NQS modelling with HiCuM: What works, what doesn't

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Outline

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Introduction: NQS basics

- **NQS basics:**
  As the operating frequency approaches the cutoff frequency, the transistor can no longer follow external excitations instantaneously. *(Non Quasi Static effect)*

- **Transient variation of electron concentration inside the base**
  
  ![Switch-off](image1.png)
  
  ![Switch-on](image2.png)

  *Fig. 5. Transient variation of electron concentration profile when $V_{EB}$ decreases from the switch-on voltage to zero.*

  *Fig. 8. Transient variation of electron concentration profile when $V_{EB}$ increases from zero to the switch-on voltage.*

  From Suzuki IEEE TED 1992
Introduction: high frequency Y parameters

- Phase of admittance parameters show NQS effect.

**Phase(y.11)**

- Frequency (Hz)

**Phase(y.21)**

- Frequency (Hz)

NQS model implementation: vertical NQS

- Phase shift network with excess charge.

\[ Q_{dei} = \frac{Q_{dei}}{1 + sT_D} \]
\[ T_D = alqf.T_f \]

HBT HICUML2V24
NQS model implementation: vertical NQS

- Phase shift network with transfer current (HICUML2).

\[ I_{xf} = V(xf\ 2) \]

Weil-McNamee formulation

\[ I_{txf} = \frac{I_{tzf}}{1 + sT_D + (sT_D')^2} \]

Gyrator equivalent formulation (L. Lemaitre)

\[ I_{txf} = \frac{d}{dt} (alit \ast T_f \ast V(xf\ 1)) + V(xf\ 2) \]

\[ V(xf\ 1) = \frac{d}{dt} (alit \ast T_f / 3 \ast V(xf\ 2)) + V(xf\ 2) \]

\[ I_{txf} = \frac{I_{tzf}}{1 + sT_D + (sT_D')^2} \]
Compact modeling of transistor having B3T technology and BiCMOS9MW layout. ($f_T$ peak = 240GHz)

- $h_{21}$: phase (current gain) $V_{BE}=0.76V \rightarrow 0.92V$, $V_{CE}=1.2V$

NQS flag = 0

DEV_L3W0_27E1B1C1

NQS flag = 1

DEV_L3W0_27E1B1C1

NQS effect in $h_{21}$ phase and modeled using HICUM L2V24 model in a transistor of $L_E = 3\mu m$ and $W_E = 0.27\mu m$. 

Modeling results: NQS modeling with HICUM L2
Parameter optimization in different devices

\( V_{BE} = 0.76\text{V} \rightarrow 0.92\text{V}, \ V_{CE} = 1.2\text{V} \)

NQS effect in \( h_{21} \) phase and modeled using HICUM L2.24 model for transistors having emitter lengths \( (L_E) = 3\mu\text{m}, 5\mu\text{m}, 10\mu\text{m} \) and emitter width \( (W_E) = 0.27\mu\text{m} \).
Large transistors show abnormality in $h_{21}$ phase at high injection level

Modeling results: NQS modeling with HICUM L2

$h_{21}$ phase for different $W_E$ (0.54, 0.84, 1.08µm) with same $L_E$ (10µm) at $V_{BE}=0.76V \rightarrow 0.92V$, $V_{CE}=0.8V$, 1.2V
NQS parameters are optimized for low injection level and plotted against emitter length ($L_E$) and real emitter area (considering the spacer width of 55 nm).

NQS parameters at $V_{BE}=0.76V$ and $0.80V$ and $V_{CE}=1.2V$

alit = 1.0
alqf = 0.5

alqf decreases at higher emitter area

Constant over length
Conclusion

- NQS basic is presented while showing the HICUM implementation.
- HBT Modeling results with HICUM L2V24 model are presented.
- HICUM provides good results but at high frequency and long devices there is scope for modification (essderc paper 2011, submitted).
- Transistors with higher emitter widths show abnormality in $h_{21}$ phase at high injection.
- Scaling of two NQS parameters show that constant value of NQS parameters ($alit=1$, $alqf=0.5$) provide a good modeling accuracy.
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