Two Port Calibration Insensitive to Flange Misalignment

ARFTG 84th Microwave Measurement Conference

Alexander Arsenovic*, Robert M. Weikle II†, Jeffrey Hesler*

(*) VDI (†) University of Virginia

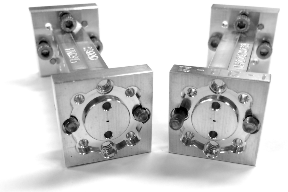
12/04/2014

Outline

Outline

Context

- As waveguide measurements continue to push upwards in frequency, waveguide misalignment caused by mechanical tolerances becomes a severe problem[1].
- This creates measurement inaccuracies due to calibration error[2, 3].
- Two Solutions
  1. Improve flange $\rightarrow$ reduce misalignment
  2. Use a calibration routine tolerant of misalignment



Why do this?

Cons:

- A calibration insensitive to flange misalignment **will not** correct for the misalignment present in subsequent measurements.

Pros:

- Eliminate flange misalignment as source of calibration error.
- Yield a direct measurement of the flange alignment.

Theory (not much to it)

- **SDDRo**[4][1] can tolerate misalignment on reflect standards
- **Unknown Thru**[5] can tolerate misalignment on the thru standard.

SDDRo + **UnknownThru** = **M**isalignment **R**esistant **C**alibration (**MRC**)

[1] equation (17) has incorrect sign in the argument

Requirments

To yield promised accuracy, **MRC** requires:

1. Misalignment is the only error mechanism
2. Two accurately known reflect standards
   - Flush Short (easy)
   - Radiating open (hard)

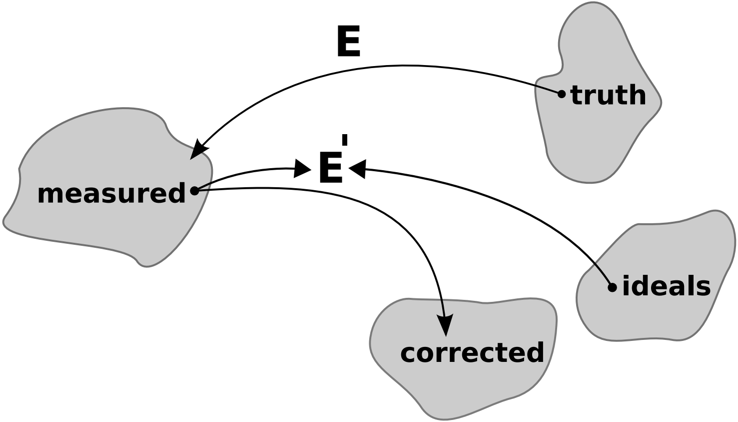
Outline

Numerical Simulation

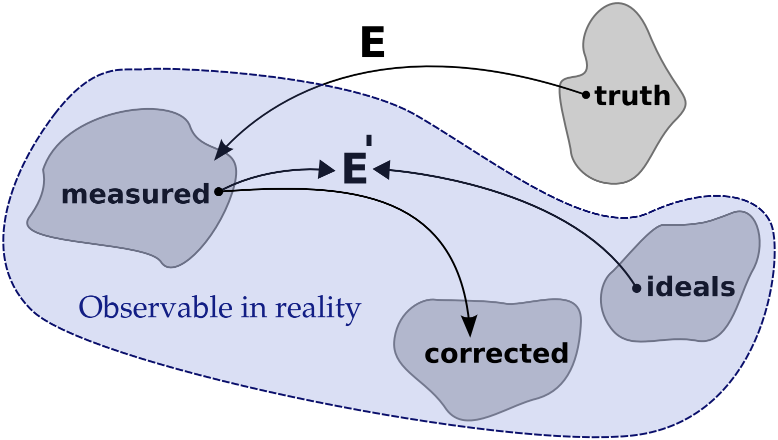
Simulation of the calibration processing chain has been used for:

1. **Verification**
   - Ensure the algorithm can accurately correct measurements given specified unknowns in the ideals.
2. **Modeling**
   - Heuristically determine causes of measurement artifacts

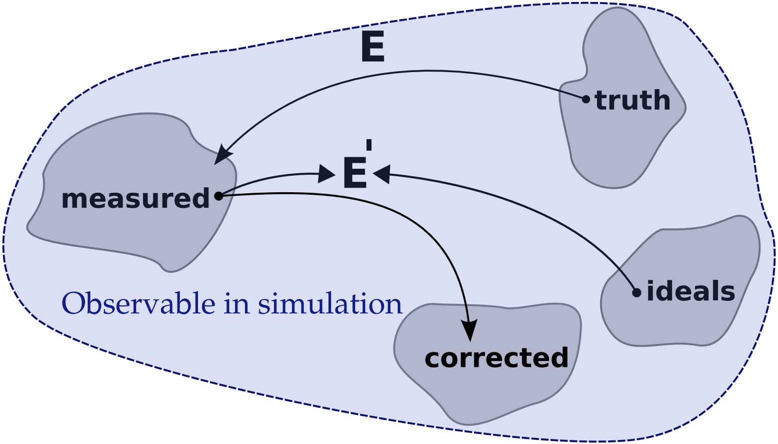
Calibration Processing Chain



Calibration Processing Chain

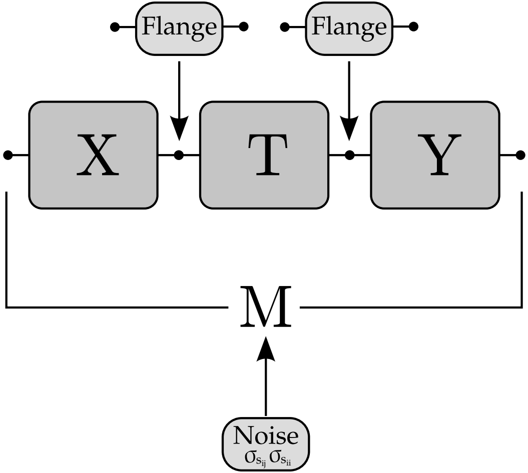


Calibration Processing Chain



In simulation everything is observable → verification is possible.
Details of verification can be found in the test-suite of scikit-rf[6].

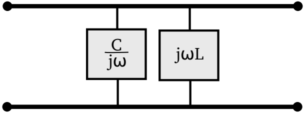
Generating Measurements



- $\sigma_{\angle S_{ij}} = .8^\circ$, $\quad \sigma_{\angle S_{ii}} = .2^\circ$

Flange Model

Circuit model used to approximate a misaligned flange



- $C = 2\text{fF}, \quad L = 4\text{nH}$

Outline

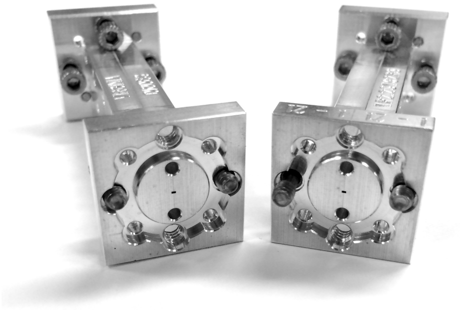
Introduction

Numerical Simulation

Measurement Results

Conclusion

Experimental Setup

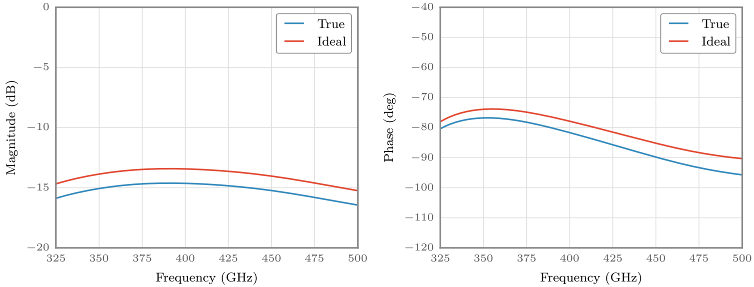


Flange pins removed.
Alignment holes reamed out to .0066” ($= .2a$)
Center dowels used in Thru

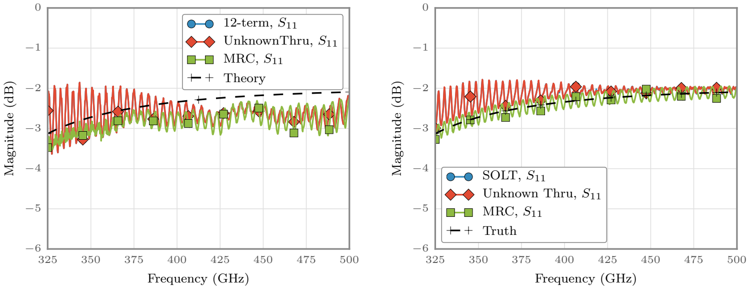
Results

The following simulation results differ from paper.

These results include error in ideal definition for the radiating open model.

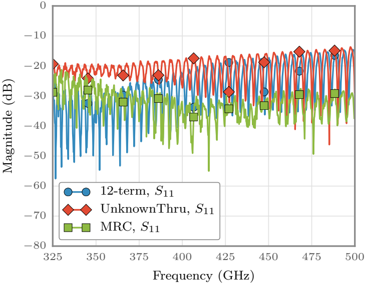


1” Straight Waveguide + Flush Short

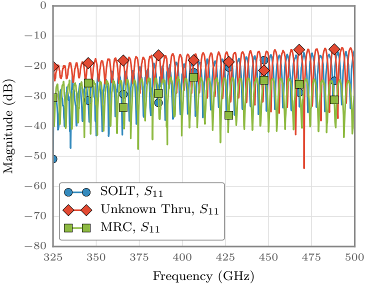


(a) Measurement (b) Simulation

1" Straight Waveguide

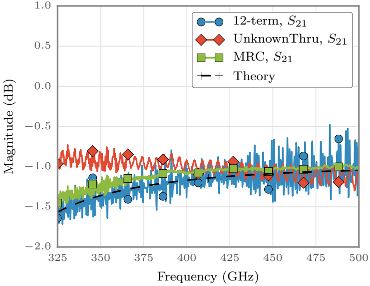


(c) Measurement

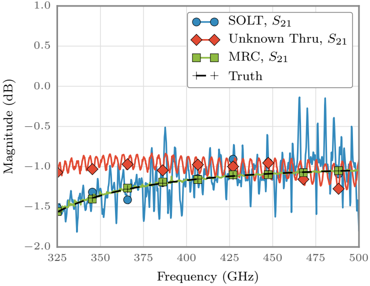


(d) Simulation

1” Straight Waveguide

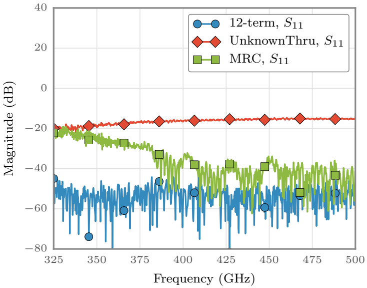


(e) Measurement

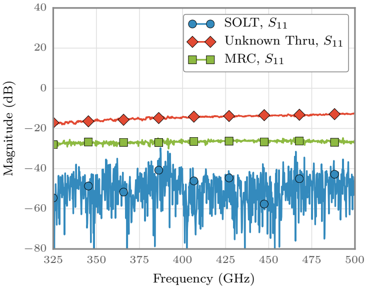


(f) Simulation

Flush Thru

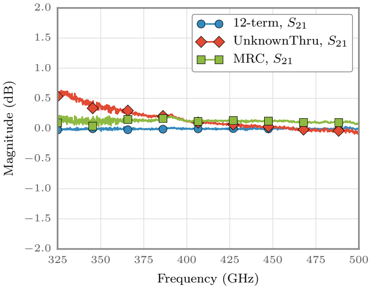


(g) Measurement

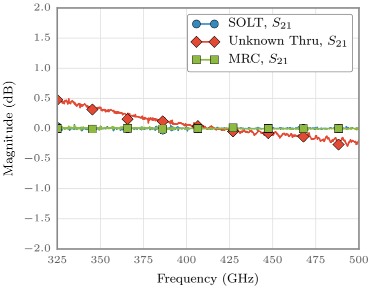


(h) Simulation

Flush Thru



(i) Measurement



(j) Simulation

Outline

Conclusion

- A two-port calibration resistant to flange misalignment has been constructed $\rightarrow$ **MRC**
- Numerical simulations have been used to
  - verify algorithms works
  - model measured results
- The simulated and measured performance indicate accuracy of radiating open model is likely a limitation.

This last point is missing from paper.

Availability

scikit-rf

Open Source RF Engineering

SDDL and **MRC** Algorithms have been implemented in the open source python module scikit-rf (www.scikit-rf.org)

The End

End Of Line

Bibliography

[1] E. W. A. R. Kerr and N. Horner, "Waveguide flanges for alma instrumentation," Nov 1999.

[2] A. Arsenovic and R. Weikle, "Comparison of competing designs for delay-short calibration standards at wr-1.5," *International Conference on Infrared, Millimeter, and Terahertz Waves*, September 2012.

[3] D. F. Williams, "500 GHz - 750 GHz rectangular-waveguide vector-network-analyzer calibrations," *Terahertz Science and Technology, IEEE Transactions on*, vol. 1, pp. 364 –377, Nov. 2011.

[4] Z. Liu and R. Weikle, "A reflectometer calibration method resistant to waveguide flange misalignment," *Microwave Theory and Techniques, IEEE Transactions on*, vol. 54, pp. 2447 –2452, June 2006.

[5] A. Ferrero and U. Pisani, "Two-port network analyzer calibration using an unknown 'thru'," *IEEE Microwave and Guided Wave Letters*, vol. 2, no. 12, pp. 505–507, 1992.

[6] scikit-rf Development Team, "scikit-rf: Open source rf engineering," 2009-present. http://www.scikit-rf.org.

SDDL by cross ratio

$$z = \frac{(a-b)(c-d)}{(a-d)(c-b)}$$

$$z = \frac{(a-b)c}{a(c-b)}$$

$$z - zbc^{-1} = \frac{a-b}{a}$$

$$\Im(z - zbc^{-1}) = 0$$

$$\Im(z) = \Im(zbc^{-1})$$

$$\Im(z) = \frac{1}{2j}\left(bzc^{-1} - \overline{b}\overline{z}\overline{c}^{-1}\right)$$

$$b = j\frac{\Im(z)}{\Re\left(zc^{-1}\right)}$$