Analysis and Design Principles of Microwave Antennas
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Lecture – 13
Dipole and Monopole Antenna (Contd.)

So, welcome to this lecture. We have seen the fields rim far fields radiated by dipoles, we have found the radiation resistance of dipole. We have seen that sometimes people prefer to have a monopole, because many times the having two poles and feeding it centrally is difficult. Just like you see, in pull is vehicles or in a vehicles, when we have a antenna the for music or anything. Now, if we want to put the swords and, then dipoles then the mechanically creates a problem whereas, the vehicle body that can serve as a conductor and then monopole will do.

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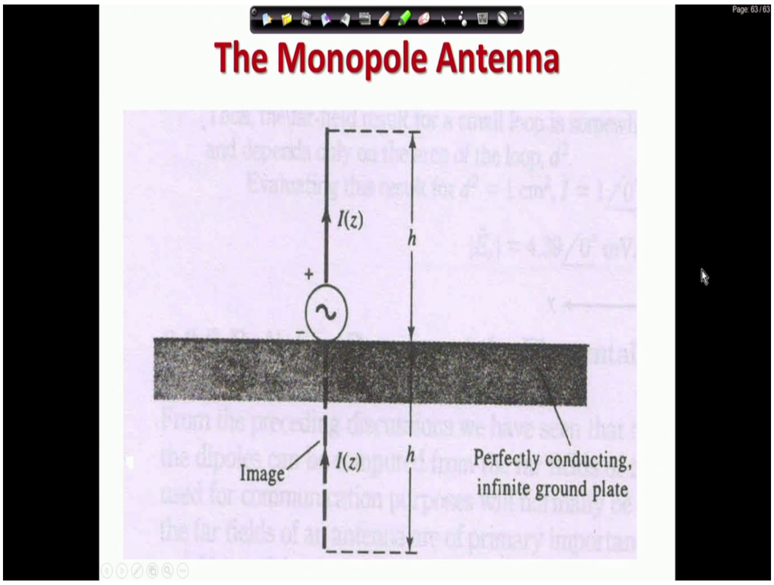

And so, if we see the monopole the monopole going to if you will see the monopoles thing. So, if I have a ground plane then this, but for a analysis we can think that it is like a this by applying image theory we can say that, it is just like a dipole without this ground plane. So, the fields radiated also will be same like dipole only difference is there would not be any field in this lower side, because this does not exist actually. So, only in the upper side the fields will be same as the dipole. So, this we can take and; that means, you see the field structure will be same as whatever we have described.

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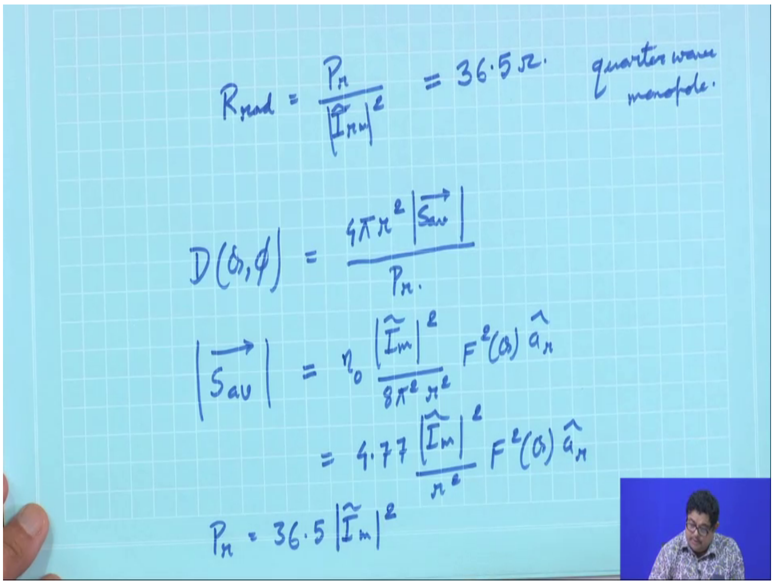

But what will be the radiation resistance R radiation is what R radiation is total power radiated by I rms square. Now, total power radiated by monopole will be half of the power radiated by dipole, because the only the upper hemisphere here is radiating. So, P r will be half of the previous case. So, can I say that R radiation resistance will be instead of seventy 3 ohm here, it will be 36.5 ohm for a monopole, or we can say it as quarter wave monopole.

Now, then I think we can see that what happens to the impedance, or what is the loss. So, another thing is what will be the directivity because, we have not seen the directive properties of the two antennas dipole and monopole. So, but we have all the ammunitions for finding that, because we have found what is the pointing vector we have found what is the total radiated power. Now, only job is to put that together what was directivity D theta phi D theta phi, when we introduced the directivity function, we ultimately saw that it is same as 4 pi r square the pointing vector average time average pointing vectors magnitude divided by P r.

So, for dipole we have calculated all these so, do that; that means, if we put these things you will get that finally, eta naught I in square by 8 pi square r square F square theta a r is the S average portion, or sorry this I should write as S average the pointing vector average will come this, or this can be further simplified, if we put this 122 pi 4.77 I in square by r square F square F theta a r. Now, P r we have already found out what is P r, P r is 36.5 just below in the last lecture I have derived that.

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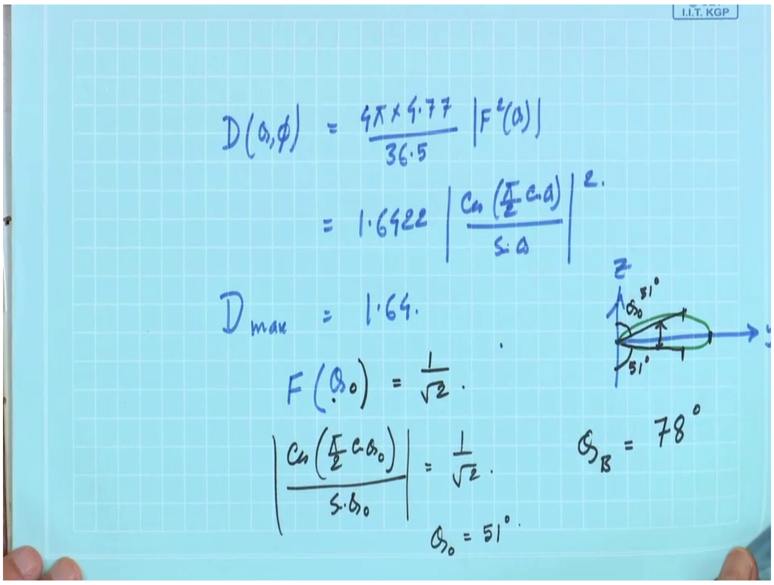

So, now, if we put it here the directivity becomes that 4 pi into 4.77 by 36.5 F square theta, this turns out to be 1.6422 F theta for up wave dipole is, now this thing we have seen that maximum value of this is 1. So, maximum directivity D max is nothing, but 1.64 so, what is our advantage what was the corresponding value for current element it was 1.5. So, directivity is a bit better 1.6 marginally better.

So, direction or directional property wise current element was also quite good that 1.5 dipole is giving only 1.6 main advantage is the radiation resist that we have seven that, dipole can really radiate good amount of power also, we can find what is the half power remove it. So, for half power remove it what we demand that, F at some rate at actually what is half power B moment.

If we plot we have seen if this is z axis the radiation pattern in the theta plane. So, if this is y so, this is something like this no they are half power half power be move it, I will have to look at the points, where compared to this it will have a half of the power; that means, voltage wise. That means, F theta will be half of that so, later angle theta naught that is happening that it is having a half of this maximum value. So, we can write F theta naught F of theta naught that will have to be 1 by root 2 that means, you put that cos of pi by 2 cos theta naught by sin theta naught that should be 1 by root 2 so, if you solve for that theta naught become 51 degree.

So, if theta naught 51 degree this side also this angle will be 51 degree. So, this is 51 degree so, what is the half power remove it will turn out to be 78 degree. So, we can say that theta B the half power be move it of a half way dipole is 78 degree, now how much it improved for current element it was 90 degree. So, compared to 90 degree we are getting a 12 degree reduction that is good that it is more focused. So, now, what is the corresponding things for monopole?

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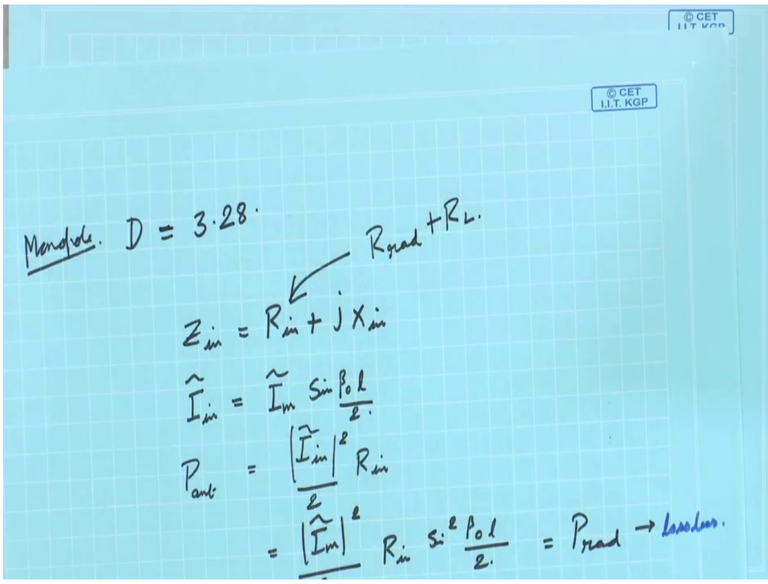

For monopole what is the directivity, if you look at directivity function what is the thing directivity expression you would look, the pointing vector is same for monopole and dipole, but power radiated that is for monopole it is half; that means, its directivity will be twice of the dipole. So, the directivity for monopole quarter lo pole directivity will be 3.28 instead of 1.64 it will be 3.28, because the radiated power is half of the monopole ok.

Now, we can find out that as a circuit element what is a dipole or monopole. So, what is this input impedance Z in, Z in we know that Z in is R in plus j X in and what is the input current. So, I in we can say is I in then sin beta naught l by 2. So, the total time average power delivered to the antenna, if we call that P antenna that will be I in square by 2 r in so, it will be I in square by 2 R in sin square beta naught l by 2

If the antenna is loss less then we can say that this total power delivered to the antenna will be equal to P rad. So, this will be equal to P rad for loss less antenna, for loss antenna there is another term we know that that term is because basically for this is a simple antenna.

So, R in is actually can be called series of R rad and R loss that we have already seen, now that R loss we need to see now actually you see though we are ideally drawing that antenna is a simple where, but actually it is well I want to make an antenna it is a rod. So, it has a diameter it has a so, it is basically a cylindrical rod. So, it has a length it has a rod; that means, through it conduction current will flow and that will put losses. So, that we already have found where we analyze transmission lines, that what is the per unit length resistance of a transmission line made of conductors.

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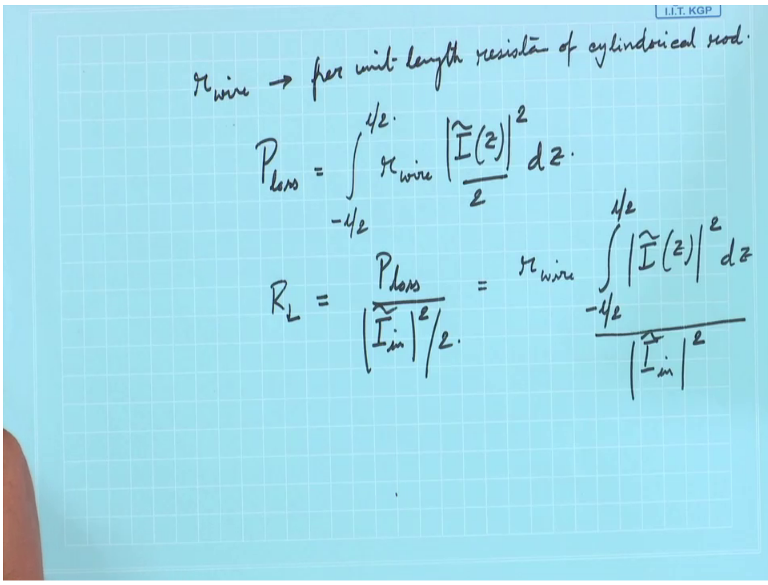

So, that we can see so, let us say that r wire is the per unit length resistance of cylindrical rod, or wire whatever we call it. So, then where they are seen ok, but in this case a so, what is the total power loss this is the loss resistance, when a due to loss resistance or due to the omic loss this power loss will be I have minus l by 2 to l by 2 r wire I z I square r loss. This is so, time average is the sinusoidal distribution that is why we are taking half half I z square then so, from here I can say what is R L our desired thing R loss that will be P loss by I, whatever input I have given I in square by 2. So, this is r wire it will come out of integration, because it is a it does not depend on the z variation what depends is the current distribution. Now, this I in is different for different length of antennas.

So, once you know the current distribution that means, once you know the length of the dipole, then you can find this current distribution also you know, at the input terminal whether the current is what is the value of the current, from the current distribution you can always find that. So, if you put that from that you can evaluate R L. So, this is the way of evaluating R L, this r wire expression is available because transmission line what is a per unit length resistance, that formula is there in terms of the length sorry in terms of the diameter and scheme depth another things; So, conductivity of the antenna.

So, these you can put this put if this is but the problematic thing is that how do find this X in actually people have found it. So, people have drawn various curves on it and we can find that out that there are for engineers, this curves are available which shows.

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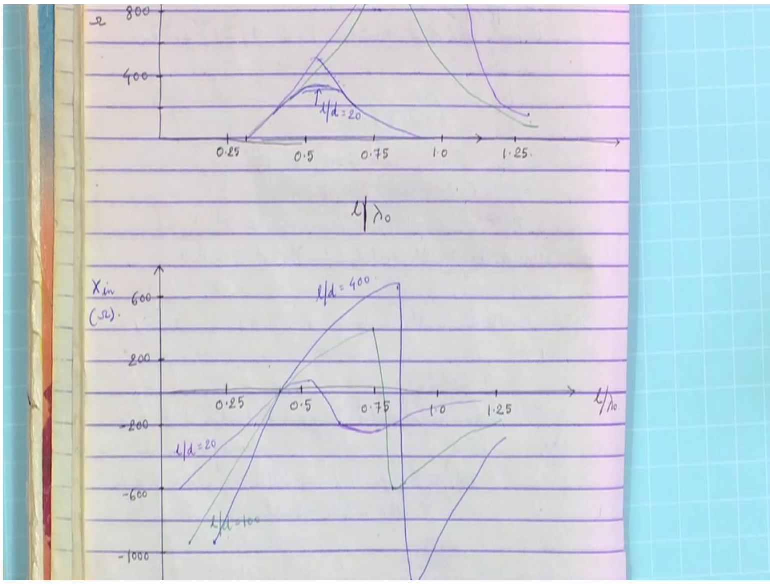

You see that this is add in versus l by lambda naught the resistance and the interesting thing here is that at z z at the value that l by lambda naught is 0.48, this is actually l by lambda naught is 0.48. At this point the reactive part is 0 and at that point if we find out that the value of this R in that is 73 ohm. So, this is the resonant point so; that means, not exactly half way of dipole a bit lower than that 0.48, because half wave dipole is l by lambda naught is 0.5 by at 0.48, we have some all various diameters so that means, whatever may be the thickness of the dipole that the reactive part goes to 0.

So, this is called a resonant dipole the first resonance, you can see that there are also another resonance that takes place something near 0.75 or 0.8 etcetera. And, but the problem there is in those places you see the radiation resistance is very high. Why? The reason is actually if you see that if the length is 0.7 or 0.8, then at the peak point at the input point the current is not going to be maximum the current is going to be minimum.

So, that makes the resistance shoots up and that is why it is a problem there, but if this is a very good one that near 0.5 we have a resonant point. So, if we make the resonant thing 0.48, then we can have a perfect resonant 1. And there the radiation resistance is also quite sizable, but if instead we make it 0.5 we say that there will be some X in is a bit positive; that means, it will be having an inductive thing so, that needs to be balanced.

So, some by some lamp putting some lamp capacitor that can be balanced, or if it is a bit lower, then it becomes capacitive. And that time you can see that there are some inductive things are necessary in the old police jeeps that, there is a coil at the bottom of the monopole, actually that is due to this that the coil serves the mechanical stability, also it gives a tunes out the additional reactance at that point. So, you see this is a good example.

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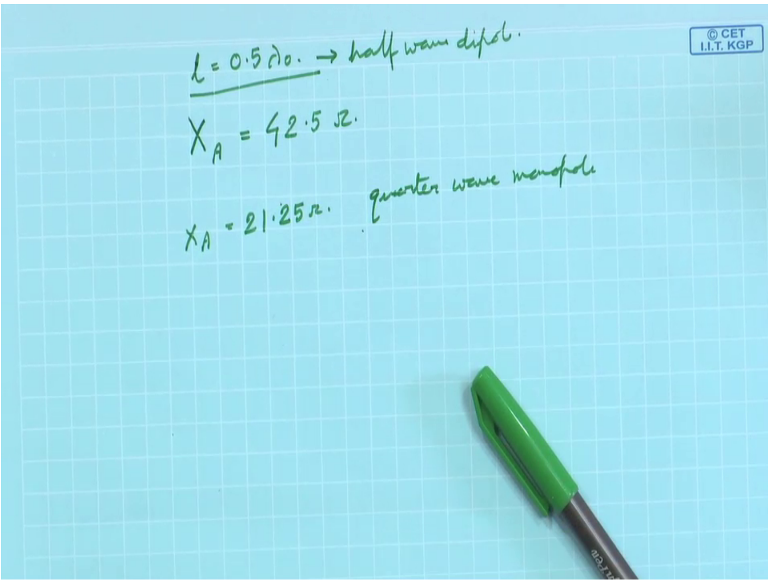

So, at 0.5 a thing actually our ba X antenna, I can say if you have a perfect lambda half wave dipole; that means, l is equal to 0.5 lambda naught half wave dipole, then if you see the actual value the X is 42.5 ohm. And if we have a monopole quarter wave monopole the X A is half of this 21.25 ohm obvious, because in a quarter a monopole you have only 1 pole. So, your loss is half of the previous one.

So, but you can actually the design of an dipole etcetera all depends on those graphs that I have shows that, whatever additional resistance reactance, you are having you need to cancel that we think. But generally do not take it beyond lambda, because then the problems of very high loss resistance etcetera comes; So, that is why there are there can be problems like this you see that it is a taken a design problem.

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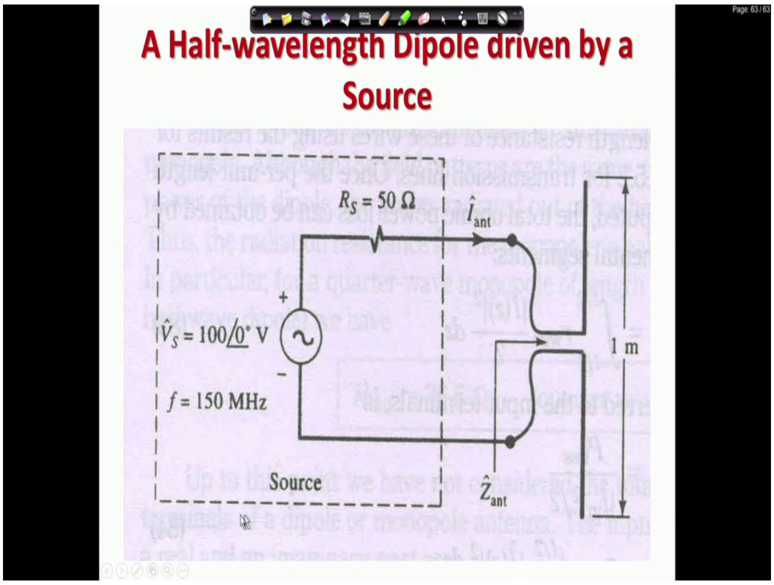

That a half wavelength dipole is driven by a source like this V S the 100 volt 150 megahertz R S is the source resistance is 50 ohm, then it is connected to the antenna and it is having a 1 meter dipole antenna. So, you can very easily find out that at suppose if you have this problem.

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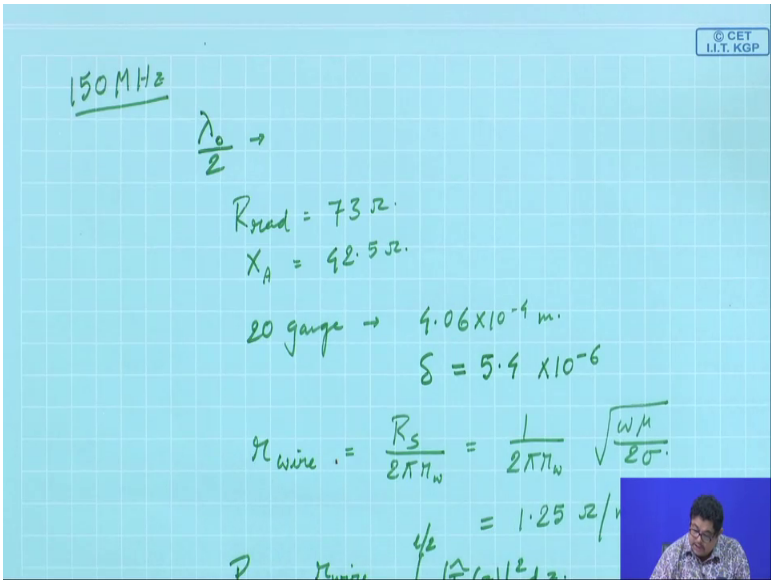

And let me take a new sheet in that where at 150 megahertz this 1 meter dipole 150 megahertz, you can find what will be the lambda. So, 1 meter will be actually 2 meter will be the lambda naught. So this, whatever is given 1 meter dipole that will be a lambda half wave dipole.

So, so we can take that its radiation resistance is 73 ohm and it is reactance will be 42.5 ohm and if we assume that the gauge of the antenna, antenna is constructed from a 20 gauge wire, 20 gauge rod. So, that radius turns out to be 4.06 into 10 to the power minus 4 meter and then we can find out the skin depth, the skin depth will be five point if you do this, you know all the values for skin depth it is a copper wire.

So, you can find skin depth will be this. So, the ready radius is much la much larger than skin depth so, high frequency approximation for wire radius resistance can be used what is that this r wire, that we are saying that at high frequencies, we know this is R S by two pi r w so, when that is 1 by 2 pi r w over omega mu by 2 sigma. So, if you do that it will turn out to be 1.25 ohm per meter the ohm power loss will be found from that P loss is we have already found this expression r wire by 2 minus l by 2 to plus l by 2 I z square d z so, though means for a half wave dipole, we can substitute I z value here and integrate it.

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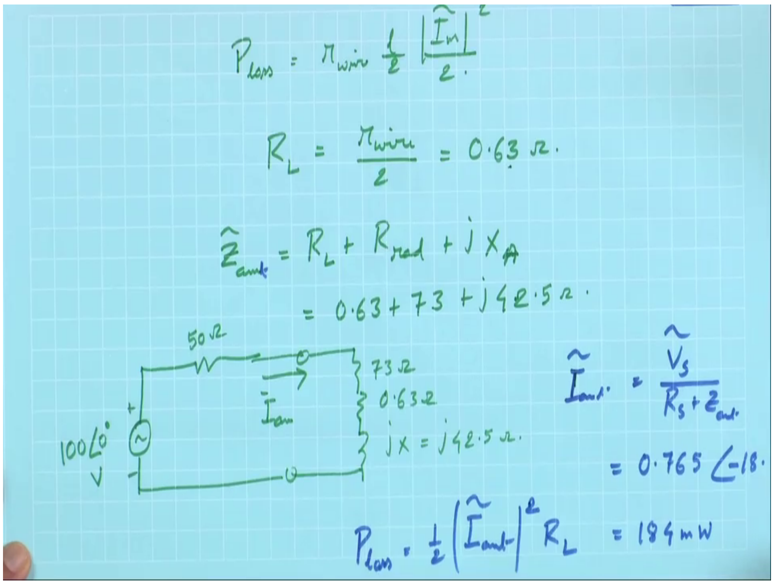

It is integrable and from that you will get power loss is r wire l by 2 I in square by 2 m and from, there you will get R L is equal to r wire by 2 that is 0.63 ohm. So, total impedance of the antenna will then be that R L plus R rad plus j X antenna and so, this will be you see that loss resistance is quite small at high frequency, compared to seventy 3 ohm resistance radiation resistance. And so, we can draw this voltage source, then we have a 50 ohm and, then can say that it is getting connected to 73 ohm, then getting connected to 0.63 ohm.

And then there is a inductance j x is j 42.5 ohm. So, we can find out what is the current I in so, I this one I think it will be 100 to volt. So, I and it will be V S by R S plus Z, Z antenna what I have written Z antenna. So, that if you do it will turn out to be 0.765 minus 18.97 degree mpa and total time average power dissipated, in antenna wire loss that is P loss that will be half, I antenna square R L so, it will turn out to be 184 milliwatt.

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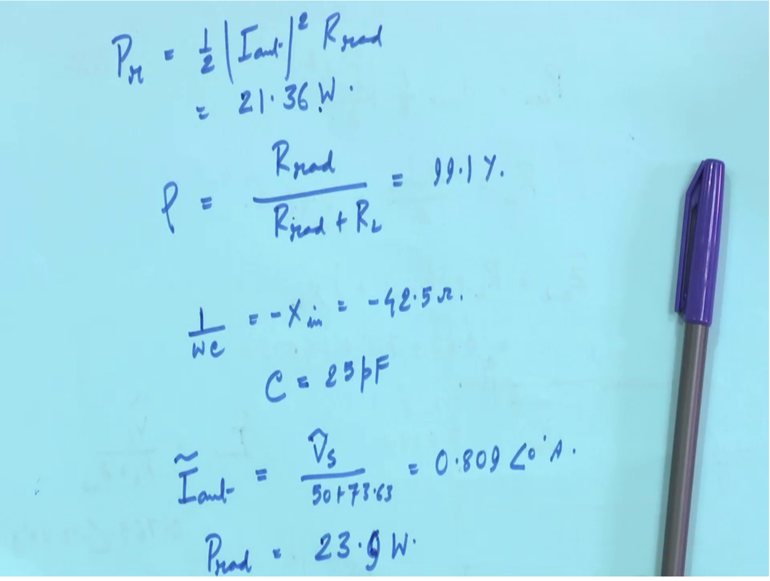

And the total time average power radiated P r that will be half I antenna square R rad, R rad is 73 ohm you put it will be 21.36 watt and so, radiation efficiency is R rad by R rad plus R L. So, that will be 99.1 percent for a microwave antenna it is typically when a dipoles at simple structure, but you see it is radiation efficiency is 99 percent, that the you can improve this for structure the you can put because, there is a inductance of 40 40 how much 42.5 ohm.

So, to nullify that we can put a capacitor in series to cancel that and, that value we can obtain that 1 by omega C will be minus X in that is minus 42.5 ohm. So, from that we can find out that capacitor required in series will be 25 picofarad at that 150 megahertz with the series capacitor the that means, here in this circuit there will have to be a series capacitor so, of C the moment we do that the current will change. So, what will become I antenna we need to do.

So, I antenna again if we recalculate it will be V S by 50 plus 73.63. So, it will be 0.8.9 and so, you see here I antenna is having no phase angle, it is because of the introduction of C it is now in phase with the voltage and P rad radiated power that will also improve 23.9 watt compared to 21.36 watt earlier. So, this is the impedance proper, if we balance out the near field that storage. So, this capacitor will now change that and antenna will be able to radiate more power due to this. So, with this I conclude this monopole and dipole thing.

But one thing is remaining that also apart from all, these antenna with this type of dipole antennas, they need another device which is called Bellan for their structure, they need it that I will introduce in the next class.

Thank you.