Evaluating Uncertainty in Vector Network Analyser Measurements

# Introduction

VNA measurement model contains lots of input quantities and has several intermediate measurements. A rigorous evaluation of uncertainty propagates traceable input quantities through the entire model and is often used in research environments and metrology labs. However, it is possible to obtain a direct measurement of residual error at the intermediate stages of the measurement model, which can provide a simpler and faster way to derive a value for the combined uncertainty in the result. This latter class of methods is widely used in industry. In this chapter we shall review both classes of evaluation.

In order to understand the differences between these classes of evaluation it is beneficial to take an initial look at the main sources of uncertainty in VNA measurements, which are illustrated in Fig. 1.

FIG 1.

Because the VNA calibration has the useful ability to correct for sources of systematic error, the only remaining systematic error is due to the calibration itself, which is inevitably imperfect. All other sources contribute random errors which vary between measurements, cannot be corrected for, and must be quantified as uncertainties.

The residual error from the imperfect calibration is interesting because it has captured both random and systematic errors present when measuring the standards and ‘frozen’ them as a combined systematic error in the measurand – in this case the error coefficients for the VNA. Due to the vectorial nature of the VNA it is possible to directly measure the residual error using the ‘ripple technique’ explained in the following section. Although this measurement cannot be used to further calibrate the VNA and reduce the combined uncertainty in measured s-parameters, it can be used to estimate the uncertainty contribution of the calibration as a whole - without knowledge of the contributions from individual standards. This class of VNA uncertainty evaluation will now be explained in more depth.

# Evaluating Residual Error in VNA Calibrations

As discussed in Chapter 2, a VNA must be calibrated before accurate measurements can be obtained. Calibration standards with specified impedances are used to characterise error coefficients particular to the measurement setup, which are then used in a mathematical correction step to post-process the measurements (s-parameters).

# Sources of VNA Measurement Uncertainty

Reference Jack W.

## Calibration Standards

### Specification

### Connection repeatability

## General Sources of Random Error

### Connection repeatability

## Additional Sources

## NVNA uncertainty sources

### Power Meter

*Power meter study?*

### Phase Reference

*NIST phase reference characterisation*

# Propagating VNA Measurement Uncertainty to S-parameter Measurements

Cal equations quite large so software typically used to propagate VNA uncertainty.

## Standalone Vendor Tools

## Keysight PNA-X Dynamic S-Parameter Uncertainty Option

## METAS VNA Tools II

## NIST Microwave Uncertainty Framework

# Evaluation of Uncertainty in MHVNA Measurements

## Measurement Models

Blockley paper etc, jacobians for

## Input Quantities

## Processing Structure

## Results

# Conclusions