

HICUM - Update

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Availability of HICUM in Circuit Simulators

(version numbers and some comments refer to latest tests (dated 6/04) at STM on LNA, mixer and frequency divider)

(Please contact simulator vendor or see vendor web-site for details and the latest status of availability)

<i>simulator</i>	<i>1st release</i>	<i>latest version</i>	<i>L2-V</i>	<i>L0-V</i>	<i>comments</i>
ADS	7/00	ADS2003C	2.1	1.0	very stable and fast
ELDO-RF	10/99	AMS2004.1/2	2.1	rec 1.1	very stable and reasonably fast
AnalogOffice	2003	rel. 04/04	2.1	1.0	numerically stable
SPECTRE-RF	10/99	5.0.33.031104	2.1	rec 1.1	have now promised to fix bugs in L2
Smart-SPICE	11/00	rel. 11/00	2.?		can be combined with UTMOST
APLAC	10/01	7.92c	2.1	rec 1.1	still limited stability for L2
HSPICE	2/01	2004.2-beta2	2.1	rec 1.1	full compatibilty with AWR-AO for L2
TEKSPICE	8/02	rel. 8/02	2.?		proprietary numerical improvements for L2
GoldenGate	?/03	3.3.14	2.?		
HSIMplus	4/02	5.0_2004.20.7	2.?	rec 1.1	latest release L2 in May04;
SPICE3F5	4/02	11/04	rec 2.2	rec 1.1	reference simulator: HB, Verilog & Compiler

- Various other (partially in-house) simulators (ASX (IBM), Eagleware, Micro-Cap, NEXXIM (Ansoft) ...)
- Verilog-A version of model code; also, L2 stand-alone simulator enabling coupling with other tools

HICUM/Level2

Version 2.2 - March 2005 release

- Verilog-A
 - preferred for maintenance (and cost) reasons
 - model compilers guarantee unified code and error free derivative generation
 - test cases and parameters (set-ups are simulator dependent !)
 - test data files still required ? (should not be the case for standardized Verilog version)
 - some language issues yet to be solved (see later)
- DEVICE (compiled SPICE-like model implementation)
 - so far to cooperation partners only (support issue if generally distributed)
 - contains implementation of derivatives
- documentation
 - changes/additions ONLY in document separately from manual; also test results
- see www for material

HICUM/Level2 (cont'd)

Version 2.2

- release procedure / quality control
 - step 1: after development of new equations (mostly physical effects)
 - => detailed proposal to cooperation partners for discussion/feedback (incl. HICUM WS)
 - step 2: incorporate feedback into formulations and internal (development) simulator
 - => provide prototype version to cooperation partners & sponsors for test and review
 - step 3: present new version (physics & numerics) to CMC for feedback
 - step 4: finalize physics-based formulation and development code
 - => transfer and implementation in production release prototype (Verilog)
 - step 5: testing of Verilog code vs. development simulator
 - (implementation done by different persons; possibly incl. EDA cooperation partner)
 - step 6: official release "through" CMC
 - step 7: update model documentation and web-site
- parameter determination ?
 - belongs to model deployment => receive requests for support, cannot handle with CMC budget

HICUM/Level2 (cont'd)

- **Version 2.2 (cont'd)**
not implemented in Verilog, but included as recommendation for simulator implementation (due to simulator specific or Verilog issue):
 - vertical NQS effects
 - correlated noise
 - node collapsing for zero series resistances
- **Version 2.1**
 - supporting model deployment, implementation issues still consumes significant resources
 - note: not all vendors have V2.1 properly implemented (or implemented at all)
- **5th HICUM Workshop**
 - planned on June 6/7 at ST in Crolles/Grenoble (France)
 - forum for presenting new model version and related results
 - information exchange on deployment issues (parameter extraction, issues ...)

HICUM/Level0

Version 1.1

- fairly high demand \Rightarrow requested by all major simulator vendors
 - has diverted some resources from Level2v2.2
- changes vs. v1.0
 - v1.1 incorporates some of the HICUM/Level2 v2.2 improvements, such as: hyperbolic smoothing, improved temperature description (s. v2.2), pnp, noise
 - Verilog code: clean up, improvement of organization, use of language constructs, limiting ..
- implementation
 - *separate* model code \Rightarrow full advantage of speed improvement
 - status: see separate slide "Simulator Availability"
- release
 - Verilog code only; send to: Agilent/Tiburon, Aplac, Cadence, Mentor, Nassda, Synopsis
 - DEVICE implementation planned

HICUM/Level0 (cont'd)

Version 1.1

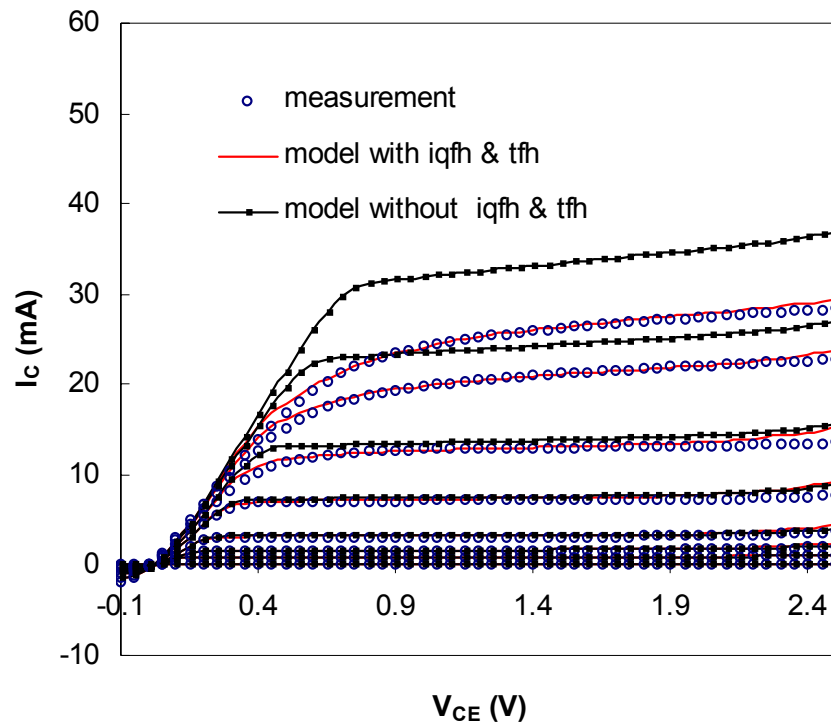
- model verification / application for various process generations
 - 150GHz SiGe BiCMOS process from Jazz (see BCTM 2002)
 - 70GHz SiGe BiCMOS process from Infineon, ST
 - 230GHz SiGe HBT from ST
 - 90GHz SiGe LEC HBT process from Atmel
- parameter extraction
 - publications (MIXDES 2004, journal paper in progress)
 - XMOD: ICCAP-based solution

Note: this model has been requested (partially) by CMC members, but is presently not financially supported by the CMC

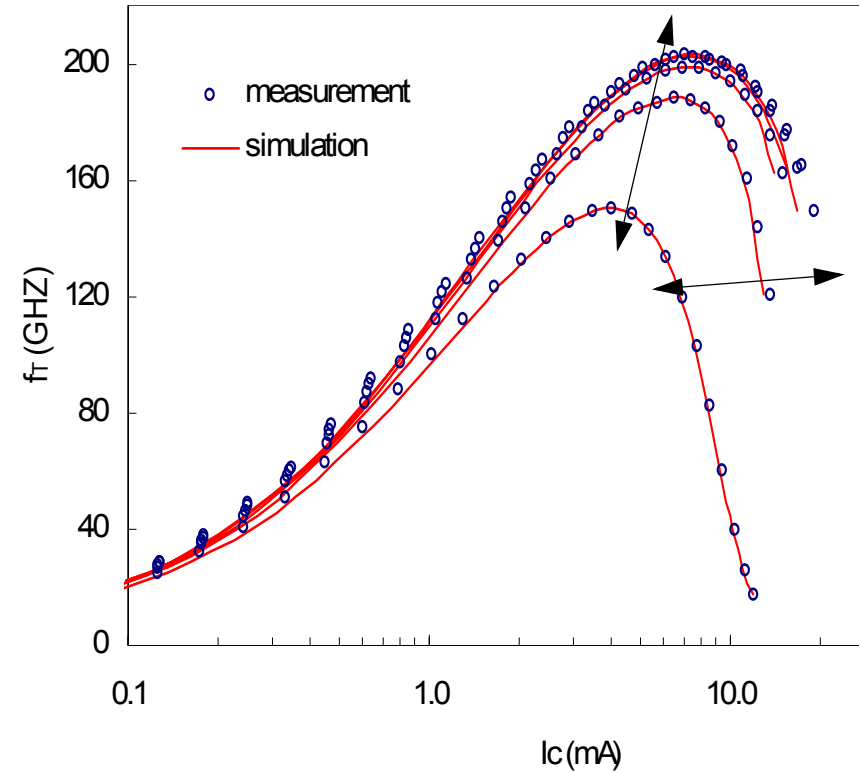
HICUM/Level0 (cont'd)

Version 1.1

output characteristics with and without
high-current correction



transit frequency ($0.3 \times 3.7 \mu\text{m}^2$)



Summary of HICUM/Level0 features

(... and improvements with respect to the SGPM)

- derived from HICUM/L2 formulation (= accurate reference)
- simple equivalent circuit with the same topology as the SGPM
- improved transfer current equation:
 - bias dependent forward Early-effect
 - non-ideality coefficient (avoids ambiguities in parameter extraction for BJTs)
 - simple explicit high-current/quasi-saturation correction
- improved transit time and minority charge model:
 - quicker and more reliable parameter extraction
 - significantly higher accuracy (based on simplified HICUM/L2 formulation)
- internal base resistance: more accurate and physics-based description of both conductivity modulation *and* emitter current crowding.
- (weak) avalanche breakdown in the base-collector junction
- includes parasitic (bias independent) BE and BC capacitances
- full temperature dependence and first-order self-heating network (& external thermal node)
- parameter determination:
 - single device parameter extraction possible
 - *automated* generation of geometry scalable parameters from HICUM/L2 at no **extra** effort/cost

Verilog-specific issues

- **limiting**
 - support of a standard (SPICE-like ?) pnjlim feature would be helpful to overcome convergence issues at (very) high currents (SPECTRE related ?)
 - high currents in electrothermal simulation
 - special temperature increase limiting ?
 - need simulator to flag thermal runaway to user
- **Non-Quasi-Static effects**
 - vertical NQS effect: function absdelay() is not recommended => what to use?
 - lateral NQS effect: need to have $C=C_{JEI}+\dots$ in parallel to RBI with charge $C*VRBI$
- **Correlated Noise**
 - correlation factor is frequency-dependent! => how to implement ?
- **Model compiler(s)**
 - have difficulties to get model compilers working (properly)
 - tried intensively for Level0 (simpler model formulation):
 - SPECTRE: need to have match between UNIX-OS, SPECTRE/CFI(?), and ADMS 1.46 version

Model release issues

Request for reference Harmonic Balance simulator and data

- => escalating burden for model developer who is not in simulator development business
- cannot use commercial simulator (and code) for model delivery => licensing issues:
 - model developer and user side have to have same simulator (and version)
 - cannot release (C-)code to competing EDA companies
 - as developer do not even know code inside commercial simulator
- => accuracy/quality check of data very difficult
- option:
 - will a non-commercial simulator be accepted that has a small shipping and support fee ?
 - e.g.: SPICE3 from Prof. J.-C. Perraud at CAEN (France) includes HB and Verilog
 - consensus at CMC meeting on March 14/15, 2005:
 - verification of d.c., a.c., transient model implementation is sufficient for model developers

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Other information ...

- ... related to Cadence slides from 12/04 (re. HICUM implementation)
- model benchmark from Toshiba (presented at MIXDES 2004) ; simulator: ADS

	DEV	Transient 1/8 DIVIDER	HB IP3 MIXER	HB TONE gainstage
HiCUM	0.80	77.2	220.7	3.3
Mextram 503	0.80	70.9	193.7	Didn't converge
Mextram 504	0.76	90.6	189.0	Didn't converge
VBIC	0.87	89.2	231.6	5.08
Gummel Poon	2.48	11.9	112.5	2.39

Table. 4. Summary of simulation benchmark test in seconds.