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# Compact 2*1 Reader Array Antenna Operating in ISM Band for RFID Applications

*Zakaria* El Ouadi[1], *Jamal* Amadid[1], *Asma* Khabba[1], *Abdessalam* El Yassini[1], *Saida* Ibnyaich[1], and *Abdelouhab* Zeroual[1]

[1]Instrumentation, Signals and Physical Systems (I2SP) Team,
Faculty of Sciences Semlalia,
Cadi Ayyad University,
Marrakesh, Morocco.

**Abstract.** This paper proposes a compact 2*1 reader array antenna for RFID system having high directivity, good gain, and good reflection coefficient. The structure consists of two main radiating rectangular patch antennas connected in parallel with a common impedance of (50 Ω). These patches are printed on an RT/duroid 5880 substrate possessing a dielectric constant $\boldsymbol{\varepsilon_r}$ equal to 2.2 and 0.0009 as a loss tangent. It operates in ISM (Industrial, Scientific and Medical) band with a resonant frequency of 5.8 GHz. The structure is implemented on a compact size of 38.77× 59.44× 1.6 $mm^3$ equivalent to an electrical size of $0.74\lambda_0\times 1.14\lambda_0\times 0.03\lambda_0$, where $\lambda_0$ is the free-space wavelength at the resonant frequency. The gain achieved by the final design of the proposed antenna is equal to 9.83 dB, the directivity is around 9.99 dB and the coefficient of reflection ($S_{11}$) is equal to -49.48 dB. The proposed antenna design is optimized and simulated using Computer Simulation Technology software (CST Microwave Studio).

## 1 Introduction

The technical needs for Radio Frequency Identification (RFID) systems have expanded in the industrial, scientific, and medical fields as a result of current wireless communication development around the world [1, 2]. Patch antennas can meet the demand for low-profile and low-cost antennas for RFID applications [3, 4].

RFID systems have become extremely popular in a variety of fields in recent years, because it facilitates the daily life of persons in different areas, especially in a distribution logistics and transportation, purchasing, industries, etc [5– 7].

RFID is a remote identification technique that makes use of radio waves to detect objects or living beings, it appeared in the 1950s after the first radio-frequency identification systems Identification Friend or Foe (IFF) used during the Second World War (WWII) to detect friendly aircraft from enemy aircraft [8].

For this technology, there are four different types of bands for RFID systems. We have the (LF) means Low Frequency between 125 and 134 kHz, 13.56 MHz is in the High Frequency (HF) range, 860 MHz to 960 MHz is for Ultra-High Frequencies (UHF), 2.45 GHz and 5.8 GHz in the microwave (MW) range [9, 10].

The RFID system is used to send data wirelessly, it is made up of three main components, the reader, the tag, and the host system which is a machine between the tag and the reader that allows the exploitation of the data [11–13]. A simple RFID system is presented in figure 1.

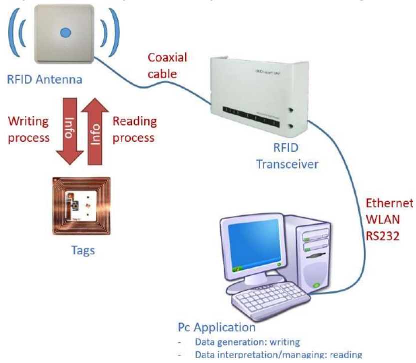


Figure 1. Simple RFID System

RFIDs are in fact seen as the gateway to the famous development phase of the information society, recognized by a commonly used name: the Internet of Things (IoT), in which the internet no longer only connects computers and communication terminals, but almost every object in our daily environment, such as clothes, refrigerators, cars, etc [14].

The association of the two technologies RFID and the Fifth-Generation (5G) in the Smart Factory permits simpler, faster, more supple and more secure following of products. We always require readers when we employ RFID labeling. When 5G-enabled readers become available, they will be able to connect directly to the 5G network. This will allow for a large increase in the number of reading points, possibly reading points for mobile devices, provide more accurate data, which can then be used to improve processes. In a networked factory, robots could be equipped with a reader and use it to collect product information or instructions.[15].

A small 2*1 reader array antenna working in the ISM band is suggested in this study for RFID applications, to improve gain, efficiency, and directivity, two rectangular patch antennas are arranged in an array.

## 2 RFID Patch Antenna Design

The proposed design is constituted of two rectangular radiating patch antennas printed on an RT/duroid-5880 substrate, which has a dielectric constant $\varepsilon_r$ = 2.2, a thickness (h) of 1.6mm, and a loss tangent of 0.0009. The structure of the simple antenna and the proposed 2*1 array antenna are shown in figure 2. The dense substrate (substrate has lower dielectric constant value) for good antenna performance, is the most desired, because it offers high efficiency, bandwidth, and fields that are loosely bound for the free space radiation [16, 17]. The values of the parameters of the single and the proposed antenna are shown in Table 1.

Table 1. Dimensions of the different parameters of the single and the proposed antenna

| Parameters | Dimensions (mm) | |
|---|---|---|
| | *Single Antenna* | *Proposed Antenna* |
| $W_{sub}$ | 39.44 | 59.44 |
| $L_{sub}$ | 28.77 | 38.77 |
| $W_p$ | 22.44 | 22.44 |
| $L_p$ | 16.54 | 16.54 |
| $d$ | - | 28.03 |
| $W1$ | 0.5 | 0.41 |
| $L1$ | 5 | 6.28 |
| $Wf$ | 4 | 4 |
| $Lf$ | 6.76 | 7.26 |

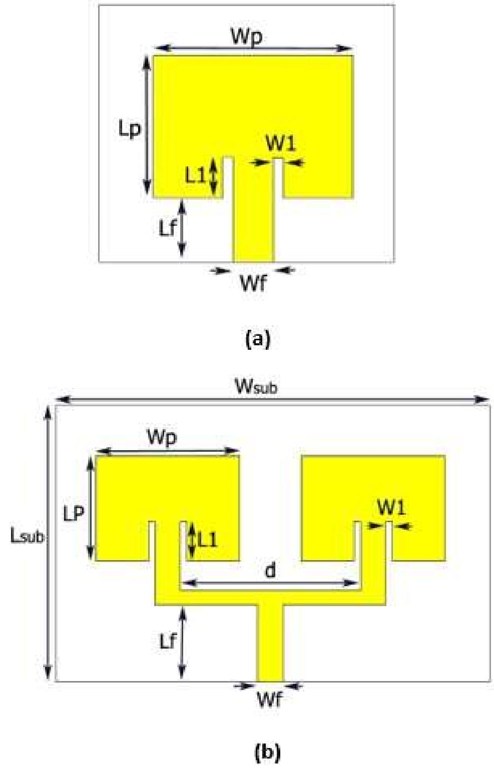


Figure 2. Evolution of the proposed 2*1 array antenna: (a) Single Antenna, (b) Proposed 2*1 Array Antenna

## 3 Simulated results for the proposed RFID Patch Antenna

The proposed 2*1 array antenna was simulated with the CST software, and the obtained results are compared to previously published papers in the literature.

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### 3.1 Reflection Coefficient

We can clearly observe in figure 3 that the minimum of reflected waves is obtained at the frequency 5.8 GHz.

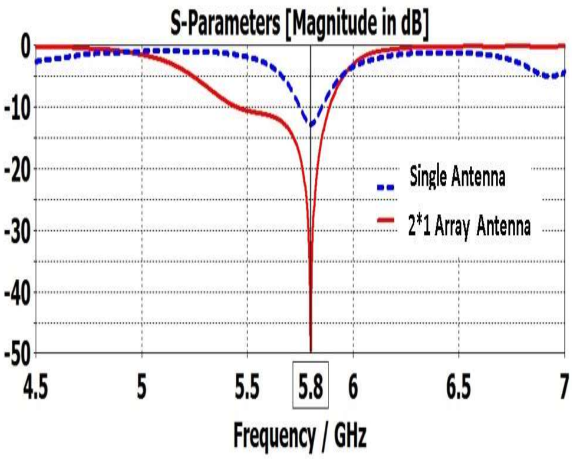



Figure 3. Simulated reflection coefficient of the patch antennas versus frequency

The obtained values of the reflection coefficient are $S_{11} = -49.48$ dB at 5.8 GHz for the proposed 2*1 array antenna and $S_{11} = -12.84$ dB at 5.8 GHz for the simple antenna.

### 3.2 *Zin* parameter

Figure 4 show the real and the imaginary part of the input impedance of the simulated patch antennas.

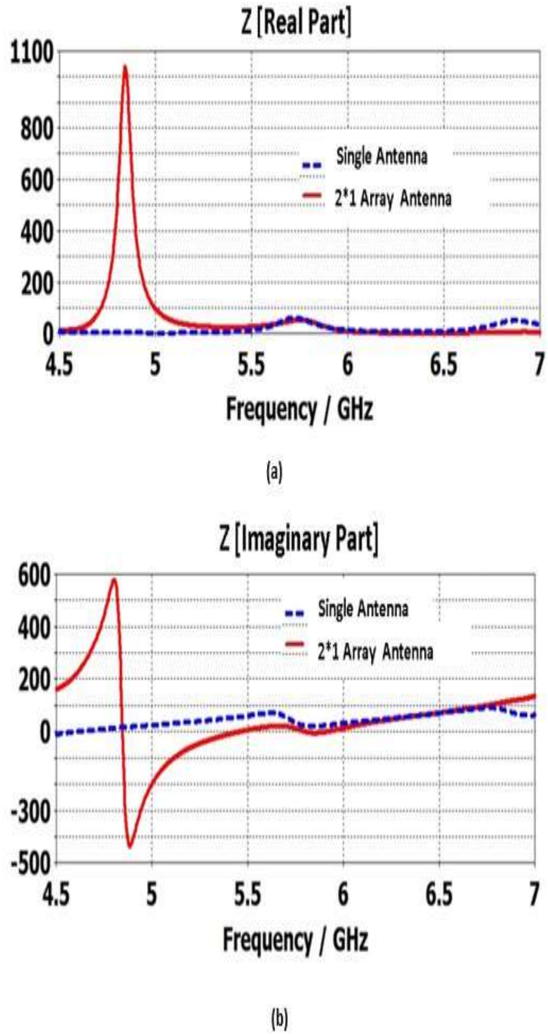



Figure 4. Input Impedance versus frequency for the single antenna and the proposed 2*1 array antenna: (a) Real part (b) Imaginary part

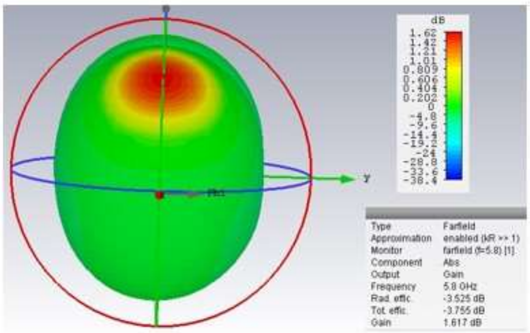
At the resonance frequency 5.8 GHz, the expressions of the input impedance of the single antenna and the proposed antenna are Zin = (46.15 + j22.15) and Zin = (49.68 − j0.11), respectively.

We remark in these expressions that, the Zin of the proposed 2*1 array antenna seems more suitable because its imaginary part is closer to zero and its real part is closer to 50 Ω.

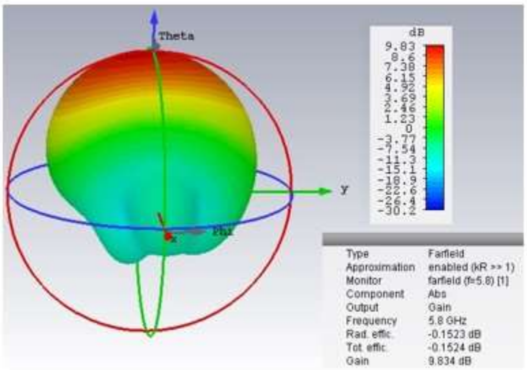
### 3.3 Antenna gain and Directivity

The simulated 3D view radiation pattern of the gain at the resonance frequency 5.8 GHz is depicted in figure 5 for the single antenna and the proposed 2*1 array antenna. Figure 6 is dedicated to the directivity of the single antenna and the proposed 2*1 array antenna.

It may be seen from these figures that the gain and the directivity of the proposed 2*1 array antenna are about 9.83 dB and 9.99 dB, respectively, while the single antenna has a gain of 1.62 dB and a directivity of 5.14 dB. Therefore, we can say that there is an improvement of these two performances.

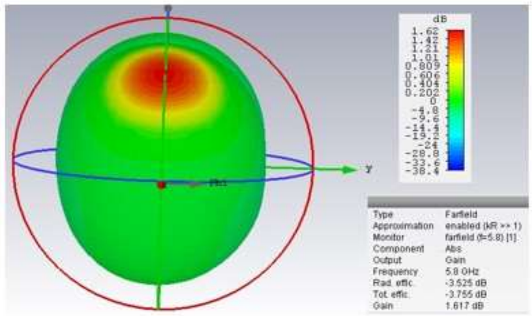



(a)

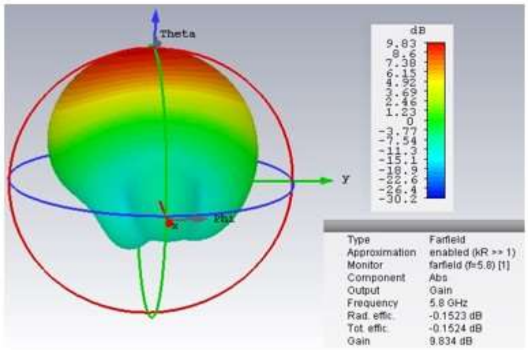



(b)

Figure 5. 3D radiation pattern (Gain) at 5.8 GHz: (a) Single Antenna (b) Proposed 2*1 array antenna




(a)




(b)

Figure 6. 3D radiation pattern (Directivity) at 5.8 GHz: (a) Single Antenna (b) Proposed 2*1 array antenna

### 3.4 2D Radiation Pattern

The simulated 2D radiation pattern at the resonance frequency 5.8 GHz in the E-plane and H-plane is presented in figure 7 and figure 8, respectively. The simulated results shows that the radiation pattern of the proposed 2*1 array antenna is omnidirectional in the E-plane and H-plane.

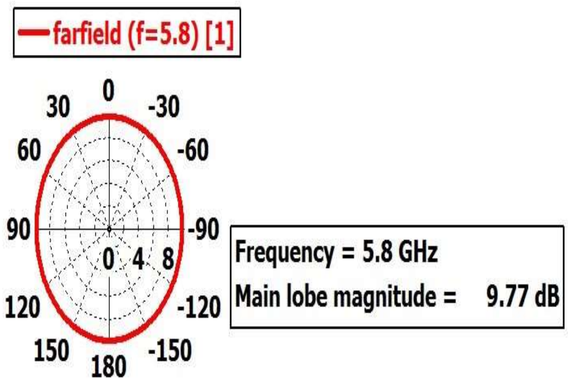



Figure 7. 2D radiation pattern: H-plane to that of the single antenna.

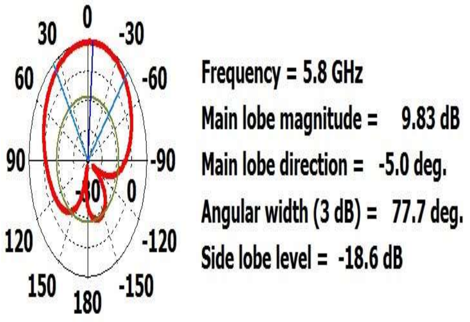



Figure 8. 2D radiation pattern: E-plane

### 3.5 2D Radiation Efficiency and Gain

Figure 9 show the simulated radiation efficiency and gain versus frequency for the proposed 2*1 array antenna.
We remark that, at the resonance frequency 5.8 GHz the gain is equal to 9.83 dB as we have seen in the 3D representation and the radiation efficiency is around 96.55 %.

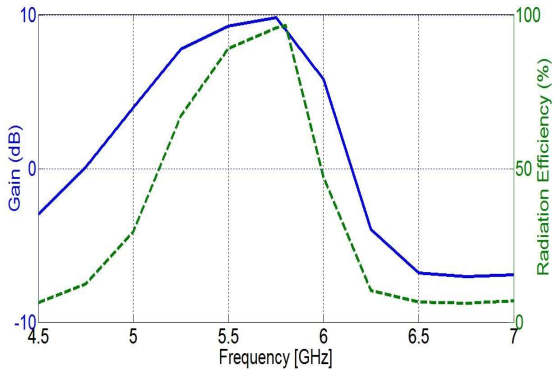



Figure 9. Simulated Gain and Radiation Efficiency versus frequency for the proposed 2*1 array antenna

### 3.6 Comparison

This proposed 2*1 array antenna was also realized by using ANSYS HFSS software which is based on the finite element method. Figure 10 shows the reflection coefficient simulated by this software.

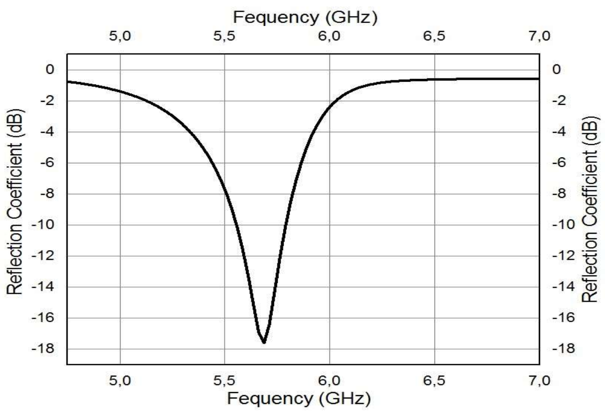



Figure 10. Simulated coefficient of reflection vs. frequency for the proposed 2*1 array antenna by using ANSYS HFSS

We can therefore comment that the obtained results with the ANSYS HFSS and CST software have the same shape of the curve but there is a difference in the value of S 11 and a small shift in the resonance frequency, this shift is due to the different calculation methods used by each software.
The obtained results of the proposed 2*1 array patch antenna are resumed and compared with other published papers in Table 2. We remark that the proposed antenna is compact and has achieved a good results in terms of gain and reflection coefficient. Noting that, in [18] the configuration used is a microstrip tree profile shaped Ultra-Wide Band (UWB) antenna with a partial ground plane. A monopole radiator with an inverted U form with expanded ground planes and a coplanar waveguide (CPW) feed line is presented in [19]. In [20] a co-planar waveguide-fed nonuniform radiator is designed, and the study in [21] presented a ground structure defected meandered line monopole antenna.

Table 2. Comparative study

| Antenna Parameters | *Fres* (GHz) | *Reflection Coefficient (dB)* | *Gain (dB)* | *Size ($mm^2$)* |
|---|---|---|---|---|
| Reference [18] | 3.2 and 6.5 | -27 and -16 | 2.63 and 4.2 | 27 × 40 |
| Reference [19] | 5.8 | -21.9 | 2.4 | 10.7 × 11 |
| Reference [20] | 0.963 | -23.7 | 0.5 | 50 × 60 |
| Reference [21] | 5.82 | -33.6 | 5.1 | 29 × 29 |
| Proposed Antenna | 5.8 | -41.76 | 9.83 | 38.77 × 59.44 |

### 4 Conclusion

In this paper, a 2*1 RFID reader array antenna has been suggested. This antenna is implemented on an RT/duroid- 5880 ($\varepsilon_r$ = 2.2). The obtained reflection coefficient ($S_{11}$) is around -49.48 dB, this implies that the quantity of reflected waves in our system is not excessive which is too suitable in the antenna field. Also for the input impedance of the proposed 2*1 array antenna its value showed a very good match compared to that of the single antenna.
The RFID reader is designed for the ISM band as well as in wireless communication with a good gain of 9.83 dB and a good directivity of 9.99 dB.

## References

[1] M. El Bakkali, M. El Bekkali, G.K. Sodhi, P. Singh, L. Kansal, *Crossed Dipole Antenna for RFID applications*, in *2021 International Conference on Computing, Communication, and Intelligent Systems (ICCCIS)* (IEEE, 2021), pp. 782–785

[2] P.P. Sahu, D.P. Mishra, T.K. Das, S.K. Behera, *Design of a Chipless RFID Tag for 2.4 GHz and 5.8 GHz ISM Band Applications*, in *2020 IEEE International Students' Conference on Electrical, Electronics and Computer Science (SCEECS)* (IEEE, 2020), pp. 1–4

[3] M.A. Al-Amoudi, International Journal of Applied Science and Engineering Review (IJASER) 2, 1 (2021)

[4] J. Colaco, R. Lohani, *Design and Implementation of microstrip patch antenna for 5G applications*, in *2020 5th International Conference on Communication and Electronics Systems (ICCES)* (IEEE, 2020), pp. 682–685

[5] R. Akter, M.J.H. Khandaker, S. Ahmed, M.M. Mugdho, A.B. Haque, *RFID based smart transportation system with android application*, in *2020 2nd International Conference on Innovative Mechanisms for Industry Applications (ICIMIA)* (IEEE, 2020), pp. 614–619

[6] S. Mohamed, K. Sethom, *Incorporating RFID Technology and IOT into a E-Commerce: A Step toward Intelligent Purchasing Processes*, in *2020 20th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA)* (IEEE, 2020), pp. 328–332

[7] W. Wanhua, *Design and Research of Logistics Distribution System Based on RFID*, in *Journal of Physics: Conference Series* (IOP Publishing, 2020), Vol. 1544, p. 012193

[8] L. Bowden, IEE Proceedings A (Physical Science, Measurement and Instrumentation, Management and Education, Reviews) 132, 435 (1985)

[9] K.S. Leong, P. Cole, *Dual-frequency antenna design for RFID application*, in *International Technical Conference on Circuits/Systems, Computers and Communications (ITC-CSCC 2006)* (2006)

[10] D. Kim, J. Yeo, IEEE Transactions on Antennas and Propagation 60, 2620 (2012)

[11] M. Takahashi, T. Nakajima, K. Saito, K. Ito, *Characteristics of wristband type RFID antenna*, in *Proceedings of the Fourth European Conference on Antennas and Propagation* (IEEE, 2010), pp. 1–4

[12] N. Vikram et al., *Design of ISM band RFID reader antenna for IoT applications*, in *2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)* (IEEE, 2016), pp. 1818–1821

[13] A. El Yassini, S. Ibnyaich, M.A. Jallal, S. Chabaa, A. Zeroual, *Design of an UHF RFID Tag Dipole Antenna for RFID devices*, in *2019 International Conference on Wireless Technologies, Embedded and Intelligent Systems (WITS)* (IEEE, 2019), pp. 1–4

[14] F. Bernardini, A. Buffi, D. Fontanelli, D. Macii, V. Magnago, M. Marracci, A. Motroni, P. Nepa, B. Tellini, IEEE Transactions on Instrumentation and Measurement 70, 1 (2020)

[15] M.B. Eunni, Ph.D. thesis, University of Kansas (2006)

[16] D.M. Pozar, Proceedings of the IEEE 80, 79 (1992)

[17] E.O. Hammerstad, *Equations for microstrip circuit design*, in *1975 5th European Microwave Conference* (IEEE, 1975), pp. 268–272

[18] A.Z. Hossain, N.B. Hassim, J.A.J. Alsayaydeh, M.K. Hasan, M.R. Islam (????)

[19] S. Bhaskar, S. Singhal, A.K. Singh, Progress In Electromagnetics Research 82, 89 (2018)

[20] M. Mansour, H. Kanaya, *Design of a Compact CPW Antenna Operating at the 920 MHz ISM/RFID Band*, in *2020 IEEE International Symposium on Antennas and Propagation and North American Radio Science Meeting* (IEEE, 2020), pp. 1315–1316

[21] T.K. Das, B. Dwivedy, S.K. Behera, AEU-International Journal of Electronics and Communications 118, 153130 (2020)