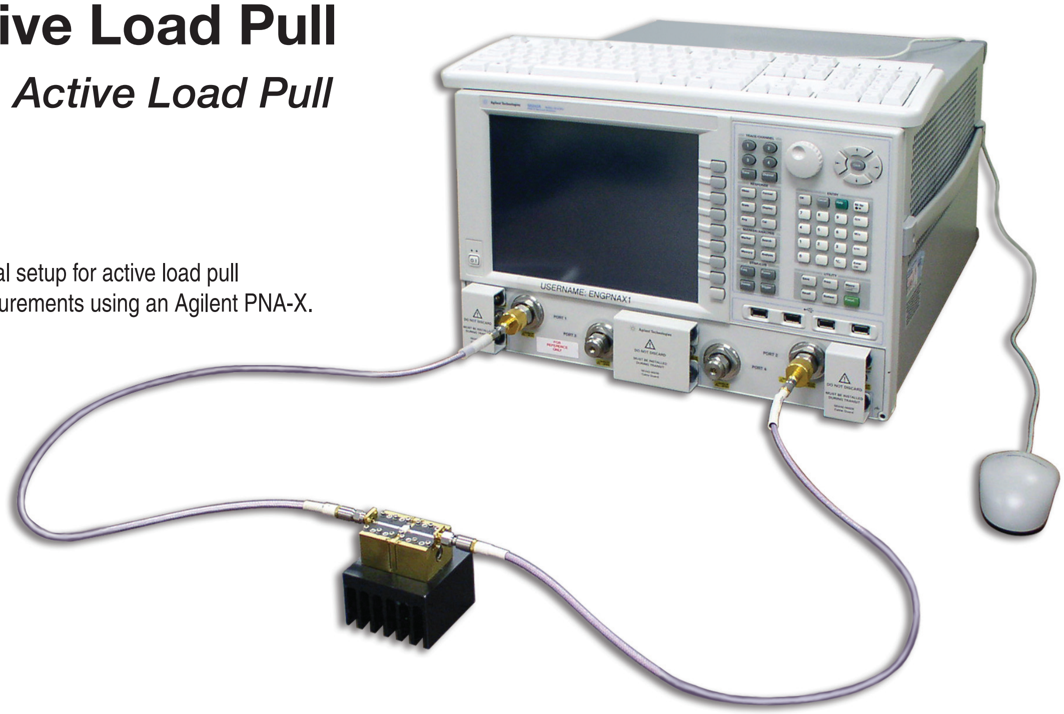
Using Maury ATS Software to Extend the Agilent PNA-X to Active Load Pull

An Introduction to Active Load Pull



Typical setup for active load pull measurements using an Agilent PNA-X.

Introduction

The goal of load pull is to measure the response of a device as a function of load impedance. To clarify, our load pull system must present a set of controlled impedances to the DUT while measuring a list of parameters at each point. The impedance presented to the DUT can be stated in various formats: Impedance Z_L (consisting of R+jX), VSWR (as a complex number in magnitude and phase), and Γ_L (as a complex number in magnitude and phase). Considering our DUT as a two-port device shown in Figure 1, Γ_L is nothing more than a_2/b_2, or the ratio between the reflected- and forward-traveling waves. A generalized form of the formula can be written as

$$\Gamma_{x,n}(f_n) = \frac{a_{x,n}(f_n)}{b_{x,n}(f_n)}$$

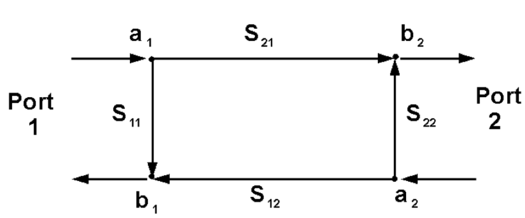


Figure 1. Two-port Scattering Parameter Model

In a traditional passive mechanical tuner system, reflection occurs by interrupting the electric field of an airline using a metallic probe. The probe is inserted into the airline at some variable depth; the farther the probe penetrates into the airline and interrupts the electric field, the greater the reflection, or Γ_L. With this method, it is clear that a_2 will always be lower than b_2 due to the reflection limitation of the mechanical tuner (not all the energy can be reflected) as well as the losses between the DUT and tuner (energy is dissipated before reaching the tuner, lowering the amount of energy that can be reflected). Typical vales range between Γ_L=0.8 and Γ_L=0.92 at the device reference plane.

A closer examination of the formula $\Gamma_L=a_2/b_2$ reveals that there is no limitation on separating the sources of a_2 and b_2. It is obvious that b_2 is the wave coming from the device, of which we have no direct control; however a_2 need not be a reflected version of b_2 but can be a new signal entirely!

Active Load Pull

Active injection load pull, more commonly referred to as active load pull, relies on external sources to inject a signal into the output of the DUT, thereby creating a_2. Because a_2 is no longer limited to a fraction of the original reflected signal, as is the case with the

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traditional passive mechanical tuner, external amplifiers may be used to increase a_2 nearly indefinitely so that Γ_L can achieve unity (Γ_L>1 is theoretically possible but has no practical consideration).

The simple active tuning chain consists of a signal source, a variable phase shifter and a variable gain stage, shown in Figure 2. Common signal generators, such as the Agilent ESG, PSG or MXG, have built-in amplitude and phase control of the injected signal and are ideal for active load pull.

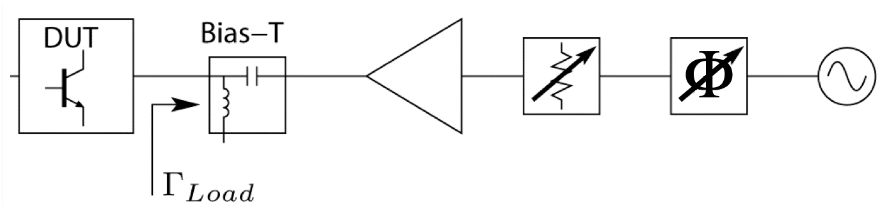

Figure 2. Open-Loop Active Tuning Block Diagram

Harmonic load pull, or tuning impedances at multiple frequencies simultaneously, becomes simple when using active load pull techniques. A multiplexer can be used to merge multiple active tuning paths, one per frequency, so that $\Gamma_{x,n}(f_n)=\dfrac{a_{x,n}(f_n)}{b_{x,n}(f_n)}$ is satisfied. Any loses inherent to multiplexers are easily overcome by the amplifiers used in each active tuning chain.

Hybrid Passive-Active Load Pull

Both traditional passive mechanical tuner systems and active injection load pull systems have their advantages and disadvantages. While mechanical tuners are simple, less expensive and can handle high power, there is no physical way to overcome the losses involved with the system that limit achievable Γ_L. While active load pull systems are extremely quick, capable of Γ_L=1 and easily integrated for harmonic measurements on-wafer, high-power setups require more-expensive band-limited amplifiers.

It is possible to obtain the advantages of both systems while minimizing the disadvantages, using a technique referred to as hybrid load pull. Hybrid load pull refers to a combination of active and passive tuning in the same system. Traditional passive mechanical tuners can be used to reflect high power at the fundamental frequency allowing a much smaller active injection signal, using much smaller amplifiers, to overcome losses and achieve Γ_L=1. Additionally, since the powers at harmonic frequencies are often well below the power of the fundamental signal, less-expensive wideband amplifiers may be used with active tuning to accomplish active harmonic load pull with Γ_L,nf=1. In both cases, only a low power is required for active tuning.

Using The PNA-X For Active Load Pull

So far, the main topic of discussion has been the creation of Γ_L, or more specifically the origin of the a_2 wave needed to achieve the desired Γ_L. The PNA-X is ideally suited to the task of both providing the required a_2 for the active load pull as well as the receivers to measure the applied and transmitted power. Key benefits of the the PNA-X in this application are: wide power range, fast and accurate control of source phase control, clean source (harmonics -55 dBc), wide frequency coverage (10 MHz to 50 GHz) and flexible test set to add external components such as amplifiers. The PNA-X monitors the tuned impedance by measuring the a_1, b_1, a_2 and b_2 waves at desired frequencies and making corrections as required. Even without tuning the source, the knowledge of a_1 and b_1 allows a calculation of the device input impedance and results in the determination of delivered power to the DUT.

In this case, the Agilent PNA-X is the ideal instrument for active load pull. It not only provides the real-time impedance monitoring by measuring the a- and b-waves, but its internal sources are used for the active signal injection.

Conclusion

Active load pull has historically been a product offered in limited release and requiring heavy support. It has been of interest to educational institutions with limited appeal in industry. After decades of minimal activity, active load pull is being revitalized and commercialized by the teams at Maury Microwave and Agilent Technologies. Together, the companies offer user-friendly, commercially-viable active load pull and hybrid load pull solutions based on Agilent's PNA-X and Maury's proven ATS software.

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