70 kHz to 220 GHz Single Sweep VNA Measurements Utilizing Nonlinear Transmission Line Technology

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Agenda

• Motivation
• Broadband technology
• 220 GHz connections
• 220 GHz power calibrations
• 220 GHz on-wafer probing
• System performance
VNA Configurations

- 20 GHz VNA
- 40 GHz VNA
- 70 GHz VNA
- 110 GHz VNA
- 125 GHz VNA
- 145 GHz VNA
- 220 GHz VNA

RF freq Option

2&4 port Baseband Units
2&4 port Broadband Units
mmWave Systems

mmWave Waveguide Modules
• New communication systems migrating well into the mmWave bands
• 3\textsuperscript{rd} harmonic of 60 GHz is 180 GHz. 5\textsuperscript{th} harmonic of 38 GHz is 190 GHz.
• Accurate device characterization (inductors, capacitors, resistors, etc.) needs to sweep from near-DC to well beyond the harmonic frequencies in order to provide accurate models.
• Radical new wafer processes taking place
• Broadband VNA measurements perform device characterization and sub-system verification during new product design development.
Device Characterization: Turning S-parameters into extracted parameters

- Devices such as capacitors and inductors need characterization beyond fundamental operating range for accurate circuit simulation and performance.
Device Characterization: Turning S-parameters into extracted parameters

- Typical applications need characterization well above 70 GHz baseband VNAs. Characterization to the 2\textsuperscript{nd}, 3\textsuperscript{rd} and even 5\textsuperscript{th} harmonic ideal.
Broadband Device Characterization for Accurate Models

Example 1: Stability issues

- We can observe certain behavior of amplifiers, not explained by perfectly fitted models up to 110 GHz.
- Predicting stability right is highly depending on an accurate isolation and phase description by the transistor model.

*Blue and black lines predict amplifier stability based on S-parameter data taken up to 110 GHz.*

*Green lines are actual stability performance.*

Excerpted from EuMW 2017

Looking again on Example 1: Stability issues

- Extended frequency rare model can predict stability issues right.
- Model extraction at frequencies > 110 GHz necessary for precise transistor descriptions.
- Having this model in advance would have saved one design iteration!

Value of extreme broadband sweeps!

- Red line stability prediction based on S-parameter measurements to 450 GHz.
- Green lines are actual stability performance.
Broadband Measurements to 220 GHz

- VectorStar with broadband options
- mmWave test set
- Non-linear Transmission Line modules to 226 GHz
- 220 GHz MPI probes
Non-linear Transmission Line (NLTL) technology provides excellent conversion efficiency and noise floor performance for optimum system dynamic range at mmWave frequencies in a small, tightly integrated package for stability and performance.

New NLTL module adds a source band for frequencies 140 – 226 GHz.

NLTL harmonic sampler converts test and reference signals to IF from 30 GHz to 226 GHz and located close to the DUT port.

Electronic ALC control provides up to 50 dB of power level control.
UG-387 flange provides alignment for 0.6mm coaxial male/female pin connection

- Unique module interface provides a direct to probe connection eliminating the need for a 0.6 mm threaded connector.
Broadband Measurements to 220 GHz

Slot-less 0.6mm female center conductor

Slotted 0.6mm male pin center conductor
Broadband Measurements to 220 GHz

- Miniature mmWave module connects directly to probes without cables for best dynamic range and stability.
- Probes available in 50, 75, and 100 um pitch.
- Probes are field replaceable.
- Calibration substrates support LRM, ALRM, TRL and multiline TRL.
An important attribute for probes is providing good visibility during touchdowns.

Good visibility means accurate repeatable touchdowns reducing the need for multiple repeat landings, longer life on calibration substrates and DUT pads, and reduced risk of ‘over-skate’.
Broadband Power Calibration to 220 GHz

- Power calibration flattens power level variations to the DUT input
- Also provides absolute power reference
Broadband Power Calibration to 220 GHz

- Factory power calibration performed at the module port.
- For many situations power level variations and accuracy may be adequate using factory calibration since no additional cables are required.
Broadband Power Calibration to 220 GHz

- Perform coaxial power calibration up to 70 GHz or 110 GHz depending on sensor
• Perform waveguide power calibrations with a WR06 and WR05 power sensor up to 220 GHz.
Broadband Power Calibration to 220 GHz

- Network extractions available in power calibration menu.
- De-embed adapters using s2p files
• Embed the probe using supplied s2p file
• Network extraction positions power calibration to the end of the probe tip
• Power applied to DUT port is now leveled and accurate
Broadband VNA Measurements to 220 GHz

• Coaxial and waveguide adapters available to support alternative interface options.
• NLTL module can be calibrated in 1mm coax, 0.8mm coax, WR06 waveguide and WR05 waveguide.
• Full band calibration available at the probe using a calibration substrate and LRM, ALRM or multiline TRL algorithms.
NLTL module offers excellent mmWave noise floor receiver sensitivity (-119 to -104 dBm) for wide dynamic range performance.
Tightly integrated NLTL modules continue to offer excellent stability.