Antennas

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Hello and welcome to today's lecture on tuneable and dual band micro strip antenna. So, why do we need tuneable micro strip antenna? Now suppose let us say you have designed an antenna and the designed frequency was supposing 1 gigahertz and after the design you have done the fabrication. Now what you find is that instead of 1 gigahertz it may be1.05 gigahertz or 0.95 gigahertz because your design should not be too off also. In fact, if you design antennas using the simple design equations given by us in the earlier lecture you should be able to get an antenna within plus minus 5 percent, but now suppose instead of 1, let us say we got 1.05 gigahertz. So, now, there are multiple options are there. One is that you actually make another antenna and for the other antenna you need to choose the dimension. So, you can use the concept of f 1 l 1 equal to f 2 l 2.

So, for example, whatever length you have taken for which you are getting 1.05. So, l 1 into f 1 which is 1.05 and the desired is 1. So, you put 1 there and l 2 find the new length and do another fabrication. And also if the feed point is not matched with the 50 ohm, then you need to shift the feed point also towards the edge or towards the centre depending upon whether the impedance is low or impedance is high, but these things require multiple fabrication things. And sometimes you want a quick fix solution. So, we are going to tell you today how even though you have fabricated the antenna which is not working properly, or it has a slight shift in the resonance frequency or may be slight shift in the impedance, how we can take care of that problem without fabricating another antenna. So, let us start with tuneable micro strip antenna.

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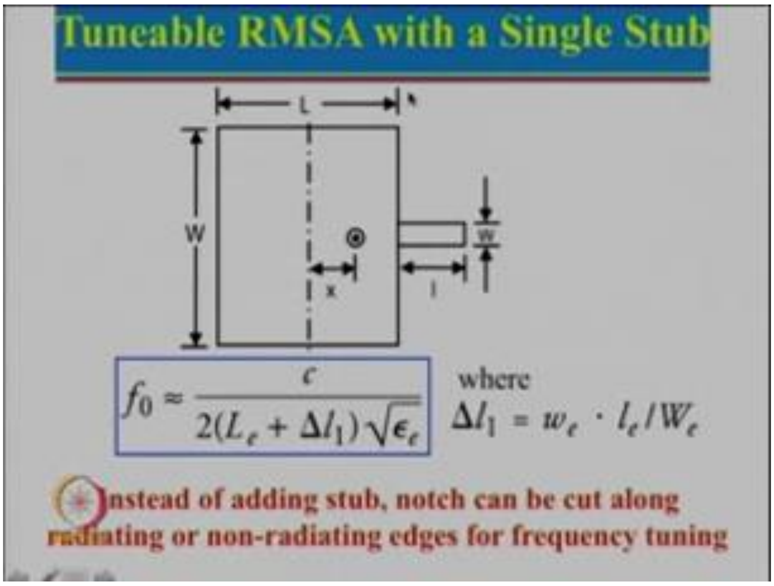

So, will first start with a tuneable micro strip antenna, and then will talk about dual band will first see that what is the need of dual band antenna. And then will talk about dual band micro strip antenna. So, let us focus right now on tuneable micro strip antenna. So, one of the simpler way to design a tuneable rectangular micro strip antenna with a single stub. So, what we really have here. So, let us say this is the antenna which has been fabricated with the length of l width W. And here is the feed point and for this particular case now, you measured the frequency which is not really the desired frequency it is slightly shifted either increased or decreased.

So, now by adding a stub over here we can actually reduce the frequency. I will tell you how to increase the frequency also. So, suppose we add a stub over in this direction and this stub can be simply added take a copper foil. And that copper foil can be soldered over here and rest of the thing you can use a something like a simple tape and tape it over there. So, let us say now this length which we have added and this width over here. So, strip has a width of W and a length l. Now this whole thing can be now approximated as that if you find the area of this which will be l into W which is a small w.

Now this particular thing you now equate to the effective W over here. So, we can actually say if we say it is an effective W and think that effective length increase will be delta l 1. So, we can say that delta l 1 will be nothing, but W effective multiplied by l effective which is area of the stub we always use effective length to account for the fringing field from the stub and that divided by w e which is the effective width of the micro strip patch. So, this gives us delta l 1. So, now, we can find out the resonance frequency as same as before c divided by 2 l e, but now l e has this additional delta l 1 coming into picture that is because of this stub here.

So, actually speaking now let us say we got 1.05 gigahertz earlier and we want this to be 1. So, you put one here we know what is l effective find out what should be corresponding delta l 1. And then correspondingly then you can use finite length and width of the stub. And this can be always cut or added little more to tune the frequency. Now this also does one additional thing. So, now, think about this now. So, effective length is increased on this side here. So, if it is effective length is increased on this side then the 0 axis of the field will be slightly shifted on this side. So, if the 0 axis is shifted slightly on this side. So, what will happen now input impedance will reduce? So, you have to also check when you do the measurement c, what is the impedance you got.

Suppose you got impedance of say 60 ohms, so if the effective width centre is shifted to this side that 60 will become say 55 ohms, but suppose you got only about 40 or 45 ohm. Then what should do instead of adding stub one this side you put a stub on this side over here, and when you put a stub one this side. Now the centre will be shifted along this here. So, if the 0 axis is shifted away. So, impedance at this will increase now suppose you got exactly 50 ohm or 55 ohms which is a good matching then what you do you add stub on both the directions. So, now, by adding a stub what you really can achieve you can reduce the resonance frequency, but what if the resonance frequency is already less and you want increase it. So, adding stub will not help in that case what you can do you can actually cut a notch?

So, suppose now you cut a notch in this side. So, what will happen? Now effective length will reduce and that will increase the frequency. So, you can use the same concept either you cut a notch over here or you can cut a notch over here or you can cut notch on both the side and by doing that you can increase the resonance frequency. Now again cutting notch in very important where you cut it, if you cut here resonance frequency will increase because the effective length is decreased; however, if you cut the notch only let us say in this direction. So, if you cut notch here if you recall compact micro strip antenna then this configuration will look more like a c shaped micro strip antenna which is compact. So, if you just cut a slot like this here, then effective length will be increasing.

So, that will reduce the frequency and if you cut a notch here let us say as well as you cut a notch here then it will resemble something similar to H-shaped micro strip antenna. And again the path length has increased. So, resonance frequency will change accordingly. So, you can cut a notch appropriately with the smaller values then you can tune the frequency either to the higher side or to the lower side.

But now let just see the numbers by adding this stub here how much change frequency really takes place.

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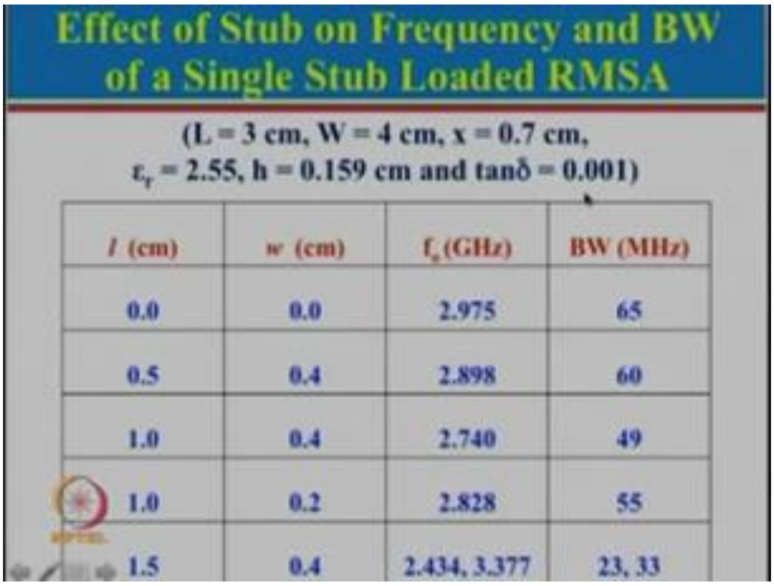

So, let just see the various values here. So, here we have taken a case l equal to 3 centimetre W as 4 centimetre feed point has been fixed. Because once you do the experiment feed point will be fixed and these are the substrate parameters. So, what in the table you see over here, this is the effect of the stub. So, what we have done we have taken a length of the stub of different values and even the width has been taken different value. So, let us start with this. So, if there is a no stub added; that means, l is 0 w is 0 then in that case resonance frequency is 2.975 gigahertz and the bandwidth is about 65 megahertz.

Now let us say this is not the desired frequency you want to reduce it. So, then if we add a stub of length 0.5 and width 0.4, you can see that the resonance frequency reduced from 2.975 to 2.898. If we increase the length further, we can see that the resonance frequency is reduced further and here it shows the effect of the width also. So, you can see that length is same, but the width is reduced by the half if the width is reduced by half the area of the stub will reduce and hence delta l 1 will reduce. So, that is why 2.828. It increases back if you reduce this here. So, really speaking from 2.975 you can tune down to 2.7 4. If you see the variation here that is about 230 megahertz.

So, that is close to about 8 percent. So, by adding this stub you can tune the resonance frequency by almost 5 to 8 percent, but then something strange also happens if we take this length stub length equal to 1.5. Now just this 1.5 is approximately half of 3 centimetre; that means, this length will be now lambda by 4. And if this length is lambda by 4 something else happens. Now what you can see here instead of having a single resonance, which we were getting this resonance is split into 2 part. So, there is a lower resonance here and there is higher resonance here.

So, why that happens? So, let us see if this length is equal to lambda by 4 will go back to the figure. So, if the length is lambda by 4 this is an open circuit. So, open circuit will create a short at this particular point. So, you can see that the boundary condition has changed significantly. Now at lower frequency wavelength will be large and if the wavelength is large then this length will be less than lambda by 4 and if this length is less than lambda by 4 it will act like capacitive impedance over here. And if frequency is high then this length will be slightly greater than lambda by 4 then this will offer an inductive load at this particular point.

So, now just recall for a rectangular micro strip antenna, we were looking at a smith chart. So, just imagine there is a smith chart here. So, resonance frequency is actually the lower resonance was here. And as you keep the frequency is actually changing. So, this is the inductive part and here it is capacitive part. So, now, at the lower frequency this stub adds capacitance. So, it was inductive earlier you add a capacitance. So, that becomes a resonance comes close to the central axis. And when this particular thing at higher frequency this offers an inductive load and on a smith chart the impedance curve would have been here which would be impedance value now, you are adding inductance to that it will come to the real axis. So, you need to imagine all this figure here and that is why at l equal to lambda by 4, we actually see the split in the resonance frequency and we actually get a dual band antenna.

Now, the only problem with this configuration is that the bandwidth at each of the band is relatively small compared to the bandwidth for the other rectangular patch or stub loaded patches here. So, now, let just look at another configuration. So, we can see that by adding a stub or cutting notch we can tune the frequency.

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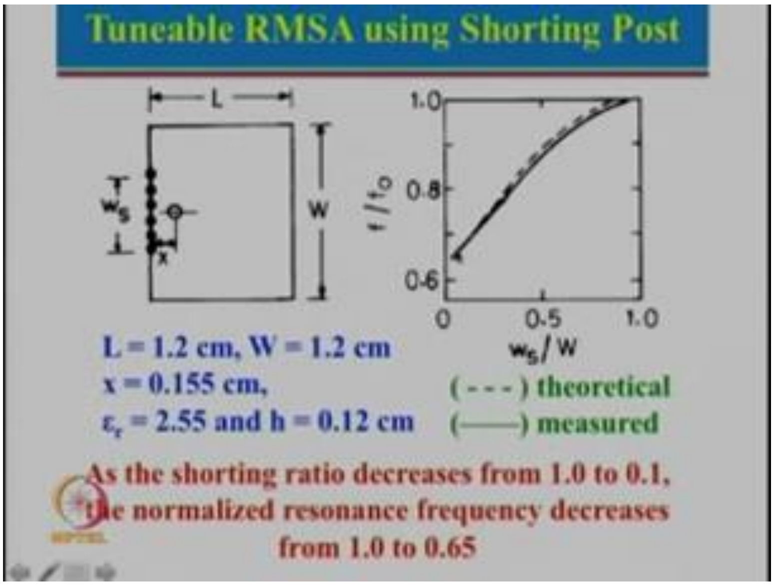

And other way to do the tuning is by adding number of shorting pins. In fact, we did discuss about this configuration when we talked about compact micro strip antenna. And we had discussed that if this W S divided by W is changed then the resonance frequency changes because effective length changes. So, let just recheck again suppose the way it is shown here if this is W S then from here to here length will lambda by 4. If it is fully shorted, then this length will be lambda by 4. If there is a single short, then this entire length will be lambda by 4 and since the length is increasing. So, what happens? Resonance frequency will decrease. So, for these cases here l equal to 1.2 W equal to 1.2, x fixed over here epsilon r parameters are given here. So, these are the normalised frequency values.

In fact, it is important to actually know what is the normalised value because the requirement may be different for different application. So, it is good to see what happens the normalised value here. So, one can actually see if the width is fully shorted, if that is normalised to one then as partially shorting takes place, then we can see that the resonance frequency is changing and by changing the width of this here we can actually tune the frequency from 1 to 0.65. So, here generally speaking what you do? You start with the lesson number of shorting post, and then you increase the number of shorting post to get the desired exact frequency.

Now another way to do it is. So, once you put the shorting post that is fixed you cannot tune it any further. So, there is another way also instead of using a proper shorting post you can actually put pin diodes here. So, pin diodes are nothing, but just to tell normal diode has a p n junction p n n a pin diode has p i n. So, these are the thing and generally p i n diodes are used at microwave frequency. So, if these pin diodes are forward bias they will act as a short circuit, and if the pin diodes are reverse bias they will act as open circuit. So, if we put number of pin diodes over here at number of places here. So, by switching them off or on we can vary the shorting position here and thereby we can do the tuning of the frequency.

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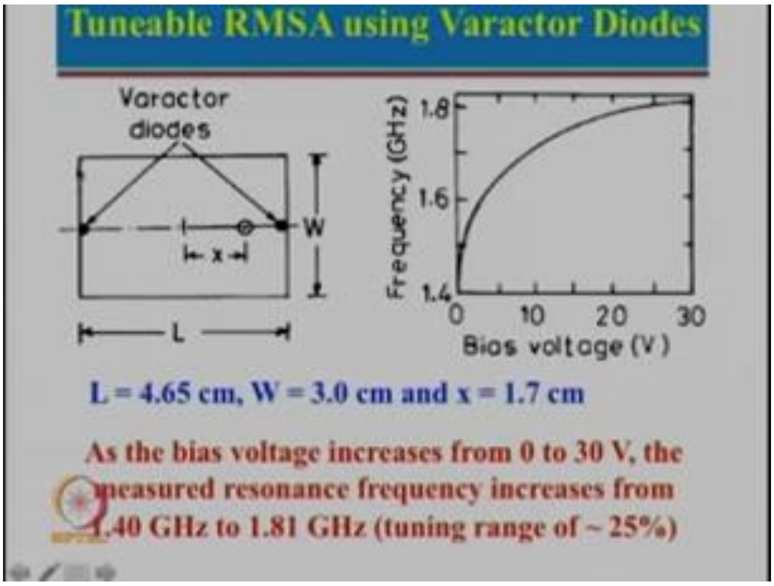

So, this is the one of the way you can tune the frequency. Instead of using pin diodes we can also use another device which is known as a varactor diode. What is a varactor diode varactor diode is again a diode, but it is capacitance varies with the reverse bias voltage. So, let us see how we have put here in this particular figure. So, here is length and this is width here. The 2 varactor diodes are shown over here.

Now just to tell you the biasing circuit is not shown over here, the varactor diode has to be biased properly and a reverse bias voltage has to be given. So, these are the length width and x values for this particular patch, and a varactor diode voltage just to tell you what we have here. So, this is the bias voltage and this is the frequency respond. So, what we can notice here is just to mention this is a reverse bias voltage and that is 0 10 20 30. So, as the reverse bias voltage increases we can see that the frequency is changing, but; however, just to tell you what really a varactor diode. If we look at the varactor diode characteristic, the varactor diode characteristic is actually reverse bias voltage here. And for the varactor diode we normally show capacitance over here.

So, if we have a capacitance here for varactor diode capacitance response is like this. So, higher value it reduces to the lower value. So, now, if the capacitance is lower here, think about the rectangular patch is nothing, but equal to if we can represent this as a parallel combination of r l c. So, if now c is changed or external capacitance is added. So, how is the resonance frequency defined omega 0 is one by square root l c and if the smaller capacitance is added or a large capacitance. If a large capacitance that is the capacitance characteristic large capacitance is added frequency will reduce, if you actually look at the characteristic of this it is just reverse of the characteristic of a varactor diode which is like this here so; that means, capacitance increases resonance frequency reduces. So, by changing the bias voltage from 0 to 30 volt what we can see that the resonance frequency changes from 1.4 to 1.81 gigahertz. And that is a tuning range of about 25 percent.

Now, see something like this I just want to tell this is not a broadband antenna. So, at a given value of the biasing voltage, there will be some frequency over. Here the bandwidth of the antenna is relatively narrow, but this bandwidth is basically getting tuned. So, let us say if the biasing voltage is here then the resonance frequency will be let us say around 1.7 bandwidth will be still close to about say 2 percent or so. Now, the biasing voltage is changed. So, it goes over here now the biasing voltage is changed over here, for example, then it will be 1.65, but with the bandwidth of say approximately 2 percent. So, that is the way it is not a broadband antenna it is a tuneable antenna.

Now these kinds of things are actually required for example, let us say we want to use an application for example, say ground penetrating radar, for ground penetrating radar. Let us say what we do we send a signal down to the earth it reflects back from whatever metallic portion or dielectric portion is there it reflects back over here. So, generally if you use only one frequency then one frequency goes back down there and comes back. And you can measure the amplitude and phase of the reflector signal, but that is not sufficient to detect the buried object. So, the concept which has been used is stepped frequency radar or stepped frequency FMCW radar. So, in that case what happens? You change the frequencies in steps. So, let us say you send one frequency measure the reflector then you change the second frequency measure.

So, now there are 2 options. One is we change the frequency which can be designed using varying the input of the VCO which is a voltage control oscillator. Now there are 2 options one is you use 2 broadband antenna or the other option is we can use 2 narrow band antenna, but they are tuned with frequency. So, as the VCO voltage changes which changes the resonance frequency, that same VCO voltage can be modified and that can be used to tune the varactor diode which will change the frequency. So, this way you can realise a compact micro strip antenna which can be tuned by changing the voltage and this change will be similar to that of the change in the VCO. So, many applications where we want to transmit a signal for a narrow bandwidth, but we want to tune that for a different frequency this kind of a concept can be used very approximately.

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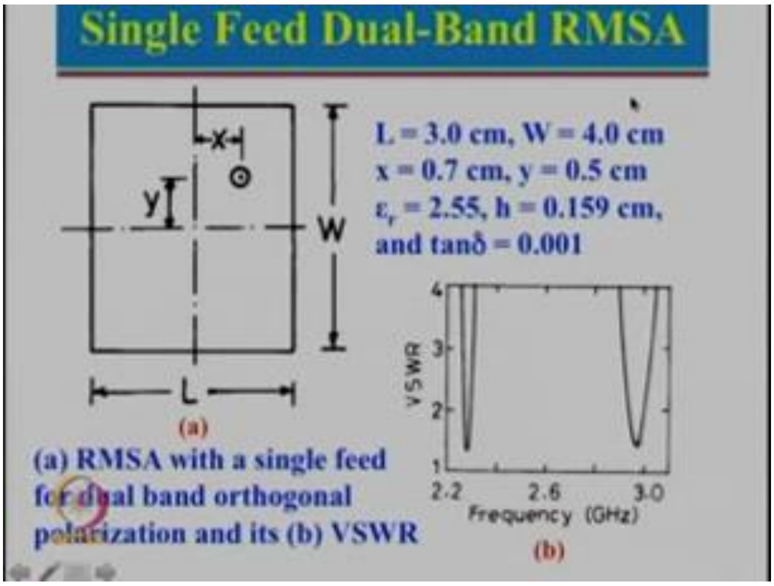

So, now let just go to the next configuration which is a dual band rectangular micro strip antenna. Now I just want to say there are several applications where we require dual band micro strip antenna. For example, an application can be where we transmit a signal at one frequency, and we receive the signal at different frequency. So, here is a one configuration, where we are using single feed; however, there are many times requirement where you use dual feed also, but let just see one by one. So, the single feed point in fact, if you recall rectangular micro strip antenna we did discuss something like this here, but let just look into here.

So, what we have here a length l which is 3 centimetre this is the width which is 4 centimetre and now this feed point can be optimised corresponding to the length here and corresponding to the width. So, now, it is at a diagonal. So, when the feed is along the diagonal then what happens it will excite both the modes this one here also and this one here also. So, at lower frequency since W is large. So, this mode will get excited and at higher frequency because l is small this mode will get excited. So, you can actually see the VSWR plot here. So, there is a decent matching also one frequency you can see is around 2.3 or so. And another one you can see close to 3 gigahertzes. Now these 2 frequencies correspond to the length and w. So, this frequency corresponds to length 3 centimetre and this one corresponds W equal to 4 centimetre.

In fact, depending upon the design requirement, suppose we want this to be even lower than this value you can increase W if you want this to be increased, we can increase W here, but; however, I just want to mention here of this particular feed point actually gives orthogonal polarisation. Why it gives orthogonal, because when the length is excited at this particular frequency that time the e field is this here. So, that would be the e plan, but at a lower frequency when W is dominant then in that case e plain is in this side. So, you can actually say that e plain is changing polarisation changes from this plain to this plain. So, if an application requires orthogonal polarisation one can be used for transmit and receive then this is a good configuration.

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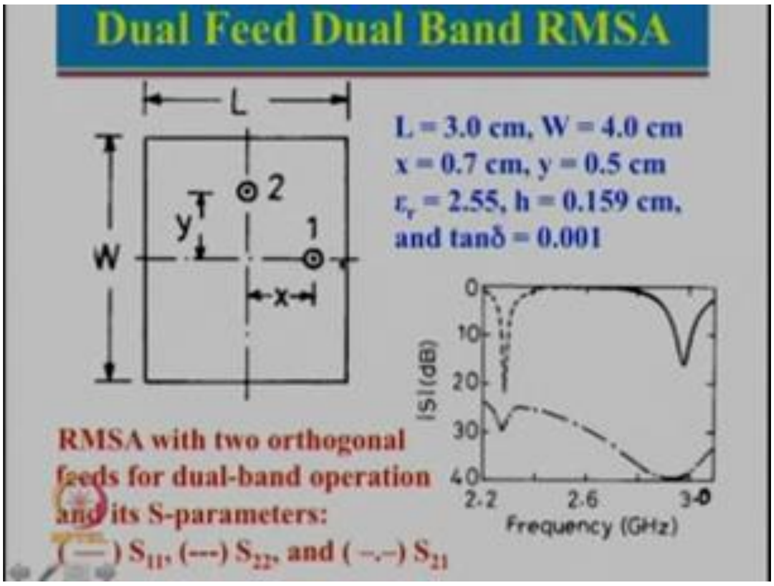

Now, as I mentioned not always we want a single field sometimes we want dual field also. So, here it is exactly the same example as before. Except that now there are 2 feed point. So, we have taken the same dimension 3 centimetre 4 centimetre x y are same, but now there are 2 feed 1 and 2. So, you can actually see the response this response is almost similar to the previous case here. So, this response here corresponds to you can see here dotted that is S 22, S 22 is over here. So, this corresponds to width W becoming resonant and this response which is actually S 11 that corresponds to the length being resonant, but over here now one additional important thing is there. When there are 2 feeds we would like to know what is the isolation between the 2 feeds.

It is very important to have this isolation, and just to refresh the memory. So, when we feed at this point, then this axis here will be a null axis. And when this is fed over here then corresponding to this width this acts as a null axis. So, you can see that for this feed this is along null axis for this feed this is along null axis. So, that is why the isolation between them is fairly good, you can see the response which is S 21 response. So, between 1 and 2 and S 21 will be same as S 12. So, that is same. So, over here you can see that the isolation is roughly better than about 24 dB across the entire band of 2.223, but that is not really too much of an interest. What is of interest is corresponding to this here what is the isolation.

So, if you see that in this particular range here, where let us say reflection coefficient is less than 10, if you see over here that is almost 27 28 dB is the isolation. Whereas, we are getting a much better isolation in this particular band if you see corresponding to minus 10 dB if you draw here. So, this value is somewhere less than 35 dB. So, we are getting a very good isolation in this particular situation. So, here now what the problem is again that for this frequency the polarisation will be in this plain E plane polarisation and for this feed point polarisation will be in this plain so; that means, there will be 2 orthogonal polarisations.

So, in the next lecture we will actually look into how to design same polarisation for the same feed point so; that means, for a give feed point let us say if this is the feed point we look at an alternate configuration where at both the band polarisation will be same.

So, just to recap, today we talked about tuneable micro strip antenna, we looked at different techniques. So, one technique was we can add a stub to do the frequency tuning or we can cut a notch and the stub and notch can be also cut carefully, so that you can do little bit of impedance variation also, for proper impedance matching. Then we also saw that we can do the tuning by adding shorting post or instead of that we can use pin diode. Then alternate technique we looked at it is a varactor diode by changing the reverse bias voltage of a varactor diode. We can tune the frequency by almost 25 percent and then we looked at the dual band orthogonal polarisation, but in the next lecture now we will also see dual band for the same polarisation.

Thank you very much will see you in the next lecture, bye.