Evaluation of the Travelling Wave Dipole Antenna Parameters Using an Adaptive Neuro-Fuzzy System

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Abstract (1/2)

- This work presents an alternative method, based on artificial techniques, to manipulate the travelling wave dipole antenna radiation, using data extracted from their analytical solution.

- The Adaptive Network Fuzzy Inference System (ANFIS) has been used, as a basis for constructing a set of fuzzy rules with appropriate membership functions in order to obtain the theoretical data.

Abstract (2/2)

Basic references

[1] T. N. Kapetanakis, I. O. Vardiambasis, G. S. Liodakis, and A. Maras "Solving the Inverse Loop Antenna Radiation Problem Using a Hybrid Neuro-Fuzzy System," *20th Telecommunications Forum (TELFOR 2012),* pp. 1193-1196, Belgrade, Serbia, 20-22 Nov 2012.

[3] J.-S.R. Jang, "ANFIS: adaptive-network-based fuzzy inference systems", *IEEE Trans Systems, Man Cybernetics,* vol. 23, no. 3, pp. 665-685, May 1993.

[5] C.A. Balanis, *Antenna Theory, Analysis and Design*, 3rd ed., New York: Wiley, 2005

ANFIS (1/5)

- The ANFIS, originally proposed in [3], has emerged as the combination of two powerful intelligent techniques: a) the artificial neural networks and b) the fuzzy logic approach, which have been adopted and tested to solve many real-world problems in recent years.

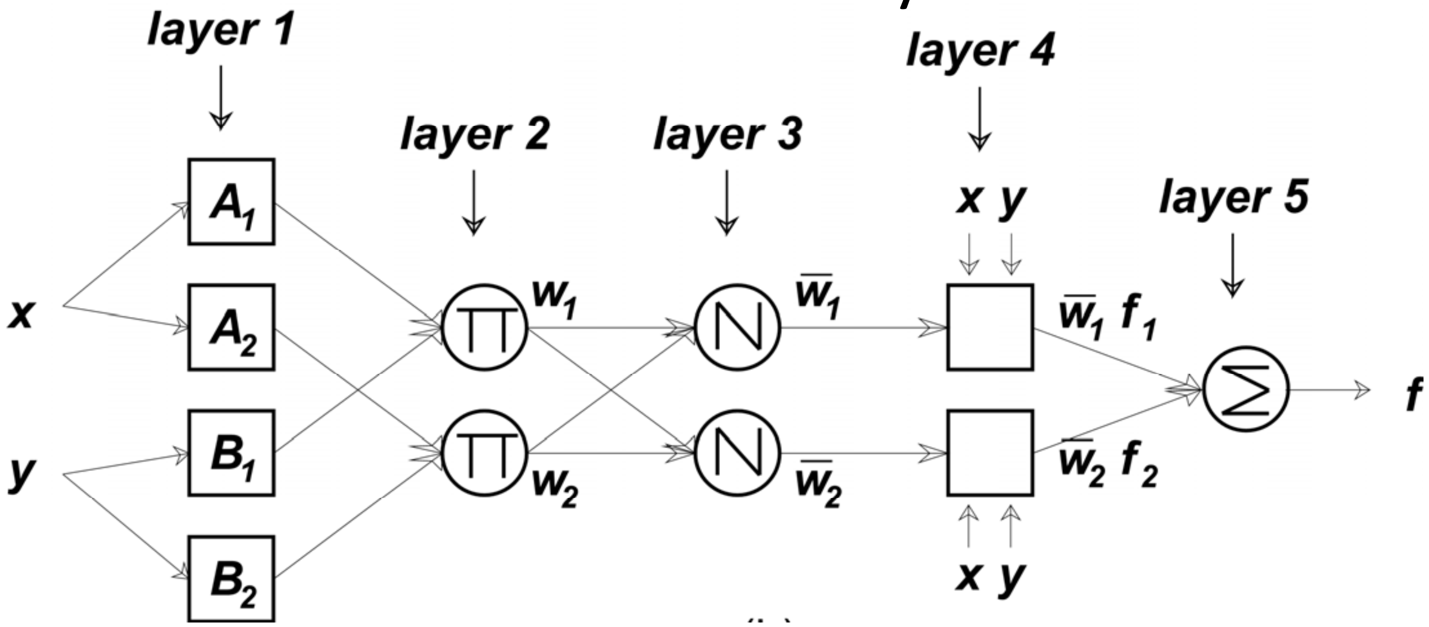
- This combination of fuzzy logic and neural networks into adaptive network architecture is the main fact making ANFIS so attractive in our investigation.

ANFIS (2/5)

- Specifically, ANFIS integrates the greater learning capability of neural networks with a fuzzy logic approach to construct a fuzzy inference system, with membership function (MF) parameters, which are tuned using a back-propagation algorithm either alone or in combination with a least squares method.

ANFIS (3/5)

- The architecture of the ANFIS network is shown above. It is structured in five layers.



$$\text{Rule 1: If } x \text{ is } A_1 \text{ and } y \text{ is } B_1, \text{ then } f_1 = p_1 x + q_1 y + r_1,$$

$$\text{Rule 2: If } x \text{ is } A_2 \text{ and } y \text{ is } B_2, \text{ then } f_2 = p_2 x + q_2 y + r_2$$

ANFIS (4/5)

- **Layer 1:** Every node i in this layer is an adaptive node with a node function. Can be any appropriate parameterized membership function, such as the generalized bell function, the Gaussian function, or the sigmoid function.

$$O_{1,i} = \mu_{A_i}(x) \quad \text{for i=1,2} \qquad O_{1,i} = \mu_{B_{i-2}}(y) \quad \text{for i=3,4}$$

- **Layer 2:** Every node in this layer is a fixed node labeled Π, whose output is the product of all the incoming signals representing the firing strength of a rule, or in other words performing the fuzzy AND function.

$$O_{1,i} = w_i = \mu_{A_i}(x) \cdot \mu_{B_i}(y) i = 1,2$$

ANFIS (5/5)

- **Layer 3:** Every node in this layer is a fixed node labeled N. The node i calculates the ratio of the i[th] rule's strength to the sum of all rules' firing strengths. The output of this layer is called normalized fire strength.

$$O_{3,i} = \overline{w}_i = w_i / (w_1 + w_2) \quad i = 1,2$$

- **Layer 4:** Every node i in this layer is an adaptive node with node function:

$$O_{4,i} = \overline{w}_i f_i = \overline{w}_i \left(p_1 x + q_1 y + r_1 \right)$$

where $\overline{W_i}$ is a normalized strength from layer 3 and (p_i, q_i, r_i) is the parameter set of this node. Parameters in this layer are referred to as consequent parameters

- **Layer 5:** The single node in this layer is a fixed node, which computes the overall output as the summation of all incoming signals.

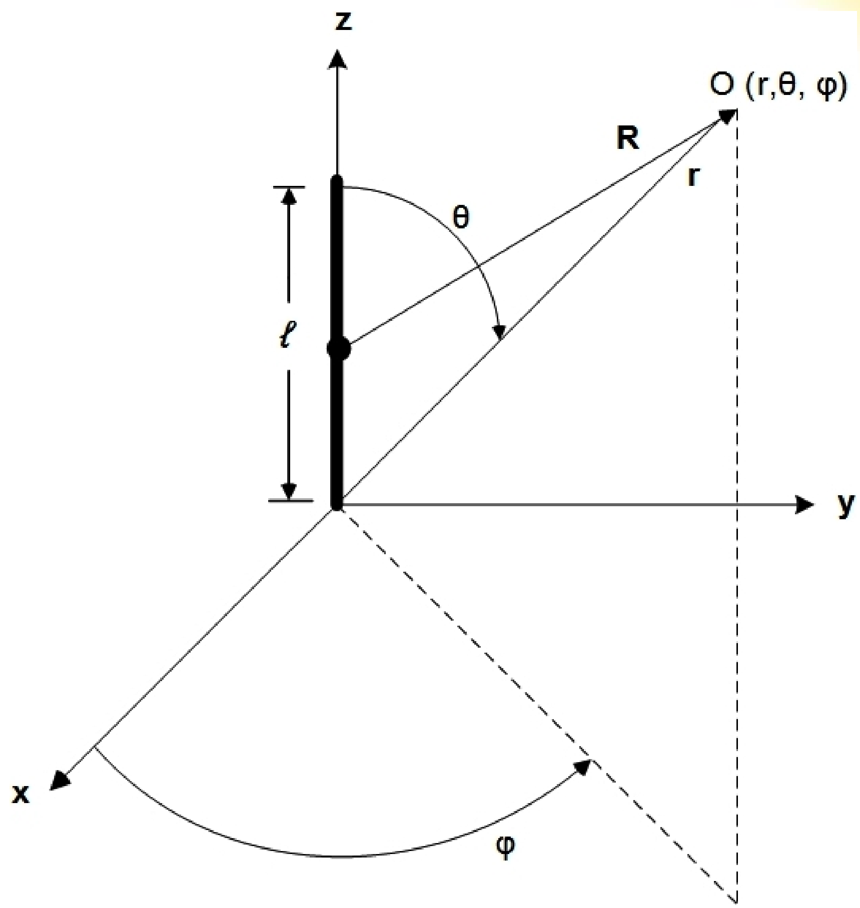
$$\text{Overall Output} = O_{5,i} = \sum_i \overline{w}_i f_i = \left(\sum_i w_i f_i \right) \Big/ \sum_i w_i$$

Electromagnetic Problem Formulation (1/3)

- The problem consists of a long wire of length ℓ directed along the z-axis.
- The current distribution is

$$\mathbf{I} = \hat{a}_z I_0 e^{-jk_z z'}$$

where k_z the phase constant of the wave along the wire.



Travelling wave dipole geometry

Electromagnetic Problem Formulation (2/3)

The radiation resistance can be obtained after some extensive mathematical manipulations from:

$$R_r = \frac{2P_{rad}}{|I_0|^2} = \frac{n}{2\pi}\left[1.415 + \ln\left(\frac{k\ell}{\pi}\right) - C_i\left(2k\ell\right) + \frac{\sin\left(2k\ell\right)}{2k\ell}\right]$$

Where P_{rad} the total radiated power, I_0 the current amplitude, C_i (x) the cosine integral, n the intrinsic impedance, k the wave number and ℓ the length of the antenna [4].

Electromagnetic Problem Formulation (3/3)

The parameter which defines the directional properties of the antenna is the directivity and mathematically defined by the equations:

$$D(\theta) = \frac{4\pi U(\theta)}{P_{rad}} = \frac{2 \cdot \sin^2\left(kL\sin^2(\theta/2)\right) \cdot \cos^2(\theta/2)}{\cos^2(\theta/2) \cdot \left[1.415 + \ln\left(\frac{2l}{\lambda}\right) - Ci(2kl) + \frac{\sin(2kl)}{2kl}\right]}$$

$$C_i(x) = -\int_x^{\infty} \frac{\cos(\tau)}{\tau} d\tau = \int_{\infty}^{x} \frac{\cos(\tau)}{\tau} d\tau$$

Where P_{rad} the total radiated power, I_0 the current amplitude, $C_i(x)$ the cosine integral, k the wave number and ℓ the length of the antenna [4]

ANFIS model (1/2)

- In this work, two neuro-fuzzy models are designed in order to estimate the travelling wave antenna radiation parameters.
- Using the first model, radiation resistance Rr is obtained as a function of antenna length ℓ and current amplitude I0 (as input variables).
- The second model, the directivity D_0 is obtained as a function of antenna length ℓ and current amplitude I_0 (as input variables).

ANFIS model (2/2)

- In our model, 600 analytically extracted datasets were used as training (500) and testing (100) data for both models.

- The MFs' types tested include the Gaussian, the sigmoidally, the generalized bell, the Gaussian combination, the s-shaped, the Z-shaped, and the Π-shaped.

- Finally, 5 Gaussian and 8 Gaussian combination MFs were used for the models, respectively.

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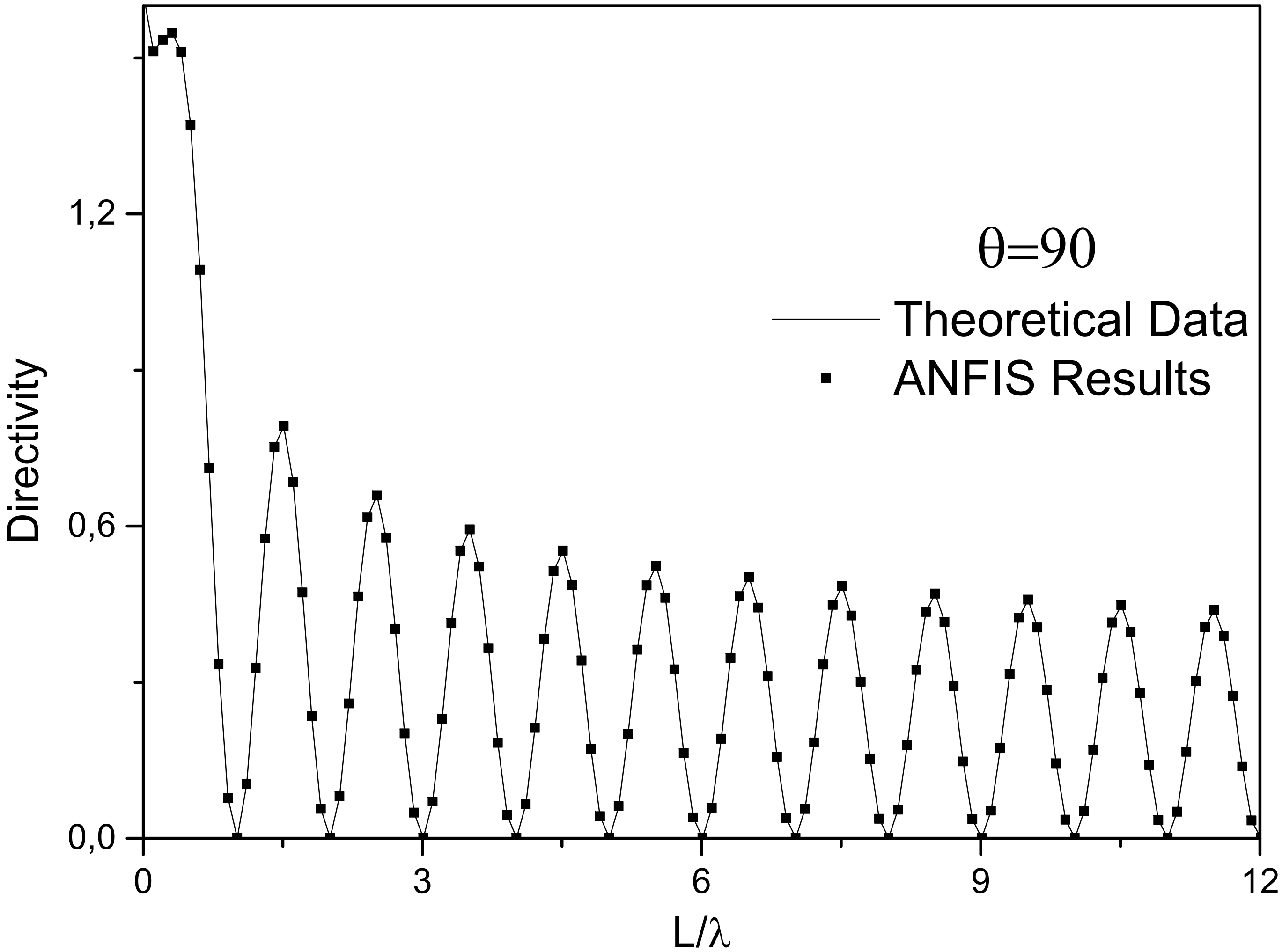
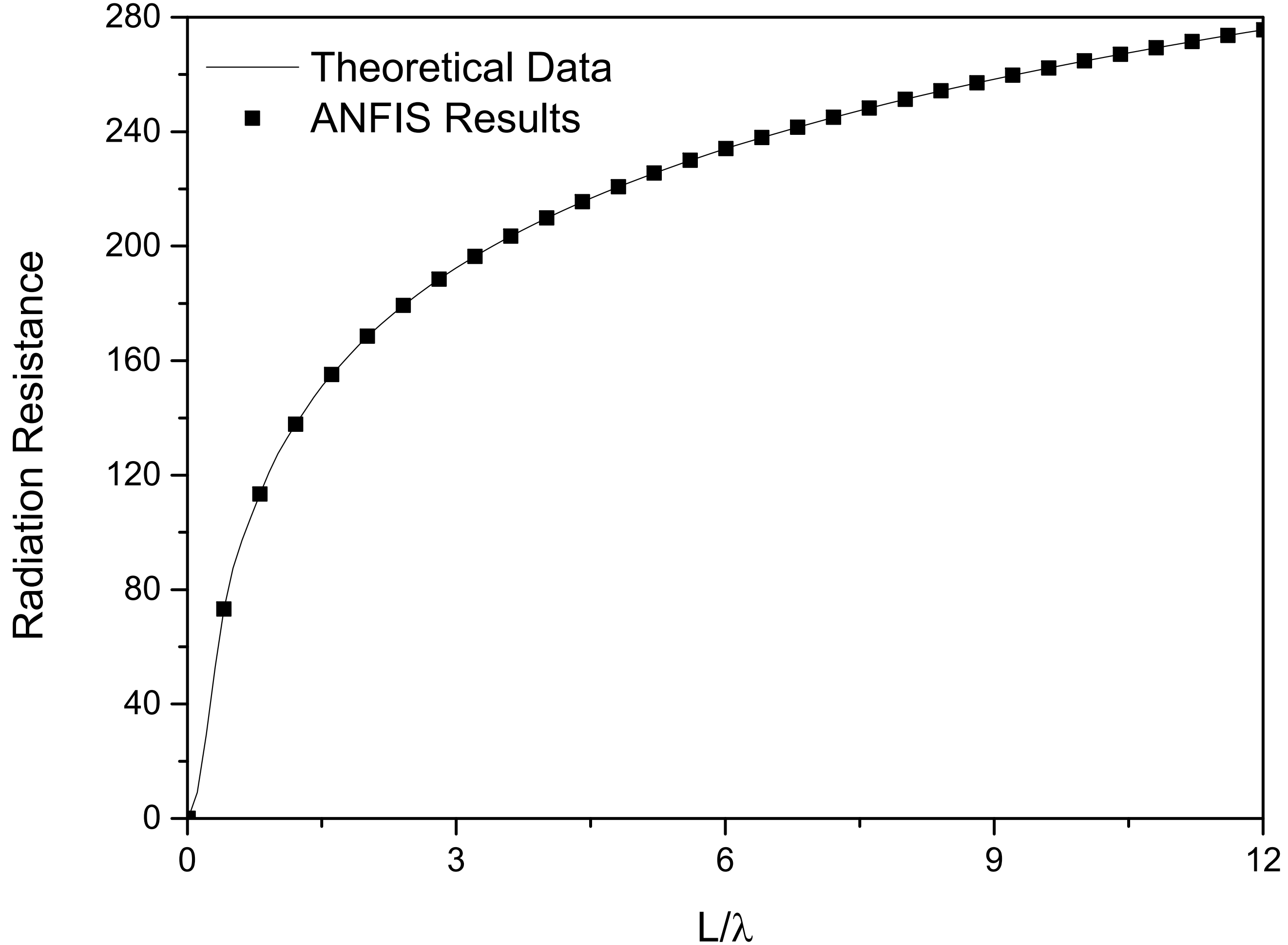
Numerical results (1/4)



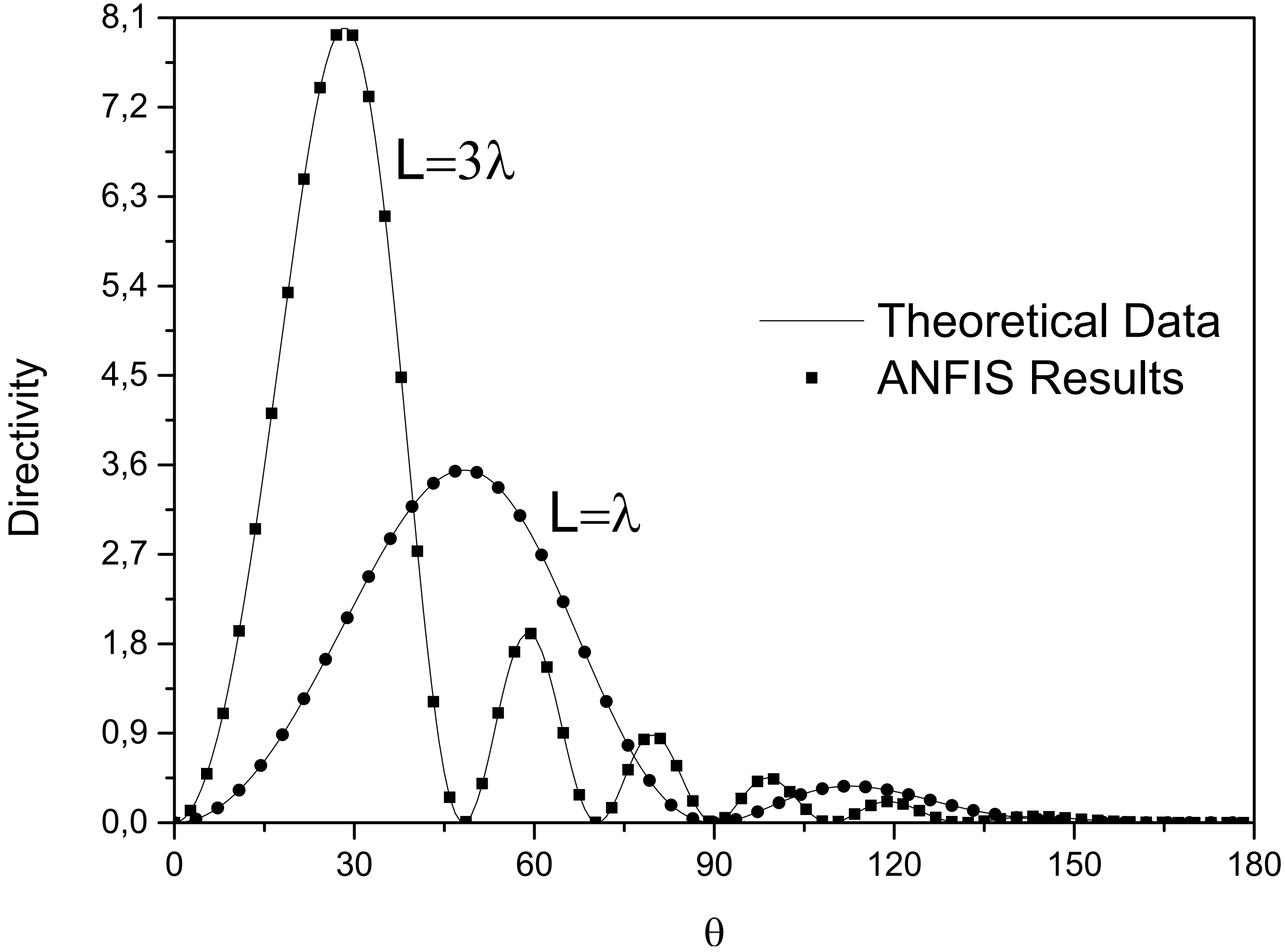
Comparison of directivity D_0 (dimensionless) for a travelling wave dipole for various lengths.

Numerical results (2/4)



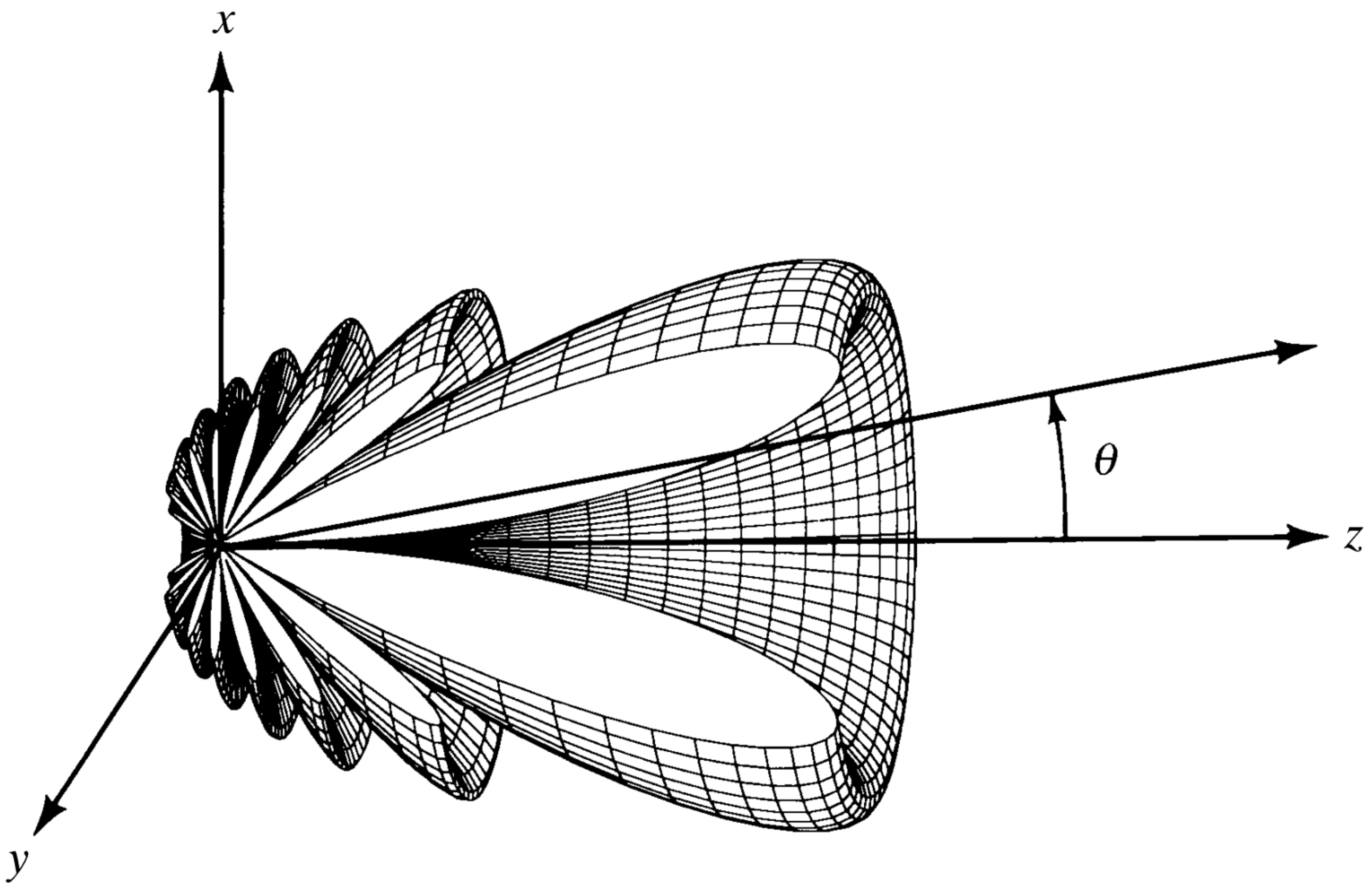
Comparison of radiation resistance R_r for a finite dipole for various lengths.

Numerical results (3/4)



Comparison of directivity D_0 L=3λ and L=λ for various θ.

Numerical results (4/4)



3D pattern of a travelling wave dipole of ℓ=5λ

[C.A. Balanis, *Antenna Theory, Analysis and Design*, 3rd ed., New York: Wiley, 2005]

Conclusion

- In this paper, a neuro fuzzy based generic algorithm are proposed to analyze the radiation parameters of a travelling dipole.
- The results obtained using the proposed algorithm were found matching with those obtained using the analytical solution.
- From the results, it is evident that the proposed algorithm is convenient to implement antenna radiation parameters estimation.

References

[1] T. N. Kapetanakis, I. O. Vardiambasis, G. S. Liodakis, and A. Maras “Solving the Inverse Loop Antenna Radiation Problem Using a Hybrid Neuro-Fuzzy System,” *20th Telecommunications Forum (TELFOR 2012)*, pp. 1193-1196, Belgrade, Serbia, 20-22 Nov 2012.

[2] K. Guney and N. Sarikaya, “A hybrid method based on combining artificial neural network and fuzzy inference system for simultaneous computation of resonant frequencies of rectangular, circular, and triangular microstrip antennas,” *IEEE Trans. Antennas Propag*., vol. AP-55, no. 3, pp. 659–1668, March 2007.

[3] J.-S.R. Jang, “ANFIS: adaptive-network-based fuzzy inference systems”, *IEEE Trans Systems, Man Cybernetics*, vol. 23, no. 3, pp. 665-685, May 1993.

[4] D. Pujara, A. Modi, N. Pisharody, and J. Mehta, “Predicting the Performance of Pyramidal and Corrugated Horn Antennas Using ANFIS”, *IEEE Antennas and Wireless Propag. Letters*, vol. 13, pp. 293–296, 2014

[5] C.A. Balanis, *Antenna Theory, Analysis and Design*, 3rd ed., New York: Wiley, 2005

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YOUR ATTENTION

ANY QUESTIONS ?

NO? GREAT! BYE

Estimation of Linear Wire Antenna Parameters Using Neural Networks

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