Microwave Integrated Circuits
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Broadband Impedance Matching
Mod 02, Lec 07

Hello! welcome to another module of this course 'Microwave Integrated Circuit'. We are here, we are starting with week 2. In the previous module we had covered microwave components. And in this module we are going to cover an important application of microwave engineering, which is matching. Now we have already discussed what is matching in the previous classes. Let me just refresh what we mean by matching.

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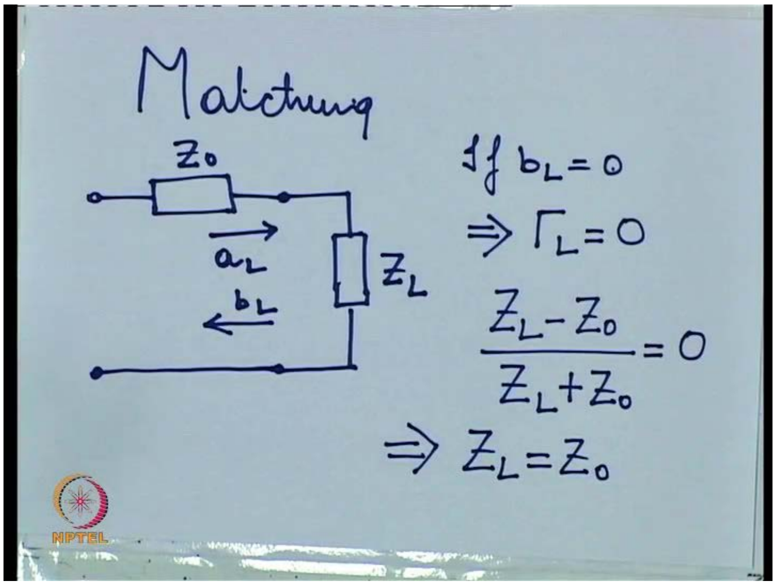

So matching we saw; was if you have a load connected and if this load is supplied by a transmission line or any other network which has a characteristic incidence Z 0 say; and there is an incident wave AL and a reflected wave BL then; our load ZL is said to be well matched with respect to the transmission line having a characteristic impedance Z 0, if BL is equal to 0. This is also; this also can be written as gamma L is equal to 0. Now gamma L we know is equal to Z L minus Z 0 upon Z L plus Z 0, so then this should also be equal to 0, and this being 0 implies ZL should be equal to ZS. Now this is the basic matching problem.

However; when, see the transmission line or whichever device which we connect to the end of the transmission, to the end of the load, if these conditions are satisfied then it will be matched.

But then often it happens that this is true only for a particular frequency, not for all frequencies. So in that cases if we want to say match this load for a wide range of frequencies, not just for a single frequency; then what do we do? So that is what we call broadband matching.

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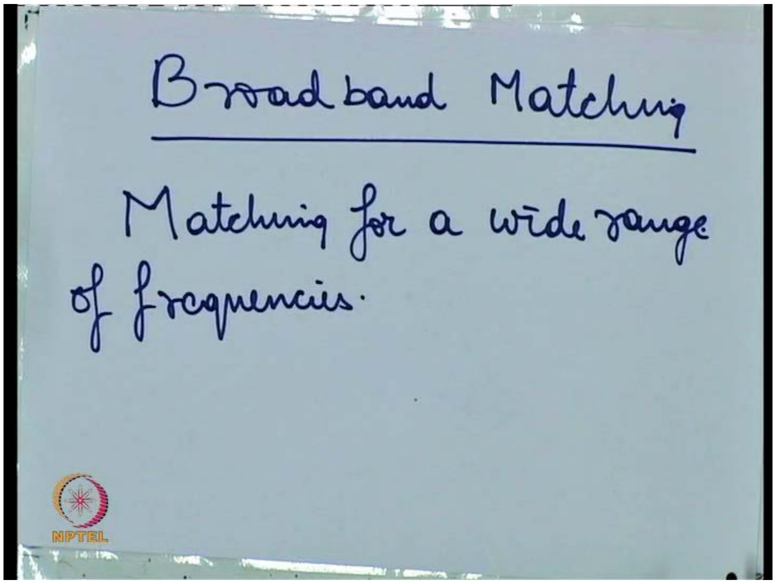

It means matching for a wide range of frequencies. Now the first thing to understand this broadband matching; the first element that we need to consider is the quarter wave transforming, that we had discussed in the previous class. So once again, let’s go back to the quarter wave transformer for a moment.

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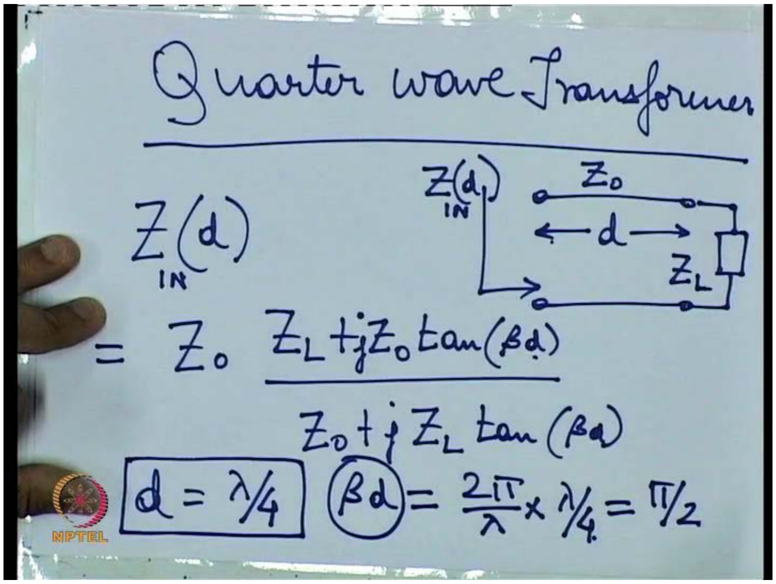

Recall how we had derived expression for a quarter wave transformer. The impedance, the input impedance of a transmission line of length D, having characteristic impedance Z 0 and say we have a load ZL connected as shown, then the input impedance Z D, Z in D is given by this expression.

Now when this expression; when we have a length D, given by say lambda by 4 or in other words the electrical angle beta D is equal to 2 pi upon lambda multiplied by the distance lambda by 4 that makes a total electrical angle of 5/2, so either, so the quarter wave length can be defined either ways. If the length D is equal to lambda upon 4, or the electrical angle of the length of transmission line is pi by 2, then what we observe is, when we substitute into the previous expression that I just wrote down.

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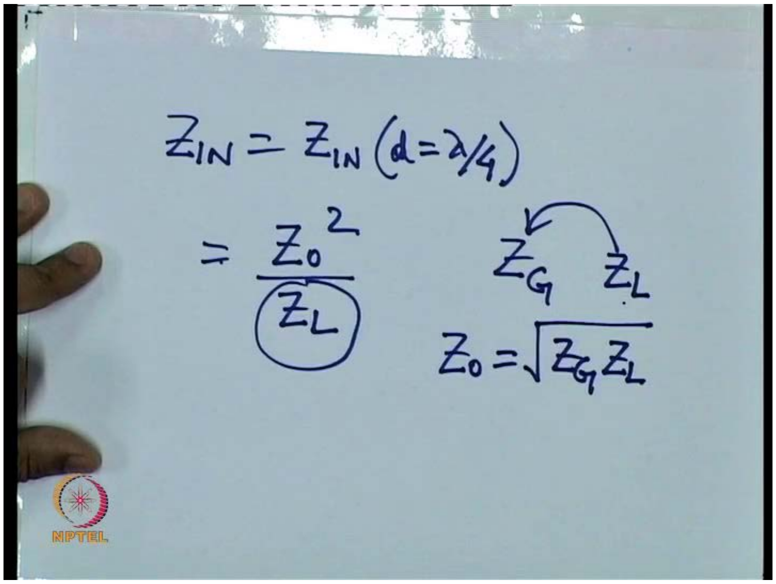

Then what we get is Zn is equal to Z in D is equal to lambda upon 4 which is equal to Z 0 Square upon ZL and from this I said that this is the expression for , it is an inversion expression. What I mean is if ZL is the short then Z in will appear to be as an open or if ZL is an open then Z in will appear to be a short.

And then we also discussed that suppose we want to convert, say we, say we have two values ZG and ZL and if you want to convert ZL to ZG; then we choose a quarter wave length, quarter wave transformer having characteristic impedance Z 0 given by ZG upon ZL. Here of course both ZL and ZG have to be real. So this is the basic expression for a quarter wave transformer.

And now that we know what is the basic expression for a quarter wave transformer; let us sees the frequency response of a quarter wave transformer. Because this quarter wave transformer will provide the transformation only at a particular frequency, the frequency for which it is a quarter wave transformer and not for other frequencies. Now the reason we see the frequency response of the quarter wave transformer is because, we want to see what happens at say a small offset from this frequency for which the transmission line is a quarter wave is of quarter wave.

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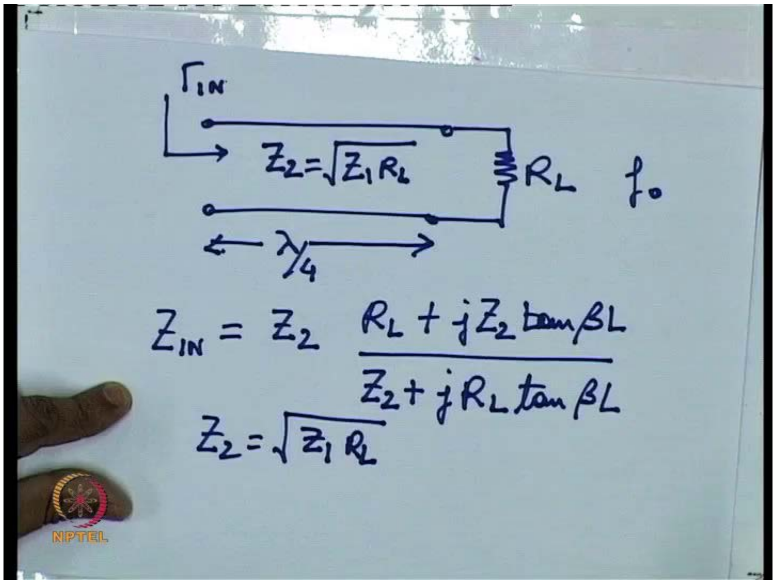

So if we try to do that, when we go back to our expression, let's suppose we have a transmission line with load RL connected and it has, say we have a quarter wave length transformer at a certain frequency F 0, say. So this is lambda by 4 at frequency F 0 and the characteristic impedance is equal to. Okay, then for small offsets the ZE can be written as Z2 RL plus JZ2 tan of beta l Upon Z2 plus JRL tan of Beta L with Z2 being the square root of Z1 and RL. So Z 1 is the value to which we convert the load RL at the frequency for which the transmission line is a quarter wave length.

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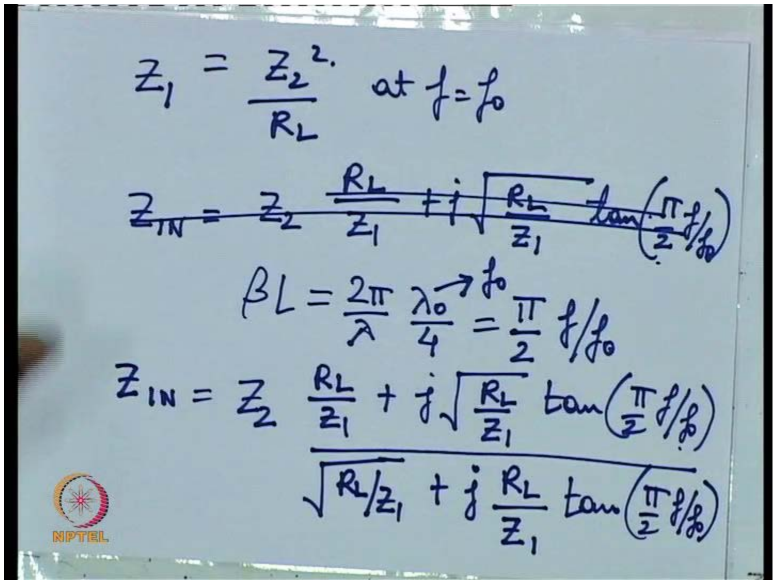

So now if we substitute; here Z1is equal to Z 2 square upon RL or the value of the input impedance at F equal to FCL, Now with this expression, if we go back to, no if we go back to the expression for Z in then it comes, we can we can write it like this; By dividing the numerator and denominator by Z1 we can write our expression like this. Now here this expression I by 2F upon F 0 is actually the value of beta L. Beta recall is equal to 2 pi upon lambda. But then L is equal to lambda 0 upon 4, where lambda zero corresponds to the frequency F0 for which the our transmission line is the quarter, is the quarter wave length length.

So lambda is the wave length of the current frequency that is it may not be equal to lambda 0, it may be for a frequency which is slightly shifted away from F0. And this is equal to pi upon 2 F upon F0. Then Z in, sorry I didn’t write the whole expression, I will cut this down I’ll just do it so that I can write it once again. Z2 is equal to RL upon Z1 plus J square root of RL upon Z1. Tan of 5/2 F uponF0. This whole was, okay.

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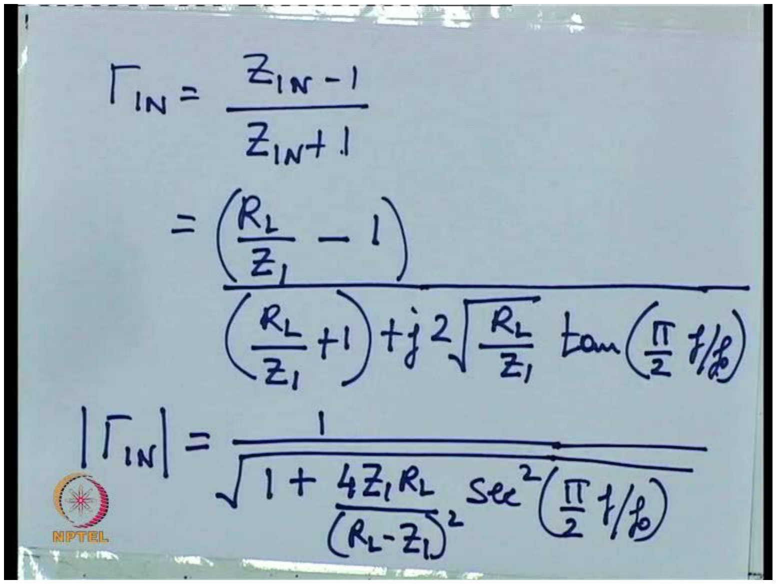

So then since I Know Z in I can find an expression for gamma N. Gamma in, the input reflection co-efficient will be given by Z in minus 1 upon Z in plus 1 and this after some mathematical steps comes out to this expression. And then if I write an expression for the magnitude if this gamma in it comes out to. So this is my expression for the gamma in on the magnitude of the input reflection co-efficient.

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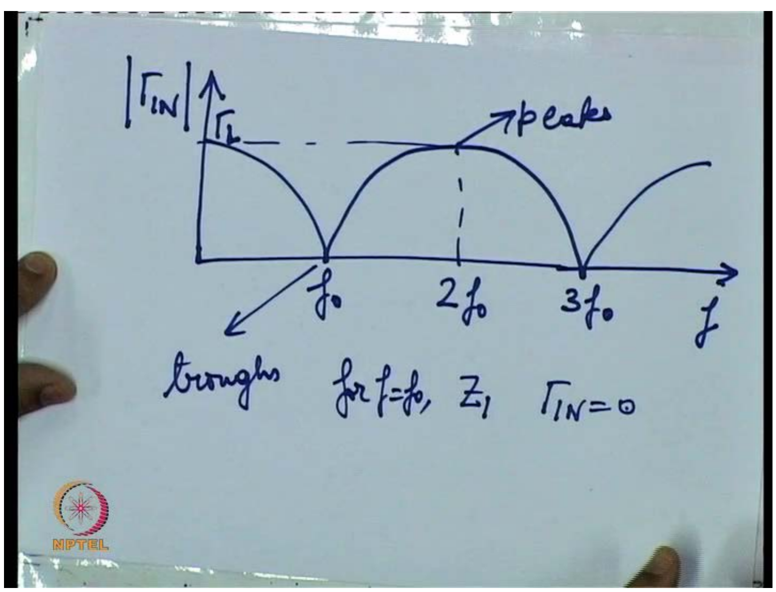

If I plot this expression, the kind of graph that I get is like this. So there are troughs and then there are peaks. For F equal to F0 okay, the input impedance is Z1, hence gamma in is equal to

0That is one simple definition. Now this whole expression is repeated here. For every odd multiples of F0, it is repeated. and for even multiples you see that gamma in reaches a maximum value and that is given by the value of gamma L. The maximum value that is reached is equal to Gamma L.

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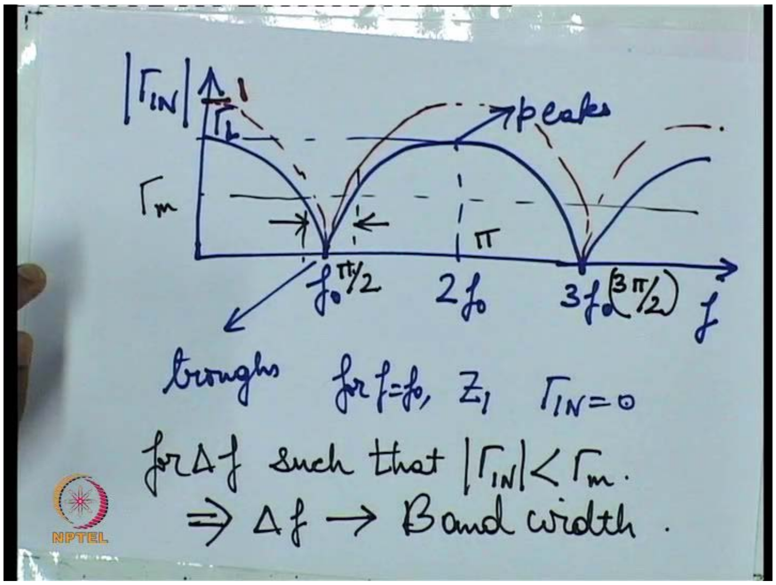

If you change the value of Gamma L, say we keep on changing the value of gamma L, then what happens is, say if we increase the value of gamma L, then our graph changes like this, That is we change our ZL so that gamma L increases. But gamma L will have a maximum value of 1, one which we cannot increase it and uhh, that's all basically. We cannot make any further changes. We can only keep changing our ZL so that our gamma L changes and that way he can control the band width.

So now that I mention the term band width let me define what it is. In the case of impedance matching, the concept of band width is a little different from the normal 3bp band width we are familiar with filters. Suppose I choose a certain value gamma N and this is the value as say that any time my value of the magnitude of gamma in is below this gamma M, then that frequency range over which magnitude gamma that is for F such that magnitude of gamma in is lesser than gamma N. I call that range of frequencies or say I say, delta F well that delta F is called a band width. Okay.

Now this 2 F0 also corresponds to the length pi F0 corresponds, as we know on a quarter wave is of length 572 electrical length and this corresponds to 3 pi upon 2.

Some of the conclusions we can reach is ,okay, one thing that we saw was that, if we keep increasing the value of gamma L then the band width actually decreases, Isn't it. Because this becomes narrower the band width decreases with increase in gamma L. and the second thing that we see is that the input reflection co-efficient magnitude is a periodic function of frequency, and a perfect match is obtained, wherever we have these troughs, that is odd multiples of F0.

Now we have defined what is the bandwidth. we said that whenever the magnitude if the input reflection co-efficient is lesser than certain value gamma M , that we ourselves have say we defined, then that constitutes, those range of frequencies for which the gamma M value, Gamma in, pardon, the magnitude of gamma in value is lesser than gamma N , is the band width. Band width of the quarter wave transformer.

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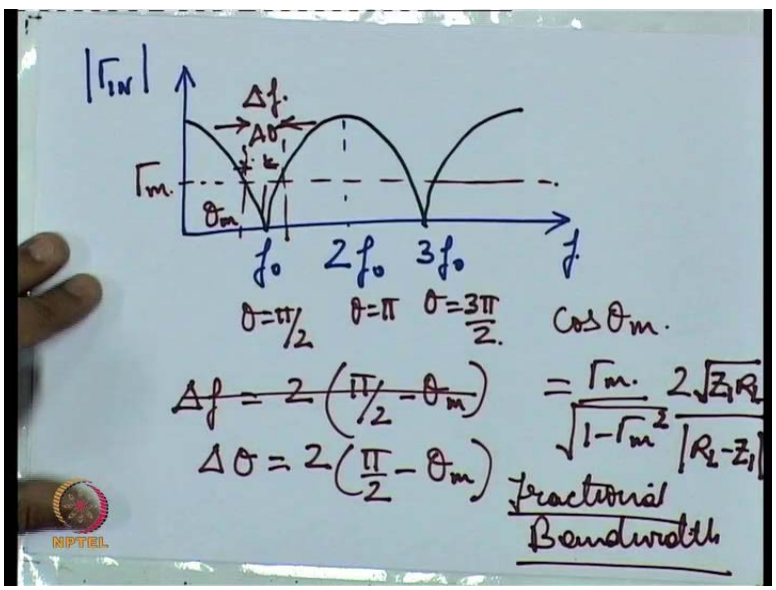

So now if we go back once again to our curve, so we have F this is magnitude gamma E, this is , this is the curve that we just saw and these are the values of F0, 3 F 0, this is 3F0, and then I define certain value gamma E, gamma N like this. now. And so suppose this point, where the this value of frequency for which the input the gamma N modulus is equal to gamma M, I call that electrical angle theta M.

So as you know at the point F 0 theta will correspond to pi by 2 and at 2F0 theta will be equal to pi, at 3F0 theta will be equal to 3pi by 2, this we just discussed. Now the spoken band width delta F is equal to twice of pi by 2 minus theta M. Okay. Or we can you know say that, I should I should have written this, I should have written this a delta theta. Delta theta which corresponds to delta F, so I can write here delta theta also.

Delta theta is equal to twice of pi by 2 minus theta M, because this is pi by 2, this is pi by 2 minus theta, twice of that is delta theta. and this theta M is found out from this relationship; cos theta M is equal to Gamma M over 1 minus gamma M square, okay. So we kind of find out the value of theta M and from there we can find out the value of, uhh; we can find out the value of delta theta and we have a term called fractional band width.

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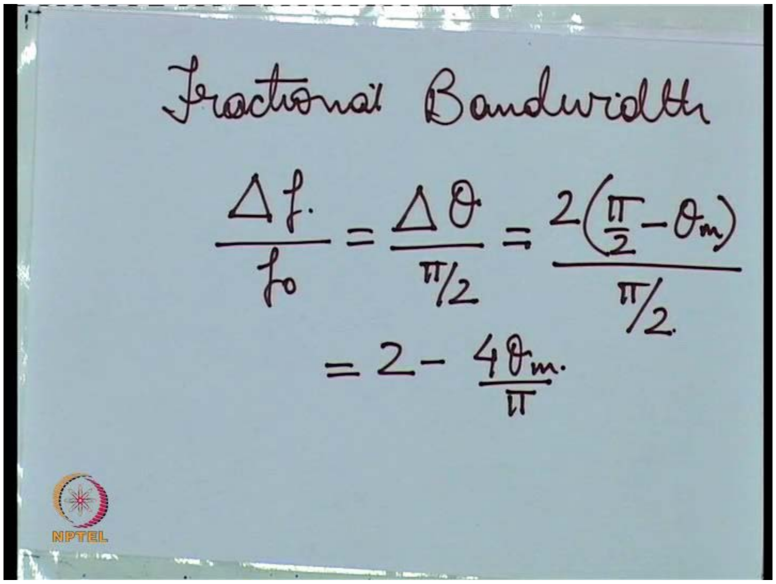

So let me define what is fractional band width. Fractional band width is defined as this ratio, which I can also write as equal to delta theta upon pi by 2 and that is equal to twice of pi by 2 minus theta M upon pi by 2. Which comes out as 2 minus 4 theta M upon pi. Now the way usually these designs happen is that you are given a value of gamma N from which you find out the value of theta M and from which you can find put the fractional band width. So this is the maximum fractional band width that is possible from a quarter wave transformer.

Now this module was of course on broadband impedance matching, and we see that with a quarter wave transformer you can get only a certain band width. You cannot go on increasing the band width. You can increase, decrease the band width by increasing gamma L or by decreasing gamma L you can increase the band width, But there are some limitations.

Now always our requirement may not be same as that what is, what can be provided by quarter wave transformer. so then we have to look to other mark-ups to obtain an even higher band width, such a method is obtained not by one section of transmission line but many sections of transmission lines cascaded with each other. So that is called multi section, that kind of structure is referred to as a multi section impedance matching circuit or a multi section broad band matching circuit, which we shall cover in the next module.

Thank You.