and the receiver.

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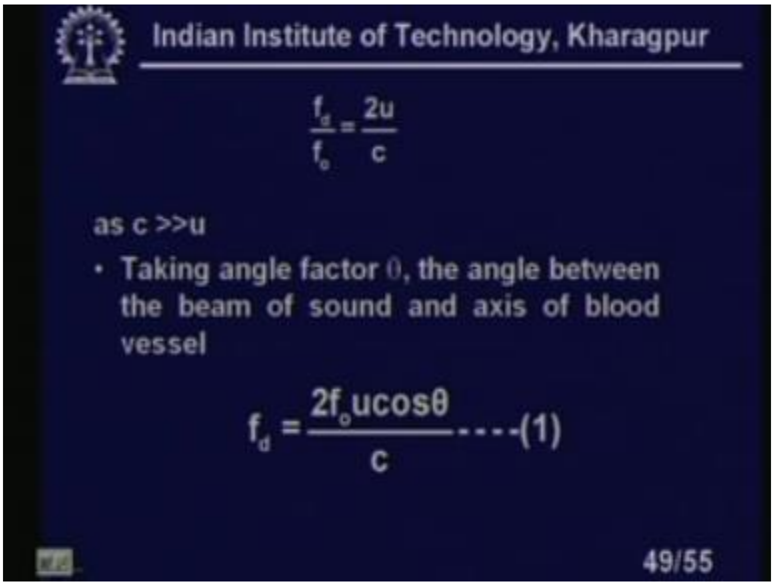

So, of the fd by f naught equal to two u by c as c is much much greater than u. Velocity of the ultrasonic must be much much greater than the velocity of the blood flowing in the artery. So, what I can say that taking angle factor theta the angle between the beam of sound and the axis of blood vessel fd equal to twice f naught u cos theta by c equation number 1.

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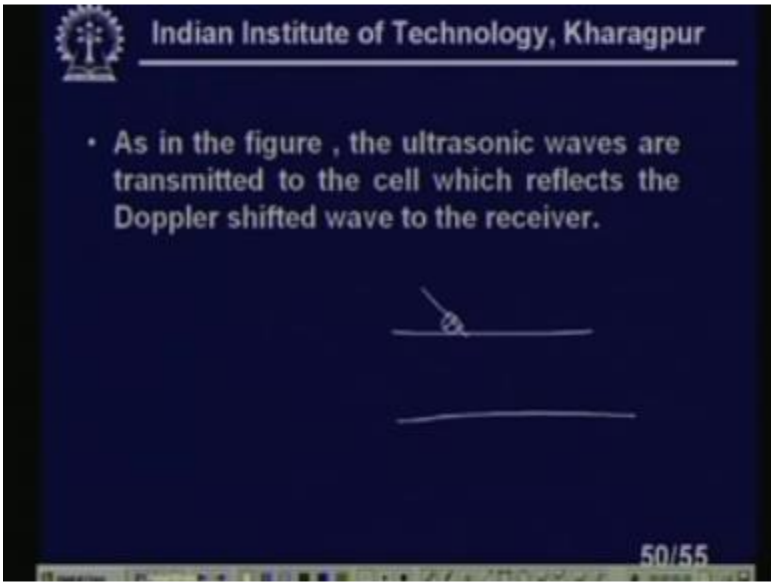

And as in the figure the ultrasonic waves are transmitted to the cell which reflects the Doppler shifted wave to the receiver, right. As in the figure the ultrasonic waves are transmitted to the cell which reflects the Doppler shifted wave to the receiver right. So; that means, I have a ultrasonic waves it is getting reflected and coming to the receiver. How does it look? It looks like this one ultrasonic waves are there. So, I have a source here sorry.

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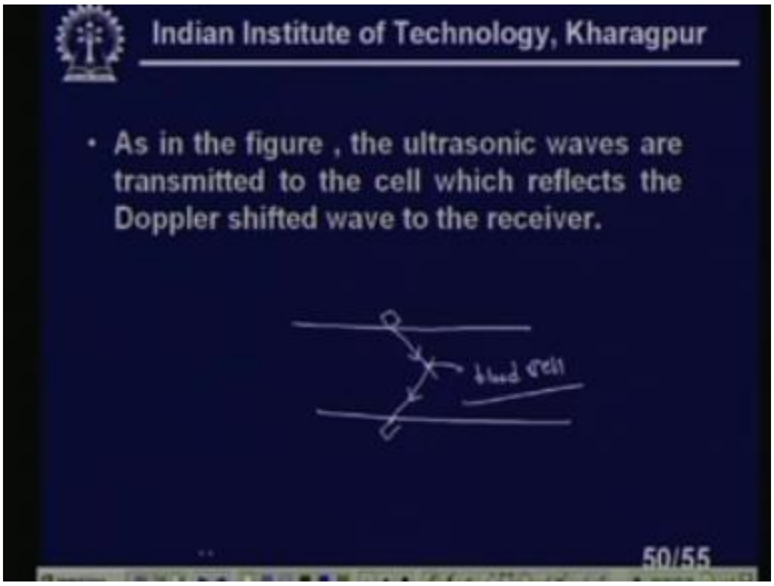

So, I have a source and I have a receiver here ultrasonic waves I am transmitting. So, it is getting here reflected back from the blood vessel. This is our blood vessels, blood cells rather I should say blood cell right. Reflects the Doppler shifted wave to the receiver. So, this getting reflected I am. This is getting reflected.

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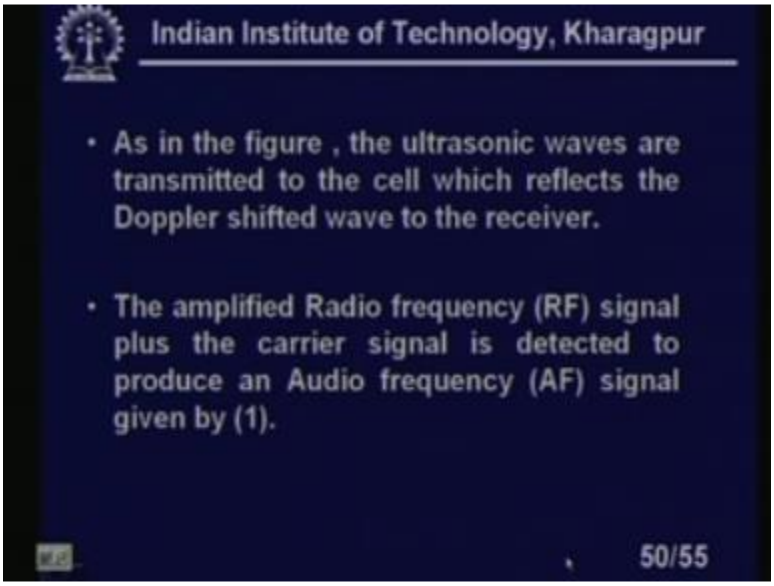

The amplified radio frequency signal plus the carrier signal is detected by the produce an audio frequency signal. It is the basic principles of a audio I mean our heterodyne receivers. This classical method actually utilized here also AF signals given by equation 1.

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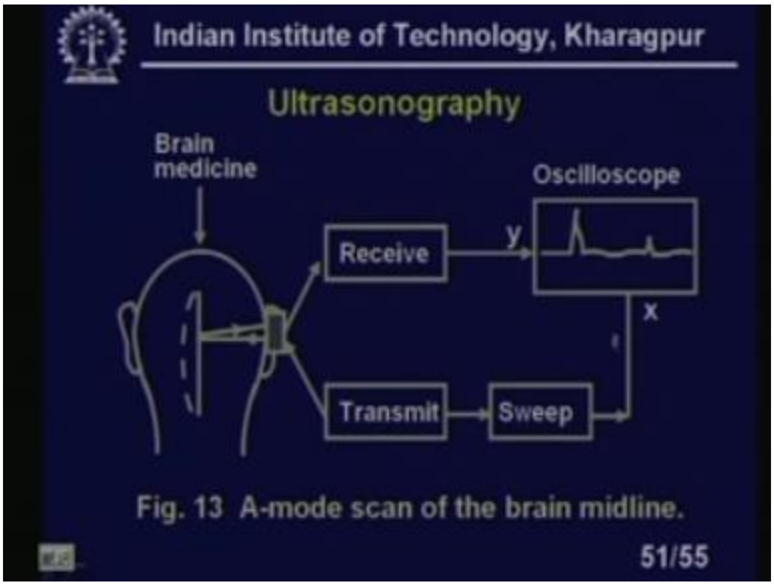

Now, ultrasonography you see this is a this is a I should say the last I mean example of a I mean this is a very I mean very wide subjects. I mean its studies very difficult to accommodate in this particular end of the I should say of the of this particular lesson. But it is extensively used for measurements of many to know especially when the child is in the home of a women. So, that that time also it is utilized to know the health of that type of the baby in the home right. Anyway there are other applications of the ultrasonography we will discuss that part. You see the brain medicine A mode scan of the brain midline I have a receiver transmitters. So, transmitting signals it is transmitted and we have oscilloscopes and sweep as usual I am giving into the vertical this I am giving in the sweep I am giving to the horizontal. I have to know I have to make it stationary, because the signal is to be stationary. You know that is the basic principle of the when we give to the horizontal waves or horizontal plates right. So, that is actually utilized here. A mode scan of the brain midline.

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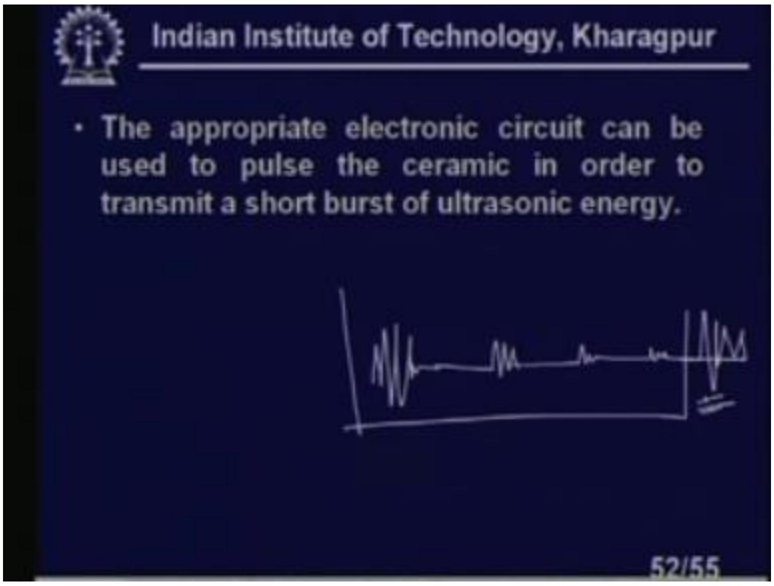

The appropriate electronic circuit can be used to pulse the ceramic in order to transmit a short burst of ultrasonic energy. Always please remember in all these method we are always have transmitting a short burst of the energy. How does it look? We have seen that already we have shown. That is your transmitting signal looks like this. Then it is getting reflected it is lower and lower. Again I will transmit this is one width again I will transmit. So, this is a short burst of signal. So, it is not it a continuous signals you cannot make a if you transmit a continuous signal no where you can make the measurement clear?

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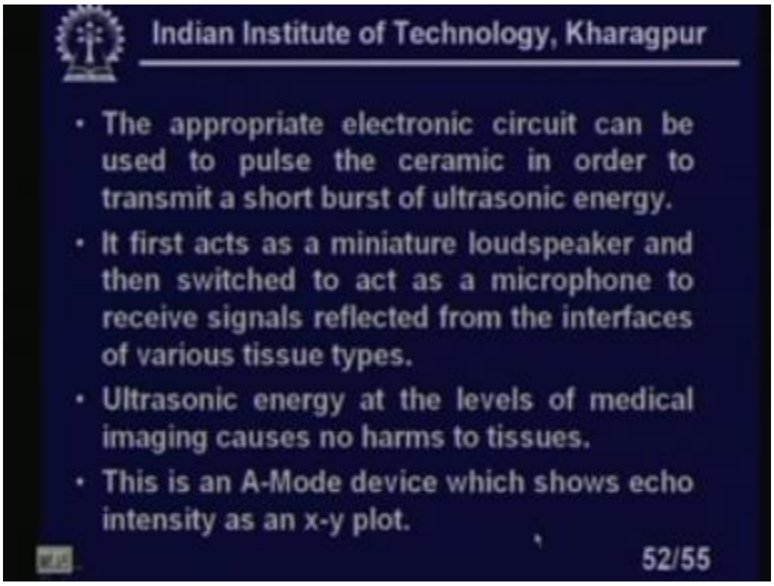

It first act as a miniature loudspeaker and then switched to act as a microphone to receive the signals reflected from interface of various tissue types right. I can use this speakers also and transmission and for receiver I we can use the microphone. Ultrasonic energy at the level levels of medical imaging causes no harms to tissue that is very important, because any other methods we will give you harm the tissues. So, ultrasonic energy will not harm the tissues. Because whenever you are using the medical instrumentation you have to look at the safety and it should not harm the human being. It will not damage anything. So, those part you have to this is an A mode device which shows echo intensity as an x y plot we have shown Y we are giving the amplitude of that reflected waves and x plates we are giving the sweep. So, I will get a stationary waves.

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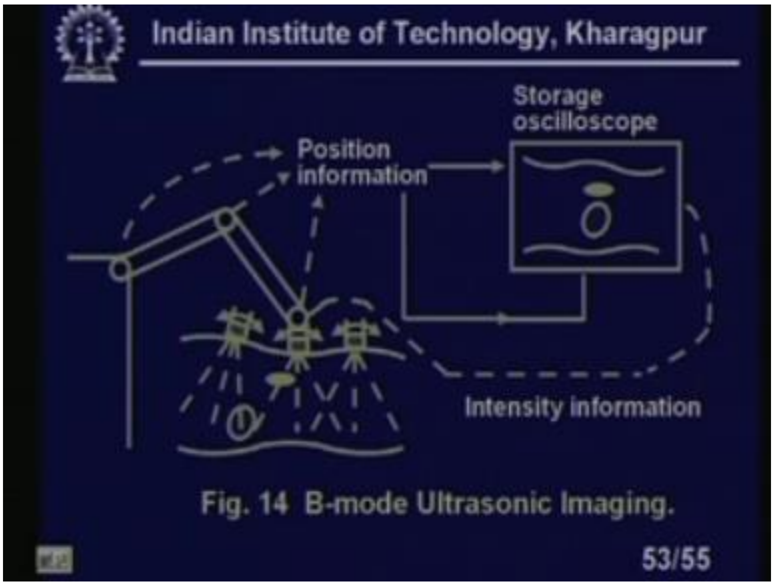

This is the some information I mean B mode ultrasounds imaging intensity informations. It looks like this.

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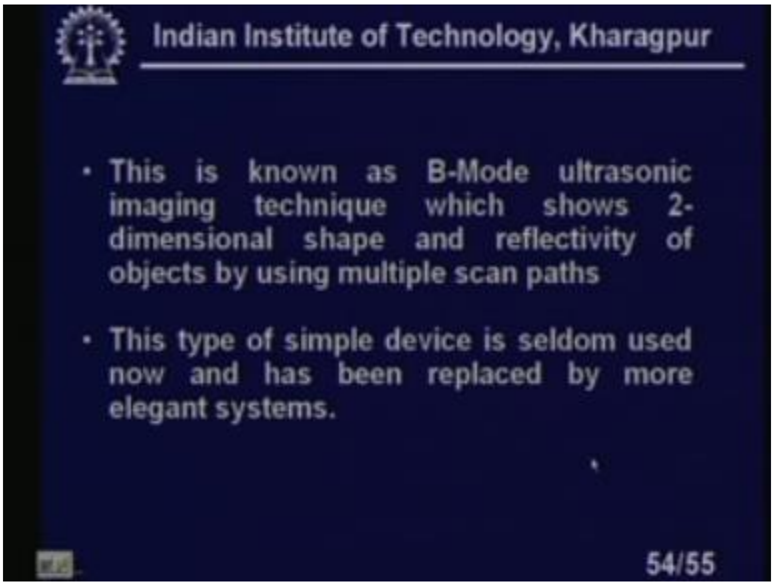

This is known as B mode ultrasonic imaging techniques which shows 2 dimensional shape and reflectivity of the objects by using multiple scan paths. This type of simple device is seldom used now; however, has been replaced and more elegant systems. So, with this I come to the end of lesson 25 which is on the ultrasonic sensors. Welcome to the lesson 26 of industrial instrumentation. In this lesson basically we will cover a nucleonic instrumentation.

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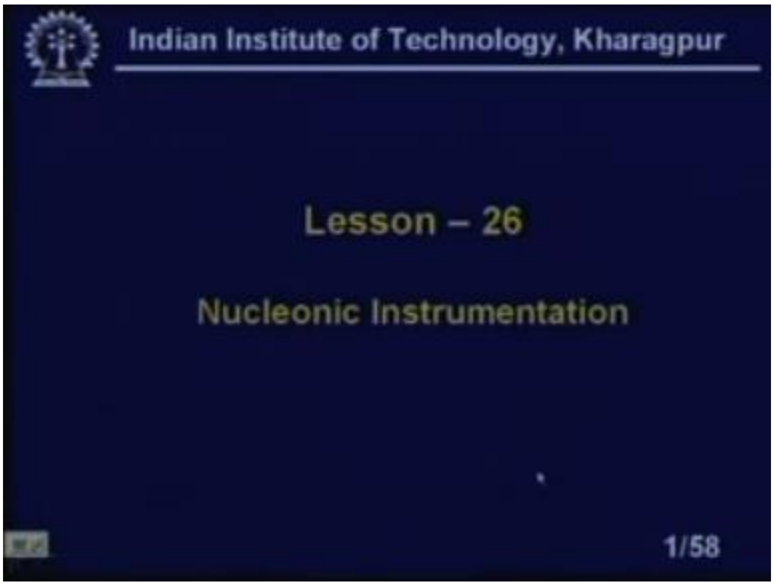

Let us look at Nucleonic instrumentation means that we will use some radioactive sources. And there will be corresponding detectors and there are some advantages of this of this type of instrumentation. Because we have seen that the in the in the lesson 25, we have covered the ultrasonic instrumentation. So, there are some typical advantage of ultrasonic, but there are some cases like. If you want to launch that ultrasonic waves in the air it is just impossible where the radioactive waves can I mean moves through air. So, that is the great advantage of this particular instrumentation. So, it is to be covered very extensively. Let us look at the contents of this particular lesson.

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Contents; principles of nucleonic instrumentation, radioactive sources, radioactive source elements. What are the different elements which will code or I mean it will make the radioactive sources? Basically radioactive sources means alpha beta gamma rays, but what are the elements which we will actually used for used? We actually used in the nucleonic instrumentation that we must study. Its application in industrial instrumentations; that means, we will find the label gauge the there is typical applications. All the measurements of level then typical applications of the measurements of the coating of a sheets and the rolling mills. So, there are various applications we will finding this particular type of instrumentations.

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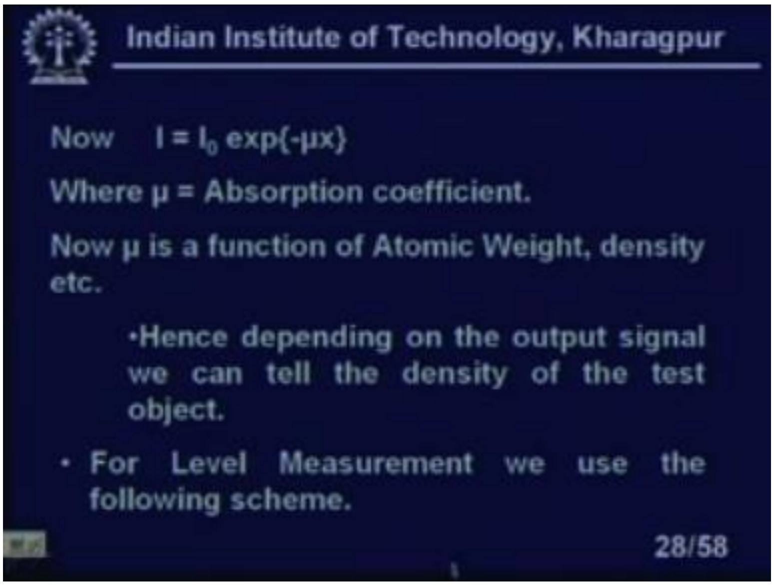

So, we have same or if the densities I mean the density might be different, but the atomic weight it can be the same. For level measurement we use the following scheme.

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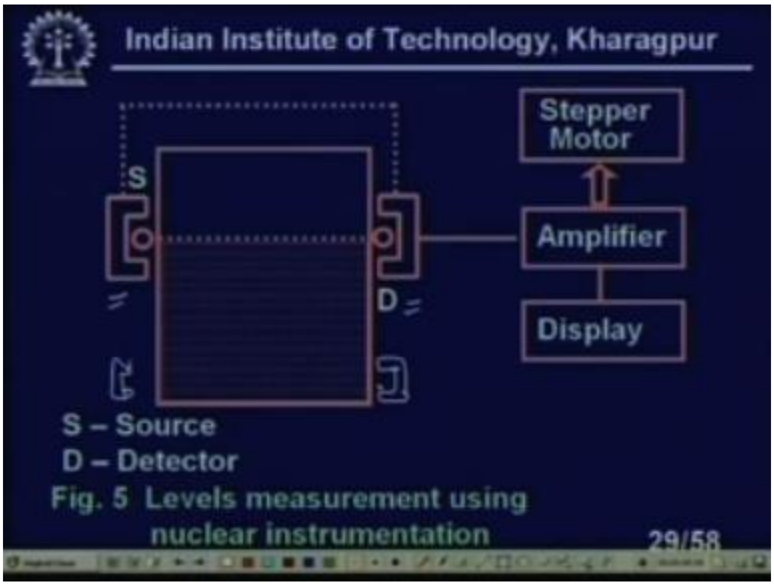

This is of the scheme of the level measurements. We have a source you see here. We have a detector here and. So, this is the level measurement using nuclear instrumentation. So, I have a liquid here. So, how it works?

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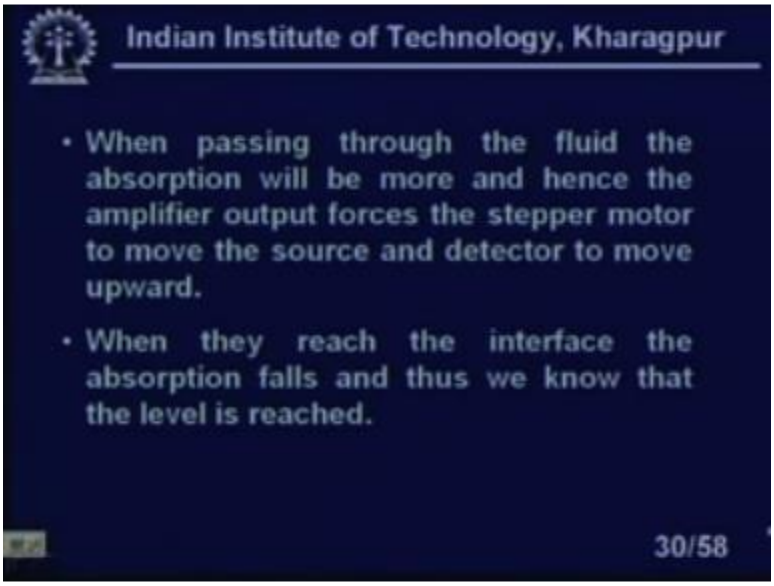

Let us look at… When the passing when passing through the fluid the absorption will be more and hence the amplifier output forces the steeper motor to move the source and detector to move upward right. You see what will happen? So, when passing through the liquid this will. So, it will always try to move this steeper motor to move it upward right. When they reach the interface the absorption falls and thus we know that the level is reached clear? Let me do it again. So, the this principle is something like this if this 2 system this I mean. Let me take a; that means, this stepper at this source and detector will be initially at the bottom here. And please note that in the nucleonic instrumentation. So, the either it is a great problem.

So, we have to think of all this whenever you are using what type of I mean radioactive materials using though the half life. And all those thing is not that large, but the amount of ways to you thing off. So, the proper sometimes there is a are there. So, until unless you, we can manage with some other instrumentation, which is non nonhazardous like the ultrasonics and any conventional, instrumentation of level gauge or density measurement that is to be used. But in some situations as I told you like the detections of the leak in the pipe underground or suppose the in a close containers I want know the level of the liquids.

And all these things very difficult to know it is specially it is sealed. If the container might be closed it does not matter because if I have a inside I mean electronics already installed inside. So, I can inside I can detect, but if it is a separate container suppose ah a cylindrical drum I want to know that how much the liquid contains which we cannot see from outside. So, that type of situations I can use this type of radiation technique or I mean technique. So, this is to be basically I mean all of us you have to careful; that means, that I have told you several times. That means f I can manage with other instrumentation system conventional nonhazardous systems. We are not suppose to use the radioactive sources right. So, with this I come to the end of this lesson 26.