# A MOMENT METHOD FOR SYSTEM OF CONDUCTING SURFACES AND WIRES

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**SUMMARY** An electric field integral equation (EFIE) has been solved by the method of moments for a system of three-dimensional arbitrary shaped conducting closed or open surfaces and wires. The surface-patch and thin-wire approximations have been applied to the surfaces and wires, respectively. A set of triangular functions has been used as expansion/testing functions and then details of discretized EFIE has been developed through same process for the surfaces and wires. The method is suitable for three dimension objects where there is no surface-wire junction. Results for current distribution and input impedance have been obtained for a center feed dipole parallel and perpendicular to a 1λ (wavelength) square flat surface.

## 1. THEORY

Consider a geometry of arbitrary shaped perfect conductor scatterers in a homogeneous medium as shown in Fig.1. The scatterers may consist of closed or open surfaces and wires. The surface is modeled by triangular patches introduced in [1] and the wire is approximated as the thin-wire[2].

The electric field boundary condition $\mathbf{n}\times(\mathbf{E}^i+\mathbf{E}^s)=0$, where $\mathbf{E}^i$ is incident field and $\mathbf{E}^s$ is scattered field on the scatterers, is considered.

By using a triangular expansion/testing function sets the electric boundary condition is descritized and tested. The result may be given as

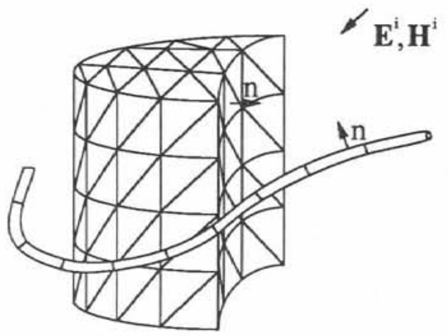



Fig. 1 Three-dimensional arbitrary shaped conducting surface and wire scatterers.

$$[ZJJ][J] + [ZJI][I] = [VJ] \qquad (1)$$

$$[ZIJ][J] + [ZII][I] = [VI] \qquad (2)$$

[J] and [I] are NJ*1 and NI*1 surface and wire current matrixes respectively. [VJ] and [VI] are NJ*1 and NI*1 incident field matrixes of the surface and wire respectively. [ZJJ], [ZII], [ZJI], and [ZIJ] are NJ*NJ, NI*NI, NJ*NI, and NI*NJ matrixes of mutual impedance between surface-surface, wire-wire, surface-wire and wire-surface elements, respectively. NJ and NI are number of surface and wire current unknowns respectively.

The elements of the matrixes are given by

$$VJ_{m,1} = \mathbf{E}^i{}_{mJ^+} \cdot \rho^c{}_{mJ^+} + \mathbf{E}^i{}_{mJ^-} \cdot \rho^c{}_{mJ^-} \quad (3)$$

$$VI_{m,1} = \mathbf{E}^i{}_{mI^+} \cdot l^c{}_{mI^+} + \mathbf{E}^i{}_{mI^-} \cdot l^c{}_{mI^-} \quad (4)$$

$$ZJJ_{m,n} = j\omega\,[\mathbf{A}_{mJ^+,nJ} \cdot \rho^c{}_{mJ^+} + \mathbf{A}_{mJ^-,nJ} \cdot \rho^c{}_{mJ^-}] + 2[\Phi_{mJ^-,nJ} - \Phi_{mJ^+,nJ}] \quad (5)$$

$$ZJI_{m,n} = j\omega\,[\mathbf{A}_{mJ^+,nI} \cdot \rho^c{}_{mJ^+} + \mathbf{A}_{mJ^-,nI} \cdot \rho^c{}_{mJ^-}] + 2[\Phi_{mJ^-,nI} - \Phi_{mJ^+,nI}] \quad (6)$$

$$ZIJ_{m,n} = j\omega\,[\mathbf{A}_{mI^+,nJ} \cdot l^c{}_{mI^+} + \mathbf{A}_{mI^-,nJ} \cdot l^c{}_{mI^-}] + [\Phi_{mI^-,nJ} - \Phi_{mI^+,nJ}] \quad (7)$$

$$ZII_{m,n} = j\omega\,[\mathbf{A}_{mI^+,nI} \cdot l^c{}_{mI^+} + \mathbf{A}_{mI^-,nI} \cdot l^c{}_{mI^-}] + [\Phi_{mI^-,nI} - \Phi_{mI^+,nI}] \quad (8)$$

where

$$\mathbf{A}_{m,nJ}{}^{\pm} = \frac{\mu}{4\pi} \iint_{\mathbf{r}' \text{ on } T_{nJ}{}^{\pm}} f_{nJ}{}^{\pm}(\mathbf{r}') \frac{e^{-jkR_m}}{R_m}\, ds' \quad (9)$$

$$\mathbf{A}_{m,nI}{}^{\pm} = \frac{\mu}{4\pi} \int_{\mathbf{r}' \text{ on } L_{nI}{}^{\pm}} \mathbf{f}_{nI}{}^{\pm}(\mathbf{r}') \frac{e^{-jkR_m}}{R_m}\, dl' \quad (10)$$

$$\Phi_{m,nJ}{}^{\pm} = \frac{-1}{4\pi j\omega\varepsilon} \iint_{\mathbf{r}' \text{ on } T_{nJ}{}^{\pm}} \nabla'_s \cdot f_{nJ}{}^{\pm}(\mathbf{r}') \frac{e^{-jkR_m}}{R_m}\, ds' \quad (11)$$

$$\Phi_{m,nI}{}^{\pm} = \frac{-1}{4\pi j\omega\varepsilon} \int_{\mathbf{r}' \text{ on } L_{nI}{}^{\pm}} \nabla'_l \cdot f_{nI}{}^{\pm}(\mathbf{r}') \frac{e^{-jkR_m}}{R_m}\, dl' \quad (12)$$

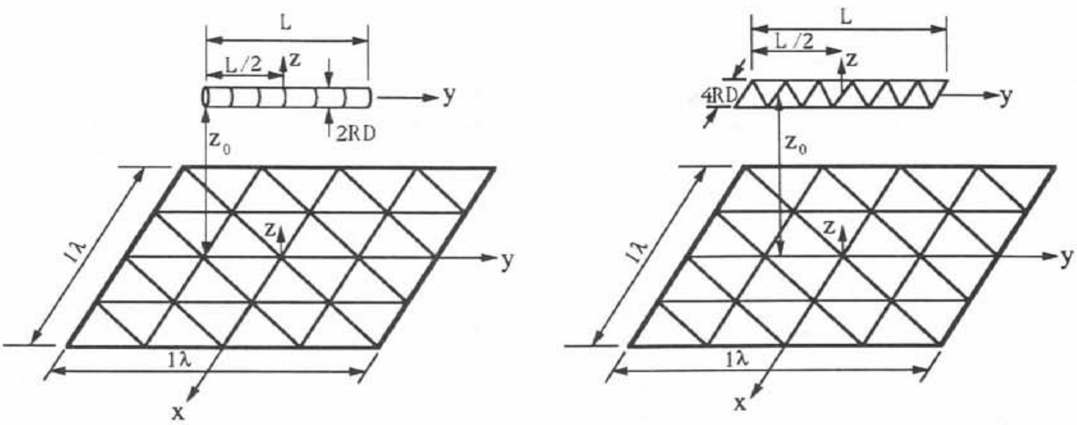
and $\mathbf{E}^i{}_m{}^{\pm} = \mathbf{E}^i(\mathbf{r}^c{}_m{}^{\pm})$, $R_m = |\mathbf{r}^c{}_m - \mathbf{r}'|$, excepting for ZII where

$R_m = \sqrt{|\mathbf{r}^c{}_m - \mathbf{r}'|^2 + RD^2(\mathbf{r}')}$ (RD is radius of the wire).

## 2. NUMERICAL RESULTS

Fig.2(a) and Fig.2(b) show a half wave wire dipole parallel with a $1\lambda$ square flat surface and its electromagnetical equivalent, respectively, where the wire is replaced by a equivalent strip[3]. The scatterer of Fig.2(a) has been treated by the surface-patch/thin-wire method while Fig.2(b) has been treated only by the surface-patch method. Fig.3 and Fig.4 show the current distributions of the half-wave wire and strip dipoles for different amount of $z_0$, respectively. The current distribution on the surfaces conformed as well as Fig.3 and Fig.4 conformity. Fig.5 and Fig.6 show the input impedance of the half-wave dipoles on the plates against $z_0$.

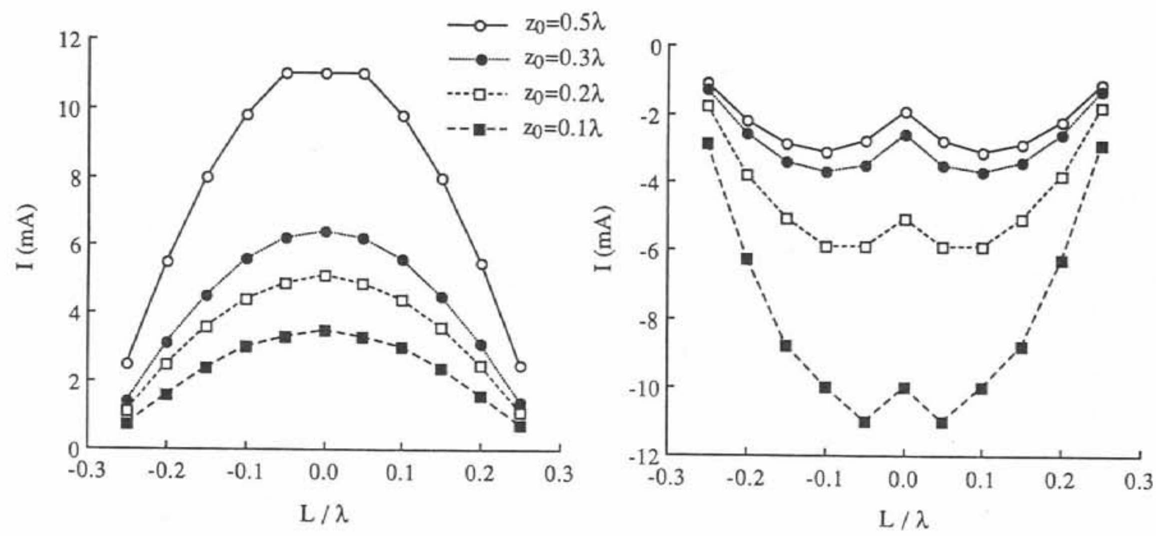
The combination of a dipole perpendicular to the flat plat also has been solved by the method. The results like the parallel combination are accurate.




(a) The wire dipole parallel with the surface.

(b) An equivalent combination for (a).

Fig. 2 A dipole parallel with the 1λ square flat surface.




(a) real parts.

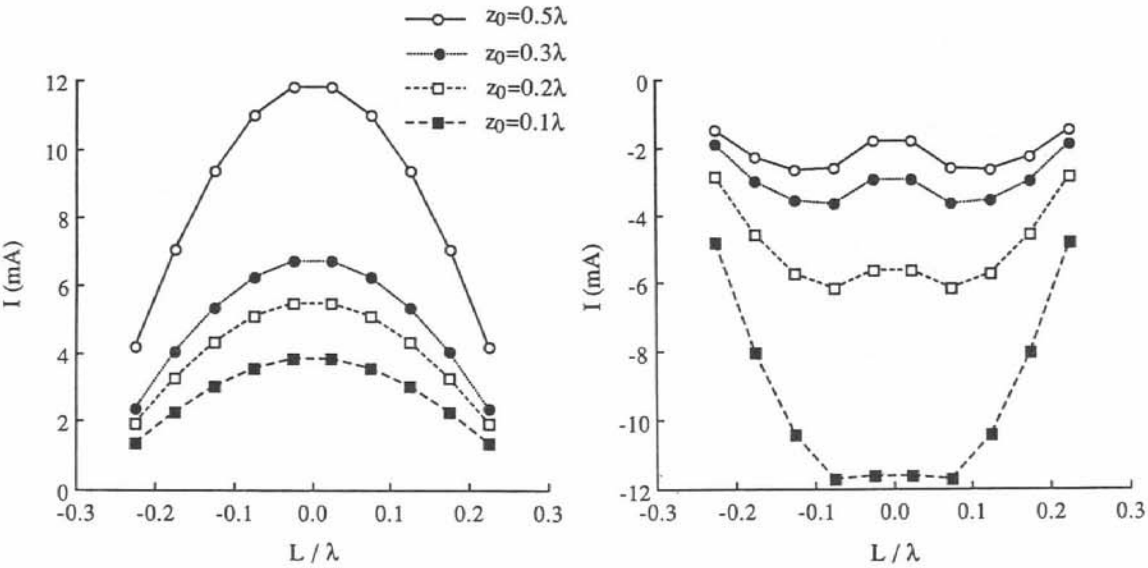
(b) imaginary parts.

Fig. 3 The current distribution on the half-wave wire dipole parallel with the surface.

## 3. CONCLUSION

The triangular-Galerkin method of moments is developed for electromagnetic analysis of a system of three-dimensional arbitrary shaped conducting surfaces and wires. There is no wire-surface junction between system elements. The electric field integral equation is applied to the scatterers therefore the open and closed surface treatment are possible. The current expansion and boundary condition testing process are identical for the surfaces and wires.

The first advantage of the method is using thin-wire approximation for the wire elements that makes simple handling of the scatterer and CPU-time and storage size reduction. The second advantage is triangular surface-patch approximation for the surfaces that makes possible handling of structures




(a) real parts. (b) imaginary parts.

Fig. 4 The axial current distribution on the half-wave strip dipole parallel with the surface.

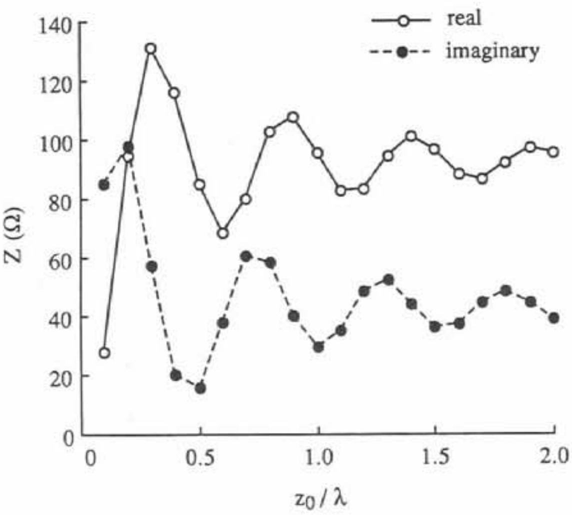



Fig. 5 The input impedance of the half-wave wire.

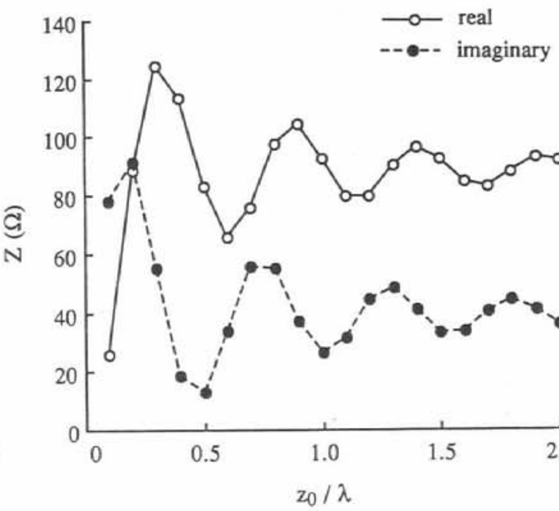



Fig. 6 The input impedance of the half-wave strip.

with curvature in all dimensiohs and provides direct calculation of near field quantities like the current distribution and input impedance.

The analyzed structures are a thin-wire dipole perpendicular and parallel to a 1λ square flat surface. The current distributions on the wire and surface and input impedance of the wire are investigated.

## References

[1] S.M. Rao, D.R. Wilton and A.W. Glisson, "Electromagnetic scattering by surfaces of arbitrary shape," IEEE Trans. Antennas & Propag., **AP-30**, 3, pp.409-418 (May 1982)

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