# A CPW-SIW Planar Dual-Band Antenna for ISM Applications

Radhoine Aloui[1], Zied houaneb[2], Hassen Zairi[3]
Research Laboratory Smart Electricity ICT, SEICT,
LR18ES44, National Engineering School of Carthage
University of Carthage.
Tunis, Tunisia.
[1]Radhoine.aloui1990@gmail.com [2] zied_houaneb@yahoo.fr
[3] hassen.zairi@gmail.com

Fermin Mira[1], Ignacio Llamas-Garro[2]
Centre Tecnologic de Telecomunicacions de Catalunya
(CTTC/CERCA)) Castelldefels, Barcelona,
Spain.Castelldefels, Barcelona, Spain.
[1]fermin.mira@cttc.cat, [2]ignacio.llamas@cttc.es

*Abstract*—**A dual-band low cost antenna for Industrial, scientific and medical (ISM) applications with circular polarization at 5.8 GHz is presented. The proposed antenna is excited through a single feed line connected to the patch. Two omni-directional radiation patterns are obtained for the two ISM bands. The proposed antenna is patterned on an RF30 rectangular dielectric (28 mm x 40 mm) with 1.52 mm thickness. The antenna exhibits a super-wide frequency bandwidth from 5.4 GHz to 6.4 GHz centered at 5.8 GHz, and 0.5 GHz bandwidth for the first resonance frequency, centered at 2.4 GHz. An improvement in return loss has been obtained by introducing a Coplanar Waveguide (CPW) feed implemented in Substrate Integrated Waveguide (SIW) technology. A prototype antenna is fabricated using standard PCB fabrication. Measured results show a good agreement between simulation and measured results.**

***Keywords- Dual-band; ISM antenna; Single layer; micro-strip; SIW technolgy.***

## I. INTRODUCTION

ISM-band antennas are a crucial component in sensor nodes, used for high quality data transmission in wireless sensor networks. A dual-band antenna made on a simple planar layer has the flexibility and simplicity required to be integrated into chemical sensors, operating at infrared wavelengths [1]. In previous years, researchers have been interested in developing the called Substrate-Integrated Waveguide (SIW) [2], a simple technology compatible with planar circuits with ease of integration with other components, thus with characteristics that can improve the performance or packaging of RF circuits. The SIW technology is compatible with rectangular waveguides and microstrip or CPW technology. SIW planar technology involves simple PCB fabrication techniques and has been used for ISM band applications [3]-[5]. Many passive circuits have been developed using SIW technology [6]-[10]. Highlighting antenna development, several multiband antennas have been presented in previous years for specific applications. In [11], an antenna for MIMO application works at a single frequency with two different modes of operation. A multiband multimode antenna can be found in [12]; the antenna design has a circular patch on the top of the structure, where a SIW cavity is used for the outer antenna, and includes a perpendicularly placed connector. The antenna has a degraded gain for the TM02 first mode and a high gain for other modes. A dual-band antenna working in the ISM band with low profile for body centric communications is presented in [13]; the antenna has low gain for the first band with an omnidirectional radiation pattern and an unidirectional radiation pattern for the second resonance frequency. The antenna uses two connectors perpendicular to the top patch.

In this paper, a planar dual-band antenna fabricated on a single layer of dielectric material is described in section II. The antenna includes a microstrip line and ground plane as shown in Figure 1. The proposed ISM antenna is used for wireless sensor data transmission. The two antenna frequency bands of operation can be independently tuned as discussed in section III, by adjusting the microstrip line dimension parameters, and the width of the ground plane. The measurement and simulation results are presented in section IV. Finally, section V provides a conclusion for this work.

## II. PROPOSED ISM ANTENNA STRUCTURE

The proposed antenna with and without CPW-SIW technology is composed of micro-strip lines patches, as shown in Figure 1. The designs can be connected using a simple SMA connector attached to the substrate side. The microstrip line is designed to resonate at the frequencies of 2.4 GHz and 5.8 GHz, as shown in Figure 2. RF30 material is used as the substrate, with a dielectric constant value of 3.35, loss tangent of 0.001, and substrate thickness of h=1.52 mm. The design of the microstrip patches is based on conventional theory. The width and length of the patch were calculated using the following standard expression [14].

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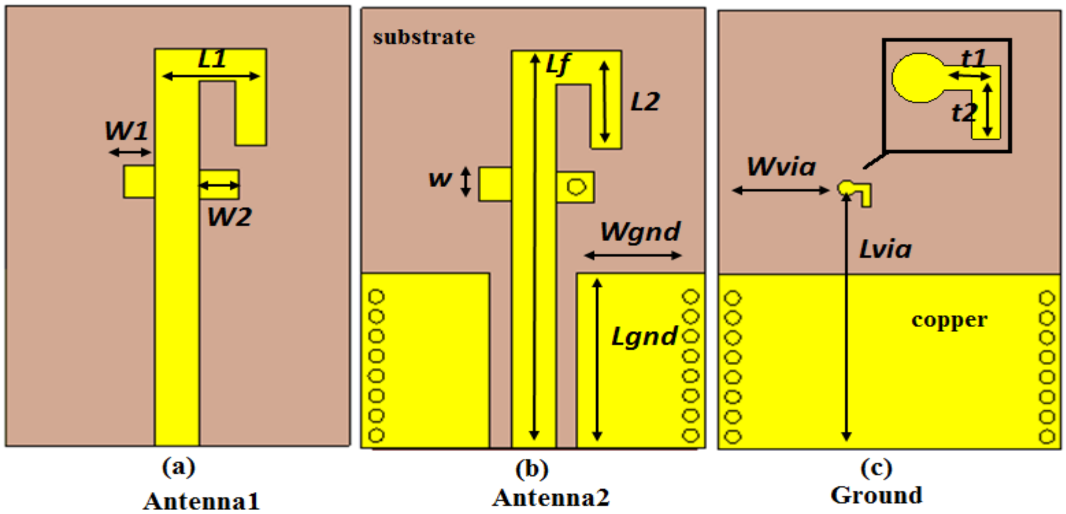


Figure 1. Proposed antenna, (a) Top view antenna without SIW, (b) Top view with SIW, (c) Bottom view.

$$Width = \frac{c}{2 f_0 \sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (1)$$

$$Length = \frac{c}{2 f_0 \sqrt{\varepsilon_{eff}}} - 0.824h \left[ \frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \right] \quad (2)$$

The proposed antenna is made on a sheet of low permittivity substrate with dimensions 28mm x 40mm x 1.52mm. Table I summarizes the design parameter value used to produce the antenna. In this paper, a single layer structure, with simple side interface with the connector is used. The proposed antenna involves microstrip lines, coplanar waveguide (CPW) and SIW technology. The bottom ground plane dimension must also be carefully taken into account to provide the desired band of operation.

TABLE I. DIMENSION OF STRUCTURE

| Parameters | $L_{gnd}$ | $W_{gnd}$ | L1 | L2 | Lf | W |
|---|---|---|---|---|---|---|
| Value [mm] | 24.2 | 10.4 | 9 | 8.8 | 34 | 2 |
| Parameters | t1 | t2 | $L_{via}$ | $W_{via}$ | W1 | W2 |
| Value [mm] | 1.4 | 2.05 | 22.15 | 10.2 | 3 | 3.7 |

The bandwidth enhancement technique and the VSWR results are demonstrated in the following section. The impedance matching at 2.4 and 5.8 GHz bands can be adjusted with the proposed structure, which was found to be effective in obtaining a high impedance bandwidth in the antenna's upper operating band.

## III. RESUSLTS AND DISCUISSON

In this part, an initial proposed antenna has been simulated and compared with the CPW-SIW technology antenna.

### A. *Initial design*

The proposed antenna is simulated using CST commercial software; CST software is based on the integral method (FDTD). Figure 2 shows a comparison between simulated results using the proposed antenna with and without using CPW-SIW. The dimensions of the microstrip radiating conductors and the ground plane in the bottom part of the antenna are shown in Figure 1.

Through numerical analysis, the reflection coefficient in the ISM bands in minimized, while the reflection coefficient is maximized elsewhere. According to the result in Figure 2, an improvement is obtained when the CPW-SIW structure is introduced. The VSWR is below 3 dB for the two ISM bands, centered at 2.4 GHz and 5.8 GHz. Figure 2 and Figure 3 show an improvement in results between the two antennas, according to the S-parameters and VSWR, obtained. From the simulation results of Figures 2 and 3, an impedance bandwidth with $|S11| < -10$ dB is obtained, with ranges from 2.2 to 2.9 GHz (30%) and 5.2 to 6.8 GHz (80%), where 19% VSWR is achieved. Fig.4 shows the improvement obtained when inducing the CPW-SIW structure in terms of radiation pattern at 2.4 GHz and 5.8 GHz. The maximum gain of the proposed antenna is approximately 3.4dB. The simulated spinning linear radiation patterns in two orthogonal planes (xoy and yoz) for the two resonance frequencies of 2.4 GHz and 5.8 GHz are plotted in Figure 4, respectively.

The radiation pattern shows an improvement when the CPW-SIW technology is used, with an omnidirectional radiation pattern at 2.4 GHz and an unidirectional one at 5.8 GHz.

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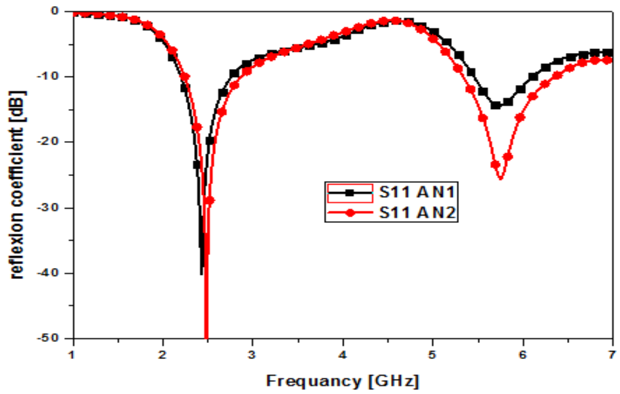



Figure 2. Reflexion coefficient comparaison.

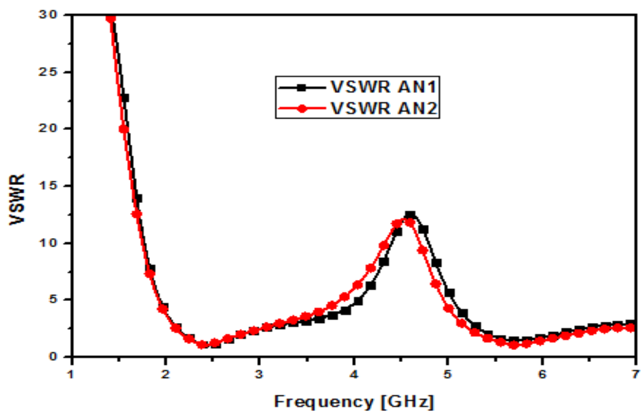



Figure 3. VSWR of the antennas versus frequency.

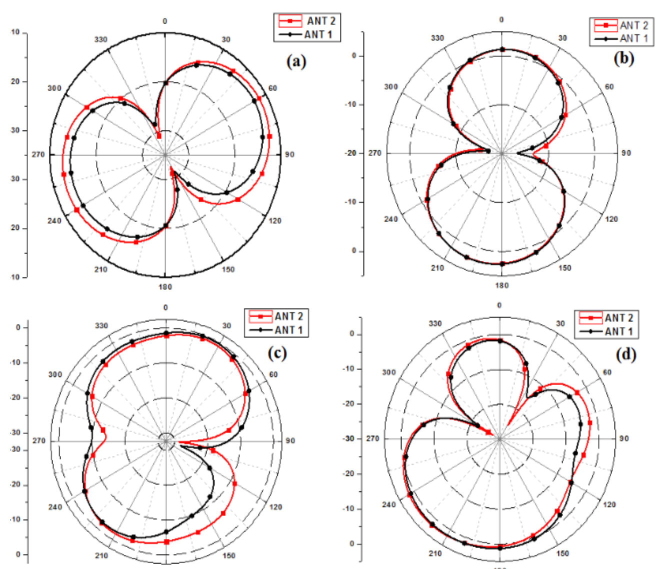



Figure 4. Radiation pattern (a) E field 2.4 GHz (b) H-field 2.4 GHz (c) E-field 5.8 GHz and (d) H-field 5.8 GHz

## B. *Band tuning technique analysis.*

Although the precedent design resonates at 2.4 GHz and 5.8 GHz exactly, the resonant frequencies are not independently tunable. A dual-band and dual-mode antenna is attractive and very useful when a single band frequency can be tuned to the desired frequency of specific applications, while keeping the other band fixed.

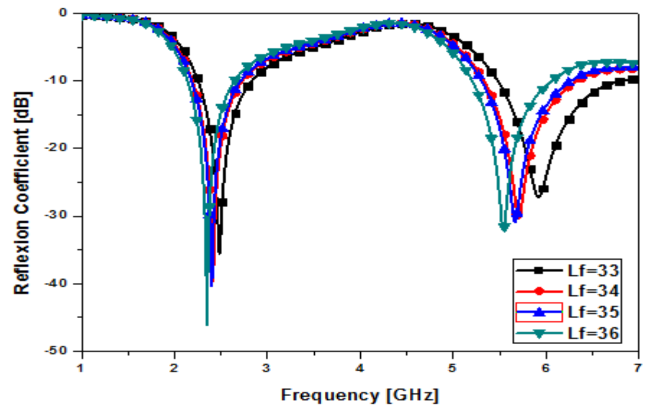



Figure 5. Reflexion coefficient versus $L_f$.

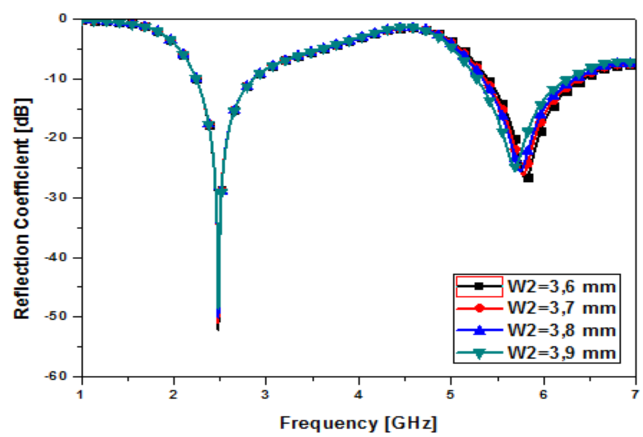



Figure 6. Reflexion coefficient versus $W_2$.

In this paper, to independently tune the resonant milti-band frequencies of the antenna, design parameters are varied as follows. Lf and W2 are the most important parameters for frequency tuning. Figure 5 shows the different reflection coefficients vs Lf parameters. This result illustrates that the two bands can be tuned at the same time, so it is not reasonable to adjust the two bands at once. On the other hand, we can tune the high resonance frequency (5.8GHz), where W2 can be adjusted to modify the second resonance frequency. Figure 6 showns the reflection coefficient versus frequency for different W2 parameters. Figure 5 and Figure 6 contain the reflection coefficients versus Lf and W2 parameters, respectively. Increasing the parameters produces decreased resonance frequencies. While, increasing W2 provides modifying the sencond resonance frequency independently, while the first resonance stays fixed.

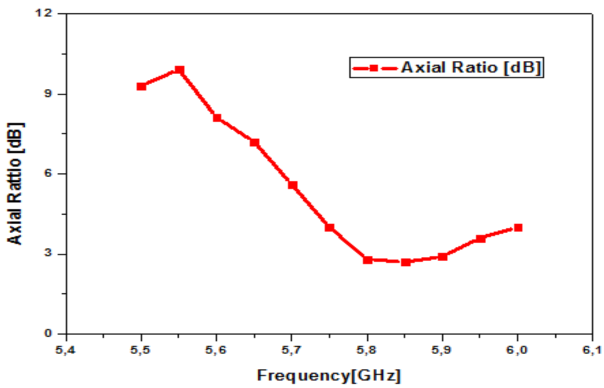
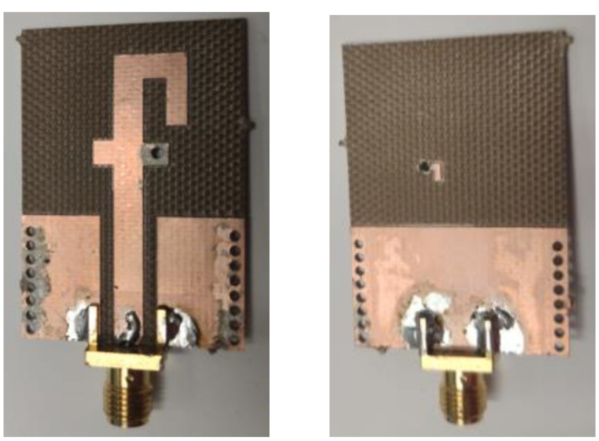



Figure 7. Simulated axial ratio versus frequency of the proosed antenna.

## IV. EXPERIMENT RESULTS

The proposed ISM antenna is simulated using CST studio software, based on FDTD method (integral method). The antenna was mesured in the frequency range from 2 to 6 GHz. SIW technology is used with vias having a diameter of 1.2 mm. The diameter of the vias hole at the microstrip line defining the antenna is 1.4 mm. The antenna prototype is fabricated and measured in an anechoic chamber after optimization performed through simulations. A photograph of the antenna top side is shown in Figure 8.



(a) (b)

Figure 8. Photograph of the antenna prototype (a) top side (b) bottom view

The simulated and measured reflection coefficient results are shown in Figure 9. The measured and simulated results show a good agreement, except for slight frequency shift at 5.8 GHz, which may be caused to the probe-feed position after fabrication, fabrication tolerances and soldering. The measured relative bandwidth for the first mode is 500 MHz. At 5.8 GHz, the bandwidth is 1000 MHz bandwidth. The bandwidths of operation are 8% and 20% at 2.4 GHz and 5.8 GHz, respectively. The simulated antenna gains are about 2.71 dB and 3.43 dB at 2.4 GHz and 5.8 GHz, respectively. Antenna radiation patterns are shown in Figure 10, corresponding to the frequencies of 2.4 GHz and 5.8 GHz. The antenna radiation patterns results show agreement between measurement and simulation, obtained for the two antenna bands of operation. For antenna measurements, an extended ground plane was used using copper tape.

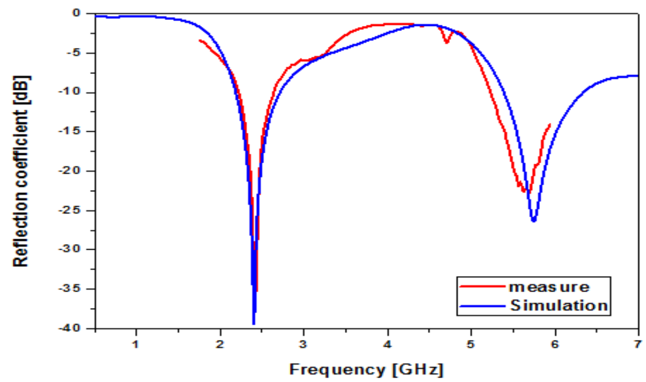
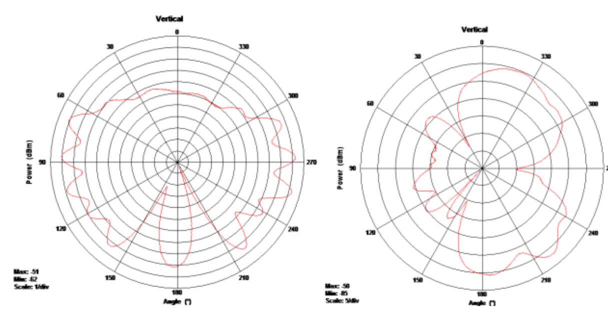
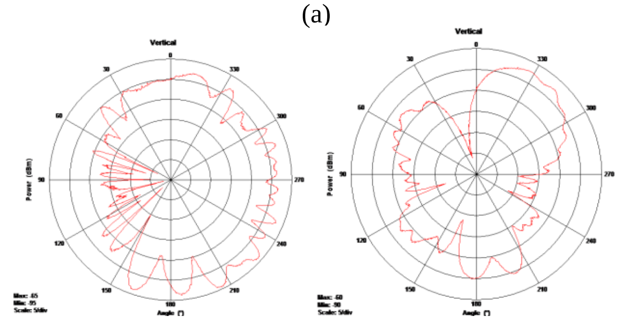



Figure 9. Simulation and measured reflection coefficient of the antenna.



(a)



(b)

Figure 10. Measured radiation pattern of the antenna (a) E-field and H-field at 2.4 GHz; (b) E-field and H-field at 5.8 GHz.

Table II shows a comparison among ISM antennas. The proposed antenna has good gain with bandwidths of 250 MHz and 1 GHz at 2.4 GHz and 5.8GHz, respectively. The proposed antenna exhibits circular polarization for the second resonant mode. Figure 7 showns the axial ratio for the frequency range from 5.4 to 6.1 GHz.

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TABLE II. ISM ANTENNA COMPARAISON

| Parameter | Frequency | [15] | [16] | [17] | [18] | Proposed antenna |
|---|---|---|---|---|---|---|
| Gain | F1=2.4 | 1.73 | 2.07 | 2.02 | 2.01 | 2.72 |
| [dB] | F2=5.8 | 5.4 | 1.17 | 4.06 | 3.45 | 3.22 |
| Bandwidth | F1=2.4 | 48.7 | 250 | 200 | 350 | 350 |
| [MHz] | F2=5.8 | 200 | 250 | 650 | 1000 | 1000 |
| Polarization | F1=2.4 | L. | L. | L. | L. | L. |
| Linear/Circular | F2=5.8 | L. | L. | L. | L. | Cir. |

## V. CONCLUSION

In this paper, a circular polarization, dual-band antenna for ISM band is reported. An improvement is achieved when using a coplanar waveguide at the input feed including an SIW structure. The CPW-SIW structure improves the antenna response S-parameters and gain. To be able to use this design for sensor networks, the proposed dual-band design can be independently tuned in frequency and bandwidth of operation. The planar antenna structure and its performance makes it a suitable candidate for integration with ISM applications and sensor nodes.

## ACKNOWLEDGEMENT

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