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THEORY OF LOAD AND SOURCE PULL MEASUREMENT

Introduction

Load pull consists of varying or "pulling" the load impedance seen by a device-under-test (DUT) while measuring the performance of the DUT. Source pull is the same as load pull except that the source impedance is changed instead of the load impedance.

Load and source pull is used to measure a DUT in actual operating conditions. This method is important for large-signal, nonlinear devices where the operating point may change with power level or tuning. Load or source pull is not usually needed for linear devices, where performance with any load can be predicted from small signal S-parameters. **Figure 1** shows a typical setup for performing power measurements.

Calibrating to measure output power and gain consists of measuring the available input power at the power source reference plane and the coupling value of the directional coupler. If the coupler had perfect directivity, then coupling could be measured with only a short at the source power reference plane. However, finite directivity causes the apparent reflection to vary with reflection-phase, so a more accurate coupling value is found by taking the average of both short and open measurements. This minimizes directivity errors, although good coupler directivity is still important for the best accuracy.

Once the available input power and coupling are known, the output power, transducer gain, and power gain can all be measured with any combination of source or load impedance. Output power is the power delivered to the load. Transducer gain is the ratio of delivered output power to available input power. Power gain is the ratio of delivered output power to delivered input power.

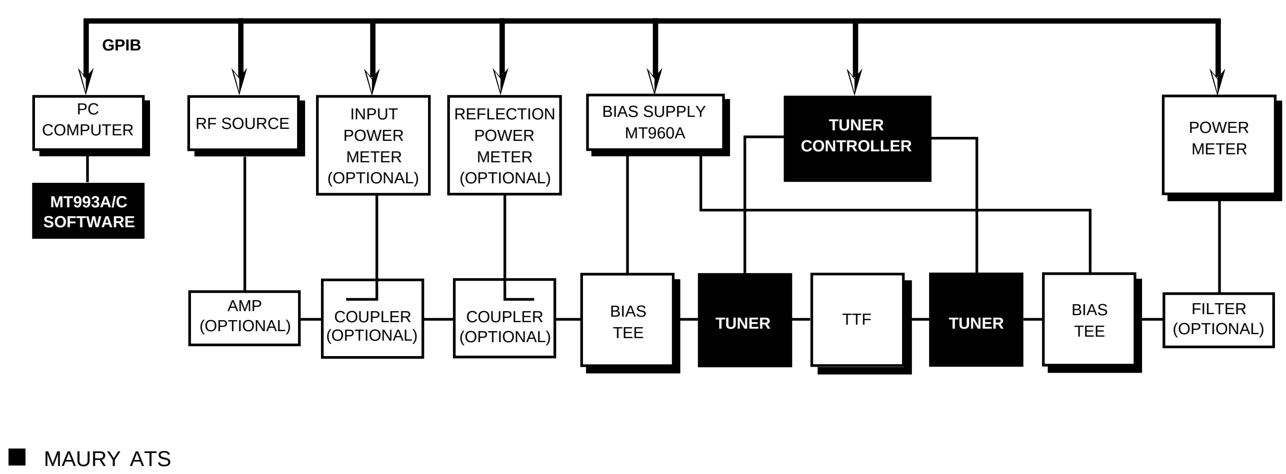

Figure 1: Typical Setup for Performing Power Measurements

2900 Inland Empire Blvd. • Ontario, California 91764-4804
Tel: 909-987-4715 • Fax: 909-987-1112 • http://www.maurymw.com

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The objective of the measurement is to get the power and gain values at the DUT reference planes. Although the tuners are very low loss, bias tees and other components may be included as part of the "tuner" characterization, so the loss must be considered. To get the output power at the DUT reference plane, the dissipative loss of the load tuner is added to the raw measured output power. To get the available input power at the DUT reference plane, the dissipative loss of the source tuner is subtracted from the calibrated available input power. To get the delivered input power at the DUT input reference plane, the reflected power at the source is subtracted from the calibrated available power at the source. The dissipative loss of the source tuner is then subtracted from the result to shift from the source power reference plane to the DUT input reference plane.

NOTE: Power gain errors are likely if there are large mismatches at the DUT input. Here, the measured delivered power is a small difference between two large numbers. Errors from noise, drift, and finite coupler directivity vary wildly. If the apparent reflected power is greater than the calibrated available power, delivered power cannot be calculated at all.

The major errors in power gain are avoided by using the source tuner to match the DUT input, if the DUT does not oscillate. Therefore, if power gain is to be measured, be sure to do a source pull after the load pull, and then look at power gain.

If a DUT begins to oscillate, power gain becomes almost meaningless. Also, an oscillating DUT may generate some power in the reverse direction causing the apparent reflected power to be greater than the calibrated input power, even when the DUT input is matched. This is indicated by asterisks in the delivered power or power gain columns of the printouts.

In the full load pull measurement, the source tuner is set to a fixed position, and power and gain are measured at a variety of randomly located load impedance points. After all of the data are taken, the reflection plane is divided into a rectangular grid, and the apparent power at each grid point is calculated. This is done by interpolating on a surface determined by the surrounding points with the closest points being weighted the most. Higher resolution comes from using finer grid spacing, and accuracy depends upon the spread and resolution of the points in the area.

The advantage of the random contouring method is that no knowledge of what contours are desired is required before the measurement. This provides much more flexibility than an approach requiring contours to be searched, for example, and allows the tuners to be pre-characterized for best accuracy. Extrapolation outside the measured points is not reliable, so it is important to surround the area of interest on the reflection plane.

The contouring method makes no assumption about linearity or other behavior of the DUT. Contours of nonlinear DUTs are usually not circular, and may take unexpected shapes, especially when the DUT comes close to oscillation. Contour plotting often tells more about a device than any other method. Source pull contours are measured and calculated in the same way as the load pull contours are measured and calculated. The only difference is that the load tuner is set to a fixed position, and the source tuner is the one that is varied.

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