Principles and Techniques of Modern Radar Systems
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Lecture - 26
Tracking Radar (Contd.)

Key Concepts: Conical scanning, disadvantage of sequencial scanning, introduction to monopulse, idea of pulse split ratio

Welcome to this NPTEL lecture on Principles and Techniques of Modern Radar System. So, we have seen the lobe switching, we have or sequential lobbing, alternating 4 beams that gives us this thing. Now here I want to make that till now, we were talking of elevation and azimuth.

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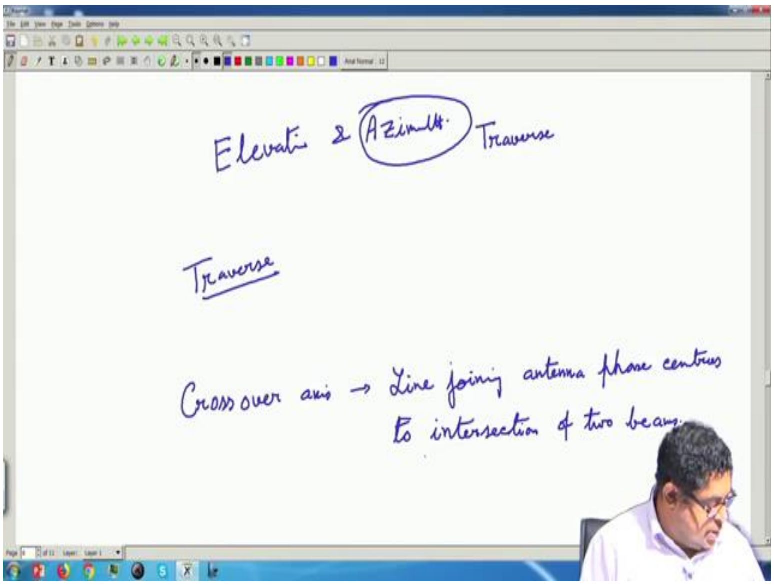

In tracking parlance actually this azimuth also sometimes is called traverse angle. Now, there is a slight difference between traverse what is a traverse angle? Azimuth angle we all know this comes from fundamental that spherical coordinate concepts. What is traverse? Traverse angle is angle measured in the slant plane containing the target. Actually what happens?

Suppose in a measurement we need to have one of the measurement first suppose you know the range of the target then either you measure elevation first or azimuth first. So, usually elevation is measured first; that means, the beam is now put is with the z axis now the elevation is done and found out that at certain angle you are getting the target. So, you now know the elevation.

So, now you are at a circular plane in that elevation angle. So, the angle measured in that is called traverse. So, you can say that azimuth angle projected in the horizontal plane, that is actually traverse angle, but whatever we require elevation and azimuth thing. And also in the last class we have seen the definition of crossover axis because this term will be coming in all types of tracking radar analysis cross over axis is what? Line. So, I can define it as line joining antenna now antennas are distributed structure.

So, what is the meaning of line joining antenna? Line joining antenna phase centres actually every antenna can be equated with a point as if antenna is represented by a point. In reality it is not it is a fictitious representation in antenna courses we have discussed lot about antenna phase centres. So, line joining antenna phase centres to intersection of two squint beams. As last time I am I think I have the picture I discussed that this point joining the two beams.

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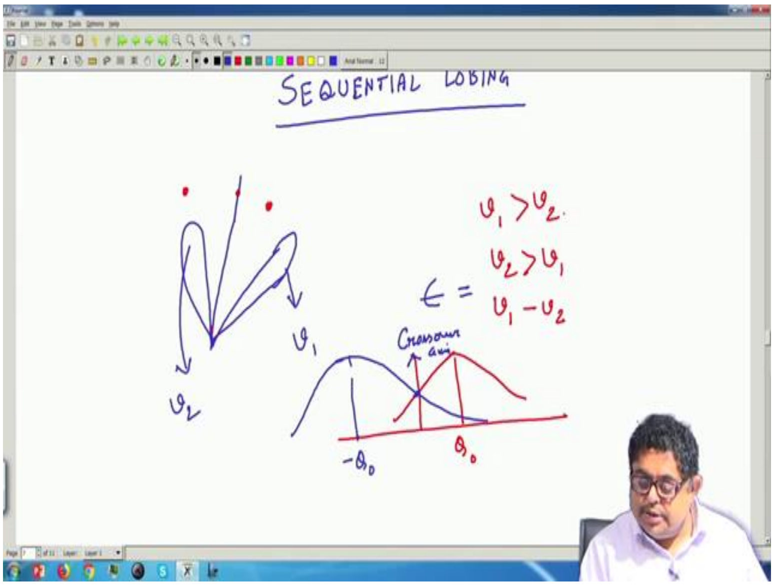

So, from the antenna phase centre; that means, from here antenna phase centre to this point this is the crossover axis intersection of two beams. Now, we can say that lobe switching operation that we have seen previous thing that lobe or beam switching that was interlaced in elevation and traverse now actually.

So, then people thought that instead of doing sequentially, if we can do the whole thing; that means, because switching the beam positions in those days it was a mechanical movement. So, that was taking lot of time etcetera instead people thought that will put the antenna rotating.

But since it's a pulse radar. So, at some positions it will get the returns. So, actually the beams though the antenna is continuously rotating, the received echo signal is not continuous because the operation is pulse. So, at the position of the pulse radar or at the position of the sending of the pulse radar; obviously, there is a beam position. So, that means, automatically the beam can be switched if we go on rotating the antenna that method is called conical scan.

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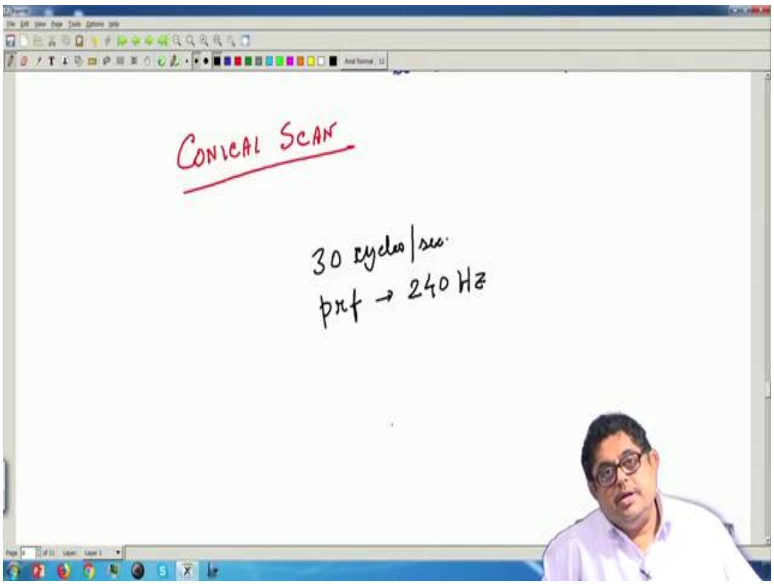

Conical because any antenna can be if you want to have both traverse and elevation information, then it should be rotated in the conical scan. So, beam motion is continuous in conical scan, but target gets illuminated only when each transmitted pulse reaches it. So, typically the antennas scanning rate is 30 cycles per second etcetera and suppose my prf typical prf we have seen of a pulse radar 240 Hertz so; that means, you can say that for one complete scan I will have 8 beam positions.

So, let in a conical scan setup let the antenna is moving and so; that means and if the target is not on crossover axis they then you can see that you are getting returns for one full rotation you are getting 8 returns and echo strength we can know that these 8 returns echo strength is modulated approximately sinusoidally at scanning frequency this is greatest. So, we get the maximum echo when the target is close to the beam axis. So, just in this case we need to demodulate the received signal. So, we know the modulation envelop. So, we can easily demodulate. So, this normalized and compared to a reference sinusoid at scanning frequency.

So, just by a pair of phase sensitive detector it can be done. So, two correction signals will come for two orthogonal angular direction. Actually this type of conical scan antenna was extensively used in World War II. Here utmost precision of angle will not come and still it is used in rough estimates that will not very precise tracking radar.

But we should understand the drawback of these that there is a principle sources of error or what? In both these things; that means, lobe switching or sequential switching and this conical scan actually you are sending or seeing the target sequentially; that means, at different points of time.

Now, the inherent assumption is the targets RCS is not fluctuating, but in practical cases if target’s RCS fluctuates, then actually a two different things you are getting. If that suppose at two beam positions the target’s echo fluctuates by considerable amount, but radar will understand that as a that due to the angular position that change of echo signal came. So, it will not understand that is a fluctuating RCS.

So, that will give a lot of error in the phase measurement. So, that was inherent in all these sequential lobing whenever you have time sequential and also actually people have found that this fluctuation of RCS for the target has considerable power spectral density in the vicinity of the scanning frequency. You see that this RCS fluctuation when we will study later that various Swerling model that time we will see that is not very high, but what is our scanning frequency you see 30 cycles per second 30 Hertz etcetera.

So, generally the RCS fluctuation also have a sizeable PSD in those frequencies. So, that results in severe errors in angle measurement. So, what I said that physically what happens? Radar cannot distinguish between pulse to pulse variations in echo amplitude due to target displacement from antenna axis and echo amplitude variation due to target RCS. So, actually these two are two different things.

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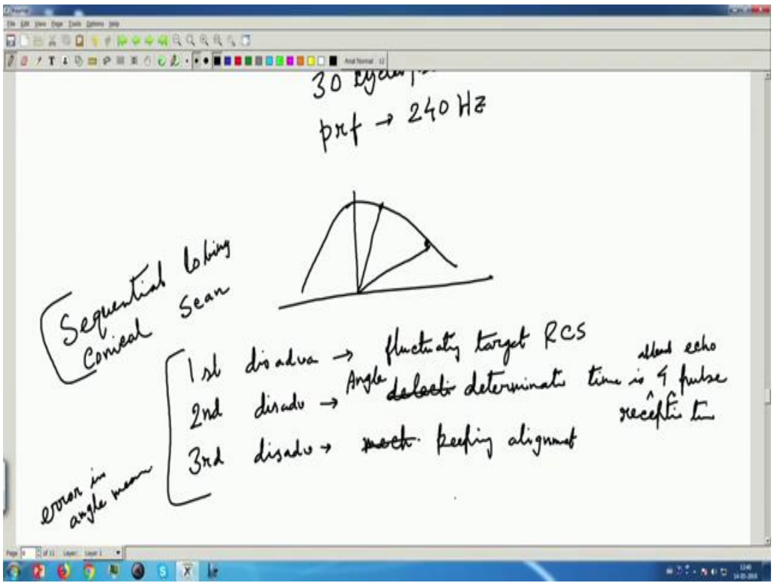

Actually you see that if this is my radiation pattern, then if the target is here I will get something, if the target is here I will get a reduced thing. Now, suppose if I see these I will think that okay the this angle is more because compared to this angle this angle is more. But if radar will then say that the angle measurement so, the target is such a angle away. But this fluctuation could have been caused by the RCS fluctuation of the target. So, that time even if the target is at this position I can conclude that this is the thing. So, this is quite considerable on this scheme.

And another disadvantage of all these sequential scheme is that there is a limitation that gets imposed on the data rate. Because you can process or you can get the angle information only after you have got 4 echos from a target. So, that may take sizable time so; that means, your in a fast moving scenario it may be a bottleneck because to get that angle information you are taking quite a good amount of time. And if nowadays with high speed targets or high angular accelerating targets, it's a problem suppose if a manoeuvring thing the measurement tracking radar will not be able to measure with those backward technology

And another disadvantage. So, we have seen the first disadvantage of sequential any sequential scheme. So, I will say sequential lobing as well as conical scan. Both the cases the first disadvantage we said that fluctuating target RCS and for that it poses what problem.

Second disadvantage as I said that the detection time for detection say the determination time determination angle determination time is 4 pulse 4 echo pulse reception time. I will say at least 4 echo pulse reception time. So, this is problematic for high angular accelerating targets that it requires lot of time.

And third disadvantages is that if you have a mechanically scanned antenna, then mechanical vibration makes it hard to maintain accurate alignment of the crossover axis. So, third disadvantage I will say mechanical vibration or keeping alignment with the reference. So, that is problem because I in conical scan it is a continuously rotating. So, that has a vibration or in sequential also you will have to move it. So, keeping alignment is a problem. So, that will give rise to all this will give rise to error in angle measurement.

So, the idea or motive was that time that can we not send a single pulse get the information in that pulse without moving anything and derive all these information, but as I said that you require squint beams. So, you require at least 4 returns from a single one because you require the information from azimuth or traverse you require 2 information and 2 information from elevation. So, 4 returns you require.

So, if you send a pulse you get one echo, but can we have certain arrangement by which I can have 4 echos at one go simultaneously. So, that is called mono pulse that is why the name with the single pulse you can do that your hardware will be complicated, but you can do that actually that is the mono pulse concept.

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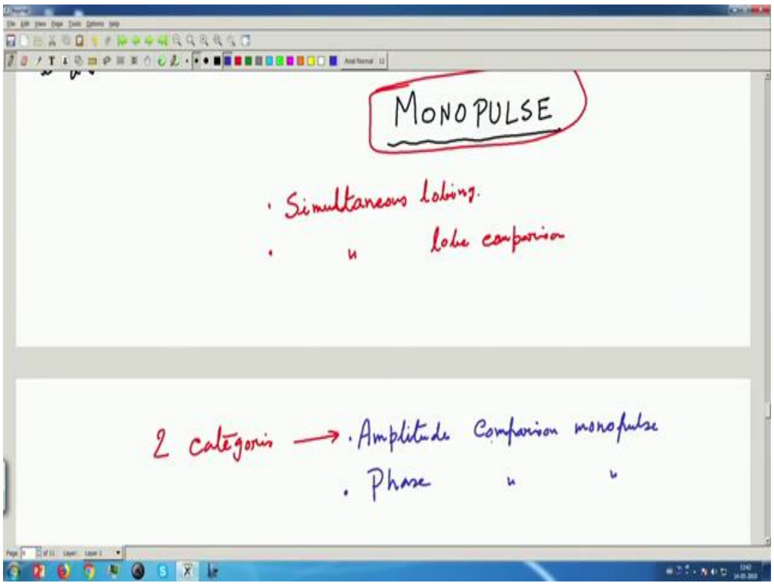

Very very important concept and in technology wise also it is mastering that is a challenge our country also after a lot of humps and bumps finally, our country has this capability. So, this mono pulse also is called also very important tracking concept its also called simultaneous lobing as opposed to that sequential lobing. So, simultaneous lobing sometimes it is called simultaneous lobe comparison technique all that what I said that 4 those comparisons you should make.

Now, there are 2 categories of monopulse 2 categories; one is amplitude comparison monopulse another is phase comparison monopulse. Now we will discuss amplitude comparison monopulse only, phase comparison monopulse is another technique, but we would not go there only one we will use to have an idea.

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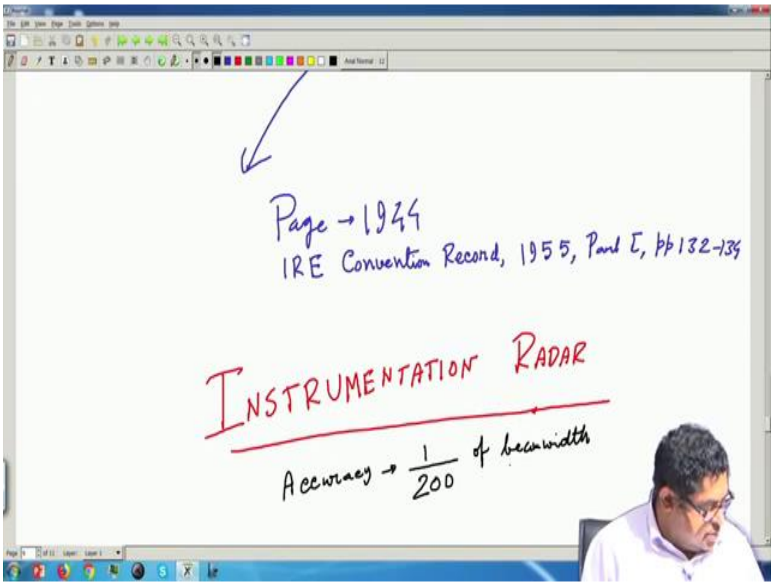

So, this amplitude comparison monopulse it is similar in concept to lobe switching, as I said that instead of comparing the target echos in 4 sequential beam positions; that means, up down left right it forms the 4 receiving beam simultaneously and makes the comparison during one pulse time.

Now, if you require only information in one coordinate; that means, either azimuth or either traverse or elevation only then instead of 4 you require 2 receiving beams now please remember in all these cases there is only a single transmitting beam. And that will illuminate the target from target when the return comes this monopulse that forms 4 receiving beams 4 receiving squinted beams and from that determines so; obviously, since it is done at within a single pulse time higher data rate, ideally the here that target fluctuation pulse to pulse does not come into picture here because in one pulse you are measuring. So, whatever the RCS that is all for 4 receiving beams.

Actually theoretically there should not be error due to this RCS fluctuation, but in the construction of this monopulse is a bit challenging and due to imperfections in the this actually its a fully microwave based design and the deviations from the ideal because in the construction everything cannot be constructed so, accurately. So, there will be errors in the measurement, but that is very very reduced compared to all these sequential schemes.

Cost is more because the equipment is more complex and it also requires multiple receivers. The monopulse because the processing part is more the hardware is also more in monopulse, but in actual case only once you are sending the pulse and getting all the information that is the advantage.

Actually the inventor of monopulse was one engineer Page, his name was Page in 1944, he submitted a report to Naval Research Laboratory and actually this whole concept you can have in IRE convention record the paper is available. So, you can go to IEEE site and its a really in radar thing it is a revolutionary concept 1955 part 1 page 132 to 134 that.

Now, application of this monopulse tracking is; obviously, in tactical control of gunfire and up missile launching and guidance this is essential as I said, but military application; obviously, is there because you can very precisely making tacking missiles etcetera. But space application; tracking of space vehicles satellites and other space objects, then in analysis of trajectory, analysis of echo variation of moving targets, extraction of target size, shape, rotation all these are intelligent applications of these.

Then even when a missile is being tested that time also monitoring and evaluation of exercises at test ranges, that is done by this technology, then tracking space vehicle during launch to determine the correctness of orbit or trajectory, to give signal for destruction if path is faulty beyond correction all that; that means, all these tracking they you require this monopulse.

Actually this sometimes this angle measurement radar very precise angle measurement radars they are also called by a name instrumentation radar. So, instrumentation radar is nothing, but this monopulse radar more or less…. Actually instrumentation radar could have been anything, but nowadays this; that means, these are basically for precise angle measurement this instrumentation radars is used and its accuracy as I said that up to million is possible, but minimum that should be 1 by 200 of beam width without that it will not be called an instrumentation radar.

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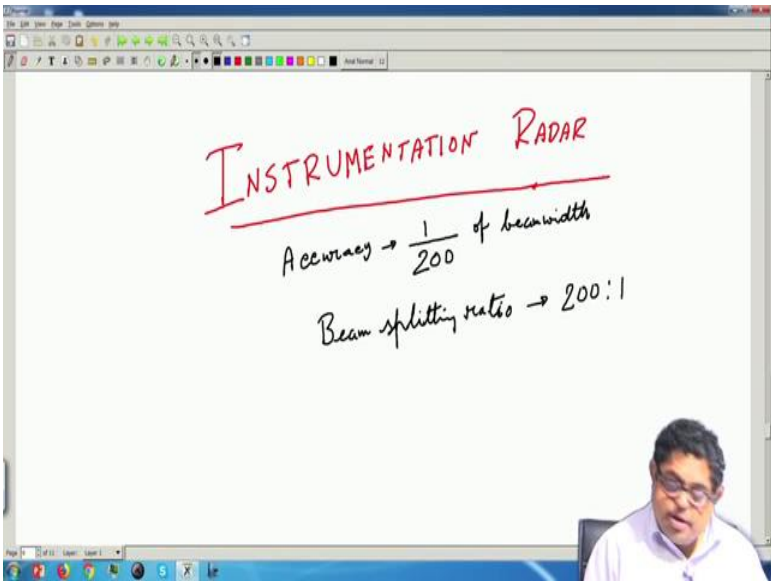

So, sometimes this accuracy we call it like this, but this instrumentation radar people use a term beam splitting ratio; that means, with how much the beam is a beam width how much split you can make; that means, that is your resolution. So, this is 200 is to 1 you see the same thing, but it may be like this.

Now, we will discuss this whole monopulse concept with a baseline design; that means, a very typical design, as we did for pulse radar that we started the discussion and based on that we have seen various modifications, that here also we will see that baseline monopulse radar. So, that I introduced today then actually you see that you have a.

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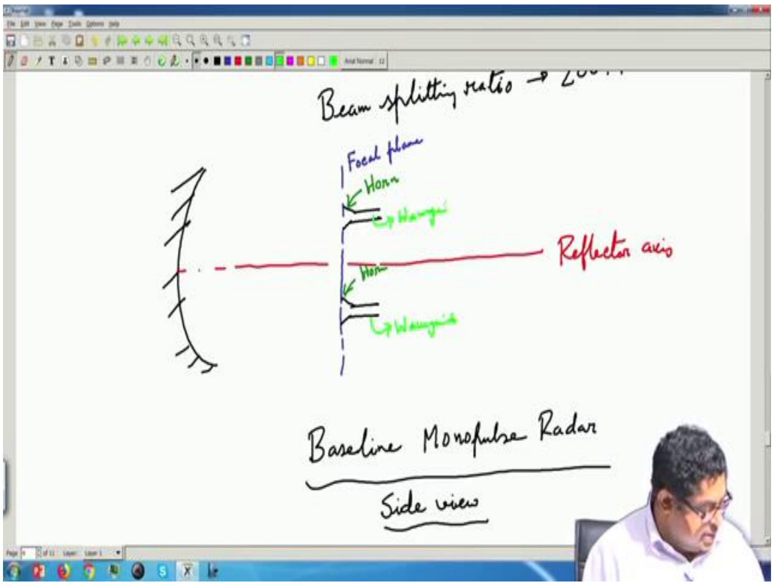

So, I will say that baseline or typical monopulse radar I will draw this block diagram first and there will be some terms in the next lecture we will discuss that. So, there is a reflector, so, a dish and there are. So, this is called reflector axis and at the focal plane. So, I will say that this is the focal plane this blue dot line. There are 4 waveguides 4 horns backed by waveguide this is rectangular waveguide this is horn.

I am drawing two why because this is actually this baseline drawing this is my side view. So, from any side if I see I will be able to see the two horns. So, I will say that this is what? This is the horn, this is the horn and this is the waveguide this is the waveguide. So, there will be waveguides. So, this is thing and then how they are connected at the back plane that we will see. So, this is side view. What is the front view or axial view? So, this is from side I am seeing, but from the axis if I see I will draw that also.

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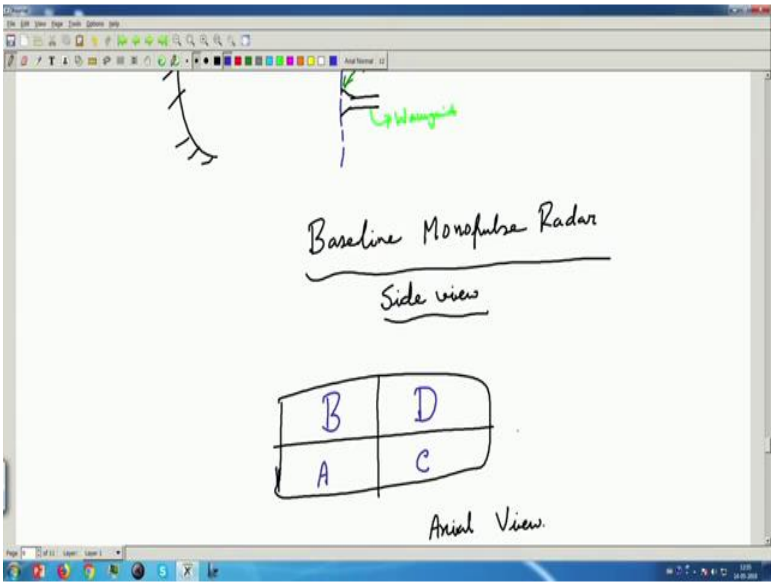

So, side view, this is my axial view. So, axial view will be something like this. So, these are the 4 feed horn I said. So, there will be 4 feed horns and these. So, I have just introduced this I will discuss one by one each of them in the next class and then we will see the microwave beauty, the microwave engineering that how your back plane where lot of microwave engineering concepts will come can give you the precise angle measurement, at least 1 by 20th of the beam width.

That means, if beam width is 1 degree 1 by 20 200s of that or even better ones very precise ones even can give you 1 by millionth of a beam width. So, what is there? How that is obtained that is a really good story to learn we will see it in the next class.

Thank you.