Advanced Microwave Guided-Structures and Analysis
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Lecture 68
Application to the Coupling Problem: Aperture-Coupled, Probe-Coupled and Waveguide Coupled Structures (Contd.)

So welcome to this lecture session on the coupling problem and the illustration and application of the coupling problem to the dielectric resonator antenna. Let us go to the slides and discuss the probe coupled dielectric resonator antenna configuration.

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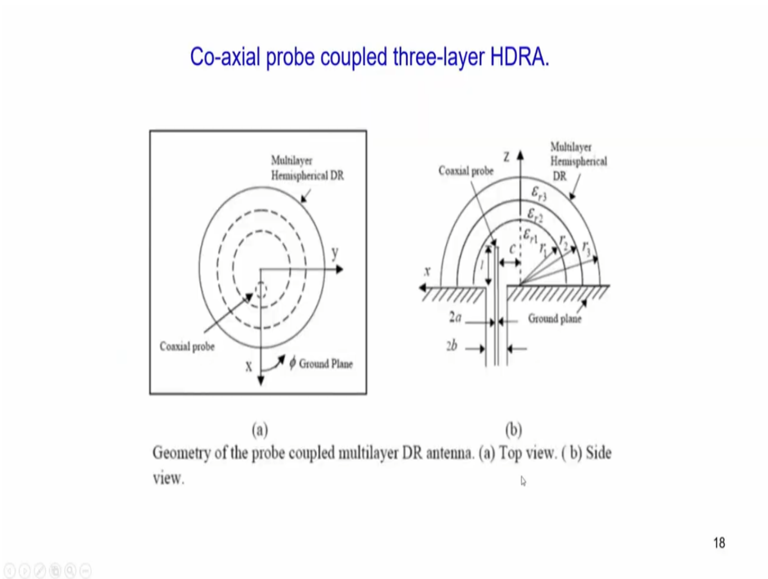

This is the configuration of the probe coupled dielectric resonator antenna. You see there is a three layer dielectric resonant antenna with a probe in the first layer. The outer conductor of the probe is shorted to the ground plane and the inner conductor protrudes up to the dielectric resonator antenna and feeds the antenna. This is the footprint of the antenna on the ground plane and this is the location of the coaxial probe.

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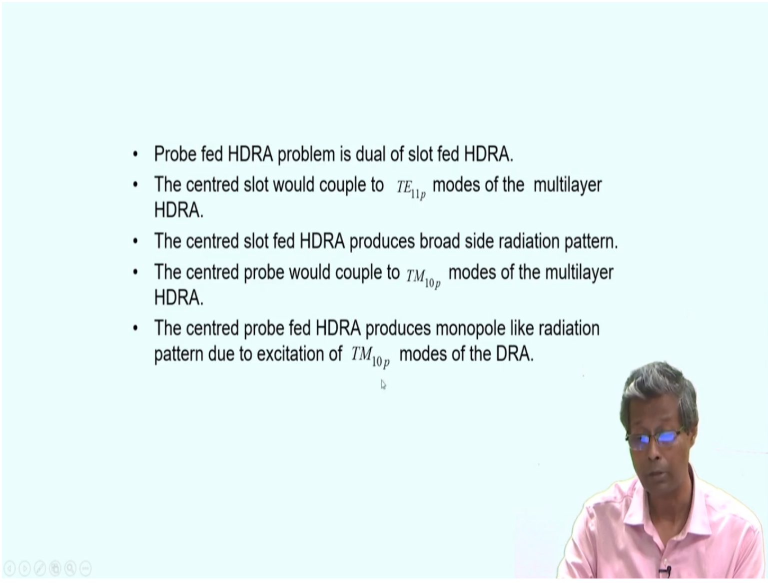

So, the probe fed HDRA problem is dual to the slot fed HDRA problem. Since they would excite different modes. You see, the center slot would couple to the TE11p modes of the multi-layer HDRA. We have seen that in our case it was TE111 and TE112. And the centered slot fed HDRA reproduces broadside radiation pattern, because TE11p modes produce broadside radiation pattern.

The centered probe on the other hand would couple to TM10p modes of the multi-layer HDRA. And the centered probe fed HDRA produces monopole like radiation pattern, in contrast to the broadside radiation pattern characteristics of the aperture coupled slot, in contrast to the broad side pattern generated by the slot coupled HDRA.

And the monopole like pattern is due to the excitation of TM10p modes of the HDRA with the coaxial probe. So, the slot essentially couples to TE11p generating broadside pattern. The probe couples essentially to TM10p modes generating end fire pattern or generating monopole like pattern.

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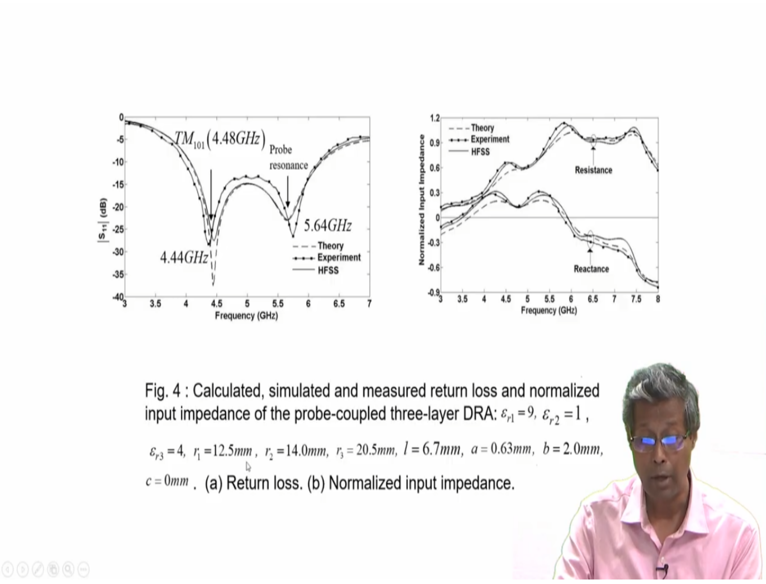

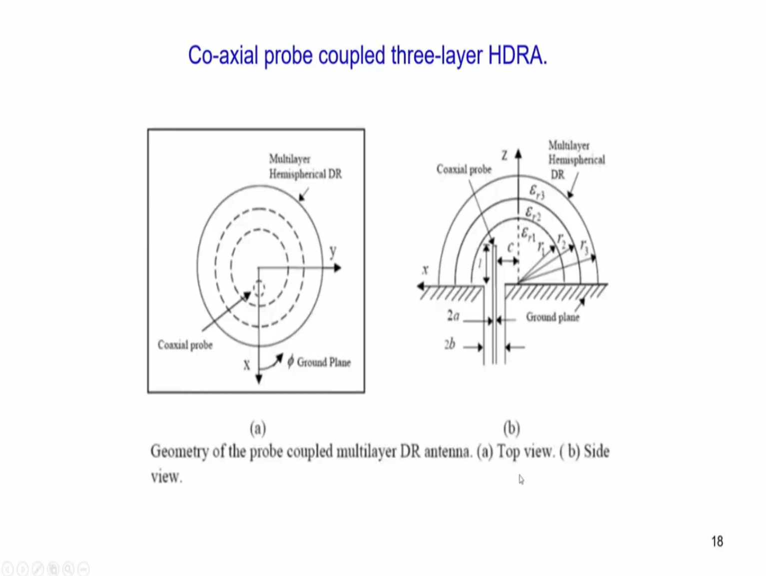

So, you see that this is the coupling characteristics or the reflection coefficient characteristics of the probe coupled three layer HDRA with ε_{r1} 9 the second layer permittivity 1, the third layer permittivity 4. r1 as 12.5 millimeter; r2 as 14 millimeter; r3 as 20.5 millimeter. l, the length of the probe, here is l the length of the probe.

C the probe displacement. l as 6.7 millimeter C as 0 millimeter. And a and b, a is the radius of the inner conductor of the probe and b is the radius of the outer probe conductor. So, a is 0.63 mm and b is 2 mm. So, we see that there are two essential dips, the first dip is contributed by the TM101 mode, the second dip by the probe resonance.

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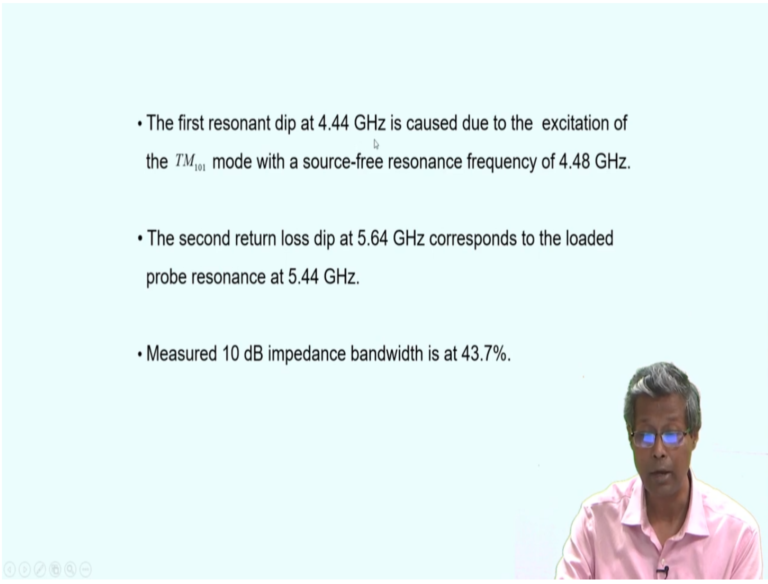

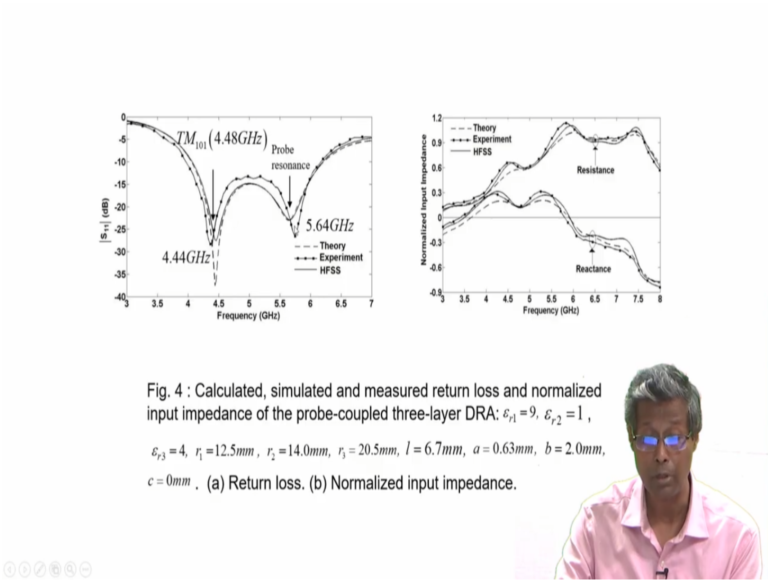

So, the first resonance dip at 4.44 gigahertz is caused by the excitation of the TM101 mode with a source free resonance frequency of 4.48 gigahertz. So, you see this is at 4.44 gigahertz. The second return loss dip at 5.64 gigahertz corresponds to the loaded probe resonance at 5.44 gigahertz. So, this is at 5.64 gigahertz, which is contributed by the probe resonance.

So, the merger between the 2 results in a wide impedance bandwidth. The measured 10 dB impedance bandwidth is at 43.7 percent. So, which is actually larger than the case of the slot, where we got around 30 percent impedance bandwidth, with the centered slot and this is the case of the centered probe, as we said C is equal to 0.

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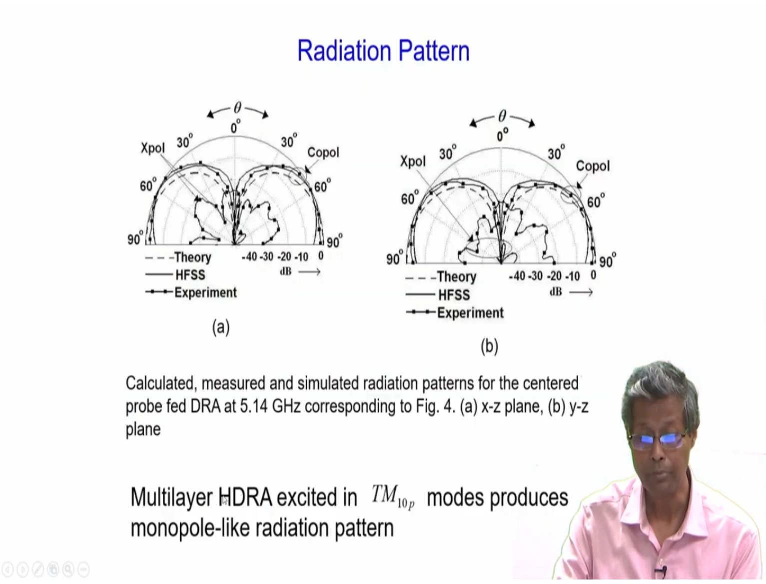

So, these are the radiation characteristics in the XZ plane and the YZ plane. So, you see the null at the center. So, this is the typical feature of the TM10p mode. So, the multi-layer HDRA excited in the TM10p mode produces monopole like radiation pattern. We call this pattern monopole like because this is the same pattern produced by a monopole antenna. So, we call this a monopole like pattern, so also called an end fire pattern, because the radiation is along the horizon and we have a null at the center at theta equal to 0.

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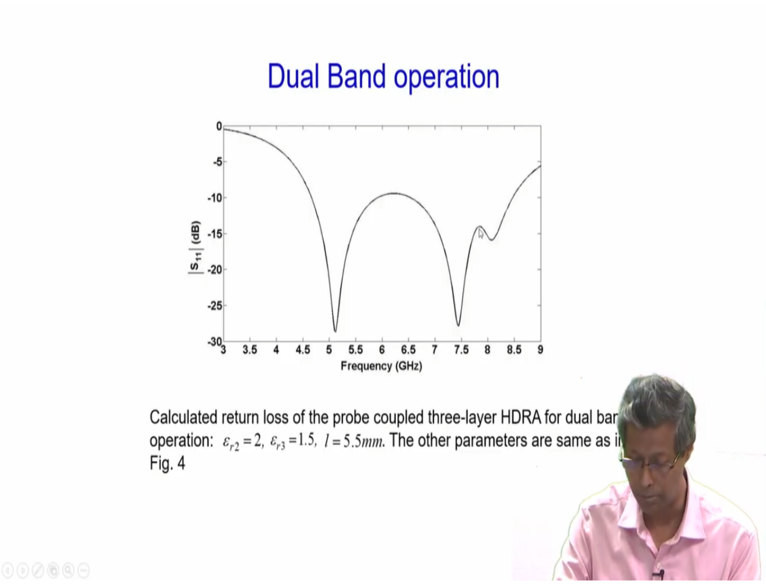

So, we exemplify our dual band operation with this. Though this result is kind of a bit theoretical, so we took epsilon r2 2 and epsilon r3 as 1.5, which is you know, not a very closer to practical values. But we just, you know like, show kind of theoretically that yes, oh okay; we can tailor the permittivities and the tune the probe length to achieve dual band operation. And I am sure that if we tinker with the parameters of the coaxial probe, we will be able to arrive at dual band antenna characteristics, you can try them.

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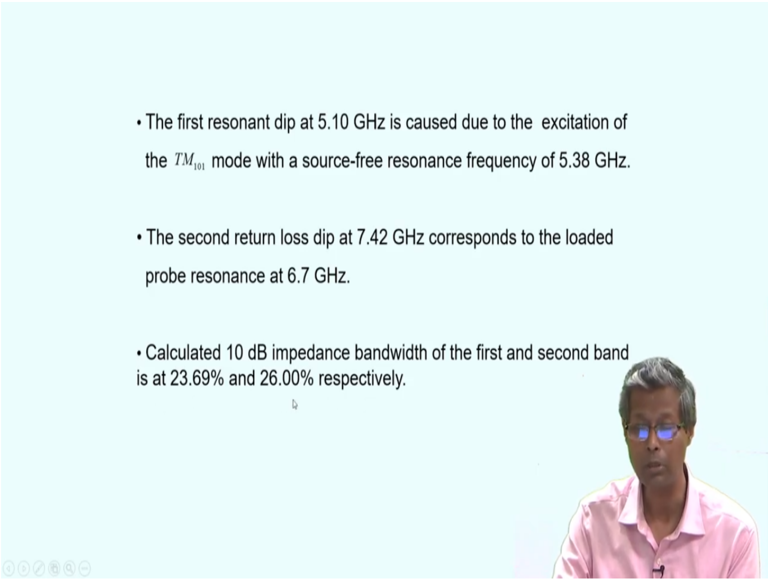

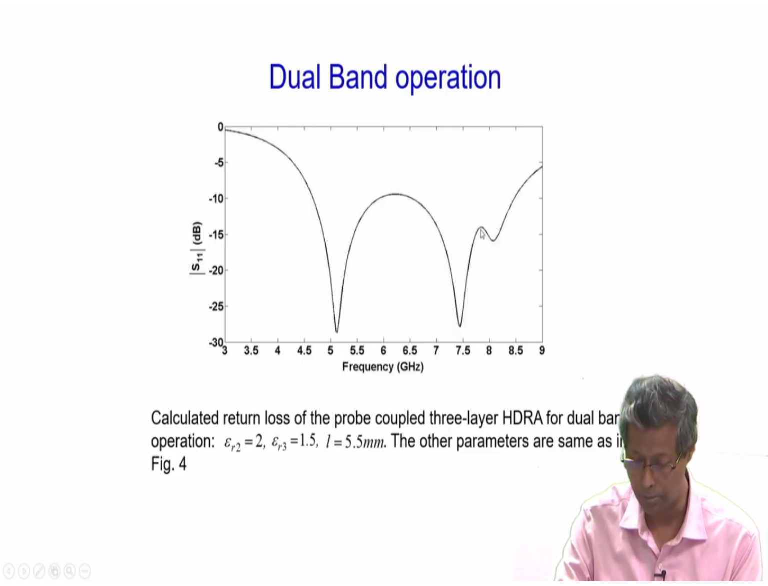

So, the first resonance dip is at 5.10 gigahertz, is caused due to the excitation of the TM101 mode, with the source free resonance frequency of 5.38 gigahertz. So, this is at 5.10

gigahertz. It is due to the excitation of the TM101 mode. And the second return loss dip corresponds to the loaded probe resonance at 7.42 gigahertz. And the corresponding source free probe resonances at 6.7 gigahertz.

So, this is the probe resonance at around 7.5 GHz and the calculated 10 dB impedance bandwidth of the first and second band are 23.69 and 26 percent. The calculated 10 dB impedance bandwidth of the first and second band is at 23.69 and 26 percent respectively. So, we have relatively wideband at both the resonances.

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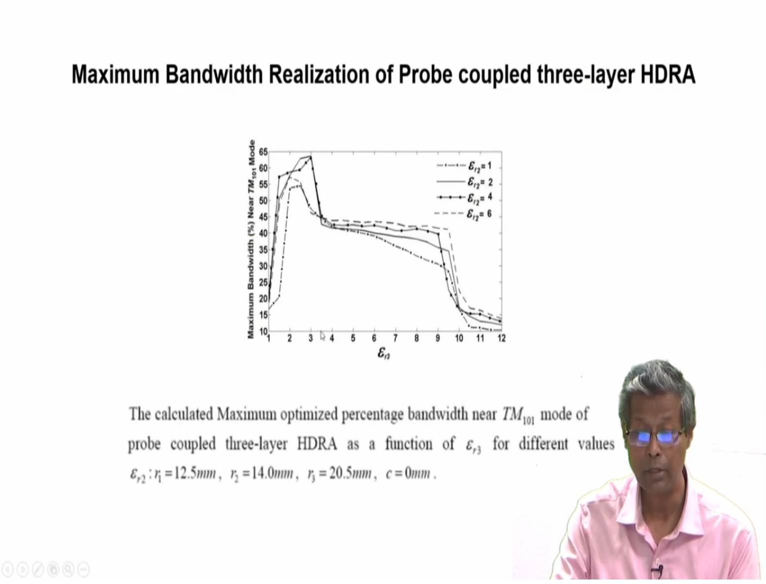

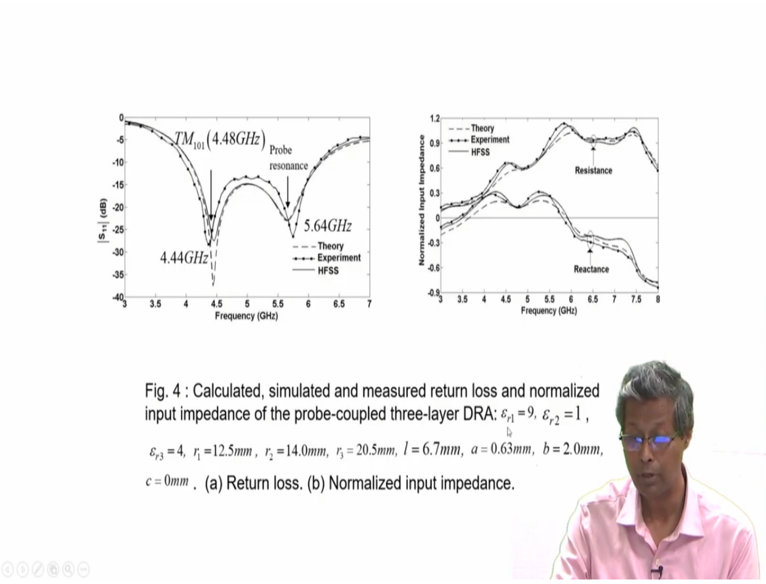

This is the curve for the maximum bandwidth realization for the probe coupled HDRA. So, here we have r1 12.5 millimeter and r2 14 millimeter, r3 as 20.5 millimeter, centered probe and we show epsilon r1 equal to 9, as we chose in this figure, as we chose in this figure epsilon r1 equal to 9. So, we see that the maximum bandwidth of about 63 percent or so is achieved at epsilon r2 equal to 4 and epsilon r3 equal to 3. So, 9 4 3 would be a kind of optimum value for realizing the maximum bandwidth, out of this structure, which is around 62 percent.

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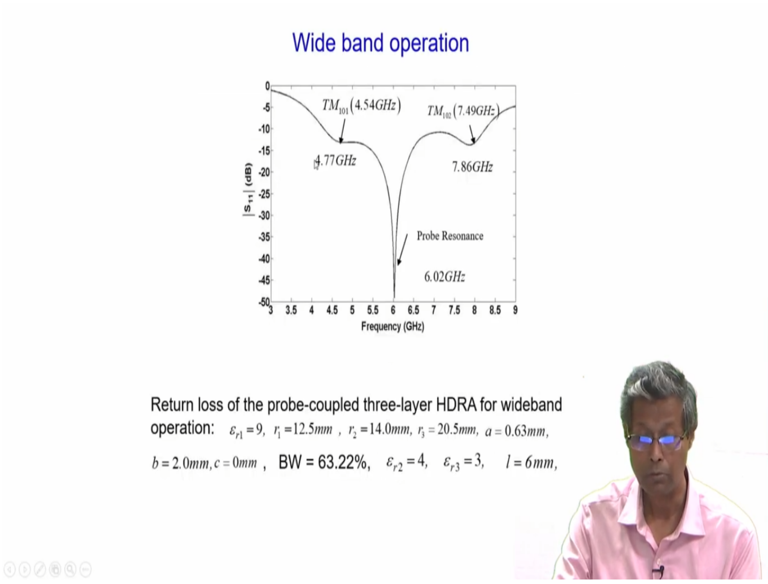

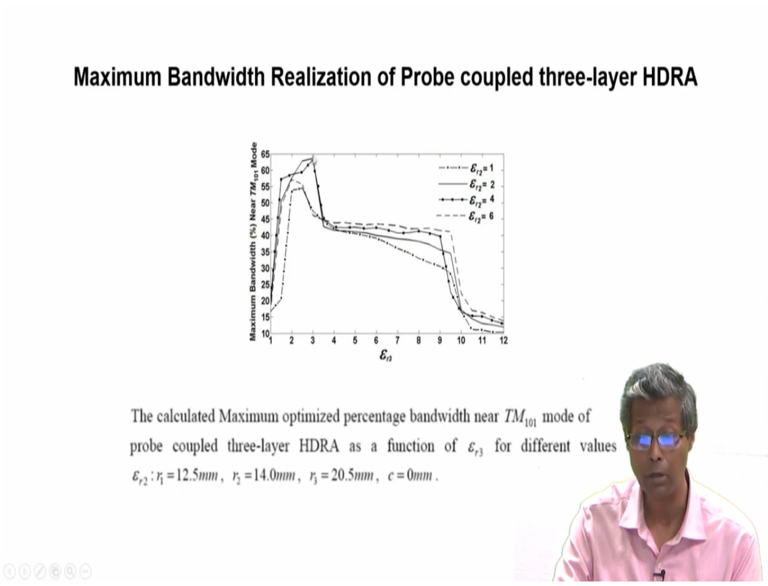

So, we next show that so epsilon r1 9 and epsilon r2 4 epsilon r3 3. So, 9 4 3 combination as is obtained from this figure, the peak of this, this bandwidth curve. So, r1 12.5 millimeter r2 14 millimeter and r3 20.5 millimeter, a as 0.63 millimeter, the inner coaxial probe, inner conductor radius, and the coaxial probe outer conductor radius at 2 millimeter and the centered concept of the design of the centered probe. So, we obtain a bandwidth of 63.22 percent, very close to what is here. And the length of the probe should be optimized to obtain the maximum bandwidth.

So, you see the first dip is contributed by the TM101 mode. The third dip is contributed by the TM102 mode. Again, you see that the value of p is different. So, that we have a shift in resonant frequencies, but the field distribution do not change, from here to here. And here is the probe resonance. So, they all contribute, so they all contribute to have a wide impedance bandwidth of 63.22 percent. So, this ends our part with the probe excitation or probe coupled structures.

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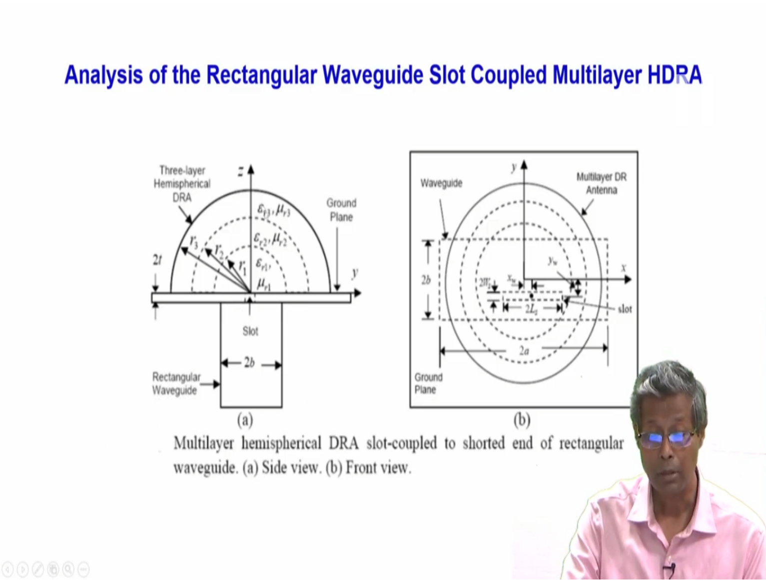

Next, we go to the waveguide couple structure. The rectangular waveguide coupled to the dielectric multi-layer dielectric resonator antenna. So, typically, the rectangular waveguide has been used to couple to the dielectric resonant antenna previously including the case of a single layer dielectric with a focusing DRA and dielectric resonator, which is coupled to the rectangular waveguide through, you know like, up to a drilled in probe like this.

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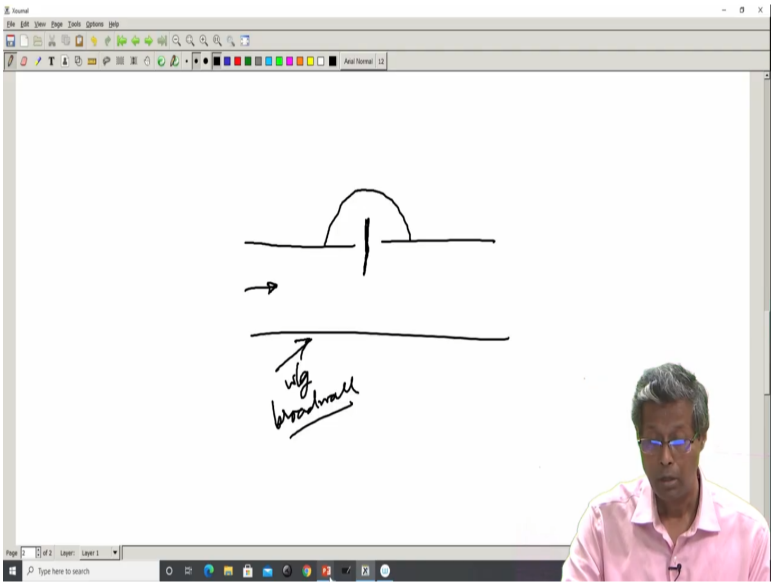

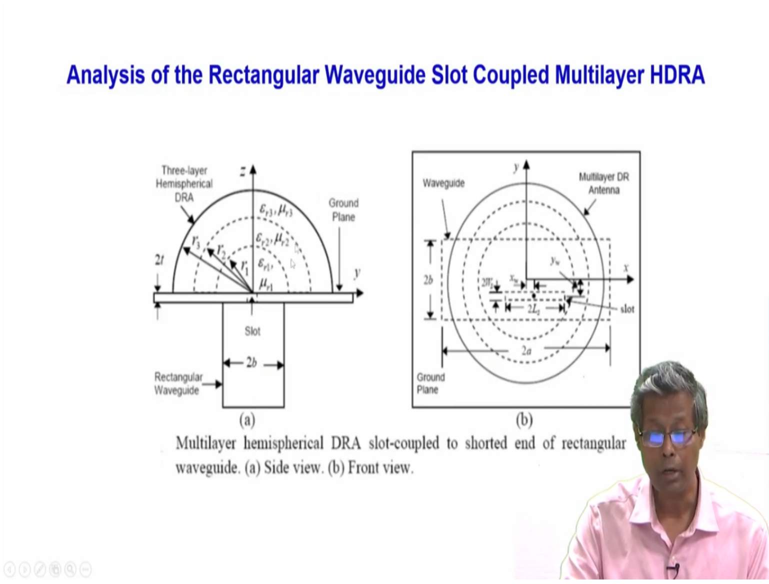

So, it is kind of, this is the waveguide. And this is the broad wall of the waveguide. This is excitation, waveguide excitation. So, this is my waveguide broad wall. So, if I have a DRA here. So, there was a drill, a probe which is drilled through the DRA and insert inside the waveguide, which is an invasive procedure, because we are drilling inside the DRA, like in a probe couple structure we discussed before.

So, in order to avoid that we propose an alternate mechanism. Now the reason the waveguide is a difficult structure to couple with the DRA is because it is a non TM structure and it is a closed environment, you see, it is a totally closed environment, which we use for reduced interference feeds. Because if you have a waveguide which is placed nearby, this waveguide does not couple to this waveguide, because it is a totally closed environment and also as a high power feed.

So, we have in this case three layers of DRA and the three DRA layers or the multi-layer DRA configuration is used to offer both an impedance match, because these layers work as an impedance transformer, matching the free space impedance to the slot impedance. Because it is a difficult matching environment, so we have to use the impedance transformer mechanism of the multi-layer DRA.

As well as the multi-layer DRA enables us to get a broadband characteristic by coupling with multiple DRA modes or the DRA mode with the slot resonance. So, what was initially a difficult structure to excite and we needed more complex schemes like a focusing DRA or a drilling probe. This is one of the architectures, which enables a match as well as simultaneously a relatively broader impedance bandwidth. So, this was our fabricated structure.

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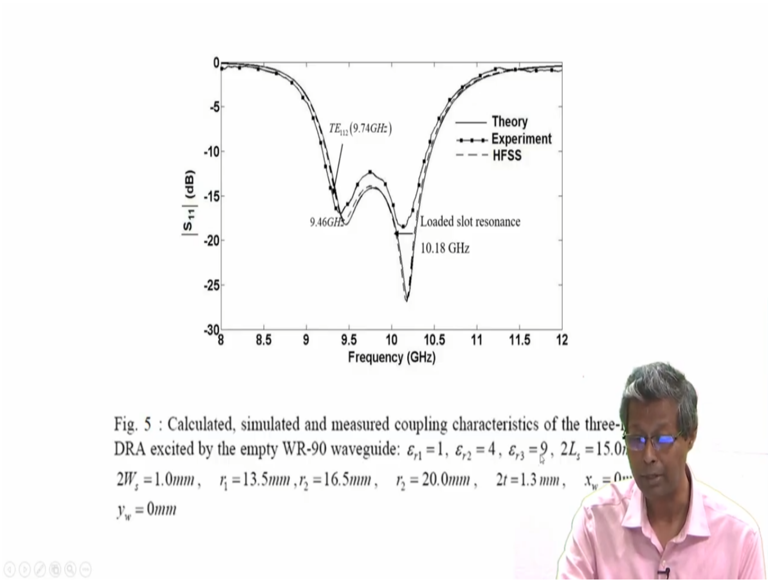

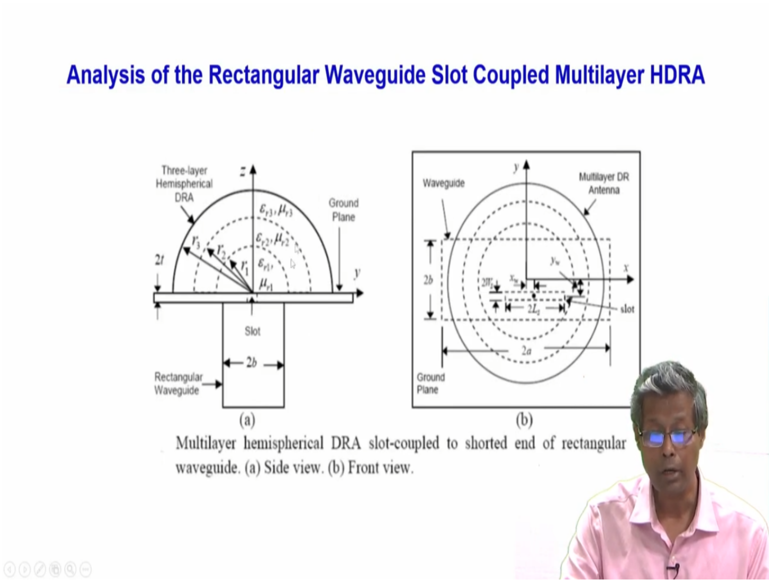

And this is the reflection coefficient characteristics. So, this is the first resonance, which is contributed by the TE112 mode of the DRA. And the second resonance which is contributed by the loaded slot resonance. So, we have the first layer 1 permittivity. The first DRA layer of 1 permittivity. The first DRA layer for the waveguide configuration has always to match with the waveguide permittivity.

So, because the wave-guide permittivity is 1, the material inside the waveguide has a permittivity of 1. Therefore, the first layer of the DRA is also chosen to have a permittivity of 1. The second layer of permittivity 4 and the third layer of permittivity 9. The slot length is 2 ls, if you see here the slot length is 2 ls the slot width is 2 ws. So, 2 ls is 15 millimeter, the slot length 2 ws, the slot width is 1 millimeter, r1 is 13.5 millimeter, r2 is 16.5 millimeter, r3 is 20 millimeter, 2t is the thickness of the ground plane. It is the thickness of the ground plane. So, 2t is 1.3 millimeter and it is a centered slot.

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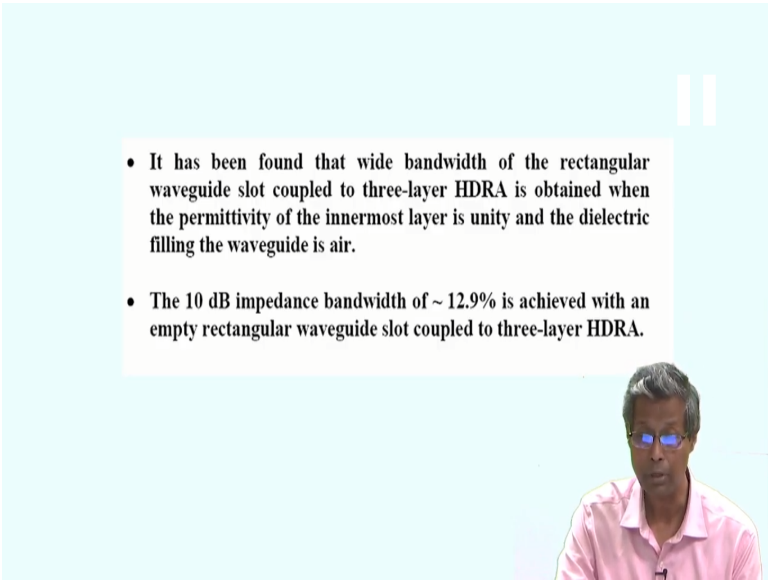

So, we see that a wide bandwidth of the rectangular wave-guide slot coupled to the three layer DRA is obtained when the permittivity of the innermost layer is unity and the dielectric filling the waveguide is air. We already discussed that. And the 10 dB impedance bandwidth of 12.9 percent is achieved with an empty rectangular waveguide slot coupled to the three layer HDRA. So, where the coupling itself is a problem where getting an impedance match itself is difficult. We achieve a bandwidth which is a modulus bandwidth of 12.9 percent, which is not too bad for the waveguide coupled DRA.

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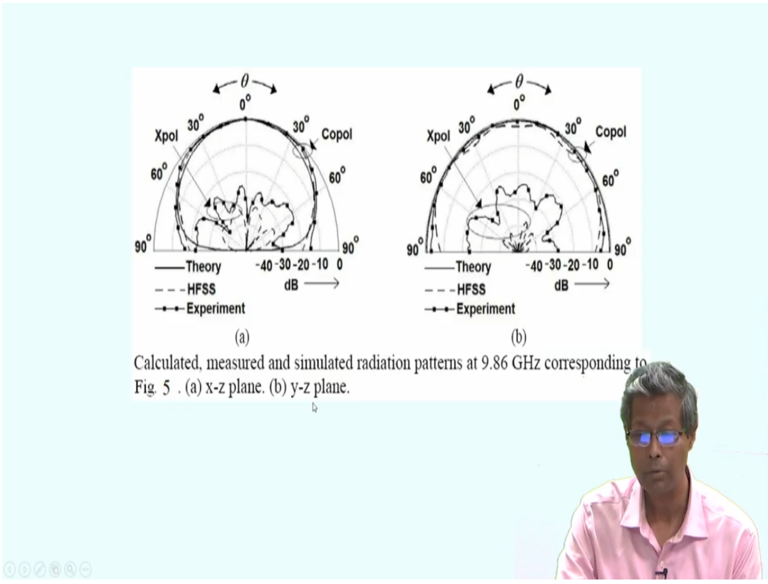

This shows the broadside radiation characteristics of the antenna structure in the XZ plane and YZ plane.

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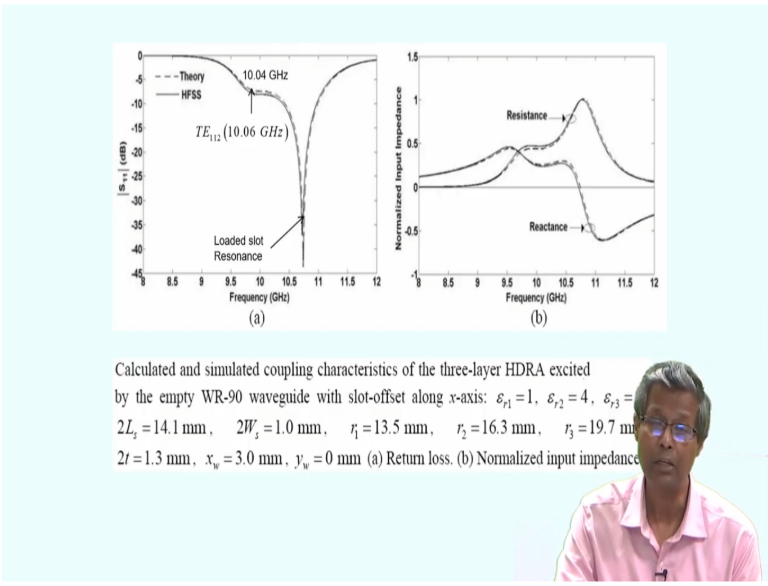

And this shows, what happens if I have an offset slot? So, in this case Xw, the x offset is 3 millimeter the y offset is 0 millimeter, there is no y offset, the x offset is 3 millimeter, epsilon r1 equal to 1, still epsilon r2 4, epsilon r3 9, the length of the slot, the width of the slot, they are 14.1 millimeter and 1 millimeter, respectively. r1 is a 13.5 millimeter; r2 is at 16.3 millimeter, r3 is at 19.7 millimeter, with the thickness of the ground plane at 1.3 millimeter.

So, we see that due to the x offset the TE112 resonance almost vanishes. And we are left with only the slot resonance, which leads to a relatively lesser bandwidth or a narrower bandwidth.

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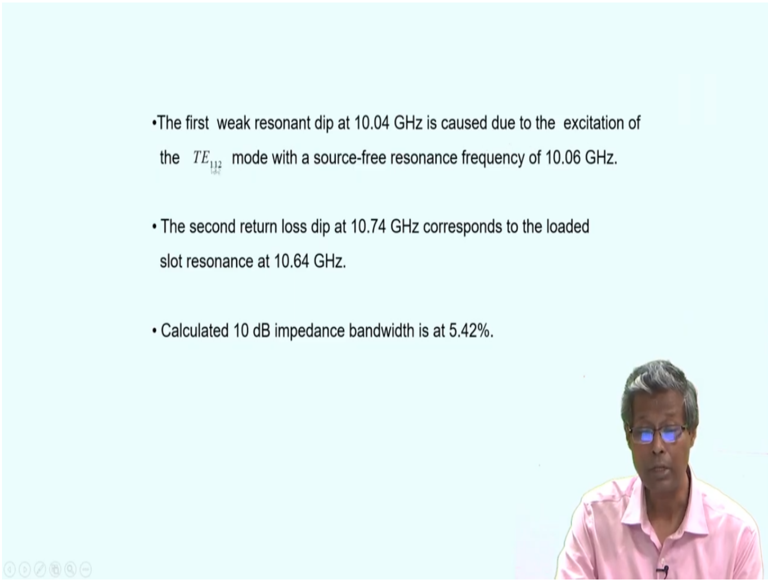

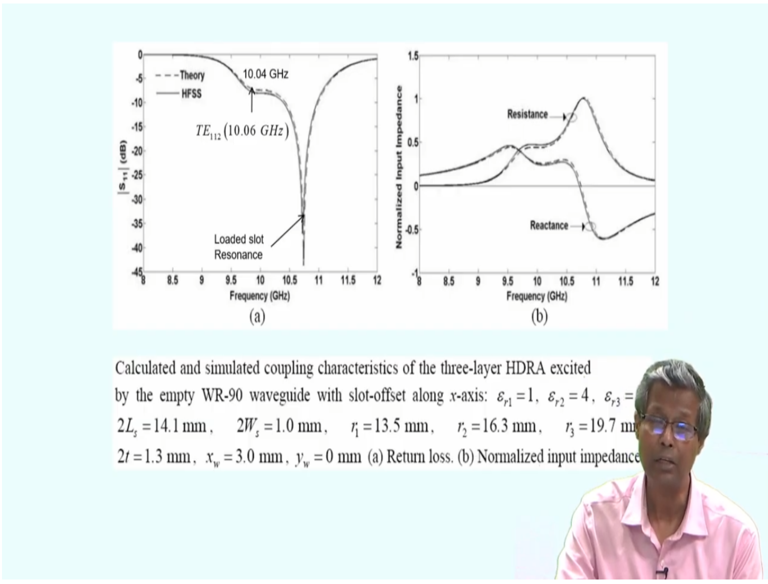

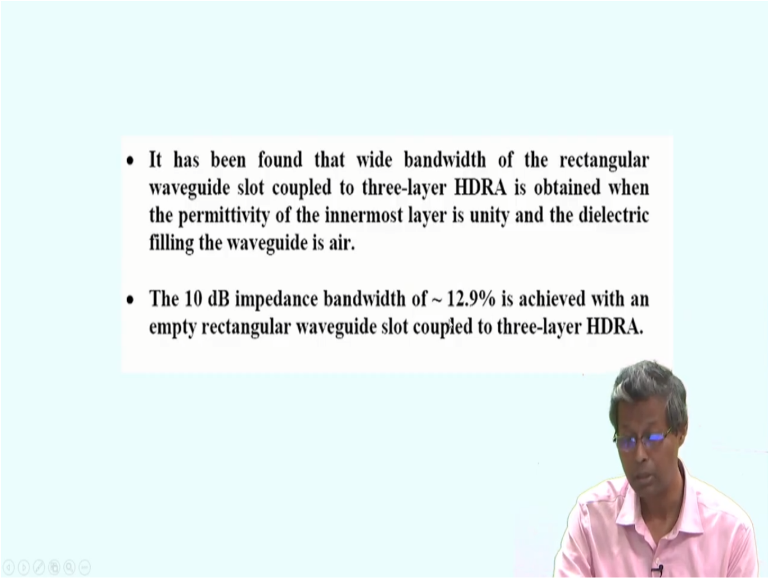

So, the first weak resonance dip at 10.04 gigahertz here, which is the TE112 resonance, is caused due to the excitation of the TE112 mode, with a source free resonant frequency of 10.06 gigahertz. The second return loss dip at 10.74 gigahertz, which is here, corresponds to the loaded slot resonance at 10.64 gigahertz and the calculated 10 dB impedance bandwidth is 5.42 percent, which can be compared to the 12.9 percent. It is seen that the x offset, the x offset slot results in the narrowing of the impedance bandwidth of the DRA.

So, a center slot configuration is preferred for the rectangular waveguide feed to the dielectric resonator antenna. So, these practical designs illustrate one very important thing that how, as we repeatedly said, how the resonant dips occurs. The scientific excitation of the modes, the scientific investigation of degenerate modes, the scientific investigation of modes which are different at different resonant frequencies, or the purposeful excitation of modes with preferred modal indices, how they help.

How the antenna analysis helps and complements the simulation tool in order to come up with a very optimized antenna structure, which are more suited to meeting the vendor requirements. So, this is where the practical utility one of the ways, in which the practical utility of the modes is deeply illustrated.

There are definitely other ways when we come to the Green's functions approach or when we come to the antenna analysis, we see, how the concept of the modes leads us to a very quick analysis of the antenna, when we compare our time taken with the Green's function analysis with the simulation tool.

So, the computation time drastically reduces. And for large antenna structures, the antenna analysis is relatively much quicker using the Greens function technique based on the modes compared to the simulation technique or the simulation tools.

So, I hope that you had a good understanding of the concepts which have been covered in the course, notably the excitations and the mode structures of the rectangular based structures which we discussed, of the cylindrical structures we discussed, and how finally we combine the knowledge of the modes to come up with realistic antenna structures. Thank you for your understanding of the course.