Prediction of the Input Impedance of two Coupled Dipole Antennas in the Echelon Form

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Abstract

In this paper, the previously introduced fuzzy modeling method is used to model the input impedance of two coupled dipole antennas in the echelon form. The initial data of two coupled dipole antennas in the parallel and collinear form, which are required for the model, are obtained using the MoM. Then, the knowledge of two coupled dipole antennas in the echelon form is easily predicted based on the knowledge of two coupled dipole antennas in the parallel and collinear form and the concept of spatial membership functions. Also, the problem behavior is well approximated. Comparing the proposed model results with MoM shows an excellent agreement with a vanishingly short execution time comparing with MoM.

1. Introduction

As we know, there are a number of successful analytical and numerical methods to analyze an antenna either in the form of individual elements or arranged with other similar elements to form a phased array, e.g. the method of moments (MoM). However, these methods are time consuming and require large storages especially for large arrays. In contrast with these methods, qualitative inferences and soft calculating methods could be taken into consideration. A new modeling approach by using fuzzy inferences for computing the input impedance of an isolated monopole antenna has been introduced by Tayarani et.al [1]-[2]. The same method has been used to compute the input impedance of two coupled monopole antennas by the authors successfully [3]. In this paper, we generalize the introduced method in [3] to model the input impedance of two coupled dipole antennas, which are excited identically, in the echelon form. At first, the same method is used to extract the knowledge of two coupled dipole antennas both in the parallel form and in the collinear form. Then using a new concept, which is called spatial membership functions [5], knowledge of two coupled dipole antennas in the echelon form is extracted based on the knowledge of two coupled dipole antennas both in the parallel form and in the collinear form. Behavior of two coupled antennas is then well approximated to the behavior of the isolated dipole antenna. Finally, we show that our modeling results are in a very excellent agreement with MoM, in addition, the execution time is vanishingly reduced.

2. A fuzzy model for two coupled dipole antennas in the parallel form

In this section, an array of two coupled dipole antennas in the parallel form with a=2.7mm (dipole radius) is considered as shown in figure.1.

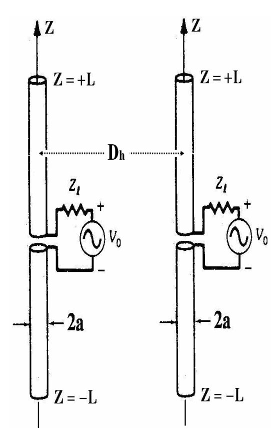

Figure 1. Two coupled dipole antennas in the parallel form

With the use of the introduced method in [3], the resulted membership functions for several samples,

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which model moving circles and partial phase, have been shown in figure.2.

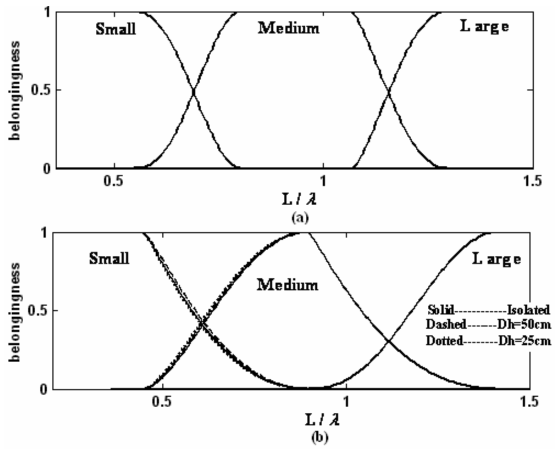

Figure 2. Membership functions of two dipole antennas in the parallel form and isolated dipole antenna (a): moving circles (b): partial phase

As it is seen in figure.2, the membership functions from the modeling moving circles have not been changed at all and only slight changes in membership functions for the partial phase are seen. It means that we could use the membership functions of the isolated dipole antenna. In this manner, the only parameters which change from one to another by changing spacing are the initial point values that can be supposed as a knowledge base and can be extracted simply through applying the proposed algorithm in [3]. The knowledge base for the first circle and line has been shown in figure.3. Note that all quantities in figure.3 have been normalized to these quantities for the isolated dipole antenna.

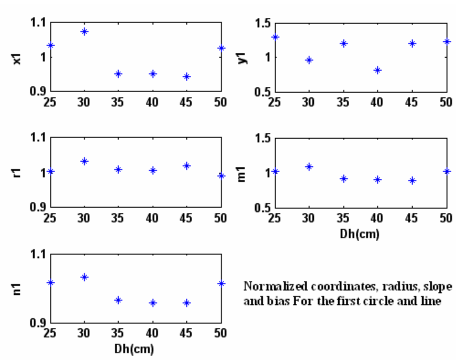

Figure 3. Extracted knowledge of two coupled Dipole antennas in the parallel form for the first circle and line

Now, we can read the inputs of our fuzzy system, circles and lines, through the figure.3 and then using the membership functions of the isolated dipole antenna, the input impedance for each coupled dipole is generated. For instance, a sample with $D_h = 27\text{cm}$ is run. The predicted input impedance has been shown in figure.4. As shown in figure.4, an excellent agreement with a vanishingly short time is achieved.

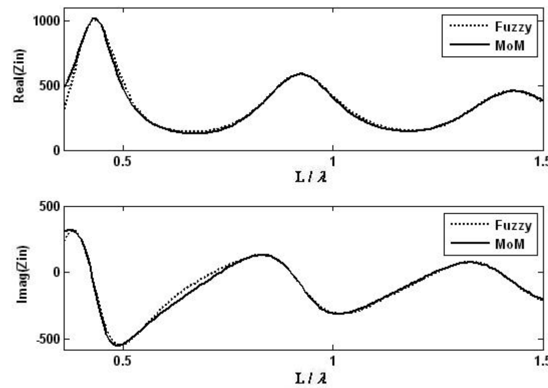

Figure 4. Predicted input impedance of two coupled dipole antennas with Dh=27cm

3. A fuzzy model for two coupled dipole antennas in the parallel form

In this section we model an array of two coupled dipole antennas, the same as the previous section but in the collinear form as shown in figure.5.

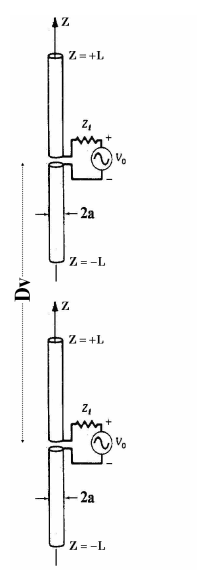

Figure 5. Two coupled dipole antennas in the collinear form

The resulted membership functions of two coupled dipole antennas in the collinear form have been shown in figure.5, 6.

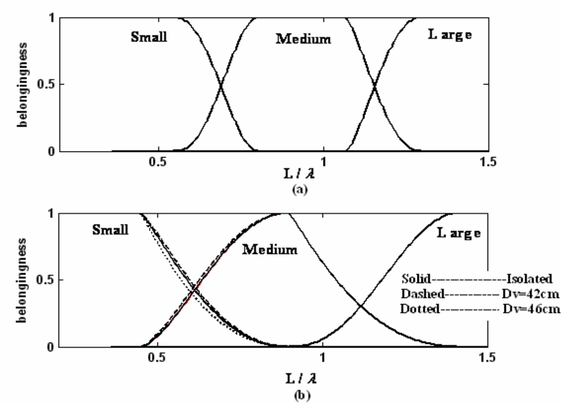

Figure 6. Membership functions of two dipole antennas in the collinear form and isolated dipole antenna for (a): moving circles (b): partial phase

As it is seen in figure.6, the same as the previous section, the membership functions are approximated to the membership functions of the isolated dipole antenna as an approximation once more. Now, we can extract the related knowledge through the proposed method in [3] for each sample. In this case, the extracted knowledge for the first circle and line has been shown in figure.7.

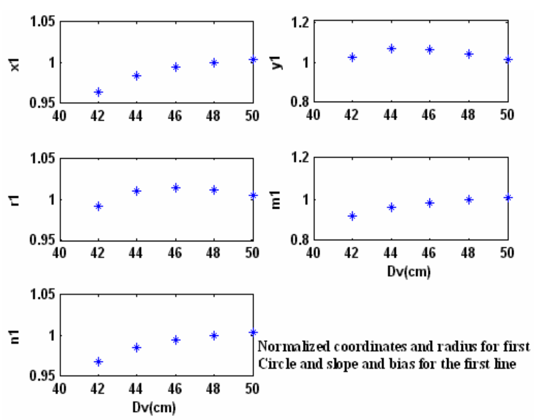

Figure.7. Extracted knowledge for two coupled Dipole antennas in the collinear form for the first circle and line

Now, we can read inputs of our fuzzy system (circles and lines in the figure.7), and then using the membership functions of the isolated dipole antenna, the input impedance is easily extracted. For instance, a sample with Dv=45cm is run. As shown in figure.8, a close agreement is achieved and the execution time is vanishingly short.

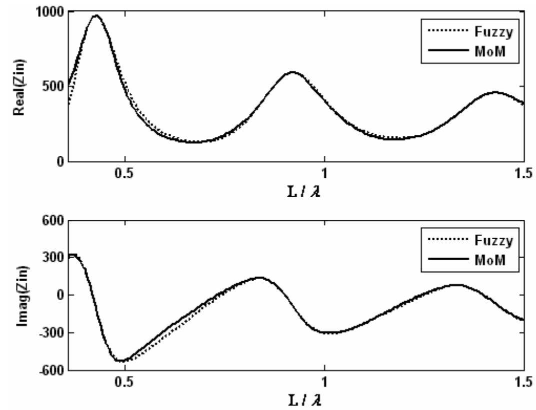

Figure 8. Predicted input impedance of two coupled dipole antennas in the collinear form with Dv=45cm

4. Extracting knowledge of two coupled dipole antennas in the echelon form

In two previous sections, we modeled two coupled dipole antennas both in the parallel form and in the collinear form, and then we obtained their knowledge bases separately. In this section, we consider two coupled dipole antennas in the echelon form as shown in figure.9.

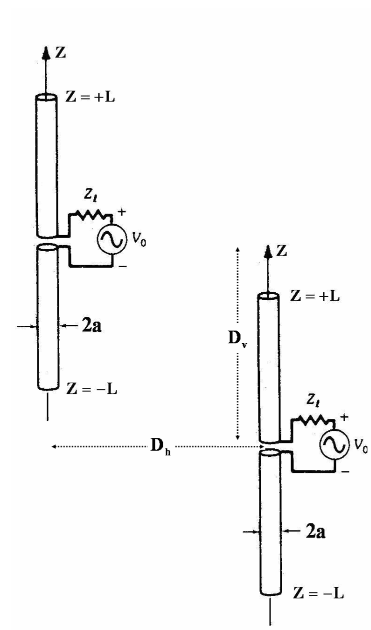

Figure 9. Two coupled dipole antennas in the echelon form

In the previous sections, two sets of membership functions from modeling moving circles and partial phase were found, which saved the array behavior. As we know, two coupled dipole antennas can be converted to two particular cases: two coupled dipole antennas in the parallel form when Dv=0 and two coupled dipole antennas in the collinear form when Dh=0. Therefore, we have two SIMO (Single-Input-Multi-Output) systems: the first: two coupled dipole antennas in the parallel form, the second: two coupled dipole antennas in the collinear form. Now, we can combine these two SIMO systems using the definition of the spatial membership functions proposed for the first time by S. B. Shouraki in [5] for combining two separate SIMO systems. The functions used here are the same as those defined before in [4], but in the spatial form as follows:

$$\alpha_i(D_h, D_v) = \begin{cases} \frac{1}{2}(1-\cos\pi\left(\frac{\psi-\varphi_1}{\varphi_2-\varphi_1}\right)^{\beta_1}) & \text{for } \varphi_1 \to \varphi_2 \\ \frac{1}{2}(1+\cos\pi\left(\frac{\psi-\varphi_1}{\varphi_2-\varphi_1}\right)^{\beta_2}) & \text{for } \varphi_2 \to \varphi_1 \end{cases} \quad (1)$$

Where

$$\psi = \tan^{-1}\left(\frac{D_h}{D_v}\right), \ \beta_1, \beta_2 = \text{optimizing parameters}$$

The spatial membership functions, which are here used, have been shown in figure.10. For our application, we use only one fuzzy set for each variable having the belongingness value of one at its individual axis and are decreasing smoothly to zero at the other one. Now, using the following equations, we can infer the knowledge base for the two coupled dipole antennas in the echelon form as eqs.2:

$$x_i(D_h, D_v) = \frac{x_i(D_h)\alpha_1(D_h, D_v) + x_i(D_v)\alpha_2(D_h, D_v)}{\alpha_1(D_h, D_v) + \alpha_2(D_h, D_v)} \quad (2a)$$

$$y_i(D_h, D_v) = \frac{y_i(D_h)\alpha_1(D_h, D_v) + y_i(D_v)\alpha_2(D_h, D_v)}{\alpha_1(D_h, D_v) + \alpha_2(D_h, D_v)} \quad (2b)$$

$$r_i(D_h, D_v) = \frac{r_i(D_h)\alpha_1(D_h, D_v) + r_i(D_v)\alpha_2(D_h, D_v)}{\alpha_1(D_h, D_v) + \alpha_2(D_h, D_v)} \quad (2c)$$

$$m_i(D_h, D_v) = \frac{m_i(D_h)\alpha_1(D_h, D_v) + m_i(D_v)\alpha_2(D_h, D_v)}{\alpha_1(D_h, D_v) + \alpha_2(D_h, D_v)} \quad (2d)$$

$$n_i(D_h, D_v) = \frac{n_i(D_h)\alpha_1(D_h, D_v) + n_i(D_v)\alpha_2(D_h, D_v)}{\alpha_1(D_h, D_v) + \alpha_2(D_h, D_v)} \quad (2e)$$

Where $\alpha_i(D_h, D_v), i = 1,2$ is spatial membership functions, and $x_j(D_i), y_j(D_i), r_j(D_i), m_j(D_i), n_j(D_i)$ $i = h, v,\ \ j = 1,2,3$ is knowledge of two SIMO systems. Finally $x_i(D_h, D_v), y_i(D_h, D_v), r_i(D_h, D_v)$ are the inferred coordinates and radii of circles respectively and similarly $m_i(D_h, D_v), n_i(D_h, D_v)$ are for inferred lines. Now, using the inferred knowledge and the membership functions of the isolated dipole antenna, the input impedance for each dipole antenna is generated. Our fuzzy system is run for a sample with Dh=27cm, Dv=45cm. As shown in figure. 11, a highly excellent agreement is achieved in addition, the execution time is considerably reduced.

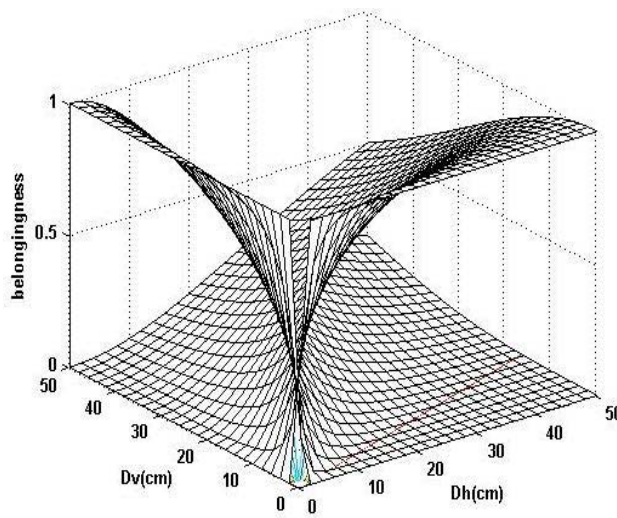

Figure 10. Spatial membership functions for combining two independent variables

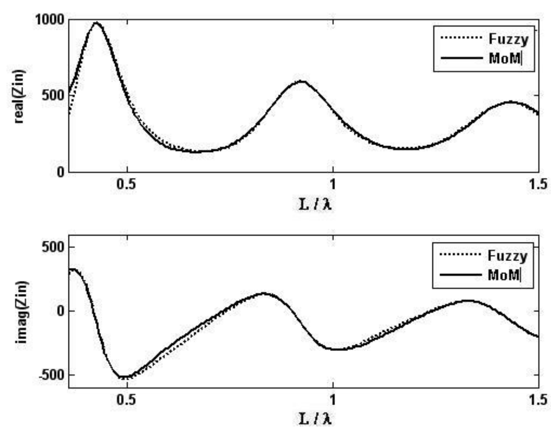

Figure.11. Extracted input impedance for two coupled dipole antennas in the echelon form with Dh=27cm, Dv=45cm

5. Conclusion

In this paper, we have generalized the introduced method in [3] to predict input impedance of two coupled dipole antennas in the echelon form. The knowledge base was extracted using the knowledge of two coupled dipole antennas in the parallel form and in the collinear form and a new concept, which is called spatial membership functions. The array behavior was then approximated to the behavior of the isolated dipole antenna. Therefore, using the obtained spatial knowledge, and membership functions of the isolated dipole antenna, the input impedance for the new structure is generated. Comparing our modeling results with the accurate results (MoM) shows a highly excellent agreement with vanishingly short execution time. This paper is the first step toward modeling the planar array of dipole antennas that is underway.

6. Acknowledgment

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7. References

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