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Product Note 42

Active Modules for Harmonic Load Pull Measurements

This Note describes the structure, utility and limitations of Active Modules used in on-wafer and harmonic load pull testing of very low impedance power transistors.

Introduction

Load Pull testing of power transistors in the Cellular and PCS frequency range require tuning to very low impedances, of the order of 0.5 Ω. This is possible to achieve using FOCUS' High Reflection Tuners and λ / 4 microstrip transformers for the fundamental frequency. In the cases of Harmonic Tuning and On-Wafer testing however, the losses of the di- or triplexers and the wafer-probes and cables limit the tuning range even of high reflection tuners. In this cases an "active-type" solution is required, such as "Active Load Pull" (ALPS see Product Note 33) or an "Active Module", compatible with FOCUS' tuners and software.

The Active Module, model AM-xx-yy [*]

Active Modules can be build using a power amplifier (PA), two circulators (C1,C2) and a band pass filter (BPF) in a closed loop. They allow to compensate the losses of test fixtures and the return loss of passive tuners for very high reflection factor load pull testing. A reflection factor up to 1 can be generated at DUT reference plane (figure 1).

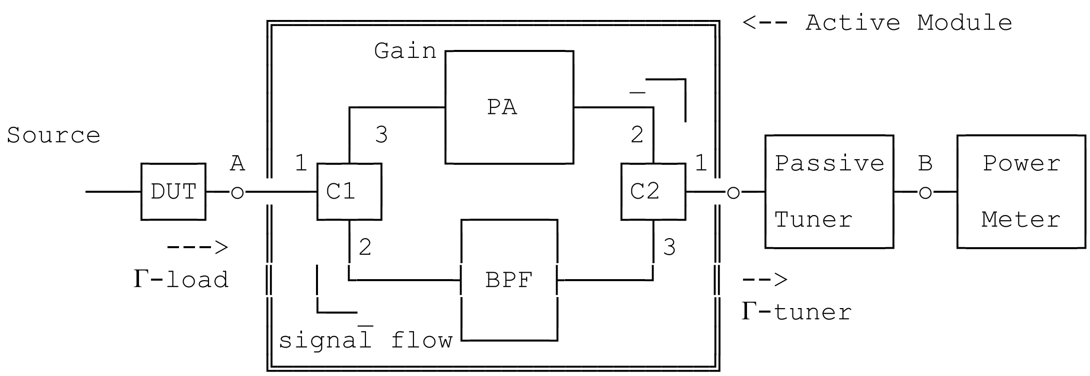


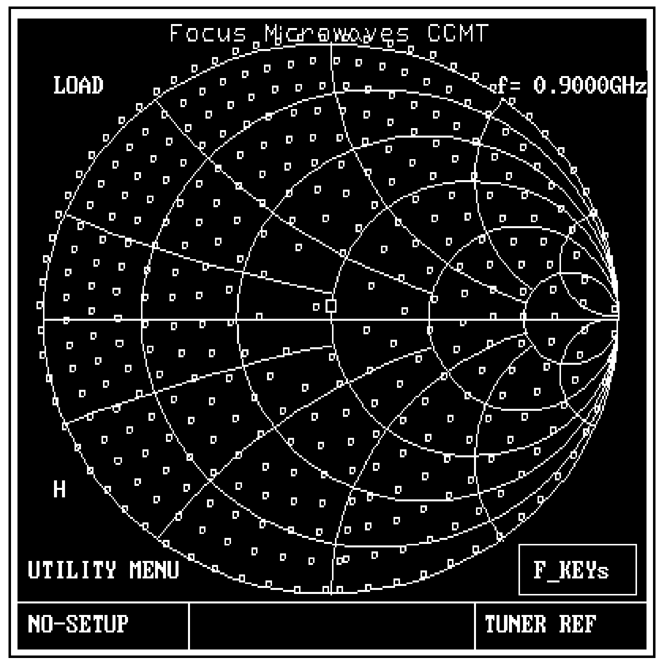
Figure 1: Block diagram of Active Module

[*] -xx =Frequency Range, -yy = Power Range

The unit receives the power leaving the output of the DUT and sends it via circulator C1 and band pass filter BPF to a second circulator C2, which then diverts the signal to a passive tuner. The signal reflected by the tuner is send via circulator C2 to a power amplifier and then via C1 back to the output of the DUT, which sees a reflection factor, who's amplitude and phase depend on the **"Gain" of the amplifier** and the **reflection factor generated by the passive tuner ("Γ-tuner")**.
The band pass filter BPF in the active module is required in order to minimize the risk of oscillations, since the loop gain of the module may be >1, depending on the reflection of the tuner, the output impedance of the DUT and the gain of the amplifier.

Calibration

The Active Module AM and the passive tuner (model CCMT-1808 in most cases) forms an integrated unit from port A to port B (figure 1) and must be calibrated as such. The CCMT calibration software does not distinguish between a "tuner-alone" or a combination of "tuner-active module".
The calibration software will drive the passive tuner CCMT in-order to generate the reflection factor requested by the user (in this case close to Γ=1.0). This can be done also "in-situ" using FOCUS' Windows software for tuner calibrations, in which case the DUT has to be replaced by a THRU LINE on-wafer and the combination "tuner-active module" will be calibrated without connecting-disconnecting any components.
Figure 2 shows a "tuner-active module" calibration pattern at 0.900 GHz. It is clear that reflection factors >1 can be generated. The impedance interpolation and mouse tuning capability of the CCMT software are fully preserved for these calibration files.



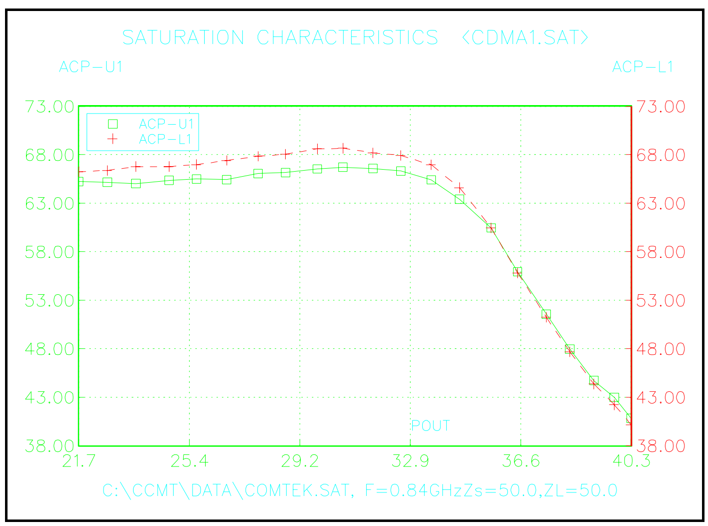
Limitations

The reflection factor at the input of the active module (port A) can be calculated from the following equation:

Γ-load = Γ-tuner * Gain (Power, Frequency)

It is obvious that the **Gain** of the amplifier is an **integral and sensitive component of the tuner calibration**. It must be made certain that during the complete operation (variation of frequency and input power) the Gain and Phase of the amplifier does not change. It is here assumed that the other (passive) components of the setup (isolators, band-pass filter) do not change their behaviour within the operation power range. Any change in the gain (or phase) of the amplifier will lead to an error in the tuner calibration data. This imposes the condition for a highly linear amplifier. In the case of code modulated signals (like CDMA) additional linearity requirements emerge which may further limit the capability of such a system. Quantitative data on such an amplifier are provided in the next section of this document.
A further drawback has to do with the operation bandwidth: The phase instability of YIG filters inhibits their employment in this system (in FOCUS' active load pull system ALPS, however, YIG filters can be used, since that system measures the impedances "on-line", see PN 33). Active Modules as presented here, though, must use fixed (coaxial, microstrip or dielectric resonator) filters. Only those filters provide sufficient phase stability but they cannot be tuned. This fact limits the available operation bandwidth.

CDMA (ACPR) Measurement Limitations



The linearity requirements of the power amplifier included in the Active Modules (AM) are more severe, especially in the case of CDMA modulated signal sources.
In this case the power handling capability of the amplifiers is reduced by more than 6 dB from the nominal P1dB power level. Figure 3 shows the ACPR performance of a 10 Watt (40 dBm) amplifier used in one of FOCUS active modules: If the ACPR of the DUT exceeds 58 dBc then this amplifier could only be driven up to 34 dBm output power (2.2 Watt approximately). Otherwise the system would not provide enough margin for accurate ACPR measurements on this particular device.

Harmonic Load Pull using CCMT and Active Modules

The setup employs basic components of the CCMT system. CCMT is a passive load pull system using two mechanical broadband tuners for source and load pull tuning. For harmonic tuning purposes CCMT is extended with a diplexer or triplexer at the load side of the DUT and additional tuners control the harmonic impedances. Since test fixtures, wafer probe stations and triplexers introduce losses which limit the tuning range of the CCMT system, the system can be extended by using active modules for each harmonic frequency, in order to compensate for those losses. CCMT is an accurate wideband system which can handle high power levels, when not used with the active module extension. CCMT uses traditional techniques for measuring power and gain.
A harmonic Source Pull can be performed by inserting a di- or triplexer and one or two additional tuners at the input side of the setup (figure 4). Figure 5 shows tuner calibrations at the two harmonic frequencies 2f=1.8 GHz and 3f=2.7 GHz. It is clear that due to the active modules used in this configuration the triplexer losses can be compensated and the reflection factor at DUT reference plane can reach 1.

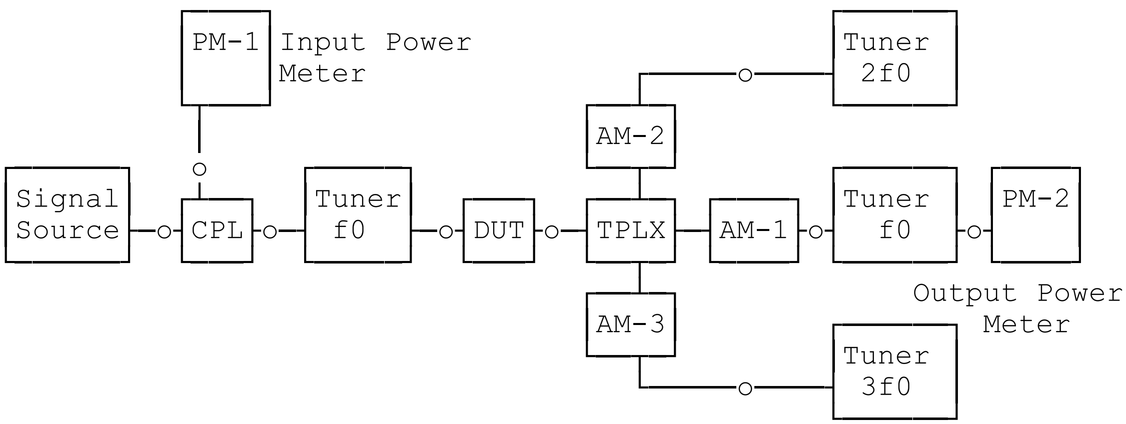


Figure 4: Setup for Harmonic Tuning and Load Pull (HLP) using CCMT with Triplexer (TPLX) and active module extensions (AM)

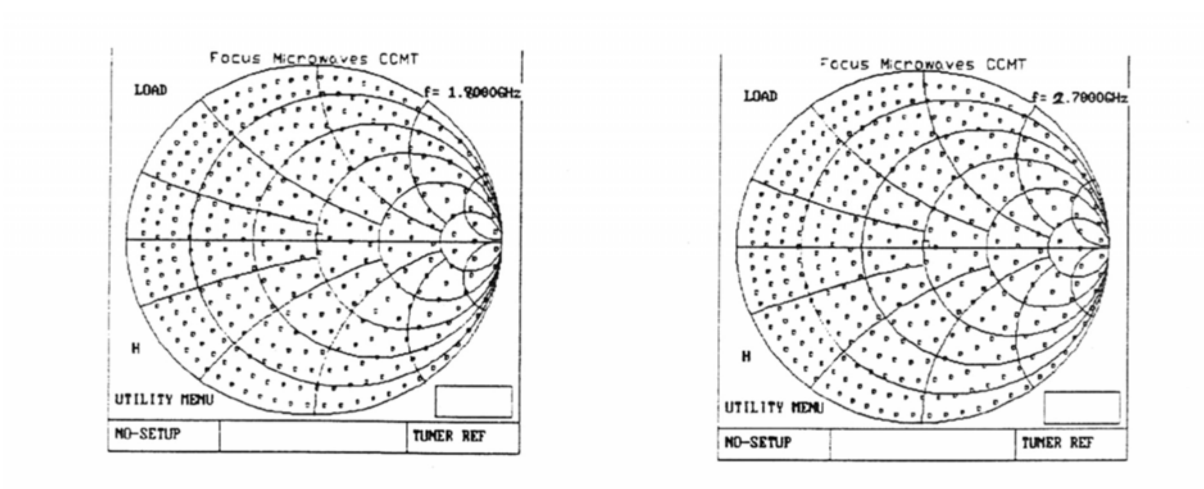


Figure 5: Tuner/Active Module calibration at harmonic frequencies 1.8 and 2.7 GHz