Analysis and Design Principles of Microwave Antennas
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Lecture – 08
Polarisation of Antenna

So, in this lecture we will see Polarisation of an Antenna. Now polarisation is actually in antenna if it is a radiating antenna or transmitting antenna, polarisation has one meaning, if it is a receiving antenna polarisation has a slightly different meaning.

Now, please remember that polarisation of an antenna means that one thing is polarisation is different in different directions. So, when we say polarisation of an antenna; we should also specify in which direction polarisation we are talking just the concept of directivity gain etcetera that.

Generally we say an antenna has so much directivity and the antenna has so, much gain. But it is with respect to certain angle or certain direction solid angle; that means theta phi direction. Similarly polarisation is also there that polarisation of an antenna in a given direction is defined as the polarisation of the radiated wave; when the antenna is excited.

That means whatever wave it is radiating, the polarisation is for that. So, to understand antennas polarization; we need to understand what do we mean by polarisation of a wave; that means, an electromagnetic wave what is the polarisation is this what is the definition of polarisation of that.

Now; before going there; I now want to say that what is the reverse case? That means, if the antenna is receiving antenna. What is the meaning of polarisation of the antenna? So, in that case it is the polarisation of the incident wave or incoming wave to the antenna from a given direction which results in maximum available power at the antenna terminals. What do you mean by that?

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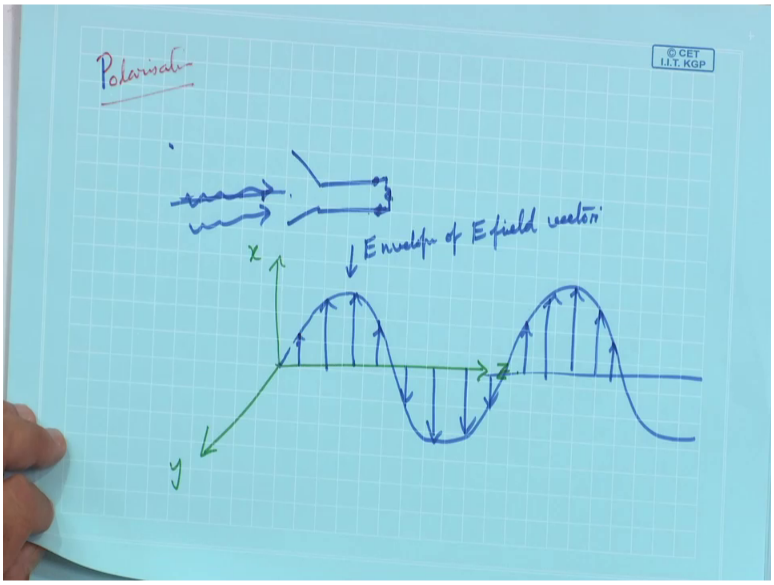

So, this is a receiving case; that means I have a receiving antenna. So, this is my antenna the wave is coming; so, I am saying from this direction I want to see. So, this wave what is its polarisation? Provided I get maximum power maximum available power here.

So, if not then there will be a mismatch there will be loss etcetera. Now, as I said if the direction is not stated, because many times we will see that it is a so and so polarized antenna that means, he is not specifying theta phi in that case the polarize; the direction is taken to be the direction of the maximum gain.

So, antennas maximum gain that has a direction because gain is a theta phi function. So gain without theta phi means in a maximum of that function; so, in that direction the polarisation is stocked when nothing is specified.

Now then let me recall what is the polarisation of an wave electromagnetic wave? Actually it was taught in electromagnetic theory. So, it is that property of a radiated electromagnetic wave, which describes the time varying direction and relative magnitude of the electric field vector of the wave.

So, what is the polarisation of the, of an electromagnetic wave? It is the time varying direction and relative magnitude of the electric field vector. Basically in mathematical terms we can say the locus of the electric field vector with time.

So, the it is basically the locus of the end point of the electric field vector at a fixed location in space. And the sense in which that locus is test as observed along the direction of propagation.

Now, these are actually exact terms, but to understand that let me draw a plane wave. Suppose a plane wave generally what we say that the plane wave electric field vector is something like this.

So, this is the envelope of the electric field vector envelope of E field. So, obviously; that means, this is a you see special description of the wave. That means, at a particular time I am seeing that at this point electric vector is like this, at this point electric vector is like this etcetera.

Now, instead if I take a; if I fix a point and go on see that what is the polarisation what is the electric field vector as time progresses; you see I will get a picture like this.

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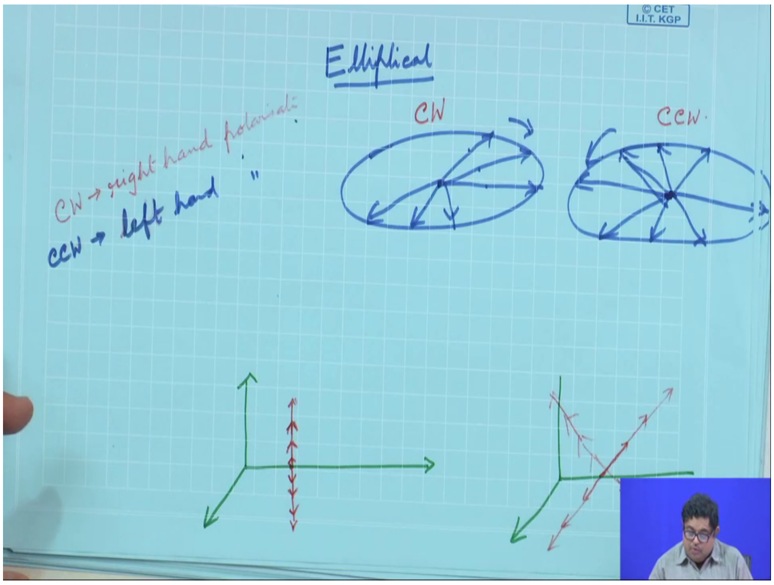

You see suppose any point you fix. So, here if I fix I think you will agree that I will get; suppose I am at this point I am here. So, I will see something here, next moment it will rise a bit.

Then it will again be like this, then it will be like this, then it will be like this, then it will be like this, then it will be like this, then it will be like this, then it will be like this, then after that again it will be like this, like this, you see there this is what a plane wave; obviously, I have drawn a plane wave.

But instead of drawing its generally we always draw the thing as a spatial variation, but if you see time variation this electric field vector its int how it traces? What it is tracing? It is tracing a line; so, it is a linear polarisation.

Now, instead of this, this also is a linear polarisation case. You see it not be always like this vertical or horizontal; it can be something like this, this is also in case of linear polarisation, this is also in case of linear polarisation.

But linear polarisation again is a special case actually all things need not be linear. So, polarisation it basically most generally; it should be classified as elliptical. Why? Because this E field vector in general that can be broken because you see wave is propagating in a direction the E field that is can have a 2 dimensional representation. So, usually we represented it with x and y; so, in general this electric field vector will be having an x component and also a y component.

So, in general the locus that it will trace as the time progresses; if I stay at a particular point and see the electric field vector at that point over time I will see that the tip of that electric field vector is tracing a an ellipse.

Special cases of that sometimes this ellipse becomes a circle that time we called it is a circular polarisation. Sometimes that ellipse becomes a line that time we call it a linear polarisation.

Now, the E field vector when it traces an ellipse what is an ellipse? This is an ellipse. Now as time progresses I can the electric field vector tip; suppose this is the tip of electric field vector these are all electric field vector with time. So, you see in this case it is tracing an ellipse in a clockwise direction.

I can also have a case where; so, this is a ellipse so; that means, I will show that this is a clockwise; this is an anticlockwise. So, this gives us the sense; so this one is called CW clockwise sense; this is called CCW; counter clockwise sense.

Now sometimes the CW is called right hand polarisation, right hand polarized wave and CCW is left hand polarized wave; for obvious reasons you see that CW means right hand

and this CW is left hand. These are nomenclature, but the more important is this clockwise, counter clockwise.

Now, what we require for our things is as I was saying that most general description of an instantaneous E field will be something.

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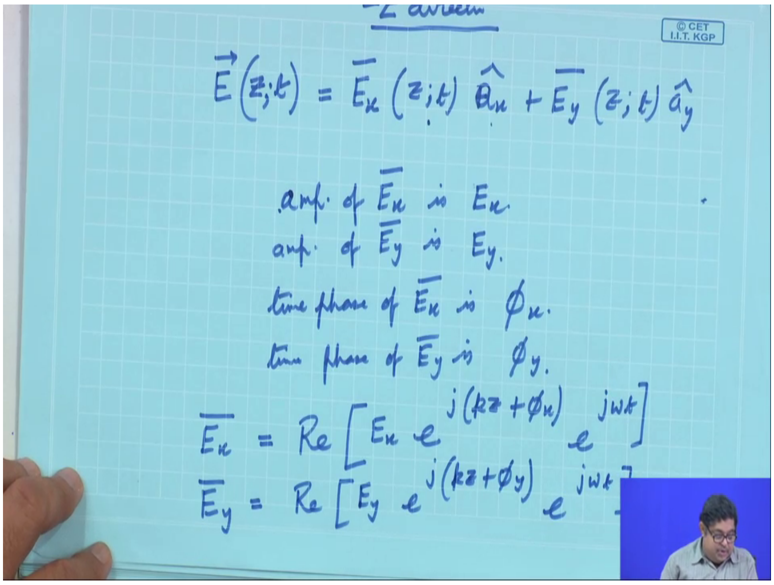

We know that if anything is a field it should have I mean a field and wave; it should have a time function as well as a space function. So, E z t; so this can be; if I say that I will have x and y component any 2 dimensional component. So, I can the instantaneous E field of a plane wave travelling in a; please remember this discussion is travelling in a minus z direction, can be written as E x z t, a x plus E y z t a y.

In the Cartesian coordinates say x y here unit vectors and E x is the amplitude of the x component of the field, E y is the amplitude of the y component of the field. And time phase of this E x component or I will write it like this because there are also the time phase. Let us also say that; so, I will write like this the amplitude of E x is E x, amplitude of E y is E y, time phase of E x is phi x, time phase of E y is phi y.

So, can I write what is this phasor E x? It is the real part of E x e to the power j k z because it is a wave going into minus z direction; minus j k Z plus phi x E to the power j omega t. And what is the E y phasor? It is real E y, E to the power j k z plus phi y E to the power j omega t.

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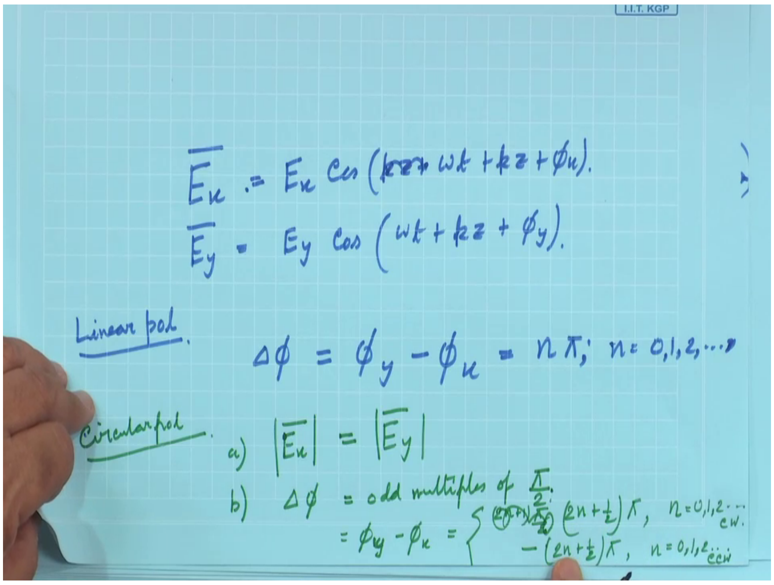

So, I can just write E x is nothing, but E x cos k z plus cos omega t plus k z plus phi x and E y is E y cos omega t plus k z plus phi y.

Now, for the wave to be linear polarized what I demand? The time phase difference between the 2 components must be an integral multiple of pi; that means, what I want is del phi; which is nothing, but phi y minus phi x that should be n pi; n is integer. This is called linear polarisation

For circular polarisation; what I demand. That E x magnitude and E y magnitude to be same also I want time phase difference is odd multiples of pi by 2. So, that means this means I want phi x phi y minus phi x is equal to 2 n plus 1 pi by 2 (Refer Time: 18:36) plus 2 n odd multiples of pi by 2. So, I can write 2 n plus half into pi n is equal to 0, 1, 2 etcetera for CW and minus 2 n plus half pi n is equal to 0, 1, 2 etcetera for CCW.

You can simply do it; actually in class 12 some of you may have done it. And please remember that if the wave propagation direction is reversed; that is instead of wave propagation in minus Z direction, if I have Z direction then these 2 will be opposite; that means, this will be CW, this will be CCW.

So, for circular polarisation the important thing is; magnitude of the 2 component should be same and time phase the time phase difference between the 2 components should be odd multiples of pi by 2. So, this is the demand for circular polarisation.

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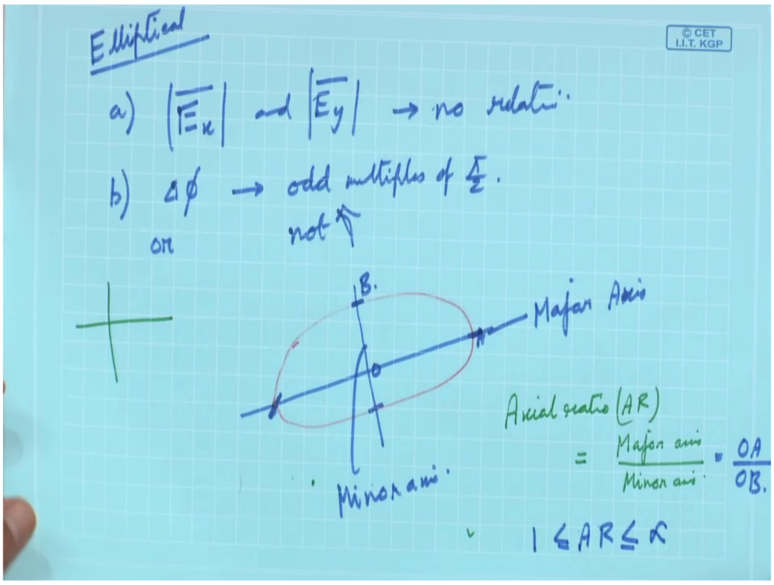

And what is elliptical polarisation? So, elliptical polarisation means that magnitude wise; magnitude wise I do not require any relationship. So, E x magnitude and E y magnitude no relation and time phase difference. So, delta phi; it may be odd multiples of pi by 2 or not odd multiples of pi by 2. That means, here also no difference; that means, this was the most general case.

Now that if it becomes odd multiples and these 2 are equal that become circular if the time phase difference become that odd multiple of a; sorry integral multiple of pi or you can say even multiple of pi by 2, then it is a linear etcetera. So, ultimately we can say that if this is our actual rectangular direction, but the ellipse maybe having a tilt. So, this ellipse; obviously, if this is larger this is called major axis of the ellipse; that means, here to here and here to here it is called the minor axis of the ellipse.

Now, this how much is this to actually you know that these 2 means what is the maximum of the E x component and what is the maximum of the E y component. That ratio is an important characteristic thing of the polarisation of the wave; that ratio is called axial ratio, axial ratio AR. That is given as major axis by minor axis.

So, if we say that this is O and this is a, and this is let us say B. So, I can say it is O A by O B. And generally this axial ratio will vary from 1 to infinity. So, this is the polarisation of the wave; if we understand that then we can understand that if for a transmitting wave it will be the antennas polarisation; that means, the antenna is radiating a wave.

So, in general the antenna will have elliptical polarisation, but if the two radiated waves the x and y component they have this relationships then they may become circular or then they become (Refer Time: 24:08).

So, now what is polarisation loss factor? The polarisation of the receiving antenna may not be the same as the polarisation of the incident wave. If they are equal; that means, whatever the polarisation of the incident wave and the antennas polarisation; that means, as a that; as a transmitting antenna is polarisation is same, then this receiving antenna will be able to extract maximum power otherwise there will be a polarisation mismatch.

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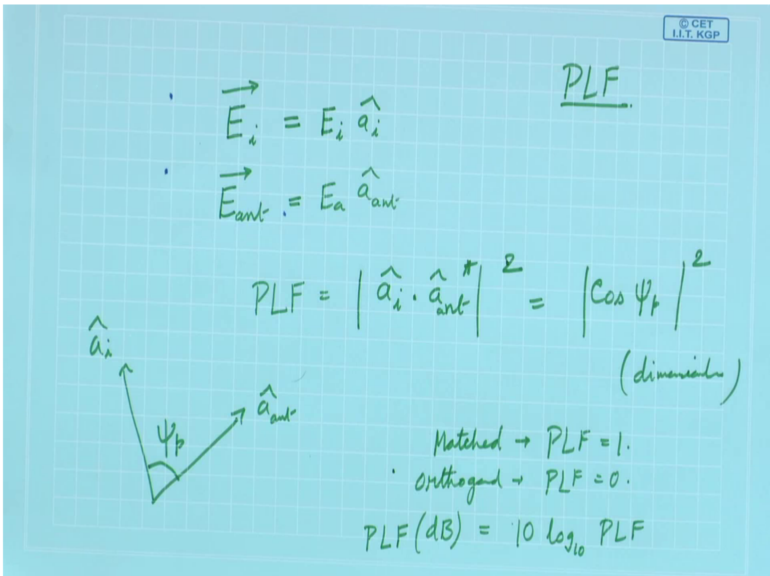

So, let us say that we have a incident wave. So, this is again I am discussing polarisation loss factor; already we have seen it in case of a efficiency time. So, that suppose I write like this that a i is the unit vector in the direction of the incident E field. And the polarisation of the receiving antenna that is let us say E a. So, what is the unit vector a antenna, a antenna is a unit vector in the direction of the antenna polarisation.

Then what will be PLF? PLF will be simply the magnitude of these 2 directions dot product antenna; you can say this square. So, if we draw that this is the a i vector and this is the a antenna vector; then and this angle is phi p. So, I can write this is cos; phi p square. This is also a dimensionless quantity cos phi p; so, that means, this 2 angles.

So, by that so now we can ask that if the antenna is polarisation match. So, what will be the value of PLF? That means, in that case this angle will be 0; so cos 0 is 1. So, we can say that matched case PLF is 1 and fully mismatch case; that means orthogonal case PLF will be 0. So what I can say; so orthogonal PLF will be 0; sometimes people say PLF dB. So, is log of this PLF.

Now, here multiplied I will have to use 10 or 20; it is all power thing that is why it is 10, 10 log 10. Now these polarisation loss factor is important for link budget calculations; in space communication and radio astronomy etcetera. Because this since they are having a very tough budget; so, these factor some cos theta thing that is important for them. So, that is why this also should be taken into account.

Now, so we have seen in detail what is the polarisation of the antenna because a designer should be knowing what is exactly mean by polarisation. Then we will see that sometimes in the actually antenna is it is design etcetera is completely different from any other element that is in the whole link, but when antenna should always be either connected to the transmitter or to the receiver.

Now, from if you look from the transmitter or look from the receiver antenna is nothing, but it should be characterized by an block; who is doing something he is radiating etcetera. But to a transmitter it is taking some power and it is developing something.

So; that means, anything in electronics any 2 port network; we characterize it by an impedance. We do not characterized it by voltage or do not characterize it by current because those are our excitation and affects etcetera.

But the characteristic of the block that is the ratio of this voltage by current, that is the impedance. Because that does not change whatever voltage I give whatever current I give as long as that impedance is within the range of its validity the impedance uniquely characterizes the 2 port network.

So, antenna also when a transmitter is looking at antenna it should be characterized by an impedance it may be a radiating device, but it is taking power. So, that time it should be behaving as an impedance.

Similarly, when it is receiving; it is taking the power; but finally, it is delivering it to a load, that load maybe a spectrum analyser, that load maybe simply a resistor, that load maybe simply an inductor anything. So, that time it should also be described by a impedance. So, that; that means, ultimately here you see when we analyse the antenna; it is a completely field theory concept. We have seen in case of current element how we solved Maxwell's equations to find out what are the E h etcetera.

But then from there you have seen that we were able to find out how much power etcetera it was giving. And ultimately we could see that a current element what is its radiation resistance. That means, we again could relate that field theory thing to a lower level theory, you call circuit theory that it is also a radiation what is taking place we have model designed as an resistance.

So, now we should be able to model this whole thing; also we have seen that near the antenna there is a field which is not propagating it is a reactive field; that means, it should be characterized by some reactance. So, there are we also have seen that there are losses in the antenna etcetera; so, there is a loss in resistance also.

So, loss in resistance a radiating resistance then a reactance so; that means, it is an it should be characterized by an impedance that is called input impedance of the antenna. And actually a transmitter looks at the input impedance because a transmitter knows that you will have to deliver the power.

How much power you will deliver to it? How much of that will be used for that calculation we need to characterize the antenna by its input impedance. Similarly in the receiver side ultimately receiver will have to know that I will have extract power from the receiving antenna.

So, what is the impedance of that antenna; receiving antenna so that I can extract power. So, these are required and this will take up in the next class that what is the input impedance of the antenna. And then we will see a concept which is required for receiving antenna that is the effective aperture of the antenna so that we can do all this calculations.

So; that means, we can now go at our will from field theory to circuit theory. So, that we can do the circuit problems microwave circuit problems. Also we will be able to find out what are the fields radiated by the antenna at any point in the whole universe; what is the field that antenna gives that will come from field theory.

And knowing that field theory values will be able to tell what are the impedances, what are the as the transmitter sees, as the receiver sees.

Thank you.