Accurate Characterization Method for Cross-Line on CMOS Based on Two-Port Measurements

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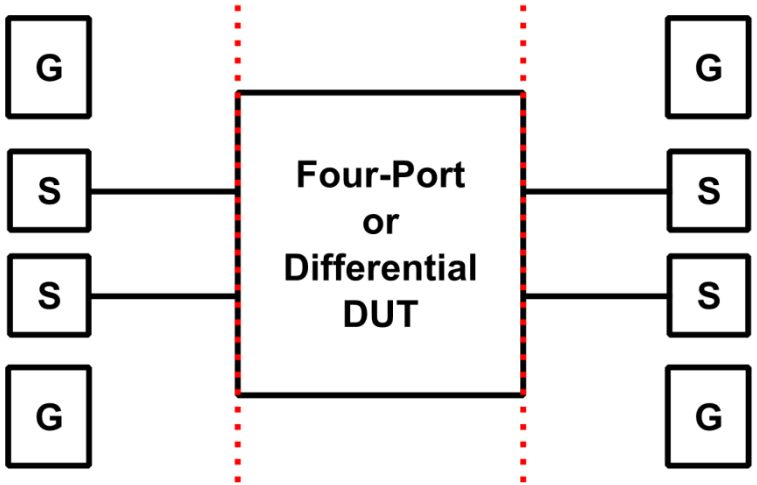
Issues of Multi-Port Measurements

- De-embedding
- Cross-talk and coupling between probes
- Most common VNAs Two-Port
- Decreased Dynamic Range



Characteristics of Cross-Line

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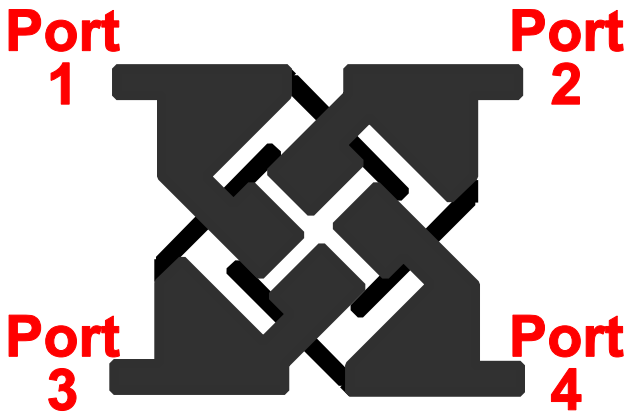
- The structure is a four-port symmetrical and reciprocal one

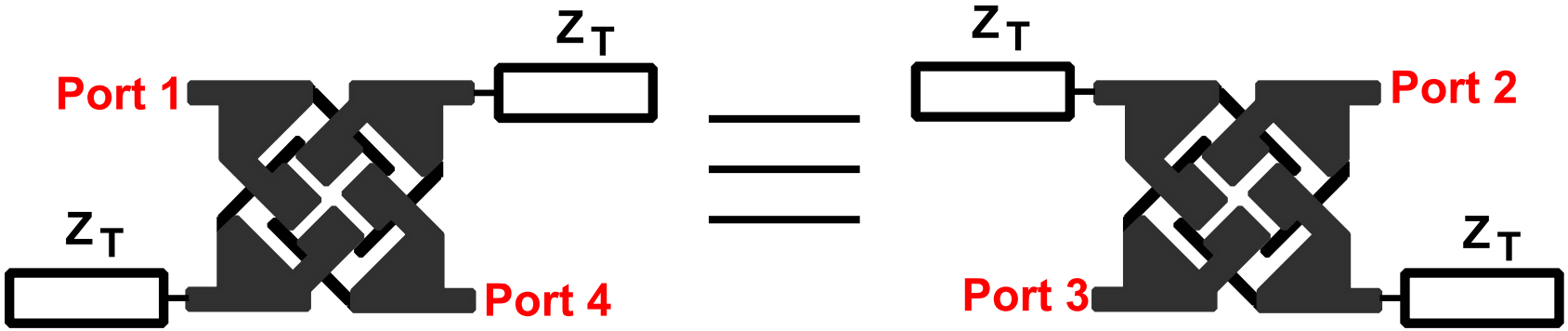


$$S_{CCC} = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{12} & S_{11} & S_{14} & S_{13} \\ S_{13} & S_{14} & S_{11} & S_{12} \\ S_{14} & S_{13} & S_{12} & S_{11} \end{bmatrix}$$

- Four different S-parameters
- Four unknowns to be solved

Characteristics of Cross-Line

- Terminating port 2 and 3, or port 1 and 4 would result in **same** S-parameter response
- Reciprocal and symmetrical



Two-Port Characterization Method

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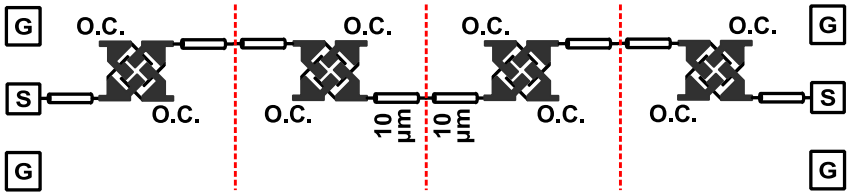
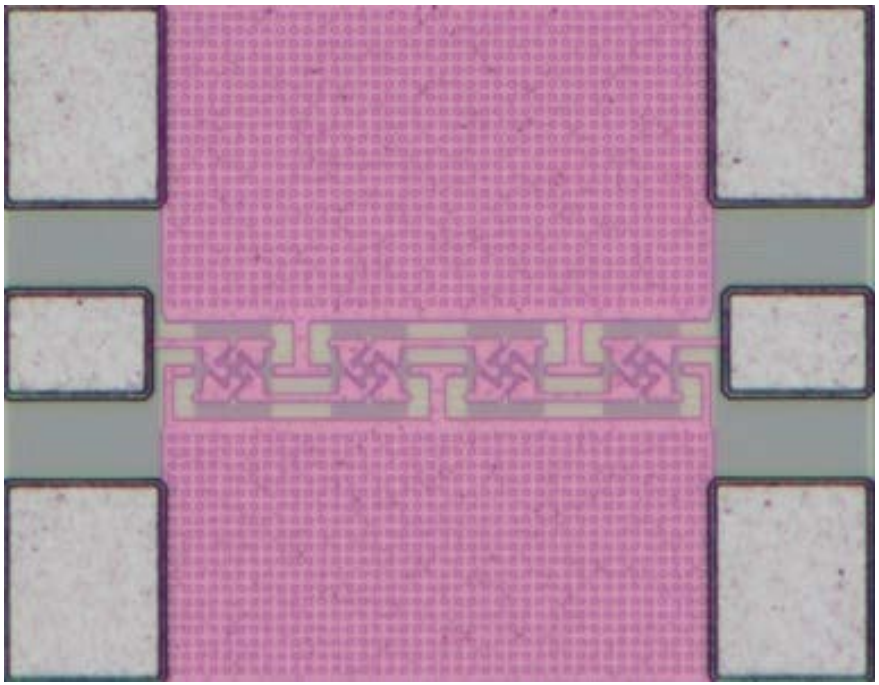
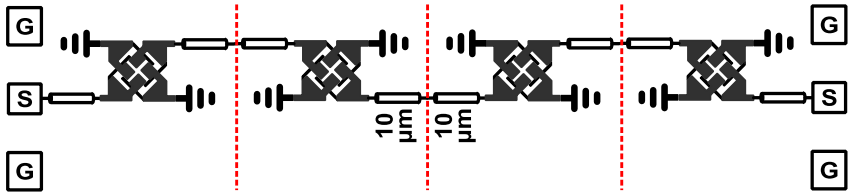
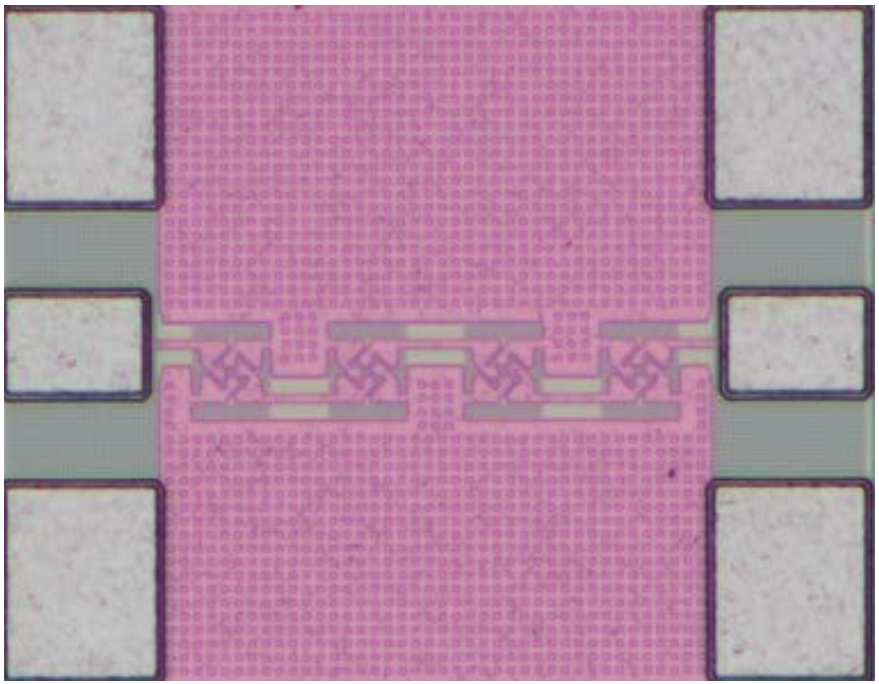
- Open Circuited





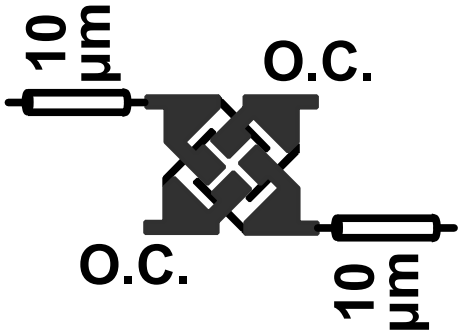
- Short Circuited

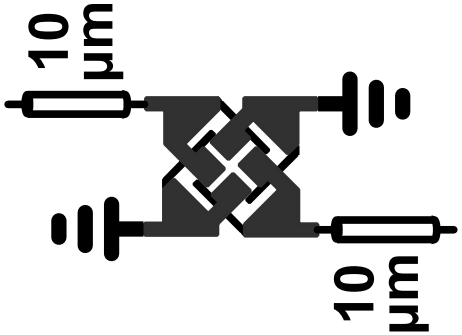




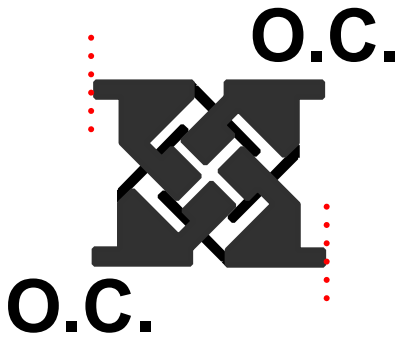
Method of Characterization

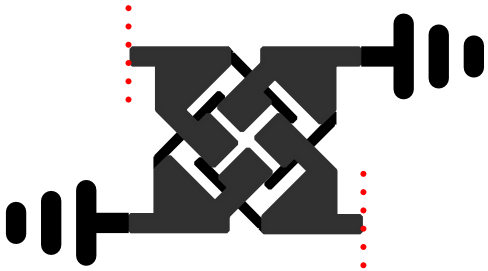
- Remaining is the four times cascaded same structure
- Can be solved for one for each case



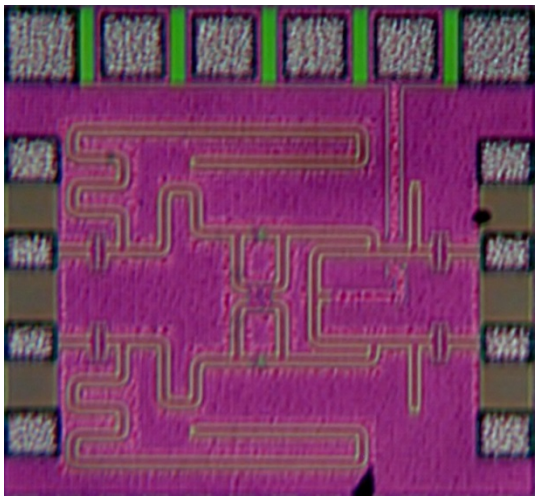


- Additional 10 μm transmission lines to be de-embedded





Comparison on Differential Amp.

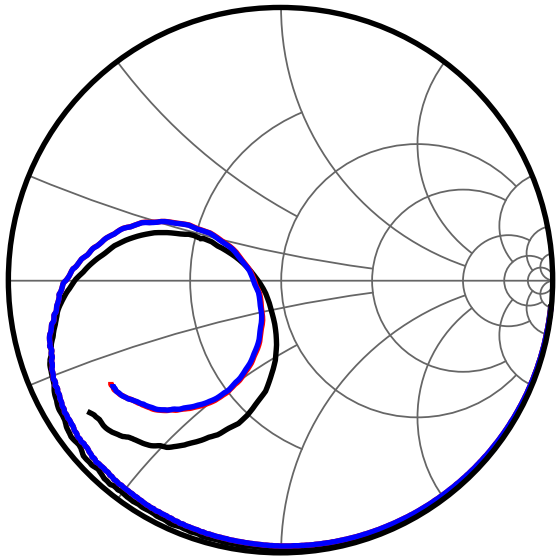


Measurements

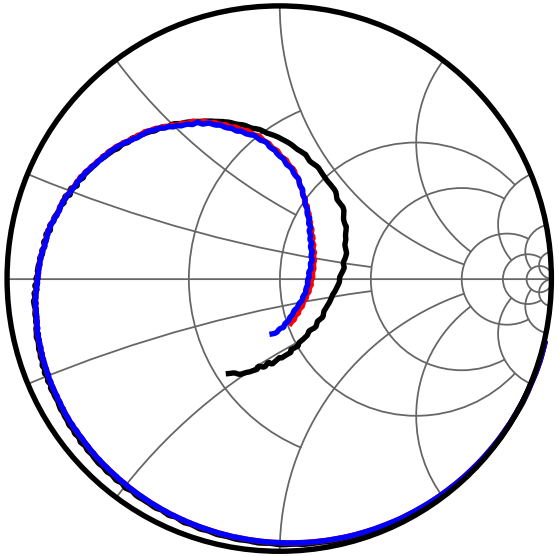
W/ Proposed Method (Two-port)

W/ Differential Characterization (Four-port)

Diff. Input RL

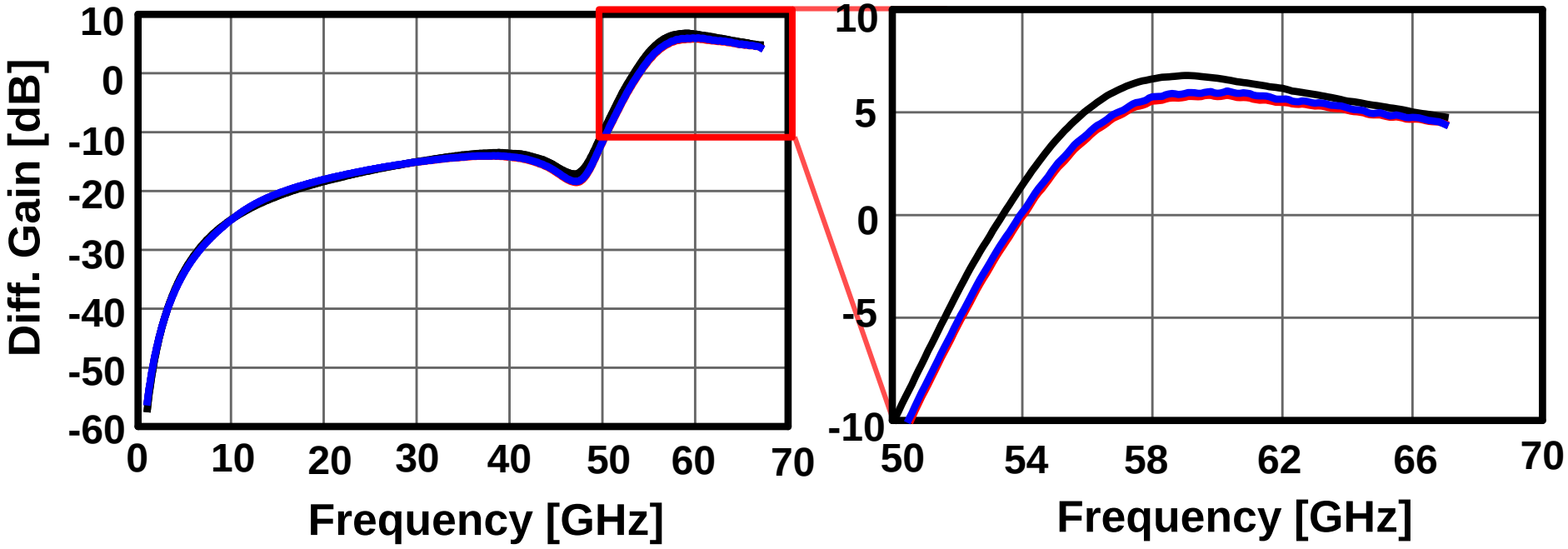


Diff. Output RL



Four-Port: Tokgoz *et al.*, SiRF 2015

Differential Gain



Measurements

W/ Proposed Method (Two-port)

W/ Differential Characterization (Four-Port)

Four-port results: Tokgoz *et al.*, SiRF 2015

Conclusions

- Importance of **symmetry** for the cross-coupled amplifiers
- **Two-port characterization** method for a four-port device
- **Well-matched** with four-port measurement results up to 67 GHz

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THANK YOU VERY MUCH FOR YOUR ATTENTION!