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 **Applications of Load-Pull Systems in Transmission Lines**

The journal paper “Introduction to Load-Pull Systems and their Applications” by Mohammad S. Hashmi and Fadhel M. Ghannouchi is the 43rd part in a series of tutorials on instrumentation and measurements that was published in the IEEE Instrumentation & Measurement Magazine. At the beginning of the journal we can see that the use of a load-pull technique is employed to analyze and estimate the performance of transistor devices in applications where non-linear characteristics are encountered. As an example, we can use a transistor in a power amplifier in which the S-parameter characterization techniques are limited due to non-linearity.

Since the introduction of the load-pull techniques 40 years ago there have been optimization advancements of RFPAs. The idea behind the load-pull technique is to provide measurement in relation to the reflection coefficient at the load-port of devices and to systematically vary the impedance applied to the DUT in a controlled way to provide optimal performance from it. To determine the required impedance to be used the load reflection coefficient is physically changed experimentally with the following relationship:

We can see that load-pull technique is based on the reflection coefficient at the load port, and since we know that the instantaneous values of reflected voltages will be the same along a transmission line until the source or load is reached, it is then possible to use the load-pull system at any point on the transmission line, but close to the load port would be the most efficient place since at this point the system can change the load reflection coefficient more easily. This system is used to optimize the operation of the transistor when it reaches the point of non-linearity. At this point the transistor may behave erratically so the load-pull system helps to stabilize the system. If the transmission line can operate within a certain percent difference from the intended operational frequency the efficiency of the transmission line will provide higher quality and any transmitted information will have a lower chance of suffering corruption during its transmission.

In our transmission course we learned how a transmission line works and how we can find the required parameters on the Smith chart by following a specific procedure. This paper deals with techniques used to find the optimal conditions of a certain device, such as a transistor, to make the overall system more effective. This means that what I have read in this journal increases my knowledge about how RPFS and other devices that can be affected by non-linear can be optimized with load-pull techniques that implement the Smith chart to find required parameters. Now I have seen an application of the smith outside of the academic examples given in class which helps me to better understand it.

The load-pull system includes passive and active load-pull techniques in which the passive load-pull technique is “employed in applications requiring high speed measurements while the active load-pull technique is more commonly used in applications requiring high reflection coefficient values”

The main advantages of the passive load-pull technique are the rapid impedance synthesis, relatively higher power handling capability and measurements of high power devices without any non-linear effect, ease of usage, low maintenance cost, relatively low implementation cost, and the absence of any oscillation. The limitation of this technique is that it not possible to synthesize reflection coefficients that are near the edges of the Smith chart. This means that PDUs with an output of about 2 Ohms would not work to produce a synthesis of the matching impedance.

The active load-pull techniques on the other hand work with a signal insertion at the load port in an open and closed-loop system that makes it possible to “synthesize coefficients near and on the boundary of the Smith Chart”. To use the open-loop system an algorithm is required for iterative convergence in order to synthesize the desired reflection coefficients. The closed loop active technique improves the slow impedance synthesize that was seen in the active open-loop technique. In this case the load reflection coefficient depends on the values of the loop, such as the attenuator and amplifier gain. The drawback of this system is the possibility of oscillations due to the required high gain and high linearity in the feedback loop. With a more selective filter it is possible to reduce the oscillation considerably, but the system becomes more complex and therefor more expensive.

A new technique to improve the passive load-pull system is called “pre-matched load pull” in which two probes can generate smaller reflection coefficients and .

These can be combined to produce the following:

The pre-matching probe changes the matched impedance of 50 Ohms to another area of the Smith Chart, which defines the pre-matching probe’s reflection coefficient. The limit of this pre-matched technique is 1 Ohms due to the loss inserted by adapters and the “associated fixture hosting the DUT.”

When the active and passive are used together the name hybrid load pull is used. In this case the desired load-pull functionality is achieved and all the measurements can be satisfied.

As I mentioned before, oscillations in a closed-loop system are prone to have oscillations problems due to the feedback in which high gain is implemented. The recent advancement of the Envelope load-pull (closed-loop) overcomes the problems with undesired oscillations

The other recent advancement is called the Enhanced loop passive load-pull technique in which an impedance tuner and a passive loop are cascaded together. The passive loop moves away from the 50 Ohm by gamma load and then to synthesize the high reflection coefficient at the load reference plane, the impedance tuner adds its own contribution to the reflection coefficient generated by the passive loop.

In conclusion, the load pull is a very important technique that is used to improve the stability of devices when they have to be used in the non-linear characteristic region. In new advancements such as the Envelope load-pull were mentioned along with several other techniques that are used to improve the efficiency of transmission systems.

**Additional Load-Pull System Reference:**

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

**Additional Smith Chart Reading:**

[**Electronic Applications of the Smith Chart : In Waveguide, Circuit, and Component Analysis**](http://sss-mag.com/sales.html#2002001), by Phillip H. Smith. Hardcover - 263 pages 2nd edition (October 2000).