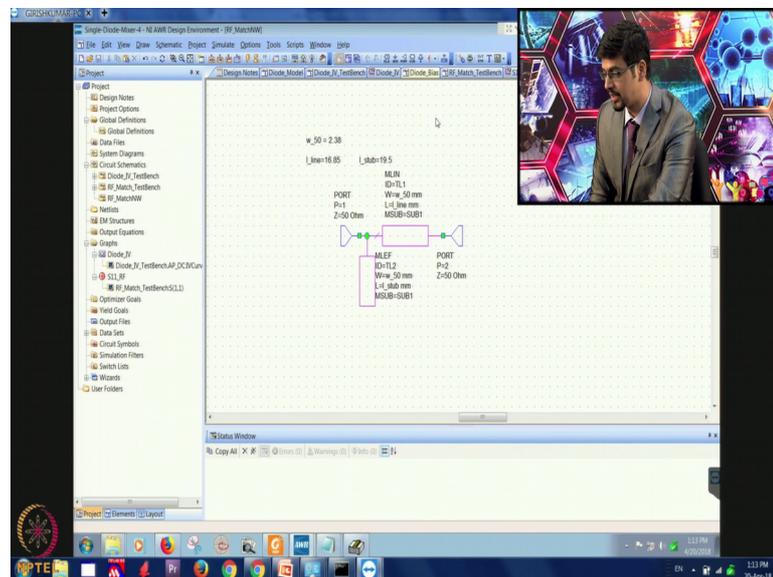


Microwave Theory and Techniques
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Module - 12
Lecture – 60
Mixer Design in NI AWR Software – II

Hello and welcome to Mixer Design using CAD tool which is NI AWR, we will continue with the design in this lecture.

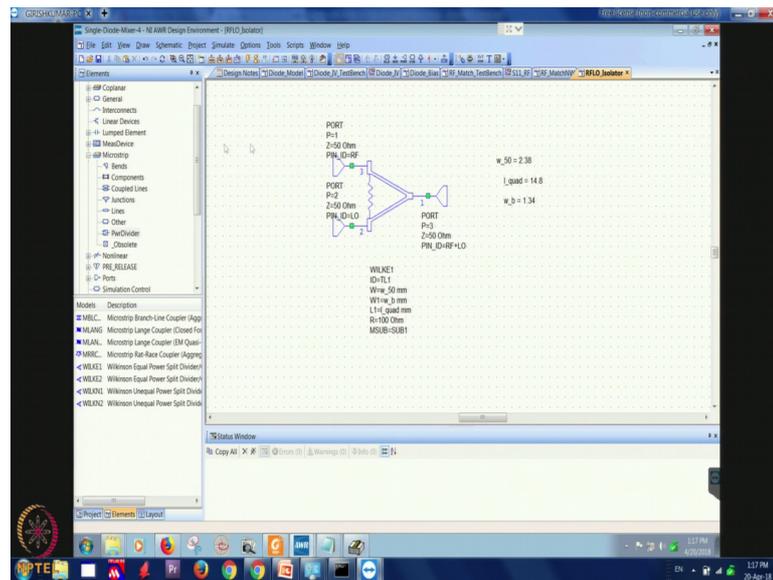
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Next part, we want to design the RFLO isolation circuit. There are various options available; you can use coupling structures or you can use power combiners. Remember that the 2 ports of the power combiners are isolated from each other. Similarly, the 2 ports of coupling structures can be isolated to each other depending on which coupling structure you are going to use. In this particular case we will use a simple power combiner as a RFLO isolator circuit.

So, again schematics, right click, new schematic RFLO isolator, create and go to elements Microstrip power divider, you can see Wilkinson Equal Power Split chip resistor, you can select this.

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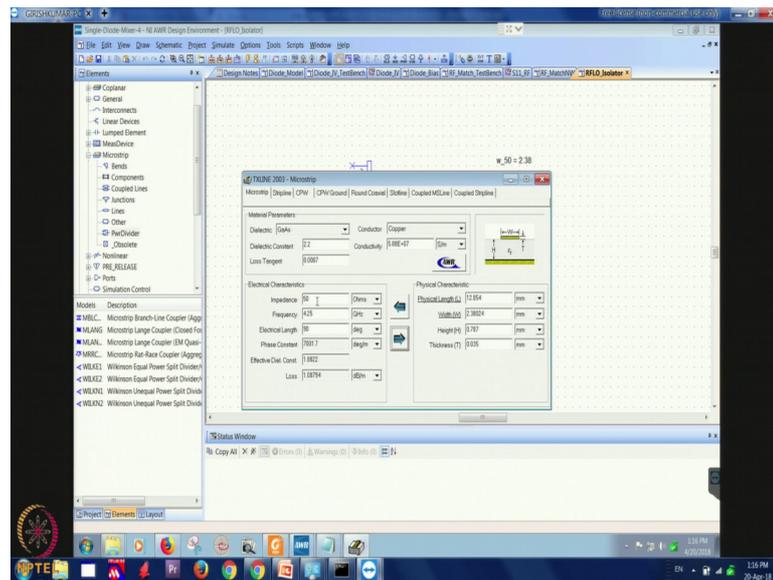


It will rotate remember that Wilkinson power divider, we have studied. So, these are the properties which can be entered from here as well, but the meaning you have to see from this window itself. So, W is the Feeding line width at ports 1 2 3 which should be 50 ohm characteristic impedance lines.

So, I will set it 2 variables w 50 width of branch lines which is 50 route to sorry set to w b length of the branch lines λ by 4, I will set it to L quad and R is 100 ohms because the system impedance is 50 ohms which will not change, the substrate is sub 1 ok.

Now, this variables we have to define. w 50 is equal to 2.38. Now, L quad should be equal to λ by 4 at the LO frequency. The RF value isolator has to be designed at a LO frequency because LO power is quite high and which should be isolated from leaking into the RF and the if ports. So, we will make use of this tool again.

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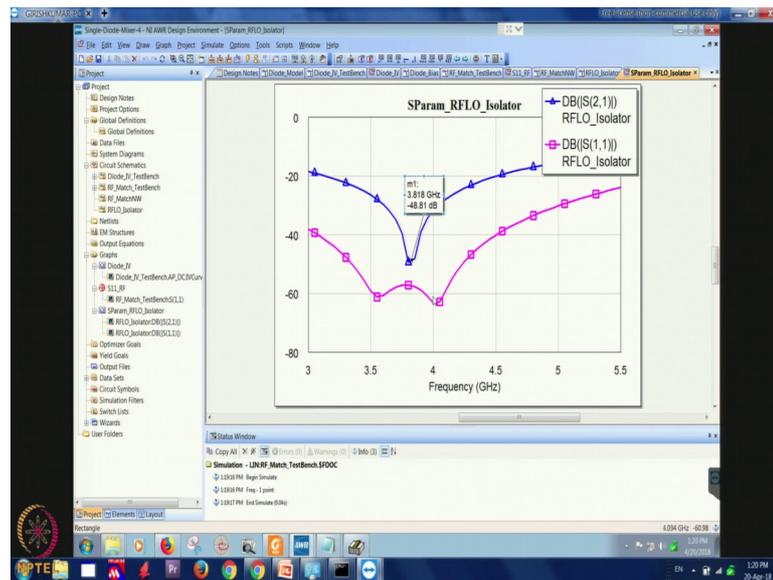


Remember the importance of the line is 70.7, the frequency is 3.75, electrical length is 90 degree; substrates details remain the same. Convert, you see that the width is 1.34 and the length is 14.8.

So, L quad is 14.8 and w b is 1.34. 1.34 L quad ok. Now adding ports; port 1 here, port 2 here and port 3 here ok. I will name ports as RF, this is a LO and this is RF plus LO ok.

So, let us see the response of this particular circuit. I will create a new graph. I will say RF SParam RF LO isolator; type is rectangular, create, add new measurements, select the circuit RFLO isolator, linear S parameters; S11 in dB and S21 again in dB. So, applied S21 S11 apply. Now, the sweep frequency, we have not specified; its only 1 and 2 gigahertz as you can see default project options we will set it later.

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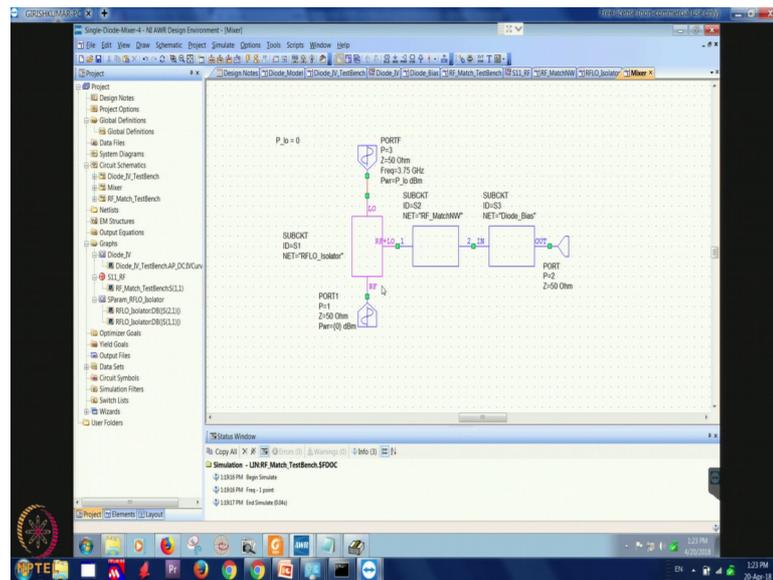
Click go to options, Project Options or rather than that go to the schematic, right click options and check it, uncheck the single point operation and we want to see the operation from 3 to let us say 5.5 gigahertz the step frequency of 0.05 gigahertz. Apply, get 51 points and if I simulate I get this response.

So, as you can see the notch are not at exactly 3.75 gigahertz's which is around here. So, we need to optimize the length. So, go to isolator, added tune tool, hit on L quad, go to the graph again, enable the tuner and since you going to shift to a higher frequency; we will reduce the length slowly till we get now before that let us analyze this.

So, this is port 1 port 2. So, S11 is return loss at port 1; S22 will be the return loss at port 2. S22 will be the return loss at port 2 and s 2 1 is the isolation between port 1 and port 2. So, that is what we are looking at.

I will hit the marker, I will check the frequency which is 3.8 currently. I have to yeah this looks pretty much good. I will freeze to this length. So, the isolation is around 48 dB and the return loss is also good at the RF port. So, this completes the design of RFLO isolator. Now, let us add this things together to make the mixer. New schematic let us say mixer add sub circuit, first we will have the RFLO isolator.

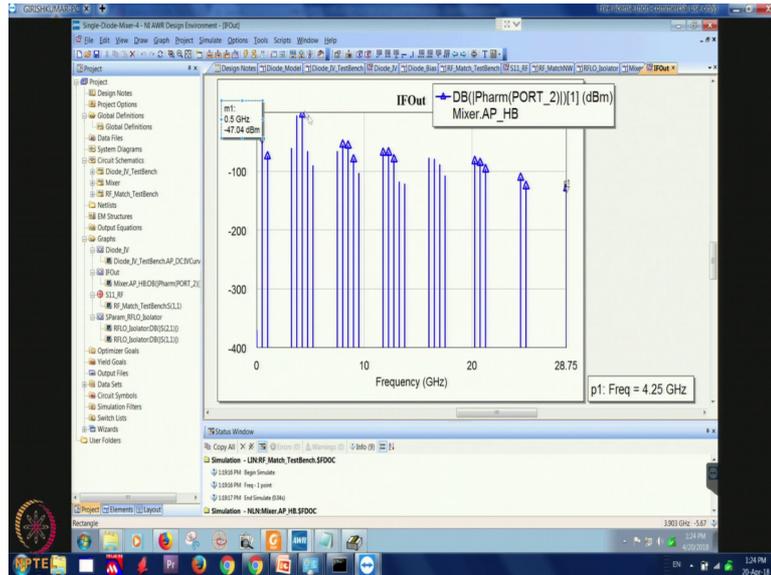
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Then, I will go for the matching network and then, I will use the diode which is diode bias ok.

Now, at the RF and LO, we are going to add harmonic ports because we want to simulate the non-linear part of the device. So, go to ports select harmonic balance, port 1 to be the RF port and port 2 should be the IF port. So, I will choose a normal port small signal port for RF and then, I will choose harmonic port which is port 3 for LO. Now, for this particular project mixer again I have to set frequencies go to options and check this part, say single point and set the frequency to 4.5 gigahertz because that is the RF frequency. Double click on this, go to port and say tone 2 to have the frequency setting. So, if you see now the frequencies applied over here, you can enter 3.75 gigahertz. The power is going to be varied. So, I set it to PLO equation p_{LO} is equal to let us say 0 dBm initially and this is my mixer circuit. This is the RF port RF LO IF. I want to simulate this and want to first check, how does the output spectrum looks like?

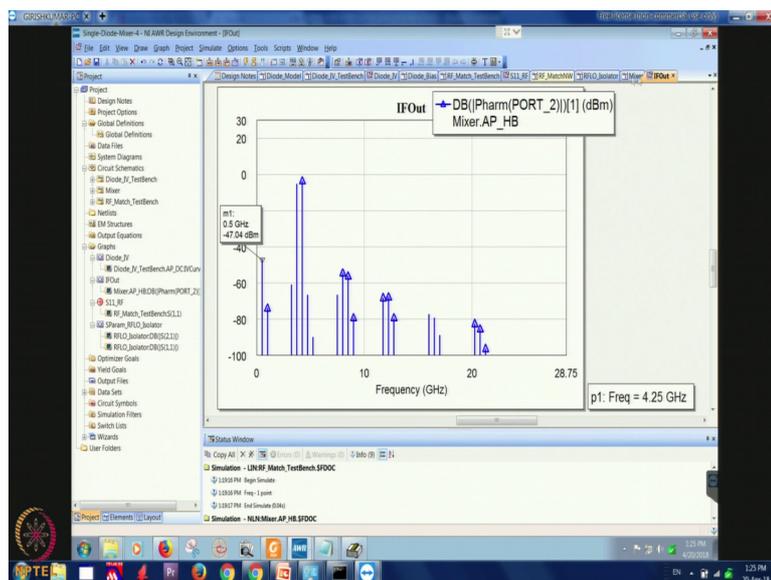
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So, I will add graph IF out add measurement, we have to go to non-linear power and we have to click on harmonic domain frequency domain power Pharm. The circuit is mixer. We want to see the output at port 2 and sweep frequency should be 4.25 gigahertz dB, apply, ok. If you simulate, you see this. This is our output of the mixer right, click add marker; if you see this is at 0.5 gigahertz which is our desired IF and these are various spurious signals, over these you see these are the leaking RF and LO signals.

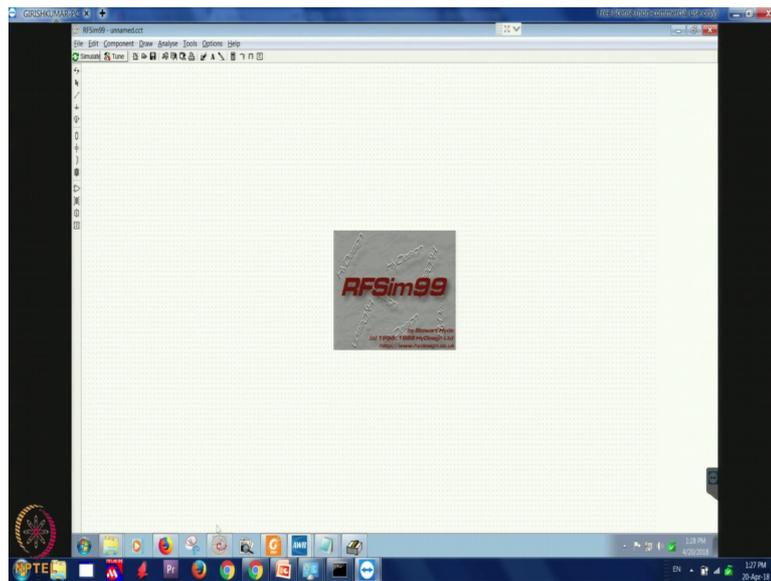
Now, the range is quite high. So, let me modify the axis limits minimum for the left axis. Let us say I keep it to minus 100 and max as let us say 30 apply ok.

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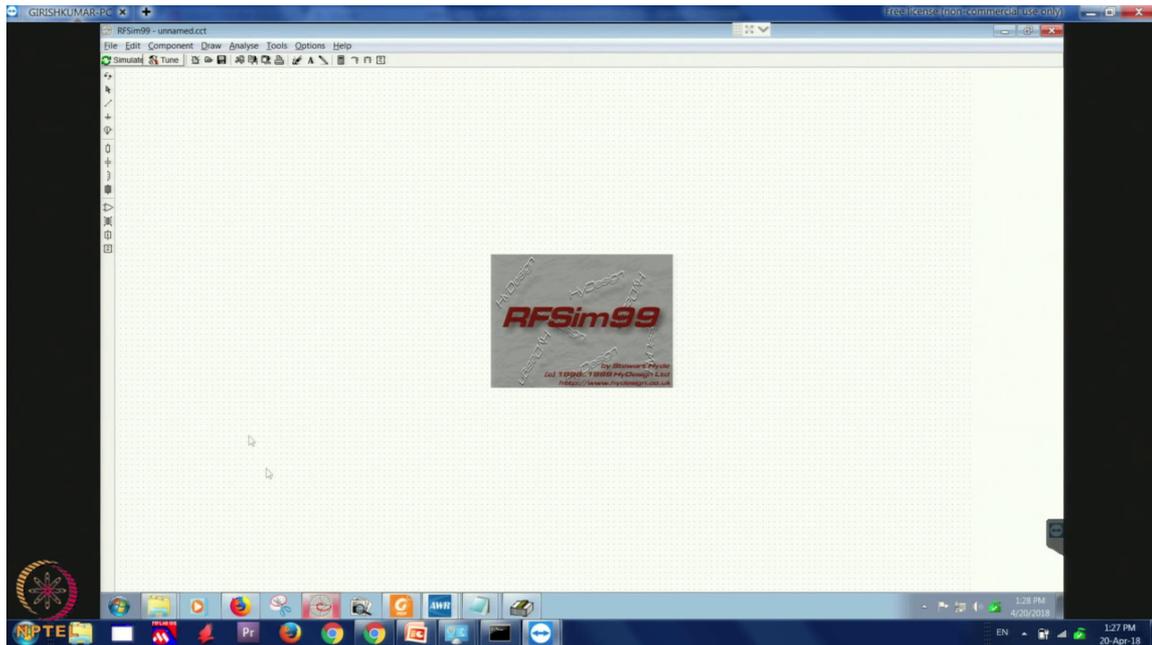
So, right now if you see the power is minus 45 dBm a type which is quite low and we are going to see the effect of LO power on the if output. So, tune tool, tune the power go to the graph, enable the tuner minimum value is 0 maximum is let us say 20 and now if you see if you vary the LO power, the IF power increases which enables a higher conversion gain or lower conversion loss. We will study this with a sweep on LO power, now we will use the if filter to remove all the spurious signals over here.

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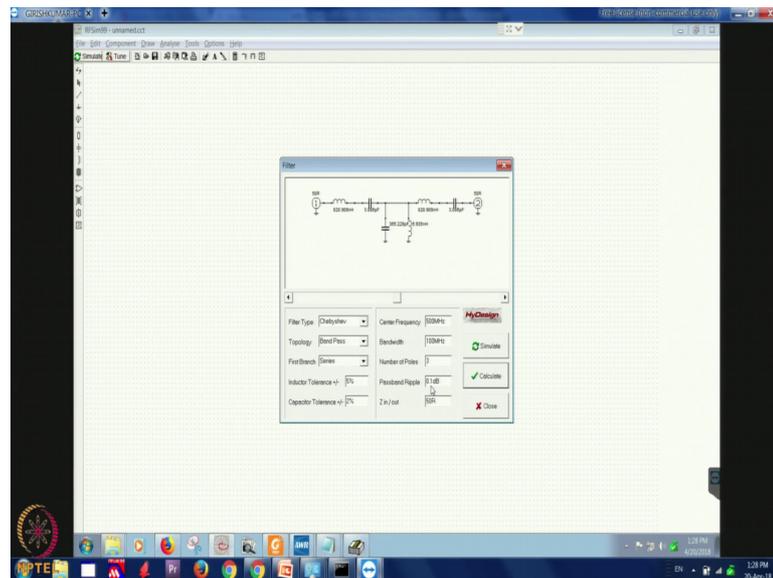


For that we will make use of a tool RFSim 99.

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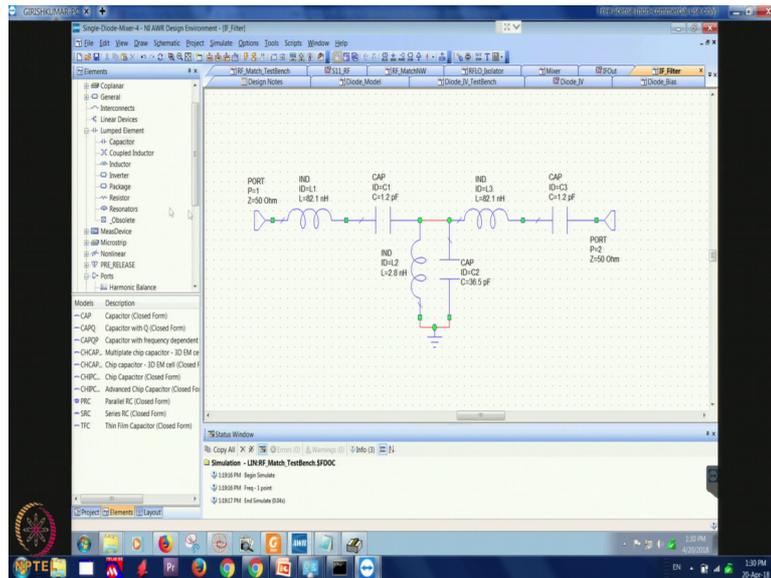
So, go to tools, design filter.



We will choose the Chebyshev filter, we want a Band Pass filter. First element is series. Centre frequency we require is 500 megahertz. The bandwidth is 100 megahertz; I will tell you how the bandwidth is chosen. Number of poles 3, 0.1 dB ripple; calculate, you see that these are the values.

Again, go to schematic, new schematic, IF filter, create, elements, lumped, Inductor closed form; Capacitor, closed form.

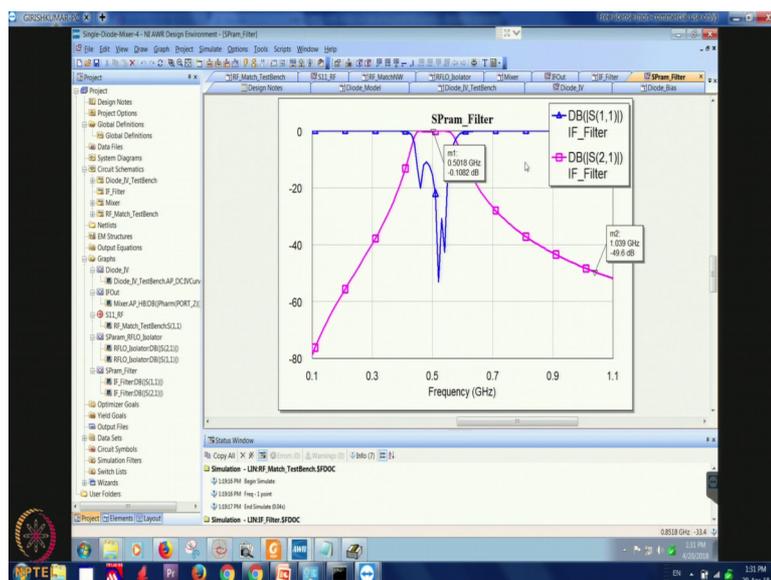
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Now, these values of inductors 82.1 nano henry; it is 82.1 nano henry. Now these values of inductors are 82.1 nanohenry; its 82.1 nanohenry; capacitor is 1.2 picofarad; 1.2 picoparad. Copy paste add the shuntum, inductance value is 2.8 nanohenry.

Capacitor is 36.5 pico and these things have to repeat; add ports, add graph, SParam, filter, add measurement, go to linear port parameters s parameters source IF filter and S 11 dB apply and S 21 apply ok.

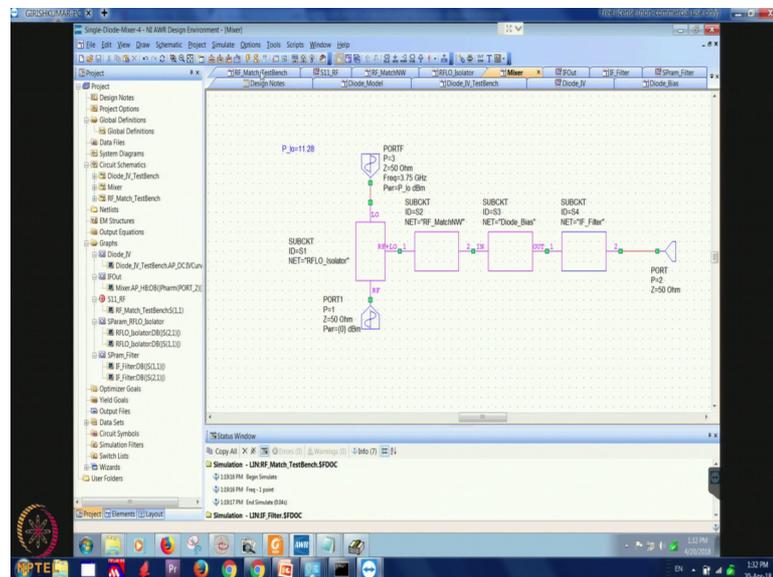
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Go to project, IF filter right click, right click options uncheck this; uncheck this; you want to see the response from 0.1 to let us say 1.1 gigahertz. Step to be 0.01 apply 1 1 points, simulate you see this is the filter response, add marker. This is add 0.5 gigahertz you get a(Refer Time: 15:45) loss of point 1 dB around and if you add another worker at 1 gigahertz which is approximately 48 dB of attenuation is achieved at 1 gigahertz which is required because if you see at the output of IF this is the signal which is closest to IF which is at 1 gigahertz ok. We have we want to remove this signal substantially ok.

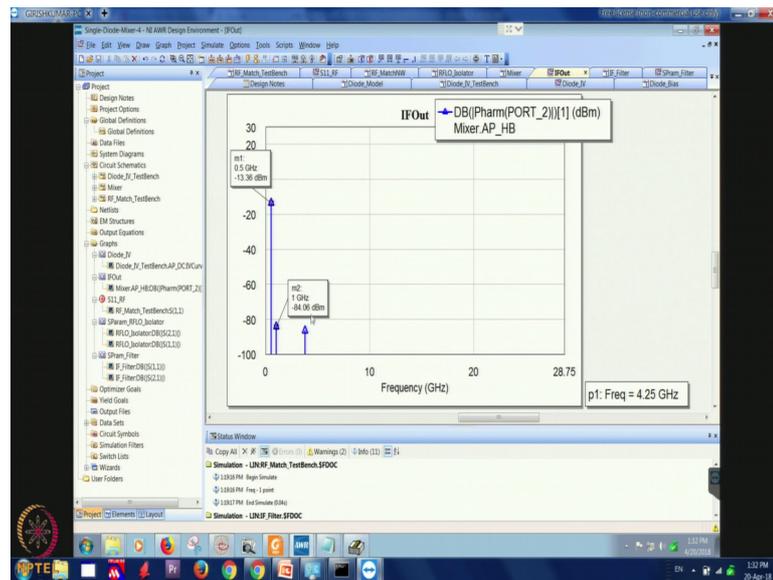
So, this is my IF filter I am going to add it to my mixer circuit. So, I will stretch it.

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Add sub circuit IF filter ok, I will add it to here; save it. If I simulate again, I see the IF out.

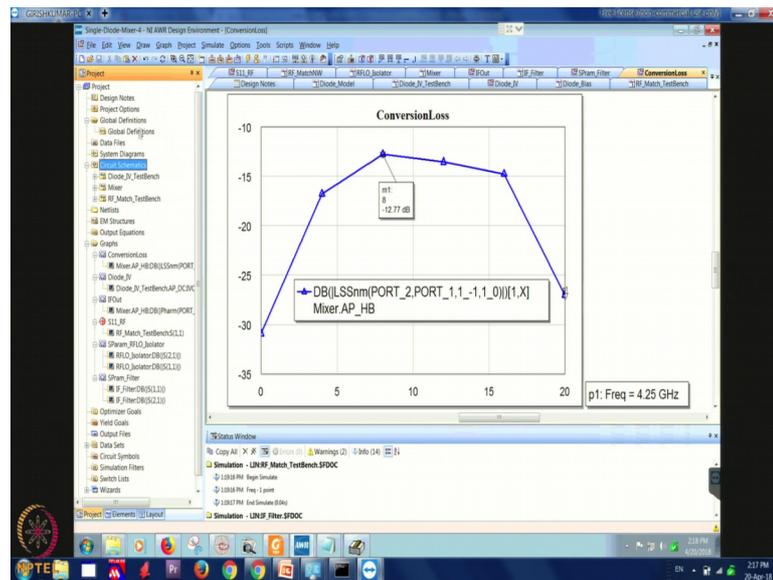
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Now, we see the IF signal is at 13.36 dBm minus 13.36 dBm and all the spurious signals have been removed substantially, good.

Now, we will see the conversion performance for that let us go to the mixer. let us add a sweep variable for the LO power starting from 0 stop to 20 step size 4 ok. Place it here and let us keep the RF power at minus 10 dBm save it. Now, add new graph. Conversion Loss create, add new measurement, go to non-linear, go to power LSS and small large signal S parameter at harmonic, choose the circuit to be mixer to port is port 2 IF port, from port is port 1. The harmonic is 0.5 at port 2 and harmonic is 4.25 at port 1. Sweep frequency 4.25 and variable used for x axis by apply ok.

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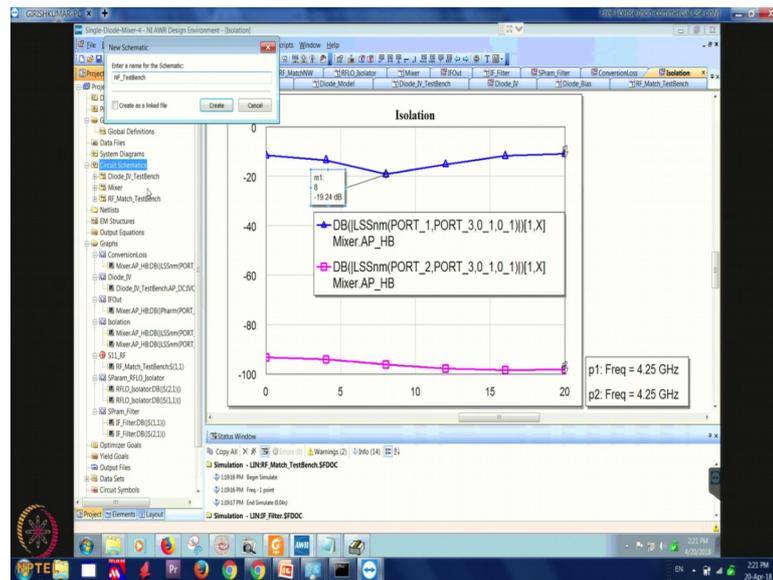
And I simulate again, I see that this is my conversion last performance. If I add marker and I set it to maximum value. I see that the minimum conversion loss is obtained at a LO power of 8 dBm.

So, this is a convergent loss performance of the desired mixer so far. We observe that at lower LO power levels, the conversion loss is very high. It decreases as the LO power is increased and at an optimum LO power of 8 dBm, get conversion loss of around 12.77 dB. If we further increase the LO power, the conversion loss degrades.

Next we will see the isolation performance. For that, we will create a new graph; we will use the same mixer circuit. We will say isolation, rectangular, create add new measurement non-linear power LSSnm and in this case, we want to see to is the RF port which is port 1; from is the LO port which is port 3. At port 1, we want to see what is the LO power. So, the harmonic that needs to be chosen is 0 1.

So, 3.75 gigahertz is LO power and at port 3, we should have the same harmonic which is 3.75 gigahertz and we sweep for different LO power levels. We apply we also want to see the isolation between the IF port and the LO port apply ok.

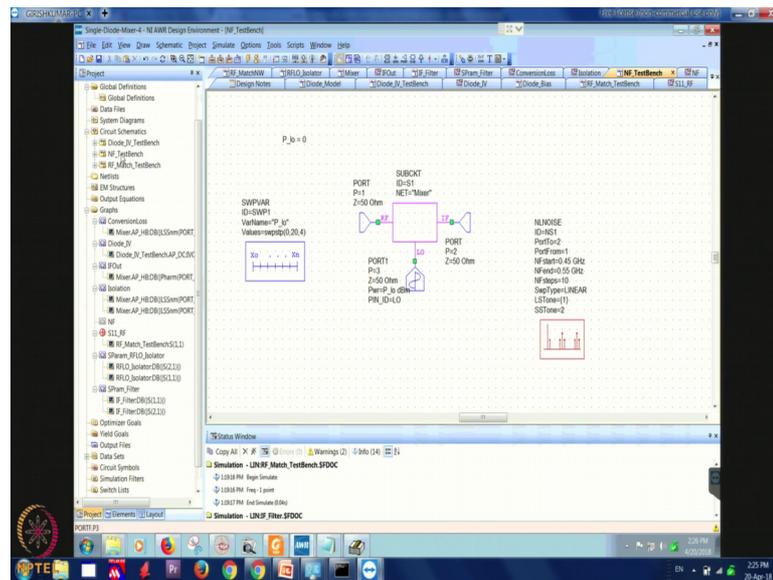
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If you simulate this, you see that the pink curve which is LO isolation is quite good which is greater than 90 dB; whereas, the isolation between LO and RF port is greater than 10 dB and it attains its maximum value at let us have a look minimum again 8 dBm LO power. So, again this is optimum LO power for maximum isolation between LO and RF port. Again, these are large signal simulations it is important that we simulate it using large signal analysis.

Next, we will move to noise figure; for that we have to create a noise figure test bench. So, go to schematic, right click new schematic, noise figure test bench and in this case I will use the entire mixer circuit as a sub circuit.

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It is better that we name the ports so that we do not connect ports wrongly. So, port 1 is RF; name this port as RF ok. Port 3 is LO; name this as LO and port 2 is IF; name this as IF ok.

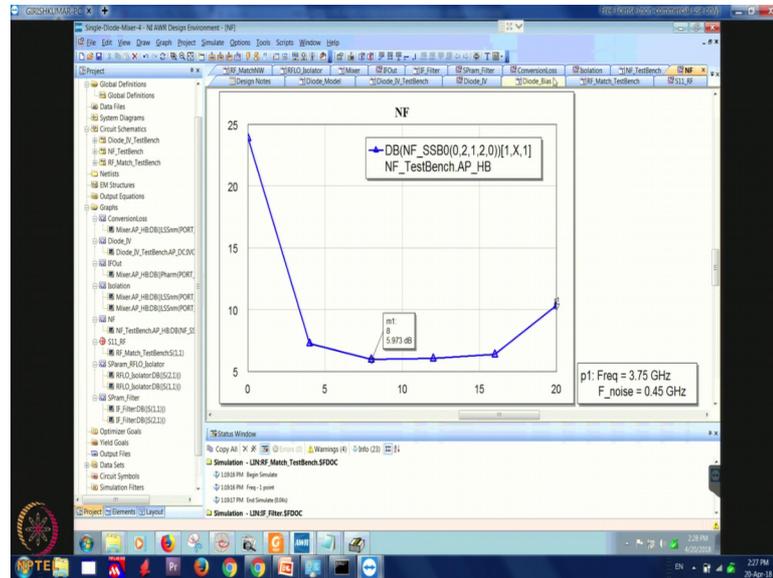
So, in the NF test bench, now if you see RF LO and IF. For noise figure simulation, the RF port is treated as a small signal port. So, you connect a simple small signal port to the RF LO is considered as a large signal port. So, we use harmonic port for LO. So, I will use just copied this port and paste here; IF is again small signal port ok.

Now, for noise figure analysis, we need to add a component. Go to elements, go to measuring devices controls and so drag this, see the component NL noise. We have to add this noise component for noise figure analysis. So, port to is port 2 which is the IF port; port from is port 1 which is RF port. So, noise is being added from RF to IF which is correct. Now, we have to set appropriate values of NF start and NF end and these values will correspond to the RF bandwidth. Let us say the RF signal centre at 4.25 gigahertz as bandwidth of around 100 megahertz.

So, the IF ranges from 0.45 gigahertz to 0.55 gigahertz. So, NF start, I will set it 2.45 and NF end, I will set it 2.55 and steps I will use 10 steps. Once this is done we have to define the Plo. So, add equation Plo equal to 0 and means at a sweep from 0 to 20 step of 4 for the LO power level.

Now, to view noise figure we will create a new graph of rectangular type N F test bench, you have to set this to tone 1 and in the project options, uncheck the default, set single point and set the frequency as 3.75 it ok.

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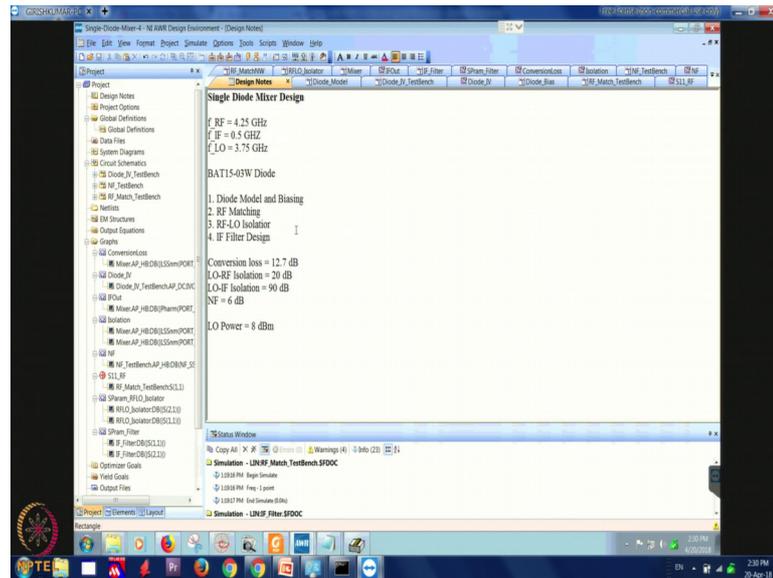


Now if you go here add new measurement, choose NF test bench Noise, Noise figure SSB and you see that the source is NF test bench output large signal harmonic which is 0, input large signal harmonic as 1; upper you have to uncheck this. Sweep frequency you have to set to 3.75 gigahertz and use x axis as the sweeping LO power level. If you apply ok, and if you simulate, you get this performance for noise figure.

So, this is a noise figure performance against various LO power levels. We will add marker and we will check the minimum noise figure which is 5.9 dB and which happens to be at the same LO power at which we get best isolation and best conversion loss. So, it is the LO power if of 8 dBm that gives us minimum noise figure maximum isolation and minimum conversion loss. So, this is our final mixer circuit.

We have a RF LO isolator circuit where LO and RF are applied. We have RF input matching network. This is are diode which is biased at appropriate biasing point and after that we have an IF filter to reduce the spurious response and to filter only the if frequency from port 1 to port 2. At port 2, we observe the IF output ok.

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So, we completed the mixture design and in the notes, we can add the performance. So, conversion loss was around 12.7 dB. We had LO RF isolation equal to around 20 dB. LO IF isolation of around 90 dB and we got a noise figure of around 6 dB and all these things are obtained at LO power level of 8 dBm.

So, this completes are design of a single diode mixer using a CAD tool which is national instruments NI AWR design platform. We studied how to model the diode; how to bias the diode how to design different passive circuits like Wilkinson power divider or you can use coupler as well.

We studied how to design a matching network using this tool. We studied how to design the IF filter and how to combine all these components into the final circuit. And then, we also studied how to use the simulation parameters to study various performances which is conversion lost performance, noise figure performance or isolation performance. With this we will stop here.

Thank you.