Low Impedance Measurement Using Low Cost SDR VNA

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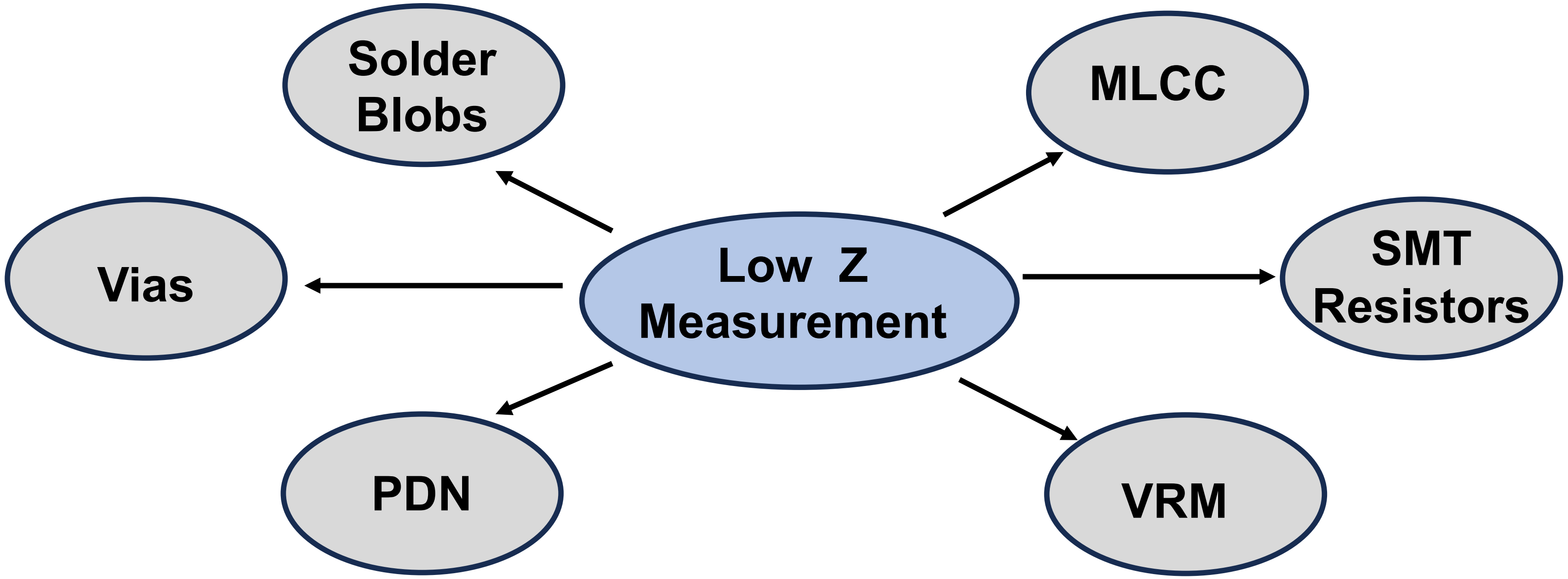
Agenda

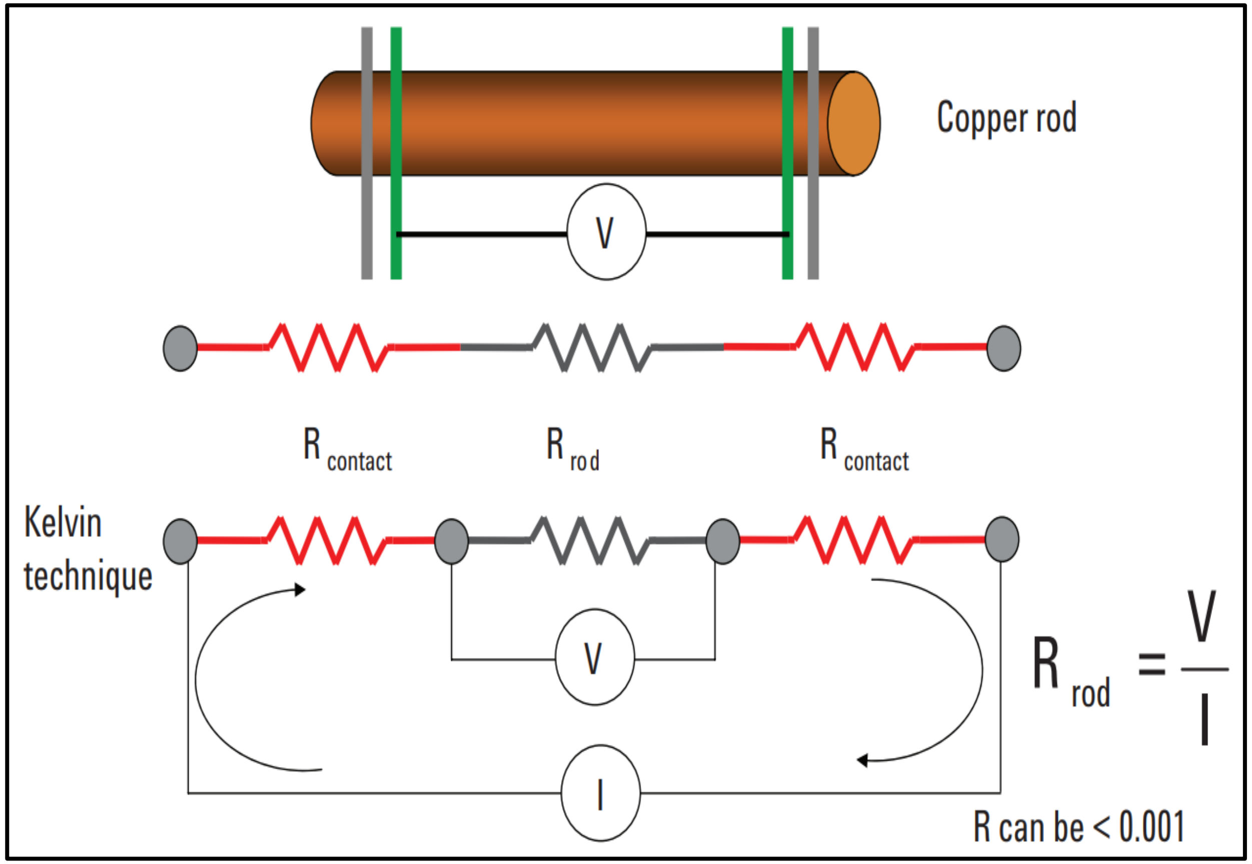
- Need for Low Impedance Measurement
- Two Port Measurement Method
- Lowest Impedance measured by the SDR VNA
- RLC Characteristics Trends of Circuit Elements
- Takeaways

Need for Low Impedance Measurement



- PDN components have target impedances in the mOhm range.
- Not practical to measure Z < 0.1 Ohms using return loss 1-port VNA.
- Real world limitations of Signal to Noise ratio & fixturing reproducibility.
- 2- Port method is a **low-cost method** to measure impedances even < 0.1 ohms.

4 – Point Kelvin Method for Low Z Measurement



Measurement Set up for Calculating the Resistance.

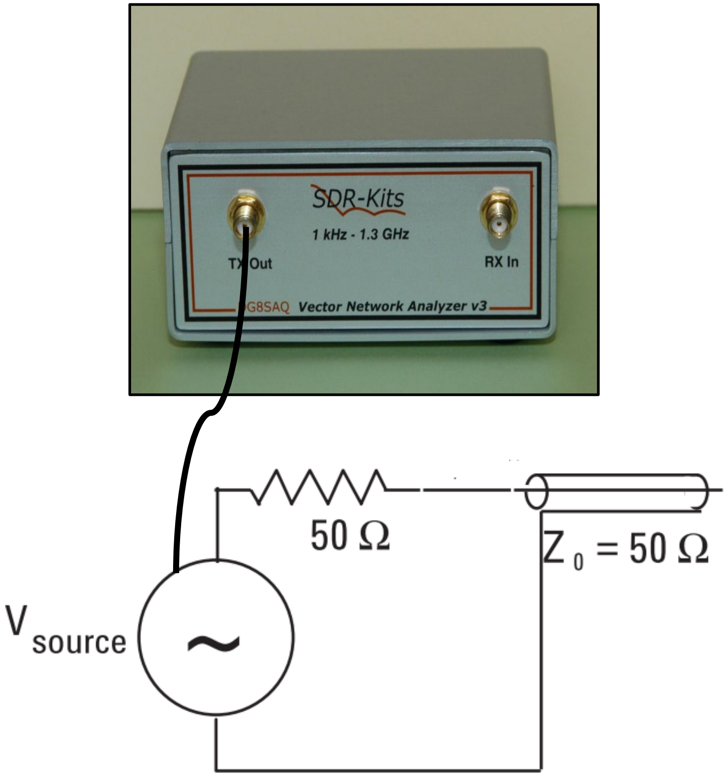
Rated Resistors (in Ohm)	Measured Resistance (Uncertainty ± 0.002) (in Ohm)
10	10.006
1	1.003
0.50	0.505

Measured resistors are within 1% tolerance of the rated values.

Next, we will correlate the measured & simulated impedance.

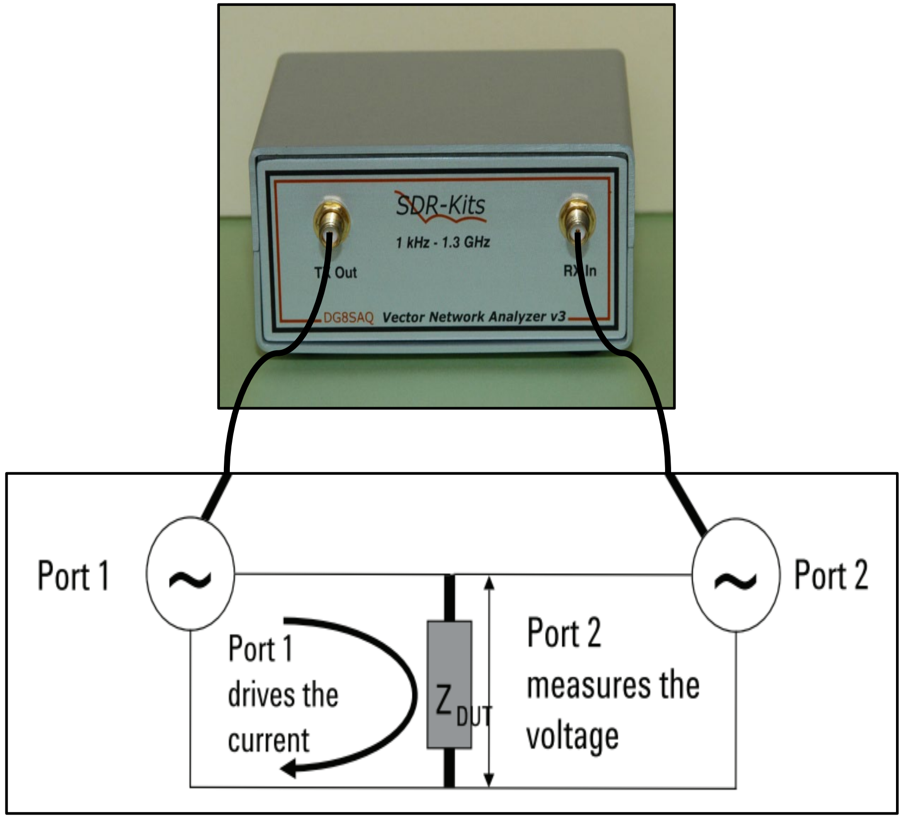
Low Impedance Measurement – 1 & 2 Port Method

1- Port Method (Z > 0.1 ohms)



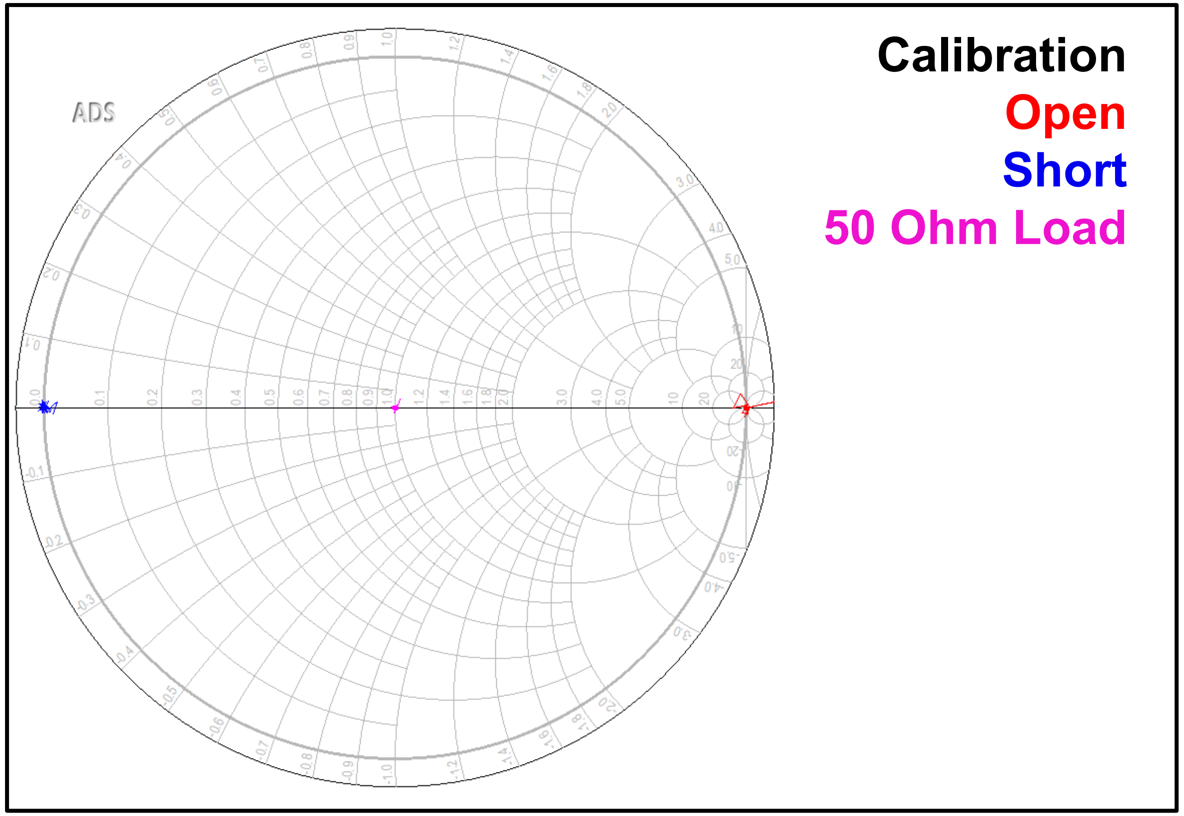
$$S_{11} = \frac{Z_2 - 50}{Z_2 + 50}$$

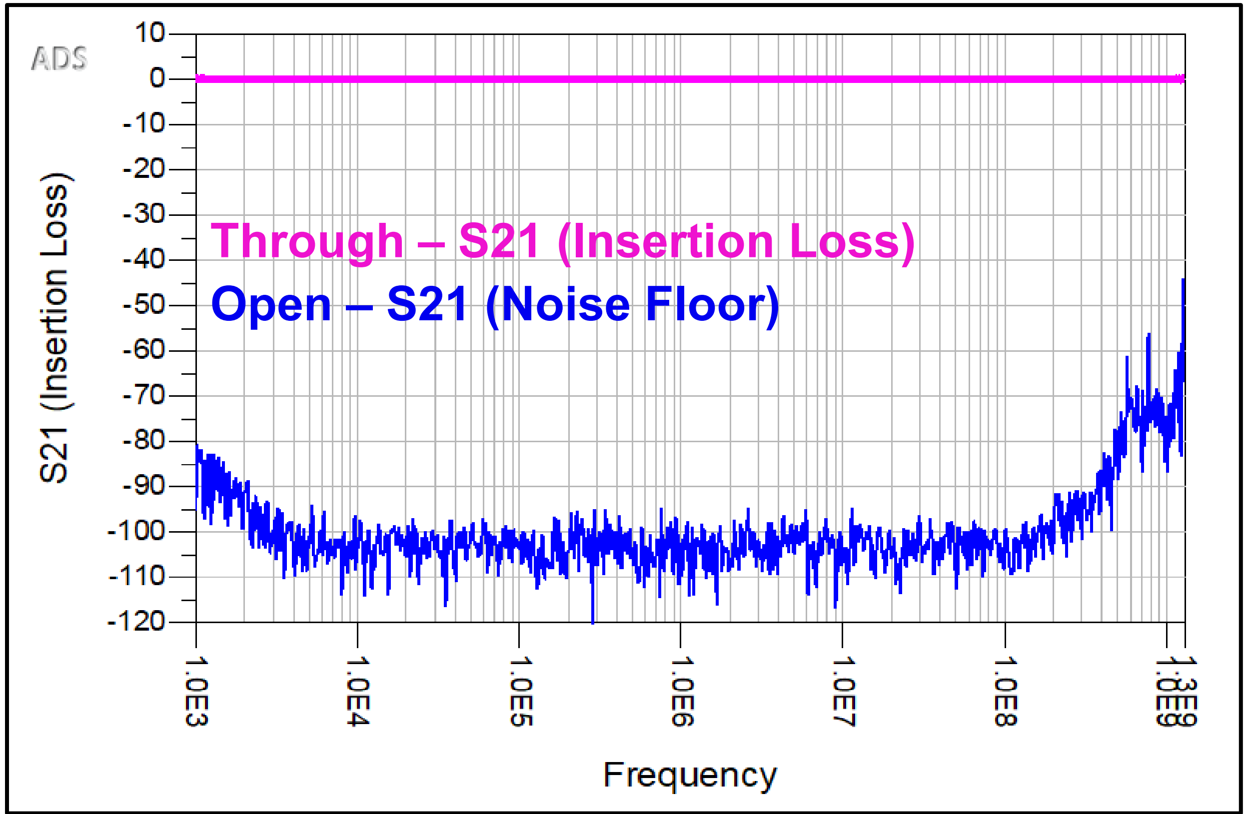
2- Port Method (Z < 0.1 ohms)



$$Z_{DUT} = 25 \frac{S_{21}}{1 - S_{21}}$$

SDR VNA Calibration – Open, Short, Load & Through

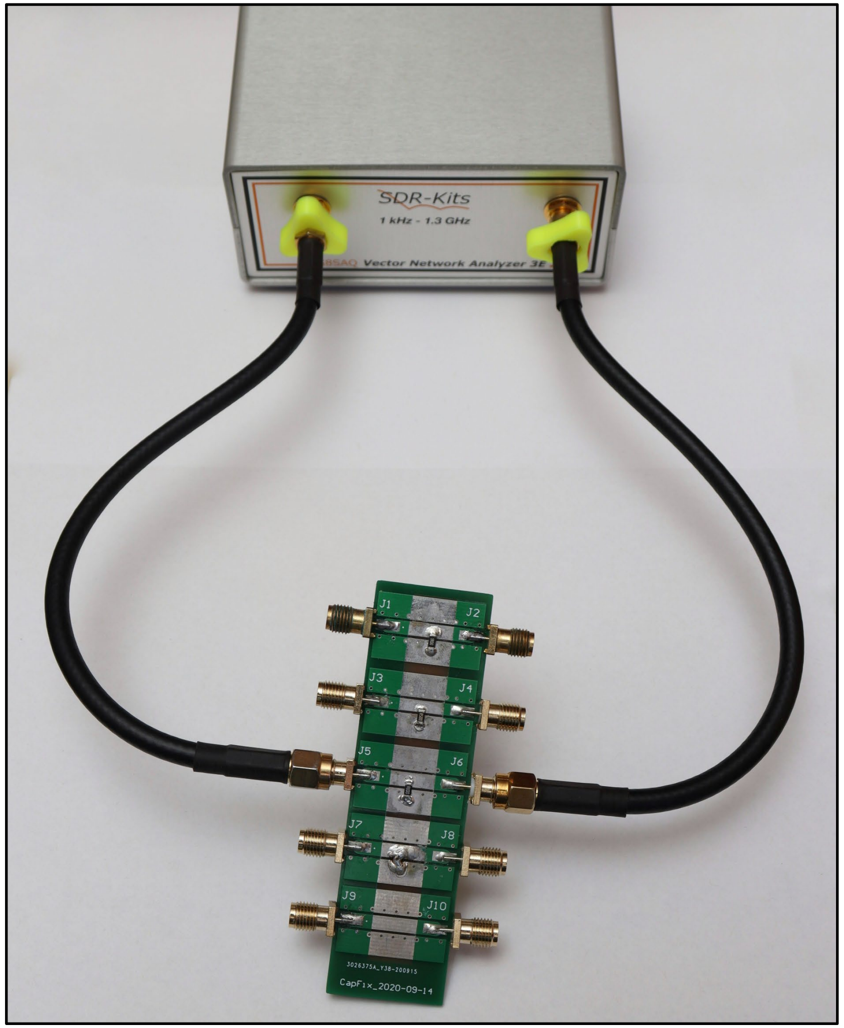


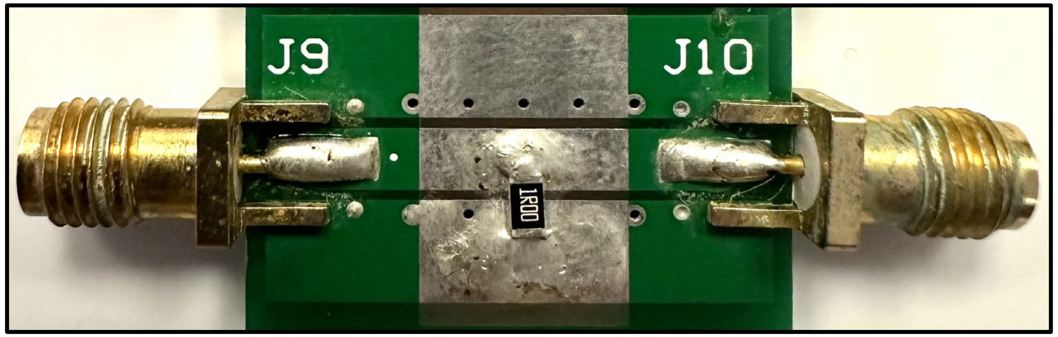


- Open, short & 50-ohm load plotted on a Smith Chart.
- SDR VNA is calibrated.

- Thru - Insertion Loss is 0dB (100% Transmission)
- Noise Floor is the lowest impedance measured by the SDR VNA.

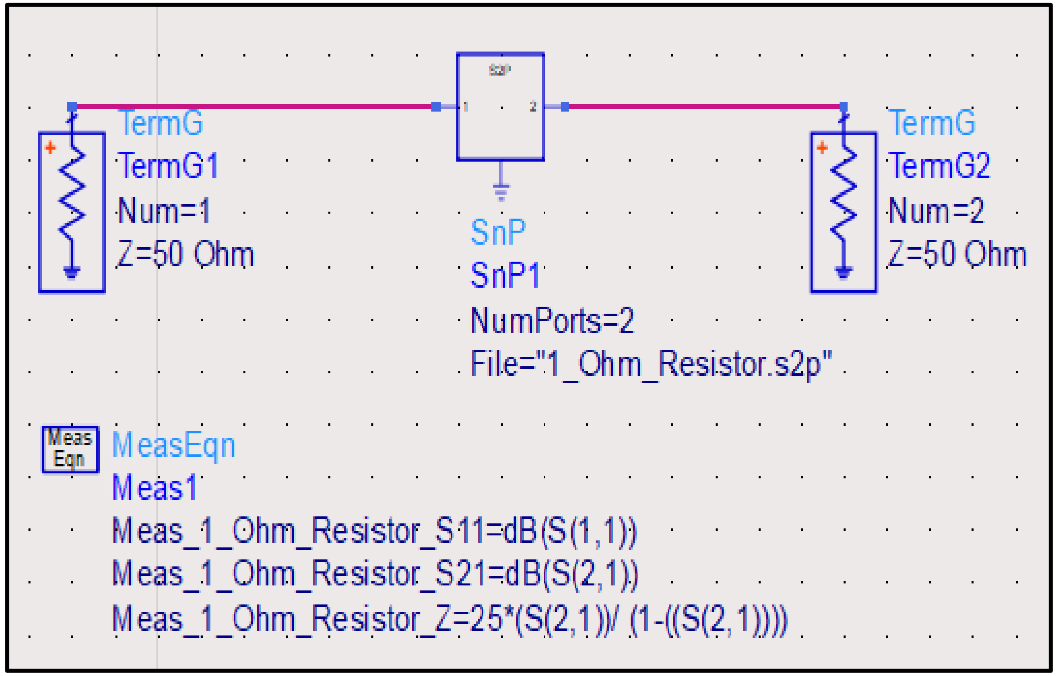
Correlation in Measured & Simulated Resistor Impedance





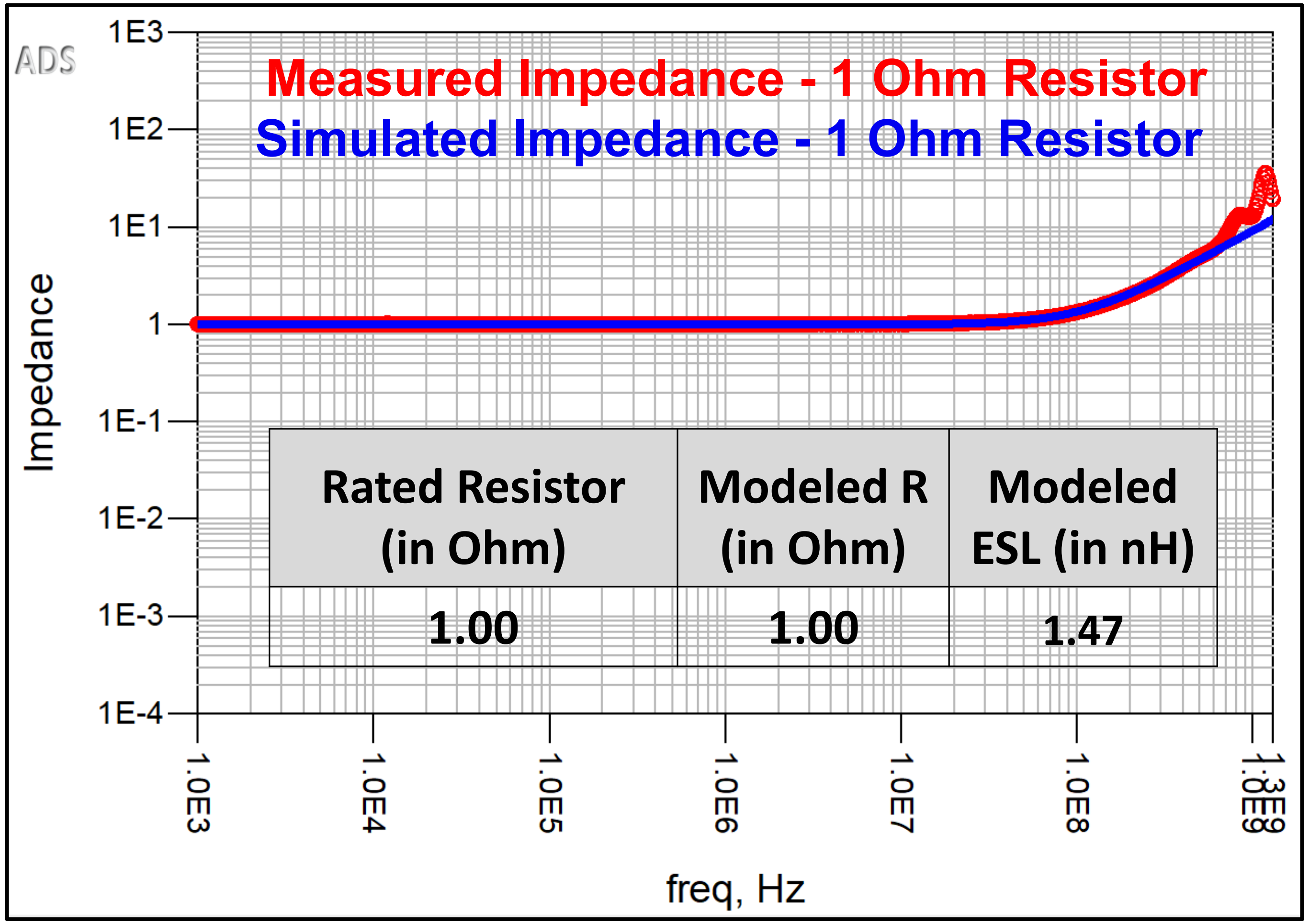
1 Ohm Resistor

Breakout Board

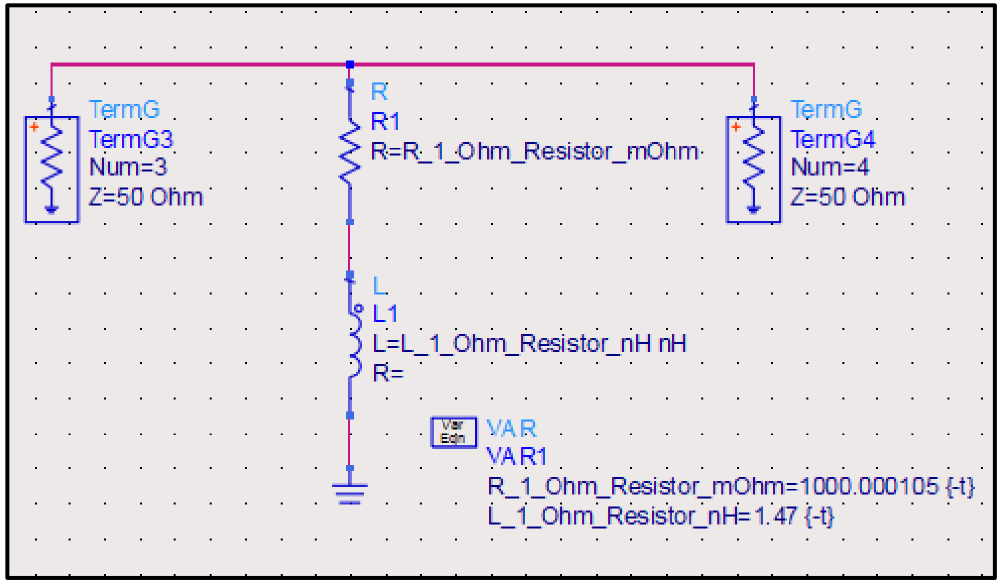


Plotting Measured Impedance in ADS

Measured & Simulated 1 Ohm Resistor Impedance



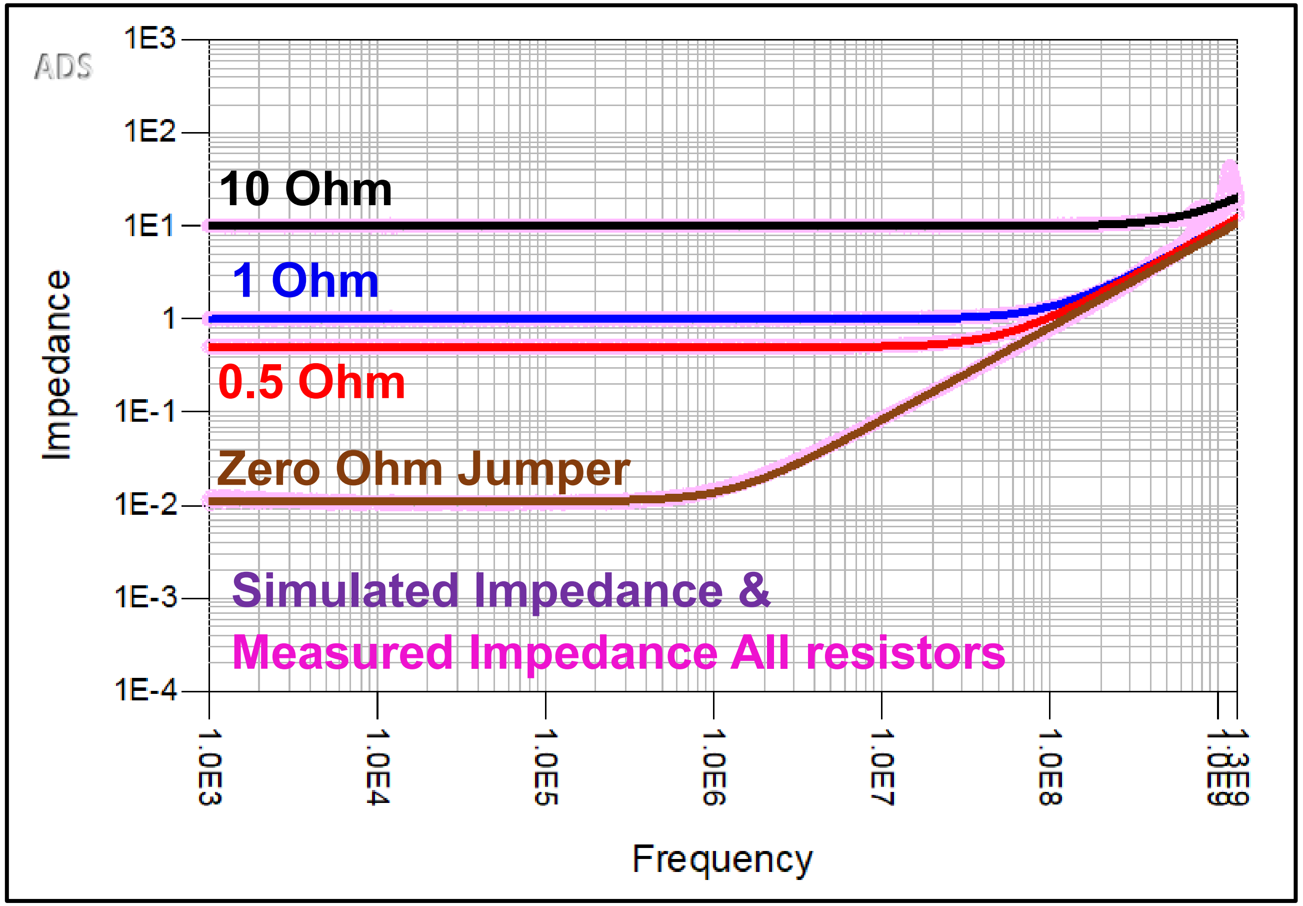
Rated Resistor (in Ohm)	Modeled R (in Ohm)	Modeled ESL (in nH)
1.00	1.00	1.47

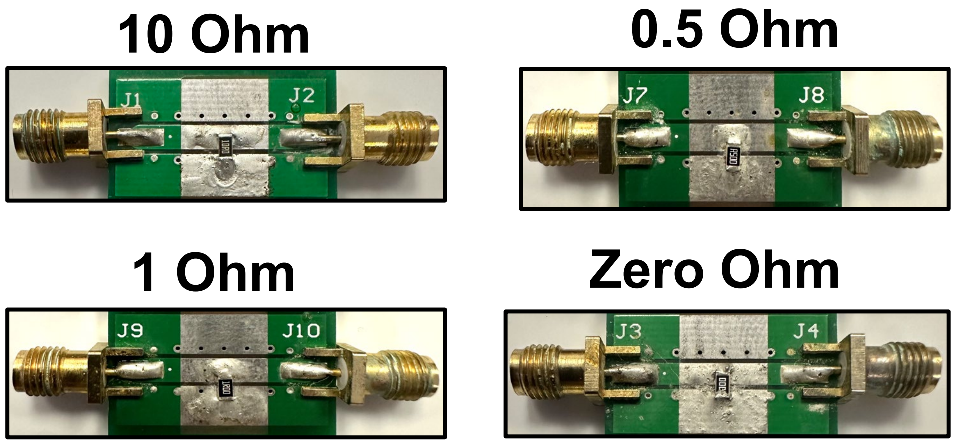


This simple RL model is an excellent model for the impedance behavior of this real resistor from low to high frequency.

Measured & Simulated Impedance correlate accurately.

R & L Characteristics of SMT Resistors

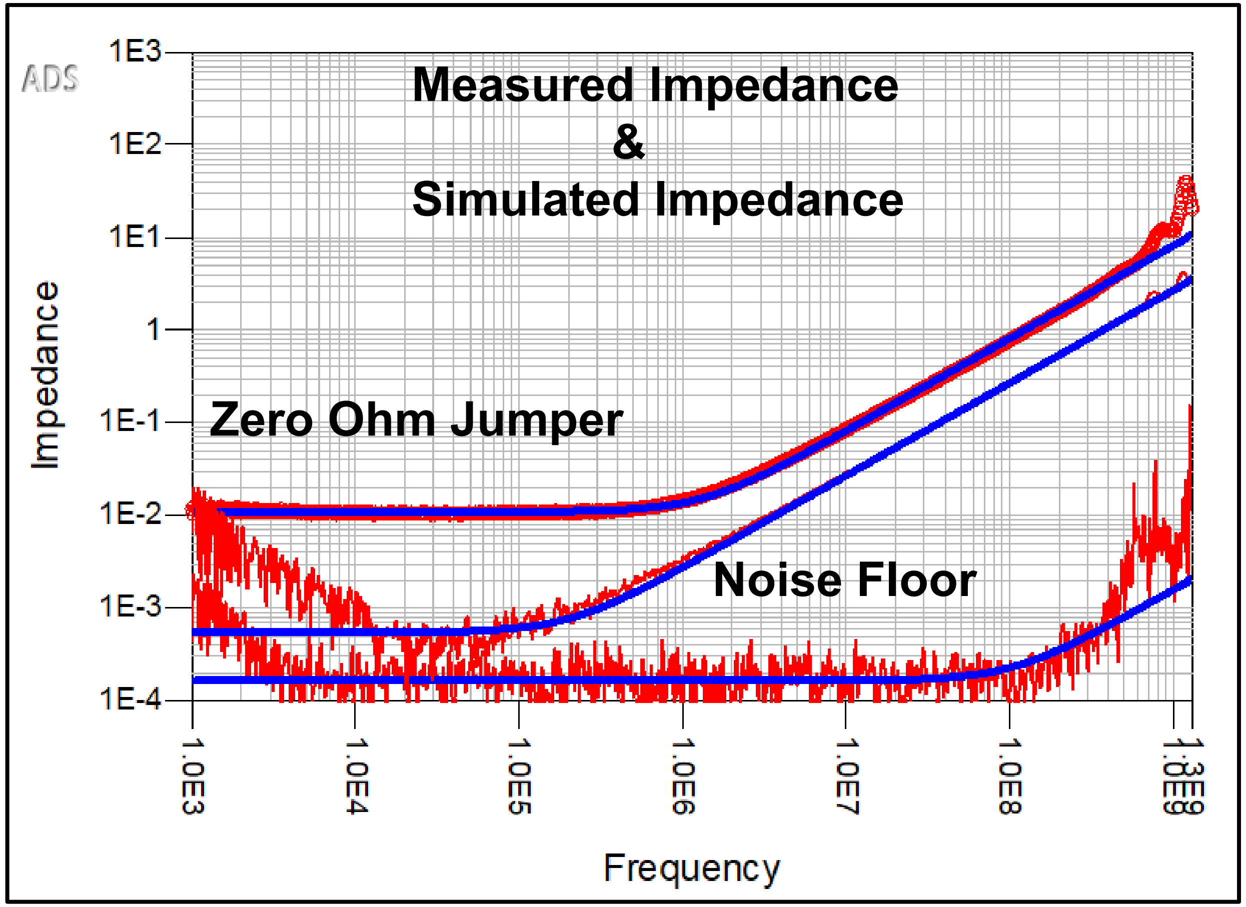




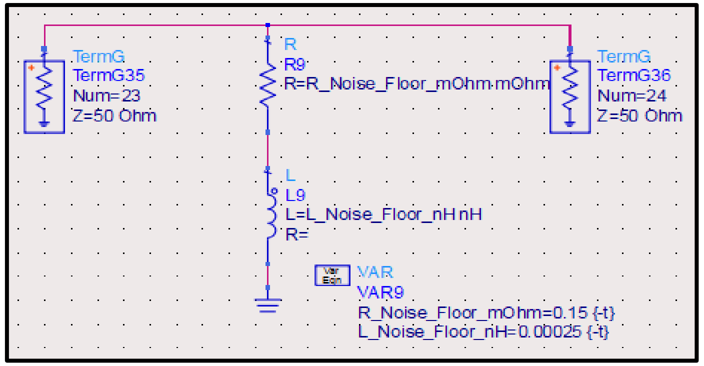
Rated Resistors (in Ohm)	Modeled R (in Ohm)	Modeled ESL (in nH)
10	10.00	1.47
1	1.00	1.47
0.5	0.50	1.47
Zero Ohm Jumper	0.011	1.45

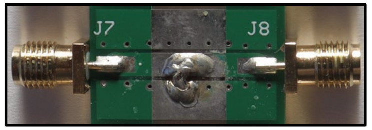
Similar ESL values due to identical footprint.
Zero Ohm Jumper has the lowest resistance.

Lowest Impedance Measured by SDR VNA



Lowest Impedance measured by the SDR VNA is the Noise Floor.





Solder Blob
(Made wide & thick to have Low R & L)

Resistor Structures	Modeled R (in mOhm)	Modeled ESL (in nH)
Zero Ohm Jumper	11	1.45
Solder Blob	0.55	0.45
Noise Floor	0.15	0.00025

Noise Floor Resistance: 0.15 mohm
Noise Floor Inductance: 0.25 pH

Takeaways

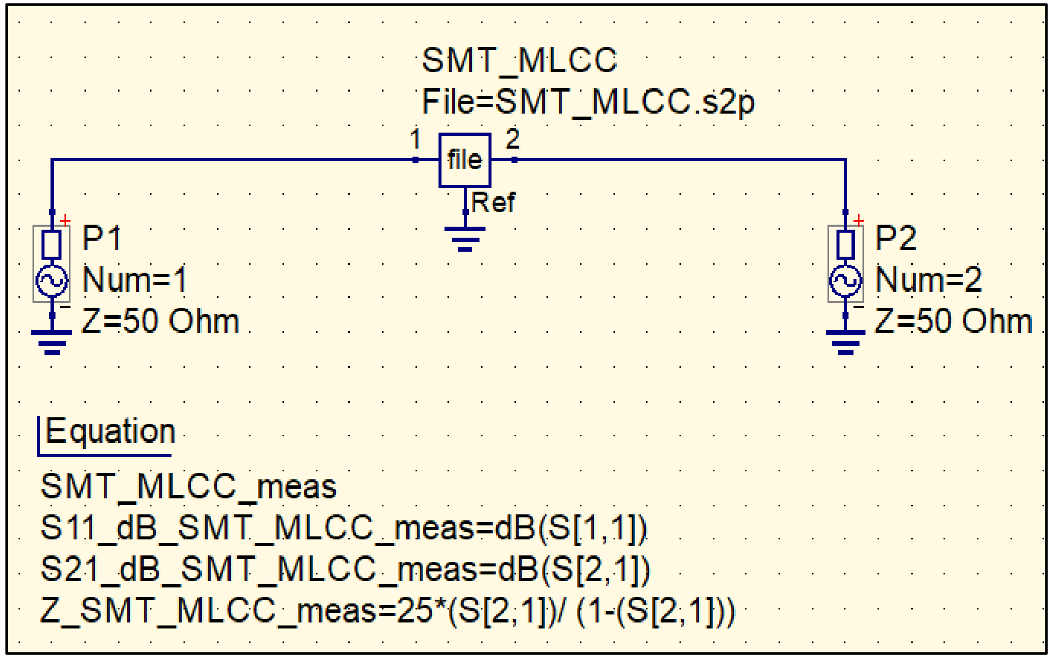
- The 2-port method can eliminate the artifacts associated with contact impedance of the probes or fixturing to the DUT.
- 2- Port Method is a low-cost and reliable method for Low Z Measurement.
- First order RL models can be used to hack the impedances measured with the 2-port method to correlate measured & simulated data.
- SDR VNA can measure resistances & inductances in the mOhm and pH range respectively.
- ESL of components depends on their footprint.

Questions?

RLC Equivalent Z for an SMT MLCC

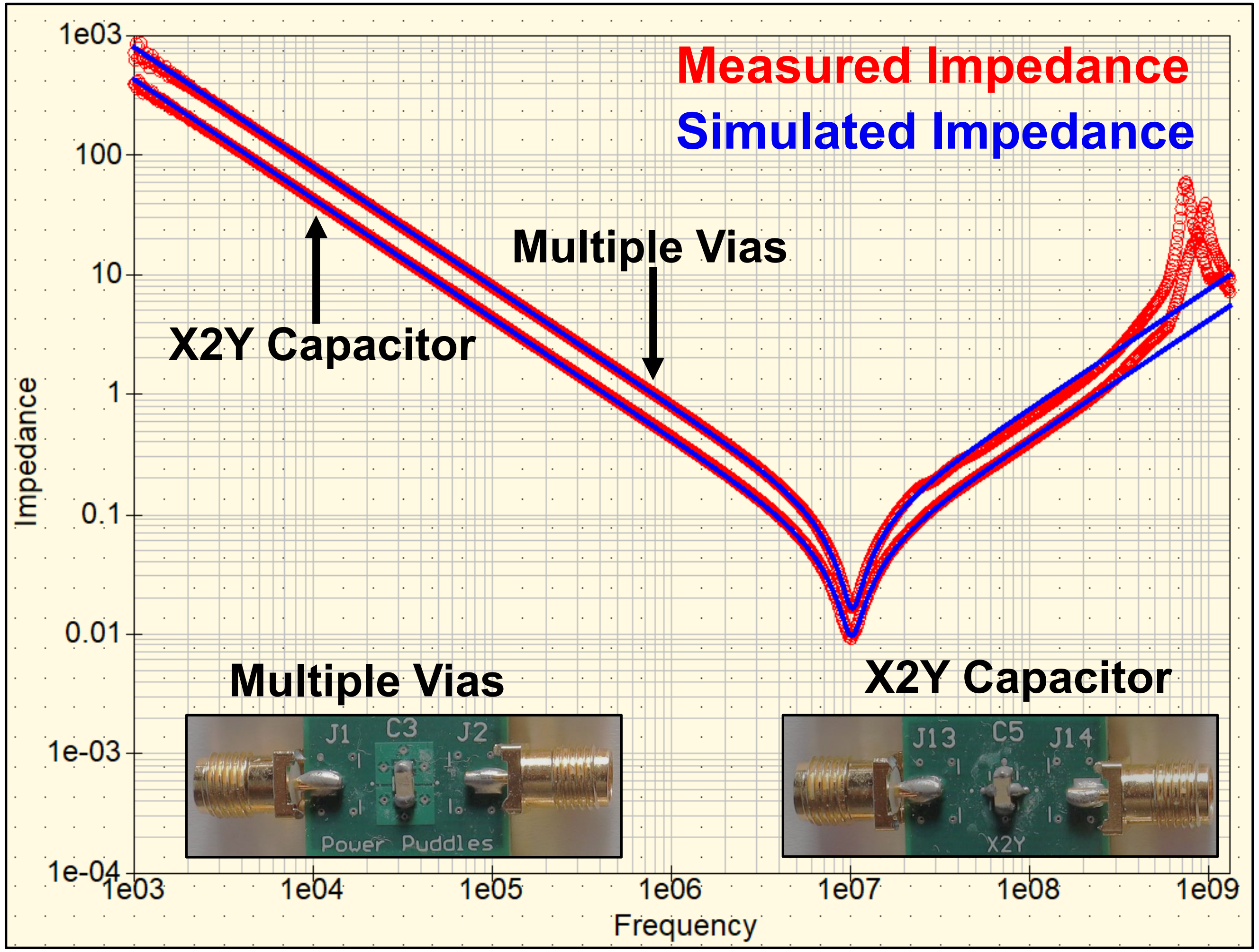
15 uF SMT MLCC

Breakout Board



Plotting Measured Impedance in Qucs

Reduced Inductance of MLCC – X2Y



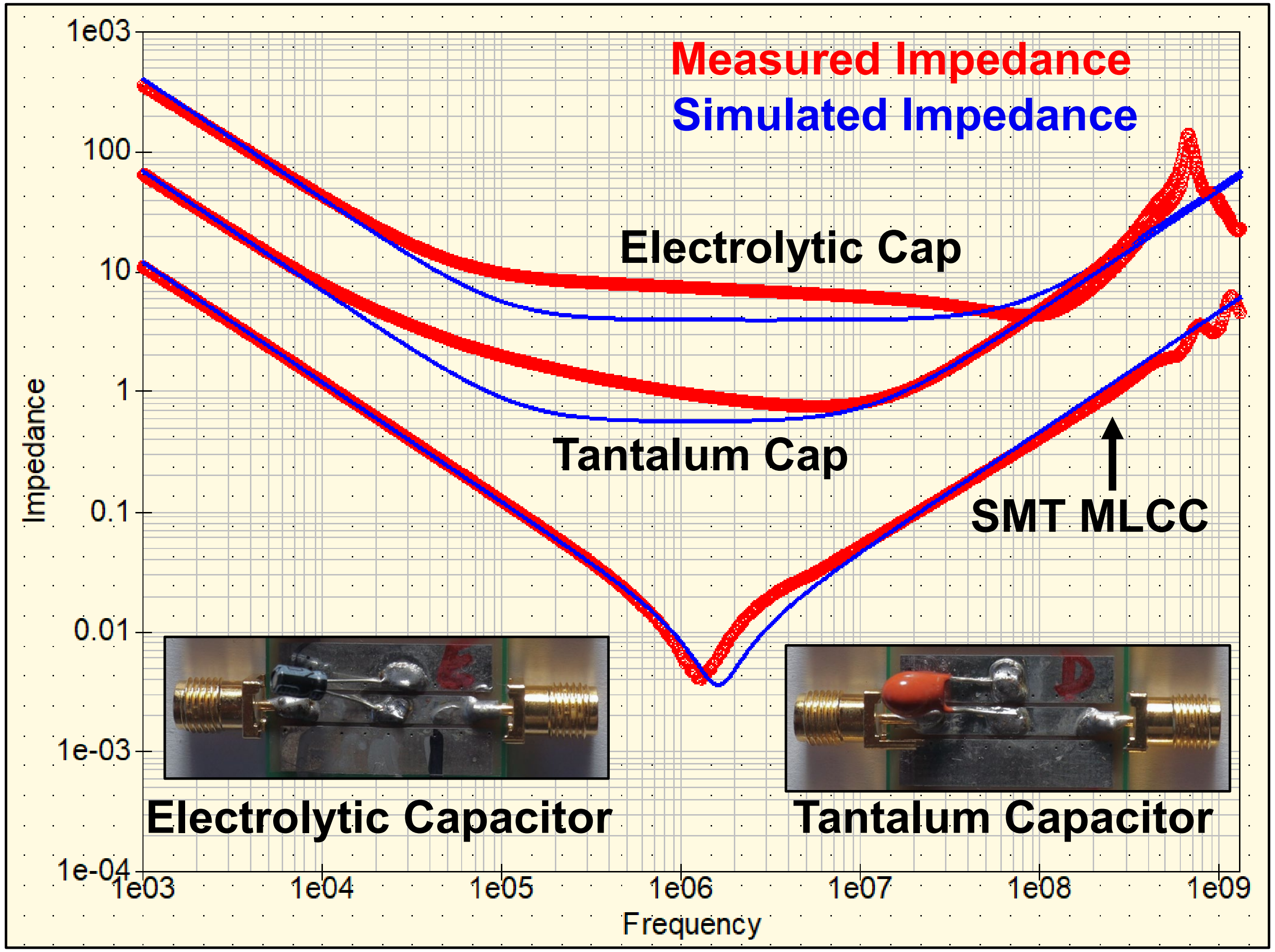
Board Structure	ESR (in mOhm)	ESL (in nH)	C (in uF)
Multiple Vias	16.3	1.225	0.20
X2Y	9.63	0.675	0.368

X2Y capacitors have a much lower inductance than Multiple Vias structure.

There is a reduction of a factor of 2 in ESL.

This translates into a reduction in the impedance at high frequency by a factor of 2 and could enable a parts count reduction by a factor of 2 as well.

RLC Equivalent Z for Electrolytic & Tantalum Capacitors



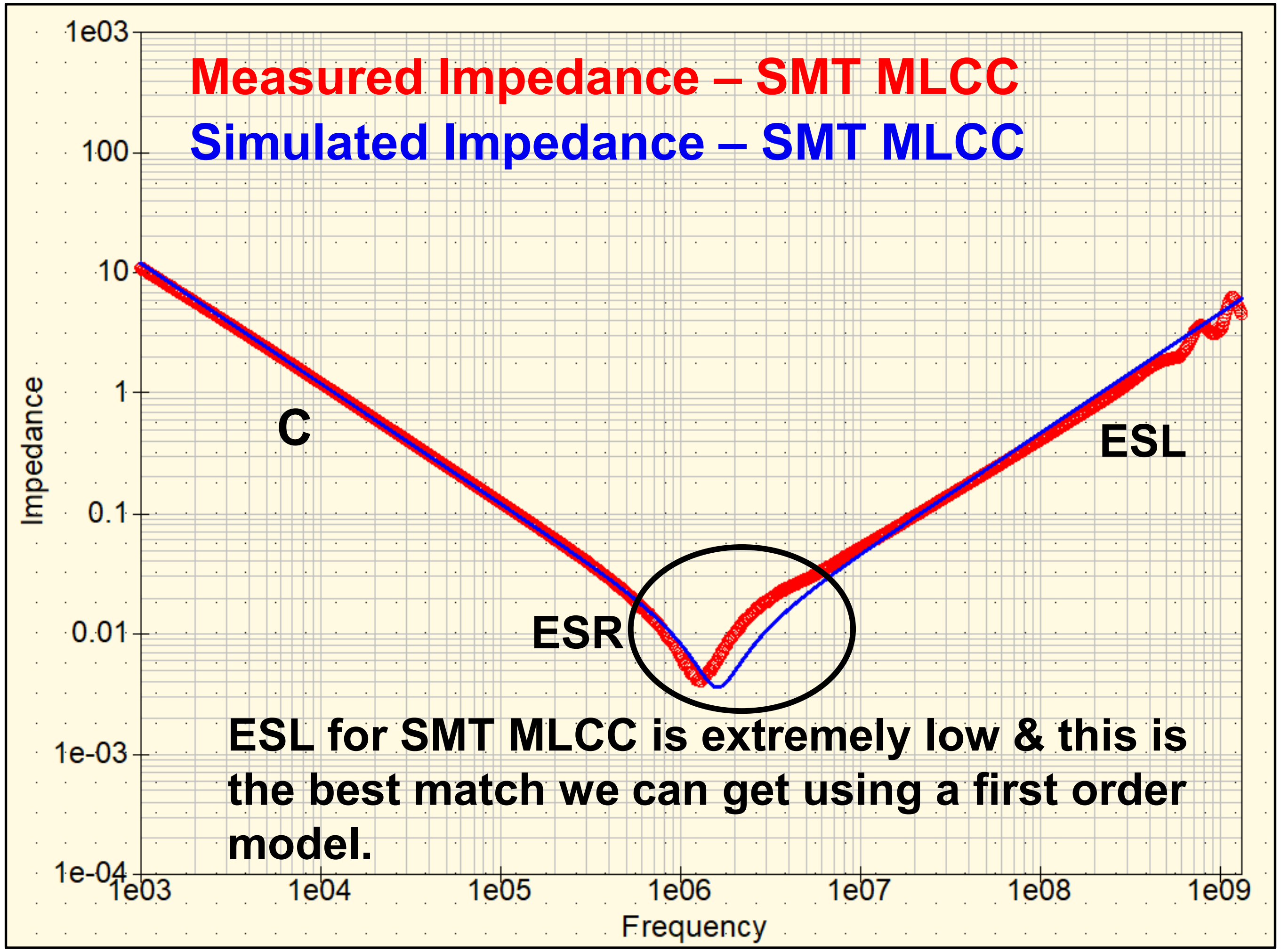
Rated Capacitance (in uF)	ESR (in Ohm)	ESL (in nH)	C (in uF)
15 (SMT MLCC)	0.00366	0.75	13.2
0.47 (Electrolytic)	4	8.4	0.39
2.2 (Tantalum)	0.57	7.70	2.28

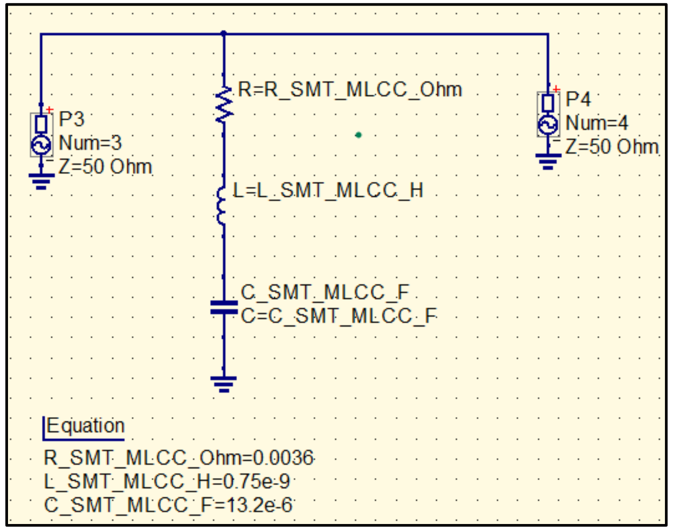
This is the best match we can get with a first order simulated RLC model.

ESR for the SMT MLCC is much lower than the Electrolytic & Tantalum Capacitors.

Electrolytic & Tantalum Capacitors have a much higher ESL due to the leads.

RLC Equivalent Z for an SMT MLCC

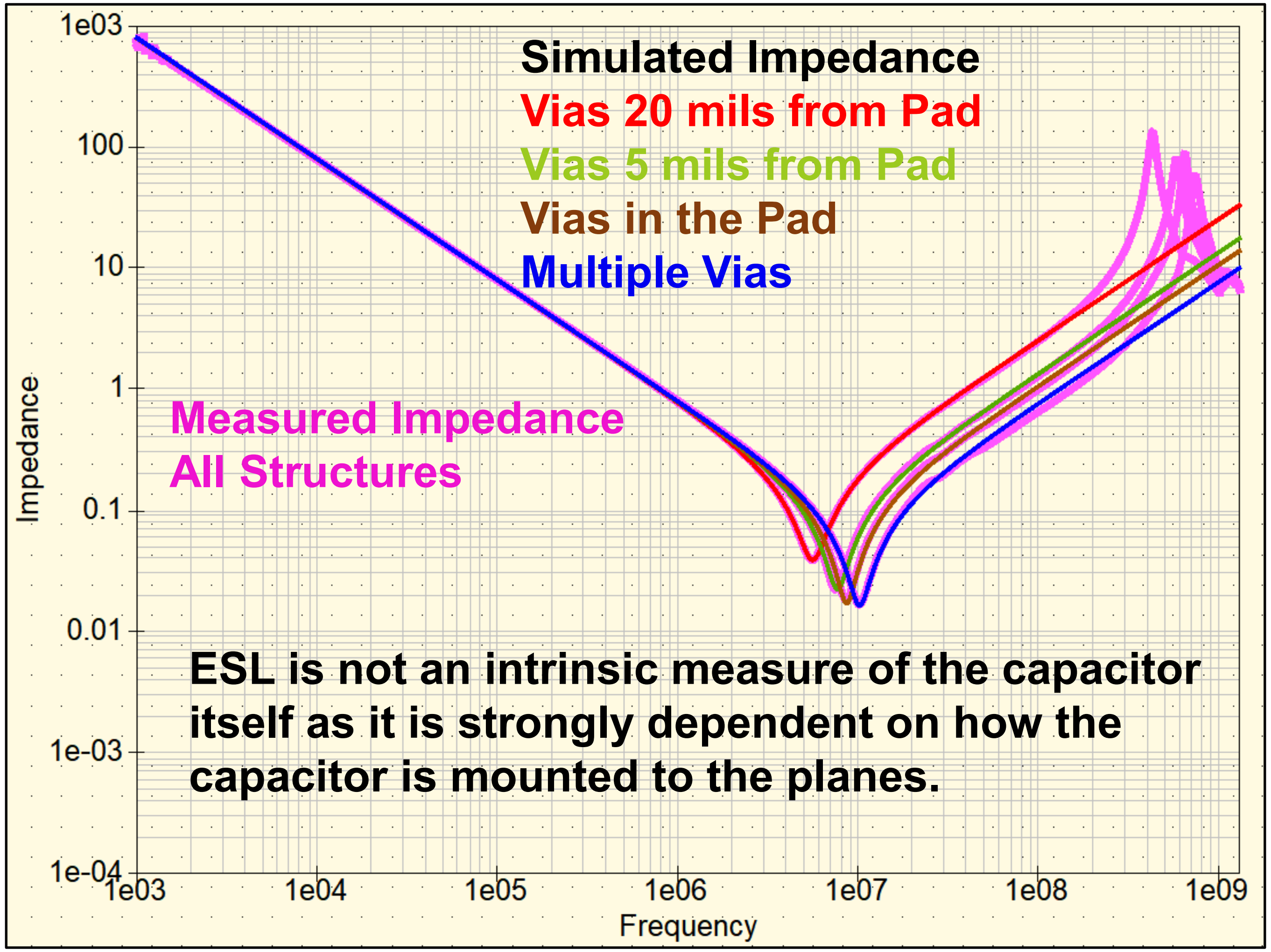




Rated Capacitance (in uF)	ESR (in mOhm)	ESL (in nH)	C (in uF)
15	3.6	0.75	13.2

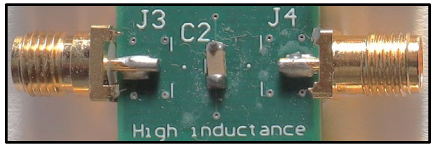
This simple RLC model is good enough to match the impedance behavior of the real SMT MLCC component.

ESL of 0.22 uF MLCC with different Via positions

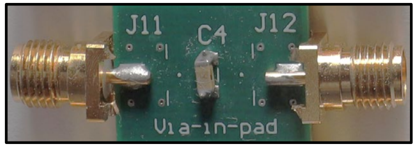


Via Position	ESR (in mOhm)	ESL (in nH)	C (in uF)
20 mils from Pad	38.8	4.05	0.20
5 mils from Pad	22.3	2.15	0.20
In the Pad	17	1.7	0.20
Multiple Vias	16.3	1.225	0.20

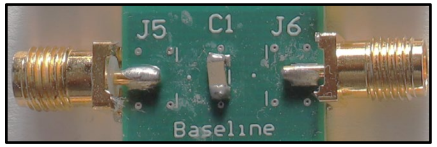
Vias 20 mils from Pad



Vias in the Pad



Vias 5 mils from Pad



Multiple Vias