Impact of adapters on LISN's input impedance calibration: How to improve accuracy and reliability of the measurements?

Part 1

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Outline

• Problematics of AMN calibration (input impedance)
  – Strong impact of the adapters to a phase measurement
  – No correction applied
  – No traceability
• Calculable adapter developed
• Introduction of correction method
• Example: Phase calibration
• Conclusion
Calibration of AMN

• Requirements of the standard CISPR 16-1-2
  – Impedance (absolute impedance and phase) (L-PE; N-PE)
  – Voltage division factor
  – Isolation
Impedance calibration

- Impedance is measured between N-PE and L-PE
- Tolerance CISPR 16-1-2 is 20% of the magnitude and 11.5° of the phase
- OPEN, SHORT, LOAD is made at the end of VNA cables (N-type)
- Traceability is lost by adding undefined adapter
Calibration plane definition

The correction to be applied is calculated by taking into account the input reflection coefficient $\Gamma_{in}$ measured by the VNA and the S matrix of the adapter.

- Calibration and measurement plane is different
- Use of an homemade adapter whose input impedance is unknown
- No calibration kit exists to make the calibration at the input of the EUT port

\[
\Gamma_{LISN} = f(S_{11}, S_{12}, S_{21}, S_{22}, \Gamma_{in})
\]

(S) of the adapter obtained by calculation

\[
(S) = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix}
\]
Undefined adapters – poor reliability & reproducibility
Impedance calibration comparison

• Impedance calibration of ESH2-Z5 using 3 different adapters
• Measurements were done using E5061B.
  – Compensation at the end of VNA cables (adapter influence not included)
Phase calibration comparison :Results

- Example of phase measurement comparison
- Newly developed adapter is the only one within specification at higher frequencies according to the CISPR 16-1-2
- New adapter is the most suitable for higher frequencies
Lost traceability

- LISN: poor reproducibility and reliability
  - For the same device, EMC laboratory measurements are performed with an adapter and the user performs his tests with the LISN network with another adapter without applying any corrections.

**EMC laboratory**

![EMC laboratory equipment](image1)

**User**

![User equipment](image2)

**Calibration Certificate**

![Calibration certificate](image3)
Adapter development: 3 different methods

- Aim: S-matrix of the adapter (for each frequency)
- 3 methods (COMSOL, CST Microwave Studio and MATLAB)
- Simulation are in good accordance
Adapter N-type/CEE 7/4

- Material: brass + gold plated
- Dielectric is macor $\varepsilon_r = 6$
- Effectively remove the systematic errors from the measured data (directivity effects, cable losses, mismatches)

$$(S) = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix}$$
Recalculation and uncertainty

- S matrix of the adapter obtained
- Recalculation of „true“ reflection coefficient on measurement plane
- Uncertainty was evaluated using Monte Carlo method

\[
(S) = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix}
\]

\[
\Gamma_{\text{LISN}} = \frac{S_{11} - \Gamma_{\text{in}}}{S_{22}(S_{11} - \Gamma_{\text{in}}) - S_{12}S_{21}}
\]

\[
Z_{\text{LISN}} = Z_0 \frac{1 + \Gamma_{\text{LISN}}}{1 - \Gamma_{\text{LISN}}}
\]
Impact of the adapter is removed

- Impact on magnitude: 0.5 Ω ($f=30$ MHz)
- Impact on phase: 2.8° ($f=30$ MHz)
- Type A: 0.01 Ω and 0.03° (repeatability)
- Type B: 0.24 Ω and 0.32° (systematic error of the method)
- Uncertainty ($k=2$) 0.50 Ω; 0.65°

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<thead>
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<th>CISPR 16-1-2</th>
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Impact

• Error correction method for removing systematic error developed
• Published paper in:
  – CPEM 2014
  – EMC Europe 2015
• Few adapters were already sold to calibration laboratories
• Output of this task is discussed in CISPR/WG1/A about LISN calibration issues