Advanced Microwave Guided-Structures and Analysis
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Lecture 53
Analysis of Guided Structures (cont.)

Welcome to the continuation of the lecture on the non-radiating dielectric guide. We have been discussing about the characteristics of the LSE mode. Let us go to the characteristics, or the field profile of the LSE mode.

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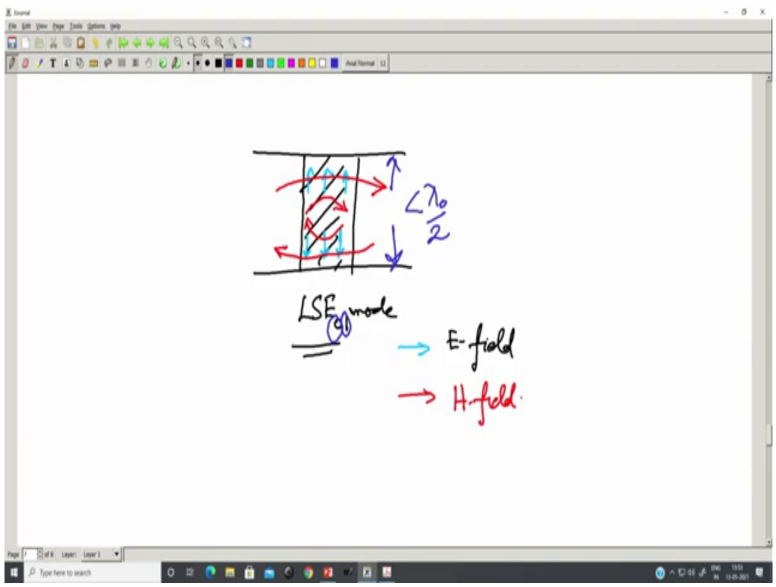
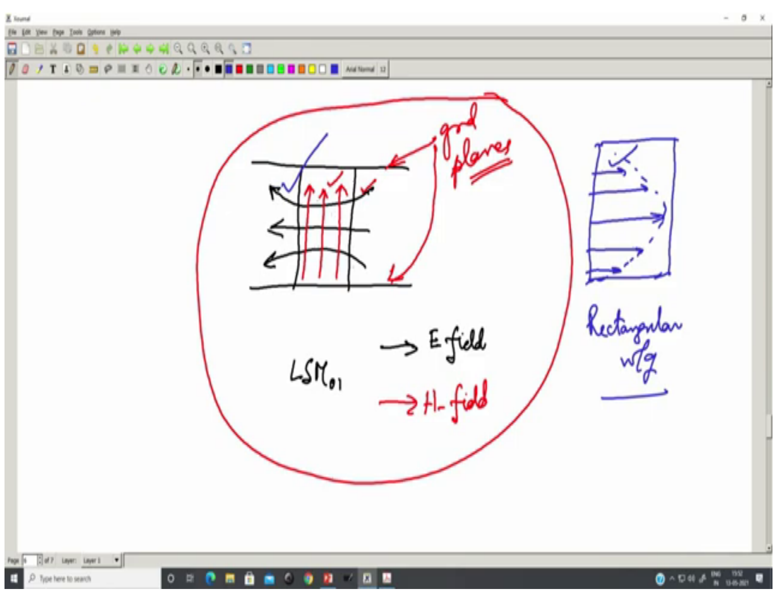
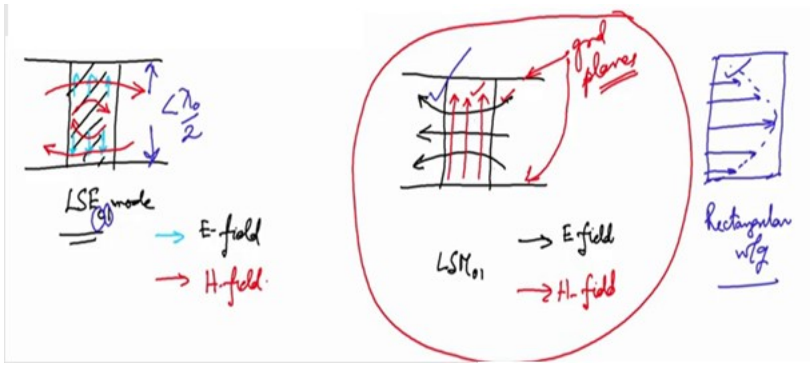




So, let us draw the NRD again in order to illustrate the LSE mode.



So, this is the electric field and magnetic field profile of the LSE_{01} mode.

So, you can see that, the electric field is totally tangential to the air dielectric interface. So, this is the LSE_{01} mode. So, this is the lowest Eigen number, along this direction and there is a half wavelength variation in this direction.

So, we see that in a nutshell the LSE_{01} mode, the principal property of the LSE_{01} mode, it is the absence of the magnetic field component, normal to their dielectric interface, which we have, which we are seeing here.

So, the magnetic field is entirely tangential to the air dielectric interface, while for the LSE_{01} mode, no component of the electric field exists normal to the air dielectric interface. The same the no there is the electric field is completely tangential to the air dielectric interface; there is no normal component of the electric field to the air dielectric interface.

So, it can also be seen that, the configuration of the LSM_{01} mode, if you look at go back to the LSM_{01} mode, its configuration closely resembles that of the dominant TE_{01} mode of the rectangular waveguide, why we say that is that as we said that we have a rectangular waveguide its dominant mode will have a configuration like this. So, the electric field will be like this.

So, you see that this electric field matches in direction with that electric field. So, therefore we say that the rectangular waveguide dominant mode, or the TE_{01} mode, the field configuration of that mode matches that with that of the LSM_{01} mode. As we also discussed that the low loss nature of the NRD is fundamentally due to the field profiles of its modes. Because the LSM_{01} mode field profile the magnetic field is, is normal to the metallic plates.

So, a reduced electric current in the metallic plates, whereas if you look at the LSE_{01} mode, the magnetic field is along the metallic plates, it is tangential, its more tangential to the metallic plate. So, there will be currents induced in the metallic plates leading to loss.

So, therefore the LSE's modes are more lossy than the LSM modes. So, therefore the low loss nature of the NRD, in the most, in the most often used mode, which is the LSM mode, it is fundamentally due to the field profiles of its modes. And also so there are 2 important conditions for the low loss nature one is the field profile of its modes and number two the distance between the ground planes being less than the half of free space wavelength.

So, this distance being less than half of free space wavelength. So, these are the two fundamental reasons why the NRD is less lossy is a very low loss guided structure compared to other structures, or even other, other very similar structures like the edge guide.

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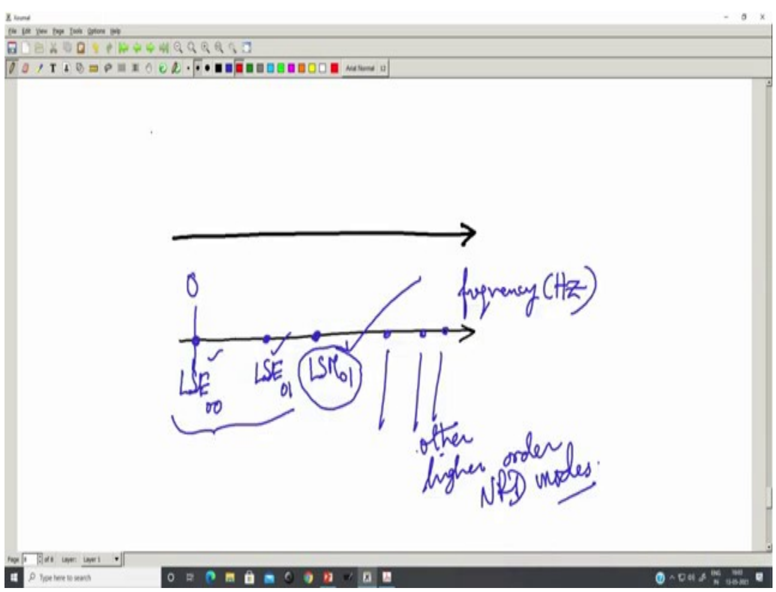
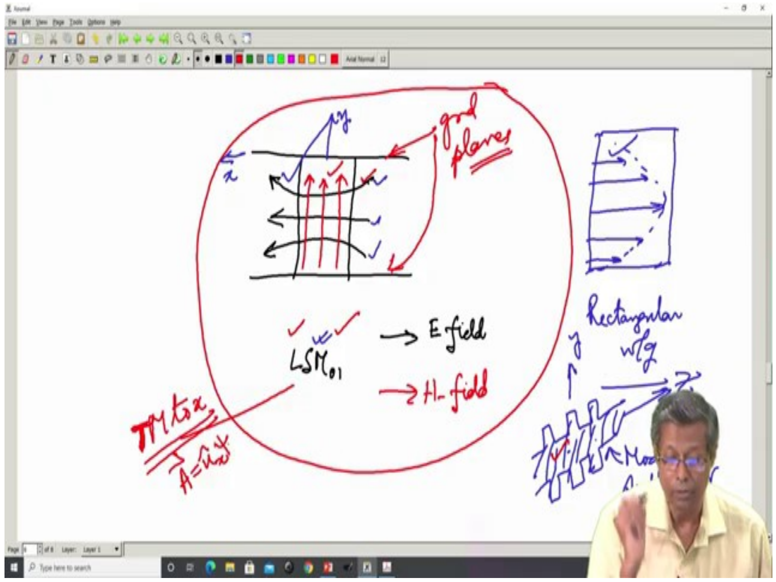
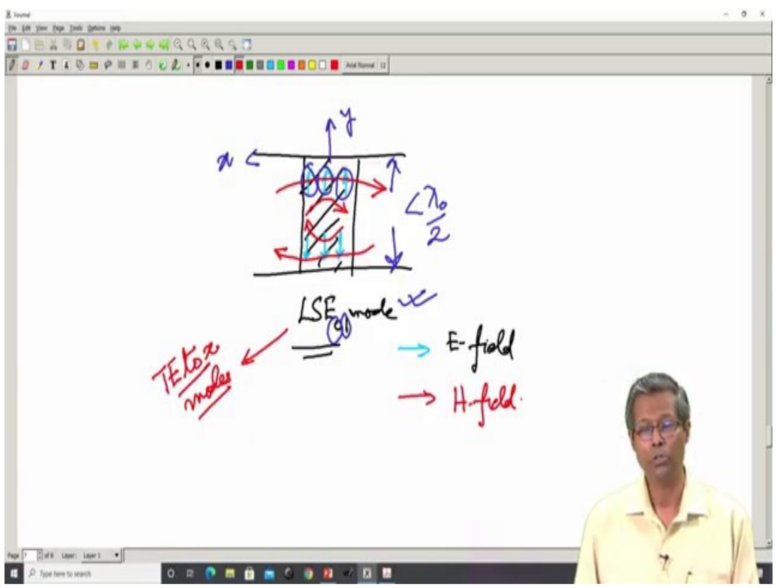
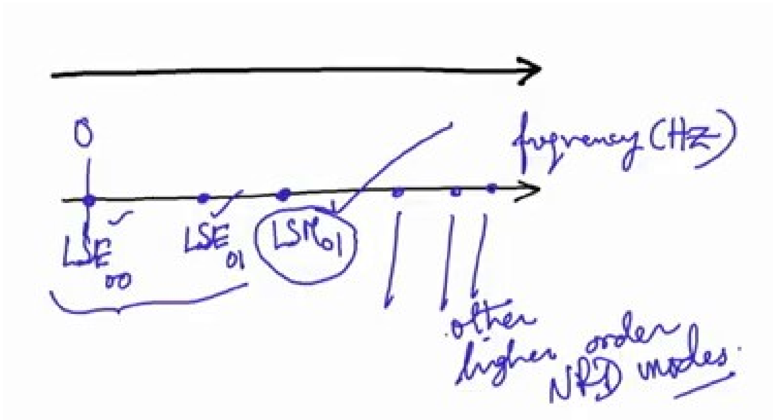






So, if I arrange the modes of the NRD in ascending order, the lowest one will be the LSE_{00} mode. So, this is frequency hertz, which has a 0 cut off frequency. So, it would propagate a dc followed by the LSE_{01} mode, which is the next higher order mode and then followed by the LSM_{01} mode, which is the next higher order modes. And then will come the other higher order NRD modes.



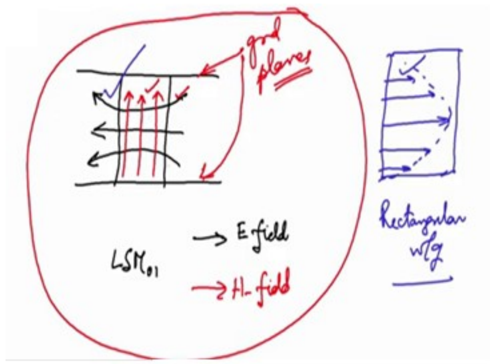
So, you see if we are preferentially using the LSM_{01} mode, because of its low loss, we have to very well appreciate that there are two modes, LSE_{00}, and LSE_{01}, which have a lower cut off than the LSM_{01}. And therefore these two modes will have a tendency to get generated at any kind of discontinuity surface imperfections of the NRD, curved sections and the like.

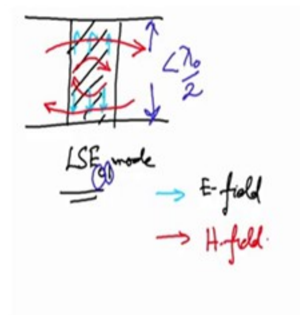
So, this must be very carefully born in mind, the clear difference between the rectangular waveguide situation, where we are using the dominant mode and the NRD guide, where we are constrained to use a lower loss mode with a higher cut off frequency.

So, therefore the other two modes, which are preceding to that they have a tendency to get excited at any kind of discontinuity, or curve sections and this has to be taken into account. And as we said that if that is not permissible, then we can we have to use components like mode suppressors in order to suppress the LSE_{01} mode, or the LSE_{00} mode.

Now, how do we use the mode suppressor, for example if we have to use the mode suppressor, we have to look at the field profiles of the LSM_{01} mode, you see that the field profile of the LSM_{01} mode is the electric field along the ground plane. So, if we insert a metallic plate ideally along the y, z plane that is principally not going to affect the electric field, because it is normal to the metallic plates.

So, that is not going to affect the electric field. However, if I insert a metallic plate along the y, z plane, that is going to short out these electric fields. Because these are tangential, they would be tangential to the metallic plates. And therefore that is going to prevent the LSE_{01} mode from getting propagated. But there are lot to this to the design of such mode suppressors other than just shorting out the electric field.





There are bandwidth issues, there are many other issues and you know like the design of such mode suppressors, or any mode suppressor is a very challenging research topic on its own. The other thing which should be borne in mind is that if you consider the LSM_{01} mode and if you say that if I insert a mode suppressor along the y, z plane nothing is going to happen to the LSM_{01} mode, it is not principally correct.

Because you see that the magnetic field is along the y, z plane. So, if I insert a metallic plate, or typically it happens like a corrugated plate kind of thing with a structure like this so a structure like this a corrugation a corrugated type plate. So, this is an example, or a typical picture of a mode suppressor and this will be inserted, if this is the y and that is the z direction.

So, if you insert this kind of a structure on the y, z plane you appreciate that the magnetic field which is along the y, z plane, because it is the LSM_{01}. So, the magnetic field is along the y, z plane, it is tangential to this ground plane. And therefore currents are going to be induced on this surface. And therefore that is going to increase the loss, in fact that we have to deal, we have to also see what is the polarization of such currents and how they interfere with the mode propagation.

So, please bear in mind that, the design of a mode suppressor has to take into account many factors, including loss, including bandwidth, including how well it suppresses the undesired modes, and you know like a lot of such factors, which are going to be relevant in the suppression of the undesired mode and in the propagation of the desired mode.

But the desired mode is not going to be totally unaffected by the insertion of the mode suppressor, this has to be carefully borne in mind. So, now that we have a physical picture of the NRD, its hybrid modes, its essential difference between the rectangular waveguide and such guided wave structure both in terms of advantages, disadvantages, modal characteristics, use of the non-dominant mode, and things like that. Let us come to a more mathematical description, or the analysis of the NRD.

So, the analysis of the energy at this point is not a very difficult job, the reason why I tell it, it is not a difficult job is that, we have already studied other kinds of mode functions. Because you see that the modes in the NRD if I say they are the LSM_{01}, or the LSE_{01}, the LSM_{01} is characterized by no magnetic field along the x direction.

So, that is therefore I can say this is a TM to x mode, it is transverse magnetic to x. There is no magnetic field along the extent, we have made this mode before, we have even written down the potential functions of this x. So, the LSM_{01} mode is nothing, it is nothing, but the same as the TM to x mode, which is given by the mathematical description of such fields are given by A equal to $u_x\psi$.

Similarly, the LSE_{01} mode, or the LSE modes, I should not say 0 1 the LSE modes are a general class of TE to x modes, because there is no electric field along the x direction, the electric field is totally confined in the y, z plane. So, it is a TE to x mode, it is the other name for our TE to x mode, we have already made this TE to x mode, before we have already written down its field distribution from the potential function.

So, once the potential function is given, we can write down the field distribution. So, let us see how we can use the knowledge earned in our previous lectures, in order to understand the foundation, in which the, or I should say in order to understand the mathematical foundations of the NRD modes. How the NRD modes can be expressed mathematically?

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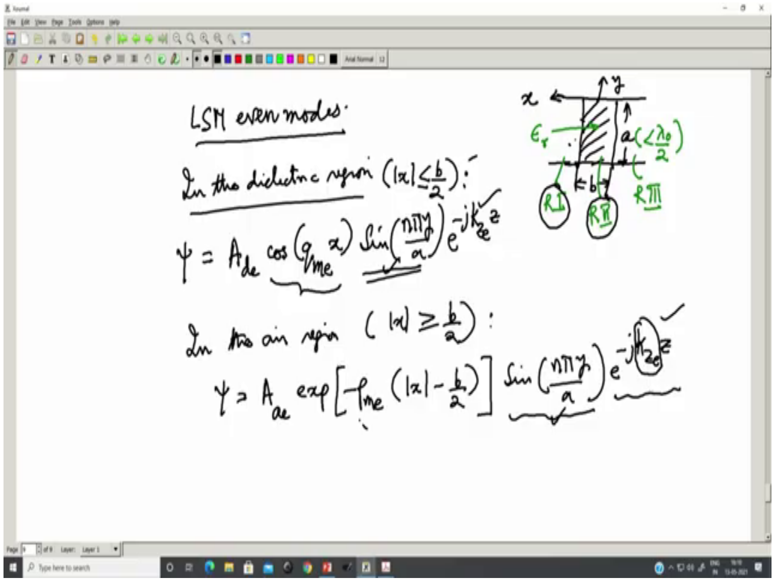
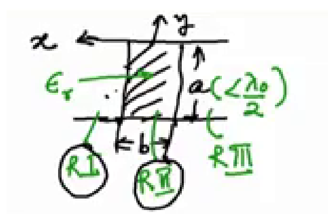
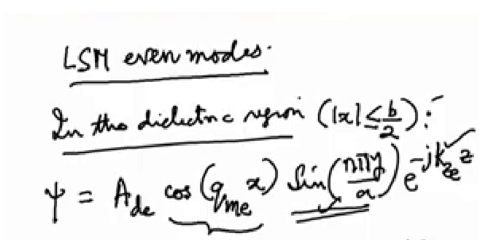


So, let us go to the LSM even modes, we said that LSM even modes are characterized by the potential function having an even distribution, or a co sinusoidal distribution along the width, which was along the x direction. So, in the dielectric region, let us draw a mini picture here, so that you we can relate the picture with the fields.

Let us draw a mini picture here.



So, for the LSM even modes, we have a co sinusoidal distribution of the potential function here.So, in the dielectric region,



So, this models the reflection in the y direction. So, because of the presence of you already know how to choose this sine, and why it is not cos, we have already done that exercise in the rectangular wave guide, in order to preserve the characteristics that the tangential electric field has to be 0, on the metal on the ground plane. And this denotes the propagation along the z direction, e refers to the even mode.

So, this is the nomenclature of the LSM even mode, in the dielectric region. In the air region

In the air region $\left(|x| \geq \frac{b}{2}\right)$:

$$\psi = A_{ae} \exp\left[-p_{me}\left(|x| - \frac{b}{2}\right)\right] \sin\left(\frac{n\pi y}{a}\right) e^{-jk_{ze}z}$$

So, in order to describe the variation of the fields along the x direction, it is evanescent that the waves are dying decaying down along the x direction.

So, the y direction variation of the field is unaffected. So, it is the same as this and again the there is nothing happening along the z direction. So, that z direction variation of this wave number will be the same as the dielectric region. Because the phase has to be matching, the phase has to match along the air dielectric interface, otherwise we cannot match the fields.

So, this is called the phase matching condition. So, the concept is illustrated.

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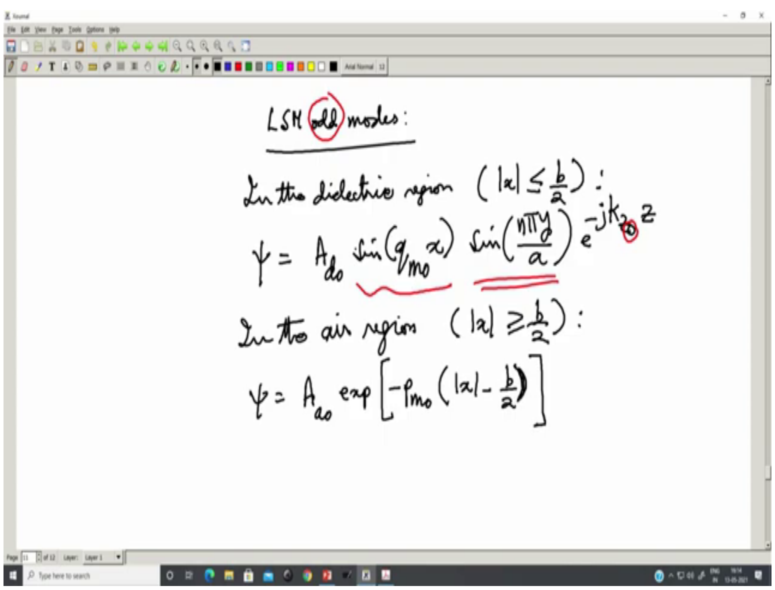

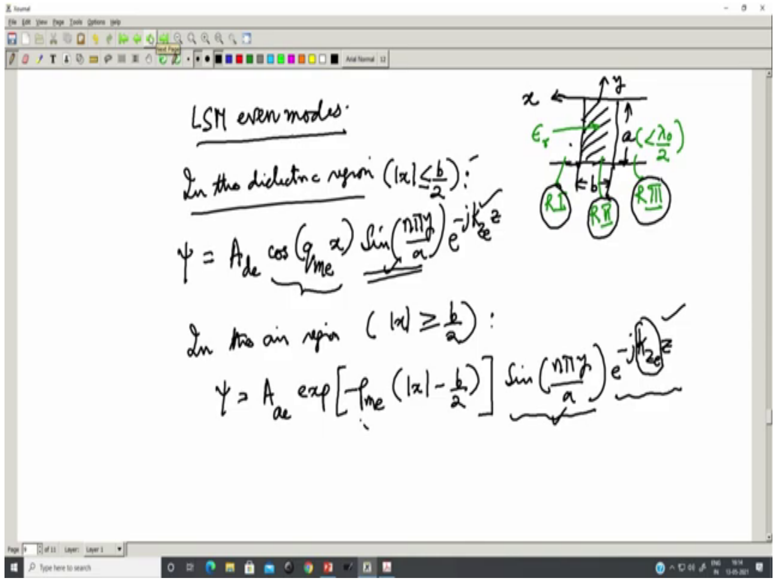

Now, we come to the LSM odd modes, for the LSM odd modes in the dielectric region,

LSM odd modes:

In the dielectric region $\left(|x| \leq \frac{b}{2}\right)$:

$$\psi = A_{do} \sin(q_{mo} x) \sin\left(\frac{n\pi y}{a}\right) e^{-jk_{zo} z}$$

So, again d stands for dielectric, o stands for odd, we have now the sin variation.

Because we are dealing with the odd mode, therefore it is a odd variation with respect to x inside the dielectric region, this stays as it is, it satisfies the fact that the tangential electric field has to vanish on the two ground planes and then we have this $k_{zo}z$, standing for the fact that it is a propagation constant along the z direction for the odd mode.

So, this ends the nomenclature in the dielectric region. In the air region,

In the air region $\left(|x| \geq \frac{b}{2}\right)$:

$$\psi = A_{ao} \exp\left[-p_{mo}\left(|x| - \frac{b}{2}\right)\right]$$

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In the air region ($|x| \ge \frac{b}{2}$):

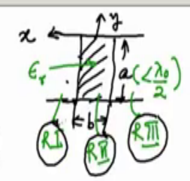
$$\psi = A_{ao} \exp\left[-p_{mo}\left(|x| - \frac{b}{2}\right)\right] \sin\left(\frac{n\pi y}{a}\right) e^{-jk_{zo} z}$$

(for $x \ge \frac{b}{2}$)

$$= -A_{ao} \exp\left[-p_{mo}\left(|x| - \frac{b}{2}\right)\right] \sin\left(\frac{n\pi y}{a}\right) e^{-jk_{zo} z}$$

(for $x \le -\frac{b}{2}$)

LSM even modes:

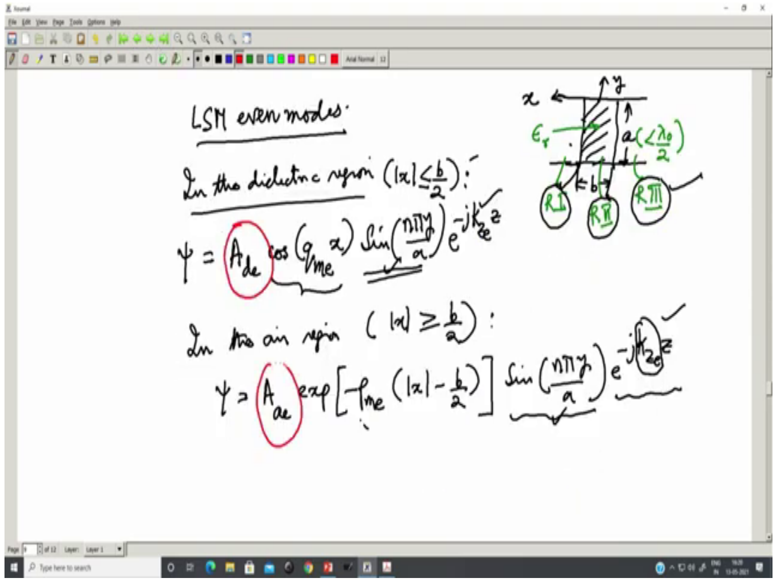


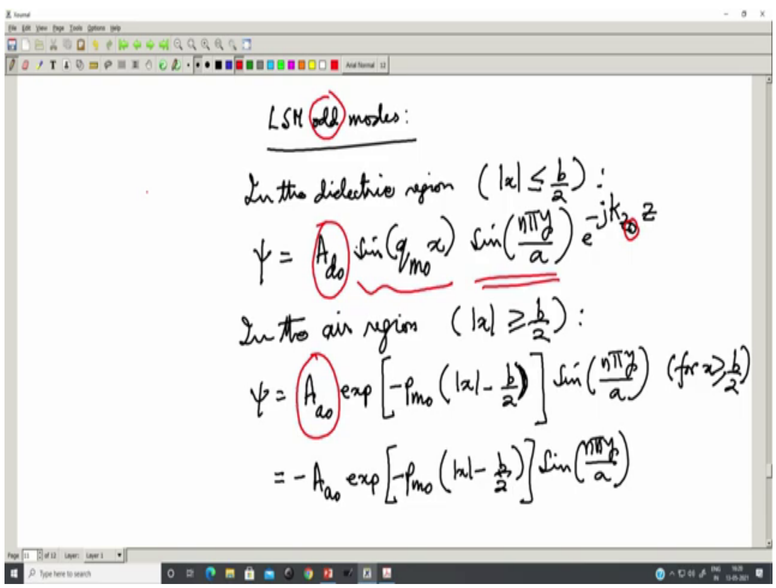
In the dielectric region ($|x| \le \frac{b}{2}$):

$$\psi = A_{de} \cos(q_{me} x) \sin\left(\frac{n\pi y}{a}\right) e^{-jk_{ze} z}$$

In the air region ($|x| \ge \frac{b}{2}$):

$$\psi = A_{ae} \exp\left[-p_{me}\left(|x| - \frac{b}{2}\right)\right] \sin\left(\frac{n\pi y}{a}\right) e^{-jk_{ze} z}$$





So, we have the two forms of the potential function for mod x, we have the two forms of the potential function for x greater than or equal to b/2 and x less than or equal to minus b/2.

So, this is necessary in order to match the fields for the odd mode, the match the fields for the odd mode on the region 1, and on the region 3, the air dielectric interface on the region 1 and the air dielectric interface on region 3 and to describe the variation of the fields in the region 1 and region 3, for the odd mode.

So, this you can clearly see by after writing the expressions for the electric and magnetic fields for the odd mode, as why this has to be expressed in two different ways for the odd mode and in one concise form for the even mode. So, in the above q m e, so in the above, or in the above expressions q_{me}, p_{me}, q_{mo}, p_{mo}, are the Eigen values of the characteristic equation for the LSM even and odd modes.

We already said that, the subscript e refers to the even mode and the subscript o refers to the odd mode. So, this subscript o, it refers to the odd mode, also present in the propagation constant kz, the these all these terms, which are present here, all these terms, which are present here A_{de}, A_{ae}, A_{do}, A_{ao}, they refer to the amplitude terms of the potential functions. So, let us stop here for this, and we will continue from here.