Principles And Techniques Of Modern Radar Systems
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Lecture - 24
Pulsed Doppler Radar (Contd.) and Search Radar

Key Concepts: Block Diagram of a pulse Doppler radar, Discrimination between the MTI and pulse Doppler radar, Introduction to functional types radars.

Welcome to this NPTEL lecture on Principles and Techniques of Modern Radar System.

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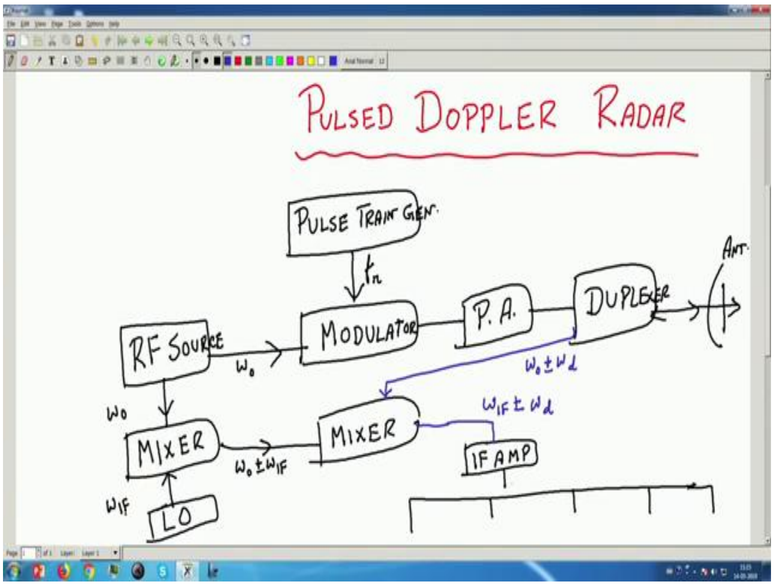

We extensively used the pulse radar. So, we have seen last day the pulse Doppler radar, that actually after the phase detector, what is the block diagram. Today I will so I will modify the pulsed radar block diagram general block diagram I gave, that was for MTI filter.

So, if we have a pulsed Doppler radar, then the complete block diagram we have not seen last time, we have seen only after this. Actually, that thing is valid, but the phase detector is no more there.

So, I will today give that pulsed Doppler radar block diagram. So, first block we have pulsed train generator, then this is put to a power amplifier, first it will put to a mixer. And, also the after these there is a power amplifier, and then it is given to a duplexer.

So, from the duplexer, we are going to the antenna. So, this is the antenna and here you see that, we have a local oscillator at megahertz type of frequency, that is giving the thing and also we have RF source, that need not be so stable Klystron or our nowadays TWT that will do. That is given to a multiplier and you see that actually instead of mixer, we should call this a modulator. So, pulsed train generator that goes to a modulator, amplitude modulation basically with the pulsed train. So, pulsed train generator is giving you at a PRF f r. So, it is coming and with the power amplifier, it is given to duplexer. Now on the return path this antenna is taking so, from duplexer the return signal.

So, I will use a different signal, that is taking these to the here. So, we can say that the transmitted signal was omega naught. So, these will be having a Doppler. So, omega naught plus minus omega d, that is put to a mixer. And, these mixer already you see these RF is already mixed with these. So, we are having to this mixture is mixed with omega naught plus omega IF.

So, this will come out as omega IF plus minus omega d, Doppler then IF amplifier. Generally it is a match filter and then we are seeing that it I will erase these things. So, from this mixer we are getting this thing. So, IF amplifier is amplifying. Now, we will be having the for pulsed Doppler the range gates.

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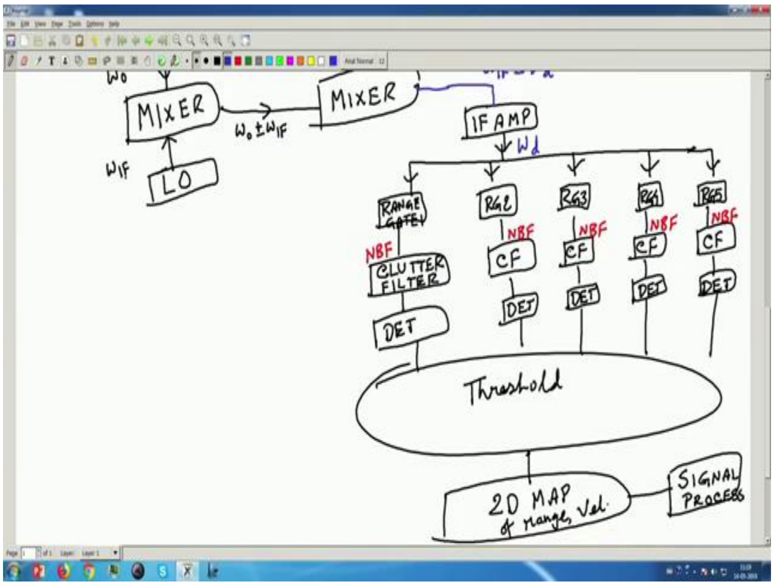

So, I can say range gate I am assuming let us say we have 5 range gates.

So, this is RG 2, RG 3, RG 4, RG 5. So, the whole range we are discretizing like this. So, the simultaneous or simultaneous…. the path is there, but these range gates will be switched one by one, first the gate 1 gate 2 depending on the range, then we have the clutter filter, we are calling it may be an MTI filter.

So, range has been extracted. Now, clutter filter, this may be an MTI no problem. So, this same thing has been repeated at every path, then this clutter filter is also a narrow band filter. So, I will write that it is a narrow band filter, because now pulse shape is no more important. So, all these it can be NBF. Also before these after range gate there can be a boxcar generator as were shown earlier, that to rebuild the pulse through the narrow band filter and then after these as usual the detectors, then after that.

There is a threshold detection to remove the various other false alarms. And so, finally, what is outcome of this we get a range verses velocity a 2 D MAP of range one dimension is range, another dimension is the you can say Doppler or velocity whatever you say range velocity. So, this is the thing with which the signal processing is done.

So, the next block of a pulse Doppler is after these the signal processor. Who will also see the signal processing when will see this thing. So, this IF amplifier this is also one processing of the signal, because correctly you will have to put these IF amplifier usually a matched filter and this one will see in the signal processor. So, this is the overall block diagram you see that this. After this IF amplifier we know we can get, this is our Doppler filter having and also it is having the range information.

So, this is the block diagram. This I have not given in the last class. So, this is the complete pulse radar block diagram, Block diagram of pulsed Doppler radar.

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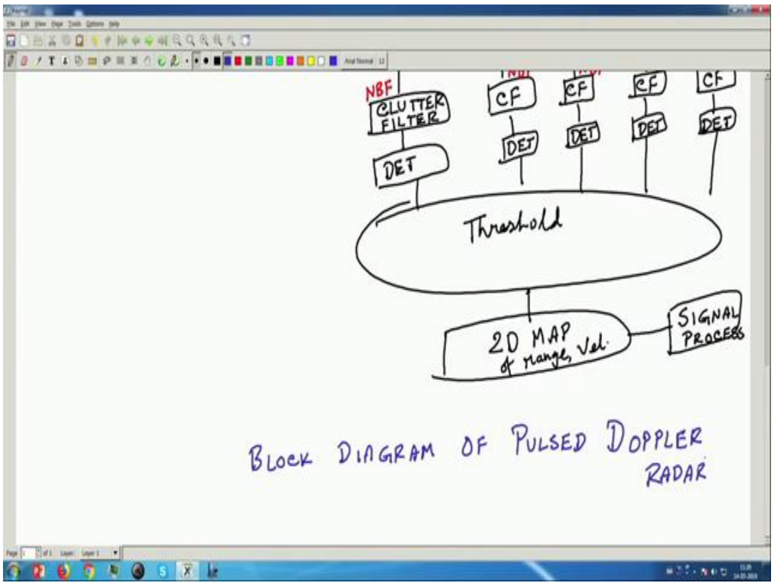

So, what are the salient features of these or in which way from the earlier MTI radar diagram this is different, that let us see that that difference.

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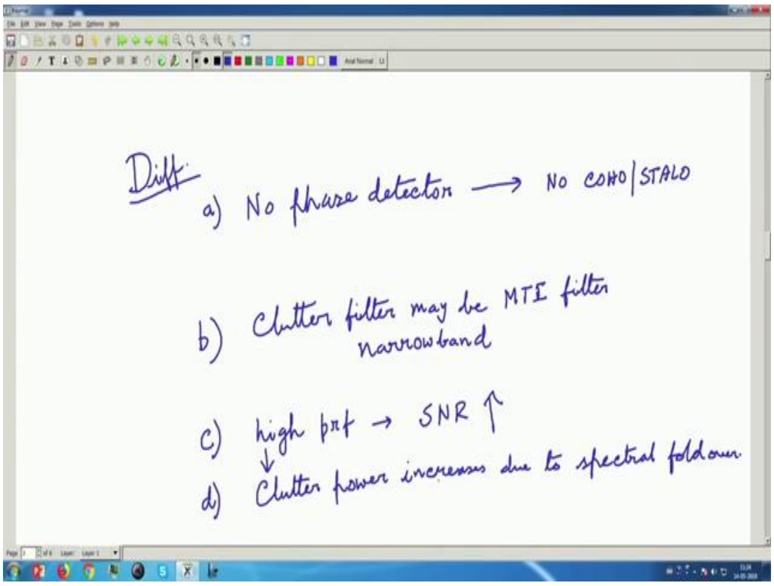

So, the first thing that you have noticed probably, that now there is no phase detector in the receiver chain. So, here the phase is not getting detected so, no phase detector and since there is no phase detector. So, the concept of STALO and COHO; that means, two stable oscillators that was there in pulsed Doppler to have the synchronization at every pulse, the phase should be precisely synchronized. So, that thing is not required.

So, we can say that the fallout is no COHO/STALO concept. So, stability is not so, important from the RF oscillator. So, basically one local oscillator is there with moderate stability and RF oscillator is there in this thing. Then, what we are saying clutter filter that narrow band filter, that may be an MTI filter. So, or maybe some other design as PRF is very high.

So, first blind speed is outside the Doppler space. Now, we can say that the clutter filter may be MTI filter may not be also and it is what, but whatever it is a narrowband, that will do no broadband filter is required, because already you have extracted the range here then due to high PRF.

So, as the pulsed Doppler works on high PRF so, high PRF means lot of average signal power increases. So, high PRF says that SNR is high SNR is improved then, but the negative point is that high PRF means many clutters they fold over because you are sampling.

So, many clutters are fold over. So, clutter power also increases. This is also fall out of high PRF that clutter power increases due to the spectral fold over but fortunately you can use narrowband filters whose clutter rejection capabilities you have already seen that you can have high roll off, at clutter spectrum in the pass band you can employ, because all the MTI filter technology that can be utilized here; so no problem.

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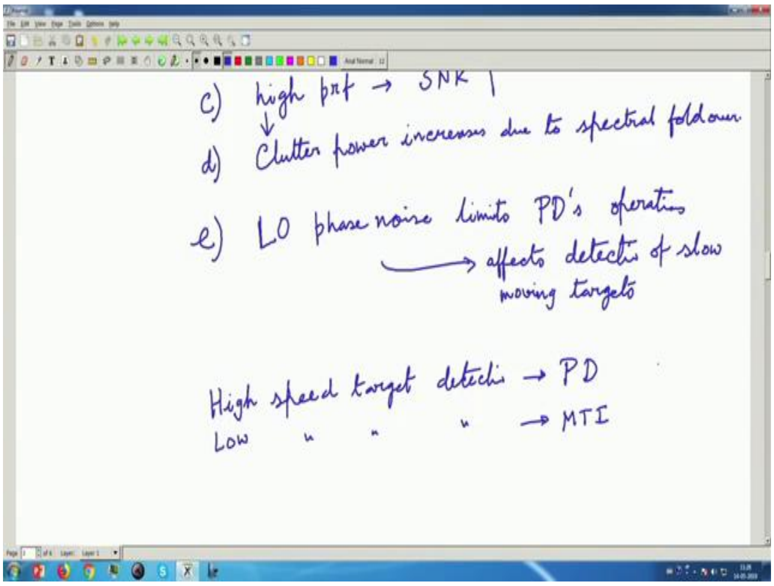

Then, actually since we have not with the removal of the phase detector the COHO/STALO concept has gone. Then, what limits the ability of these actually the you see any oscillator will have some phase instability. So, it will have some phase noise. So, LO it will also have some the local oscillator that will have some phase noise. So, we can say that these phase noise; LO phase noise limits the PD's operations.

So, not the clutter can be easily removed in pulsed Doppler radar, but LO phase noise is the now limiting factor, but phase noise actually that is the detection of slow moving targets get affected, due to that phase noise, because phase noise is not so high thing it is a short spectrum around the LO frequency. So, this LO phase noise that will affect detection of slow moving targets; that means, for small Doppler only this will affect slow moving targets.

But, you see a pulsed Doppler radar is never interested to have detection of slow moving targets. For that MTI radar is a better option, it is purpose is to have the high speed targets. So, it does not bother; that means, LO phase noise so. So, now, we can say that if your problem is a high speed target detection, you go for pulsed Doppler radar, if you have comparatively low speed target detection, you go for MTI radar.

So, this is now finally, the outcome of all these discussion. Initially we said that they have ambiguity in one domain and unambiguity or certainty in another domain. So, now, we are saying that this is the thing so; you choose now, that which is your interest? So, high speed target detection, if you want to detect missiles, high speed aircraft etcetera, you should have PD. And, you with that you do not try to detect the low speed things that you may fall, whether if you have low speed detection, then you forget about these high speed targets and go for MTI this is that clear cut distinction ok.

Now, basically the burden is now on signal processing. So, that signal processing; that means, from that 2 D map how to extract how to correct for various things in range gating there will be some problems etcetera. So, all those will discuss in the signal processing part in later part. So, with this I can now conclude these pulsed radar thing; that means, we have seen the types of radar from the standpoint of what is the transmitter type, whether the transmitter is continuous wave or transmitter is pulsed.

Now, we will go and see that another functional aspects of radar, that is from functional type. So, I will say that what a radar does?

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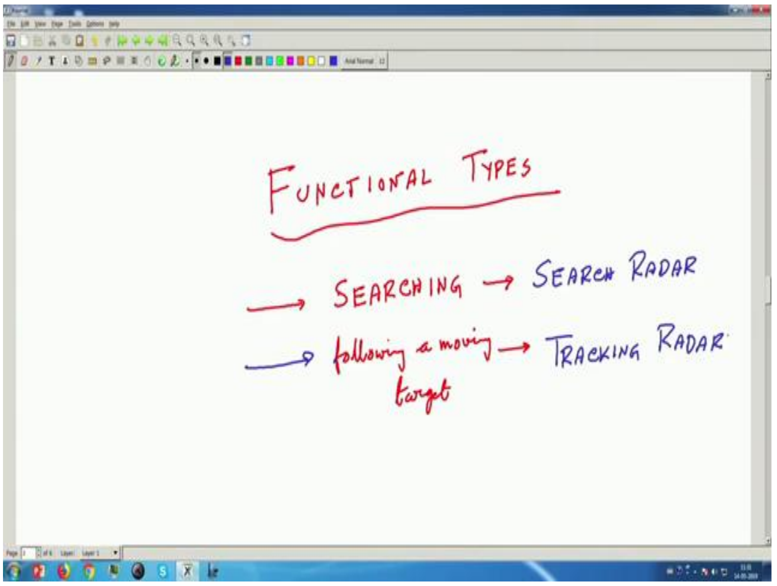

A, radar a radar basically performs one of the two functions, because you see detection, but detection after detection one in so, functional types of radar types. So, first is that it detects. So, on a given a thing it will have to first find the target. So, that is called searching operation, that you are searching for a target.

So, searching is done by search radars. Now, after searching what you will do you will have to; obviously, take some action, because if there is a threat etcetera you will have to mitigate that threat. So, or in actually defense parlance they call it firefighting. So, if an enemy aircraft is coming you will have to take action. So, that is called firefighting radar for that you now need to drag this radar attract this target that this object is coming.

So, exactly what is its trajectory you will have to make a track for that and accordingly you will have to your anti-aircraft gun should fire something fire something or you should launch a missile etcetera. So, you should know that track. So, the next part is that following so, searching is one thing, searching for a target, then you are doing that, another job is following once you know so, search radar gives that information following a moving target.

You will have to follow him you will have to gather more information from him the radar which does that that is called a tracking radar. And so, we will discuss these two aspects of the radar one by one first we will see the search radar.

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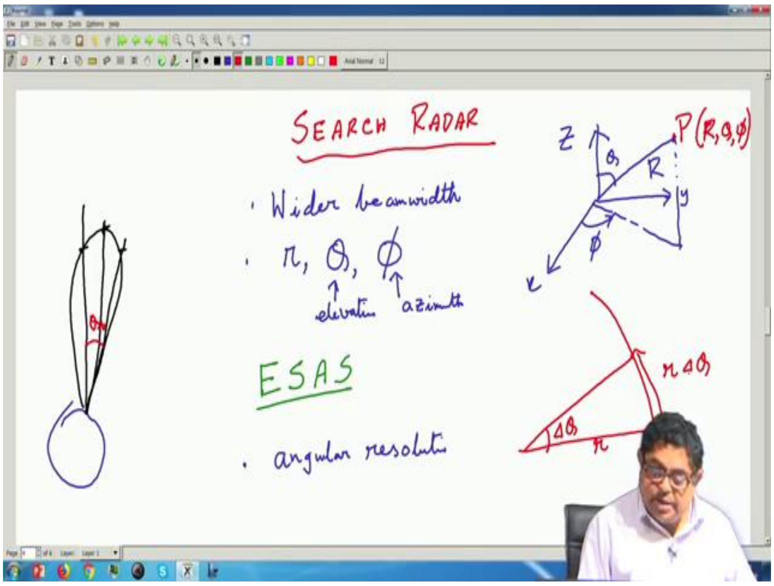

Now, while searching you see the, who searches basically radar has an antenna, that antenna is searching and that antenna is producing a beam that beam is rotated; that, rotation maybe by mechanical rotation of the antenna or by electronically, but that beam rotates and you get.

Something like in you will see whenever you go to the airport, you will see that some, one antenna is moving and the beam is rotating. Now in the night sky in the night you will see sometimes it is circus etcetera they come, you can see that there is a beam which goes on.

So, electromagnetic beam we cannot see, but the microwave beam, light beam fortunately we can see, but radar also does something and if a strong echo comes then it knows that there is something. So, search radar measures that, that what is the range and what is the approximately, what is the location, that is given to the a thing.

So, while searching a large volume of space needs to be covered, if the radar employs a narrow beam then it will take a long time to search, and by the way if some high speed target comes it will miss that. So, for searching you need a beam which is having considerably wider beam width.

So; that means, so, this is one point the search radar. So, the first point I will say that comparatively wider beam width; that means. So, that it can search in a very fast it can search and approximately it can find the position. Now, when it sees an echo, when it understands that there is a target.

Now, it will have to give some rough estimate of what is the position of the target? Range is one position, but you know that in a actually radar range means it is a in a spherical coordinate we call it the radial distance. So, r, but in a 3 dimension we require 3 coordinates. So, r is one thing then another thing is theta, another thing is phi 2 more angle informational required one angle is called theta is called elevation. So, this is elevation angle and this is azimuth angle. So, we know that basically elevation means, that if you have a coordinate system like this.

So, if this is your Z axis. Now, the this is your range R. Now, this is your theta and this thing you project on the xy plane and that projection whatever angle it makes with the elevation that is phi. So, if you give that this point gets this point P that uniquely gets fixed in the space. So, these azimuth and elevation they needs to be specified by the antenna. Now for mechanically scanned antennas as the radar antenna scans, its beam moves across a volume of space, when the target is intercepted the reflection returns in microseconds.

Now, by that time the antenna has moved to some other position, but we can neglect that we can say that since the antenna is not searching radar, antenna is not rotating at a very fast speed an electromagnetic thing. So, typical distances, in microsecond it does not move much. So, we can ignore that; obviously, there will be a error in the measurement.

But, we can do that on the other hand if we have an electronic scanning antenna system, which is called nowadays almost the modern radars are using that. Electronic scanning antenna system, where the antenna is not rotated mechanically, but the phase difference between the different antenna elements are so, chosen electronically, that the beam itself moves.

So, in that case that problem is also not there, but for mechanical nowadays in our country we most of the radars are having this mechanical system. That is why you should know that the search radar cannot measure these theta and phi very accurately. Now, when we are measuring this elevation and azimuth, the what is the actually resolution angular resolution, that is related to the beam width angular resolution, how suppose I have an antenna? Now, that let us say is producing a beam like these.

So, beam width means what this is the peak I take 2 lines, which are approximate region, generally we call 3 dB beam width so, from this part 3 db down. So, this angle between these two lines, that is called the beam width theta B. So, anything within this sector theta B we call that it is in the same angle. So, resolution of an radar antenna that is given by the beam width.

Now, for search radar as these almost the beam width resolution is of the order of the beam width, but for tracking radar actually we will see that you need much more precise information, because if you are missing these, because as the distance is in kilometers say 100s of kilometers. So, you see that the if you miss it by small amount of error is there, then in the actual case because we know the for a circular path is the, if I have a angle error of delta theta, the actual linear error will be r into delta theta in this case my r is very large. So, a small error here will give a large error in the position.

So, that is why the tracking radar that will have several orders of magnitude less than the beam width of the antenna, then their resolution will be such. So, that is the fundamental difference between the search radar and tracking radar, that search radar more or less of the order of the beam width usually beam width are 1 degree, 1.5 degree 2 degree; that means, a search radar can give an this angular resolution of the order of a degree.

Whereas, a tracking radar can give you 1 by 100, but we will see a technique by which even 1 by millionth of a degree accuracy is also possible. Actually by that way all the modern launching of various extra extraterrestrial spacecraft etcetera, landing in moon etcetera, that time you require that precise measurement that is done by tracking radars. So, that concept will see in tracking radar. Actually our main purpose of this study is to have that thing that, how if you have a beam width of theta b you can have a accuracy of 1 by 10 000, 1 by 1 lakh 1 by 1 million.

So, that type of accuracy is possible from a technique called mono pulse which actually I ultimately will discuss in detail, but to continue the thing that we have a search radar. So, search radar the, what is the generally you see in these all these radars for searching, they have a either they use a para horn back horn feet with a parabolic dish.

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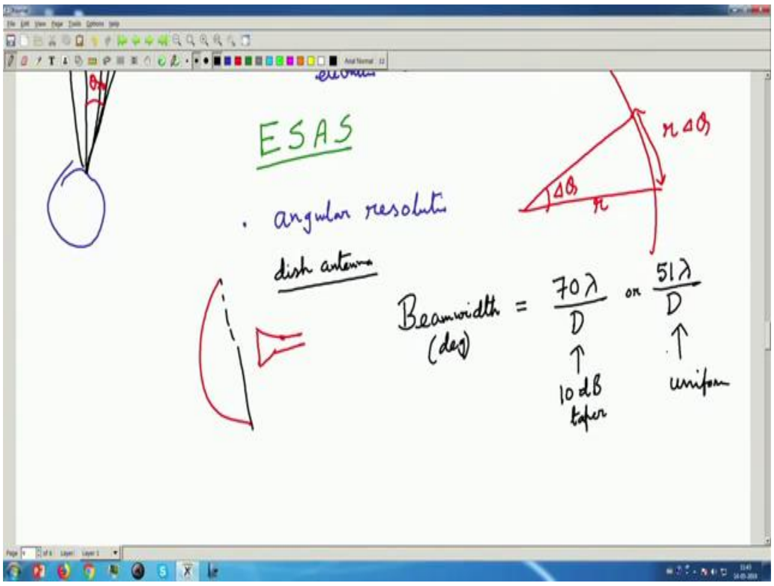

So, there is a horn that is feeding. So, at the focus is there. So, this system this antenna system the parabolic dish antenna system, generally there is an at the aperture plane, there is a illumination is not kept uniform, this is done to have the side lobe levels lower. Actually, the please refer to our NPTEL lectures on antenna microwave antenna, they are all these things are discussed just I will take those things that, what is the bandwidth of a parabolic dish with 10 DB illumination the beam width of this dish antenna. Now, this is have 2 quantities either 70 lambda by D or 51 lambda by D.

Now, which one; that means, this is wider than this. So, this is a better one. Now, if you have a 10 DB tapered illumination; that means, from the center; center is more illuminated and the edges of the aperture that is illuminated 10 dB down excitation. So, in that case you will have. So, I will say 10 dB taper, then you have these beam width the whole these beam width is in degree, please remember that this is already the radian to degree conversion technique.

So, 70 where lambda it is a free space wavelength and D is the maximum dimension of the thing or the parabolic dish diameter. And, if you have uniform illumination, then you have less beam width; that means, that is better, but that has a problem in it is side lobe, that is why always the illumination from this horn is done design the horn is such designed that, there is a taper usually 10 dB taper is used.

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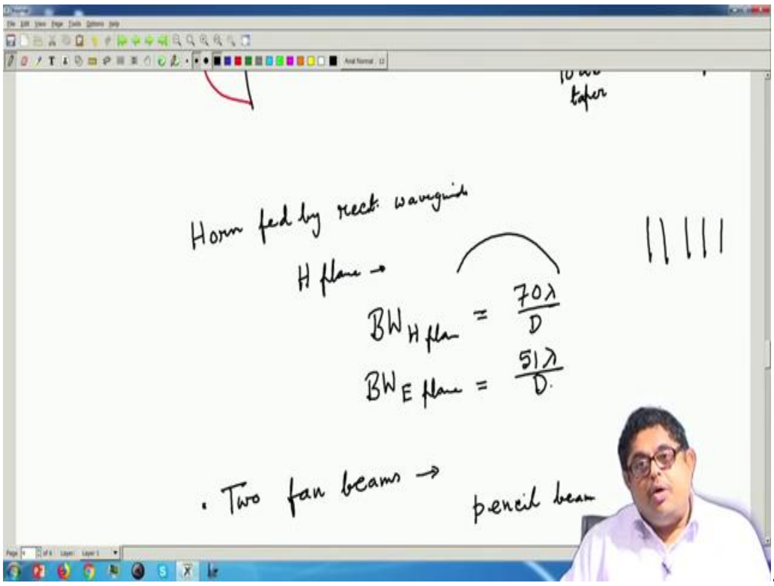

So, now in the H plane of the antenna for a horn for a horn we know that for a horn, fed by a rectangular guide horn, fed by rectangular wave guide we know that in H plane, the field is maximum at the center and 0 at n something like this. And so, it is a tapered illumination.

So, we can say that beam width in the H plane of a horn antenna, that will be given by that 70 lambda by D and in the E plane the E plane we know the field structure is something like this so uniform. So, we can say that beam width of the horn in E plane that will be given by 51 lambda by D.

So, actually the shape of the antenna determines beam shape, a beam which is narrow in azimuth and wide in elevation, or narrow in elevation wide in azimuth that is called fan beam. Why we required you see that together I cannot measure theta and phi both elevation and azimuth. So, such that what it has it keeps 2 beams, 2 fan beams, 1 fan beam is so, I will say that it has 2 fan beams. I have already said what is a fan beam, it has narrow beam width in one direction either in azimuth and let us say wide in elevation or so, any of the angular space, it will have narrow and another one wide.

So, that is called fan beam. So, 2 fan beams and suppose first it tries to find the azimuth. So, it will then have a fan beam, which is narrow in azimuth and wide in elevation. So, it will determine the azimuth position, then it will switch on the second fan beam which is narrow in elevation and wide in azimuth by that it will determine the elevation information. So, by this search radar operates.

So, and in certain cases you need not have any one of the information. Suppose the ship detection, suppose ship based radar is finding the position of another ship. Now, it knows, what is the elevation? Because ship does not have any elevation difference, you know the elevations more or less.

So, in elevation plane it does not need so, it will have a narrow azimuth beam, the fan beam needs to be narrow and it can detect. Whether whereas, in the case of aircraft you cannot have that because aircraft can have various azimuth and various elevations. So, you need to have 2 fan beams for these.

So, so in case of planes first a narrow azimuthal fan beam is rotated through 360 degree. Let us say at the most or if you know that from which sector you have threats etcetera coming on your aircraft coming, then instead of 360 some laser angle will suffice, then a second fan beam you can narrow in elevation moves up and down until a target is detected at the same range at the previously acquired echo.

So, you can now find second if several targets are detected, that happens sometime that several targets are separated in various azimuth and elevation several targets are detected, then they are correlated according to range. So, an azimuth echo and elevation echo, if they are having same names then they are correlated and assumed to come from the same target.

So, search radars can acquire many targets at different ranges simultaneously on the other hand suppose the weather radar; weather radar on a plane locate storm only in the planes path. So, it can use a narrow beam actually in radar parlance the narrow beams are called pencil beam.

So, a weather radar can have pencil beam for searching and also it can go on tracking. So, once you are having pencil beam basically you are doing it like a tracking radar. So, the same beam can do both the search and track operations ok. So, with this we conclude the topic of search radar in the next one will see tracking radar.

Thank you.