한국통신학회 1987년도 추계학술발표회논문집(1987. 11. 14)

모멘트 법에 의한 선도체의 유도 전류 계산

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Computation of Induced current distribution on Straight wire configurations by Method of Moments

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ABSTRACT : The method of moments is applied to a thin-wire antenna with juntions. By applying the matrix methods to Pocklington's integral equation the induced current and the input impedance of a thin-wire antenna are investigated. Treatments for wire junctions and incident plane waves are out-lined. Examples are include here for wire antenna with reactnce-compensating element and wire scatterer with junctions.

I. Introduction

Many authors have been assumed uniform or sinusoidal current distributions on wire antennas. Evidently resultant field values are influenced by the assumed current distributions. However, with the aid of high speed computers, the current distribution can be determined more exactly without too much exhaust in analytical setup by a formulation based on Pocklington's equation.

In this report an approximate technique based on the integral formulation for thin-wire with junction is presented. The input impedance of wire antennas with reactance-compensating element and the current induced in a thin wire by obliquely incident plane wave are illustrated by employing the proposed numerical techniques to these wire structures. Illustrative computations are restricted to the each wire radius(a) less than both the wire length(L) and the wavelength(λ) under considerations.

II. Formulation of the problem

1. Integral equation and method of moments[1,2]

An electric field $\underline{E}$ is impressed to a wire shown in Fig.1. We consider the scattering field $\underline{E}^s$ in terms of scalar and vector potentials. For the present problem these two potentials are given by

$$\underline{E}^s = -jw\underline{A} - \nabla\phi \quad (1\text{-}1)$$

$$\underline{A} = \mu\int_{l'} I(l')\hat{l}'G(\underline{r},\underline{r}')dl' \quad (1\text{-}2)$$

$$\phi = (-1/jwe)\int_{l'}[dI(l')/dl']G(\underline{r},\underline{r}')dl' \quad (1\text{-}3)$$

where $G(\underline{r},\underline{r}')=EXP(-jkR)/4\pi R$ and $R = \sqrt{(r^2+r'^2) + a^2}$. $\hat{l},\hat{l}'$ are unit vectors lying along the wire at the observation point $\underline{r}$ and source point $\underline{r}'$ respectively. By assuming that currents are zero at the wire ends, we can obtain Pocklington's equation in terms of an electric current source.

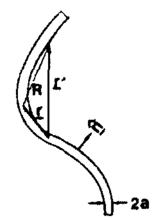

Fig.1. Coordinate for an arbitrary thin wire.

$$\underline{E}^s = (1/jwe)\int_{l'} I(l')[-\frac{d}{dl}\frac{d}{dl'}\hat{\underline{l}} + k^2\hat{\underline{l}}']G(\underline{r},\underline{r}')dl' \quad (2)$$

Since the wire is assumed perfectly conducting

$$E_t^s = -E_t^{inc} \quad (3)$$

or

$$L(I) = -E_t^{inc} \quad (4)$$

where

$$L = (1/jwe)\int_{l'}[-\frac{d}{dl}\frac{d}{dl'} + k^2\hat{\underline{l}}\cdot\hat{\underline{l}}']G(\underline{r},\underline{r}')dl'. \quad (5)$$

The current induced in a known impressed electric field can be obtained by solving the inhomogeneous equation (4).

Triangle functions are employed as a current expansion function as well as a testing function, which is known as Galerkin's method. Defining the inner product

$$\langle W, L(I)\rangle = \int_l W L(I)dl \quad (6)$$

the current on I is expanded as

$$I = \sum_{n=1}^{N-1} I_n J_n \quad (7)$$

where $J_n = T(l-l_n)$ and I_n is expansion coefficients to be determined. Triangle functions $T(l-l_n)$ are approximated by four pulse steps $S_n(i)$ as shown in Fig.2. We take the symmetric inner product of (7) with each testing functions$\{W_m, m=1,2,...,N-1\}$

$$I_n\langle W_m, L(J_n)\rangle = \langle W_m, -E_t^{inc}\rangle \quad (8)$$

These set of equations can be written in matrix form as $[Z_{mn}][I_n]=[V_m]$. The element of $[V_m]$ are given by

$$V_m = -\sum_{j=1}^{4} S_m(j) \int_{\Delta l_m} E_l^{inc} dl \qquad (9)$$

whereas the element of $[Z_{mn}]$ are

$$Z_{mn} = (1/jew)\sum_{i=1}^{4}\sum_{j=1}^{4} S_n(i)S_m(j) \int_{\Delta l_m}\int_{\Delta l_n} \left[-\frac{d}{dl}\frac{d}{dl'} + k^2\, \hat{l}\cdot\hat{l}'\right] * G(r,r')\,dl\,dl' \qquad (10)$$

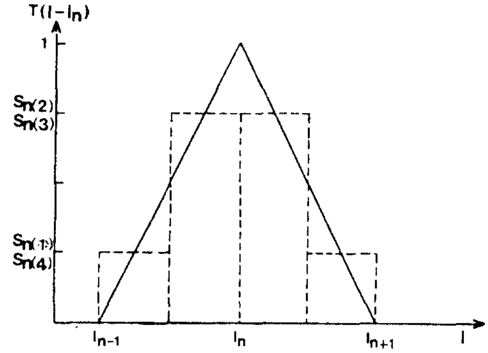

Fig.2 Triangle function (solid) and four pulse approximation(dash).

Given a set of voltages the current matrix can be obtained by inverting $[Z_{mn}]$. For the most purposes it is sufficiently accurate to treat the test current on Δl_m as if it were a point source, and use

$$V_m = -\sum_{j=1}^{4} S_m(j)\, \Delta UL\, E_l^{inc} \qquad (11)$$

$$Z_{mn} = (1/jew)\sum_{i=1}^{4}\sum_{j=1}^{4} S_n(i)S_m(j)\, \Delta UL * \int_{\Delta l_n} \left(-\frac{d}{dl}\frac{d}{dl'} + k^2\, \hat{l}\cdot\hat{l}'\right) G(r,r')\,dl' \qquad (12)$$

where $\Delta UL = (l_{m+1} - l_m)/2$.

2. Incident plane wave[3)]

The propagation vector K, which lies in YZ-plane, subtends an angle with the positive Z-axis and the electric vector E is at angle with respect to the YZ-plane as shown in Fig.3. The component of the field along the vertical wire and the horizontal wire are

$E_z^{inc}(z) = E^{inc}(0)COS(\psi)SIN(\theta)EXP(jkzCOS(\theta))$

$E_x^{inc}(z) = E^{inc}(0)SIN(\psi)EXP(jkzCOS(\theta))$

where $E^{inc}(0)$ is the incident electric field at the origin coodinate.

3. Wire junction[4)]

As a method of treating wire junctions, the idea of one wire overlapping another at a juction is introduced. For this concept, the current at the wire end which is the end of the overlap is zero while the current at the point where the junction was is not zero.

Suppose M wires meet at some junction, then KCL is satisfied by overlapping wire i by two segments on to wire i-1, except that wire 1 is not overlapped on to wire N. THat the number of overlaps is M-1 rather than M is required to insure on idependent set of expansion functions. This method is shown in Fig.4 for three wires.

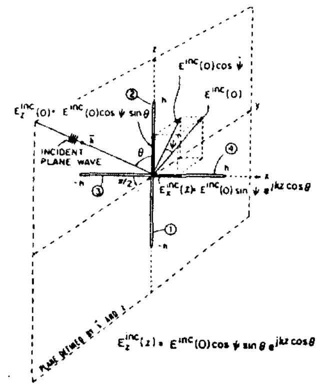

Fig.3. Definitions for incident plane waves.

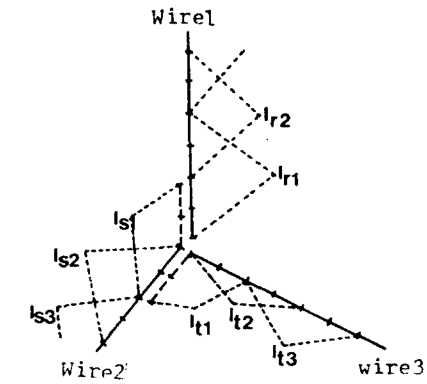

Fig.4 Junction treatment(basis functions shown dashed).

III. Results

As a wire antenna problem consider wire with reactance-compensating element. The equivalent source of the centerfed antenna is magnetic frill generator[5)] for a 1-volt excitation. Fig.5 show the input impedance for antenna as a function h where $(h+l)=\lambda/4$. These data compare favorably with results obtained by Simpson[6)] when converted to the equivalent half space problem. Fig.6 shows input impedance for an antenna as a function of h_2 where $(h_1+h_2)=\lambda/5$. By choosing its length l and height h appropriately it may be possible to compensate the antenna reactance.

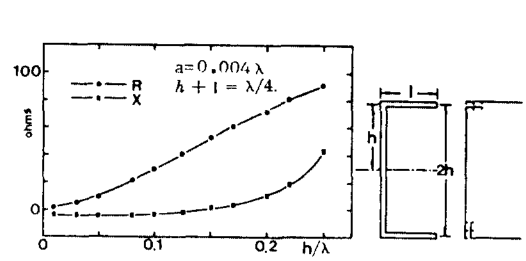

Fig.5. Impedance of symmetrical inverted L antenna, $(h+l)=\lambda/4$.

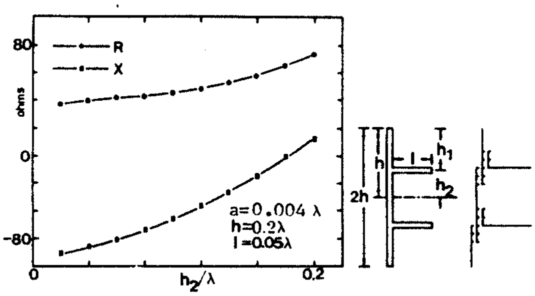

Fig.6. Impedance of antenna with reactance-compensating wires, $h_1 + h_2 = \lambda/5$.

As a wire scatterer problem consider a equilength wire-cross and a receiving antenna, i.e., wire antenna with a reactance-compensating wire. As shown in Fig.7, when $\theta = 90^\circ$, the horizontal wire exist in the neutral plane to the vertical wire and vice versa. the vertical wire and the horizontal wire behave as if isolated, and also at the junction $[I^2(x) + I^2(z)]^{1/2}$ is constant. Fig.7 and Fig.8 show that wire currents induced by an incident plane wave at an angle (θ, ψ) satisfy exactly KCL at the junctions. When $\theta = 90^\circ$, they show the familiar distribution of forced currents.

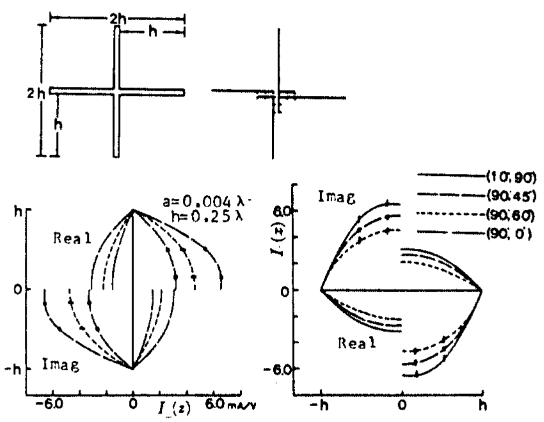

Fig.7 Currents on the equilength crossed antenna.

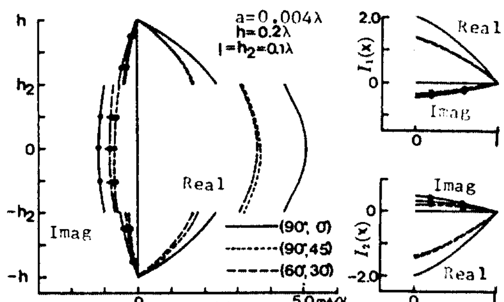

Fig.8 Currents on the receiving antenna, i.e. , antenna with reactance-compensating antenna.

IV. Conclusion

In this work a numerical approach has been presented, based on method of moments and Pocklington's equation, to thin wire antenna with junctions. Numerical results are obtained for the input impedance of the wire antenna with reactance -compensating element and the currents on the wire scatterer by obliguely incident plane wave.

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