Advanced Microwave Guided-Structure and Analysis
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Lecture – 52
Analysis of Guided Structures (cont.)

Welcome to the lecture on continuation of analysis of guided structures. Now, in this session we are going to investigate the non-radiating dielectric guides the propagation characteristics and the modes in such kinds of guides.

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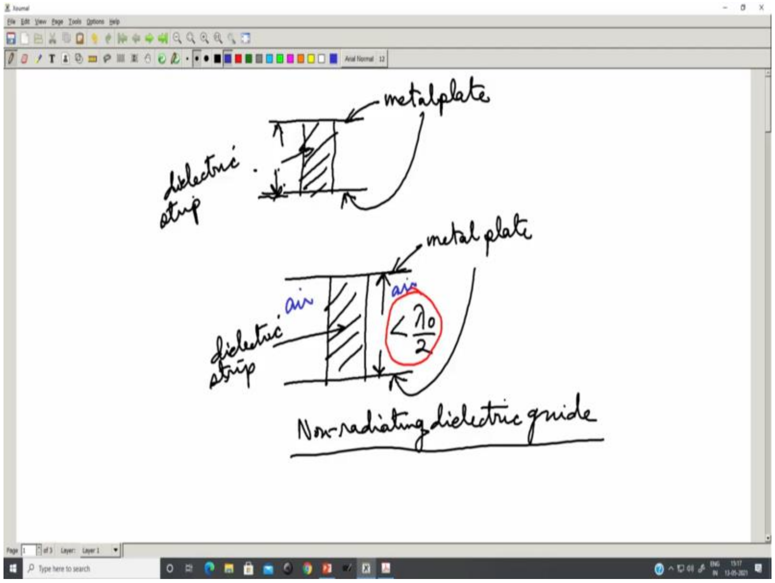

So, typically the non-radiating dielectric guide is two parallel metal plates; so, this is a metal plate. And so is this a metal plate; so, two metal plates within which a dielectric strip is inserted. So, this is a modification of the h guide, in which the distance between the two ground planes or the two metal plates is less than $\lambda_0/2$; so, this distance is less than $\lambda_0/2$.

So, the non-radiating dielectric guide is typically two metal plates also called ground planes. So, this is a metal plate and so is this a metal plate; and within the two metal plates there is a dielectric strip, so this is a dielectric strip. And the distance between the two metal plates is constrained to be less than $\lambda_0/2$.

So, this is principally the difference between the non-radiating dielectric guide and the traditional h guide; so, this is the configuration of the non-radiating dielectric guide. So, this constraint that the distance between the metal plates is less than $\lambda_0/2$, is what distinguishes the non-radiating dielectric guide. This constraint is what distinguishes the non-radiating dielectric guide from the h guide.

The non-radiating dielectric guide is also characterized by very low loss properties up to even 94 gigahertz. So, the waves in the air region are evanescent in nature. So, let us investigate, therefore, the characteristics and the modal characteristics of such guides which enable it to be low loss propagating medium.

So, the electromagnetic fields and propagation characteristics in the NRD can be completely described by using two sets of modes. So, let me draw the NRD guide once again.

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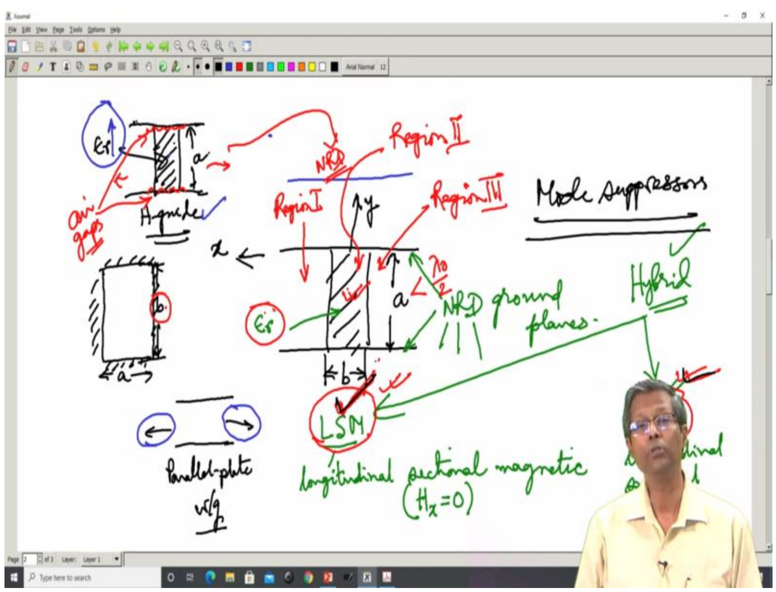

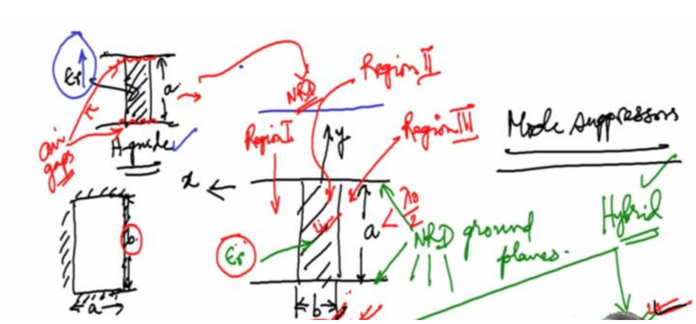

So, this N stands for non-radiating dielectric; so in short we call this NRD. So, then the modes in the NRD are either LSM; LSM stands for longitudinal section or sectional magnetic. This mode is characterized by the absence of the magnetic field along the x direction. So, therefore the normal component of the magnetic field, which is normal to the dielectric strip is 0. In other words, the magnetic field is totally tangential to the dielectric air interface; therefore we can say that the magnetic field is totally confined or contained in the yz-plane.

Such a magnetic field is called longitudinal sectional magnetic; because it is along the longitudinal section of the NRD. And the other kind of modes is the longitudinal sectional electric, which is characterized by the fact that Ex again the normal component of the electric field on the dielectric air interface, which is Ex is 0.

So therefore, for the LSM modes the electric field is totally contained in the yz plane; or it is totally contained in the on the surface of the dielectric, with no normal component of the electric field along the x direction. So, you now see that both the LSM and the LSE modes have the uz component. So, that means LSM mode has z-component of the electric field and the magnetic field; and the LSE mode has a z-component of the electric field and the magnetic field.

So, therefore, because the presence of the both components of the electric and magnetic field along the z direction; such modes are also referred to as hybrid modes. This can be distinguished from the rectangular waveguide, where we either have the z-component of the electric field to be zero; or the z-component of the magnetic field to be zero. The TE to z or the TM to z modes, so this distinguishes the non-radiating dielectric waveguide from the rectangular waveguide.

Because there are there are four metallic walls of the rectangular waveguide; such kinds of guides have or encounter high amount of loss; particularly at the millimeter wave frequencies or beyond. So, in order to combat such kind of loss, we have tried to eliminate two of the walls of the rectangular waveguide. And hence we came to this kind of an open guided wave structure.

But, if we just eliminate the two walls of the rectangular waveguide, we come to a parallel waveguide; we just straight away eliminate the two walls of the waveguide. So, in the parallel plate waveguide, the radiation loss from these two ends would be significant. And so also would be the condition with the H-guide; so this is the parallel plate waveguide.

And if we also compare this with the H-guide, where this is the dielectric strip again with; so this is ε_r with this distance a; there is no constraint on this distance a. So, under such a condition also what essentially happens is that we attempt, we have attempted in the H-guide. You look it is in the shape of an inverted H; that is why it is called an H-guide. So, in this case we have attempted to confine the electromagnetic field inside the dielectric strip.

So, if I increase the permittivity; the more the permittivity the idea is the more confined will be the modes inside the dielectric strip. And the radiation loss which is present in the parallel plate waveguide can be counteracted, or can be reduced. That was the philosophy of the development of the H-guide, so to combat essentially the radiation loss from two sides of the parallel plate waveguide by inserting a dielectric strip.

And therefore, the higher the permittivity of the dielectric strip, the more the mode confinement inside the strip. But, there are a number of problems to the H-guide, that is one problem is that we are dependent on increasing the permittivity of the dielectric strip, in order to counteract the radiation loss from the two sides. So, increasing permittivity of the dielectric strip, entails a number of problems.

First of all, that high permittivity dielectric strips are brittle; so for mil grade or space grade applications, where the circuit components are subjected to violent g forces in many cases. So, and violent like harsh environments, so the H-guide may not be like it may not be suitable; because the high permittivity strips are brittle. Secondly, the when you want to stick the high permittivity dielectric strip to a metallic on a metallic surface there are invisible air gaps, so these are air gaps. We need to be careful of such a case, because we are dealing with in many cases millimeter wave propagation. Such air gaps are not visible to the naked eye; but they are there and they will interfere, they are also here. So, these are the air gaps, they are also here; and they will alter the model characteristics of the H-guide.

So, these some of these reasons actually prevented the development the future development of the H-guide. In addition to the fact that the radiation loss from the two sides of the H-guide were still not acceptable. So, in order to develop an improved version of the H-guide we came to the NRD guide, in which the only constraint or the only difference with the H-guide was this distance a being less than $\lambda_0/2$.

Because this distance a is less than $\lambda_0/2$; so this region offers a cut-off. So, this is a cut-off region for the wave; and therefore, the waves in this region are evanescent. So, because no electromagnetic wave can travel, if the distance between the two metallic plates is less than $\lambda_0/2$. We need a minimum distance of $\lambda_0/2$for the electromagnetic wave to travel; we need this as minimum $\lambda_0/2$.

So, therefore, when we are offering a below cut-off operation in the air region, the waves in this region the waves in region one and region three becomes evanescent. And then we are not dependent on the permittivity or increasing the permittivity of the dielectric strip to a very high value, in order to counteract the radiation from the two sides of the NRD guide.

So, this principally distinguishes the NRD guide from the H-guide that even like a moderate value of this ε_r. A moderate value of the permittivity of the dielectric strip would actually result in a low loss guided structure, way up to 94 gigahertz and even beyond. But, we have to contend with more complex modes, like the LSM and the LSE modes of the guide; which we said as hybrid in the sense that they are they possess both the z-component of the electric and the magnetic field.

Unlike the rectangular waveguide, so, more complex guided structure. In addition, we will we are going to come to this situation that the LSM mode is more preferred for NRD mode operation; because of its lower loss compared to the LSE mode. However, the LSE mode has a lower cut-off than the LSM mode; we are going to come to these aspects. So, therefore, this complicates matters for the NRD; because we have to use a mode which is the LSM, which has a higher cut-off than the LSE.

We did not do that for the rectangular waveguide the TE_{01} mode which we used is the dominant mode; and it is it has the lowest cut-off, and we are using that mode. So therefore, there is no question of using components like mode suppressors. But, the question of such components arises, because the LSE mode is the dominant; or the principle LSE_{00} mode is the dominant mode compared to the often used LSM_{01} mode, which is the higher order mode.

But, we are constrained to use the LSM_{01} mode which is the higher order mode; because it is less lossy than the LSE_{00} mode. And like if the characteristics or the design demands that the LSE_{00} mode is has been appreciably excited; because it is dominant mode. So, it has that propensity or it is the tendency to be excited at curvatures or discontinuities. So, if the excitation of the LSE_{00} mode is appreciable, then it has to be suppressed.

And such kind of suppression has to be done by components called mode suppressors. So, the mode suppressor would essentially stop the LSE mode, and enable the propagation of the LSM mode. So, let us now review the characteristics go in a little bit more details on the features of the NRD guide. So, as we said for the first set of modes, the magnetic field is entirely parallel to the air dielectric interface.

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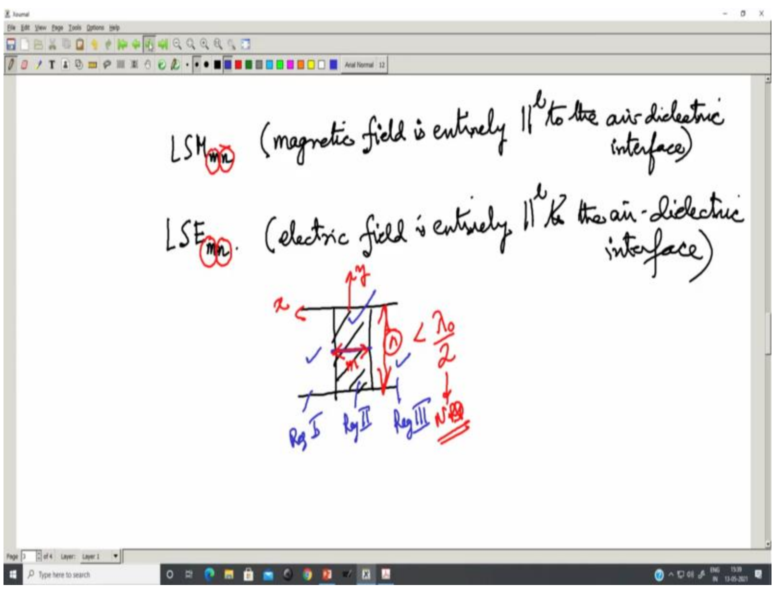

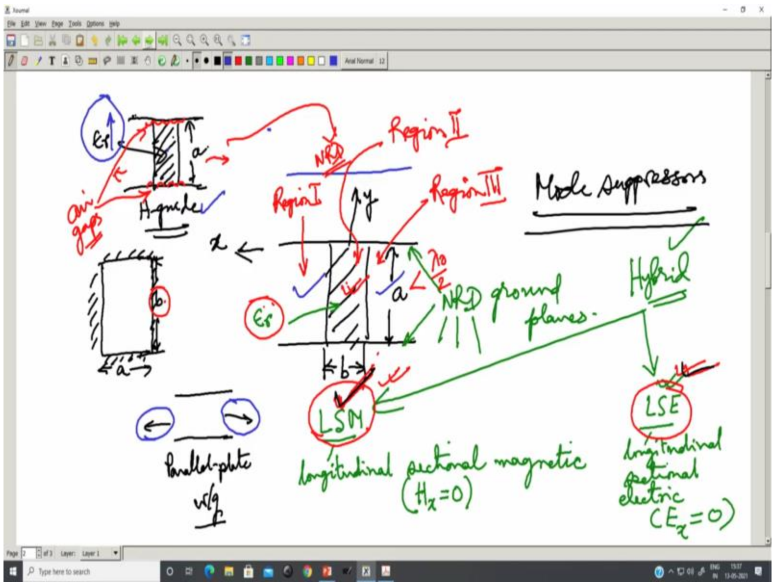

And that is known as the LSM_{mn} mode, as we said longitudinal sectional magnetic. Similarly, for the second, the electric field completely lies in a plane parallel to the air dielectric interface; and that is called the LSE_{mn} mode. We are going to come to what the mn denotes; so that is the longitudinal sectional electric. So, here the magnetic field is entirely parallel to the air dielectric interface; and here the electric field is entirely parallel to the air dielectric interface.

The subscript m, so this subscript describes the transverse variation of fields inside the dielectric strip. So, that means that this is the wave number which describes the variation of the fields inside this strip. So, as we marked this one was my y, so this was my x; so this describes the transverse variation of the fields along the x direction inside the strip.

This can be either of the co-sinusoidal or the sinusoidal type. So, inside this strip, the fields can vary either it can the variation can be even or co sinusoidal type, or odd which is the sinusoidal type. For both the LSM and the LSE modes, the corresponding potential functions can possess either co-sinusoidal variation or a sinusoidal variation inside the dielectric region.

So, here the potential function can have either co-sinusoidal or a sinusoidal distribution; and therefore it can have even or odd symmetry about the center. So, for the co-sinusoidal variation, it will be even mode; and for the sinusoidal variation as we said it will be the odd mode; so, LSM even or LSM odd, or LSE even or LSE odd. So, the other subscript n, which is this subscript describes the variation of the standing wave pattern between the ground planes of the NRD.

So, it describes the variation of the fields in this direction; so, m is along this direction, m is along that direction, so let us put it like that. So, that describes the modal numbers or the Eigen numbers m and n, for both the LSM and LSE modes. So, therefore we also discuss that the modes in the NRD poses both the electric and magnetic field components, along the longitudinal propagation direction; and therefore, they are hybrid in nature.

However, one should note that the TM mode propagation is not possible in the NRD, as in the parallel plate guide; because of the presence of the dielectric strip. So, the TM mode propagation is not a possibility in the NRD guide; so there is no TM mode propagation in the NRD guide. We have also discussed and it is important to appreciate that the essential difference between an NRD and an H-guide; the H-Guide which suffers from considerable leakage and radiation loss.

It is, is the restriction in the distance between the ground planes to less than half of free space wavelength in the NRD. So, in the NRD this distance between the ground planes, is less than $\lambda_0/2$ for the NRD; whereas no such restriction happens or is there in the H-guide. This essentially distinguishes the H-guide from the NRD.

So, as such, we have also seen that the fields in the air region in the NRD, which are region one and region three if you go back to the figure. In these two regions in the air regions, this region and this region; they are below cutoff and are evanescent in nature. So, the fields in these two regions are below cutoff, and they are evanescent in nature; so region one, region two, region three. So, fields in region one and region three, are evanescent and below cutoff.

However, the presence of the dielectric in region two removes the cutoff condition between the ground planes; and causes the EM waves to propagate down the structure essentially confined within the dielectric strip. So, the presence of the dielectric will remove the cutoff condition, and enable the waves to propagate inside the dielectric strip.

Because of this leakage and radiation losses at curve sections or discontinuities are almost non-existent in the NRD. This is a very important point to note is a very important point to note that this is what; this is the principal cause of the low loss and low leakage properties of the NRD. Also, the electric field profile of the LSM_{01} mode, which is commonly used as the principle wave guiding mode in most applications, is essentially parallel to the ground planes. So, if we note the, if we note the LSM_{01} mode.

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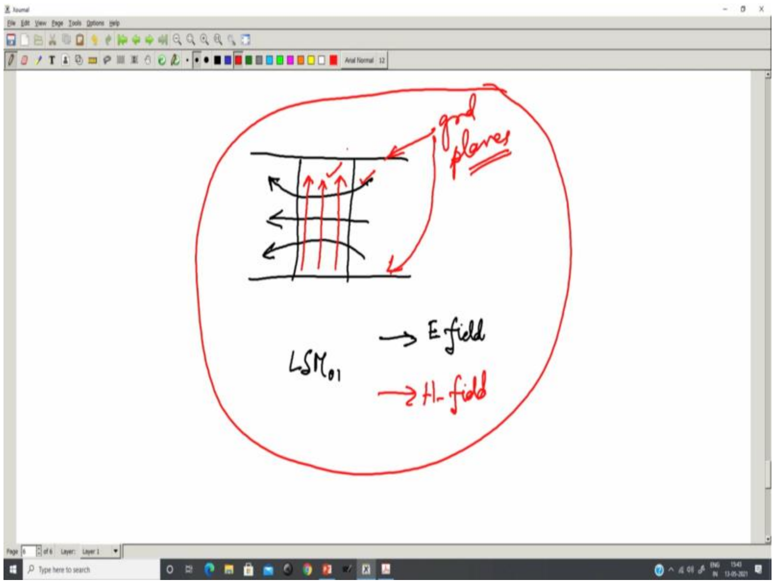

Essentially, you have this. Essentially, if we have this kind of a structure; so, the field properties of the LSM_{01} mode can be drawn as shown in fig. So, essentially because the electric field is tangential to the ground plane, these are the two ground planes.

Because the electric field is tangential to the ground plane, it is in this direction; so therefore, the transmission loss of the guide is reduced. Essentially, because you see that the magnetic field is normal to the ground plane. So essentially, there is no current induced on the ground plane due to the magnetic field, which reduces the transmission loss of the energy.

So, this property is very important that this decreases, the fact of the electric field profile of the LSM-01 mode, being the most popular mode. In most NRD applications being parallel to the ground planes, decreases the transmission loss of the guide significantly; and makes it an extremely low loss wave guiding medium at millimeter wave frequencies.

So, this has to be understood from the perspective of the field profile; the field profile, the low loss characteristics of LSM_{01} mode has to be understood from the field profile of the LSM_{01} mode. These facts, coupled with the fact that the NRD based discontinuities are purely reactive due to their non radiative nature; presence of unique and sought after advantages in millimeter wave component design.

Because there is no radiation; so the NRD based discontinuities are purely reactive; and therefore, these, this presents. You know like this is a very desirable characteristics in the millimeter wave component design. So let us stop here; we are going to continue from here.