Transmission lines and electromagnetic waves
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Lecture – 27
Dielectric-Ideal Conductor Interface

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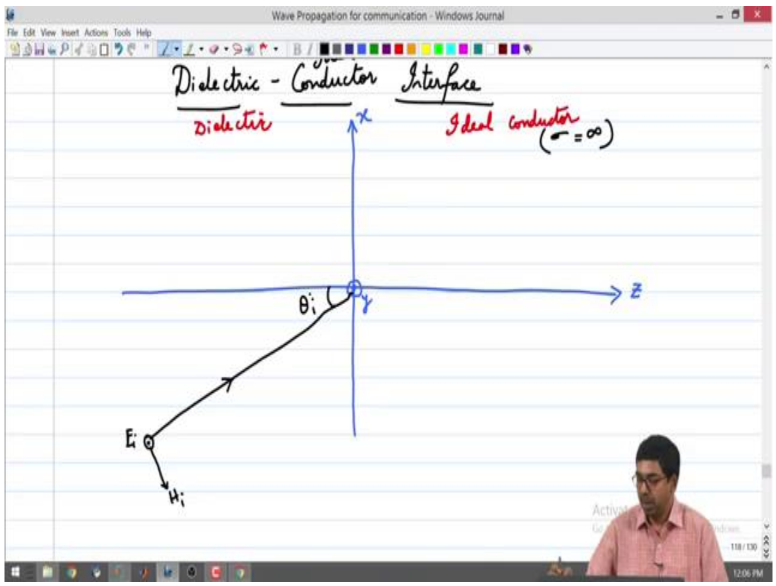

We will get started alright. So, I think now we are going to start with Dielectric-Conductor Interfaces ok. So, we are starting with the interface between a dielectric and an ideal conductor. Previously, we had seen the dielectric interface in detail for two polarizations right.

Now, we are going to go ahead and see the dielectric and ideal conductor interface right. So, the objective of this lecture is very similar to the objectives that we had for the prior lecture for dielectric. That is, we want to calculate the transmission and the reflection coefficients all right and we want to make some inferences all right. Now, I will draw a geometry that I want to consider all right first and then I will make a few points and then we will proceed to the actual derivation ok.

So, in this case the coordinate system that we pick is going to be identical to the case that we picked for the dielectric. So, I am going to have the x axis pointing up ok, going to be having the z axis going in the horizontal direction. This is the same coordinate system that we had used for the dielectric interface.

And if you want to form a right handed triode the y will be pointing out of the plane ok all right. So, here we want to be able to talk about a dielectric on the left side all right and that is also going to be the medium from where the incident wave is going to go ok. So, we are going to have a source at the dielectric medium. It is going to go and hit an interface and it is an interface between a dielectric and an ideal conductor all right.

So, conductivity is infinite ok, sigma is equal to be equal to infinity ok. So, there are a few points to note. So, first I will draw the incident wave and then we will start with the few points to note ok. So, I am going to be having a wave going in the similar direction as what we had for the prior lectures. I am going to have it launched from here and it is going to go and hit the interface.

This is the direction of your k. Once again, we know that we can formulate this problem in multiple ways depending upon the polarization configuration that you choose alright. So, we can start with perpendicular polarization because we have done perpendicular and parallel polarization before analytically for dielectric interface.

We also wrote a program for perpendicular polarization alright. So, you may remember the terms much more than parallel polarization. I will begin with perpendicular polarization right. So, here that means that I am going to be having an E field in the y direction right.

So, I am going to mark that as E_i. This means that the magnetic field is going to be pointing downwards ok. The other thing that we need to mark over here is the angle of incidence which is θ_i all right. So, there are a few points to make before we go to a full blown derivation of the coefficients. The first thing is the concept of ideal conductor means that no fields are going to exist inside of the conductor right.

In the electric case, you will not have a potential difference between two parts of the conductor which means that you will not have any fields ok. So, the job is actually pretty simple. Transmission coefficient need not be calculated at all only the reflection coefficient has to be calculated ok.

So, we have to keep in mind that there is going to be absolutely no transmission for a semi-infinite medium of an ideal conductor all you are going to get is reflection, right. So, that makes the job a little bit simple, right. I draw a reflected ray ok.

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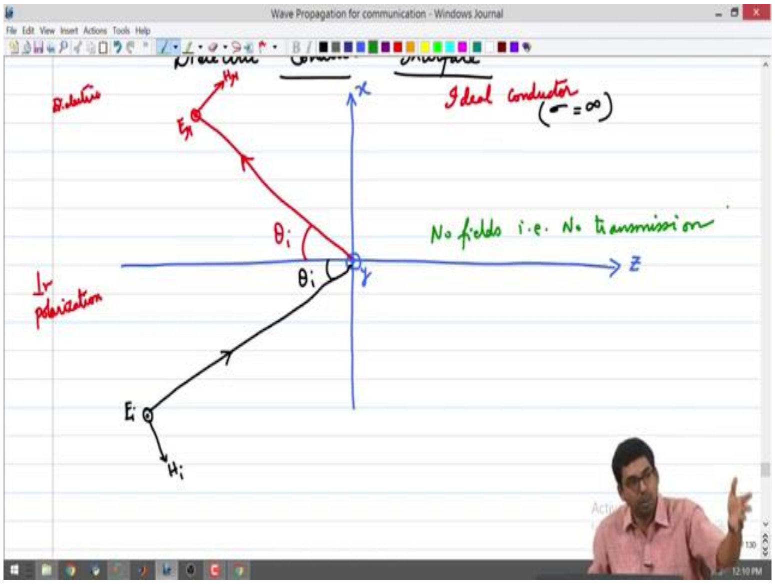

We will make some assumptions related to the polarization all right. And one of the things that happens is you can make an assumption related to the E direction H direction extra. You can calculate the reflection coefficients, the reflection coefficient will be in line with what will happen physically, that means, in this case I am going to demonstrate what it means alright. So, I am going to assume that the electric field direction does not change at all, right.

So, I am going to say that let me assume the direction E_r to be in line with E_i all right. It is an assumption all right if that were the case the magnetic field would have flipped and it would be pointing like this.

So, I will remove this word dielectric from here that will give me some space too, right. This is how it would look all right. Now what this means is suppose I were to calculate the reflection coefficient assuming that the direction of the reflected electric field is still pointing outwards and I get a negative value.

It will mean that the direction I have assumed is opposite to the direction as dictated by the physics alright the boundary conditions. So, what I can do is then I can look at whether the reflection coefficient is positive or negative. If the reflection coefficient is positive the assumption is fine. If the reflection coefficient is negative it means that compared to what direction, I have assumed I have to take a 180 flip that is all.

So, it really does not matter how you make an assumption as long as your physics and boundary conditions are going to be correct ok. So, here we are assuming that everything is going to be the same and we will see at the end whether our assumed directions are correct or not ok. So, right now we do not know we assumed this.

Angle of reflection is going to be equal to the angle of incidence and in this case you have no transmitted wave at all ok. And we are talking about perpendicular polarization and I will also mark that there are no fields inside of the conductor. So, this already gives us a hint that whatever happens the reflection coefficient has to be unity ok.

So, it already gives us we already know that the electric field reflection coefficient has to be unity all right, but we are just going to see whether the assumed direction is going to be the same or not. And also what are the total fields in steady state going to look like in the medium one.

Suppose you are launching an electromagnetic wave it goes and hits the interface bounces back we already know from our programs right that if it goes and hits a boundary and comes back it will start interfering with the incident wave the reflected wave and the incident wave will start interfering with each other. What do the total fields in medium number one look like, this is a question that we are going to answer.

So, we will start with the formulation alright and the mathematical description of the electric field alright. Looking at this diagram it is identical to what we had drawn before alright for the dielectric interface.

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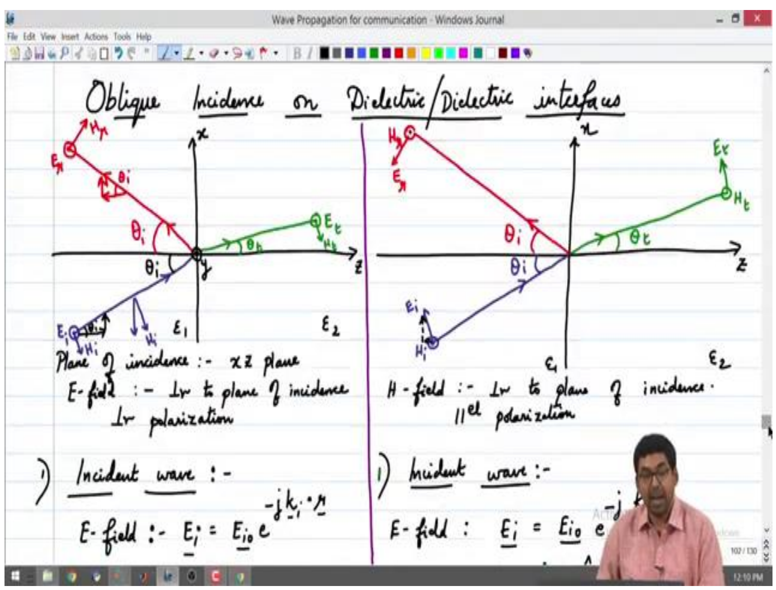

So, if I were to go back to my notes alright, I have oblique incidents on dielectric interface. In this part the description of the electric field is going to be identical right.

So, whatever I had derived for the incident electric field over here is going to be the same expression because my coordinate system is same, direction of travel is same, all the variable names are the same, all right which means that I just need to do $E_{i0}e^{-jk_0.r}$ ok and I would have got some expression for the description of the electric field alright.

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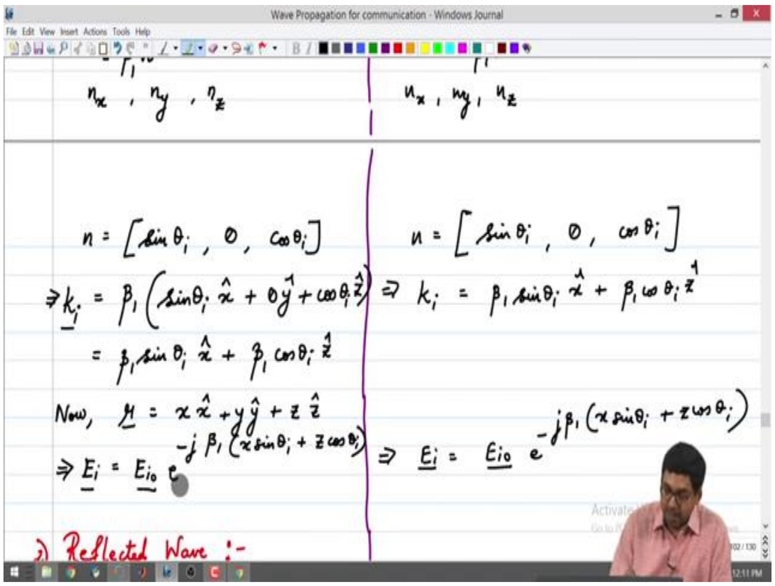

And it looks like

$$E_i = E_{io}e^{-j\beta_1(xSin\theta_i + zCos\theta_i)}$$

All I need to do is take the same thing and plug it in over there because the expression for the incident field is going to be the same.

So, I go back ok.

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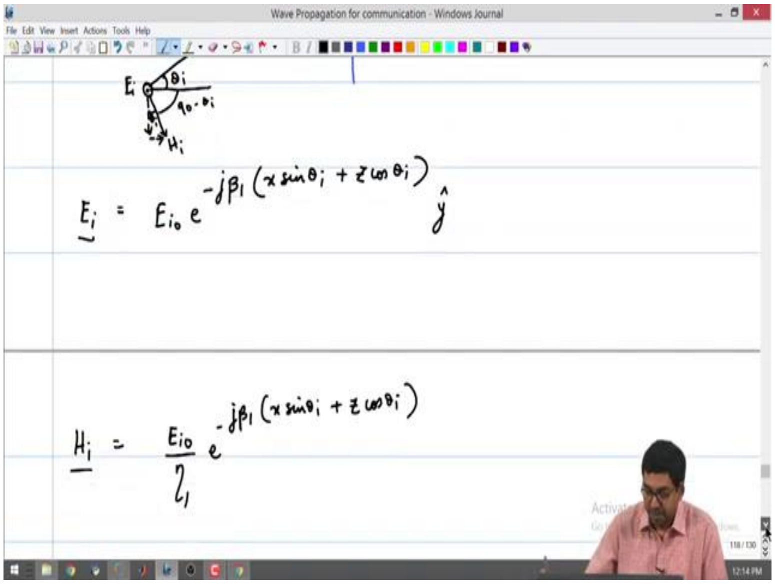

So, I write down my incident field E_i has a magnitude of E_{i0} right and the phase part is $\beta_1(xSin\theta_i + zCos\theta_i)\hat{h}$ ok. It is identical to what I had written before.

The only thing now I am going to pay attention is to the magnetic field. Previously, I had just written magnetic field magnitudes right. So,

$$E_i = \frac{E_{io}}{\eta_1} e^{-j\beta_1(xSin\theta_i + zCos\theta_i)}$$

But in this case, I want to be a little bit more precise. I want to calculate what Hx is. I want to calculate what is Hz and I will make a decision about their magnitudes once I have the full expressions ok.

Because when we wrote the program we saw that the electric field had a y component and then we had Hx and Hz. We also plotted them alright. We also found that the two of them were looking very different ok. So, it means that now we are in a position to look at it more closely try to get the expressions for Hx and Hz separately and then try to draw some more inferences as you know what is zero, what is not zero, what is the standing wave, what is not standing wave extra ok.

So, I think now I am going to write down the full vector expression for the magnetic field also. So, I am going to write which Hi is equal to, of course the magnitude part is going to be divided by the intrinsic impedance of the electric field incident right multiplied by I already know that the form of the expression from the perpendicular polarization that it is going to look exactly like this all right.

So, if you go back to the notes and look at the form of the expression for the magnetic field it could have been identical ok. So, I will still have $e^{-j\beta_1(xSin\theta_i+zCos\theta_i)}$. The only thing that I want to be very specific about is if I look at the diagram that we have drawn the incident magnetic field is pointing downwards ok which means that I can project this on the vertical and the horizontal axis right. So, I can take this to be a sum of two vectors one pointing downwards and one pointing to the right ok alright.

And I can use trigonometry, I can say that θ_i. So, I can draw a line over here I can say that alternate interior angles this is θ_i, this is 90 - θ_i, this is once again θ_i ok.

So, now I can say that this component over here is going to be my x component and the horizontal component is going to be corresponding to the z component ok. And the reason why I want to pay more attention is because the boundary conditions are different for these different components, all right.

So, in the previous case we did not have any free charges so we just use tangential fields equal to 0 right. But here we have to be very careful when applying the boundary conditions all right. So, that is why I want to split them into two components and want to apply the correct boundary conditions right.

So, now I have the expression the general form and I want to split this into a x and a z component. I saw that the projection of the vector in the axis was going downwards. So, I will have $-\hat{x}Cos\theta_i$ because it is pointing downwards.

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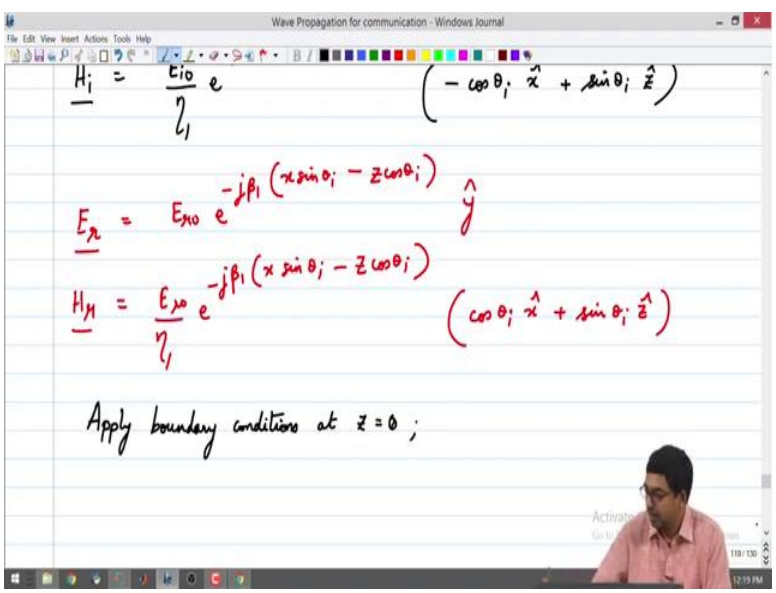

So, I will just say that the x component is going to look like $-Cos\theta_i\hat{x}$ ok and the z component was pointing in the direction of positive z axis alright and that value was Sinθ_i. So, I have $Sin\theta_i\hat{z}$ ok.

So, this completes the description for the incident fields. I do not have any transmitted fields the only thing now I have to worry about is reflected fields ok. So, I will go ahead and write down the expression for the incident I mean reflected electric field.

Let's say that we do not know much about it. So, we are just going to say that it has a magnitude of E_{r0} ok. Ultimately, you will, you will get the you know reflection coefficient extra you can figure out what is E_{r0} with respect to E_{i0} as of now we are just using the same method that we use for the dielectric interface ok.

Maybe that the reflection coefficient is equal to 1 and E_{r0} is equal to E_{i0} maybe it is equal to minus one time but we are going to figure that out ok. So, the general form is $E_{r0}e^{-j\beta_1}$ and the way we had written it for the perpendicular polarization was it is still travelling along the positive x direction, but going in the negative z direction alright.

So, if you go back and look at the expression we will be having $xSin\theta_i - zCos\theta_i$ this corresponds to the k, that you are going to be taking right. So, the k value is going like this. So, you need to a decompose k in two directions then you will end up getting $xSin\theta_i - zCos\theta_i$.

Once again the way I have drawn the diagram I am assuming that this electric field is still pointing in the y direction right. So, this is an assumption that I am making, but I can be corrected after I finish the entire derivation right. So, the point is you can fix the problem, you can fix the directions in the way you feel comfortable , you can make the derivation.

Once you finish the derivation the transmission and the reflection coefficients will tell you whether the assumed directions are correct or not. That is alright. So I have the reflected field to have a y component and its expression is like this. Similarly, I can go ahead and write down the reflected magnetic field just oops. I am sorry.

$$E_r = E_{ro}e^{-j\beta_1(xSin\theta_i - zCos\theta_i)}$$

$$H_r = \frac{E_{r0}}{\eta_1}e^{-j\beta_1(xSin\theta_i - zCos\theta_i)}$$

So, we have to multiply this whole term just like we did for the incident field with the decomposition of your reflected magnetic field. So, now, I have $Cos\theta_i\hat{x}$.

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What is that?

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Ok. So, now, I have the full expressions for incident and reflected fields. Now I have to be applying some boundary conditions alright. So, in order to our objective is to find out the reflection coefficient and the directions of the reflected field with respect to the incident field right.

So, the convenient way is we have to take some position. So, the place where we will apply the boundary condition is z equal to zero. So, you can get rid of some terms in your math alright and then we can see what fields will add up and what fields will not add up extra right. So, the boundary conditions are z equal to zero. So, I will just say that we apply.

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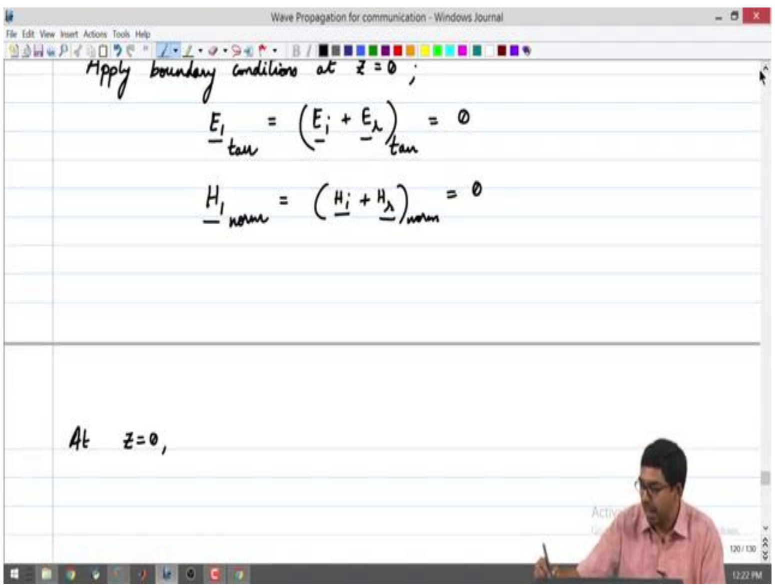

So, we apply boundary conditions at z equal to 0 tangential electric field right ok. Tangential electric field which is going to be say the sum of your incident is 0 ok.

Also note that the way we have assumed the direction of the electric field, the entire electric field is tangential to the interface anyway. So, I have just written

$$E_{1_{tan}} = (E_i + E_r)_{tan} = 0$$

But the way we have drawn the entire value of the field is tangential. So, we could just take the sum and then equate it to 0. That would be a boundary condition at z equal to 0 as far as the electric field goes right.

For the magnetic field the condition is different alright and we need to be a little careful all right. We have a condition for the normal component of the magnetic fields alright ok. This will ensure that you do not have fields inside of the conductor. So, you have to either remember this or go back and try to derive this for an interface using gauss's law alright. But I think it is ok to remember this

$$H_{1_{norm}} = (H_i + H_r)_{norm} = 0$$

So, this is the reason that we split the electric field into x and z components. So, that we can apply the boundary condition only to that particular component all right. Now let us have a look at what do these things mean , do they mean something different or do they mean the same thing alright?

So, let us say that at 0 equal to 0 ok. I will have the incident plus the reflected fields tangential component is equal to 0 right that is what I need to worry about. So, I substitute z equal to 0 for E_i z equal to substitute 0 for a E_r and then I have to add them up together right.

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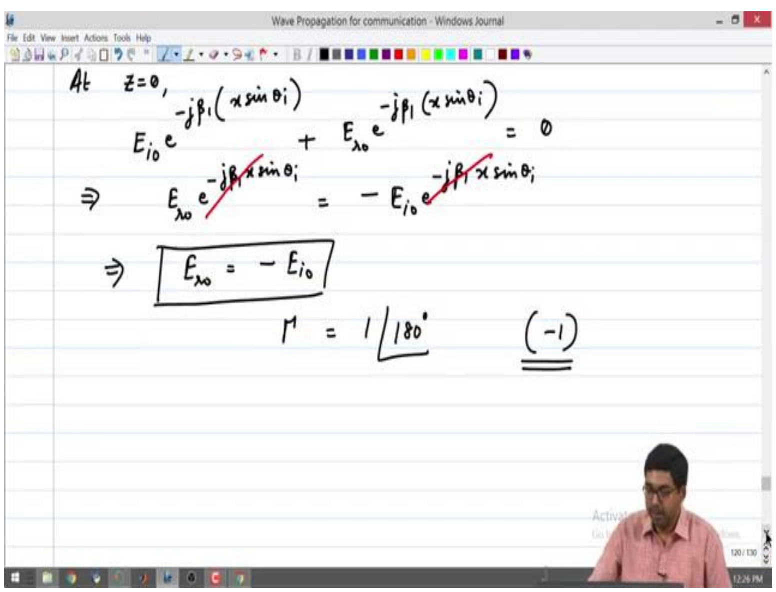

So, I am going to say that

$$E_{io} e^{-j\beta_1(xSin\theta_i)} + E_{ro} e^{-j\beta_1(xSin\theta_i)} = 0$$

So, if you go back if you look at the expressions right. So, you will substitute z equal to 0 and get rid of this; only this part remains ok. And the same way for the incident electric field only will only one part will this part become 0 and this is what remains ok alright.

Now, what do these mean this means that the sum of these two is equal to 0 or I can say that rearranging this

$$E_{io}e^{-j\beta_1(xSin\theta_i)} = -E_{ro}e^{-j\beta_1(xSin\theta_i)}$$

I have some common terms right can cancel them and then this will give me the inference that

$$E_{ro} = -E_{io}$$

So, even if you make an assumption about the electric fields in some direction it does not matter as long as your derivation is going to be following that alright and as long as you apply the correct boundary conditions you will end up with the correct value and the direction of the reflected field.

I think in the prior derivations some people had confusion why we had taken this direction to be flipped the other direction is not flipped extra. The reality is does not matter alright as long as you are consistent with the right hand rule for E, H and k and as long as you apply the correct boundary conditions it does not matter, your end result will tell you whether your assumption is correct or you need to reverse your assumption that is all, alright.

So, E_{r0} as equal to E_{i0} is the result I am having. This tells me two things. First of all, it tells me that the magnitude of the reflection coefficient alright the electric field reflection coefficient magnitude is equal to 1 and it also imparts a phase of 180 degrees to the reflected field with respect to the incident field. So, they are out of phase by you know 180 degrees. So, you can always say that this one at an angle of 180 degrees or you could simply write this as minus 1 there is no harm in that also ok.

Now, you can start drawing some analogy to transmission lines even here alright. You can remember a with respect to transmission lines when we were dealing about smith's chart extra, we used to draw the short circuit on the left hand side of the Smith impedance Smith chart and the gamma plane was in such a way that gamma corresponding to short circuit was minus 1 and there it was voltage reflection coefficient alright.

So, in the transmission line when you had voltage reflection coefficient to be minus 1, the condition that you were applying was a short circuit right. So, you can say that this particular case is analogous to a short circuit in your transmission line. It is not the same, but it seems analogous to that because just having an electric field which is volts divided by meter right.

So, an analogy could be there alright. So, it is also if you have normal incidence you will just have minus one and going back in the same direction you can end up having standing waves with perfect standing wave ratio right ok.

So, there is some analogy even with transmission line, but it gets difficult simply because the angle of launch comes into the picture in the case of transmission line you never had the question of oblique incidence, it was always going hitting at normal incidence and coming back here. You can always say that my θ_i could be equal to 0 and that case will exactly boil down to a complete analogy with transmission lines ok.

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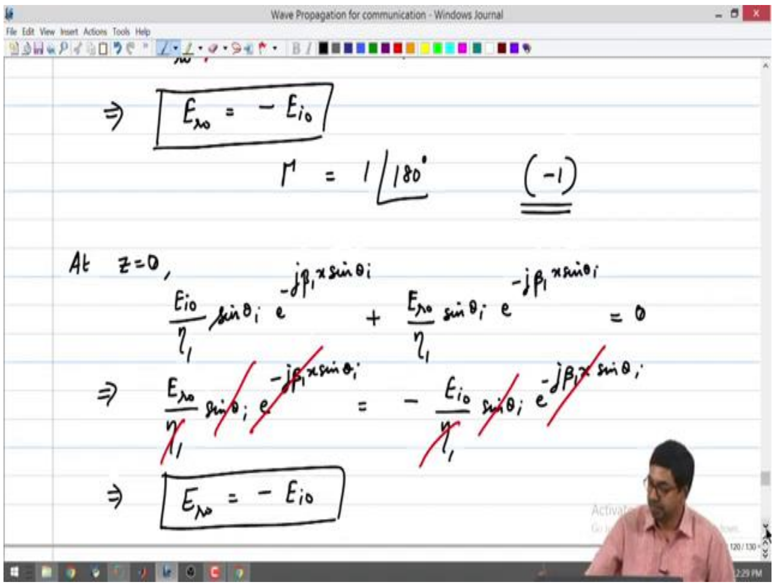

So, now let us look at the other boundary condition at z equal to 0 ok. I had a hat H equal to 0 the nominal components of the H have to be added up and that has to be equal to 0 ok right.

So, I will be having

$$\frac{E_{io}}{\eta_1} e^{-j\beta_1(xSin\theta_i)} + \frac{E_{ro}}{\eta_1} e^{-j\beta_1(xSin\theta_i)} = 0$$

So, I have just taken the expression substituted z equal to 0 and I am just writing the remaining terms that I am having over here alright. And I am, I am using only a normal component ok normal component, normal component is only the z component in this case ok, so I am taking only the z component.

But what does this mean? Does it give any useful information? I can quickly see that I can rearrange this alright. So, I can rearrange this and write this down as

$$\frac{E_{ro}}{\eta_1} e^{-j\beta_1(xSin\theta_i)} = -\frac{E_{io}}{\eta_1} e^{-j\beta_1(xSin\theta_i)}$$

There are some common terms alright, can slash of the common terms.

Once again you end up getting the same information again that the reflected field alright. So, remember in the previous dielectric interfaces you needed two equations to solve for reflection and transmission coefficients because there was a transmitted and reflected field. This case you do not have a transmission coefficient at all. So, the two equations end up giving the same result alright.

So, once again it is reinforcing that

$$E_{ro} = -E_{io}$$

This means that if you are trying to solve some problems you can always try to apply the boundary conditions only for the electric field. Figure out the direction of the electric field that is going to be good enough. Even if you applied the condition for the magnetic field normal, it means that effectively you are applying the same boundary condition again you will end up getting the same result as the reflection coefficient is equal to minus 1 right.

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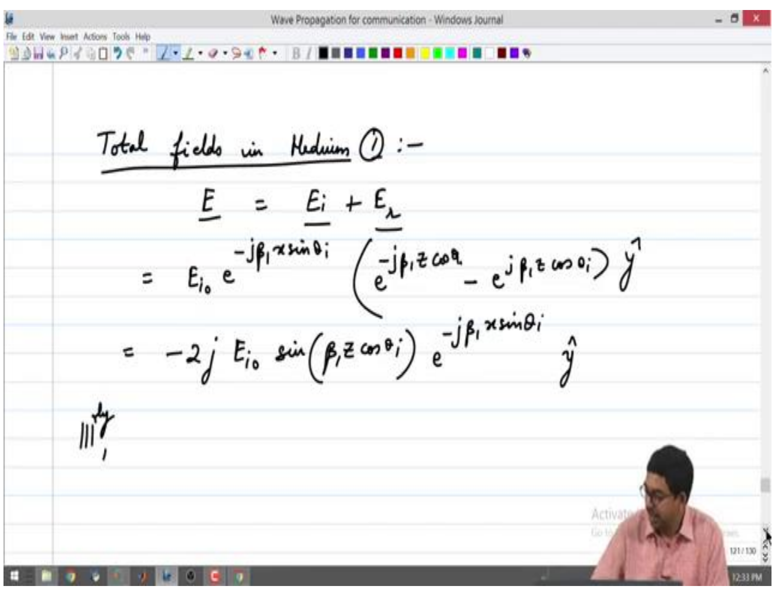

So, having got this right, one can ask a question as to what are the total fields in medium 1 ok, total fields in medium and suppose I write the field to be equal to $E = E_i + E_r$. So, all I have to do is take the expressions and add them up together. That is all alright, right. So, I am going to be having

$$E_{io}e^{-j\beta_1(xSin\theta_i)}(e^{-j\beta_1(zSin\theta_i)} - e^{-j\beta_1(xSin\theta_i)})$$

The way I have written it, it looks like it is in power.

So, I will just correct that, just bring that down so that you do not have to. Oh Boy simply cannot choose it. I think it is yeah ok.

The minus sign is simply coming because E_r is negative of E_i alright. So, it looks like $e^{-j\beta_1(zCos\theta_i)}$ ok. That minus sign will cause confusion so I will just put it here.

So, it is $e^{-j\beta_1(zCos\theta_i)}$. So, all I have taken is taken the expressions added them up together and I have grouped the z terms together because I want to perform some trigonometric operations with them. I can use Euler's formula to say that you know the difference between the exponential will give me a sinusoid. So, it will be 2 j something, but because it is $-j\beta_1(zCos\theta_i) - e^{-j\beta_1}$. So, it will be

$$E = -2jE_{io}Sin(\beta_1 zCos\theta_i)e^{-j\beta_1(xSin\theta_i)}$$

So, I just wanted to get that with respect to z. So, that is why I have grouped them up together ok. So, I can just write this as $-2jE_{io}Sin(\beta_1 zCos\theta_i)e^{-j\beta_1(xSin\theta_i)}$ and this is a huge expression all right and there is not much we can do to visualize this alright.

So, we will be quickly writing a program ok whenever we have such a lengthy expression because it has got cosine inside of a Sin argument alright and then it has got a product with exponential it becomes tough even if you have got the expression visualization becomes really tough when you have this kind of expression. So, we will be writing a program in octave to just see what this means all right and then we will draw some inferences as of now this is an expression we have got ok.

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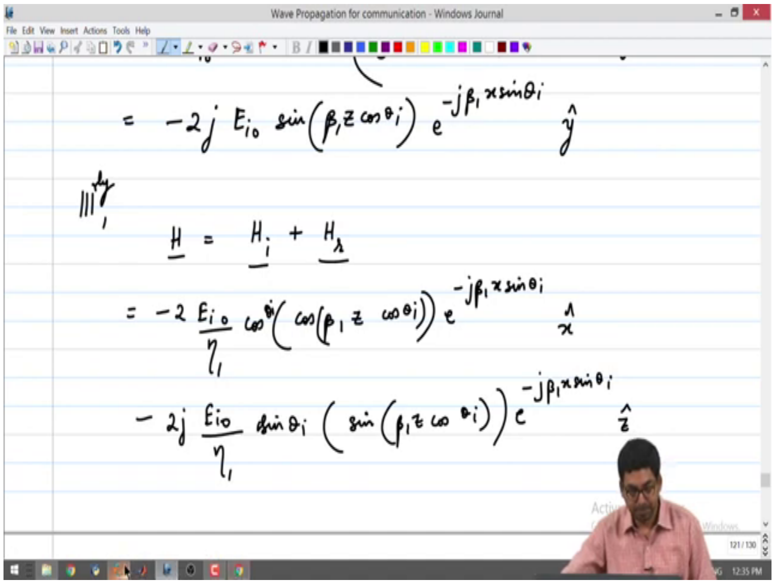

Similarly, you can also write down you know the expressions for the magnetic field. So, you can always say that I have total fields to be equal to

$$H = H_i + H_r$$

There is a very lengthy expression alright, I will just write it down alright. And it involves grouping the z terms and applying the Euler theorem to take the difference of the sum between the two exponentials in this case ok. So, I will just write it down then we will talk about it right.

This is the x component and then I have a z component which looks like, you can do this patiently by just adding the two terms and then applying some you know grouping for grouping together they a exponentials and trying to apply some of the groups equal to going to give you a cosine and the difference between them is going to give you a sin.

But this is a very big expression to form any picture in the mind alright. So, what we are going to do is quickly I am going to fire up octave alright, whenever I have a large expression like this I am going to fire up octave and then I am going to plug in some values I am going to figure out what is known what is unknown and I am going to make some plots ok then only we can figure out what exactly is going on. So, I will go ahead and open octave right.

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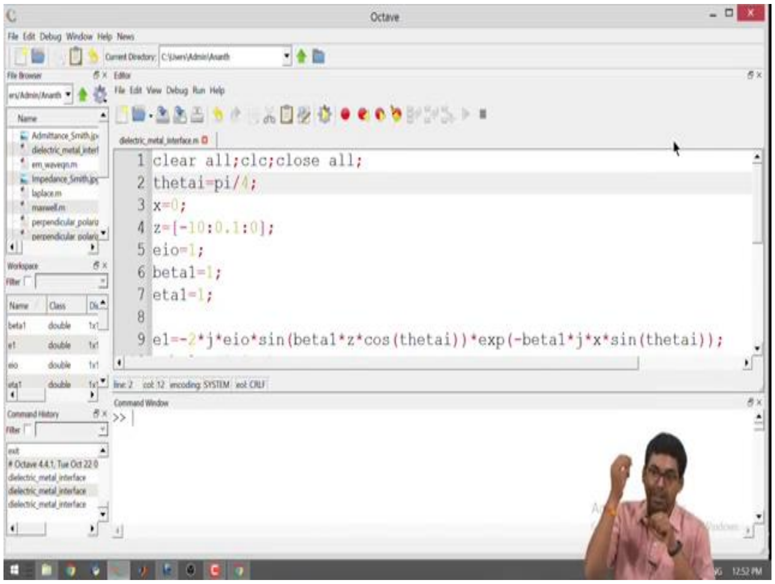

And I will write a small program just to visualize these expressions ok. So, I will start with ok all I am going to do is I am going to start with what are the quantities that are fixed or known alright. So, to understand this we have to assume a fixed angle of incidence first let we have to say that let θ_i b fixed ok. And let us say that I will start with the θ_i that I consider to be easiest, θ_i equal to 0 will remove some of the terms already it is easy for me to understand what is going on. So, I will start with theta equal to 0 all the sinusoids will vanish and cosines will become 1 alright.

So, my expression will look a little reduced right and I have x$\sin\theta_i$, x$\cos\theta_i$ all these things coming into the picture and honestly I mean I could apply this at z equal to zero, but x could be anything the boundary condition is applied at z equal to 0 x could be anything. So, conveniently I can choose x equal to zero. So, that I reduced the expression even more alright. So, if I had x $\sin\theta_i$ Now I know that it is 0 ok.

Then I just want to understand the dependence on z because the incident field is going this way and then going back this way there is some travel in the positive z direction and then going in the negative z direction I would like to understand what is happening. Since I assume θ_i to be equals 0 it looks like the incident wave will go normal to the incidence I mean an interface and then it is going to travel back.

So, I just want to plot the total fields as a function of this z in the dielectric right. So, I am going to take some region say minus 10 a to 0 alright 0 will be the interface z equal to 0 is the interface and we are going leftwards to some units of minus 10 ok because only fields exist only there in the right hand side we do not have any fields we do not have to plot anything over there.

So, z equal to 0 is the interface and you go backwards to all the way to minus 10 ok. Then I need to have a few more quantities incident electric field 1 ok because it is easy to get 1 volt per meter and see what happens whether it becomes minus 1 minus 2 extra right. So, 1 volt per meter then there are other terms like beta coming into the picture β_1 ok.

And I think for the magnetic field case you also need to know the characteristic impedance η_1 ok. So, I fix as many quantities as possible to ones and zeros. So, if I reduce my expression a lot then I try to figure out what happens. It is very very easy for us to understand what exactly is going on. So, I have fixed everything to a very convenient number. Then I am just going to take the expression for the electric field e one is what we had written, alright.

So, it was

$$E = -2jE_{io}Sin(\beta_1 zCos\theta_i)e^{-j\beta_1(xSin\theta_i)}$$

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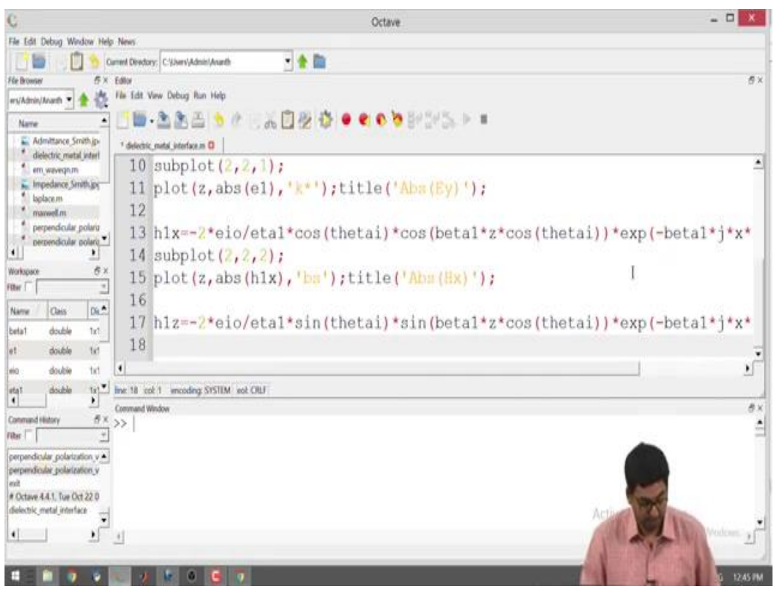

So, I will just move the j to the second because octave accepts like that, $\beta_1$xsinθ_i ok. So, I have just taken the expression and plugged it in as it is ok. I want to start creating some plots. I will divide the screen into four because I have Hx, Hz, I need at least three. I will just do them like this one spot will be vacant so that is fine right.

So, I will just make a subplot 2 rows 2 columns, first plot that I want is of the electric field right. So, I want to create a plot of position z right and then I want to plot say absolute value of even.

So, I want to see the magnitude of the event involving both the reflected and the incident field summed up together as total fields ok.

And I will also give a title to it because later on we'll be having different plots. So, I am just saying the absolute value of E in this case was Ey, yeah, also make this let us make it different plots of different styles or something so that it is visible ok. Now, I am going to go ahead and run this ok.

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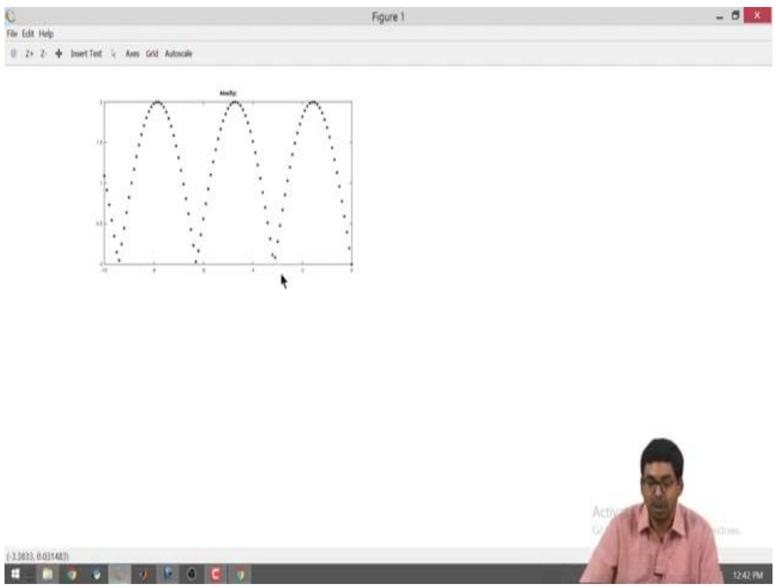

So, I am getting some plot alright and I will make the derivations or inferences once I have all the three components ok. But for now I see that there are a few things that I can quickly notice. The first thing that I noticed is with respect to the z direction ok.

I am having a standing wave pattern all right because the absolute values are going to 0 at some places which you will be calling as nodes and the absolute values are going to 2 I supplied only 1 volt per meter, normal incidence the reflected one is adding up to the incident one and the net field present in medium number 1 is 2 volts per meter. So, that is very clear all right and then it is, it is going back and forth right.

So, I would like to and another thing that I noticed is at the interface which is z equal to 0 my electric field is 0 all right. So, it seems to be satisfying the boundary condition also. So, now, I will go ahead and make similar plots for Hx and Hz. So, I will just say h1x ok ah.

I will have minus 2 times ok. We need to see the expression

$$H = -\frac{2jE_{io}}{\eta_1} Sin\theta_i (Sin(\beta_1 z Cos\theta_i)) e^{-j\beta_1 (x Sin\theta_i)}$$

I think that part I am just going to copy and paste it from the line about because it is the same wow that is a lengthy expression.

I am also going to copy paste the plot comments ok. So, I have taken only the x hat component of a magnetic field and I have made it as h1x while doing this I will also finish h1z because I have to go back and forth between the two things. So, it's so it is $-\frac{2jE_{io}}{\eta_1}$ ok. So, I will copy paste from the previous lines a little bit. So, this part is the same into I think there is a $\sin\theta_i$ ok.

Then I have $\text{Sin}\beta_1 z\text{Cos}\theta_i$ i think the remaining form will be the same, there is no change there. Yeah, so I will go ahead and make a plot out of this.

So, I have just used bs this means blue color line with square markers alright. I do not think I even specified a line so it is blue square markers and just means that red diamond is what I remember or I will make it a red and upward triangle. So, at least I know that it will work. So, it will just make some triangles for this plotting this particular graph. So, those three graphs look a little different ah.

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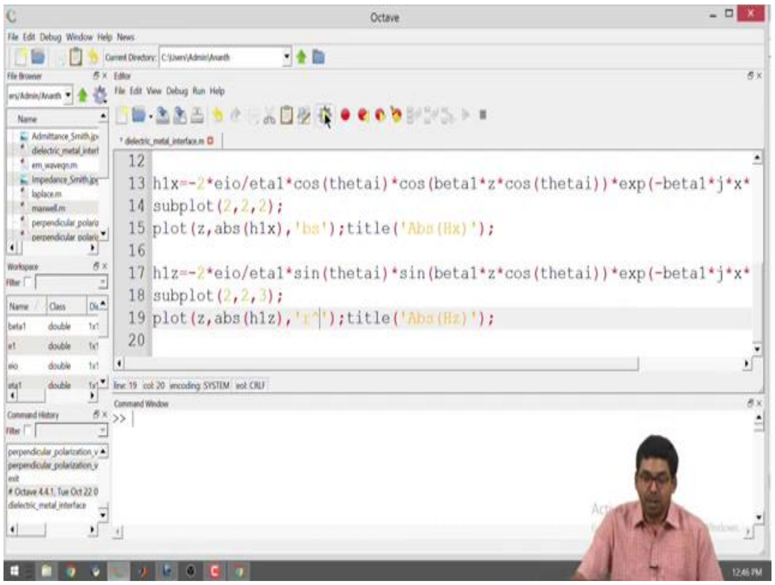

Yeah, k star just means black color star alright, bs just means that blue color square red color triangle pointing upwards that is what it means. So, I just want a three different plots ok I am just going to go ahead and run this all right

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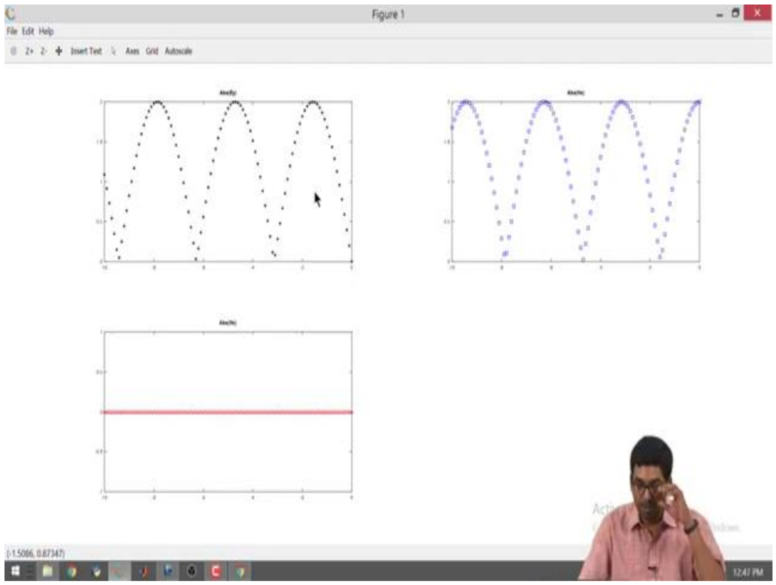

Now, I think we can start to make some analysis right, so what did these expressions mean at the boundary? The electric field is clearly 0, ok throughout this region Hz is 0 well it is understandable. Because you had normal incidence it did not have a component at all. It had normal incidence which means that your x was pointing in one way and the x was pointing in the other way, but it did not have a component in the z direction at all because your direction of propagation was plus z.

And then when it is bouncing back it's direction of propagation is minus z. So, the magnetic field did not have a set component at all. So, it is zero, for θ_i equal to 0 alright.

The other thing that we notice is Hx alright is maximum at the interface Ey is minimum at the interface one can always calculate a pointing vector alright and I can say that in this case. I will take Ey alright crossed with Hx ok and I will get that the net power in x direction because I am having y cross z right a y cross x alright I am having net power in z direction will be 0 ok.

So, in the z direction I do not have a power transfer alright, but what about in the other direction. So, I think we have to look at this more carefully what does this magnetic field being equal to 0 even mean. Let us put some other angle right let us make the θ_i to be equal to pi by 4 right. So, it is 45 degrees with respect to the normal at the interface and then let us run this to get a little bit more idea alright.

Now, I see that it makes a little bit more sense right. So, I am having Hz Ey Hx all of them to be non 0. Once again I noticed that at the interface electric field becomes 0 at the interface z component of the magnetic field is 0 alright and at the same place the magnetic field x component is maximum alright. So, if I look at this graph I have placed this graph one on top of the other deliberately so that I can see when Ey peaks Hz also peaks when Ey goes to 0 Hz also goes to 0 alright.

So, I can say that Ey and Hz are in phase ok Ey and Hz are in phase. Now if I look at Hx wherever E goes to minimum H goes Hz goes to minimum Hx has gone to maximum wherever there is a peak for Ey there is a dip for Hx alright. So, I can say that Hx is a system phase quadrature, alright or it is out of phase alright by 90 degrees ok with respect to Ey or Hz ok and when you have Ey crossed with H x.

Since the electric and the magnetic fields are out of phase by 90 degrees you do not have a power transfer in that direction it is very similar to the case of having inductors and capacitors in circuits where your voltage and current will be out of phase by 90 degrees. So, you will not have inductors and capacitors consuming any power is a similar case alright.

So, I think now you have a tool there are also other inferences one can make at 45 degrees the value peak value of the electric field that I will have in the immediate number one is still towards per meter ok and I am also having a magnetic field all right it is 1 by I mean which is square root of 2 times a 1. So, it is 1.41 here 1.414 here. So, there are some you know derivations that you can think about ok.

But the critical part is when we have applied the boundary condition the normal component of the electric field alright the normal component has become 0 the tangential component has become maximum ok.

So, this means that we need to think about the effects of this. And one of the things that we now need to talk about is a surface current, ok. So, we need to talk about what kind of surface currents will exist in the surface of the conductor right alright.

So, summary is in the case of a dielectric conductor interface. In the dielectric medium you will be having standing wave patterns with respect to z with respect to x it is a travelling wave. So, if you have a look at all the expressions that we have with respect to x, it is a travelling wave with respect to z you just have a standing wave alright. Because at fixed values of z you have some fixed value that is a maximum minimum extra as defined, but with respect to x it is a travelling wave ok.

And the other things that we have seen from the diagrams is that there is something going on with the tangential component of the magnetic fields in the case of a dielectric conductor interface and we are going to talk about surface currents in the next class alright.

So, I will stop here. I hope that now if you have lengthy expressions one of the things that you can do is go back open octave, fix large numbers of quantities to zeros and ones and try to write a simple program and see how to visualize these, at least this part you should be able to do. But if you do not do that it is very tough to actually go back and draw with paper and pen because you have to calculate so many things in the mind right.

So, this confidence you should have all the perpendicular parallel polarization you should be able to figure out what is fixed, what is varying and then find out the unknown quantity confidently is ok.

So, we will meet in the next class right away.