Course name: EMI /EMC and Signal Integrity: Principles, Techniques and Applications.
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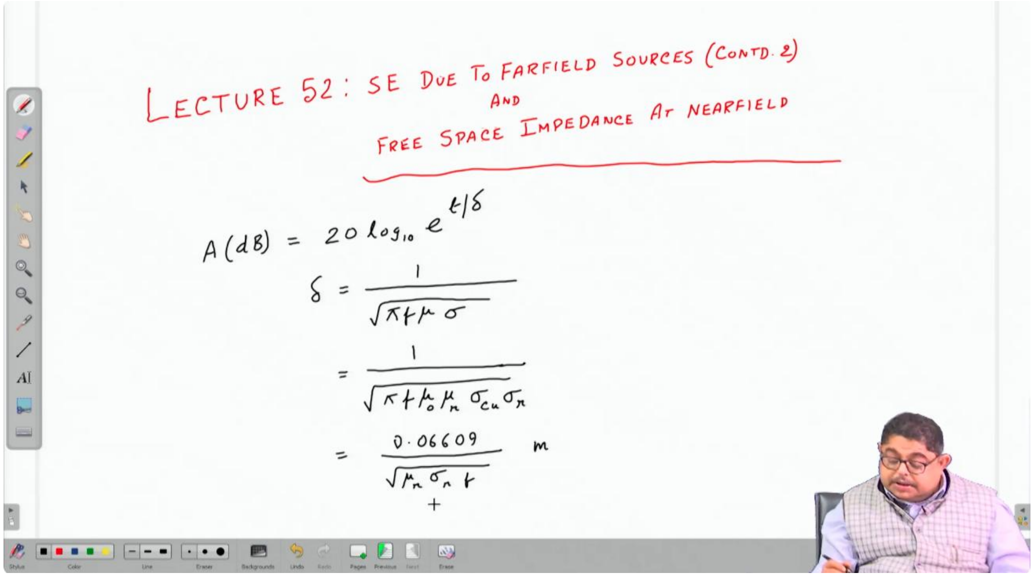
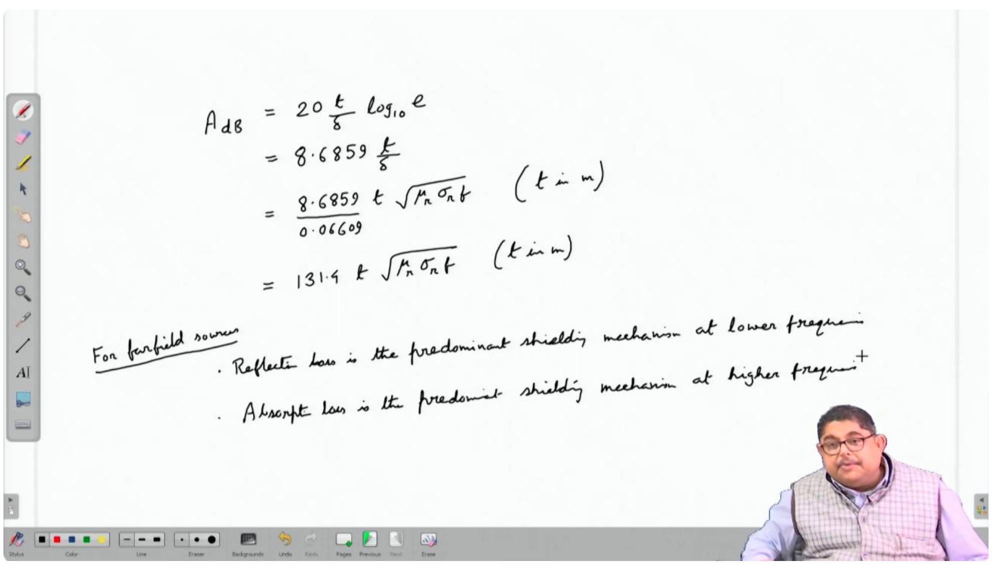
Week :11
Lecture 52: SE Due to Farfield Sources (Continued) and Free Space Impedance Ar Nearfield

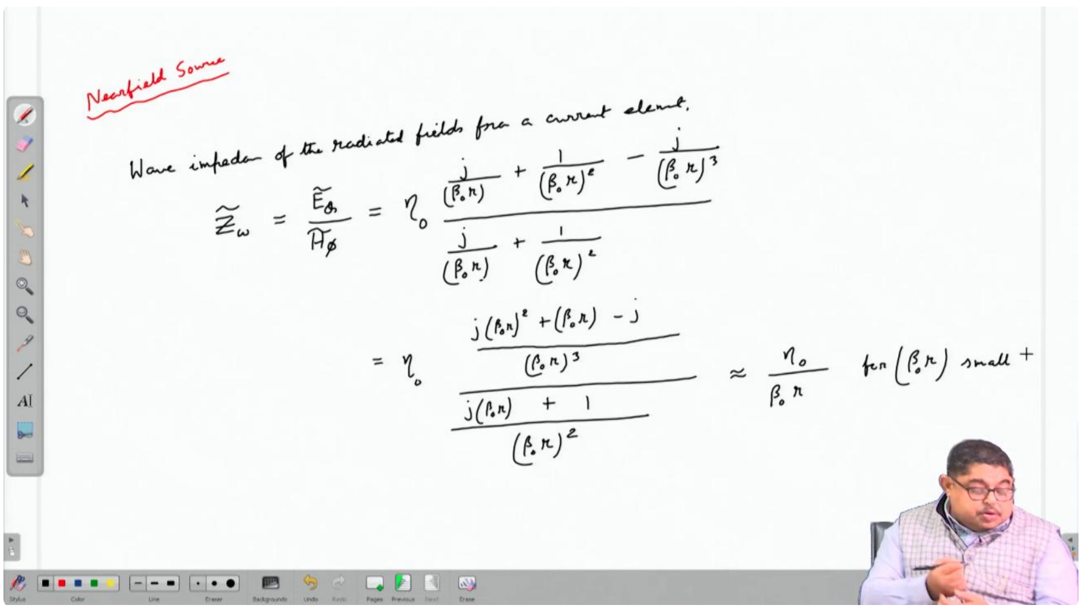
Welcome to the lecture of the course on EMIMC and Signal Integrity Principles, Techniques and Applications. We were discussing the shielding effectiveness due to far field sources in the last class. So, some portion is left. So, that we will continue then we will move on to the near field impedance descriptions. So, reflection loss I covered in the last class, absorption loss we have seen the expression of absorption loss. Let me see in a previous a we have seen that absorption loss is 20 log 10 e to the power t by delta. So, that we will now put the material parameters in this expression. So, the first thing is skin depth. So, we know that skin depth is given by pi f mu sigma. Then we can write this as pi f in place of mu we can write mu naught mu r and in place of sigma we can write epsilon c u epsilon i sigma c u sigma r.So, this if we put the values pi we know mu naught we know 4 pi into 10 to the power 7 sigma u I have given in the last class that 5.8 into 10 to the power 7. If you put all these values it will come as 0.06609 by root over mu r sigma r and f and the unit will be m meter. This is the skin depth so unit will be meter.



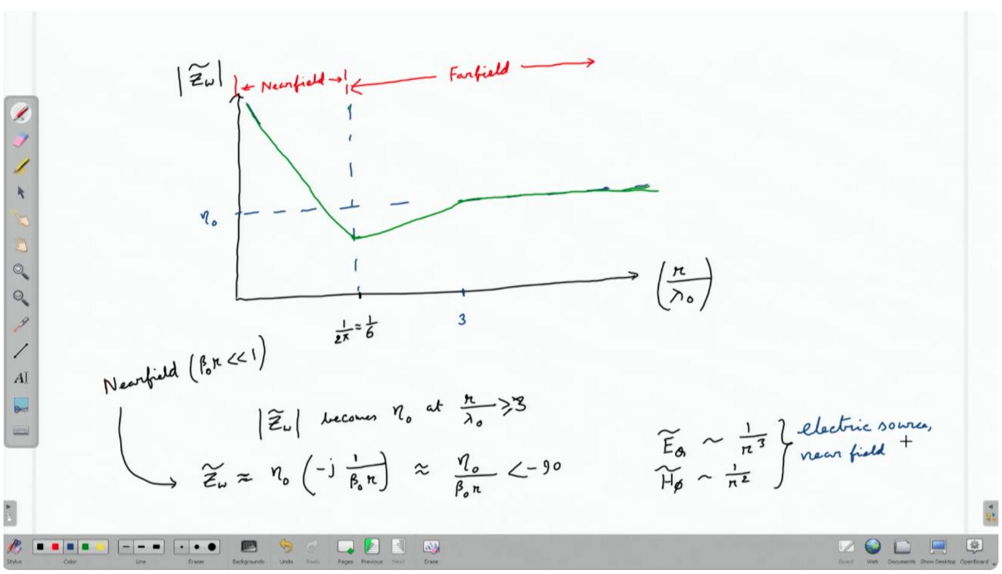
So, if we put that in a t b expression. So, a t b is 20 log 10. So, let me bring that t by delta 20 t by delta log 10 e is log 10 e is 8.6859 that multiplied with 20 that will be 8.6859 t by delta. So 28.6859 that t will give and delta expression will put 0.06609 and root over mu r sigma r f where t is in meter, but that is generally unusual the thickness. So, if we put it in or, but you will have to properly take the unit. So, if you do this calculation it is 131.4 t into mu r f again to remind that t is in meter it is written. So, you see that absorption loss unlike reflection loss that increases with frequency and you can also note that reflection loss was a function of sigma r by mu r, but absorption loss is a function of sigma r into mu r. So, for far field sources we can draw the conclusion for far field sources our conclusion is that reflection loss reflection loss is the predominant shielding mechanism of the reflection loss at lower frequencies and absorption loss is the predominant shielding mechanism at higher frequencies. That means, absorption loss is due to the travel of the wave through the shield reflection loss is whatever gets reflected at the boundaries. So, that this is an insight which came after we derived the expressions. So, this will be helpful that where you are trying to make shielding affecting at what frequency. So, what you should see whether you will try to adjust the reflection loss or try to adjust the absorption loss that is an good insight these two lines giving.



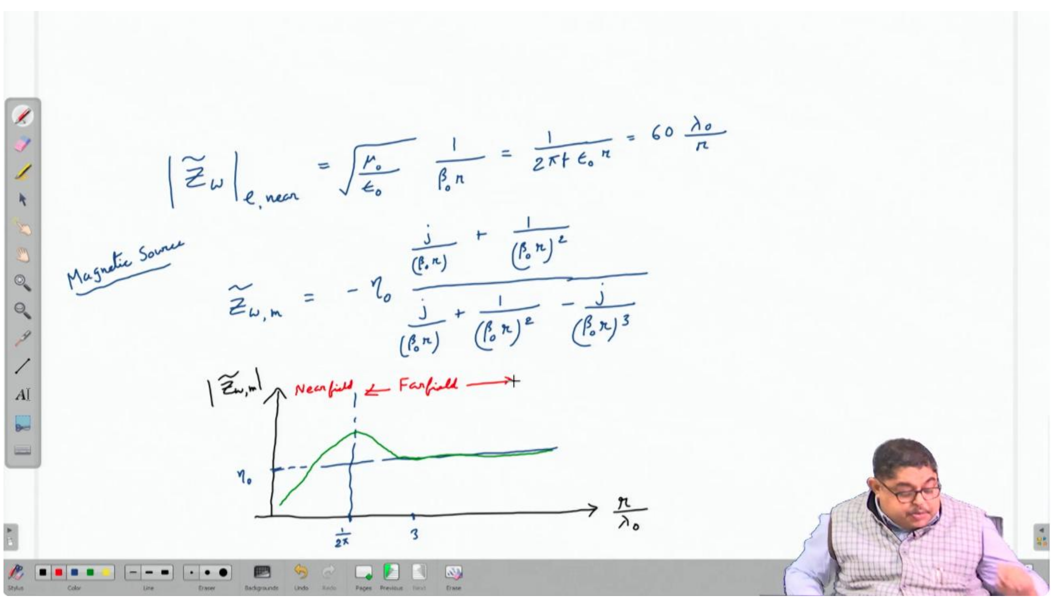
Now, let us switch over to the discussion on near field sources. As I already said that in EMC cases they were very common because from a nearby circuit from a nearby oscillator it may come that may not have sufficient distance to call far field. So, now there let us start the discussion with a hertzian dipole or a current element. Now already while finding radiated emission we have discussed this elemental radiator. So, we know it is field well. So, what is the wave impedance? Wave impedance of the radiated fields from a current element. So, let us call that z wave that is we know that E theta by h phi is wave impedance also we can say E phi by h theta etcetera. So, there are with any coordinate there are three directed wave impedances. So, let us take this one that expression if you look at the that time gave you the expressions exact expressions of fields not with far field approximation the field expression it will be E theta by h phi will be J by beta naught r plus 1 by beta naught r square minus J by beta naught r cube divided by for h phi there will be J by beta naught r plus 1 by beta naught r whole square. So, if I simplify this it will be eta naught. So, the numerator the highest order term is eta naught cube. So, let me write J beta naught r square plus beta naught r minus J and in the denominator the highest term is beta naught r square. So, it will give you J beta naught r plus 1. So, that will be roughly if you consider that beta naught r is much smaller that means, A is not at the source and the receptor are not very far beta naught r is small you will get that it is eta naught by beta naught r or beta naught r is small.



And so we can draw this as the magnitude versus r by lambda naught beta is actually 2 phi by lambda. So, that 2 phi you will have this and if I draw a line at 1 by 2 phi roughly is equal to 1 by 6 you can say. And then the impedance sorry if you plot it comes like this. So, this is the impedance in free space. So actually we can say roughly this is the near field. And this is the far field that means, r is equal to lambda naught by 2 phi that is the boundary between near field and a field. So, you can see that the near field when beta naught r is much greater than 1, well less than 1 near field is when beta naught r is much less than 1. So, when we are much less the impedance free space impedance or wave impedance of the wave generated by a current element it is having a very high value much much above the intrinsic impedance of free space. So see now if you increase the distance it is coming down at a distance of r by lambda naught is equal to 1 by 2 phi it comes below the 277 ohm value. Then if you increase further it goes and roughly at r is equal to 3 m lambda naught it becomes equal to eta naught and thereafter it stays there that means, in throughout the after these distances if you go on increasing the distances the wave impedance is constant. So, we can say that Z w becomes eta naught at r by lambda naught greater than greater than equal to 3. Now in the near field here what is g omega Z I mean wave is roughly you can see it is n naught from the expression I have given it will be evident that when you have beta naught r is much less than 1. So, this term will prevalent so you have eta naught minus j 1 by beta naught r and this is you can write as eta naught by beta naught r minus 90 degree. So, impedance has a value eta naught by beta naught r in the near field and its phase is minus 90 degree. Also we can see that in this near field e theta that is varying as 1 by r cube and h phi that is varying as 1 by r square. This also is evident from this expressions that this one is electric field e theta for h phi it is 1 by r square. So, we can say that this is for electric source near field we are calling electric source because this is the case of a current element and almost all the radiators they are superposition of these. So, this type is maintained for any radiator which have conduction current on it and it radiates. Also, this current element or electric dipole or this electric sources they are called high impedance source. Why? Because you see that in the near field their impedance is much higher, wave impedance is much higher than the intrinsic impedance of free space that is why they are called high impedance source in cross talk analysis we have seen what is a high impedance source. So, here this is an example.



Now, let us convert this impedance into the material constants by including that. So, we can write it like this z omega electric source near that means in the near field this is our expression was eta naught by beta naught r. So, eta naught is root over mu naught by epsilon naught 1 by beta naught r that is you can easily find bring frequency here by beta naught is 2 pi by lambda naught. So, lambda naught can be converted as f and v, v is the velocity applied. So, if you do that it will come 1 by 2 pi f epsilon naught r. So, this if you from f if you go to lambda naught you can easily go by knowing that it is electromagnetic wave travels if the velocity applied. So, you can write this as 60 lambda naught by r is the near field value of an electric source. Now, let us consider a magnetic source. Magnetic source, so an elemental magnetic dipole that is a loop that is a elemental magnetic dipole. So, consider that we will find its field then we will find its wave impedance. Now it is basically dual of the electric field. So, if we use the principle of duality or you can actually probably in antenna classes you have derived it from the basic principles. So, in antenna books this expression is given. So, I am just writing the expression that will be a minus sign will come and j by beta naught r plus 1 by beta naught r square divided by j by beta naught r plus 1 by beta naught r whole square minus j by beta naught r whole cube. So, if we draw this, this is j u magnitude, this is r by lambda naught. So, this is r by lambda naught. Same type of thing, only thing it is very low in the near field. So, roughly you can say this is the near field, this is the far field. So, in the near field the impedance is very smaller, very much small compared to eta naught that means free space impedance, but it at the near field, far field boundary it overshoots eta naught, then it comes down and by at a distance r by lambda naught is equal to 3, it comes to the value of eta naught.



So, we can say that j omega m is minus j eta naught beta naught r, this from the expression given you can easily find. So, this is eta naught beta naught r n minus 90 degree. So, we can say that h theta is proportional to 1 by r cube E phi is proportional to 1 by r square for magnetic sources near field. So, magnetic dipole is referred to as a low impedance source for obvious reasons. Now, what is the magnitude of this in terms of the parameters? So, we can write j omega m is equal to 2 pi f mu naught 0 r is equal to 2369 r by lambda naught. Now example of a magnetic source is a transformer. So, if you have a transformer in the circuit, you will get the in the near field the wave will be having this type of variation. Electric source is a process of a DC motor spark gap, they are the example of electric sources or any antenna radiating. So, this electric source and magnetic source will have to see them separately because their impedances are different, one is a high impedance another is low impedance. So, their shielding effectiveness will also be different. So, separately we will have to consider. In far field there was no separation because far field is a stable zone where we already got a fixed impedance that that impedance we take as eta naught, but here in the near field we cannot do that. So, when we saw deeper we saw that the impedances one is a high impedance, there are high impedance case there is low impedance case. So, for that we need to find shielding effectiveness for both of them separately that we will do in the next class. Thank you.