Analysis and Design Principles of Microwave Antennas

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Lecture – 09
Impedance of Antenna

Welcome to this lecture, in the last lecture we have seen that sometimes, it is very much necessary to find out the antennas impedance. So, today will discuss the Impedance of the Antenna.

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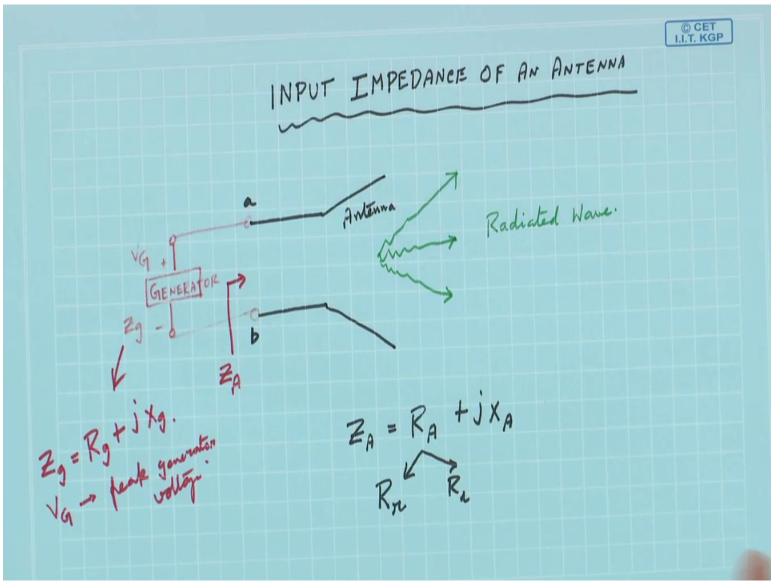

Now, input impedance of an antenna is defined as the impedance that is presented at the input terminals of an antenna. So, if this is an antenna it is connected to a generator the generator is having a voltage peak voltage V G and, generator impedance is Z g that is connected to these so these two terminals of the input terminals of the antenna.

So, here whatever we are seeing the so, at this point whatever we are saying that, we can call as the antennas impedance that means, the voltage to current ratio at this point this a b terminal that will be called the antennas impedance. So, this is the case in the transmitting mode.

Now, we can write the antenna input impedance Z A as a real part and an imaginary part, why imaginary we have discussed because there will be some reactive field near the antenna so, impedance wise it will be some reactance and; obviously, we have seen that there are losses in the antenna.

So, there will be some loss resistance also it is radiation a lot of radiation is taking place from a good antenna. So, they are that we can whatever radiated power that, we can model as a radiation resistance so, all everything together that will give the real part of the impedance.

Now, for simple antennas the two parts that is this R A that we have earlier discussed that will have a radiation resistance also that will have a loss resistance. So, radiation resistance is not a loss mechanism, it is actually the radiation that is taking place. So, it is desirable higher R r means more radiation radiated power is taking place and, this is the loss mechanism so, resistance due to the loss in the circuit of the antenna that is the in the conductor in the dielectric etcetera, also the mismatch etcetera all those losses.

So, though this two now, for simple antennas they can be modelled as series elements, always it cannot be done in modern or complex antennas, where you have a ground plane, where you have a lossy dielectric always this R r and R l cannot be put in series. But for simple antennas which will be generally discussing in this class, if we assume that R r and R l are in series, then we can further simplify this impedance model that will go.

So, now fortunately at microwave frequencies this loss resistance R l, this is not very high by proper designing of antenna, we can make this loss quite low compared to R r.

Now, coming back to our approach of visualising antenna as a circuit element for calculating various values of transmitter, which may have some blocks which are analyzed by circuit approach; so, here we are assuming that the generator that is having a driving the antenna, that has an impedance of Z g so, this Z g also, we can say that these Z g is also having a resistive part. And a reactive part and also V G it is the peak generator voltage, peak voltage of the generator is this.

Now, we can for this whole circuit, we know that we can have a actually you see antenna is a open end radiating thing. So, we cannot analyze the circuit, because there is no load seen here, actually this antenna is behaving as a load to this whole circuits. So, to simplify and to come to our known things, because we want unless until the circuit is closed with we cannot put the currents here, actually there is displacement current going on but to have our understanding, we can have a equivalent Thevenin equivalent circuit that I will draw now.

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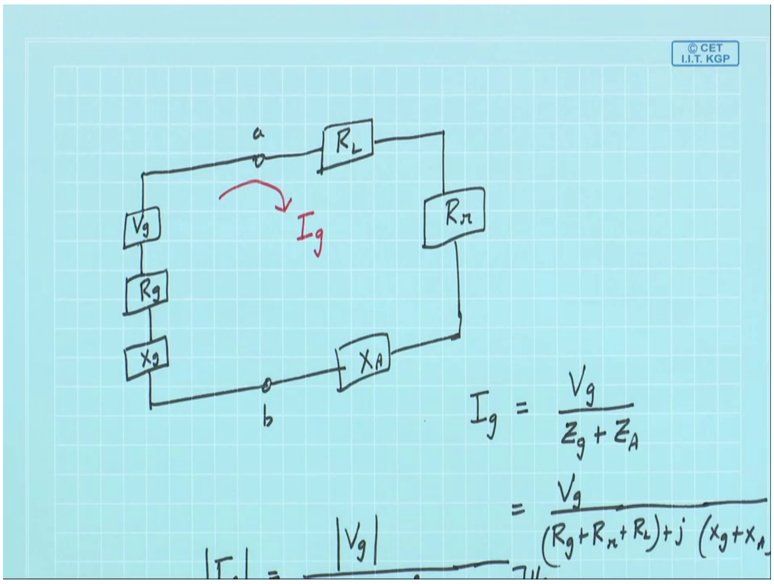

So, Thevenin equivalent circuit of this antenna, we can draw from our whatever knowledge we have about electronic circuits, various theorems from that we can draw like this, you see.

Now it looks like a thing actually the same thing as the previous one we have done, but compared to this looks a more, normal our analysis and it is now apparent that actually our load is the radiation. So, radiation resistance is the load in these. So, now we can say that there is a current flowing through the circuit I g obviously, this I g is a complex quantity.

So, we can we want to find how much power is radiated and, how much power is lost in the antenna etcetera or in the circuit. So, for that we will have to find out the expression for I g so, we now that what will be I g? I g is V g by that Z g plus Z. Now, we know that for simple antennas, we can write this Z j I can write as R r plus R L plus j g plus x A ok.

So, from here I can now write what is the magnitude of this I g, that is simply V g by V g plus R r plus R L square plus x g plus x a square quite simple.

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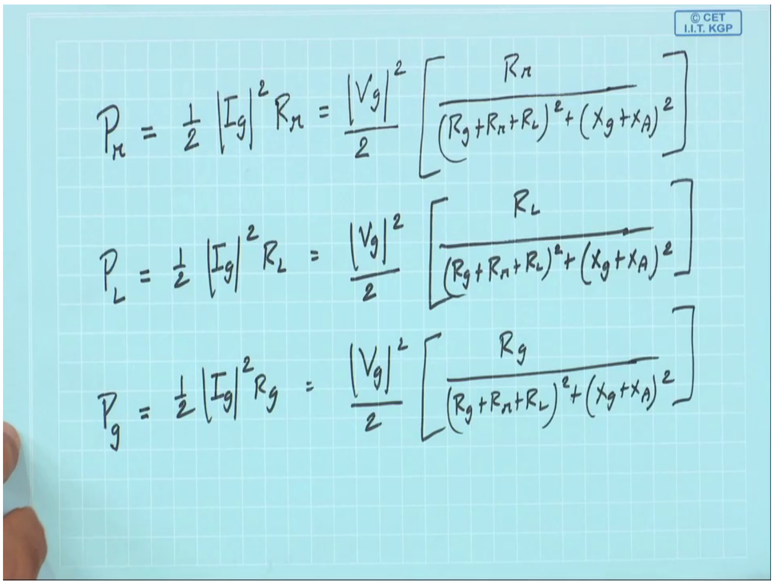

Now, now we can find out what is the power radiated by antenna. So, if I call that P r power radiated by antenna, that will be simply half I g star into I g start that is I am writing I g mod star and mod square.

Now, it is looks simple, similarly the other part that what is the power lost power dissipated at heat in the antenna, that will be half I g square R L clear concept. So, that is the reason we always try to find the equivalent circuit.

So, where is the remaining power obviously, the remaining power is dissipated in the dissipated as heat, in the internal resistance of the generator. So, that we can call P g is a power that is dissipated inside the generator that will be again half I g square R g.

Now, we will invocate theorem that is well known, for electronic students that maximum power transfer theorem. So, again if we look at these diagram this Thevenin equivalent.

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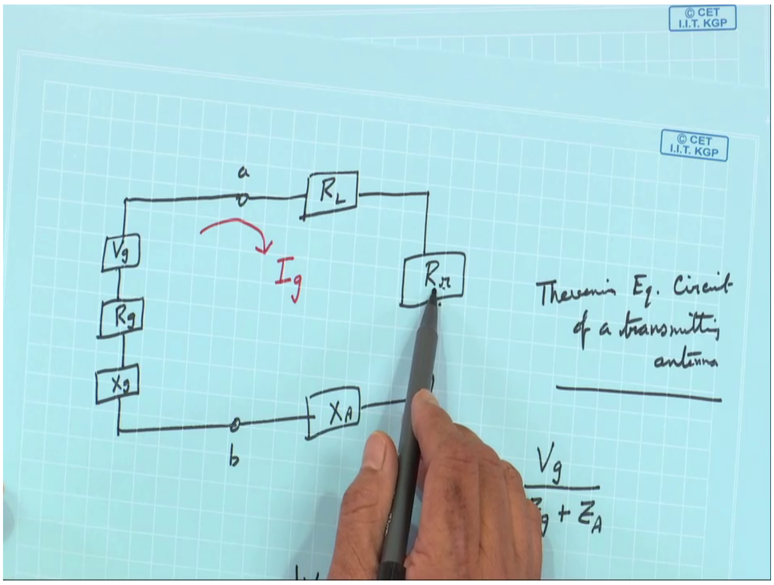

This is actually the Thevenin equivalent circuit of a transmitting antenna. So, here we can say that our objective is to maximize the power radiated so; that means, what is the maximum power, that can be delivered to this radiation resistance, that will happen when we have conjugate matching.

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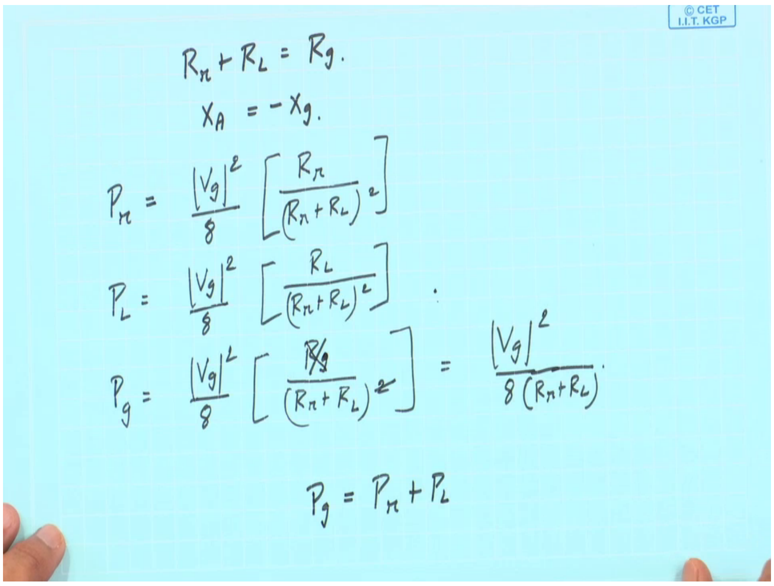

So that means, the condition for that is R r plus R L should be equal to R g and X A should be equal to minus X g. So, under this scheme we can say that, when this conjugate matching takes place, what is P r? It is V g square by 8, here is the same expression.

You put this condition this will come R r by R r plus R L whole square, P L as I said that usually for microwave antennas this R L is much less than R r. So, most of the power is being radiated obviously, some loss is there and what is power dissipated in the generator.

But here again under this condition I can say I can cut this and cut this. So, it is V g square by 8 or let me write V g square by 8, R r plus R L. So, under conjugate matching we can say that P g is equal to P r plus P L.

So, also we can find out the maximum power supplied by the generator, how much power is not (Refer Time: 14:53).

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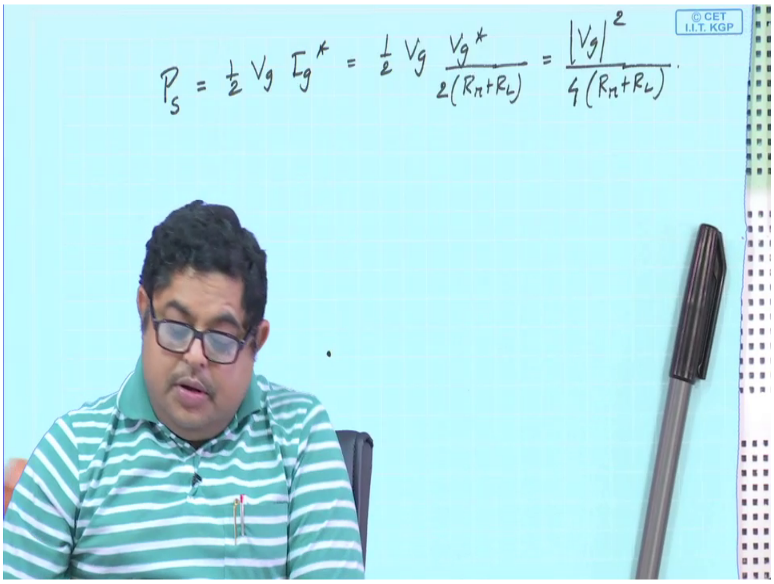

Power supplied by the generator is half V g I g star so, it is half V g Vg star by 2 R r plus R L, 2 coming because of conjugate matching so that is coming as V g square by 4 R r plus R L.

So, you see that water ever total power is supplied by the generator, only half of that under conjugate matching can be radiated and half get is dissipated in the internal resistance of the generator and the remaining half power goes to antenna.

Now, if we can make antenna loss less, that is conductor and dielectric loss to 0, then that amount of power also will get radiated. So, that is why you always try to do well try to use the very good conductor like, that is why if you want very good, or very small loss, then you can have gold, or a silver actually silver is the best one, but silver cannot be machined easily.

So, gold and you can use gold for making antenna, or you can use copper for making antenna and also the dielectric those are very loss low loss dielectrics are used so, that these R L factor is very small.

Also we assume that the impedance matching is there between the antenna and the interconnecting transmission line because, here when we are saying that connecting this here we have not explicitly shown.

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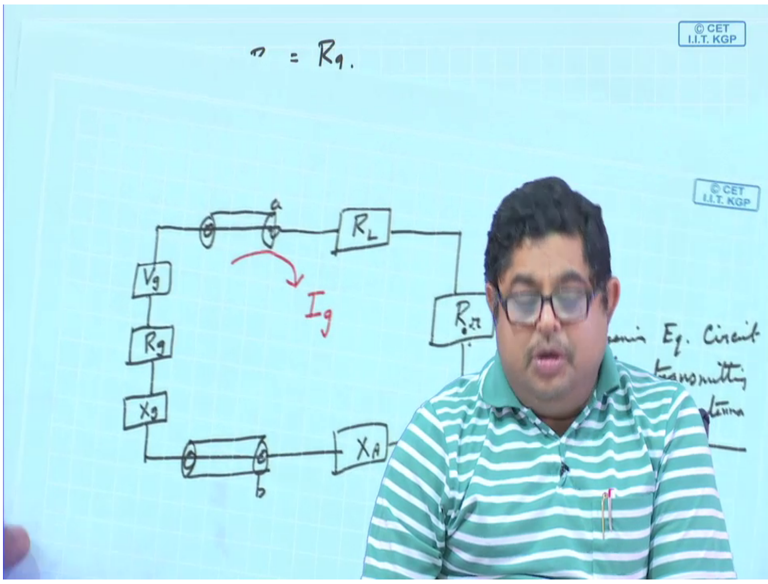

But obviously, the generator cannot directly connect to the antenna. So, there will be a transmission line, we are assuming that the transmission line, we are having an impedance match, if not then some amount of more power will be lost. If match Then the whatever power is supplied V s the P s that can come to the half of that can be delivered to the antenna.

So, you see the usefulness of antennas impedance, that is why any antenna, we generally try to find what is the impedance. And you have seen that people generally demand that the for antennas, nowadays modern antennas people say that, the reflection loss should not be more than 10 dB.

So, that is why that means, one-tenth of the power can be made to lost. So, it is an 10 dB impedance bandwidth is a useful parameter for an antenna.

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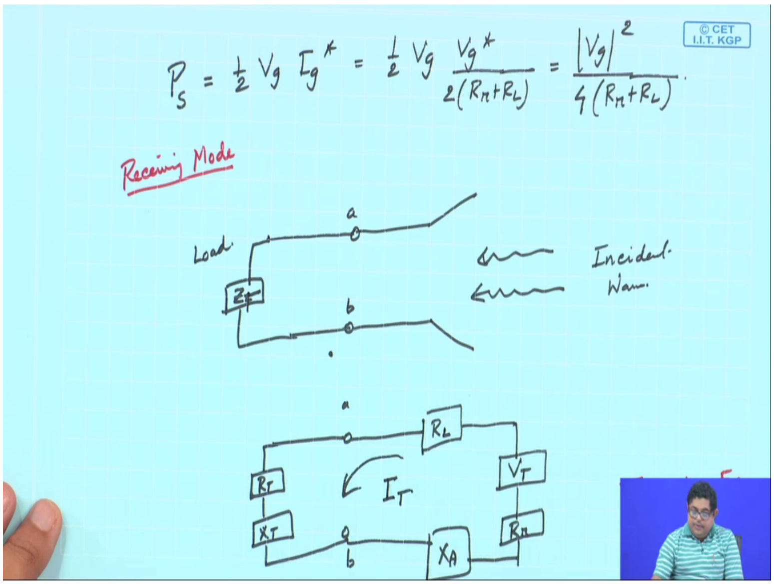

Now, what will happen in the receiving mode? So, let us draw the receiving mode, because that one we have seen in the transmitting mode in the receiving mode, we have that antenna, now in this case the wave is coming ok.

These are the incident wave from some distance source this is coming, the antenna is receiving, then through a transmission line the antenna will be connected to some load, that load maybe a spectrum analyzer maybe a receiver anything, but let us say so.

Let us call that load as because Z L will be getting confuse so, Z T let us call ok. So, if we this is a load let me call this is a load. Now, what will be the Thevenin equivalent of this, [FL] I am not marked a b.

So, if now let us draw the Thevenin equivalent so, the side a b this side, I can easily draw the Z T will be some real part so, R T and some a part reactive part X T and, this antenna I know how to model. So, there will be a lossy part R L capital L, now R L, then there will be a induced voltage on the antenna because this incident wave is coming.

So, at this antennas if you say a output terminal, there will be a voltage induced, because of this field there will be an electric field, electric field between two points, so there will be a voltage let me call is V T. And then there will be that radiation resistance of the antenna.

And then this reactive part of the impedance that near field affect etcetera. So, this is the Thevenin equivalent, I can say that this is the Thevenin equivalent circuit of the antenna and obviously, now there will be a current flowing I T.

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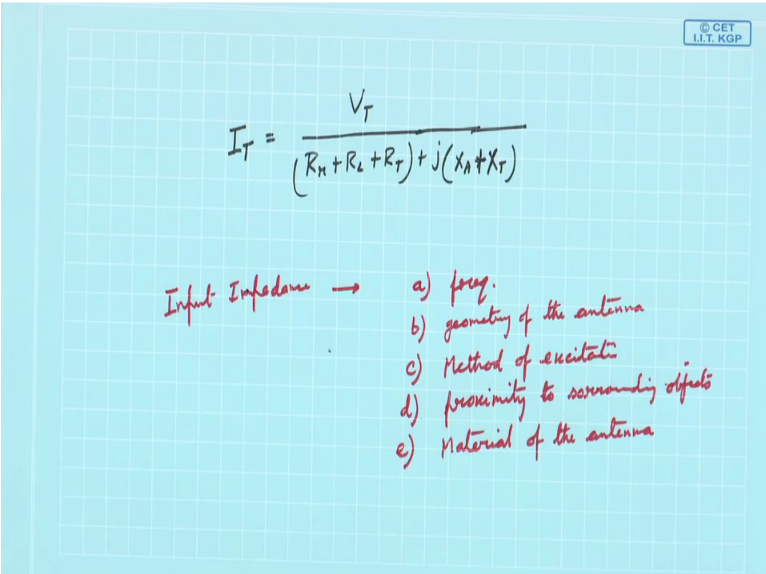

So, what is I T now, I can very easily write I T is V T induced, voltage divided by R r plus R L plus R T plus j X A plus X T ok.

So, now from here similarly we can find out how much power will come etcetera, how much power R r will dissipate how much etcetera. Now, the input impedance of an antenna so, we have seen it. Now it is generally a function of frequency because all these things, that are different frequency the reactive part etcetera that will change. So, it is a function of frequency and antenna is matched to the interconnection transmission line, when we say that suppose this antenna as I said that, there will be a transmission line here to connect it that transmission line has a characteristic impedance.

So, we are assuming it is matched, but characteristic impedance is a real quantity and over a narrow frequency band only it will be matched that other frequencies there will be a mismatch so, that needs to be take into account.

So, I can say that the input impedance of an antenna depends on several things on what first; obviously, it is dependent on frequency of operation at different frequencies obviously, impedances etcetera they are different. Then, it depends on geometry of the antenna, because it is an antenna so, when we are saying radiation resistance that depends on the geometry as we have seen, that radiation resistance of a current element etcetera.

And later also we will see that better and better antenna means, better your radiation efficiency so; that means, your R r will change so; obviously, input impedance depend on geometry of the antenna.

Then also the method of excitation of the antenna, because for high frequency things, how you excite the antenna, how you put this transmission line. How it is connected to the antenna, there are various ways of connecting loop coupling, probe coupling etcetera and, that will change the impedance and that will drastically may change the impedance, if the excitation is not proper you would not get the proper coupling etcetera. So, input impedance definitely depend on method of excitation.

Then here one thing we are not saying that, we are assuming that near the antenna, there is no other structure, but in reality any conductor any structure even a dielectric structure nearby that will affect, because antenna is radiating a field that electromagnetic field will go there.

Then that there will be some secondary currents induced, in those bodies and that will again reradiate and that will come here. The net effect of that is a mutual coupling so, a mutual impedance so, that means, input impedance, whatever we are discussed here that was the total effect; that means, self impedance plus mutual impedance. So, that mutual impedance will get effected, the movement I have a nearby thing.

The thing is in the in the low frequency, or in the circuit theories generally we do not have this impedance of certain thing is not dependent on someone else, but you have seen when we have two coils, then they are nearby so there are mutual things, now actually there are though that is a low frequency case but there is a magnetic coupling.

But here you see electromagnetic coupling is also there so, any conductor dielectric nearby that will affect the antenna, that will give an mutual impedance and that will affect the total impedance, that is why I can say that proximity to surrounding objects, objects nearby surrounding means the. Then any other thing also obviously, the material of the antenna, because all those loss etcetera depends on what material, we are using for the antenna.

So, you see input impedance, though we are giving a certain values, but we should remember that all these things effect this input impedance. So, we have seen how to model using even in circuit theory, we can have this antenna model. So, that is a nice way that we have started the current element from the analysis from field theory.

Once we have known that field theory gives us all the informations and from that, if required when we are connecting the antenna with a transmitter, or when we are connecting the antenna with a receiver, or load we can model the antenna as an circuit theory object. So, we can find a impedance for that.

We have seen the moment to have found that we can found Thevenin equivalent, then we can apply maximum power transfer and you can find out what is the condition for maximum power transfer and, by that we can have what is the power dissipated in the antenna etcetera, or how much power the antenna is putting to the load all those things, we can calculate in our usual way.

So, input impedance is a very important parameter we will see that, this impedance actually the narrow band antennas for them, if we know the impedance and, if we can make the reactive part of the antenna at a particular frequency 0, then that antenna can be called as a resonating antenna actually that is the practice in dipole etcetera, we will see next when we will go to those things.

Our job is to make that, if we can somehow cancel that reactive part, then we can say that antenna whatever we are giving it is resonating; that means, it is putting the whole thing into the as a radiation is taking place and there is no reactive storage of energy. All the energy that is given provided there is some loss, but other energy is there that time we say that antenna is resonating.

So, resonant antenna is the normally narrow band antennas at wideband antennas, we cannot make resonant for them we design these non-resonant, but this antenna impedance is a good way of seeing what is happening to the antenna, how much it is radiating how much it is losing. And also for other elements the generator or the receiver, it gives us that how much power I can take, how much power I can give etcetera ok.

Thank you.