Distortion Contribution Analysis of strongly non-linear analog circuits

Adam Cooman, Piet Bronders & Gerd Vandersteen

agency for Innovation by Science and Technology

Vrije Universiteit Brussel

Analog design = LTI

Design flow based on Linear System Theory

- Non-linear performance at a (too) late stage
- No indication about the source of distortion

We need to find the source of distortion

Distortion Contribution Analysis

Pinpoint the dominant source of distortion

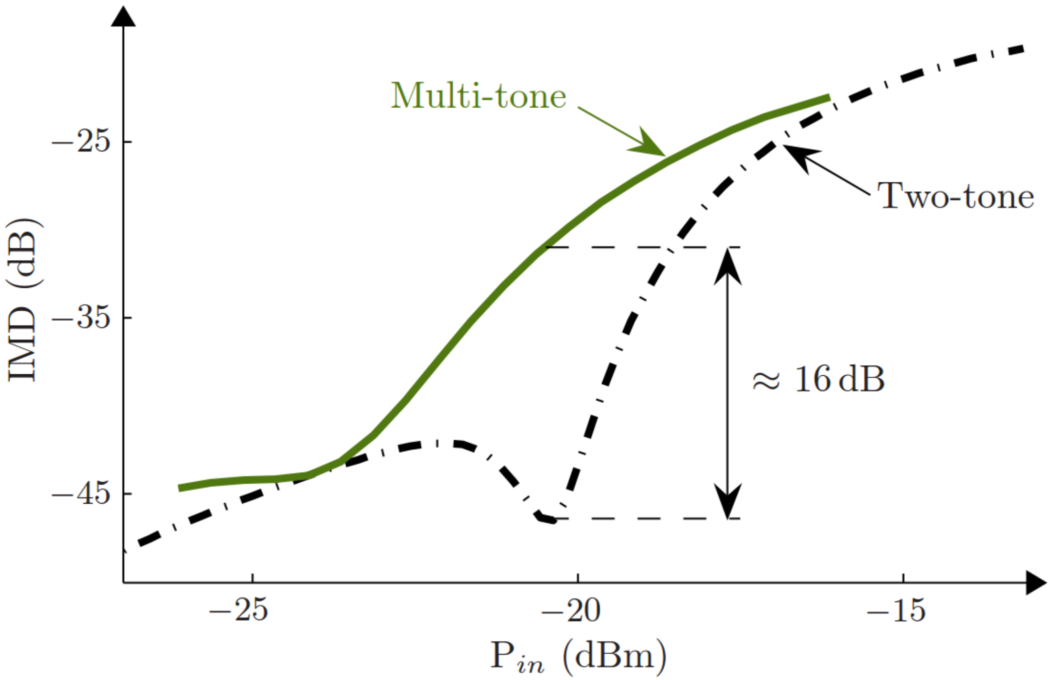
to solve possible problems effectively

Usually: Volterra analysis

under 1-tone and 2-tone excitations

Modern signals ≠ One- or Two-tones

Distortion depends on input signal class



Realistic testing = Realistic excitation

Overview

Multisines and the BLA

Estimation of MIMO BLA

DCA of a Doherty PA

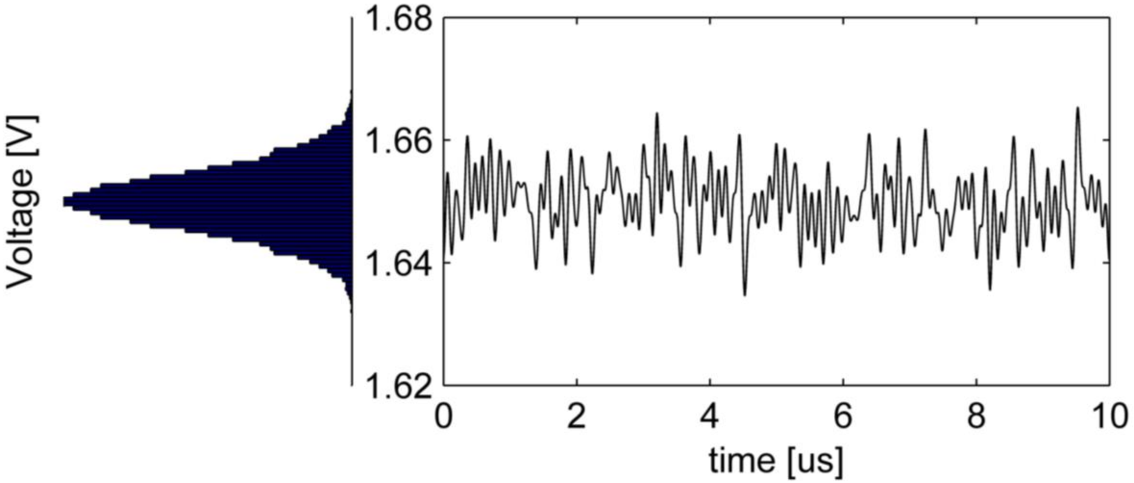
Multisines ≅ modern signals

Many tones

Amplitude control

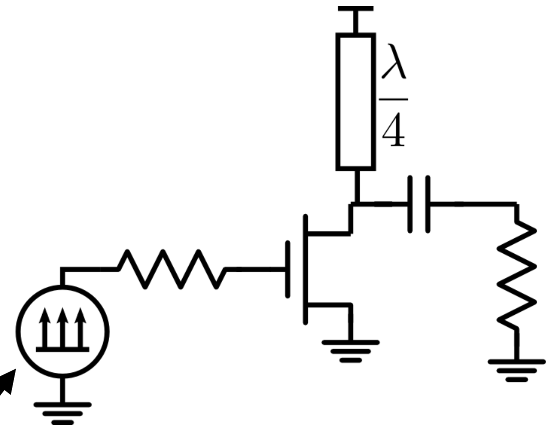
Random phase

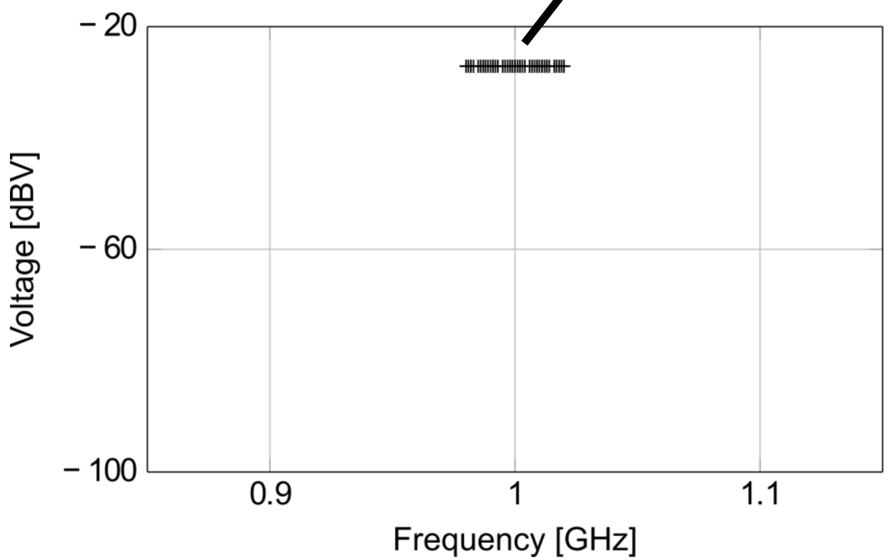
$$u(t) = \sum_{k=1}^{N} A_k \sin(k2\pi f_0 t + \varphi_k)$$

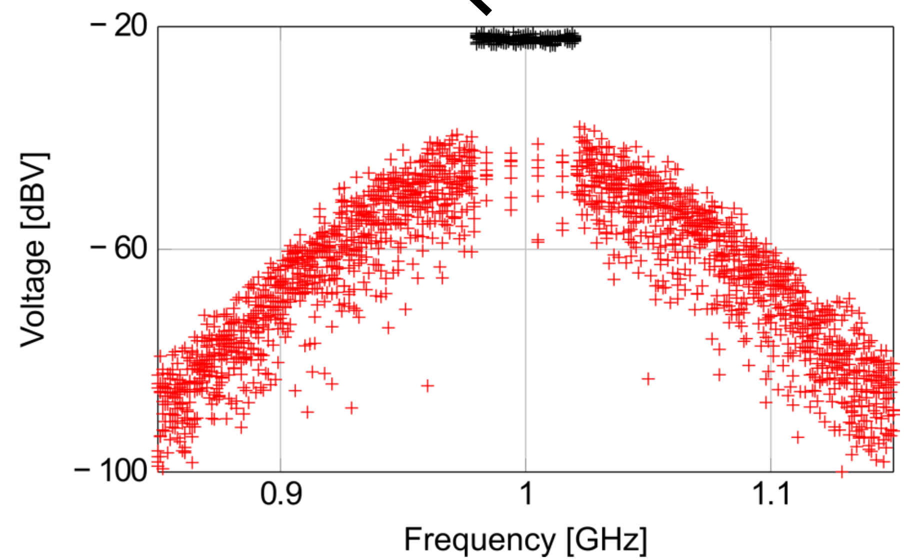


Example: Class-C + multisine

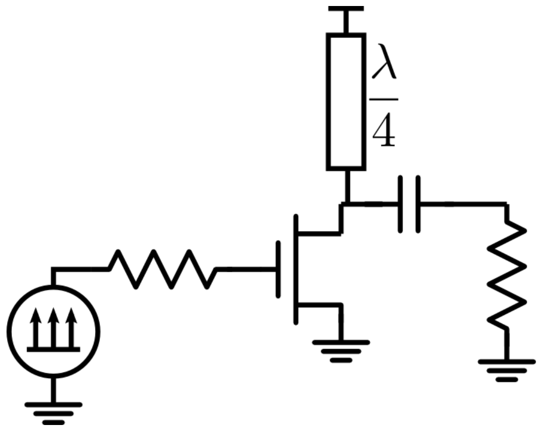
41 bins, 40MHz BW
Random-phase
Gaussian distributed

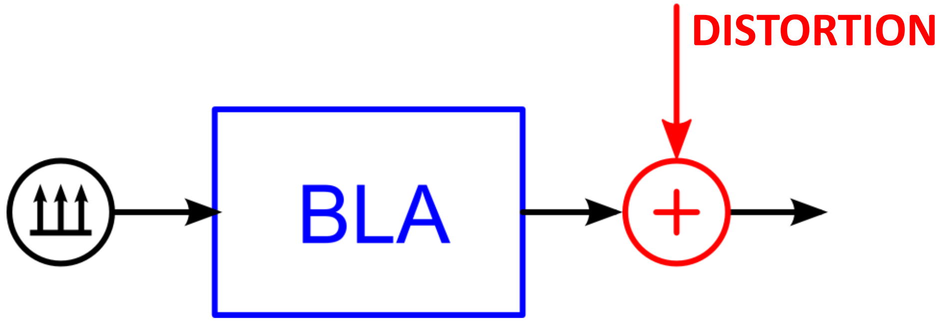


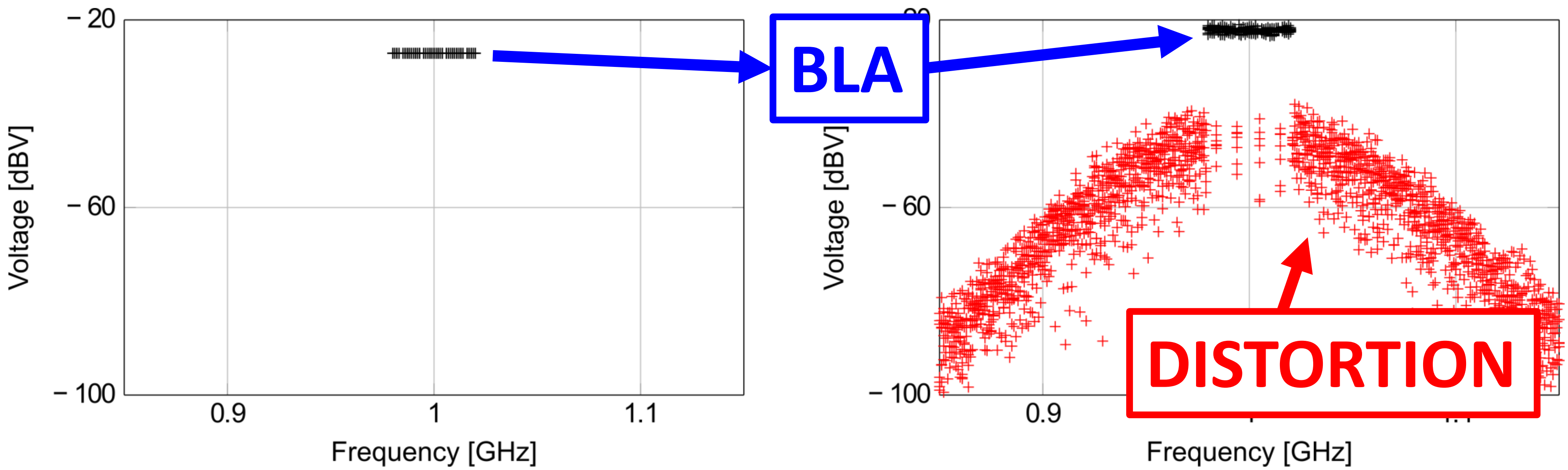




Example: Class-C + multisine







Best Linear Approximation

Only valid for fixed class of input signals

- Power Spectrum fixed
- Distribution Fixed

Distortion term = $OUT - BLA * IN$

LOOKS LIKE NOISE!

Overview

Multisines and the BLA

Estimation of MIMO BLA

DCA of a Doherty PA

Real circuits have reserve gain

$V_{in} \rightarrow V_{out}$ model is not representative

Port-based representation needed.

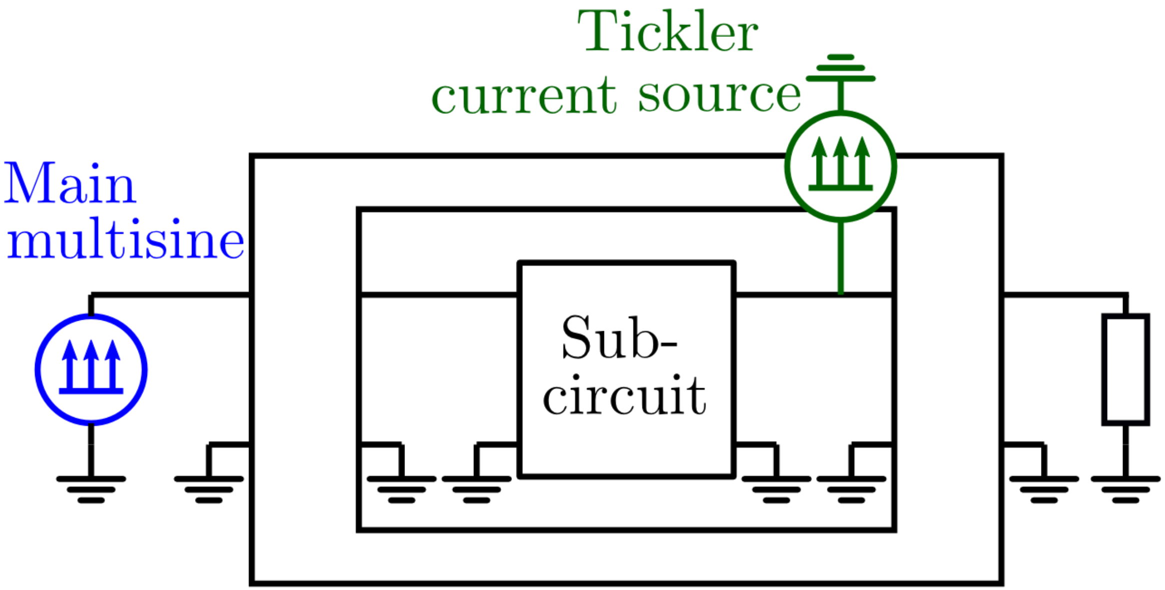
We will use S-parameters

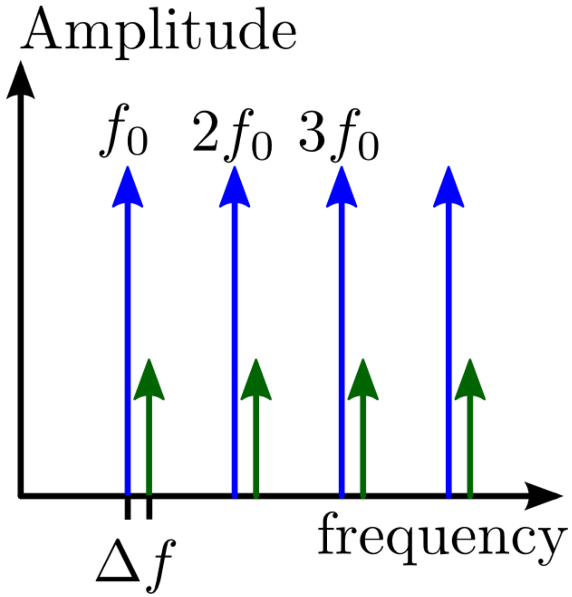
$$\begin{bmatrix} B_1 \\ B_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} A_1 \\ A_2 \end{bmatrix}$$

Multiple-Input Multiple Output (MIMO)

Estimating MIMO BLA

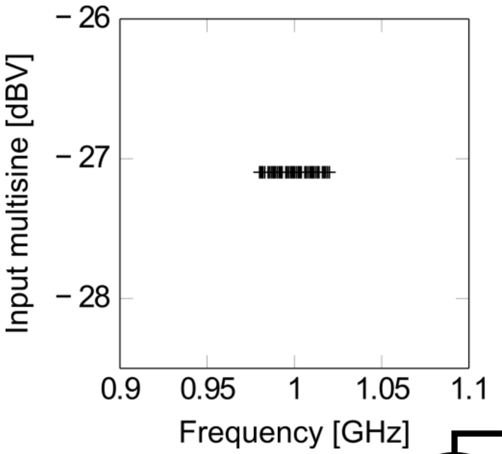
2 inputs = 2 excitation signals

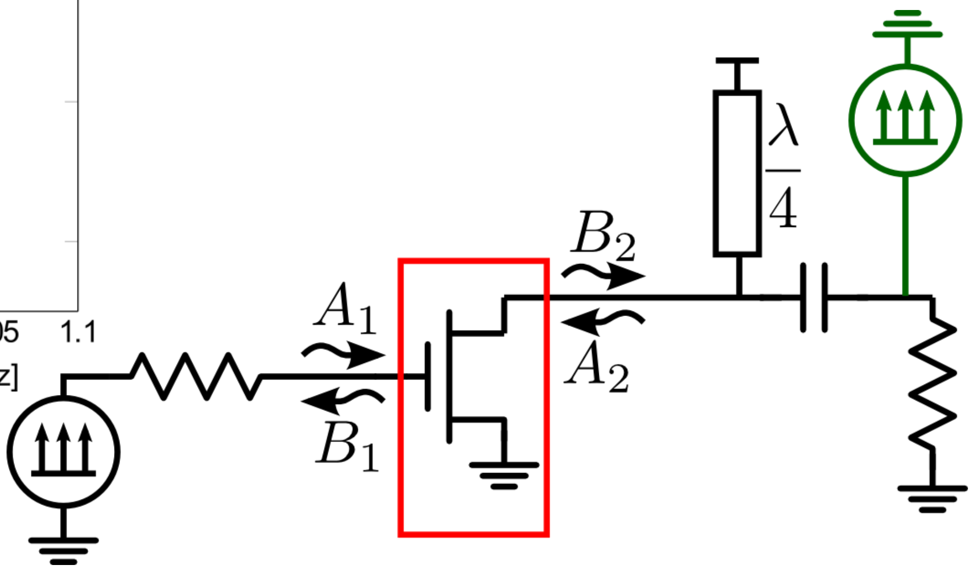


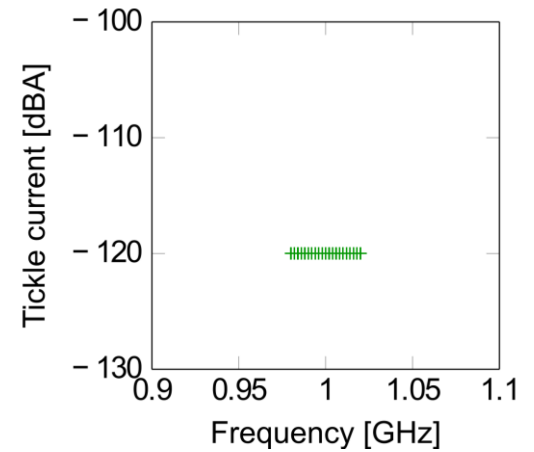


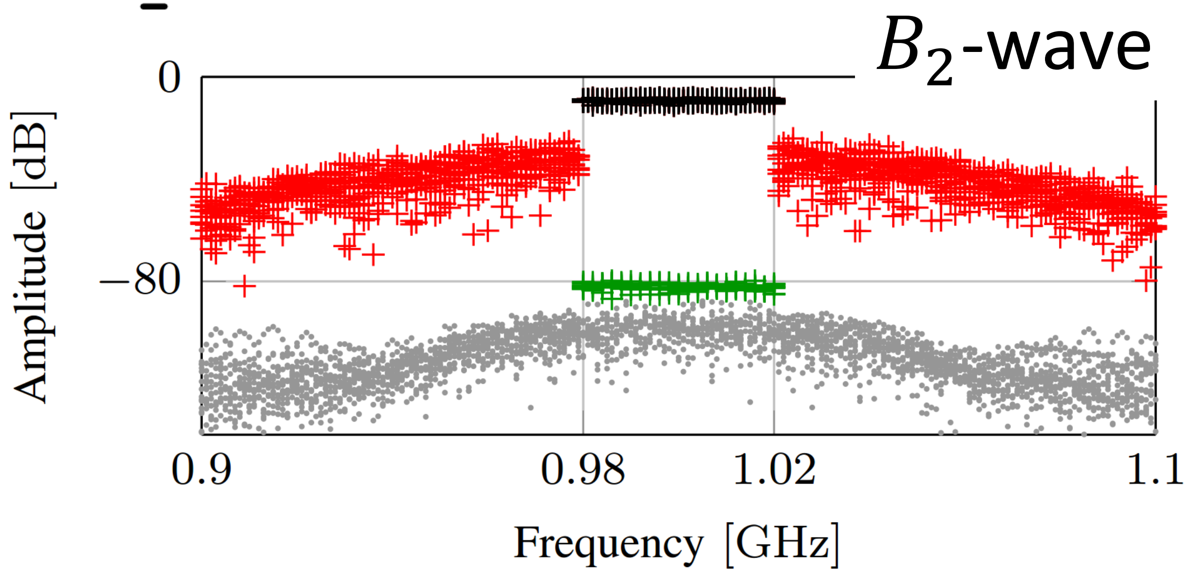
Add tickler multisines to excite correctly

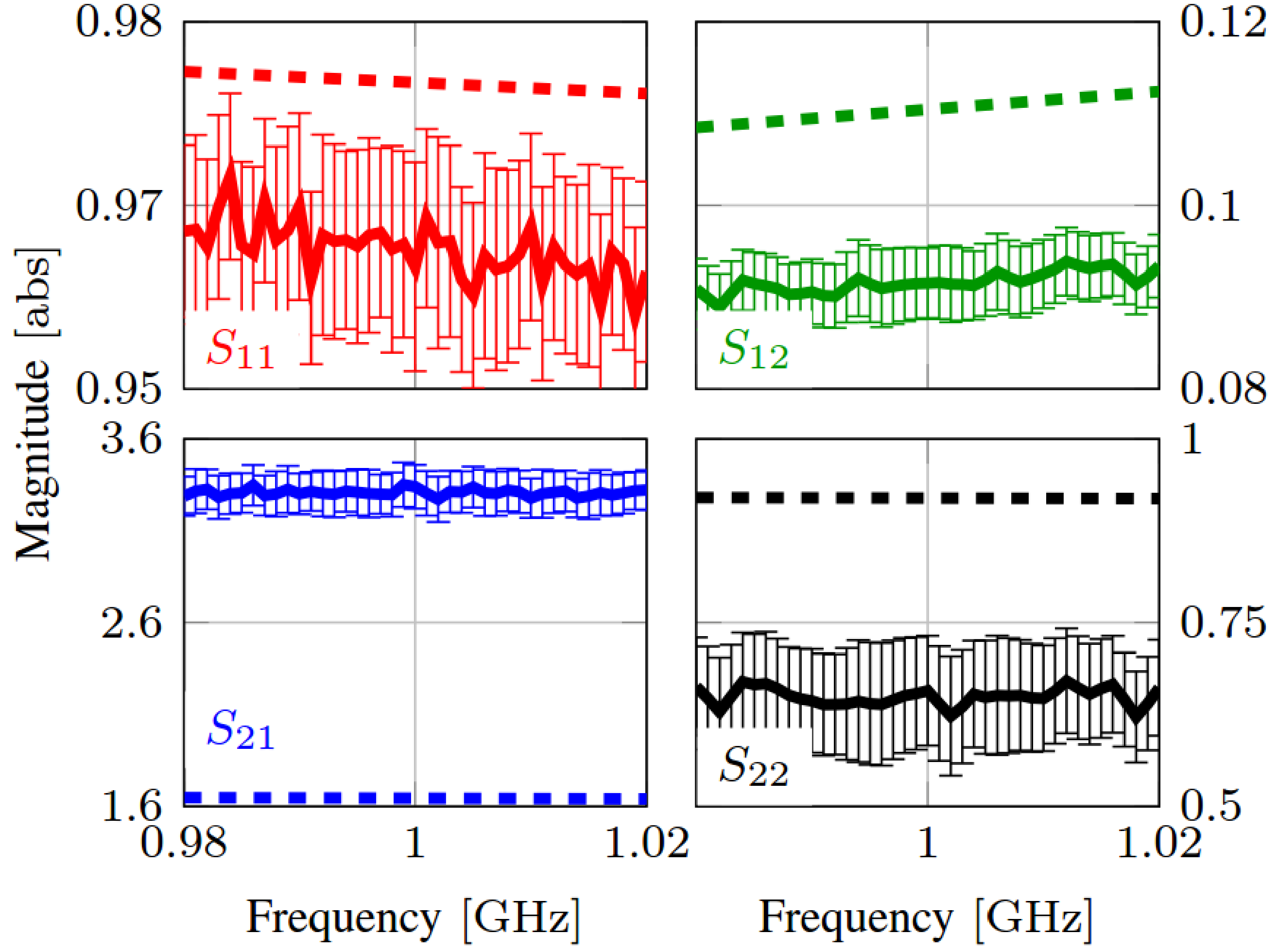
MIMO BLA of the class-C example










0.98
0.97
0.95
3.6
2.6
1.6
0.12
0.1
0.08
1
0.75
0.5
S_{11}
S_{12}
S_{21}
S_{22}
Magnitude [abs]
0.98
1
1.02
1
1.02
Frequency [GHz]
Frequency [GHz]

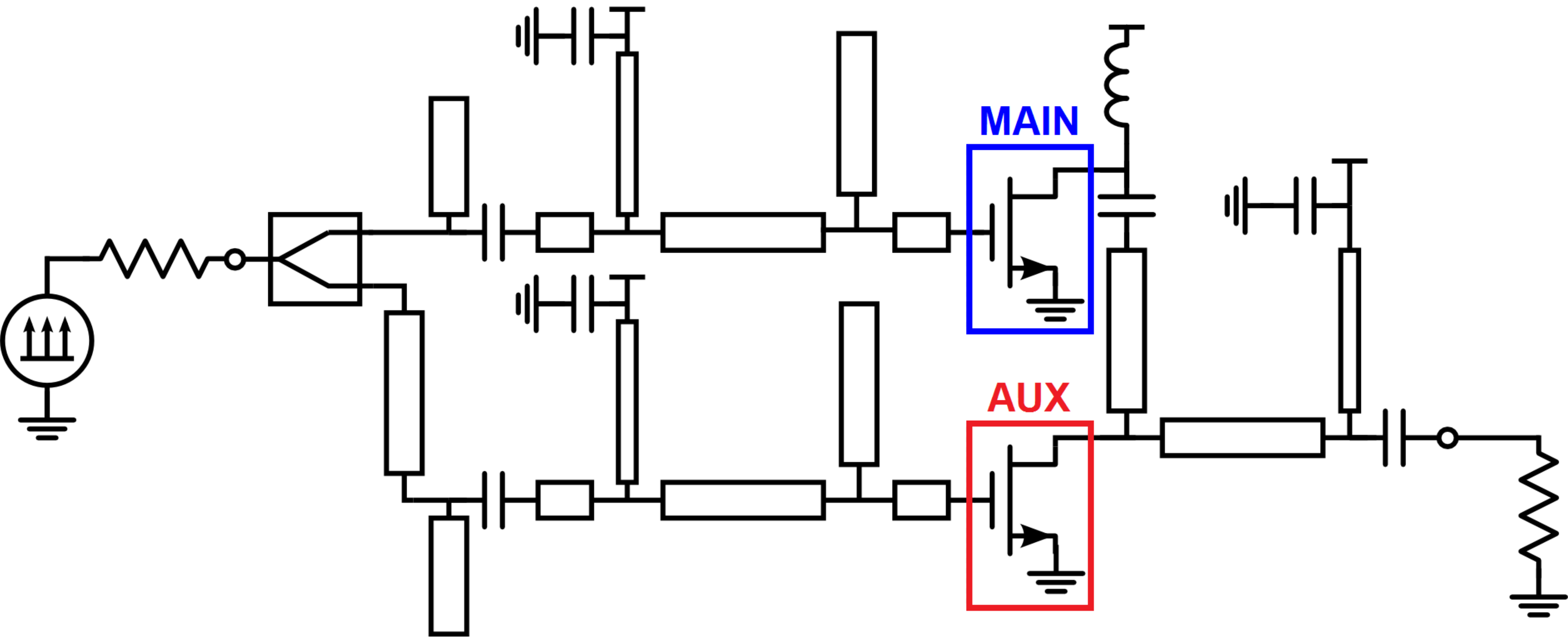
Overview

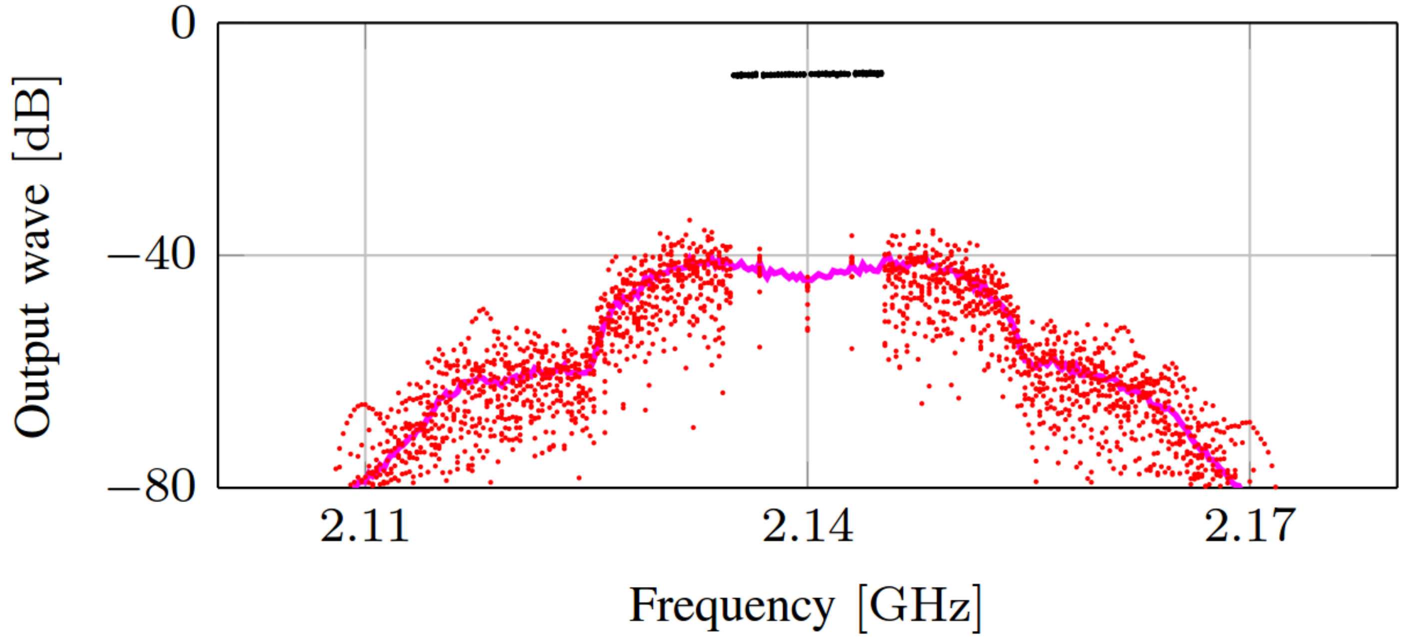
Multisines and the BLA

Estimation of MIMO BLA

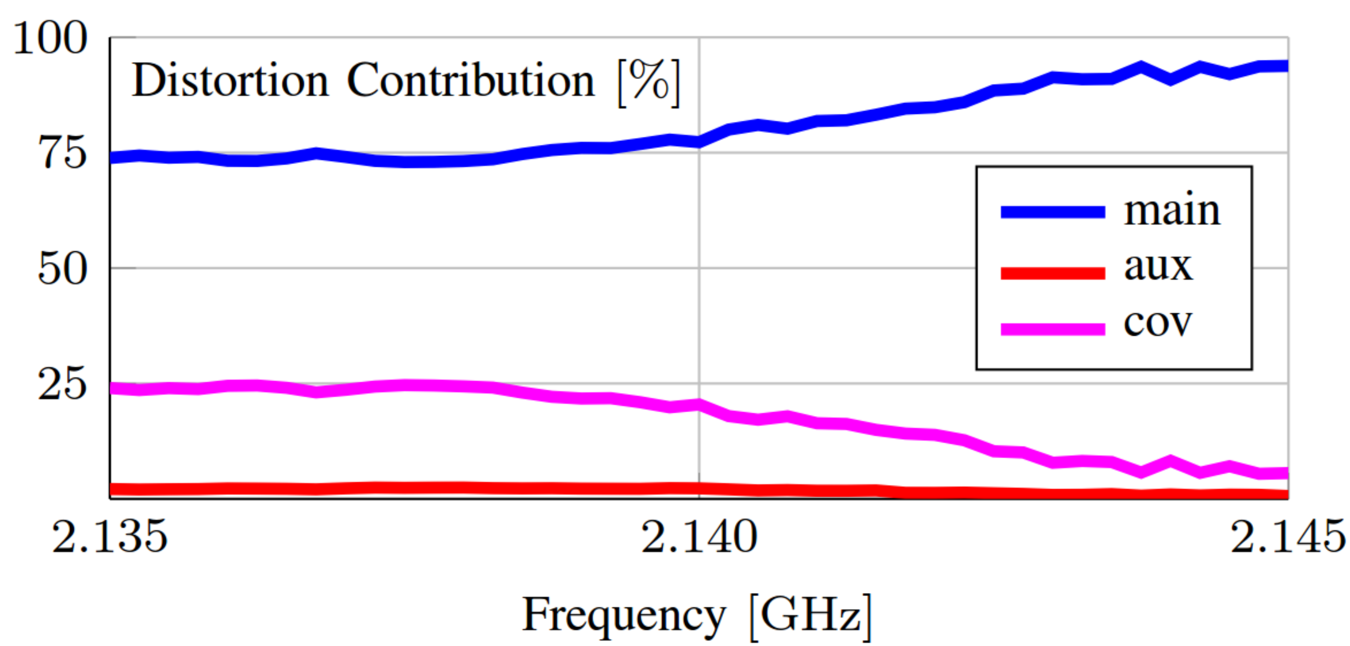
DCA of a Doherty PA

DCA of a Doherty amplifier





0
−40
−80
Output wave [dB]
2.11
2.14
2.17
Frequency [GHz]



100
75
50
25
Distortion Contribution [%]
main
aux
cov
2.135
2.140
2.145
Frequency [GHz]

Conclusions

Analyzing distortion?

Use realistic excitation signals

Want to find the dominant source?

BLA + Noise analysis

Multiple inputs?

Add ticklers and zipper them

Distortion Contribution Analysis of strongly non-linear analog circuits

Adam Cooman, Piet Bronders & Gerd Vandersteen

agency for Innovation by Science and Technology

Vrije Universiteit Brussel