NPL
National Physical Laboratory

EMRP
European Metrology Research Programme
Programme of EURAMET

The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

4 port VNA versus 2 port VNA: A comparison of methods for measuring the S parameters of a directional coupler

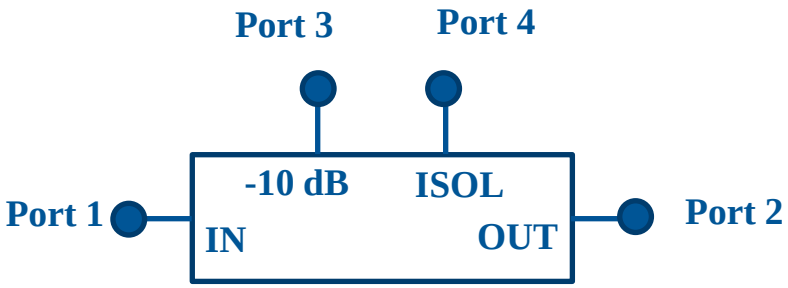
Martin Salter

4th European ANAMET Seminar
METAS, Bern, Switzerland
3rd June 2015

Overview

- A comparison of three different methods for measuring the S-parameters of a 4-port directional coupler (two methods using a 2-port VNA and one method using a 4-port VNA)

4-port directional coupler



- Marki Microwave 10 dB coupler, 6-67 GHz, female 1.85 mm connectors
- Measure S-parameters by different methods and compare results

Methods to measure S-parameters of coupler

- Method 1: Measurement of the DUT using a 2-port VNA with no correction applied for the mismatch of the terminating loads

- Method 2: Measurement of the DUT using a 2-port VNA with a correction applied for the mismatch of the terminating loads using the “matrix renormalisation” method

- Method 3: Measurement of the DUT using a 4-port VNA

VNA Calibration (1)

- SOLR (“unknown thru”) calibration – either 2-port or 4-port
- Short-circuit, open-circuit, load (SOL) female calibration standards
- Female-female adapter as unknown reciprocal thru

VNA calibration (2)

- 1-port calibration (SOL) at VNA measurement ports – either two ports or four ports

- Thrus
  - 1-2 (2-port VNA)
  - 1-2, 1-3, 1-4 (4-port VNA)

Characterisation of the calibration standards

- Characterise short-circuit, open-circuit and near matched load standards with respect to an LRL calibration of the VNA (define “data-based” standards)

- Estimate the electrical delay of the thru by measuring the input VRC of the adapter terminated in an offset short-circuit with measured VRC

Method 1: 2-port VNA with no mismatch correction

- 6 connections of DUT to VNA
- Terminate two unused ports of DUT with near matched loads
- Near matched loads assumed perfect (no mismatch correction applied)

Method 2: 2-port VNA with mismatch correction

- 6 connections of DUT to VNA
- Four loads – each assigned to terminate a specific port of the DUT
  - Port 1: Near matched load 1
  - Port 2: Near matched load 2
  - Port 3: 3 dB attenuator + open-circuit
  - Port 4: 20 dB attenuator + short-circuit
- Measure VRCs of loads
- Apply mismatch correction for loads using matrix renormalisation

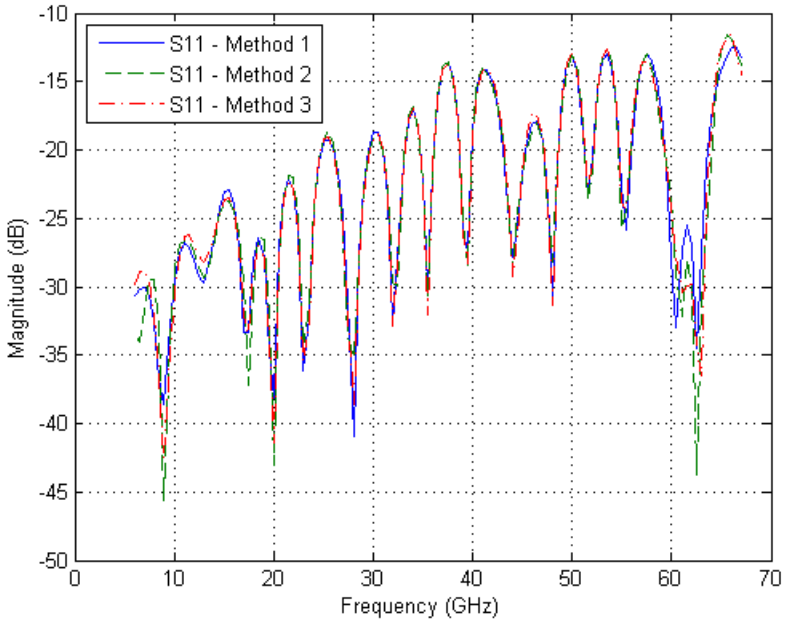
Method 2: 2-port VNA with mismatch correction

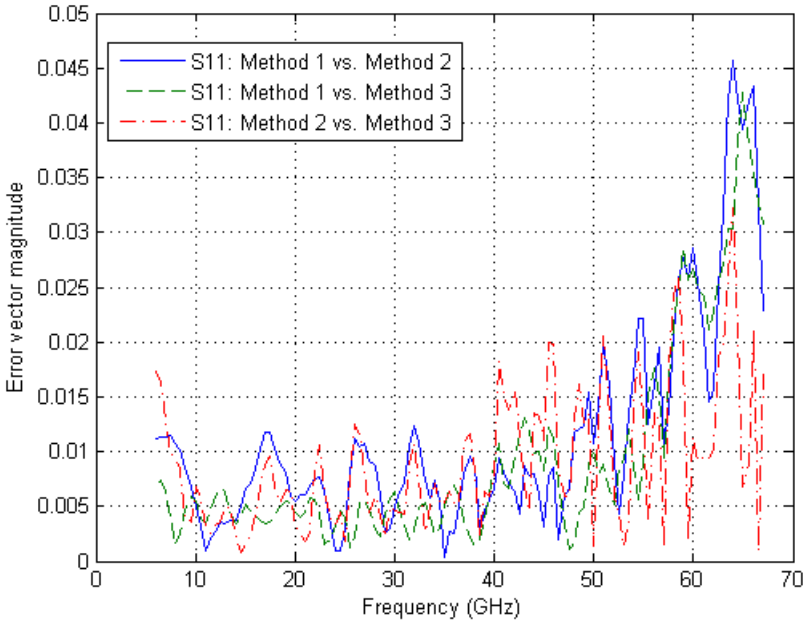
- Renormalise each of the six measured 2 by 2 scattering matrices for the partial 2-ports to Z_i and Z_j where *i* and *j* are the DUT ports connected to ports 1 and 2 of the VNA and Z_i and Z_j are the impedances of the corresponding terminating loads;
- Combine the six renormalised 2 by 2 scattering matrices into a single 4 by 4 scattering matrix for the 4-port (normalised to Z_1, Z_2, Z_3 and Z_4);
- Renormalise the 4 by 4 scattering matrix for the 4-port to 50 ohms at all ports.

Method 3: 4-port VNA

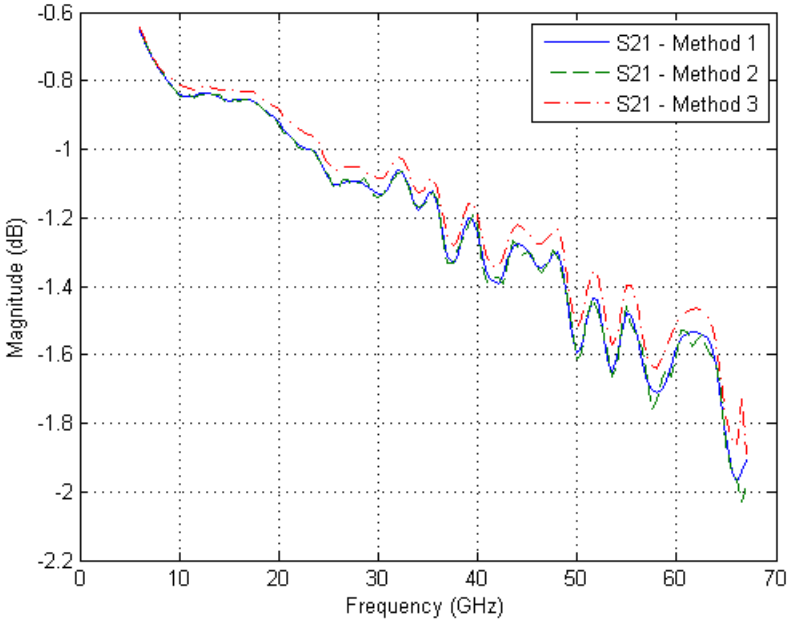
- 1 connection of DUT to VNA
- No terminating loads required

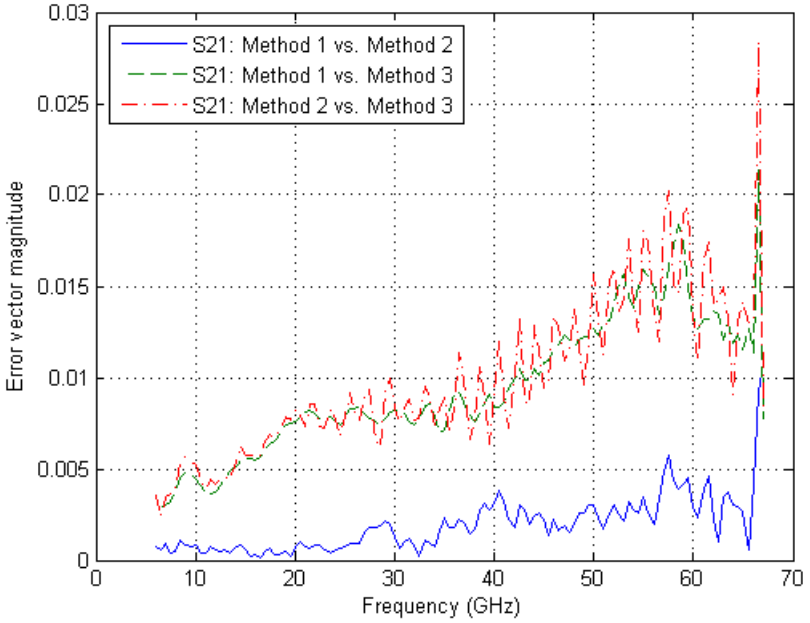
Match – S11


S11 - Method 1
S11 - Method 2
S11 - Method 3
Magnitude (dB)
Frequency (GHz)
-10
-15
-20
-25
-30
-35
-40
-45
-50
0
10
20
30
40
50
60
70

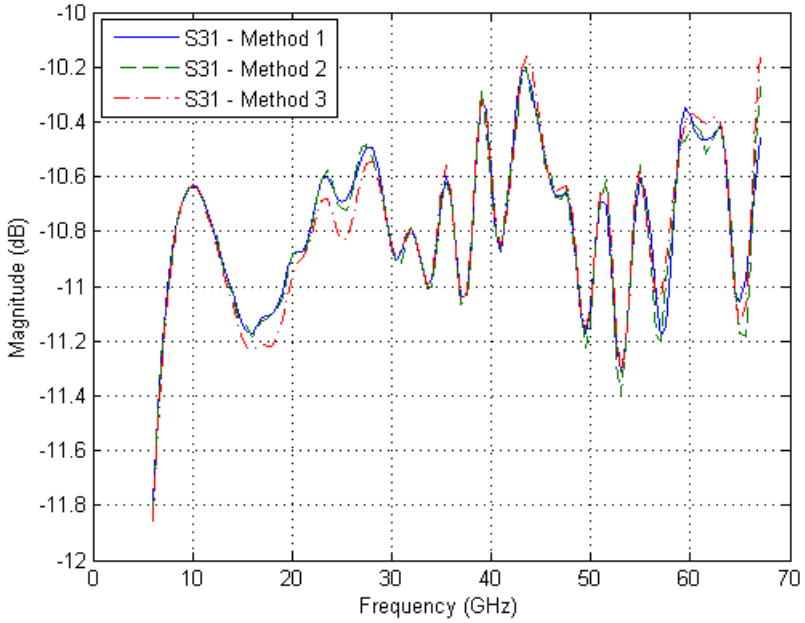

S11: Method 1 vs. Method 2
S11: Method 1 vs. Method 3
S11: Method 2 vs. Method 3
Error vector magnitude
Frequency (GHz)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
60
70

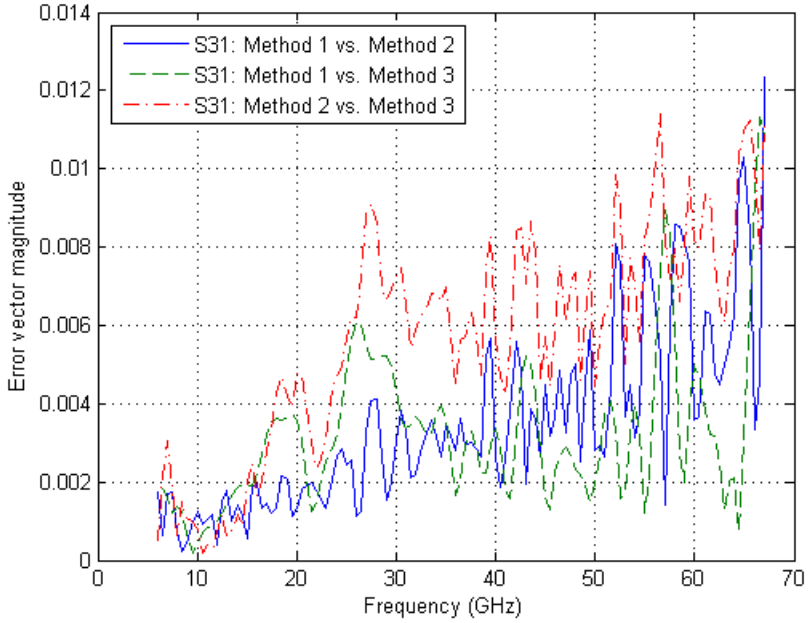
Transmission – S21



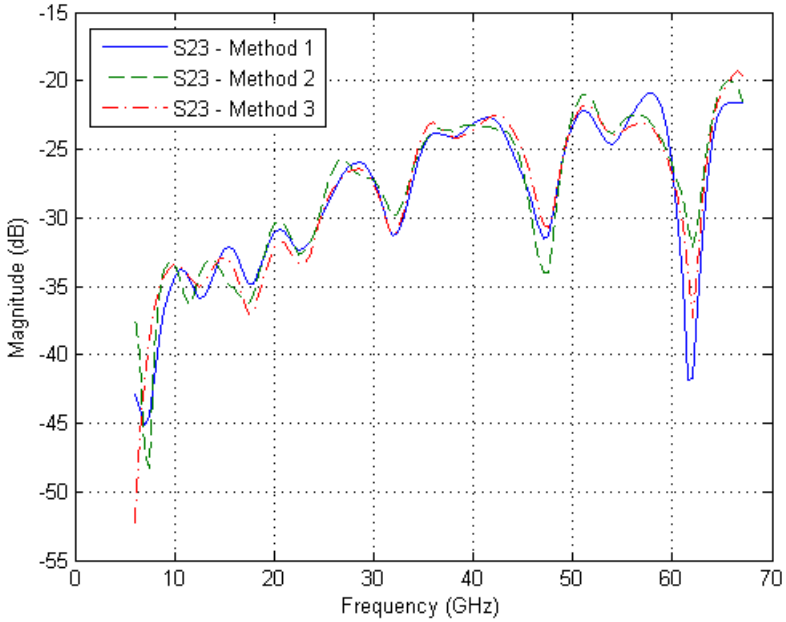


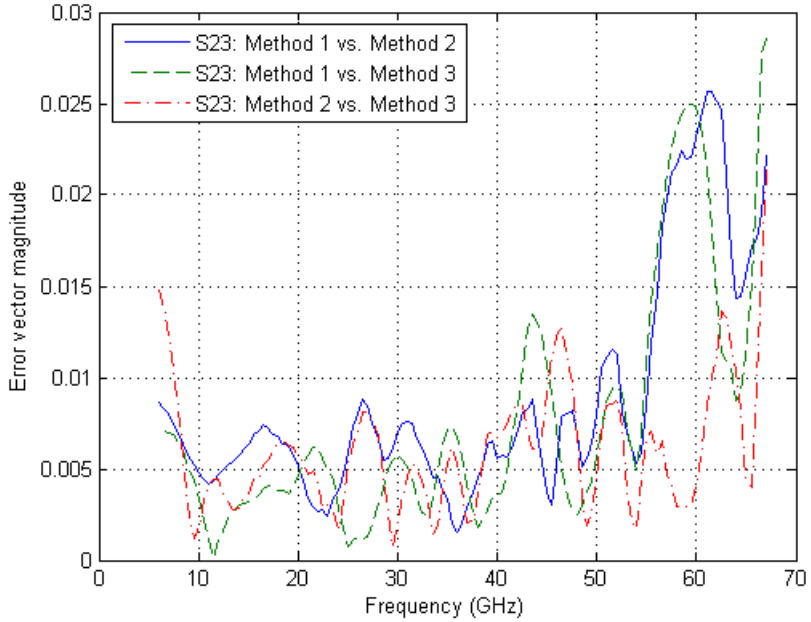
Coupling – S31





Isolation – S23





Differences between methods - summary

S-parameter	Typical observed EVM between measurement methods	
	Below 50 GHz	Above 50 GHz
S11	0.02	0.05
S21, S31 & S23	0.015	0.03

Acknowledgement

- This work was funded through the EMRP project SIB62 “Metrology for new Electrical Measurement Quantities in High Frequency Circuits” www.hfcircuits.org

EMRP
European Metrology Research Programme
Programme of EURAMET

The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union