Electronic Calibration Units

Temperature Stability Tests

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Outline

- Equipment
- Preparation and setup
- Short-term stability measurements
- Infrared imaging of ECUs
- Conclusion
Measurement setup

**Equipment**

- VNA Rohde & Schwarz ZVA-50, 2-port, “metrology grade”
- Electronic calibration unit R&S ZV-Z52, 4-port, 10 MHz – 24 GHz
- Test port cable Gore NMD 2.4 mm to 3.5 mm female
- Adapter 3.5 mm male - male
- Temperature controlled chamber
- IR camera
Preparation and settings

- Ensure stable laboratory conditions (± 0.2 K)
- Ensure thermal equilibrium of both VNA and ECU (warm-up)
- Set IF bandwidth of VNA to a small value (10 Hz), no averaging
- Set VNA source power properly to enable linear receiver operation
- Avoid cable movement (where possible)
- Measure only a limited number of frequency points
- Check inner conductor recession and stability of both ECU and cable connectors
- In case of electro-mechanical ECU switches: perform several switching cycles
Temperature stability (TS) tests

- Investigate change of VNA error terms after connecting the ECU until thermal equilibrium is reached (TS1)

- Investigate change of DUT S-parameters immediately after performing an ECU-calibration of VNA (TS2)

- Investigate change of ECU states due to external temperature variations (TS3)
Stability measurements

Stability tests TS1

Test TS1a
- Install test port cable between ECU and VNA
- Choose a limited number of frequency points
- Let ECU reach thermal equilibrium
- Connect ECU and **immediately** start measuring ECU states repeatedly
- Calculate VNA error terms from ECU switching states raw data
- Calculate VNA error term drift (vector difference)

Test TS1b
- Repeat test while directly connecting ECU to VNA test port
Results test TS1a

Directivity drift

![Graph showing Directivity drift over time]

- Red line: 1 GHz
- Blue line: 13 GHz
- Green line: 24 GHz

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Stability measurements

Workshop “Electronic Calibration Units” and European ANAMET meeting
Results test TS1a

Source match drift

![Graph showing source match drift over time with different frequencies (1 GHz, 13 GHz, 24 GHz).](image)
Results test TS1a

Tracking drift

![Graph showing tracking drift](image)
Results test TS1b

Directivity drift

![Graph showing Directivity drift](image)
Results test TS1b

Source match drift

![Graph showing source match drift over time for different frequencies (1 GHz, 13 GHz, and 24 GHz). The graph plots the deviation (ΔM) against time (s).]
Results test TS1b

Tracking drift

![Graph showing tracking drift for different frequencies (1 GHz, 13 GHz, 24 GHz) over time (in seconds)]
Stability measurements

Stability tests TS2

Test TS2
- Install test port cable between ECU and VNA
- Connect ECU, wait for thermal equilibrium
- Perform one-port calibration using ECU
- Disconnect ECU and **immediately** connect mechanical one-port standard (open, short, load)
- Immediately measure mechanical standard
- Calculate drift (vector difference)
Results test TS2

Short:

![Graph showing stability measurements over time for different frequencies.](image)
Results test TS2

Open:

![Graph showing stability measurements over time for different frequencies (1 GHz, 13 GHz, 24 GHz) over a time period of 60 seconds. The graph indicates the variation in stability (ΔS) with time. The data is shown in a logarithmic scale for the y-axis, ranging from 0 to 6 x 10^-3.]

Stability measurements

Workshop “Electronic Calibration Units” and European ANAMET meeting
Results test TS2

Load:

![Graph showing stability measurements](image)

Stability measurements

Workshop “Electronic Calibration Units” and European ANAMET meeting
Stability tests TS3

Test TS3
- Place ECU inside a temperature chamber
- Perform a one-port ECU calibration at laboratory temperature
- Increase chamber temperature stepwise up to 40°C
- Measure all ECU switching states after thermal equilibrium has been reached
- Calculate drift of ECU states (vector difference)
Results test TS3

“Short” switching state
Stability measurements

Results test TS3

“Open” switching state

[Graph showing time vs. temperature with different frequencies]
Results test TS3

“Load” switching state
Results test TS3

Drift of “Open” switching state vs. temperature

![Graph showing drift of open cable vs. temperature](image)
Infrared imaging of ECUs

- Infrared images give insight into the heat distribution (at ECU ports)
- Image sequence vs. time can investigate heat flow
Infrared imaging of ECUs
Conclusions

- Settling time of connection between **ECU and VNA cable**: approx. 1 min
  **ECU and VNA test port**: approx. 3 min

- For “optimal calibration”, ECU should **not** be operated under extreme temperature conditions

- To be investigated: ECU warm-up process **after** “ready” sign has been turned on

- To be investigated: change of ECU state due to heat treatment
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