Radio Frequency and Microwave Measurements

# 2.1 Introduction

In order to characterise NL behavioural models we need to accurately measure the device’s response to electromagnetic wave stimuli.

Additional challenges present in RF and microwave measurements when compared to DC/LF measurements. Use of vector network analyser to perform these measurements. Traditionally linear, we will start with classic introduction and progress to nonlinear variant.

# 2.2 Electromagnetic Wave Parameters

## 2.2.1 Wave Definitions

Voltage, Pseudo, Power

## 2.2.2 Derived Metrics and Figures of Merit

S-Parameters, Gain, Losses, Matches

For NL we must use models to capture the relationships between frequencies, we will visit later. However, gain typically quoted as that at fundamental (classical linear definition).

# 2.3 Vector Network Analysers

Measure scattering parameters. Very accurate as ratio measurements which avoid errors explained later. Several architectures possible.

## 2.3.1 Architecture

The reflectometer

Two-port reflectometer

Sampling methods (sampler, NLTL, heterodyne)

## 2.3.2 Error Models

One-port model

Two-port models

X terms etc

## 2.3.3 Calibration

Three known loads

Sliding load

Self-calibrations

Thru-reflect-line

TRL Variants

# 2.4 Large Signal Vector Network Analysers

Devices operating in NL regime have cross-frequency behaviour and power –dependent behaviour. VNA cannot capture, we need to move away from ratios and measure absolute waves. Need power and phase calibration to separate the waves.

## 2.4.1 Absolute 8-Term Error Model

Error model used with NL VNAs. Talk about separating e01 and e10. Talk about different options for power and phase cal (Zhang).

## 2.4.2 Power Meter Calibration

Introduce power meters, then Keysight power meter model

## 2.4.3 Phase References

Introduce types – SRD, NLTL, clipped amp, etc. Check Keysight type.

Discuss NIST characterisation – photos?

Drift measurements

# 2.5 Conclusions

NL additions add extra error sources which may be significant

Phase reference must be left for x hours to warm up.