EFIE-based MoM (Part III)

- Scalar Potential

Surface Impedance

- Voltage and Current Excitations
- Volumetric Formulation

E8-202 Class 9

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Module 2: Method of Moments

- 2D vs 2.5D vs. 3D Formulations
- Electrostatic Formulation: Capacitance matrix extraction
- Magnetostatic Formulation: Inductance matrix extraction
- Electric Field Integral Equation (EFIE): S-parameter extraction
- Partial Element Equivalent Circuit (PEEC) Method
- Magnetic Field Integral Equation (MFIE) and Combined Field Integral Equation (CFIE)
- PMCHWT Formulation: Dielectric modeling
- Parallelization techniques

References

- S. M. Rao, D. R. Wilton and A. W. Glisson, "Electromagnetic scattering by surfaces of arbitrary shape", *IEEE Trans. Antennas Propagation*, vol. AP-30, pp. 409-418, May 1982.
- D. H. Schaubert, D. R. Wilton, and A. W. Glisson, "A tetrahedral modeling method for electromagnetic scattering by arbitrarily shaped inhomogeneous dielectric bodies," IEEE Trans. Antennas Propag., vol. AP-32, pp. 77–85, Jan. 1984.
- Walton C. Gibson: The Method of Moments in Electromagnetics, 1st Ed., Chapman and Hall, Chapter 3
- Roger F. Harrington: Field Computation by Moment Methods, 1993, Wiley-IEEE Press, Chapter 7

EFIE Algorithm: Vector Potential

```
for i=1:Nt
        for j=1:Nt
                s=integral(exp(-jkr)/r);
                v=integral(rho*exp(-jkr)/r);
                for ik =1:3(number of basis for obs triangle i)
                        for jk = 1:3 (number of basis for source triangle j)
                                Calculate constant
                                Z(gik, gjk) += constant*rhot.(r1*s+V);
                        end
                end
        end
end
```

EFIE Scalar Potential

$$\left\langle \nabla\phi, f_t \right\rangle = -\int_T \phi \nabla \cdot f_t dt$$

How?

$$\left\langle \nabla\phi, f_t \right\rangle = \frac{l_s l_T}{j\omega 4\pi\varepsilon_0 A_s A_T} \int_T \int_S \frac{e^{-jk\left|r-r'\right|}}{\left|r-r'\right|} ds dt$$

EFIE Algorithm: Scalar Potential

```
for i=1:Nt
        for j=1:Nt
                s=integral(exp(-jkr)/r);
                for ik =1:3(number of basis for obs triangle i)
                        for jk = 1:3 (number of basis for source triangle j)
                                Calculate constant
                                Z(gik, gjk) += constant*s;
                        end
                end
        end
end
```

Surface Impedance Matrix

$$E_t = Z_s\left(\hat{n} \times \vec{H}\right)$$

Leontovich Impedance Boundary Condition

$$Z_s = \frac{1+j}{2}\frac{1}{\sigma\delta}$$

$$\delta = \frac{1}{\sqrt{\pi\mu\sigma f}}$$ Skin Depth

Surface Impedance Matrix

$$E_i = j\omega A + \nabla\phi + Z_s J$$

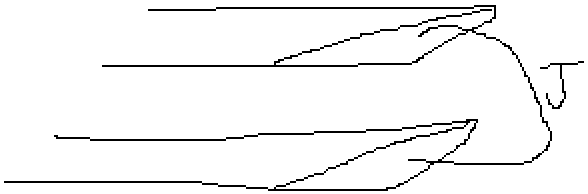
$$\langle Z_s, f_t \rangle$$

Is this a dense matrix?
How many terms per row?

Circuit Excitations

- Coupled EM-ckt
- Delta gap Voltage
- Delta gap Current

Coupled ckt-EM



$$\phi_1 - \phi_2 = 1$$

Yong Wang, Dipanjan Gope, Vikram Jandhyala and C.J. Richard Shi, "Generalized KVL-KCL Formulation for Coupled Electromagnetic-Circuit Simulation with Surface Integral Equations", *IEEE Transactions on. Microwave Theory Tech.,* vol. 52, no. 7, pp. 1673-1682, July 2004.

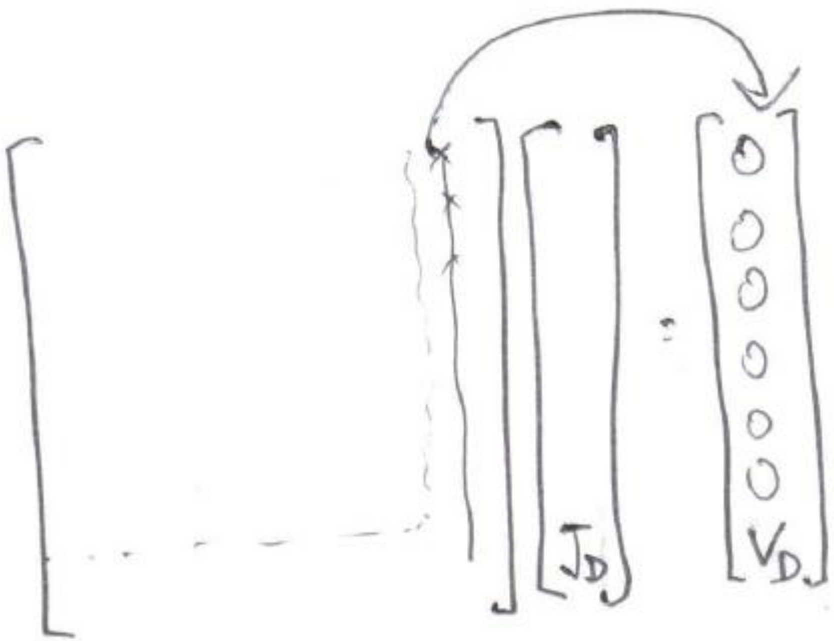
Delta-Gap Voltage Source

$$\int E_{inc} \cdot f_r \, d_t$$

$$= \int \frac{\vec{V}}{d} \cdot \hat{n} \cdot f_l \, d_t$$

$$= \frac{V}{d} \cdot l d = V l$$

Delta-gap Current Source



$$J_D = \frac{1\,\text{Amp}}{l}$$

Circuit Representation of EFIE

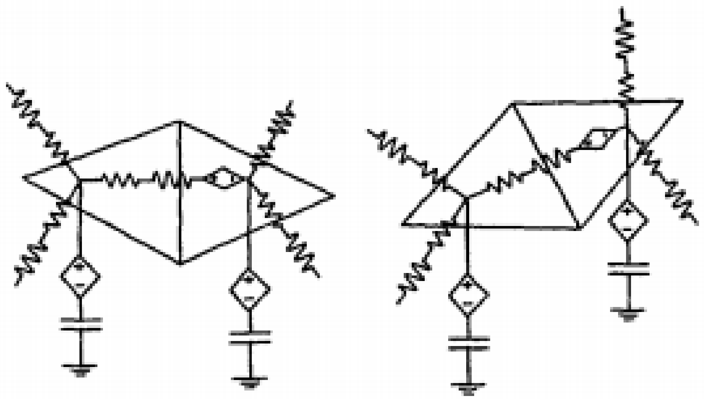


Figure 1. PEEC elements defined on triangular meshes.

Y. Wang, V. Jandhyala and C. J. Shi, "Coupled Electromagnetic-Circuit Simulation of Arbitrarily-Shaped Conducting Structures", *Proc. Electrical Performance of Electronic Packaging conf.*, vol 10, pp. 233-236, Boston, Oct 2001.

Data Structures

- N2XYZ
- P2N
- E2P
- E2N
- P2E

Dielectric Handling

- Multilayered Greens Function (not 3D)
- PMCHW
- Volumetric Basis: SWG