Active load pull measurement setup

The load pull measurement setup developed by MC2-Technologies is based on the Agilent PNA-X N5245A. The minimum options required for the vector network analyzer are:

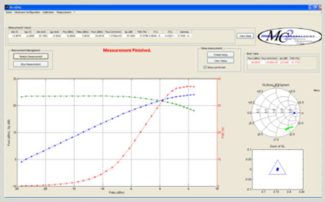
Reference	Description
N5245A	VNA PNA-X 10MHz-50GHz
N5245A-400	4 ports, dual source
N5245A-423	4 ports, add internal combiner and mechanical switches
N5245A-510	Nonlinear component characterization**
N5245A-514	Nonlinear X-parameters**
N5245A-080	Frequency offset
N5245A-H08	Pulse measurements
N5245A-021	Add pulse modulator to internal 1st source
N5245A-022	Add pulse modulator to internal 2nd source
N5245A-025	Add four internal pulse generator

** Option requirement on the VNA if the option “X-parameters measurement ref S ALP XP-2010RA” is selected.

One needs a power measurement probe with USB or GPIB interface and working within the frequency range needed for the application. This probe is required during the setup calibration step. The power supply for biasing the devices under test is also needed and a coaxial calibration tool like the Ecal systems from Agilent as well. If the X-parameters versus Z_L option is selected, the VNA must have the option X-parameters. Agilent supply the phase reference with the option.

Product description

This product is an active load pull measurement setup based on the PNAX N5245A from Agilent devoted for power devices non-linear



Key Features

- Full automated active load pull
- User friendly
- Batch compatible for successive measurement
- Smart impedance convergence
- Pulsed load pull compatible
- Flexible pulsed time windows adjustment
- Load pull measurement up to 20W
- X-parameters measurement
- Damage prevention automatically managed by software

characterization such as field effect and bipolar transistors. This product is separated in two main parts:

- The software which drives all the measurement system acquires data and takes in charge data processing and rendering.
- The hardware part composed by the test set H-ALP-0820-TS-2010RA (or H-ALP-0220-TS-2010RA depending on options selected) compatible with the VNA N5245A or N5242A and finally several power amplifiers and coaxial cables.

Associated equipment description

The equipment is composed by the test set working within the frequency range 8-20GHz (or 2-20GHz following the option) delivering 20W average output power or 30W peak power within pulsed configuration (depending of the duty cycle and the pulse width). This test set allows the incident and reflected wave measurement (a1, a2, b1, b2) at the device under test (DUT) input and output. These waves are measured by the VNA's receivers located in front panel. We have designed the measurement system in such a way that the VNA is protected against breakdown especially when the maximum available power is required. The measurement system has been designed with coaxial 2.92mm connectors and can also protect the VNA up to 200W available at the DUT input and 1kW at the output.

By default the maximum power available at the DUT input is 5dBm (test set losses included). The option H-PA-022001W allows 20dBm as **minimum** power available within the frequency range 2-20 GHz. In order to synthetize output impedance with a minimum reflexion coefficient of 0.7 when the DUT is delivering 20W at least, one has to use a power amplifier to amplify the a2 wave injected at the DUT output. This amplifier must deliver at least 20W associated with 30dB gain within the working frequency. MC2-Technologies can supply those amplifiers as options (H-PA-020620W) delivering 20W associated with 35dB gain within the frequency range 2-6GHz and the option (H-PA-061820W) have the same characteristics but within the frequency range 6-18GHz. The coaxial cables 2.92mm and 2.4mm for connecting the test set to the VNA are supplied by default.

Software description

Standard configuration S-ALP-CW-2010RA

This software is devoted to power measurement using the test set developed by MC2-Technologies combined with the VNA PNA-X from Agilent. During the calibration step or measurement procedure, the user is assisted by the software making the use easier. Indeed the software pops up windows when critical step or values are reached to avoid any material breakdown. The software also manages the VNA configuration. The software has a user friendly interface and three kind of power measurement can be carried out:

- Scattering parameters within small or large signal configuration
- Power characterization with fixed impedance Pout=f(Pin)
- Optimal impedance circle measurement at fixed injected power with PAE (Power added Efficiency), Power gain, Output power, gate or drain current measurement.

Calibration

Before carrying out measurement, the load pull system has to be calibrated. This calibration is done with several steps requiring roughly between 5 and 10 minutes and this time is independent from the frequency point numbers. The software saves data's for each calibration and measurement step:

- Save step by step during the calibration procedure
- Global save of the whole system including the configuration and so on.

The calibration data's can be imported in such a way that the user does not have to re calibrate the system.

Small or large signal scattering parameters

The DUT S_{ij} parameters can be measured within the same frequency range as the one done during the load pull system calibration. The user set the DUT input power and the bias point. The software automatically set a current limitation for safety purpose and avoids DUT damages. The test set developed within this solution allows large signal S_{ij} parameters measurement (hot S_{ij})

Power characterization with fixed impedance Pout=f(Pin)

During this procedure, the system measures the output power delivered by the DUT when the input power varies with a fixed impedance synthetized at the DUT output. The user can define the convergence accuracy with impedance and injected power adjustment. You can also set the biasing conditions, current and power compliance. If these limitations are reached, the power measurement is stopped with a dedicated and safe procedure to avoid any damages.

Furthermore for damage preventing purpose the software manage the power delivered at the DUT input to avoid damages by injecting higher power than allowed by the DUT:

- Incrementing the input power to reach the compression level defined
- Incrementing the input power to reach the maximum PAE defined

The impedance load can be managed in several ways:

- The impedance is manually set
- If the S_{ij} parameters for the DUT have been measured before, the measurement file is automatically imported to set the optimum load impedance
- Circle measurement with fixed injected power the optimal impedance can be automatically defined.

Circle at fixed injected power

This procedure enables the DUT characterization with varying the load impedance but at fixed input power. The software set the frequency, the input injected power, the starting impedance value, the

back off value regarding output power one and the maximum impedance modulus value. The load convergence accuracy can be managed by the software. Biasing conditions, the current and power limitation can also been set by the user. These different limitations define the load impedance areas the system is able to synthetize. Thus if one limitation reached the system exclude the smith area inducing this limitation and won't synthetize this impedance anymore. The risk areas are constantly calculated by the software to avoid DUT damages.

The first load impedance can be set with two ways:

- The impedance is manually adjusted
- The DUT S_{ij} parameters have been previously measured, the measurement files is automatically loaded

The injected power delivered at the DUT input can be set with three different ways:

- The value is manually set
- The power level can be determined for a compression level if a Pout=f(Pin) measurement have been previously carried out.
- The power can be set regarding a ratio between the PAE measured and the maximum PAE value if a Pout=f(Pin) measurement have been previously carried out

The impedance management can be carried out in two different ways:

- The "quick way ": this method induces from the beginning the way the phase is adjusted to reach the optimum load impedance. Nevertheless some load impedance can lead to instability or dangerous areas (ie S_{11}>1 or too high current).
- The "direct way" method which favours one direction for the phase adjustment and these one is always redefined during measurement. This method allows reaching the optimum load impedance value with a straight forward way minimizing critical impedance probability.

Using Batch function for multiple successive measurement

The user can program a measurement list with different configuration which will be successively executed. This allows, for example, the S_{ij} measurement, then Pout=f(Pin) and / or circles at fixed injected power for different biasing conditions. This ability allows the software to use previous measurement results to set the next ones. Each measurement are therefore stored in different format (mdf, txt, xls) defined initially by the user. One should also note that the mdf files generated by the software can be directly imported into ADS.

Pulsed measurement option (Ref S-ALP-P-2010RA)

This option is devoted to the large signal measurement in a pulsed way. This one requires the pulsed "narrow band" option on the PNA-X. The software automatically set the VNA configuration thanks to its user friendly interface. The setup includes:

- Width and temporal position of the acquisition window on the dedicated receiver for the a1 wave.
- Width and temporal position of the acquisition window on the dedicated receiver for the b1 wave.

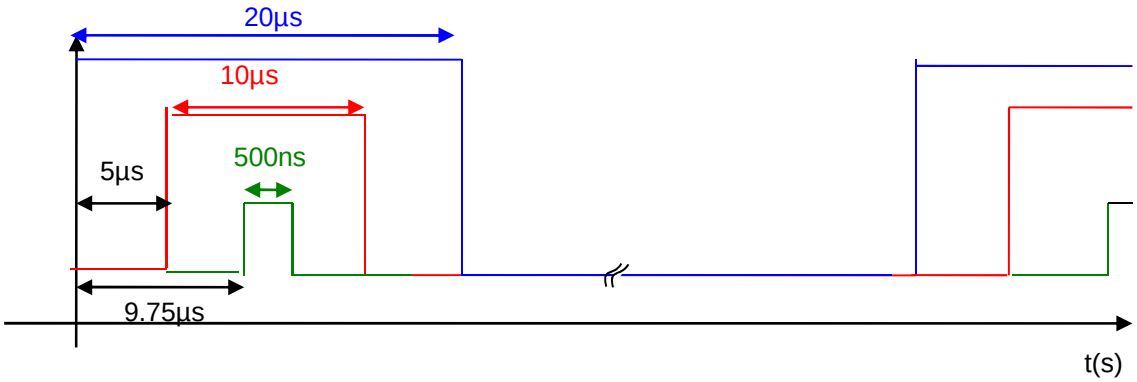
- Width and temporal position of the acquisition window on the dedicated receiver for the a2 wave.
- Width and temporal position of the acquisition window on the dedicated receiver for the b2 wave.
- Width, duty cycle and signal temporal position for the port 1 and 2

Furthermore, one (or several) of the four internal pulse generator can be used to synchronize external pulse generators (not supplied) devoted for the DC and pulsed biasing. By adjusting very easily the delay and pulse width, the user can manage the temporal position of the DC and RF pulses. The interface allows the user to graphically set the pulses timing using an oscilloscope combined with a quadratic detector (not supplied by default).

Configuration example

- The internal pulse generator N°1 is used for the RF modulation generated by the sources 1 and 2.
- The internal pulse generator N°2 is used for timed windows configuration. Therefore all windows will have the same width
- The internal pulse generator N°3 is used to synchronize external pulses generator for biasing the DUT
- The user sets:
    - 1% duty cycle, 10µs pulse width and 5µs delay
    - The time window has 500ns width and 9.75µs delay
    - The DC pulse generators have 20µs width with no delay.

Assuming the user has done previously done the synchronization between all internal pulse generators, the signals diagram is presented bellow:



In this example, the acquisition window is centred within RF impulsion, which is itself within DC biasing pulse. Obviously the user can shift as he wants both the RF pulse compared to the DC ones and the acquisition windows compared to the RF pulse. For example one can study the DUT performances regarding the acquisition time window position compared to the RF pulse or study thermal and traps effects. This option is also compatible with the batch abilities of the software. Therefore one can set a batch with different pulse configurations.

2F0 and 3F0 measurement option (Ref S-ALP-MT-2010RA)

This option allows the load impedance at 2F0 and 3FO measurement. These information's can be very important for validating the nonlinear model accuracy.

Current measurement with multiple reference (Ref S-ALP-MI-2010RA)

If the DUT is composed of several stages, the software can measure the current consumption for each stage. The measurement is carried out thanks to several multimeters driven by GPIB interface. The user can therefore set different compliance values for each stage. The multimeters are not supplied by default.

X-Parameters measurement reference option (ref S-ALP-XP-2010RA)

This option allows DUT X parameters measurement when the output load is not 50 Ohms and when the DUT is working in nonlinear regime. The results recorded by the software can be directly imported into ADS for nonlinear modelling purpose.