Effect of a Local Ground and Probe Radiation on the Microwave Characterization of Integrated Inductors

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Measurement Model for Integrated Inductors

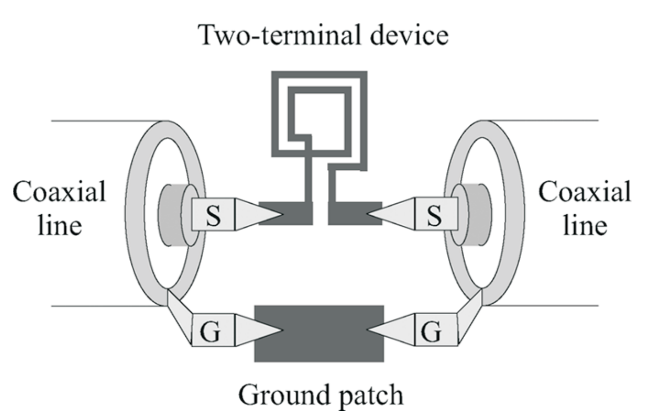


Fig. 1. Schematic of 2-port S-Parameter Measurement of 2-Terminal Device

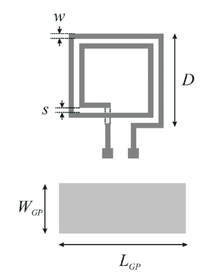


TABLE I
NUMBER OF TURNS (N), DIAMETER (d), TRACK WIDTH (w), AND SPACING (s) OF INDUCTORS L1 AND L2

Inductor	N	d (μm)	w (μm)	s (μm)
L1	3	300	20	10
L2	2	600	40	20

TABLE II
LENGTH (L_{GP}) AND WIDTH (W_{GP}) OF THE FOUR GROUND PATCHES A—D, AS USED IN THE INDUCTOR EXPERIMENTS

Ground patch	L_{GP} (μm)	W_{GP} (μm)
A	600	100
B	600	300
C	600	600
D	1200	1200

Fig. 2. Test Structures used for this Study

- Metal patch as local ground reference
- μw ports at device terminals / ground patch
- TEM signals from VNA delivered at S and G contacts of a RF Probe

Results using conventional meas. methods

- 2-port S-Parameter Measurements:
  - HP (Agilent) 8510 VNA
  - Infinity Probe GS 200μm
  - LRM Calibration

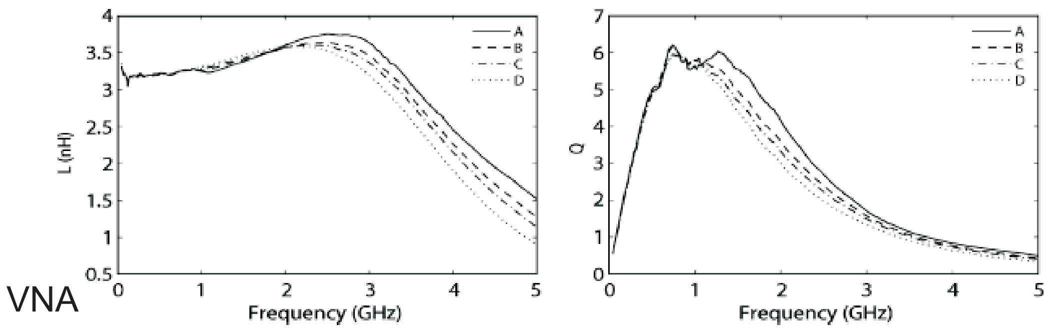


Fig. 3. Inductance and Q-Factor for L1

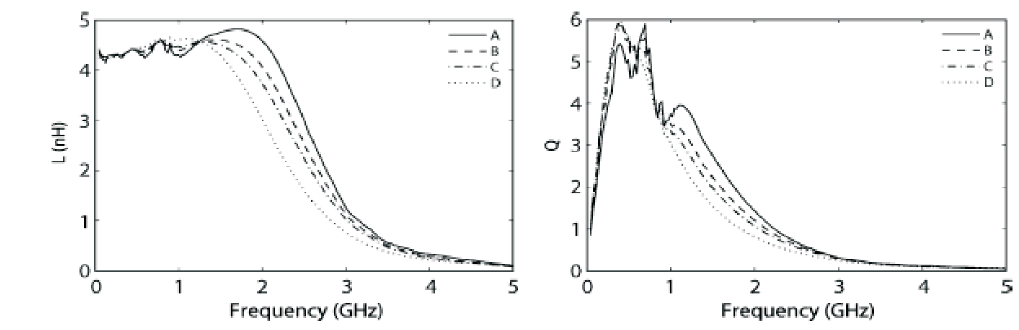


Fig. 4. Inductance and Q-Factor for L2

Grounding Effects

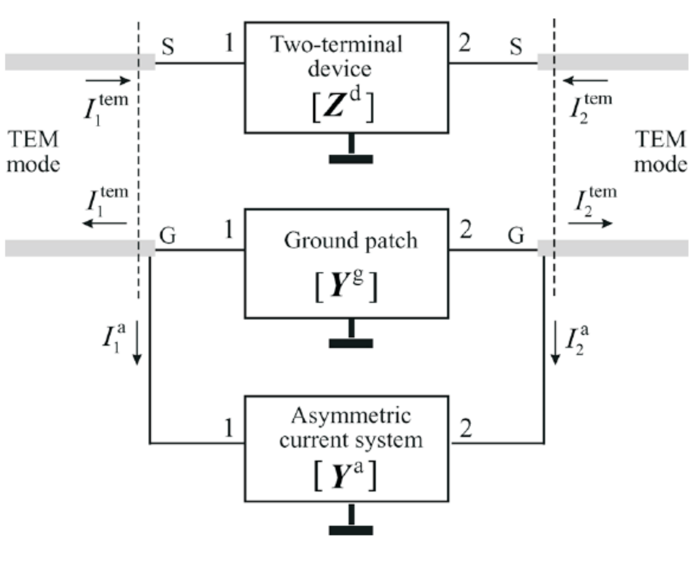


Fig. 5. Measurement model for two-terminal device
S-Parameter reference plane at dashed line

- Device has “ground” that differs from probe G pads
- Admittance $[Y^g]$ of G pads (patch)
- Admittance $[Y^a]$ looking into probes G contacts

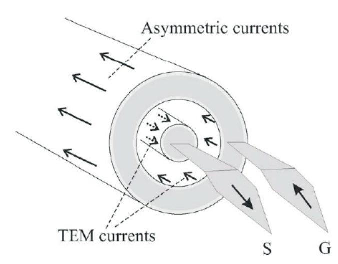


Fig. 6. Cross section of coaxial cable inside RF probe

DUT and Pads / Probes in Series

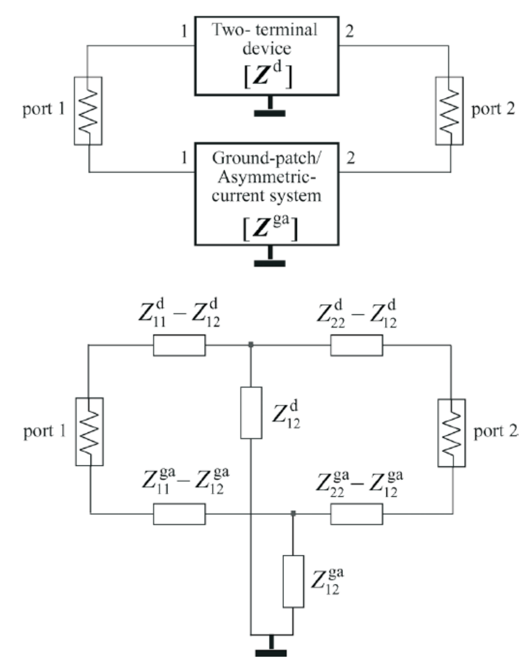


Fig. 7. Defining an overall matrix Z^{ga}

- Small probe separation case
- Pads/probes parasitics appear in net Z_{12} only
- Z_{11}-Z_{12} and Z_{22}-Z_{12} terms are clean
- Low impedance ground patch → clean
  $1/y^g \rightarrow 0$, y^a swamped,
  $z_{12}^{ga} \rightarrow 0$

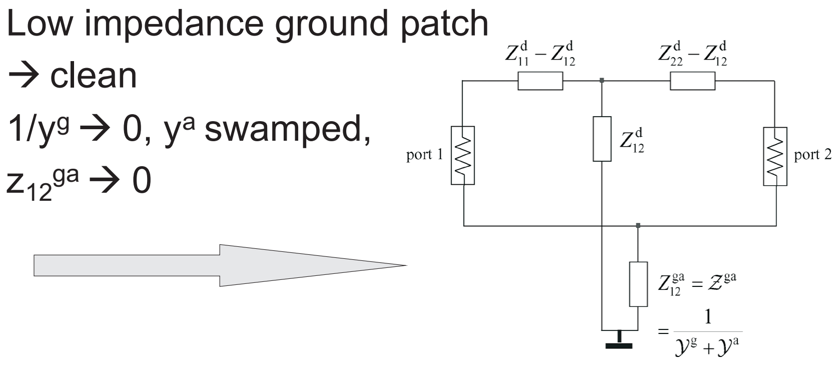


Fig. 8. T-Network for small probe separation case

Pads / Probes Ground deembedding

- New test structure with $Z_{12} = 0$
- Signal pads couple to device ground and not to each other
- Identifies Z^{ga}
- $[Z_{corr}] = [Z_{raw}] - Z^{ga}$
  i.e., substract constant Z^{ga} from each term of matrix $[Z_{raw}]$

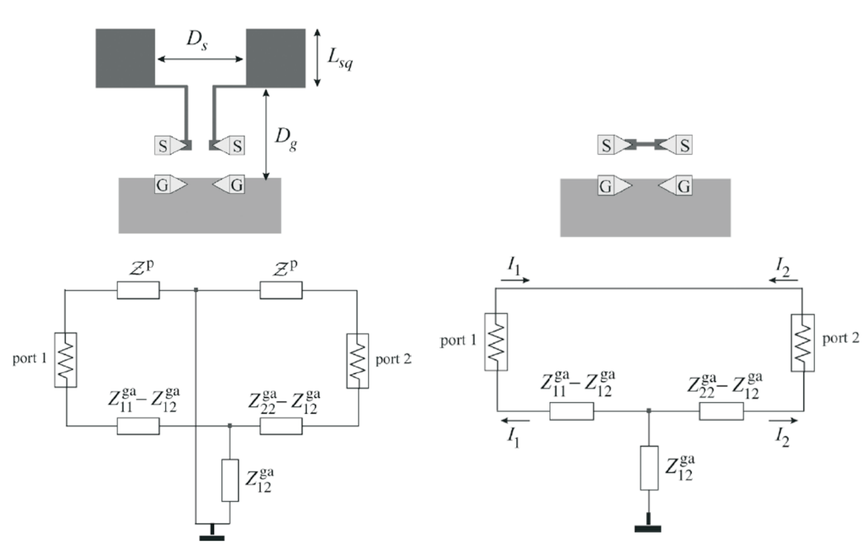


Fig. 9. Isolation and Thru test device structures for deembedding

Results after deembedding

- Considerably less variability
- Almost independent from used ground patch
- Note: High resistance contact (possible particle) observed in L2a

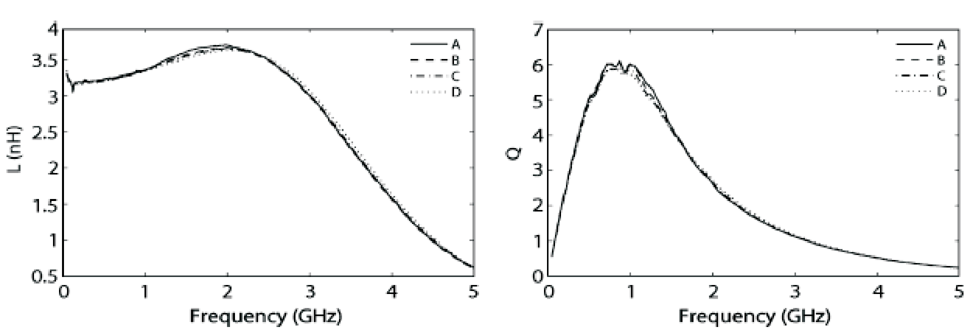


Fig. 10. Deembedded Inductance and Q-Factor for L1

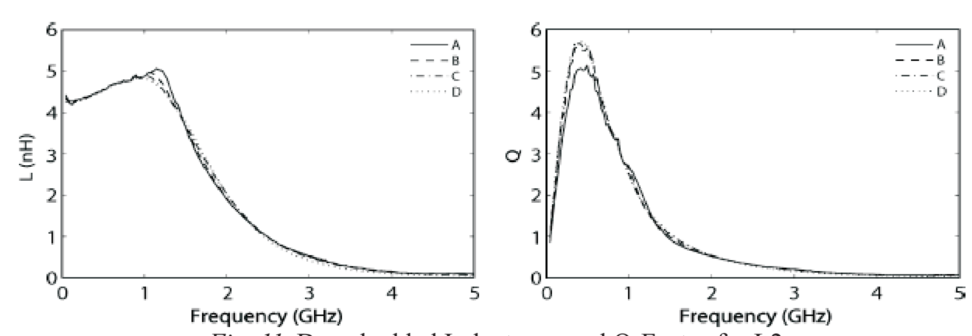
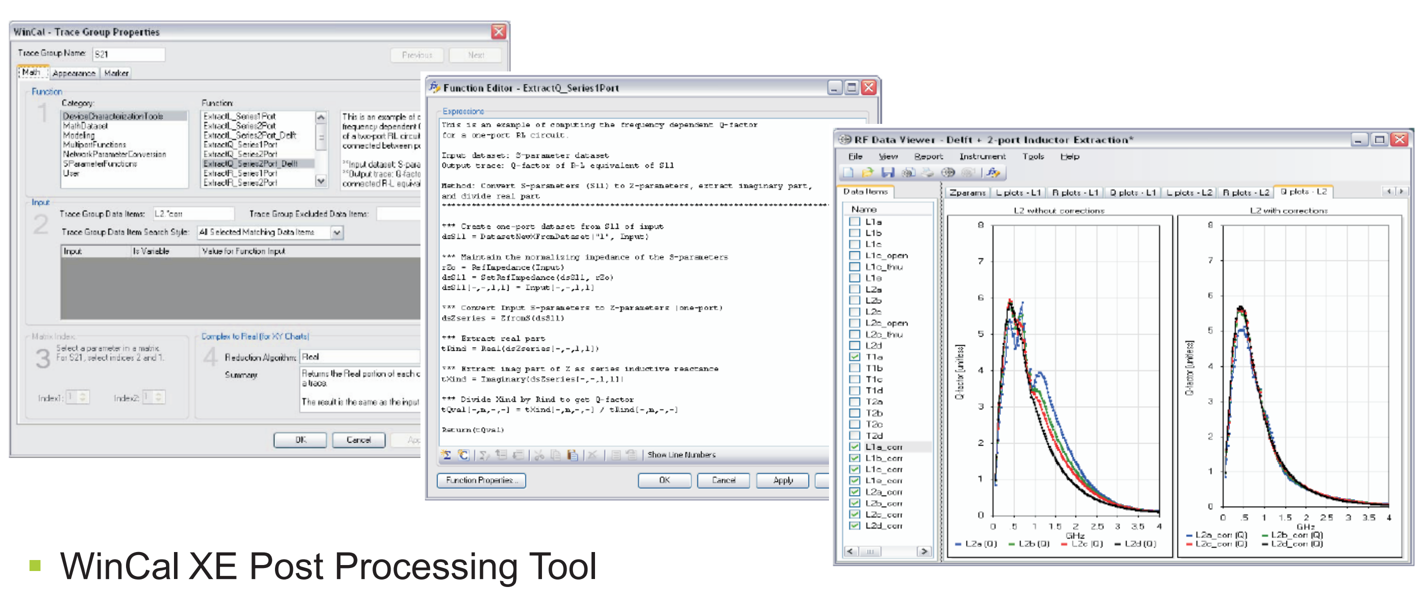


Fig. 11. Deembedded Inductance and Q-Factor for L2

WinCal XE Implementation



- WinCal XE Post Processing Tool
- See WinCal XE report file “Delft + 2-port Inductor Extraction.wrp”

Conclusions

- S-Parameter measurements of integrated inductors depends on local ground patch
- Parasitic asymmetric currents causes unexpected ripple
- A model to analyze the effect of ground structure ans asymmetric currents was developed
- Model was verified by experimental measurements of spiral inductors with different ground patches
- De-embedding technique developed and applied
- De-embedded results almost independent from used ground patch