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TRANSIENT SCATTERING BY ARBITRARY WIRE STRUCTURES

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With the current interest in the transient response of wire antennas and scatterers, it has become necessary to consider various techniques for the accurate determination of this time dependent behavior. Since the integral equation approach has proven so useful in the space-frequency domain for wire structures and in the space-time domain for large structures[1,2], it is useful to consider this technique for the analysis of thin wire structures. An analysis using time dependent potentials has been pursued by Sayre[3] but numerical results have been presented only for straight wires and loops. Also, a formulation in terms of a time dependent Hallen's integral equation for arbitrarily curved wires has been achieved[4] but numerical results have been obtained only for straight wires.

In this paper the time dependent electric field integral equation is formulated and is reduced to a form suitable for digital computer solution. The Fourier transform is used to transform the time independent electric field integral equation for scattering by a perfect electric conductor

$$\hat{n} \times \bar{E}^{I}(\bar{x}) = \frac{1}{4\pi j \omega \epsilon}\, \hat{n} \times \int_S \left(-\omega^2 \mu \epsilon\, \bar{J}_s\, \varphi + \nabla_s' \cdot \bar{J}_s\, \nabla' \varphi\right) ds$$

$$\bar{x} \in S$$

to the time dependent form

$$\hat{n} \times \bar{E}^{I}(\bar{x},t) = \frac{\mu}{4\pi}\, \hat{n} \times \int_S \left\{ \frac{\partial}{\partial \tau} \bar{J}_s(\bar{x}',\tau) \frac{1}{|\bar{x}-\bar{x}'|} - c^2 \rho(\bar{x}',\tau) \frac{(\bar{x}-\bar{x}')}{|\bar{x}-\bar{x}'|^3} - c \frac{\partial}{\partial \tau} \rho(\bar{x}',\tau) \frac{(\bar{x}-\bar{x}')}{|\bar{x}-\bar{x}'|^2} \right\}_{\tau = t - \frac{|\bar{x}-\bar{x}'|}{c}} ds$$

$$\bar{x} \in S$$

where J_s is the surface current density, ρ is the charge density, $\bar{E}^I$ is the incident electric field, and φ is the free space Green's function $\exp(ikR)/R$, $R = |\bar{x}-\bar{x}'|$. Upon specializing this equation to a thin wire one obtains the time domain integral equation for thin wires. In doing so the thin wire approximation[5] for the distance between source and observation points is used (for straight wires, $|\bar{x}-\bar{x}'| = \sqrt{(s-s')^2 + a^2}$ where s and s' are axial coordinates and a is the wire radius).

This integral equation formulation and the collocation technique used in its solution is discussed. Also, the interpolation schemes, which allow accurate representation of the induced wire currents in space-time and which are used in the algorithm, are described. These schemes are especially important since they represent methods which permit shortcomings in previous approaches to be overcome in that they permit the entire space-time cone to be covered continuously without restriction as to the space and time sample density.

Numerical results for the time dependent backscatter cross section of various wire targets when illuminated by a Gaussian shaped pulse are presented. These results are Fourier transformed to the frequency domain for a comparison with extensively validated independent data. The targets considered are straight dipoles, vee-dipoles, loops, and zig-zag bands, as well as multiple scatterer targets such as coaxial rings, ring and zig-zag bands, and multiple zig-zag bands. The wealth of frequency domain information which is available from a single time domain computation is clearly demonstrated by the results.

Finally, the relative advantages and disadvantages of time domain calculations versus frequency domain computations are outlined.

References

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