Antennas
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Module – 05
Lecture – 19
Microstrip Antennas (MSA)

Hello and welcomes to today's lecture. Today we are going to discuss about micro strip antennas. So, in micro strip antenna we are going to discuss about different types of antennas.

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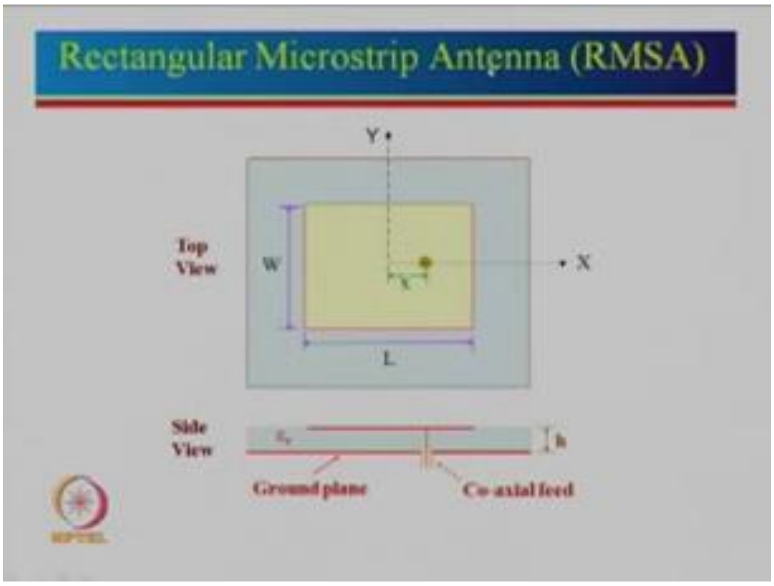

But we will start with a very simple thing which is a rectangular micro strip antenna. Let us see what a rectangular micro strip antenna is first of all an what is a micro strip antenna. So, micro strip antennas is actually very simple configuration, where what we have is a we have a ground plane, and then we have a dielectric material whose dielectric constant is epsilon r, thickness of the substrate is h, and then there is a patch which is printed on the other side. And if the shape is rectangular it is known as a rectangular micro strip antenna. If the shape is circular it will be circular micro strip antenna. Or if it is a triangular shape it will be triangular micro strip antenna. And this whole thing is actually known as a substrate.

It is very similar to you might have seen a printed circuit board inside your mobile phone or TV or any electronic gadget. It is very similar to that that we have a printed circuit broad where one side there is a ground plane or a copper. Then we have dielectric material and on a top there is a copper and in fact, if you see any of these micro controller they have so many parallel lines running here. But for a micro strip antenna very simple thing which is required. Just keep the group plane at the bottom as it is so do not touch it out. So, that will be the case for majority of the micro strip antenna. And the top can be as I said it can be circular or triangular or hexagon shape that is what the name comes out.

So, let just see the basic thing we will start with a very simple rectangular micro strip antenna. So, a rectangular micro strip antenna is defined by it is length, which actually determines the resonance frequency of the antenna. Then it there is a width. In fact, we will see that if smaller is the width, lesser will be the radiation, larger is the width, larger will be radiation which leads to larger bandwidth as well as larger gain. Now we need to feed the antenna. So, we are using a coaxial feed to feed the antenna. And this coaxial feed is chosen such a way that wherever the input impedance is roughly 50 ohms we connect with this, 50-ohm coaxial connector and in fact the beauty of this is so you can do the matching directly. There is a no need of any external impedance matching network.

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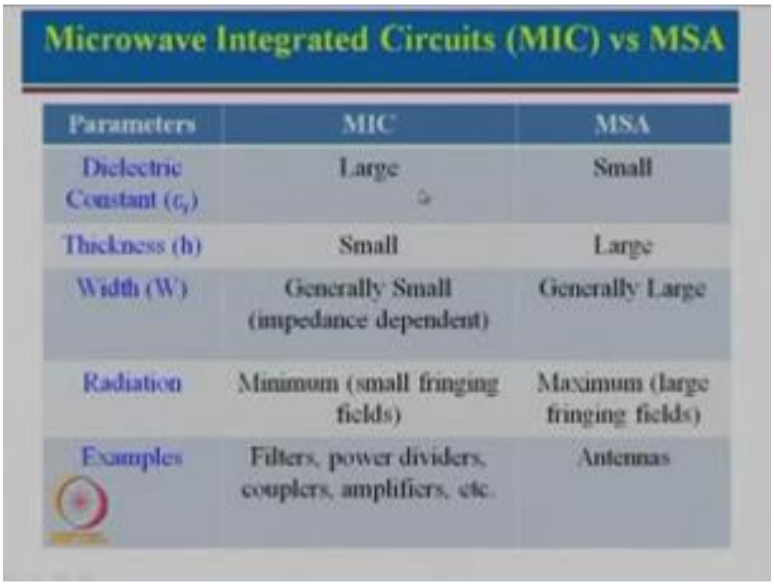

So, let just see what are the characteristic. So, we will compare here micro strip antenna with a microwave integrated circuit. The reason I am showing microwave integrated circuits have been in existence for a very long time, whereas a micro strip antenna the starting point was in 1953, where this was observed that there is some radiation going on. But it was almost 2 decades later. That was in 1974, when Manson had proposed how to practically use this one here. But again MIC; were there people have been using MIC and the substrates were getting printed. So, a substrate is defined by it is different parameter for example, dielectric constant epsilon r. So, for MIC we would prefer epsilon r to be large, whereas for micro strip antenna we prefer epsilon r to be small. And I will tell you the reason and thickness we generally take for MIC small thickness, for micro strip antenna it is large thickness. A width is generally taken small in case of MIC; we take large width in case of let say rectangular micro strip antenna.

Now, all these 3 conditions here. Actually lead to minimum radiation or maximum radiation. So, in case of MIC we do not want any radiation to take place. And how radiation takes place it is basically from the fringing field. So, in the case of MIC we always want to minimize the fringing field and in case of micro strip antenna we always want to try to maximize fringing field. So, how does this fringing field helps. So, again think about that antenna which I mentioned to you and on top of that we have a radiating patch. So, think about this suppose if the patch is very thin. So, what will happen the fringing field will be there, but that will be very small or before that even think about the parallel plate capacitance.

Suppose we have a one ground plane and there is another parallel plane. So, for the parallel plate there will be fringing fields all along. And if we increase the thickness there will be more fringing field. If the epsilon r is increased which reduces the size of the antenna, then the fringing fields will reduce. So, the whole purpose for an antenna is try to increase the fringing field as much as possible. So, the difference the main difference between MIC and MSA is that in MIC we do not want to any radiation to take place.

For example, the examples are filters power dividers couplers amplifiers etc. So, let us say if we are designing a low pass filter. What we really want is for lower frequency whatever is the input that goes as an output. And for higher frequency it should do the attenuation, but suppose if the radiation takes place, then what will happen. Let us say we are giving one, we are not getting out as 1 we may be getting 0.9 or 0.95, now part of that can be accounted for that there are some dielectric losses. So, that is why we need a good quality substrate or there may be some conductor losses because of the conductor, but then there are radiation losses. So, MIC we want radiation losses to be small, for antennas we want radiation losses to be very high. In fact, the term radiation losses actually is used from circuit point of view. Otherwise from antenna point of view radiation is the desired thing.

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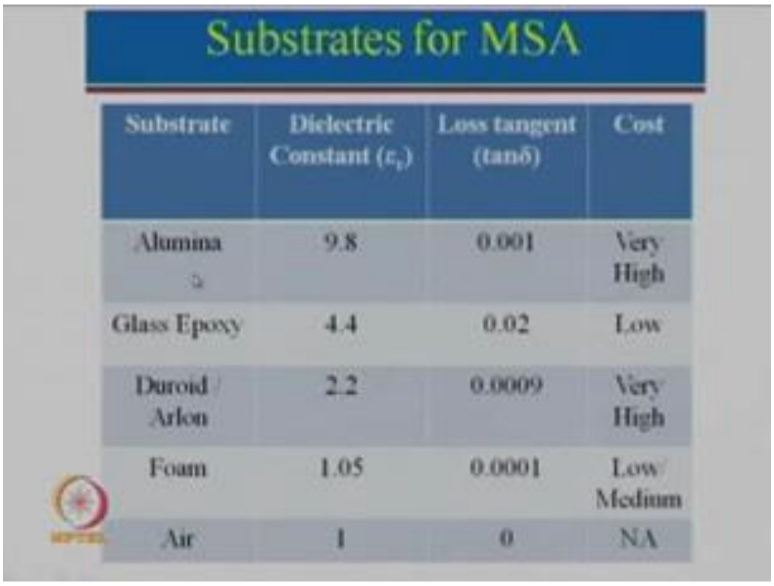

Substrates for MSA

Substrate	Dielectric Constant (ε_r)	Loss tangent (tanδ)	Cost
Alumina	9.8	0.001	Very High
Glass Epoxy	4.4	0.02	Low
Duroid / Arlon	2.2	0.0009	Very High
Foam	1.05	0.0001	Low/ Medium
Air	1	0	NA

So, now let just look at what are the substrates to be used for micro strip antenna. So, we have given some popular names over the substrate. So, let us say alumina is one of the substrate which was earlier used extensively, and even today used extensively for microwave integrated circuit. Only in very few applications we would use alumina for micro strip antenna and most of the time that application could be a compact antenna. Now the typical dielectric constant of that is 9.8 even though that may vary from 9.6 to about 10.2. It has a very low loss tangent which is 0.01.

What is loss tangent well it is related in the simpler way with dielectric constant in a sense a dielectric constant is a complex quantity; epsilon r is actually defined as epsilon r dash minus j minus r double dash. And that can be written as in the form of tan delta which is the ratio of the 2 epsilon. So, it is very low so; that means, dielectric losses are very small the only problem with the substrate is it is very high caused of course, alumina is not very useful as an antenna because it is a high epsilon r leads to very less radiation.

Then next very low cost alternative is to use glass epoxy substrate also popularly known as f r 4 substrate. Now this is the commonly used substrate for all printed circuit board. The typical dielectric constant can be 4.4, but in the reality it may be from 3.8 to about 4.6. The problem with this is that the last tangent is very high which is 0.02, but bit advantage is the cost is very low. I mean just to tell you the idea between low and very high, the cost can be 30 to 50 times more than this particular substrate. So, overall cost of the antenna increases significantly.

Now, these are the 2 popular brand names Duroid and Arlon substrates are available the typical substrate dielectric constant is around 2.2. In fact, this is actually a variation of glass. So, we know that the glass is a refractive index of 1.5. So, refractive index is related to dielectric constant relation is dielectric constant square root of that epsilon r is equal to refracting antenna. So, if refracting index is 1.5 epsilon r will be 1.5 square which is 2.25. So, these substrates actually are variation of this. In fact, they are typically fiber reinforced glass. So, fiber is put here. In fact, this is also glass, but epoxy is glassy material. And we know that glass cannot be used it can be broken very easily. So, that is why these fiber glasses are used and typical dielectric constant may vary from 2.5 to about 2.5 also.

I just want to tell there has a Teflon can also be used. Teflon has a dielectric constant of 2.5. The beauty is that the tan delta is very small it is 0.0009 or it has variation again 0.001 to about 0.0015 also, but again the cost is very high we can use foam also the foam has a typical dielectric constant of 1.05 you can see the loss tangent is really very small the cost of the foam is in general very low, but if you want the grated foam then that cost is about medium cost and of course, the best material actually is air has a dielectric constant of one loss tangent is actually 0 and you know that you do not have to pay for the air right.

So, this is really a very good alternative and in fact the lowest dielectric constant also leads to the highest bandwidth among all of these cases also, as well as the highest gain. Only thing is how to make antenna in air and that is where lot of thought process has to go how to use air effectively as a substrate. So, we can see that this PCB is really a light weight thing I mean you need, you only need to print the antenna on an substrate now substrate is thin. So, you can actually make out from there.

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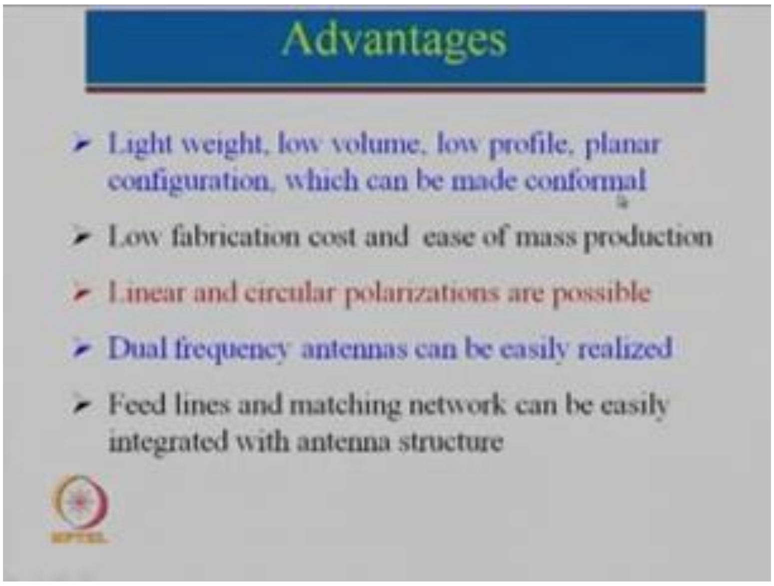

That it has a very light low volume low profile planar configuration which can be made conformal. In fact, these days flexible PCBs are also available which can be wrapped around the mobile phone or it can be wrapped around the plane or missile or satellite and so on. So, the fabrication cost is more except that if you use expensive substrate then this material cost may be more, but when we talking about a microwave antenna the size is very small. So, overall cost may not be too much. And since it uses the PCB technology mass production is very easy you can produce millions of pieces without any problem.

Now, using micro strip antenna we can design it both for linear and or circular polarization. In fact, here also one can design antenna for both horizontal and vertical polarization. So, that is very easy to do it. Now we can design very easily dual frequency antenna using micro strip. In fact, these days' people have triband quart band pentaband also using micro strip antenna. And another beauty is that feed line matching network can be easily integrated with the antenna structure. Now because of these advantages it finds lot of applications of course, it has disadvantages.

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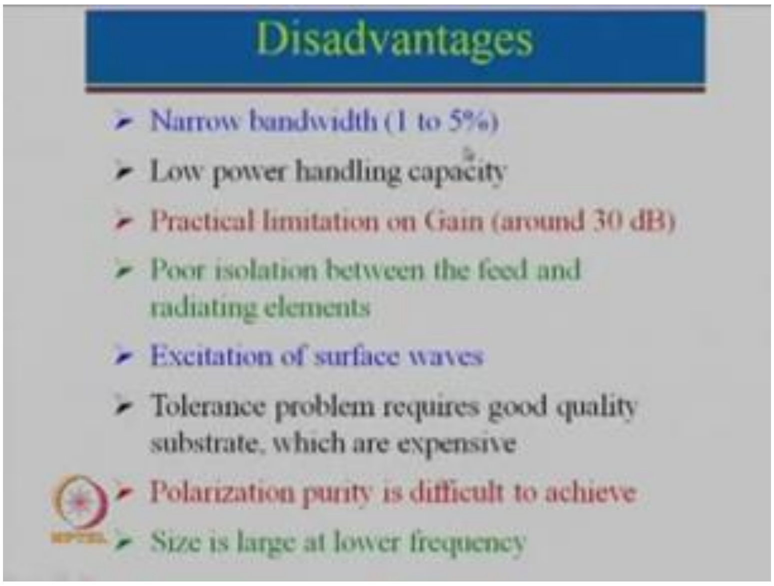

So, let us see what are the disadvantages. So, the top most disadvantage for a micro strip antenna is the bandwidth is limited, which is 1 to 5 percent. Now I just want to tell you my PhD thesis was on broad band antenna and that was in 1979, I submitted the thesis in 1982. So, it is almost like 34 years back we had designed micro strip antenna for bandwidth of 20 percent 25 percent 30 percent also. So, so in these lectures we will talk about what are the broad band techniques how to increase the bandwidth.

Now, the next disadvantage is low power handling capacity which is obvious if you use a printed circuit board which is very thin how can you use your high power; however, here also the remedy is there. That one can use metallic plates thick metallic plate suspended over a air and they can handle very high power also. The next practical limitation is on the gain. So, typically micro strip antenna array can be give us about 30 dB or so however, now it is lot of research is going on. So, people have broken the barrier of 30 dB. So, there are arrays of 30 dB 30 4 dB 36 dB and so on. But still if somebody wants a gain of 40 dB or 50 dB 60 dB or 70 dB then the only solution right now is to use reflector antenna. There are some problems with the isolation between the feed and radiating element. So, if you use feed to feed the radiating element there will be some coupling. So, isolation is poor; however, in the last 3 decades' lot of research has been done now how to increase the isolation.

Excitation of surface wave, what is surface wave, suppose for example, if we take a typical micro strip antenna which is radiating let us say in the broad side direction which is perpendicular to the surface of the patch, but what happens, the fringing fields are there from the patch to the ground plane. So, these fringing fields which are at the edge they start propagating along the surface. And which is not a desired thing. Of course, again now lot of research is going on how to reduce the surface waves and there are certain conditions if we meet then surface waves can be reduced.

Now, tolerance problem of low cost substrate is expense the problematic. So, that is why we need to use good quality substrate which are expensive, but will also show you how to use even a low cost thing for better performance. Polarization purity is difficult to achieve yes it used to be a disadvantage, but nowadays again many techniques have come which improves the polarization purity.

Now, of course, the one big disadvantage is size of micro strip antenna is large at lower frequency now. So, designing a micro strip antenna at let us say 1 megahertz is almost a forbidden thing because at 1 megahertz wave length will be 300 meter. So, even if somebody wants to design a lambda by 2 antennae which is 150 meter you even make it on a dielectric thing it is still running into 50 meter who is going to make a 50 meter printed circuit port. So, that is major disadvantage; however, lot of research has been done to realize compact micro strip antenna. And I just want to mention I had published a book on broad band micro strip antenna and that was published by artech house in 2003 and we have devoted one full chapter on compact micro strip antenna. So, as we can see that advantages of micro strip antennas are just too many and even the disadvantages which I have mentioned they have been overcome many of them. So, that is why these micro strip antennas find lot of applications.

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So, if you look at your mobile phone inside, it has a micro strip antenna. Or there is a variation of that there are printed monopole antennas are there. So, pagers use to have micro strip antenna. So, Doppler radars and others they use micro strip antenna. Satellites are major user of micro strip antenna because of it is light weight low volume. Radio altimeter is typically used for an aero plane. So, when the airplane is flying it would like to know. So, micro strip antennas are fantastic because of it is light weight low volume it can be fleshed with the body of the plane. It is these are being used in the missiles also again. Main advantage of all of these thing is the small volume and we can get all these polarizations and multi band configuration so. In fact, micro strip antennas have been used as feed elements in complex antennas also. In fact, more than a decade back what we done was we replaced the horn antenna of a 4 gigahertz parabolic dish.

So, remember decade back there used to be a large 8 feet parabolic dish which had a horn antenna as a feed. So, what we did we studied the characteristics of the horn antenna which was feeding that reflector antenna. And that horn antenna was we replaced that with that micro strip antenna. And we reduce the size significantly. So, when we are progressing in this particular lecture for micro strip antenna will show you the details of that. So, of course, it is being used for satellite it is also being used for biomedical radiator.

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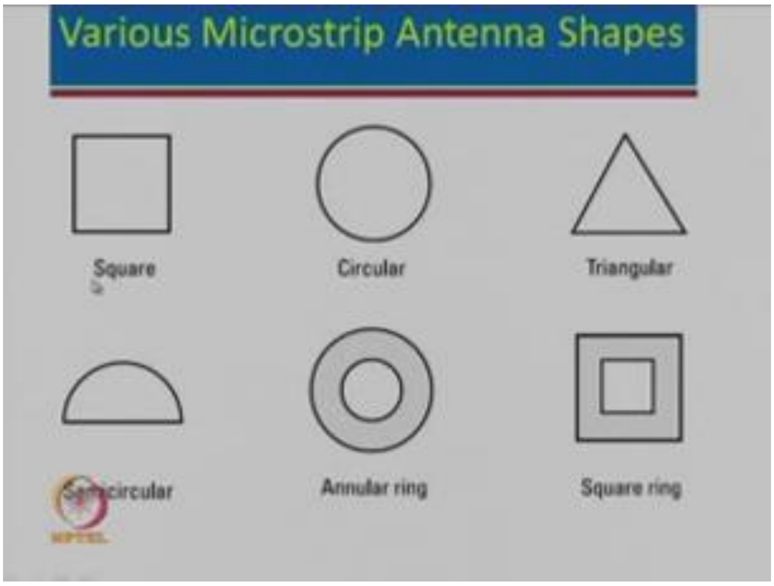

So, let us see what are different shapes of micro strip antenna. I just mentioned about rectangular, but. So, many different shapes have been used. So, square micro strip antenna circular triangular even in triangular there are lot of variations are there. Equilateral triangle antenna isosceles triangle antenna 30 60 90 triangular antenna and so on then semicircular antenna in fact, people have used sectorial antenna also 30 degrees 60 degree 120 degree and so on. Then annular ring can be used or a square ring can be used or even a triangular ring can be used. And besides that there are many other configurations like the pentagon antenna octagon hexagon and so on.

So, depending upon the shape and then lot of times you cut different kinds of slits and slots or use slotted configurations and you can realize varieties of these different types of micro strip antenna. And one has to see what are the advantages and disadvantages of all of these configuration. So, how do we feed these micro strip antennae? So, there are various techniques how to feed micro strip antenna.

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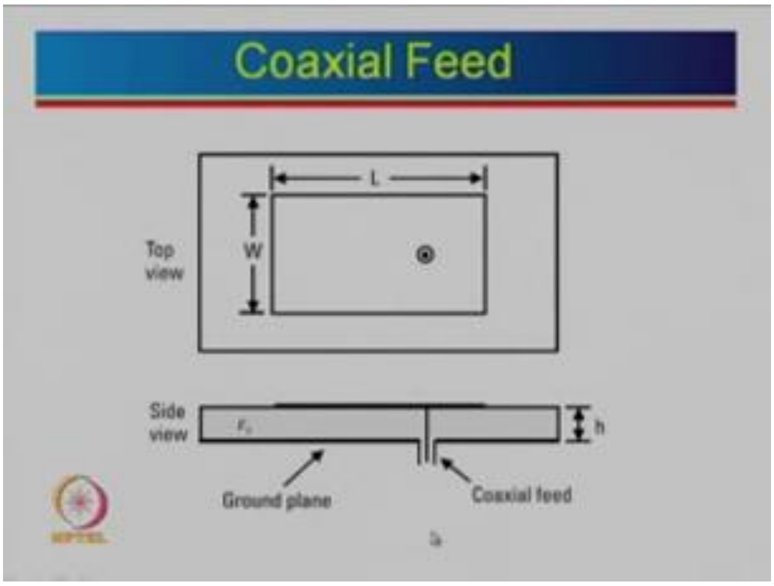

So, one technique we have already discussed. So, here we have a rectangular patch we are using a coaxial feed right over here. And what do we do we you take a coaxial wire you can connect that with the SMA connector or n type connector and what is normally done then that coaxial wire or connected the ground of that. Or the outer shield of that is soldered to the bottom ground substrate, and then the center pin is a drill hole is drilled here that center pin goes through, there and we solder it into the top patch here. And that is all a micro strip antenna is. So simple PCB use a coaxial field it needs to be optimized job is done. So, that is the one type of the feed.

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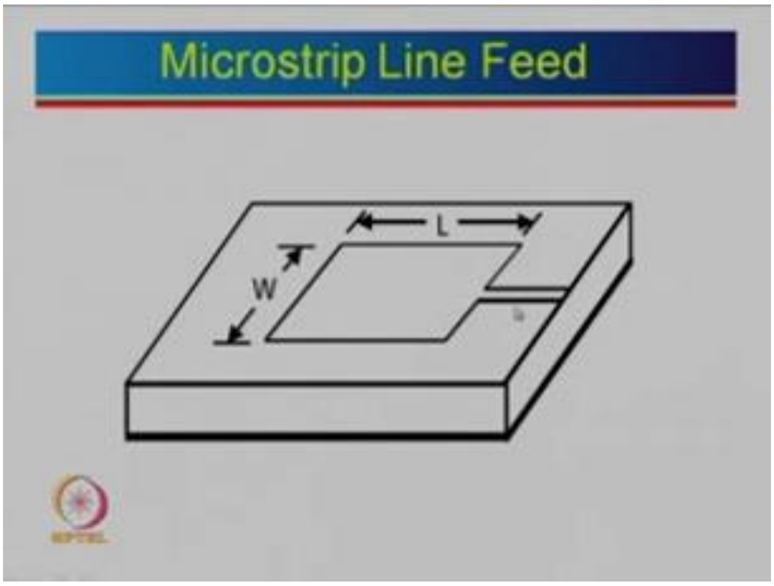

Then say another type of the feed is micro strip line feed. Where we connect this micro strip line to the patch in which this type of feed is very popular specially for arrays. Where we have n number of elements and we need to connect all those n elements, most of the time a micro strip line feed is used for that purpose.

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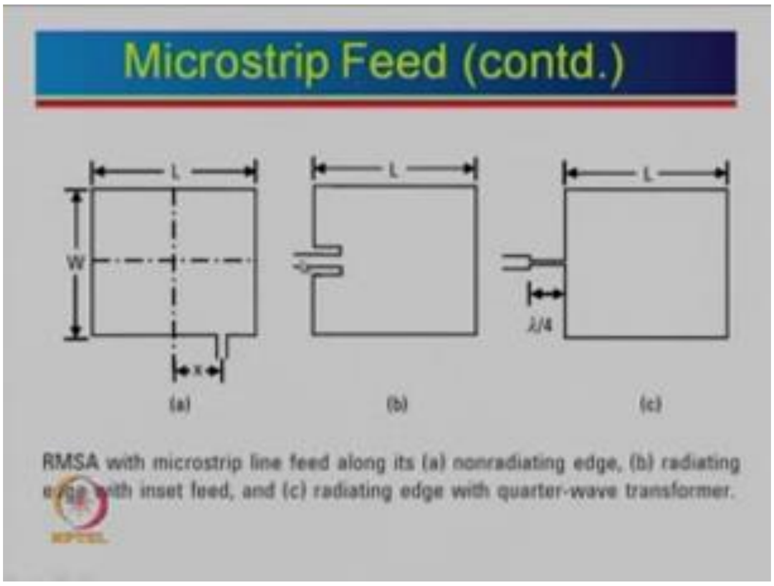

There are some variations are also there for this case. So, one can feed instead of feeding along this axis here one can also feed along this, will see what are the advantages and disadvantages. And instead of feeding here one can actually feed it over this is also known as inset feed, why it is done. In fact, this is actually done if you recall for coaxial feeds we were feeding somewhere here. Why we were feeding here we could get the impedance margin, instead of feeding here with the micro strip line which impedance is high as will see shortly. So, instead of feeding at this point where impedance is very high which results in impedance miss match, we actually cut an inset over here we used to almost this point to get a matching. So, that is what is known as an inset feed and sometimes if we cannot do any of these, what we do it is we use a lambda by 4 quarter wave transformer.

So, whatever is this impedance that can be transformed to another impedance. So, just to think about if this impedance is set to 200 ohms and what we really need is a 50 ohm here. So, you can actually use a quarter wave transformer of 100 ohms. So, input impedance at this is given by z 0 square by z L which is the load impeder. So, if I take this as 100. So, 100 square divided by 200 will give me 50-ohm impedance which will be perfectly matched.

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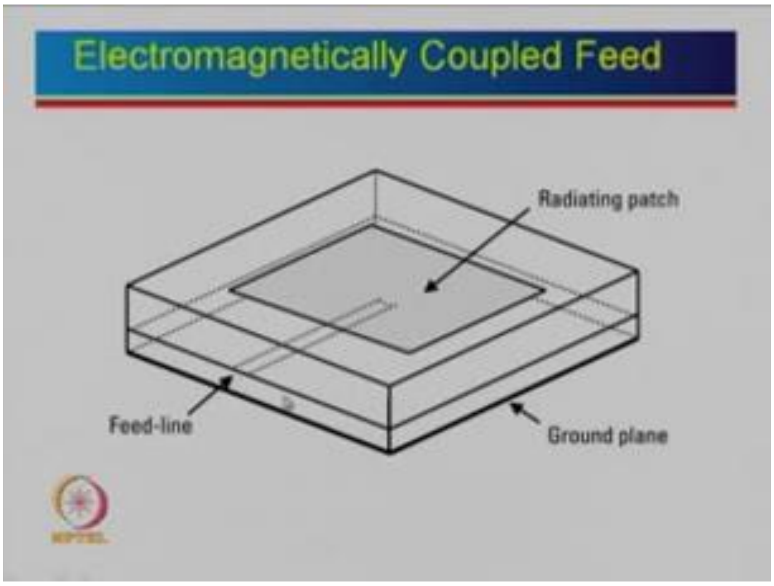

Another way to feed is electro magnetically coupled feed. Actually speaking there are 2 different substrates used here. So, there is a bottom substrate is here which consist of the feed line. And this bottom substrate can actually use the concept of MIC; that means high dielectric constant and thin substrate. So, we can optimize the performance from MIC point of view. Whereas the top substrate is printed on that is taken as a thick substrate of low dielectric constant, and then the patch is printed on that. And how this patch gets excited, this feed line is going there. So, when this feed is fed there, we can see that the current will be 0 here current will be maximum. So, by using this electromagnetically coupled. So, this coupling is through the magnetic field. So, that magnetic field gets coupled to the top patch and it excites that. That is what is known as electromagnetically coupled field.

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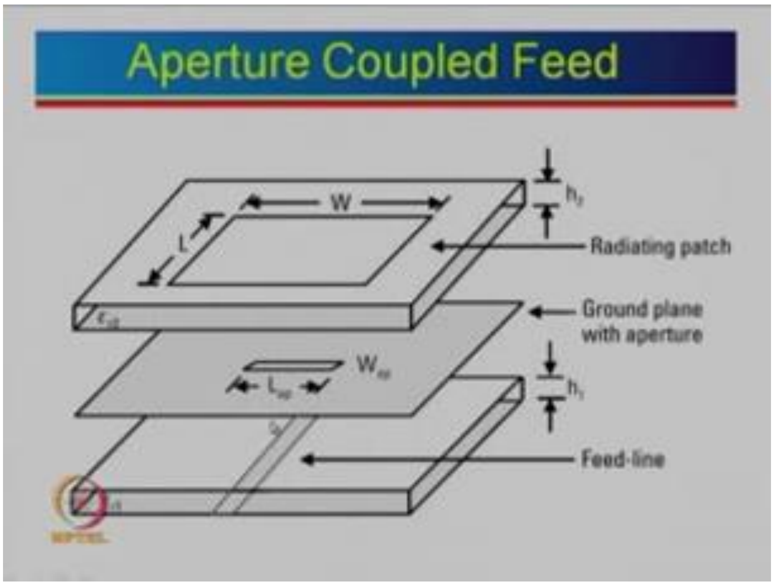

Then there is another feed which is known as aperture coupled field. So, again it is consisting of the 2 substrate one is the bottom here and another one top here. This is the common ground plane. So, it is just shown as a separate thing you do not need separate. So, this ground plane will correspond to this over here. So, you just keep the copper as it is, but cut a slot in that here. And the patch is on top of the substrate and on the other side. So, this is on the bottom side now there is a feed line. So, again this feed line will actually have a current distribution which will have a magnetic field, that magnetic field will couple through here and excite the top patch. So, that is how the top patch will be there. The only disadvantage with this particular feed is that there is a back radiation. So, front to back ratio of this is relatively very poor.

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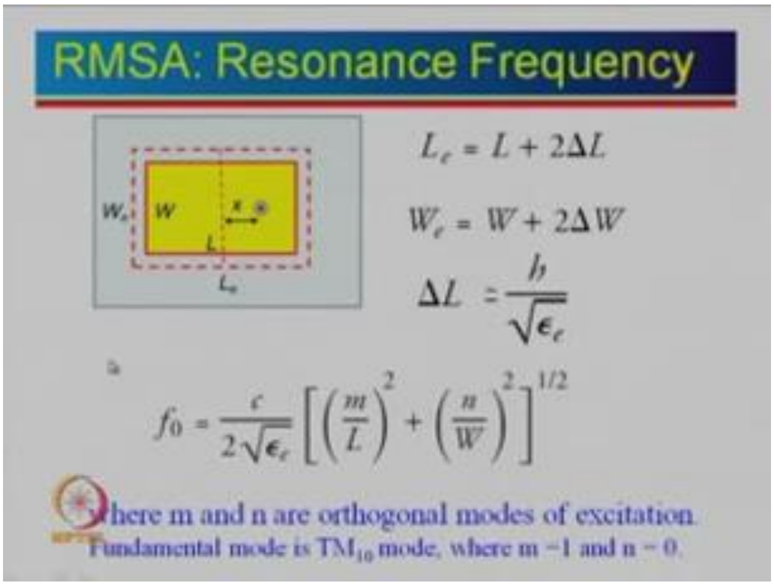

So, now let just look at a very simple rectangular micro strip antenna and how we define it. So, this is substrate which has a finite size. And here is a rectangular patch which is shown over; here the feed is as before. Now we know that if there are a 2 parallel plates are there will be fringing field. So, fringing field what does, it actually increases the effective capacitance. So, for example, there is a plate capacitance that is given by c p is equal to epsilon 0 epsilon r a by h where a is area. Now there is a fringing field. So, due to the fringing field the total effective capacitance increases. So, that can be compensated that we just assume that the length is and width they are arbitrarily more compared to the physical dimensions.

So, if you look into that then this is the fringing field around this. So what we have now the effective length will be will be physical length plus delta L delta L on both the side. Similarly, effective W will be physical W plus delta extension on both side and of course, to calculate delta L they are so many numerous expressions are available one line to 5 line and so on. But I suggest that you use this very simple expression and that is delta L is equal to h by square root epsilon. And after that what we need to know is that this length should be approximately lambda by 2 for fundamental mode. So, the resonance frequency can be defined by this particular expression here, but to just make things simple majority of the time we use a fundamental mode which is 1 0. So, this is 1 this is 0. So, if this is 0 then this term is out this is 1 here. So, one by L, L square root it comes out here. So, frankly speaking f 0 is nothing, but c divided by 2 L square root epsilon i.

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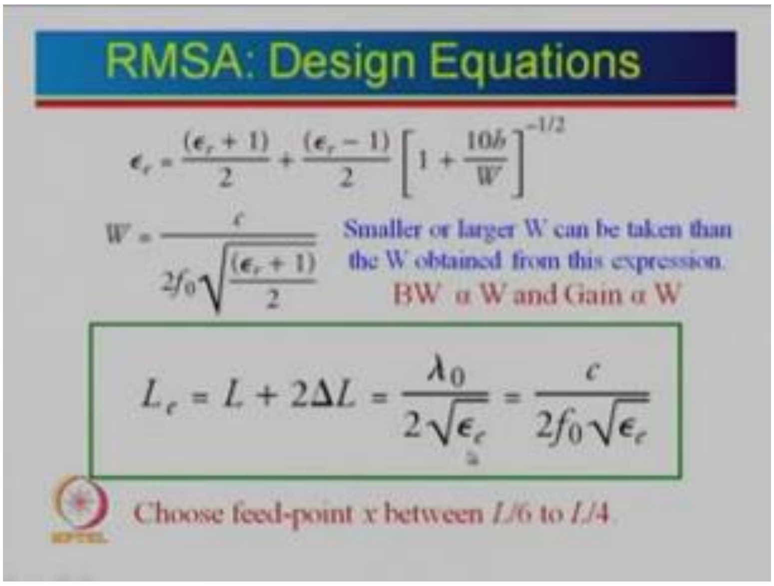

So, I just want to share so L is nothing, but equal to lambda 0 by 2 and why square root epsilon I because that is the effective wavelength. And we substitute lambda 0 equal to c by f. So, just by using this simple expression we can find out what is the effective length.

So, in the next lecture we will talk about how to design rectangular micro strip antenna in less than 15 minutes and maximum error it we about just 1 percent or so. So in the next lecture will see how to design rectangular micro strip antenna, we will also see how to choose the proper substrate to get the desired bandwidth and then we will move on to the other geometries like circular micro strip antenna triangular micro strip antenna, will also cover how to increase the bandwidth. So, what are the different broad band techniques are there. Will also see later on how to realize a compact antenna, how to design circularly polarized antenna and then towards the end will talk about lots of different micro strip antenna arrays, which can realize different desired gain as well as half power beam width.

Thank you very much looking forward to see you next time, bye.