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Application Note 62

Hybrid Active and Harmonic Tuning

Open loop active load pull profits from readily available high quality synchronized synthesizers (S1, S2) and harmonic receivers, also available integrated in dual source vector network analyzers, such as the PNA-X™ and ZVA™ to create a virtual load for transistors which are difficult to match using traditional passive tuners (Figure 1).

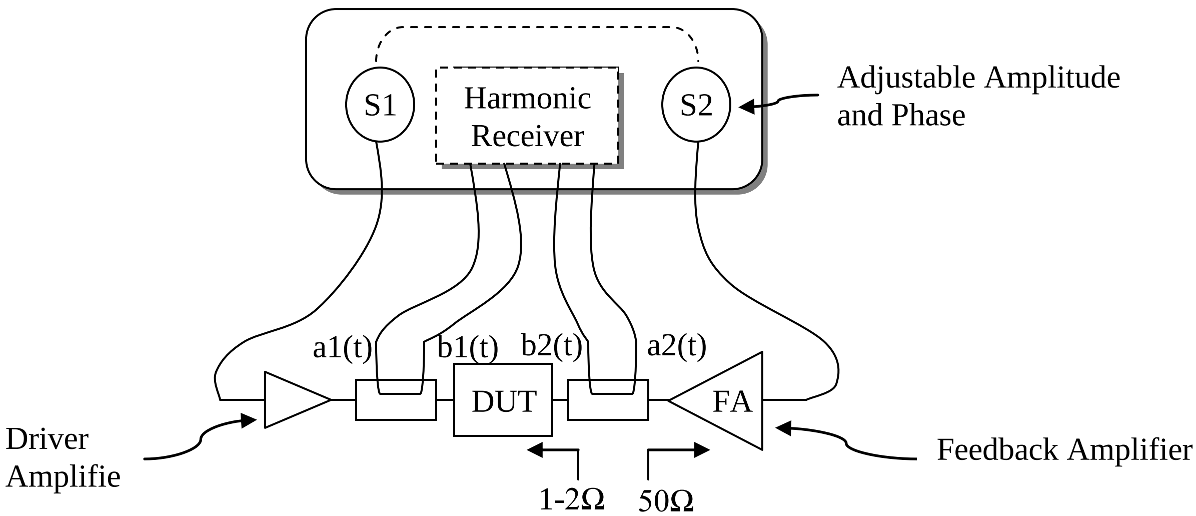

Figure 1: Active Injection Load Pull at fundamental frequency, Fo.

This configuration has a number of advantages, including simplicity of the setup, online impedance and power measurements and fast electronic tuning. The main drawback of this configuration is <u>the requirement of large feedback amplifiers (FA), due to the large mismatch between the amplifier's output impedance (50Ω) and the internal impedance of the DUT (typically 1-2Ω)</u>. To match a 100W device with 1Ω internal impedance an amplifier of more than 1300W is required [1]. The setup of Figure 1 can be extended to harmonic tuning (Figure 2). In this case one or more external synchronized signal sources are needed (S3, S4..) which allow injecting power at 2Fo and 3Fo into the output of the DUT through a power combiner, isolator, di- or tri-plexer etc.

In all cases, <u>however the same large mismatch problem remains</u> and, even if the harmonic feedback power required is lower than at the fundamental frequency Fo, still, higher frequency power amplifiers are more expensive as well.

[1] Zaid Aboush et al: Active harmonic load-pull system for characterising highly mismatched high power transistors; IEEE 2005

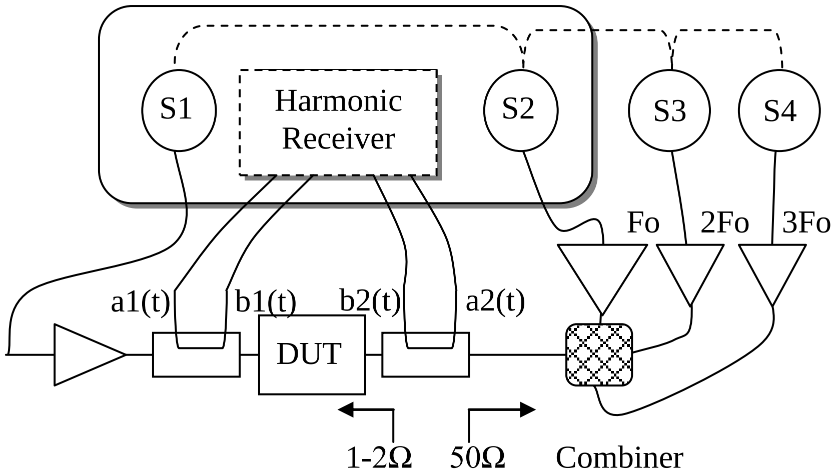

Figure 2: Active Injection at harmonic frequencies.

Reducing the power of the main feedback amplifier (FA) is possible by inserting a wideband impedance tuner between the output of the FA and the output of the DUT (Figure 3).
In this case the passive tuner creates a "pre-matching" impedance of 7-10Ω, in which case the overall mismatch is acceptable: 5:1 or 7:1 instead of 50:1 in the case of Figures 1 and 2.

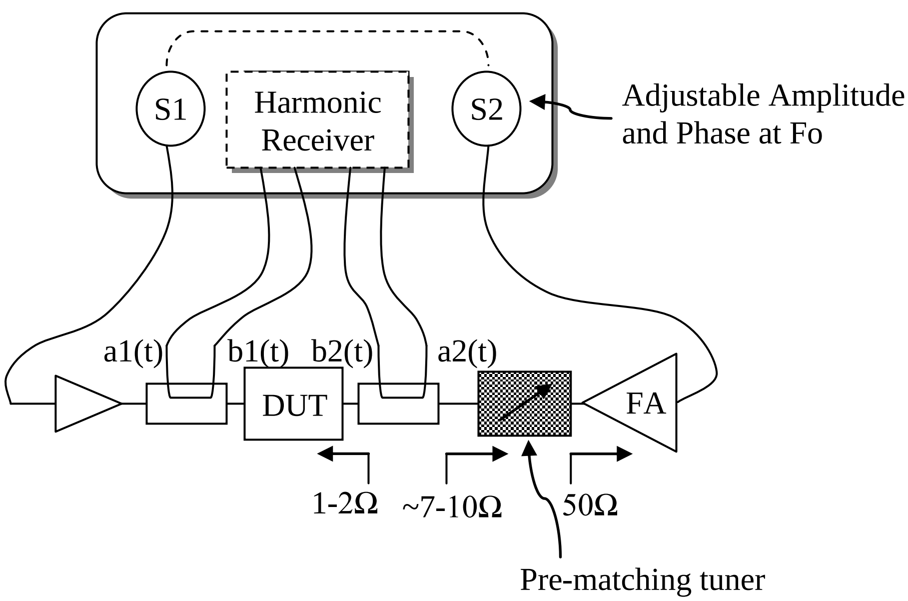

Figure 3: Active Injection Load Pull at fundamental frequency, Fo, using wideband (fundamental) tuner to reduce FA power.

In terms of the reflection factors on the load Smith chart the situation is as shown in Figure 4: The passive wideband (fundamental) tuner creates a reflection factor in the vicinity of the optimum load impedance (which cannot be reached using the passive tuner alone) and the active power injection creates the additional reflection factor needed to reach the border of the Smith chart (Γ=1). Because the mismatch conditions are better, the required power to be injected is, typically, 10-13dB lower than in the case of Figures 1 and 2.

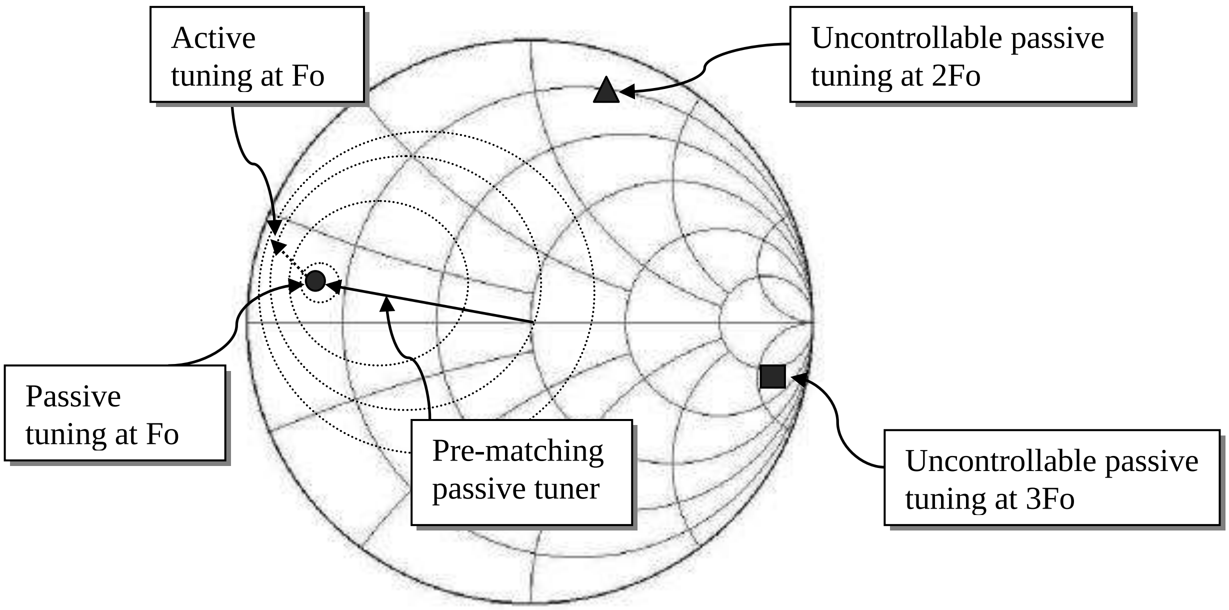

Figure 4: Passive and active tuning in a hybrid load pull system.

However,

The available passive tuners are by nature wideband. They are (misleadingly) called “fundamental” tuners, but, in fact, they generate as high a reflection factor Γ at 2Fo, 3Fo etc. as at Fo: |Γ(Fo)|≈ |Γ(2Fo)|≈ |Γ(3Fo)|... This is shown in Figure 4.

This means that, depending of the position of the (uncontrollable) Γ(2Fo), Γ(3Fo) etc. the mismatch at the harmonic frequencies may be even much higher than the original 50:1, when no passive tuner is used at all; (imagine an easily possible case, where Γ(2Fo) is ~180° opposite the optimum Γ.dut(2Fo); or as an example Z.dut(2Fo)=1Ω and Z.tuner(2Fo)≈1000Ω or Γ≈0.9<0°).

I view of this, realistically possible, situation it is probably better not to use wideband tuners at all and live with the high power feedback amplifiers, both for Fo and 2Fo, 3Fo etc.

The alternative is using multi-harmonic tuners of the MPT family: In this case the harmonic impedances of the passive (MPT) tuner can be set closest to the expected optimum harmonic impedances of the DUT, thus reducing the required harmonic power to be injected. In many cases it will not even be required to employ additional harmonic injection, since the passive harmonic tuning will precisely deliver information about the phase of the optimum harmonic impedances, even if it cannot reach the amplitude; and, as is an accepted fact in the art that the optimum harmonic reflection factor is typically =1: ($|\Gamma(2Fo)|=|\Gamma(3Fo)|=1$), this would be sufficient information for the amplifier designer.

This is possible by using **HAILP**, Focus Harmonic Active Injection Load Pull (Figure 5).

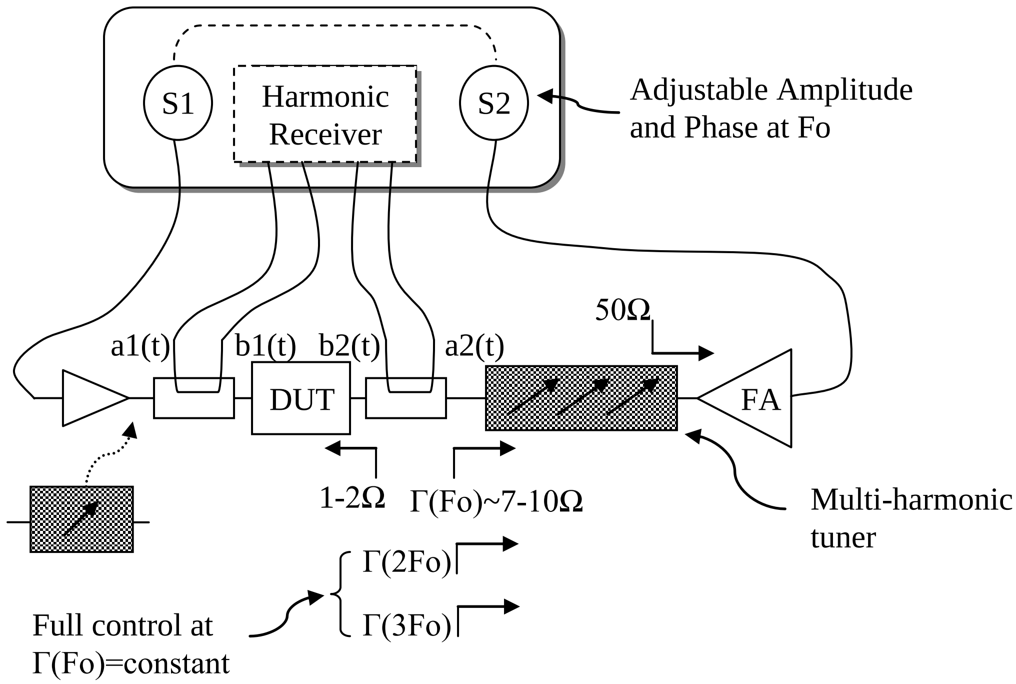

Figure 5: Multi-harmonic tuner (MPT) allows optimum power transfer at Fo and passive tuning at 2Fo, 3Fo..

In this setup the harmonic reflection factors are limited due to the tuning range of the MPT and the additional loss of the coupler and the probes to the DUT. If this seems insufficient, despite the fact that the optimum harmonic impedance phase will be delivered accurately by the test setup, additional harmonic signal sources can be added, as shown in Figures 2 and 6, whilst maintaining the advantage of power pre-matching at those frequencies using the MPT (Figure 6).

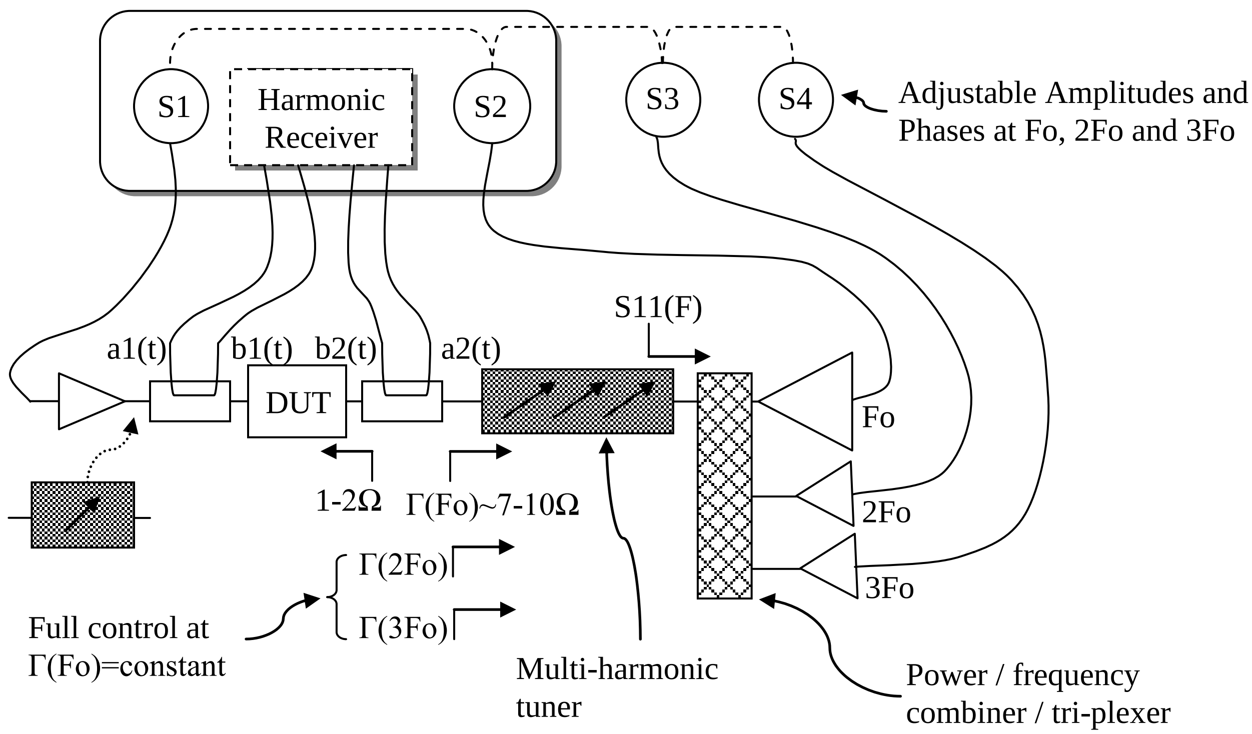

Figure 6: Multi-harmonic active injection Load Pull system using MPT

The use of a di- or tri-plexer is going to limit the bandwidth and hamper the wideband tuning capacity of the MPT, since the load reflection factor S11(F) at frequencies outside the band are very high). A similar situation occurs when using isolators instead of triplexers and the isolators are available with only limited bandwidth. In those situations a simple wideband power combiner/coupler is a recommended compromise.

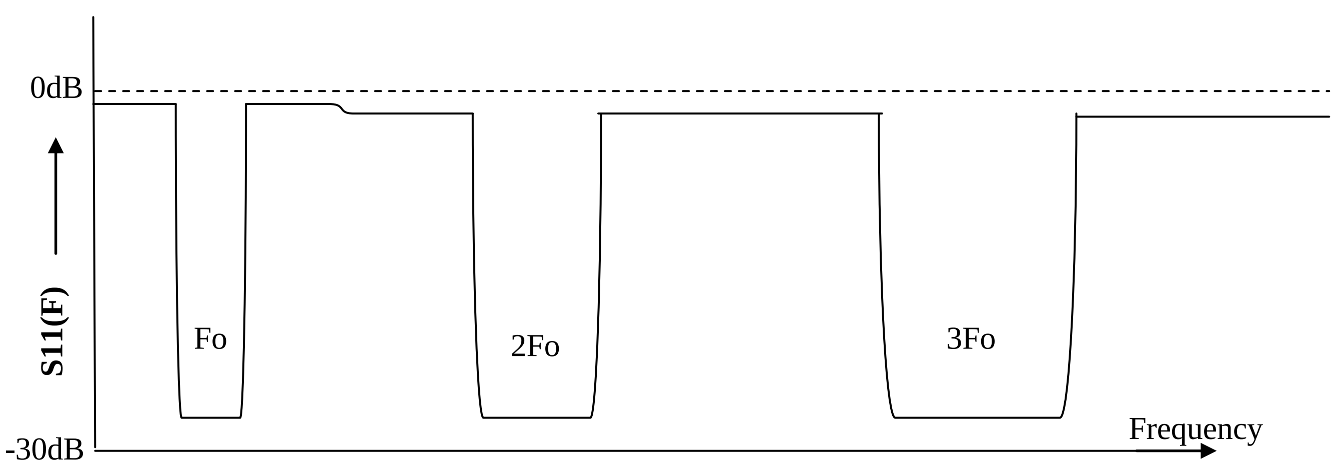

Figure 7: Reflection factor of a frequency triplexers; high reflection outside the harmonic bands

The setups in Figures 5 and 6 can be completed by inserting either a wideband or a multi-harmonic tuner at the input of the DUT in order to create traditional source tuning and source pull and, simultaneously reduce the required driver amplifier power (Figures 5, 6, 8, 9).

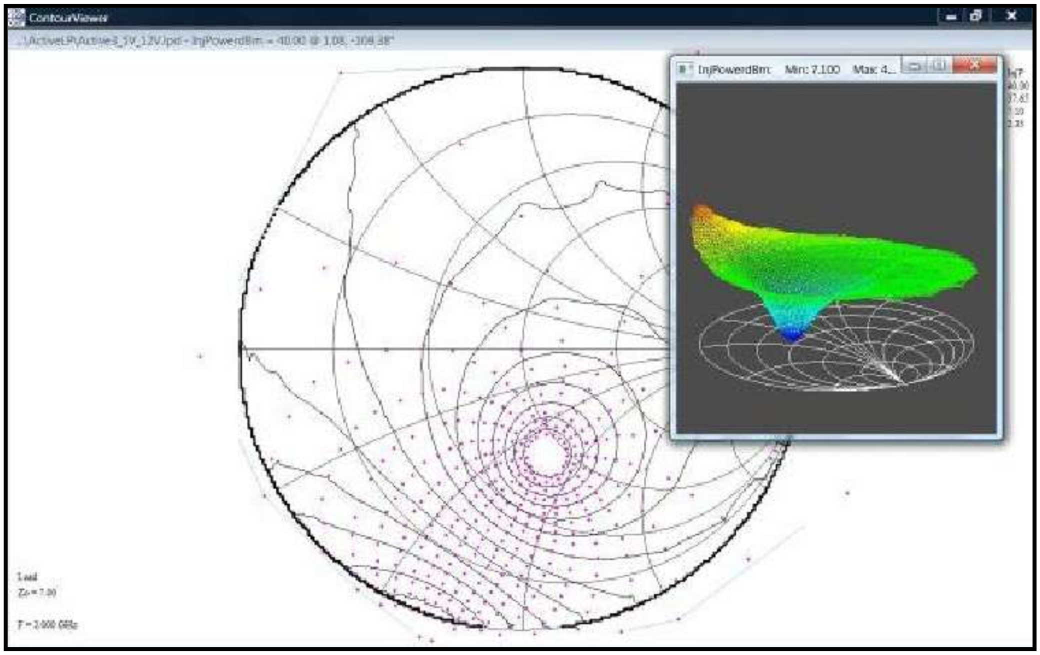

Figure 8: Reduced injected power in the area of passive tuning at Fo (Zo=7Ω)

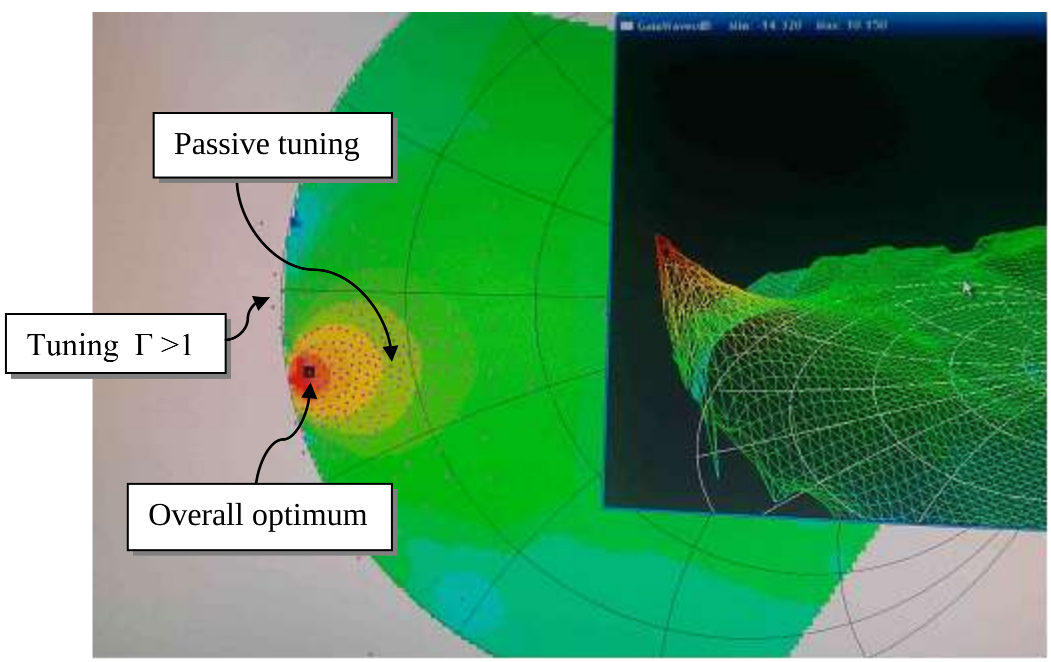

Figure 9: Passive and active injection tuning to the border of the Smith chart