Impedance Testing For Mobile Phones

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ABSTRACT:

Load Pull is an invaluable tool for the mobile phone community, helping to design more robust and efficient products and guarantee their sucessful functionality in real-world environments. Mobile phones and their sub-components can be tested in various stages: the internal power amplifier (PA), the front-end module (FEM), or the phone in its entirety.

Maury MT993 ATS software is used to test PAs and FEMs for dozens of parameters including Power, Gain, Efficiency, Harmonic Power, Inter-modulation Distortion (IMD), Error-Vector Magnitude (EVM), Adjacent Channel Power Ratio (ACPR), etc.

Maury MT910 series software is a standalone application designed specifically for the testing of mobile phones in transmit and receive modes, for output power and sensitivity respectively, as a function of VSWR magnitude and phase.

An Introduction to Load Pull

The following is an excerpt from Maury Microwave Corporation Application Note 5C-041, Theory of Load and Source Pull Measurement:

> "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."

For a full introduction, please download Maury data sheet 5C-041 or a number of other application notes from:

http://www.maurymw.com/support/appnoteslibrary/appnoteslib.htm

Power Amplifier and Front End Module Load Pull

A basic load pull setup consists of:

- Tuners to vary the source and/or load impedance seen by the DUT
- Signal generator to provide input signal to DUT
- Power meter with sensors to record input and output power levels (to be de-embedded to the DUT reference plane)
- Spectrum analyzer to read power levels at individual frequencies (including harmonics), to measure multi-tone parameters (IMD, TOI . . .) or to measure modulated parameters (EVM, ACPR . . .)
- DC power supply to provide bias to DUT
- Components for amplification, attenuation, biasing, coupling . . .

The first scenario (**Figure 1**) demonstrates the standard source/load pull bench used to test transistors and power amplifiers of all sizes in over eighty percent of test benches worldwide (as of release date).

The second scenario (**Figure 2**) is similar to the first; however it includes only the output tuner needed to vary the load impedance. For FEM testing, this may be the setup of choice.

There are cases when a signal generator is not needed to perform measurements, as the test board containing the FEM might have the ability to generate a signal itself. In this case, the standard block diagram is modified as shown in **Figure 3**.

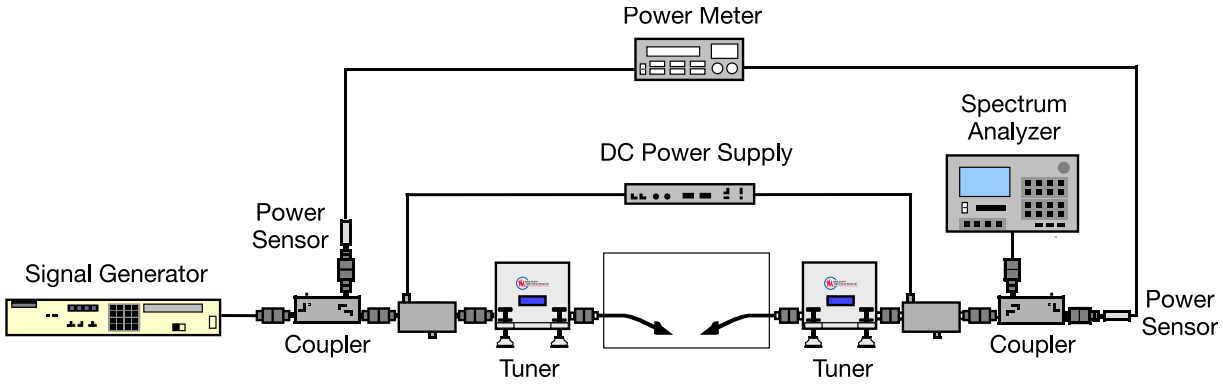

Figure 1. Typical load pull bench setup for testing transistors and PAs

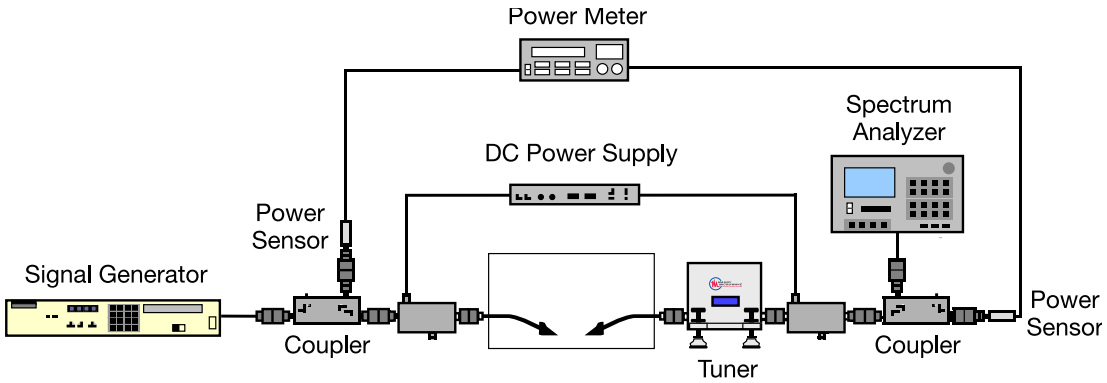

Figure 2. Typical load pull bench setup for FEM testing

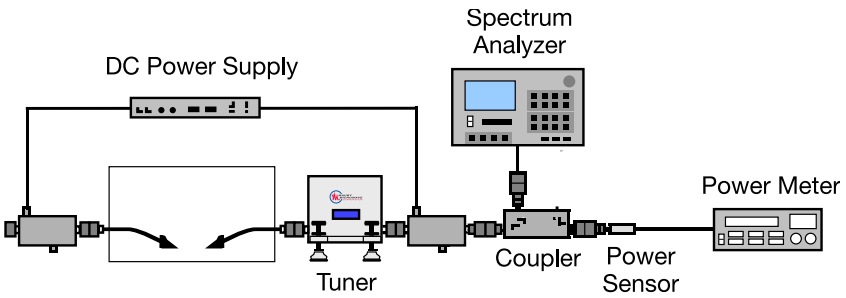

Figure 3. Typical load pull bench setup for FEM testing without a signal generator

However the setup may look, the basic principles remain the same. We use a tuner to vary the impedance seen by the DUT and measure a multitude of parameters as a function of impedances. We can then plot the results over the Smith Chart (see **Figures 4 and 5** as examples) and decide which impedances meet our specific needs.

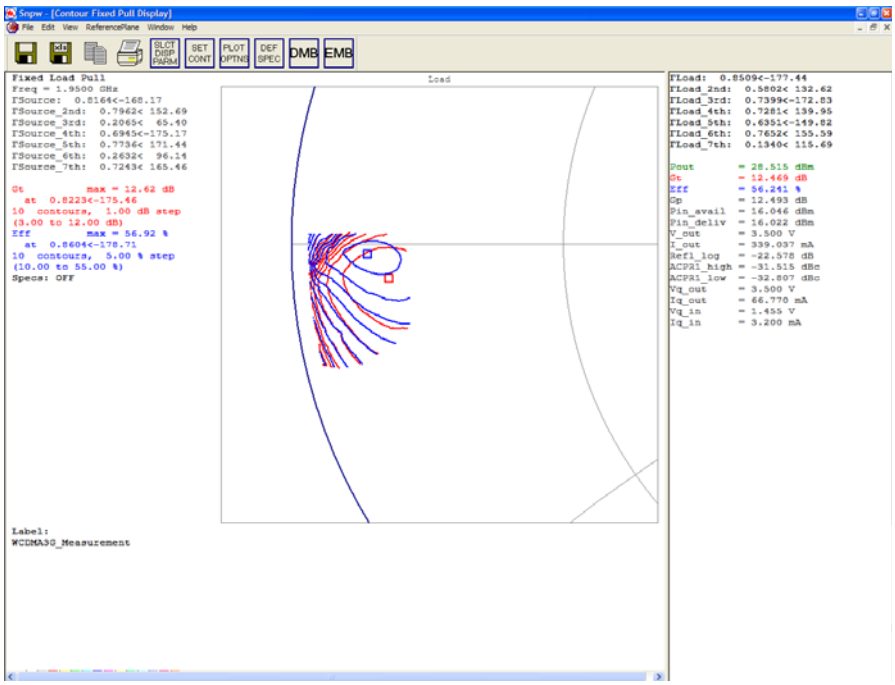

Figure 4. Gain and Efficiency as a function of load impedance

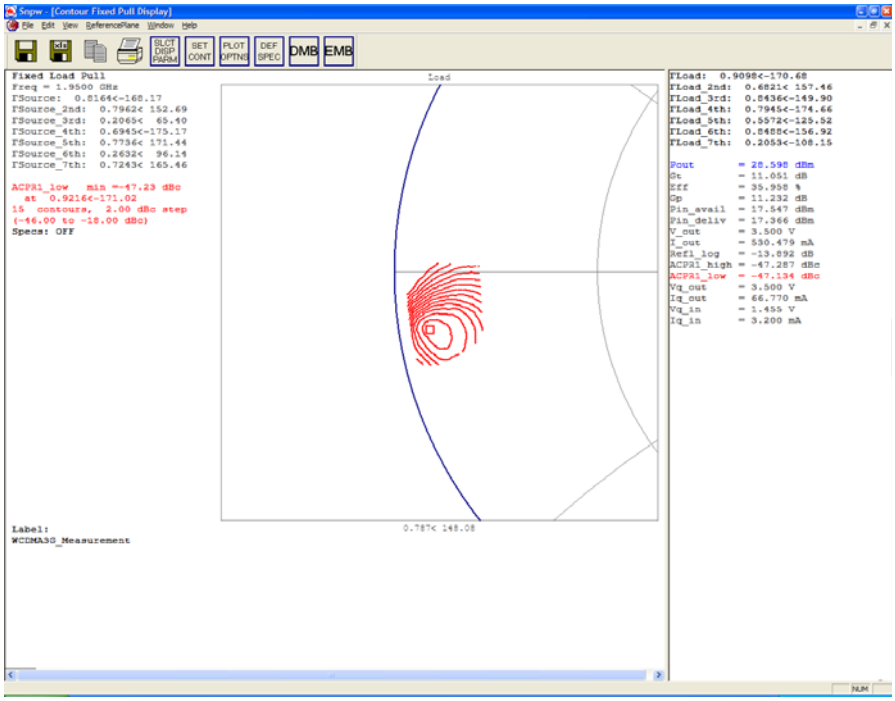

Figure 5. ACPR as a function of load impedance

Mobile Phone TX/RX Load Pull

Mobile phones must guarantee proper functioning in non-ideal real-world environments, such as a lost or damaged antenna, usage in a tunnel or locker, being held close to the body or in a pocket surrounded by coins, etc. Each of these scenarios can be regarded as non-ideal from an RF standpoint, meaning non-50 ohm. We are able to use a single tuner to vary the VSWR magnitude and phase seen by the antenna port of the phone and test its performance in transmit and receive mode.

In order to perform TX/RX tests on mobile phones, the following equipment is needed: a phone to act as device under test (DUT), a tuner to vary the VSWR seen by the phone, a DC power supply to vary the voltage applied to the phone, a Wireless Communication Test Set to act in signaling or non-signaling mode and test power and bit-error rate (BER), and appropriate Maury MT910 series software (see **Figure 6**).

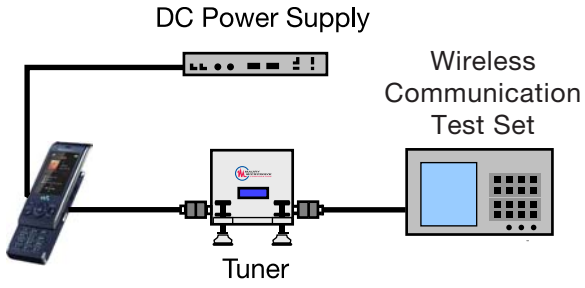

Figure 6. Equipment needed to perform TX/RX load pull tests on mobile phones

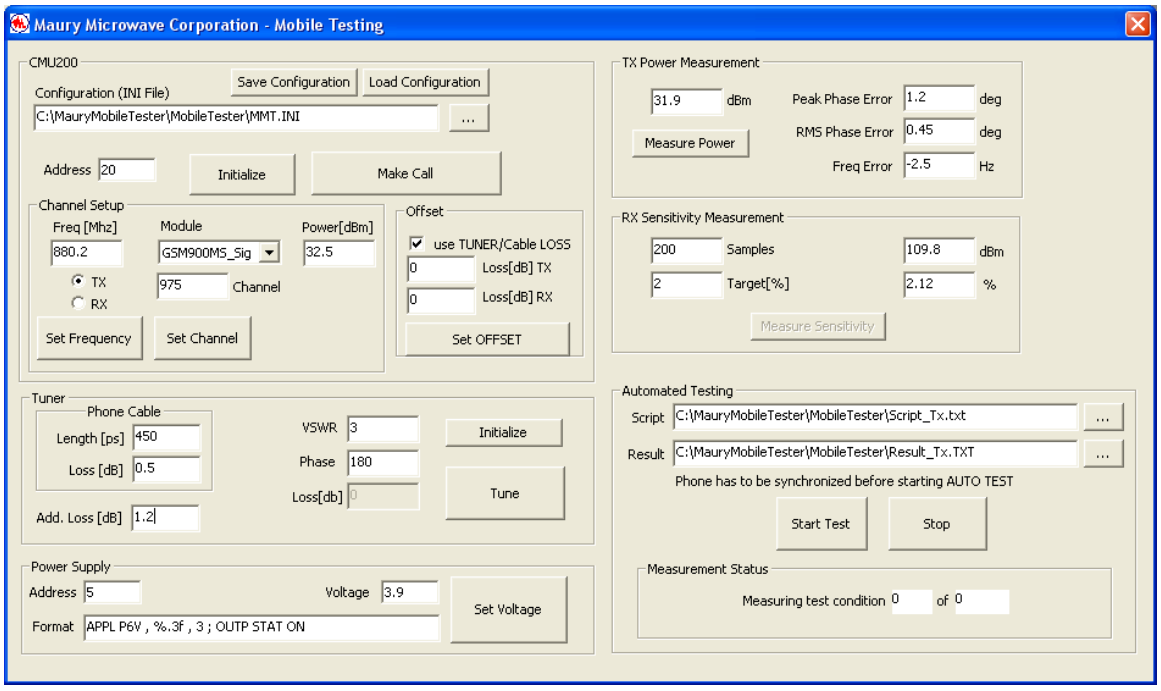

Figure 7. Maury MT910 series Automated Mobile Testing System Software

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Transmit Load Pull

The goal of load pull in the phone's transmit mode is to measure the output power as a function of VSWR magnitude and phase. The Wireless Communication Test Set is used in signaling mode to establish a call with a mobile phone, specify a channel/frequency (e.g., ARFCN 128 is 824 MHz uplink and 869 MHz downlink for GSM850), set the power control level (e.g., PCL 5 is 33dBm at GSM850) and measure the power delivered from the phone. Maury MT910 series software will vary the VSWR and battery voltage as determined by the user and record the output power de-embedded to the antenna port or the FEM inside the phone. The software procedure is automated thanks to the use of a simple test sequencer which allows the user to enter a list of channels/frequencies, battery voltages, VSWR magnitudes and phases.

Mode	Source VSWR	Source Phase	Load VSWR	Load Phase	Ptarget	Vbat	Freq	Ipeak	Pout	Peak PErr	Rms PErr	Freq Err
GMSK	1.000	0.000	1.000	0.000	32.500	3.400	880.200	0.000	32.121	1.428	0.470	-9.880
GMSK	1.000	0.000	1.000	0.000	32.500	3.900	880.200	0.000	32.780	1.305	0.450	-14.530
GMSK	1.000	0.000	1.000	0.000	32.500	4.300	880.200	0.000	32.675	1.278	0.442	-18.400
GMSK	1.000	0.000	2.000	-180.000	32.500	3.400	880.200	0.000	32.523	1.367	0.466	2.780
GMSK	1.000	0.000	2.000	-180.000	32.500	3.900	880.200	0.000	33.444	1.283	0.451	-3.550
GMSK	1.000	0.000	2.000	-180.000	32.500	4.300	880.200	0.000	33.499	1.293	0.451	-10.330
GMSK	1.000	0.000	2.000	-90.000	32.500	3.400	880.200	0.000	31.183	1.455	0.470	-27.120
GMSK	1.000	0.000	2.000	-90.000	32.500	3.900	880.200	0.000	32.130	1.309	0.455	-14.660
GMSK	1.000	0.000	2.000	-90.000	32.500	4.300	880.200	0.000	32.164	1.326	0.456	-3.750
GMSK	1.000	0.000	2.000	0.000	32.500	3.400	880.200	0.000	30.054	1.514	0.477	-8.140
GMSK	1.000	0.000	2.000	0.000	32.500	3.900	880.200	0.000	30.636	1.330	0.454	-10.910
GMSK	1.000	0.000	2.000	0.000	32.500	4.300	880.200	0.000	30.550	1.333	0.457	-11.040

Table 1. Shortened TX Results at PCL=5

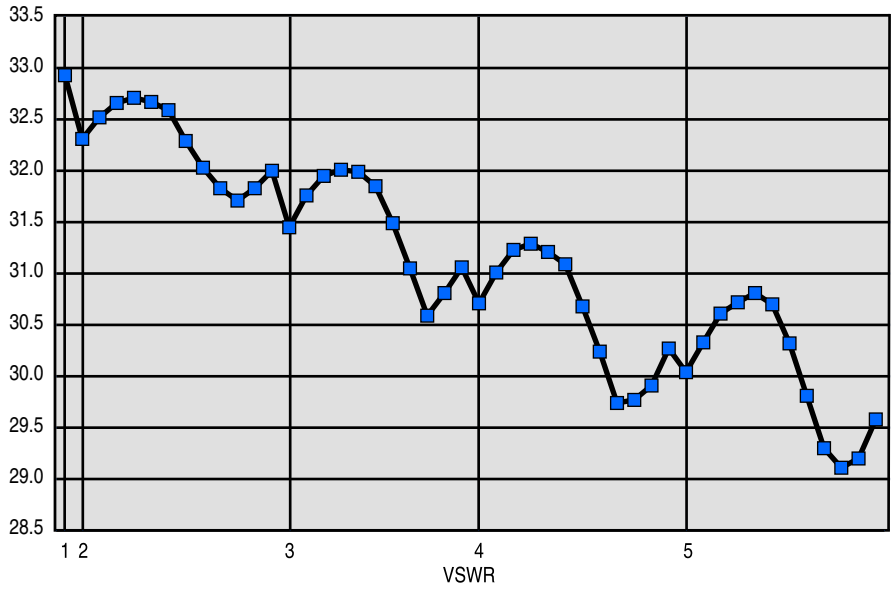

Figure 8. Graphical representation of TX results

Receive Load Pull

The goal of load pull in RX mode is the sensitivity-measurement of the phone; at what power level will a user-specified bit-error rate (BER) be achieved, as a function of VSWR magnitude and phase. The Wireless Communication Test Set is used in signaling mode to establish a call with a mobile phone, specify a channel/frequency, and send a low-power burst (in the order of -105 to -110 dBm) to the phone and measure the resulting BER. Maury MT910 series software will vary the VSWR and battery voltage as determined by the user, measure the resulting BER, and vary the burst-power until the required BER is achieved.

Mode	Source VSWR	Source Phase	Load VSWR	Load Phase	Ptarget	Vbat	Freq	Ipeak	Sensitivity	BER
GMSK	1	0	1	0	-109	4.03	925.2	0	-111.9	2.051
GMSK	1	0	2	-180	-109	4.03	925.2	0	-111.9	2.051
GMSK	1	0	2	-90	-109	4.03	925.2	0	-112.1	2.051
GMSK	1	0	2	0	-109	4.03	925.2	0	-111.6	2.154
GMSK	1	0	2	90	-109	4.03	925.2	0	-111.5	2.256
GMSK	1	0	3	-180	-109	4.03	925.2	0	-111	2.051
GMSK	1	0	3	-90	-109	4.03	925.2	0	-111.4	2.256
GMSK	1	0	3	0	-109	4.03	925.2	0	-110.9	2
GMSK	1	0	3	90	-109	4.03	925.2	0	-110.2	2.103
GMSK	1	0	4	-180	-109	4.03	925.2	0	-110.2	2.103
GMSK	1	0	4	-90	-109	4.03	925.2	0	-111.3	2.205
GMSK	1	0	4	0	-109	4.03	925.2	0	-110	2.103
GMSK	1	0	4	90	-109	4.03	925.2	0	-110	2.308
GMSK	1	0	5	-180	-109	4.03	925.2	0	-109.9	2.308
GMSK	1	0	5	-90	-109	4.03	925.2	0	-110.5	2.103
GMSK	1	0	5	0	-109	4.03	925.2	0	-110	2.154
GMSK	1	0	5	90	-109	4.03	925.2	0	-108.5	2.051
GMSK	1	0	1	0	-109	4.03	925.2	0	-111.5	2.103

Table 2. Shortened RX Results at BER=2% ±0.4%

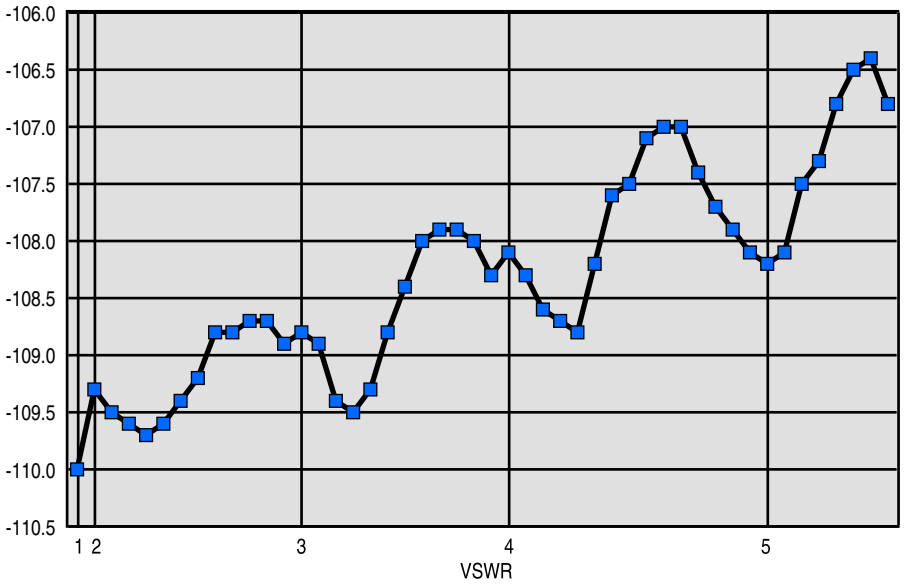

Figure 9. Graphical representation of RX results

Conclusion

Maury Microwave Corporation offers solutions tailored for all mobile phone testing needs, from the PA stage to the FEM to the phone itself, with full-featured MT993 Series ATS software capable of dozens of measurement parameters and the MT910 Series Automated Mobile Testing System Software which automates the testing of a mobile phone in TX and RX mode over a multitude of channels/frequencies, battery voltages and power levels.

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