A Fast Hybrid Model in Analyzing Nonlinearly Loaded Dipole Antenna and Finite Dipole Antenna Array

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Introduction

Nonlinear loads are connected to scatterers in order to control scattering response. One of loaded scatterers is nonlinearly loaded dipole antenna array. A number of studies have been done on it [1-5] in which method of moments; MoM is together with one of nonlinear techniques, for instance, Volterra series model [1], Harmonic balance technique [2], reflection algorithm (RA) and Newton inexact approach (INA) [3], genetic algorithm [4] and nonlinear currents [5]. The central problem in such applications is to compute the induced voltage across nonlinear load at different harmonic frequencies.

It is well known that such problems suffer from repetitive, complex and time consuming computations of the effect of external wave illuminated to scatterer for any incidence directions and mutual coupling effects among antennas in array usually carried out by MoM [6].

To our knowledge, there are no excellent approximations for the induced current due to the external wave in any incidence direction and the mutual coupling effect in array, except [7] modelling induced current by variational method, but confined to dipole antenna of small length, and [8] modelling mutual coupling effects in array of two parallel-coupled dipole antennas by RBF-neural network model in which training process takes ages.

In contrast with all mentioned methods above, our past studies based on fuzzy inference could remove these drawbacks. Our fuzzy-based models can easily extract the behavior of array and the knowledge bases of spacing between antennas and external wave as simple curves. In this study, we combine our proposed fuzzy models for the mutual coupling [9] and the external wave [10] with Volterra series model. The resulted hybrid model is much faster than the past studies [1-5] without loss of accuracy.

In the section below, comparing the results of two hybrid models, fuzzy plus Volterra and MoM plus Volterra [1], for nonlinearly loaded antenna and finite antenna array are illustrated.

Analysis of Nonlinearly Loaded Dipole Antenna and Finite Antenna Array

In this section, a nonlinearly loaded dipole antenna and array shown in figure 1 having the same dimension and nonlinear load as [1-5] are considered.

As it has been explained in [1-5], to analyze, one needs to compute the short circuit current due to the incident plane wave and input admittance of dipole antenna in transmitting mode. Therefore with the use of the knowledge base of incident angle in figure 8 of [10], and the membership functions of transmitting dipole antenna, the short circuit induced current in any incidence direction is easily computed. Then by using Volterra technique, the induced voltage

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at different harmonic frequencies for the incidence $E^i = 0.5V / m, \theta_i = 45^\circ$ is computed. The results of induced current and voltage and finally normalized scattering response are shown in figures 2, 3 a, b respectively. As it is seen in figure 3b, an excellent agreement with accurate one is achieved also the execution time is considerably reduced.

Analyzing nonlinearly loaded finite antenna array is the same as single one, except that, the fuzzy model of input admittance of each antenna in array including mutual coupling effects in [9] is replaced instead of input admittance of single dipole antenna. Computations of the induced voltage across nonlinear load in the array of two collinear-coupled dipole antennas with the same previous incidence and $D_v = 42cm$ by the two hybrid models are shown in figure 4.

Note that owing to nonlinear characteristic of load, the harmony 2ω is zero and not shown in figure 4.

Table 1 compares the computation time of induced voltage by the two hybrid models from analyzing the nonlinearly loaded dipole antenna and finite antenna array. All computations were carried out by Matlab software on a 2.41-GHZ Pentium 4 with 2GB of Ram.

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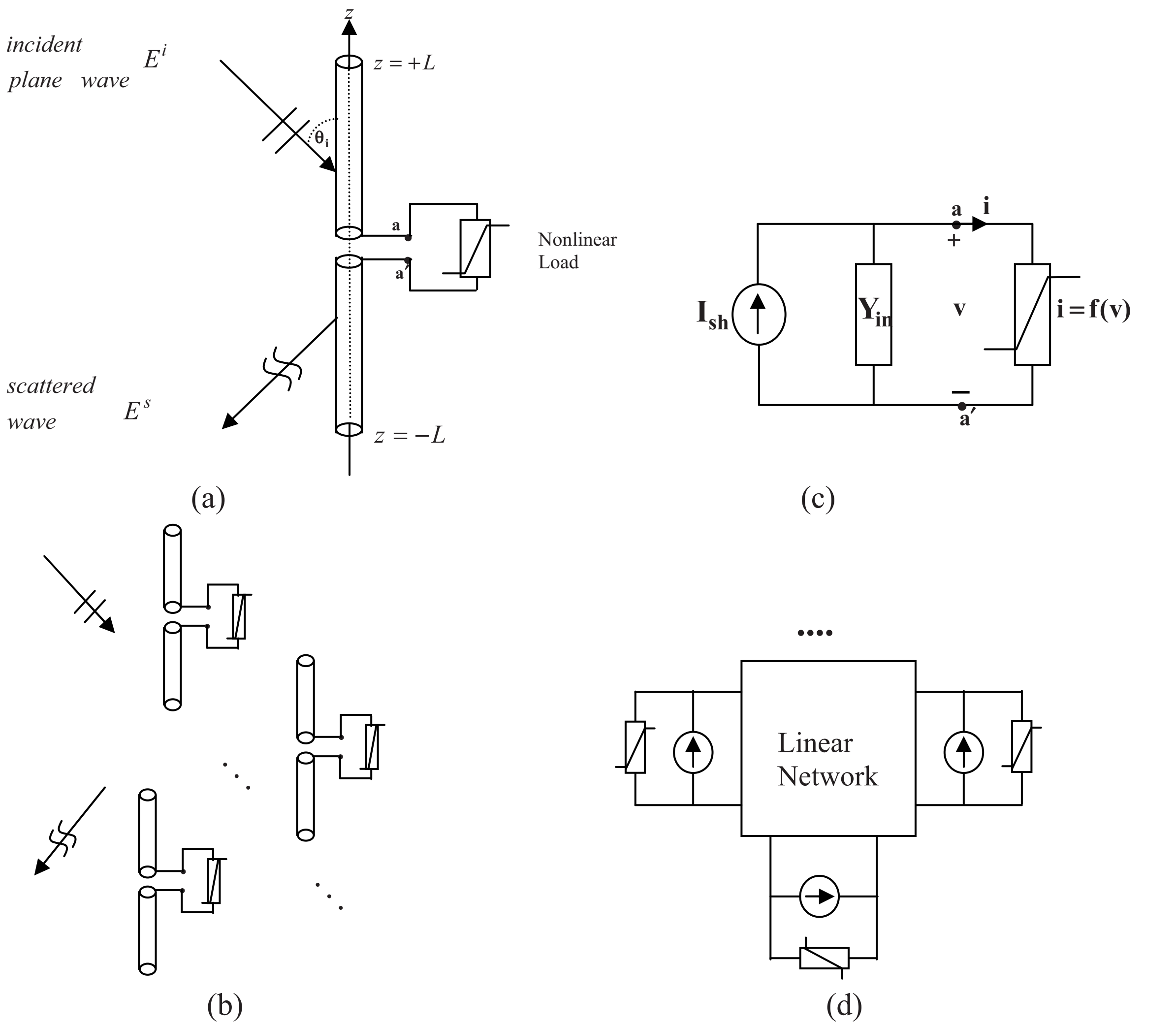

Figure 1. (a), (b): Schematic diagram of nonlinearly loaded dipole antenna and dipole antenna array. (c), (d): equivalent microwave circuits for (a) and (b) respectively.

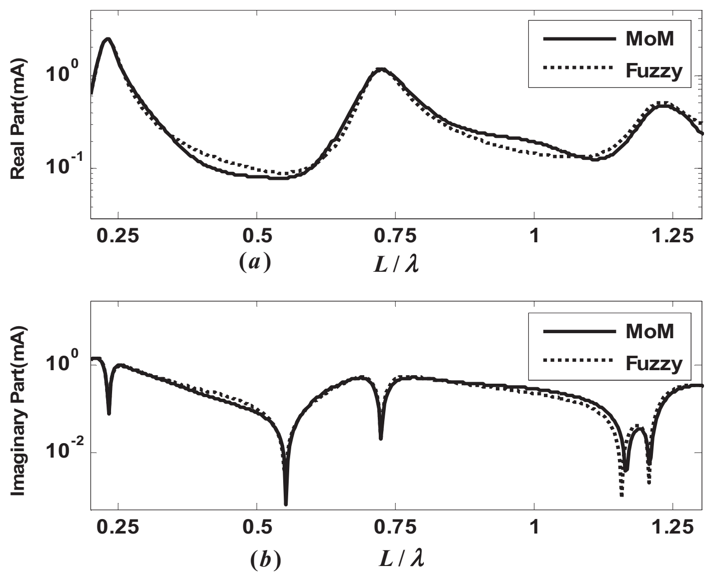

Figure 2. Comparing modeling of the induced short circuit current by the two different methods. (a):real part, (b): imaginary part.

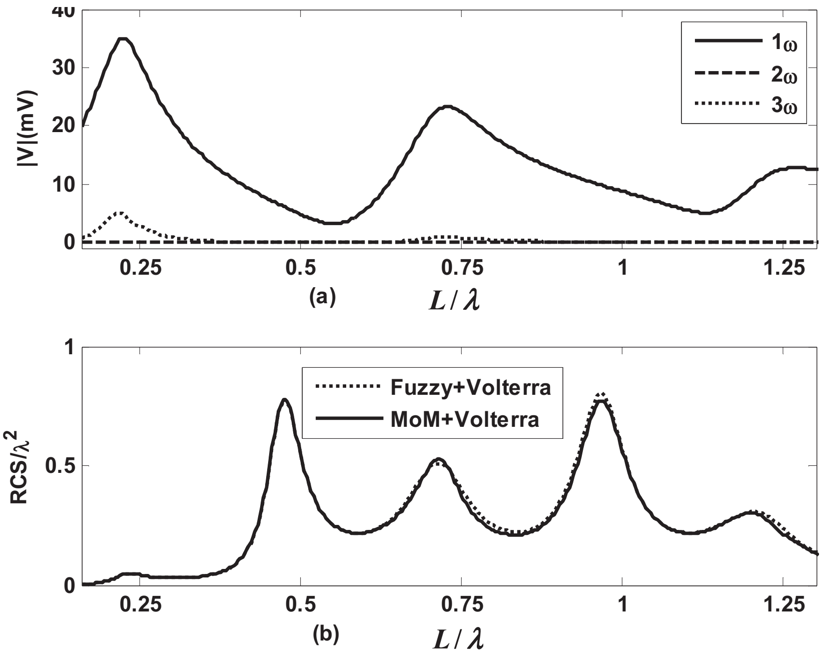

Figure 3. (a): The induced voltage across nonlinear load and (b):Normalized RCS in the incidence direction at the fundamental frequency.

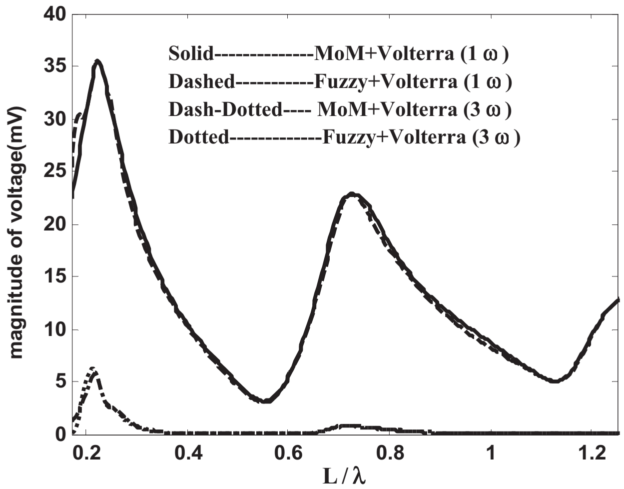

Figure 4. The induced voltage at different harmonic frequencies for two collinear-coupled dipole antennas with $D_v = 42cm$.

Table 1. Comparing the execution time for two hybrid models.

Hybrid Model / Problem	Fuzzy + Volterra (this paper)	MoM + Volterra ([1])
A dipole antenna loaded nonlinearly	$\approx 0.2\,\sec$	$\approx 1.3\,\min$
Array of two collinear-coupled dipole antennas loaded nonlinearly	$\approx 0.5\,\sec$	$\approx 4.9\,\min$