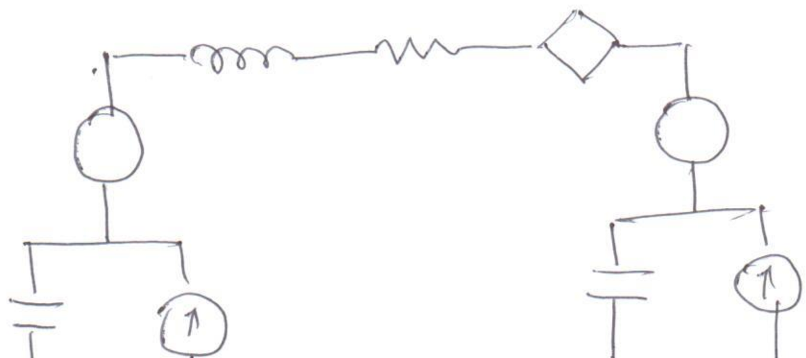
EE 262 Lecture 18

Advantages of PEEC

1. Volumetric form^n ideal for on-chip cases (volumetric current flow)
2. Better low freq stability.
3. "Stamps" provide interface between ckt and EM.
4. Multipurpose solver (.tran, .ac, .cap, .ind)

$$E_0(r,t) = \frac{J(r,t)}{\sigma} + \sum_{k=1}^{K} \frac{\partial}{\partial t}\left[\frac{\mu}{4\pi}\int G(r,r')\,J(r',t')\,dv'\right] + \sum_{k=1}^{K} \nabla\left[\frac{1}{4\pi\epsilon}\int G(r,r')\,q(r',t')\,dv'\right]$$



$$t' = t - \frac{R_{ij}}{v}$$

rPEEC : PEEC with retardation

$$U_i(\omega) = \sum_{j \neq i} \frac{P_{ij}}{P_{jj}} \phi_j(\omega) e^{-jkR_{ij}}$$

Freq. domain

Time domain.

$$ODE \longrightarrow DDE$$

delay differential eq^n.

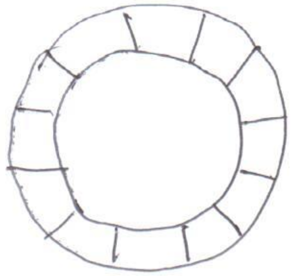
Maintain a history of v, i for a window

if $t - t'_{ij} < \tau$ no delay.

$t - t'_{ij} > \tau$ interpolation. τ_{k-1} and τ_k.

τ is the time step

Storage in the form of circular buffer



$$\text{buffer size} = \frac{R_i^{max}}{v\tau} + \frac{\ell_{step}^{max}}{\tau}$$

Why?

Dielectric PEEC

Recollect :-

$$E_0(r,t) = \frac{J(r,t)}{\sigma} + \frac{\partial A(r,t)}{\partial t} + \nabla\phi(r,t)$$

J_c

$$\nabla \times H = J^c + \frac{\partial D}{\partial t}$$

$$= \left[J^c + \epsilon_0(\epsilon_r - 1)\frac{\partial E}{\partial t}\right] + \epsilon_0 \frac{\partial E}{\partial t}$$

new J

implies: on a conductor.

$$\frac{J(r,t)}{\sigma} + \frac{\mu}{4\pi}\int G(r,r')\,\frac{\partial J}{\partial t}\,dv' + \frac{\nabla}{4\pi\epsilon_0}\int G(r,r')\,q^T(r',t')\,dv' = 0.$$

$$\Rightarrow \frac{J(r,t)}{\sigma} + \frac{\mu}{4\pi}\int G(r,r')\,\frac{\partial J_c}{\partial t}\,dv'$$

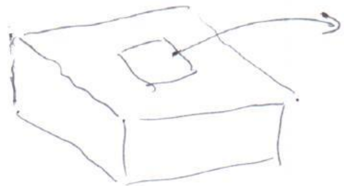
$$+ \epsilon_0(\epsilon_r - 1)\,\frac{\mu}{4\pi}\int G(r,r')\,\frac{\partial^2 E}{\partial t^2}(r',t')\,dv'$$

$$+ \frac{\nabla}{4\pi\epsilon_0}\int G(r,r')\,q^T(r',t')\,dv' = 0.$$

on a dielectric

$$E(r,t) + \ldots\ldots\ldots = 0.$$

Discretization :-



$q_T = q_F + q_B$.

$q_T = q_F$ for conductor in air.

$q_T = q_F + q_B$ for conductor touching diel.

$q_T = q_B$ for dielectric ~~inte~~ touching dielectric.

$$E_y + \epsilon_0 (\epsilon_r - 1) \frac{\mu}{4\pi} \int_v G(r, r') \frac{\partial^2 E_y}{\partial t^2} \, dv' + \cdots = 0.$$

Testing :-

$$\frac{1}{a} \int_{v_l} E_y \, dv_l' = \frac{1}{a} \iint_{l\,a} E_y \, da \, dl = V_c$$

Assume extra capacitance as :-

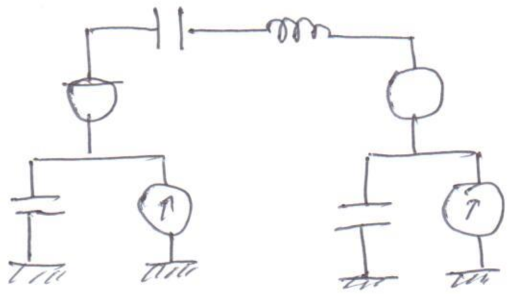
$$C_\gamma = \frac{\epsilon_0 (\epsilon_r - 1)\, a}{l}$$

Now.

$$\epsilon_0 (\epsilon_r - 1) \frac{\mu}{4\pi} \int G(r, r') \frac{\partial^2 E_y}{\partial t^2} (r', t_d) \, dv'$$

$$i_c = C_r \frac{dv_c}{dt}$$

$$V_L = L_{p_{rr}} \frac{di_c}{dt} = L_{p_{rr}} C_r \frac{d^2 v_c}{dt^2}$$



Debye model for dielectric

$$C_e(s) = \left(\epsilon(s) - \epsilon_0\right)\frac{A}{d}$$

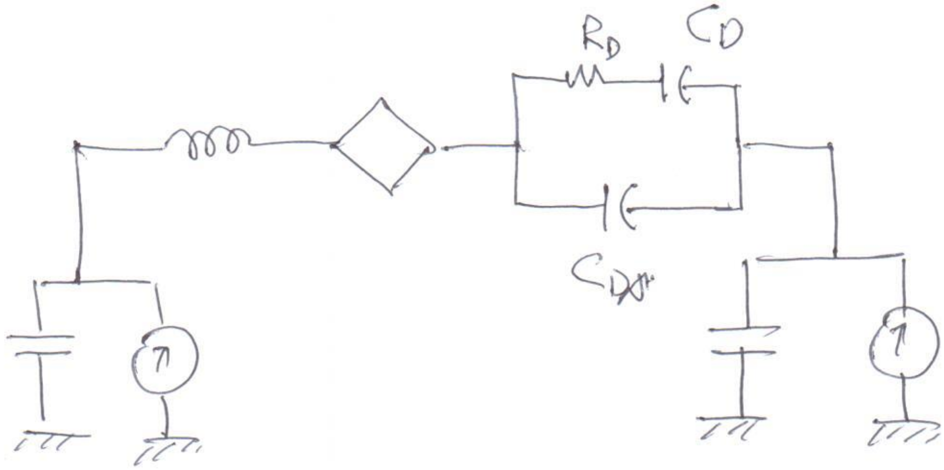
$$= \epsilon_0 \frac{A}{d}\left[\left(\epsilon_\infty - 1\right) + \frac{\left(\epsilon_s - \epsilon_\infty\right)}{1+s\tau}\right]$$

$$s C_e(s) = \epsilon_0 \frac{A}{d}\left[s\left(\epsilon_\infty - 1\right) + \frac{s\left(\epsilon_s - \epsilon_\infty\right)}{1+s\tau}\right]$$

$$s C_e(s) = s C_{D\infty}(s) + Y_{RC}(s)$$

$$C_D = \frac{\epsilon_0 A}{d\left(\epsilon_s - \epsilon_\infty\right)}$$

$$R_D = \frac{\tau}{\left(\frac{\epsilon_0 A}{d\left(\epsilon_s - \epsilon_\infty\right)}\right)}$$



3 pole debye model