Principles and Techniques of Modern Radar Systems
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Lecture - 10
CW Radar

Key Concepts: Working principle of CW radar, Block diagram of a basic CW radar, Mathematical model of CW Doppler Radar

Welcome, to this NPTEL lecture on Techniques and Principles of Modern Radar Systems. In last few classes, we have discussed some basic parameters and techniques of radars, particularly with pulse radar. Today, we will see various functional types of radar. So, we will start with CW Radar as I said that historically this was the first radar that was developed and nowadays also this radar is used actually pulse radar is a better option for very long range things, but for short ranges due to the simplicity of these radar this is still used and more and more the civilian applications are coming for radar. The CW radar is gaining again popularity.

So, we will see today the CW radar. CW radar means that if the transmitter is operated continuously instead pulse fashion. So, the high frequency carrier signal that is sent continuously, then the radar is called CW. You know it is much easier to produce a continuous wave that is a sinusoidal wave sinusoidal generators we know any second order LC circuit that can produce that. So, that is why production of these CW radar is quite easy.

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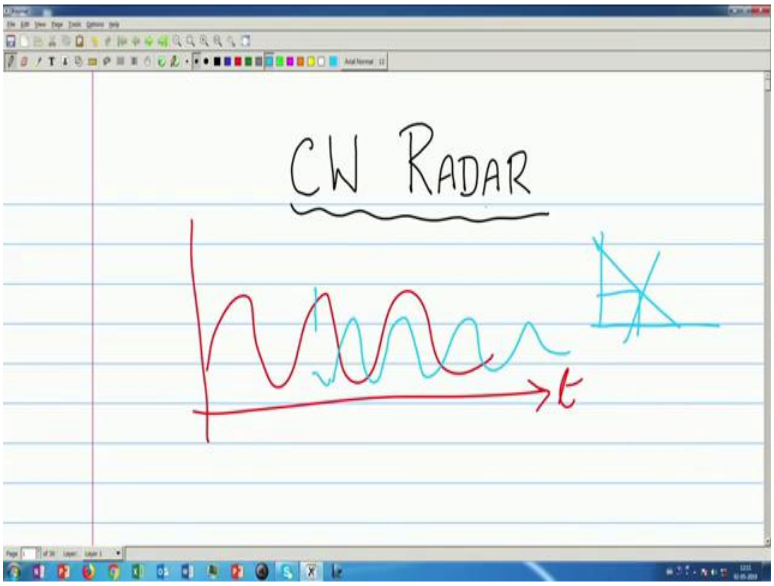

And now, the problem is that if I have a continuous wave in time suppose this is the time axis and this is my amplitude of the wave. The problem is that I am sending it and also after sometime let us say that this I am receiving the thing. But, in a CW radar there is no starting position and ending position you see that if I get suddenly this plus this what I will find that this is the in response to this one I have got this I would not be able to say. So, I would not be able to measure the time between the transmitted pulse and the return pulse.

So, because there is no timing mark here in a pulse you see the on-off time is there. So, when the return will come I will be able to say that will be also in the form of pulse. So, I will be able to say that, but here that timing mark is not there that is why CW radar actually should not be called a radar because range measurement is not possible with this classical CW radar. So, the radar stands for radio detection and ranging. So, CW radar cannot detect that.

But, it can what was the purpose it can detect? It surprisingly can detect the velocity we know what is velocity it is the rate of change of range. So, that first derivative it can detect that we will discuss now and also we will say one more thing that you see that the here unlike pulse radar there will be two separate antennas. One for receiving and one for sorry one for transmitting one for receiving because we will have to see what is the transmitted pulse transmitted signal and what is the receiving signal.

Now, the already we have seen that for any radar the transmitter power is high. So, transmitting antenna is sending relatively high power of signal, but in case of CW radar since the range is not much it is still it is some let us say some one Watt or something or some milliwatt power and the if the range is few kilometers, you will get some milliwatt or microwatt power the receivers will send that. So, by separating them in space some isolation is created so that the see the transmitted signal does not come there.

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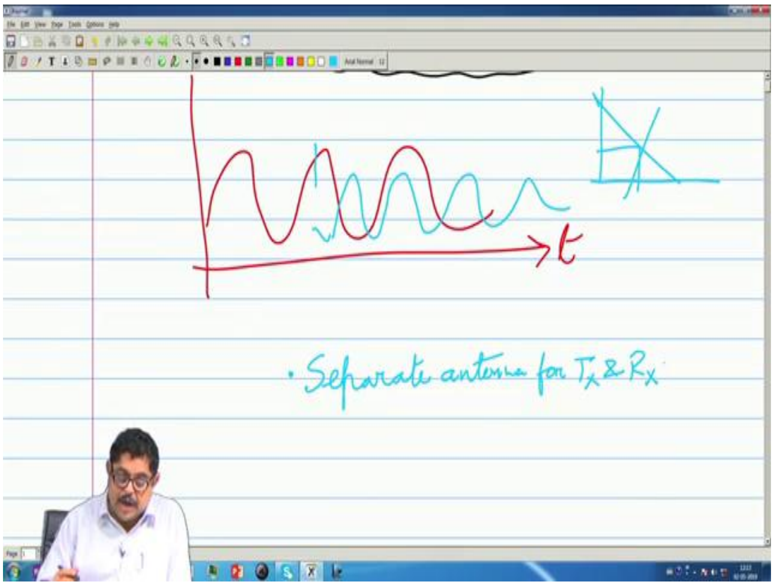

So, we will have. So, one thing characteristic of this is separate antenna for transmitting and receiving systems. Now, obviously, the radar generally is used for detecting the moving object or if the object is stationary suppose the earth it is if we consider it stationary and some aircraft is flying so, there is a relative velocity we have seen that if there is a relative velocity between the radar and the target then there is a Doppler shift produced.

So, we can say that whatever transmitted signal we have sent the returned echo that will be Doppler shifted. So, there is a change of frequency of the signal. So, actually this is a mark. So, if we now can find out how much this Doppler shift has been produced, then we can find out that what is the relative velocity of the target with respect to the radar. This is the principle of CW radar. So, you see that.

So, actually I can say that very stringent isolation between the transmitter and receiver is not required here which was the case for pulse radar. We have seen that pulse radar since it is a high power radar so, we require very stringent isolation between the receiver and transmitter otherwise the receiver will get saturated when the transmitter is put on.

But, here is no such thing here both transmitter and receiver actually they are separated they are two different ones, but some amount of coupling is required because if I want to detect that with respect to the transmitted signal how much Doppler shift in frequency has been obtained. So, I require a copy of the transmitted signal also, that is why that by deliberately some coupling is there. Generally, by space separation they are isolated there is a link by which the transmitted signal is fed. So, let us better discuss with a block diagram of the radar.

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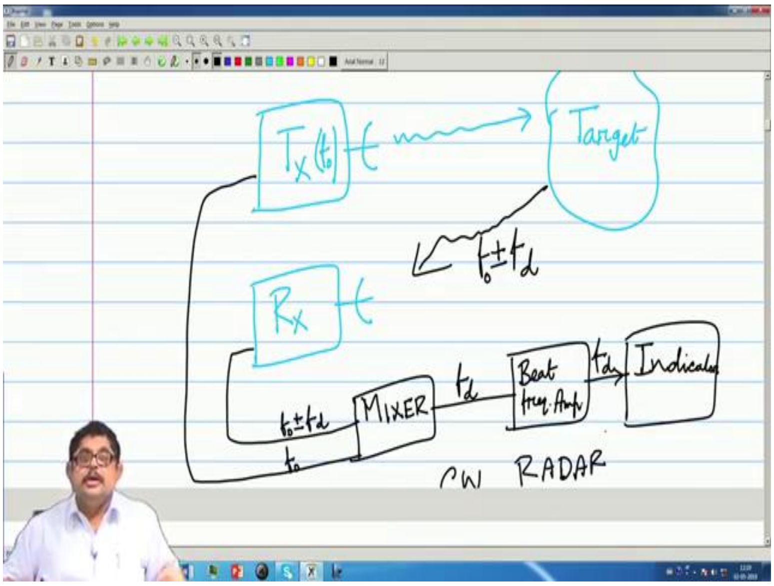

So, suppose I have a transmitter, I have a receiver. So, the transmitter is connected to an antenna, the receiver also is connected to an antenna and the let us say the transmitter is sending a frequency of f naught let us call that. It is a CW radar. So, a single frequency sinusoidal frequency it is sending. So, there will be waves going, let us say that this is the target. Now, from the radar again the signal will come. So, I can say that the frequency of these will be f naught depending on whether the target is approaching the radar or receding from the radar the Doppler shift will be either plus or minus. So, that signal will come.

Now, receiver will get that signal what receiver will do that it will now send that signal to a mixer. So, that we call a RF mixer there it will be put and mixer requires two inputs.

So, one of these you know that this is f naught plus minus f d. Also from the transmitter one signal will be put. So, this signal is f naught. So, the outcome that will be f d. This we know that mixer does this. So, this f d and now the signal needs to be amplified because obviously, this is a weak signal.

So, we call it beat frequency amplifier. We put an amplifier which is at a much smaller frequency. So, putting an amplifier is not an problem. So, that also the output is f d and then we give it to a indicator or display anything. So, this indicator can be having a chart that depending on what is f d. So, we have found that expression; f d can be always considered to what is the radial velocity of the target. So, mathematically this we can make the model that.

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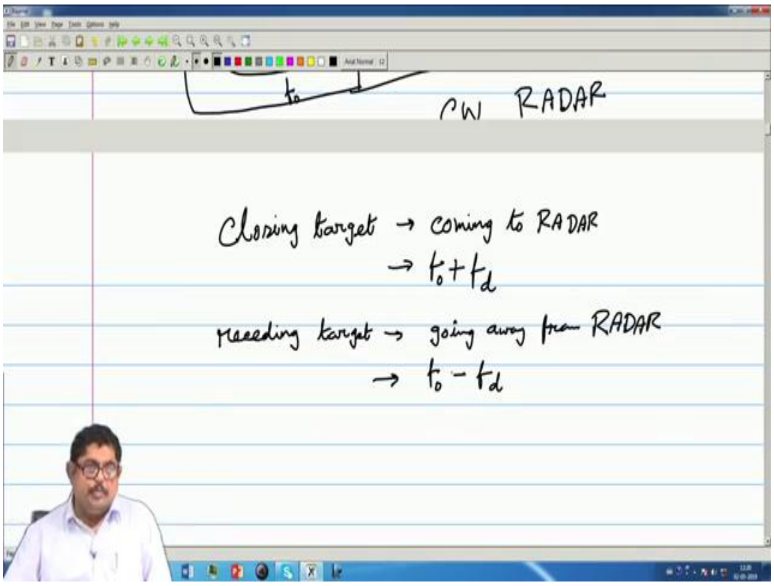

So, the thing is that now there are two terms here comes that closing target. Closing target means a target which is coming to radar closing target coming to radar. So, for a closing target I can say that the we all know that for closing target the Doppler frequency Doppler shift will be positive. So, we will get the received signal will be f naught plus f d and for receding target; receding target; that means, that going away from radar and for that the Doppler shift is negative.

Now, actually you see the mixing operation there the sign is gone. So, we can find the velocity, but whether if this a closing target or receding target if we use this previous block diagram these diagram does not this block diagram this is a CW radar block diagram CW radar block diagram.

So, in this the due to the mixing operation the sign of f d is lost because you have seen after mixer we are not getting plus minus f d, but there are circuit by which we can find out that we will see that because I would not be knowing whether the target is closing or receding that is an important information because generally the enemy thing will be closing.

Now, our own targets they maybe closing they may be receding, but we need to understand that what type of whether the target is closing or receding.

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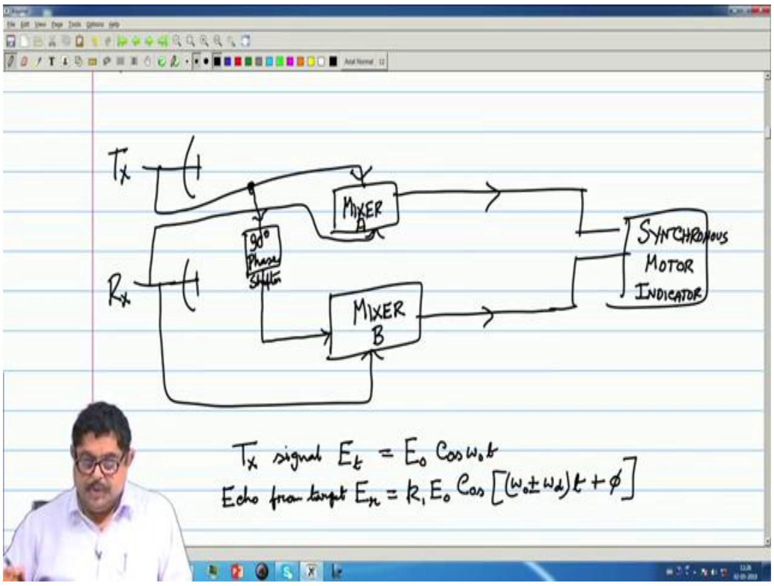

So, now we will see a we will modify the previous block diagram to get the sign of radial velocity. So, for that what we will do, again that; again that let us say this is the transmitting antenna and this is the receiving antenna and now here we put two mixers. So, one I am calling mixer A sorry mixer A and another one I am calling mixer B. Let me use easer let to erase this, so, mixer A and mixer B.

Now, just here we require an additional element additional element that we need a 90 degree phase shifter; 90 degree phase shifter, you know phase shifters. So, usually they are made of ferrite or some reciprocal material and then non reciprocal material and then. So, 90 degree phase shift you have seen in communication classes also etcetera the SSB modulation that time we require a ninety degree phase shift etcetera. So, it is a Hilbert transformer etcetera so, that thing 90 degree phase shift.

Now, this what we do, we take the signal. Now, how this mixers are fed? So, from the transmitting signal let us say that from the transmitter this mixer A that is given this and the other thing will come directly from receiver. So, mixer A is like the previous case. The previous block diagram mixer A is like that, mixer B is new. So, in mixer B this this transmitted signal that is also given to this 90 degree phase shifter.

And this output is taken and given to the mixer B and mixer B also is given the receiver signal ok. So, what is the modification that we have done? There are now two mixers. So, one mixer; mixer A is identical to the previous case, mixer B is only one change that the transmitted signal is being 90 degree phase shifts and given to mixer B. The other one is from receiving signal that is common in both one and this whole these two outputs of these two mixers they are now given to a synchronous motor synchronous motor indicator. So, and give this here also let me see yes.

So, mathematically now let us understand what is happening. So, I can write that what is the transmitted signal. So, T x signal, let me call these E t; t is a indicating that it is a transmitted signal. So, I can say

$$T_x \text{ signal } E_t = E_0 \cos \omega_0 t$$

I could have assumed sin also. It is a sinusoidal signal, let us say cos. Now, so, what is the echo signal? Echo from target let us call that E r; the received signal E r and that will be obviously, the amplitude will be some factor of this transmitted there will be a lot of reduction etcetera and cos.

Then I can say that there is a we are assuming a moving target, so, there is a Doppler shift I do not know what it is, but it is omega naught plus omega d into t plus in general there will be a phase.

$$\text{Echo from target } E_r = k_1 E_0 \cos\left[(\omega_0 \pm \omega_d)t + \phi\right]$$

Now, this phase is a constant phase phi which depends upon range of the initial detection. So, the more range it is that will change, but that is constant. So, you see that channel A; that means, the mixer A that is being fed with the E t and E r because directly the receiving signal and the transmitted signal are fed to mixer B.

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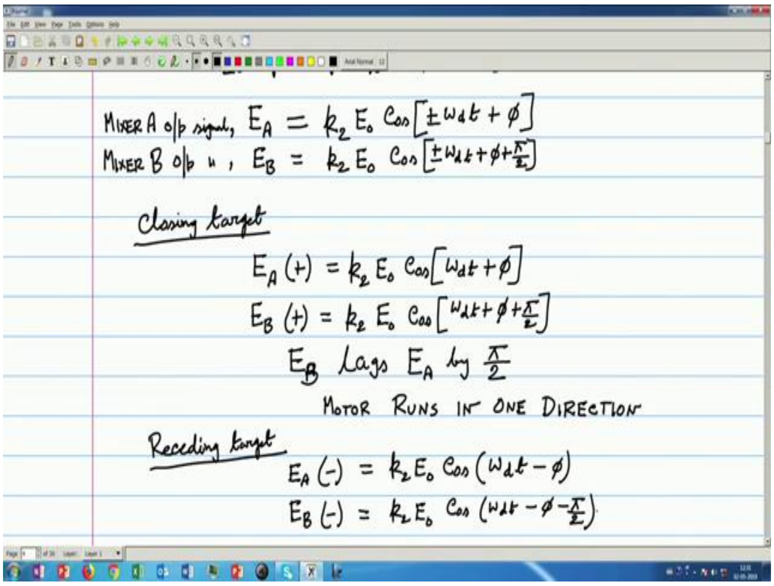

So, next I will write what is the expression for the output of mixer A that I am calling E A. What is it? Mixer A output signal. So, that I can say some other constant k 2 E naught; we know mixing operation if these two signals are fed what will we get? We will get the difference. So, that will be

$$E_A = k_2 E_0 \cos[\pm \omega_d t + \phi]$$

Similarly, what is mixer B output signal? Let me call it E B and that E B since mixers are identical I am assuming that the amplitude. Actually the; this mixers do not bother about the amplitude. So, I can write

$$E_B = k_2 E_0 \cos\left[\pm \omega_d t + \phi + \frac{\pi}{2}\right]$$

So, these are the two mixer outputs.

Now, let us specialize that what is happening for closing target what is happening for the? So, let us say that if it is a closing target. So, then I know that E A I am to show that it is closing I am writing

$$E_A(+) = k_2 E_0 \cos[\omega_d t + \phi]$$
$$E_B(+) = k_2 E_0 \cos[\omega_d t + \phi + \frac{\pi}{2}]$$

So, we can say that the mixer B output the mixture B output that is lagging mixer A output by pi by 2 angle. So, I can say that E B sorry, E B lags E A by pi by 2 phase ok.

Now, let us see. So, if this is the case then there are this phase difference between the two signals. So, if this two are now put to the synchronous motor you see that actually in the diagram this is put to a synchronous motor. So, synchronous motor will start rotating because if the two signals who are different in phase they are given to synchronous motor, synchronous motor runs more phase difference it will run more etcetera. You know the operation of synchronous motor ok.

So, I will say that the motor runs in one of the direction depending on the construction of the motor whether it will move in clockwise or anticlockwise motor runs in one direction I do not know that direction, but it is there. Then let us see what happens for receding target. So, for receding target I can similarly write

$$E_A(-) = k_2 E_0 \cos(\omega_d t - \phi)$$
$$E_B(-) = k_2 E_0 \cos(\omega_d t - \phi - \frac{\pi}{2})$$

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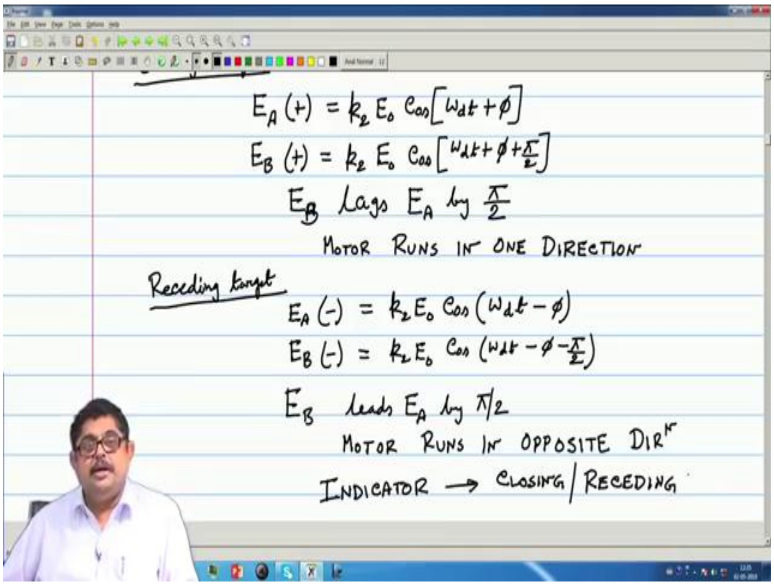

So, I can write that E B leads E A by pi by 2. So, if now this signal what will happen to the motor? I can say the motor runs in opposite direction, what it was for closing? So, opposing; so by just by noting in which direction motor is running you can put a mark on the motor because those who know their construction they will be able to say that whether it is moving in clockwise or anticlockwise. So, motor runs in opposite sorry opposite direction and so, you can now get from the motor that.

So, indicator will indicate indicator gives whether it is a closing or receding just by noting the direction. So, such a simple circuit, you see all this can be made this RF mixers are now available you even in microwave ranges etcetera very simple these things I think. So, you can always make this type of thing and also able to say what is the velocity. So, actually in labs these are made. In our lab etcetera you will see that students can easily make this.

And now we will now do one thing we will find out the exact expressions because these are that what is the exact expression C/R because here we have arbitrarily assumed this you see that the return signal something, but from the transmitted signal to return signal actually the range information is also there though CW radar would not be able to find that. But, we will drive an expression next that starting from the transmitted signal so that in terms of range we will find the expression that will be used later.

Because later actually we will see that CW radars if it cannot measure range that is a problem though it is able to measure velocity, but for range measurement we will just twig the classical CW radar then it will be able to do ranging and that time we will be requiring those expression, that is why we will do that next in the next lecture we will do that.

Thank you.