Prediction of Induced Current in Externally Excited Dipole Antenna Using Fuzzy Inference

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Abstract

In this paper, our previously introduced fuzzy modeling method is used to model the induced current in the externally excited dipole antenna. In our model, behavior of the problem is saved as a set of unchanged membership functions and the knowledge of the incident angle is extracted as very simple curves of starting parameters. Then the induced current of the externally excited dipole antenna for any incident angle can be predicted very easily by applying the starting parameters calculated from the achieved simple curves to fuzzy system. Comparing fuzzy model results with the method of moments (MoM) shows very good agreement while execution time is surprisingly short even for wide bandwidth.

1. Introduction

Wire antennas are widely used in communication systems from low to ultra-high frequencies, either in the form of individual elements or arranged together to form an array. They are also frequently used as probes to sense unknown environments or as bases for modeling more complex systems and structures. Therefore, accurate and fast analysis of them is very important. As we know, there are several analytical and numerical methods to analyze dipole antennas, either in individual or in coupled form, e.g. the method of moments (MoM) in [1], which suffer from the complex and time-consuming calculations. These will increase when good accuracy is required. In contrast with these methods, qualitative inferences and soft calculating methods can be taken into consideration. A new modeling approach by using fuzzy inference for computing the input impedance of an isolated monopole antenna was introduced by Tayarani et.al in [2]. The same method was then used by authors to predict input impedance of two coupled dipole antennas in the parallel, collinear and echelon form as three different kinds of transmitting in [3-5]. We showed that three kinds had the same behavior as the isolated dipole antenna. The question of receiving case was not addressed. In section 2 of this paper, the introduced method in [2] is briefly explained by applying it to the isolated transmitting case to its specifications is compared with receiving one clearly in the section 3. Then, we apply the same method to the externally excited dipole antenna (receiving case) to extract its behavior and its knowledge base. We will show that behavior of the receiving case is well approximated to the transmitting one, and its knowledge base is saved as very simple curves. Finally, we show that our modeling results are in an excellent agreement with accurate ones (MoM), and the execution time is also vanishingly reduced. We suppose that this method will be extremely effective for analyzing phased antenna array both in transmitting and in receiving in near future.

2. A fuzzy model for input current of transmitting dipole antenna

A dipole antenna as transmitter and receiver are shown in figure 1. At first, the transmitting case is considered with exciting voltage $V_0 = 1V$, and computed input current (input admittance) by MoM is shown in figure 2. Now, by choosing three three-point sets around even resonances (* marks in figure 2) for defining circles and introduced membership functions in [6] and Takagi/Sugeno's method in [7] this circular movement is easily modeled. The resulted membership functions from modeling are shown in figure 3. Then using the introduced definition in [2] for phase (Partial Phase), and using the same starting points for defining fitted lines (Dash-dotted lines in figure 4) we can model partial Phase as shown in figure 4.

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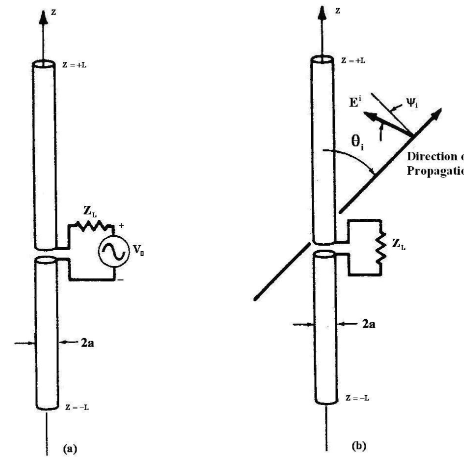

Figure. 1. Isolated dipole antenna (a): transmitting (b): receiving with $L/a = 74.2$ and $Z_L = 50\Omega$

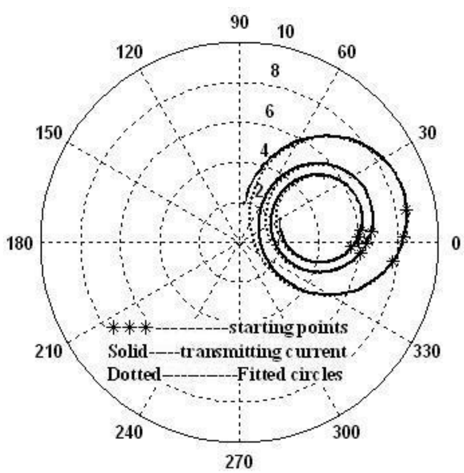

Figure 2. The input current of transmitting dipole antenna (amplitude (in mA) versus phase) as well as fitted circles

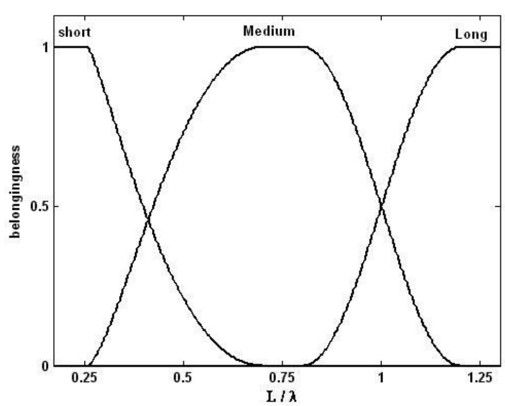

Figure 3. Membership function from modeling moving circles

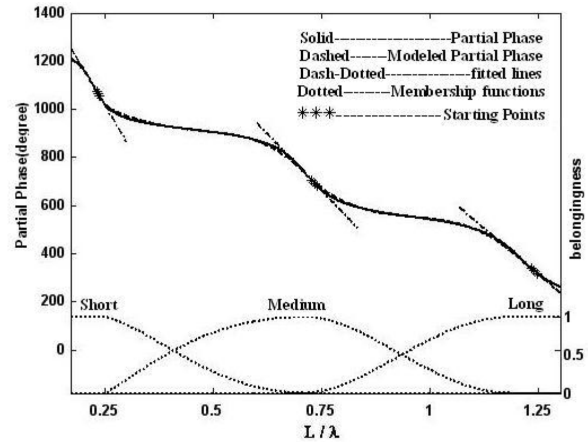

Figure 4. Partial Phase (on the left axis) with fitted lines (Dash-dotted) and its belongingness (on the right axis)

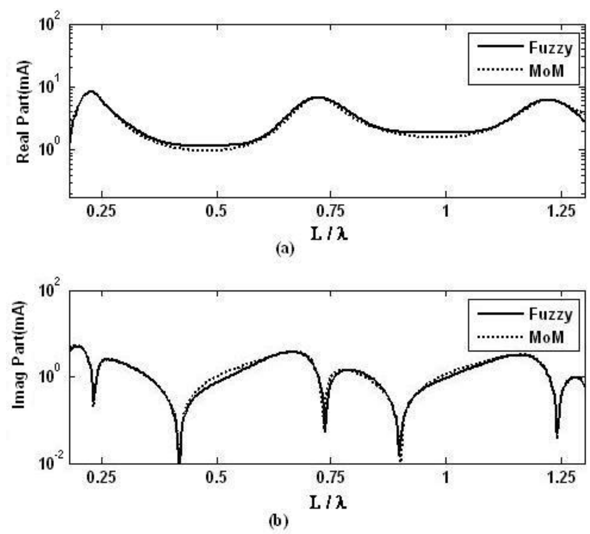

Figure 5. Modeled input current in transmitting dipole antenna (a): real part (b): imaginary part

The modeled input current as well as MoM results are shown in figure 5. As it is seen, despite complexity of input current curve, it is well modeled using our simple method. In the next section, the receiving one is considered.

3. A fuzzy model for computing the induced current in the externally excited dipole antenna

In this section with the assumption of $E^i = 1 \;\; V/m$ a few samples of the induced current with different incident angles and in the externally excited dipole antenna are computed and shown in figure 6.

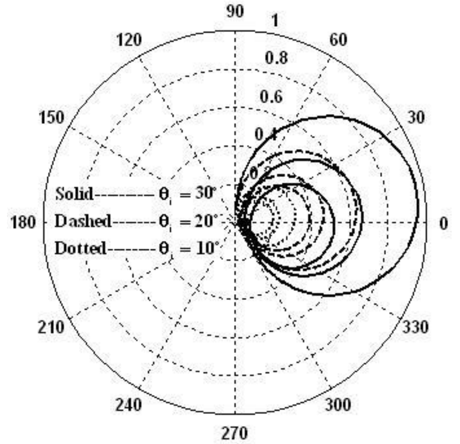

Figure 6. Induced current (in mA) in the externally excited dipole antenna with different incident angles

As it is seen in figure.6, receiving curves are changing the same as transmitting one. Therefore, we use the introduced method in the previous section for each sample. The membership functions, which model moving circles and Partial Phase for each sample, as well as transmitting case, are shown in figure 7.

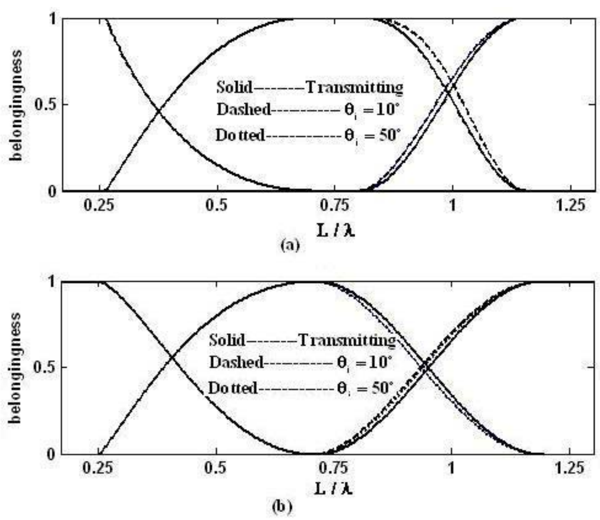

Figure 7. Comparison of membership functions for the transmitting and receiving case from modeling (a): moving circles (b): Partial Phase

As it is seen in figure.7, the membership functions from modeling moving circles and Partial Phase with different incident angles are slightly changed. Therefore, we approximate them to membership functions of the transmitting dipole antenna as a first order approximation.

Therefore, the only parameters which change with different incident angles are the starting point values that can be supposed as a knowledge base and can be extracted simply through applying the proposed algorithm. The knowledge base for the first, second and third circle and line are shown in figure.8. Since the mentioned specifications of three circles and lines are not in the same range, the curves are normalized to the individual isolated transmitting ones obtained in section 2 in other words $\{(X_n, Y_n, R_n), (Mn, Nn)\}$. Note that we can also use this above approximation for membership functions to express the behavior of two coupled dipole antennas in the parallel, collinear and echelon form to predict the input admittance as explained in [3-5].

As shown in figure.8, the normalized biases and slopes, M_n, N_n, are slightly changed around one. Therefore, we also approximate the biases and slopes of the receiving case to isolated transmitting ones. Now, using the inputs of our fuzzy system, circles and lines through the figure.9, and then using the membership functions of the transmitting dipole antenna, the induced current for each incident angle is easily predicted. For instance, two samples with $\theta_i = 10^{\circ}, 45^{\circ}$ are run. The predicted induced currents are shown in figure.9 and 10. As shown in figure.9 and 10, an excellent agreement with a vanishingly short computing time is achieved.

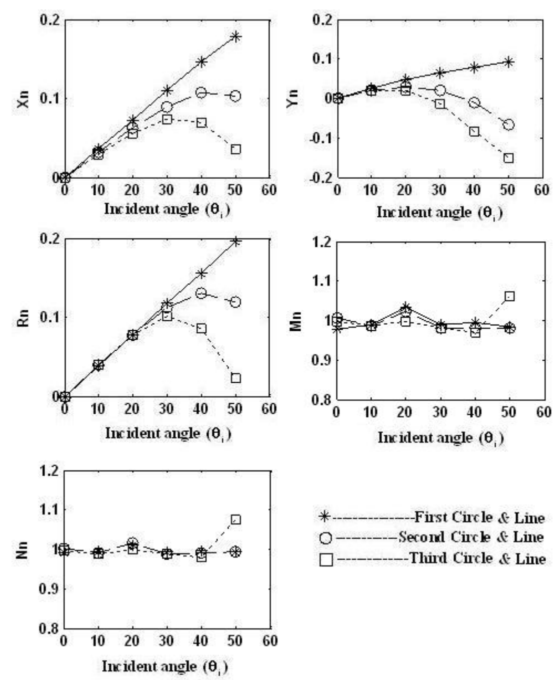

Figure 8. The knowledge base versus incident angle (degree) for the externally excited dipole antenna

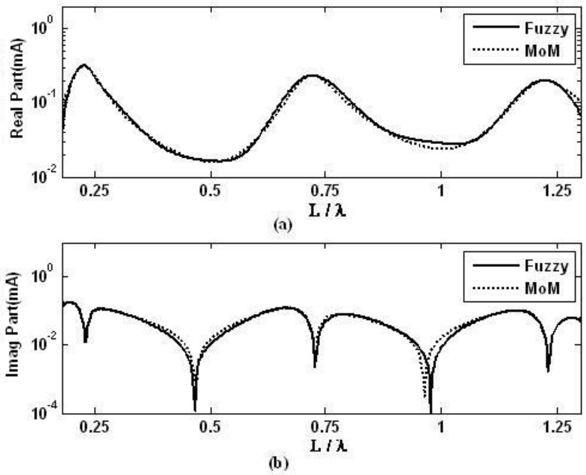

Figure 9. The predicted induced current (in mA) for $\theta_i = 10^\circ$ (a):real part, (b): imaginary part

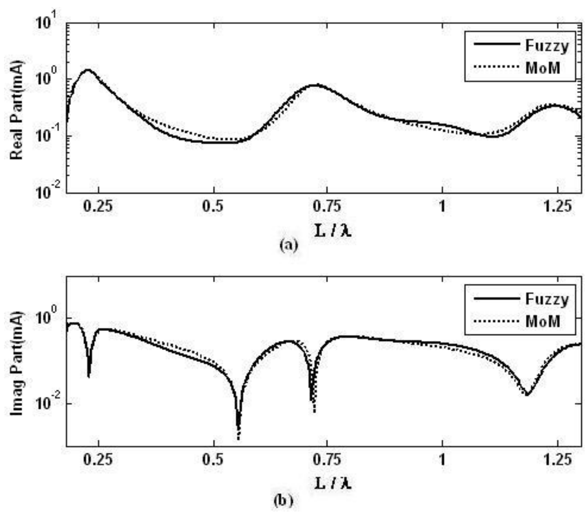

Figure 10. The predicted induced current (in mA) for $\theta_i = 45^\circ$ (a) real part, (b): imaginary part

4. Conclusion

In this paper, we used our previous method based upon fuzzy inference to predict the induced current in the externally excited dipole antenna. In our method, the behavior of the considered problem was well approximated with the transmitting one and its knowledge was saved as very simple curves. Comparing the extracted results with the accurate ones (MoM) showed an excellent agreement while the execution time was considerably reduced. It is confirmed again that the membership functions have the behavior of the system, and this is the reason for similar membership functions in transmitting and receiving cases. This method is useful for the repetitive calculations of induced current such as adaptive arrays and nonlinearly loaded antenna arrays.

5. Acknowledgment

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6. References

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