

## Extension kit for R&S Vector Network Analysers Characterisation of Nonlinear RF/HF Components in Time and Frequency domain from 20 MHz to 24 GHz



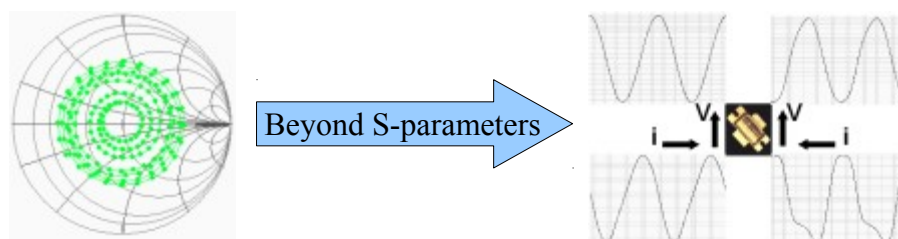
ZVxPlus: NMDG NM310 and R&S ZVA

- Extension Kit for Rohde&Schwarz VNA
  - ZVA and ZVT models
- Aimed at nonlinear harmonic behaviour
- Time Domain Characterisation
- Harmonic Characterisation including Phase
- Non-50 Ohm Characterisation
- Enables Fundamental and Harmonic Tuning
- Customisation for power applications

### Introduction

The linear behaviour of RF/HF components like filters, interconnects and transistors under small-signal operation is completely characterised by S-parameters, measured using a vector network analyser (VNA). Over time, VNAs evolved from single-ended two-port instruments to multi-port instruments to handle differential linear devices.

Triggered by the growing need for better insight in the nonlinear behaviour of components, VNA manufacturers are adding some “nonlinear” features to some of their models. These competitive features include AM-to-AM, AM-to-PM, harmonic power measurements and mixer characterisation. Unfortunately, these features characterise the nonlinear behaviour only partially.



Full harmonic characterisation of nonlinear RF / HF components

Complete harmonic characterisation of high-frequency components from 20MHz up to 24 GHz is now possible thanks to the NM310 extension kit from NMDG. The NM310 is a combination of additional hardware and software that runs on top of a selection of Rohde&Schwarz ZVA and ZVT vector network analysers. The combination of the ZVx and the NM310 extension kit is referred to as “ZVxPlus”.

As known, the network analyser reveals the linear behaviour of components through its S-parameters. But thanks to the ZVxPlus, the network analyser now also reveals the nonlinear behaviour of a device. One can actually observe the voltage and current swings occurring at the device, possibly in an non-50 Ohm environment.

### The key benefits of the ZVxPlus

- **ONE CONNECTION** from small-signal to large-signal HF characterisation
- Reliability testing of semiconductors under CW and pulsed HF conditions
- Certified quality of large-signal transistor models and design kits
- Improved large-signal models
- Better and faster amplifier characterisation and design
- **Fast and complete** test capability, even in non-50 Ohm environment
- New insight in diodes, transistors, amplifiers, multipliers and dividers
- Customisation by experts to meet the need of the customer

Using realistic large-signal measurements, the ZVxPlus allows to verify and improve transistor models extracted with the same network analyser from small-signal to large-signal conditions. It allows to optimise and validate the biasing and matching conditions of transistors by looking at the actual voltage and current behaviour. It allows to verify the reliability of new semiconductor processing technologies. With this new measurement capability, semiconductor processes will be improved, designs can progress faster and possibly new types of faster tests could result.

Amongst others, the ZVxPlus is very suitable to characterise diodes, transistors, power amplifiers, multipliers, dividers and fast switching devices.

### The key capabilities of the ZVxPlus

- **Incident and reflected waves** at input and output port under CW and pulsed excitation:
  - in frequency domain, fundamental and harmonics in amplitude and phase
  - in time domain, incident and reflected waveforms
- **Voltages and currents** at input and output port under CW and pulsed excitation:
  - in frequency domain, fundamental and harmonics in amplitude and phase
  - in time domain, voltage and current waveforms
- Realistic non-50 Ohm conditions, at fundamental and harmonics
- Connectorised and **on-wafer** calibration and measurement
- Overrange detection and **autoranging capability**
- **3D dynamic trajectories**, mapping DC and HF conditions
- Derived measurement quantities, e.g. input and output powers, gain, PAE, input and output impedances at fundamental and harmonics
- Integration with Source – and Load-pull: fundamental and harmonic tuning

On top of the standard measurement capabilities of the R&S VNA, the ZVxPlus provides calibrated measurement capability of the time waveforms of the incident and reflected waves or voltages and currents at the ports of a component under test. The time waveforms are periodical with a minimal frequency of 20 MHz and with spectral components up to 24 GHz.

These measurements can be performed under realistic conditions, including non-50 Ohm environment using passive or active tuners.

The product supports a frequency range from 20 MHz up to 24 GHz, limited by the frequency range of the selected network analyser.

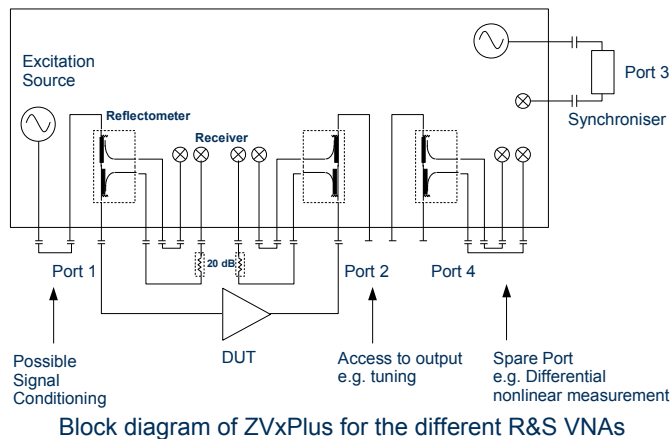
Unless customised, the power is limited by the power limitations of the R&S VNA. Using attenuators with the device under test and/or fixed attenuators in the mixer channels, the power capability can be extended.

By customisation of the test set, NM310 supports measurements requiring power beyond the power capability of the test set, provided by the VNA.

## ZVxPlus, based on R&S ZVA and ZVT

Presently the NM310 kit is available on top of the 4-port R&S@ZVA8/24/40/50/67 and on top of the R&S@ZVT8/20 (at least 3 ports), with the following options:

- Direct generator/receiver Access option (R&S@ZVAXx-B16 or R&S@ZVTxx-B16)
- Frequency conversion option (R&S@ZVA-K4)
- Optional: step attenuator option for measurement receivers at Port 1 and Port 2, allowing automatic range adaptation (R&S@ZVAXx-B31 and -B32 or R&S@ZVT20-B32)



### The kit consists of:

- Two NM211 Comb Generators (20MHz - 24 GHz); one is used as synchroniser enabling the reconstruction of time waveforms, the other one is used as Harmonic Phase Reference (HPR) supporting the required phase calibration
- NM311 3.5mm connection kit, including cables and adapters
- A license for ICE, an easy-to-use software for nonlinear HF component characterisation, supporting system configuration, absolute calibration and measurement

An 2.4mm to 3.5mm adapter kit (NM310-10) is offered for the R&S@ZVA50/67. Moreover, when the step attenuator option on Port 1 (option B31) and/or Port 2 (option B32) is missing, one needs to put external attenuators in front of the corresponding measurement receiver. Attenuator and adapter kits (NM310-xx) are then offered per port, depending on the selected VNA and the desired frequency range.

### The user needs to provide:

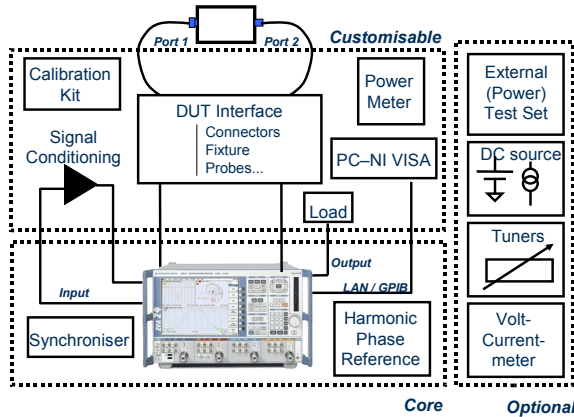
- A power meter (and sensor) in order to perform the required power calibration
- A standard calibration kit, consisting of a short, open and load, used for the relative calibration (alternatively R&S calibration unit can be used for connectorized setup)

In addition, an external high-resolution screen is advised to display the rich nonlinear information.

The ZVxPlus comes with NMDG's software package, ICE (Integrated Component Characterisation Environment). ICE is a software package that supports the complete nonlinear characterisation of components under realistic conditions with almost real-time feedback. This package allows to combine different instruments and equipments, enabling realistic stimuli – response measurements.

ICE runs on a desktop, a laptop or on the selected network analyser. Running on a desktop or laptop, external instruments can be controlled via standard GPIB. Running on the selected network analyser, external instruments are controlled via the LAN, USB or optional GPIB connection of the network analyser. Thanks to the open system approach of ICE, the system can easily be extended from a basic component characterisation system to an advanced characterisation system.

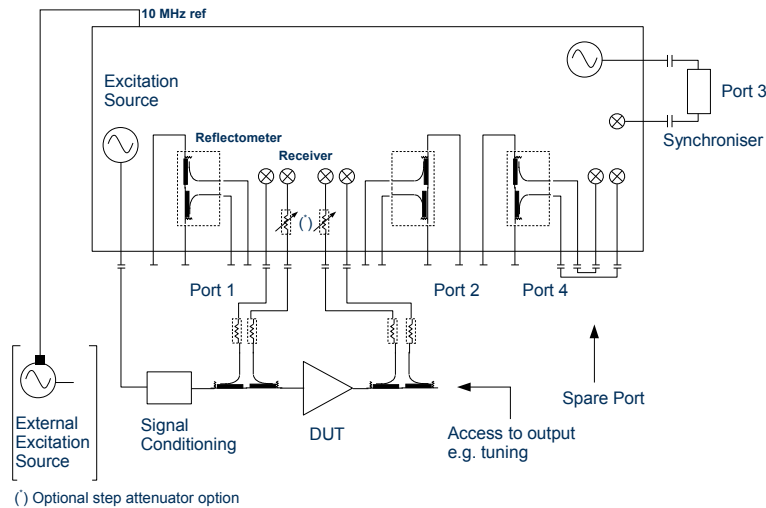
### Customisation of the ZVxPlus



Configuration and customisation of ZVxPlus (ZVA 24 as example)

In contrast to straightforward linear S-parameter measurements, a nonlinear device under test must be characterised under almost realistic conditions. Depending on applications, these conditions are different. Therefore, setups to characterise nonlinearities require often customisation.

Based on a long term experience and relying on the flexible ICE, NMDG offers customisation on top of the ZVxPlus to adapt it to customer needs and to link it into the customers process.



( ) Optional step attenuator option  
Extending power capability with external test set.

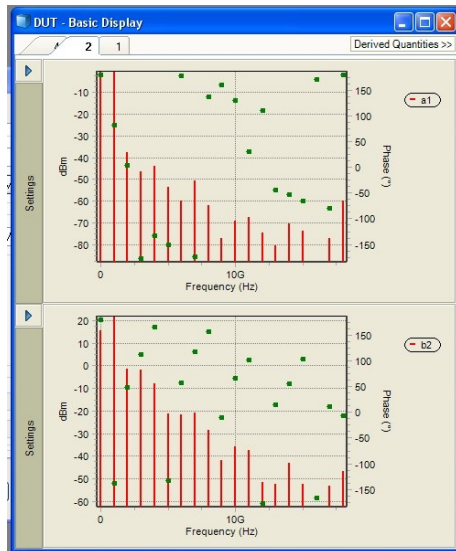
The standard ZVxPlus is limited in power capability. Using an external test set with proper coupling and attenuation, the ZVxPlus can be extended in power range. Moreover, the internal source power range can be extended using proper signal conditioning. Using passive tuner technology or using fundamental and/or harmonic active tuning techniques, it is possible to study the behaviour of the component in a non-50 Ohm environment.

## Data Displays

With an easy-to-use graphical user interface, the user configures and calibrates the system to perform accurate harmonic measurements. Measurement data can be saved in different data formats.

The data, i.e. incident and reflected waves or voltages and currents at the ports of a device under test, can be visualised in different ways.

### Spectral data in frequency domain



Amplitude and phase of incident and transmitted waves in frequency domain

Similar to a spectrum analyser, the ZVxPlus allows to visualise the spectral data of the measured quantities in frequency domain.

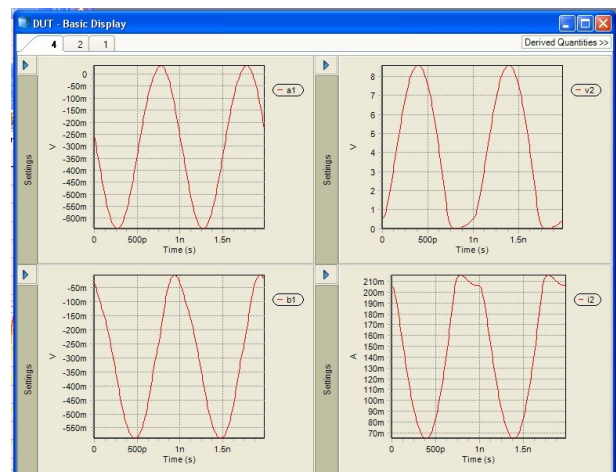
The unique feature is that the spectral data includes calibrated phase information.

### Time-domain waveforms

An oscilloscope is an indispensable tool on the lab bench to probe signals and to diagnose the proper behaviour of circuits. For analogue circuits and components operating at an ever increasing signal frequency and information density, voltage information only is not enough. The advantages of using vector network analysers instead of oscilloscopes have clearly been proven for linear RF and HF applications. The ZVxPlus provides the same advantage for nonlinear RF and HF applications.

Using the ZVxPlus, one can accurately measure and observe the voltage and current behaviour of a component or circuit interacting with its environment. The ZVxPlus is a powerful diagnostics tool.

These measurements are also directly comparable to the voltage and current probes that one commonly uses in simulators to understand what is going on.

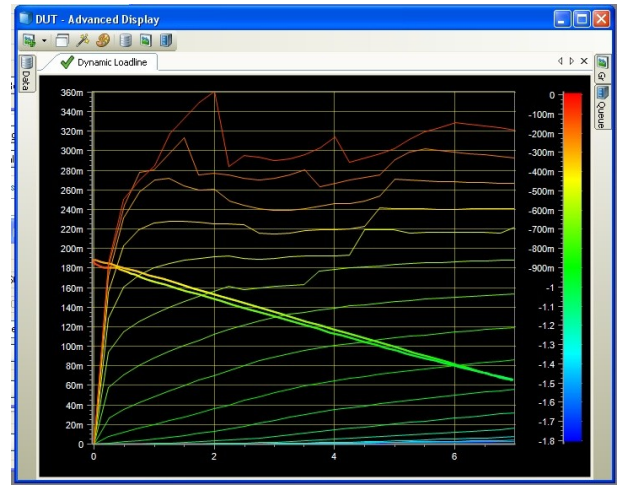


Time domain waveforms (from top to bottom, left to right: incident wave at input, reflected wave at input, output voltage, output current)

### 3D dynamic trajectories

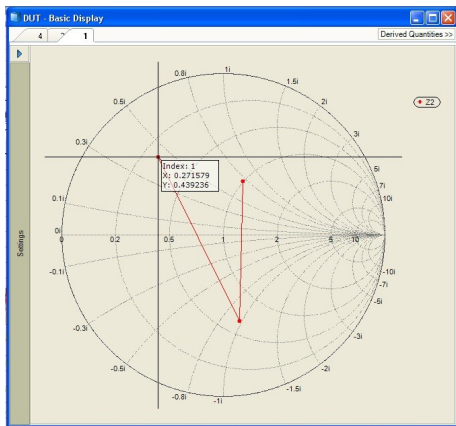
By combining the measured quantities, it is now possible to visualise, almost in real-time, different dynamic trajectories such as the output current waveform versus output voltage waveform, i.e. the dynamic loadline, on top of DC output characteristics of the device under test.

Furthermore, as both quantities at input and output of the device are measured simultaneously, the ZVxPlus allows to map, for example, the dynamic excursion of the gate voltage to the static gate voltage, using gradient colours. Different phenomena such as trapping and memory effects or delay between input and output can now be visualised in real-time.



3D dynamic loadline

### Input and output impedances on Smith Chart



Output impedances with open termination at fundamental, second and third harmonics

Using measured incident and reflected waves, it is possible to calculate and visualise the impedances at DUT input and the output impedances presented at output of the device, at fundamental and harmonics on Smith Chart representations.

### Derived quantities

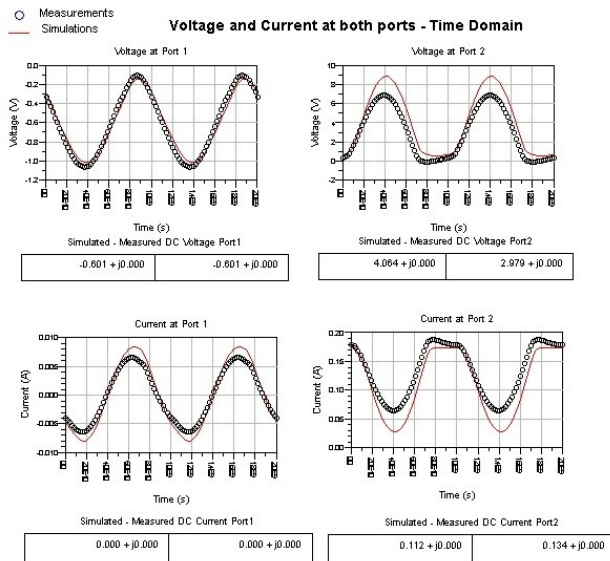
Thanks to the measurement of the basic quantities, one can easily calculate derived quantities such as gain, delivered input and output powers, efficiency and power added efficiency.

Settings - 1GHz		
Quantity	Value	Unit
Gain(f)	22.80541	dB
PAE	42.98027	%
Efficiency	43.07371	%
Pdel_in(f)	-3.06488	dBm
Pdel_out(f)	23.53832	dBm

Derived quantities

## Some Applications

### Model verification and tuning



Comparison of measured and simulated voltage and current waveforms

State-of-the-art model verification consists of confronting source-pull and load-pull measurements to simulations. Unfortunately, derived quantities like available power, TOI and SOI are used and these can agree, even when the model is not predicting the voltage and current behaviour properly.

With ZVxPlus, a transistor model can now be verified at the level of the mathematical formalism. The ZVxPlus confronts measured voltage-current behaviour to simulated voltage-current behaviour. These are the essential quantities.

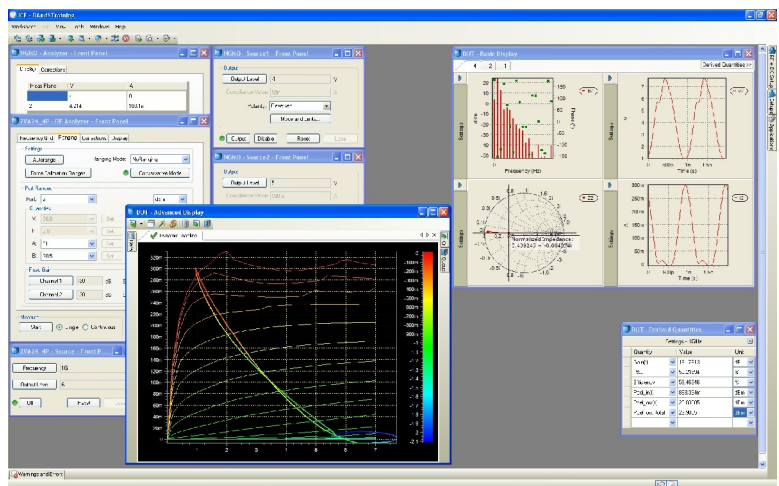
In order to enhance the agreement, it is possible to tune the model parameters. This tuning becomes much easier by confronting the basic quantities instead of using derived quantities.

### “On the fly” amplifier design

It is possible to perform measurements in a non-50 Ohm environment by combining the ZVxPlus with tuning technology. Due to the access to the input and output port, fundamental and harmonic active tuning is possible (see block diagram). Once the system is calibrated, one can modify the setup at these ports without invalidating the calibration.

Thanks to the ZVxPlus it is now possible to match transistors at both fundamental and harmonics to optimise their performance based on instantaneous feedback provided by the voltage and current waveform measurements.

The observed waveforms can immediately be compared with the optimal waveforms, described in the textbooks for different modes of operation of amplifiers.



Amplifier set in class AB operation optimising fundamental and 2<sup>nd</sup> harmonic terminations. Direct visualisation of transmitted wave, output impedances, output voltage and current waveforms, derived quantities and dynamic loadline.

## Order information

Designation	Type	Order number
20MHz-24GHz ZVxPlus Kit	NMDG NM310	NM310
2.4mm Adapter Option for NM311 on ZVA50/67	NMDG NM310-10	NM310-10
20GHz Attenuator Option per port for ZVT8/20 ZVA8/24	NMDG NM310-20	NM310-20
20GHz Attenuator Option per port for ZVA40	NMDG NM310-40A	NM310-40A
20GHz Attenuator Option per port for ZVA50	NMDG NM310-50A	NM310-50A
20GHz Attenuator Option per port for ZVA67	NMDG NM310-67A	NM310-67A
40GHz Attenuator Option per port for ZVA40	NMDG NM310-40B	NM310-40B
50GHz Attenuator Option per port for ZVA50	NMDG NM310-50B	NM310-50B
50GHz Attenuator Option per port for ZVA67	NMDG NM310-67B	NM310-67B
20MHz – 24GHz Comb Generator Synchroniser/HPR	NMDG NM211	NM211
3.5mm Connection Kit	NMDG NM311	NM311
2.4mm Adapter Kit for NM311 on ZVA50/67	NMDG NM311A	NM311A
20GHz Attenuator Kit for ZVT8/20 ZVA8/24/40/50/67	NMDG NM302	NM302
2.4mm Adapter Kit for NM302 on ZVA50/67	NMDG NM302A	NM302A
40 GHz Attenuator Kit for ZVA40	NMDG NM304	NM304
50 GHz Attenuator Kit for ZVA50/67	NMDG NM305	NM305

## More information

Rohde&Schwarz VNA

[www.rohde-schwarz.com](http://www.rohde-schwarz.com)

ZVxPlus, NM310 and other products and services, focusing on nonlinear RF and HF characterisation, behavioural modelling and test:



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May 2011 - Product description and specification are subject to change without notice.