Microwave Integrated Circuits
Prof. Jayanta Mukherjee
Department of Electrical Engineering
Filter design: Image parameter method, Insertion loss method
Mod 05, Lec 21

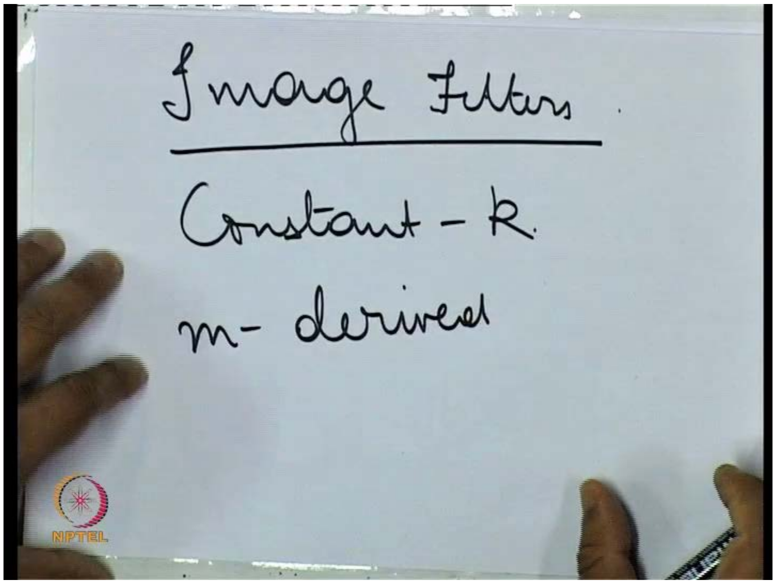
Hello! Welcome to another module of this course 'Microwave Integrated Circuits'. In the previous modules we had discussed about narrow ban filters and I have said that because of the special properties of the distributed elements like shortened transmission lines it is actually easier to realize resonator as compared to lumps equivalence or equivalence of lumped elements like l and c.

Then we also showed some improvement in the design of such resonators using the gap couple ratings and then we discussed how using those elements you can design band pass and stop filters. In this module I will be introducing to another class of narrow band filters called constant K and M derived filters. These filters belong to a class of filters known as image filters. So let us discuss these filters in detail.

Now first thing that I want to state about these filters is that now a day's not many of the filters that are designed, are designed as image filters, but they had a special place in the olden days when synthesis methods were not that developed. So what these methods relay on is having identical sections of similar elements in cascade and the rule is that more the number of sections you have, the better the performance of the filters will be.

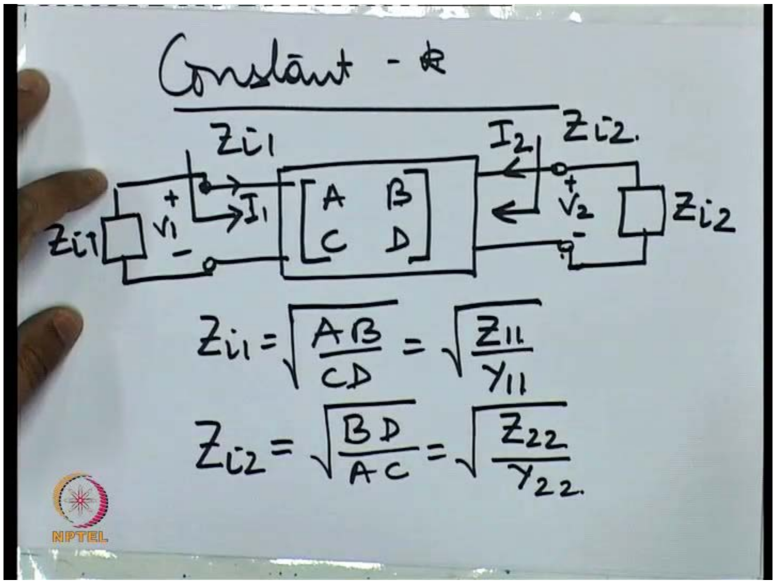
So the basic fundamental units of this filter is a unit cell and two parameters characterize these cells, one is what is that knows as the image impedance, and the other is known as the propagation constant. So let us discuss these, what are these unit cells.

[Refer Slide Time: 02:30]



So in image filters as I said that they can have two different types of image filters one is known as the constant K and the other is known as the m-derived.

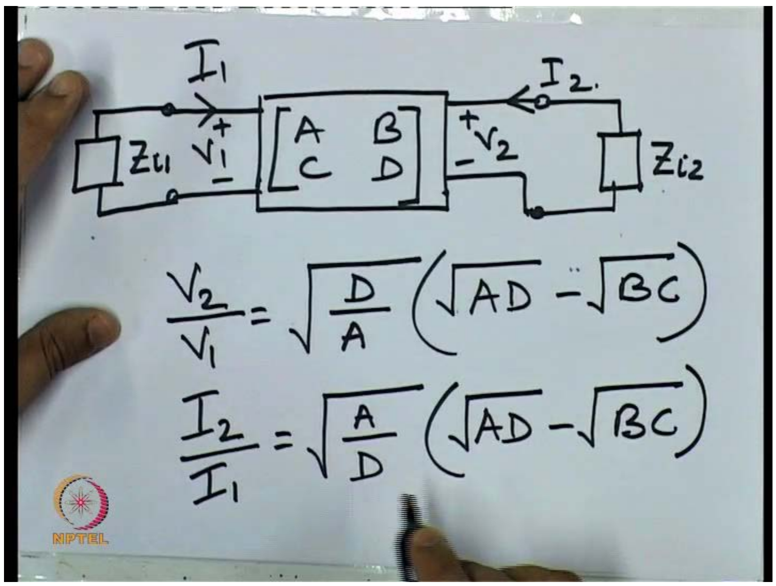
[Refer Slide Time: 02:50]



Now, let us see what is this constant K filters. Before discussing this, this type of filter let me a slight diversion and let us just try to establish what is this concept of image impedance. So suppose you have a two port network represented by its ABCD matrix, then the image impedance is defined as that impedance which when connected to any port. Suppose I connect an impedance ZI1 here and this is the impedance ZI2, then ZI1 is said to be the image impedance at port 1 and the input impedance at the port 1 is also ZI1 and ZI2 is said to be the image impedance at port 2, if the input impedance at port 2 is also ZI2.

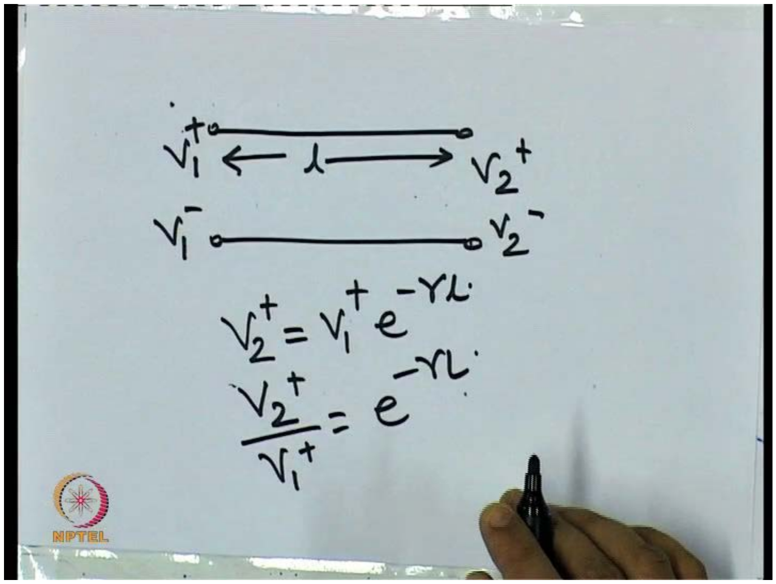
Suppose this is the this is where the voltage and v1 is the voltage at port 1 and v2 is the voltage at v2, I1 is the current at port 1 and I2 is the current at port 2, then it can be showed that ZI1, is equal to AB upon CD which is equal to Y11. Now this is the concept of image impedance.

[Refer Slide Time: 05:10]



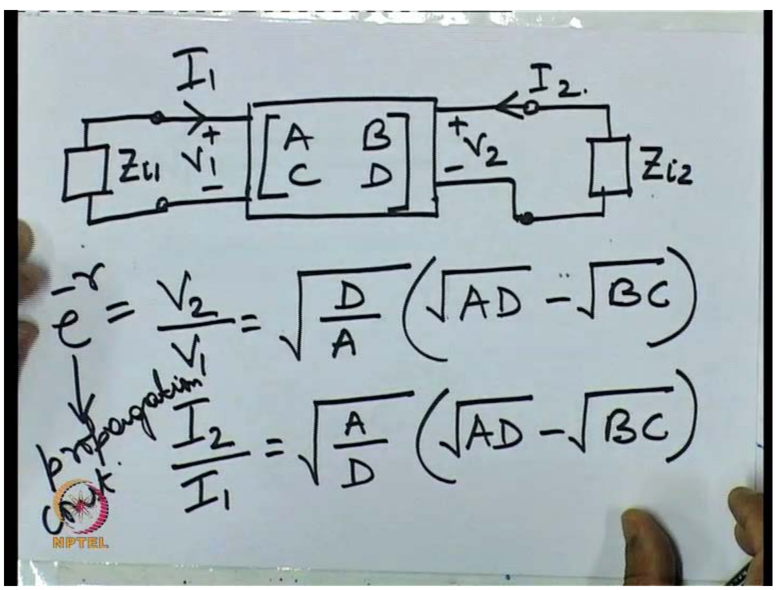
Now, coming back to the same network once again, suppose the two ports are terminated by their image impedances, then we can have this relationship between this voltage at port 2 upon voltage upon port 1 like this. Now what is this ratio v2 upon v1 and I2 upon I1?

[Refer Slide Time: 06:40]



Now if we go back to a transmit ion line equivalent because there we had seen suppose V1 plus and V1 minus, V2 plus and V1 minus. we had seen that v2 plus is equal to V1plus e raise 2 plus gamma L. So it's like this ratio v2 plus upon v1 plus is equal to minus gamma L.

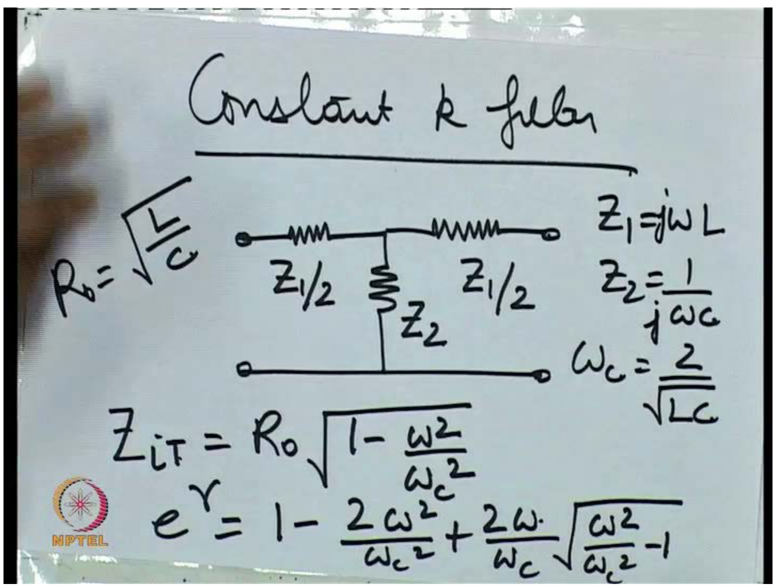
[Refer Slide Time: 07:40]



Now applying the same logic if we find this ratio v2 upon v1 and equate it to this term e raised to minus gamma, this is called. This is equivalent to propagation constant. Of course the only... there is difference, here this ratio doesn't depend on any length whereas for a transmission line which we saw there is a gamma L term, here there is just a minus gamma term also this is the ration of the absolute voltages, not the incident or the reflected waves.

But still this v2 upon v1 gives... can be termed as a propagation constant and the proper value of this propagation constant depends on whether the game is real or imaginary and determines whether the wave will be attenuated or passed. So, if gamma is purely imaginary, then there is no loss and the wave will be passed, if gamma has some real term which shows attenuation then.. Then over that particular frequency there will be a tenure ship, so this is the principle. Depending on what this value of propagation constant is we can define the pass band or the stop band of the filter.

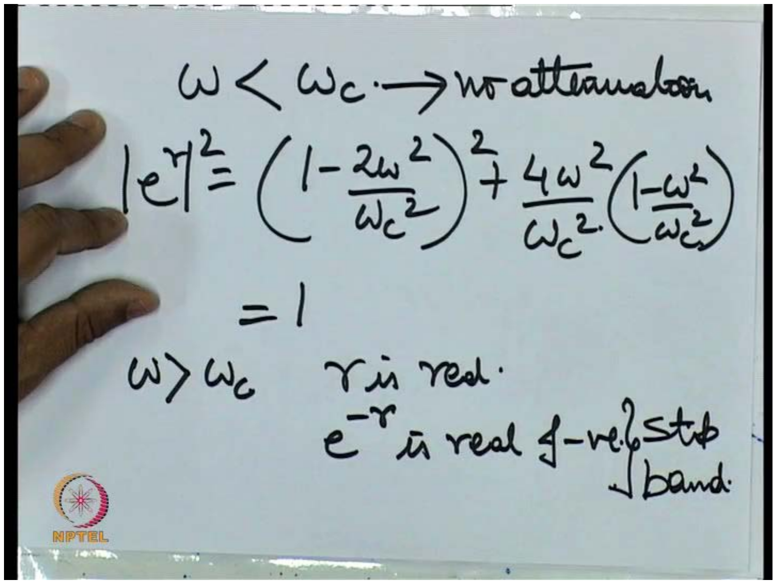
[Refer Slide Time: 008:55]



So based on this now let us come to the constant K filter term that I mentioned but didn't explain in full. The constant k filter has an unit cell which is given like this, now that image impedances, this is a symmetrical circle will be the same at all the ports They are given like this and the propagation constant is given like this. Now the derivations for these terms are given in this book by Pozar, as mentioned in the syllabus for this course, if you wish you can go through them.

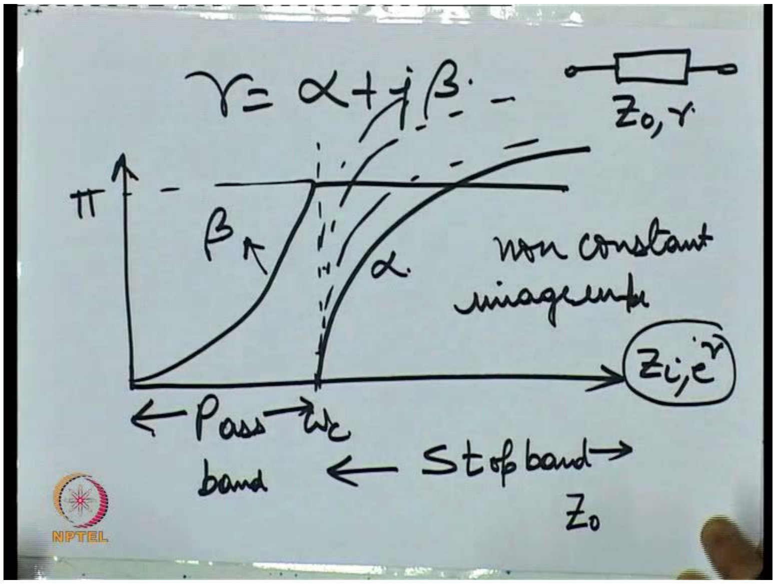
Now suppose if Z1 is equal to omega L and Z2 is equal to 1 upon omega C, then omega C, this term is given by this relation 2 upon LC and this R 0 term is written by square root of LC, that should be J.

[Refer Slide Time: 10:40]



Now taking this further, what we see is at for a certain frequency where omega is lesser than omega C, this propagation constants, this magnitude square is given by.... and this is always one because when omega is lesser than omega c, gamma is purely real and if gamma is purely real than the magnitude square will always be one. So in another words for omega lesser than omega C there is no attenuation, and it corresponds to the past band of the filter. For omega greater than omega C, gamma is real and hence E to the power minus gamma is real and negative and this corresponds to stop them.

[Refer Slide Time: 12:01]



So then if we plot alpha and beta or the gamma, i.e. if I represent gamma as alpha plus J beta and if I plot these individual alphaas and betas then and suppose this is omega C then beta will be like this and alpha will be like this. As you can see alpha is 0 in the past one, alpha always represents attenuation, hence this is the past band of omega lesser than omega C, where as beta increases from 0-pie from the past one and then omega c it remains at pie and remains constant after.

But, note from this graph itself the problem is, for a single unit cell the attenuation is quite low in the stop band, of course when you have large number of such unit cells then it cascades with each other, then this alpha, this characteristics will go on changing like this and see for a infinite number of stages we will get an ideal filter which is perfect square wave form.

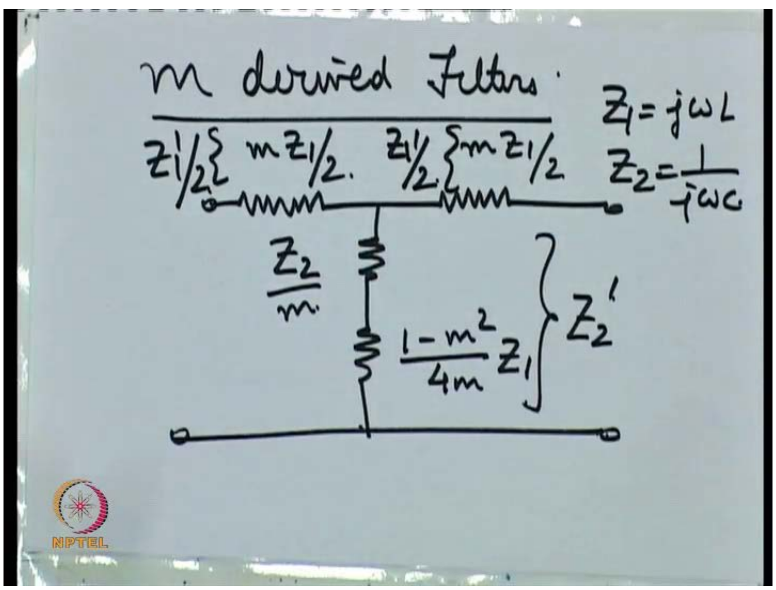
But since the large numbers of filters are not possible and also there is... in addition to this slow attenuation in the stop band this is also the problem of non constant image impedances. Now you can image this image impedance and the propagation constants are just like in a transmission line, we have these two parameters, one is Z0 and gain which completely define the characteristic impedance, for this image filter also, this image impedance and this propagation constant.

They completely define the unit cell and we have seen for matching purposes a transmission line is to be connected to impedance Z0, similarly for matching purposes a unit cell or the entire image filter needs to be connected to the image impedance. Now if the... see the way it goes is that the image impedances for the unit cells are what it is to be seen for its input and output for each unit cell. As far as... since this structure is symmetric the image impedances will be the same on the input and the output port.

So if we want to just cascade large number of unit cells then it is very easily possible since the image impedance at the input and the output is constant. But at the between each and the each unit cell it is not a problem because they are... they have the same input and output image impedance and they can easily be matched, if it varies, if the image impedance varies with frequency then it will vary for all the unit cells.

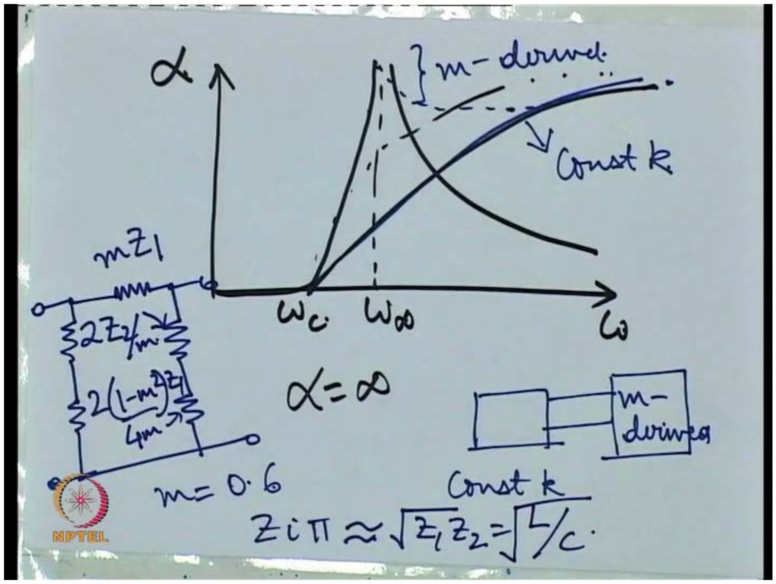
But at the input and the output of the entire chain of unit cells there that might be a problem because we prefer usually a constant real input and output impedance where as this image impedance keeps varying with frequency, it might be imaginary, it might be real or it might be complex, so to... so there are the two problems associated with the constant K filters.

[Refer Slide Time: 16:01]



To get over this problem, somewhat there is another type of image filters called M derived filters. so m derived filters are the variations, their structure is somewhat like this... So this is the structure, it is a slight variation instead of Z1 upon 2, we now have MZ1 upon 2 and what used to be Z2 is now actually a combination of an inductor and a capacitor. Now this is a basic structure of a or the basic construction of a M derived filter if we plot the attenuation of this filter, the derivations are again given in the book by Pozar.

[Refer Slide Time: 17:40]



I will just directly plot the attenuation graph to give you a better idea, so here if suppose I plot alpha with frequency, then the (struc) then the characteristics that I will get is something like this. Omega C remains it remains the cut off frequency, just like in the constant K filter, but now you see the attenuation is much higher in the stop bank. Till omega C, alpha is equal to 0, but then beyond omega c the attenuation increases rapidly, there is a frequency called the omega infinity where alpha is infinity and beyond alpha infinity you can see that the alpha value decreases gradually.

So again this is the problem of the m derived filter as well. Whereas just between omega c and omega infinity the attenuations is quite high, beyond omega infinity, however the attenuation is not that high. On the other hand for the constant k filter beyond omega C large frequencies which are far away from omega C, there the attenuation is quite high because for a constant k filter those characteristics was like this.

So for these high frequencies the value of alpha was high. so usually also... also one more thing that I would like to mention for these M derived filters is that the... the problem of image impedance is not solved entire, so what is done usually is a combination of this M derived filter and this k filter is often done and actually if we do that, for example let's say, let me take that red pen. Say this is the characteristics, suppose this is the characteristics of the constant K and this is the characteristics of the m derived. Then a composite filter will have characteristics something like between this. Dotted black represents the composite characteristics of a constant K in cascade with a m derived.

Also to solve the problem of the image impedance not being constant with frequency if you... we can derive the pie equivalent of this m derived filter, which will be something like this and the same is repeat here as well. It can be shown that when M is chosen as 0.6, ZI pie that is the image impedance of this pie equivalence will be nearly equal to Z1 upon Z2, which is equal to L upon C, L upon C square root. So here, for this particular value of M the value of this image impedance remains somewhat constant.

So in summary we saw the a particular class of filter called image filters, now depending on how many stages of thee... of the unit cells that you use that depends whether it is a broad band or a narrow band filter. So a clear classification like we have said between narrow band and the broad band filters cannot exactly be made for this image filters.

But the concept is interesting because it is just like a transmission like where we have a larger... if we have a large number of sections then we can design certain attenuation in the soft band and a certain cut off frequency. However with the present day where we have the advanced technology for synthesizing our desired filter response these filters are not that common. So in the next module we will be studying about synthesizing filters as we said that the broad band filters.

Thank you