APPLICATION NOTE

PARALLEL CAPACITANCE

in

High Power RF Resistors

October 17, 2007

High Power Resistors in RF/Microwave Applications

Most of the high power resistors used in RF and Microwave frequencies are found in Wilkinson power dividers/combiners in power distribution circuits. For best performance, the 100 Ohm isolation resistor, when used in a Wilkinson divider, should have very low capacitance to minimize the effects on insertion loss. Additionally, the isolation resistor must be able to absorb half of the input power on each input port when used in a Wilkinson combiner.

Discrete resistors can also be used to design high power attenuators. For low frequency applications, this maybe practical; however, at high frequencies, the parasitics of each individual resistor will degrade the attenuator performance making this approach less desirable.

High power resistors come in different shapes and sizes. For example, the most popular are: SMT resistors, resistors with leads (with and without dielectric cover), and resistors with leads and dielectric cover mounted on a conductive flange as depicted on Figure 1.

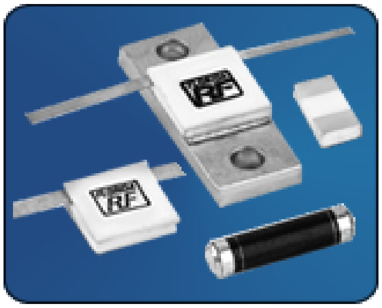

Figure 1. Illustration of various high power resistors

Specifications for High Power Resistors

Typical specifications for high power resistors include: resistance value, maximum power rating (in most cases based on 100˚C base temperature), power de-rating curve and mechanical dimensions. In addition, maximum or typical value for capacitance maybe provided.

While resistance and maximum power specs are self explanatory and very useful to a design engineer, capacitance specification is more ambiguous. In most cases there is no explanation given at what frequency the capacitance was measured and/or the test methodology used.

The shunt capacitance in question results from the RF fringing fields between the resistive film area and the ground plane. There are other sources of capacitance e.g. (input and output pads), but the effects are less significant for all practical purposes, especially at lower frequencies.

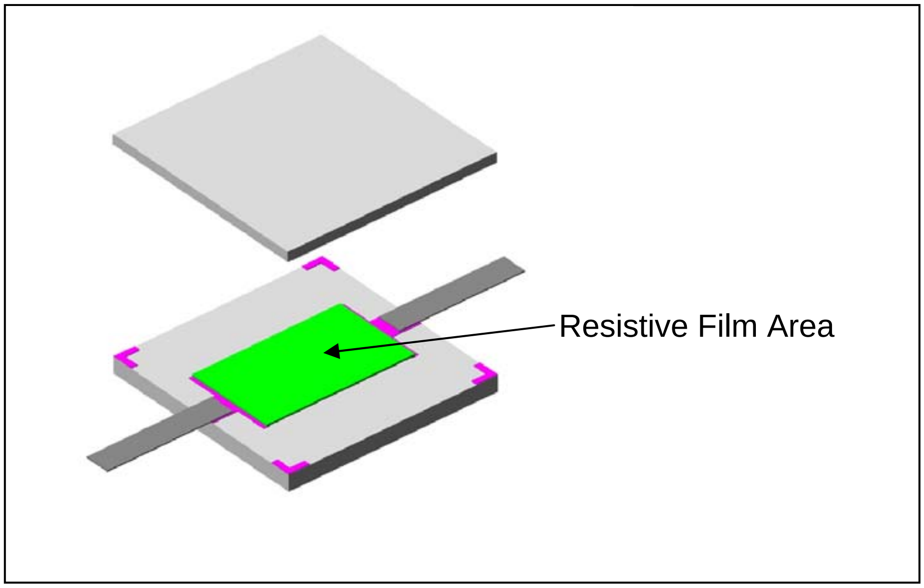

Figure 2. Exploded view of a high power resistor.

Regrettably, there is no standard for measuring capacitance for high power resistors above 1 MHz. According to MIL-STD 202G (method 305), the recommended frequencies for the capacitance measurement are: 60 Hz, 120 Hz, 1 KHz, 100 KHz, and 1 MHz.

One can argue that the capacitance measured at 1 MHz would certainly satisfy the MIL standard 202 requirement; however, capacitance information is not very useful for a design engineer trying to use this resistor at 2.7 GHz. This is certainly the case for designs used in base stations that operate in the gigahertz range.

This application note attempts to clarify the capacitance measurement for high power resistors manufactured by Florida RF Labs and EMC Technology.

Test Methodology and Capacitance Extraction

High power resistors, when used at RF and microwave frequencies exhibit lossy transmission line characteristics. Figure 3 shows the lumped element and high frequency equivalent circuit model for a resistor. The shunt capacitance in Figure 3 can be extracted from measured S-parameters data. The type of fixture, calibration techniques, dielectric constant of the material can all influence the measured results.

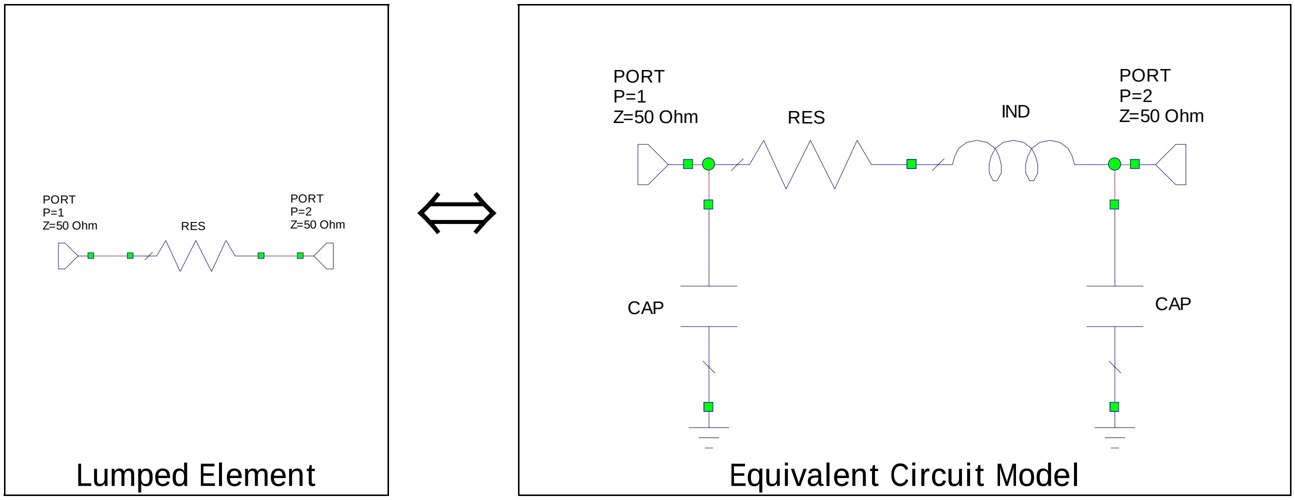

Figure 3. Lump element and equivalent circuit model of a resistor

In order to illustrate the capacitance extraction process, a 500W 50 Ohm resistor (tab and cover style) was mounted as shown on Figure 4. The reference planes in Figure 3 were established by calibrating-out the effects of the fixture.

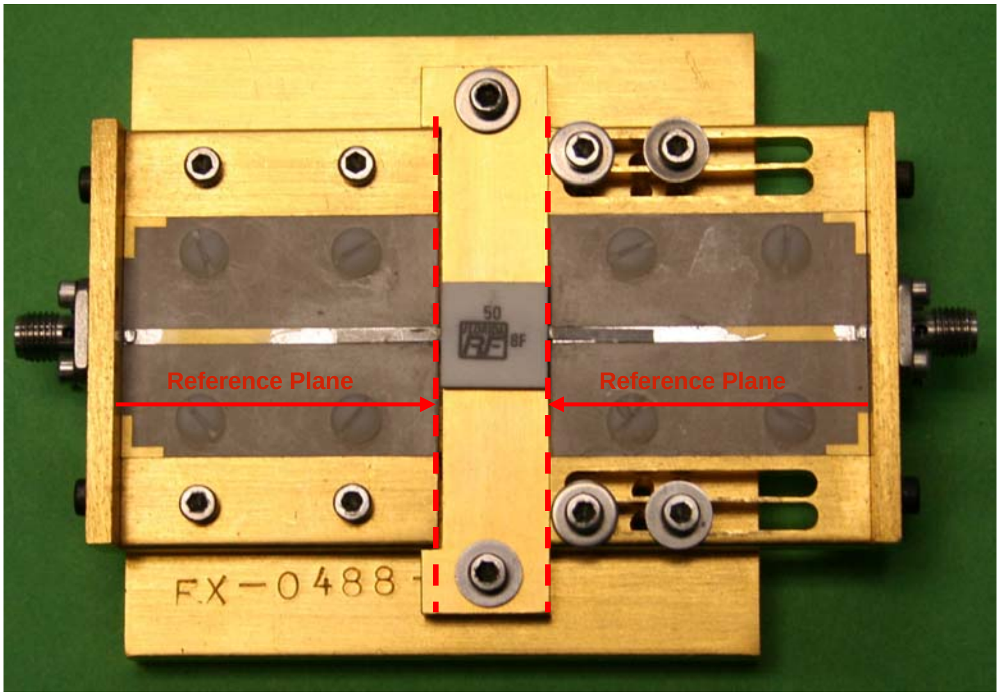

Figure 4. Florida RF Labs 500W 50 Ohm Resistor Mounted in RF Test Fixture

Measured Vs. Modeled Data

In order to verify the parameter extraction process an EM resistor model, was created in Microwave Office. The S-parameters from the EM analysis and the measured S-parameters are plotted on an admittance Smith chart as shown in Figure 5. As seen from Figure 5, there is a good correlation between measured and modeled data up to 2.7GHz

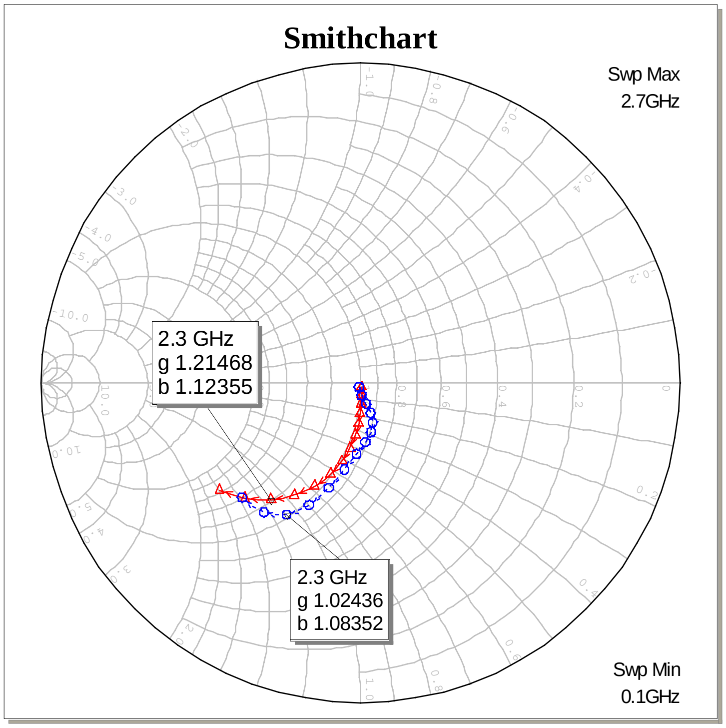

Figure 5 Normalized admittance data on a Smith chart. Blue trace measured, red trace modeled data

Capacitance Calculations

To obtain the parallel capacitance for the resistor, we can use values for b directly from the chart at any frequency of interest as demonstrated in the example below.

Example

From the blue trace (measured data), at 2.3 GHz, b = 1.083. Substituting b in the formula below gives capacitance of 1.5pF.

$$C = \frac{b}{\omega \cdot Z_o} = \frac{1.083}{2\pi \cdot 2.3x10^9 \cdot 50} = 1.5\ pF$$

If we repeat the calculation for b from the red trace (modeled data), the capacitance at 2.3GHz is 1.55pF. Again, this shows good correlation between measured and modeled data.

In addition to the single frequency calculations, swept data for shunt capacitance over frequency can be used as presented in Figure 6. There is a good correlation between the S-parameters from the EM model and the measured S-parameters.

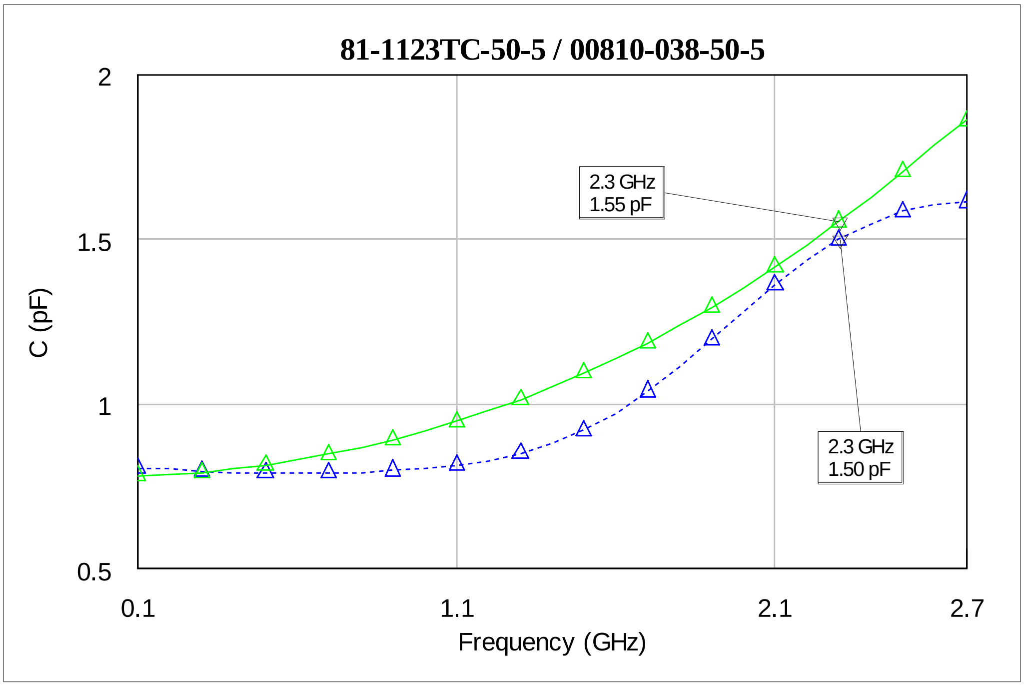

Figure 6. Parallel Capacitance and susceptance Plot of a 50 Ohm Resistor. Green trace modeled data, blue trace measured data

Summary

High power resistors are widely used in a power distribution circuits. The parallel plate capacitance (shunt to ground) due to the RF fringing fields from the resistive area (film) to ground becomes an important design parameter. Typical specification for the capacitance is given at 1MHz; however, a higher frequency values are more meaningful for designing in the gigahertz frequency bands.

Test methodology and procedure for extracting this capacitance were provided in this application note. Good correlation between the EM model and the measured data shows that the shunt capacitance can easily be extracted from measured S-parameters.