Boundary Conditions for Device Simulation in Mixed Area

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Abstract - **This paper extends the capabilities of device simulation by studying, characterizing, and improving the boundary conditions around the physical device simulation so that advance radio frequency (RF), and high speed components can be accurately modeled. The many small variation of parameters take effect on functions and his approximation. This work proposes directions of solution parameter of analyst simulation in specific boundary. Paper presented by way of example calculation of parameter for MOSFET element and graphical staff.**

Keywords - **device simulation, model, mix area, boundary condition.**

I. Introduction

By each iteration of process simulation needed information the value of current and value of electrical tension. For each small variation in form $v = \Delta V e^{-j\omega t}$ needed linearization of current $i = \Delta V e^{-j\omega t}$ and his calculation. With this operation used thoroughly law of Kirchoff.. In this current is;

$$i = Yv = \left(\frac{dI}{dV} \Delta V + j\omega \frac{dQ}{dV} \Delta V \right) e^{-j\omega t} \qquad (1.0)$$

and ratio of real current and real tension to current ant tension calculated be done; $dI / dV = \Delta I_R / \Delta V$,
tool responded and for $dQ / dV = \Delta I_I / (\omega \Delta V)$.

II. In particular of method

Algorithm for description change and analyst function of calculation value of simulation is presented in many work [6], [8], [2] and ICECT; ICEST forum. In publication show interest the algorithm of frequency dependence element. This operation is non desirable by trivial simulator. Problem is interesting from point of frequency. As a eliminated the frequency $\omega \to 0$, signal and small variation of signal have decrypted in;

$$\begin{bmatrix} J & -D \\ D & J \end{bmatrix} \begin{bmatrix} X_R \\ X_I \end{bmatrix} = \begin{bmatrix} B \\ 0 \end{bmatrix}, \ldots \qquad (1.1)$$

Were J is matrix of Jacoby from elements. X_R and X_I is reality and imaginary component. Important parameters presented be; $\Delta\psi$, Δn and Δp. [2]. with B be reflected boundary conditions, and D - frequency. That expressed with matrix. [6], [7];

$$D = \omega \begin{bmatrix} 0 & 0 & 0 \\ 0 & j\dfrac{\partial G_n}{\partial n} & 0 \\ 0 & 0 & j\dfrac{\partial G_p}{\partial p} \end{bmatrix} = \omega K \ , \qquad (1.2)$$

where: frequency characteristic is presented in non-linear vector G. If divide reality and imaginary part to writhed;

$$JX_R - DX_I = B, \ ; \ DX_R + JX_I = 0, \qquad (1.3)$$

Reality component possibility presented in;

$$X_R = J^{-1}(B + \omega K X_I), \quad X_I = -J^{-1}(\omega K X_R),$$

If frequency ($\omega \to 0,$) to component $\omega K X_I$ is ignore and for X_R possibility;

$$X_R = \lim\left(J^{-1}(B + \omega K X_I)\right) = J^{-1}B, \qquad (1.4)$$

, analog in appearance;

$$X_I = -J^{-1}(\omega K X_R) = \omega \tilde{X}_I, \qquad (1.5)$$

Where X_I and $\tilde{X}_I$ is depended frequency parameters models. For each iterations ΔI calculated parameters from X_R and X_I is Ψ, n and p. Therefore ΔI possibility calculated whit two components – reality and imaginary;

$$\Delta I = F(X_R) + j\omega F(\tilde{X}_I), \qquad (1.6)$$

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Function $F(X)$ literalized about X_R и X_I et courant value have two component – reality and imaginary;

$$\frac{dI}{dV}=\frac{F(X_R)}{\Delta V},\ \frac{dQ}{dV}=\frac{\omega F(\tilde{X}_I)}{\omega\Delta V}=\frac{F(\tilde{X}_I)}{\Delta V}, \qquad (1.7)$$

In this method (method Newton) form calculations of iterations be observe following priority; (especially if formula accepted frequency component). That is very often by approach characteristic specific communication devices.

- Calculation of two component increment time from work, but give possibility of put coefficients in matrix et achievement got approach.
- Give way possibility of ignore some frequency approach who are non desirables in integrated area from simulation.
- Make easier transfer the parameters between models. Give possibility some parameters to by ignored and other approach.
- Algorithm to by some more effective from case where ΔV = 1.0V.

III. Exposition

A. Determination of currant in model

Flow currant consists in two components – reality and imaginary. Calculation of reality component based of parameters; $\Delta I_n, \Delta I_p, \Delta I_i$, founded constant currant resolution from;

$$I_n = A(qD_n\Delta n - q\mu_n n\Delta\Psi), \qquad (1.8)$$

$$I_p = A(-qD_p\Delta p - q\mu_p p\Delta\Psi), \qquad (1.9)$$

Currant owing of small change calculated in reality functions;

$$\Delta I_n = \Delta\Psi\frac{\partial I_n}{\partial\Psi} + \Delta n\frac{\partial I_n}{\partial n}, \qquad (2.0)$$

were currants consisting in two component. Real part ΔI are received by parameters $\Delta\Psi, n$ and Δp and evaluate resolution whit *Xr,* and imaginary – whit *Xi*. To value are calculated form specific case and method of connection in mixed area.

B. Very small variation in mix area;

For approach very small variations currant signals and fix lap in model electron device need have real value. Connection input / output pin models need transfer very small currant variation for very small time period. Expression is;

$$I_\Delta = \varepsilon\frac{\partial E}{\partial t} = \varepsilon\frac{\partial}{\partial t}(-\Delta\Psi), \qquad (2.1)$$

Approach small change currant signal possibility whit high precision if in model provide for restrict value and have algorithm of processing. Very import part of modeling is fact of reaction approach characteristic et method of calculation of this model function at small variation without existence noise. . In define this problem need read variation in form; $\Delta Ve^{-j\omega t}$ at algorithm of linearization of ratio *I/V* with $e^{-j\omega t}$. Neglect component $e^{-j\omega t}$ insert inaccuracy by connect characteristic and transfer parameters. This process reiterates and fault of iteration multiply. This cause of correct read very small variation of currant and correct integer in system equation needed value Ψ, in each point in model;

$$\Psi = \Psi_{k(dc)} + \Delta\Psi_k e^{-j(\omega t - \Phi_k)}, \qquad (2.2)$$

Supported (1.3) and [2], [7] for each small variation currant in each pin of model possibility writhed;

$$I_{kl(\Delta)} = \varepsilon\frac{\partial}{\partial t}\left(\frac{\partial\Psi}{\partial x}\right) = -A_{kl}\frac{\partial}{\partial t}\left(\frac{\Psi_k - \Psi_l}{\Delta L_{kl}}\right), \qquad (2.3)$$

Used method Popov-Sendov (numerical method) can be able currant;

$$I_{kl(\Delta)} = -A_{kl}\frac{\partial}{\partial t}\left(\frac{-j\omega(X_{Rk} - X_{Rl}) + \omega(X_{Ik} - X_{Il})}{\Delta L_{kl}}\right)e^{-j\omega t}, \qquad (2.4)$$

This non originally (physically) change but this is solution in very high accuracy. With at this are choices coefficient and variation. Some other priority is performance currant in addition sum in case included boundary parameter in concrete point calculation. Received sum is linear and if lay operator *H* for reality and imaginarily parts possibility give *In* and *Ip* used (2.4) This expression have two part et reality part included boundary coefficient;

$$\mathrm{Re}(\Delta I_d) = \varepsilon H\left(\frac{\omega A_{kl}(X_{Ik} - X_{Il})}{\Delta L_{kl}}\right), \qquad (2.5)$$

If accept $\omega \to 0$, then ω^2 incline toward 0. This process is height and a minimal variation is insignificant com reality part. In some case boundary conditions is important and these variation need included in volt-ampere characteristic. Transfer these boundary in equation in next model scheme is condition of correct simulation. For imaginary part are;

$$I_m(\Delta I_d) = \varepsilon\omega H\left(\frac{A_{kl}(X_{Rk} - X_{Rl})}{\Delta L_{kl}}\right), \qquad (2.6)$$

In this way problem of approach in $\omega \to 0$, none presented.

C. Transient annalists frequents element in mix area

Calculation and including small variation in transient annalist allow moment t_0 and simulation time t_s for very small period Δt. Decision in $t_s = t_0 + \Delta t$ is normally. In this way, each iteration calculates currant and tension for dish time moment. Way used method constantly currant annalist calculated step by step at changes is reality of part of time period $t_0 + \Delta t$. This demonstrate whit matrix Jacobin for calculate *Xr* and *Xi* in model whit parameter Ψ, n and p.

Calculation currant is analog in (2.5) and (2.6). Small variations of value are finding in (2.0).

IV. WORK PROBLEM

Change small variation currant by annalist**.**

Small change signals and functions in time make calculation difficult. This fact hampers but small currant and tension is blend with signals noise. In transient analysis important is time function. This is idealizing function and approach of frequency elements is difficult. When this elements are work in mix area and change value of parameters whit functions, resolve is some more. In this case should deduce work whit this equation should reflect this small variation. At the same time equation are satisfy demand of work in mix area. On this basis are construct interface for transferring parameters in mix area.

If time of simulation is; t_s to $t + \Delta t$, is period of annalist. Change in function variation is;

$$\Psi_k(t_0) = \Psi_{k(t_0)}, \tag{2.7}$$

Used (**2.1**), to possible define change from Ψ, for each time step;

$$I_{dk} = \varepsilon \frac{\partial}{\partial t}\left(-\frac{\partial}{\partial x}(\Psi)\right) = -\varepsilon A_{kl}\frac{\partial}{\partial t}\left(\frac{\Psi_k - \Psi_l}{\Delta L_{kl}}\right), \tag{2.8}$$

if this formula develop in full reach value from currant;

$$= I_{do(kl)} - \varepsilon A_{kl}\left(\frac{(X_{Rk} - X_{Rl}) + j(X_{Ik} - X_{Il})}{\Delta t \Delta L_{kl}}\right), \tag{2.9}$$

Observably on have two components for analysis – one as classic algorithm and other for transient analysis whit on algorithm as frequency parameters. If frequency parameter is not necessary et. $\omega \to 0$, to her possibility ignore. In other case read really and imaginary parts;

$$\mathrm{Re}(\Delta I_d) = -\varepsilon H\left(\frac{A_{kl}(X_{Rk} - X_{Rl})}{\Delta t \Delta L_{kl}}\right), \tag{3.0}$$

$$\mathrm{Im}(\Delta I_d) = -\varepsilon H\left(\frac{X_{Ik} - X_{Il}}{\Delta t \Delta L_{kl}}\right) = -\varepsilon \omega H\left(\frac{\tilde{X}_{Ik} - \tilde{X}_{Rl}}{\Delta t \Delta L_{kl}}\right), \tag{3.1}$$

Calculation reality component depend on frequency impossibility. For concrete case decision at imaginary component needed. Verification this thesis based simulators used algorithms in (1.0), or crested new models toward existing. Many work of this problem view created concrete algorithm for specific case. Generally cases they used specific interfaces in products; SYNOPSYS, CADENCE or simulators Philips. Shown formulas are able used for created new interface or perfecting exist module. For control calculation used laboratory result [3], [4], work whit this result simulator IBM FIELDAY and Device PISCES [3], [4], and interface created in this case; [1], [6].

V. EXPERIMENTAL INVESTIGATIONS

Annalist for check mix approach.

Annalist make for *dI/dV* by *DC* annalist from MOSFET element, when frequency is zero and two experiment by frequency various at 0,1 to 100Hz. Result from premier two case is laboratory and viewed in test bulletin [3], [2], [8]. Also to element created calculation from formulas in paragraph; 1.0 and 2.0, as from received results builder graphical function and compare whit laboratory test.

Basic parameters used whit MOSFET transistor is;

- *5V tension;*
- *Switching time from 0 to 5V – 100ps;*
- *work time t_s = 50ps;*
- *Calculations step $\Delta t = 5 ps$;*
- *Tension of gait from 2.0V to 3.0V by step 0.01V;*

Calculated dI/dV and $\Delta I/\Delta V$ and his derivative. Manifest small signals and his relationship variations. Also calculations cost dI_i/dV_1, dI_i/dV_2, give possibilities investigate connection drain whit for opposite element (input primitive model).

VI. INFERENCE

Specific parameters of MOSFET element are included in (3.0), (3.1), and calculate. At fig. 1.0 and fig. 2.0 view that deference his received whit experimental measure value and calculated value is five percent not more. In this sum of percents not included error of calculations (value grow round) and calculations of value outside range.

In this case result, address one self accepted accuracy is goodish, by approach of classic models or simulators [5], [3].

When ignore frequencies variations elements $\omega \to 0,$ to this propose is about 1%.

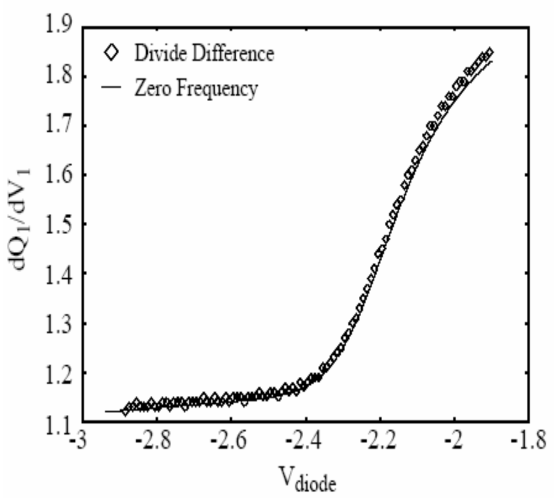

Fig. 1. Test results

VII. CONCLUSION

Offered method included two components at calculations currant in models simulations. This is component of reality parts, and component of imaginary parts.

- View similar / equal approach in currant whit small variation.
- Give possibilities of calculated small change variations. If this not needed give point of ignore.
- In approach add frequency dependence whit imaginary component.
- Result is five percent of two parts, and many one per reality component.

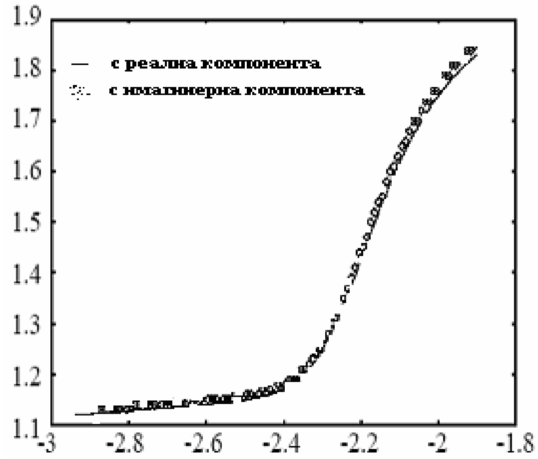

Fig. 2. Calculated result approach

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