Principles And Techniques Of Modern Radar Systems

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Lecture - 25
Tracking Radar

Key Concepts: Introduction to tracking radar, classification of tracking radar (continuous track and track while scan), Necessity of symmetrical squint beam: analytic justice, sequential lobbing

Welcome to this NPTEL lecture on Principles and Techniques of Modern Radar Systems. We were discussing the functional aspects of radar. So, search radar we have discussed in the last class today we will discuss the Tracking Radar.

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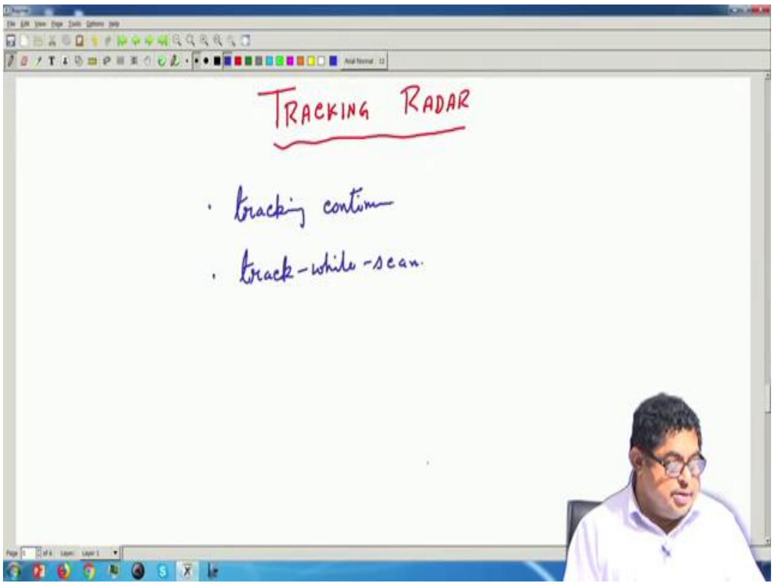

Now, what is a tracking radar? A radar that follows a moving target already acquired is a tracking radar. So, a tracking radar can follow a target continuously, then that is called the tracking continuously or it can sample the angular position on each scan of the track because suppose after some time it is doing because always continuously following that becomes not so, required. So, after certain interval it is finding the position. So, that is called the track while scan. Whatever technically the tracking means tracking the angles of azimuth and elevations precisely.

Now, tracking could have been in range also, tracking could have been in Doppler also, but usually the tracking radar uses the tracking in azimuth and I mean and tracking terminology that could have been general, but it is not general in the radar parlance, it basically means azimuth and elevation tracking or angle tracking.

A tracking radar usually points a pencil beam at the known target position supplied by the search radar. Now if the target moves from that position then and error signal is produced in the receiver of the tracking radar. This error signal indicates that in which direction now radar should move to again lock on the target. So, there is servo mechanism with the radar so, based on that error signal that goes as tracker moves in the indicated direction.

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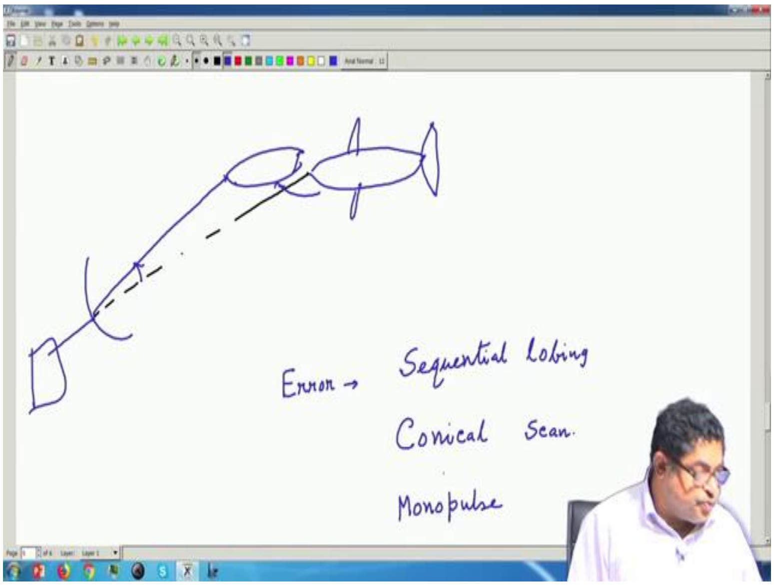

So, suppose you have a target like this, and let us say the radar is seeing this now radar is located in this direction. So, search radar said that look at this direction. It has done, but it is a moving target. So, after some time the target has come let us say here. So, from here it has come to here. So, this time you see that same nose at a different angle.

So, now radar should have the capability to sense that it needs to change this orientation so; that means, these angle movement should be indicated by an error signal. So, that how it is done we will discuss, but this error signal actually this errors signal should be such that gradually as the tracking radar moves in the indicated direction, the error signal should decrease finally, when the error is 0; that means, the tracking radar is looking at the target precisely.

Now, this error signal producing. So, I will say that there is an error signal that needs to be produced which will say the moving target’s track information and accordingly the antenna should rotate the beam either mechanical rotation or the beam should rotate electronically.

Now, these errors signal production that can be produced by three methods one is called the sequential lobbing, another method is called conical scan and finally, we will see a method called monopulse. I have already told you about monopulse, this is the best method the very good method for angle tracking, but historically this came later. So, we will discuss it one by one.

Now, as I already said that the resolution angle resolution of a tracking radar is much several order of magnitude better than the antenna beamwidth. So, now what is the concept of resolution? Resolution means if there are two targets or what is minimum separation of two targets in the angular space; that means, what is the minimum angular separation of two targets so that the radar will be able to say that there are two different targets.

If the radar says for two targets that there is only one target then its resolution is poorer than the required separation of them. So, the resolution depends on the ability of the radar receiver to compare two signals almost equally two echo signals almost equal. The fundamental limit to this is the system noise caused by mechanical or electrical disturbances etcetera.

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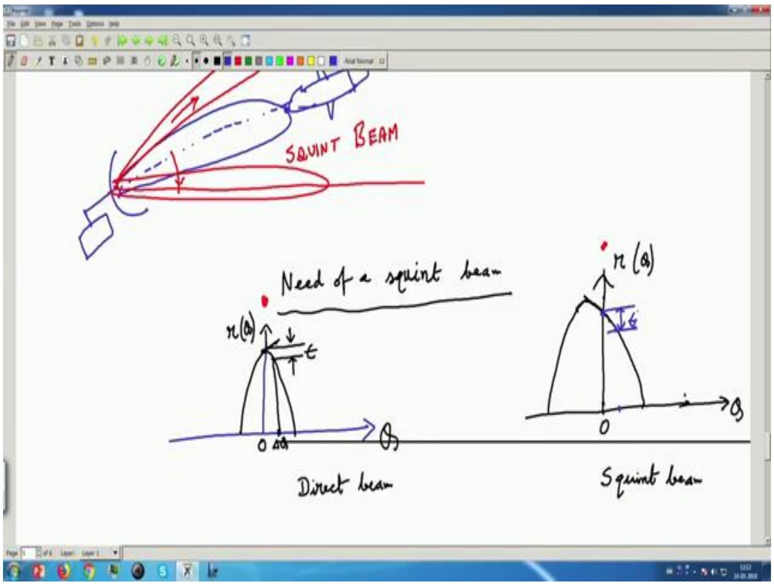

Now, we will see a concept that suppose the tracking radar is seeing; the suppose there is a target as I was drawn that picture that. Suppose the radar is radar is looking at the target directly; that means, at the nose directly it is pointing the beam let us say the beam is like this.

Now, it can find out that echo if I up pointing these I can find the echo I can measure, but you generally this is not done; that means, directly the radar does not see the target the beam never directly sees this why? To understand that we will see actually always radar instead of one it produces two oblique beams they are called squint beams; that means, the target is here. So, the radar actually instead of this produces two beams instead of that it will produce one beam like this, and another beam like this. We will measure that that these also we will get this return because you see some these are all polar diagrams I am drawing. So, from that it will find this error signal.

Now, why that is done? Analytically first we will answer then we will see the actual thing. So, these beams which are not directly aligned with this antenna's axis direction because you see these beam axis is these. So, there is an angle offset angle with that this angle is called squint angle. What we I was non-technically saying oblique beam actually it is called squint beam. So, this is a squint beam, this is squint beam etcetera.

Now, what is the need of a squint beam in a tracking radar we will see that that need of a squint beam. So, let us say that I have a radiation pattern, because this beam actually if I know the radiation pattern, I know what is the; at various angular points, what is the return that is called the radiation pattern of the antenna.

Let I the antenna is producing a direct beam. So, I am calling that the response of the antenna angular response of the antenna or radiation pattern of the antenna versus theta actually I am plotting that let us say this is. So, this is the beam actually what we say the beam? Actually this is the radiation pattern of the antenna. So, this is a 0 angle and this is called a direct beam; whereas, I will draw in another one a squint beam. So, the same r theta, but in this case the antenna can produce a squint beam.

So, squint beam; so, let us say that this same thing, but you see this is squinted by how much if I make this angle I will be able to tell. So, this is again theta this is 0 etcetera.

Now, let us say that from I have a very small thing, but to show I am showing. So, let us say that at an angle delta theta. So, what is delta theta? I can say that in the radiation pattern the difference from the 0 and this is epsilon let me call it epsilon or error.

Now, actually why I am doing this, suppose the same thing that direct beam was produced and if the target is at the theta 0 or at the axis of the beam direct beam, then I will get the return. Now if it is slightly off that then I will get something else and I know since the radiation pattern is known. So, how much error I will make that I can calculate by; so, what is this epsilon error r of 0 r as a function of or r at a value 0 minus r at a value delta theta that is called error signal.

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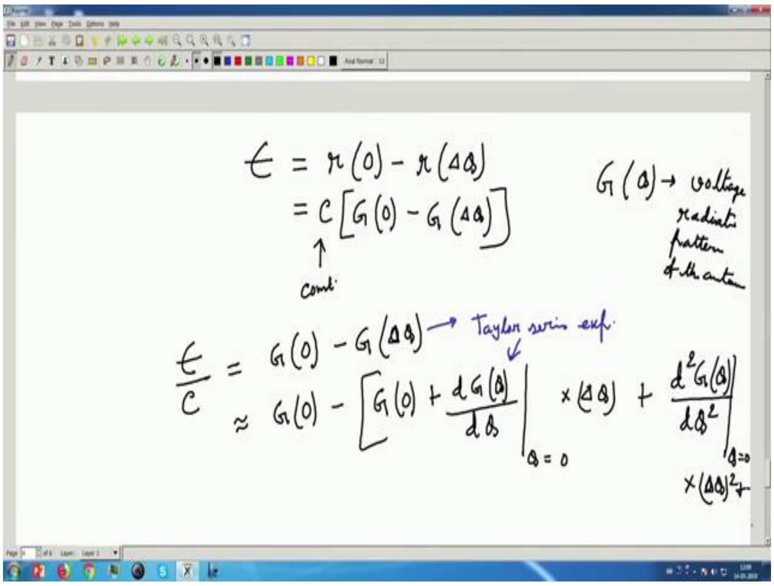


Now, a radar could have done that. So, I will write that this error signal epsilon will be r of 0 minus r of delta theta where this is an amplitude error. So, the target is instead of at the axis it is at an offset delta theta. So, I know this will be the error now this is the return.

So, we can say that if the gain pattern of the antenna is this, then I can say that the or I can say that this G theta is the voltage radiation pattern of the antenna.

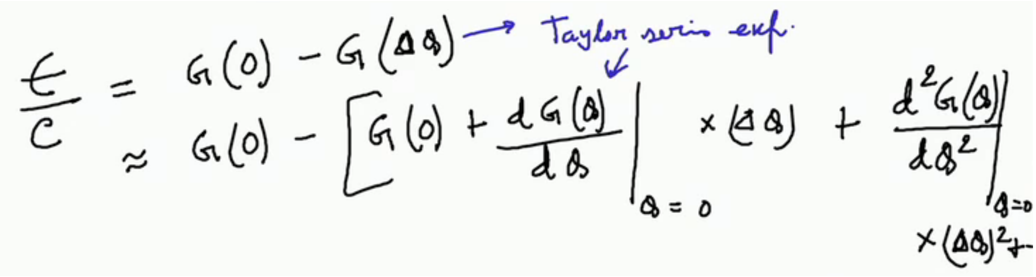
$$\epsilon = r(0) - r(\Delta\theta) = C\left[G(0) - G(\Delta\theta)\right]$$

So, G 0 is the voltage that is given by the antenna, when you look at an angle 0 and G delta theta is when you are at an angle delta theta from the reference.

Then what is the voltage and C it is a multiplayer. So, this is for a relative thing now for your actual thing how much return you are getting that is this. So, C is a constant we can say for our model that C is a constant okay.

Now, since the radiation patterns they are continuous thing they are analytic. So, we can find out what is the expression of G delta theta, if I know G naught by expanding G delta theta in Taylor series. So, what I am doing I am writing what is epsilon by C that is G 0 minus G delta theta and if I expand G delta theta in a Taylor series since delta theta is small it is nearby 0.

So, by Taylor series I can expand that is why I am writing approximately it will be G naught minus what is this? Taylor series. So, I am writing here that Taylor series function and give it here. So, G 0 plus d G theta d theta, theta is equal to 0 multiplied by delta theta plus other terms, for now I may write, but ultimately we will not use that d 2 G theta d theta 2 again at theta is equal to 0 multiplied by delta theta whole square plus dot dot dot ok.



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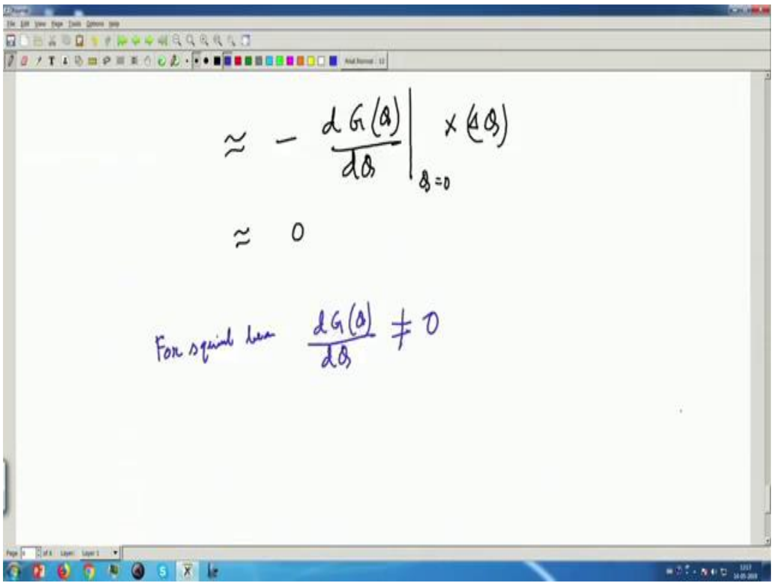

Now, if I restrict only this first order terms. So, I can write this is nothing, but minus d G theta d theta at theta is equal to 0 into delta theta roughly this. So, what is this? That means, now you see that what does this error signal signify; that I require actually if my measurement is to be very accurate because tracking radar needs this angle measurement very accurate. So, I require that for a small change in delta theta there will be a large value of this thing; that means, I require d G theta d theta or slope of the radiation pattern curve to be very high, but what is happening at the direct point you see the thing. What is the slope at this point at the direct beam point or at theta is equal to 0, the slope is 0. So, basically the value of these will be almost 0, now what is the problem? The problem is since I am trying to look at a point directly the sensitivity of my measurement is very very lower actually 0 if I look at anything directly.

$$\frac{\epsilon}{C} \approx -\left.\frac{dG(\theta)}{d\theta}\right|_{\theta=0} \times (\Delta\theta)$$
$$\approx 0$$

But the whole thing will change sorry if we look at this picture. You see here I can say that suppose the object is on the axis as before. So, let us say that there is a target here also there is a target now instead of looking here I am looking here this is a example of a squint beam okay.

Now, here what are the points? So, I will have looking at this point and another point delta theta away. So, this is the error signal and from our expressions everything is same, but this thing is for squint beam d G theta d theta is not zero you see this slope of this curve is not zero only at this point it is 0. That is why squint beam is a must in case of any measurement any angular measurement to be done with very precision.

Now, what the, but what is the ill effect of this? You see that if the radiation pattern is generally radiation patterns are these that along the axis of the antenna it is maximum and other position it is falling. So, if I am pointing at some other angle or if I have a squint then; obviously, this point and this point they are magnitudes are much lesser than these two points. So, though my slope is more, slope is nonzero, but I am suffering some signal loss so; that means, there is a loss of the signal or echo signal you see that is a weak signal so, suffering any loss there.

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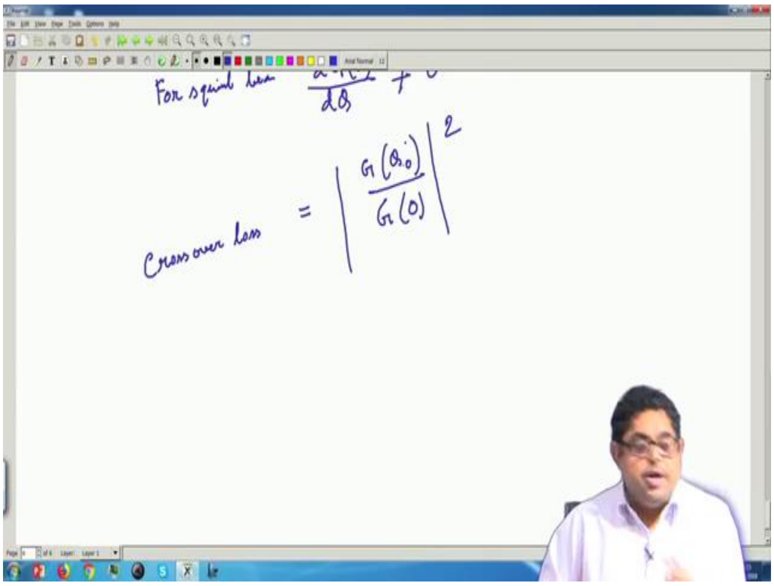

So, this loss is called crossover loss due to shifting to; that means, I am shifted to so, here we need to quantify this. So, suppose the squint beam it is at a position minus theta naught. So, what is minus the naught the maximum position. So, since it is shifted to this side I am calling it minus theta naught if it had been shifted to this side that would have been plus theta naught. So, crossover loss is what? You see how much power loss is obviously, power.

So, it is G theta naught by G 0 this ratio.

$$\text{Cross over loss} = \left| \frac{G(\theta_0)}{G(0)} \right|^2$$

So, G theta naught by G naught it is a the numerator is less than the denominator we are making square because it is a power. So, this is the your negative point of having a squint beam. So, this is the idea that for measurement angular precise angular measurement you should not have a direct beam because then your sensitivity will be the lowest, you choose a squint beam. Now usually two squint beams are used.

Now, we will discuss the now we will discuss the first method that, we have seen I already wrote there that you have sequential lobing.

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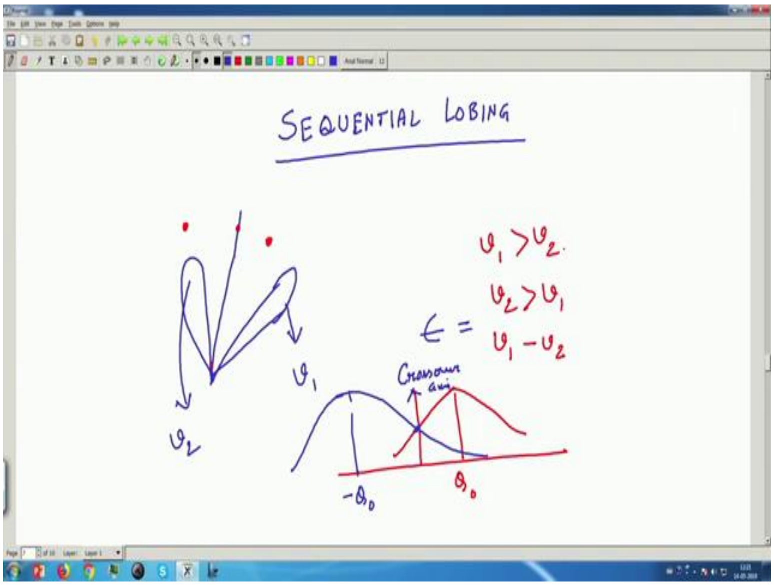

So, we will discuss sequential lobing. So, you have two fixed beams now you see that one antenna, antenna can be designed properly so, that it can have multiple number of beams. So, we are not always; that means, an antenna please remember, an antenna can have multiple beams. So, what we will say that in sequential lobing whether a single antenna or multiple antennas, they produce two squint beams.

Now if you want to measure the azimuth, you require two squint beams which are narrow in the azimuth direction if you want to require elevation, then you require two very narrow beams in elevation directions. So, you need to have four beams, two in azimuth directions and they will have squint in symmetrical directions about the antenna axis and also in up and down or elevation direction you need to squint beams. So, we say that the beams these beams are in sequential lobing they are switched sequentially to a single rx.

Now, difference between the echo amplitudes of the beams are given to a receiver, and receiver compares. So, in the azimuth direction it has let us say this in azimuth direction it got. So, these two are two squint beams sorry I should have made the thing similar in magnitude. Now this now from here suppose from this position it got let us say v 1 is a return echo and in this position v 2.

But it has the radiation pattern. So, it can form the angle and if these v 1 and v 2 they are same then; that means, the target is at this position symmetrically now suppose the target instead of that target is here. So, let us say the target is now here. So, here you see the return from this beam this is a polar diagram remember. Return from this beam it has more thing compared to that because its radiation is falling. So, v 1 will be larger if it is here. So, in if it is in this coordinate, then v 1 will be larger than v 2 whereas, if the target is here, then v 2 will be larger than v 1. So, if error is made as v 1 minus v 2 then if you get a positive signal, then you know that target is here. So, you will have to rotate your antenna system and as you rotate this magnitude of this v 1 and v 2 is going down.

Similarly, and finally, when you get 0 that time your antenna axis is, this axis is called crossover axis; what is meant by crossover? So, if you have this actually instead of polar diagram if we have a rectangular diagram, you can understand that; what will be the pattern for squint beam? So, this is called let us say theta naught and another squint beam is this is minus theta naught.

Now, you see the there is a point where the amplitudes of both the beams are same; that means, these two are intersecting points. So, if you from your reference if you draw this, this is the crossover axis. And so, you see that sign of the error signal that gives in which direction you should move and switching axis or crossover axis sometimes it is also called switchover axis.

So, basically a cluster of four feed horns illuminating a single antenna arrange so that the right left up down sectors are covered by successive antenna positions both transmission and reception at each position the beams are switched sequentially hence it is called sequential lobing. So, this is one form of tracking radar. So, sequential lobing by that we can find out what is the azimuth and elevation of the actual thing.

Thank you.