Principle and Applications of Electron Paramagnetic Resonance Spectroscopy
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Lecture – 08
EPR Instrumentations – II

Hello, we will continue discuss the various components of an EPR spectrometer. We have seen the source of microwave, which is usually Klystron or a Gann oscillator. Why do we need to use my wave guides, how it restricts us to work only at a fixed frequency mode. We have also seen role microwave cavity, and how it allows us to place the sample at the maximum magnetic field, with the minimum of electric field.

The next important component in the spectrometer is the magnetic field, and since the experiment involves, keeping in the frequency constant, and vary the magnetic field, magnetic field has to be varied continuously, and it is usually done by using an electromagnetic, and you know the electromagnet is possible.

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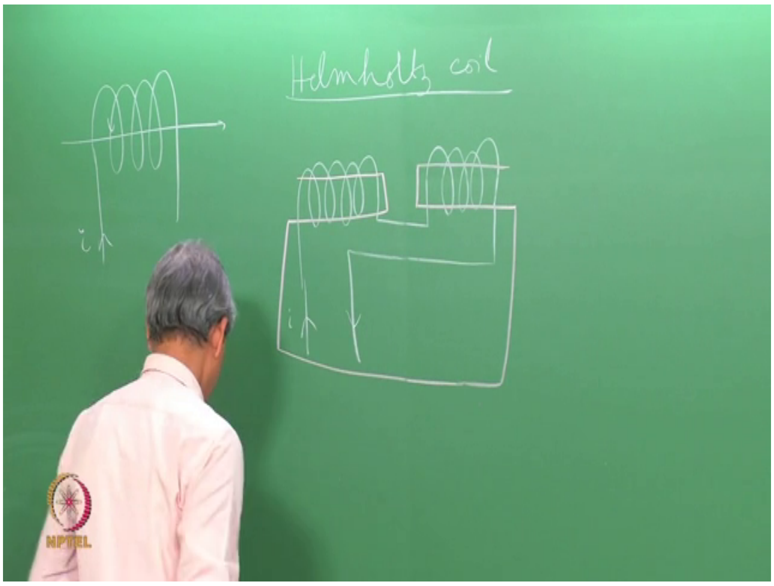

If I have a coil and pass current through this with i, then current flows through this and it can form a magnetic field, solid node. In fact, now for EPR experiment, we use a special type of coil called a Helmholtz coil. So, let us say start from here, coil goes here, and then there is a gap, another part of coil comes here and then here, we apply current here, i goes here and here. So, the magnetic field will form here, and this is you can guess the, this is the place where sample is kept there, but this is not good enough, because the magnetic field strength will not be very high. To increase that, we insert a magnetic soft iron core here. So, the magnetic field lines are forced to stay inside.

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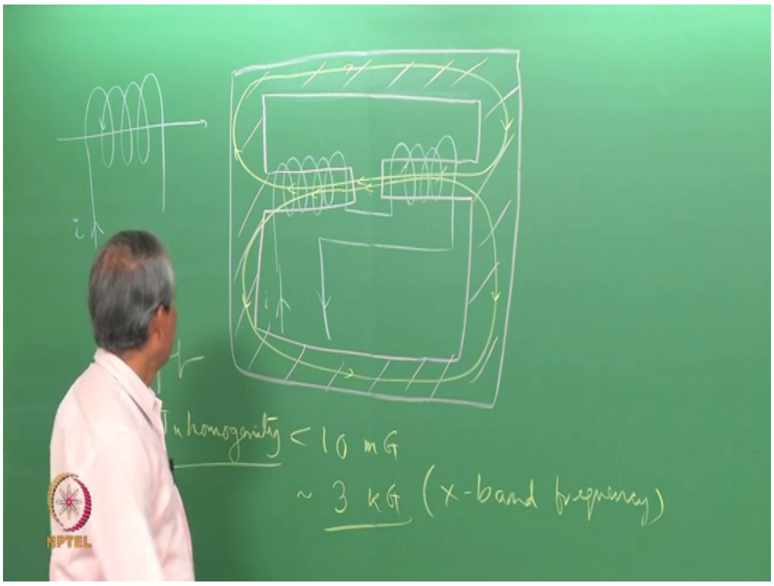

This is soft iron core coil is round around this core, and to complete the magnetic field lines these are can you (Refer Time: 02:38). This is a yoke. So, they double yoke arrangement is used. These all made up of soft iron core. So, here the magnetic field lines will have this set of, let us say. Similarly here this magnetic field lines are completed.

So, these gives very homogeneous magnetic field and the centre of this two pole pieces there. A current can be varied, then the magnetic field also vary here. What is required is that, the magnetic field that is seen by the sample has to be very homogeneous. Why. Because many EPR spectra, come with very narrow, very closely space nine and narrow lines there. If the field is not homogeneous, or if homogeneity, if homogeneity is more than this width or even the separation is here, then these lines cannot be resolved. A typical requirement is that, in homogeneity within the sample. You know the sample is kept in cavity. So, let us say within the cavity dimension, the in homogeneity should be less than 10 milligrams. This is the in homogeneity, and this is necessary in the presence of a magnetic field, which is of the order of. Let us say 3 kilogram, which is our x band frequency, which is the typical requirement of the homogeneity of the magnetic field there. Now how to measure the magnetic field very precisely, usually one uses a gauss meter, which is made up of Hall Effect.

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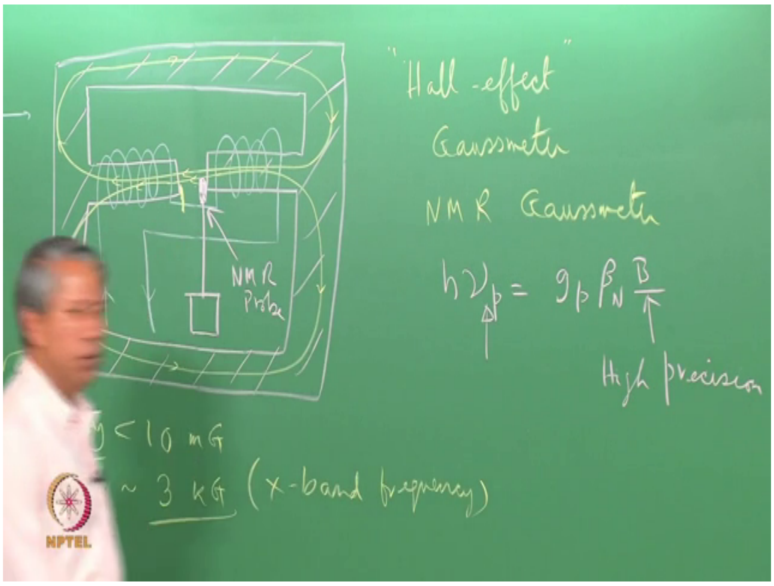

So, this Hall Effect gauss meter, the prob is kept somewhere here, and the magnetic field can be measured. Now this measurement is usually good enough for common, not very precise measurement, where one does not require these type of precision, but one need this type of precision, one uses another technique which is based on this N M R technique N M R gauss meter, is nothing, but a very small N M R spectrometer is made, and N M R sample is kept very here, let us say here. This is the N M R problem; this is the N M R machine, small N M R machine.

So, here the resonance condition for N M R is, let us say nu of proton N M R is used there, nu of p will be g of proton Bohr Magneton and B of this magnetic field here. So, one looks at the resonance frequency of the sample of proton; that is kept here, and then frequency can be measured very accurately, and with high degree of precision. And from this and knowing this or other find out this with a high precision, that way the magnetic field can be measured. The next important component of the spectrometer is of course, the detector.

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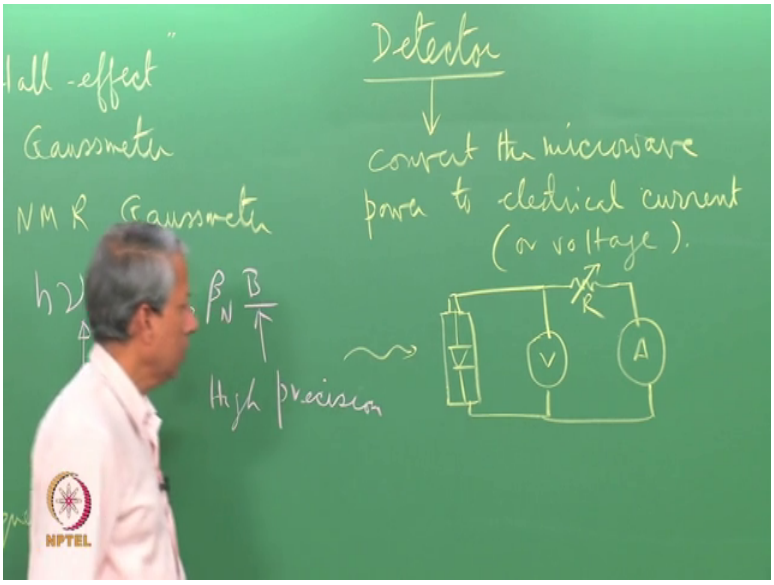

So, detector job is to measure the microwave power; that is coming out of the cavity, and which will carry the information about the absorption of microwave by the sample. So, what it does is to convert the microwave power to electrical current or voltages. So, that it can be further amplified and recorded.

Now, the detector that is used an EPR spectroscopy, is usually a detector silicon diode, something like this. This is a diode, so diode is kept inside. There is an hole this on this one. This looks at the electric field of the microwave, and current is produced here which is related to the intensity of the microwave. So, here put a volt meter, and put a resistance and current meter this one, this is (Refer Time: 08:44) varied. So, by just seeing the variable resistant, I can vary the current. So, this is a simple detector.

Now, the trouble is that, this being a diode, it is not a linear device. Current that is generated here, because of the microwave power is a non-linear function of the power that is falling on the diode, then it looks like this, diode current versus the power.

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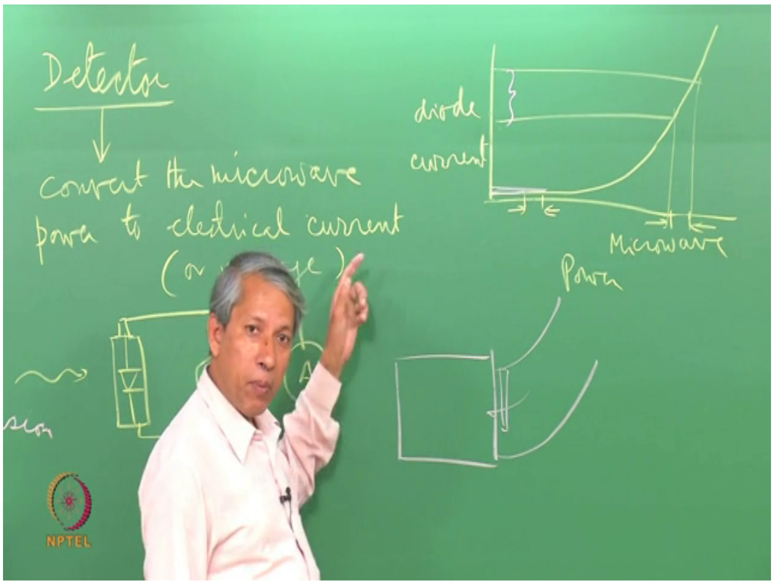

So, it sort of like this type of region. So, it very low level of microwave power, the current is very small, and then at the power increases, it should (Refer Time: 09:55). So, the sensitivity therefore, very much depends on, where I am working. Now go back to our discussion of the microwave cavity, where I said that the EPR absorption gives a small disturbance in a cavity, and that causes some extra reflection of microwave from the cavity.

So, if the extern reflection is a measure of, let us say reflected for by given by this magnitude here, then the diode current will change by very imperceptible amount here, here to here, very small amount. Instead the same disturbance, if checking place somewhere here, then we see that, there will be this much change in the diode current. So, here it becomes much more sensitive for the same change of reflected power from the cavity. If the diode is working here it is become insensitive, went works here, it is much more sensitive. So, it is very important therefore, to decide, where we want to work. Obviously, we want to work here. Now to do that; i therefore, have to adjust the operating position of the diode, somewhere in this region there.

Now, this is easily done by giving a bias power to the diode; that is you allow a constant microwave power to fall on the diode all the time, and that we can decide where we are. Now this can be done two ways; microwave power enters here, and using this highly stunning arrangement here. I match it very well, and I say ideally a matching should be such that, no power gas refracted from here. You stop that, suppose it sacrifice some amount of sensitivity and miss match deliberately. Let micro power gets out of this, and we bring this operating condition somewhere here; that is the way one can do.

And then EPR spectrum will be adding more to the reflection, and then that will EPR signal, but then we see we sacrificing some amount of sensitivity by deliberately mismatching the cavity matching. So, another way to do would be that, we work the critical matching, so that no reflection takes place. So, we find some other path to bring microwave to the diode, which we will see later in our EPR spectrometer diagram, which is called the biasing the diode using a different path of the microwave power that falls on the diode.

Now here how much bias power I can give. The way it looks like, the more the (Refer Time: 12:57) type of arrangement that if you go, keep on increasing, the sensitivity seems to be increasing, but that does not happen, like all electron device. A diode also produces noise, and this noise depends on the bias power. The bias power if you keep on increasing, noise also increases, and that is shown here quantifiably in this slide here.

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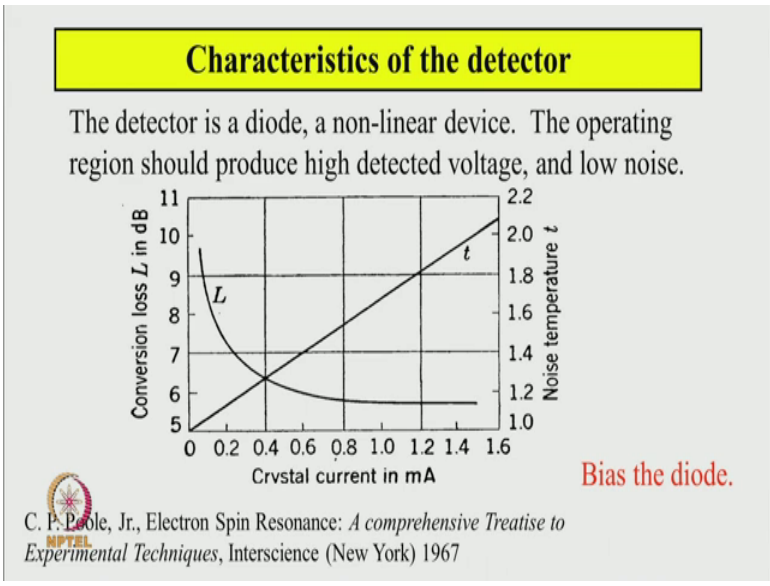

So, this is the crystal current. So, we increasing crystal current is possible by increasing the microwave power falling on the cavity, on the diode. So, L stands for the loss for converting the microwave to the voltage. So, as the crystal current increases, the loss decreases; that is what I said that if you keep on increasing here, it efficiency of conversion from volt microwave power to voltage increases, but same time, the noise which is may, let us thermal noise, which is a related to its some set of parametrical temperature, that keeps increasing here, the linear direction. So, increasing crystal current, increasing bias increases the noise component. So, we cannot keep on increasing the bias in this passion here. You have to have certain compromise. I get a optimum sensitivity and optimum noise

So, with this we have covered all the major components of an EPR spectrometer. Before I conclude, I like to introduce a unit of measuring this various characteristics of this microwave components and a microwave power.

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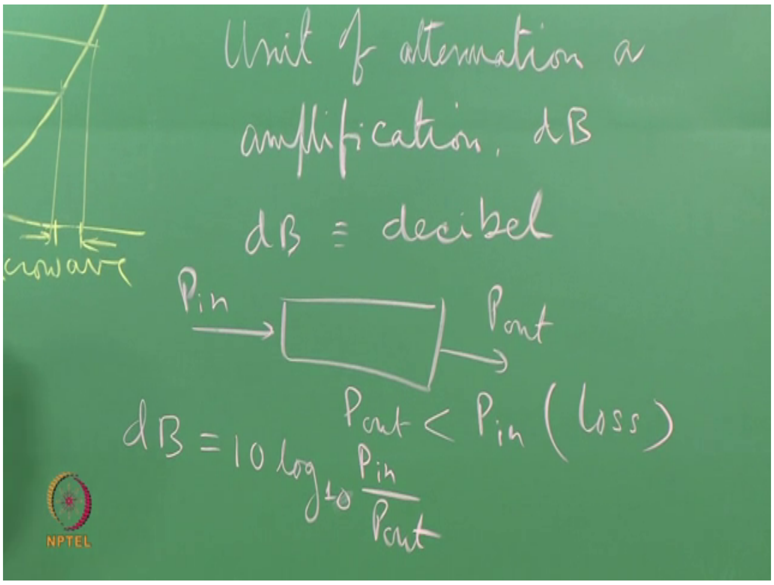

And this unit is called unit of. Let us say attenuation or amplification, which is called dB. dB stands for decibel, what it is. Before I say what it is, all microwave components, when they carry microwave, they lose certain amount of it radiation; that is a loss. This one here. So, radiation goes through this tube, this hollow portion here.

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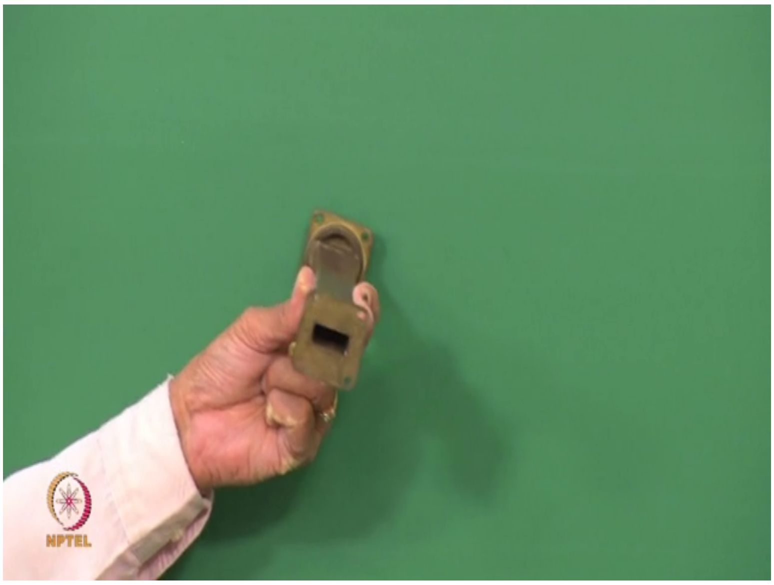

But idea is that, it whatever goes in must come out, nothing should be lost here, but that is not possible. No matter how good it is, how good the conductivity is, which decides the quality of trans loss. There will be certain loss always present there. Now how much the micro power getting lost; that is given by this unit dB. Now did you find. Let us say some (Refer Time: 16:01) here, power is going in, power is coming out. So, here the dB, if it is, a power is getting lost; of course, P out will be less than P in; that is some loss is taking place there, dB in, loss in dB is given as 10 log to the base 10 P in by P out. So, this is a logarithmic scale. So, if, let us say P in is, or P out into 2. Sorry there is the half the power is coming out here whatever region, then if you put it here.

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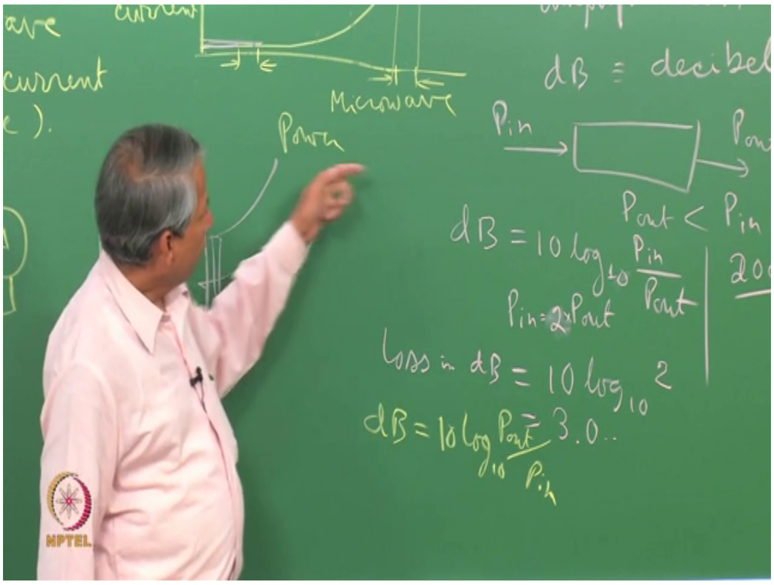

And this will be loss in dB will be 10 log base 10 to 2. If you do this log 2, then 10, this will be about 3.0 something come here. So, this, about 3 dB loss is taking place here, when half the micro power goes in there, because of the logarithmic nature and all of this, best, and very easy to mentally come out of quick number. Let us say that something like this, that suppose the loss is a 20 dB, then this 10 is there. So, these three ratio must be 2. So, 20 dB here; that means, the ratio will be 100.

So, 100 the power is coming here; that is 20 dB. Suppose instead of loss, there is some device which amplifies the signal, power goes in and comes out, the higher than that. The same way I can define the amplification factor in terms of dB that will be. Here this is higher than that. Again let us say the 20 dB means, the ratio will be 100 that is if 1 milliwatt goes in 100 milliwatt comes out, the amplification is 20 dB. So, this is therefore, a ratio measurement. For every device there will be certain loss, because of its own intrinsic loss of this one. And then there could be property of this of, the device could also be such that in one direction micro power goes in.

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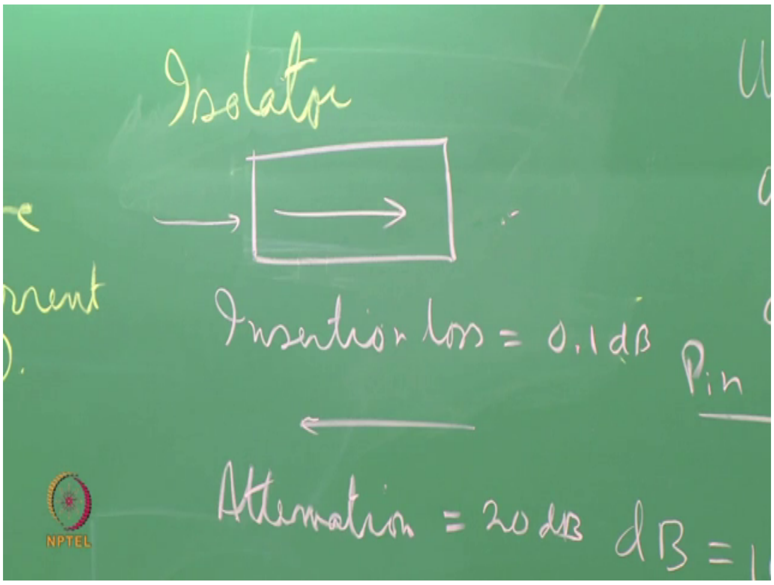

And other direction it does not come out. Will see some example later, physical non reciprocating device, one of the way, is call the isolator. So, this is the, let us say microwave isolator and we would drove with this way. So, the power goes in here, it comes out here, with where it will loss. So, I call insertion loss. Let us say, of the (Refer Time: 19:53) say 0.1 dB; that means, you can figure out from here that almost 99 percent micro radiation come out here also approximately, but in other direction here, microwave goes in and or comes out there, this could be, attrition could be, let us say about 20 dB; that means, if the radiation start enter here, only would 100 of that will come out of here.

So, this is isolator. It is a unidirectional device where microwave power is allow to go through in one direction ok. Again I am saying that these are the relative or ratio measurement which give some idea about the characteristic of that, but sometimes you also like to mention the absolute power of the microwave radiation, and (Refer Time:20:49) milliwatt is the unit. Sometimes it is to miliwatt; one uses an equivalent definition of microwave power in terms of d B m. This is called d B m.

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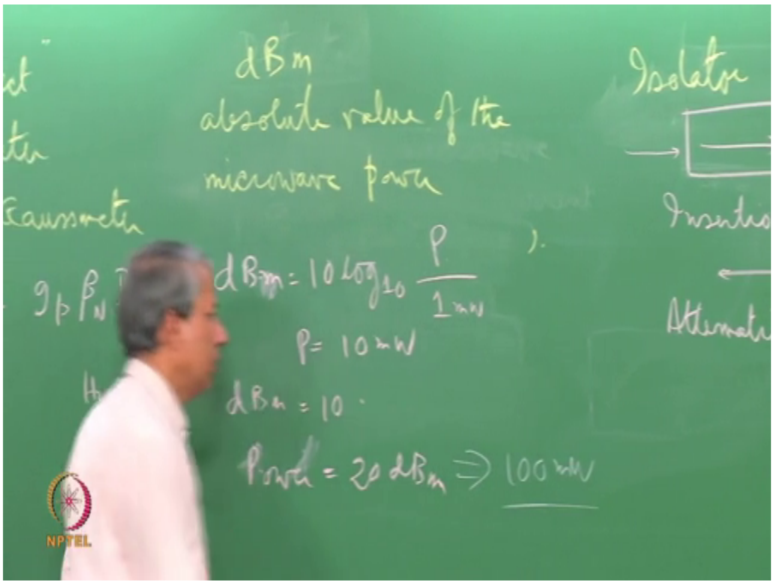

This is the absolute value of the microwave power, and in a very similar passion, this is defined as d B m is equal to small m here, not a subscript d B m, not subscript 10 log base 10 power by 1 milliwatt. See here the reference power is kept in 1 milliwatt.

So, you see that, if it is power; that is falling on the whatever system you can think of is 1 milliwatt. Then these becomes 1 log 10 equal to 0. So, 0 d B m is 1 milliwatt of power, but if P is, let us say 10 milliwatt, then in d B m will be, this by this is 10 log 10 is 1 10. So, 10 d B m power is, equivalent to 10 milliwatt of power. Similarly 100 on, if power is equal to 20 d B m, what will be the actual power. These will be 20. So, this ratio has to be 100. So, 100 milliwatt of power corresponds to 20 dB of is corresponds to 10 milliwatt. With this we end this discussion.