Antennas
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Module - 01
Lecture - 05
Antenna Fundamentals-II

Hello and welcome to today's lecture on Antenna Fundamentals which is continuation of the previous lecture.

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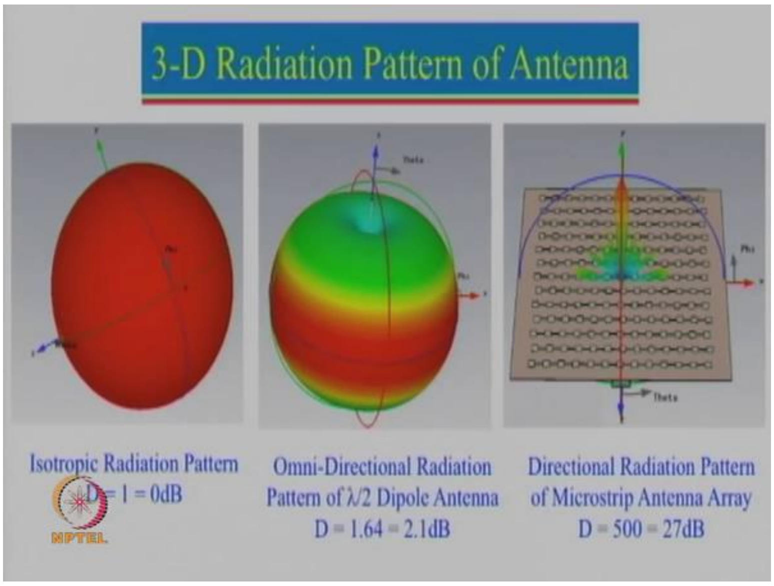

In the previous lecture we have started with the antenna fundamentals and then we quickly talked about 3-D radiation pattern of Isotropic antenna then Omni-directional antenna after that Directional antenna.

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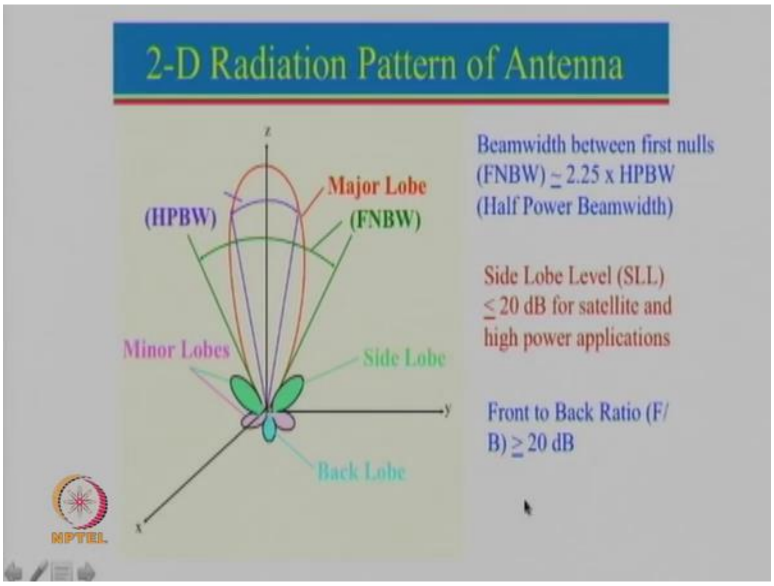

Then we looked at the 2-D radiation pattern we defined major lobe, half power beam width, first null beam width and various side lobe levels.

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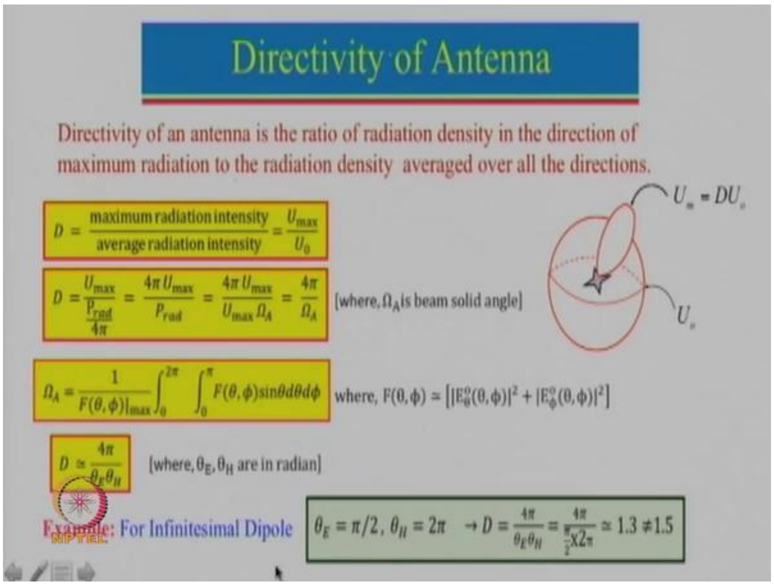

Then we defined the directivity definition. So, what is the directivity and we have looked into the very simple expression for directivity from half power beam width how we can calculate the directivity.

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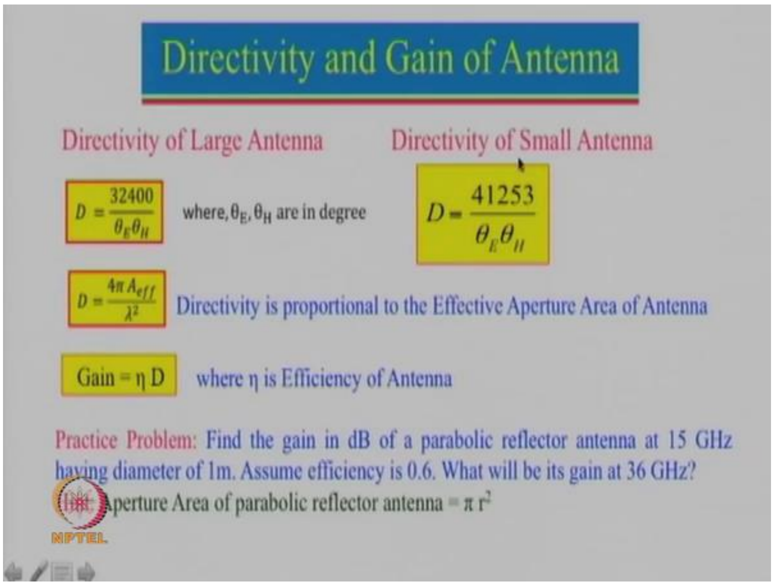

And then we have given 2 different expression, this is in terms of degrees which is direct conversion of 4 pi by theta E theta H into degree and this is the expression to be used for larger antenna. You can see that this value is slightly smaller than this value here because this value here does not account for all the side lobes which are inherently present with the large antenna.

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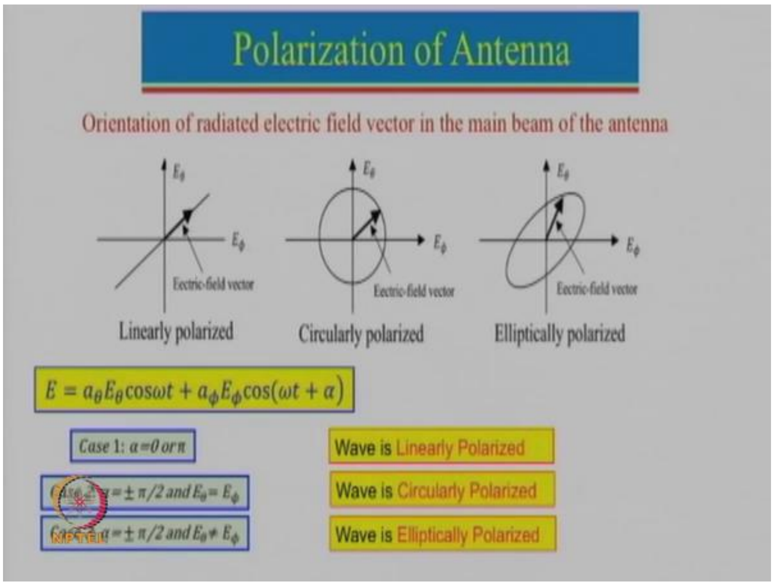

Then we talked about the different types of polarization - linear polarization, circular polarization, elliptical polarization and then do we define axial ratio for circularly polarize antenna.

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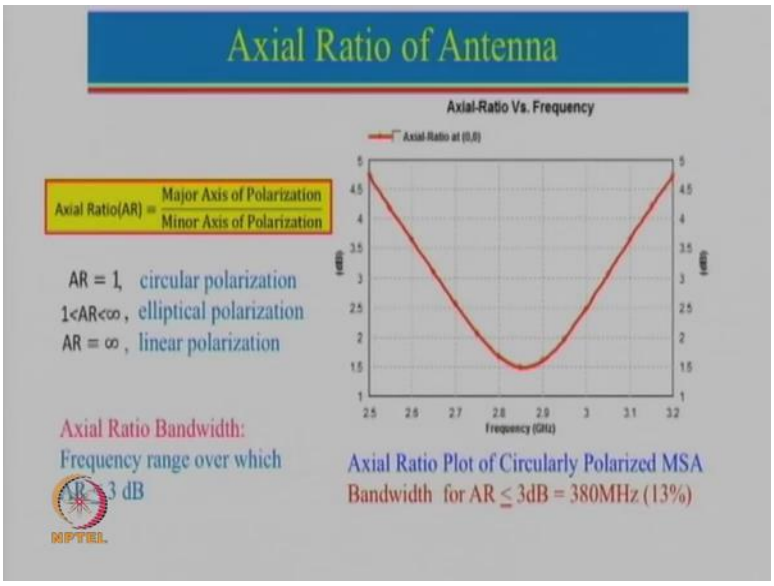

Ideally axial ratio can be 0 dB or axial ratio can be 1, but practically we take up to about 3 dB bandwidth. So, axial ratio bandwidth is generally defined frequency range over which axial ratio is less than 3 dB.

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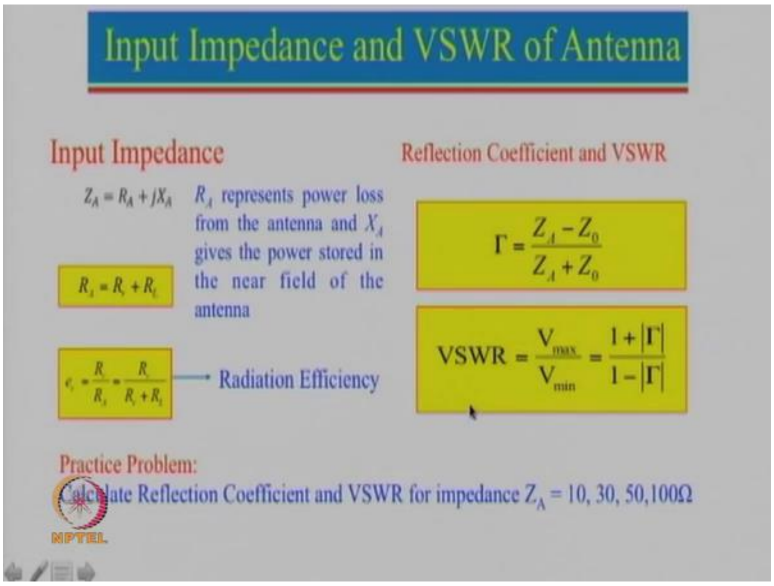

Then we looked at quickly input impedance, a input impedance can be a complex quantity which can be a real part as well as the imaginary part, and from there we looked into how we can calculate a reflection coefficient which actually tells us what is the reflected power and then from reflection coefficient we can also define what is VSWR.

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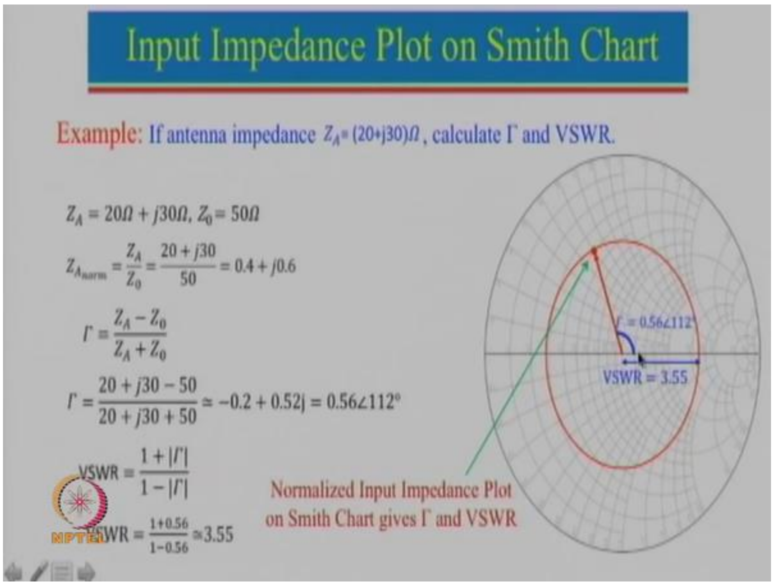

And since impedance is a complex number we should actually use Smith Chart which makes life much easier this is a graphical representation of the complex impedance and we had looked into how a complex impedance can be plotted on the Smith Chart and very easily we can find out the VSWR, reflection coefficient and its angle.

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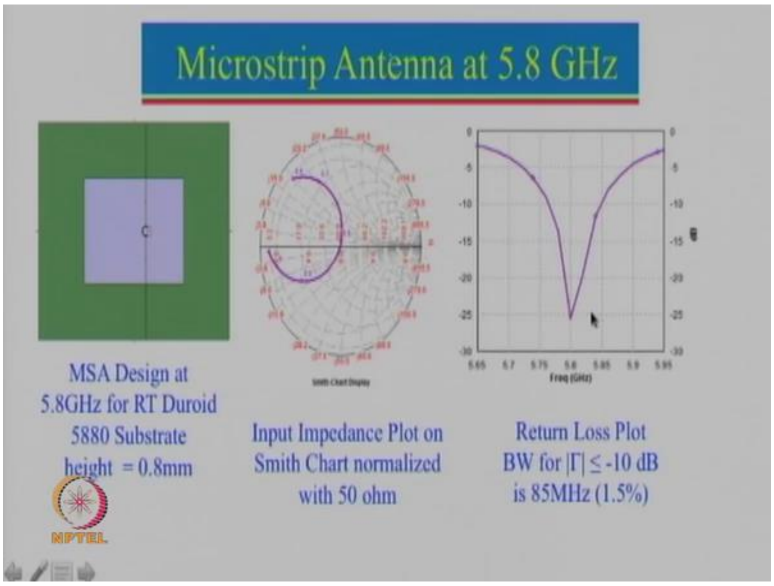

Then we looked into the microstrip antenna design at 5.8 gigahertz. So, I did mentioned about a microstrip antenna this is a rectangular microstrip antenna which is defined by its length and width and we can choose a feed point properly such a way that it is actually matched to 50 ohm line. So, this is the 50 ohm point which is the central point of the Smith Chart I also call it bulls eye and this is the frequency response. So, this is the lower frequency.

As we increase the frequency the plot is shifting around and a perfect match is obtained over here and this is the corresponding return loss plot and we define bandwidth for reflection coefficient less than minus 10 dB and in this case it is just about 85 megahertz which is just 1.5 percent. Now, this bandwidth is not sufficient, but later on when we talk about various microstrip antenna techniques we will talk about how to get broad bandwidth.

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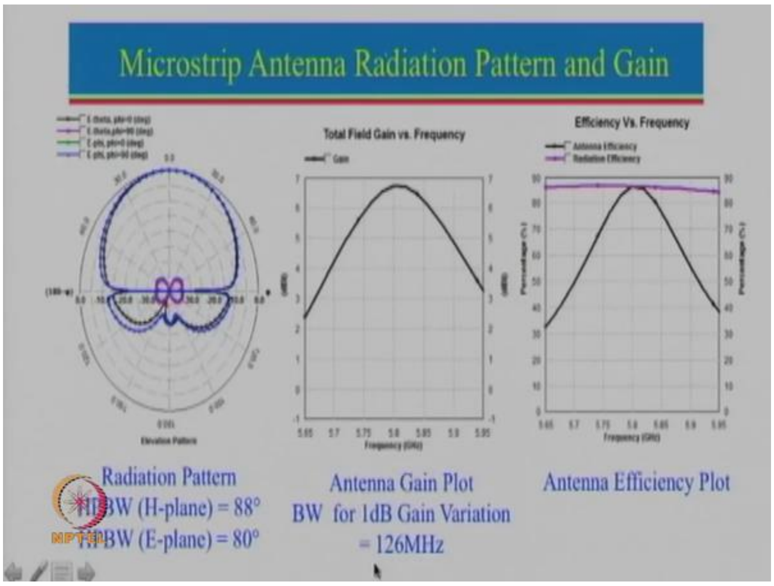

Now, one should remember that antennas are not defined only by its impedance plot or reflection coefficient plot they are also defined by its radiation pattern, a gain plot and efficiency. So let just see; what are the different radiation pattern. So, these are the 2 field which are E-plane and H-plane radiation pattern this shows actually a cross polar component and this is the back radiation. So, one can see over here back radiation is fairly less that is possible verily because a larger ground plane has been taken in this particular case. If this ground plane is reduced to let us say this value then the back radiation will increase and if the ground plane is exactly equal to the size of the patch then the back radiation will be almost equal to the front radiation.

So, nevertheless this is a good design and we can see that the front to back ratio is fairly good we can also see that half power beam width in H-plane is about 88 degree; half power beam width in E-plane is about 80 degree. Now this is the gain plot. So, one can actually see that the maximum gain is slightly less than 7 dB, but one can see that also as frequency changes gain varies. So, generally a 1 dB gain variation is acceptable. So, we can say that the bandwidth for 1 dB gain variation is approximately 126 megahertz.

Now these are the 2 plots for antenna efficiency or this plot corresponds to the radiation efficiency and one can see that these antennas are fairly good radiator, but however, the total antenna efficiency is what we are interested and this one is varying with frequency much more than this one over here actually this also accounts for the reflection coefficient variation.

So, if you just look at the reflection coefficient variation one can see that this is the reflection coefficient and at this point reflected power is close to zero and corresponding to minus 10 dB a reflected power is approximately about 0.5 dB and that is why gain reduces. So, it is actually important that when we look at the antenna we should look at all the characteristic, just broad band VSWR does not really mean that it is a good antenna we have to also see the radiation pattern how much radiation pattern varies over the bandwidth defined by let us say VSWR less than 2 or less than 1.5 and what is the efficiency of the antenna. You can see that the efficiency of the antenna is fairly less at these frequencies.

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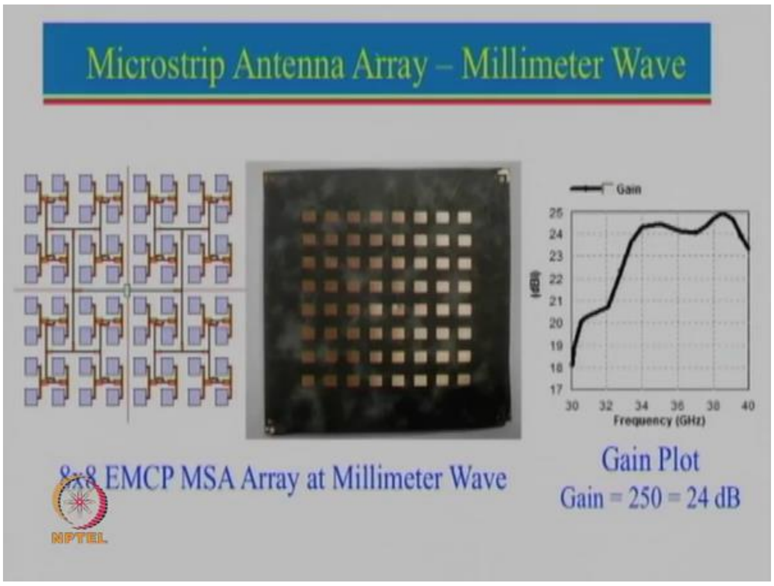

So, now let just look at another example, this is an example of a 8 by 8 electromagnetically coupled microstrip antenna array at millimeter wave. A millimeter wave is generally defined from 30 gigahertz to 300 gigahertz and the reason why we have used these numbers of elements because we just saw that typically gain obtained is about 6 to 7 dB by using a single element. Now if you want a larger gain then what we can do? We can use multiple numbers of elements.

So, let just very quickly look at what is going on here. So, here is an example of a 8 by 8 electromagnetically coupled microstrip antenna array at millimeter wave. So, millimeter wave frequency range starts from 30 gigahertz to 300 gigahertz. So, let just see what we have done here. So, it is a 2 by 2 element first, let just look at it these 2 by 2 elements are actually fed with the microstrip line over here and these are being fed. Now these 2 by 2 you can see that this is another combination now these 2 are connected together and this is the 2 by 2 array, 2 by 2 array which are connected over here. So, now, this becomes a 4 by 4 array and then these 4 by 4 array are connected together to form 8 by 8 array. So, this is the modular way of designing an antenna array.

What is electromagnetically coupled? Electromagnetically coupled is that there is a one patch or which is you can corresponding to the feed point it is there and there is another patch which is on top of the bottom patch. So, it is actually a 2 layer microstrip antenna array, 2 layers have been used mainly to obtain broad bandwidth.

So, here is a gain plot. One can actually see that right from 34 gigahertz to about close to 39 gigahertz one can actually see that the gain is more than 24 dB and that is equivalent to about 250. Now in the previous case for a single antenna the gain was between 6 to 7 dB now we can see that gain is about 24 dB. So, by using a large number of arrays one can actually get a larger gain. So, instead of 8 by 8 if we had used suppose 16 by 16; that means, the array size is increased by 4 times, maximum gain which can increase is about 6 dB, but because of some feed losses it may be about 5 to 5.5 dB. So, we can get about 29 dB or so, a 30 dB will be equivalent to gain of 1000.

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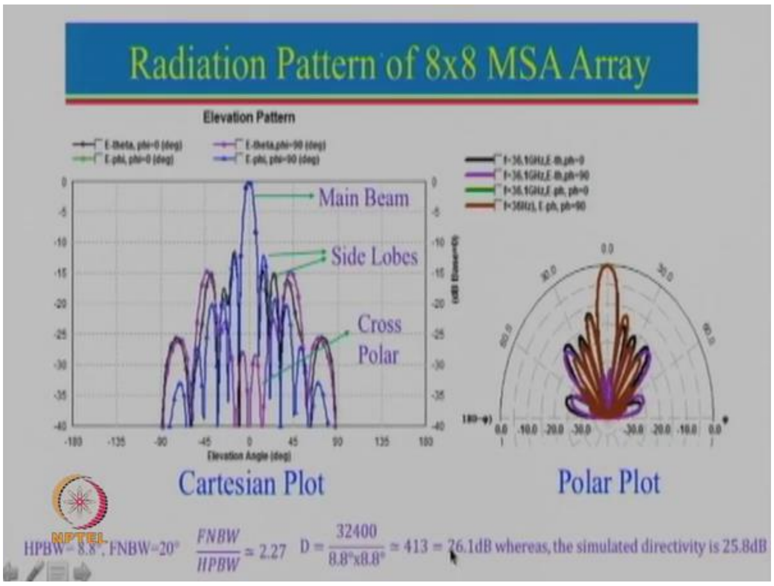

Now let us see also the radiation pattern plot of that. Now I have shown here both the plots here this is the polar plot, this is a Cartesian plot. Polar plot is in terms of the angle. So, one can see that oh this E and H-plane are almost same, their beam width is also same the reason for that is because it is an 8 by 8 is a symmetrical array and that is why E and H-plane are relatively symmetrical and one can actually notice over here that half power beam width is about 8.8 degree in both the plane. Then we have a first null beam width. So, first null beam width is approximately equal to 20 degree. So, if you take the ratio which is about 2.27.

Now, let just see this is a Cartesian plot. Cartesian plot is mainly are the radiation intensity versus or this one here is again in the x direct 0 to 180 and this is 0 to minus 180. So, it is a spread out, this is shown in the angular fashion, this is more shown in the flatter portion. So, one can actually see here the same thing, main beam here, these are the side lobe levels and these are the cross polar levels. So, generally we prefer if it is a good linearly polarize antenna we prefer that these cross polar levels should be definitely less than 20 dB. So, you can see that this is a 20 dB line. So, the cross polar levels are definitely less here.

Of course, cross polar level increase in the other portion, but that is not very important we are more concerned about the cross polar in the main beam. Now from here we can actually use the earlier formula which I had mentioned, for larger array one can use 32400 so if you use that formula the number comes out to be about 26.1 dB, where as the directivity which is simulated is about 25.8 dB. So, you can see that this number is relatively close to this number. So, one can use a very simple formula like this to find out what is the directivity of the antenna.

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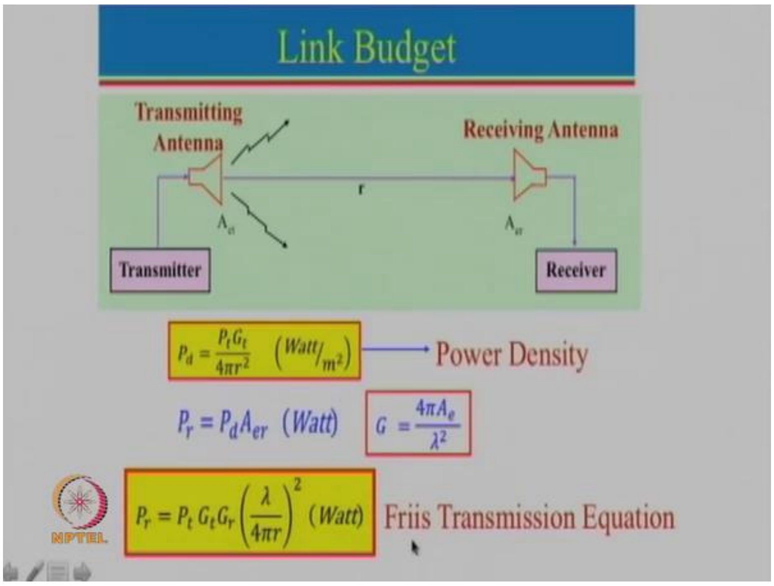

Now, one of the most important things when we are designing an antenna system or power transmission power receives is actually known as a link budget. In fact, this is a very very important thing. So, you should please pay more attention to this. So, generally how do we define link budget? Let us say we have a transmitter which is transmitting through a transmitting antenna then at a far away distance there is a receiving antenna with their receiver. So, now, what we need to define, so when we do a link budget we know that we would need to cover let us say a 1 kilometer distance or 10 kilometer or in case of satellite communication this arc would be 36000 kilometer. So, one needs to take into that range.

So, according to the range define, then we also see transmitting antenna that all depends upon what is the area we want to cover. Suppose we want to have only point to point communication then this should be a large gain antenna with the very small half power beam bit, but if we need to cover wider area then this should have a relatively smaller gain and wider beam width. So, the transmitter power again depends upon what is the range we want to cover and also what is the receiver sensitivity. So, just to give you an example for example, we all use let us say mobile phone - now the receiver sensitivity of mobile phone is actually as good as minus 100 dBm and in fact, for some mobile phone it works even at minus 108 to minus 110 dBm also. In fact, majority of the mobile phones show full strength at minus 70 dBm.

So, what we need to do? We need to do the link budget design. So, what we start with a very simple thing we need to find out what is the power density. It is relatively simple, so let just see here this is the transmitted power which is P t. Now if this transmitted power is radiating equally in the sphere let us say for an isotropic antenna then this should be divided by the area of the sphere which is 4 pi r square; however, since we are not using an isotropic antenna we are using an antenna with the gain of G t. So, then we multiply with that gain and this will be the power density along the maximum gain.

Now, here is a receiver. So, receiver will receive the power. So, power received by the receiver will be power density multiplied by the effective aperture area of the receiver. So, that will be the total power received we define in terms of watt, this could be transmitted in let us say it could be 1 watt or 10 watt or 100 watt, 1000 watt depending upon application and now we had seen that the relation that we had saw earlier d is equal to 4 pi A by lambda square and gain is related with the d which is directivity that is efficiency multiplied by directivity. So, efficiency directivity is combined here this is known as effective aperture.

So, if we know effective aperture which is for receiver we substitute this value here. So, this will be effective aperture will be lambda square this will be G r divided by 4 pi you put over here. So, this is the equation. This equation is also known as Friis Transmission Equation. So, this is a very important equation for any link which we need to design. So, let us see what it depends upon.

So, the receiver received power or receiver sensitivity you can say depends upon the transmitted power, the gain of the transmitting antenna, gain of the receiving antenna, it is proportional to lambda or inversely proportional to frequency square because lambda is c by f and it is also inversely proportional to r square; that means, if the distance is doubled power received will be reduced by 4 times. And if you want the same thing then we may have to increase the power, suppose the receiver sensitivity is fixed and if you are doubling the distance then the transmitted power has to be increase by 4 times.

So, these are the things which we require to design any link system. I also want to mention a few additional things whenever we do something like this here there is always a margin. So, generally an acceptable margin is about 10 dB gain margin is kept. So, that the system works properly over any adverse condition. So, for example, you might have noticed that when you are watching a TV using let us say dish antenna. So, the signal is coming from the satellite, dish antenna is pointed towards the satellite, but during the rainy season you might have noticed that signal is not there specially during very heavy rain because what happens - water absorbs the radiation and also water diffracts the radiation.

So, the re power received by the dish antenna is relatively reduce and that is why you do not get the signal. So, gain margin is always very very important to do.

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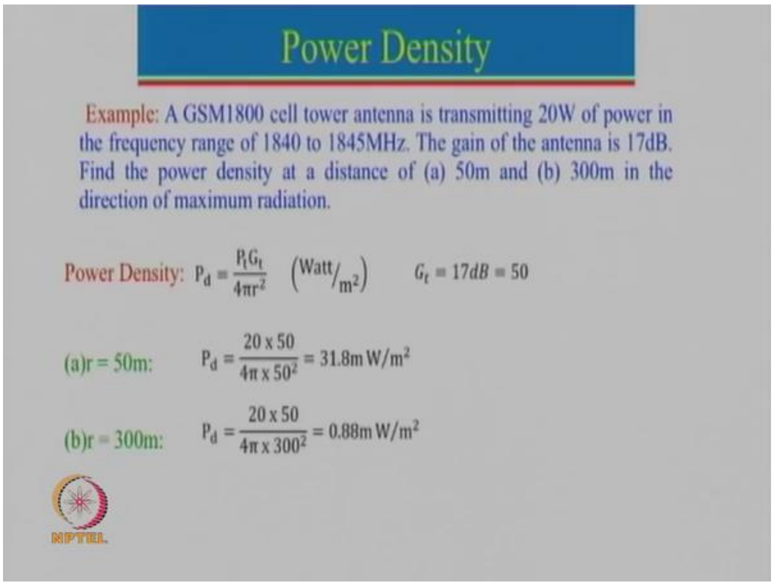

So, now let just take an example how do we calculate the power density. So, I have taken a real life example which is happening in India. So, let just take an example of a GSM1800 cell tower is transmitting about 20 watt of power in the frequency range of let us say 1840 to 1845. Now just to tell you the GSM1800 range is from 1810 to 1800, 80 megahertz, but a typically an operator might have a bandwidth of 5 megahertz.

Now, the gain of the antenna is 17 dB which is again very commonly used in India and we want to find out what is the power density at a distance of 50 meter and at a distance of 300 meter in the direction of maximum radiation. So, let us see now how we can calculate power density. So, we just saw that the power density is given by this particular expression here; that means, it is proportional to transmitted power gain of the antenna and the distance.

So, now the gain of the antenna is given in terms of dB which is 17 dB we need to convert that dB into numeric value which is 50. So, at 50 meter now we can substitute the value, so this is say 20 is the transmitted power in terms of watt, then 50 is coming from here which is gain divided by 4 pi into 50 square because we have taken r as 50 meter, so the unit will be watt per meter square. Now this value comes out to be 31.8 milliwatt per meter square I have accounted that 10 to the power 3 factor over here and when the distance is increased from 50 meter to 300 meter the radiation density decreases correspondingly. One can actually see that here. So, 50 to 300 distance is increased by 6 time. So, this radiation density should reduce by 36 times.

Now, let us see here what is going on about the radiation norm in the country and around the world. Now in India we have allowed the radiation density can be 4 50 milliwatt per meter square for GSM 900 for GSM1800 we have allowed the radiation density to be 900 milliwatt per meter square. So, one can say that this value is less than 900 milliwatt per meter square; however, in India we had adopted ICNIRP guidelines and the ICNIRP guideline ICNIRP stands for very nice name International Commission for Non Ionizing Radiation Protection.

So, people would think that it is some international body; however, it is nothing but an NGO in Germany which was formed by a person who had a link with the industry and in fact, in the ICNIRP guideline itself it is written that it is only for short term exposure and not for long term exposure, and what is short term defined by them? Short term defined by them is averaged over 6 minutes.

So, India had adopted ICNIRP guideline till 2012 and in fact, we have been to various government bodies we made a lot of presentations to TC, DOT, TRAI and we finally, convinced them and in fact, we wanted a much lower radiation norm, but they reduce it only to one-tenth. So, which is now one-tenth of ICNIRP guideline now if ICNIRP guidelines are only valid for 6 minutes then one-tenth will be valid only for 60 minutes which is for one hour. So, what is good for one hour we have adopted it for 24 hours. So, that is why people who are living close to cell tower radiation are exposed to very high radiation.

Now to create awareness to the people about high cell tower radiation and also people use cell phone for hours and hours every day. So, there are lot of health hazards associated with cell phone. In fact, WHO has classified cell phone radiation as possible carcinogen class 2B and that was done in May 2011. So, it is already 5 years and when I talk to people majority of the people are not even aware that it is possible carcinogen. So, I think it is the government's responsibility of all over the world that they should tell the people that it is possible carcinogen.

So, to create awareness we had conducted a one workshop at a IIT, Bombay in November 2011, we had made a one video at sea deep at IIT, Bombay. So, I am going to show you that video for next 5 minutes, please see that and enjoy.

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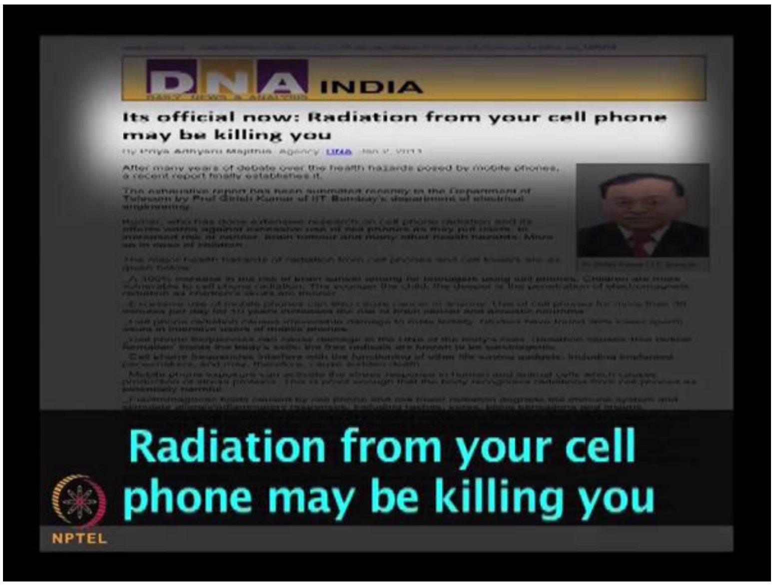

News from the media: (Refer Time: 22:50) cell phone radiation in actual health hazardous.

[FL] a studied done by MITs Electromagnetically Academy say cell phones also interfere with one sleep patterns.

Next time you want a buy mobile phone I suggest you carefully go through yoga menu especially the chapters of safety.

A team 31 scientists in 14 countries share radiation made by cell phones is quite possibly (Refer Time: 23:34).

The city of Saint Francisco tomorrow takes up (Refer Time: 23:36) to warn its citizens about using cell phone [FL].

Now an international panel of scientists is raising questions about whether there is a link between cell phones and cancer if you are talking for more than 20 minutes on your cell phone the EMR raises the ear lobe and brain temperature die up to 2 degrees. It is also penetrating the brain skull and it is heating the brain tissues inside there.

And when it is cooking the brain then what it leads to sleep disorder then memory loss, lack of concentration, irritation and ultimately to brain tumor [FL] it sense one pulse to the base station every minute. 180 watt of microwave power is being transmitted towards your body which could be your heart which would be your hand which could be the pant pocket. So, you have to decide which part of the body you do not like.

The cell phone emits electromagnetic radiation which is transfer to the cell phone towers so they must pose a bigger risk then the mobile phone itself.

A specifically for people who are living close to the cell tower it is the whole body which is absorbing microwave radiation, unlike a cell phone where only the brain is getting affected or the upper body.

[FL] so they are absorbing the radiation continuously or [FL] health problem [FL].

One common doctor when on (Refer Time: 25:40) them marks cell phone use likely caused his (Refer Time: 25:43) malignant brain tumor called an Oligodendroglioma.

It is actually (Refer Time: 25:50) that thing in my head 10,000 hours.

Actually [FL] that is the actual solution mobile phone [FL] you must keep the mobile phone at least one foot away from your body.

Cell tower [FL].

So you just saw this video, and in the next lecture I am going to tell you about what are the radiation health hazards from cell phone, as well as from cell tower. We will divide the next 2 lectures - first part will be on cell phone and then the second part will be on cell tower. So, where we will tell you; what are the possible health hazards and what are the precautions taken so that you can enjoy this wonderful technology in the best possible way.

Thank you.