Electronic Calibration Units

Temperature Stability Tests

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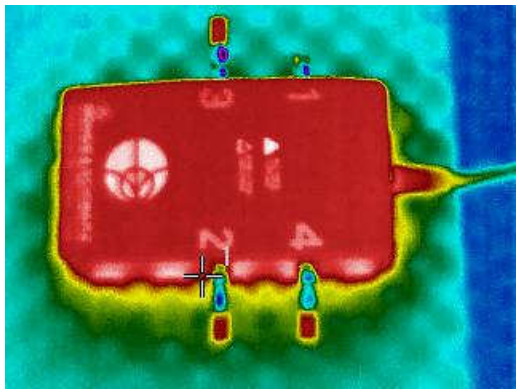
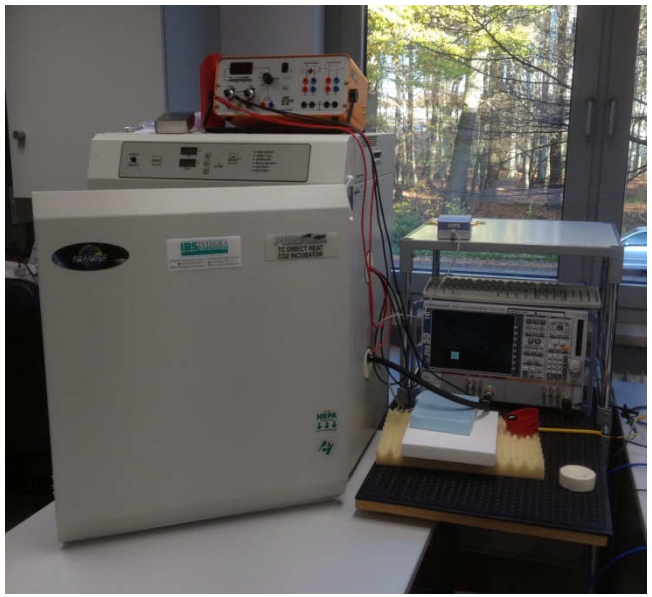
Outline

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

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

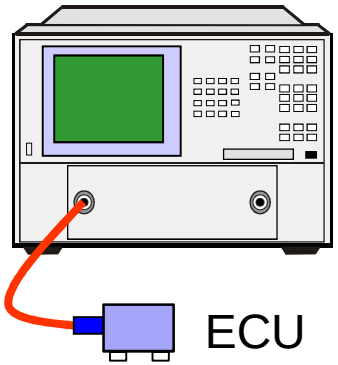
- Ensure stable laboratory conditions (± 0.2 K)
- Ensure thermal equilibrium of both VNA and ECU (warm-up)
- Set IF bandwidth of VNA to a small value (10 Hz), no averaging
- Set VNA source power properly to enable linear receiver operation
- Avoid cable movement (where possible)
- Measure only a limited 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

- Determine the influence of temperature variations on the electrical properties of the ECU states (and on the VNA error terms)
  - 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 tests TS1

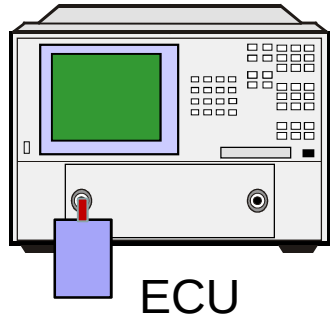
Test TS1a



- 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)

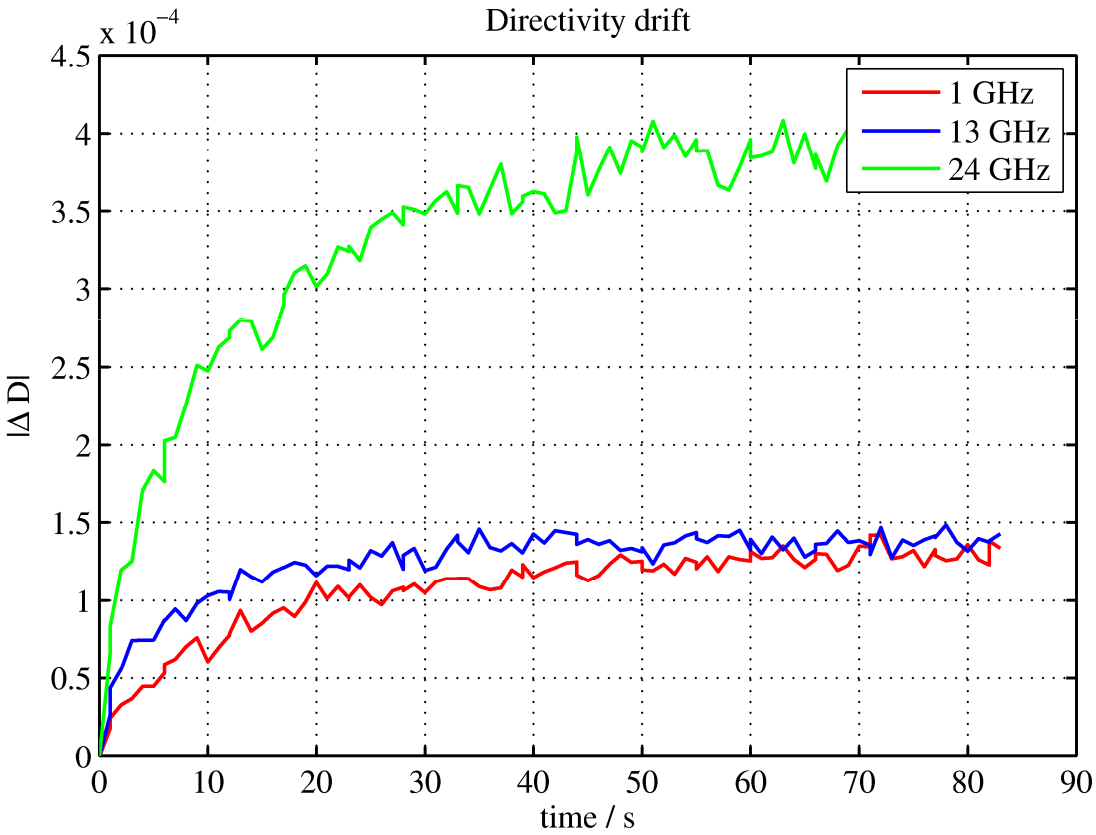
Test TS1b

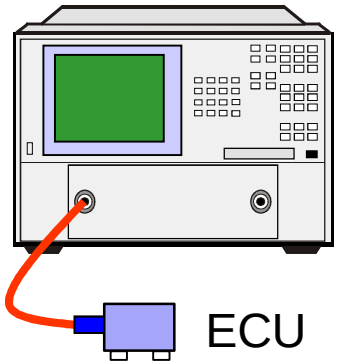
- Repeat test while directly connecting ECU to VNA test port



Results test TS1a

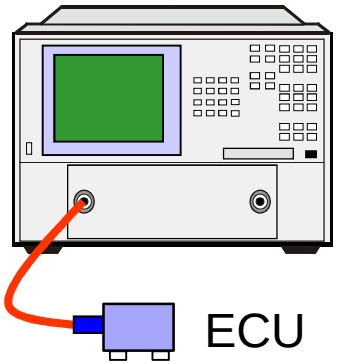
Directivity drift

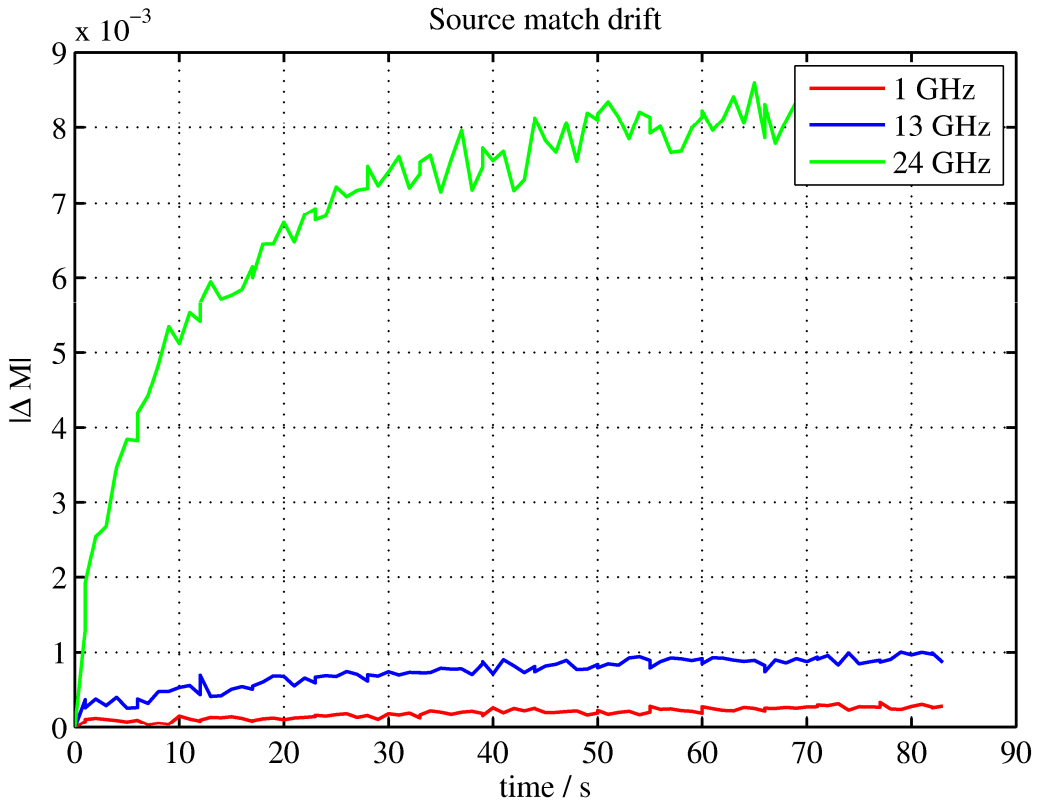




Results test TS1a

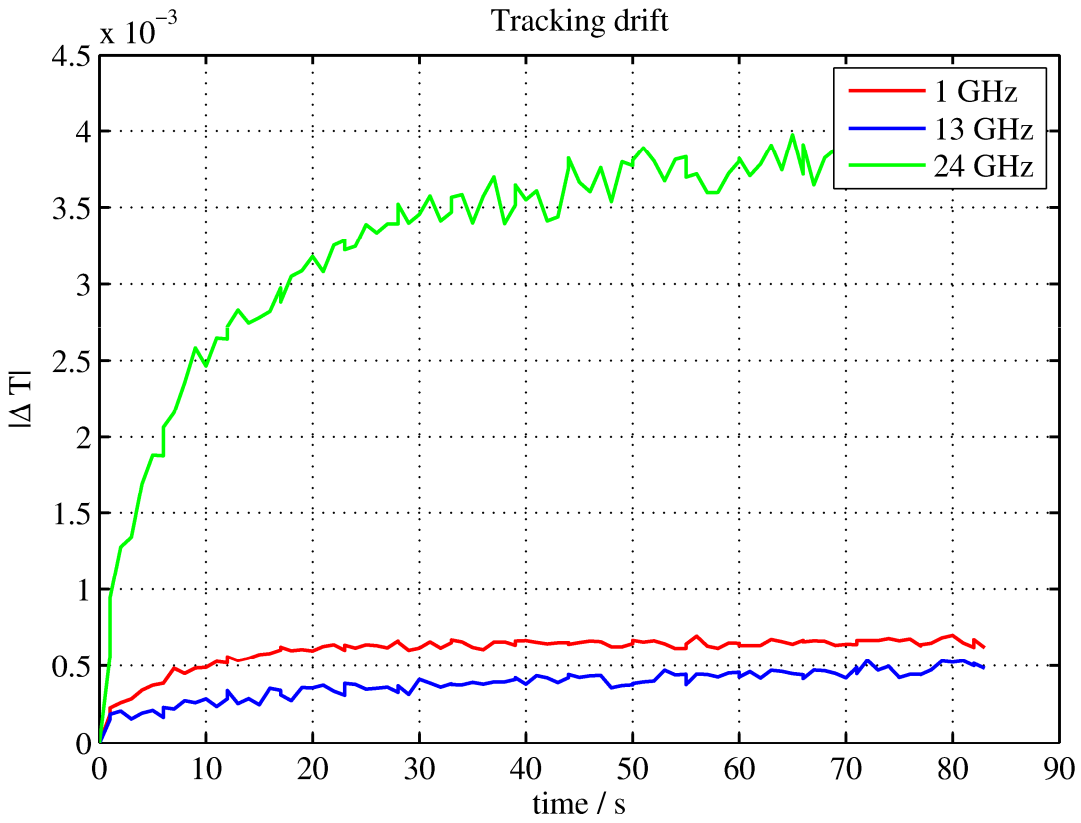
Source match drift

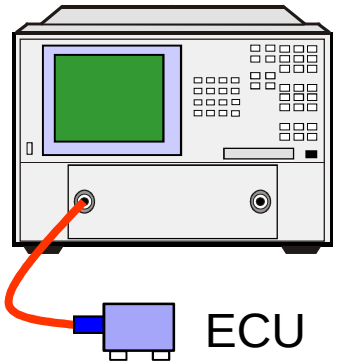




Results test TS1a

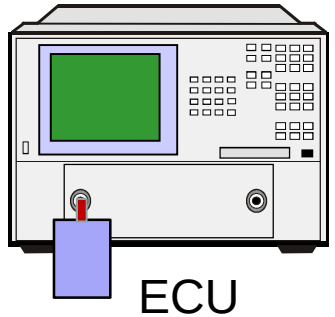
Tracking drift

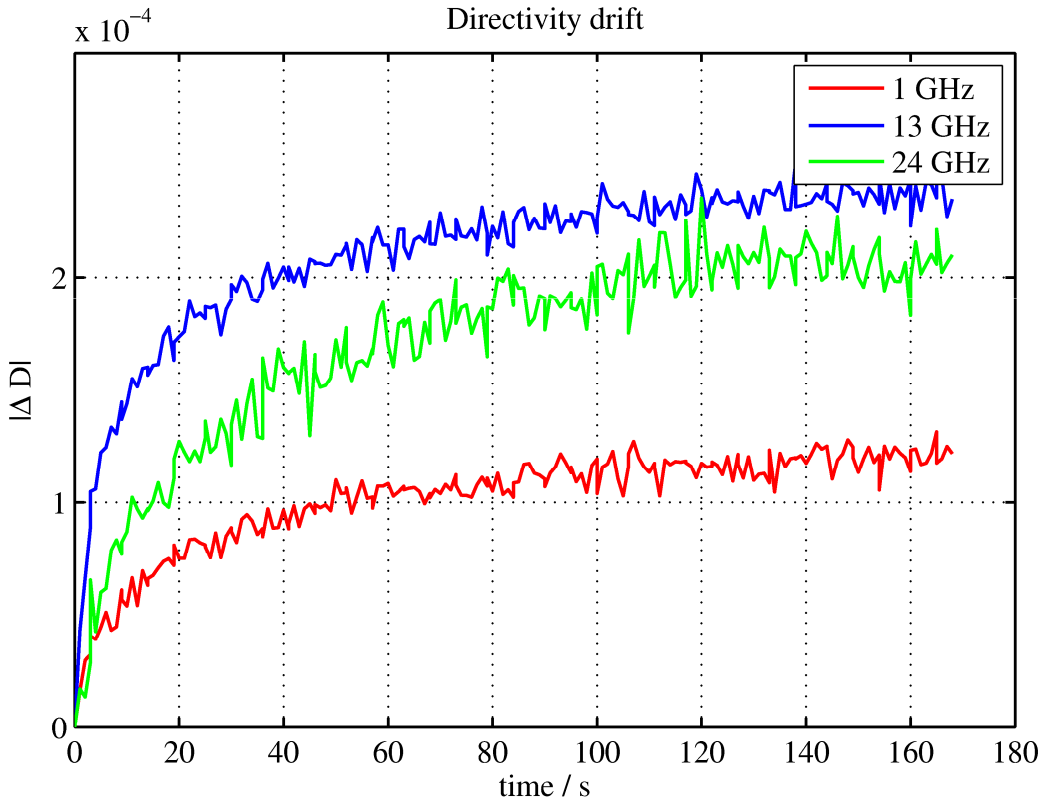




Results test TS1b

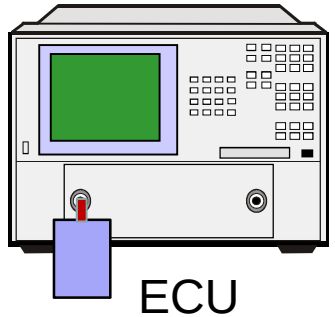
Directivity drift

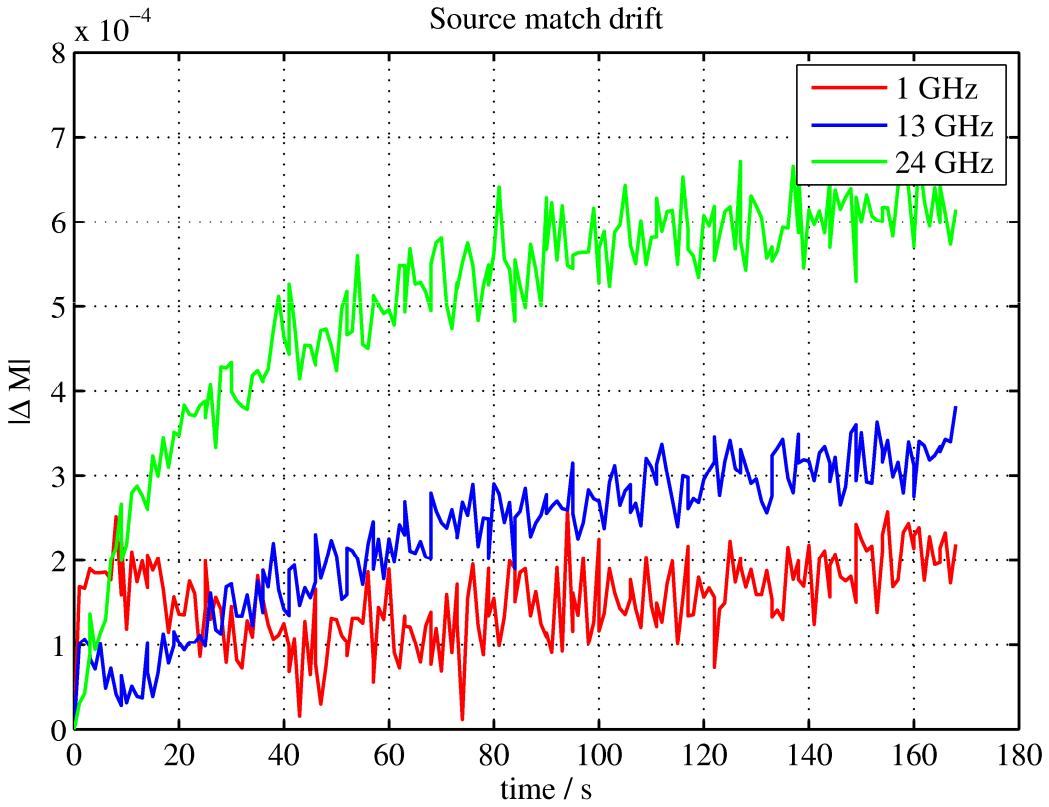




Results test TS1b

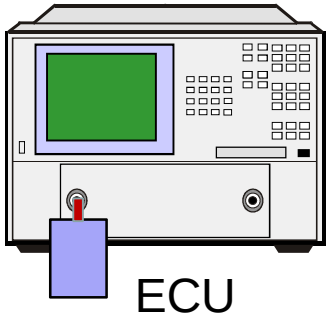
Source match drift

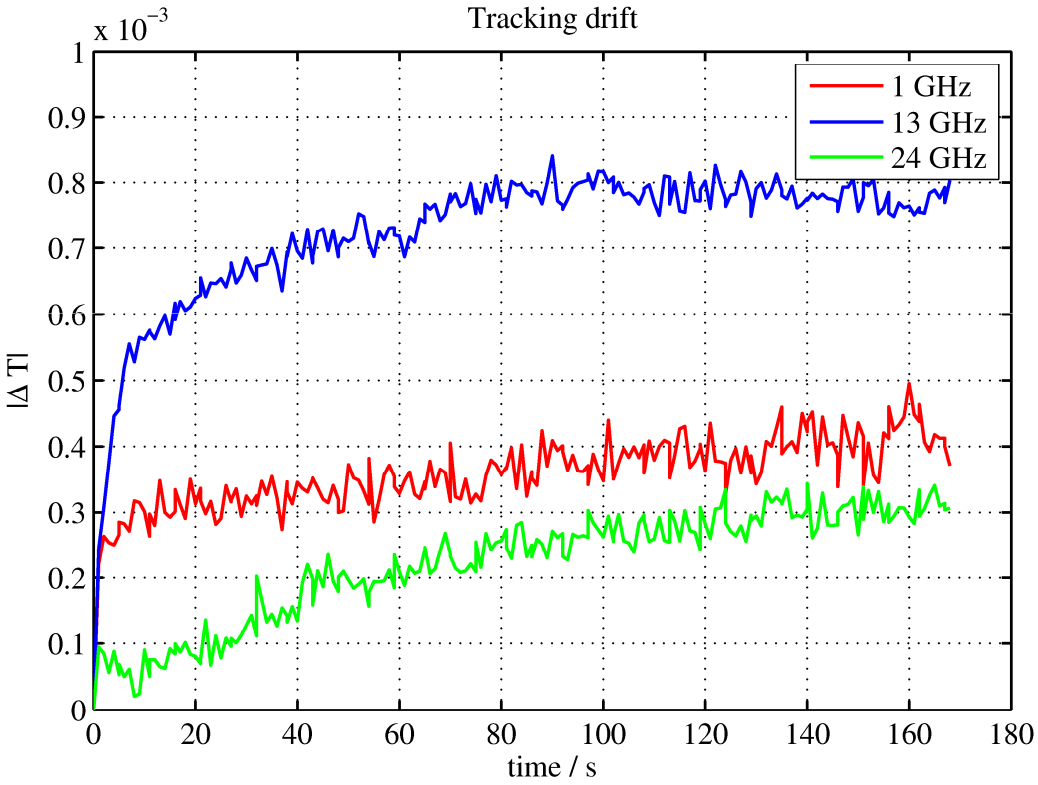




Results test TS1b

Tracking drift

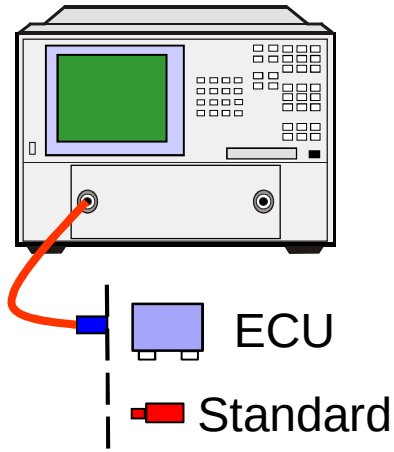




Stability tests TS2

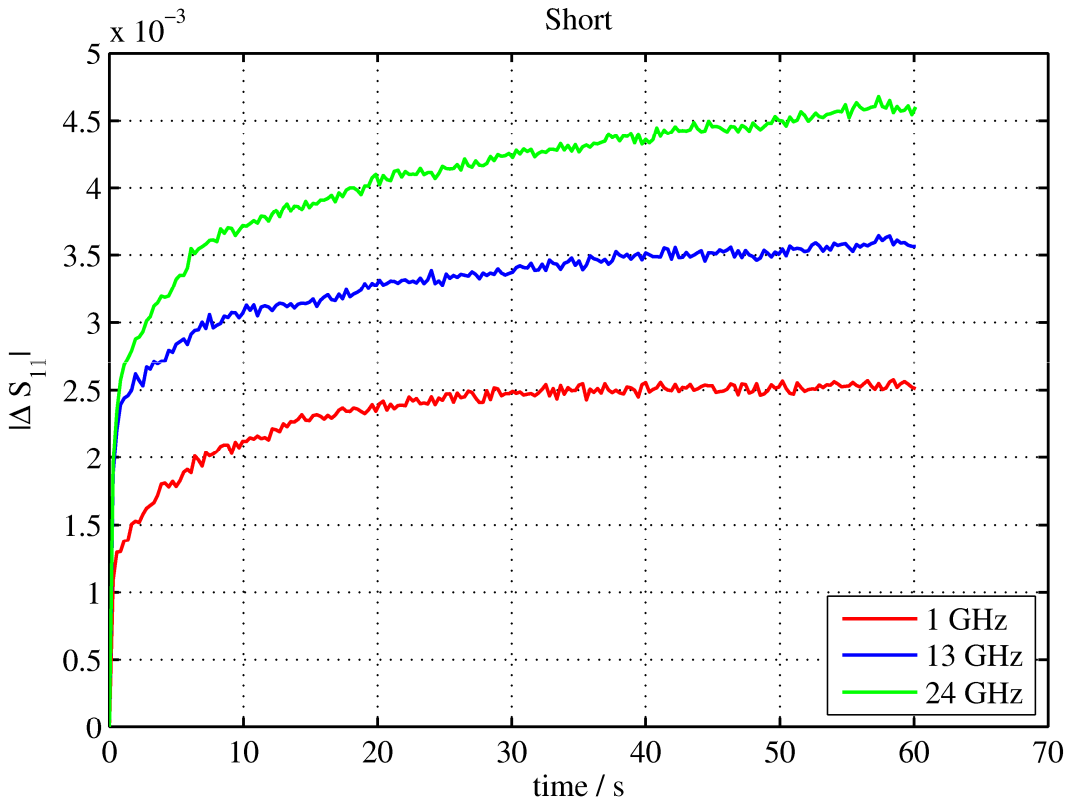
Test TS2

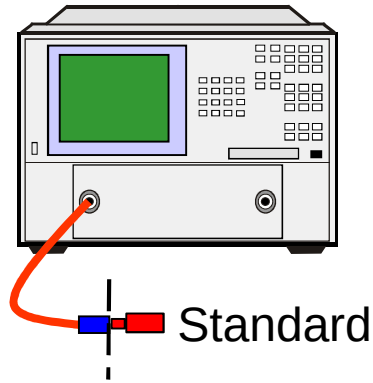
- Install test port cable between ECU and VNA
- Connect ECU, wait for thermal equilibrium
- Perform one-port calibration using ECU
- Disconnect ECU and **immediately** connect mechanical one-port standard (open, short, load)
- Immedialely measure mechanical standard
- Calculate drift (vector difference)



Results test TS2

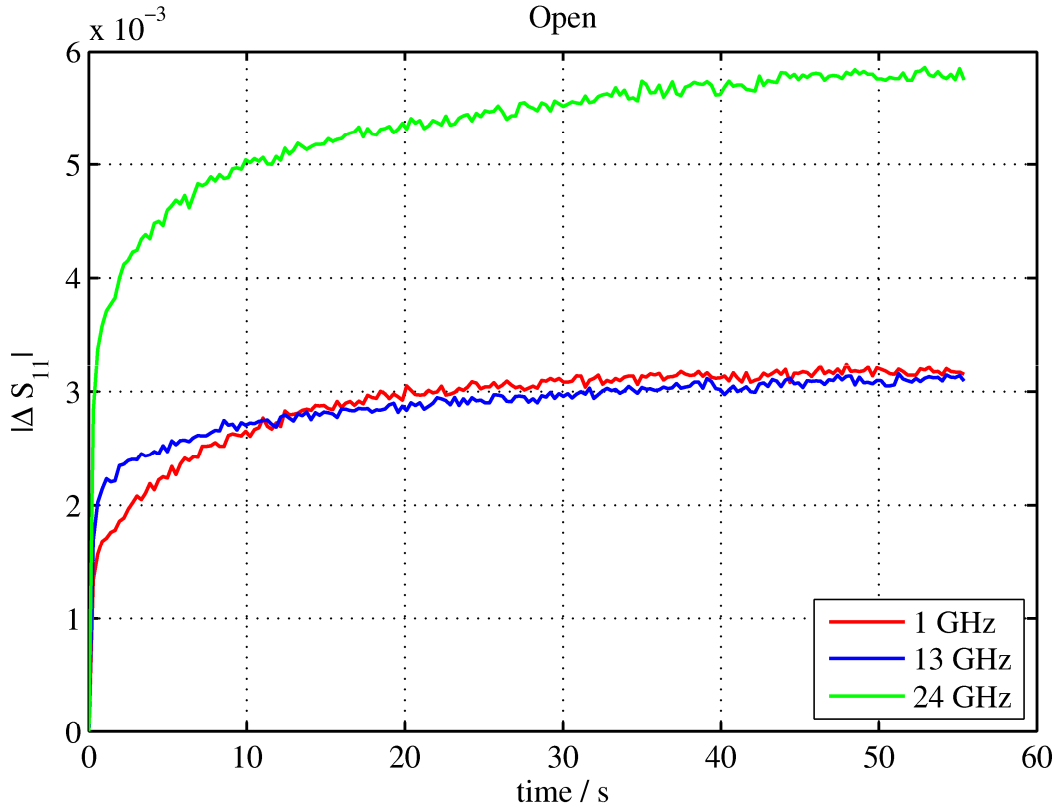
Short:

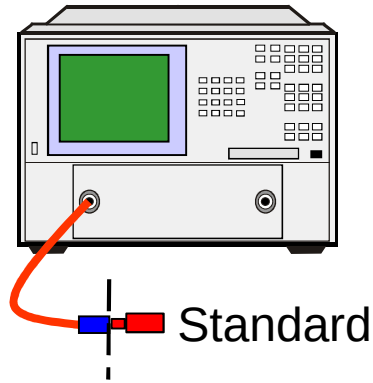




Results test TS2

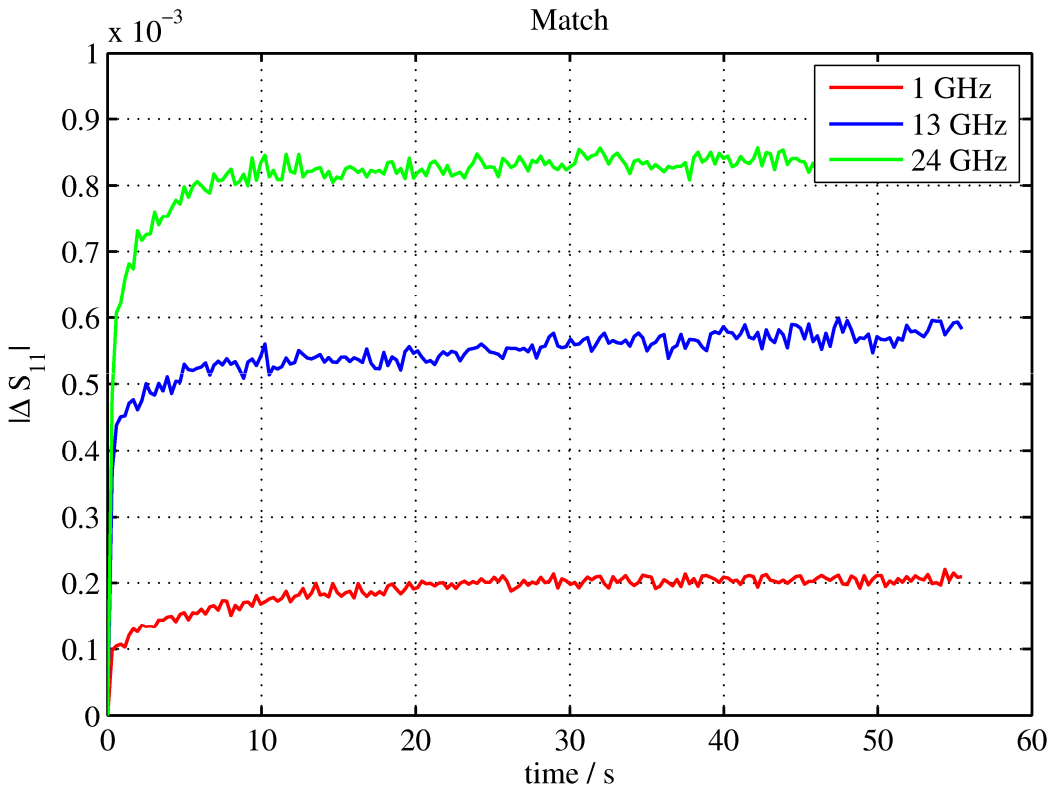
Open:

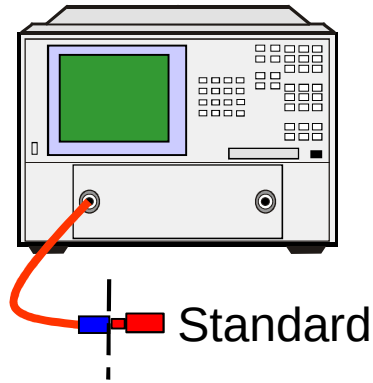




Results test TS2

Load:

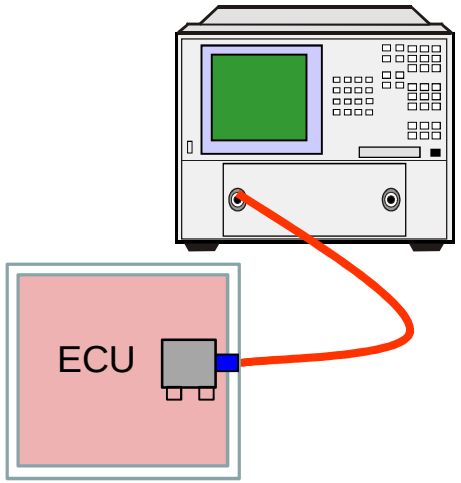


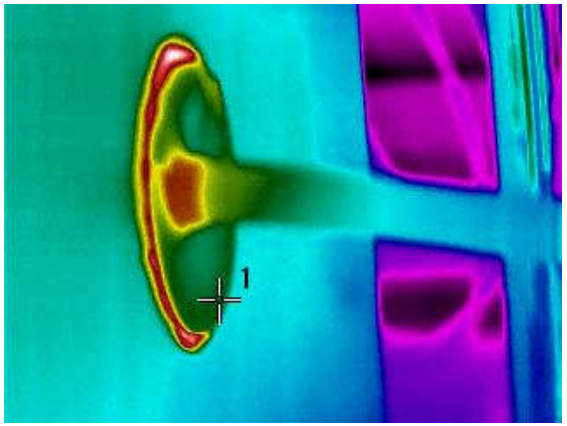


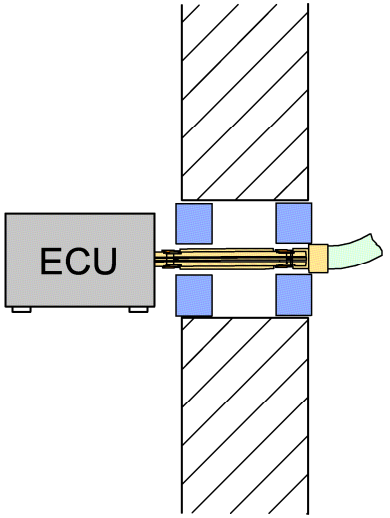
Stability tests TS3

Test TS3

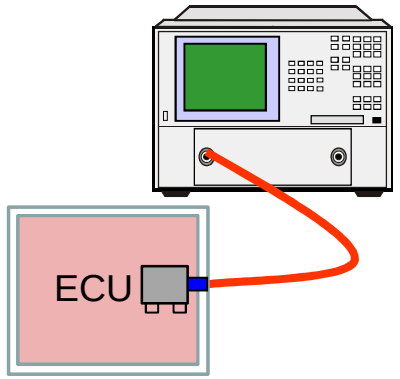
- Place ECU inside a temperature chamber
- Perform a one-port ECU calibration at laboratory temperature
- Increase chamber temperature stepwise up to 40℃
- Measure all ECU switching states after thermal equilibrium has been reached
- Calculate drift of ECU states (vector difference)



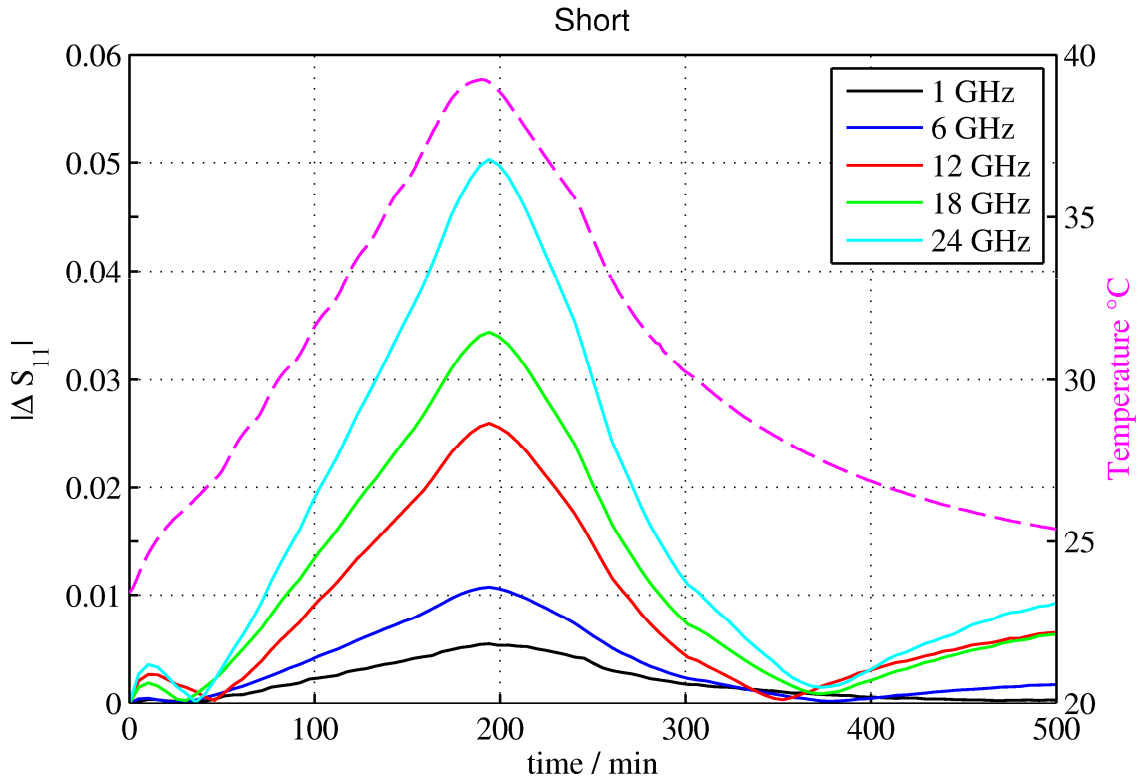




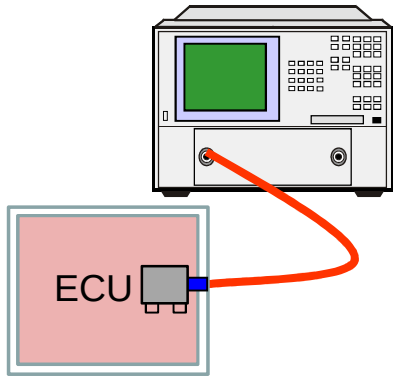
Results test TS3



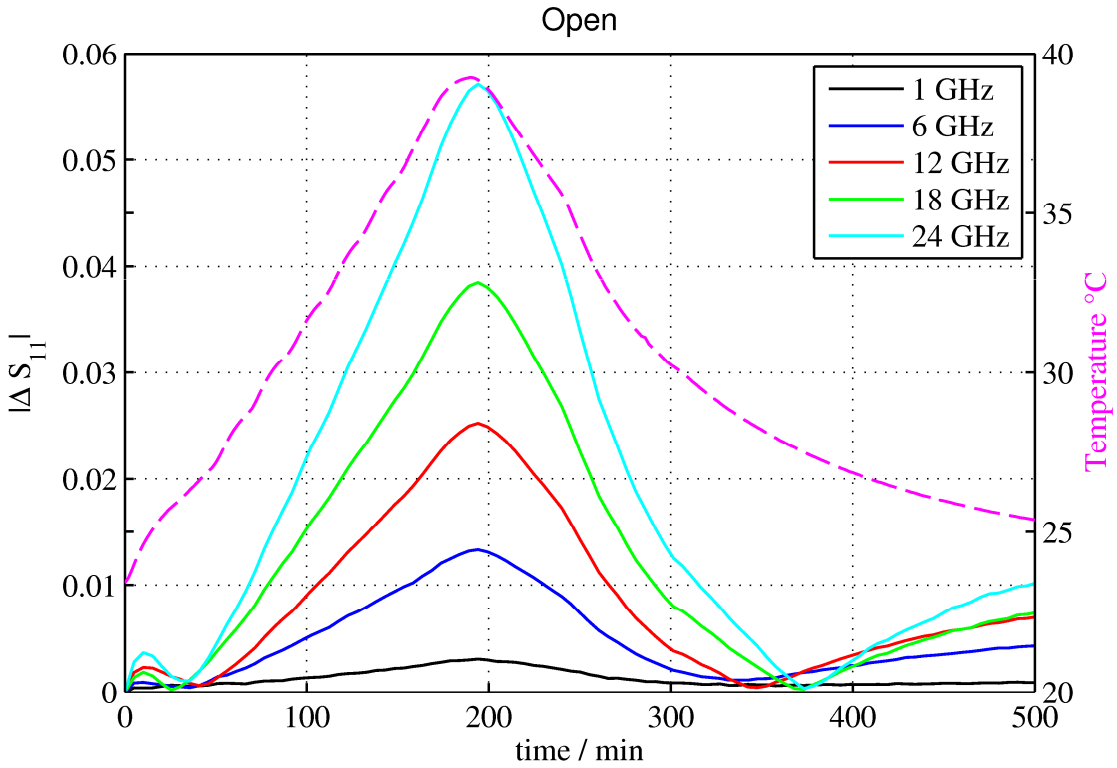
“Short” switching state



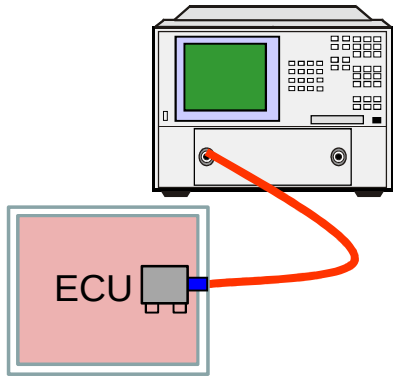
Results test TS3



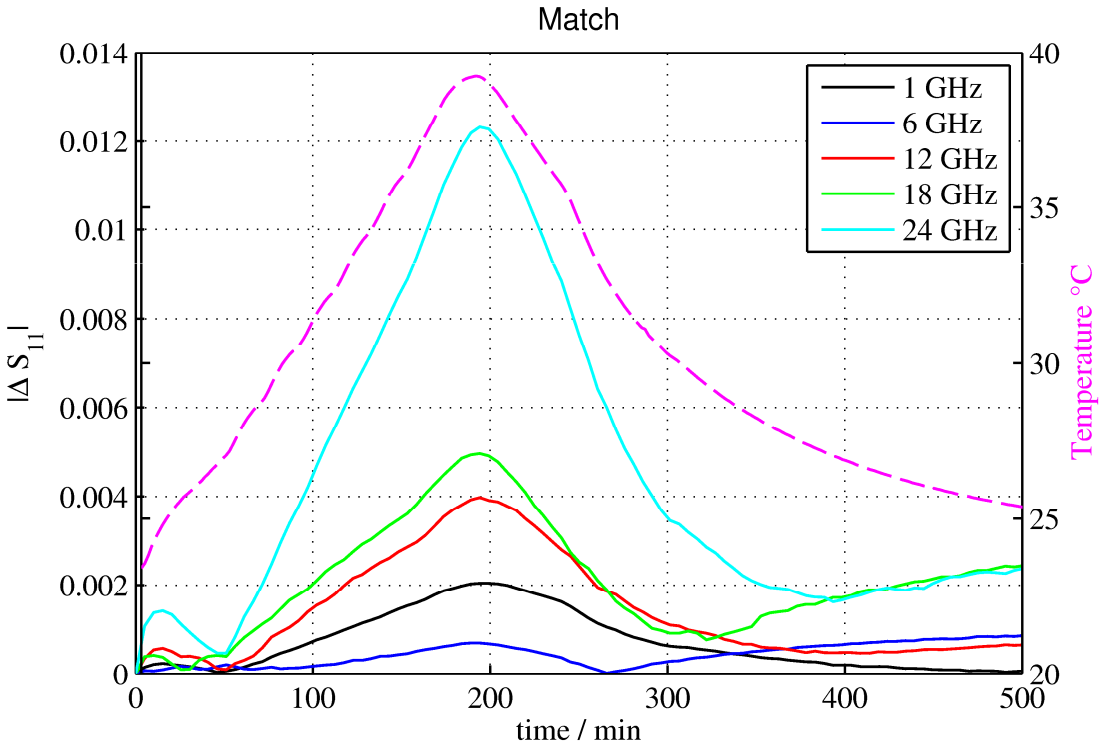
“Open” switching state



Results test TS3

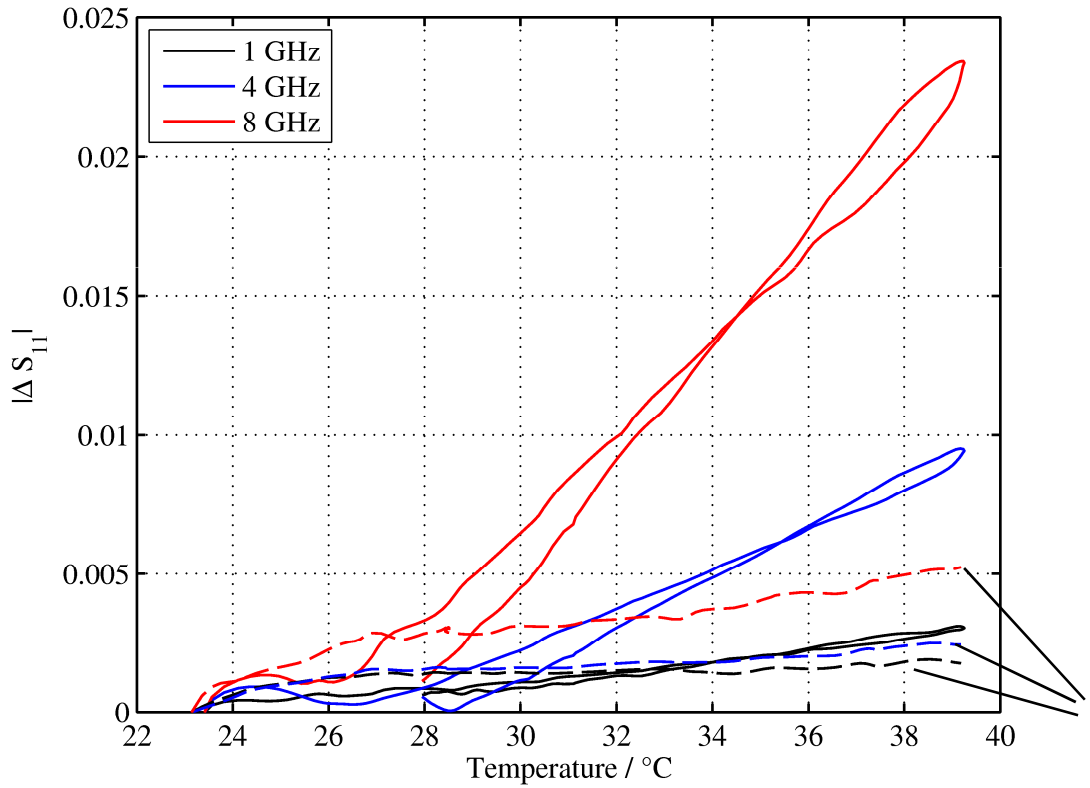


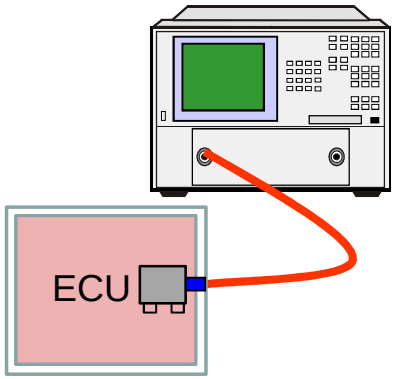
“Load” switching state

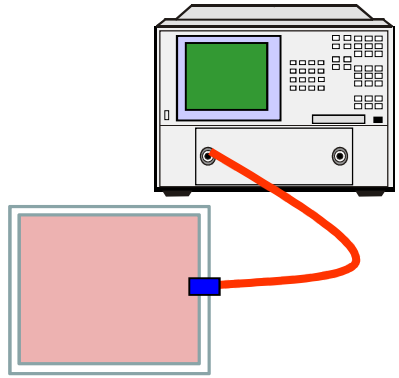


Results test TS3

Drift of “Open” switching state vs. temperature



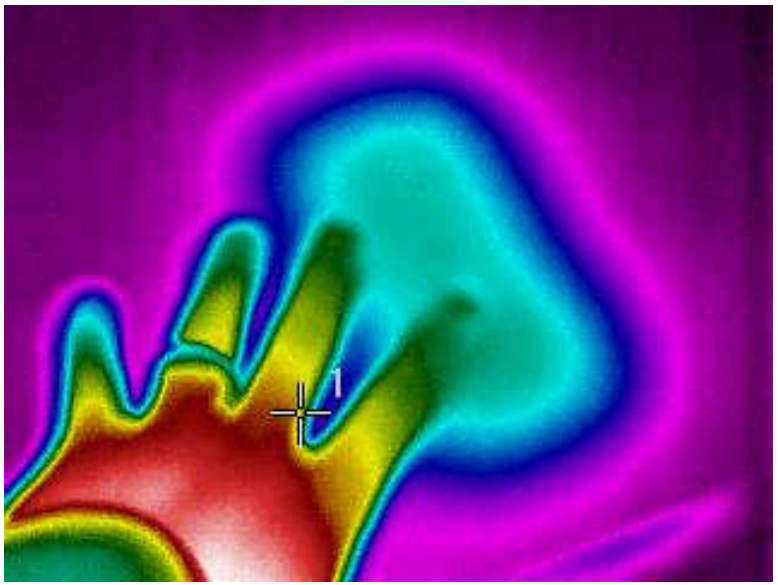




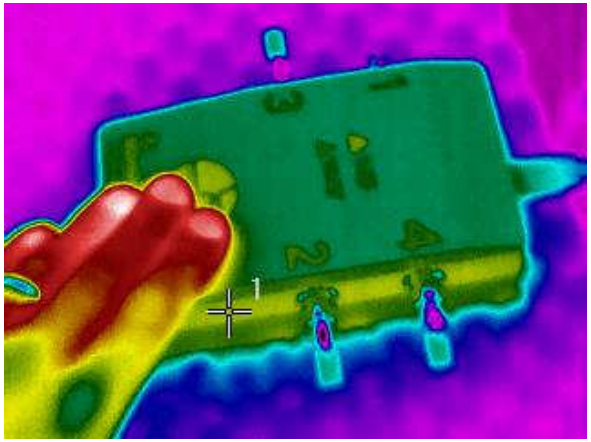
Drift of open cable vs. temperature

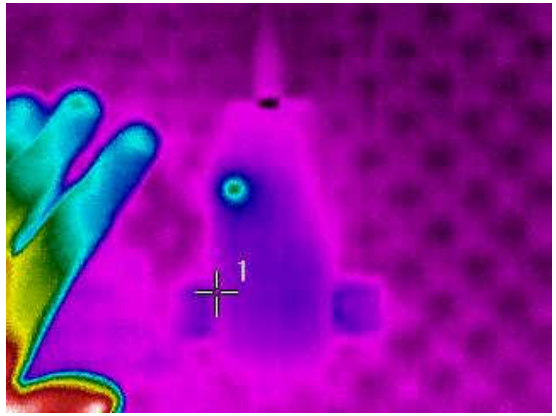
Infrared imaging of ECUs

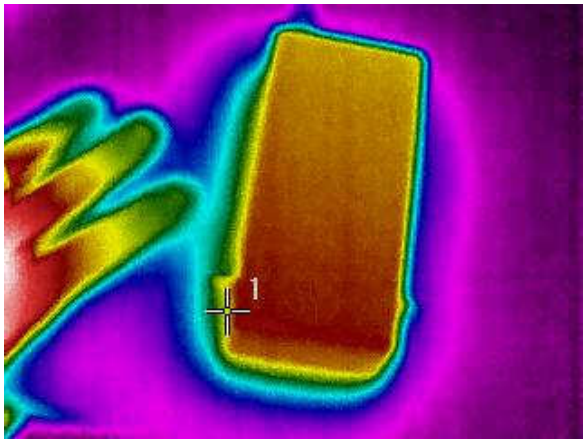
- Infrared images give insight into the heat distribution (at ECU ports)
- Image sequence vs. time can investigate heat flow



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

Acknowledgement

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