COMPRESSION ANALYSIS
OF A HIGH POWER BJT AMPLIFIER

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Introduction

harmonic balance (HB) technique: an efficient method for nonlinear steady-state circuit analysis

application of HB method to nonlinear analysis and design of microwave circuits such as amplifiers, mixers and frequency doublers

analysis of high power amplifiers may be a challenge to HB solvers since the strong nonlinearity of the circuits may cause problems such as non-convergence

the success of the simulation depends on the accuracy of models and the intelligent use of nonlinear HB simulators

compression analysis of a BJT high power amplifier:

- parameter extraction for the BJT model
- small-signal and large-signal analysis
- Monte Carlo statistical simulation
- sensitivity analysis

MEE Benchmark of CAD Vendors

nonlinear CAD benchmark by Microwave Engineering Europe of software vendors with products significantly beyond the entry level (November, 1993)

nonlinear simulation of a bipolar transistor power amplifier originally designed by R. Jennings and P. Perry at University College Dublin, Ireland, for communication applications around 2 GHz

the amplifier worked well in practice but proved very difficult to simulate using nonlinear HB simulators

OSA, Hewlett Packard, EEsof and Compact Software participated

Circuit Structure and Characteristics

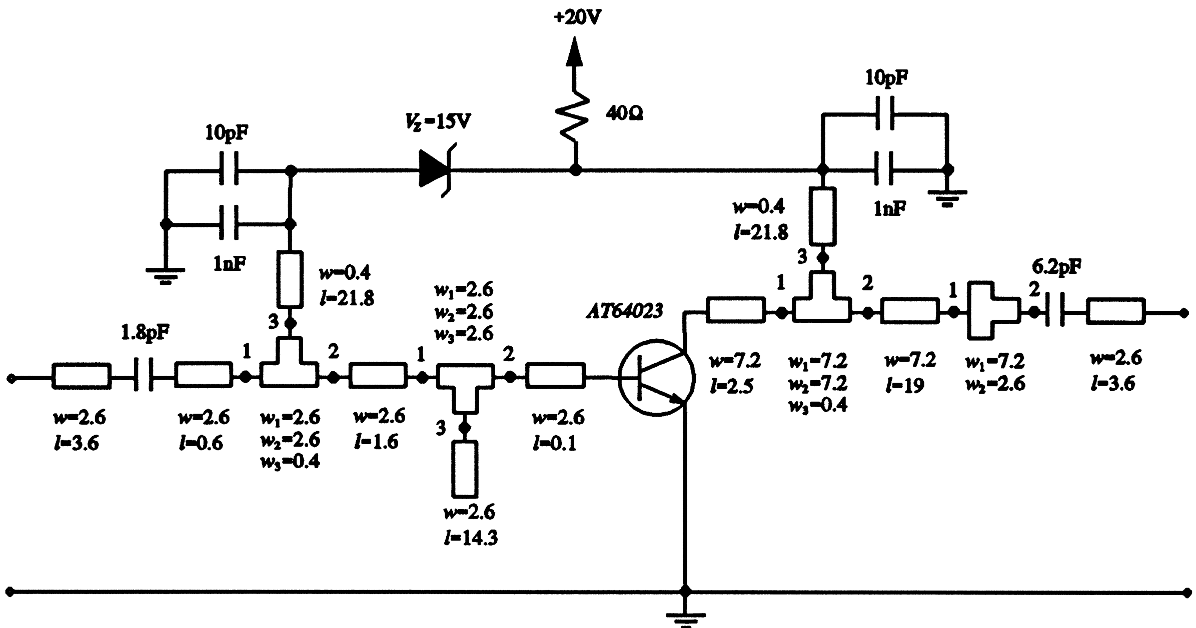
a single bipolar transistor (the Avantek AT64023) biased for a constant collector current (100 mA) and a constant collector emitter voltage (16 V)

distributed elements for input and output matching circuits realized in microstrip on standard 1.5 mm FR4 board

a high power driver to saturate other high power devices being tested under nonlinear operation

a very narrow band response centered at 2 GHz with the power characteristics having been somewhat sacrificed in favour of good impedance and gain characteristics

Circuit Schematic



units: mm
substrate thickness 1.5 mm
relative dielectric constant 4.75
metallization: 35 μm thick copper

Device Model for the Bipolar Transistor

SPICE Gummel-Poon nonlinear model augmented by a diode circuit to model the distributed base capacitance and resistance, and a package model provided by Avantek

some discrepancies noticed between the model provided by Avantek and the measured S-parameter data also provided by Avantek

the reason for such discrepancies can be attributed to the still fairly common "disjoint" modeling of small- and large-signal operation of the transistor

model refinement for a better S-parameter fit using the parameter extraction capabilities of OSA90/hope assuming that the S-parameter measurements are more reliable

OSA90/hope employs unified DC, small-signal and large-signal modeling and ensures consistent responses from the DC, small-signal and HB analysis

Small- and Large-Signal Simulation

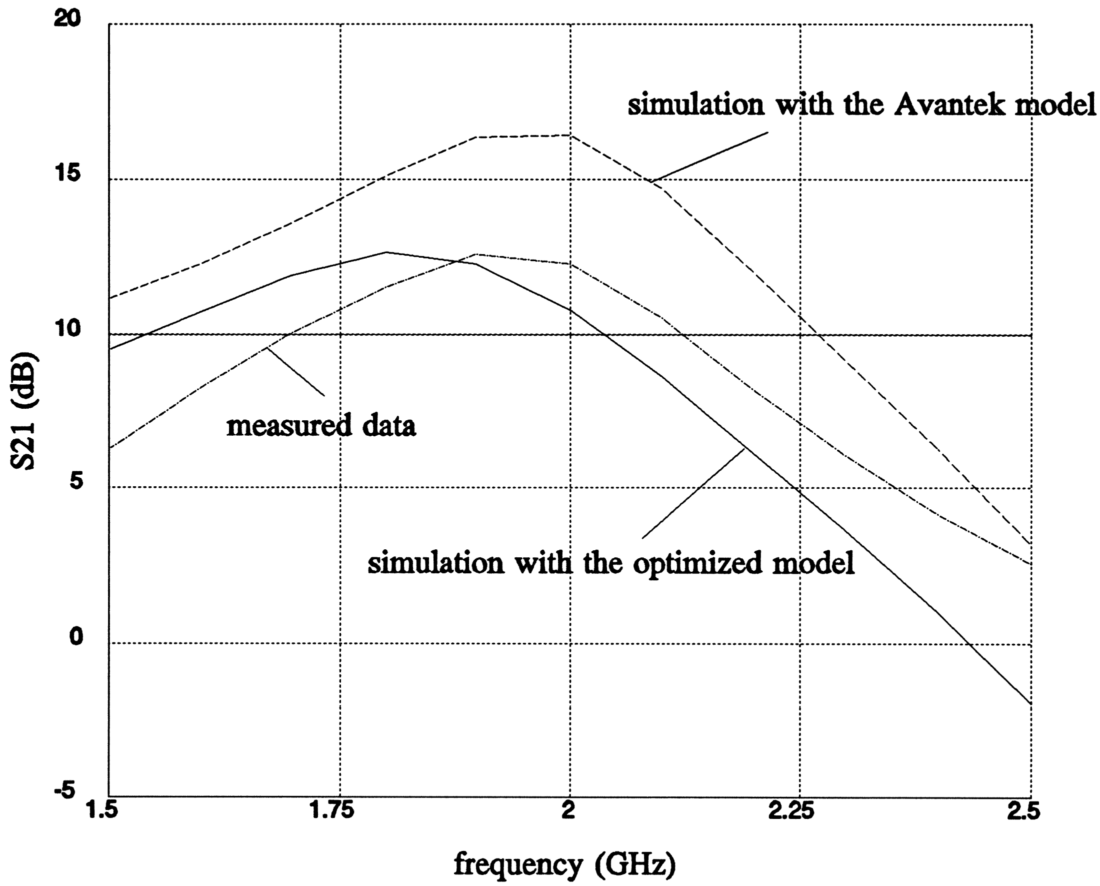
small-signal linear and large-signal nonlinear HB simulation of the amplifier using OSA90/hope

16.35 dB small-signal gain and 26.6 dBm output power at 1 dB gain compression at 2 GHz obtained using the model provided by Avantek

10.74 dB small-signal gain and 23.43 dBm output power at 1 dB gain compression at 2 GHz obtained using the optimized model extracted from the measured *S* parameters given by Avantek

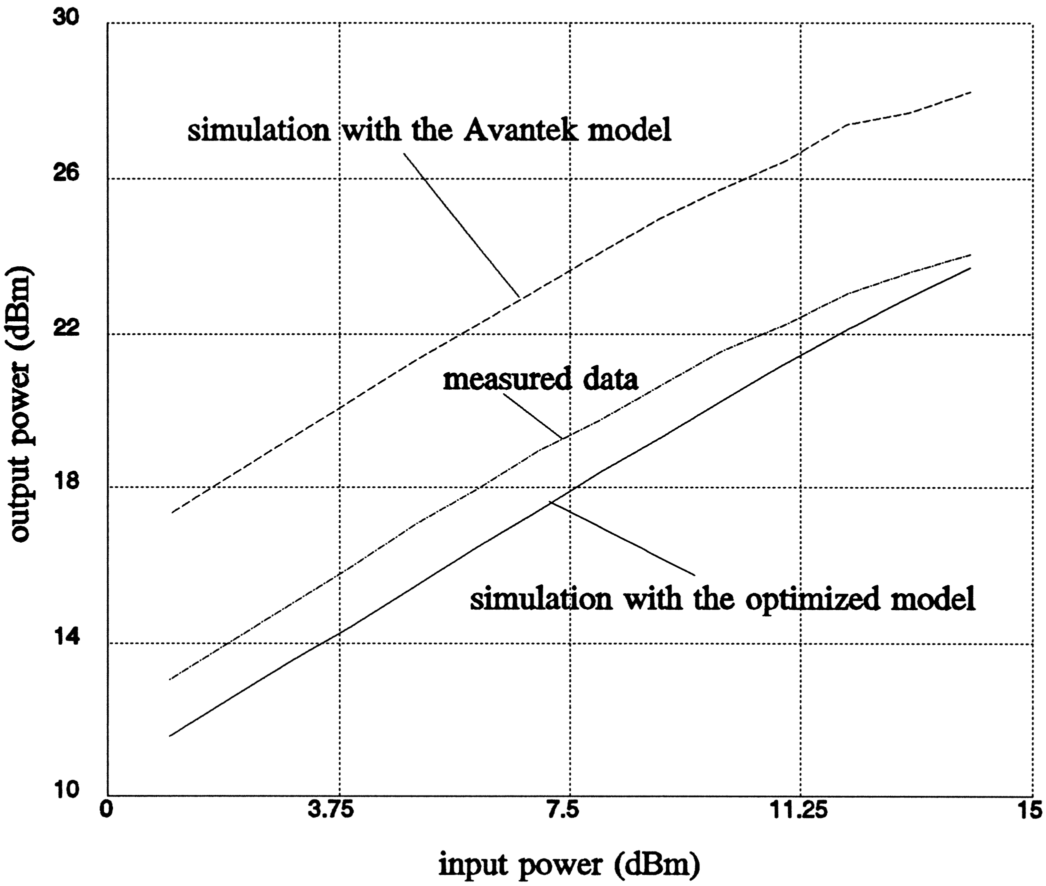
12.2 dB small-signal gain and 23.0 dBm output power at 1 dB gain compression at 2 GHz measured for the actual circuit

Small-Signal Gain of the Amplifier



measured data not supplied to participants

Output Power vs. Input Power of the Amplifier



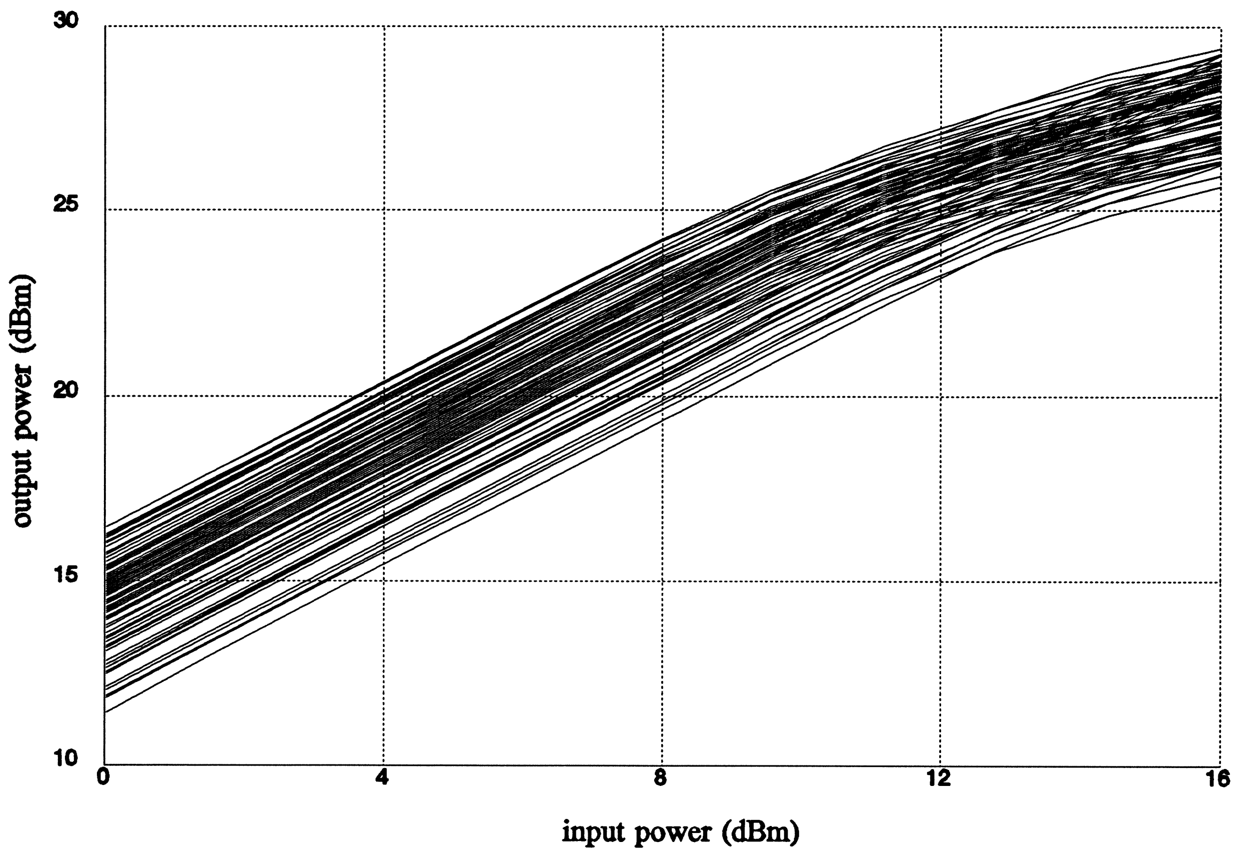
measured data not supplied to participants

Statistical Analysis

investigation of the effects of parameter tolerances of the transistor model on the output power

Monte Carlo simulation using 100 outcomes by assigning tolerances to the model parameters

Monte Carlo Sweep of Output Power vs. Input Power



Sensitivity Analysis

sensitivity analysis of the output power at 1 dB gain compression w.r.t. the elements in the matching circuits

the response is more sensitive to

- the length of the open stub in the input matching circuits

- the lengths of the microstrip lines in the output matching circuits

Conclusions

we have presented the compression analysis of a high power BJT amplifier

better agreement between our simulation results and the measurements of the amplifier has been obtained using the refined model rather than the Gummel-Poon model provided by Avantek

this exemplifies potential problems with vendor-supplied device models and a limited confidence the designer should have in such models

different model implementations in different CAD packages and different parameter extraction procedures may contribute to this problem

it is more reliable to establish the model from measurements in a consistent manner within the same CAD environment

the statistical analysis by Monte Carlo simulation indicated that the BJT model accuracy is very important in the circuit simulation

Our sensitivity analysis identifies the circuit elements critical for the design

References

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