Lecture23: Small-signal simulation

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Calendar

- Plan for remaining lectures
  - IEDM business trip

Mon	Tue	Wed	Thu	Fri	Sat	Sun
		~~16 (L18)~~	17	18	19	20
~~21 (L19)~~	22	~~23 (L20)~~	24	~~25 (L21)~~	26	27
28 (No lecture)	29	~~30 (L22)~~	Dec.1	2 (L23)	3	4
5 (No lecture)	6	7 (No lecture)	8	9	10	11
12 (L24)	13	14 (L25)	15	16 (Final)	17	18

Small-signal simulation

- Continuity equation

$$\frac{\partial}{\partial t} n + \nabla_r \cdot \mathbf{F}_n = 0$$

- In the last lecture, we considered the transient simulation.
  - Using the simplest backward Euler,

$$\left.\frac{\partial n}{\partial t}\right|_t \approx \frac{n(t) - n(t - \Delta t)}{\Delta t}$$

- Today, we consider the small-signal simulation.

Basic assumption

- It is assumed that quantities are decomposed into two terms.
  - DC and time-varying
  - The time-varying term is small. (Limitation of this analysis)
  - For example,

$$n(t) = n_{DC} + \delta n(t)$$

- What happens?
  - In the case of the continuity equation,

$$\frac{\partial}{\partial t} \delta n(t) + \nabla_r \cdot \mathbf{F}_n(\mathbf{E}_{DC} + \delta \mathbf{E}(t), n_{DC} + \delta n(t)) = 0$$

  - Up to now, no approximation has been introduced.

Linearization

- Now, using the small magnitude of the time-varying terms, the linearization is performed.
  - The electron flux is given by

$$\mathbf{F}_n = -\mu_n n\mathbf{E} - D_n \nabla n$$

  - Using the linearization,

$$\mathbf{F}_n \approx -\mu_n n_{DC}\mathbf{E}_{DC} - \mu_n \delta n(t)\mathbf{E}_{DC} - \mu_n n_{DC}\delta\mathbf{E}(t) - D_n \nabla n_{DC} - D_n \nabla \delta n(t)$$

  - It can be decomposed into two terms.

$$\mathbf{F}_{n,DC} = -\mu_n n_{DC}\mathbf{E}_{DC} - D_n \nabla n_{DC}$$

$$\delta\mathbf{F}_n(t) = -\mu_n \delta n(t)\mathbf{E}_{DC} - \mu_n n_{DC}\delta\mathbf{E}(t) - D_n \nabla \delta n(t)$$