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Using the 'ripple technique' to evaluate residual errors in waveguide VNAs

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Overview

This presentation aims to provide answers to two questions:

Q1: Does the ripple technique, as described in the EURAMET VNA Guide cg-12, work when applied to waveguide?

Q2: If "yes", why not include it as part of the revision of this Guide?

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Outline

- What is the ripple technique?
- How can we test it in waveguide?
- Experiment description
- Results
- Summary

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What is the ripple technique?

- A practical method for evaluating residual systematic errors remaining in a Vector Network Analyser after calibration (i.e. after the error-correction process has been applied by the VNA/user)

- The residual errors are due to the error correction process being less than perfect

- The ripple technique provides an evaluation of the residual **Directivity** and **Test Port Match** error terms for each of the VNA’s calibrated test ports

- These can be major contributing error terms to the VNA’s overall measurement uncertainty

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What is the ripple technique?

- The existing EURAMET VNA Guide cg-12 recommends using the ripple technique in coax
  - 7 mm (including Type-N) and 3.5 mm
- It also says:
  - “The procedure may have to be modified for other connector types, **including waveguide transmission line**.”

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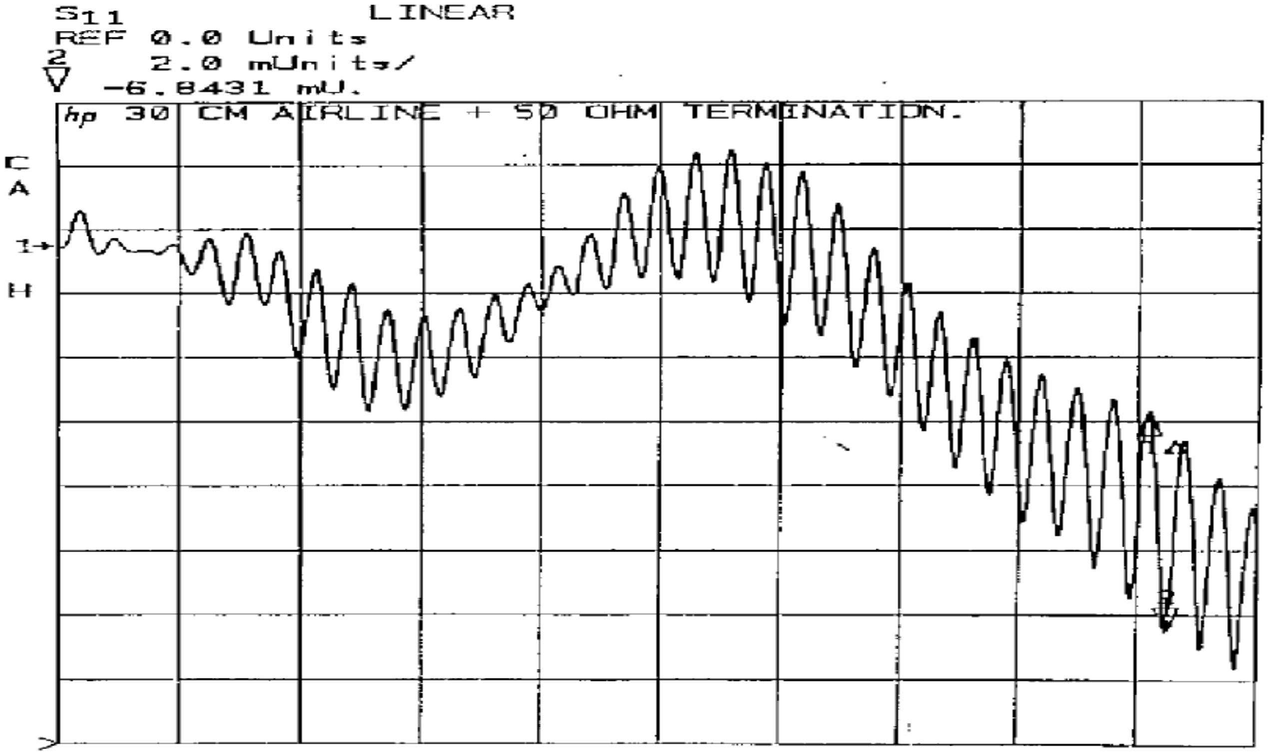
What is the ripple technique?

- According to the EURAMET Guide, in 7 mm and 3.5 mm coax:
  - Residual **Directivity** assessed using:
    - Section of precision line + ‘matched’ load
  - Residual **Test Port Match** assessed using:
    - Section of precision line + short-circuit

What is the ripple technique?

- Residual Directivity



Start frequency: 2.000 GHz Stop frequency: 18.000 GHz

Figure 1: A non-perfect 50 Ω load is connected to a 30 cm airline. The other side of the airline is attached to port 1. This figure shows which kind of typical response will be obtained measuring S11 as function of frequency. From the ripple an effective directivity can be determined.

What is the ripple technique?

- Residual Test Port Match

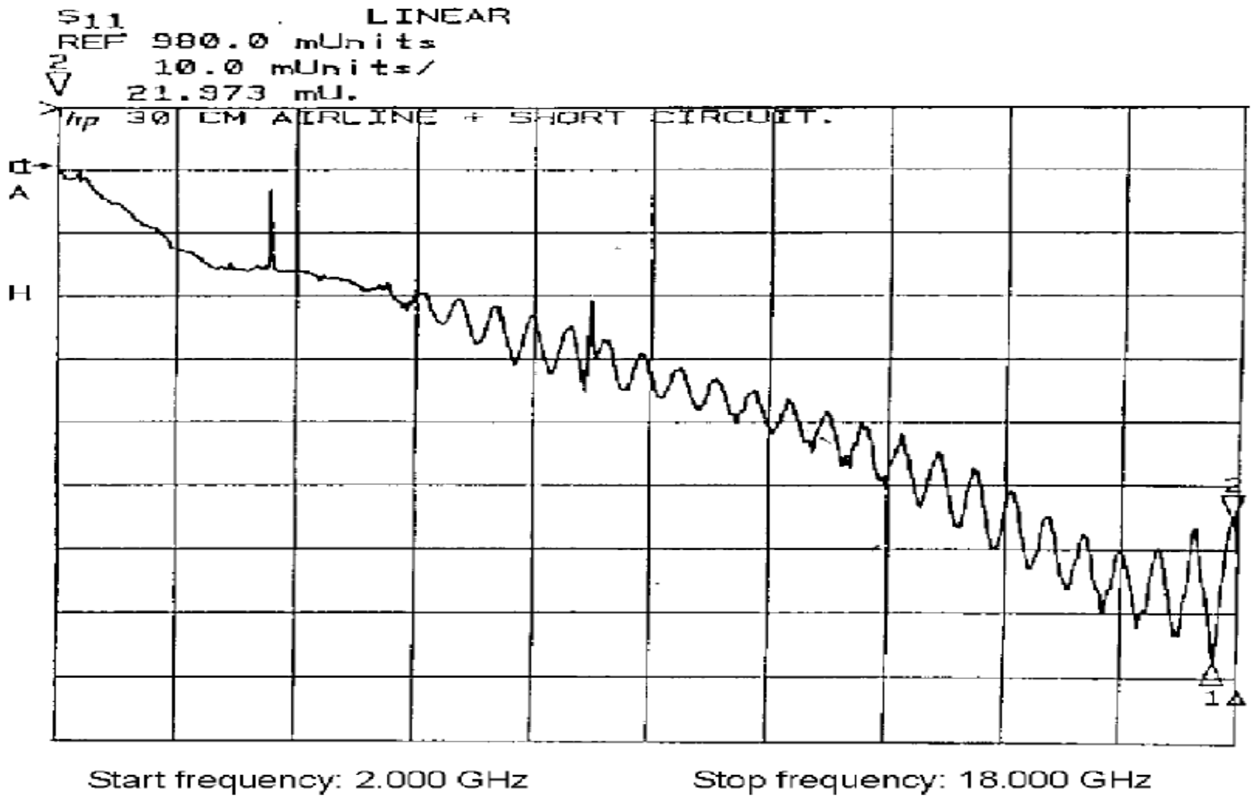


Figure 2: A short is connected to a 30 cm airline. The other side of the airline is attached to port 1. This figure shows which kind of typical response will be obtained measuring S11 as function of frequency. From the ripple an effective source match can be determined.

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How can we test it in waveguide?

- Residual **Directivity** assessed using:
  - Section of precision waveguide + ‘matched’ load

- Residual **Test Port Match** assessed using:
  - Section of precision waveguide + short-circuit

Experiment description

- Pick a waveguide band
  (X-band: 8.2 GHz to 12.4 GHz)

- Do three types of VNA calibration:
  - TRL (Thru-Reflect-Line)
  - TRL (using a poor quality line)
  - TRM (Thru-Reflect-Match)

- Use the section of precision waveguide with matched load(s) and short to determine residual directivity and test port match, respectively

  (choice of 2 matched loads: L1 and L2)

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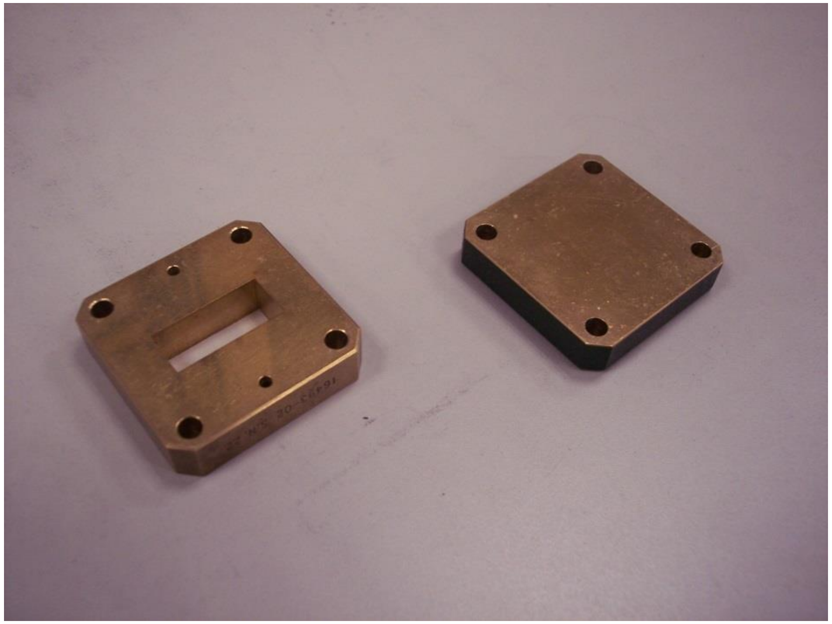
Experiment description – CAL 1: ‘good’ TRL cal

- The TRL calibration uses the Line standard to define the characteristic impedance of the calibrated VNA

- This leads to good quality calibrations (i.e. small residual errors)

- A good reference calibration, defining state-of-the-art



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Experiment description – CAL 2: ‘poor’ TRL cal

- A poor quality line is used as the Line standard
- This will lead to increased residual errors because the calibration standards are less well defined
- Expect residual directivity and test port match to be larger than the ‘good’ TRL

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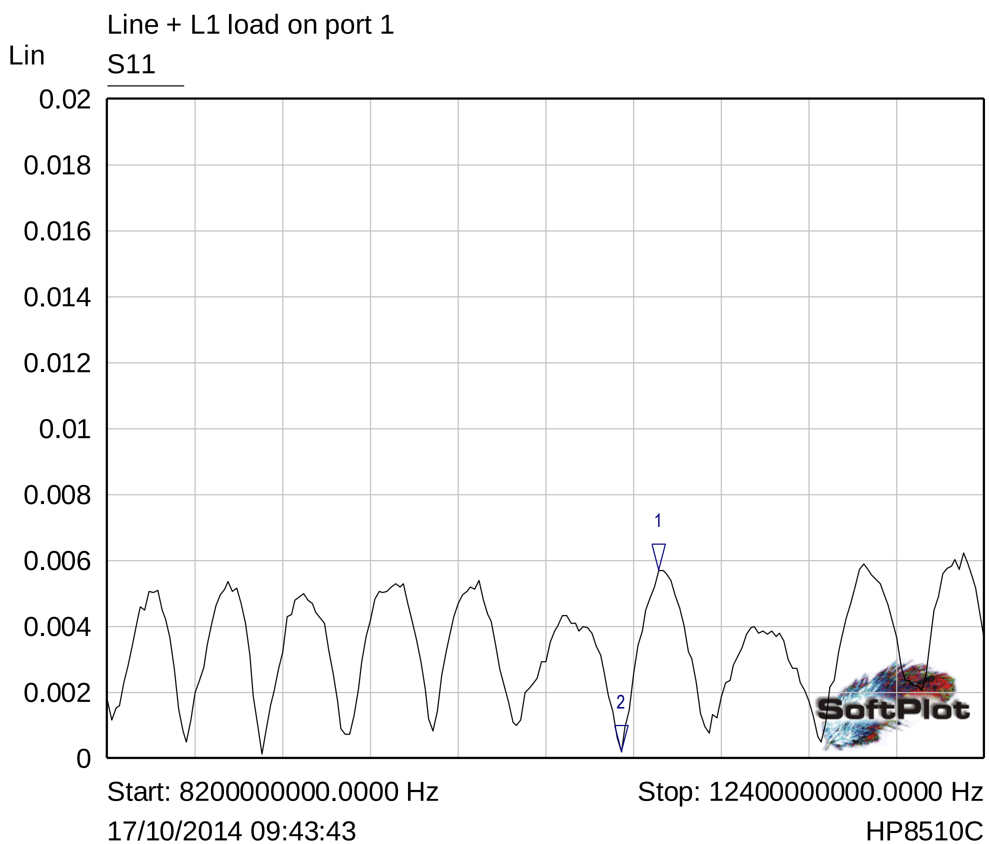
Experiment description – CAL 3: TRM cal

- A ‘matched load’ is used to set the impedance on the system
- A different calibration ‘matched load’ has been used for each test port (L1 and L2)
- Residual errors may be different due to these difference calibration loads

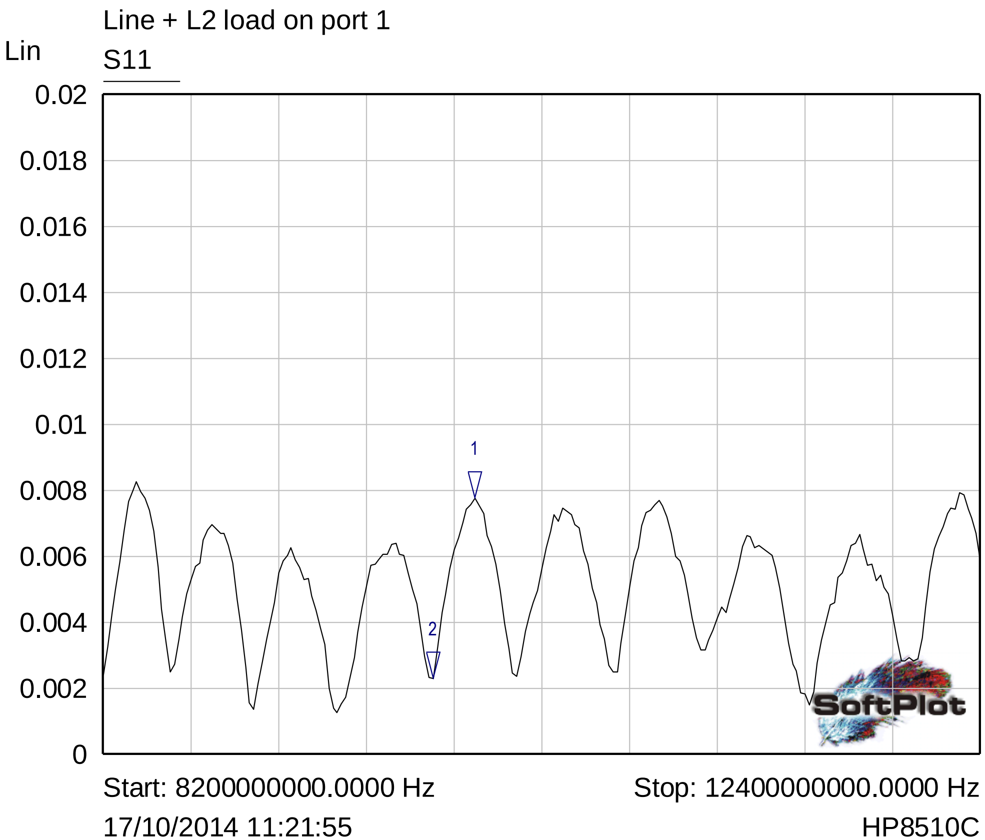
Results – CAL 1: Good TRL cal – Port 1 directivity (using L1)



Mkr	Trace	X-Axis	Value	Notes
1 ▽	S11	10840000000.0000 Hz	5.69 mLin	
2 ▽	S11	10660000000.0000 Hz	197.46 uLin	

Directivity ≈ 0.003

Results – CAL 1: Good TRL cal – Port 1 directivity (using L2)



Mkr	Trace	X-Axis	Value	Notes
1 ▽	S11	9980000000.0000 Hz	7.78 mLin	
2 ▽	S11	9780000000.0000 Hz	2.31 mLin	

Directivity ≈ 0.003

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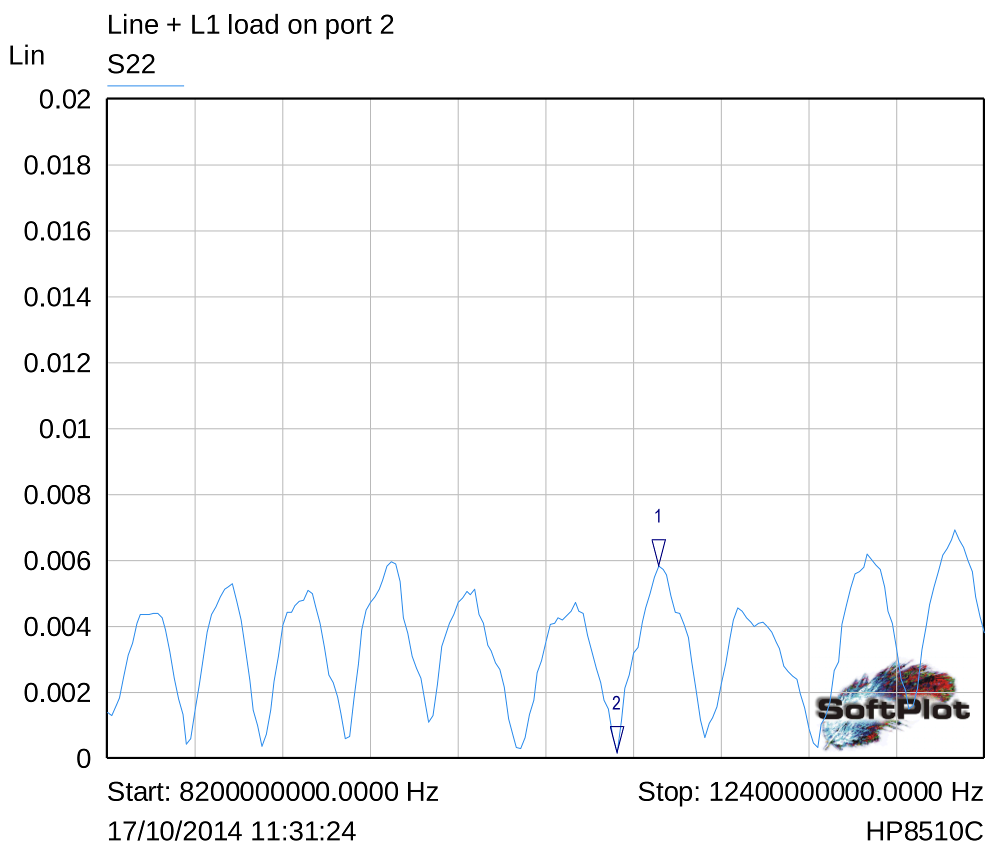
Results – CAL 1: Good TRL cal – Port 2 directivity (using L1)



Mkr	Trace	X-Axis	Value	Notes
1 ▽	S22	10840000000.0000 Hz	5.84 mLin	
2 ▽	S22	10640000000.0000 Hz	171.34 uLin	

Directivity ≈ 0.003

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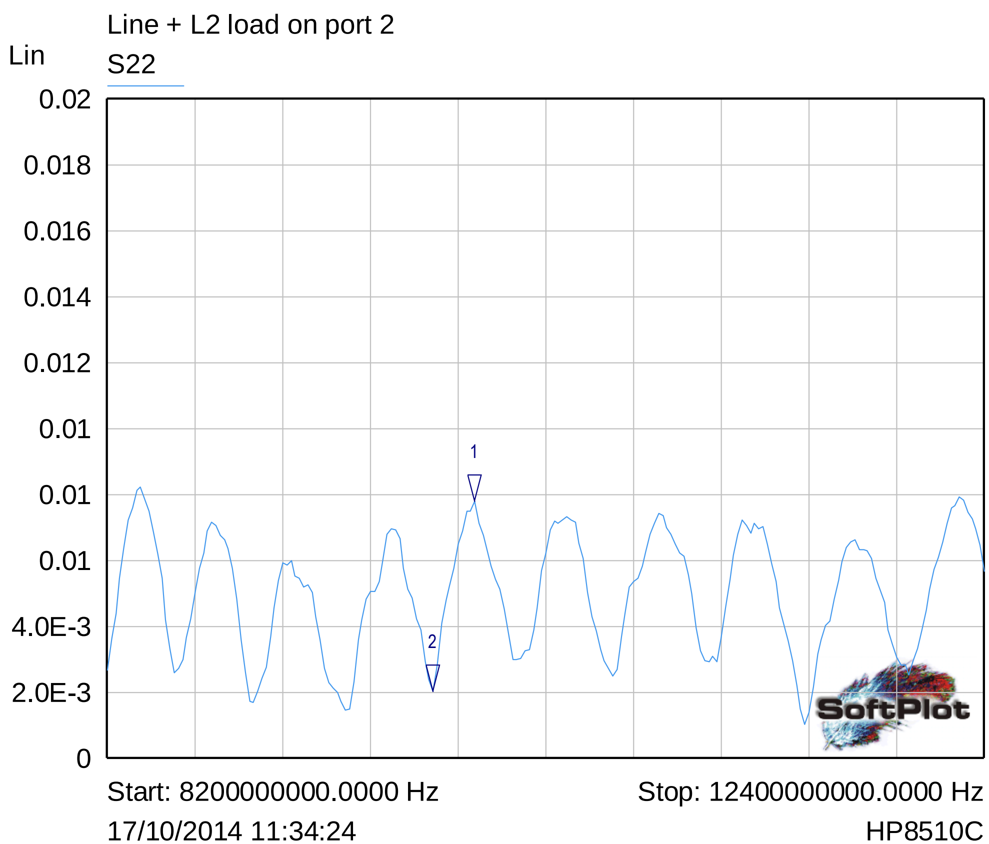
Results – CAL 1: Good TRL cal – Port 2 directivity (using L2)



Mkr	Trace	X-Axis	Value	Notes
1 ▽	S22	9960000000.0000 Hz	7.80 mLin	
2 ▽	S22	9760000000.0000 Hz	2.04 mLin	

Directivity ≈ 0.003

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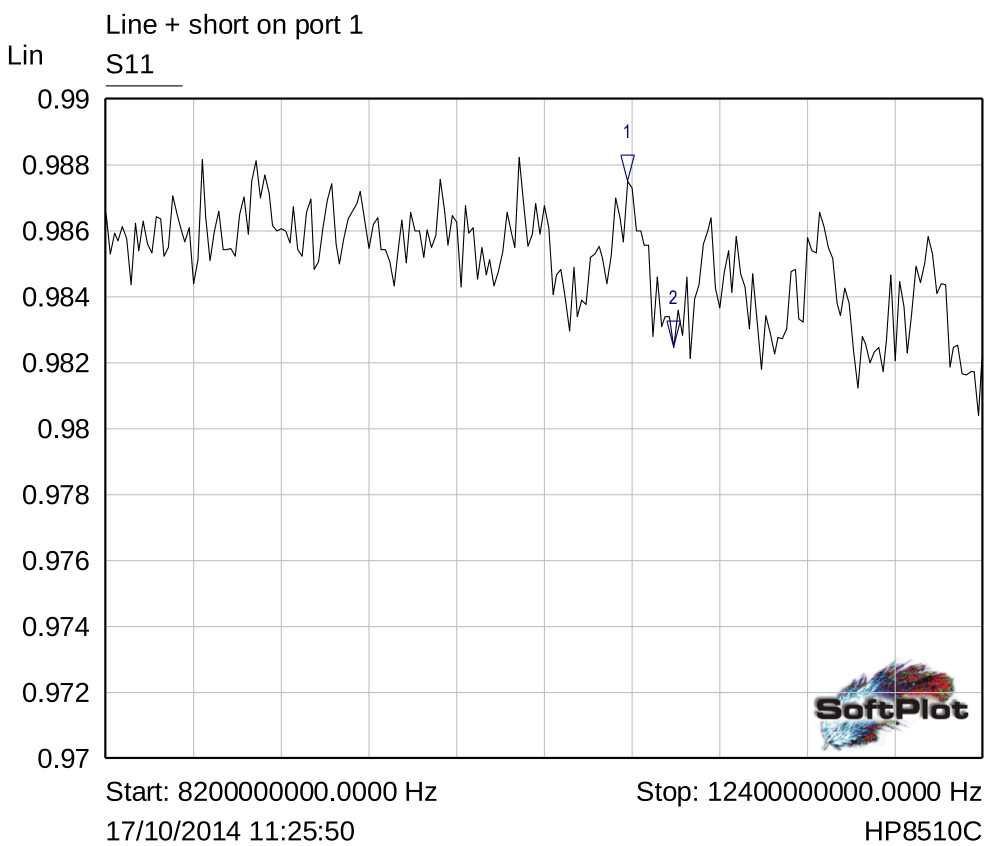
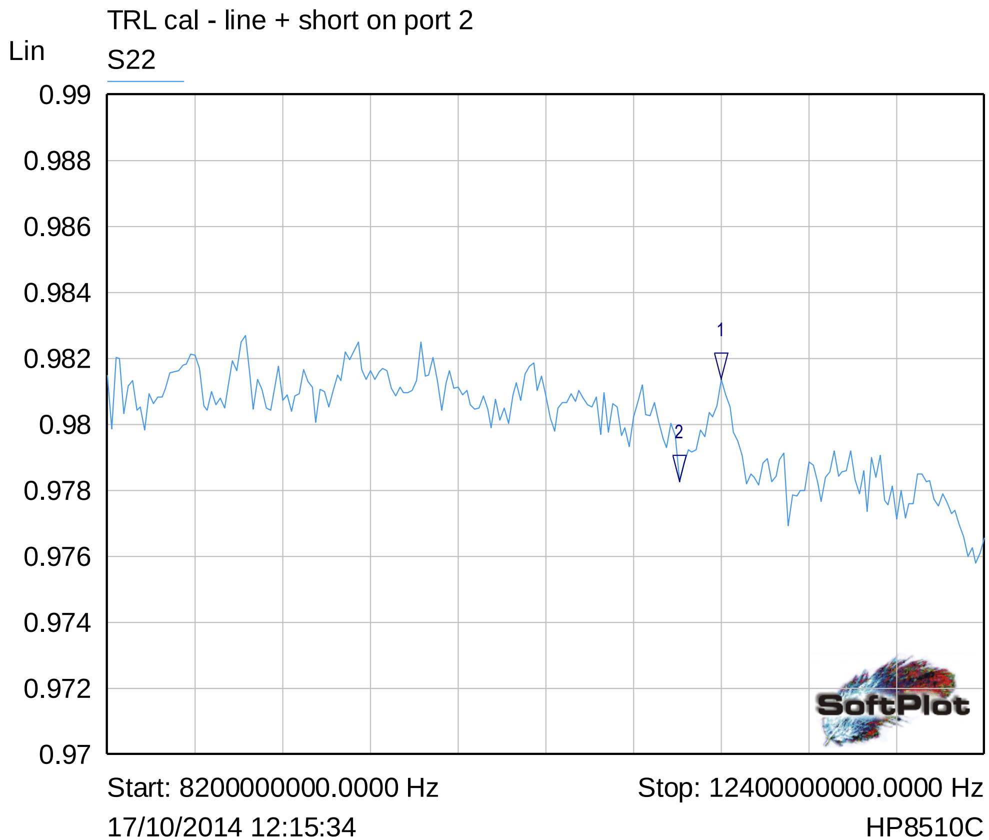
Results – CAL 1: Good TRL cal – Port 1 Test Port Match



Mkr	Trace	X-Axis	Value	Notes
1 ▽	S11	10700000000.0000 Hz	987.50 mLin	
2 ▽	S11	10920000000.0000 Hz	982.45 mLin	

Test Port Match ≈ 0.003

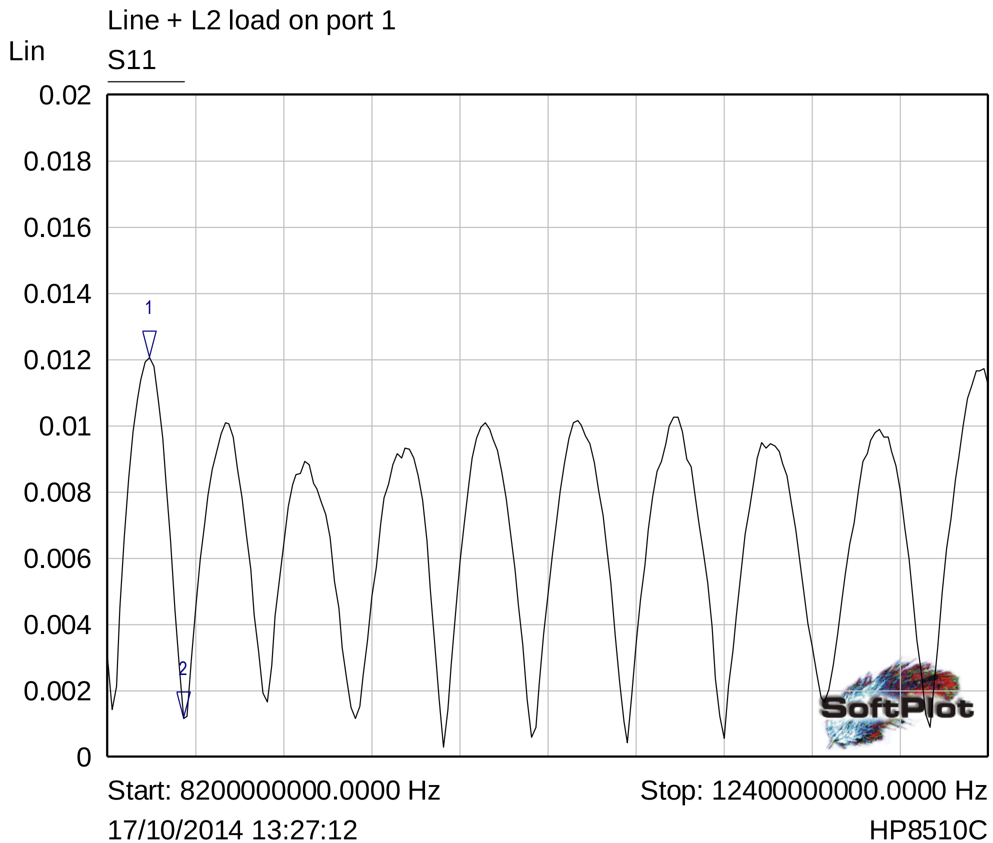
Results – CAL 1: Good TRL cal – Port 2 Test Port Match



Test Port Match ≈ 0.002

Mkr	Trace	X-Axis	Value	Notes
1 ▽	S22	11140000000.0000 Hz	981.38 mLin	
2 ▽	S22	10940000000.0000 Hz	978.26 mLin	

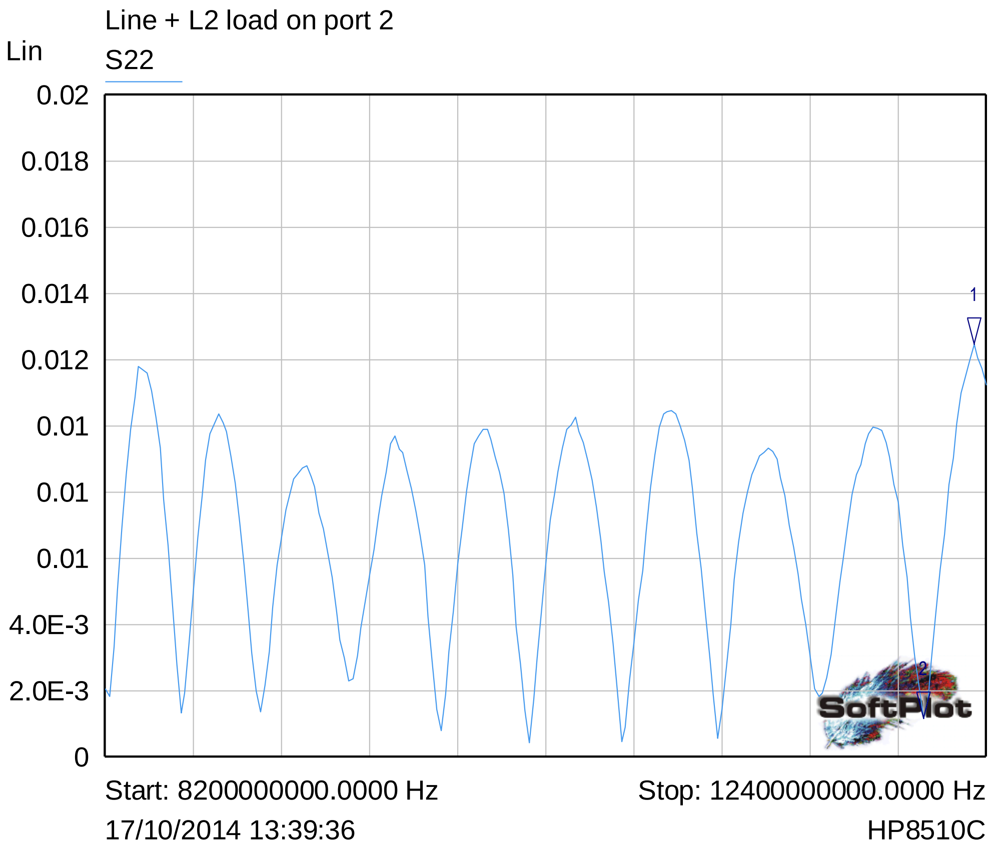
Results – CAL 2: Poor TRL cal – Port 1 directivity (using L2)



Mkr	Trace	X-Axis	Value	Notes
1 ∇	S11	8400000000.0000 Hz	12.07 mLin	
2 ∇	S11	8560000000.0000 Hz	1.17 mLin	

Directivity ≈ 0.006

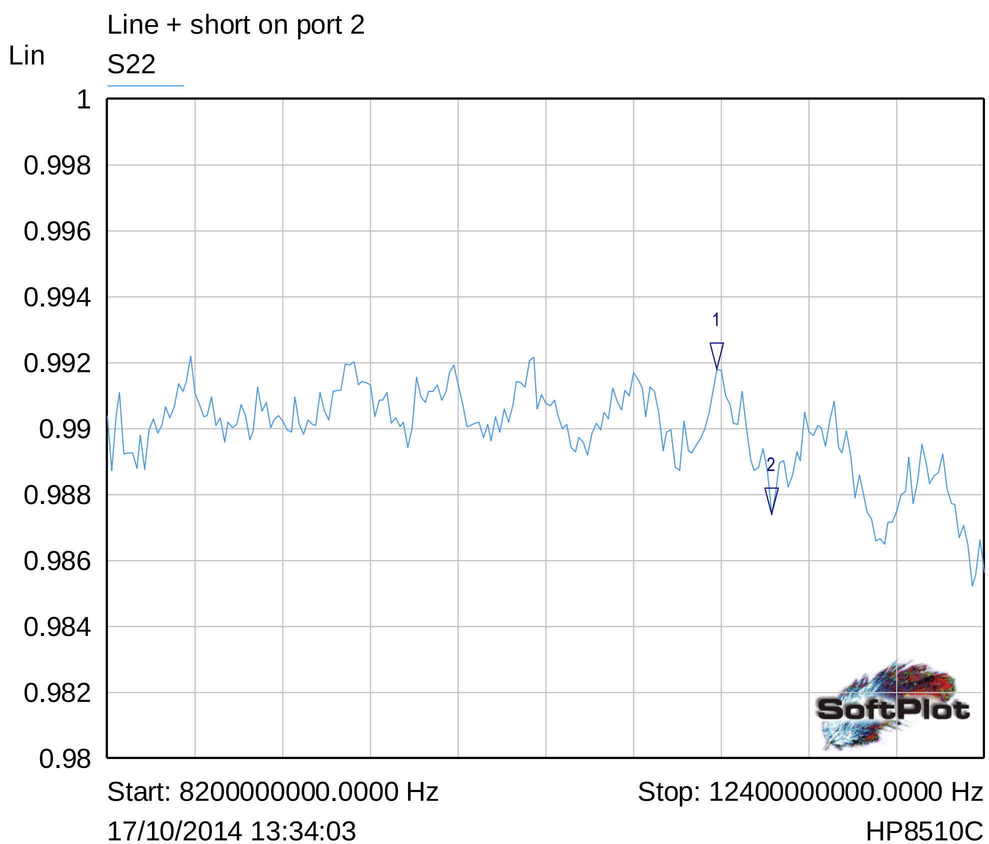
Results – CAL 2: Poor TRL cal – Port 2 directivity (using L2)



Mkr	Trace	X-Axis	Value	Notes
1 ▽	S22	12340000000.0000 Hz	12.47 mLin	
2 ▽	S22	12100000000.0000 Hz	1.17 mLin	

Directivity ≈ 0.006

Results – CAL 2: Poor TRL cal – Port 2 Test Port Match



Mkr	Trace	X-Axis	Value	Notes
1 ▽	S22	11120000000.0000 Hz	991.80 mLin	
2 ▽	S22	11380000000.0000 Hz	987.42 mLin	

Test Port Match ≈ 0.002

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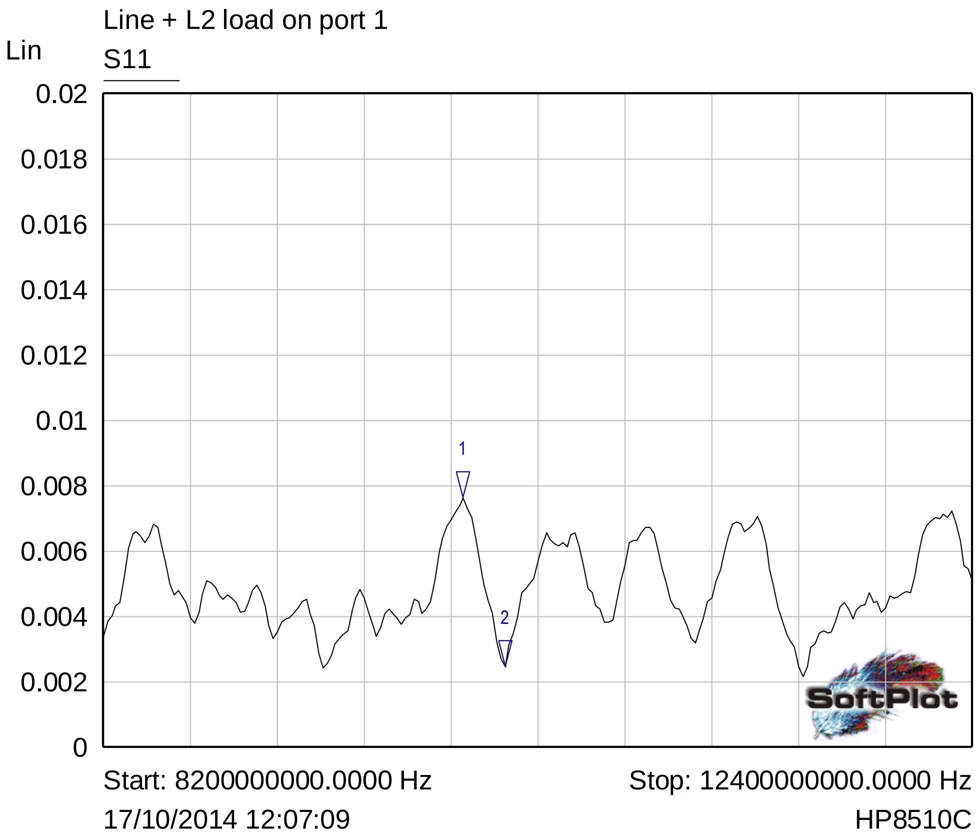
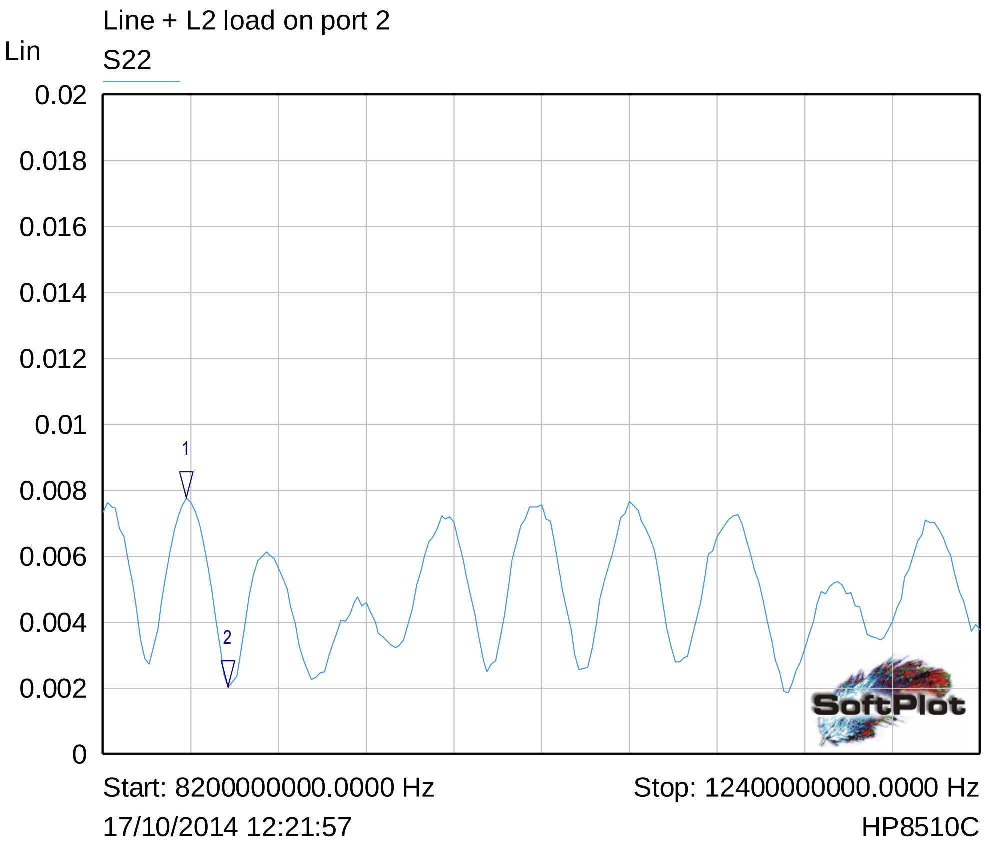
Results – CAL 3: TRM cal – Port 1 directivity (using L2)



Mkr	Trace	X-Axis	Value	Notes
1 ▽	S11	9940000000.0000 Hz	7.65 mLin	
2 ▽	S11	10140000000.0000 Hz	2.46 mLin	

Directivity ≈ 0.003

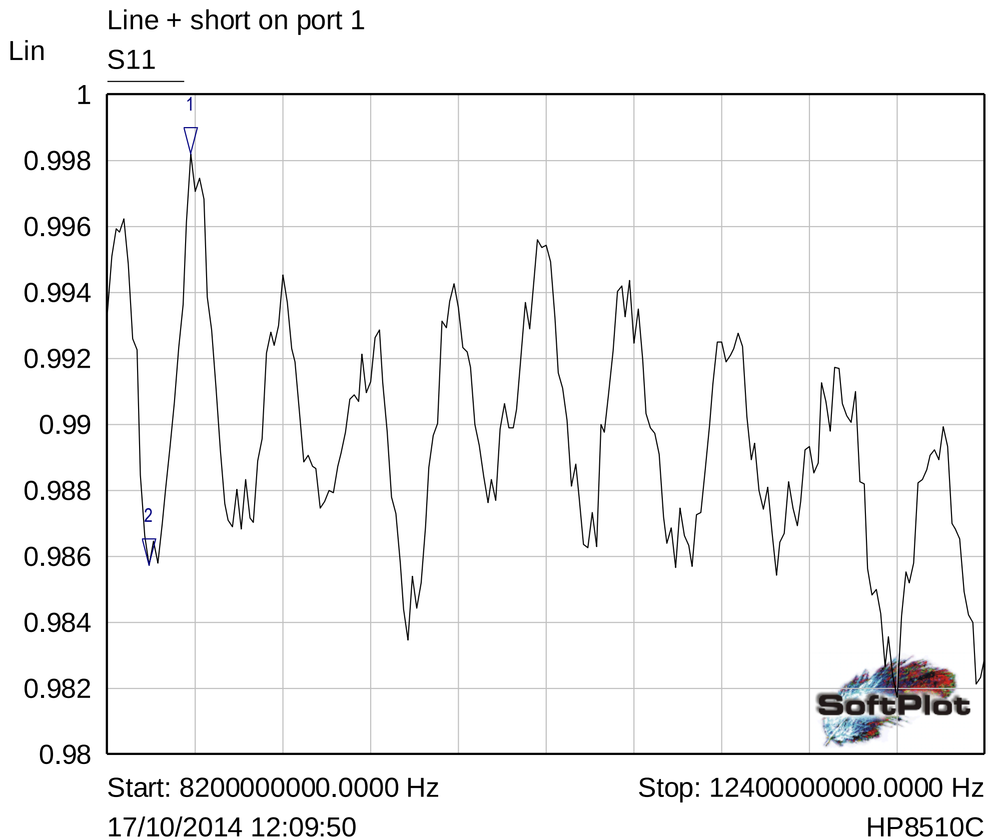
Results – CAL 3: TRM cal – Port 2 directivity (using L2)



Mkr	Trace	X-Axis	Value	Notes
1 ▽	S22	8600000000.0000 Hz	7.78 mLin	
2 ▽	S22	8800000000.0000 Hz	2.02 mLin	

Directivity ≈ 0.003

Results – CAL 3: TRM cal – Port 1 Test Port Match



Mkr	Trace	X-Axis	Value	Notes
1 ∇	S11	8600000000.0000 Hz	998.22 mLin	
2 ∇	S11	8400000000.0000 Hz	985.74 mLin	

Test Port Match ≈ 0.006

Results – Summary values

Calibration type	Residual Directivity	Residual Test Port Match
Good TRL	0.003	0.003
Poor TRL	0.006	0.003
TRM	0.003	0.006

Summary

Q1: Does the ripple technique, as described in the EURAMET VNA Guide cg-12, work when applied to waveguide?

YES !!

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Summary

Q2: Why not include it as part of the revision of this Guide?

- There is no good reason why not to include it
- There are good reasons to include it:
  - It will help laboratories to evaluate uncertainties in waveguide measurements
  - It will help laboratories to obtain ISO 17025 accreditation for waveguide measurements

These are both very good scientific and commercial reasons for including waveguide in the upcoming revision of the Guide

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