

Microruban Dipole Antenna for RFID Applications at 2.45 GHz

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ABSTRACT

Radio Frequency Identification (RFID) is a technology used mainly to identify tagged items or to track their locations. The most used antennas for RFID application are planar dipoles. For antenna design, it is necessary that the antenna has an impedance value equal to the conjugate of the impedance of the integrated circuit IC. To have a good adaptation allowing the maximum power transfer, there are several techniques. In this work we focus to the adaptation technical T-match which is based on the insertion of a second folded dipole in the center of the first dipole. This technique is modeled by an equivalent circuit to calculate the size of the folded dipole to have new input impedance of the antenna equal to the conjugate of the impedance of the IC. We also look to present a conceptual and technological approach of new topologies of linear dipoles. We proceeded to fold at right angles of the radiating strands in order to explore other topologies of type L and Z. The interest of this microstrip folded dipole is their effectiveness to achieve coverage of Blind directions. The results obtained by the platform Ansoft HFSS, allowed us to obtain a quasi-uniform radiation patterns and the reflection coefficients that exceed -37 dB.

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1. INTRODUCTION

Radio Frequency Identification (RFID) is an intelligent, efficient and flexible technology. RFID is an automatic identification method which uses radio waves for reading the data contained in devices called RFID tags or labels [1].

RFID technology is used to monitor, identify and track objects, animals and people away. The RFID system has two key features: RFID Tag (Label) and RFID Reader. Today, this technology finds use in access controls, vehicle safety, animal tracking and patients in hospitals and other applications [2]. In the present article, we introduced first, the technology of matching T-match [3]. Then, we compared the simulation results of the dipole antenna adapted with T-match and the simulation results obtained by dipole antenna in topology I. The platform used is Ansoft HFSS which is based on the finite element method (FEM), we also made a comparison at the circuit parameters and radiation dipole antennas before and after matching to know the influence of the addition of the folded dipole. We present in a second step, a theoretical and conceptual approach to explore new topologies of linear dipoles. We proceeded to fold at right angles of the radiating strands in order to explore other topologies L and Z [4], for obtaining substantially uniform radiation patterns, with coverage of shadows because the dipoles do not radiate in their own direction, this limits their field of use. The theoretical model of the dipoles considered in this research, is a wired microstrip model with

a sinusoidal distribution of the current density, very suitable for the evaluation of radiation characteristics of many antennas such as dipoles.

2. THEORIE

2.1. The technical T-match

T-match is a technique of impedance matching of the microstrip dipoles antennas, with this method, the planar dipole with length l and width w is connected to a second planar dipole with length l' such as ($l' < l$) and width w' , placed at a distance (s) from the first dipole center (Figure 1(a)) [3]. This second dipole is considered a folded dipole two-legged. T-match behaves like the equivalent circuit, represented on (Figure 1(b)) [3]. It can be proven that the impedance at the antenna point source is given by equation (1):

$$Z_{in} = R_{in} + jX_{in} = \frac{2Z_t[(1+\alpha)^2Z_a]}{2Z_t + [(1+\alpha)^2Z_a]} \tag{1}$$

or:

- a. $\alpha = \frac{\ln(s/r_{e'})}{\ln(s/r_e)}$ is the current division factor between the two conductors of length s , with $r_e = 0.25w$ et $r_{e'} = 0.25w'$.
- b. $Z_t = jZ_0 \tan\left(\frac{Kl'}{2}\right)$ is the impedance of short stub input, formed by the transmission line of two conductors of length $l'/2$, width w and w' and the separation s (Figure 2) [3], with $K = 2\pi/\lambda$ is the wave number, $Z_0 \cong 76 \log_{10}\left(\frac{s}{\sqrt{r_e r_{e'}}}\right)$ is the characteristic of the two-conductor transmission line impedance (Figure 3) [3].

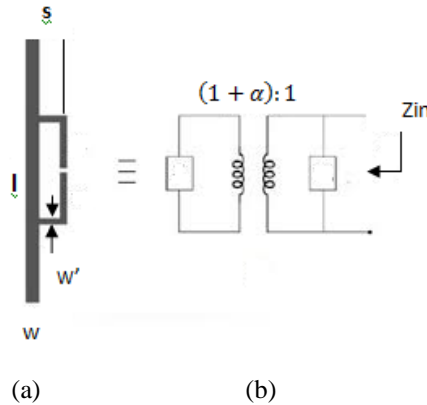


Figure 1. T-match: (a) For a Planar Dipole, (b) The Equivalent Circuit

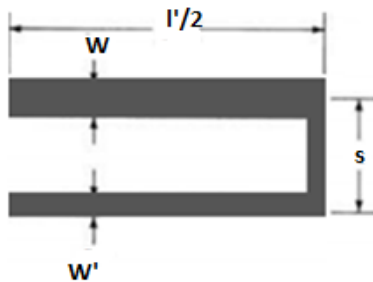


Figure 2. Short-Circuit Formed by the Transmission Line of Two Conductors of Length $\ll l'/2 \gg$, width "w", "w'" and the Separation "s"

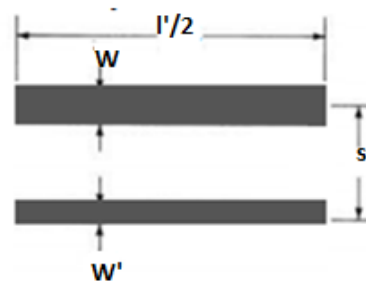


Figure 3. Transmission Line has Two Conductors

The geometrical parameters, l' , s and w' of T-match, can be adjusted to have an antenna input impedance Z_{in} equal to the conjugate of the impedance of integrated circuit Z_{ic} [3]. For this we have designed a planar half-wave dipole antenna, to compare the results of suitable antenna with T-match using the platform Ansoft HFSS.

2.2. The miniaturization of the dipole antenna

Practically, the folding of strands is made in the constant total length. But the fact of folding the dipole causes a decrease in the electrical length of the resonator and thus a shift of the resonant frequency. An adjustment of the total length of the dipole during the folding is therefore justified in order to bring resonance in the band's work. Experimentally, it was found that the length l of the strand of the dipole checks that $\frac{\lambda_g}{4} < l < \frac{\lambda_0}{4}$ or l_g is the wavelength guided in the microstrip line and λ_0 is the wavelength in the vacuum. This shows that the effective wavelength in wireframe microstrip dipoles must consider a propagation in an effective permittivity medium different from the effective permittivity of the microstrip lines associated. Taking into account the literature, an expression of the effective permittivity associated with microstrip dipoles can be given to a good approximation by equation (2):

$$\epsilon_{eff} = 1 + \frac{\epsilon_r - 1}{2} \left[1 - \left(\frac{W/h}{1 + (W/h)} \right) \right] \quad (2)$$

ϵ_r : The relative dielectric constant of the substrate.

w : The width of a strand of the microstrip.

h : The substrate thickness.

The effective wavelength associated with microstrip dipoles is theoretically given by the relation (3):

$$\lambda_{eff} = \frac{\lambda_0}{\sqrt{\epsilon_{eff}}} \quad (3)$$

The total length of the planar dipole can be put in the form (4):

$$2l = \frac{\lambda_0}{2\sqrt{\epsilon_{eff}}} \quad (4)$$

Figure 4 represents the different forms of miniaturization [4].

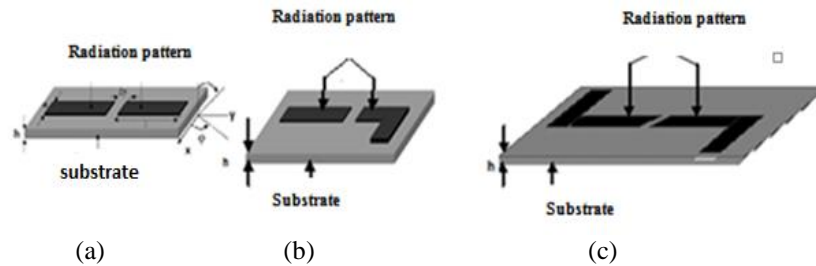


Figure 4. Microstrip Dipole and the Coordinate System Associated with: (a) Topology I; (b) Topology L; (c) Topology Z

In this paper, the theoretical model considered is a wireframe microstrip since $w \ll \lambda_{eff}$. It adapts perfectly with the thin cylindrical dipole with radius $a \ll \lambda_0$. This allows evaluating with good approximation the radiation characteristics of the linear dipoles considered. Concretely this means that the corded dipoles folded strands or not, evolves with a sinusoidal current distribution in the dipoles on topology I axis oy [4] and can be put in the form (5):

$$J_Y = J_0 \sin[K_{eff} (1 - |Y'|)] \quad (5)$$

Considering the wave radiated a long distance by the dipole Oy as being locally plan, the electric field in the direction θ can be given by:

$$E_{\theta}(\theta, \varphi) = g_{\theta}(\theta, \varphi) \quad (6)$$

or :

$$\begin{cases} g(\theta, \varphi) = -j\omega \frac{I_0 \mu_0}{4\pi} \sqrt{1 - \sin^2 \theta \sin^2 \varphi} \\ f(\theta, \varphi) = \iint_{S'} \sin[K_{\text{eff}}(1 - |Y'|)] e^{j(K_x x' + K_y y')} d_{x'} d_{y'} \end{cases} \quad (7)$$

with:

$$-\frac{W}{2} \leq x' < \frac{W}{2} \quad (8)$$

$$-\frac{\lambda_{\text{eff}}}{4} \leq y' \leq \frac{\lambda_{\text{eff}}}{4} \quad (9)$$

$$\begin{cases} K_x = K_0 \sin \theta \cos \varphi \\ K_y = K_0 \sin \theta \sin \varphi \end{cases} \quad (10)$$

$$K_0 = \frac{2\pi f}{c} \quad (11)$$

$$K_{\text{eff}} = K_0 \sqrt{\epsilon_{\text{eff}}} \quad (12)$$

$$0 \leq \theta \leq \pi, \quad 0 \leq \varphi \leq \pi \quad (13)$$

3. SIMULATION AND RESULTS

3.1. Planar Dipole Antenna in Topology I

Figure 5 represents the proposed antenna for this research. This is a design of a planar antenna half-wave dipole in topology I with length $2l=55\text{mm}$ and width $w=3\text{mm}$ on the HFSS platform, it operates at 2.45 GHz. The substrate was chosen as the epoxy FR4 having a relative permittivity $\epsilon_r=4.6$ and a height of 1.6 mm.

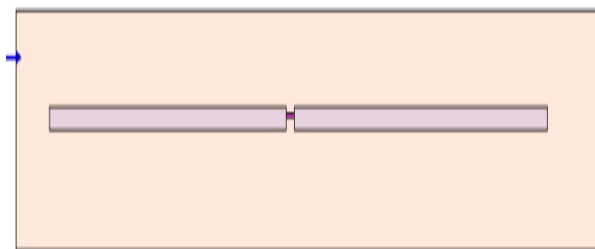


Figure 5. Planar Dipole Antenna in Topology I

The simulation of the planar dipole antenna that operates on the 2.45 GHz resonance frequency gives the following results in Figure 6. Figure 6 shows a minimal reflection at the resonance frequency equal to -24dB. The radiation pattern in two dimensions in the planes E and H is illustrated in Figure 7, having two main lobes.

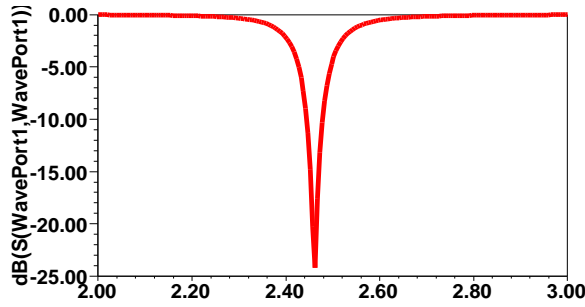


Figure 6. Return Loss of the Planar Dipole

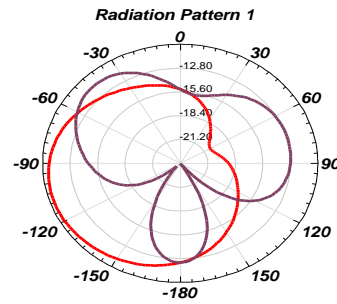


Figure 7. 2D Radiation Pattern of a Planar Dipole Antenna in the E & H Plan

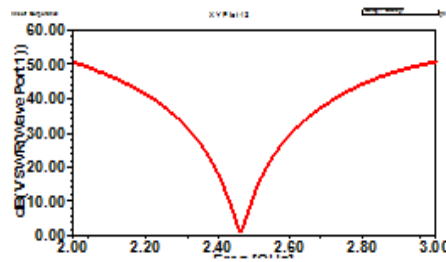


Figure 8. SWR of the Planar Dipole Antenna

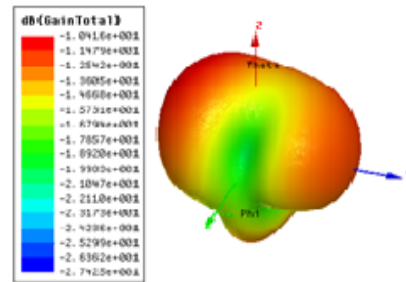


Figure 9. 3D Radiation Pattern

Figure 8 shows the SWR of the planar dipole antenna in topology I, $SWR=1.08 < 2$. Figure 9 represents the 3D radiation pattern shows that the antenna is omnidirectional according to the angle phi, and bidirectional according to angle Theta.

3.2. Antenna Planar Dipole in Topology L

For the design of the planar dipole antenna topology L, we chose the same type of materials, the same dimensions of the dipole antenna topology I, but with a folding at right angle of the right strand. Figure 10 shows the planar dipole antenna topology L using Ansoft HFSS:

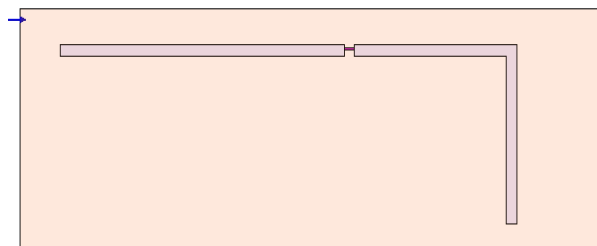


Figure 10. Planar Dipole Antenna in Topology L

Figure 11 represents a return loss is equal to -29 dB.

Figure 12 represents the SWR of this antenna is equal to $1.2 < 2$.

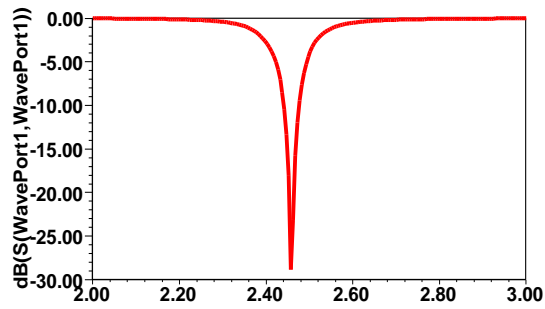


Figure 11. Return Loss of the Planar Dipole Antenna in Topology L

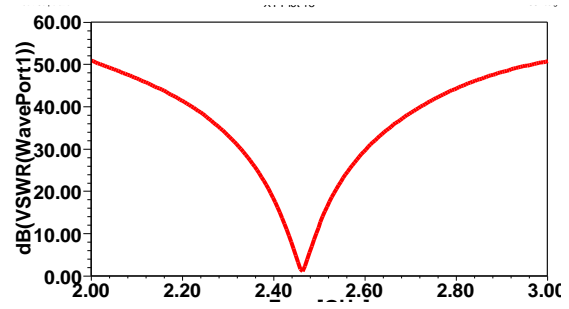


Figure 12. SWR of the Planar Dipole Antenna in Topology L

Figure 13 shows a 2D radiation pattern of the antenna in the S & H plan. Figure 14 represents the 3D radiation pattern has two main lobes. The antenna is omni-directional according phi is according Theta.

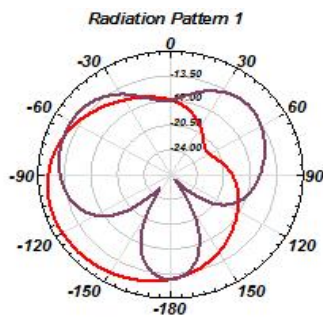


Figure 13. 2D Radiation Pattern

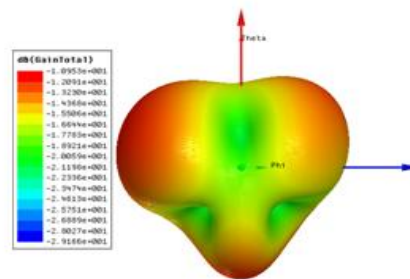


Figure 14. 3D Radiation Pattern

3.3. Planar Dipole Antenna in Topology Z

The design of a planar dipole antenna in topology Z is to fold the two strands of antenna. We chose the same type of materials used for planar antennas dipoles topologies I, L. The figure shows the proposed antenna on HFSS platform (Figure 15).

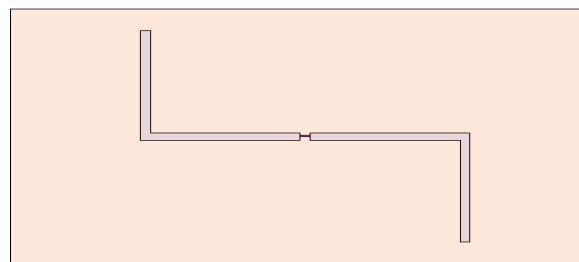


Figure 15. Planar Dipole Antenna Topology Z

The simulation results of this antenna that resonates at 2.45 GHz give in Figure 16. Figure 16 shows a return loss $S_{11} = -33$ dB. Figure 18 shows that the frequency 2.45 GHz we had a gain of 4 dB.

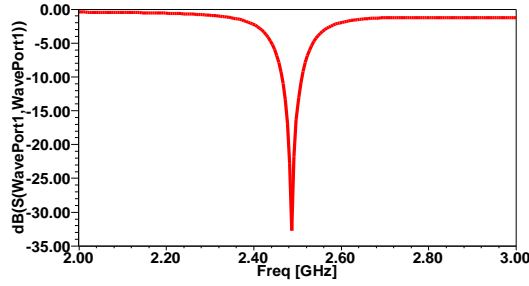


Figure 16. Return Loss of Dipole Antenna in Topology Z

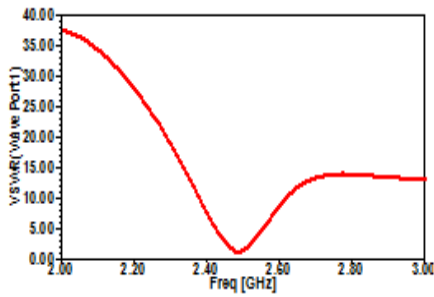


Figure 17. SWR of Dipole Antenna Topology Z

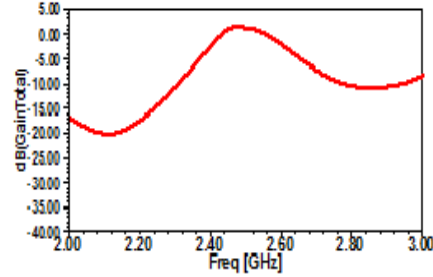


Figure 18. Gain of the Antenna Topology Z

Figure 19 shows a 2D radiation pattern of the antenna in the E & H plan

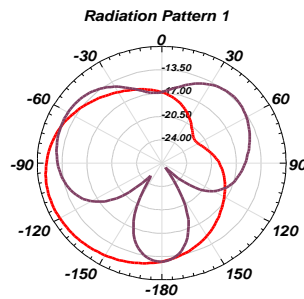


Figure 19. 2D Radiation Pattern

3.4. Planar Dipole Antenna Adapted with Technical T-Match

For the design of the antenna adapted with the T-match, we add to the dipole above a second folded dipole has two legs, as shown in Figure 18 as $l' = 10$ mm, $w' = 2.5$ mm (Figure 20).

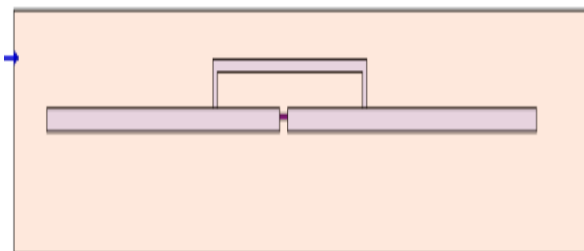


Figure 20. Suitable planar Dipole Antenna with Technical T-match

The simulation of this antenna with HFSS software gives the following results in Figure 21. Figure 21 shows that our antenna resonates at a frequency of 2.448 GHz with minimal reflection equal to -39 dB. The Figure 23 shows that the gain of the antenna adapted with the T-match technique is 4.5 dB. Figure 22 shows the SWR of antenna with T-match.

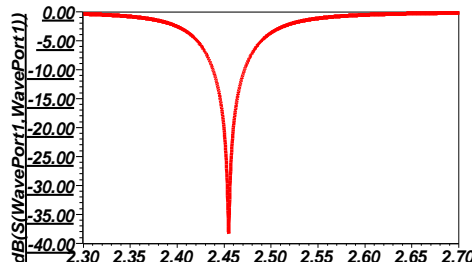


Figure 21. Return Loss of the Antenna Adapted with T-match

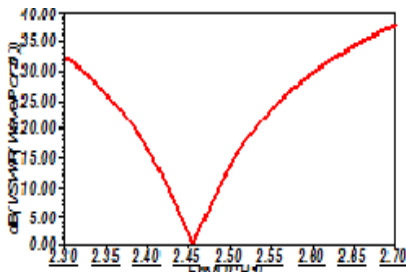


Figure 22. SWR of Antenna with T-match

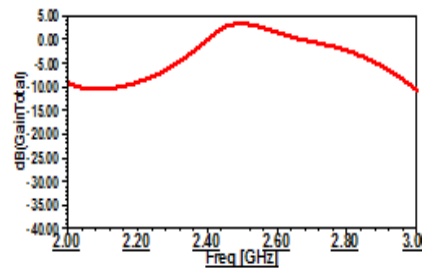


Figure 23. Gain of Antenna Adapted with T-match

Figure 24 shows a 2D radiation pattern in E-plane H, which has two main lobes. According to the simulation results, we note that antenna adapted with technical T-match with minimal reflection equal to -39 dB, and the return loss of the dipole antenna in topology I is equal -24 dB. This means that our antenna is suitable. Figure 25 shows a 3D radiation pattern. According to the simulation results, we have obtained satisfactory results as confirmed by the results found in the study [4].

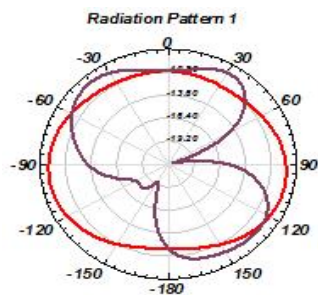


Figure 24. Radiation Diagram 2D

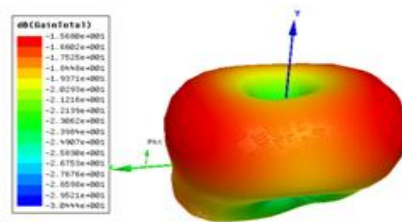


Figure 25. 3D Radiation Pattern

4. CONCLUSION

In this work, we presented the design of a planar dipole antenna, the potential of new topologies of linear dipoles have been exploited. Three topologies with particular geometries have made the subject of this presentation: the dipoles topology I, L and Z which operate at the frequency 2.45 GHz for RFID applications. Models of linear dipoles with folded arms allowed us to obtain almost uniform radiation patterns, and minimal reflection beyond -30 dB. In a second step, the study and design of a planar dipole antenna topology

I adapted with technical T-match, we added a folded dipole with two legs. The simulation tool used in this work is the software Ansoft HFSS, that give satisfactory results for our proposed antennas, minimal reflection with a reflectance exceeding -37 dB.

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