Augmented Circular UWB Antenna for Dual-Band WLAN and C-Band Communication in Military Mini-Drones

Abdelmaoula Bouaza and Rachida Touhami

Abstract−This paper presents a novel UWB circular microstrip antenna (UWB-CMSA) designed for handheld devices with a partial ground plane, achieving resonance from 1.5 GHz to 11.2 GHz. The antenna effectively covers various bands including GPS (1.575 GHz), DCS (1.71 - 1.88 GHz), PCS (1.85–1.99 GHz), UMTS (1.925 - 2.175 GHz), Bluetooth (2.4 GHz), LTE (2.5/2.69 GHz), WLAN (2.4/3.5/5 GHz), WiMAX (2.5/3.5/5.5 GHz), and X-band applications (8-12 GHz) encompassing satellite communication and military radar. The antenna exhibits good gain values (ranging from 2.45 dB to 5.5 dB) across these desired frequency bands and maintains high efficiency. The design was validated through fabrication and Vector Network Analyzer (VNA) measurements, demonstrating excellent agreement with simulated results. Uniquely, the antenna is shaped like the emblem of the Algerian Civil Protection Agency, allowing for seamless integration into their equipment (drones, communication devices, fire trucks, etc.). This integration enables diverse applications in the 1.5 - 11.2 GHz range, including identification, localization, and environmental monitoring in critical situations. Furthermore, the proposed design incorporates the Civil Protection emblem for potential performance enhancement when mounted on mini drones. CST software was employed for design and simulation purposes.

***Keywords*− UWB, GPS, WiMAX, X-band, WLAN, VNA.**

I. Introduction

Modern wireless communication systems utilize multiple frequency bands to achieve high data rates. This necessitates antennas with wide operating bandwidths. Multiband, wideband, and ultra-wideband (UWB) antennas accommodate diverse applications within a single antenna system. Cost-effectiveness is crucial; ideally, the chosen antenna (multiband or UWB) can be seamlessly integrated with the communication system. [1]. The emergence of UWB technology has captivated academia and industry since the Federal Communications Commission (FCC) allocated the 3.1-10.6 GHz spectrum for UWB communication applications in 2002 [2]. This extensive spectrum allocation has spurred significant interest in developing UWB technology for short-range wireless communication, imaging radar, remote sensing, and location confirmation applications.

UWB antenna design prioritizes three key objectives: high gain, wide operating bandwidth, and good radiation efficiency, all while maintaining efficient manufacturing processes. UWB antennas offer a distinct advantage over traditional narrowband systems –compact size and low profile [3]. Additionally, planar UWB antennas are favored for their thin profile, lightweight construction, and ease of manufacturing, making them well-suited for multimode communication systems [4].

Research has explored various antenna shapes for achieving UWB characteristics, including rectangular, circular, elliptical, and curved monopoles, as reported in [5-8]. Microstrip patch antennas offer design flexibility and can be realized in various shapes such as dipoles, squares, rectangles, triangles, circles, circular rings, ring sectors, and disk sectors. Circular patches are particularly advantageous due to their design flexibility, offering the highest bandwidth in GHz, acceptable loss characteristics, enhanced gain, and desirable electric and magnetic field patterns [9].

The integration of well-known logos into the design of patch antennas has recently attracted significant attention from researchers. This approach enables the antenna to serve a dual function: acting as a radiating element for communication over multiple frequency bands, while simultaneously maintaining the appearance of a conventional logo. Such logo-based antennas are particularly advantageous in military applications, where the logo is often already present on uniforms or equipment, ensuring visual discretion and reducing the likelihood of the antenna being identified, thereby enhancing camouflage capabilities [10-12].

Augmented antennas, or multifunctional antennas, are antennas that, in addition to their traditional functions of transmitting and receiving electromagnetic waves, integrate one or more additional features designed to enhance their performance and meet specific requirements [10]. These antennas may be tailored to function as Rectennas [13], sensor antennas [14], or aesthetically integrated graphic antennas [10-12].

This work presents the design, fabrication, and characterization of a novel circular Ultra-Wideband (UWB) patch antenna operating from 1.5 GHz to 11.2 GHz. This bandwidth encompasses both Wireless Local Area Networks (WLAN) and C-band applications. The antenna's design is inspired by the Algerian Civil Protection Agency emblem, facilitating seamless integration with their equipment, such as drones, communication devices, and fire trucks. This integration enables a variety of functionalities within the 1.5 – 11.2 GHz range, including identification, localization, and environmental monitoring during critical situations. The proposed antenna demonstrates satisfactory return loss (S11), gain, and radiation

Manuscript received December 3, 2025; Accepted June 28, 2026.

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Digital Object Identifier (DOI): 10.53907/enpesj.v6i1.356

efficiency. For potential use in military applications, the antenna can be mounted on a mini drone.

II. ANTENNA DESIGN

A. Evolution Of The Single Element Design

The fundamental antenna structure, designed using equations from references [1-5], is illustrated in Figure 1. The antenna is fabricated on FR-4 substrate material with a dielectric constant of 4.3, a loss tangent of 0.025, and a thickness of 1.6 mm, as shown in Figure 2. This configuration, known as a Circular Monopole Slot Antenna (CMSA), exhibits UWB characteristics from 2.4 GHz to 12 GHz, encompassing the essential frequency bands for various handheld device applications. Notably, the CMSA geometry serves as a foundational structure for further design enhancements.

$$F_{mn} = \left(\frac{cX_{mn}}{2\pi\sqrt{\varepsilon_{eff}}}\right) \quad (1)$$

where F_{mn} is the resonant frequency, c is the speed of light in free space, X_{mn} is the first-order Bessel function root, r is the radius of the patch, and ε_{eff} is the effective dielectric constant.

In a circular antenna, the TM11 mode is dominant and is given refer to (4), for ε_{eff} refers to (2). Equation (3) gives the effective radius (r_e) considered due to fringing fields [15-16]. Equation (5) gives the width of the feed.

$$\varepsilon_{eff} = \left(\frac{\varepsilon_r+1}{2}\right) + \left(\frac{\varepsilon_r-1}{2}\right)\left(1+\frac{12h}{w}\right)^{-\frac{1}{2}} \quad (2)$$

$$r_e = r\left(1+\frac{2h}{\pi r \varepsilon_r}\left(ln\frac{\pi r}{2h}\right)+1.7726\right) \quad (3)$$

$$F_{mn} = \left(\frac{1.8412c}{2\pi r_e\sqrt{\varepsilon_{eff}}}\right) \quad (4)$$

$$w_f = \frac{7{,}48h}{e^{\left(\frac{z0\cdot\sqrt{\varepsilon_r+1.41}}{87}\right)}} - 1{,}25\ T \quad (5)$$

where ε_r is relative permittivity, h is substrate height, w is the width, Z_0 is the single-ended impedance, and T is the trace thickness.

The evolution steps of the creation of the antenna are shown in Figure 1.

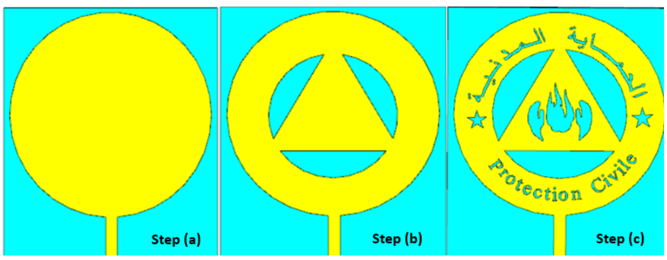

Fig. 1: Evolution steps of the proposed antenna

The structure of the proposed antenna is depicted in Figure 2, and all parameters of the proposed antenna are: Ls =65 mm, Ws = 56 mm, Lg = 11 mm, Lf = 11 mm, Wf = 3 mm, a = 28 mm, b = 15 mm, and c = 27.5 mm.

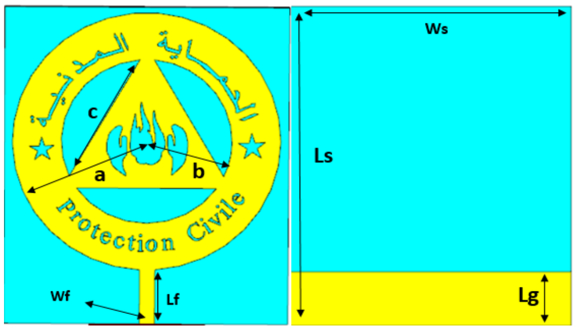

Fig. 2: Structure of proposed antenna: (a) Front view (b) Back view.

The initial design (Step 1) consisted of a simple circular monopole with a partial ground plane. This configuration produced a single two-wide band ranging from 1.7 GHz to 4 GHz. To achieve the UWB, a triple semi-circular slot was incorporated on the patch in Step 2. This element increased the current path length, resulting in UWB from 1.7 GHz to 11.2 GHz. Step 3 involved adding the shape of the Algerian Civil Protection Agency. This modification maintains the same frequency bandwidth.

B. SIMULATION RESULTS

The evolutionary stages of the proposed antenna design are presented in Figure 1. The simulated S_{11} results, obtained throughout the design process, are displayed in Figure 3. The simulated gain and radiation efficiency are shown in Figure 4.

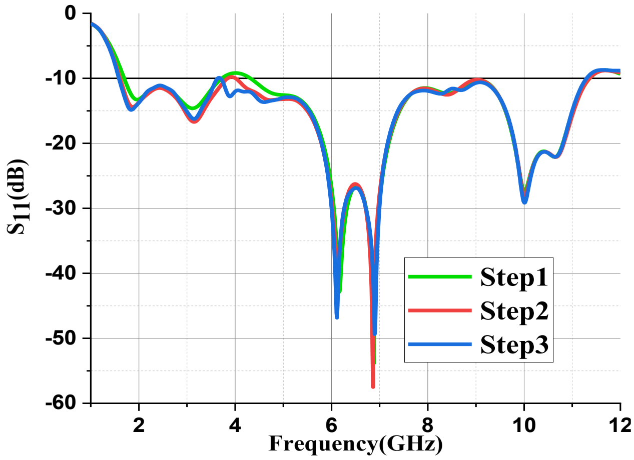

Fig. 3: Simulated S11 of the evolution steps of the proposed antenna

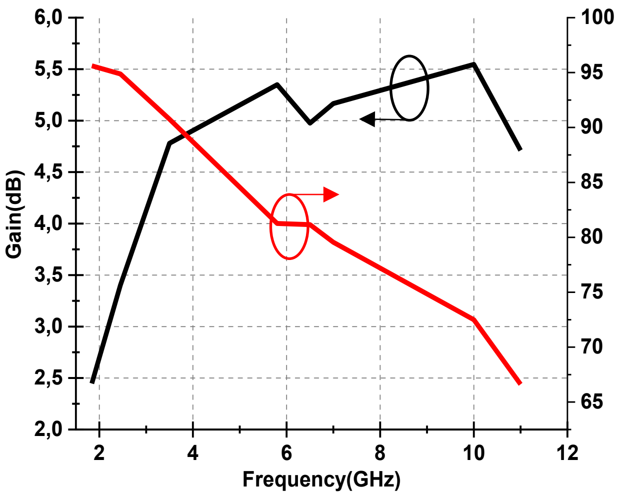

Fig. 4: Simulated Gain and efficiency plot of the proposed antenna

III FABRICATION, MEASUREMENTS, AND DISCUSSION RESULTS

The fabricated prototype is shown in Figure 5. The measured reflection characteristics of the proposed antenna are observed with the help of the VNA NA222A Network Analyser.

Fig. 5: Fabrication prototype of the proposed antenna.

The measured results exhibit good agreement with the simulated results, as shown in Figure 6, demonstrating a similar bandwidth.

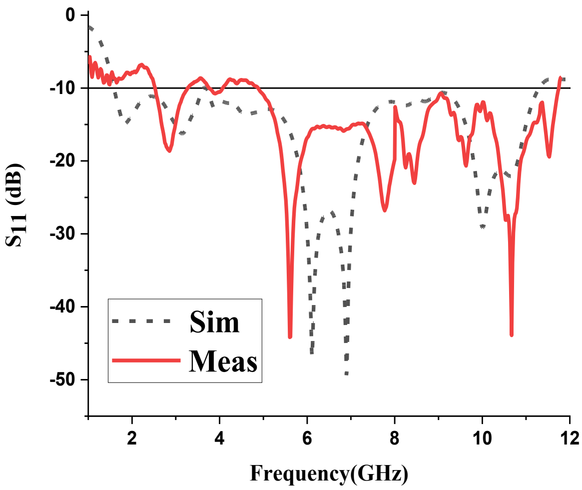

Fig. 6: Simulated and Measured Reflection Characteristics of the proposed antenna in free space.

The proposed prototype for integrating the antenna with the drone is illustrated in Figure 7.

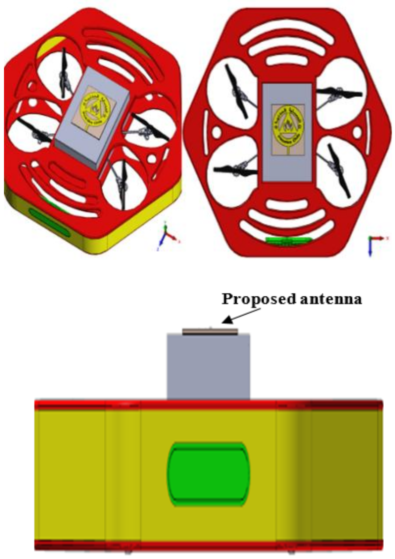

Fig. 7: Positioning of the proposed antenna on the drone.

As depicted, there is excellent compatibility between the antenna and the drone, making our antenna an ideal candidate for this application.

IV. CONCLUSION

This work presented the design, simulation, fabrication, and measurement of an ultra-wideband (UWB) antenna fabricated on FR-4 substrate. The antenna operates effectively from 1.57 GHz to 11.2 GHz, demonstrating good agreement between simulated and measured S11 results. It achieves good gain values (ranging from 2.45 dB to 5.5 dB) across the desired frequency bands while maintaining high efficiency. Furthermore, the antenna's design, inspired by the Algerian Civil Protection Agency emblem, facilitates seamless integration into their equipment such as drones, communication devices, and fire trucks. This integration enables diverse applications in the 1.5 – 11.2 GHz range, including identification, localization, and environmental monitoring in critical situations. Additionally, the antenna's high gain and broadband characteristics make it suitable for independent use in military applications requiring strong signal strength, such as radar and tracking systems, particularly within the C-band. This versatility underscores the antenna's potential as a valuable solution for various military applications.

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