Estimation of Linear Wire Antenna Parameters Using Neural Networks

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International Symposium on Ambient Intelligence and Embedded Systems (AmiEs-2016)
22 - 24 September, 2016 Heraklion, Crete, Greece

Contents

Abstract (1/2)

We present an Artificial Neural Network (ANN) model for predicting the radiation parameters of a linear dipole antenna.

The proposed model can be used as an alternate approach to linear dipole antenna radiation problem using ANNs, avoiding either the associated lengthy and time-demanding analytical methods or and the 3D full wave software.

The ANN array model can predict in less time and with minimum computational resources, the radiation parameters of the above antenna.

Abstract (2/2)

Basic references

[6] T.N. Kapetanakis, I.O. Vardiambasis, G. Liodakis, and A. Maras, “Neural network solution of the circular loop antenna radiation problem,” *20th Telecommunications Forum (TELFOR 2012)*, pp. 1193-1196, Belgrade, Serbia, 20-22 Nov 2012.

[5] T.N. Kapetanakis, I.O. Vardiambasis, G.S. Liodakis, M.P. Ioannidou, and A.M. Maras, “Smart antenna design using neural networks,” *8th International Conference New Horizons in Industry, Business and Education (NHIBE 2013),* pp. 130-135, Crete, Greece, 29-30 Aug 2013.

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

Artificial Neural Networks (1/3)

ANNs are inspired from the capability of the human brain to perform certain computations.

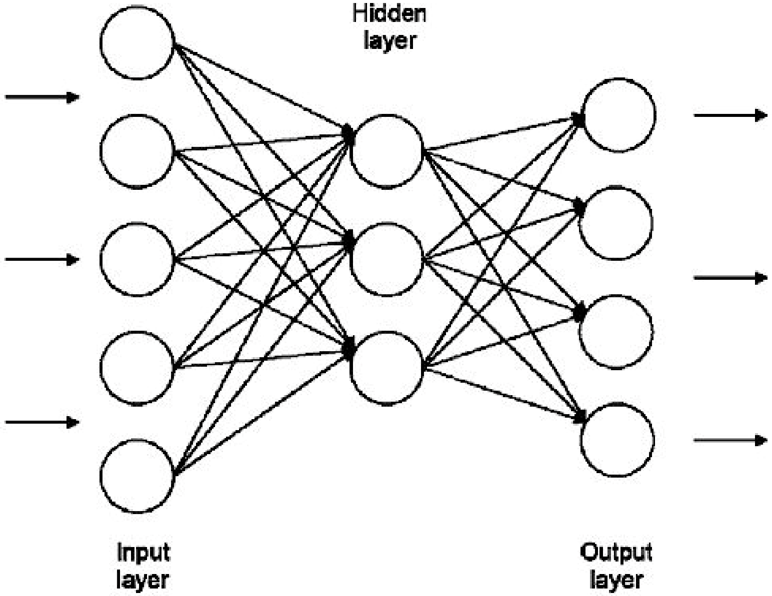
They are computational networks attempting to simulate the complex functions of the nerve cells (neurons) of the biological central nervous system.

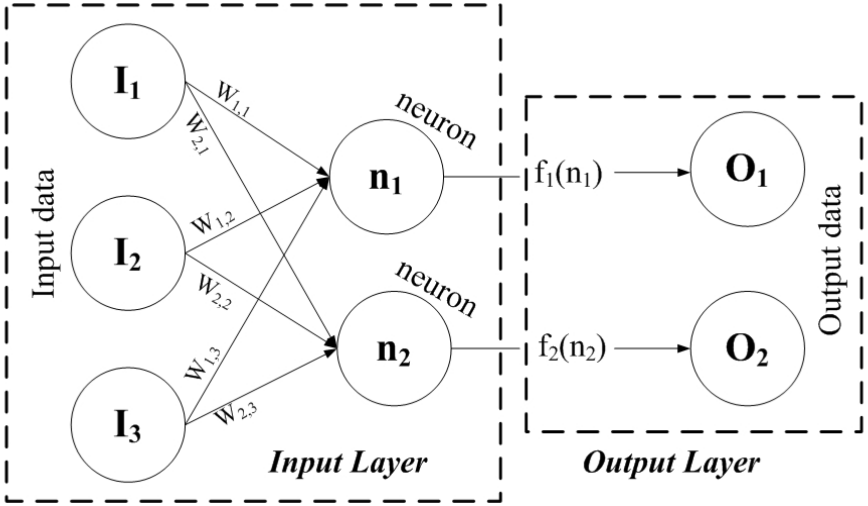
Thus, a feed forward multilayered network can be considered as a universal approximator [1]-[3].

Backpropagation ANNs are widely used for various complex electromagnetic problems, such as the design and analysis of waveguides, transmission lines, antennas, etc [1]-[3], [5]-[6].

Artificial Neural Networks (2/3)

Typical neural network architecture





A typical neural network architecture has three layers:

1) the input layer,

2) the hidden layer and

3) the output layer.

Artificial Neural Networks (3/3)

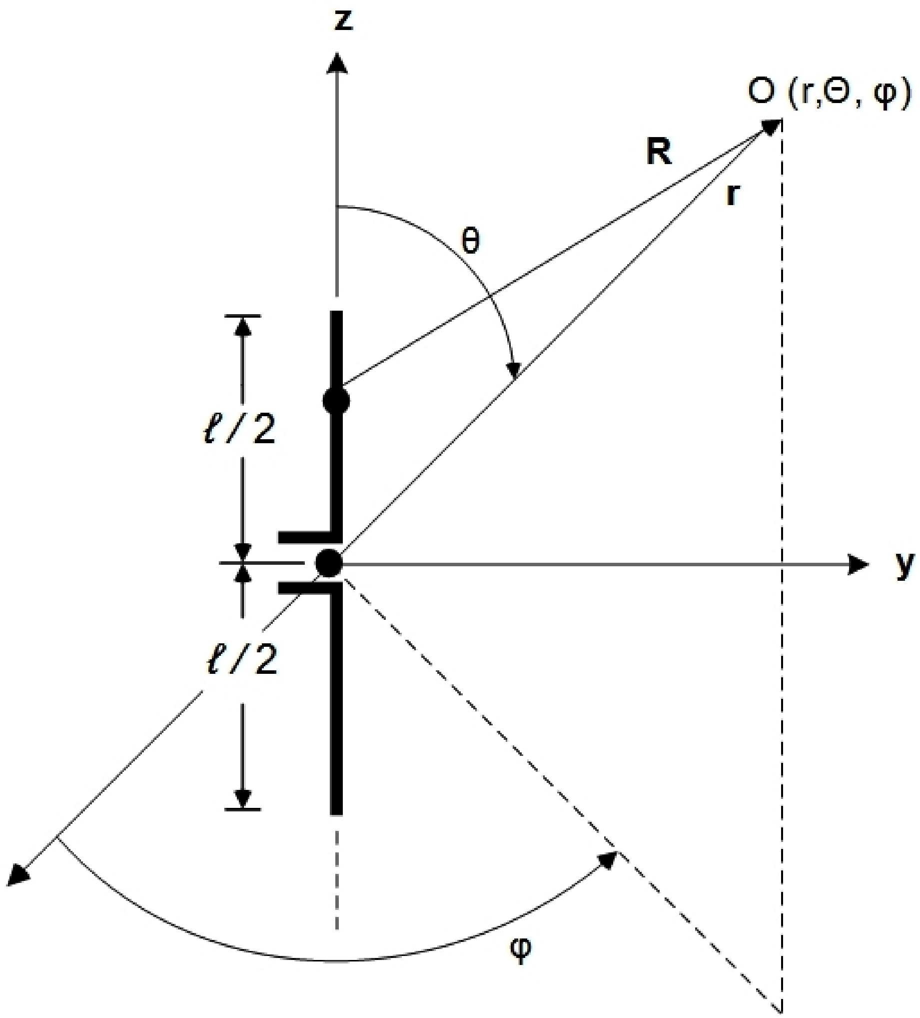
General workflow for any electromagnetic problem

The workflow for any electromagnetic problem under consideration, involves the following step-by-step procedures:

1) Definition of the number of inputs and outputs,
2) Collection of the data required to train, validate, and test the network,
3) Separation of the data to train, validate and test sets,
4) Decision for the suitable ANN type,
5) Configuration of the ANN parameters (number of hidden layers, neurons, epochs, and transfer functions type),
6) Initialization of weights and biases,
7) Training of the ANN,
8) Validation of the ANN,
9) Optimization of the ANN, and
10) Use of the ANN.

Electromagnetic Problem Formulation (1/3)

- The problem consists of a thin dipole of finite length ℓ symmetrically positioned about the origin with its length directed along the z-axis.
- In order to reduce the complexity we assume that the dipole has smaller diameter than the operating wavelength. The antenna is center-fed and the current vanishes at the end points [4].



Finite dipole geometry

Electromagnetic Problem Formulation (2/3)

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

$$
\begin{aligned}
R_r &= \frac{2P_{rad}}{\left|I_0\right|^2} = \frac{n}{2\pi}\left\{C + \ln(k\ell) - C_i(k\ell)\right. \\
&\quad + \frac{1}{2}\sin(k\ell)\times\left[S_i(2k\ell) - 2S_i(2k\ell)\right] \\
&\quad \left. + \frac{1}{2}\cos(k\ell)\times\left[C + \ln\left(k\ell/2\right) + C_i(2k\ell)\right] - 2C_i(k\ell)\right\}
\end{aligned}
$$

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

Electromagnetic Problem Formulation (3/3)

The radiation pattern of a dipole becomes more directional as the length increases. The parameter which defines the directional properties of the antenna is the directivity and mathematically defined by the equations:

$$D_0 = 4\pi \frac{F(\theta,\varphi)\big|_{max}}{\int_0^{2\pi}\int_0^{2\pi} F(\theta,\varphi)\sin\theta\, d\theta\, d\varphi} = \frac{2F(\theta,\varphi)\big|_{max}}{Q}$$

$$Q = \left\{C + \ln(k\ell) - C_i(k\ell) + \frac{1}{2}\sin(k\ell)\left[S_i(k\ell) - 2S_i(k\ell)\right] + \frac{1}{2}\cos(k\ell)\left[C + \ln\left(k\ell/2\right) + C_i(2k\ell) - 2C_i(k\ell)\right]\right\}$$

$$C_i(x) = \int_\infty^x \frac{\cos(y)}{y}dy \qquad S_i(x) = \int_0^x \frac{\sin(y)}{y}dy$$

$C_i(x)$: the cosine integral,

$S_i(x)$: the sine integral,

k: the wave number and

ℓ: the length of the antenna

ANN array model (1/2)

- The inputs of the ANN were the antenna lenth ℓ and the current maximum I_0. On the other hand the outputs were the antenna radiation resistance Rr and the directivity D_0.

- A feed forward backpropagation ANNs using two hidden layers were trained for the dipole antenna parameters extraction.

- The first hidden layer has 65 and the second hidden layer has 40 neurons.

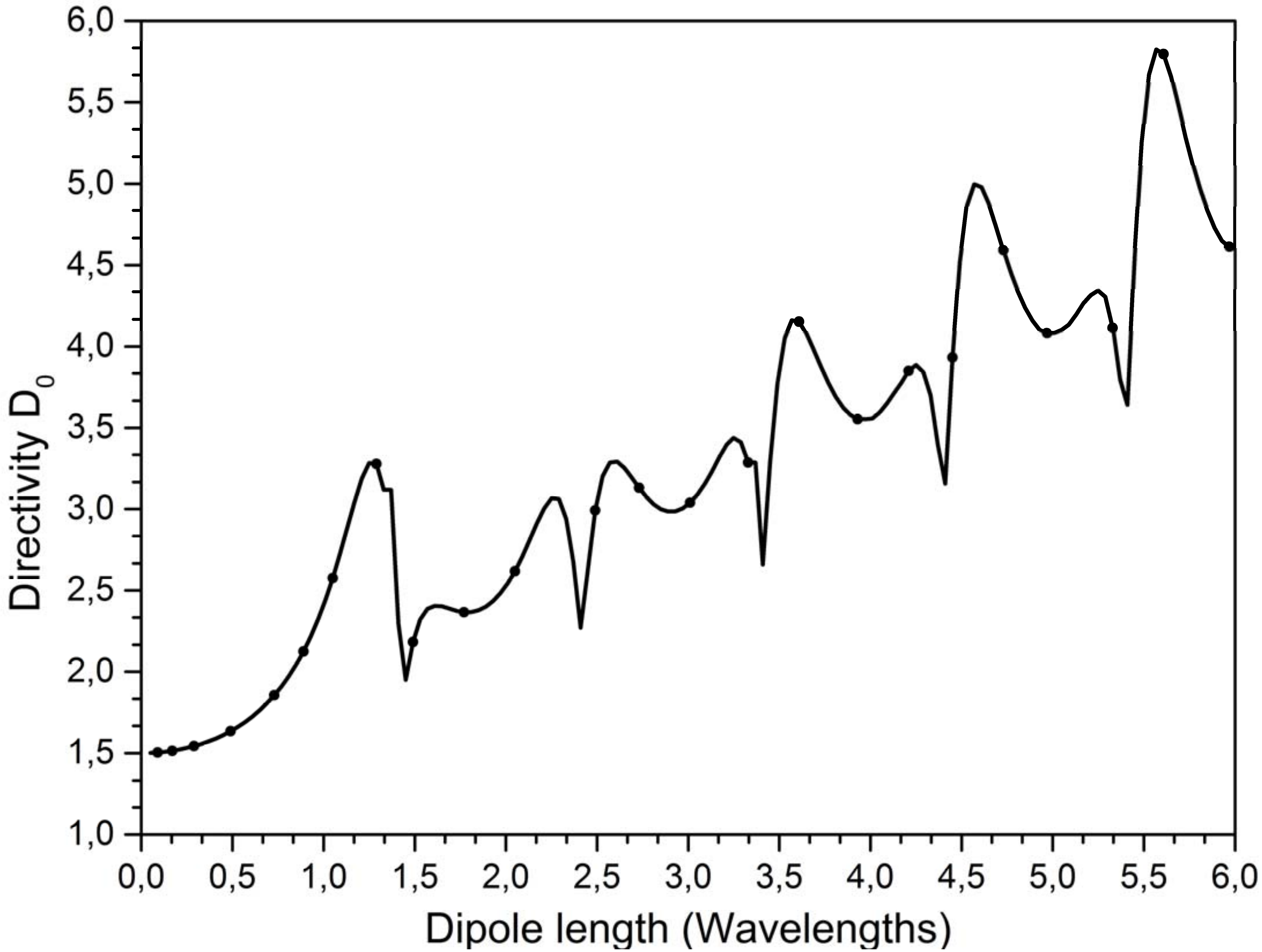
ANN model (2/2)

- The “sigmoid” transfer function is chosen for both the hidden layers and the Levenberg-Marquardt training algorithm.

- Were obtained 800 data sets using the above mathematical analysis. The training data set has 600 samples, the validation data set has 100 samples and the testing data set has 100 samples.

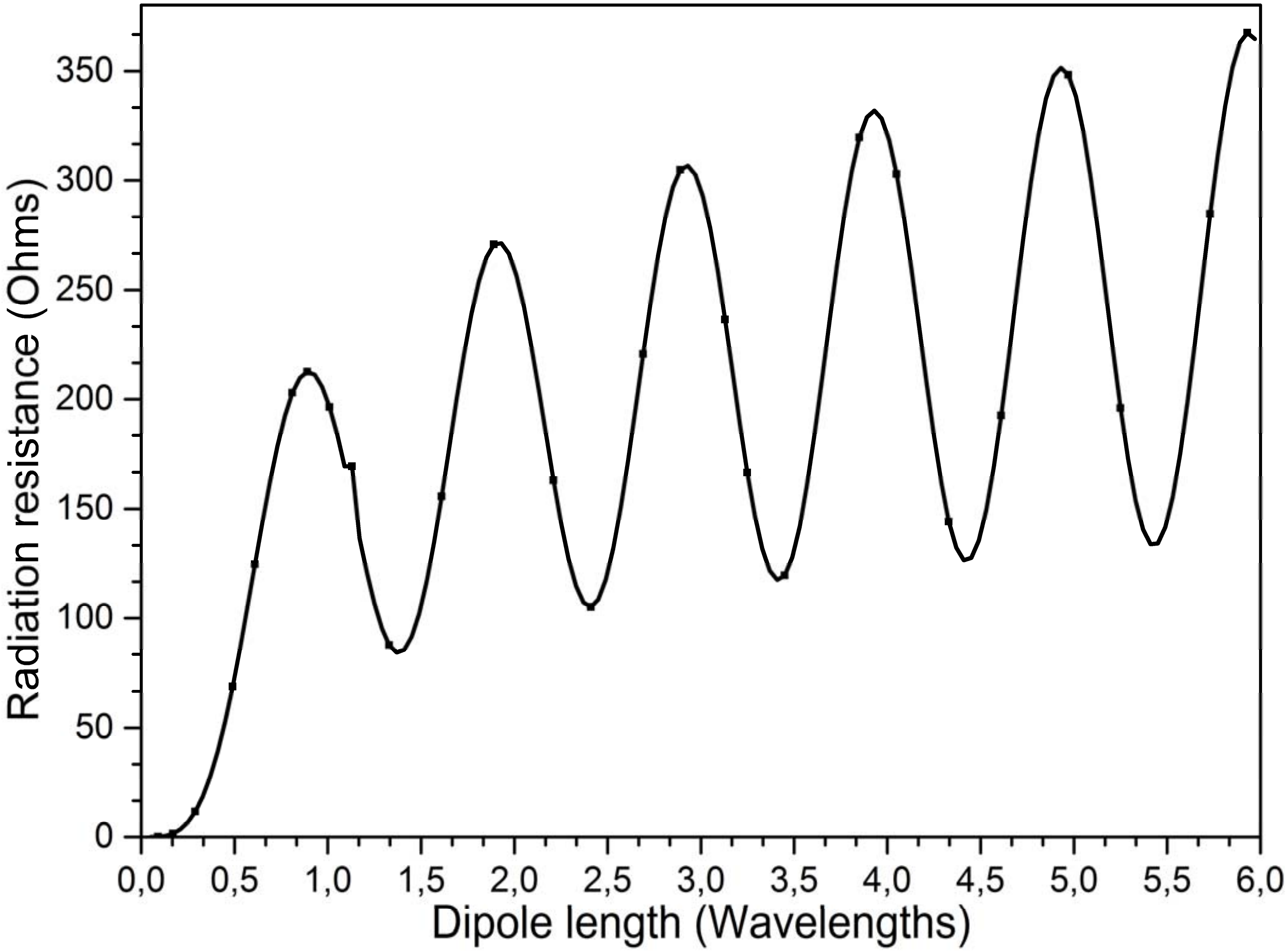
- The ANN is validated by comparing their results to the analytical results and ensuring an error below 7%.

Numerical results (1/4)



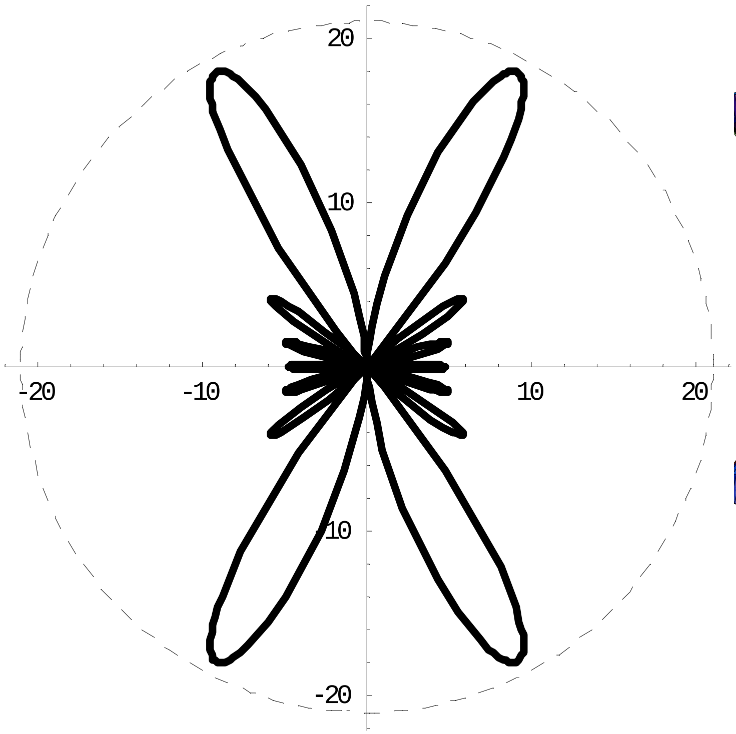
Comparison of directivity D_0 (dimensionless) for a finite dipole for various lengths.

Numerical results (2/4)

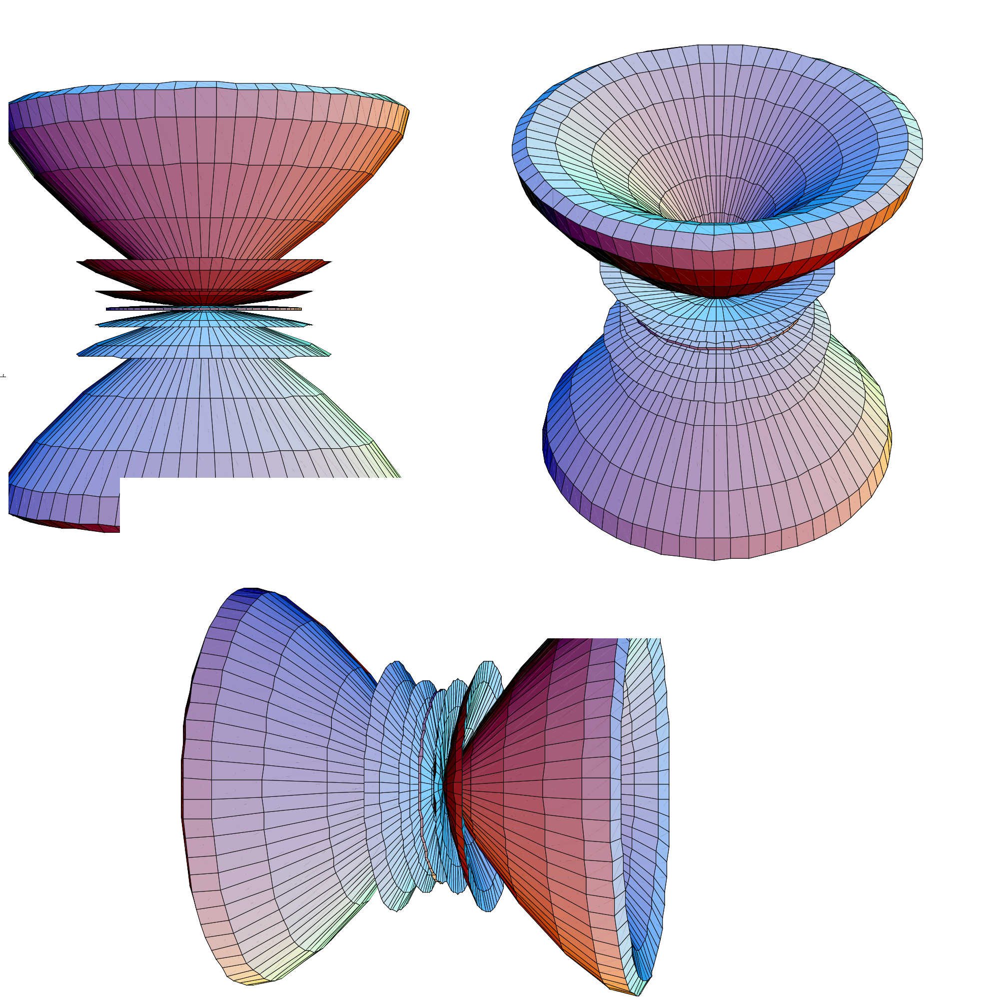


Comparison of radiation resistance R_r for a finite dipole for various lengths.

Numerical results (3/4)

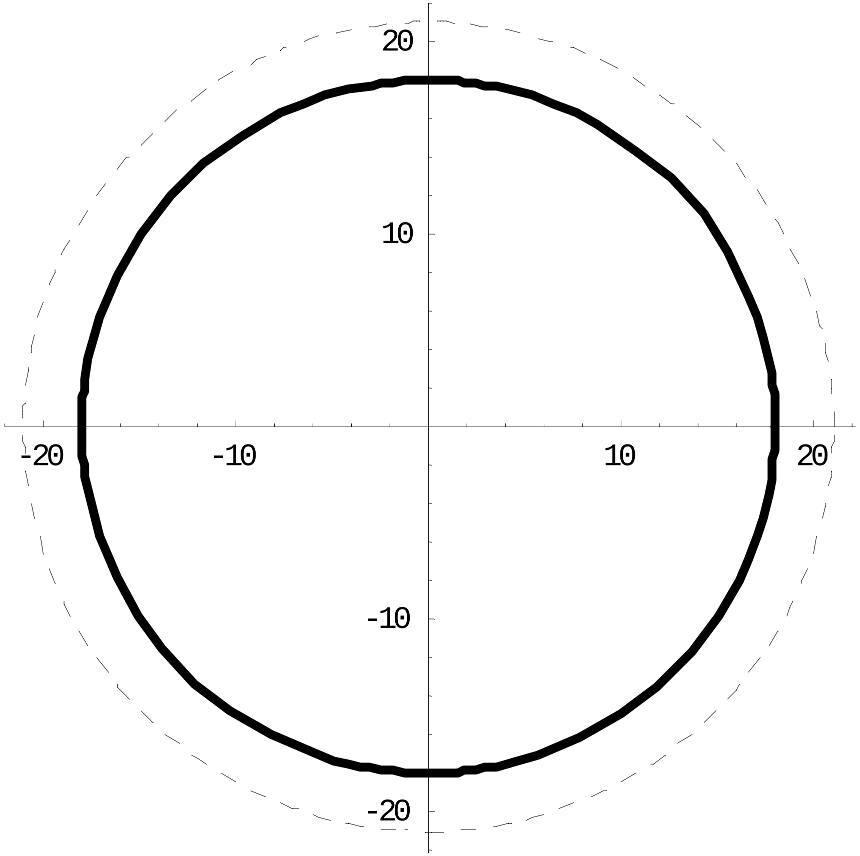


(a)

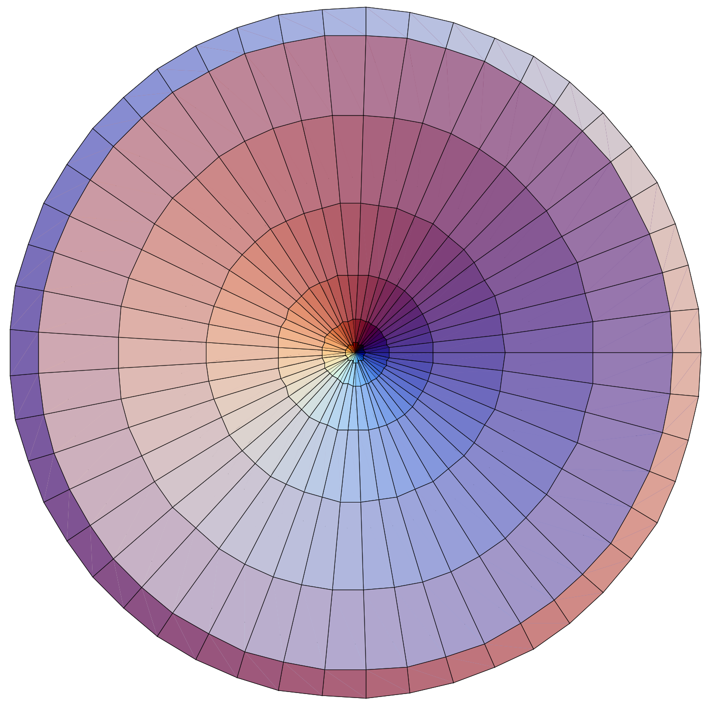


2D and 3D radiation patterns for a thin d … along z-axis in free space. (a) Elevation plane (θ) pattern for ϕ=0 and (b) the corresponding 3D pattern.

Numerical results (4/4)



(a)



(b)

2D and 3D radiation patterns for a thin dipole of length L=3.5λ, placed along z-axis in free space. (a) Horizontal plane (ϕ) pattern for θ=π/8 and (b) the corresponding 3D pattern.

Conclusion

- In this paper, ANN based generic algorithm are proposed to analyze the radiation parameters of a thin dipole of finite length.
- The results obtained using the proposed algorithm were found matching with those obtained using the analytical solution.
- An advantage of neural computation is that, after training, a neural network completely bypasses repeated use of complex iterative processes for new data presented to it.
- From the results, it is evident that the proposed algorithm is convenient to implement antenna radiation parameters estimation.

References

[1] M.A. Arbib, *The Handbook of Brain Theory and Neural Networks*, The MIT Press, 2003.

[2] C. Christodoulou, M. Georgiopoulos, *Applications of Neural Networks in Electromagnetics*, Artech House, 2000.

[3] S. Haykın, *Neural networks: A comprehensive foundation*, Prentice Hall, 1999.

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

[5] T.N. Kapetanakis, I.O. Vardiambasis, G.S. Liodakis, M.P. Ioannidou, and A.M. Maras, “Smart antenna design using neural networks,” *8th International Conference New Horizons in Industry, Business and Education (NHIBE 2013)*, pp. 130-135, Crete, Greece, 29-30 Aug 2013.

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Thank you for your attention

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