IMNLab Calibration Tutorial

In this tutorial the users will learn how to obtain the calibration data for IMNLab optimization through a real circuit. Also some useful tips are presented for achieving best accuracy.

1. Unit Under Testing

The wide-band gain block TQP3M9007 evaluation kit from Qorvo is used a sample. This amplifier has high OIP3 of 41dBm, low noise figure of 1.3 dB. Also the returnloss is fairly good in the whole working band 100 – 4000 MHz. Actually the author uses TQP3M9007 as pre-amplifier for a 5W DVB-T/T2 power amplifier. Qorvo has provided two versions of evaluation kit for TQP3M9007. One works from 500-4000MHz, see Figure 1. Another version works from 30-500MHz by changing the bill of material, see Figure 2. Those two circuits are extracted from the datasheet.
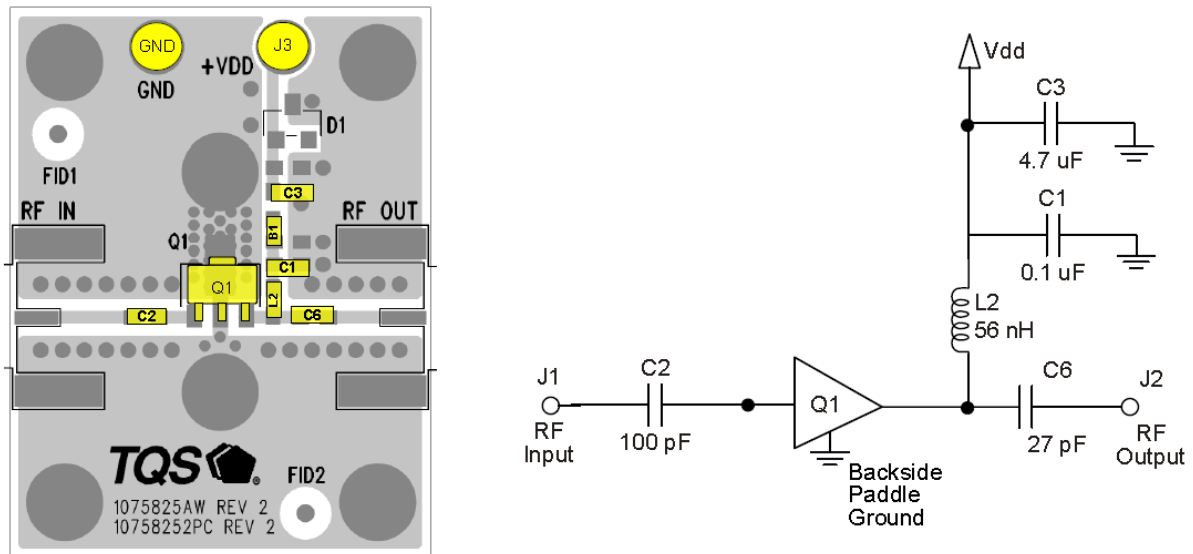
Application Circuit Configuration

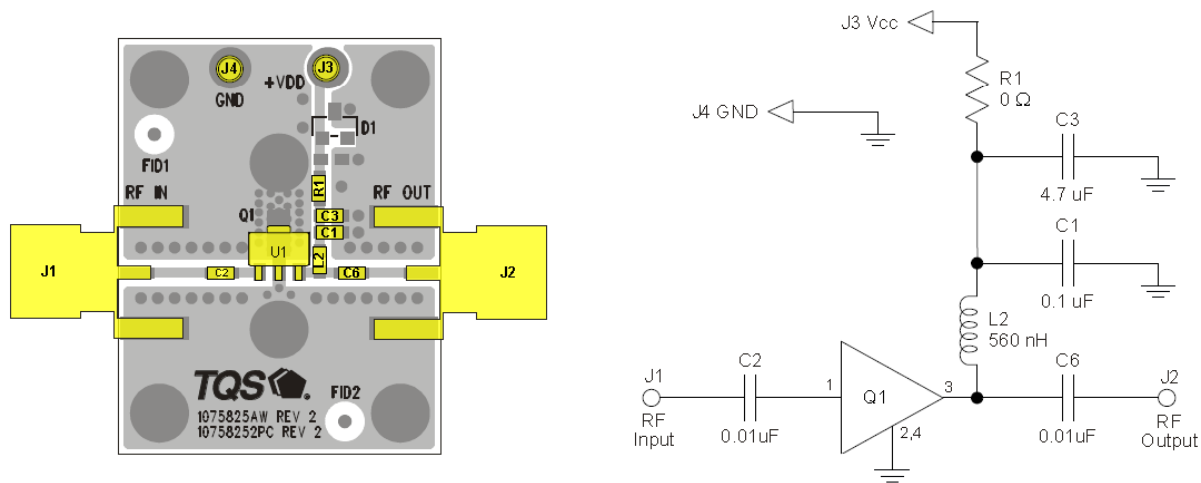Figure 1. TQP3M9007 application circuit 500 – 4000 MHz.

Figure 2. TQP3M9007 application circuit 30 – 500 MHz.

In the custom application for DVB-T/T2 gain amplifier, the target is to optimize the circuit to UHF band 470 – 862 MHz. In order to utilize IMNLab to find the optimal component values, one needs to obtain the calibration data. IMNLab uses the calibration data to calculate channel S-parameter and load impedance, then searches for optimal bill of material.

2. Coarse Component Optimization

Since the interested band in our custom design is 470 – 862 MHz, non of the application circuits presented in the datasheet is optimal. First we change the RF choke L2 to 150nH. Murata high-Q inductor LQW18ANR15J80 is used since it has high impedance in 470 – 862 MHz. Also the DC-block capacitor C2 and C6 is changed to 1nF, with EIA 0603 in size.

3. Calibration Data Measurement

In this section, the measurement procedure is described in details. Before any measurement, the user should always make sure the network analyzer is properly calibrated. If not sure, calibrate the network analyzer when the instrument has reached its working temperature. DO NOT mix the instrument calibration with the IMNLab data calibration. One shall refer to the manual to calibrate the network analyzer. In this tutorial the frequency span is set to 300 - 1000MHz. A little margin lies at both ends of the band.

After the network analyzer is properly calibrated, the user may start measure the calibration data for IMNLab optimization. There are four data sets should be measured: *LOAD*, *OPEN*, *SHORT* and *MATCH*. There is no special sequence for measuring those four data sets. But the user may find out that starting from *LOAD* usually leads to less soldering work.

In this tutorial only the input port is optimized. The optimization procedure for output port is the same.

A. Data Measurement for "LOAD"

First we measure data for *LOAD*. The set up is shown in Figure 3. The evaluation kit is powered up

with a laboratory power supply. The output is terminated with an SMA terminator. The input port is connected to the network analyzer measurement cable.
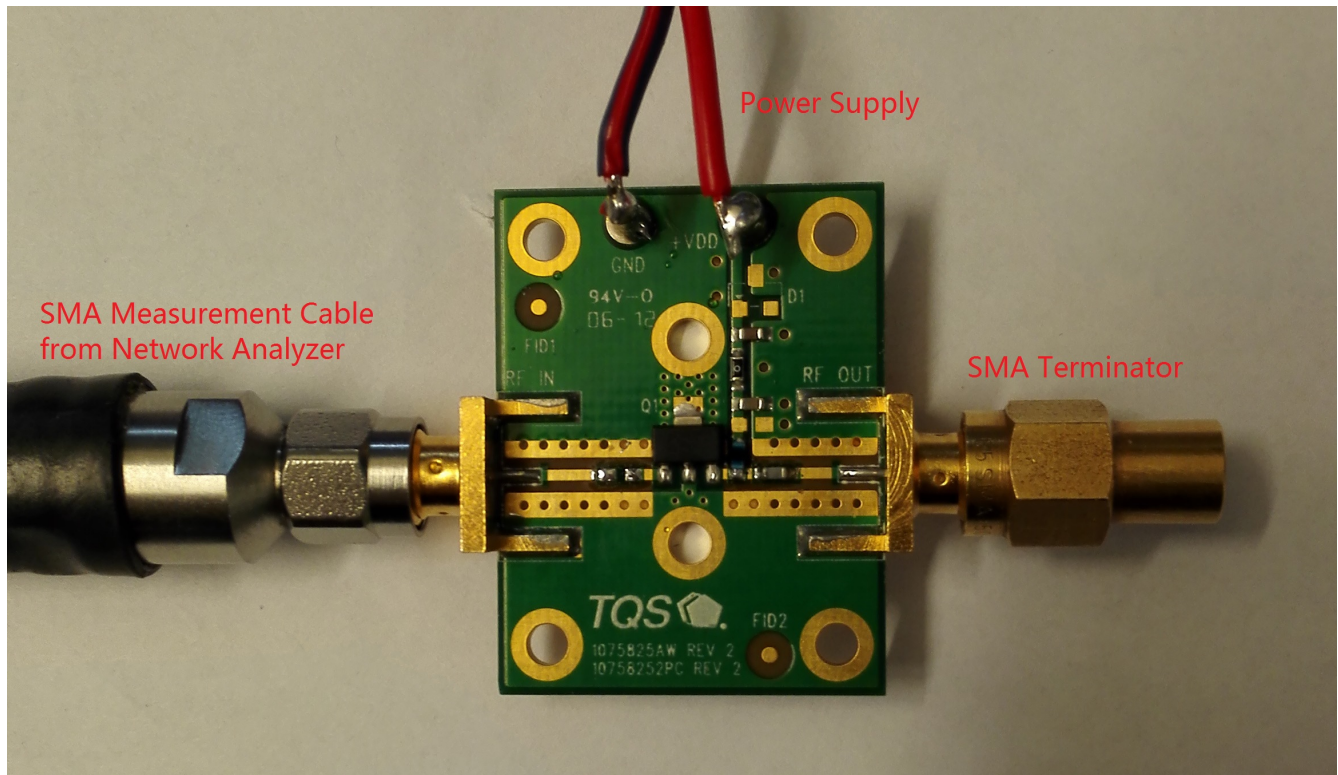

Figure 3. Lab configuration for *LOAD* Measurement.

It usually takes several minutes for the amplifier to reach the stable temperature. The user can save the data when the impedance, i.e. S11, shown in network analyzer to be stable. Averaging over a certain number of data sets may reduce the random noise.

In this tutorial, the measured S11 data is save as "load_tqp3m9007_input.s1p". It will be used by IMNLab later. IMNLab accepts all Touchstone format files. In this tutorial, "DB" format is used to save the data. In this format, the magnitude in dB and the phase are save as pairs. Touchstone files are just plain text files and can be viewed by any text editor. Below the saved file load_tqp3m9007_input.s1p is shown:

```
# HZ  S  DB  R    50.00
! Rohde & Schwarz Vector Network Analyzer
!
!
!
3.000000000000000E8    -1.019251350047855E1   1.475072473818571E2
3.035000000000000E8    -1.021731072335316E1   1.469564675910578E2
3.070000000000000E8    -1.024015987069517E1   1.463961113077517E2
 .                      .                      .
 .                      .                      .
 .                      .                      .
9.930000000000000E8    -1.554680577663541E1   7.580726094839871E1
9.965000000000000E8    -1.558653918918111E1   7.554785583701803E1
1.000000000000000E9    -1.562189332918832E1   7.529199213850576E1
```

B. Data Measurement for "OPEN"

By removing C2, one can measure the data for *OPEN*. The picture underneath microscope is shown in Figure 4. One can see clearly that C2 is removed from the input port and the track connected to input connector is actually floating.
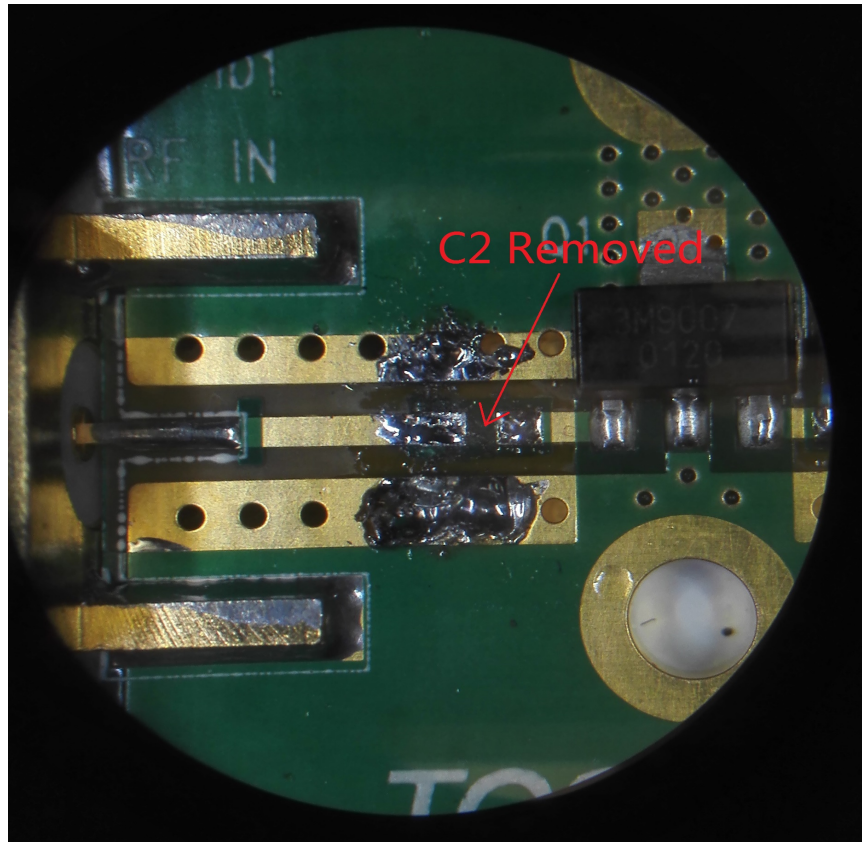

Figure 4. Configuration for *OPEN* Measurement.

Note that this time no active component is included in the measurement chain, the user may save the data immediately. Also averaging data to reduce the measurement noise. The obtained data is save to file "open_tqp3m9007_input.s1p".

C. Data Measurement for "SHORT"

Then one needs to measure the data for *SHORT*. Note that C2 is still removed. Zero Ohm resistor is soldered from the track end to GND plane. For most cases one zero Ohm resistor to GND is good enough. One may also use more zero Ohm resistors to reduce the parasite effect. As a rule of thumb, one zero Ohm resistor with EIA 0402 size counts about 0.5nH inductance.

In this tutorial, the S11 for one zero Ohm resistor is compared to the case for two zero Ohm resistors. The configuration is shown in Figure 5. The left one shows that one zero Ohm resistor is soldered from the track end to GND plane. The right one shows that two zero Ohm resistors are soldered from the track end to GND plane to reduce the parasite inductance.
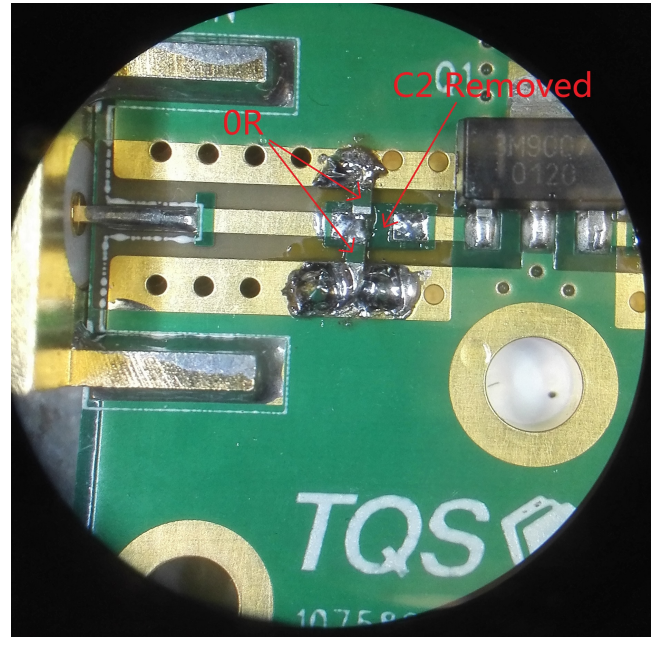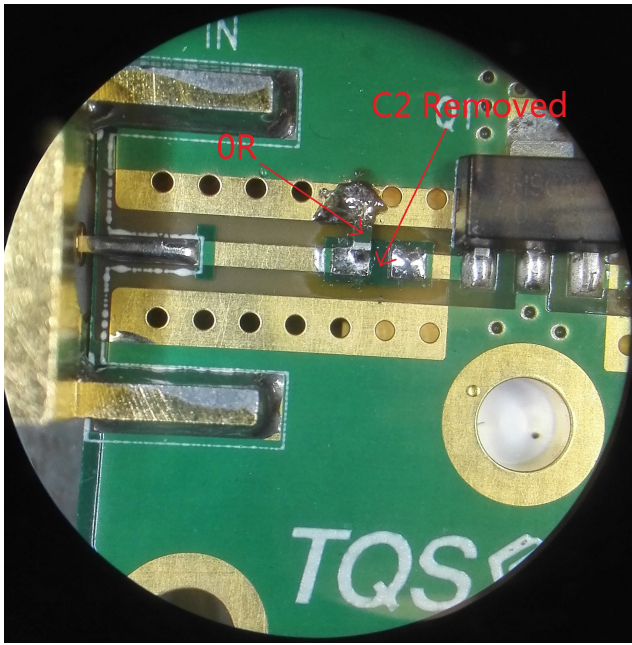
Figure 5. Configuration for *SHORT* Measurement. Left: one zero Ohm resistor, right:two zero Ohm resistor.

The difference of a single zero Ohm resistor and two zero Ohm resistors in parallel is plotted in Figure 6. One can see that the gap between those two case is already obvious at 300 MHz, and is getting even bigger at 1000MHz. Therefore it is highly recommended to solder at least two zero Ohm resistors in parallel to measure the calibration data for *SHORT*. Averaging data to reduce the measurement noise. The obtained data for two zero Ohm resistors in parallel is save to file "short_tqp3m9007_input.s1p".
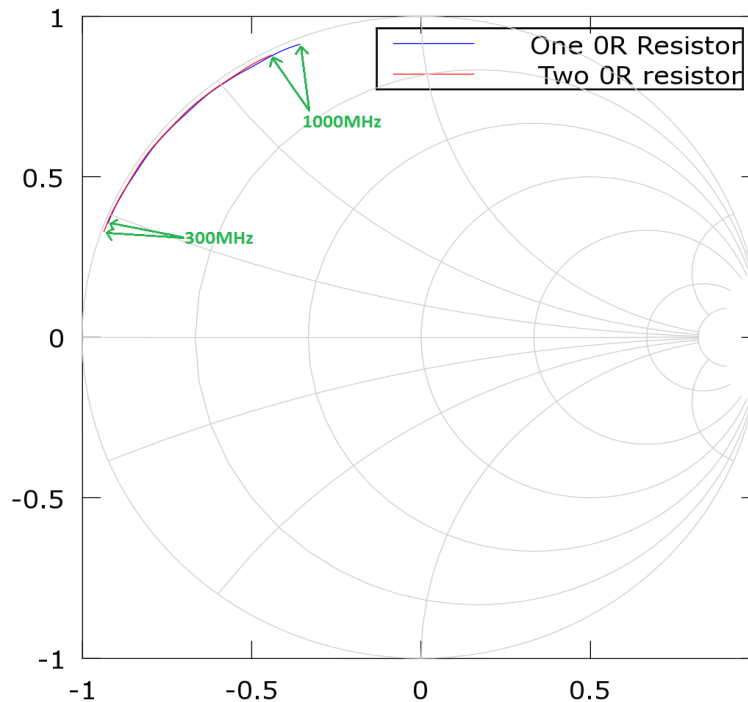

Figure 6. Impedance comparison in Smith chart. Blue: one single zero Ohm resistor; Red: two zero Ohm resistors in parallel.

D. Data Measurement for "MATCH"

The last calibration data is *MATCH*. To obtain this data, one should solder a resistor between the track end and GND plane. The resistor value is equal to the system impedance. In this example, the system impedance is 50 Ohm. Similar to the *SHORT*, two configurations are compared. The first one is to solder a single 50 Ohm EIA0402 resistor. Another configuration is to solder two 100 Ohm EIA0402 resistors in parallel to obtain a total impedance of 50 Ohm.
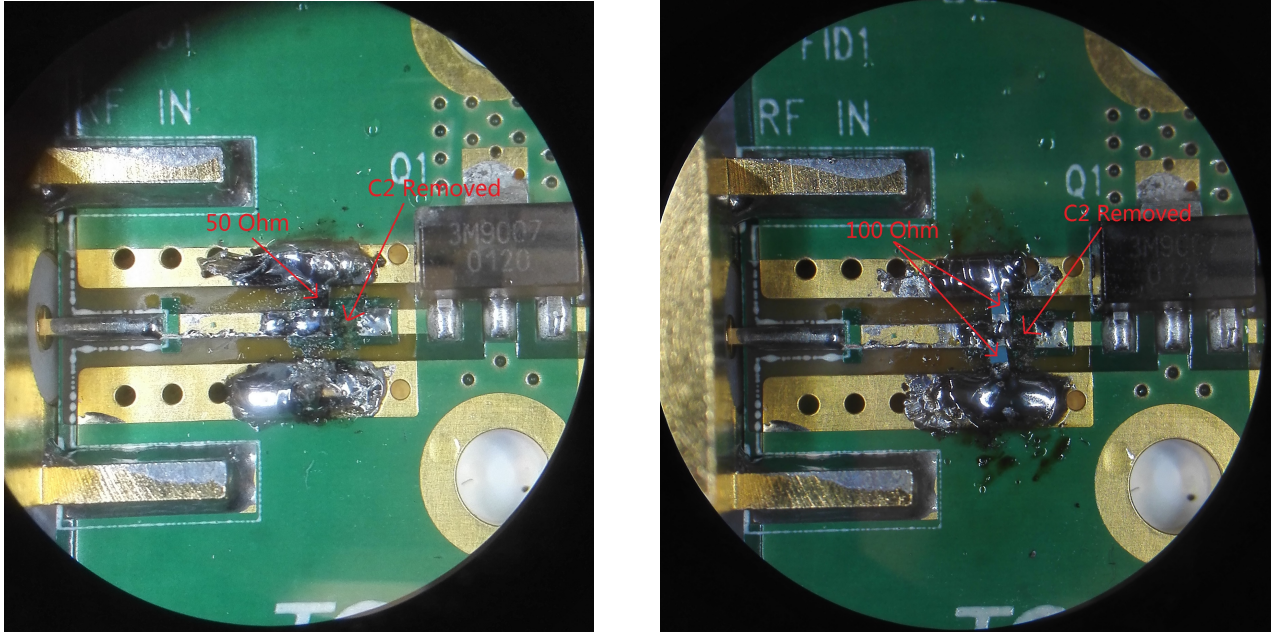

Figure 7. Configuration for *MATCH* Measurement. Left: one 50 Ohm resistor, right:two 100 Ohm resistor.

The impedance for the two configurations is compared in Figure 8. It is shown that there exists obvious gap. It is therefore recommended to solder two resistors in parallel to obtain system impedance for measuring the calibration data for *MATCH*. The obtained data for two 100 Ohm resistors in parallel is save to file "match_tqp3m9007_input.s1p".
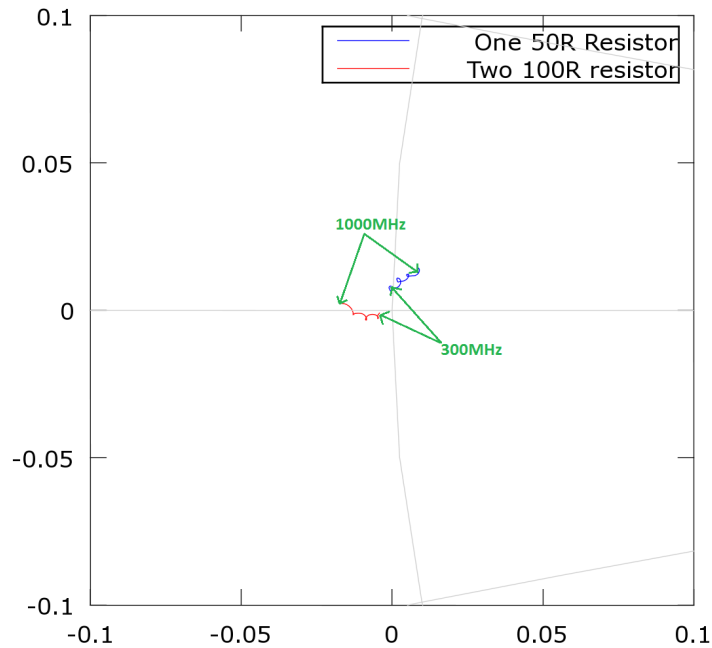
Figure 8. Impedance comparison in Smith chart. Blue: one single 50 Ohm resistor; Red: two 100 Ohm resistors in parallel.

4. Load Calibration Data in IMNLab

Now all the calibration data *OPEN, SHORT, MATCH, LOAD* has been measured and stored in *.s1p files. The next step is to load the calibration data to IMNLab, then to search for optimal impedance match network. This optimization procedure will be described in the IMNLab tutorial.

It may be worthy to point out the in this example we only do the optimization for the input port. In reality, one should also optimize the output port to achieve the best results. Due to the non-ideal isolation between input port and output port, the impedance match network added to the output port will affect the input returnloss, and vise verse. In this case, the user may optimize the input port and output port iteratively. Fortunately since the calibration data for *OPEN, SHORT, MATCH* is independent to the amplifier itself, one only needs to measure the *LOAD* again.