Principles And Techniques Of Modern Radar Systems
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Lecture – 17
Double DLC and Recursive MTI Filter

Key Concepts: Concept of Double DLC/three pulse canceller, Alternate implementation of DDLC, Recursive MTI filter/ Implementation MTI filter with feedback.

Welcome to this NPTEL lecture on Principles and Techniques of Modern Radar Systems. We were discussing MTI Filter. Out of that we have seen in the previous class, the single delay line canceller. We have seen that it is has a problem of blind speed and for that actually we have seen that ultimately the DLC that is suffering from two drawbacks. That one is the stop band notch around the DC is not sharp. So, it will not be able to remove the clutter to the extent that is desirable in the radar applications and also its pass band response is not uniform.

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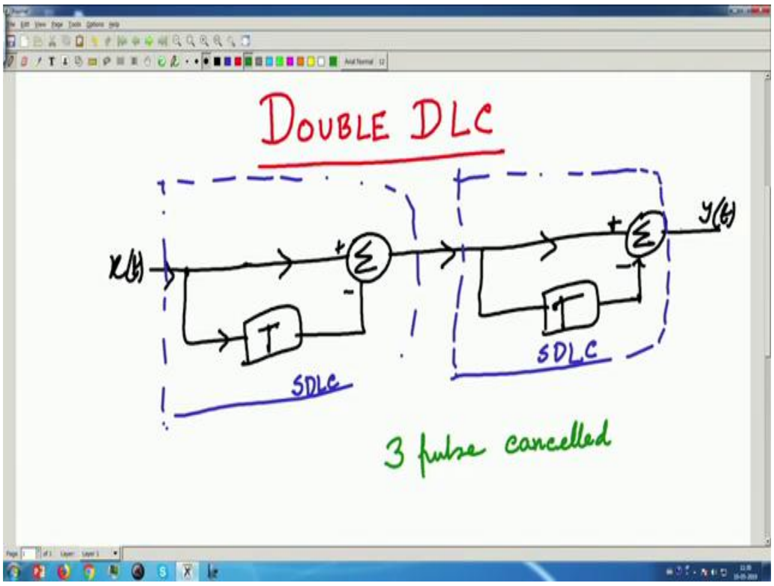

So, today we will see some betterment of that. So, that thing is called double DLC that means you put two stages of single DLC. So, the block diagram will be that; I will have a this is a single DLC. So, let x t is coming and we are putting it here, we are putting delay. So, this is a I can say single DLC. So, and say SDLC and then this one again we are giving to another stage of SDLC and let me call these y t is the final output.

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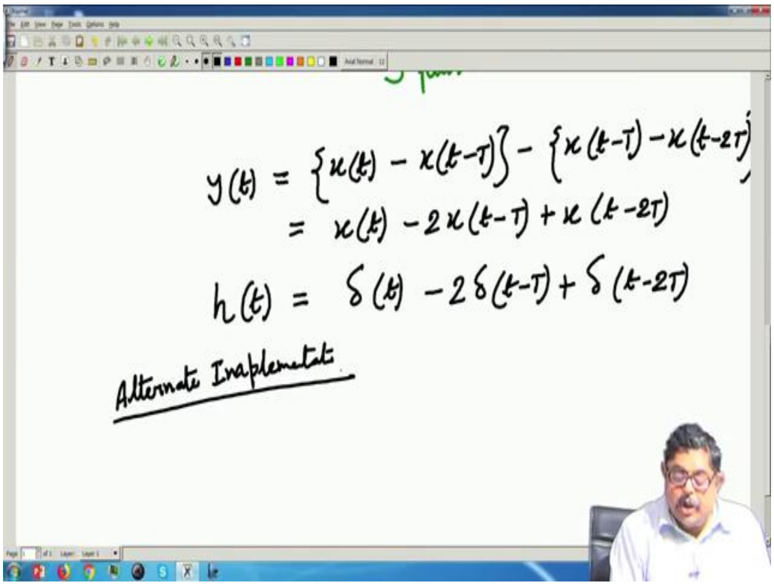

So, this is another stage of SDLC. So, two stage DLC. So, now, we can we should call it a 3-pulse canceller, because now the original pulse and 2 delayed pulse. So, total 3 pulse should be received then only the output can be seen. So, that is why it is also called 3 pulse DLC and we can derive its transfer function that y t is you know first the first one that is x t minus x t minus t then x t minus t minus x t minus 2 t. So, this is basically x t minus 2 x t minus t plus x t minus 2 t.

$$y(t) = \{x(t) - x(t-T)\} - \{x(t-T) - x(t-2T)\}$$
$$= x(t) - 2x(t-T) + x(t-2T)$$

So, the moment I write this I know what is the impulse response? The impulse response is delta t minus 2 delta t minus tau plus delta t minus 2 t.

$$h(t) = \delta(t) - 2\delta(t-T) + \delta(t-2T)$$

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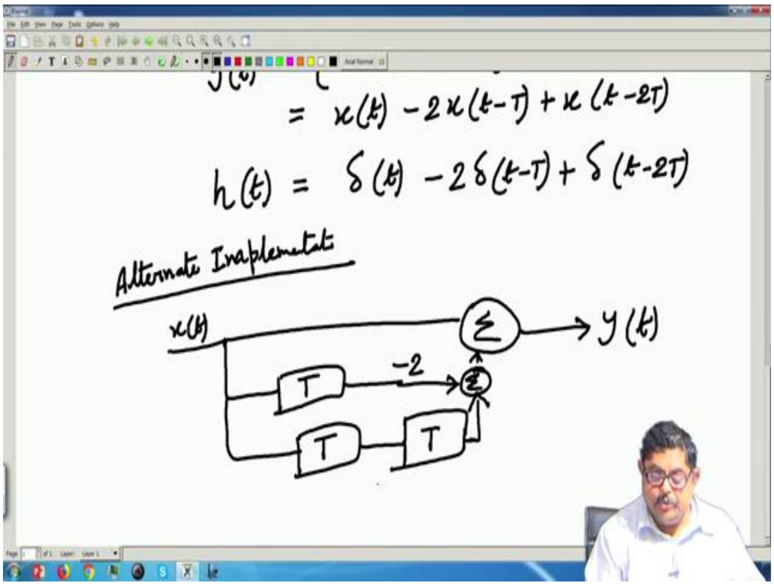

So, by seeing this we can say the there is another implementation of the same circuit for this same impulse response. So, you see that I can have another implementation or alternate implementation of the this double DLC, that I can do it in a transversal filter form, which we will be a to realize it will be easier. So, I have the x t, basically I will put a summer here and this one I will take to a delay of T. And before giving here I will put a weight of minus 2 here, because this minus 2 and then there is another delay element and that.

So, in this path I will have to have 2 delays. So, these this is also T and so, here I can put instead of the say summer. So, this output you take as y t. So, these you know that this is the called transversal filter implementation. Here it is easier because instead of cascading two stages you can have this just put the weights here.

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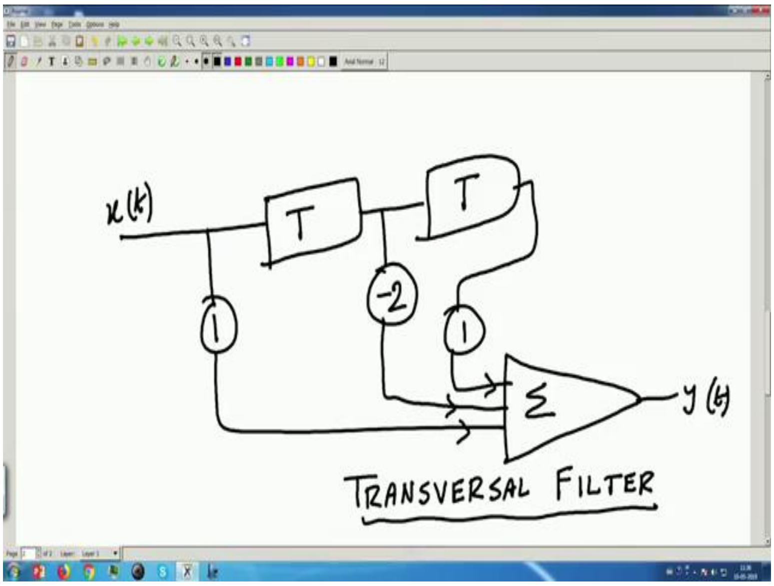

So, instead of this we can use that transversal filter. So, I will say that the transversal filter implementation of DDLC so, this is much easier. So, you put that original one is weighted 1, this one minus 2 and this one will be again 1. So, this is a so x t is coming. So, this we know because ISI filters in communication. There also done like this transversal filter. So, it is a alternate way of implementation and much simpler. If you once you can write the impulse response from that these can be done, the implementation. So, this is our output y t we can say.

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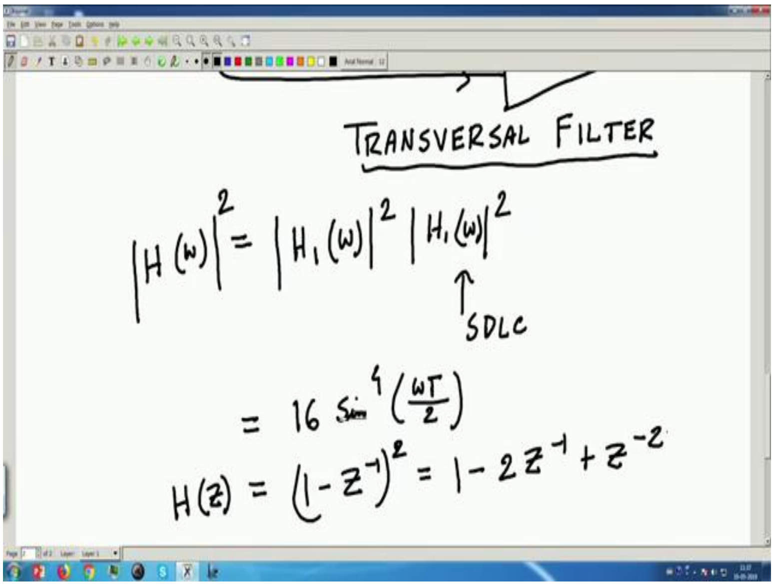

So, we have already seen the impulse response. So, immediately we can write the transfer function of this. So, I can write that transfer function will be so, can I see that the transfer function is simply that, actually we want yesterday also we have plotted the power so, I am that is why writing this. So, that is since they are two cascaded things, I can say that this is nothing but so, this is for single DLC. So, multiplication of that so, I yesterday we have seen these values so, I can directly write 16 sin 4 th omega T by 2.

$$|H(\omega)|^2 = |H_1(\omega)|^2 \, |H_1(\omega)|^2$$

$\uparrow$ SDLC

$$= 16 \sin^4\left(\frac{\omega T}{2}\right)$$

So, this is our thing and in z domain I am writing now that if I want to write the transfer function in z domain then, we know this is 1 minus 2 z inverse plus z to the power minus 2.

$$H(z) = (1 - z^{-1})^2 = 1 - 2z^{-1} + z^{-2}$$

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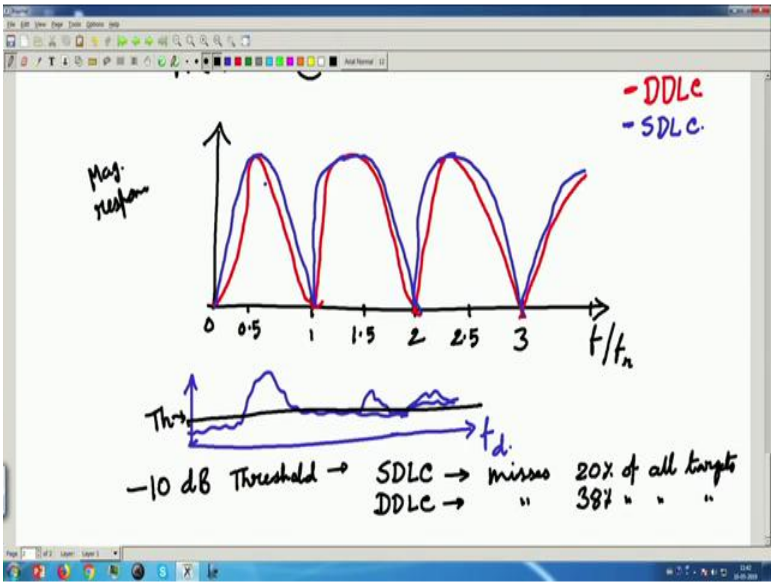

So, now, we can plot that what is the magnitude response, voltage magnitude response. So, if we plot that same thing that magnitude response. So, here I am plotting f by f r. So, this is 0 let us say 1, let us say 2, let us say 3, this 0.5, 1.5, 2.5 and let me use so, this is for so, I can say that red is for DDLC double and if we compare this with SDLC; SDLC will be something like this. So, you see that DDLC, what is the effect of DDLC; that has made the near the notch, stop band notch is much sharper.

So, one problem it has solved that the notch is much sharper so, clutter at innovation will be better, but it has one problem that it is more non uniform in the pass band. You see compared to SDLC, the DDLC is more non uniform in pass band. So, it will miss more targets whose who will be severely attenuated. So, it will miss many targets. So, now, actually what happens if you remember that in the pulse radar block diagram after the, phase detector circuit we have these MTI filter and MTI filter output is looks something like this if you remember that there are clutters and then there is something so, this is verses your f d so, this is the clutter thing etcetera, so, there are some targets.

So, to have the targets identified we need to put some threshold and those above the threshold they will be called targets. So, if any target is severely attenuated so, that it falls below that threshold so, I will say this is the threshold limit then it would not be detected. So, that means, if we use a DDLC, compared to SDLC we will get many more targets will go. So, there is a statistics that actually, if we have a this threshold is at minus 10 dB threshold then, if you have a SDLC or two pulse canceller that rejects or misses 20 percent of all targets. For the same threshold DDLC it misses 38 percent of all targets.

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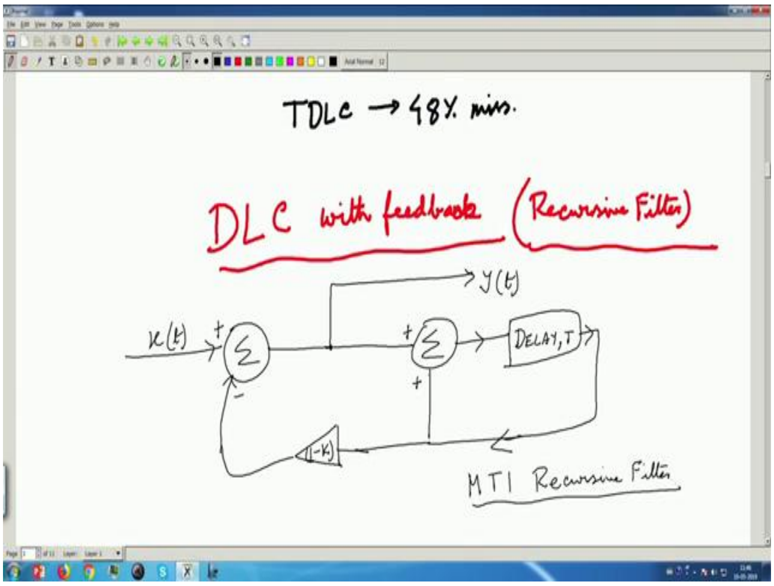

Now, if you have a triple delay line canceller then that goes to 48 percent miss. So, you see these are the negative points of adding more number of delay line canceller units in cascade, but; obviously, there is an improvement happening that is at the clutter attenuetion. So, it will be able to suppress much more clutter, but at the same time this is also doing. So, you see that putting more and more number of the delay line canceller units stages is not advisable.

So, we need to have something to have a pass band which is uniform. Now, that is done with a technique called actually the idea is taken from the filter design, that if we have a recursive filter, if we can have some feedback then, that will be good. So, DLC with feedback that we will see. So, we will put a feedback loop I say that this is a concept of recursive filter that people have tried and found that gives a very good answer.

So, suppose I have a we need to provide a feedback path, actually this is the output that is taken, this is the input. Now here actually this cleverly what is done that there is a feedback loop given here and this feedback loop gain is 1 minus k; k is a parameter. So, this is plus so, you see a negative feedback is given. And here the there is a delay also, because it is a DLC. So, we will have to now give a delay. So, that delay is given here and these. So, you see that thing is coming we are having a feedback loop. So, that feedback loop is given and the output is taken, but; obviously, here there is a with the delay this is given.

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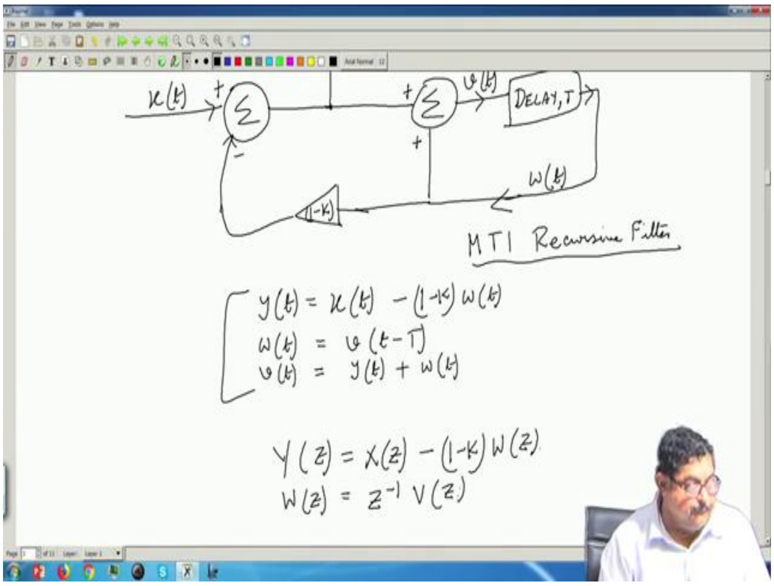

Now let us analyze the circuit. So, this is called MTI recursive filter. So, for analysis what will have to do is x t y t is there, these stages will have to give some new name. So, let us call it v t arbitrarily am naming let us say this is w t. So, this will do. So, what is my y t? Y t is x t minus 1 by k into w t. Simple this is y t. Now what is w t? W t is v t minus T and what is v? It is y t plus you see w t.

$$y(t) = x(t) - (1-K)\,w(t)$$
$$w(t) = v(t-T)$$
$$v(t) = y(t) + w(t)$$

So, once we do that now we can go to the z domain and easily find out what is the transfer function. So, if we do that, I think you will notice that these are my three-time domain equation. So, in the z domain this will be Y z will be X z minus 1 minus K W z then W z is Z inverse V z and V z will be Y z plus W z.

$$Y(z) = X(z) - (1-k)\,W(z)$$

$$W(z) = z^{-1}\,V(z)$$

$$V(z) = Y(z) + W(z)$$

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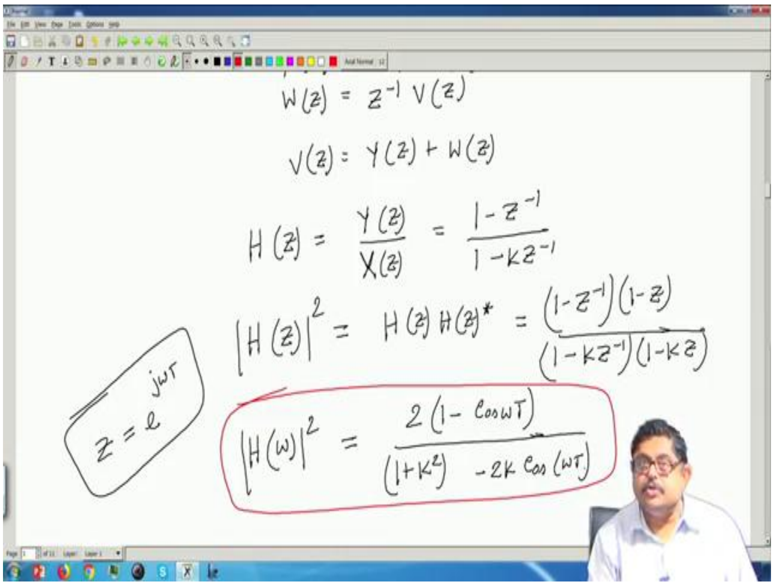

So now, it has been algebraic equation. So, you can easily manipulate and the transfer function H z which is nothing, but Y z by X z. That will be if we do 1 minus z inverse by 1 minus k z inverse.

$$H(z) = \frac{Y(z)}{X(z)} = \frac{1 - z^{-1}}{1 - kz^{-1}}$$

So, you see compared to a single DLC, this was single DLC’s function now you have in the denominator these. So, this k is in your hand it can play that we will see.

So, before that let me see the what is the power transfer function. So, this will be that H z into H z star and that I know it will be 1 minus z inverse into 1 minus z by 1 minus k z inverse into 1 minus k z. So, this if we manipulate, we will we can find the thing and if I now switch over to omega, because we know that what is a relation between omega and z. I think all of you know that z is e to the power j omega T.

So, if we put that we can get the expression that 2 into 1 minus cos omega T by 1 plus k square minus 2 k cos omega T this will come.

$$z = e^{j\omega T}$$

$$|H(z)|^2 = H(z)\,H(z)^* = \frac{(1-z^{-1})(1-z)}{(1-kz^{-1})(1-kz)}$$

$$|H(\omega)|^2 = \frac{2(1-\cos\omega T)}{(1+k^2) - 2k\cos(\omega T)}$$

So, this is an important relation it shows us something and here you note that if I remove the feedback; that means, if I put k is equal to 0 what happens? This is nothing, but the thing that we obtained for single DLC.

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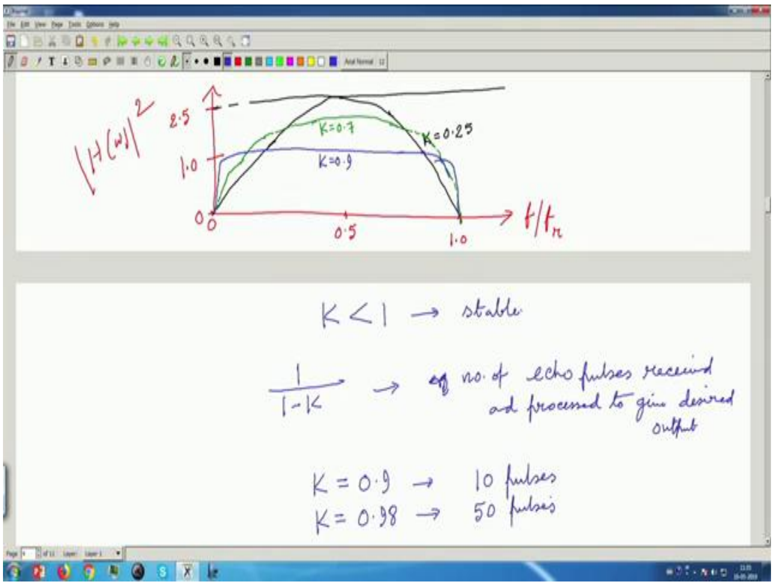

So, you see and now the time is we will have to plot this that if I plot this H omega square for various values of; various values of k because k is my parameter now. So, here this is 0, this there will be 1, there will be a 2.5 and here is 0, here is 0.5, here 1.0 then it goes on repeating. So, there let us see various values. So, k is equal to 0, I am not doing. That we already know that or let me put it up then. Let us say small value k is equal to 0.25. So, that will be this is k is equal 0.25, then k is equal to 0.7. Let use green so, this is k is equal to 0.7.

You see that more k I make then, am coming more uniform in the pass band and if we make k is equal to 0.9; let us say k is 0.9 is this is k is equal to 0.9 like that if I go on increasing k to more values, it will be more uniform. So, this was a thing we were asking that in the pass band it should be uniform so, that thing we got.

Now one question is since this is a feedback loop. So, there is a question of oscillations, stability problems. So, that thing people have shown that if we restrict k is less than 1 then, it is a stable circuit it will not oscillate and actually people have also shown we are not going into that maths that; this 1 by 1 minus k this is has a physical meaning that k is a parameter, but 1 by 1 minus k this is equal to or this is equal to number of echo pulses received and processed to give desired output.

So, that means, how many pulses like previously we were saying 2 pulse canceller 3 pulse canceller. So, what is the number of pulses for any feedback? So, k if that value is 0.9, as we are seeing that then we require 10 pulses. So, we will have to wait for 10 pulses before we get these type of thing. Similarly, if we get k is equal to 0.98 then this will turn out to be almost 50 pulses. So, it is now your choice; that means, you will have to wait for some time before you get the thing, but this is a processing thing. So, that is not much a problem.

So, we have solved the problem of blind speed, that near the blind speed you see the blind speed is still there, but the uniformity in the pass band has been done by these MTI filtering; the delay line canceller. Now we will see that what is that technique by which the without doing anything on PRF and without making a low frequency radar, can we extend the blind speed further, that we will take up next that is called staggering on multiple PRF's if we operate the radar with multiple PRF's, then these blind speed goes.

So, we have now found that given a blind speed how we can make the pass band response uniform and also put deep notches in the (Refer Time: 27:49). So, how much deep these notches putting that we will see later when we will discuss the figure of merit of this MTI filters, but it will put a very deep notch as well as it will have the pass band.

So, we have solved one problem that what is the good MTI filter which can which won't meets many targets. So, that we have seen, now we will see a technique by which with this, but we will now change the PRF in various fashions and that will help us to extend the blind speed first blind speed further, so that we can operate with the thing, that we will discuss in the next class.

Thank you.