Design Principles of RF and Microwave Filters and Amplifiers
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Module No # 3
Lecture No # 13
Conditional Stability enforcement for Microwave Amplifier

Welcome to this thirteenth lecture of this lecture series on design principles of RF filters and amplifiers you are discussing RF amplifier and we have say in the last class we have seen that depending on the S parameter values sometime we have unconditionally stable devices, transistors. Sometimes we have potentially unstable devices so we need to choose proper load impedance and source impedance so that we can make the device conditionally stable that means a range of values of gamma L and gamma S or ZLN and ZS needs to be defined for which the amplifier will be stable.

So today we will see that and then we will see that is there any simplified way of finding from the S parameters whether the device is conditionally unconditionally stable or potentially unstable. So we can recall that in a loaded transistor amplifier. That means if I have a transistor with its S parameter known an impedance level Z0 we will connect a source. Similarly we will connect a load and we have seen that depending on impedance level here.

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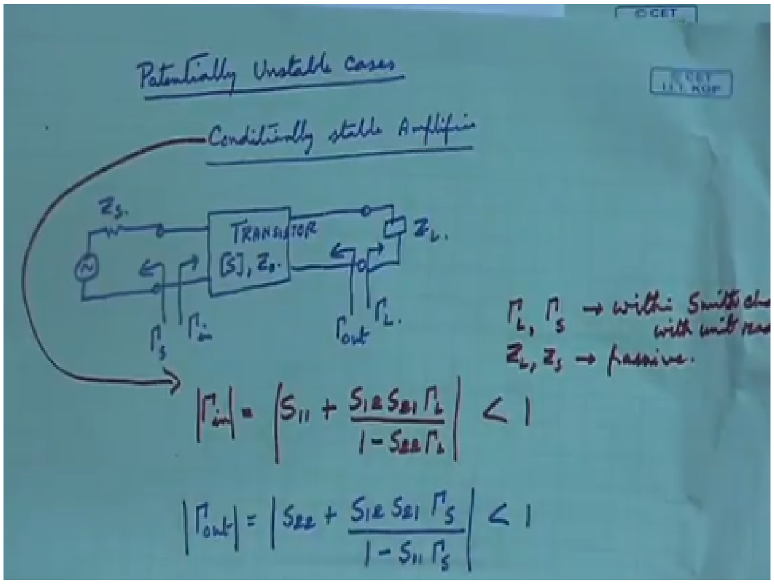

There will be a reflection coefficient both sides that means towards the source that is called gamma S there will be gamma S here there will be gamma in here. Similarly here there will be depending on the mismatch in general there will be gamma L and there will be gamma out also we have seen various gain definitions etc.,

We have seen that transducer power gain will give us the actual value of the power that is dissipated in the load by power available from the source that ratio that means in the loaded condition that investor the full system its power gain that is the useful criteria which will try to maximize finally and achieve a amplifier design. Now last day we have filled that obviously our gamma L and gamma S that means the corresponding ZL and ZS they are passive.

So they should lie within the Smith chart unit circle immature and gamma L gamma S they should be also within the Smith chart with unit radius normalized with that unit radius and we have seen that gamma in is given by S11 + S1 to S21 gamma L by 1 - S22 gamma L that we have already seen and we demand that the device to be unconditionally or whenever potentially unstable also want to be conditionally stable.

We require that gamma in that means this should be less than 1 and also gamma out that is S22 + S1 to S21 gamma S by 1 - S11 gamma is this also needs to be less than 1 otherwise we'll have oscillations so now with which range of gamma L and gamma S will enforce this condition that will see. To do that we see a smith chart there we will find out that actually you see the border region from here is that gamma IN if it is less that 1 it is conditionally stable.

But if gamma In is greater than 1 it is unstable similarly gamma out magnitude less than 1 it is stable conditionally stable and come out greater than 1 it is unstable so these leads us to say that basically the border region is this that gamma IN = 1 if we can locate this locus similarly gamma out magnitude = 1. Then we can divide the whole smith chart into two regions one will be stable region another is unstable region from the stable region will choose our gamma L and Gamma S.

So these, the boundary, the boundary between stable and unstable region in a smith chart is given a name it is called the stability circle, Why circle? Will just now see that it ultimately turns down to be a circle this locus. So this boundary that means locus of all these boundary region the boundary point that becomes a circle that is called stability circle.

So in the you know this smith chart we can consider these as a both as a reflection coefficient plot as well as a corresponding impedance plot so in the reflection coefficient plane. We can say that stability circles are nothing but locus of gamma In equal to 1 or gamma out equal to 1 in reflection coefficient plane of the smith chart.

So that means we have two such locus's so we will have two stability circle, one we call output stability circle that means which determines the value of gamma L that gives the boundary that means for gamma IN is equal to one as you can see that gamma IN is basically a function of gamma IN is basically a function of gamma L as well as parameters of the transistor.

So this output stability circle is when gamma IN = 1 that we call output stability circle similarly gamma out = one that we call in put stability circle because these depends on the choice of source impedance or gamma reflection coefficient gamma S so there are two stability circles. Now let us see one by one. Let us first see the output stability circle.

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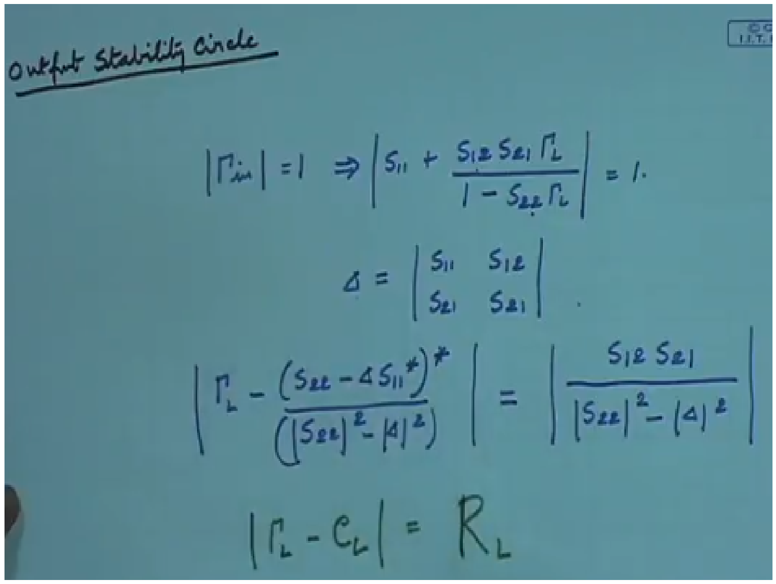

So output stability circle is given by gamma in magnitude = 1 that implies we have S11 + S12 S21 gamma L by 1 - S22 gamma L = now this we can now this equation we can manipulate remember this is values all r S parameters and gamma L we are complex numbers. Also we can define this quantity gamma is the determinant of the S matrix.

So gamma is nothing but S11 is to 1-S21 S12 in general gamma is also complex. So these if we just manipulate these we if we solve for because you see this is one equation where S11 S12 S21 S22 are known quantities gamma L is unknown quantities. So we can solve or gamma L and that gives that gamma L – S22 – delta S11 star whole thing star or conjugate divided by S22 Square – delta square so you see this is simple manipulation remembering the quantities are complex.

So gamma L can be retained as gamma L is equal to this is a real number this is the magnitude of whole thing plus this complex number and magnitude so in this complex plane this represents a circle because you see that this is of the form I can write it as a form that gamma L minus some this is a complex number. So CL it is a complex number is equal to some real value so that I can say as RL.

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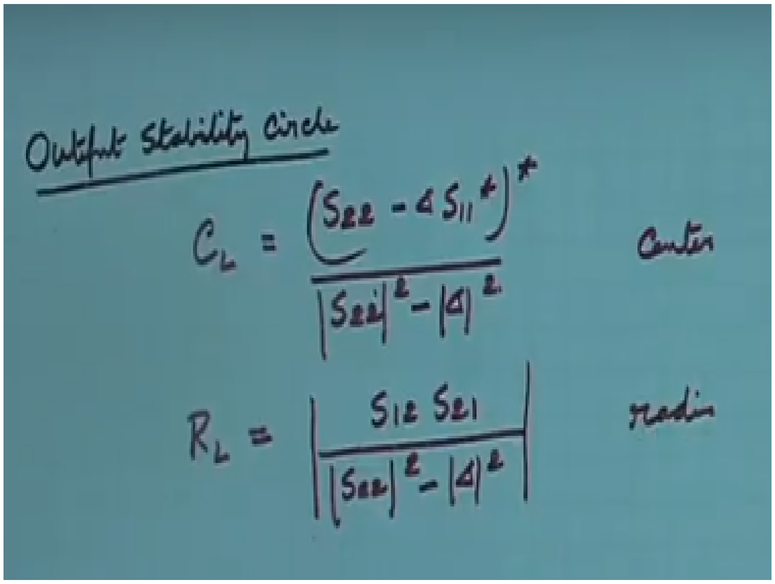

So these represents the circle that is why the same output stability circle so here CL is the centre of the circle RL is the radius of the circle. So we can say that output stability circle it has it is circle is a as a center at CL = S22 – delta S11 star whole thing star divided by S22 square – delta square this is the center of the circle. You know that for the circle if I know the center and radius I can draw the circle knowing the S parameter values or measuring them I can find what is this circle this is the radius of the circle.

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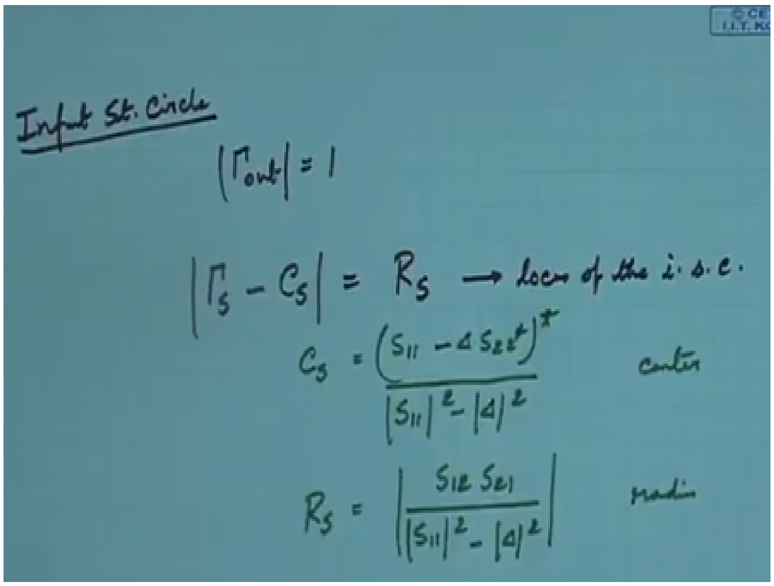

Similarly, I can have input stability circle which will be given by gamma out = 1 again gamma out you know is a function of gamma S. So with that we can find out gamma S if we properly rearrange then gamma S – Cs = Rs this is the low cast of the circle of the input stability circle and what are this values Cs turn out to be S11 – delta S22 star, star means conjugate.

And RS is S12 s21 by S11 square - delta square this is the center of the circle this is the radius of the circle for memorizing you see that CL the S22 is replace by S 11, S11 is replaced by S22 here, S22 is replace by S11. Similarly this S22 is replace by S11 so equations are similar now what these circles do. That means if I have a smith chart if like this then this stability circles there are various choices one thing can be stability circle is completely outside.

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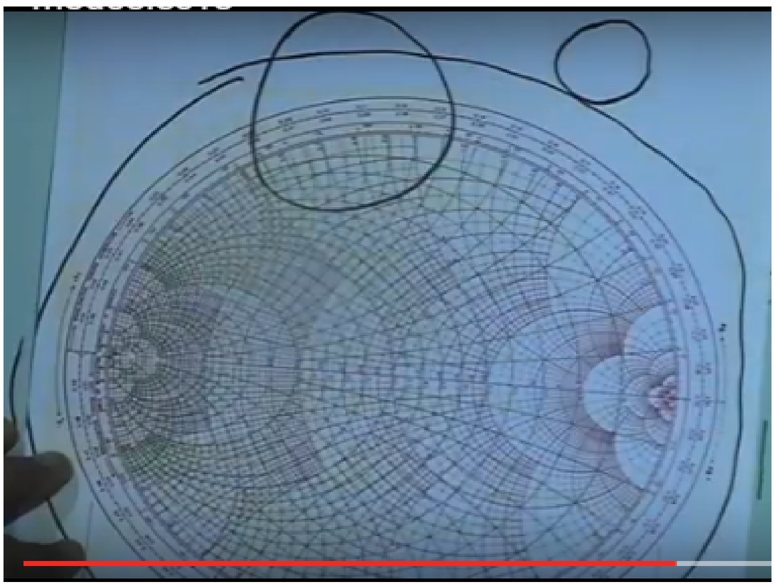

If this is stability circle that means you see that they are not intercepting also I can have instead of these another stability circle is like this. It is completely enclosing the smith chart or the third choice is the stability circle is intersecting with the smith chart. So let us first see that intersection part so if we have this intersection one let us say this is the output stability circle with somewhere centers CL and radius RL.

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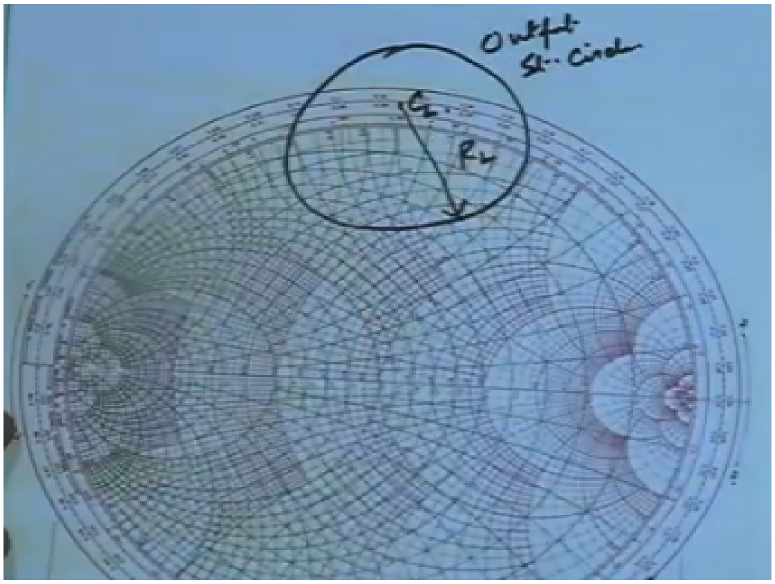

Now what it says this is the output stability circle, so you see that these one has divided this whole smith chart into to region one region is this portion and another region is the one that is inside the circle. Now since this is a boundary this output stability circle means this is the locus of this point gamma in = 1. So I know that one of these either this region or this region will be conditionally stable and another region is unstable.

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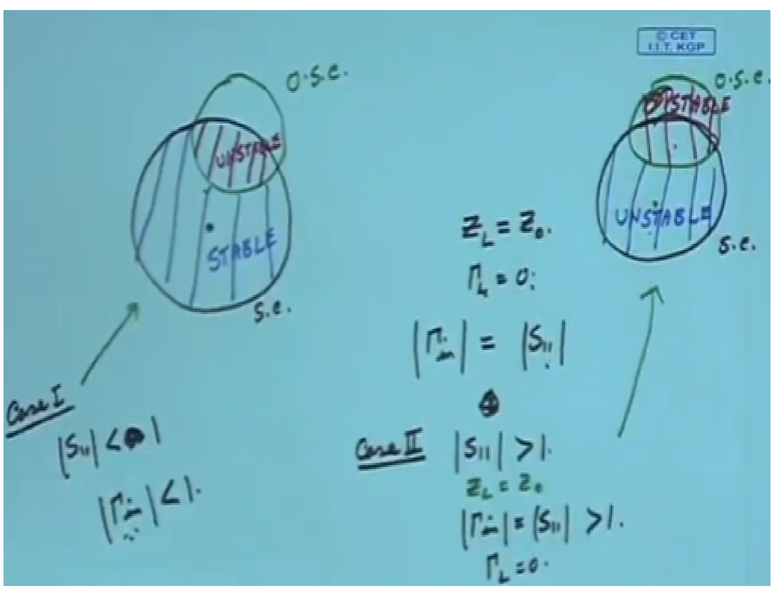

Now I will have to determine which region is stable and which region is unstable. So for that let me draw these that suppose this is my smith chart and this is my let us say output stability circle. Now what I do there can be two cases that is suppose first to determine that which one is stable whether this region is stable or this region is stable. What I need to do in my thing if you see that let me make a choice in my mind ZL = Z0 that means I am choosing the load impedance choosing this load impedance choosing this load impedance same as Z0.

If I do that immediately I can see that gamma I will become 0 so ZL is equal to Z0 makes gamma I is equal to 0 and then I can see from this expression that if gamma n is equal to 0 gamma in magnitude becomes S11 magnitude. So this is one of the choice as we have seen in simple matching we do it instead of conjugate matching I can do this and in that case you see gamma n becomes S11. Now there can be two possibilities this gamma S11 magnitude that can be less than 1 or greater than 1.

Let us say case 1 when it is S11 is less than 1. Now if S11 is less than 1 immediately I can see that but let me write here that gamma IN, in this case becomes less than 1 which was my condition for stability. So that means and where this point lies, you see gamma I = 0 this point will always lie at the center of the Smith Chart. And I know that in this region at this point gamma IN is less than 1 so this is a stable region immediately I got my answer that this is the stable region of the Smith Chart.

So I can say this is a stable region and obviously this one that means this portion of Smith chart is unstable. So I will choose my gamma L from the stable region then I will enforce that the input side is stable. Also now there can be the second case that case 2, case 2, what is case 2 that S11 value I do not have any play with these because manufacturer has given is, it can be greater than 1. If it is greater than 1 and I have made this choice that Z1 = Z0.

So immediately see that gamma IN again becomes S11 but this time it is greater than 1 so I know that this choice that gamma L = 0 this point lies at the center. Let me again, so this is for this case. Let me again draw these. This is the Smith Chart and this is my output stability circles and this is the point now in this case I see this is for case 2 this is the case, you see that gamma L = 0 has led me to gamma N is greater than 1 so this is an unstable region in this case.

So I immediately say that this zone is unstable and then I know that this region is stable region so here, sorry not this whole thing this part inside because my gamma L should be passive so up to this point so then I need to choose my gamma L only from this place if I choose it here I will get an instead of an amplifier it will become an oscillator.

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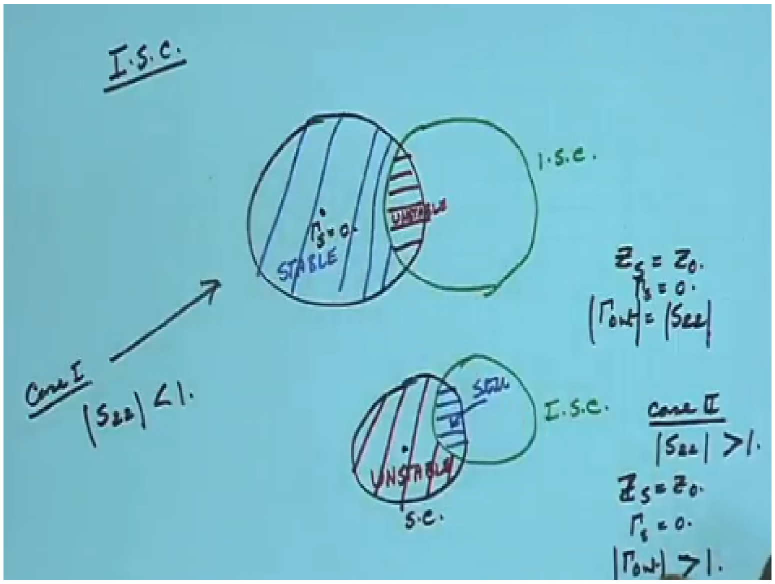

Similarly, I can do the whole exercise for input stability circle. Let this is my Smith Chart and let input stability circle is something like this. This is my input stability circle and that also has divided you can see again the thing here and here that this portion and this portion, so I need to now decide again I do the same thing that I find out that.

Let us take ZS = Z0 that means here I choose ZS = Z0, immediately that makes my gamma S go to 0 and if gamma S go to 0 I know gamma out is simply S22 magnitude. So I got gamma out = S22 magnitude and gamma S = 0. Now I know gamma S, this is my gamma S = 0 point and this is S22. So again there can be case 1 that I have S22 magnitude let less than 1 in that case I know in case 1 know that gamma s equal to 0 so this is the stable region.

So I can immediately say that this is my stable region stable and this portion unstable. So I should not find my gamma S from here I should choose my gamma S anywhere from here so this is for case 1 so I can do the same exercise for case 2 this is my let us say smith chart and this is let us say some other input stability circle and in case 2 I know that S11 can have greater than 1.

In that case my with this choice of ZS = Z0 gamma S will become 0 and gamma out that will be equal s22 that will be greater than 1. So I know that this point of the smith chart as an unstable region. So I will say that these becomes now my unstable region and this is my stable region. So I should choose my gamma S from here so this is for intersection case as I said that I can also have that this is the smith chart and any of the stability circle suppose input stability is this output circle is this.

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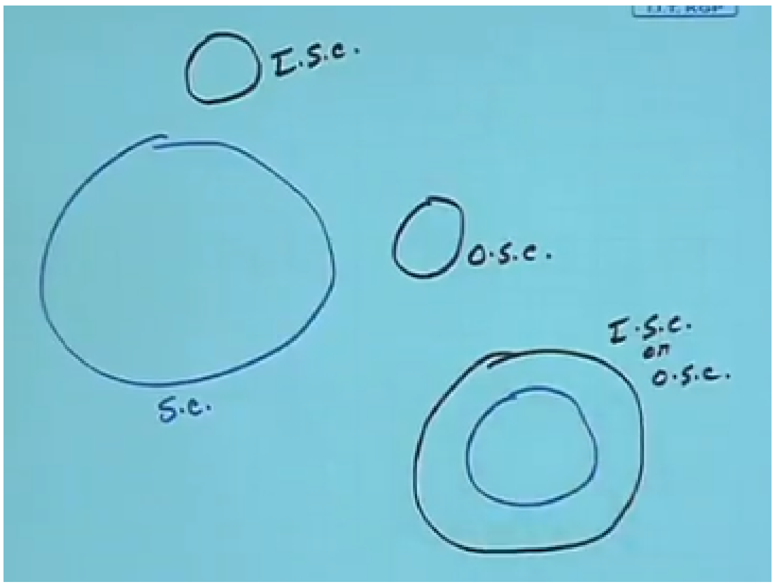

So that means there is no introduction here so I can easily find out that ok in this case. If I locate that there are no intersection means that device is unconditionally stable. Similarly I can also have the case that the stability circle is completely like this ISC or C in that case also I see there are no interaction. So no problem I can have this thing carry on so by this so we can find out that what are the ranges is gamma and gamma L for which we can have the conditionally stable amplifier.

So we will choose accordingly to that, but do we need to plot this circle always that we will see in the next lecture that always? That is not necessary sometimes we can simplify just by some analytic expressions we can find out whether the device is unconditionally stable if it is unconditionally we need not draw this stability circles.

But if it is conditionally or potentially unstable then we need to draw this and locate this points look at these ranges of gamma and gamma L for which I can make the amplifier stable. And so I can use the device even though it is potentially unstable but for my enforced condition of load impedance and source impedance it will behave as a stable device stable amplifier. Thank you.