Principles And Techniques of Modern Radar Systems
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Lecture – 14
Pulsed Radar

Key Concepts: Simplified block diagram of a pulse radar, Introduction to clutters (stationary targets), Classification of pulse radar.

Welcome to this NPTEL lecture on Techniques and Principles of Modern Radar System. We were discussing various types of radar in previous few lectures, we have seen in detail the CW radar. Today we will see, the Pulsed Radar.

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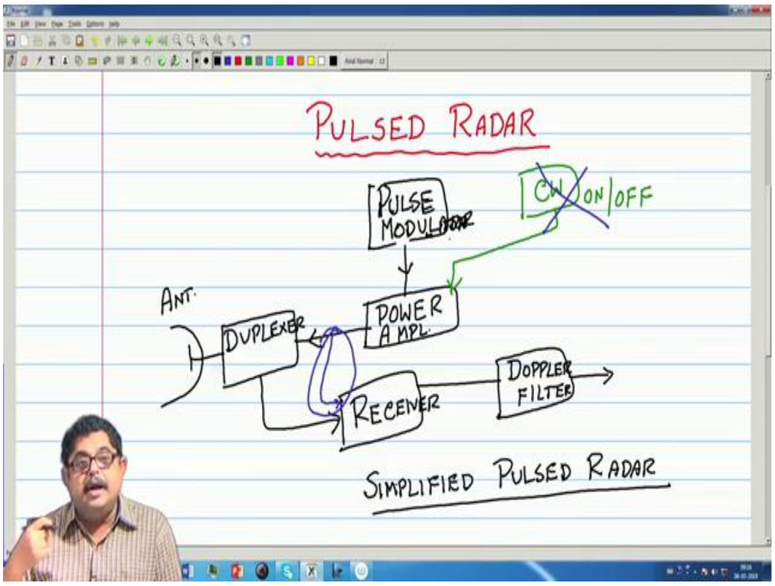

Now, the pulsed radar means instead of sending the signal transmitted signal continuously will have a pulsed radar. So, fast I will draw a very simple block diagram and then we will see the actual block diagrams that are used. So, first is there will be a pulse modulator, then that if the pulse is not of high power you require a power amplifier. Then that will be given, but we already know that in pulse radar generally the same antenna is used for transmission and reception.

We have discussed that antenna is a costly device at RF this high micro available and since pulsed radar is not always transmitting and when it is not transmitting it is listening. So, the same transmitter can be used. So, for that we needed duplexer and that is connected to the antenna. Now, when the transmission is off, the receiving antenna this same antenna is then receiving and so, duplexer has another path by which the received signal comes to the receiver. And from there, there is a Doppler filter and we get the velocity of the target also the range. So, actually instead of Doppler filter I could say the processor various processor. So, this is a simplified diagram; simplified pulsed radar.

Now, the first question that comes to our mind, if we look at these block diagram that we know CW production is easier. So, I could have instead of this pulse modulator I could have kept a CW modulator. Let us say that if I could keep a CW modulator; CW transmitter, it will produce RF continuous waves. And then I will simply make it on and off and that I will give here. So, instead of these if I do these can it work as a pulsed radar a CW radar, then on and off. So, far the pulse on time I will make it on then there will be a switch that will make it off.

Then the receiver will listen etcetera. The question is no because something is missing in the simplified diagram, actually to have this measurement receiver actually it in a pulsed radar also requires a very important connection that whatever is getting transmitted it should have that in the receiver. So, that it can compare what is happening, because we know that the measurement requires the thing also Doppler that will require that what is the transmitted frequency and compare to that how much shift is there. So, there is a connection required.

So, due to this part actually this scheme would not work. So, this was the correct scheme that there should be a pulse modulator, because if I do it with CW that on and off. So, during off time the problem will be that the receiver would not get any replica. So, the reference signal is lost to the receiver. So, receiver will not be able to make out what to do with the received signal and it would not be able to extract the range velocity etcetera.

So, that is the first part you should remember that you require a high power, high frequency pulse modulator for this. Now a previously also, we mentioned that a pulsed radar can distinguish between moving target and the stationary target. Now, here we will say that is a stationary target its return that comes to the radar that is called by a term called clutter.

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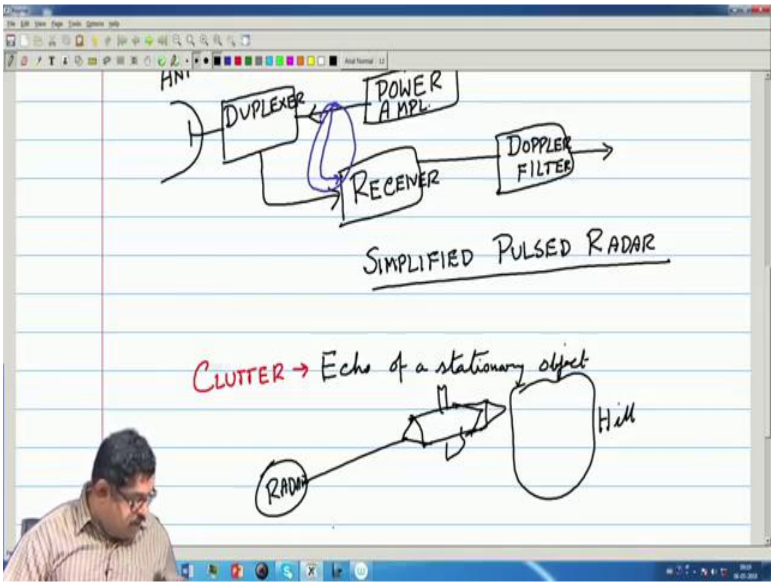

So, this is an important term that, what is clutter? So, here I am defining clutter, that's echo of a stationary object. Now, generally we are not bothered with this stationary object, because actually the pulsed radar's job is to detect the moving target. So, this is clutter and it is an unwanted thing. So, we need to make, but sometimes the clutter is much high and the actually target's echo that is buried in the clutter. Suppose aircraft is flying near the hill; hill is in the backdrop of the aircraft, the radar is looking the this is the radar it is looking at an aircraft, the aircraft is coming here and suppose there is a large hill here.

So, this hills return sometimes may be 60-70 dB maybe higher than the return from this scatter from these aircraft. So, clutter removing is a very serious job and actually pulsed radar get it inherently, we will see that pulsed radar can easily detect, but it requires some extra circuitry, one filter it requires actually that is the this Doppler filter or sometimes it will be called MTI filter etcetera. So, that will do the job because this if I see the Doppler actually it does not have any Doppler. So, it can be easily detected that this is a clutter ok.

And now, the second question that I want to ask is, you see this thing I also said this question earlier that that suppose the pulsed radar can furnish information about the target motion, because it is measuring range, we know the moment we are putting a pulse. We the weveform has a timing mark.

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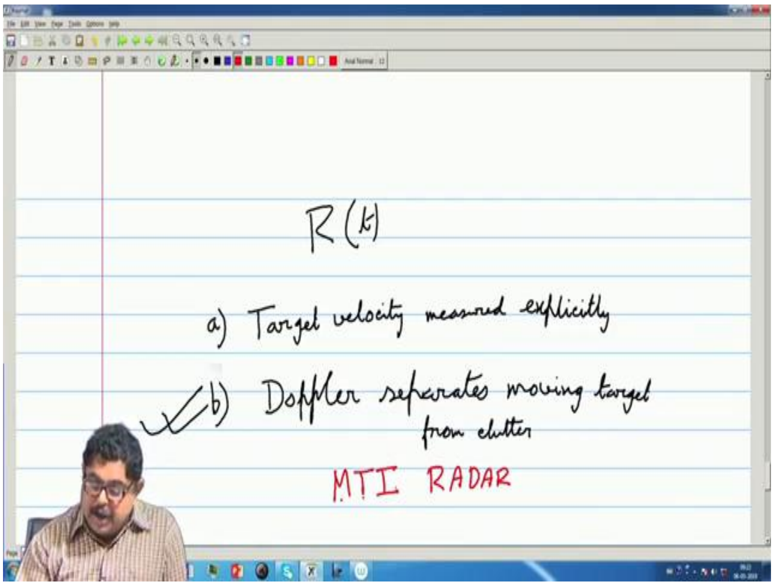

So, I can easily measure range and with time if we measure range; that means, if I measure R as a function of time. Then from this thing if I differentiate this because I have the timing information. So, if I know R t I can find velocity. So, from the range measurement and with the doing that range measurement with time continuous or with some discrete intervals, I can find the velocity of the target. But that is not done because there are two reasons that one is the velocity of the target.

If I have a Doppler measurement, then target velocity is measured explicitly, but as I say that nowadays signal processing is there. So, I can implicitly could have done that, but this part b is more important that this thing actually we will not be able to remove the clutter, whether if I do the Doppler measurement. So, Doppler actually separates moving target from clutter. So, this is the most important part that that is why all pulsed radar they have a Doppler measurement capability.

Now, with this capability, this separating this moving target from clutter or indicating, which one is moving target actually the there is a name one class of radar is called MTI radar or MTI capability. So, those radars we have these MTI capability are called MTI radar. So, MTI stands for moving target indicator, moving target indicator M T I. Now actually pulsed radar broadly has two classes one class is called MTI radar, another class is called pulsed Doppler radar now.

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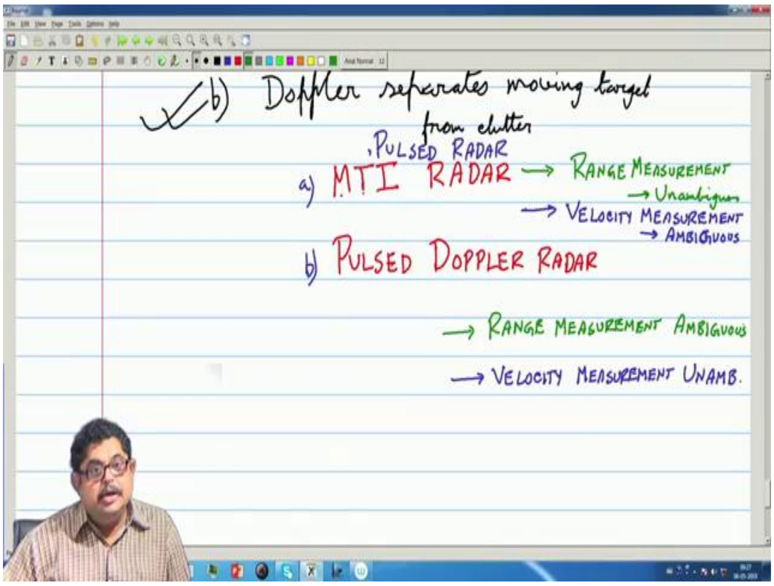

So, I can say that pulsed radar has broadly these two classes MTI radar or pulsed Doppler radar. Now, you should know the difference there is a subtle difference between these two actually MTI radar, when we will see it will become clear, but note down that MTI radar it has a it you see any pulsed radar with this MTI facility, they will have both the range measurement and the velocity measurement capability.

Velocity is the range is measured from time measurement, time transit time measurement and the velocity of the target is measured by measuring the Doppler shift produced in the echo signal compared to the transmitted signal. Now, both of this measurement now, we have seen that the range measurement that can be ambiguity in the measurement ambiguous range and unambiguous range these concept we have seen. Similarly we will just see next there can be also ambiguity in the Doppler measurement that we will see that is called blind speed. So, some speed radar cannot see those are called Dopplers blind speeds. So, there is ambiguity in the Doppler measurement also.

Now, MTI radar is designed. So, that your range measurement is unambiguous and its the velocity measurement maybe ambiguous. So, what is mean that it is giving very precise thing for range measurement, it is more interested in range measurement that is why it is making that unambiguous. Velocity measurement it is doing, but it knows that it is not so much important. So, it is ambiguous where as pulsed Doppler is the opposite, it is very much required it is not so much interested in the range measurement, it more importantly it wants to measure unambiguously the velocity.

So, I can say that pulsed Doppler for pulsed Doppler the velocity measurement is unambiguous, where as its range measurement may have ambiguity. So, from this actually their application is also indicated that actually you see that for a if you have a high speed target, then pulsed Doppler is used because high speed targets are dangerous, because you do not have much response time to tackle them. So, they are velocity measurement needs to be done very precisely and you will have to take action whereas for low speed targets we required MTI radar ok. So, these are a very subtle difference between them.

Now, we will come to a typical pulsed radar block diagram and we will understand that actually pulsed radar this diagram with this pulse Doppler radar its almost in new thing mainly in awacs etcetera where you are measuring the radar is not grounded radar is in a flying aircraft or flying satellite etcetera. There this block diagram is not applicable, that is modern advancement of radar, but generally the MTI radar that type of radar this block diagram we will be useful. So, let us see. So now, we know that; obviously, we will have to have a pulse modulator.

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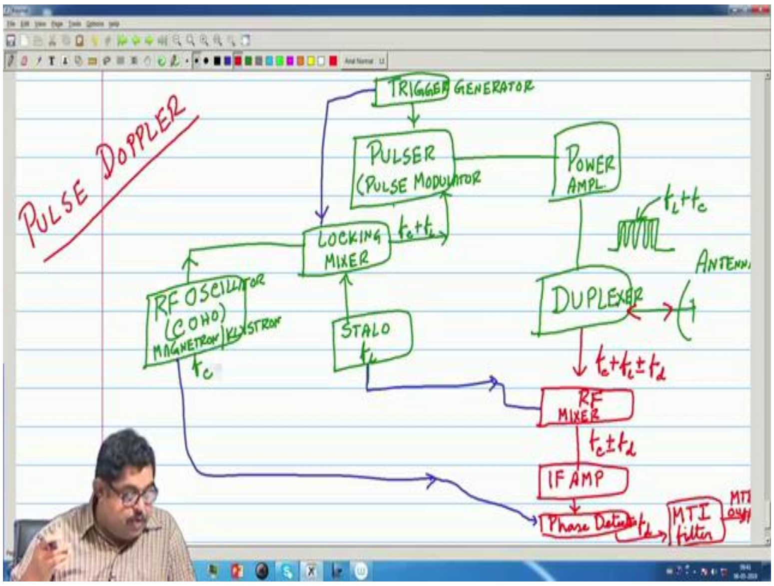

So, we will see that pulsed radar the pulse modulator in the transmitter portion of the radar. So, we require a generally radar people call it pulser, actually I will say that you should know it is nothing, but our that so called pulse modulator. What we discussed in the simplified diagram.

So, this pulse modulator, now the problem is that we will have RF oscillators and you know that RF oscillators, which were used in the early pulsed radar they were mainly magnetron based. And, they were not very stable in phase, but you see to measure the frequency actually frequency phase these are almost similar type of thing. So, if the phase is not stable when you will give the reference to the receiver, then there will be error in the measurement that is why you would require a very stable phase RF signal. So, magnetron was used because it gives you high power in early days it was the thing later klystron there, but still if you want to have a very precise measurement you need to make that stable. So, to make that stable actually two oscillators are used in this circuit.

So, I will draw the diagram later, we will explain first. There is an RF oscillator and usually earlier people call it COHO. It could have been made by magnetron or klystron etcetera which are microwave tubes. You required radar is these pulsed radars are high power. So, you cannot have bother type of semiconductor based a though with the advent of the semiconductor technology may be one day we will get that but still people use this type of Magnetron, Klystron or T W T etcetera.

Now, this is called COHO. COHO means, coherent oscillator we will discuss it is the part of COHO and let us say it is producing at a frequency of f c RF wave with carrier frequency f c. Now this is given this signal is, this f c signal is not transmitted directly or not given to the pulser directly. There is a locking mixer basically a mixer RF mixer locking mixer there. So, mixer requires two inputs. So, one of that is f c and there is also another oscillator it is not so, RF level. It is called STALO. So, it is a local oscillator stable local oscillator and that frequency let us called f l.

So, it is given to them and what the a gives this mixer is producing, the sum of these two f c plus f l and that is given to the pulse modulator. So, and pulse modulator is fired by a trigger generator. This trigger actually gives on and off time. So, basically this is determines the PRF etcetera. So, trigger generator actually influences the pulse modulator. This thing now after this pulse modulator I have an RF pulse if required there can be a power amplifier or if actually sometimes the whole pulse modulator block diagram inside there is a RF power amplifier that is ok.

That is given to a duplexer, as we have seen we require duplexer and then that duplexer gives it to an antenna ok. So, this is the transmitted part. Now, what is the job of this STALO, you see that this RF oscillator it may not be so, stable, but what happens this STALO is giving it and mixer. So, makes it stable and now this whatever f c plus f l is given at every pulse, it is now coherent with the transmitted pulse. So, I have a reference actually that reference is put here. So, I will use blue colour for this references. There are two references that will go here.

And also you will see that this trigger generator, whatever it is giving to the pulser, it is also the trigger is also given to the locking mixer. So, locking mixer knows when to lock the phase. So, whatever RF oscillator is giving the phase, now that phase is brought down to a standard value. So, even if the RF oscillator is not so stable in phase, but at every pulse on time the phase is brought to a standard value by this locking mixer.

So, now we have a coherent, that is why it is called a coherent oscillator. Though actually it may not be a coherent oscillator on its own, but with this circuitry the transmitted signal always is of a known phase and that phase reference we will see will be given to the receiver side will be used also this trigger generator you see it is making the pulse it is giving it signal to the pulse modulator also it is giving the thing locking mixer to lock the phase of the RF oscillator. So now, we have a stable locked in phase RF pulse that pulse is transmitted by the antenna.

Now, let us see what happens to the receiver. So, I can see what will be the transmitted frequency. So, while so let me write that this f c plus f l with a pulse thing. So, I have a I can say an pulse and there I have this thing. So, this signal frequencies f l plus f c and its phase is also known, a very known stable phase this is sent. So, there is target will produce the signal that will give me a Doppler shift. So, this duplexer on its return path, it will give me what is the signal f c plus f l plus minus f d depending on the closing target or the receding target. That is put to a mixer RF mixer. Now this RF mixer is fed by this reference f l. So, its output will be f c plus minus sorry plus minus f d. And this now this is a very weak RF signal. So, this signal is again put to a IF amplifier.

Now, this IF amplifier it put to a phase, but still we have f c. So, we will have to remove f c. So, that removal that this f c frequency is coming here that reference is put to that. So, this is a phase detector again in CW radar we have seen what is a phase detector?

Basically again a mixer sort of thing, with some additional circuitry so now, the output that is coming that will be the f d Doppler. So, that Doppler will be measured, but while measuring you see that we will have to remove the clutter etcetera. So, that is why this is a MTI filter, what is an MTI filter? We will see next. So, from this I get the MTI output ok.

So, this is the typical block diagram of a pulsed radar, I should say basically MTI filter type of pulsed radar. Pulse Doppler is a different thing. So, I can briefly summarize, what I have said that in any pulsed radar the transmitter is turned on and off by the modulator at a fixed rate and for a fixed duration. If oscillator is magnetron, the phase of the RF signal at the start of a pulse may be anything from 0 to 360 degree, but we know that in an MTI the phase of the returned echo must be compared with the phase of a reference signal.

So, echos from fixed targets will have fixed phase difference from the reference and moving targets produce echos with continuously changing phase at the Doppler frequency. So, it is necessary that the reference signal be locked in phase with the transmitted signal. So, that these two signals are coherent. The radar is called coherent MTI radar. So, despite the RF oscillator phase being random, the reference signal is coherent with transmission this is the, that is why it is called coherent M T I.

Now, duplexer it multiplexes the transmitted signal and the received signal I should actually draw it both ways. So, that the duplexer is sending. So, that two arrows should be there. So, usually this duplexer maybe a circulator maybe some T R tube modern day T R tube technology has improved. So, you can have a TR tube. Now RF oscillator usually magnetron, but presently the power amplifier is inbuilt with this and. So, it is Klystron, T W T etcetera.

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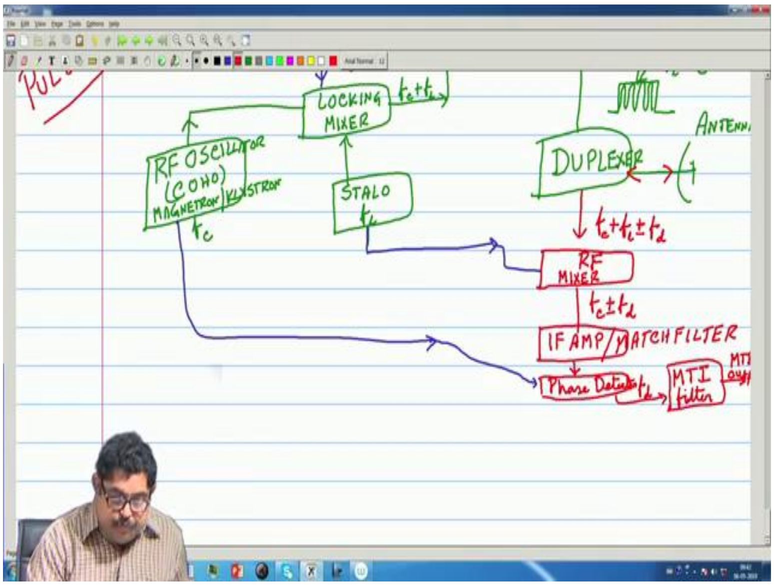

Now so, what will be the actually, the I F amplifier that I put actually that is I prefer to call it is receiving amplifier and usually it is a matched filter, which is the most appropriate filter for very low noise signal and to maximize the noise, if you know the RF signal that has been transmitted that signal shape. Then it is match to that usually it is a match filter match filter.

We will see match filter in details in the detection theory also in communication you have seen that. So, it is the and the phase detector what it is detecting you see it is having the received signal phase, it is having the transmitted signal phase so, that it compares. So, if we now plot that actually with time what you get.

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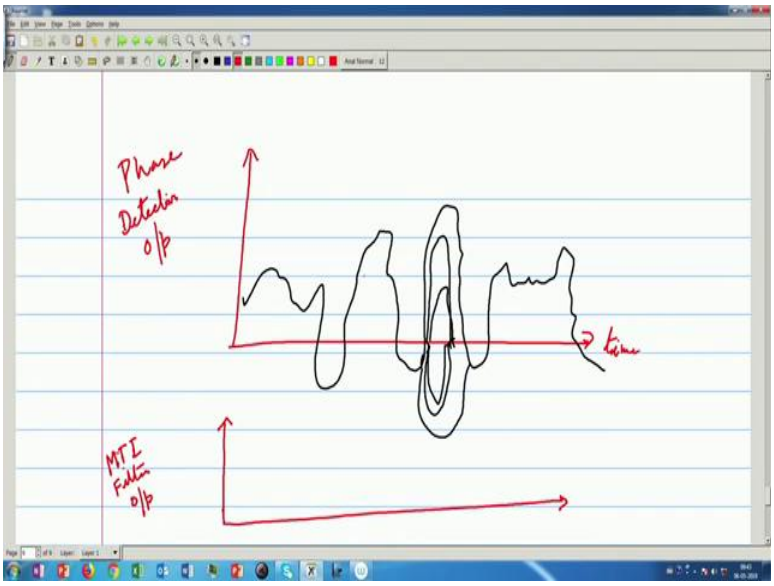

So, if I plot time verses phase detector output, you will see something like this the phase, but you will also see that there are in some places then and now how the MTI filter output we look? What MTI filter does we will see later, but finally, what will say these are all from stationary target. And moving targets you see the moving target phase is continuously changing. Whereas, the fixed targets there phase does not change. So, for all pulses the phase of the stationary targets do not change, but moving target its phase exchanging. So, you see this is the moving target these are all clutter.

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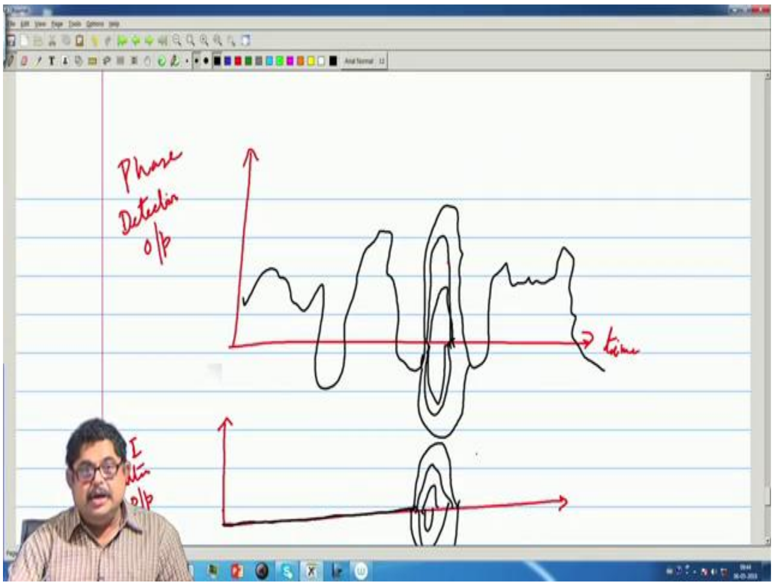

So, MTI output will look something like this that only here, it will give you an indication of that there is a target. This is actually various pulses with time you have seen various pulse things are superimposed. So, we will see that this thing will be there you will be able to understand that this is a moving target. Now generally the signals are bipolar, because phase can be in both ways. So, that is why generally if you put it an average voltage indicator it will be 0. So, generally this bipolar signal MTI filter output, that is given to a rectifier and you given to the display the display shows that there is a target.

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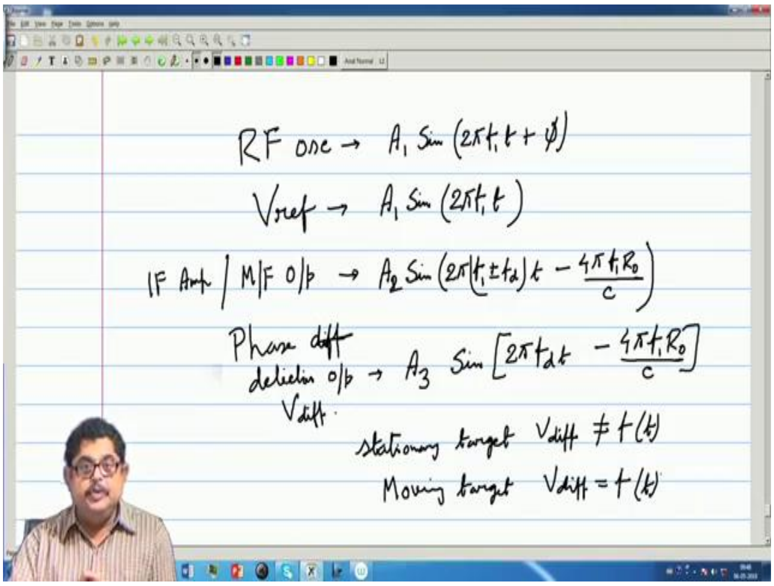

So, let us just briefly write that let us say the RF oscillator that, it signal if I call it sin 2 pi f 1 t plus some random phi.

$$RF\ osc \rightarrow A_1 \sin(2\pi f_1 t + \phi)$$

Now after the reference so, from that the COHO makes the reference signal. So, reference signal will throw away and let me say that the standard phase it makes at a start of every pulse is 0.

$$V_{ref} \rightarrow A_1 \sin(2\pi f_1 t)$$

So, it will be something like this. Now, at the output of the match filter or IF sorry IF amplifier output same; IF amplifier or match filter output.

It will be something like A 1 sin 2 pi f 1 plus minus f d into t minus4 pi f 1.

IF Amp / M|F O/p $\rightarrow A_1 \sin\left(2\pi(f_1 \pm f_d)t - \frac{4\pi f_1 R_0}{c}\right)$

These we have seen that if you a target is that a range of are naught then the phase it gets is this. Now after mixing so, that means, I have this standard reference signal and these. So, the phase detector after mixing I can say the phase detector output; phase sorry detector output can be written as some or I can be reference 1 it can be made a 2, it can be made A 3 A 3 sin 2 pi f d t minus 4 pi f 1 r 0 by C

Phase diff detection O/p $\rightarrow A_3 \sin\left[2\pi f_d t - \frac{4\pi f_1 R_0}{c}\right]$
V_{diff}.

So, that actually we have plotted in the previous one. Now for stationary target this is not a function of time. So, I can say that if this signal I called or I can say that this output let me call V difference. So, for stationary target, V difference is not a function of time and for moving target V difference is a function of time. Now what the MTI filter does. So, that we can separate the clutter that, we will discuss in the next class. We will see various MTI filter design because that is new that you do not know. So, that we will see the next class.

Thank you.