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Applications of Load-Pull Systems in Transmission Lines

In transmission systems the overall term used when describing a variation or “pulling” of the load impedance seen by a device under test (DUT) is load pull. It is used to estimate and optimize device performance in the non-linear domain such as transistors and power amplifiers. Impedance can also be varied at any of the ports of the DUT such as the source port. Load pull provides the measurement in terms of a reflection coefficient at the load port to assess performance of the device and the associated conditions to deliver that performance in a network. Load pull is required when linearity breaks down which occurs under large- signal operating conditions associated with substantial harmonic generation or other manifestations of nonlinearity. A load pull system includes an active or passive impedance tuner; the controlling mechanism to precisely set the tuner impedance to achieve desired impedance; and equipment and test set to measure the traveling waves at the input port and at the output port of the DUT. The load-pull is an effective tool in determining the optimized matching parameters for a transistor device.

The type of impedance tuner used in the load pull test setup defines the features and types of load pull. Passive load pull (passive tuner) is employed in applications requiring high speed measurements while active load pull (active tuner) is more commonly utilized in applications requiring high reflection coefficient values. When using a passive tuner the reflection coefficient is synthesized by tuning the phase and/or the amplitude. While active load pull techniques are based on signal injection at the load port of the DUT which can synthesize reflection coefficients near and on the boundary of the Smith chart therefore extremely small impedances for matching DUTs by controlling the complex gain around the active structure. The open-loop active load-pull setup requires custom algorithms to reach desired reflection coefficients making the technique effectively too slow for high measurement throughput applications. The closed loop active load pull doesn’t need convergence algorithms because any change in the signal is immediately sensed. However in the closed loop load pull technique the synthesized reflection coefficient depends on the loop parameters, such as amplifier gain, attenuator and phase-shifter values. The main drawback of this setup is the risk of oscillations that can happen since a closed loop structure is used.

Oscillations are present in the closed loop structure of the load pull system because the loop gain cannot be very selectively controlled over frequency. Incorporating a highly selective filter in the loop can mitigate the oscillation problem to some extent, although it increases the complexity and cost of the setup. One of the latest advancements is envelope load pull (form of closed loop active load pull) which overcomes the presence of oscillations since the phase and magnitude modification of the reflected wave takes place at baseband. A passive impedance tuner and active load pull called a hybrid load-pull setup is used to achieve the desired load-pull functionality essentially satisfying all the measurement needs. A λ/4 impedance transformer is incorporated in between the DUT and the tuner resulting in an enhanced tuning range which in principal is a special type of pre matched load pull system in which the pre-matching is fixed and is provided by the quarter wave transformer. The Klopfenstein transformer fills in for a λ/4 transformer in harmonic load pull applications allowing for higher bandwidth coverage between the DUT and tuner. The pre matched load pull uses two probes called pre matching and tuning that are placed side-by-side on the central conductor capable of individually generating smaller reflection coefficients which combine to achieve a higher reflection coefficient.

One advancement in load pull configurations is called the enhanced loop passive load-pull technique consisting of an impedance tuner and a passive loop cascaded together. In this technique, the passive loop first moves the matched point farther from the center and the position of probes in the impedance tuner. The impedance tuner then adds its contribution to the reflection coefficient generated by the passive loop, to synthesize the high reflection coefficient at the load reference plane.

This paper allows the material learned in the course to be seen in an applicable format outside of the classroom. The utilization of the Smith chart in a passive tuner can be seen graphically where vertical movement of the stub/slug/probe of the tuner varies the magnitude of the reflection coefficient (ΓL) and horizontal movement varies the phase of ΓL. The desired matching impedance (ZL) at the DUT port is thus obtained by physically moving the stub/slug/probe of the impedance tuner in the vertical and horizontal directions. Maury Microwave Corporation and Microwave & RFs made available simple and clear technical papers to assist in understanding some complex techniques discussed in this paper. References and additional material used for this paper and additional reading are listed below.

<http://www.maurymw.com/pdf/applib/5C-041.pdf>

<http://www.maurymw.com/pdf/applib/5A-049.pdf>

<http://mwrf.com/active-components/appraising-different-load-pull-approaches>

<http://www.ie.itcr.ac.cr/acotoc/Ingenieria/TEM%20II/Material%20Vario/Smith_Chart_Book_Complete.pdf>