Wireless sensor nodes featuring single or double band directive antennas for agriculture applications

Nodos sensores inalámbricos con antenas directivas de banda simple o doble para aplicaciones en agricultura

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Martha Aurora Gonzalez Jaramillo ©
Universidad Distrital Francisco José de Caldas. Bogotá, D.C (Colombia)
magonzalezj@correo.udistrital.edu.co

Cesar Aníbal Echeverry Moreno ©
Universidad Distrital Francisco José de Caldas. Bogotá, D.C (Colombia)
caacheverrym@correo.udistrital.edu.co

Carlos Arturo Suárez Fajardo ©
Universidad Distrital Francisco José de Caldas. Bogotá, D.C (Colombia)
csuarez@udistrital.edu.co

Gustavo Adolfo Puerto Leguizamón ©
Universidad Distrital Francisco José de Caldas. Bogotá, D.C (Colombia)
gapuerto@udistrital.edu.co

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Abstract
Introduction—This paper presents the design of two wireless sensor nodes, with communication systems that integrate in one case a broadband antenna for operation in the 900 MHz and 2.4 GHz bands, along with a circuit that allows to select the appropriate radio for operation in some of these bands with the same antenna and the other makes use of a high gain antenna for operation in the 2.4 GHz band. The proposed design offers a solution to the problem of propagation of Radio Frequency (RF) signals in forests and plantations for applications in smart agriculture that make use of Wireless Sensor Networks (WSN).

Objective—Design of two wireless sensor nodes, with communication systems that integrate directive antennas in one case for operation in double band (900 MHz-2.4 GHz) and in the other with antennas of high gain (2.4 GHz) for applications in agriculture intelligent.

Method—The design of the wireless nodes makes use of the PSoC (Programmable Chip System) model CY8CKIT-059 5LP, which integrates temperature, humidity, inclination, distance, intensity of light and movement sensors that use ZigBee as a wireless communication protocol. The antennas are designed with appropriate electromagnetic simulators and the resulting prototypes from this process are characterized in impedance by means of a Vector Network Analyzer (VNA) and radiation patterns in an anechoic chamber. The full operation of the nodes is validated in the laboratory and in real spaces.

Results—The double-band node with logarithmic antenna allows packet transfer at distances of 4.1 km (915 MHz) and 938 m (2.44 GHz), along with a switching circuit that allows one of the bands to be selected depending on the propagation characteristics of the medium where the node will be installed. On the other hand, the node with SPA antenna allows transfer of packets up to 2.5 km (2.44 GHz). The antenna characterization results are as follows: The logarithmic antenna has a maximum gain of 2.74 dBi (915 MHz) and 3.06 dBi (2.44 GHz) respectively, with an impedance bandwidth of 3.196:1, for an $S_{11}$ < −10dB. The SPA antenna resonates at a center frequency of 2.44 GHz with a gain of 7.2 dBi; an impedance bandwidth of 16.8%, for an $S_{11}$ < −20dB.

Conclusions—This proposal improves the performance in wireless sensor networks since the approaches allow modularity, versatility and application in different areas including agriculture, enabling longer reaches and a more extensive coverage compared to the nodes that make use of conventional XBee antennas.

Keywords—Wireless Sensor Network (WSN); wireless communication; RF propagation; directive antennas, precision agriculture
I. Introduction

Wireless Sensor Networks (WSN) are systems with distributed nodes that have the capability to obtain, process, storage and exchange information through wireless links to a coordinator node. These nodes are autonomous devices that have as main components: a microcontroller, a power source, a radio-transceiver (RF) and sensors [1]. Sensor networks are used in applications such as domotic, automation, industry, agriculture, medicine, environment, traffic, among others [2]

The PSoC is a digital and analog electronic processing unit based on ARM Cortex microcontrollers family. This device has favorable features hard to find in conventional microcontrollers, such as: FPGA functionalities, block-hybrid programming and C code and low cost among others [3]

Currently, there are different sensor nodes that are differentiated by energy consumption, processing, number and type of ports, sizes and scopes [4]. The main commercial nodes are: Waspnnode by Libelium [5], Xbee IO Pro by Olimex [6], nodes Mica, Mica2, MicaZ, Lotus and Iris by Memsc [7], Imote by Crossbow and eZ430-RF2500 by Texas instrument [8]. These nodes have ranges of operation from 50 m to 1 km in the 2.4 GHz band with omnidirectional antennas. Most of wireless sensor nodes use monopole, dipole and chip antennas operating in a single frequency band (900 MHz or 2.4 GHz) with an omnidirectional radiation pattern and gains in the order of 0.6dBi to 2.1 dBi range [9], [10], [11]

The agriculture industry has started to use Wireless Sensor Networks (WSN) in environmental monitoring and surveillance, technifying crops and bringing them into the category of smart agriculture or precision agriculture. In agricultural plantation applications, WSN is used as a means of protection and control in real time, through which it is possible to detect diseases, as well as monitor soil temperature and humidity. In this context, wireless communications systems in WSN networks for applications in forests and plantations play a key role from coverage and link quality viewpoints, which requires solving problems such as propagation losses due to soil and the reflections caused by the treetops (canopy). In such a context, there have been identified several issues to tackle e.g. the propagation models in this type of environment [12]-[14], the efficiency of wireless technologies in various environments [15], the security in these networks [16], and radio diversity for reliable communication in WSNs [17] among others.

In addition, wireless sensor nodes based on omnidirectional antennas and amplifiers with low antenna power levels, have limitations in applications such as agriculture, due to the attenuation of signals in plantations and forests [12]-[14], limiting the effectiveness of such systems. Thus, this paper presents the design and fabrication of two wireless sensor nodes, one of them includes a logarithmic broadband antenna for operation in the 900 MHz and 2.4 GHz bands along with a circuit that allows to select the appropriate radio to operate in one of these bands and the other integrates a high gain Suspended Plate Antenna (SPA) for operation in the 2.4 GHz band which allows to configure a frequency and space diversity system for reliable communication in wireless sensor networks. Therefore, the two wireless sensor nodes for WSN applications aims at improving the communications performance while reduces the power consumption.

In this context, the corresponding RF system can be selected taking into account the environment, sensor network requirements and application. While the log periodic antenna enables long distance communication links in the 900 MHz band or shorter distances at 2.4 GHz, the proposed SPA antenna presents a higher gain than commercial antennas, therefore, both solution contribute to mitigate multipath signal loss, environmental fading and interference.

The first node consists of a power source, a set of sensors, a PSoC model CY8CKIT-059, a 2.4 GHz and a 900 MHz XBee radios, a low gain dual band log-periodic antenna and the switching system. Complete detail of a wireless sensor node design using log-periodic antenna is presented in [18]. The second node integrates a 2.4 GHz XBee module connected to the high gain SPA antenna, a PSoC model CY8CKIT-059 and a sensor kit. Both modules make use of the same power source and selection of the radiating system to use can be performed at any
time. Thus, the approach improves commercial wireless sensor nodes limitations in terms of communication link reach, processing, ease programming, configuration and interoperability with different sensors.

Additionally, in the first node, the communication system is managed through the PSoC, where two communication channels were programmed for two different XBee radios and an additional output to control a SPDT (Single Pole Double Throw) radio frequency switching system achieving a dual operation in 915 MHz or 2.4 GHz with the same antenna. The second node allows the RF communication with a single radio using a high gain SPA antenna at 2.44 GHz. Thus, it is possible to program two different devices and configure them to adapt the node depending on particular environment needs.

II. Methodology

This section describes wireless sensor node design including the sensors, PSoC features, the SPA and log periodic antenna design and prototype components.

A. Sensor and PSoC selection

Most of common low cost sensors used in different industries such as home automation, health, industry and agriculture were employed in the designed node and are listed in Table 1 [18].

<table>
<thead>
<tr>
<th>Sensor Reference</th>
<th>Manufacturer</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM35</td>
<td>Texas Instrument</td>
<td>Temperature</td>
</tr>
<tr>
<td>HIH-4000-002</td>
<td>Honeywell</td>
<td>Relative humidity</td>
</tr>
<tr>
<td>DTH11</td>
<td>Mybotic</td>
<td>Temperature and humidity</td>
</tr>
<tr>
<td>CMPS10</td>
<td>Robot-electronics</td>
<td>Compass and tilt</td>
</tr>
<tr>
<td>GP2Y0A02YK</td>
<td>SHARP</td>
<td>Infrared distance</td>
</tr>
<tr>
<td>Hc-SR04</td>
<td>ElecFreak</td>
<td>Ultrasound distance</td>
</tr>
<tr>
<td>GA1A2S100SS</td>
<td>SHARP</td>
<td>Light intensity</td>
</tr>
<tr>
<td>555 28027</td>
<td>Parallax</td>
<td>Movement</td>
</tr>
</tbody>
</table>

Source: Adapted from [18].

In the design of nodes for wireless sensor networks is usual to use microcontrollers as processing units due to their low power consumption, easy programming and low cost. However, these qualities can be found and improved by PSoC devices, which have features such as programming in analog and digital blocks (Flip-Flops, DACs, analog multiplex, etc.), routing capacity and internal hardware interconnections (analog routing), clock rates of up to 80MHz, all these features for approximately a $10USD price. The PSoC model CY8CKIT-059 5LP was chosen to perform the processing of analog and digital signals conveyed over different protocols [13]. The main features of this processing unit are shown in Table 2 [3].

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core</td>
<td>ARM Cortex-M3 · 32 bits</td>
</tr>
<tr>
<td>Speed</td>
<td>Until 80 MHz, 84 MIPS</td>
</tr>
<tr>
<td>Memory</td>
<td>Flash: 32 KB to 256 KB · SRAM: 8 KB to 64 KB</td>
</tr>
<tr>
<td>Peripherals</td>
<td>I²C, SPI, UART, LIN, CAN, FS USB 2.0, FS</td>
</tr>
<tr>
<td># Blocks</td>
<td>20 a 24 UDBs</td>
</tr>
<tr>
<td>Analog-Digital Blocks</td>
<td>'1 Delta-Sigma ADC (8 to 20 bits) 192 kbps @ 12 bits</td>
</tr>
<tr>
<td></td>
<td>'Until 4 DAC (8 bits)</td>
</tr>
<tr>
<td>Electric Consumption</td>
<td>'Operation: 2.7 V to 5.5 V · Active: 2 mA, Suspended: 2 μA, Hibernating: 300 nA</td>
</tr>
</tbody>
</table>

Source: Cypress Technologies.
Three different use modes were programmed, namely: Configuration mode, Demo mode (for testing), and Operation mode. The configuration is executed using a computer with RS232 serial data protocol or through a central node allowing remote configuration. In this context, the configuration and checking of the available sensors, the internal reference time, the individual node features such as the ID and the transmission state variables such as the battery level were transmitted using RS232 protocol.

The communication system is managed through PSoC where two communication channels were programmed for two different XBee radios and an additional output to control a SPDT radio frequency switching system achieving a dual operation in 900 MHz and 2.4 GHz frequencies with the same antenna. The user can also communicate through a single radio on the node using a high gain SPA antenna at 2.44 GHz. Thus, it is possible to program two different devices and configure them to adapt the node depending on particular environment needs.

Fig. 1 shows the flow diagram of the main logic programming on the PSoC. First, the RTC and UART were initialized, after that, the mode was selected: demo, operation or configuration. The transmission frequency was set through the configuration of the SPDT. Then, the chosen sensor is measured and finally the data is wirelessly transmitted and displayed to the user.

![Flow graph of the PSoC programming.](source: Authors)

B. Antenna Design

Design equations of SPA antennas are based on a microstrip patch, for this case a square patch is designed with electrical substrate characteristics, choosing the air, its dielectric constant is $\varepsilon_r = 1$, tangent losses $\tan \delta = 0$ and height $h$ corresponds to the optimal suspended space according to the frequency $(0.03 \lambda - 0.12 \lambda)$ [19]. For the SPA antenna design, is necessary a ground plane, a radiant plane, an excitation and supports of low relative permittivity [20]. The equations (1)-(5) are based on [21], [22], where (1) represents patch width $W$, (2) defines the effective dielectric constant $\varepsilon_{reff}$, (3) is the patch lengthening by edge effects $\delta L$, (4) represents the effective length $L_{eff}$ and (5) is the length of the patch $L$. In these equations represents the speed of light and $f_r$ is the central frequency.
Firstly, in the design process, the central frequency is established at 2.44 GHz, the reason is that XBee works in the Industrial, Scientific and Medical (ISM) spectrum band of 2.4 GHz - 2.4835 GHz. Based on the equations described above the corresponding values are calculated. Using parametric analysis on simulations, these parameters are adjusted: separation height \( h \), radiant patch width \( W \) and excitation point. It allows to obtain appropriate geometry for the best response in impedance coupling and gain. The final dimensions are: separation height \( h = 10 \) mm, length and width of substrate \( L = 55 \) mm, length and width of ground plane \( = 70 \) mm and excitation point is located in \((x = 5, y = 27.5)\). The prototype of the SPA antenna was made in 0.5 mm copper foil, using nylon screws in order to separate the plates and a 4 mm diameter and a 1.2 mm thick copper wire as feed point was selected.

The log periodic antenna design use equations (6)-(8), these are based on [18], [23]. In this context, (6) represents the scaling factor \( \tau \), (7) is the dipole length \( L_{\text{dip}} \) and (8) is the average impedance \( Z_a \). In these equations, \( f \) represents frequency, \( l \) length, \( w \) width, \( s \) spacing, \( \lambda \) wavelength, and \( n \) elements number. Calculated values are: \( \tau = 0.86 \) and \( n = 10 \). The dimensions of each element are:

\[
\begin{align*}
l_1 &= 65 \text{ mm}, \quad w_1 = 3 \text{ mm}, \quad s_1 = 33 \text{ mm}, \\
l_2 &= 56 \text{ mm}, \quad w_2 = 2.5 \text{ mm}, \quad s_2 = 28 \text{ mm}, \\
l_3 &= 48 \text{ mm}, \quad w_3 = 2.2 \text{ mm}, \quad s_3 = 24 \text{ mm}, \\
l_4 &= 41 \text{ mm}, \quad w_4 = 1.9 \text{ mm}, \quad s_4 = 21 \text{ mm}, \\
l_5 &= 35 \text{ mm}, \quad w_5 = 1.6 \text{ mm}, \quad s_5 = 18 \text{ mm}, \\
l_6 &= 30 \text{ mm}, \quad w_6 = 1.4 \text{ mm}, \quad s_6 = 15 \text{ mm}, \\
l_7 &= 26 \text{ mm}, \quad w_7 = 1.2 \text{ mm}, \quad s_7 = 13 \text{ mm}, \\
l_8 &= 22 \text{ mm}, \quad w_8 = 1 \text{ mm}, \quad s_8 = 11 \text{ mm}, \\
l_9 &= 19 \text{ mm}, \quad w_9 = 0.9 \text{ mm}, \quad s_9 = 10 \text{ mm}, \\
l_{10} &= 17 \text{ mm}, \quad w_{10} = 0.8 \text{ mm}, \quad s_{10} = 8 \text{ mm},
\end{align*}
\]

\[
\begin{align*}
\tau &= \frac{f_1}{f_2} = \frac{f_n}{f_{n+1}} = \frac{l_n}{l_{n+1}} = \frac{w_n}{w_{n+1}} = \frac{s_n}{s_{n+1}} \\
L_{\text{dip}} &= \frac{\lambda_{\text{max}}}{2} = 2l_1 \Rightarrow l_1 = \frac{\lambda_{\text{max}}}{4} \\
Z_a &= 120 \left( \ln \left( \frac{l_1}{w_n} \right) - 2.25 \right)
\end{align*}
\]
This antenna has two symmetrical layers and reflected patches top face feed with a lag of 180° with respect to the underside patch. A bias was used for connection between the layers. Finally, a prototype of the antenna was made using RF30 substrate. Both antenna prototypes were characterized in impedance and pattern using a Rohde & Schwarz ZVL13 vector network analyzer and the anechoic chamber respectively.

C. Prototype Integration

The node with the SPA antenna of square geometry has a total area of , in which its main components are included: PSoC 5LP, Xbee-Pro 802.15.4 S1, sensor terminals and 3V DC power with two AA batteries. The use of pigtail allows connecting and stacking the antenna on the circuit. The elements were organized in a chassis; batteries in the lower side of the chassis, PCB in the middle and antenna in the upper position.

The XBee chosen was the XBee-Pro 802.15.4 S1 that operates on 2.4 GHz-2.4835 GHz bands. It has a RPSMA connector, point-to-multipoint topology, long range, low power consumption, 18dBm transmission power, 250 kbps data rate and -100dBm sensitivity. Fig. 2 shows the wireless sensor node using a SPA antenna.

The wireless sensor node prototype with log periodic antenna occupies a space of 140 × 120 mm and has a quasi-triangle geometry, it is composed by a PSoC, an SPDT for frequency switching according to the environment and application requirements, two XBee devices: a XBee-Pro 802.15.4 S1 for 2.4 GHz band and a XBee-Pro XSC S3B for 900 MHz. The last one has 24 dBm transmission power, 20 kbps data rate and -109 dBm sensitivity. Besides, the prototype has two AA batteries and sensor terminals. Fig. 3 shows the wireless sensor node using a log periodic antenna [18].

In order to determine the maximum communication distance between the proposed nodes that make use of the directive antennas and a central node that makes use of a monopole antenna, it is established that the maximum separation distance between them is that at which the correctly received packets are lower than 100% of those sent. Finally, the communications performance of the wireless sensor nodes was assessed in a flat place featuring line of sight.
III. Results

This section presents the main outcomes of the proposed approach in terms of the node integration, antenna performance and comparison with current commercial solutions.

A. Node Results

Three operation modes allow the configuration, testing and monitoring in a quick and friendly way of the sensors and node characteristics through a RS232 connection. Fig. 4 shows the options of the configuration mode, Fig. 5 shows the data shown in the demo mode and Fig. 6 shows the results shown for the operation mode [18].

![Fig. 4. Configuration mode. Source: Adapted from [18].](image)

![Fig. 5. Demo mode. Source: Adapted from [18].](image)
The demo mode enables the user to test deactivated sensors by the configuration mode in order to know any eventual anomaly that is affecting the normal operation. In addition, it allows monitoring the other parameters previously mentioned. The information is displayed in an organized structure easy to read by the user. Finally, the operation mode displays the sensor and node information where the data units are sent as frames as shown in Fig. 6. Each frame shows the node ID, the date, the voltage of the node, followed by the sensor identification with their respective measured signal, e.g. sensor number 5 and sensor number 7 in Fig. 6. The use of frames facilitates reception, processing, storage in a central node and monitoring through an interface, as it will be used in a real environment [18].

B. Antenna Results

In this section, the results of the measurements carried out for various antenna parameters are described. Fig. 7 shows the measured and simulated reflection coefficient ($S_{11}$), in Fig. 8 is shown both the gain simulated and measured and in Fig. 9 the measured 2D radiation pattern is presented.
Fig. 8. Measured and simulated gain of the SPA antenna.
Source: Authors.

Fig. 9. Measured 2D radiation pattern of the SPA antenna at 2.44GHz.
Source: Authors.
The result for the log periodic antenna is shown in Fig. 10 where the reflection coefficient is depicted. Fig. 11 presents a simulated and measured comparison regarding the gain and Fig. 12 and Fig. 13 show the measured 2D radiation pattern for 2.44 GHz and 915 MHz respectively.

![Fig. 10. Measured and simulated reflection coefficient ($S_1$) of the log periodic antenna. Source: Authors.](image1)

![Fig. 11. Measured and simulated gain of the log periodic antenna. Source: Authors.](image2)
Fig. 12. Measured 2D radiation pattern of the log periodic antenna at 2.44 GHz. 
Source: Authors.

Fig. 13. Measured 2D radiation pattern of the log periodic antenna at 915 MHz.
Source: Authors.
As far as the SPA antenna results are concerned, a 16.8% bandwidth was obtained; this represents a 6.58% higher than the value obtained in the simulations. However, 7.2 dBi gain was measured as compared with 8.48 dBi simulated presenting a 15% of error. This antenna resonates from 2.18 GHz to 2.58 GHz at a reference of –10 dB. Finally, the S11 measurement was –14.94 dB at 2.44 GHz. The results for the log periodic antenna are better in terms of the obtained bandwidth. 3.196:1 was obtained in the experimental measurement and 3.048:1 was found in the simulations. A 3.06 dBi gain at 2.44 GHz and 2.74 dBi at 915 MHz was measured. This antenna operates from 869 MHz to 2.778 GHz at –10 dB reference, the measured S11 was –24.65 dB at 2.44 GHz and –15.17 dB at 915 MHz [18].

C. Reach

Results obtained regarding the transmission distance of the wireless sensor node are shown in Table 3. The table also compares the reached transmission distance of our approach with the transmission distance reported in the datasheets of commercial XBee radios.

<table>
<thead>
<tr>
<th>XBee Model</th>
<th>Frequency</th>
<th>Antenna</th>
<th>Gain</th>
<th>Reach</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZB S2B</td>
<td>2.44 GHz</td>
<td>Monopole</td>
<td>1.5 dBi</td>
<td>169 m</td>
</tr>
<tr>
<td>Pro ZB S2C</td>
<td>2.44 GHz</td>
<td>Monopole</td>
<td>1.5 dBi</td>
<td>115 m</td>
</tr>
<tr>
<td>Pro ZB S2C</td>
<td>2.44 GHz</td>
<td>Chip</td>
<td>0.6 dBi</td>
<td>85 m</td>
</tr>
<tr>
<td>Pro XSC S3B</td>
<td>915 MHz</td>
<td>Log-Periodic</td>
<td>2.7 dBi</td>
<td>4.1 km</td>
</tr>
<tr>
<td>Pro S1</td>
<td>2.44 GHz</td>
<td>Log-Periodic</td>
<td>3.0 dBi</td>
<td>938 m</td>
</tr>
<tr>
<td>Pro S1</td>
<td>2.44 GHz</td>
<td>SPA</td>
<td>7.2 dBi</td>
<td>2.5 km</td>
</tr>
</tbody>
</table>

Source: Adapted from [18].

D. Designed Node Comparison with Commercial Nodes

The main features of the approach presented in this paper are: significant increase in the transmission distance, multiple compatibility with dedicated sensors, possibility of including a large number sensor with different protocols and as a unique feature, the proposed node is the only one with simultaneous transmission at two different frequency bands. For comparison purposes, Table 4 and Table 5 describes the main features of the proposed approach (bold) against the characteristics of commercial solutions available on the market.

<table>
<thead>
<tr>
<th>Sensor Node</th>
<th>Antenna</th>
<th>Tx – Rx Frequency</th>
<th>Maximum Outdoor Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>WaspMote</td>
<td>Monopole RPSMA(Xbee)</td>
<td>Depend on Xbee</td>
<td>Depend on Xbee</td>
</tr>
<tr>
<td>Lotus</td>
<td>Half Wave Dipole</td>
<td>2.4 GHz</td>
<td>500m</td>
</tr>
<tr>
<td>IMOTE2</td>
<td>Half Wave Monopole</td>
<td>2.4 GHz</td>
<td>30m</td>
</tr>
<tr>
<td>eZ430-RF2500</td>
<td>Onboard Antenna</td>
<td>2.4 GHz</td>
<td>Approx. 50m</td>
</tr>
<tr>
<td>Designed at Double frequency</td>
<td>Log – Periodic bandwidth</td>
<td>2.4 GHz and 915 MHz</td>
<td>2,4 GHz: 1000 m 915 MHz: 4140 m</td>
</tr>
<tr>
<td>Designed at 2.4 GHz</td>
<td>SPA High gain and directive</td>
<td>2.4 GHz</td>
<td>2500m</td>
</tr>
</tbody>
</table>

Source: Authors.

TABLE 5. Technical specifications of WSN.
Sensor Node | Microcontroller | Sensors
---|---|---
Waspmote | Atmel ATmega 1281 | Compatible with 70 dedicated sensors.
“Lotus” | LPC1758 Cortex M3 32 bits | Dedicated: light, temperature, RH, barometric, pressure, acceleration, acoustic, magnetic and other Memsec.
IMOTE2 | ARM core Intel PXA271 | No dedicated sensors of I2c, AC97, JTAG and Camera Chip Interface protocols.
eZ430-RF2500 | TI MSP430F2274 | 3 dedicated sensors: temperature, humidity and light.
Designed at Double frequency | PSoC CY8CKIT-059 | 11 dedicated sensors and others with I2C, UART, SPI, One Wire, Digital I/O and Analog protocols.
Designed at 2.4 GHz | PSoC CY8CKIT-059 | 11 dedicated sensors and others with I2C, UART, SPI, One Wire, Digital I/O and Analog protocols.

Source: Authors.

**IV. Conclusions**

The wireless sensor node prototype designed with the SPA antenna at 2.44 GHz reached a 2.5 km communication link distance due to the 7.2 dBi gain and directive radiation pattern. This fact represents a significant achievement in the 2.4GHz band compared to commercial solutions. The sensor node with log periodic antenna reached the outstanding distance of 4.14 km at 915 MHz; this is attributed to the band frequency properties and antenna performance. The advantage of this approach relies on the possibility to operate on both frequency bands (2.44 GHz and 915 MHz) by selecting the appropriate band according to network and application needs. It was evidenced that the features offered by the PSoC technology facilitate the construction of sensor devices prototypes because it includes a large number of analog and digital peripherals that enables signal processing without additional components. This fact results in reduction of costs and space on implementations. The proposed node allows connecting an Xbee with log periodic or SPA antenna as a radiating element, the central processing unit based on the PSoC is configured by the user who can change the operation frequency evaluating aspects such as distance and interferences. This node represents an approach for an accessible device in terms of cost and configuration, contributing to the deployment of wireless sensor networks.

Wireless sensor nodes based on directive antennas demonstrate the feasibility to implement the frequency and space diversity as a solution to mitigate multipath signal loss, environmental fading and interference of signals in plantations and forests, improving the effectiveness of such systems for future smart agriculture applications.

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**References**


orcid.org/0000-0002-1460-5831

Carlos Suárez Fajardo

MSc. and PhD. degrees in Telecommunications from the Universidad Politécnica de Valencia (Valencia, Spain), for which he joined the electromagnetic radiation group (GRE) of the university. Currently holds the position of full Professor at the Universidad Distrital Francisco José de Caldas (Bogotá, D.C., Colombia). Up to date, he has published more than 50 papers in international journals and conferences in the field of antennas. His research interests include wideband and multi-band planar antennas, microwave engineering, metamaterial applications and small satellite communication systems. https://orcid.org/0000-0002-1460-5831
Gustavo Puerto Leguizamón. Telecommunications Engineer. In 2003, he joined the Group of Optical and Quantum Communications of the Universidad Politécnica de Valencia (Spain). Ph.D. in Telecommunications and postdoctoral researcher at the Institute of Telecommunications and Multimedia Applications at the same university until 2011. Currently associate professor at the Universidad Distrital Francisco José de Caldas (Bogotá, D.C., Colombia). Up to date, he has published more than 50 articles in international journals and conferences in the field of optical networks. He is evaluator of Colciencias and of the journals IEEE Journal on Lightwave Technologies, IEEE Photonic Technology Letters and Optics Express. His research interests include radio over fiber systems, optical networking and optical access networks. https://orcid.org/0000-0002-6420-9693