

Notes from the NVNA Users' Forum, November 29, 2006

The Fall version of the ARFTG NVNA Users' Forum, took place from 5 to 7 p.m. at the Omni Interlocken Hotel in Broomfield, Colorado. Organizers were Kate Remley from NIST, Dominique Schreurs from K.U. Leuven, and John Wood from Freescale.

The 20 participants introduced themselves and their connection with Nonlinear Vector Network Analyzer measurements, and then the group started on Discussion topic 1, moderated by Kate Remley, with notes by John Wood:

“Signal measurement and network analysis: When to use which?”

Is the LSNA a "Signal Analyzer" or a "Network Analyzer"?

The LSNA measures a and b waves, from which the large-signal V & I can be determined; the VSA measures voltage only - the current is not measured, but a 50 ohm system is assumed. Further, the LSNA (VNA) requires periodic signals, which are measured in a narrow bandwidth, whereas the VSA is used for wide bandwidth measurement of non-periodic signals.

From the above it would seem fairly clear...

One participant commented that in cascaded amplifier networks the input nonlinearity can be significant, meaning that the input is not 50 ohm, at fundamental or harmonics. In such a non-50 ohm network, the LSNA can measure the forward and backward waves, and describe the nonlinearity, but the Signal analyzer assumes 50 ohm input and the input nonlinearity is not captured.

A participant made the observation that the Network Analyzer/LSNA has limited options or signals that it can measure, but a Signal Analyzer or Oscilloscope is a more general purpose test instrument. Someone else pointed out that LSNA can act as a Signal Analyzer, provided the modulation is periodic

Another member observed that that basic receiver in both the Network Analyzer/LSNA and high speed oscilloscope is essentially the same - typically a high-speed sampler, with couplers, an IF bandwidth usually defined digitally by the ADC, and a local clock or trigger signal -the LSNA has a phase-locked clock. The main differences are in the details and what signals and DUTS are used. For precision metrology - use a VNA; but for more qualitative measures, or when the signal is not "NICE", use a VSA.

If the measurements are for device characterization, use the VNA/LSNA; for measuring the performance of a finished PA, use the VSA.

Digital oscilloscopes are typically of limited resolution - often only an 8-bit ADC(IF). This limits the number of degrees of freedom and accuracy that you

have. One member stated that scopes only have a high-impedance input, and hence are not accurate. Another member pointed out that in fact, many of the high-end DSOs have a 50-ohm input: so why are they not calibrated like a VNA?

One participant stated that his company uses GSG probes and a $50 + j0$ load - a microwave measurement - to estimate the DSO-probe calibration. Several circuit examples need to be measured to ensure repeatability (of probe position). This is (admittedly) not a truly precision measurement.

Someone else pointed out that the VNA used calibration to provide a systematic error correction, something that is absent in the signal analyzer.

One member commented that members of the oscilloscope community are aware of the corrections that are made at microwave frequencies, but struggle to accommodate this error correction and keep their simple measurement paradigm.

A participant commented on the lack of a nonlinear transfer standard that could be used to assess the nonlinearities in the receiver. In the VSA there are mismatch issues that complicate this (see the comment above). He asked if a simple diode could be used as such as standard? After some discussion, the answer is "no" - it cannot be compared to the linear case.

One researcher remarked on the NIST work on superconducting transmission lines that can be described by two parameters and have predictable nonlinearity. Fitting them in the little wooden box and shipping as a nonlinear calibration kit is, however, some ways off.

Ph.D. Research Report and Discussion

Maciej Myslinski, K.U. Leuven and recipient of the ARFTG Student Fellowship Award (*See attached file [PhD_myslinski.pdf](#)*)

This was a report of work being carried out in collaboration with NIST to investigate the use of an LSNA to validate behavioural model accuracy. Several problem areas were outlined. These included the difficulty of using a modulated signal with an LSNA; comparison with a VSA was made difficult by the choice of DUT, whose tuned frequency of operation was beyond the frequency limit of the VSA. This necessitated the use of a tunable receiver/down-converter to test the signal. The nonlinearities in the frequency transfer need to be determined and calibrated: the nonlinearities in the tunable receiver are particularly difficult to assess and accommodate, so it is difficult to say for certain whether the lack of flatness of response is due to the RF amp under test, or the receiver input.

Comments from participant included validating the LSNA with the VSA in a 50 ohm environment (although this does not overcome the frequency limitation of the VSA); using pads/isolators/circulators to eliminate reflections and further

mixing of nonlinear components; calibration of the IF bandwidth; and some interesting comments regarding the linearity of the ESG source used to generate the multisine signals used for the behavioural model generation and the validation: as two similar but different signal classes were used, it is not possible to eliminate this source of nonlinearity from the experiment.

Further comments were made regarding the traceability of the LSNA calibration: The LSNA is calibrated in small-signal, with S-parameters (like a VNA), for absolute power, and for phase across frequency - these latter two being one-port measurements only: there is no transfer standard for phase or group delay, variations of which will cause distortion products to appear.

Research Updates

Ohio State University (*presented by Patrick Roblin*).

See attached file ResearchUpdate_Roblin.pdf

OSU currently has several activities that involve their LSNA. These include:

(1) Extension of work initiated by Cardiff University on measuring and suppressing the phenomenon of “knee-walk out” of the I/V curve using pulsed LSNA measurements.

(2) Gate lag and drain lag. These need to be measured at baseband as well as at RF. The OSU group has developed a trigger for their LSNA to carry out time-aligned baseband measurements. This work has motivated research on ways to improve the IF calibration of the LSNA. OSU's idea is to use a transistor operating in Class B as a calibration standard, providing an alignment point for waveforms.

(3) Other activities:

- Real-time load pull & PA design theory
- Adaptive frequency-selective predistortion
- Kurokawa impedance measurements for oscillator design & phase noise theory
- Large-signal device modeling

RF Micro-Devices (*presented by Joe Gering*).

See attached file ResearchUpdate_Gering.pdf

RFMD recently carried out an internal measurement comparison of an on-wafer RFMD GaAs HBT device. Their goal was to verify measurements made using their new LSNA. They measured this device using two different measurement set-ups (LSNA and a load-pull system) and also included modeled results. The

attached file shows relatively good agreement between the three methods, but led to the question: How do you know which is correct?

A discussion on methods for measurement and/or model verification ensued.

One participant mentioned that some research groups have developed models based on DC and S-parameter measurements and then verified their models by comparison to LSNA measurements

Regarding phase calibration, one participant asked the group whether it would be possible to develop a model of a “calibration device” (such as a transistor biased to Class B operation) based on physics, and then carry out a power spectrum measurement and take it on faith that the phase information is correct. The general opinion of the group was “no”. Having an amplitude measurement that agrees with a model does not guarantee that the phase is correct.

Participants stated that historically verification has come from two National Measurement Institutes (like NIST, NPL, or PTB) who compare independent measurements that have uncertainties. The goal is for the measurements to agree to within the associated uncertainties. Once the comparison is done, then standard measurement methods and/or standards can be developed.

The general consensus was that methods for measurement verification include:

- (1) Measurement comparison between different types of instruments and/or different labs. This provides measurement assurance that one’s measurements “make sense.” This is the verification RFMD was looking for in this particular project.
- (2) Use of a physical or electrical standard to serve as a reference.
- (3) National Measurement Institutes compare independent measurements that have uncertainties associated with them. Then they develop standard test methods based on these results.

Please join us at the next meeting during IMS week in Hawaii:

Date: Thursday, 7 June 2007

Time: 4:30pm – 6:30pm

Location: Hawaii Convention Center, Room 327

For information on past meetings, visit our website:

http://www.arftg.org/LSNA/lsna_meetings.htm