Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 14 (18): 2061-2066, 2014
ISSN 1812-5654 / DOI: 10.3923/jas.2014.2061.2066

Electromagnetic Modelling and Design Principle of Parallel Plane Printed Microstrip Dipole Antennas

[1,2]C. Mbinack, [2]E. Tonye and [1]D. Bajon
[1]Groupe MOSE/Département SEPT-ex SUPAERO, Toulouse, France
[2]Laboratoire d'Electronique et de Traitement du Signal-ENSP-UY 1, Yaounde, Cameroun

Abstract: In this study, authors present approach to new topologies of parallel plane printed microstrip dipole antennas working at 2.4 GHz. Modelling its structure as an equivalent quadripole permits authors to use generalised wave formalism and the travelling wave transmission line model to evaluate with a good approximation its performances. In particular, it helps to evaluate the input impedance.

Key words: Printed microstrip dipole antennas, parallel plane microstrip lines, electromagnetic modelling, input impedance

INTRODUCTION

For consumer appliances, radiating elements should be of small sized, very easy to make and have excellent radiation features (Macphie *et al*., 1995). Microstrip dipole antennas have been identified as a solution to this requirement and have been thoroughly studied using various and diversified calculation methods (Laohapensaeng and Free, 2006; Kim *et al*., 2006; Uzunoglu *et al*., 1979). Its main interest lies on the fact that it satisfies resonance properties because it depends on the work frequency (Stutzman and Theile, 1998). It is characterised by a linear polarisation which is well suited for Wi-Fi an operating frequency of about 2.4 GHz.

The topology of the microstrip dipole antennas presented here is based on a biplane configuration of the radiating wires of the monoplane microstrip dipole antenna (Mbinack *et al*., 2007). This configuration allows a 50 Ω parallel plane microstrip transmission line to feed the dipole antenna in its center. The microstrip line has the advantage of being able to maintain a TEM propagation which is not very dispersive and its effective permittivity is well approximated by the permittivity of the dielectric substrate. To improve the antenna's performance, Jamaluddin *et al*. (2005) proposed an approach that focuses on the change of the radiating elements dimensions (width). In this study, authors propose a new approach which consists of making knees with right angles on metallization. An experimental study bearing on the influence of the Δz excitation gap width led us to the realisation of the impedance matching. In the same way, while making operate the antenna in the presence of a reflector plane, authors act to enhance the matching of this.

A mode in the form of an equivalent quadripole coupled to progressive wave transmission line model, allows authors to better assess the radio-electric features, in particular the input impedance of the so designed antenna. The model results study model will be compared with simulations and measurements results.

Topology and conceptual principle of the basic radiating structure: The biplane dipole antenna discussed here is obtained from a microstrip differential transmission line (i.e., the metallizations are arranged parallel to the top and the bottom sides of a dielectric substrate). From this point of view, the line so described has a total length $L = \lambda_g/4$ and width W_0 as shown in Fig. 1.

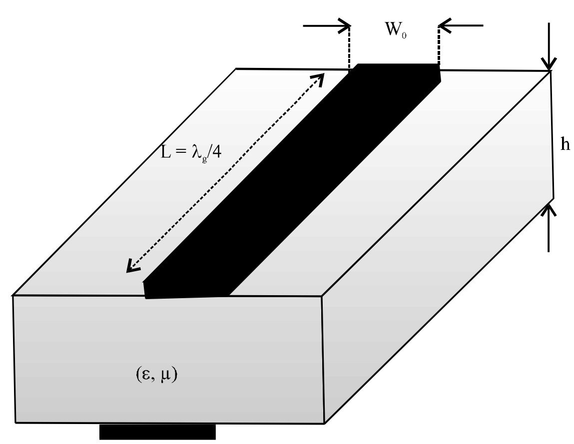

Fig. 1: Parallel plane (or differential) microstrip line modelling the dipole antenna

Corresponding Author: Clement Mbinack, Department of Physics, Faculty of Science, University of Yaounde I, P.O. Box 812, Yaounde Cameroun

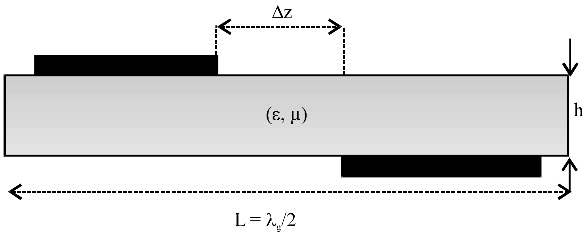

Fig. 2: Longitudinal section of the unfolded parallel plane microstrip line

For this line to be subjected to more radiation, it is unfolded by one quarter turn rotation in the opposite direction of each of the two metallizations to make a biplane dipole antenna. This increases its length from $L = \lambda_g/4$ to $L = \lambda_g/2$ as depicted in Fig. 2.

The Δz parameter which represents the excitation gap is essential in this configuration because it allows a better control of the adaptation. This configuration primarily permits to better feed the dipole antenna in its centre using a 50 Ω parallel plane microstrip transmission line.

Electromagnetic model: In the prospect of electromagnetic modelling considered here for the determination of the radio-electric characteristics of the antenna, authors will introduce the generalised waves formalism which will be coupled to the theory of progressive waves transmission lines. Building this model requires a reminder of voltage and current wave expressions at any point z on the line as follows:

$$V(z) = \underline{V_i}e^{-\gamma z} + \underline{V_r}e^{\gamma z} \quad (1)$$

and:

$$I(z) = \frac{1}{Z_C}\left(\underline{V_i}e^{-\gamma z} - \underline{V_r}e^{\gamma z}\right) \quad (2)$$

where, $\underline{V_i}$ refers to the complex amplitude of incident voltage waves, $\underline{V_r}$ that of the reflected voltage waves and Z_C is characteristic impedance of the feeding microstrip transmission line.

In this approach, the microstrip dipole antenna shown in Fig. 1, is modelled using a quadrupole or its flow graph, combined to a microstrip transmission line as illustrated in Fig. 3.

The modelled antenna of total length L, will be represented by its chain matrix:

$$[C] = \begin{bmatrix} \cosh(\gamma L) & Z_C \sinh(\gamma L) \\ \frac{1}{Z_C}\sinh(\gamma L) & \cosh(\gamma L) \end{bmatrix} \quad (3)$$

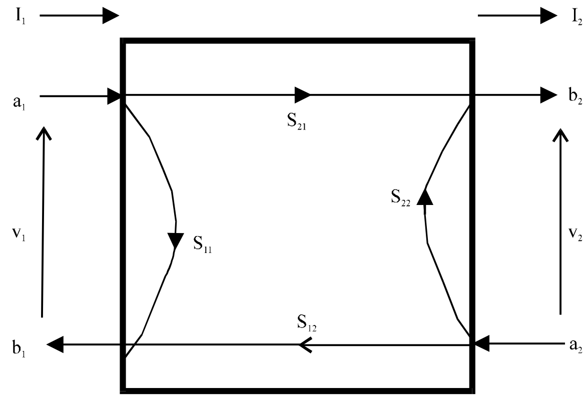

Fig. 3: Flow graph combined to a transmission line

or by its impedance matrix:

$$[Z] = \frac{Z_C}{\sinh(\gamma L)}\begin{bmatrix} \cosh(\gamma L) & -1 \\ 1 & -\cosh(\gamma L) \end{bmatrix} \quad (4)$$

In the particular case of lossless transmission lines authors are interested in cases for which authors have $\gamma = j\beta = j2\pi f\sqrt{\mu_0 \varepsilon_0 \varepsilon_{eff}}$. The above expressions of chain and impedance matrices are written as follows:

$$[C] = \begin{bmatrix} \cos(\beta L) & jZ_C \sin(\beta L) \\ \frac{j}{Z_C}\sin(\beta L) & \cos(\beta L) \end{bmatrix} \quad (5)$$

and:

$$[Z] = -j\frac{Z_C}{\sin(\beta L)}\begin{bmatrix} \cos(\beta L) & -1 \\ 1 & -\cos(\beta L) \end{bmatrix} \quad (6)$$

By introducing the generalized wave formalism as follows:

$$\begin{cases} V_1 = a_1 + b_1 \\ V_2 = a_2 + b_2 \end{cases} \quad (7)$$

and:

$$\begin{cases} I_1 = \frac{1}{Z_C}(a_1 - b_1) \\ I_2 = \frac{1}{Z_C}(a_2 - b_2) \end{cases} \quad (8)$$

where:

$$V_1 = V(-L) = \underline{V_i}e^{\beta L} + \underline{V_r}e^{-\beta L} \quad (9)$$

Is the expression of voltage waves at the input end of the dipole antenna:

$$I_1 = I(-L) = \frac{1}{Z_C}\left(\underline{V}_i e^{\beta L} - \underline{V}_r e^{-\beta L}\right) \quad (10)$$

Is that of current wave at the input end of the antenna:

$$V_2 = V(0) = \underline{V}_i + \underline{V}_r \quad (11)$$

Is that of voltage wave at the output end of the antenna and:

$$I_2 = I(0) = \frac{1}{Z_C}\left(\underline{V}_i - \underline{V}_r\right) \quad (12)$$

That of current wave at the output end of the antenna α_1 and α_2 are the input waves of the quadripole, b_1 and b_2 are the output waves of the quadrupole and taking into account only the impedance matrix, when authors combine Eq. 7 and 8 above, authors obtain the following:

$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} \quad (13)$$

Where:

$$S_{11} = \frac{(Z_{11} - Z_C)(Z_{22} - Z_C) - Z_{12}Z_{21}}{(Z_{11} + Z_C)(Z_{22} - Z_C) - Z_{12}Z_{21}} \quad (14)$$

$$S_{12} = \frac{2Z_{12}Z_C}{(Z_{11} + Z_C)(Z_{22} - Z_C) - Z_{12}Z_{21}} \quad (15)$$

$$S_{21} = \frac{Z_{11} + Z_C}{Z_{12}} S_{11} - \frac{Z_{11} - Z_C}{Z_{12}} \quad (16)$$

$$S_{22} = 1 + \frac{Z_{11} + Z_C}{Z_{12}} S_{12} \quad (17)$$

and:

$$\begin{cases} Z_{11} = -j\dfrac{Z_C}{\tan(\beta L)} \\ Z_{12} = j\dfrac{Z_C}{\sin(\beta L)} \\ Z_{21} = -j\dfrac{Z_C}{\sin(\beta L)} \\ Z_{22} = j\dfrac{Z_C}{\tan(\beta L)} \end{cases} \quad (18)$$

We can now deduce the expression of antenna impedance from the formalism of progressive wave transmission lines as follows:

$$Z_L = Z_C \frac{1 + S_{11}}{1 - S_{11}} \quad (19)$$

Authors note, however, that this approach does not take into account rigorously all the antenna characteristic parameters. To be more precise, authors we adopted another approach that focuses on electromagnetic simulations and other experiments in order to better model the source-antenna transition.

MATERIALS AND METHODS

Biplane dipole antenna in I-topology: The main idea behind this configuration was motivated by the simple fact that authors wanted to feed our dipole antenna at the centre using a 50 Ω microstrip transmission line. This facilitates the modelling of source-antenna transition using differential ports such as Momentum of ADS commercial software, as illustrate in Fig. 4. For practical and convenience reasons, after investigating the impact of Δz excitation gap on the input impedance of the dipole antenna, the microstrip feed lines were maintained parallel.

For stiffness reasons, authors made structures on a dielectric substrate with relative permittivity ε_r = 4.3, thickness h = 0.8 mm and loss angle tanδ = 10^{-3}. The radiating element has the following characteristics: Total length of line L = 43 mm; width of line W_0 = 4 mm; excitation gap width Δz = 2 min.

Biplane printed microstrip dipole antenna in Z-topology: Authors aim is to improve the efficiency of radiation of the original structure and this requires a change in profile of the latter. Therefore, authors make foldings on the radiating wires of the dipole antenna in I-topology (Mbinack *et al*., 2007). This makes it possible to get elements as L, Z, half-ring, square or spiral ring topologies. In any case, the intention is to further enhance the performance of the so made antenna, its matching in particular. This section mostly entails focusing on dipoles antenna in Z-topology due to its

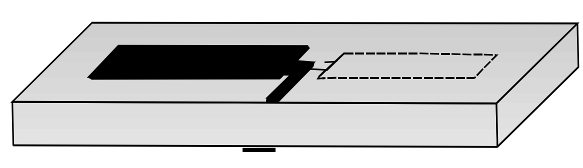

Fig. 4: Sample biplane dipole antenna fed at its centre using a microstrip transmission line

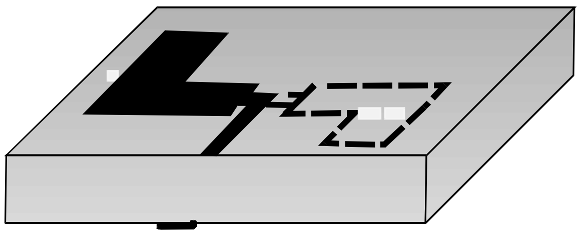

Fig. 5: Sample of a biplane dipole antenna in Z-topology fed at its centre by a microstrip transmission line

performance and to the symmetry of the original element it is intended to keep in the sense of the current flow as shown in Fig. 5.

Authors have so, designed a new structure that still allows us to model source-antenna transition so as to feed the antenna at its centre using a parallel plane microstrip transmission line. As earlier, authors used dielectric substrate with relative permittivity ε_r = 4.3, thickness h = 0.8 mm and loss angle tanδ = 10^{-3}. The dipole antenna still has a total length of L = 43 mm and width W_0 = 4 mm for an excitation gap width of Δz = 2 mm.

RESULTS AND DISCUSSION

Figure 6 shows the performance of the calculated impedance of the biplane microstrip transmission line modelling the biplane printed microstrip dipole antenna with line length L = 20 mm and width W_0 = 4 mm printed on the dielectric substrate with relative permittivity ε_r = 4.3, thickness h = 0.8 mm and loss angle tanδ = 10^{-3}. Authors can observe that the imaginary part of the dipole antenna impedance is null while its real part is equal to its characteristic impedance. What seems to be logical since our antenna was modeled as a transmission line having for essential characteristic only its characteristic impedance.

However, it should be noted that that model does not take into account the modeling of the source-antenna transition or the feed way that concerns us in this study.

In the sequel, all our antennas will be feed at their centres by a 50 Ω parallele plane microstrip transmission line.

Figure 7 shows the trend of the simulated input impedance of the biplane dipole antenna in I-topology fed at its centre by a 50 Ω microstrip transmission line. We can quickly notice the capacitive behaviour of the antenna as the imaginary part of its input impedance is

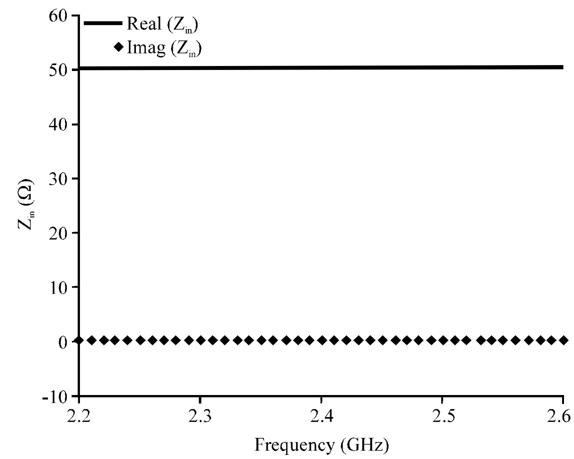

Fig. 6: Calculated impedance of the biplane dipole antenna

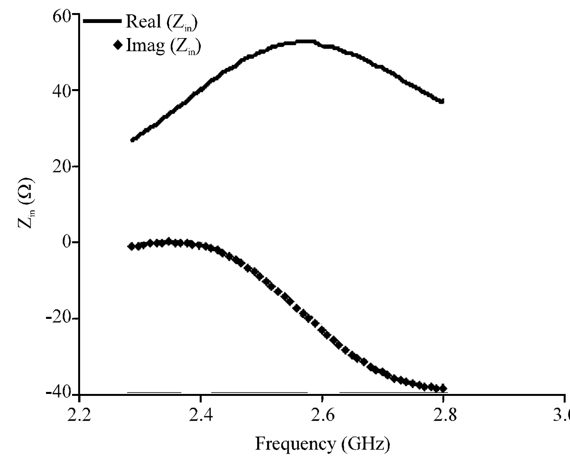

Fig. 7: Simulated input impedance of the dipole antenna in I-topology

wholly negative. However, we get an actual impedance of about 40 Ω for a resonance frequency of about 2.4 GHz. But everything seems to indicate that we should make a translation of 20 units to get the expected behaviour from the antenna. In this case, the dipole will radiate at 70 Ω for a resonance frequency of about 2.6 GHz.

Figure 8 illustrates the development of the measured input impedance of the biplane microstrip dipole antenna in I-topology. We can observe a perfect agreement with theoretical predictions, where we obtain an actual impedance of about 90 Ω for a resonance frequency of about 2.42 GHz.

Figure 9 shows the evolution of the measured input impedance of the biplane microstrip dipole antenna in

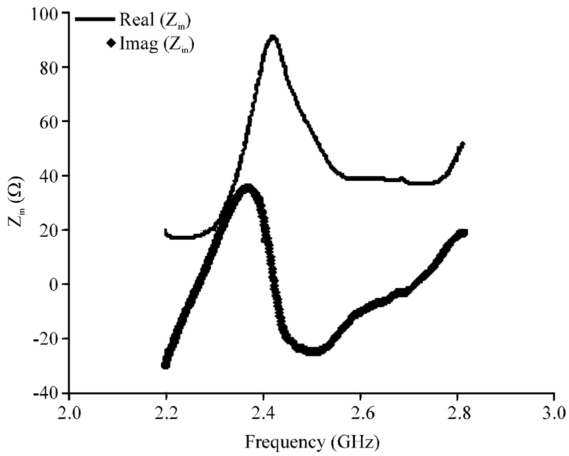

Fig. 8: Measured input impedance of the dipole antenna in I-topology

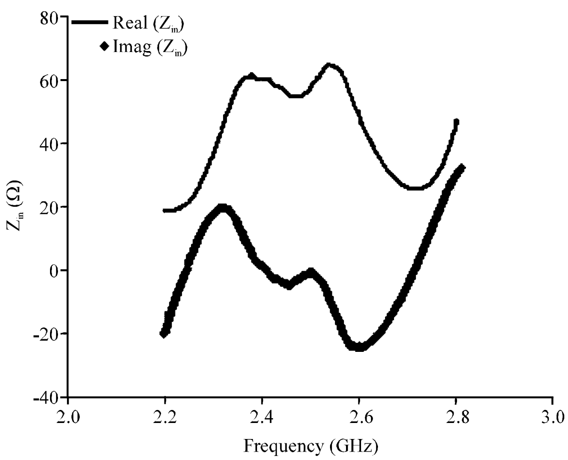

Fig. 9: Measured input impedance of the dipole antenna in I-topology in the presence of a reflector plane at $\lambda_g/4$

I-topology in the presence of a reflector plane placed at a distance of $\lambda_g/4$ from the antenna's plane. We can read an actual impedance of about 60 Ω for a resonance frequency of about 2.4 GHz.

Figure 10 depicts the trend of the measured input impedance of the biplane microstrip dipole antenna in I-topology in the presence of a reflector plane, placed towards infinity with respect to the antenna's plane. We can read an actual impedance of about 60 Ω for a resonance frequency of about 2.42 GHz. Let us note, however, the multi-band behaviour of the antenna in the presence of a reflective plane placed towards infinity or at a finite distance from its plane.

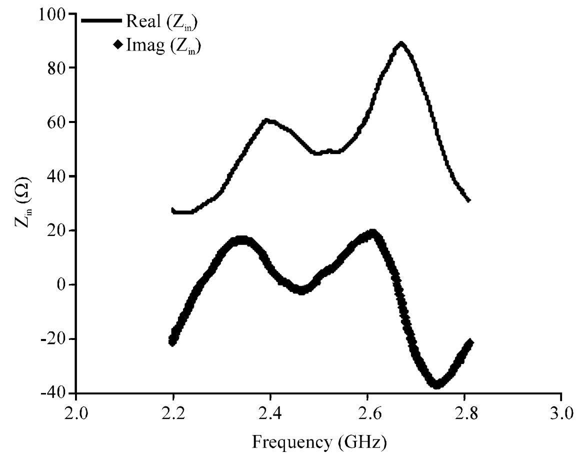

Fig. 10: Measured input impedance of the dipole antenna in I-topology in the presence of a reflector plane towards infinity

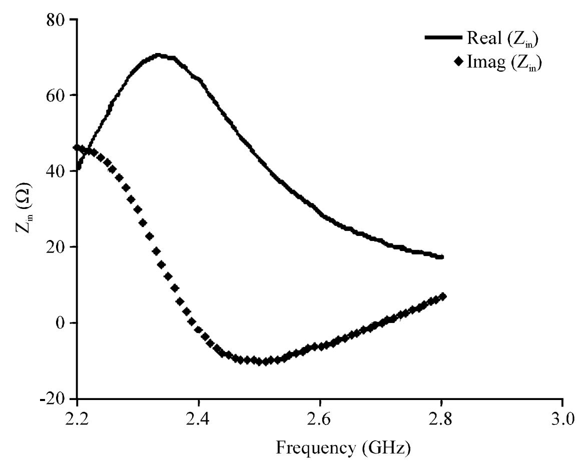

Fig. 11: Simulated input impedance of the dipole antenna in Z-topology

Figure 11 shows the trend of the simulated input impedance of the parallel plane microstrip dipole antenna in Z-topology. This trend agrees with theory and indicates an actual impedance of about 70 Ω for a resonance frequency of about 2.38 GHz.

Figure 12 depicts the trend of the measured input impedance of the parallel plane printed microstrip dipole antenna in Z-topology. Its trend also agrees with the theory and indicates an actual impedance of about 100 Ω for a resonance frequency of about 2.35 GHz. However, we get another real impedance of about 42 Ω at 2.5 GHz.

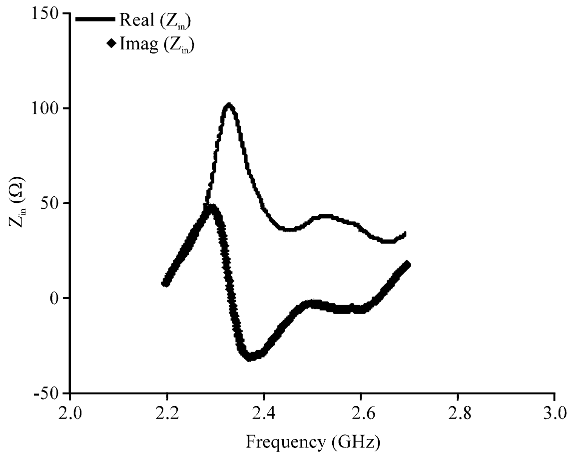

Fig. 12: Measured input impedance of the dipole antenna in Z-topology

In all cases, we should find a compromise between impedance matching and resonance frequency.

CONCLUSION

We have proposed a theoretical and conceptual approach that aimed at exploring new topologies for parallel plane printed microstrip dipoles antennas feed at its centre by a 50 Ω microstrip transmission line. We got interesting performances in terms of radio-electric characteristics such as a bandwidth of about 16%, compared to the model developed by Jamaluddin *et al*. (2005) which indicates a bandwidth of about 11%. The presence of the reflective plane provides structures with multiple and large bandwidth. The dipole antenna in I-topology runs at low impedance while the dipole in Z-topology runs on average impedance. To improve the adaptation, it is essential to adjust Δz-parameter in coupling with the methods presented above. Similarly, to catch up the working frequency, there is a need to adjust the physical length of the line modelling the dipole antenna because this on is actually different from its electrical length.

REFERENCES

Jamaluddin, M.H., M.K.A. Rahim, M.Z.A.A. Aziz and A. Asrokin, 2005. Microstrip dipole antenna analysis with different width and length at 2.4 GHz. Proceedings of the Asia-Pacific Conference on Applied Electromagnetics, December 20-21, 2005, Johor.

Kim, D.J., Y.M. Moon, S.H. Park, Y.E. Kim and K.S. Min *et al*., 2006. A small monopole antenna with novel impedance matching structure. Proceedings of the 36th European Microwave Conference, September 10-15, 2006, Manchester, pp: 819-822.

Laohapensaeng, C. and C. Free, 2006. Simplified integral equation for analysing the printed strip dipole antenna. IEE Proc. Microwaves Antennas Propagat., 153: 301-306.

Macphie, R.H., W. Gross and I.Z. Lian, 1995. The impedance of a center-fed strip dipole by the poynting vector method. IEEE Trans. Antennas Propagation, 43: 257-263.

Mbinack, C., E. Tonye and D. Bajon, 2007. Dipoles microrubans Bi-niveaux a brins replies autour de 2.4 GHz. 19eme Colloque International Optique Hertzienne et Dielectrique, Valence, France, Septembre 5-8, 2007.

Stutzman, W.L. and G.A. Theile, 1998. Antenna Theory and Design. 2nd Edn., John Wiley and Son, New York.

Uzunoglu, N., N. Alexopoulos and J. Fikioris, 1979. Radiation properties of microstrip dipoles. IEEE Trans. Antennas Propagat., 27: 853-858.