International Journal of Scientific Research and Management (IJSRM)
||Volume||10||Issue||04||Pages||EC-2022-862-870||2022||
Website: www.ijsrm.in ISSN (e): 2321-3418
DOI: 10.18535/ijsrm/v10i4.ec09

Dimensioning of Fixed Frequency Patch Antennas Based on Neural Networks

[1]TASONA DOKO Jocelyn Tanguy, [2]MATANGA Jacques, [3] MALONG Yannick,
[4] ESSIBEN DIKOUNDOU Jean-François.

[1] ENSPD, PHD Student,PO Box:2701-Douala, Cameroon.
[2] ImVIA/ICB/E3M, University of BurgundyDijon/France; Universty of Douala/ENSPD/Cameroon, PO Box:2701-Douala, Cameroon.
[3] ENSPD,CC, PO Box:2701-Douala, Cameroon.
[4] ENSPD,MC, PO Box:2701-Douala, Cameroon.

Abstract:
During the last decades the race for innovation in communication systems has not ceased to evolve, which has led to important studies in the field of antennas, which today have very different forms depending on the applications such as: mobile telecommunications, television, radio, satellites, communicating systems, radar, remote sensing, radio astronomy [1]. Among the most used antenna families are the microstrip antennas (also called printed antennas or patch antennas) [2]. These antennas are characterized by: low manufacturing cost, mass production possible, linear and circular polarization, feed and matching networks manufactured simultaneously with the antenna.
The limitations of conventional neural modeling have been overcome by the introduction of neural networks based on electromagnetic knowledge. A neural network using effective parameters in conjunction with the GALERKIN function has been developed for modeling the resonant frequency of a rectangular antenna printed on a substrate [3]. Thus, we set up a rectangular PATCH antenna model on HFSS for a resonant frequency close to 6GHZ and extract the parameters S_{11}, Z_{11}, and VSWR, and also check the training errors on MATLAB by generating the error types on a 4-input model (Thickness, Length, Width and substrate type) and one (1) output (Resonant Frequency) that will allow to extract the final dimensions of the antennas thanks to this neural model.

Keywords: Rectangular patch antenna, method of moments, resonance, neural networks, networks based on electromagnetic knowledge.

Introduction

In modern communication and wireless systems, there is an increasing demand for the integration of antennas not only with RF front-end circuits but also with intermediate frequency or even baseband components (including analog and digital signals) [4]. Due to its low cost, minimal weight and planar structure, the microstrip patch antenna (MPA) is probably the most likely candidate for this integration [5]. In particular, for millimeter-wave applications, the size of the patch antenna can be much smaller than the printed circuit board (PCB) substrate [6], where the analog and digital devices are integrated.
This paper will solve the problem of dimensioning a fixed frequency rectangular patch antenna by applying neural networks. The characterization of the antenna will be determined from its microwave parameters (resonant frequency, bandwidth, radiation pattern and gain) [7] using the electromagnetic simulation software HFSS. The rest of the paper is organized as follows Section 1 we will highlight the neural

mathematical formulations [8] of the printed antennas, in section 2 we will highlight the methods and simulation results concerning the performance on HFSS and output the optimized antenna.
We will close the work with a general conclusion that will summarize all the work done and the perspectives that could complement the present work.

Materials and Methods

The equation of the phenomenon of electromagnetic wave propagation by the MAXWELL formalism;
Presentation of the simulation tools (HFSS and MATLAB),
Finite moment method which is the operating principle of HFSS;
Transmission line methods as well as the presentation of neural network methods for the modelling of the resonance frequency.

Results and Discussion

The proposed network is designed and simulated on two simulation software HFSS and MATLAB to compare the results. In this design, we simulate and measure several parameters such as parameter S_{11}, antenna gain, bandwidth, VSWR and radiation pattern that must be evaluated at different frequencies before we can conclude that the proposed network is functional.
Figure 5 shows a set of curves that represent the variation of the reflection coefficient with the frequency for different spacing values between the elements.
After optimization and compared to the result obtained in (***Figure 6)*** we notice that the cut-off frequency is at **6GHZ** which shows the improvement of the frequency band once the dimensions of our antennas are simulated on MATLAB.

Advice on Equations

- **Step 1: Calculation of W**

$$W = \frac{c}{2fr} \times \sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

With fr resonance frequency and ε_r relative permittivity of the substrate used. **[21]**

- **Step 2 : Calculate ε_{reff}**

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \times [1 + 12\frac{h}{W}]^{-\frac{1}{2}} \quad (2)$$

With ε_{reff}: *efficient dielectric constant*; [22]

- **Step 3: Calculate ΔL**

$$\Delta L = 0.412 \times h \times \frac{(\varepsilon_{reff} + 0.3) \times (\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258) \times (\frac{W}{h} + 0.8)} \quad (3)$$

Calculation of the variation of the patch antenna length. [23]

- **Step 4: Calculation of L**

$$L = \frac{c}{2f_r \times \sqrt{\varepsilon_{reff}}} - 2\Delta L \quad (5)$$

calculation of the length L of the patch antenna [24]

Advice on Figures

- **MLT simulation algorithm**

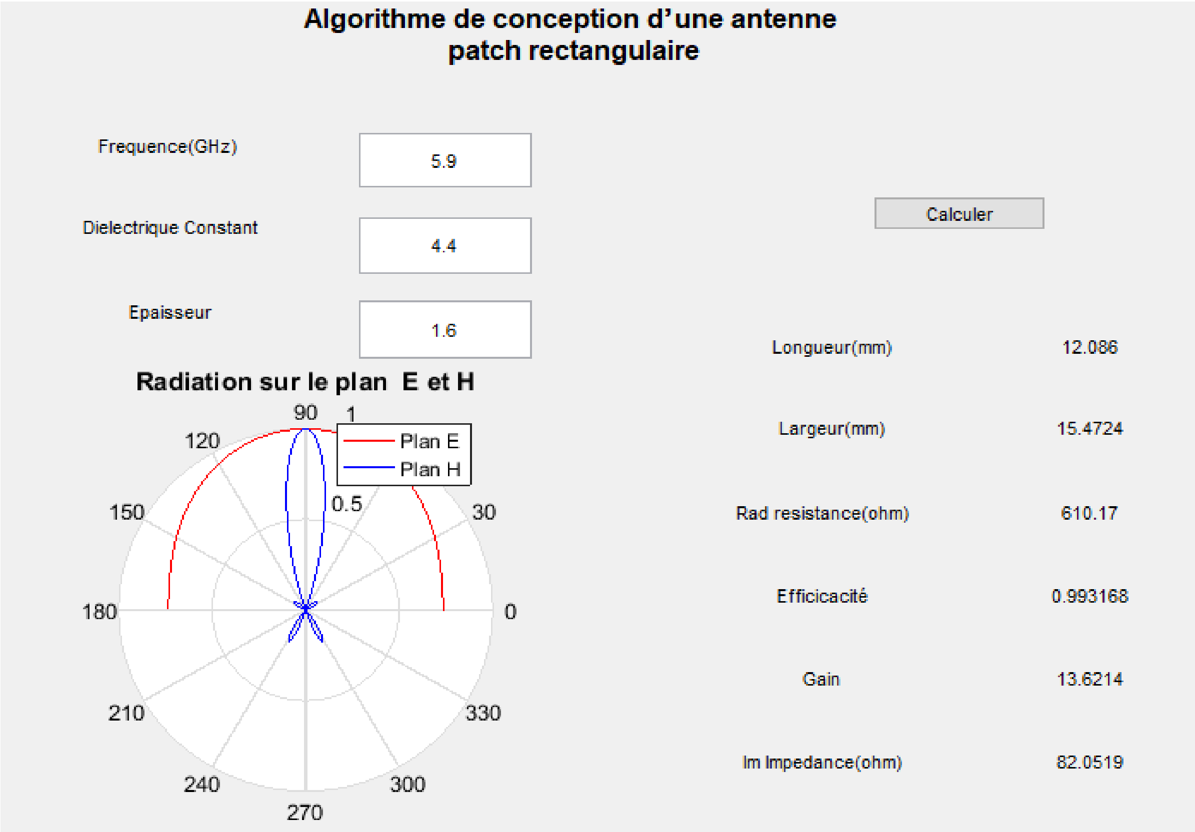

Figure *1*: Interface Antenna patch algorithm

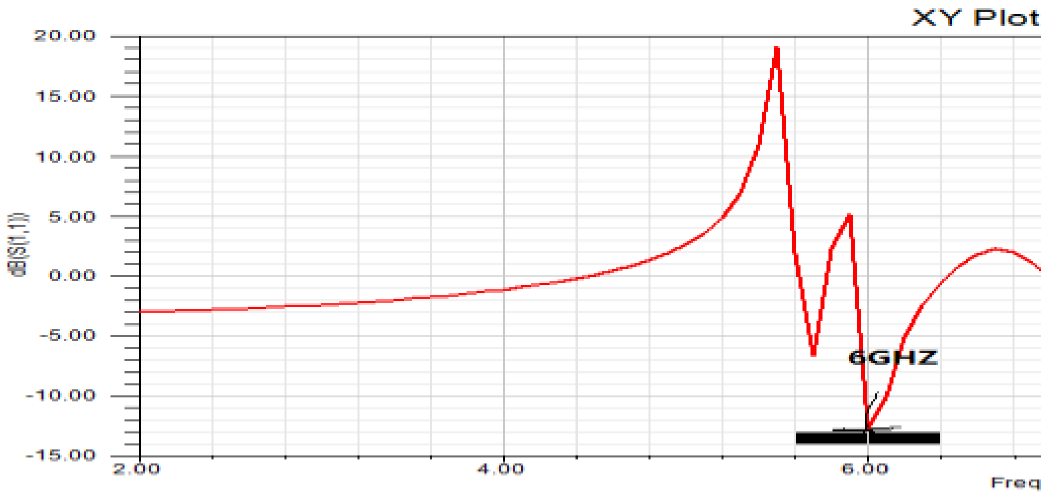

Figure *2*: Parameter S_{11} after optimization

- **Modeling the learning model**

In this work we implemented a model 4 inputs and 1 outputs according to the parameters of the antenna (Length, Width, Thickness and substrate) then output the resonance frequency.

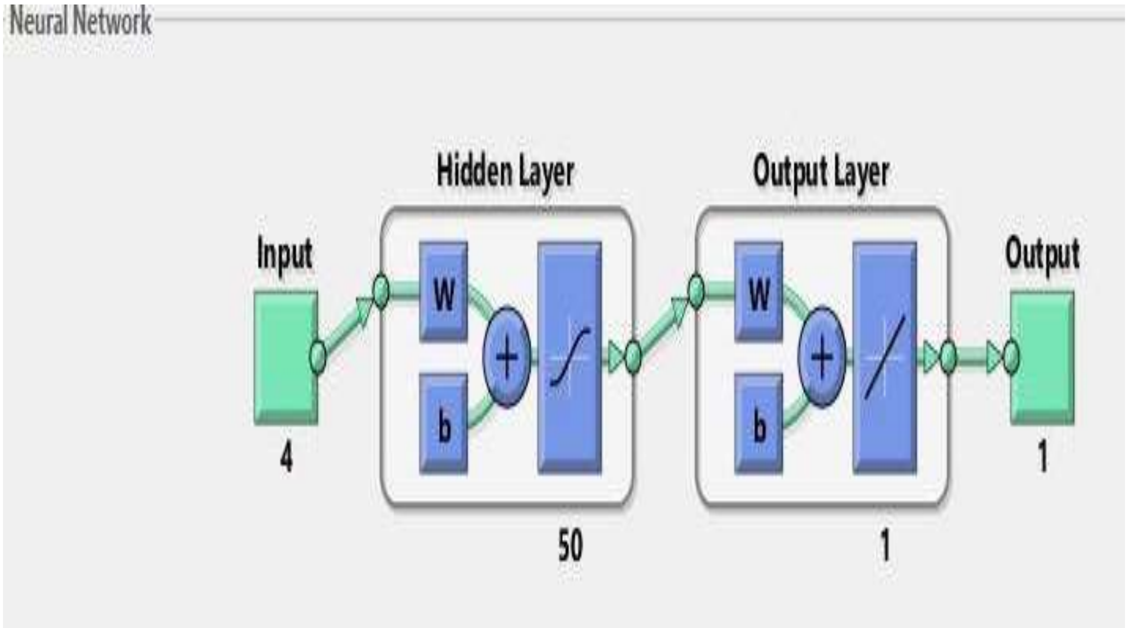

Figure *3*: Case of 50 iterations

With 50 iterations we get these results: We see for an iteration of 50 we have 452 Epoches and the simulation time according to the Levenberg-Marquardt algorithm is 4 seconds and a better performance of 52.

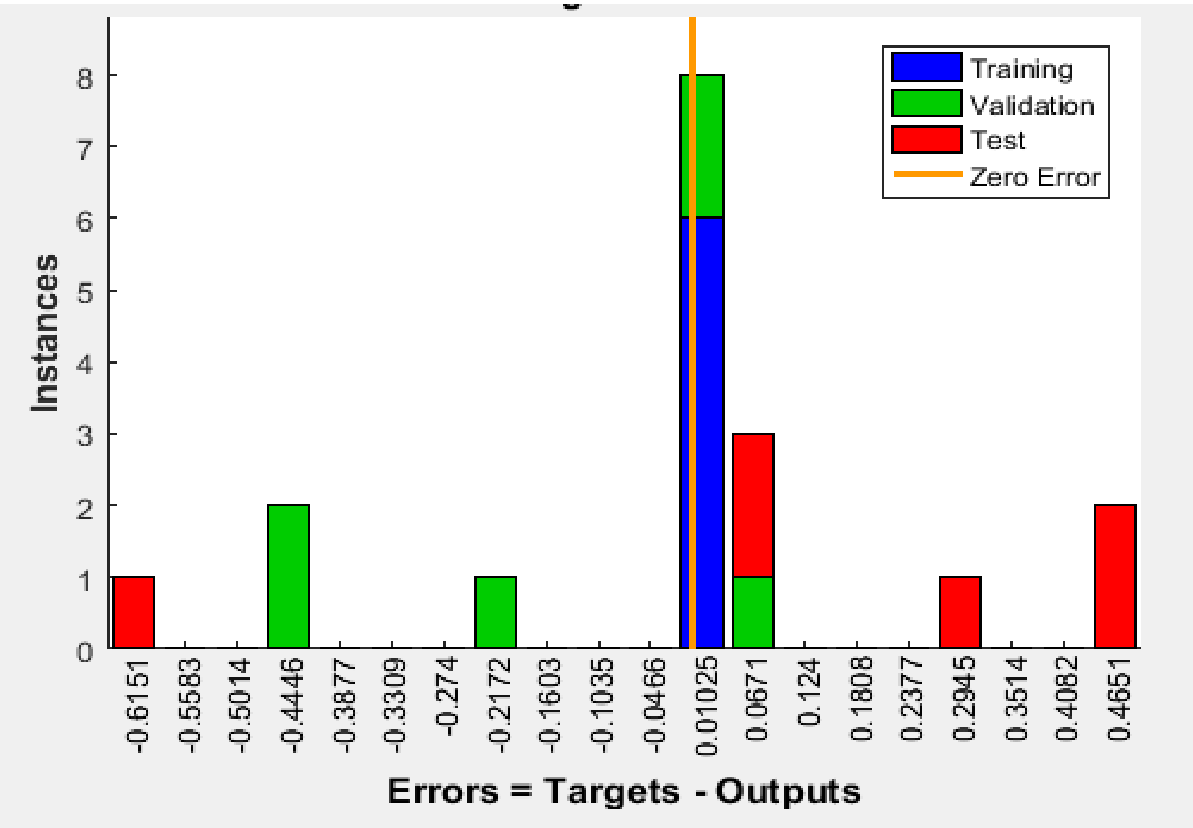

Figure *4*: Histogram of calculation errors between input parameters and resonance frequency fr.

The regression coefficients and validation values of the model are as follows:

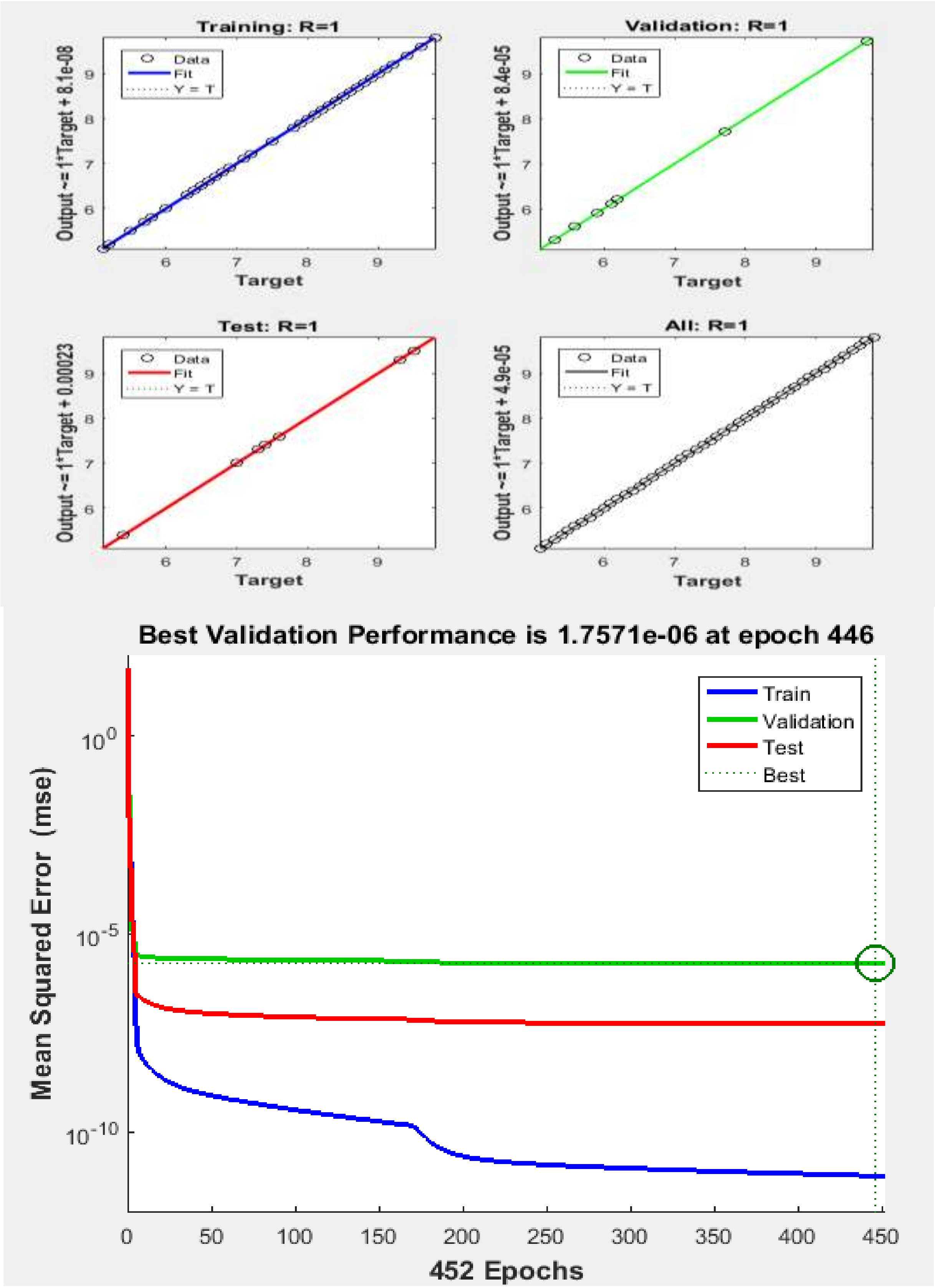

Figure 1: Different Regression from Test to Validation

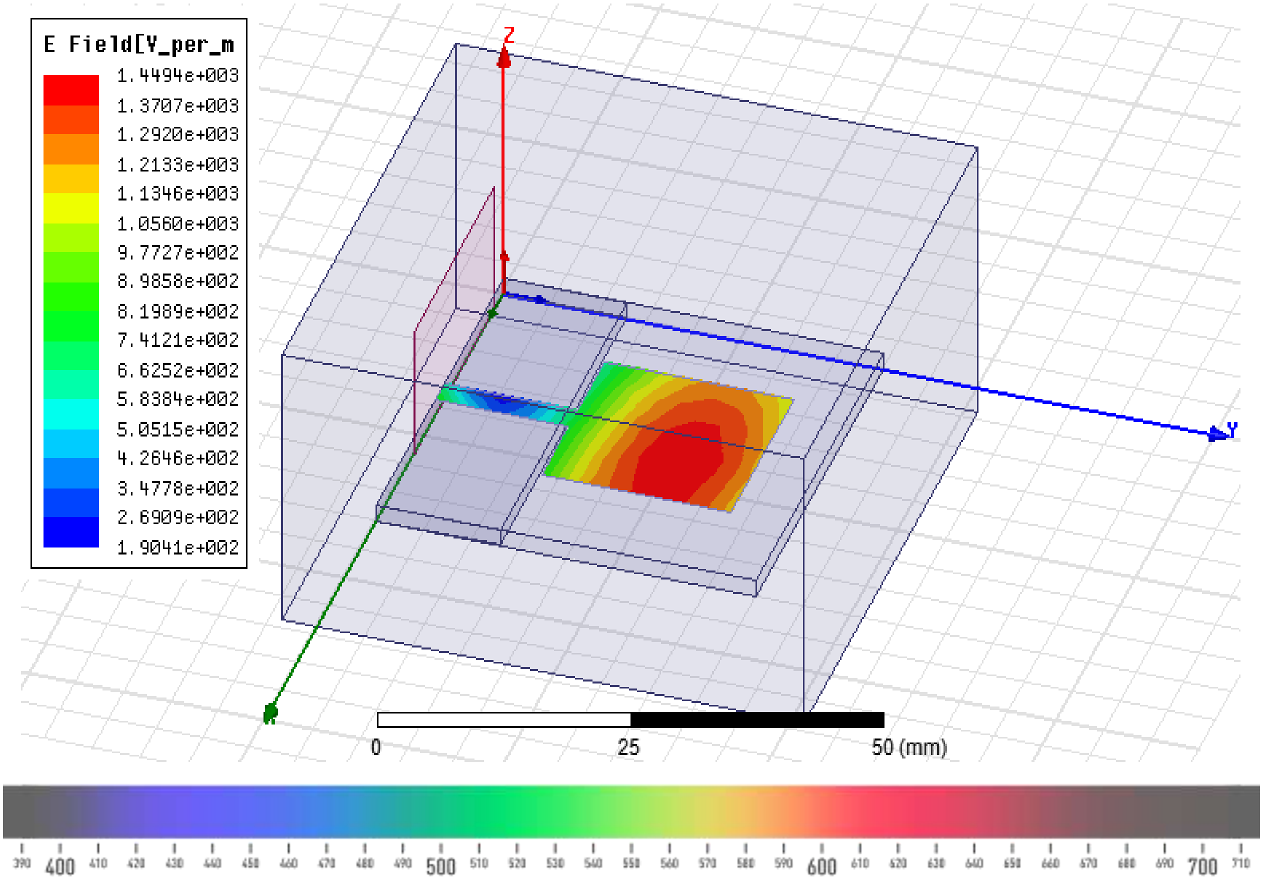

Figure 6: Radiations on Plan E

Human vision distinguishes colors in the photonic (diurnal) domain, that is to say with a luminance of **3 to 5,000 cd / m**. Comparing the effect of monochromatic radiation giving the same perception of luminosity, we find that the radiance is minimal for a radiation of wavelength close to 555 nm, which corresponds to a yellowish-green. This radiation close to the maximum of that of the sun, corresponds to the greatest visual sensitivity.

Each "spectral color" corresponds to a specific wavelength; however, the spectrum of lights present in nature generally includes all radiation, in varying proportions. Spectrometry studies the processes of decomposition, observation and measurement of radiation in narrow frequency bands. [26]

Advice on Tables

Tableau 1: Parameter W and L to obtain Resonance Frequency

W(mm)	L(mm)	Resonance Frequency Obtained after calculations and simulations			ERROR	
		MLT	MoM	ANN	ELT-MoM	ELT-ANN
16.59	12.98	5.48	5.49	5.5	-0.01	-0.02
16.3	12.78	5.587	5.59	5.6	-0.003	-0.013
16.01	12.52	5.68	5.69	5.7	-0.01	-0.02
15.73	12.3	5.81	5.75	5.8	0.06	0.01
15.47	12.08	5.9086	5.902	5.991	-0.01	-0.085
15.21	11.89	6.02	6.05	6	-0.03	0.02
14.96	11.7	6.105	6.110	6.100	-0.05	0.05

Conclusions

The rectangular patch antenna was studied according to all their physical and electrical parameters and taking into account losses in the dielectric. For the improvement of bandwidth and/or the gain of the single-layer patch antenna, multilayer antennas have been proposed in the literature. We investigated the effect of introducing an air gap between the ground plane and the dielectric substrate on improving bandwidth and the effect of introducing a protective dielectric layer for gain enhancement. An air gap antenna and a protective layer were also analyzed. A very long calculation time, complexity of formulation, presence of poles along the integration axis and sometimes non-physical solutions are the main limitations of the method used. Artificial neural networks were proposed and used for the analysis of the antennas considered. Being universal, highly nonlinear and interconnected approximaters, neural networks are capable of approximating any function, no matter how complex. Using data generated by the spectral method to ensure accuracy,

MLP neural networks (4 inputs and 1 output) have been developed for the calculation of the resonance frequency of the rectangular patch antenna. The first neural model written in MATLAB language based on the MLT algorithm, the second using the facilities made available by the Matlab Toolbox.

However, the research deserves to be continued in order to make our antenna that we have sized at fixed frequency **(6GHZ)** to be agile (reconfigurable) and also to bring out a new approach of reconfigurability in power

List of abbreviations

ENSPD **:** École Nationale Supérieure Polytechnique de Douala
MLT **:** Méthodes des Lignes de Transmission
ANN **:** Artificial Neural Network
MOM **:** Méthodes des Moments
HFSS **:** High Frequency Structure Simulator
MATLAB **:** Matrix Laboratory
VSWR **:** Voltage Standing Wave Ratio
CPW **:** Coplanar Waveguide
FEM **:** Finite Element Method
MLP **:** Multi Layer Perceptron
E3M **:** Énergie, Matériaux, Modélisation et Méthodes

Conflicts of Interest

"The authors declares that there is no conflict of interest regarding the publication of this paper."

Funding Statement

No research funding at the moment it is self-funded.

Authors' contributions

MATLAB helped to check the modelling errors of the neural network algorithm

HFSS was used to model the antenna itself at the beginning of the neural analysis and at the end of the experiment. "All authors read and approved the final manuscript."

References

1. L'information et la communication dans l'entreprise », *Bulletin des bibliothèques de France (BBF)*, 1993, n° 1, p. 76-76.
2. A. Ngom, A. Diallo,K. Talla, A. Chiabo, I. Dioum, A.C. Beye, J.M. Ribero "Antenne à double polarisation et diagramme reconfigurable destinée aux « smallcells » pour la 5G", 20 Journées Nationales Microondes- 16 – 19 Mai 2017, SAINT MALO, France ;
3. P. Gahan, K. Mumford, D. Standeford, M. Sims, C. Viola, and J. Watson, "The 4G and 5G Spectrum Guide 2017," *The Mobile Spectrum Handbook*, pp. 13–55, 2017.
4. Y. CHUNYANG, G. DEYUAN, W. WENBING, "Nonuniform linear antenna array optimization – genetic algorithm approach ", *ISAE'97 proceeding,1997*.

5. SCHEIR, G., HANSELAER, P., AND RYCKAERT, W. 2017. Pupillary light reflex, receptive field mechanism and correction for retinal position for the assessment of visual discomfort. Lighting Research & Technology, 1477153517737346.
6. B. Cockburn, G. E. Karniadakis et C.-W. Shu (eds.), *Discontinuous Galerkin methods. Theory, computation and applications*, LectureNotes in Computational Science and Engineering, 11. Springer-Verlag, Berlin, 2000.
7. E. Heidrich and W. Wiesbeck, “Wideband polarimetric rcs-antenna measurement,” in *Seventh International Conference on (IEE) Antennas and Propagation, 1991. ICAP 91.*,apr 1991, pp. 424 – 427 vol.1.
8. Baykan, Eda and Henzinger, Monika and Weber, Ingmar (2008). Web page language identification based on urls. Proceedings of the VLDB Endowment, 1 (1), 176–187.
9. F. Rosenblatt, "The Perceptron: a probabilistic model for information
10. storage and organization in the brain," Psychological Review 65.
11. Purely url-based topic classification. Proceedings of the 18th International Conference on World Wide Web. ACM, 1109–1110.
12. Gashler, Michael S., and Stephen C. Ashmore. "Training Deep Fourier Neural Networks to Fit Time-Series Data." Intelligent Computing in Bioinformatics. Springer International Publishing, 2014. 48-55, « *1405.2262* » [archive], texte en accès libre, sur *arXiv*.
13. (2014). Learning activation functions to improve deep neural networks. arXiv preprintarXiv :1412.6830.
14. Battiti, Roberto (1989). Accelerated backpropagation learning : Two optimization methods. Complex Systems, 3 (4), 331–342.
15. J.S. Hesthaven et T. Warburton, *Nodal Discontinuous Galerkin Methods: Algorithms, Analysis, and Applications* [archive]. Springer Texts in Applied Mathematics 54. Springer Verlag, New York, 2008.
16. D.A. Di Pietro et A. Ern, *Mathematical Aspects of Discontinuous Galerkin Methods* [archive]. Mathématiques et Applications, Vol. 69, Springer-Verlag, Berlin, 2011.
17. D.N. Arnold, F. Brezzi, B. Cockburn et L.D. Marini, *Unified analysis of discontinuous Galerkin methods for elliptic problems*, SIAM J. Numer. Anal. 39(5):1749-1779, 2002.
18. M.E. Brachet, M. Meneguzzi, A. Vincent, H. Politano, and P.L. Sulem. Numerical evidence of smooth self-similar dynamics and possibility of subsequent collapse for three-dimensional ideal flows. Phys. Fluids, 4 :2845, 1992.
19. M. Borrel and J. Ryan. The elastoplast discontinuous Galerkin (EDG) method for the Navier-Stokes equations. J. Comput. Phys., 231(1) :1–22, 2012.
20. M.E. Brachet, D.I. Meiron, S.A. Orszag, BG Nickel, R.H. Morf, and U. Frisch. Smallscale structure of the Taylor-Green vortex. J. Fluid. Mech., 130(41) :1452, 1983.
21. C. Brun, M. Petrovan Boiarciuc, M. Haberkorn, and P. Comte. Large eddy simulation of compressible channel flow. Theor. Comput. Fluid Dyn., 22(3) :189–212, 2008.
22. Garg et al. « Microstrip antenna design handbook », Artech House, 2001.
23. E. H. Newman, P. Bohley, C. H.Walter, "Two Methods for the Measurement of Antenna Efficiency", IEEE Trans. on Antennas and Propagation, vol AP-23, N°4, pp 457-461, July 1975.
24. K. R. Carver, J. W. Mink, "Microstrip Antenna Technology", IEEE Trans. On Antennas and Propagation, vol AP-29, N°1, pp 2 -24, January 1981.
25. I. J. Bahl, P. Bhartia, et S. S. Stuchly, ‘‘Design of microstrip antennas covered with a dielectric layer,’’ IEEE Trans. Antennas Propagat., vol. AP-30, pp. 314-318, Mar.1982.
26. M. Amir, ‘‘Analyse d’une antenne microruban à patch supraconducteur,’’ Thèse de magister, Université de Batna, Fév. 2008.

27. Robert Sève, *Science de la couleur : Aspects physiques et perceptifs*, Marseille, Chalagam, 2009, 374 p. (ISBN 978-2-9519607-5-6 et 2-9519607-5-1)
28. ILHEM GHARBI, "*Conception d'antennes reconfigurables en bandes millimétriques pour la 5G*", SUPCOM Tunis, 2021