Characterizing Components Under Large Signal Excitation: Defining Sensible `Large Signal S-Parameters'?! 

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Characterizing Components
Under Large Signal Excitation:
Defining Sensible
“Large Signal S-Parameters”?!
Overview

- Introduction
- Model Theory
- Model Extraction
- The Measurement Set-Up
- Experimental Model Verification
- Conclusions
The Story of Modeling and Measuring

Past

Modeling

Measuring

Future

Modeling

Measuring
Network Measurement and Description Group

NMDG

Physical Device

MDS + Equivalent Circuit Model

Processing

MDS + Behavioral Model

Nonlinear Network Analyzer

Rain Forest

y = f(x)
Theory of the Black-Box Model

\[ B_{ij} = F_{ij}(A_{11}^{re}, A_{12}^{re}, \ldots, A_{1N}^{re}, A_{12}^{im}, \ldots, A_{1N}^{im}, A_{21}^{re}, \ldots, A_{2N}^{re}, A_{21}^{im}, \ldots, A_{2N}^{im}, X_1, X_2) \]
The Harmonic Superposition Principle

\[ B_{ij} = K_{ij} + \sum_{k=2}^{N} L_{ijkl} A_{kl}^{re} + \sum_{k=2}^{N} M_{ijkl} A_{kl}^{im} \]

\[ K_{ij}(A_{11}^{re}, A_{21}^{re}, A_{21}^{im}, X_1, X_2) \]
\[ L_{ij}(A_{11}^{re}, A_{21}^{re}, A_{21}^{im}, X_1, X_2) \]
\[ M_{ij}(A_{11}^{re}, A_{21}^{re}, A_{21}^{im}, X_1, X_2) \]
Model Extraction

DUT

A_{11} A_{12} A_{1N} B_{21} B_{22} B_{2N}

B_{11} B_{12} B_{1N} A_{21} A_{22} A_{2N}
The Measurement Set-Up

Vectorial Nonlinear-Network Analyzer

D.U.T.

biasing circuitry and monitoring

i \times f_{FUND}

f_{FUND}

tuner

Port 1

Port 2
Practical Experiment

Non-Ideal Because of Reflection Of Harmonics

Set Of Independent Experiments Performed

Coefficients Found By Least-Squares-Error Estimation
Model Verification: Measured Input

\[ \text{Im}(A_{31}) \text{ (Volt-peak)} \]

\[ \text{Re}(A_{31}) \text{ (Volt-peak)} \]
Model Verification: Measured Output

\[ \text{Im}(B_{22}) \] (Volt-peak)

\[ \text{Re}(B_{22}) \] (Volt-peak)
Time Domain Interpretation

Collector Current (mA)

Time (ns)
The Superposition Theorem

Collector Current Differences With 3rd Harmonic Present At The Base (2 amplitudes)
Harmonic Balance Simulations
Simulations versus Measurements

\begin{align*}
E & 0.05 \ i_{1m} - 0.05 \\
D & 0.05 \ i_{1t} - 0.05 \\
C & 0.08 \ i_{2m} - 0.02 \\
F & 4.5 \ v_{2m} - 0.5 \\
A & -0.5 \ v_{1t} - 3.0 \\
B & -3.0 \ v_{1m} - 0.5
\end{align*}

\hspace{1cm}

\begin{align*}
E & 0.05 \ i_{1t} - 0.05 \\
D & 0.05 \ i_{1t} - 0.05 \\
C & 0.08 \ i_{2m} - 0.02 \\
F & 4.5 \ v_{2m} - 0.5 \\
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B & -3.0 \ v_{1m} - 0.5
\end{align*}
Conclusions

- The defined “Large Signal S-Parameters” can be measured by an automated set-up.
- The corresponding model accurately describes the hard-nonlinear behavior of any microwave component under a one-tone excitation, with the presence of relatively small harmonics.
- The model can be integrated in a commercial harmonic balance simulator.