Introduction to Load Pull

The network in the circle between the transistor and 50 ohm load sets the power output, power supply voltage, waveform shape at the collector, efficiency, linearity, harmonic suppression, 1 dB compression point...and pretty much everything else you care about in a power amplifier.
How? By setting the waveform at the Collector...which we can see at low frequencies, but not at microwaves.

Fundamental plus -0.3 20 degree shifted 2nd harmonic -- red
Fundamental plus -0.6 20 degree shifted 2nd harmonic -- blue

an efficient waveform:

\[
\cos(2\pi f_0t) - 0.3\cos(4\pi f_0t + \pi/9) -- \text{red}
\]

\[
\cos(2\pi f_0t) - 0.6\cos(4\pi f_0t + \pi/9) -- \text{black}
\]
The network between the active device and outside world is equally important for Low-Noise Amplifiers:

The network in the circle between the transistor and 50 ohm load sets the noise figure, gain, input intercept, bandwidth, input reflection coefficient, and pretty much everything else you care about in an LNA.
How to Design a PA:

- Pick a supply voltage and output power
- Choose a TriQuint power transistor
- Design a network that presents the load to the transistor...

"that the device wants"

...and how do we know that?
Load Pull is a lot like taking a spoiled child (the transistor) to the mall to shop for clothes:

- present all the possible choices
- make some selections
- hope those are still good decisions tomorrow

And always, in the back of your mind, is the fear that somebody else’s transistor will work better in the network you carefully selected.
How to Do Load Pull Measurements, part 1:

present all the possible choices

Below 500 MHz, this was traditionally done by the technician or radio operator using adjustments inside or on the front panel of the transmitter.

In the 1960s, PA efficiency above 90% was common, and PA efficiency above 70% was common in linear amplifiers.
How to Do Load Pull Measurements, part 2:

When transistors became popular for RF Power Amplifiers in the 1970s, the device engineer designed a variable network, optimized an amplifier on the bench, and then presented a reference design with careful measurements in the device data sheet. Often the design was accompanied by some simple theory that didn’t explain why some networks worked better than others.

Quote from former TriQuint Officer: “....”
Here is one important reason simple explanations fail:

third harmonic at collector 10 dB below fundamental
Waveform at Collector:

Fundamental -- Black
Fundamental plus -0.3 30 degree shifted 3rd harmonic -- red
Fundamental plus -0.3 60 degree shifted 3rd harmonic -- blue
The Language of Load Pull includes:

The Smith Chart

Formerly used to do calculations, now used to present impedance data.

...as important to RF engineers as the Periodic Table is to Chemists, and for the same reasons