

## Minutes of the 4<sup>th</sup> ARFTG NVNA Users' Forum

The 4<sup>th</sup> NVNA Users' Forum was held in conjunction with IMS2004 in Fort Worth, TX, on Thursday June 10<sup>th</sup>. Thirty-six participants signed in, representing academia and industry from around the world. The agenda was:

### Agenda:

- 5:00 p.m. – 5:05 p.m.: Introductions
- 5:05 p.m. – 5:55 p.m.: Discussion topics
- 5:55 p.m. – 6:10 p.m.: Discussion of PhD research
- 6:10 p.m. – 6:35 p.m.: Research updates
- 6:35 p.m. – 7:00 p.m.: Demos, announcements, and open discussion

### Discussion Topics

- ***“Phase calibrations - how necessary are they?” (moderator: Kate Remley)***

Paul Tasker states that phase calibrations are not essential as long as the measurement bandwidth is small as compared to the bandwidth of the samplers, e.g., a 20 GHz LSNA using 40 GHz samplers. Jan Verspecht replies that a phase calibration is necessary in order to assess which level of error is made. This is confirmed by Jim Hwang, who is another MTA-user. Depending on the circumstances of a particular measurement (frequency bandwidth, ...), the result indeed could be that this error can be neglected. Jan Verspecht mentioned that the typical error is less than 3 deg. at 20 GHz, and becomes 45 deg. towards 40 GHz. The whole point is to have a traceable standard, and this standard has to be better than what users use in practice. Dylan Williams confirms this order of magnitude of errors from the point of view of 50 GHz scopes.

Jonathan Scott said that the relative phase error is not directly an issue in case of the VSA, but traceability is still a question mark as well. Dylan Williams proposes an inter-comparison in terms of measurement of phase standards. In reply, Don DeGroot reports on his LSNA interlab nonlinear device measurement comparison project. The test conditions to be performed by the participants are specified in large detail in the interlab comparison protocol. The board with the devices-under-test (diodes) are being shipped around between the participants. To account for the fact that LSNAs differ in impedances (e.g., due to slightly different couplers), a model is being used to interpolate between the data in order to compensate for the mismatches etc. So far, only LSNA data have been collected, but this study will be expanded to MTA users in the future. As a concluding remark, Steve Pepper pointed out that the bias of the sampler has a strong influence on the sampler's characteristics, like the rise time.

- ***“What is the status of research on measurement-based behavioural modelling? Is it still academic or are these techniques being used on a large scale? What is missing to further deploy these techniques?” (moderator: Dominique Schreurs)***

John Wood started off this discussion by indicating that large-signal measurement-based models are not widely in use yet, because there are not many LSNAs out there. Paul Draxler points out that the bottleneck is not directly the measurements, but the difficulty of implementation in CAD software. Jose Carlos Pedro recently completed a model survey. He

believes that heuristic models (such as equivalent-scheme models, empirical models,...) models: they are relatively easy to measure and to extract. On the other hand, the formal or behavioural models are difficult to extract and require specific user experience to gather the adequate set of measurements. It is hard to conceive a signal that is general enough to easily extract models. A white Gaussian noise excitation would be ideal, but this has to be approximated by multisines to ease the measurements. Another limitation is that these models are only valid for a limited class of signals/operating space. These limitations should be clear to the users, for example by means of warnings (Paul Draxler).

So far the discussion was focused around the LSNA. Constructing models from spectrum analyzer measurements is more limited due to the lack of phase information, but on the other hand the dynamic range is higher (Peter Blockley). Choi Law inquired about the highest ADC bandwidth. Jonathan Scott said it is 1 to 2 GHz in current instrumentation. Steve Pepper answered that there are 20 GHz samplers now, but that there are still some distortion issues at the higher frequencies.

A concluding observation from John Sevic was that the vast majority of PA designs still rely almost exclusively on empirical methods, such as loadpull. He wonders why there is still so much reliance on those empirical methods? John Wood and Steve Cripps agree that in case of an amplifier design, the required impedances could indeed be found by dedicated source-/loadpull measurements, but a model is essential when the final objective is to design systems out of circuits.

## **Discussion of Ph.D. research**

Peter Blockley (Macquarie University, Australia) first presented us a short overview of his PhD research, after which he solicited inputs from the participants on two questions.

*“Instrument Architecture for Millimetre-Wave Time-Domain Signal Analysis”*

Current generation sampling oscilloscopes are limited by loss and discontinuity in transmission lines, connectors and adapters, not the native bandwidth of the sampling gate. Thus, evolutionary improvements in the electronic technologies will not lead to improved instrument capability. We propose a time-domain instrument based on NVNA architecture and calibration procedures that could enable the next generation of time-domain measurement instruments.

*Questions:*

- *How to measure a device with unknown spectrum, such as an oscillator?*

Yves Rolain refers to the VUB procedure by which they calibrate only after the measurements are completed. As they retrieve the significant signals from the overall spectrum by applying a statistics method, it should be possible to characterize oscillators as well.

- *How to characterize the phase reference at millimetre-wave frequencies? Can the nose-to-nose method be extended or is the answer Electro-optical?*

Dylan Williams refers to the EOS solution (see also Research Update below). Steve Pepper points out that if you know the waveform, Fourier Transform will give you the magnitude and phase as high as wanted. He warns though for sources of uncertainty, like the bias tee.

## Research updates

- **Dylan F. Williams (NIST): “NIST “Rent-a-Pulse” Program”**

We will briefly describe the operation of NIST's new Electrooptic Sampling System and how it is being used to characterize electrical pulses generated by high-speed photodiodes. We will describe the major error mechanisms and the uncertainty with which we can describe the waveforms, with a particular emphasis on the accuracy to which we can determine electrical phase. Finally we will discuss how we are making our calibrated 110 GHz photodiodes available to instrument manufacturers for the purpose of establishing electrical phase.

Presented slides (click on icon):



ResearchUpdate\_Williams.pdf

- **Frans Verbeyst (NMDG Engineering bvba): “An improved Harmonic Phase Reference for LSNA capabilities up to 50 GHz”**

An update is given on the R&D efforts to provide a Harmonic Phase Reference up to 50 GHz and to establish a calibration process and traceability path to support the specifications of the HPR.

Presented slides can be downloaded from the NMDG Engineering website, section Library. (<http://www.nmdg.be>)

- **Kate A. Remley and Michael D McKinley (NIST): “Measuring the reflection coefficient of signal sources under large-signal excitation.”**

We show how the LSNA can be used to measure the small-signal reflection coefficients of microwave sources in their large-signal operating state.

Supporting slide (click on icon):



ResearchUpdate\_Remley.pdf

## Demos, announcements, and open discussion

- Gary Simpson (Maury Microwave): “MT4463A is now reality”  
Gary presented a general update and highlighted the latest application, being loadpull measurements in real time.
- Dominique Schreurs (K.U.Leuven) and Kate Remley (NIST) developed a procedure to link LSNA measurements to the harmonic balance analysis and envelope analysis environments in ADS. For more information, they refer to the workshop handouts of the IMS2004 workshop on “More efficient Circuit Design by Means of Large-Signal Models and Large-Signal Measurements”
- Any new thoughts about ‘THE name’?  
There was no time left to exchange opinions on this subject. However, in a post-Forum discussion, there was a suggestion for the following alternative “Non-Linear Measurements Forum”

**Next Forum: in Amsterdam!**

The 5th NVNA Users' Forum will be held as a Focused Session in conjunction with the European Microwave Conference (<http://www.eumw2004.com>) in October, and will be co-sponsored by ARFTG and the European Network of Excellence TARGET. The time is October 12th at 4 p.m.

**Organizers:**

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