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Application Note 60

High-Power Load Pull at 40 MHz using Low Frequency Tuners (LFT)

Abstract
A first-of-its-kind load pull solution for high-power low-frequency devices is described. Load Pull Contours are measured at 40 MHz on an amplifier with 50+ dB gain and output power of over 250 Watts CW.

Introduction
Low frequency power amplifier designers depend on their EDA simulation tools which in many cases do not provide a complete picture. Normally, load pull data is used to improve and validate the EDA models; however, in some cases load pull data is unavailable due to technology limitations at very low frequencies. Lack of load pull data causes inaccurate and non-reliable nonlinear models. This note describes a new electromechanical tuner and measurement software, which enable designers to perform full load pull at frequencies between 10MHz and 100MHz.

Until recently, load pull was only performable at frequencies above 200MHz using a Focus Microwaves iCCMT-302 (200MHz to 3GHz) automatic tuner. Engineers and designers were not able to perform device characterization or obtain relevant data from their devices below 200MHz and had to rely solely on simulations. In 2005 Focus introduced the iCCMT-101 (100MHz to 1.1GHz) automatic slide screw tuner, which extends load pull testing down to 100MHz. The size of an electromechanical slide screw tuner is slightly larger than one half of a wavelength at the lowest frequency of operation. At 100MHz this corresponds to 1.5m (~60"). Figure 2 shows the size of a tuner as a function of the lowest frequency. New techniques had to be introduced in order to achieve the required mechanical precision for this kind of operation and RF tuner repeatability (~50dB). Below this frequency the size of the tuners becomes unfeasible and a new concept was introduced (Figure 1). The requirements are simple: 1. Lower frequency, 2. Higher power, 3. Compact size.

Figure 1: iLFT-01004 (40-100MHz); *LFT=Low Frequency Tuner*

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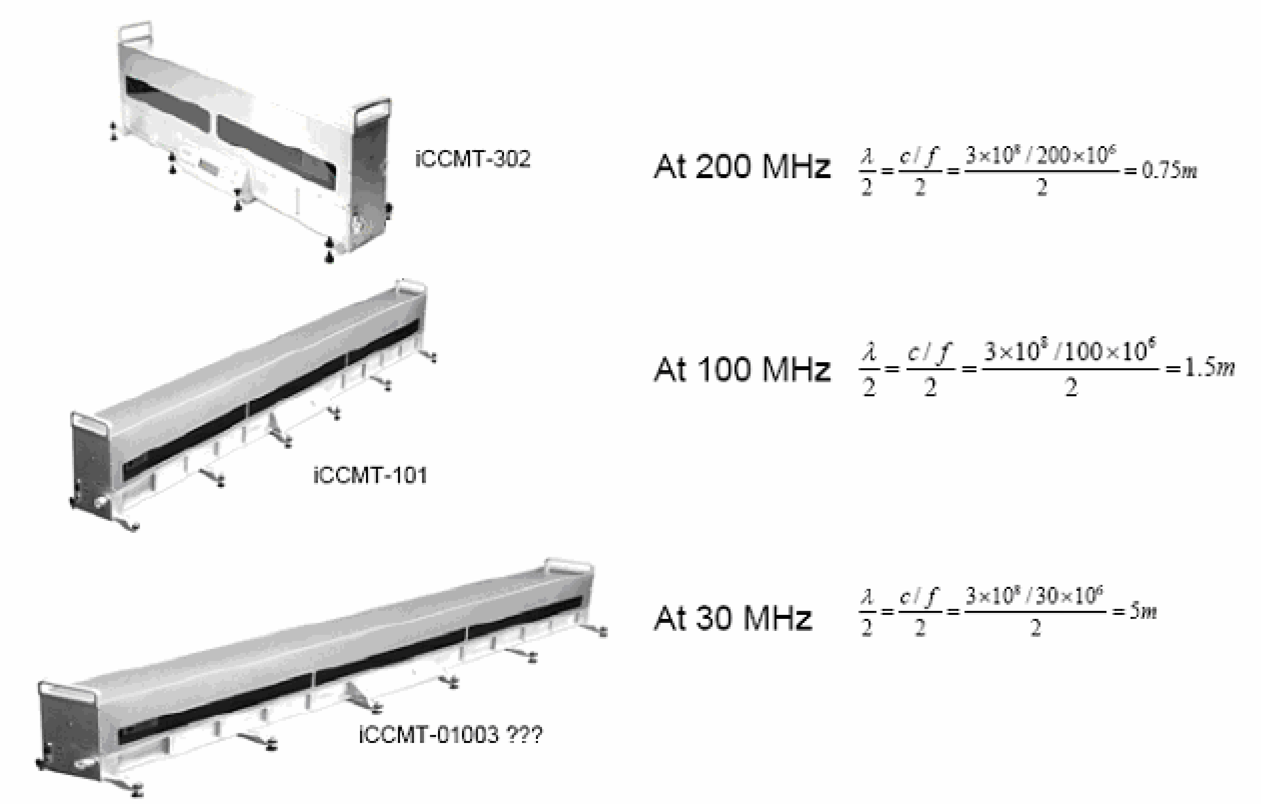

Figure 2: Required sizes of slide screw tuners; 30MHz tuner is a projection

New Low Frequency Tuner, LFT*

In 2006, Focus Microwaves released the iLFT low-frequency tuner product line, extending the ability to perform load pull down to 10 MHz (Figures 1, 3). Transistors and amplifiers are now able to be tested for various applications in defence, medical and telecommunications industries.

Figure 3: Load Pull test setup

Hardware Setup

Figure 3 shows the actual setup used for load pull at 40 MHz. Aside from standard instruments (signal source and power meter, Figure 4), a Focus Microwaves iLFT-01004 low frequency tuner is used to set impedances seen at the DUT; an AR Worldwide KMA2040 200 Watt amplifier is used as device under test, and a MCE Weinschel 250W 40dB convection-cooled attenuator is used to reduce output power to sensible levels.

*patent pending

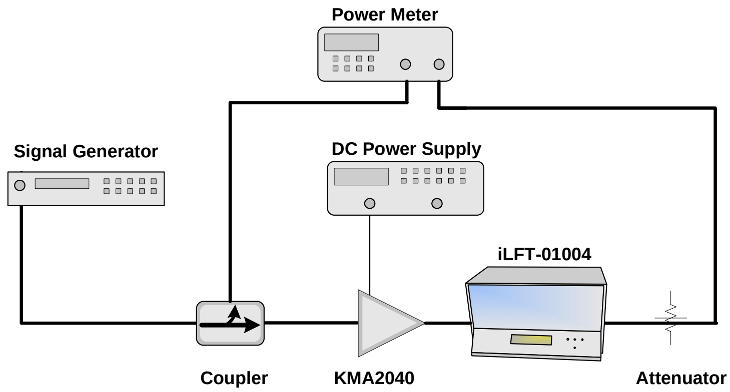

Figure 4: Diagram of Load Pull setup

LFT Calibration

Calibrating a traditional electromechanical tuner at these frequencies would take a significant time, because of the long horizontal travels involved, if possible at all. New calibration and interpolation algorithms have been introduced, which allow calibrating the LFT in a matter of 5 minutes per frequency point. GPIB drivers for all available network analyzers are available. Figure 5 shows the number interpolated points, based on such a calibration, available at 40MHz. Average interpolation accuracy is 45-50dB (Figure 6).

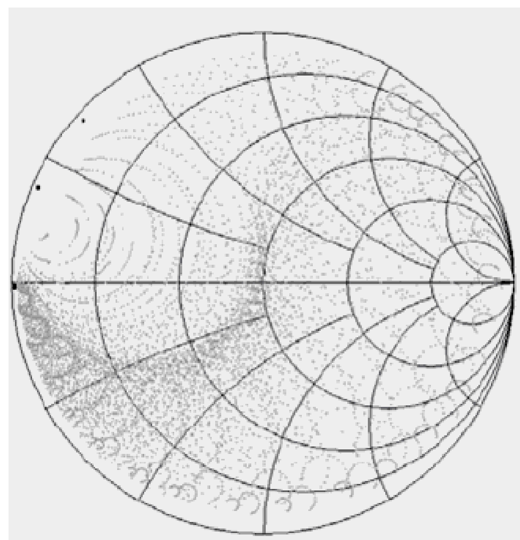

Figure 5: Distribution of interpolated points, based on a fast (5') LFT calibration

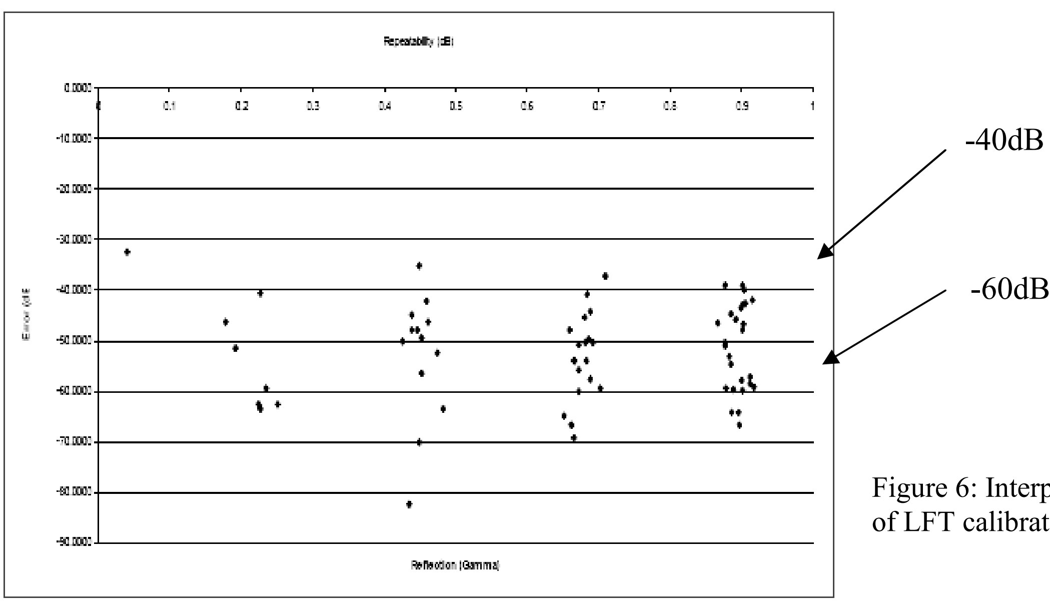

Figure 6: Interpolation accuracy of LFT calibration at 40MHz

High-Power Load Pull at 40 MHz

An AR Worldwide KMA2040 >200Watt CW Pout and >50dB Gain power amplifier acts as our DUT in our measurement setup. The signal source generates between -40 to +10dBm allowing to test our device and tuner power handling capability at various output powers; we tested specifically at 100W and 300W output power. Because the amplifier is nearly matched to 50Ω and has a mismatch tolerance of 2:1, we limited the load pull tuning range of the LFT tuner to Γ=0.33 over 360°.

Since the test amplifier is nominally matched to 50Ω, we would expect the maximum output power to be delivered to a 50Ω load, with a concentric decline in output power as the amplifier is mismatched by the tuner. We measured, however, that the optimum matching impedance shifts slightly with increasing output power and does not remain constant 50Ω, as expected. Figure 7 shows power contours demonstrating a maximum output power of 107.37Watt at Z=32.66-j3.61Ω

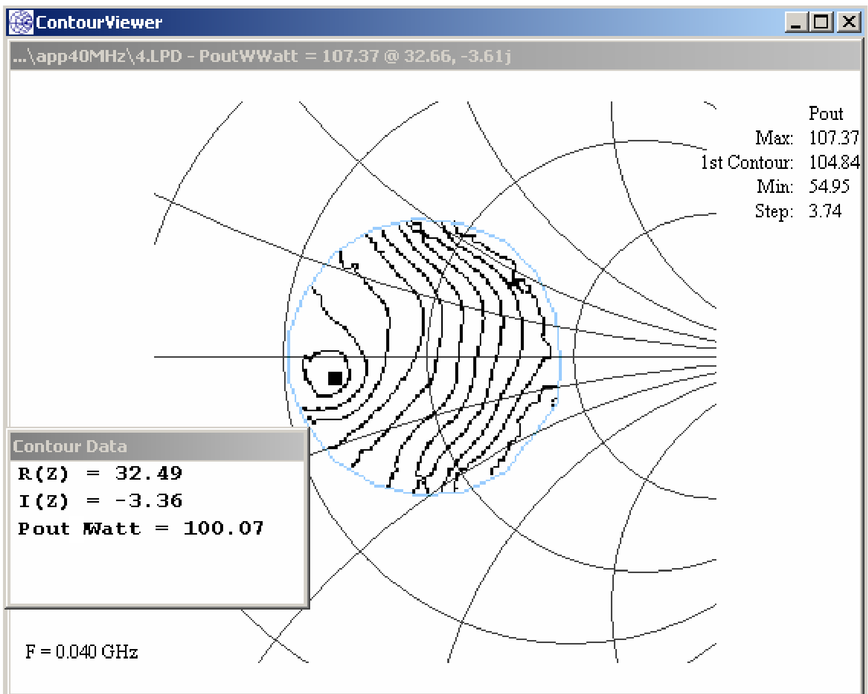

Figure 7: Output Power Load Pull Contours at 40 MHz, maximum Pout ≈ 107Watts .

We tested the amplifier past the specifications in order to determine the maximum power which could be delivered to a 50Ω load after matching with a tuner. The contours in Figure 8 show that the optimum impedance at this power level re-centres itself near 50Ω.

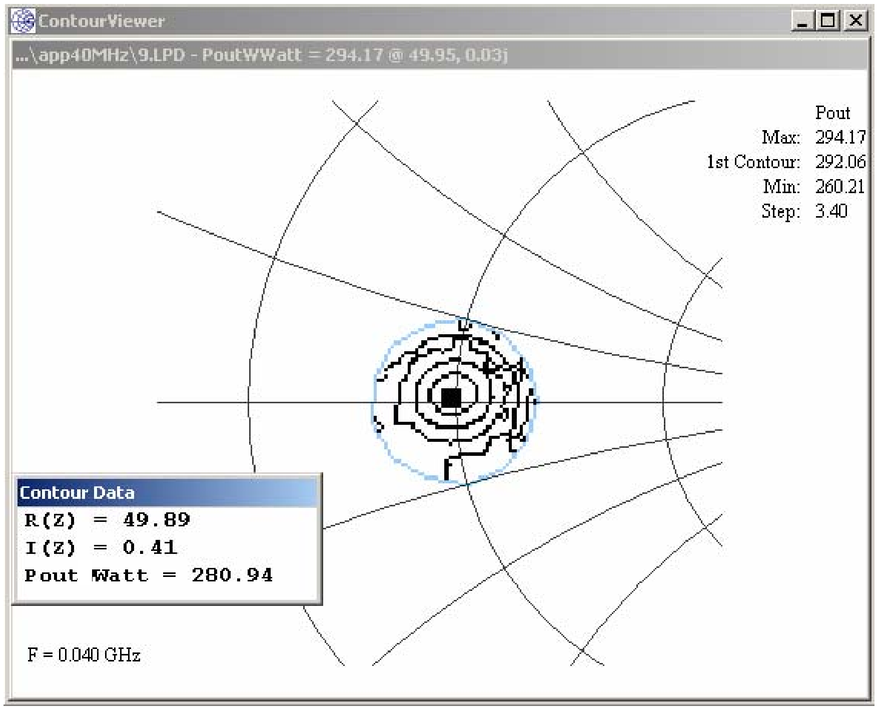

Figure 8: Output Contours at 40 MHz, maximum Pout ≈ 300Watts .

Similar tests can be performed on high-power devices such as LDMOS or others. In such a case we would expect the maximum output power and gain to be away from 50Ω. Focus' WinPower software is able to measure a multitude of parameters such as Pout, Gain, P1dB, IMD, PAE, TOI, ACPR, etc. for CW and pulsed operation at any available power level.

Hardware Note

Extensive and repeated testing at the highest power levels available here (>200Watts) showed no degradation and consistent performance of the LFT tuner.

Conclusion

These measurements are proof that load pull below 100 MHz is now possible using Focus Microwaves' new generation of low frequency tuners, **LFT**. Engineers and designers are no longer limited to rely on simulations or small signal approximations. A complete solution for low-frequency high-power load pull exists with Focus Microwaves iLFT-01004 short wave tuner and WinPower, Focus' award-winning device characterization software.

Notice: In this document the tuner used is referred to alternatively as LFT or iLFT. Both describe the same product. The prefix "i" is used to signify that the tuner uses Focus "iTuner" technology with on-board micro-processor, TCP/IP control interface, calibration memory and interpolation firmware.