**Antennas**
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**Module – 12**
**Lecture – 56**
**Reflector Antennas-I**

Hello, and welcome to today's lecture on Reflector Antennas. Till now we have talked about several different types of antennas, but reflector antennas by far can provide the largest possible gain compare to all other antennas. In fact, there are reflector antennas which can give gain of 40 dB, 50 dB, 60 dB and even 70 dB. And when we talk about all these numbers 40 dB is equivalent to gain of 10000, 50 dB is gain of 100000 and 60 dB is gain of 1 million times and 70 dB would mean 10 million times gain.

So, let us talk about reflector antennas which can give such kind of a large gain. And we will first start with the very basic thing; are reflector antenna with plane reflector, then we will talk about curved reflectors and after that we will talk about the largest antennas which are available in the world also. So, let us starts on reflector antennas.

So, this is the today's topic Reflector Antennas.

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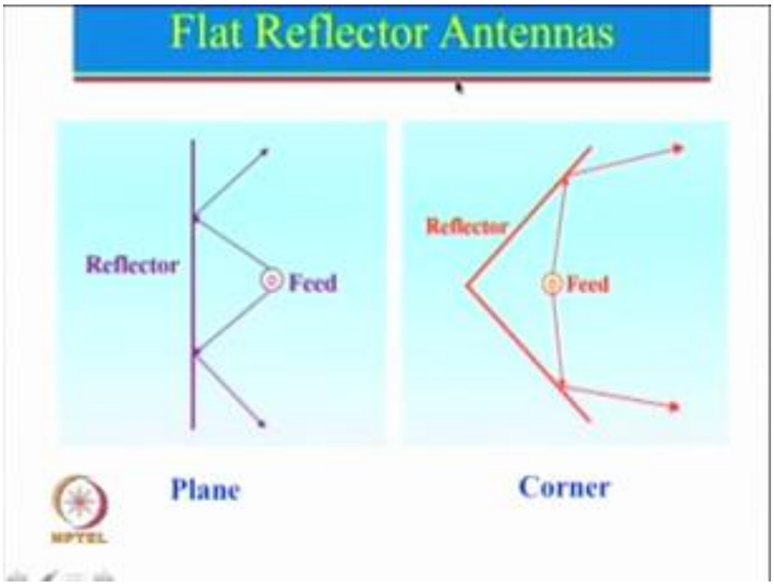

Now, we have divided it into two categories: one is a flat reflector antennas and another one is a curved reflector antenna which we will see in the next slide. Now the flat reflector antenna let us say here is a feed and we put a reflector behind this here. So what happens, this particular feed will radiate: suppose if it is a dipole antenna, so dipole antenna will radiate in this particular fashion and in that particular case the radiation going towards the reflector will reflect back. So, there will be no radiation in the backside and there will be more radiation in the front side.

In fact, we talk about this particular concept for Yagi-Uda antenna also. However, in case of a Yagi-Uda antenna if you recall we had actually taken a one dipole antenna and then behind that dipole antenna we had put another reflector antenna, and we are mentioned that the reflector antenna should be greater than the dipole antenna dimension. So, the dipole antenna would actually radiate something like this; that is what is the Omni pattern of course, directional is in this fine and then we put a reflector. So, in case of a Yagi-Uda we are put a linear antenna or the linear dimension which act as a reflector.

But now, what we are going to talk about is a planar reflector. And instead of behind the dipole if we take a wire, so then we know that the dipole is going to radiate there. So, whatever is going in this direction it is not effectively getting red blocked by this particular thing, but when we take a planar reflector something like this along with that we put a reflector which is let us say little larger. So, if you have a reflector of this particular nature which is known as a planar reflector then in that particular case we can see that there will be more radiation in the front side and much lesser radiation in the back side. So, this is the one of the thing which is a planar reflector.

Now instead of using a planar reflector we can also use a corner reflector. So, we have a one plate here another plate over here and again this one is shown here as a dipole antenna. Basically, this is the top view. So, if you look from the top side you will only see a point of the dipole antenna and this is the reflector antenna. Now generally speaking when we do the derivation what we are going to do; we will assume that these dimensions are infinite, but we also know that nothing is possible which will have a infinite dimension.

So, we will talk about what is the effect of the finite dimension and what is the minimum finite dimension we should take here.

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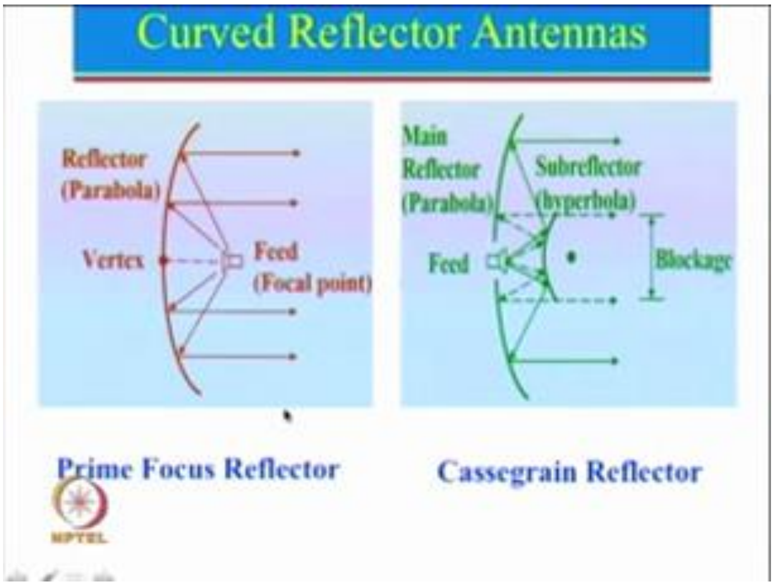


Now, let just look at the curved reflector antenna. Now there are two most important types of a curved reflector antenna, we will also talk about little variations also in time to come. One of the important one is a prime focus reflector. So, let us start with what it is. So, this is a parabolic shape reflector: you might have studied in your physics course or early mathematics course that parabola shape has a property that the rays which are coming from the infinity after the reflection they will focus at the focal point.

Or in this particular case here if you put a feed at the focal point and let us say that feed is radiating in this direction, so after the reflection they will all come back over here. And we can see that these rays will be parallel to each other. And if we look at any plane over here we would like that these thing should be in the same phase. In fact, that is the property of a parabola that after the reflection all these things are in the same phase.

So, now this is the one configuration we are put the feed at the focal point. Now this is another configuration which is known as a Cassegrain reflector. What you can see over here that this is the parabolic reflector and the feed has been put over here and then there is a sub reflector which has a hyperbola shape. So, from here if we feed this particular point; so from here the feed will radiate in this direction, so it will reflect from this hyperbola reflect back over here and goes here. So, we can see that the reflector wave is again parallel to the each other. And this is reflector is what is the basic concept, in fact it is very similar to this over here except for the difference here there is a one feed, whereas over here there is still a one feed but we have now two reflector. So, this is known as a sub reflector this is known as main reflector.

And I will just highlight you when a Cassegrain is generally used. So, generally Cassegrain is used if you want to transmit very high power. Now very high power can be generated using let us say different devices are there for some example: magnetron, traveling wave tubes, (Refer Time: 06:50) and other thing. Now those devices you can see specially designed for very high power would also require very large power supply. So, generally those things are put behind the reflector here, so somewhere here those things will be put and then directly the output of that will be connected to the feed here. Now if instead of this suppose if this high power is supposed to be put over here, if we put that here there will be a lot of blockage which will take place.

Now we can think about ok, why not we put something over here, but then we will have to provide either a coaxial connection or a waveguide connection. Now of course, for very high power coaxial cable may not be a good solution because coaxial cables have a limit on the higher power limit, whereas waveguide in general can handle higher power but then this waveguide will also act as a blockage, waveguide will also have some losses we may have to provide waveguide also.

And when we talk about high power we are talking about their are reflector antennas which transmits about 1 megawatt pulse power also. So, that is really a very huge power and the generators would be vary became bulky. So, in general Cassegrain reflectors are preferred when specially we want to use as a very high power transmitter. Even though Cassegrain reflector has a one major disadvantage and that is at this area see you say blockage, because of the large hyperbola shape here.

So, that is the reason generally people try to avoid this configuration until unless high power application is there. In general we will focus on prime focus reflector only in time to come, but today we will start with the very simple thing and that is the vertical dipole antenna over infinite perfect ground plane which is nothing but it will act as reflector here.

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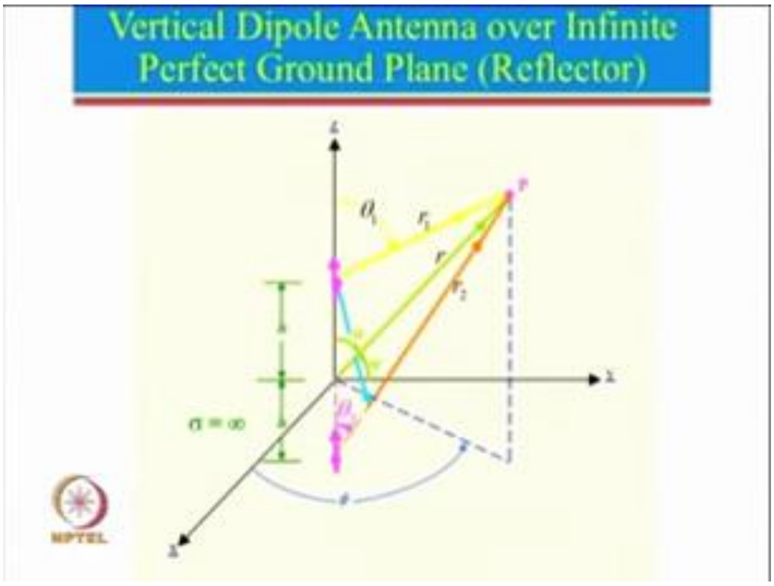


So let us see here: here is a small dipole antenna which is put over here. And in this plane we have put a infinite ground plane and when we say perfect ground plane that would mean sigma is equal to infinity. Just to tell you for copper and aluminium sigma value of the order of let us say 5 into 10 to the power 7, but for infinite it will be perfect ground plane. But you can see that 5 into 10 to the power 7 is also very large number. So, whether you put aluminium or copper or any metallic sheet that will work as a good reflector.

So now that has been put over here, and if there is infinite shape there will be a mirror image of this here. So, if you want to find out what is the radiation pattern at faraway point we can apply the array theory: the array theory will be nothing but we have a one element and the other element if this element is at distance h the image will be also at a distance h.

So, now just think about suppose if this dipole antenna is right over here. So now dipole antenna how they radiate? Well, it radiates nothing in this direction the radiation will be zero in this and maximum in this. So, which is something like this is over here, which is a kind of sin variation. Now there will not be a back radiation because of the infinite ground plane.

So, one can see that the small dipole antenna has a gain of about 1.5. And if there is a no radiation in the back side because of the infinite ground plane then the gain of the dipole antenna now will become instead of 1.3 it will be 3. And now if the dipole antenna is moved up; that means, there will be now spacing between the dipole antenna and larger than spacing we know that array factor will yield us larger gain.

So, let us see what happens when dipole antenna is right at the value h equal to 0, and what happens if h increases.

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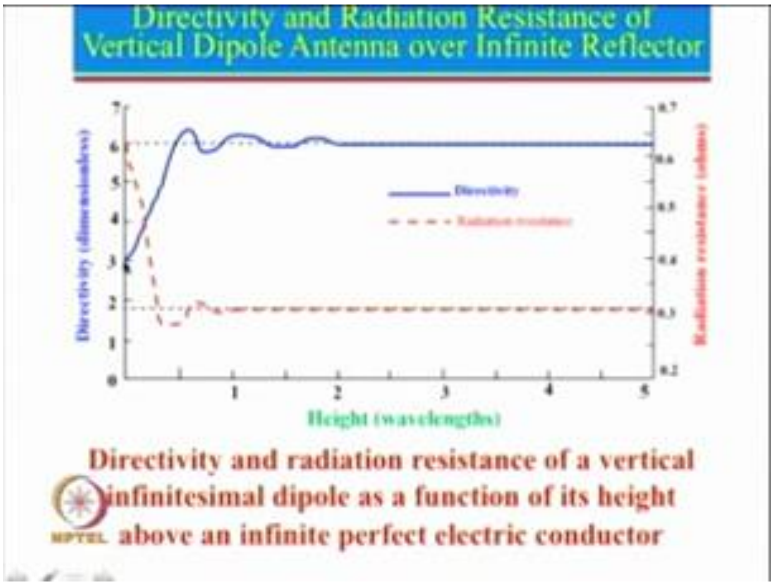


So, here is the plot of the directivity versus height as well as the radiation resistance. Let us first look at the directivity curve. So, one can see that when height is equal to 0 here then the directivity is equal to 3. The reason for that I just explained; that dipole is only going to radiate in the upper hemisphere. So, hence its directivity will increase by 2 times. So, for a normal small dipole antenna it is 1.5, for this case the directivity will become 3.

Now, as the height increases what will happen? Array factor will start giving a some array factor value multiplied by the pattern directivity. And that this is what you see over here that the gain has gone to about close to 6. I just want to mention here this directivity is dimensionless, so it is not in dB. So, you have to take 10 log thr3ee or 10 log 6 to get the proper directivity value.

So, one can see that as height increases here, one can see that the directivity is increasing and then kind of remains flat. But I just want to tell you that this particular portion practically may not even happen; the reason for that is if we increase the height significantly then the ground plane size should be very very large. And we cannot practically have a infinite ground plane. So, in general this region will not be achieved and most of the time people try to concentrate in this particular region. So, that one can get the better directivity.

So, let us see what happens to the radiation pattern.

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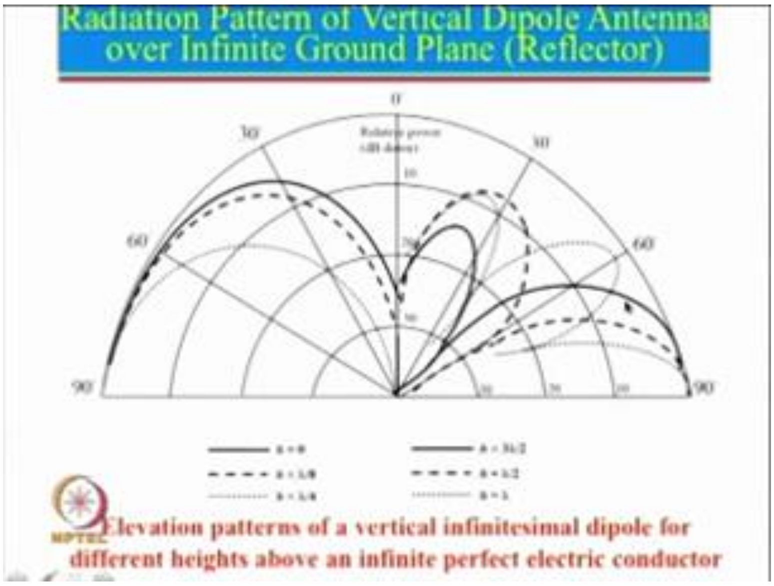


So, you can see multiple plots over here; basically what you need to see is that just concentrate on let us say this one quadrant here. In fact, this pattern will get repeated in this quadrant, but just to save the space lot of different cases have been shown. So, let us look at one by one. H equal to 0; that means, the dipole antenna is put right on top of the ground plane. So, if that is the case you can this is the plot here it is not radiating in the back side.

Now as the height increases one can see here this lambda by 8, then it is increase is to lambda by 4; we can see the pattern is becoming narrower. So, over here this is the case for lambda by 8 and when it is increased to lambda by 4 you can see this is the case over here. And one can see that half power beam width smaller hence gain will be larger. Now let us see the cases shown over here, these are the cases which are shown for larger h. One can see the case of lambda by 2 lambda 3 lambda by 2.

Now for these cases you can actually see that the radiation pattern has split here. So, basically why that happens? See think about if this h is equal lambda by 2 let just go back to the previous slide. So, if this height is lambda by 2 and this is also will be lambda by 2 total height will be lambda, and that will give rise to the grading loop and hence beam will split; and that is why directivity decreases.

Now let us also look at what happens to the radiation resistance. One can actually see that this is the normal radiation resistance of a very small dipole antenna. However, this radiation resistance increases significantly, if it is shorted which is expected because the end of the dipole which is supposed to be an open circuit has been now shorted so that will significantly change the impedance. So, in general we do not try to use the dipole antenna in this particular region here.

So, we generally try to focus the dipole antenna over a finite ground plane or infinite plane at these particular heights here which can be lambda by 4 to lambda by 2 and do not beyond that. One can see here for larger height beam is split and in general we do not try to use this particular configuration for practical purposes. Now here is a situation where there is a horizontal dipole antenna over infinite ground plane. So, again infinite ground plane is put in the x y plane: this is x plane x and y so plane will be here z is perpendicular, so here is a dipole antenna.

So, in this particular case you can see that the images in the opposite side. You can actually see this similarity in a simple way. Suppose if you stand in front of a mirror. So, what happens if you stand in front of the mirror? You can actually see that your head is in the same thing; that means if vertically if you are standing the mirror image also shows you that it is in the same way.

So for example: if this is the head in the mirror also you will see that this will be shown as a head. But whereas if you look at your hand, so your right hand looks like a left hand in the mirror and left hand looks like a right hand mirror. So, the same thing over here for vertical ground plane you see the images in the same thing, but the horizontal one has a opposite image it is like right hand becomes left hand or left hand becomes right hand. So, let us see now what happens here.

If this particular dipole is right next to the ground plane, then what will happen this actually get short circuited, so impedance becomes 0. Now as this is move above, so what will happen let us see. First we will see the directivity curve.

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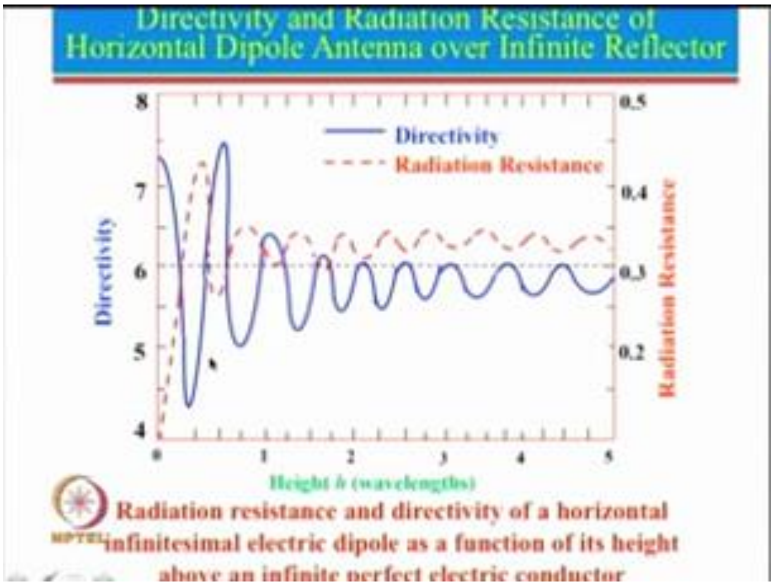


Now you can actually see here that if the height is very small directivity is fairly large it is more than 7, and as height increases you can see that the directivity decreases and then it starts increasing and then kind of its stables around. But that again this particular portion in general we will not be practical, because for these cases height is very very large; that means the ground plane has to be also very very large. So, in general this is the region which is most of often studied and looked upon.

Now here I want to just mention that when these results were published there was a lot of excitement because by putting at a very small spacing one could actually see that the gain has increase significantly. So, there was a lot of concept in the beginning gain something like a super directive antenna, in the sense that we can increase the directivity significantly even though the total height is much smaller.

But then at that time only there was another problem they notice; that if you keep it very close to this the input impedance is close to 0. And if the radiation resistance is close to 0; that means impedance matching will not happen. But however, this concept I can explain very nicely with the help of the microstrip antenna. So, just think about this particular case over here.

So, let us say we have a ground plane over here and we put the dipole antenna like this. Now the dipole antenna is put at fed at the centre, so if we feed at the centre and if it is put very close to this here then it will get shorted input impedance will go to 0. But now think about the microstrip antenna concept. So, what we do in case of microstrip antenna? In case of a microstrip antenna just see the parallel; a dipole antenna is put in the air.

Now suppose if you put a microstrip antenna in the here, and do we feed microstrip antenna at the centre; never because at the centre if you feed it will be short circuit close to 0. So, what we do in case of a microstrip antenna we always feed half centre. So, if you feed at half centre and depending upon the width of the microstrip patch here or the dipole over here and the height of the ground plane we now that the matching can be obtained.

So now, think about for this particular case of microstrip antenna. If you recall microstrip antenna suspended in air, we had notice that we could almost get a gain of 9 dB or even 9.5 dB depending upon the width of the rectangular microstrip antenna: But however, if we keep on reducing the width of the microstrip antenna and becomes as thin as this pen here. So if the width is reduce what will happen? The gain will decrease by even the directivity will increase, but this is still closer to the number what we have shown you here that it we can get a number of close to 6 or 7.

So, you can actually think about now the dipole antenna instead of feeding at the centre if we feed half centre and suspend in the air it is concept is similar to that of a microstrip antenna. So, let just look back here again. So, that is how you can think about if a microstrip antenna is put over here and there is a ground plane that can give rise to directivity of the order of 7 or in this particular region here. But if you have a dipole antenna fed on the centre then impedance will be equal to 0.

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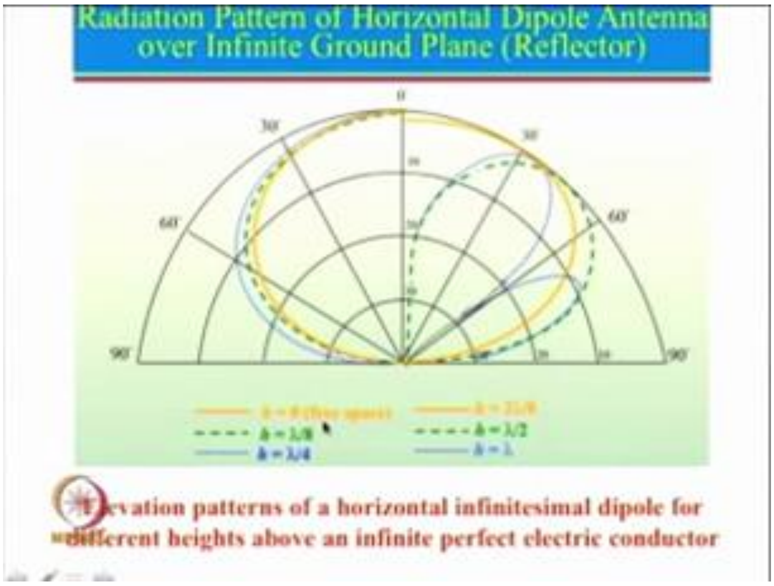


Now let just see the radiation pattern. You can again see the radiation pattern for different values of h. Let us first focus on this particular quadrant here. So, in this quadrant one can see h equal to 0, h lambda by 8 lambda by 4. So, for h equal to 0 you can see that this is the radiation pattern, and then lambda by 8 you can see that the beam broadening has taken place, at lambda by 4 beam broadening has further taken place. So however, beam width increases; that means directivity will decrease. This is similar to what I had shown you in the previous slide.

But then if the height increases, so what happens here if h is equal to lambda by 2? So if the height is lambda by 2 basically this will give rise to phase of 180 degree and that is what then happens here is that in this direction the image of that cancels out and we get a null in the broad side direction, and one can see that one can get a conical pattern. So, majority of the time this particular thing is not used, people generally focus on this particular concept over here.

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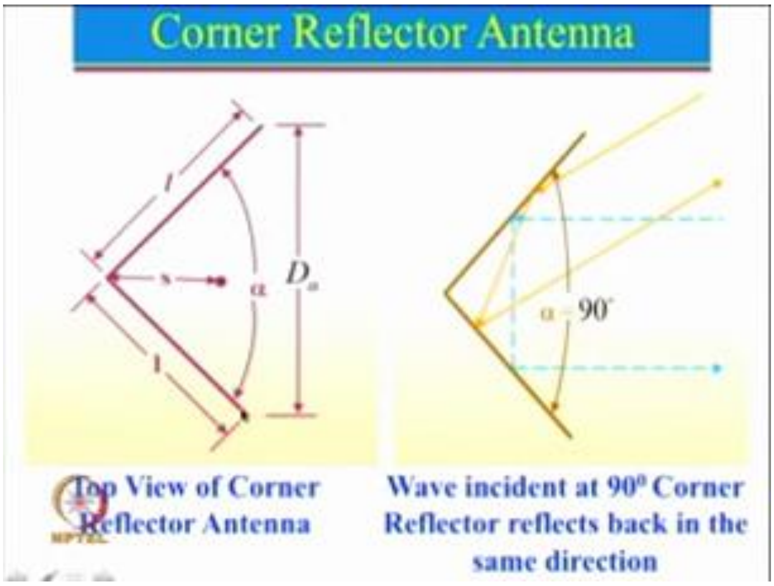


So, now we will get into the next part topic which is a corner reflector antenna. In case of a corner reflector antenna as you can see here there are two plates are here which are kept at an angle alpha and this is the top view. So, you can see here there is a dipole antenna. I just want to mention here even though I am talking about a dipole antenna, but in a reality you can have a different antenna also over here. Now, this is the general concept. So, please remember these things, so this is the length of the reflector here and in this particular side this will be the height of the reflector.

Now in the beginning we will talk about when l is close to infinity and the height of the reflector is also close to infinity. Then we will talk about practical thing. Here is a one interesting example; where actually it is not an antenna this is a just we can actually say that is why I have not written the term this is I have written 90 degree corner reflector I am not written the term antenna, it has a very nice property.

Suppose if a waves coming from this direction. So, if the wave is coming from here what will happen it will reflect, and then we can say if this angle is theta then this angle will be also equal to theta. So, it will reflect according to the Snell's Law. And then this particular thing falls over here. Since this angle is 90 degree this is theta this angle will be 90 minus theta. And if this angle is 90 minus theta reflected wave will also have a angle which is 90 minus theta. So, this one will be exactly in the same direction.

So now, you might wonder; what is the application of this particular thing. See this kind of a concept is actually used, for example something is coming here it reflects back in the same direction. So, this has a very good application where we would like to use it as a reflector. So, just to tell you something like this kind of a concept is used very nicely when let us say we have a ship which is sailing in the sea and there is radar which is being transmitted from the shore. So, from the shore its transmitting the signal would like to see; just to tell you here most of the time this is actually done for friendly ship, for the enemy it will be different concept to be used.

So, for a friendly ship what we would we like to do: let us say that we sending the signal from this direction and let us say ship is somewhere here. So, this signal goes over here and if it has a 90 degree, in fact most of the time what they do they actually use four of these things, you can call it a plus sign each of them is at 90 degree. So, let us assume that ship is like this here which is 90 degree, so signal is coming this is a 90 degree it will reflect back in the same direction.

Suppose now if the ship is moving and the direction is changing. So, suppose now the direction is change like this. So, at any given time it will always see a 90 degree from here and every time the wave will reflect back. This particular concept is actually used in a very good way in a sense that you can actually then detect how far the ship is, and you can then see what are the distances travelled by the ship and so on and so forth. However, for enemy we would like absolutely the different thing, the enemy would not like it ship to be detected. So, they would not like to put something like this here especially when you are going in the opposite countries or territory.

And in fact, this concept is also related to somewhat you can say RCS radar cross section. In fact, you might have read about stealth technique; in fact the planes are there which have a stealth technology and they cannot be detected by radar. So, in the stealth technology normally two technologies are used: one is that you have a this plane that entire plane is covered with the micro wave absorbing material, then whatever the signal comes here everything will get absorbed nothing reflects back. So, you cannot detect the ship.

Now that is the one thing all the time you cannot cover the; let us say a flying plane by micro wave absorbing material they need to have an antenna also to communicate with their own system. So, in that particular case what is done that they generally speaking use not this concept of 90 degree, but they use different angles so that the beam deflects in the other direction and not in the same direction. So, the radar transmitting from this side does not get any echo back.

So, we will actually look into even the similar thing is applied to antennas. For example, when we talked about microstrip antenna; so let us say a rectangular microstrip antenna will have a larger metal so it will have a larger RCS; radar cross section. But instead of a rectangular antenna suppose we take a rectangular ring antenna, so rectangular ring will have a metal removed from the centre portion and that means it will have a lower RCS.

So, we will talk about many different configurations of corner reflector; how images are formed and what would be the gain because of the corner reflector antenna. So, we will conclude at this particular point, and we will continue from here in the next lecture about corner reflector antenna and parabolic dish antennas.

Thank you very much. Have a good day, bye.