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*Application Note 56*

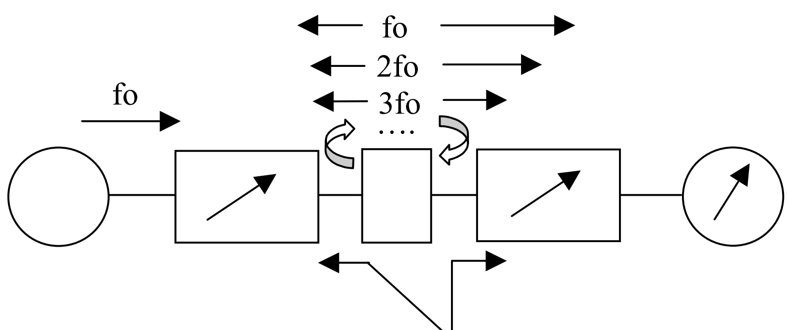
# Harmonic Effects in Load Pull using Wideband Tuners

## Summary

Load Pull testing of power transistors usually employs wideband electromechanical tuners. Harmonic signal components, generated by the non-linear DUT, must be terminated with known impedances in order to generate a meaningful set of data. This is not possible if a harmonic load pull set-up is not available, in which case distorted data will be generated. Using wideband high VSWR prematching tuners, instead of harmonic tuners, improves the situation, but creates limitations in harmonic tuning. This note compares the effect of the different configurations of tuner set-ups based on sample measurements at 2.6GHz.

## Introduction

Load pull contours, measured using wideband electromechanical tuners, are, meanwhile, part of the literature and transistor manufacturer's data sheets.
In many cases, though, these contours have been measured using a simple load pull set-up, as shown schematically in figure 1.



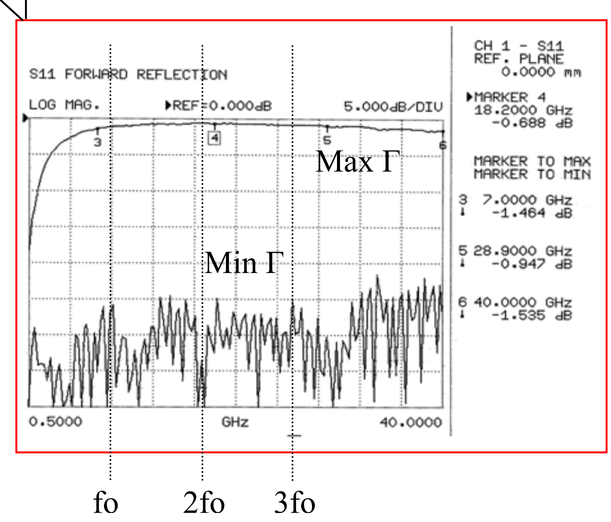




Figure 1: Load pull using wideband tuners; harmonic signal components generated by the DUT at 2fo, 3fo… are reflected, simultaneously with fo, by the source and load tuners; when tuning at fo, the impedances at 2fo, 3fo… change also uncontrollably at both source and load side. This creates distorted load pull contours (see figure 2).

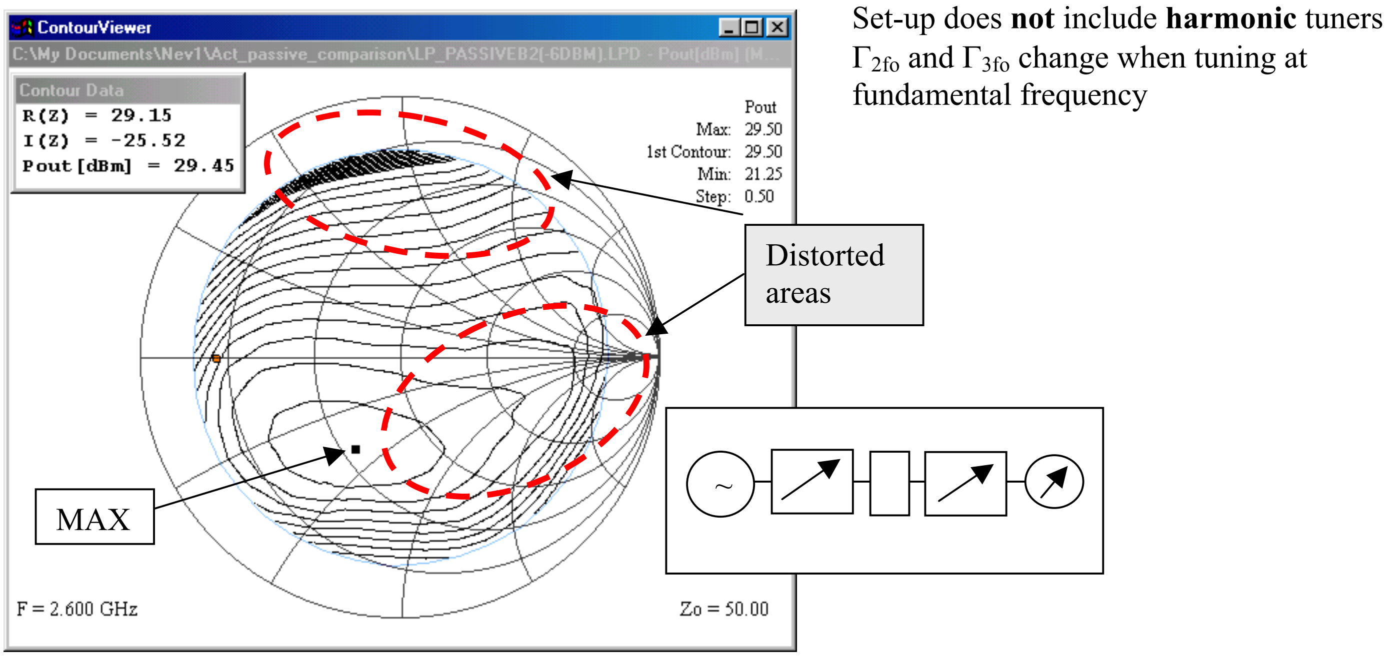



Figure 2: Load Pull contour of a power FET showing distortions on both sides of the maximum.

The contours in figure 2 have been measured using wideband 0.8-18GHz tuners at source and load. The same test has been performed using the same tuners for fundamental tuning, but two additional harmonic rejection tuners (Focus PHT-1808). The harmonic tuner have been set to reflect the harmonic signals at $2f_o$ (5.2GHz) and $3f_o$ (7.8 GHz) back into the transistor at optimal phase. The result is shown in figure 3:

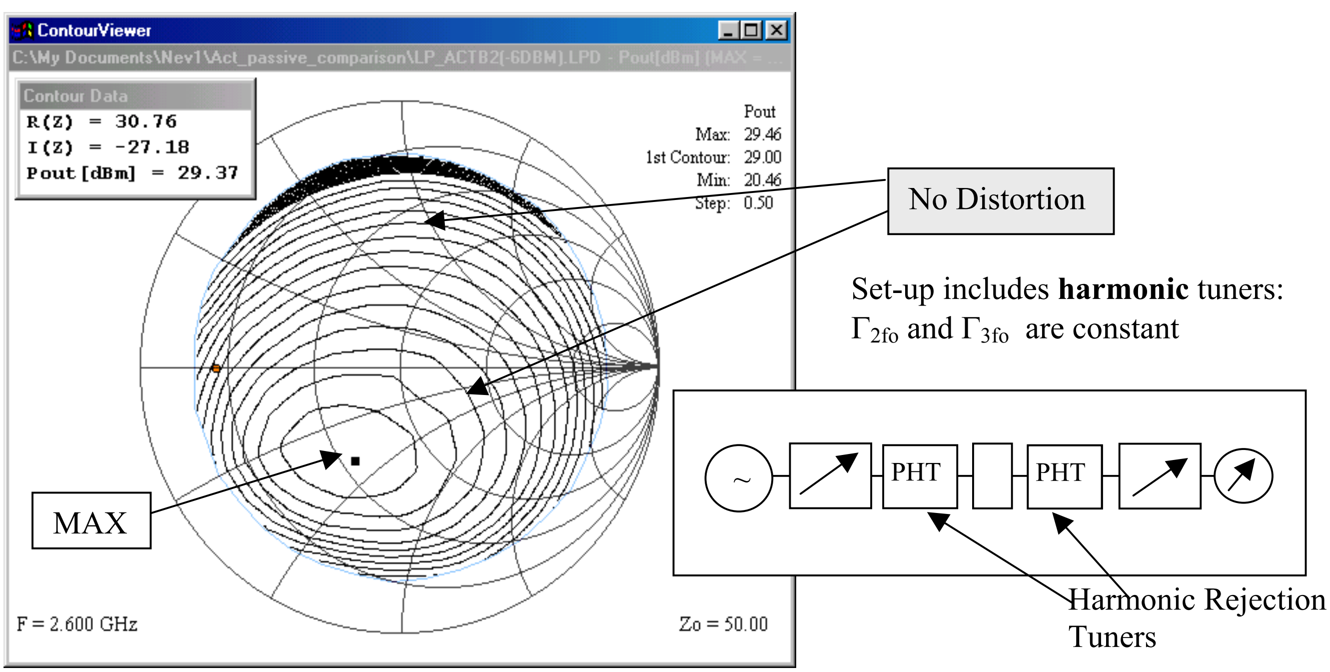
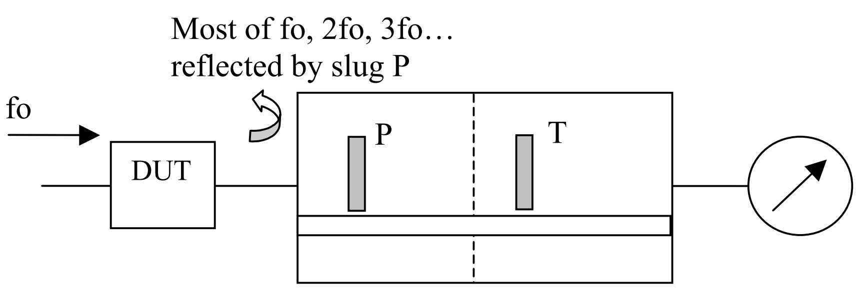



Figure 3: Load Pull contour of the same device under the same conditions as in figure 2, but measured using additional harmonic rejection tuners

The effect of uncontrollable harmonic tuning when comparing figures 2 and 3 is obvious. The result in figure 2 is difficult to detect as a measurement error, since the maximum power and the optimum fundamental load impedance itself may not be very different in both cases, especially at moderate saturation levels. This is because a wideband tuner optimises for all harmonic impedances simultaneously producing a result, which is a combination of fundamental and harmonic tuning.
This systematic measurement error becomes disturbing when an amplifier design attempt is made using such data (figure 2). The load circuit is not designed for maximum output power only, but most often is a compromise between multiple parameters, such as Pout, PAE, IMD etc. In this case the data on the contour may be several dB off the real value.

## Using a Prematching Tuner

A prematching tuner consists of a prematching slug (P) close to the DUT, which does not move during load pull, followed by a tuning slug (T) (figure 4), which serves for the actual load pull measurement (see greyed areas in figure 4).



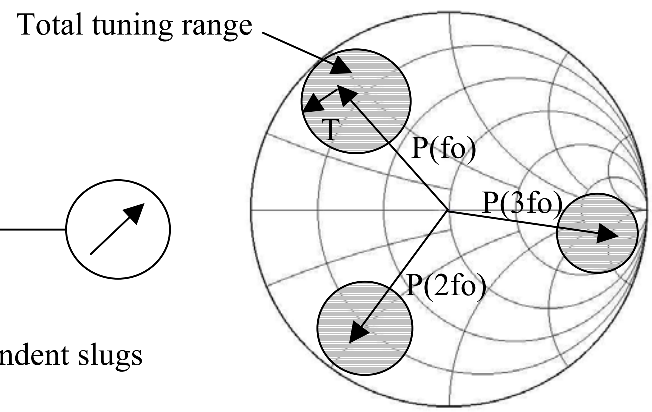




Figure 4: Prematching Tuner with two independent slugs

Both, the prematching and the tuning slugs are typically wideband. When the prematching slug P is set close to the central conductor of the airline to create a high (wideband) reflection, then most of the RF power at the harmonic frequencies is reflected at the pre-matching slug, and only a small fraction reaches the tuning slug. Thus, very low uncontrolled harmonic tuning occurs, when tuning slug T is used for load pull or peak search operations. The load pull contours are less distorted than in figure 2.

However, it is not possible to tune or optimise effectively the harmonic impedances by tuning behind the prematching slug, neither using a wideband tuning slug, nor using a harmonic rejection tuner. This is why a harmonic tuner must be inserted between DUT and prematching slug P.

## Conclusion

Wideband passive tuners always create undesired harmonic tuning during load pull testing and therefore falsify the measured data. The use of harmonic load pull, in form of harmonic rejection tuners or frequency discriminators is mandatory.