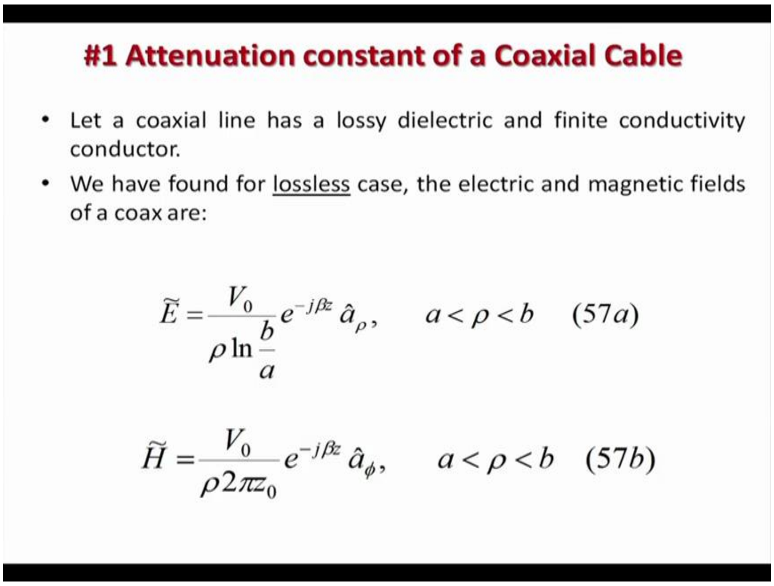
Basic Building Blocks of Microwave Engineering
Prof. Amitabha Bhattacharya
Department of Electronics and Communication Engineering
Indian Institute of Technology, Kharagpur

Lecture – 10
Coaxial Connectors

Finally, we have seen the transmission structures now I want to spend some time on losses in coaxial lines. We have seen in general that in transmission structures what is the losses, now we will calculate losses in coaxial lines because that has a trick which unless and until one starts doing that that the trick does not come out that is why we will do that. And then finally, based on those loss calculations various coaxial connectors people have made so that those are used with coaxial lines to connect any device any equipment for taking the power or measuring power etcetera. That is important because a microwave engineer should know thoroughly those coaxial connectors that is why we will spend some time on that. This lecture will be on Loss Calculation and Coaxial Connectors.

(Refer Slide Time: 01:35)

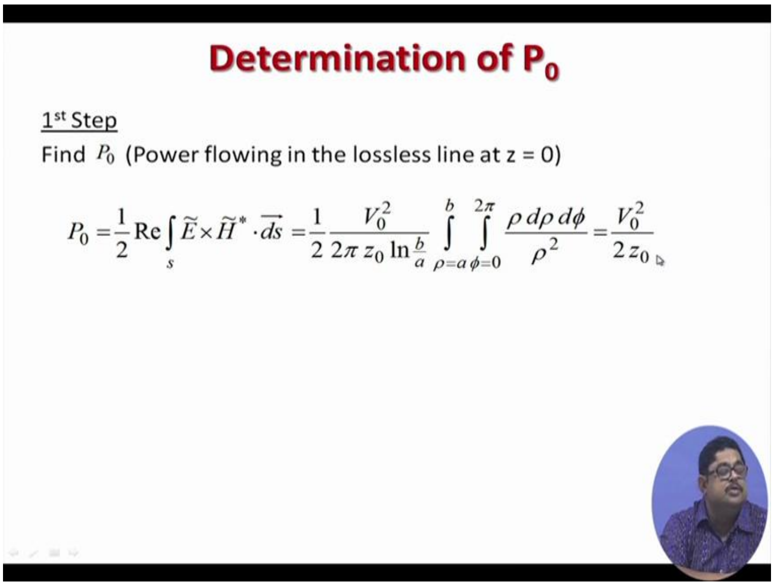


So, some sort of theoretical tutorial that let a coaxial line has a lossy dielectric and finite conductivity conductor. That means, it is that both the single conductor and the outer conductor their metal is having a not ideal it has finite conductivity. Also let us assume that between them there is a lossy dielectric. That means not a r, a r is not lossy but some other dielectric so how to tackle this problem.

Now, the technique to attack this problem is that we assume that this losses they whenever the material etcetera are not perfect still the lossless case field distribution and this lossy case field distribution is not much difference. Field distribution would not be much different on the medium, because these losses the devices are not very lossy then they cannot be used they cannot be used for power transportation. So, there are losses definitely, but lossless case and lossy case the field distribution is not much different.

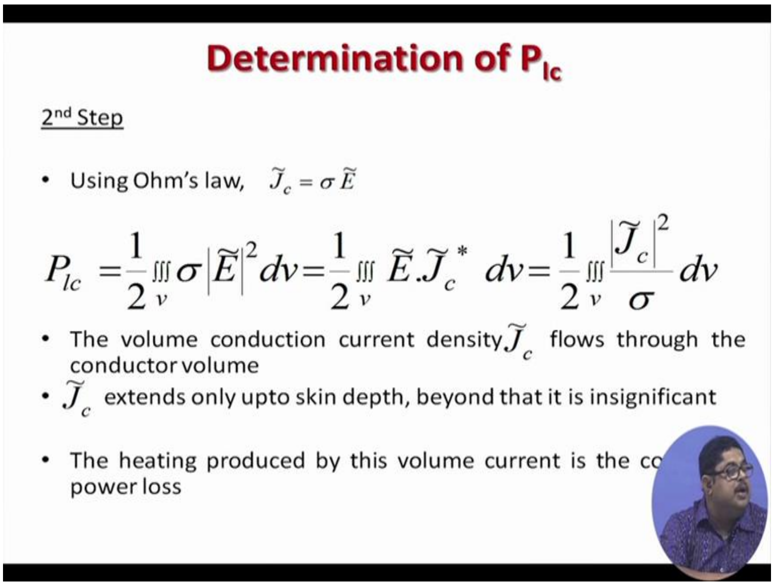
On that way we first find that for lossless case assuming lossless we are found for a coax what is electric and magnetic fields. That we have already shown in the coaxial line part that radial field distribution and magnetic fields are circular, so you see e is equal to a rho and h is equal to a phi. So that all of we know that is radially going out electric field and magnetic field is azimuthally circling.

(Refer Slide Time: 03:49)



From that we if you remember that the expression for alpha the attenuation constant is we need to find out what is the loss and what is the power flow, if we do that you can find. So first step is what is the power flow? Power flow will come from in any transmission structure, the power flow will come from the pointing vector and it is we have to integrate it over a surface. If you do that for coax we get this. The calculation is shown I am not spending time on calculation. So, it is V naught square by 2 into characteristic impedance. So, this part is over that power flow we have done seen.

(Refer Slide Time: 04:33)

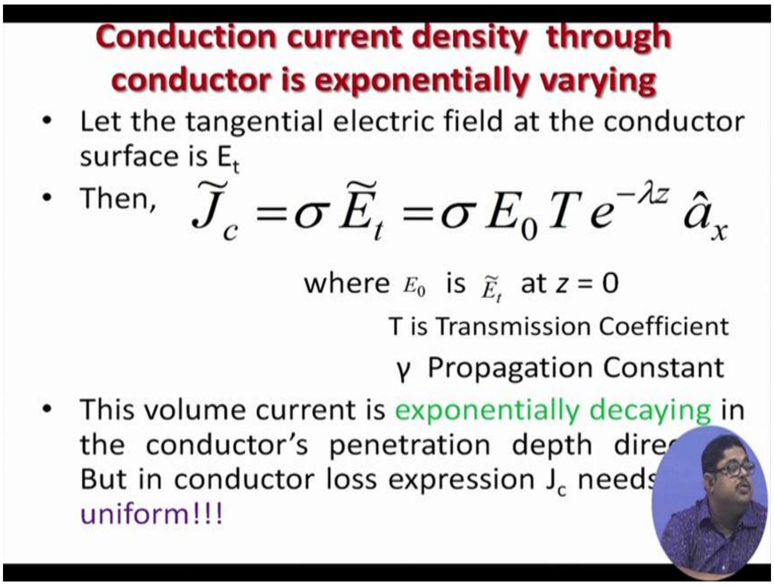


Now, second stage is will have to find the loss power loss. Now power loss will be in two ways; one is conductor loss and other is dielectric loss. Dielectric loss is easy as we will see later, but conductor loss one thing where is the loss taking place in a conductor. The point is that in a conductor the current is flowing as a volume current and you see that is across the propagation direction and current. That means if we do the calculation that is not getting the loss, the loss is getting created because the wave is also going diffusing into the conductor and we know that up to a depth if it is a perfect conductor then there is no diffusion that fields do not go inside the metal. But in any real metal the fields go inside and they go up to the actually there is an exponential variation, so we say that up to one skin depth there are significant field diffusion below more than that depth there is practically no field.

So, that we will have to now tackle that using Ohm's law we will have to find that volume that surface current density which is flowing through the volume of the conductor. So, we will have to revoke Ohm's law. Then that power loss in conductor P lc that will be coming from this, the volume conduction current density flows through the conductor volume. Now this J c it is flowing in the longitudinal direction, but also it is in the transverse direction it is going up to skin depth beyond that it is insignificant. The heating produced by this volume current is the conduction power loss.

So, remember that it goes inside the conductor if conductor is a bit thick it will go inside. So, up to one skin depth at least it will go.

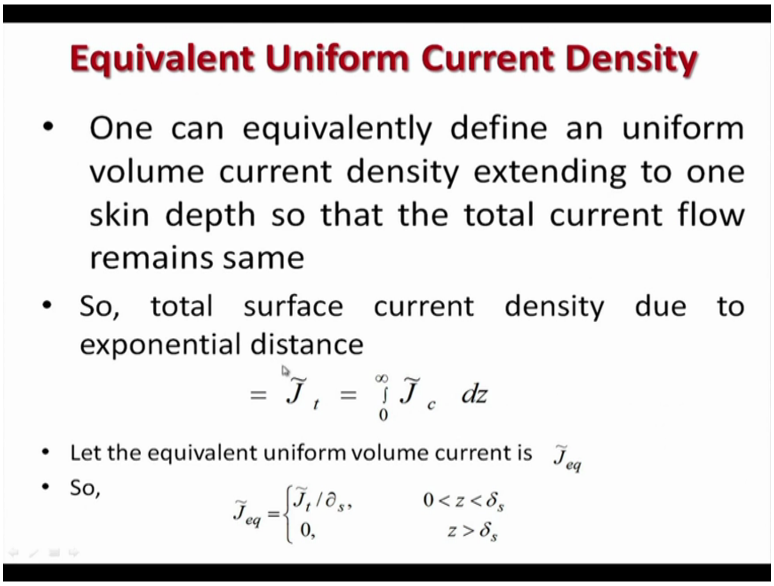
(Refer Slide Time: 07:16)



So, we start from this tangential electric field at the conductor and then from (Refer Time: 07:25) we know that this let tangential electric field will create a conduction current now that conduction while diffusing it has a exponential variation. This we have seen in (Refer Time: 07:43) theory this is called diffusion equations etcetera.

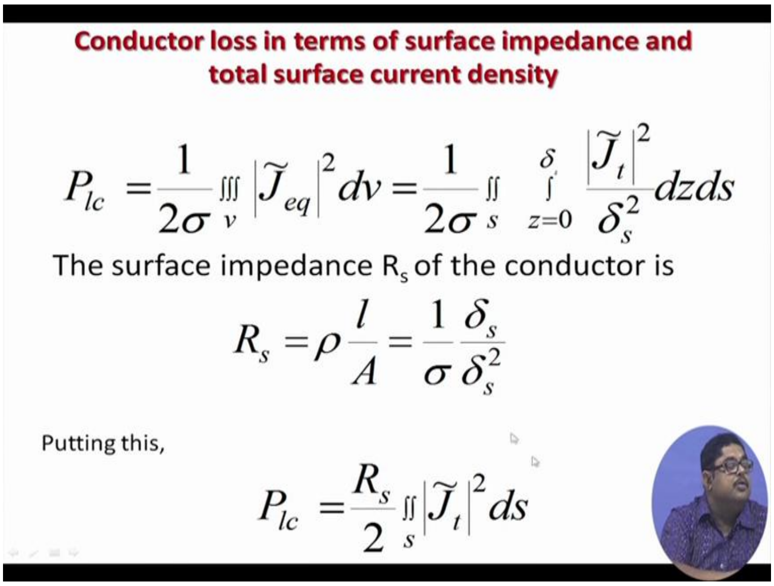
And that we are expecting this is conductivity there is a transmission coefficient that means how much it is transmitting inside because the field when it comes portion of that only goes inside that is called transmission coefficient, and it goes as propagation constant. This volume current is exponentially decaying in the conductor's penetration depth direction, but in conductor loss expression what we have found loss expression that J c needs to be uniform. When we found the lossless case thing that time J c was uniform, but actually it is not uniform. So that our expressions are assuming it is uniform; so here what is the remaining.

(Refer Slide Time: 08:40)



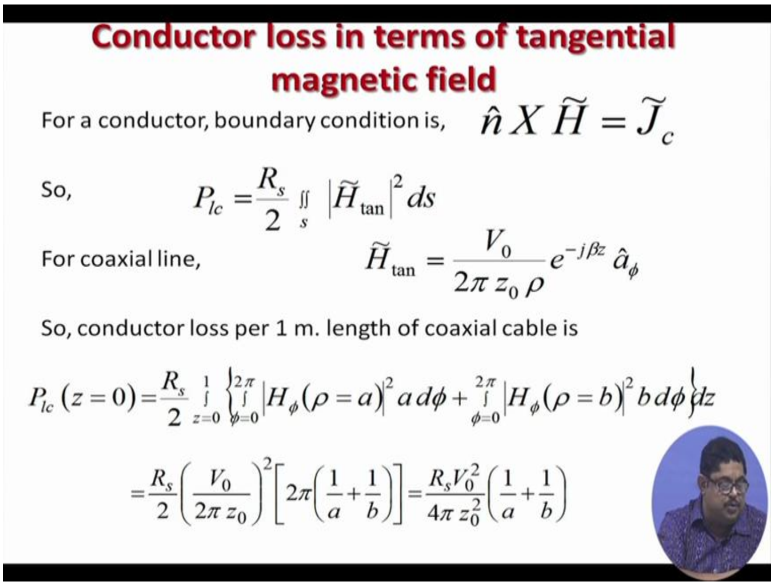
The remaining is again let equivalent to this, that one can equivalently define a uniform volume current density extending to one skin depth so that the total current flow remains same. Equivalent means total current flowing both the cases same, in one case it is varying exponentially another case you are assuming that up to one skin depth it is uniform. So, find out that equivalent current. So, that has been shown here and let that equivalent current is J subscript eq, and that eq will be given by this total by skin depth because this is uniform.

(Refer Slide Time: 09:22)



Now put that, so once you J eq in terms of the total current and skin depth so you can write this. And putting these you got the P lc that will be this is the tangential current.

(Refer Slide Time: 09:49)

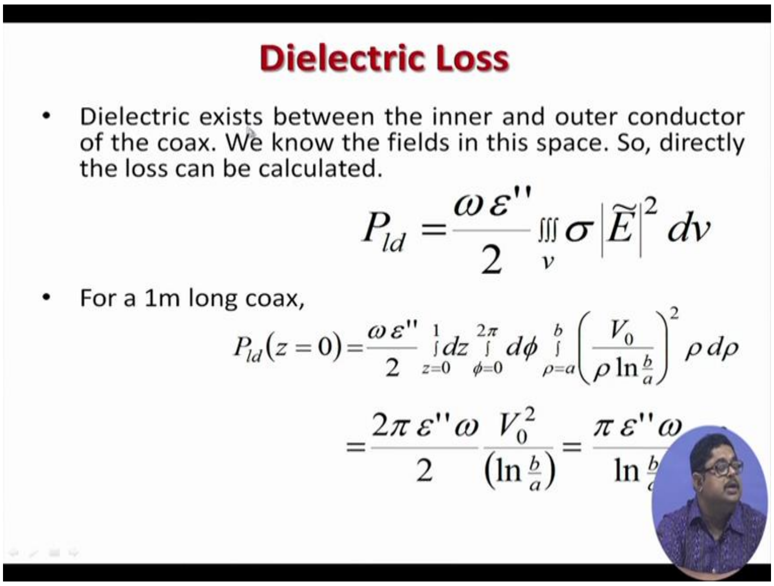


Now, tangential current the movement we get we know that in any real conductor the tangential current and the magnetic field both are tangential, and they are magnitude also same. Only they are directions in interface there are it is a surface so they are perpendicular to each other, but they are magnitudes are same. Since our previous expression shows that it is magnitude square so J t we can always replace with h tan. So, that will do because these boundary condition for any real conductor, so instead of g t will put h tan.

And we know the value of h tan in case of coax so we will put that and this is the value, so conductor loss we can calculate P lc we can calculate and these turns out to be this expression. So, you can in find out this. As I said that conductor loss there is a trick that trick is that it is the diffusion so that is an exponential mediation, but over loss less case that time assumed uniform current density. So, the trick is you define an equivalent that is the only thing. Another thing is once you have the tangential current you can always replace that magnitude wise tangential current in a conductor is equal to the tangential magnetic field.

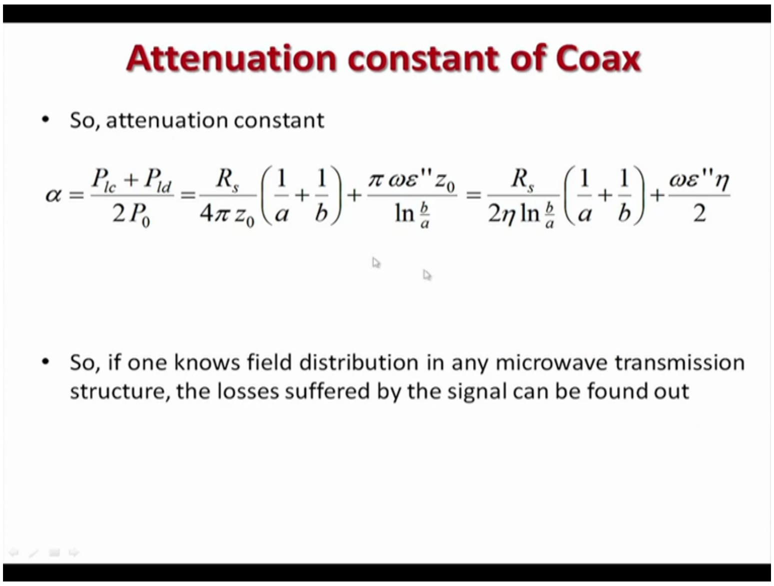
So, you do that we know the field in coax so we have calculated the power loss in these. Already we have found e naught, so we can define in alpha c. We would not do that will actually P lc we calculated will also find P ld that means dielectric loss. So, total power loss is some of that then divided by 2 into to power flow that will give us alpha. But from here also I can find alpha c which is P lc by 2 P naught. Similarly alpha d will be P ld by 2 P naught.

(Refer Slide Time: 12:17)



So, let us see for dielectric it is easy because the fields are we know between the two conductors in the coax field exist dielectric also is there, so there thing is well know formula from pointing theorem. So, P ld is given by these. So, once you know electric field you can find. And conductivity of the medium you can and the epsilon double prime that is the imaginary part of dielectric constant you can find P ld. So, that we have shown to be these value.

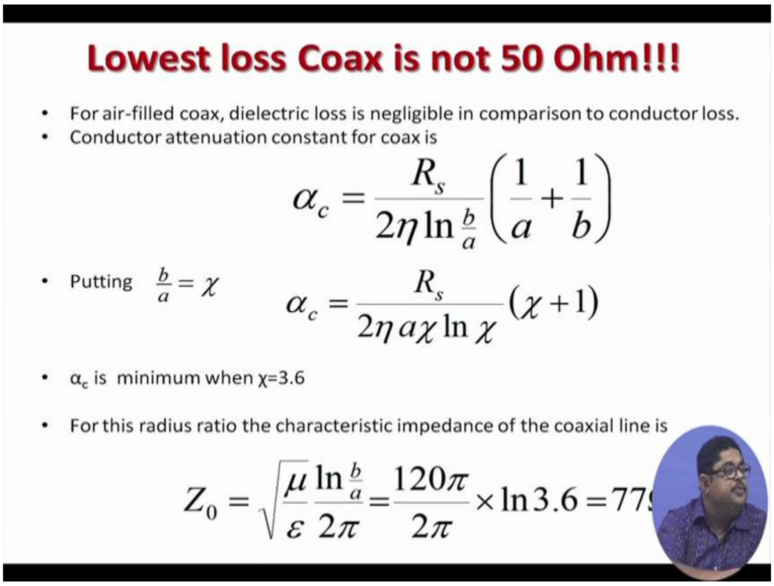
(Refer Slide Time: 12:59)



So, now we sum the total attenuation constant is this by 2 P naught. This is the value. So, if one knows field distribution actually this we have seen for coax now we have not done for others, but actually in any transmission and structure like rectangular wave guide, circular wave guide or this micro strip, strip line or any structure. This is the basic equation that power loss or attenuation constant calculation, but knowing the fields structure you should be able to find P lc, that what is the power loss. So, you need to understand the mechanism by which power loss takes place, find out it is loss. Obviously, pointing vector will always give you the power flow from that you can determine.

So, you see this attenuation of coax that is depended on this parameter. You see others are obviously what material I am conducting, material I am using that is determining the surfacing resistance, eta is a thing that is the constant, omega is the frequency; this is what is this loss tangent it is depending that is already there. But another important parameter that is design wise is this b by a ratio, you see b a or actually we can always write this 1 by a plus 1 by b in terms of b by a. So, outer conductor radius by inner conductor's radius this is an important parameter for alpha, so loss at attenuation constant will depend on that.

(Refer Slide Time: 14:54)

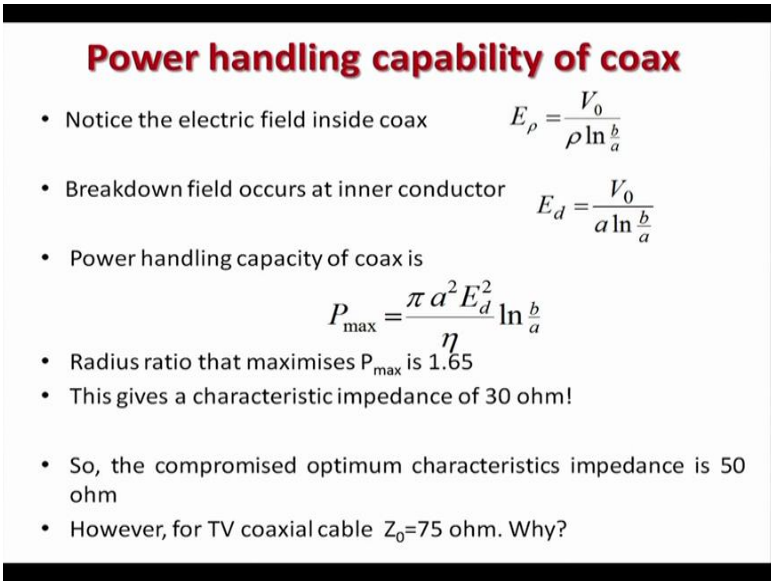


Now for air field coax dielectric loss is negligible because there is in air there is not much dielectric loss, so conductor attenuation constant, so conductor loss is the main thing so alpha c is this. Now, as I was saying you try for manipulation sake you define b by a as a psi. And once you do that you can write these then find out that for which value of psi you are getting the maximum attenuation constant, so you differentiate and find out. So, if you differentiate function you see that this ratio b by a that is 3.6 is an important thing.

So that means the conduction loss or conductor loss that will be minimum if I can choose a b by a ratio to be 3.6. So, this is preferable then you will choose that, but the flip side of that is b by a also affects the characteristic impedance of the coax. Characteristic impedance of the coax this is the formula that time we have found when you did the field analysis b by I ratio is characteristic impedance so that if you calculate this is become 77 ohm. But generally we have the in electronic industry 50 ohm is a standard that device says by equipments, measuring instruments what says we have 50 ohm.

So, if a coax is having a 77 ohm characteristic impedance to minimize loss that is not acceptable. Then people thought that ok so we will have this loss, but we will also make this impedance closer to 50 ohm.

(Refer Slide Time: 17:10)



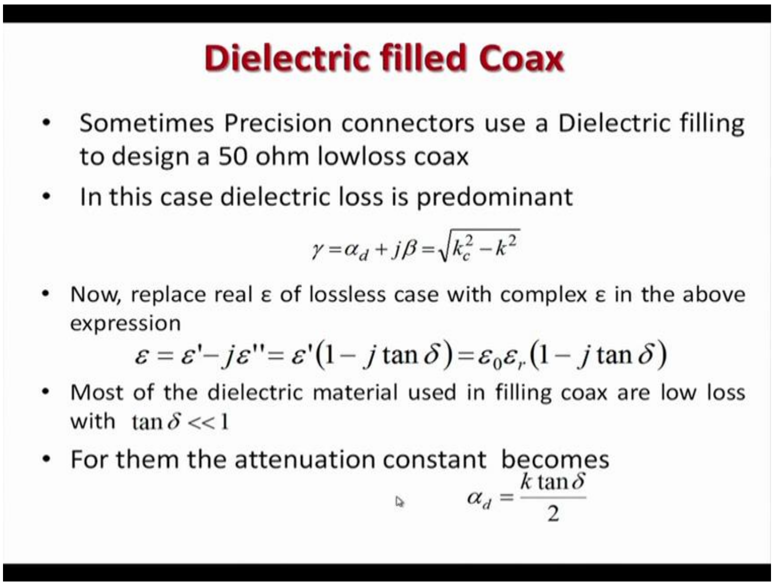
Now, also another thing is what happens to with that b by a is equal to 3.6 is loss is minimizes, but what happens to the power handling capability. That means, how much maximum electric field I can sustain without breaking down. So, electric field inside coax is this so obviously, this is maximum when rho will take the value of a. Because rho extends from a to b inner conductive to outer conductor, so when rho will be minimum e will be maximum. So, breakdown occurs at inner conductor and that breakdown value is this. So, power handling capacity of coax you find out what d c d, what is the maximum power that is gets created that this. Now maximize p max with respect to this ratio psi b by a that turns out to be 1.65. And this if you put in the characteristic impedance is given 30 ohm.

So two considerations whether you want the loss to be minimum or you want breakdown to takes place. Now once side says that make b by a large 3.6 another says it make b by a small one 1.65. The flip side is one side is giving you 77 ohm another side is giving you 30 ohm. So, the compromised case is that take it 50 ohm; that means do not minimize the loss fully, do not maximize the power handling capability fully come something in between if you do not want to use any other dielectric.

That means, for air field case this is the story. Here one thing I want to say that generally coaxial cables characteristic impedance is 50 ohm, but TV coaxial cables are not 50 ohm they are 75 ohm. The reason is that when TV antenna particularly in the TV days that folded dipole antenna actually firstly that antenna itself the was having an impedance 300 ohm folded bi folded dipole it can be made to 75 ohm, so to match that the TV people generally prefer a coax cable with 75 ohm thing.

Now, you can ask that they could have make it 300 ohm itself, but 300 ohm making is difficult because very small values of the very close spacing is required between the two conductors, because there the p b actually initially the when TV was in (Refer Time: 20:29) planes they did not use coax, because two wires shielded wires that was enough to do the that, but later when TV got up higher in frequency TV transmission particularly b by h a they required the coaxial cable. So, since the other people to where people there are having 300, 75 ohm impedance, so these coaxial people also keep it as 75 ohm.

(Refer Slide Time: 21:02)

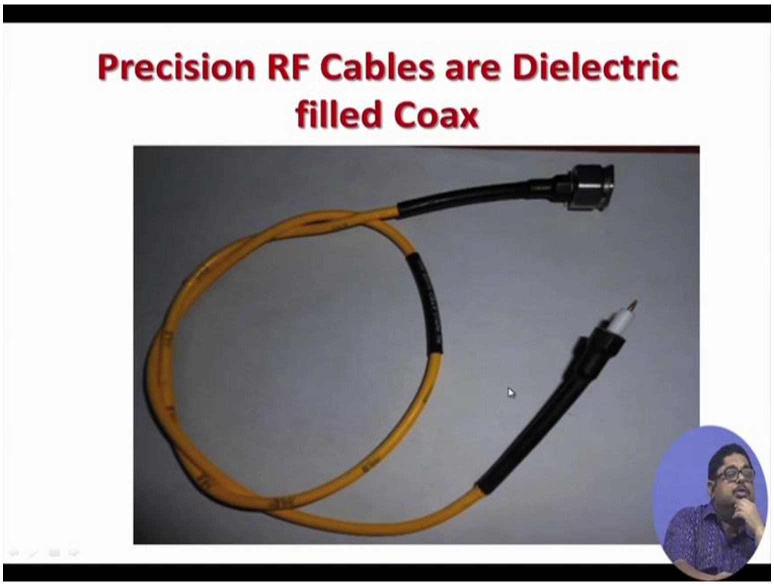


So, people now thought that instead of making an air field guide we will make dielectric filled coax. Obviously, that will make a dielectric loss more. So, loss will become more, but will have more flexibility in choosing the diameters

So, that is the practice now that very precision connectors they use a dielectric filling to design a 50 ohm lowloss coax. In this case we say that the dielectric loss will be predominant that is more than conductor loss, so to handle that we know from (Refer Time: 21:46) theory that in a loss less case epsilon you replace that epsilon with a complex epsilon; complex epsilon is not it is epsilon dash not plus minus. Because this is where propagation aim in theory books you see that if we take this as plus then it would have been not given the losses in nature. So that is why it is made a minus and in this is the thing.

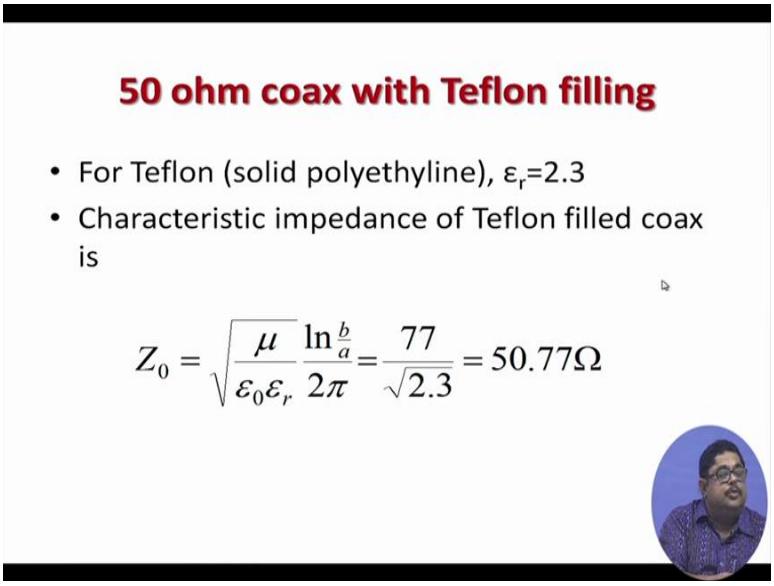
So, attenuation with this approximation as we have seen that most of the micro skinned dielectric material there at least 0.001 to 10 to the power minus 4 10 to the power minus 5 is the loss tangent, so tan delta is coax less than 1. So, (Refer Time: 22:42) alpha d the attenuation constant due to dielectric loss that is something like this.

(Refer Slide Time: 22:51)



Now, people have more flexibility that they can choose a by b ratios much smaller and or larger according to the name. This is an example of a precision RF cable you see that RF cables are very precision they are quite costly also because they are loss is quite small. You see this is a center conductor that is procuring from here and this white thing is dielectric field. This actually we have taken out this slim, so this white is the dielectric field and then the inner conductor you can see. Outer you cannot see here because it is already shielded there is the behind this or beneath this black covering there is the out outer conductor. There are some more views. So, that you can see more pronouncedly, this is the cylindrical conductor.

(Refer Slide Time: 23:58)



Now, how we can make a 50 ohm with dielectric. So, let us take Teflon is a very easily available dielectric solid polyethylene, it is epsilon r is 2.3. So, you see that what will be the expression for this so we are taking it that. Already we have seen that time that with that b by a ratio 3.6 which minimizes the conduction loss. So with that but with dielectric it will be 50 ohm. If we give the Teflon thing that is also; this is Teflon so that gives you 50 ohm exact characteristic impedance you can easily make.

(Refer Slide Time: 24:58)

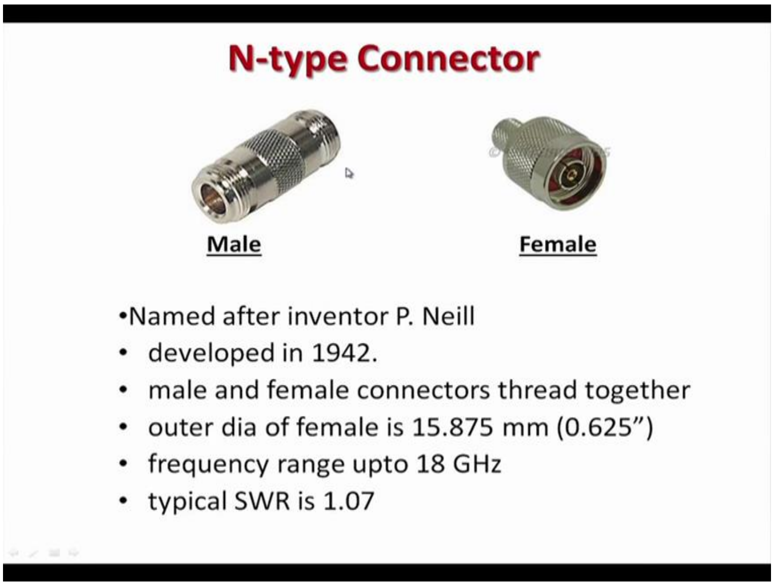
Now, you see some coaxial connectors. Already you are familiar with these BNC in most of the oscillators curve, mega hertz oscillators curve you use it, also in microwave lab, in the BSW meter you have this BNC it has a slot, so when you put it then there is a you will have to put that match that slot so that it gets heated there. It is a coaxial connectors, but this is not a microwave connector it is generally mega hertz range people use it.

So, this connectors have sex; that means one is male another is female so they met together. And these also I do not know whether you have seen these are TNC connectors. TNC stands for shaded BNC, there also have male female sex. Then these are in connectors, these are in many microwave equipment particularly the network analyzers you will see this n connector they also have sex. Then APC connectors will come just now to their description, APC is a very precision one but it is quite costly that is why now a day's people do not use it. Now SMA was very miniature small ones. So, SMA has various varieties and it is being developed. So now a day's very high up to 100 Gigahertz you can go with these SMA's, and these are some other varieties etcetera.

(Refer Slide Time: 26:56)

Previous thing was side view, this is the top view. You see in any one. So, actually male says that central conductor comes out and females you see generally that single conductor is not there so the central conductor of the male that goes into this female one.

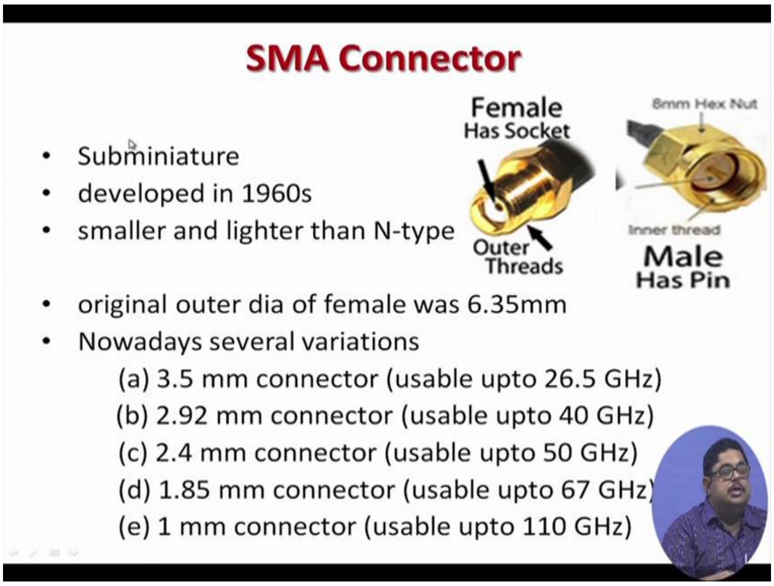
(Refer Slide Time: 27:22)



Here you can see that this male central conductor that hits inside this group of the female. Now this is the n type connector you see the it was named after it is inventor P. Neill that why n type from him, it was in 1942 when the microwave thing were developed in for radars for MIT laboratory etcetera that time it was developed. Obviously, you see the outer dia female is more because it they had.

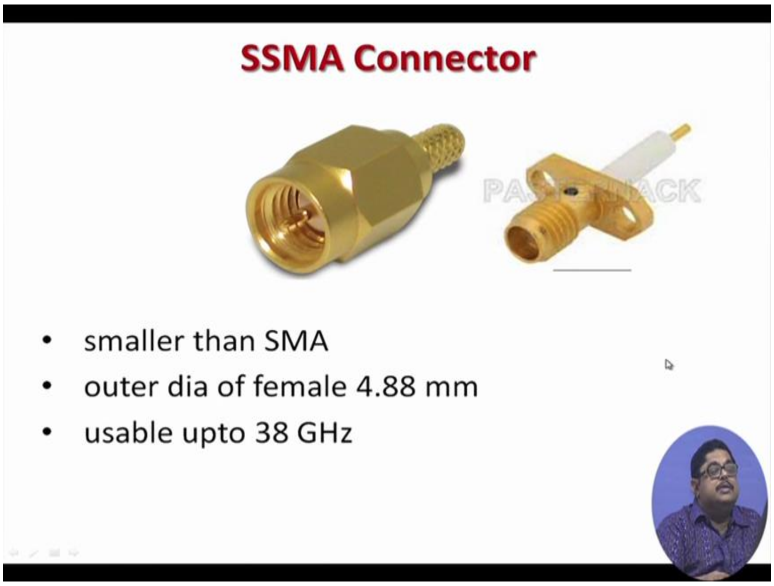
So, generally all these coaxial connectors they are diameter is specified for female. Outer conductor dia of female was 0.625 being roughly 15 centimeters. Frequency range up to 18 Gigahertz, typical SWR which shows how much reflects how much power is loss in deflection; that means it is impedance matching property. So, SWR is 1.07 quite good. N type connector is very much used now a day's not for very precision, but for moderate precision one n type connectors are used.

(Refer Slide Time: 28:52)



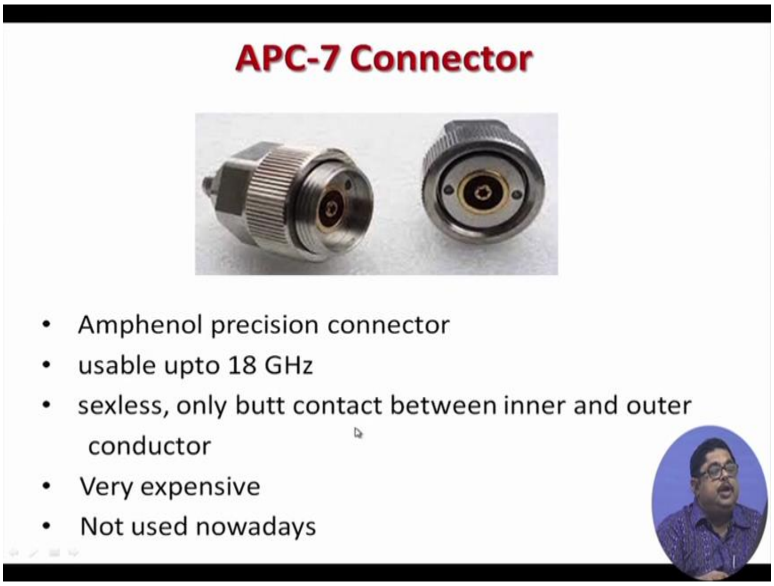
SMA connectors again you see that these are sexes male and female actually. Apart from APC all are male or female counter part. This name came from subminiature SMA's stands for subminiature things that is why SMA connectors. It was developed bit later 1960's, smaller and lighter than n type. Original outer dia female was 6.35. So, from 15 of n, so n is (Refer Time: 29:29) now a days it has got several variations. 3.5 millimeter connector that means outer dia female is 3.5 millimeter, 26.5 Gigahertz you can go. Then if you reduce further to 2.92 millimeter, 40 Gigahertz. 2.4, 50 Gigahertz; 1.85, 67; 1 millimeter connector I have not seen, but these are 1.85 they are saying theoretically 67, but that means 50 60 Gigahertz you can go to there.

(Refer Slide Time: 30:29)



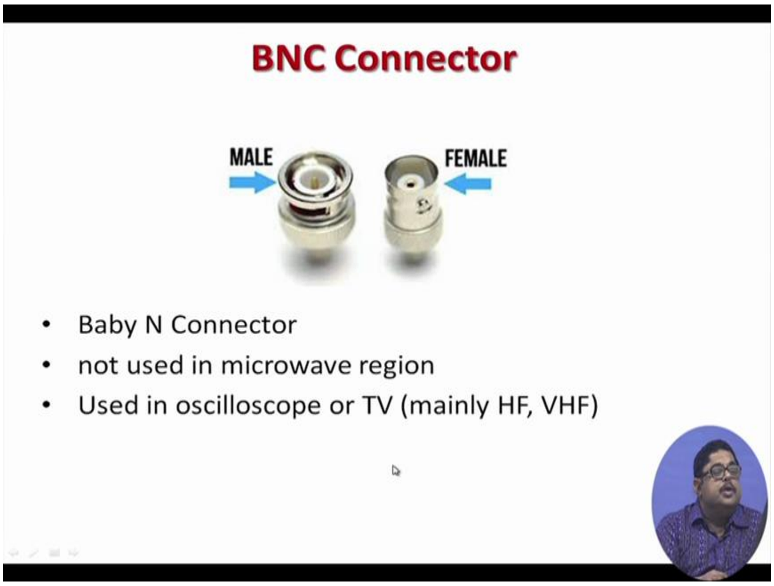
So, you see that coaxial connector going there. That means, we told that wave guide will be the higher frequency counter part of coaxial, but coaxial itself is crossing the boundary and going to millimeter wave things. This is smaller than SMA, outer dia is this.

(Refer Slide Time: 30:39)



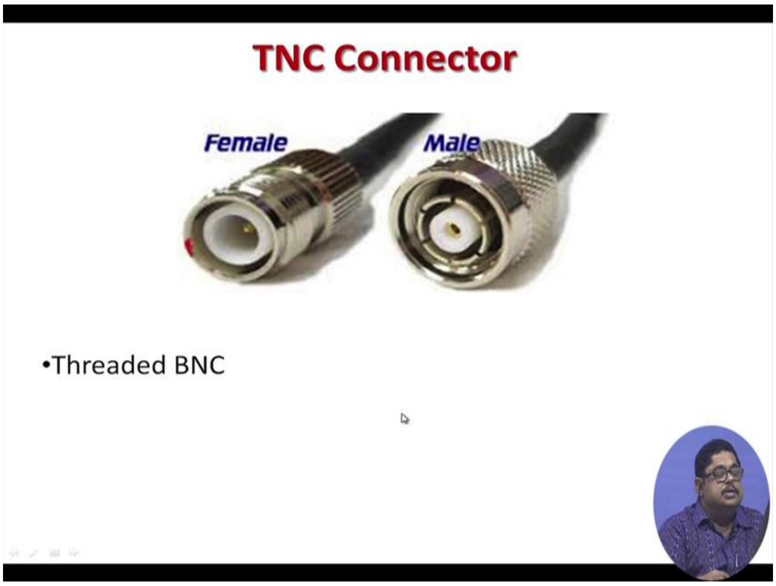
Excuse me, then APC the name comes from Amphenol precision connector. This is the only connector which is sexless. Only butt contact between outer and inner conductor so good and it is very expensive. Not used now a days if you buy any very expensive thing like recently we brought one expensive network analyzer there it was beneficial. But otherwise nowadays most of the things are SMA connectors.

(Refer Slide Time: 31:14)



BNC connector as you already side we have seen this there is a pin here that pin goes inside this slot and fix there is a (Refer Time: 31:26) is called Baby N Connector. N is after that Neill Baby N that is why BNC not used in microwave region used in oscilloscope or TV.

(Refer Slide Time: 31:40)



TNC connector - this much we have seen the various transmission structures, now this week lecture ends today. In next we will try to see that apart from this transmission of power now if I want to divide the power between two or combine the power how to do that that type we discuss in the next weeks theme.