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Application Note 40

RF probes for in-situ Optimizing Output Power Stages of Mobile Phones

A load pull technique for "in-situ" testing and optimizing output power stages of Cellular and PCS mobile phones is described. The new technique is based on coaxial RF-probes(1), developed by Focus Microwaves, which handle dc bias and several Watt RF-power and are used with Focus' Harmonic Load Pull Systems (CCMT-PHT). It allows to tune the load impedances at the fundamental and harmonic frequencies of the output power transistors, already mounted and biased in the final PC board circuitry.

Introduction

Load Pull testing is used for improving the performance of portable cellular phones. It allows to optimize the RF circuitry for high efficiency and low distortion (Intermod or ACPR). Harmonic load pull systems, introduced since about 2 years, allow also to search for the optimum harmonic load impedances.
All these techniques, however, are based on measurements made in coaxial or microstrip test fixtures and wafer probe stations, which represent an artificial test environment for the transistors. When the transistors are mounted in the final PC board, grounding and other adjacent parameters and components are different and have non-negligible influence on the "in-situ" performance of the device. Further iterations and time consuming "tweaking" is the consequence.

The technique proposed here allows to bypass these problems and perform the test "in-situ", i.e. at the output port of the power device, already mounted and biased in its final (imperfect) environment in the PC board of the portable phone.

The coaxial RF probes required for these measurements are available with different pitch sizes to fit to the terminals of the output power stages and come characterized and ready to be used and de-embedded in new and existing Focus Microwaves load pull setups.

(1) Patent pending

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Test Setup

The test setup consists of either a fundamental or a fundamental and a harmonic programmable output tuner, model CCMT-1808 and PHT-1808 respectively. Both tuner types can handle a fundamental and two harmonic frequencies up to 18 GHz, i.e. f_0 up to 6 GHz for second and third harmonic tuning or up to 9 GHz for second harmonic tuning. It also includes one coaxial high power RF probe directly mounted on the tuner and connected to the prepared terminals of the telephone PC board. The probe is characterized previously using coplanar calibration standards and its S-parameters are available in S2P format, ready to be cascaded to the tuner parameters. At the output of the fundamental tuner a bias tee and an attenuator lead to the power detector of a GPIB power meter. The bias tee can be omitted if the output stage is internally biased or the bias supply lines are included on the PC board before the connection to the RF probe. The typical setup is shown in figures 1 and 2.
Because of the very low loss of the probes (table 1) the tuning capability of the output tuner is barely reduced and can thus synthesize impedances of less than 2 W at the reference plane of the transistor (figures 3 and 4) . This should normally be sufficient for the complete testing and optimization procedure. Should an even lower impedance be required, RF probes with lower characteristic impedances can be manufactured and used.

Figure 1 A In-situ@ harmonic load pull testing of mobile phone output power stages.

The RF Probes

The RF probes are coaxial and have been developed with the actual Ain-situ@ load pull testing in mind. The probes can be used up to frequencies of 6 GHz for normal corrected AS@-parameter measurements and up to 3 GHz for medium to high power Load Pull testing.
They consist, essentially of a semirigid coaxial cable of either 0.150" or 0.080" diameter, an extended central conductor with plated tip and two spring-loaded test probes on either side to create a miniaturized three-wire transmission line to serve as a flexible interface between the coaxial cable and the coplanar terminals of the transistor chip on the PC board. If such a connection scheme is not available on the PC board, then provisions must be taken to create via holes close to the main output microstrip at the appropriate distance to ensure a good ground return. The probes are characterized using coplanar calibration standards in the factory and are supplied with a matching set of S-parameters and are equipped with male SMA connectors. They can also be characterized, permanently attached and supplied, if requested, with GPC-7 or N (male or female) adapters. The supplied data include the four S-parameters of each probe, from the reference plane of the connector (TBD) to the probe tips. If those S-parameters are included and de-embedded in the measurement, the reference plane of the test is going to be the end of the probe tips.

! Freq	S11	F11	S12	F12	S21	F21	S22	F22	Loss
0.700	0.018	157.6	0.991	-107.4	0.991	-107.4	0.016	173.2	L= 0.08 dB
0.750	0.017	136.1	0.992	-115.0	0.992	-115.0	0.014	155.4	L= 0.07 dB
0.800	0.019	129.8	0.990	-122.7	0.990	-122.7	0.016	154.6	L= 0.08 dB
0.850	0.017	117.9	0.991	-130.3	0.991	-130.3	0.012	164.4	L= 0.07 dB
0.900	0.017	90.6	0.990	-138.1	0.990	-138.1	0.013	156.5	L= 0.08 dB
0.950	0.018	75.1	0.988	-145.8	0.988	-145.8	0.010	144.1	L= 0.11 dB
1.000	0.015	60.0	0.988	-153.4	0.988	-153.4	0.009	125.7	L= 0.10 dB
1.050	0.019	34.0	0.987	-161.1	0.987	-161.1	0.008	155.1	L= 0.11 dB
1.600	0.050	-120.6	0.983	114.6	0.983	114.6	0.038	167.5	L= 0.14 dB
1.650	0.050	-128.8	0.982	107.1	0.982	107.1	0.036	159.4	L= 0.15 dB
1.700	0.052	-147.7	0.977	99.3	0.977	99.3	0.038	153.8	L = 0.19 dB
1.750	0.053	-158.6	0.979	92.0	0.979	92.0	0.037	150.2	L= 0.18 dB
1.800	0.050	-168.0	0.979	84.0	0.979	84.0	0.037	138.1	L= 0.18 dB
1.850	0.045	-171.6	0.980	76.4	0.980	76.4	0.037	132.0	L= 0.17 dB
1.900	0.045	179.9	0.980	68.6	0.980	68.6	0.034	120.5	L= 0.17 dB

Table 1 S-parameters of an **rf- load pull probe** connected to a female N-adapter in Cellular and PCS frequency bands

The probes can be used to carry more than 3 A dc current to the terminals of the transistor, assuming that the contact to the PC board microstrip is properly established. The construction of the probe pins is such that it may adapt easily to un-even PC board planes, as is expected to be in a production environment. The probe tips themselves are used in automatic PC board testers and are qualified for over 1 million contacts. The inherent elasticity of the used structure guarantees a consistent and reliable contact also under possible vibrations during load pull testing.

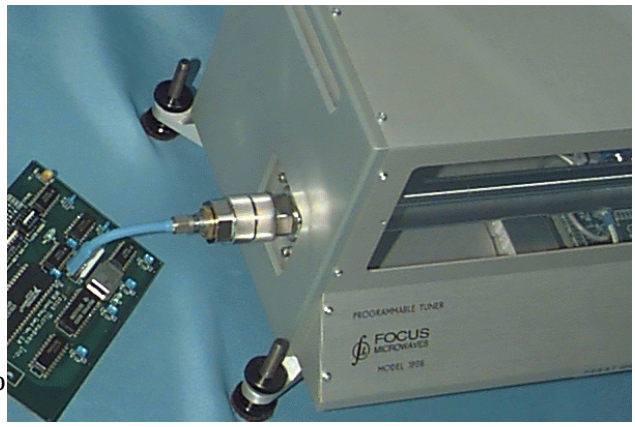
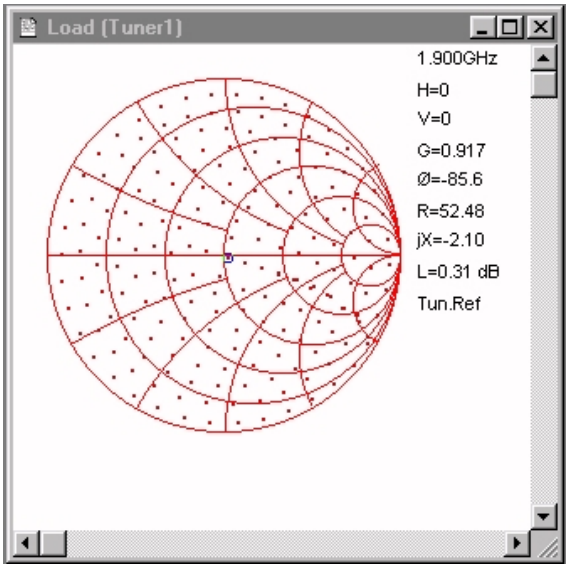


Figure 2

Calibration Test Results

The rf-load pull probes have very small effect on the calibration of the programmable tuners. Figures 3 and 4 show that the maximum G obtained with and without the probes changes only by $|\delta\Gamma| < 0.02$. This means, in the specific setup, that the system can safely load pull transistors with $|Z_{out}|$.1.8 W without using transforming probes or networks.



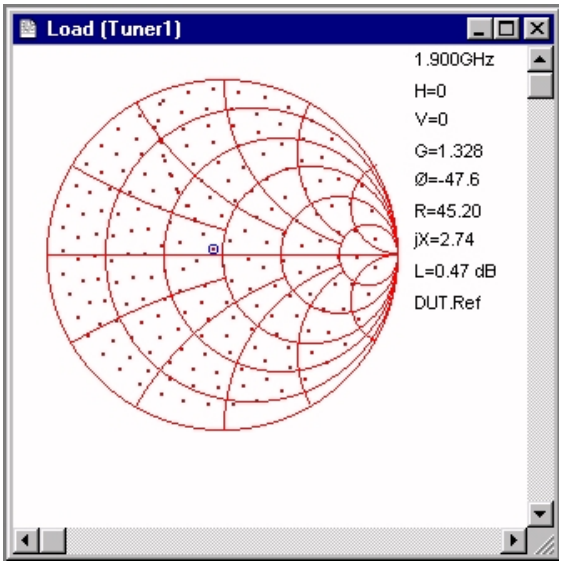


Figure 3 Calibration points (without Probe) (with Probe)

Figure 4 Calibration points