Introduction to Biomedical Imaging Systems
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Lecture - 48
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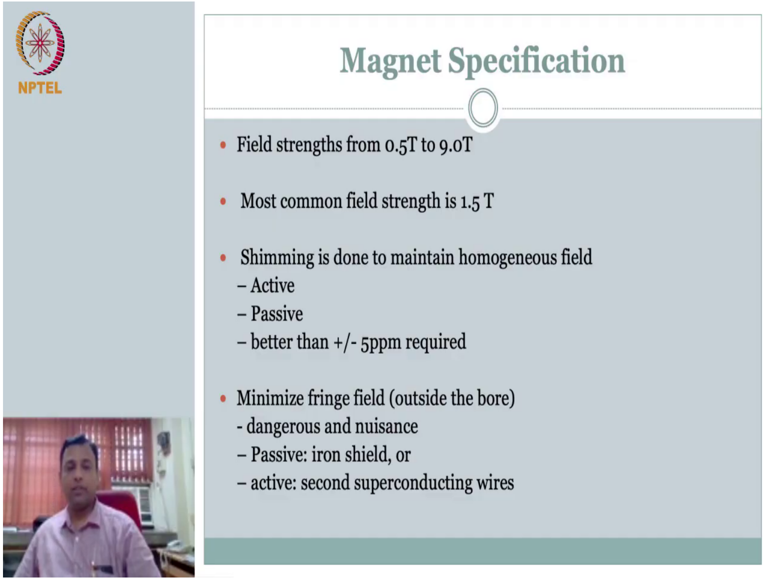

The next important component which is going to be your gradients remember we have the permanent magnet your B naught gradients are important where did we see in the block diagram if you remember.

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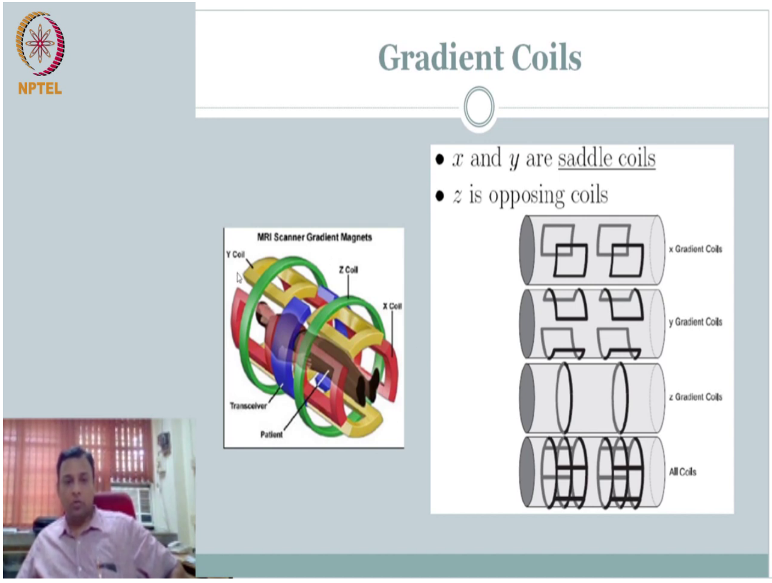

Gradients we need for a purpose of changing the magnetic field in x y and z direction how are they doing it. So, you are going to have gradient coils and of course, you are going to have 3 different directions therefore, you are going to have x gradient coils y gradient coils z gradient coils. And you can see that all of them can be nicely put together right all the gradient coils can be assembled together.

And you will notice that the name here given is x and y are called saddle coils just to remember why, when you say saddle what is saddle. The otherwise x y z is 3 dimensions, how do you remember everything. What do you mean by saddle? I think if you look at in this example if you look at y gradient you can vividly tell why the saddle you know horse back. So, if you look at this you can clearly see why the name is given a saddle it looks like saddle.

So, immediately you can recognize it is on the curvature surface y is in one direction the other is also in x both of them will look like a saddle that is why it is called saddle coil. So, a z therefore, will be your 2 parallel circles here right 2 z is your opposing coils. Notice, how we described its going forward along the bore where the patient will go from his head to feet that is our z direction so, this is kind of your bore this is your z direction so your coils are in perpendicular to that.

I found a better animation here right more well done 3D with color. So, this is the patient this is my z axis right patient lying axis. So, this is how the coils are arranged Z coil is perpendicular to the patient axis so that is your z axis and then the Z coil and then your surface saddle coil or your X coil and Y coil are arranged here ok.

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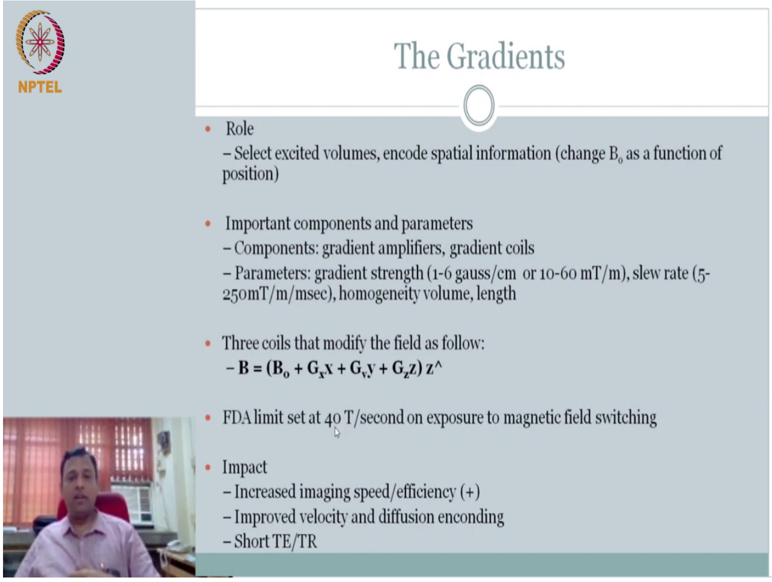

So, let us see now, what do important component is gradient? What does that do what does this gradient do? Notice, its role is to excite selected volumes with select frequency in other words we want this magnetic field strength B right static field we need that to change as a function; as a function of position right different locations should have different field that is what this tries to accomplish.

How does this try to accomplish, what are the components? What are the parameters of interest when you talk about gradients? Components are obviously, you have to have a coil right so, components are gradient amplifiers and gradient coil so you have to have amplification and you have to have the coil.

Parameters are also very straightforward jargon is slightly specific to this, but what is gradient well, we know this from mathematic what is gradient it is just changes. When we talk about anything that is changing; that means, you are interested in the slope tells us how fast this changes or how slow it changes right. So, slope is so your gradient is nothing but something to do with rate of change.

So, gradient here what is it that we are changing the field strength is what we are changing. So, parameter is gradient strength so its units is has to be magnetic field strength. So, it can be either gauss or in tesla so it is in you know 1 to 6 gauss or 10 to 60 milli tesla the change over length. So, either in centimeters or in si it is mi sorry in meters.

So, you have parameters is gradient strength how does gradients the magnetic field strength how fast or how slow it changes with length is one parameter. Clearly we are talking about how fast it changes you turn on how fast does it change right. So yeah somewhere time should come in that is called as your slew rate yours change 5 to 250 milli tesla per meter per millisecond. How fast this gradient changes apart from that; obviously, something changes the parameter of interest is the length over it is changes.

Because, then that will determine absolute terms how much is the field strength at different endpoints right. And homogeneous volume over which you can pretend that that particular field strength is homogeneous so, all these are important parameters. So, your coil essentially is changed your B is always in z direction right we are always interested in the z direction, but it is slightly changed based on the slightly changed based on the gradient properties.

So, G x x gradient strength g x g y g z so this is your b in the z direction, notice now the z direction is I mean I have always used this, but no patient is lying. So, it is always head tail you know foot to head that direction ok. You have some limits at which you want to keep the switching you cannot change rapidly because your human body right you do not want to get into unknown trouble of switching its property so rapidly so, there are some limits ok.

Let us get into some details of course, so the advantage of having these gradient coil is you can having this limits right more the better it is increased the imaging speed so you can capture faster changes. So, there are advantages you want just to be as high as possible, but there are limits right so, it will enable you to do fast switching, but you have to operate within limits.

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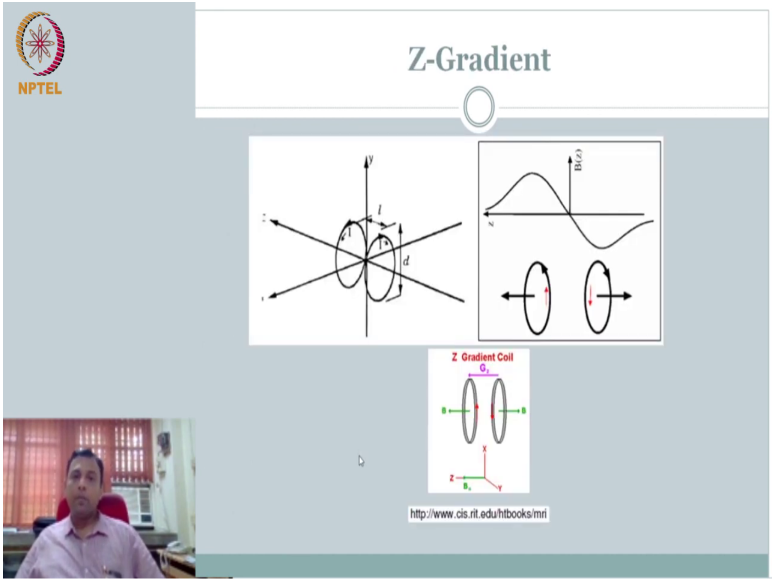

So, let us look into the detail if you take z gradient so notice is a very nice sketch. So, this is your z right patient lying so, the coil is perpendicular right that. So, this is your 2 loops that you have. So, notice what happens if I pass a current i in clockwise direction here and i in anticlockwise direction you are going to have opposite polarity ok. And depending on the length of separation and the diameter of this your field strength b of z can change see.

So, essentially from head to tail head to toe you are going to have different experience different field strengths that is what this is saying right. So, by changing the z gradient or the z coil enable us to change the field strength in the z direction to put it into the coordinates here x y z right. Now, z is along the pressure so this is how we are going to do. So, the B is always your B naught is always in the z direction the z coil essentially gives this gradient G c right how it changes here. So, it is changing the B naught experienced as a function of length in z direction.

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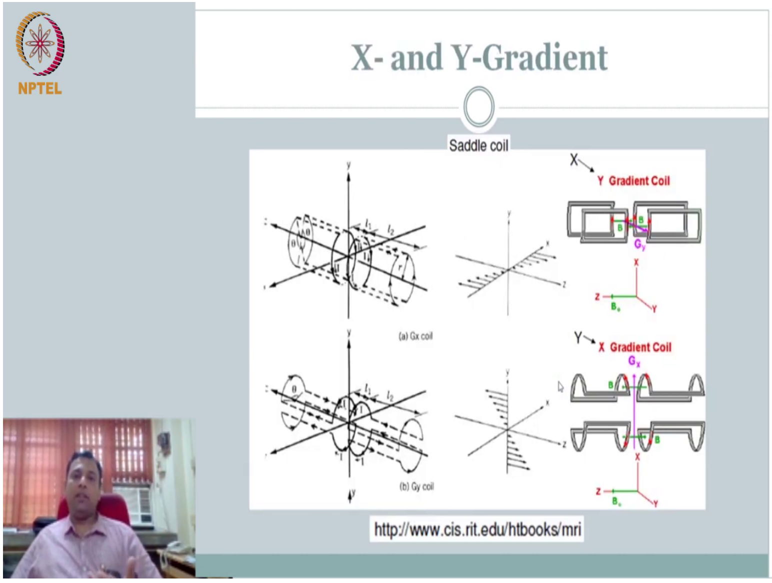

So, naturally you would expect similar thing for x and y notice there is a typo here this has to be a x gradient. So, the two other things have their radius right the coil radius and the length over which the coil is there. So, those are your parameters and you can see how the, what is the effect of gradient right the length of this arrow is changing the length any vector what you see length is a magnitude so the field is changing.

Of course, it comes to 0 so it is positive negative high becoming 0 increasing, but along x direction if you use x gradient, if you use y coil y gradient the gradient changes in y direction. All the time notice our b naught is in this direction in the z direction these are small changes or the gradients along each of the, this is what the x y gradient coil accomplishes.

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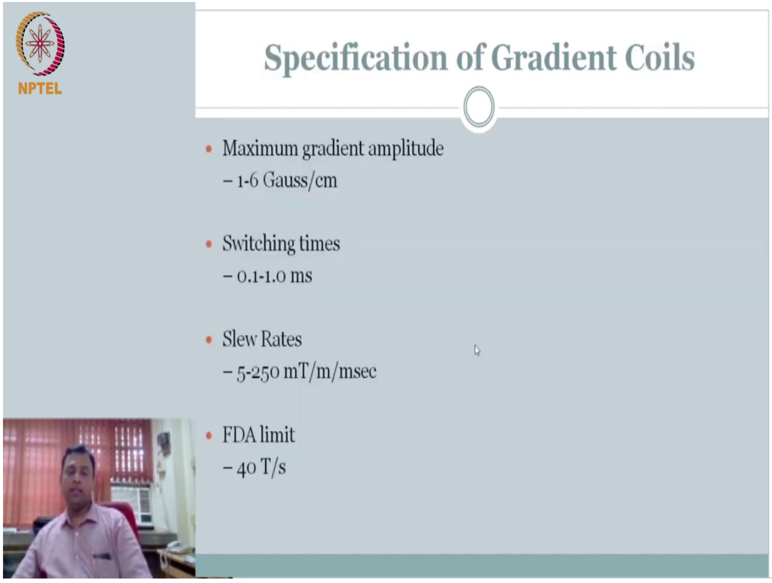

So, what are the specifications that we typically get oh we can change 1 to 6 Gaussian per centimeter switching times are very you know in fraction of millisecond. Recall from our physics you know what we were going after T 1 T 2 right a short T E, but all of those were still in the tens of milliseconds here you are looking at fraction of millisecond switching time. So, it is likewise your slew rate your only milli tesla per minute per milli second right so you have enough cushion.

So, everything is operating within the limit term whatever you do here it has to be within the known approved legal limits ok.

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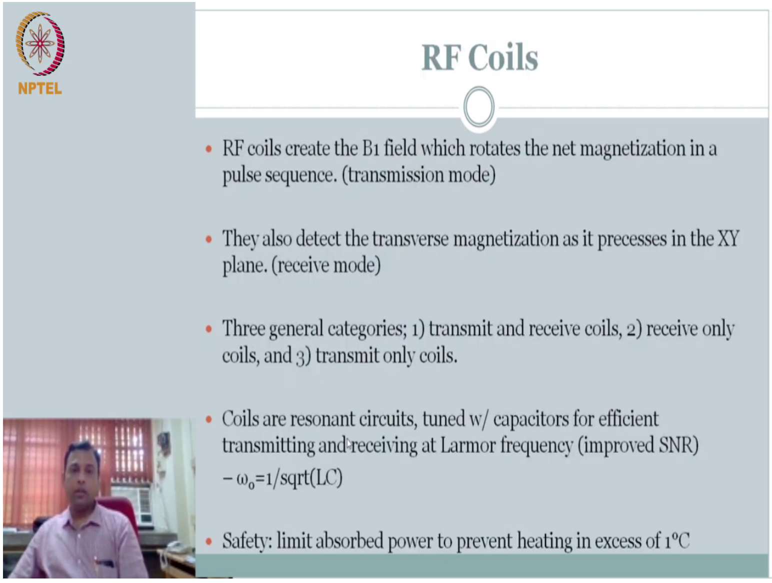

So, move on to gradient circle the other most important things are RF coil. Like I said RF coil, why do you need the RF coil? Remember the B 1 right the B 1 to push the magnetic field around. So, you need that how do we do that, first is on like the alpha pulse 180 pulse that we talked about that is excitation pulse.

So, that is on the transmission mode. So, we can have a RF coil for transmission mode we can have transverse component that are cutting right x y component. So, you can have another coil so this is transmission mode this is only receive only mode. So, technically you have three different broadly you have three different categories you can have transmit unreceived coils, you have received only coils, you can have transmit only coils ok.

What are these coils? These are essentially your see, how we are talking about it this is all free induction there is a frequency and you are measuring the frequency so; that means, you are you know the frequency you are tuning in to a frequency. So, essentially this coil and its circuits are nothing, but a resonant circuit which is tailored right tuned with capacitors for efficient transmitting and receiving at a particular frequency that you want.

So you are holding on to a particular frequency the resonance frequency or your Larmor frequency here. So, that your resonance coils that you have you are tuning it to the Larmor frequency. So, you know the omega naught is 1 by square root of LC. So, of course, you have a coil you have to have some safety limit because the heat could be generated and so it is usually done to keep the temperature raised less than a degree ok.

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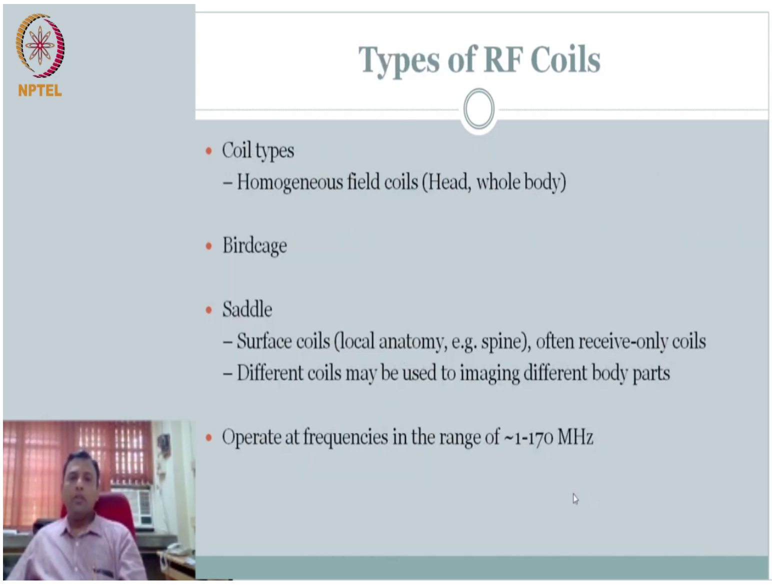

So, types of coils so you can have different types of coils what do we mean by that apart from transmit receive I said what do we mean by different type here is you can have a big coil right, you can have a big coil which can have which we call homogeneous field. So, you have it for the whole body whole head everything any location can be done. So, this is a whole body coil.

You can have dedicated coils also birdcage, saddle right here you can have surface coil. So, you can have surface for knee you can have elbow you can actually have a dedicated receive only coil for a particular location ok. So, you have different coils for different objects different parts of the body. Of course, all of them should operate within this range remember this range what is this we are talking about 42 megahertz is your tesla.

So, you should be able to operate gradients are going to change it over a range but remember our limits mostly we are talking about 1.5 tesla 3 tesla kind of scanners. So, this range is in some sense operatable for biomedical imaging.

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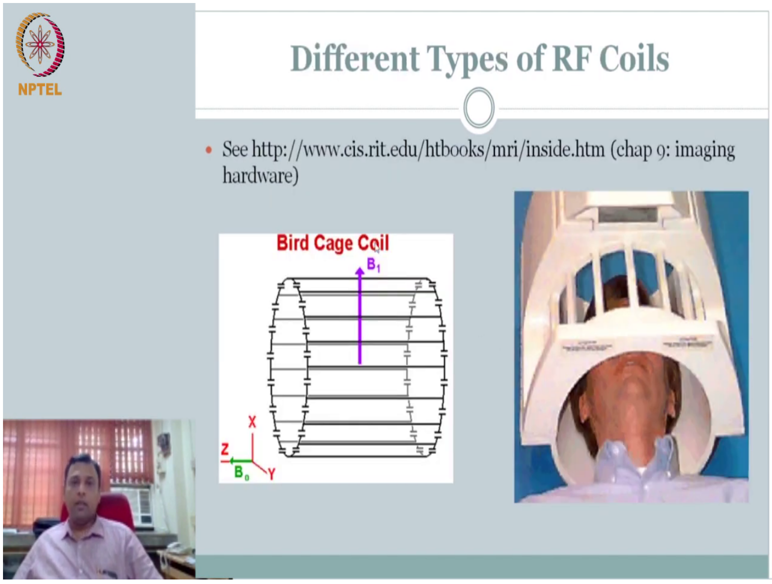

So, different coils just to demonstrative since we are not going to spend too much time on this. So, you can have a bird cage coil so essentially you are putting your tuning circuit you have some construction like this. So, so that it is called as a birdcage the shape and you know the sketch gives you the name as to why it is birdcage coil ok. Of course, here you notice this is B 1 is in the X direction.

So, always notice where do you want your body is Z direction right. So, we are always going to so we talked about the z axis your measuring always is going to be perpendicular transverse component. So, if your z is like this your measuring is going to be perpendicular to that right that is how this is ok.

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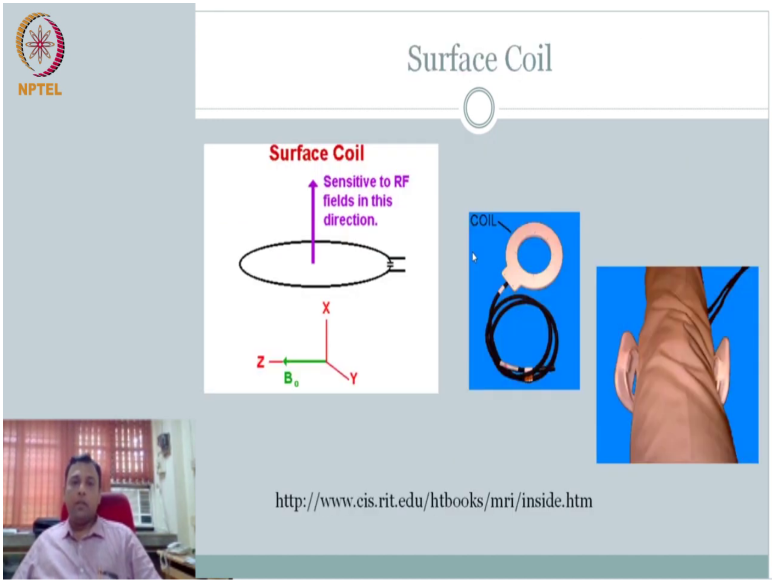

So, like that you can have surface coil notice again B is here your surface coil is measuring the XY component right the XY direction. So, you can have dedicated coil like this it is not a big deal coils are nothing but loops which have some tuned values your frequency it is tuned for a particular resonant frequency ok.

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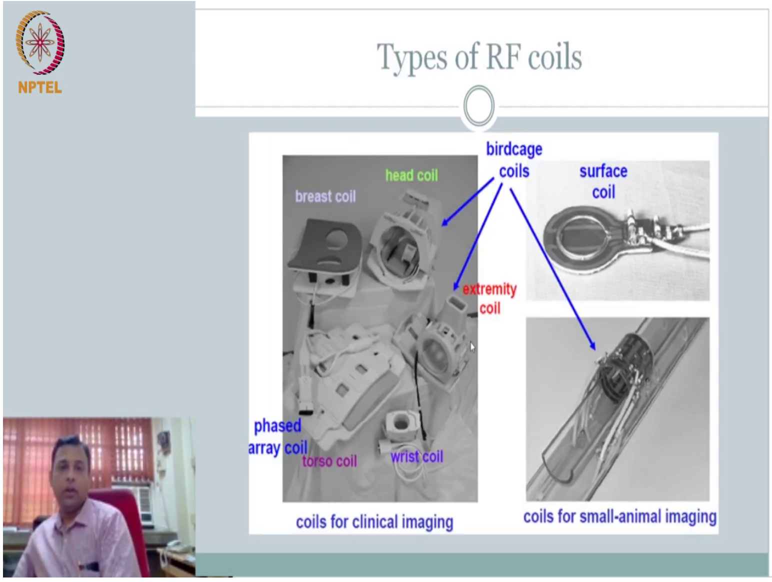

So, you can have several different coils dedicated for different organs like you see here breast coil head coil wrist coil right torso coil. So, you see the size and shape is changing depending on of course, several of them these are for small animal ok we have mice or something you can use this chamber is also small so you have a surface coil.

So, these are. So, these are very core electrical if you are interested in electrical circuits antenna you know those kind of area and electrical I think this will be very interesting and very important area that you can contribute. For the purposes of this course we are we have just understood what is the physics we know the role of this and we know there are capabilities how this is going to affect our image and image quality.

But we are not really interested in circuit design because that is not our goal of this kind of course, which is a introductory on imaging system. So, we leave it here whoever is interested has a background you may have to jump in, but this is a very interesting and active area where you can contribute ok. So, we will stop here because next we need to move forward where instrumentation is the three major components we have covered ok.

Now, we need to go on to see how we use all these instruments or these components they understood physics. So, how do we use this to realize the data and organize the data so, that we can go to image formation ok image formation, and once we know image formation here we will talk about essentially how you are collecting the data and then how do we represent it as a reconstructed image ok. So, those are the two topics that will be covered in the next two lecture videos. For now for instrumentation I think we will stop here ok.

Thank you.