Principles And Techniques of Modern Radar Systems
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Lecture – 16
Clutter and Single DLC

Key concepts: Analytical model for clutters, Spectral characteristics of clutters, Implementation of MTI filter, Analysis of impulse response of a single DLC

Welcome to this NPTEL lecture on Techniques and Principles of Modern Radar Systems. We we re discussing MTI filter and today, we will start with clutter because that is the main motive for going to MTI filter that MTI filter can remove clutter.

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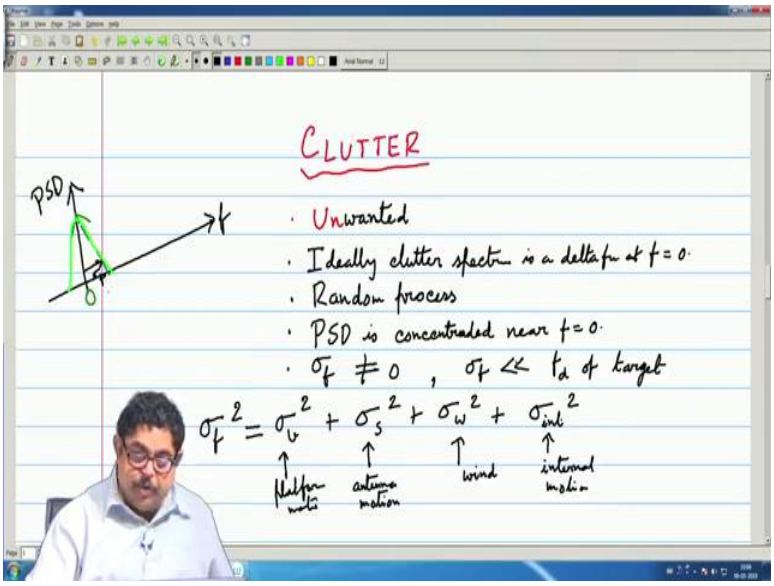


We have already defined clutter; the clutter is the echo from a stationary target. It is of no interest to us; that means, for a radar, it is unwanted sorry unwanted, but it will come because there will be various stationary targets I give an example that aircraft flowing near an hill or when the radar is looking and there is sea which has large amount of waves ocean waves so that then wind etcetera.

So, unwanted things now rain then bird, hill all this. Now, this is stationary; that means, ideally we can say that ideally clutter if we see the spectrum of the clutter because in spectral domain, the moving target and clutter can be easily separated ideally because clutter will have a delta function at f is equal to 0 because it should not have any spread it is a in f it is 0. So, at 0 you can have a delta function. So, I can say ideally the clutter spectrum is a delta function at f is equal to 0.

So, if I draw the spectrum I will come there then, but in reality we will see that clutter has a not a delta function it has a spread, why? Because there is a limited relative motion with respect to radar. One thing is as the example that the wind. So, when suppose I am seeing the clutter from a hill, but that is coming through the wind. So, in the propagation path there is a motion of the wind.

So, when the radar will get the echo from the hill that will also have some motion. Also, the radar platform that suppose the antenna is moving. So, the receive signal that gives that scanning antenna that will produce some a thing. So, wind etcetera as I said then in case of sea there will be the waves. So, they have some motion. So, those motions are very small relative to the actual target's motion, but still it is not an delta function; that means, if in the frequency domain also the clutter is random.

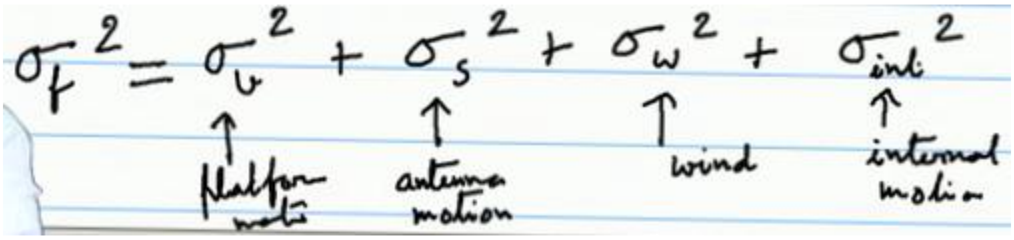
So, we can model it with a random process that sometimes I will see the clutter always definitely I would not see the clutter. So, it is a random process so; that means, its spectrum will be the power spectral density. So, ideally at this is the ideally…. this is the 0 velocity delta function, but generally it will have a spread or I will should use some other colour.

So, small spread and random processes we characterize by their that it may be 0 mean, but its second moment that its standard deviation we will call it. So, first thing is it is a random process, clutter is a mathematically modeled as a random process. So, I can say that its PSD is concentrated; obviously, the most of the power that is near the f is equal to 0. So, concentrated near f is equal to PSD is concentrated near f is equal to 0 and it is in the both sides of the frequencies because there can be motions in either directions.

So, so this clutter process that is characterized by a second order characteristic that is the its standard deviation, let us call it sigma f and that is not 0 that is the crux of all this discussion that it is ideally should have been sigma f should have been 0, but it is not zero, but; obviously, this is small. I should also say that delta f is very very smaller than the target speeds or the I can say the f d of target, the Doppler of the target compared to that it is much smaller, but it has something and this is the sigma f is overall spread and generally it can be modeled as suppose sigma sorry.

It is a total overall spread and this is the clutter spread due to platform motion, then clutter spread due to mechanical scanning of antenna, then clutter spread due to wind. So, I will say that this is the contribution of the wind; wind velocity will make this clutter spread, then this is antenna motion if it is a mechanical antenna.

Nowadays, for phased array this term will not be there then this is due to platform motion, then I can also say that the internal motion of the clutter internal motion etcetera, you can have various others. So, this overall, but this is small. So, I can say that this is the sigma f ok.



Now, what happens? A pulsed radar actually is you can consider a pulsed radar that it is sampling the echo whatever it is getting. Since, it is sending repetitive pulses, we can say that it is sensing or sampling the returned signal at a frequency f r. So, after sampling; that means, since it is doing the pulse. So, if we see the overall spectrum we can say that for pulsed radar, what will be the clutter PSD.

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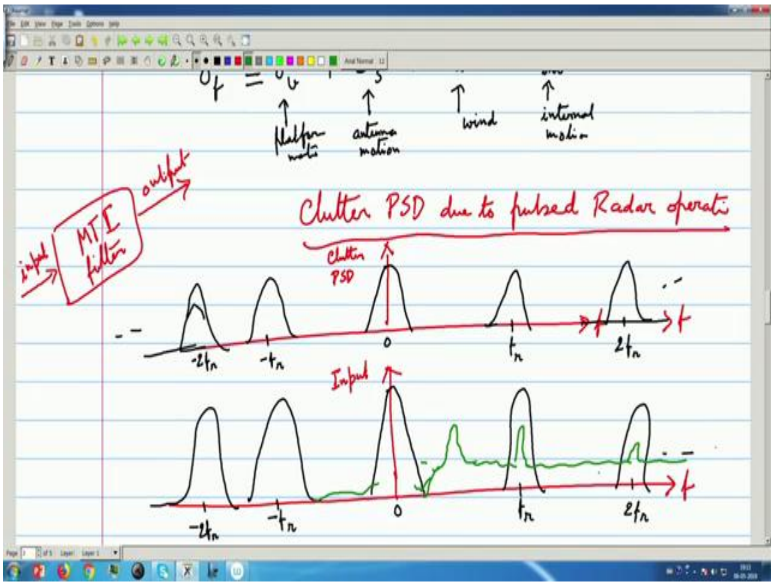

So, I can say that clutter PSD due to pulsed radar operation or basically PRF type of operation. So, there this spectrum that will be not only so, this is f this is my clutter PSD. So, this is 0, but at every fr, this will be repeated because a sampling operation type of thing is taking place. So, I can say again at 2fr it will have these minus fr minus 2fr like that.

So, we can say that in pulsed radar, the clutter PSD is concentrated around DC and also multiple integrals of PRF. Now this periodicity so, we can now if we want to remove it, then the problem is since due to this period; that means, if in these zone suppose this is a zone where target's echo spectrum also may be placed and then generally the clutters are much stronger than echo in certain cases and the whole radar pulsed radar will not be able to see the this thing. So, this is a problem for pulsed radar.

Now, what MTI filter does, it will have to remove this filter. So, I can say that, what is the suppose this is the thing. So, what now I can draw that, what is a typical input, this is in f. So, what is the input given to the so, I have the MTI filter. So, the MTI filter. So, I will say that let us say this, this is the input and output I should get this clutter removed by the MTI filter.

So, what is a typical input to this MTI filter this type of clutter? So, all same maybe my drawing is. So, at fr 2fr also this is continue, this is minus fr this is minus 2fr and also some of the targets will be there. Suppose, I use this color that let us say that there is a target here, there is a target let us say here, there is another target here, let us say these three targets are there and other places will be something like this. So, the signal is something like this that means, these are the signals.

So, now I want finally, to get only the green ones and not the blue ones and; obviously, there will be noises etcetera. So, in this that is why you see that this noise floor, if we put a threshold that can be easily removed. So, what is our desired this MTI filter response?

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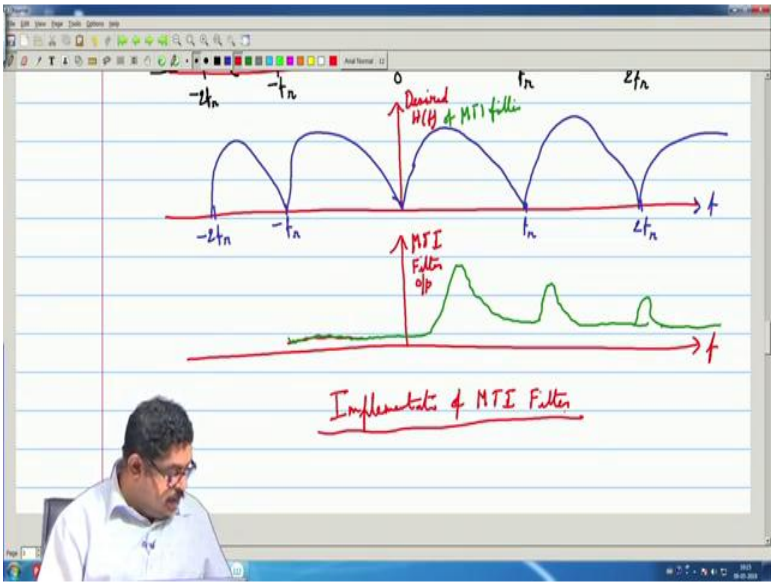

I can draw that that desired response; that means, if I call this H f. So, desired H f that I can say that we should try to have a null in the desired response. So, if I can have something like these; that means, a null. Now, I am drawing this sinusoidal shape it can be any shape, but I will try to put in very sharp null and some wide null, somewhat wide depending on the spread of the thing then if this is the H f this is the input. So, what will be the output? That means, MTI filter output now you have I can draw that MTI filter output spectrum.

So, what I will get? You see that these things will be all the black ones will be removed with multiplication with this. So, I will finally, get you see the targets. So, this is a desired thing. So, this says that what is desired of the MTI filter desired H f of MTI filter is this. So, if I can get that, already you have seen that we have got something like that so, ok.

So, we will see that, you see already the delay line canceller that we have discussed that has this type of response. So, also I have mathematically derived that it is a pure sin pi f dt that type of function. So, that can do this Doppler removal, but in the process you see that the blind speed etcetera has come.

Now, we will discuss various MTI implementation of this MTI filters and finally, we will compare them because how much clutter is getting removed I am qualitatively saying, but we should require some figure of merit for that that also we will see, there are two three figure of merits that how much clutter I am attenuating, how much MTI indicator that there is another very good performance matrix. So, those we will discuss then.

So, next we will start with this implementation of MTI filter. So, implementation, one thing I have already done the delay line canceller.

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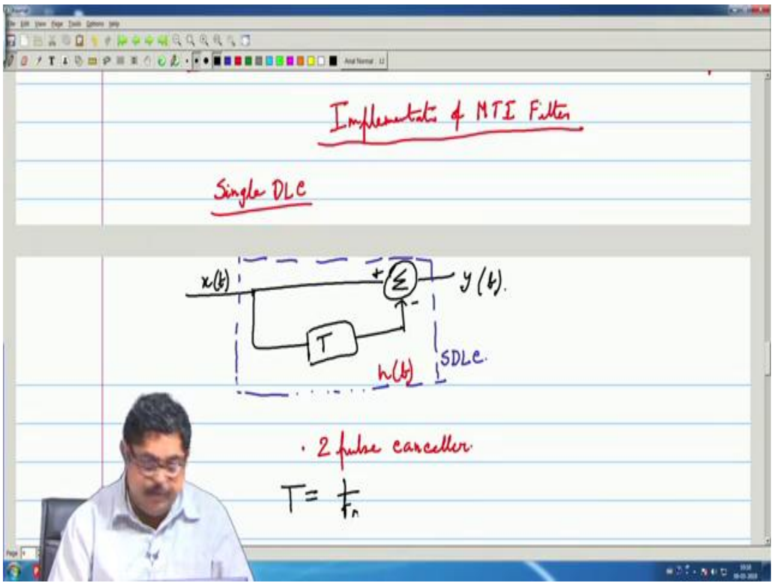

But that I will now call single delay line canceller because there is a single delay already we have seen that again just I am repeating for completeness sake that, there is a delay of T and this thing goes in a summer and we get y t. So, so, this is the this blue colored one is the single DLC single DLC and it has a transfer function that we are calling h t, impulse response that I am calling h t. The Fourier transform of that will be H f, its transfer function.

Now, this is also called a 2 pulse canceller, why 2 pulse? Because you see that its output will come after two distinct input pulses distinct input echoes have come because since you were delaying. So, this output is valid only after two echoes have come. So, pulse the phase detector output is coming either in the, you can make it either if the processing is analog you can directly put it and there is an transmission line, you can put and give it or if it is digitized as I have shown in the block diagram, you can put an A/D converter because now these frequencies are your after match filtering and phase detection. So, that is your IF frequencies, there A/D conversion is possible.

Nowadays even at RF level also you can have A/D at least S band etcetera. Even I think X band also you can have A/D whatever, but costly those things. So, these two pulse canceller so, this requires two pulse one is the direct pulse has come then you require a delay so; that means, two PRIs are required after that only you can take it; that means, after only a time up two PRI you can get it. So, this T we know is nothing but 1 by fr.

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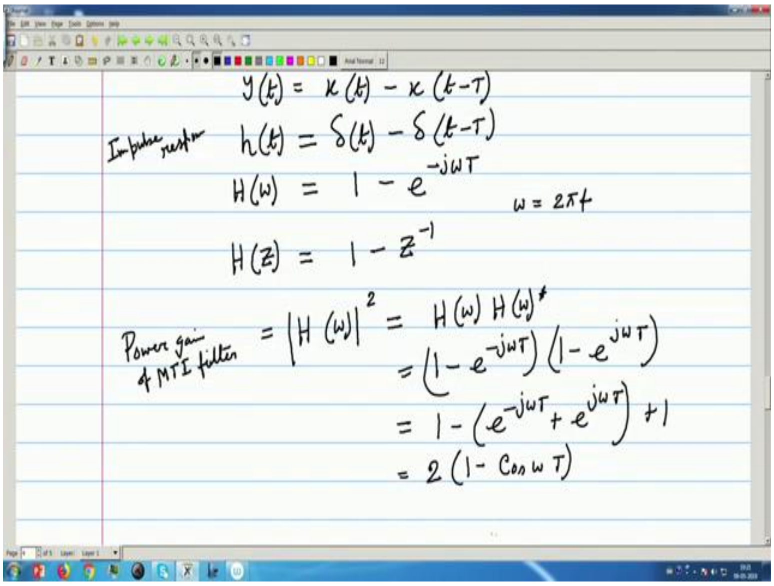

And I can write the expression of y t, what is y t? x t minus x t minus T. So, I can write the impulse response impulse response sorry, impulse response of the filter that I will call h t, what will be h t? Simply we know del t minus delta t minus T.

$$T = \frac{1}{f_r}$$

$$y(t) = x(t) - x(t-T)$$

Impulse response $\quad h(t) = \delta(t) - \delta(t-T)$

So, I can write its transfer function steady state response that will be from here I know, 1 minus e to the power minus j omega capital T.

Well, what is omega? Omega is nothing but 2 pi into f and in z domain, I can also write the transfer function in z domain because if these are digital circuits it is better to do it. So, we know that this can be written as so, this is H z.

$$H(\omega) = 1 - e^{-j\omega T} \qquad \omega = 2\pi f$$

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

Now, mainly what we are interested that how much attenuation it is giving or power how much power attenuation it is giving. So, I can easily find out what is the power gain of this power gain of MTI filter? So, that we know power gain will be H omega square and since H omega is complex. So, H omega H omega star and so; that means, it is 1 minus e to the power minus j omega T into 1 minus e to the power j omega T.

So, this you know 1 minus e to the power minus j omega T plus e to the power j omega T plus 1. So, it is 2 1 minus cos omega T and that is 4 sin square omega T by 2.

Power gain of MTI filter

$$\begin{aligned} &= |H(\omega)|^2 = H(\omega)\,H(\omega)^* \\ &= \left(1 - e^{-j\omega T}\right)\left(1 - e^{j\omega T}\right) \\ &= 1 - \left(e^{-j\omega T} + e^{j\omega T}\right) + 1 \\ &= 2\left(1 - \cos \omega T\right) \\ &= 4 \sin^2\left(\frac{\omega T}{2}\right) \end{aligned}$$

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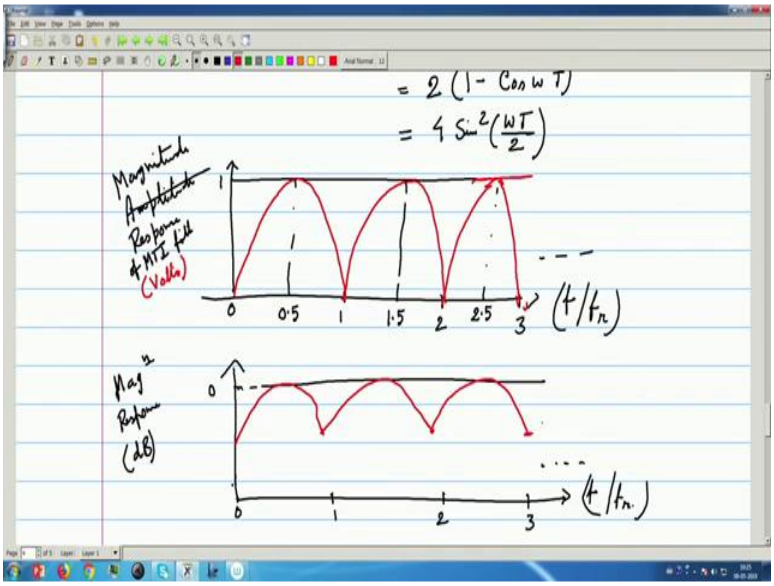

So, power wise it is a sin square thing. So, if I draw that in the amplitude response of the filter magnitude response MTI filter, I should say magnitude response MTI filter. So, you know the maximum value can be 1 and this side is, let me take it f by fr. So, at 0 it is this at 1, at 2, at 3 etcetera.

So, I know this is a sin square graph. So, if I plot it of various things so, this will be the magnitude response in Volts. The power relation will be a square of these and typically this magnitude response is also plotted in the dB scale. So, we can do that that magnitude response versus f by fr.

So, this is 0, 1, 2, 3 and we know that this value will be 0. So, this is typically given in dB, 0 dB and the graph you will see. So, this these value are typically that 10 20 dB. Now, that may not be always very good.

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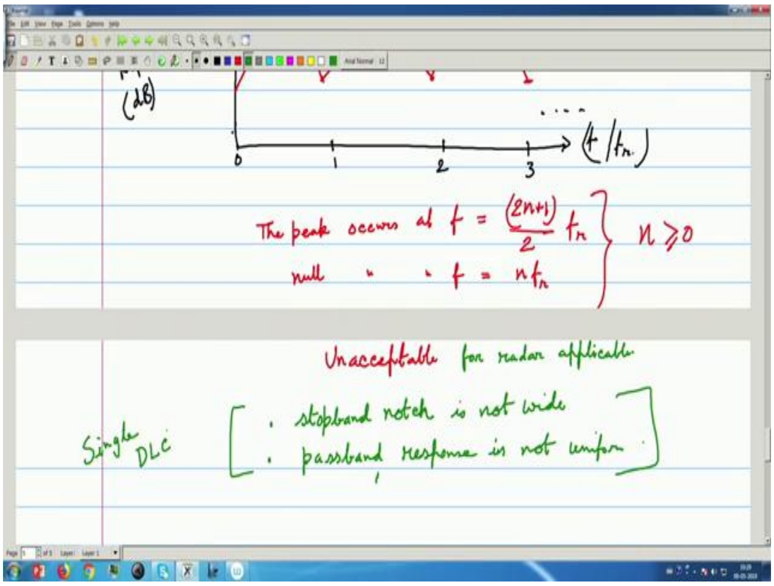

So, we can summarize what we have got from single DLC, that the peak occurs at f is equal to 2 n plus 1 by 2 fr, you will see this is the peak and null occurs at f is equal to n fr. So, this part is okay, that null is occurring at (Refer Time: 28:34) to f is equal to n fr. So, then you are removing clutter, but what happens that it is having a peak here and it other portion there is a attenuation of the other Doppler velocities Doppler frequencies so; that means, some of the velocity targets they will be attenuated compared to this peak.

So, we can say that, what is a problem in many actually in radar applications this type of response is not acceptable. So, we can say that unacceptable performance from single DLC. Actually, what we want? We want that this thing should be something like this ideally I should have something here and at 1 it should go there then everywhere it is uniformly. So, that all the target speeds they are given correctly at that position, at integral multiples of fr there should be a 0 position.

So, that should have been the ideal one, but it is not ideal it is having a severe attenuation. So, in filter unacceptable for radar applications. So, single DLC is unacceptable, we will have to better the performance and what is our problems? That stop band notch stop band notch is not wide, what do you mean by this? You see that this notch this is the stop band notch, you see near stop band if it had been wider, more and more clutter will get removed depending on the I think actually in a practical radars, the clutter spectrum spread that delta f is 5 6 hertz.

Now, if you do not have this 5 6 hertz, this notch width then some of the clutter will leak through. So, it is not having that stop band notch is not wide and second point is pass band response is not uniform. So, targets the we know due to these the targets will get non-uniformly attenuated.

So, these are the two problems that will have to, I think this writing is not clear notch. So, we need to have much wider stop band notch at least to the spread of the overall spread of the Doppler spectrum and pass band response we should be more uniform making. So, that is not possible by single DLC. So, this I will say that single DLC or SDLC. So, we will see that how to make improvement of that in the next class.

Thank you.