Principles And Techniques Of Modern Radar Systems

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Lecture - 52
Tutorial

Key Concepts: Tutorial 7

Welcome to the NPTEL lecture on Principles and Techniques of Modern Radar Systems. We have in previous lectures discussed the synthetic aperture technique.

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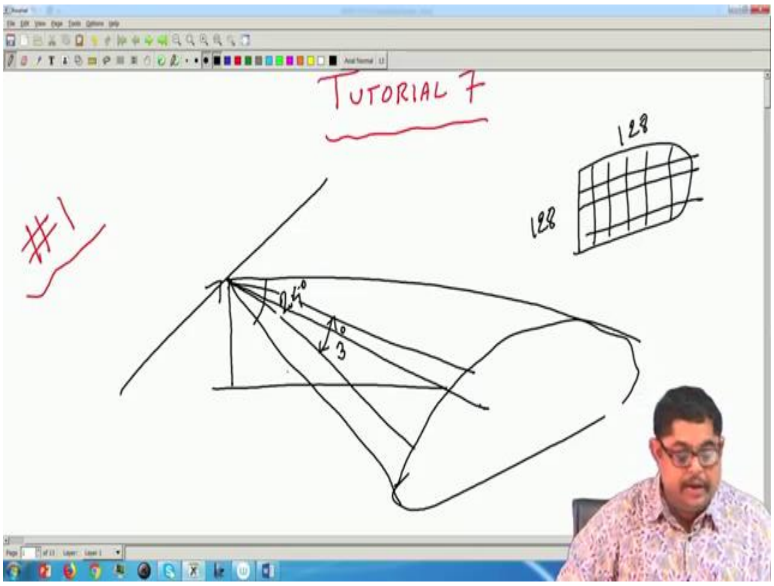

Today we will see one problem on that, it is a design problem. So, with this problem we will do the Tutorial.

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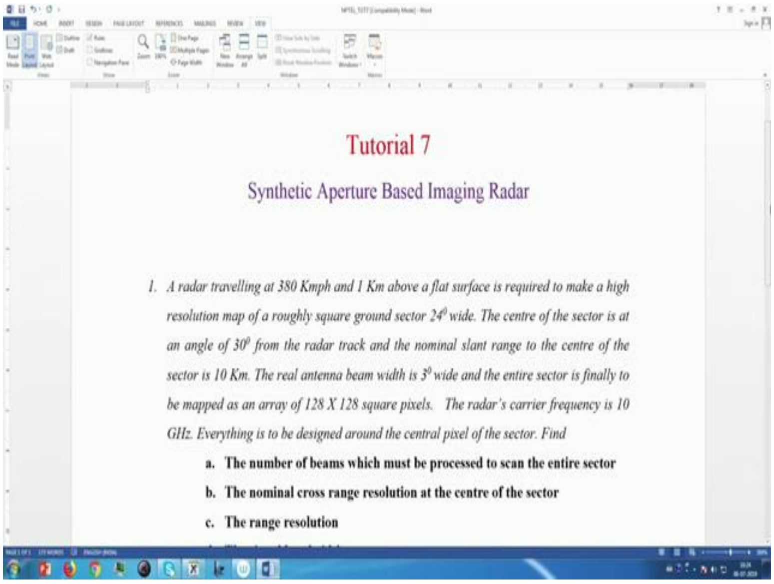

So, a radar travelling at 380 kilometer per hour; that means, it is being flown by a aircraft and 1 kilometer above a flat surface is required to make a high resolution map of a roughly square ground sector 24 degree wide. The centre of the sector is at an angle of 30 degree from the radar track. Track means the direction locus of the aircraft or radar and the nominal slant range to the centre of the sector is 10 kilometer. The real antenna beam width is 3 degree wide and the entire sector is finally to be mapped as an array of 128 by 128 square pixels

The radar's carrier frequency is 10 giga Hertz. Everything is to be designed around the central pixel of the sector. Find the following things that.

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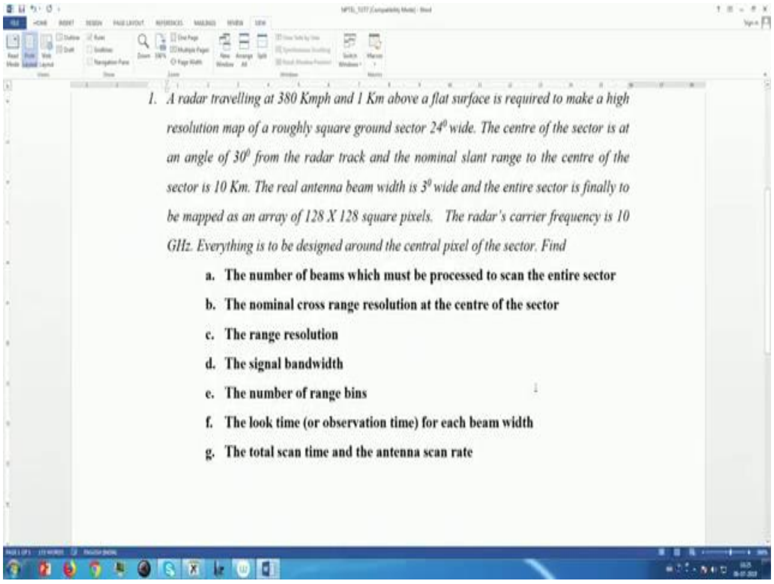

The number of bins which must be processed to scan the entire sector; then the nominal cross range resolution at the centre of the sector; the range resolution; the signal bandwidth; the number of range bins; the look time for each beam width; the total scan time and the antenna scan rate. So, it is a comprehensive problem. So, let us start with this.

So that means, the scenario is something like this, the radar or the aircraft is flowing at a height of 1 meter from the ground and there is a sector here which is, total this sector is 30 degree from any point. So, this sector is to be mapped as an image of pixels. So, this is 128 pixels, this side is also 128 pixels, so this whole sector to be mapped in that and then the following things to be.

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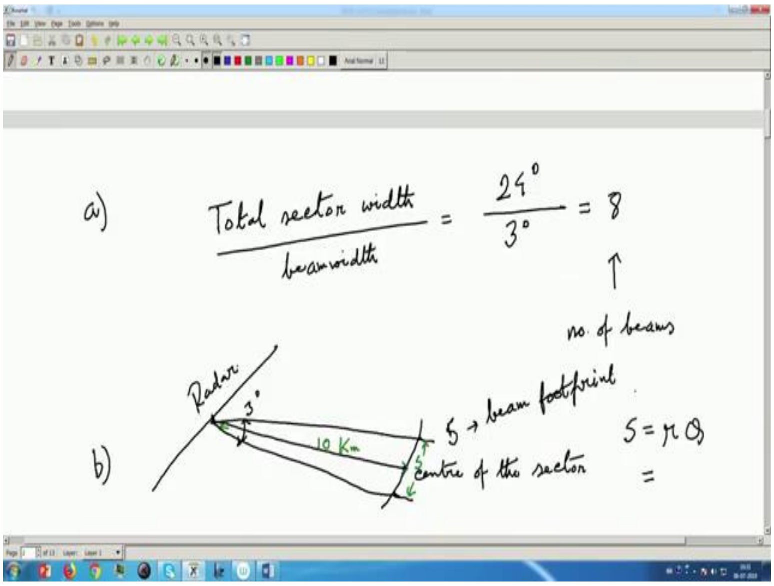

So, let us start first that, the part a question is, the number of beams which might be processed to scan the entire sector. Now when it is flowing actually, 1 beam width will be something like this. So, that beam width I think it is, the question is 24 degree. So, this is not 30, this is given in this 24 degree is the total thing and this is 3 degree required to.

So, width is 24 degree and this is beam width is 3 degree; what was said is this centre of the pixel is at an angle 30 degree so; that means, this angle is 30 degree from the. So, that is the different story. So, let us come to part a that how many beams we need to process; so that means, total sector width sector width by beam width this will give us the number. So, both the things are given in degrees; total sector width is 24 degree, angular width and beam width is 3 degree. So, 8 beams are required. So, I can say that number of beams required to process the entire sector that will be 8 as simple as that.

Then part b, the nominal cross range resolution at the centre of the sector. Now the centre of the sector is coming into play. So, let us say that this is the point centre of the sector and this is the radar at a particular time. So, it gives a 3 degree beam width; so that means, this angle is 3 degrees. So, how much it illuminates? So, it illuminates, if I say that this distance and this distance let me call that s. And it is said that the centre of the sector is at an angle of 30 degree from the radar receiver, radar track and the nominal slant range to the centre of the sector is 10 kilometer; that means this is the slant range. So, this distance is 10 kilometer.

So, 10 kilometer 3 degree beam width, so what is the peripheral link? So, it is simply S is equal to r theta, because r is very large. So, I can apply this formula S is equal to r theta, I should remember theta is in radian, so that will give me, so this is actually called beam footprint; so S is nothing, but beam footprint.

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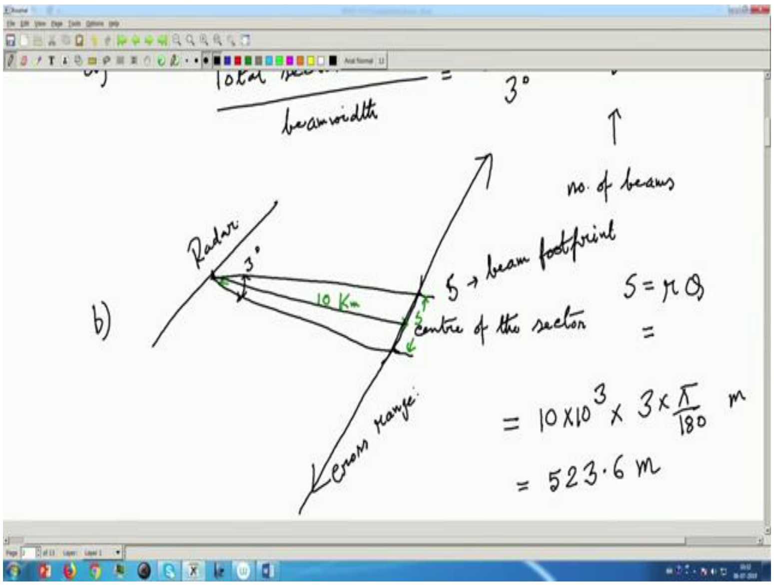

So, S is equal to r theta, this I can calculate I think, here let me calculate 10 kilometer; that means, 10 into or 10 to the power 3 meter into 3 degree. So, 3 into pi by 180 then it will be in radian. So, this gives me 523.6 meter, this is in meter so; that means, the footprint is this one beam it is footprint is this.

So, along cross range, this is the cross range. So, cross range is this, cross range. So, along cross range 128 pixels are there in the image that is already said, also along cross range there are 8 beams. So, each beam will take how many generate how many pixels?

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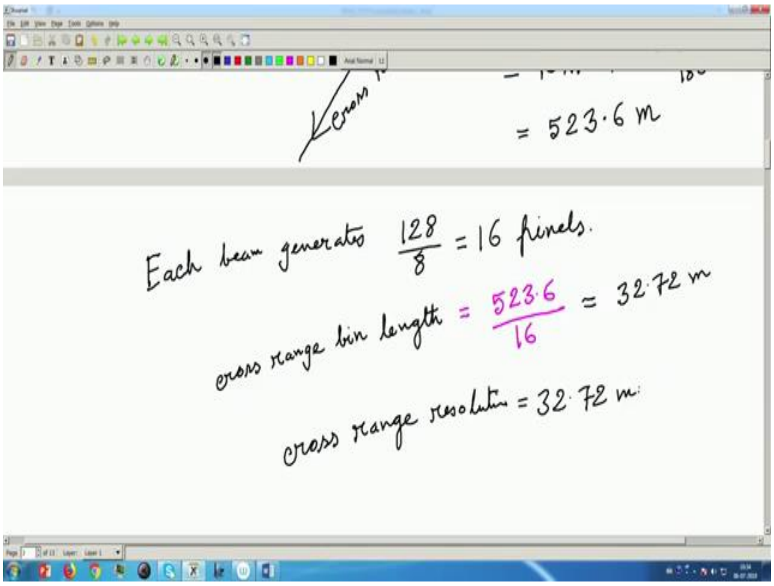

So, I can write that each beam generates 128 by 8. So, that is 16 pixels are generated by one beam. So, 523.6 meter in the cross range direction is to be divided into 16 pixels. So, cross range bin, what I will say length, I think you are understanding that these thing I am dividing into 16 pixels, there are 16 such pixels. So, each one what is the width of that.

So, cross range bin length is 523.6 divided by 16. So, that will give me 32.72 meter and that is the cross range resolution; because one bin whatever coming from that portion, one cross range beam bin I will say that everything is included there. So, you can say that, cross range resolution is 32.72 meter ok.

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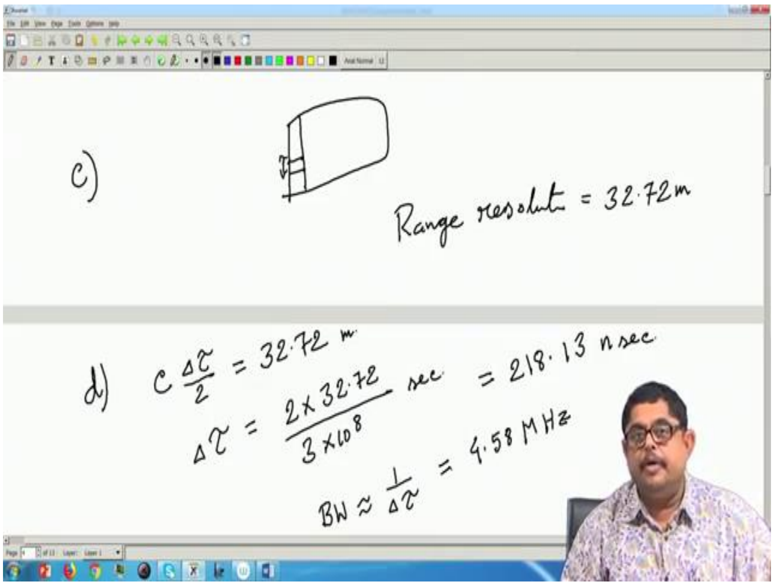

Then we are coming to part c of the story. So, what was part c problem, you can check from here what is part c the range resolution. So, the range resolution, now cross range resolution ultimately the whole thing is a square grid. So, square grid. So, I have already found that cross range this is so and so, the range will be also that. So, I can say range resolution is also that 32.72 meter.

Then let us come to part d, what is d; d is the signal bandwidth. Now the bandwidth thing come; that means, we will have to find the bandwidth now range. So, the moment bandwidth is coming pulse width will get involved. So, we know that this range resolution that I can write as c roughly delta tau by 2 this is a constant frequency radar I am assuming. So, c delta 2 by 2 will be 32.72 this is the range resolution roughly, meter. So, from that I can calculate what is delta T, delta T will be 2 into 32.72 by c; so, 3 into 10 to the power 8 in second.

So, that will be 218.13 nanosecond well. So, I can say roughly band width is 1 by delta tau; if you require more precise then you need to know the signal type etcetera. But we are assuming it is a constant frequency thing and ideally it should be that two third term, but roughly I can calculate that bandwidth will be 1 by delta tau. So, that will be approximately 4.58 mega Hertz ok.

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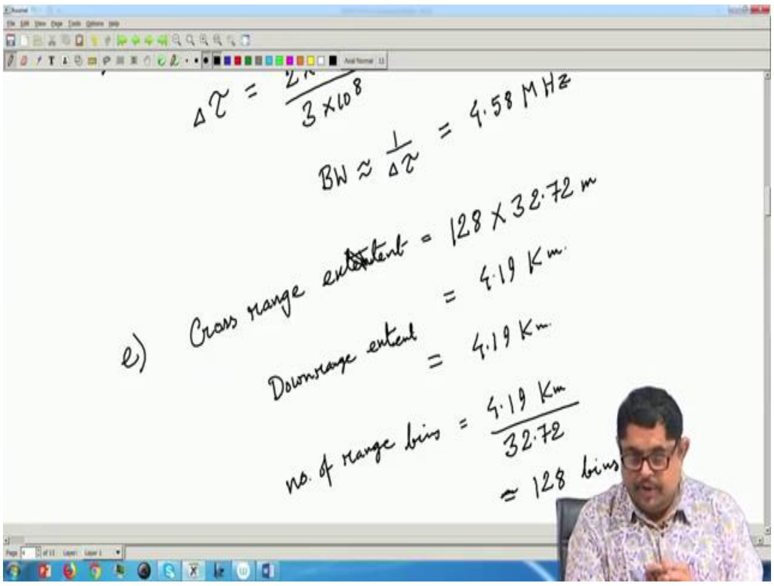

So, this 4 5 mega Hertz if you keep; you will be in the safe side. Then what is the next portion e, the number of range bin. Number of range bin will be same, that 122 has been said; but also you can calculate that. So, directly you can write 128 because it is said that 128 range bins will be there; but let us see from cross range everything is given. So, cross range extent, we can say as 128 into 32.72 meter.

So, this is 4.19 kilometer; since square grid, so we can say the down range extent is also same. Down range extent is oh extent will also be 4.19 kilometer. So, number of range bins is 4.19 kilometer by 128 not 128 that is a number. Number is number. So, it will be that 32.72, 32.72. So, that will give you again approximately 128 bins. So, 128 bins in the, next part is f.

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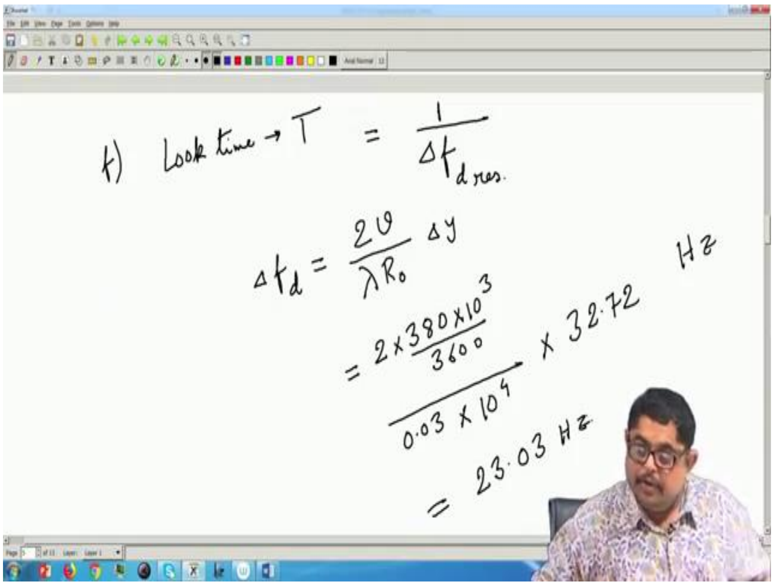

So, what is f, the look time for each beam width. So, how much time it stays at the each beam. So, that is called look time for beam width. So, look time, let us call it capital T. So, that I can say, we know from our knowledge of resolution that it is 1 by delta f d resolution; that means, Doppler frequency resolution 1 by that is the time. So, we can first calculate what is delta f d, delta f d; because you see SAR's things are not said, if it is said then we could have calculated. But here SAR's details are not said, but we can easily find out the Doppler frequency thing, because velocity etcetera are said.

So, 2 V by lambda R naught into delta y, this we know that this is the relation between Doppler, change in Doppler divided by with respect to this and this is your cross range resolution. So, velocity is given, I think 380 kilometer per hour. So, 380 this is meter than hour, so 3600 seconds divided by lambda. Now lambda is, what was lambda in the problem let us see, what is frequency, carrier frequency is 10 giga Hertz. So, 10 giga Hertz means it will come as 3 centimeter; that means, 0.03 and R naught is the distance of the ground sector. So, that is 10 kilometer so; that means, 10 to the power 4.

So, this part and delta y we know cross range resolution already we calculated 32.72. So, we can find out that this will be in Hertz. So, that will come to 23.03 Hertz.

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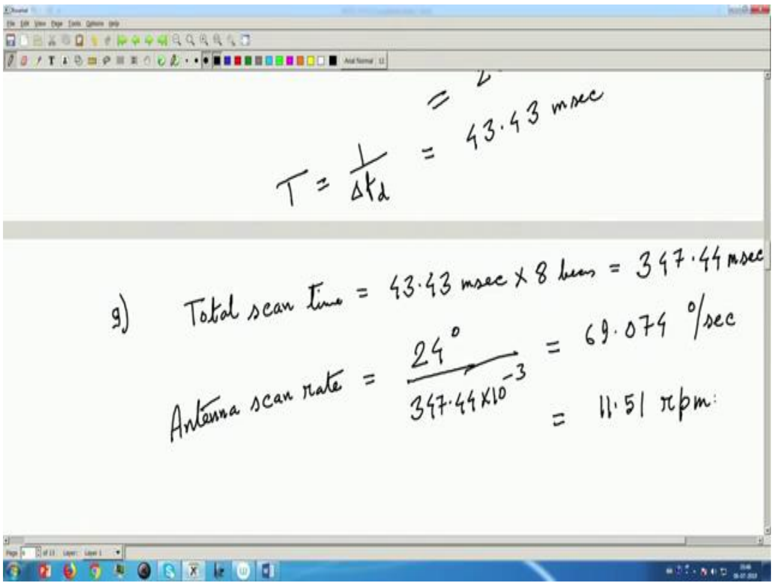

The moment I get that, I can say that look time per bandwidth will be 1 by delta f d that is 43.43 millisecond. So, this is the look time; that means, for 43, 44 millisecond it will be looking at it; and then part g, so part g is what, the total scan time. So, this is for one beam. So, total scan time and the antenna scan rate. So, total scan time will be, there are a total scan time is equal to 43 into 43 millisecond 8 beams. So, that will be if you calculate 43.43 into 8 that will give you, 43 point, 347.44 millisecond, be very careful with units in exams etcetera.

The units always you should with the answer you will have to write; otherwise, your marks will be deducted; because in engineering this is one of the very important things. Total scan time also antenna scan rate. So, it is an electronic scanning, antenna scan rate is it is total 24 degree it is saying and each beam width. So, antenna scan rate easily I can find, because 24 degree is the total sector width that it is covering in total this much time. So, I can say 24 degree by 347.44 into 10 to the power millisecond minus 3.

So, that will be 69.074 degree per second, but generally antennas are given as revolution per meter. So, you can easily convert this two how much, one revolution means 360 degree. So, if you do that conversion it will come to 11.51 rpm. So, you see that antennas scanning rate is 11.51 rpm. So, you see a complete design type of problem that you can get all these things by the basic things of radar ok.

So, thank you, this is the only problem for SAR, this is enough for whatever we have covered in the class.

Thank you.