

# Introduction to C-UAS Antenna Systems

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In recent years, a technology that until not long ago was almost unimaginable has become widespread: drones, that is, remotely piloted aircraft with no onboard pilot.

In 2025, the number of registered UAS (Unmanned Aircraft System) operators in Europe exceeded 2 million, compared to approximately 1.6 million in 2024, representing a growth of about 25% in a single year (Source: EASA). This demonstrates the increasingly widespread adoption of drones for professional and industrial applications.

The increase in drone usage has also raised new security challenges: the improper use of these devices, whether unintentional or intentional, can represent a threat to critical infrastructure, airports, public events, and even military operations.

For this reason, in recent years the field of counter-drone systems has developed, designed to detect, track, and neutralize potentially dangerous drones.

In this introductory article on counter-drone systems, we will describe these devices, focusing on the technical characteristics and the requirements that the associated antennas must meet.

There is no doubt that this particular application field represents the state of the art also in terms of the definition, design, and engineering of antennas with specific electrical, mechanical, and environmental requirements.



**COVER IMAGE:** Italian Army operator with an anti-drone "bazooka" guarding St. Peter's Square during the funeral of Pope Francis.

## 1. Introduction.

In recent years, the use of drones (UAV – Unmanned Aerial Vehicles) has grown exponentially, making them indispensable tools in numerous operational fields, ranging from precision agriculture to surveillance, logistics, and critical infrastructure management. Their ability to provide real-time data, support complex operations, and reduce operational costs has made these technologies a strategic resource.

However, the evolution of the sector has also raised new critical issues related to security and information protection. The unauthorized or malicious use of drones represents a concrete threat to privacy, the protection of sensitive areas, and the prevention of illegal activities such as clandestine surveillance or the unlawful transport of materials. For this reason, the need to implement effective countermeasure systems has become a priority for government agencies, companies, and high-risk infrastructure.

Counter-drone defense technologies, known as **Counter-Unmanned Aircraft Systems (C-UAS)**,

include various neutralization strategies, such as **kinetic measures** (projectiles, nets, laser weapons) and electronic solutions based on RF interference. In particular, **jamming** — that is, the controlled emission of electromagnetic signals to disrupt communications between the drone and its operator — represents one of the most effective and versatile solutions for the protection of strategic infrastructure.

In this article, we will examine the operating principles of counter-drone systems, analyzing their applications and the technical specifications that must characterize the antennas used in these devices. Finally, we will outline the advantages offered by a custom design, which is essential to ensure maximum performance in complex operational scenarios.

## 2. Fields of application.

Counter-drone systems are used in various contexts, both civil and military, to counter threats related to the improper or malicious use of these devices.

*Civil sector:*

- Protection of airports and airspace from unauthorized incursions;
- Protection of critical infrastructure (power plants, industrial facilities, data centres);
- Security of mass events and sensitive areas;
- Prevention of illegal activities, such as unauthorized surveillance and illicit transport of materials.

*Military and defence sector:*

- Protection of operational bases and strategic installations;
- Security of convoys and tactical units;
- Neutralization of drones used for targeted attacks;
- Support in electronic warfare operations.



**Figure 1**

*The use of low-cost drones, consisting of commercial products modified with additional batteries and explosive payloads, has created dramatic new scenarios in the war in Ukraine.*

### 3. Electronic counter-drone systems.

Electronic systems designed to safeguard the security of a given airspace from the intrusion of unauthorized aircraft can be either **DF** (direction finding) systems or **jamming** systems. In the first case, they are used to detect the presence and position of the drone; in the second case, they are used to neutralize it. A brief overview is provided below.

#### 3.1. Direction Finding (DF) systems.

*Direction Finding (DF)* technology makes it possible to accurately determine the direction from which the drone signal originates, enabling both the identification of the aircraft and the determination of its position, as well as other flight parameters such as direction, altitude, and speed. If necessary, kinetic or electronic countermeasures can then be deployed to neutralize the drone.

These electronic systems can be based on different principles relying on various types of sensors (radar, optical, acoustic).

DF systems that detect the radio transmissions between the drone and its ground operator are widely used, which, in the case of UAVs for civil use, generally occur in the 2.4 GHz band (flight control) and the 5 GHz band (video signal).

These systems are essentially of two types:

- a) Systems that decode the information contained in the radio signal transmitted by the drone, when not encrypted, and extract its navigation data. In this case, omnidirectional antennas are typically used.
- b) Systems that determine the drone's position based on the electromagnetic characteristics of the received signal (direction of arrival, signal strength, etc.), rather than on the information contained within it. In this case, directional or sector antennas are used, with mechanical or electronic scanning, acting as a spatial filter.

**Type (a)** DF systems are more compact devices and are often included in the product catalogs of drone manufacturers themselves, such as the well-known DJI. These systems are not always able to decode the signal transmitted by a drone, especially if the drone is intentionally used for malicious purposes, and therefore in such cases they may prove ineffective.

For this reason, **type (b)** systems are increasingly used, as they are potentially capable of detecting any UAV flying within the controlled airspace, regardless of the communication protocol used for the link with the ground operator. The combined use of multiple systems of this type, properly deployed along the perimeter of the area to be protected, also allows very accurate triangulation to determine the drone's position and flight parameters.



**Figure 2**

*Custom multiband DF system integrating both multi-sector elements and omnidirectional antennas within a structure specifically designed for the application.*

### 3.2. Jamming systems.

The so-called *jamming* technique generates electromagnetic interference on both the drone communication frequencies and the GPS positioning signals, inhibiting both the reception of flight commands from the ground operator and the GPS data required for *homing*, i.e., the activation of the automatic return-to-home function.

A more sophisticated technology used in the military field is **spoofing**, a technique that does not directly interrupt communications but instead manipulates them by sending counterfeit GPS signals. In this way, the drone is deceived about its actual position and is induced to deviate from its original route or to land in a controlled area. This technique is particularly useful in scenarios where it is necessary to divert a hostile drone without raising suspicion.

The most advanced electronic counter-drone systems incorporate both detection capabilities (*DF*) and the electronic countermeasures required to neutralize the drone (*jamming, spoofing*).

## 4. Antennas for counter-drone systems.

The practical implementation of these technologies opens up a very wide range of scenarios, as there are very different types of devices, such as fixed systems for the protection of sensitive locations, systems installed on land or naval vehicles, and even portable devices, such as the anti-drone “bazooka” shown in the cover image.

This implies the need to design and manufacture very different antennas on a custom basis, with well-defined electrical specifications and often integrated into hardware with stringent mechanical and environmental requirements. In fact, antennas used in counter-drone systems must meet extremely rigorous technical requirements to ensure effective threat neutralization, operating under variable environmental and operational conditions. The design of these devices requires an optimal balance between electrical performance and mechanical robustness, adapting to specific application requirements.

If we take the counter-drone systems described in the previous section as a reference, the electrical design criteria start from a set of initial requirements which, in this specific case, may include:

- a) *Omnidirectional antennas or sector/directional antennas;*
- b) *Antennas for DF-only applications and antennas for jammer applications;*
- c) *Frequency bands.*

To these are added mechanical and environmental requirements, which are generally:

- d) *Presence of mechanical and environmental constraints on the system dimensions;*
- e) *Integration into a multi-antenna structure that also houses the electronic subsystem.*



**Figure 3**

*Multiband jammer system employing numerous omnidirectional antennas mounted very close to each other: in this configuration, it is difficult to ensure perfect omnidirectionality for each operational sub-band, as well as satisfactory impedance matching.*

### 4.1. Electrical characteristics.

#### a) Omnidirectional or sector/directional antennas.

The ideal coverage of an anti-drone antenna is represented by the upper hemisphere, so as to effectively monitor any approaching airborne object. In the case of **omnidirectional antennas**, particular care must be taken in the design of a radiating element characterized by high rotational symmetry with respect to the vertical axis (z-axis). At the same time, it is necessary to consider the coexistence of multiple antennas operating over different frequency bands, so as not to distort their respective radiation patterns in the azimuth plane.

In systems that use multiple **sector or directional antennas** to cover all directions and thus determine the target's direction, it is necessary that the radiation patterns be free of side lobes, with a high front-to-back ratio (**Figure 4**). The integration of multiple sectors into a single structure with rotational symmetry about the z-axis must also ensure high isolation between two adjacent sectors; in other words, the antennas of each sector must not be affected by the proximity of the other sectors that are part of the system (**Figure 5**).

In both cases, the radiation pattern in the vertical plane must be able to cover almost all elevation angles. In this case, an up-tilt, either mechanical or electrical, can be implemented in order to limit the dispersion of energy toward the lower hemisphere.

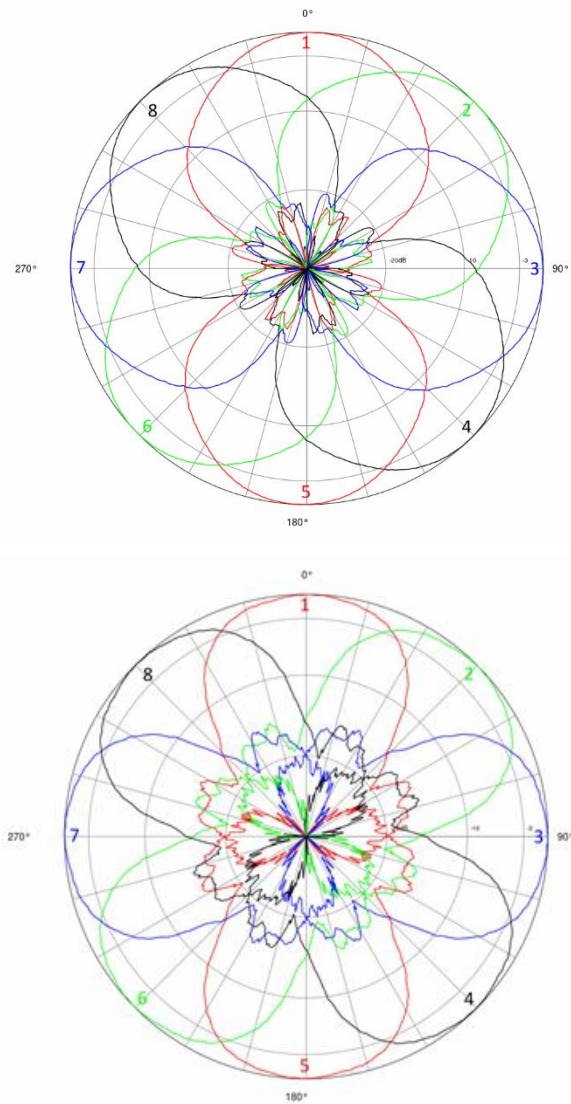
#### c) DF antennas and jamming antennas.

The definition and sizing of the radiating elements change significantly depending on whether the system is intended for DF-only operation or for a system that also includes a jamming function. In the first case, the system operates in receive-only mode, whereas in the second case it must also transmit a jamming signal with a power level on the order of several hundred watts.

#### c) Frequency bands.

In the civil sector, most counter-drone systems are multiband and operate in the 2.4 GHz and 5 GHz bands, whereas in military applications antennas must be designed to operate over wide bandwidths, with electrical characteristics such as impedance matching and beamwidth remaining as constant as possible across the specified portion of the spectrum.

In wideband systems operating over multiple octaves, for example from 700 MHz up to 6 GHz, the antennas can be conveniently divided into multiple sub-bands in order to ensure uniform electrical performance.



Radiation patterns in the azimuth plane of the multi-sector DF system shown in Figure 2, in the 2.4 GHz and 5 GHz bands.

## 4.2. Mechanical and environmental characteristics.

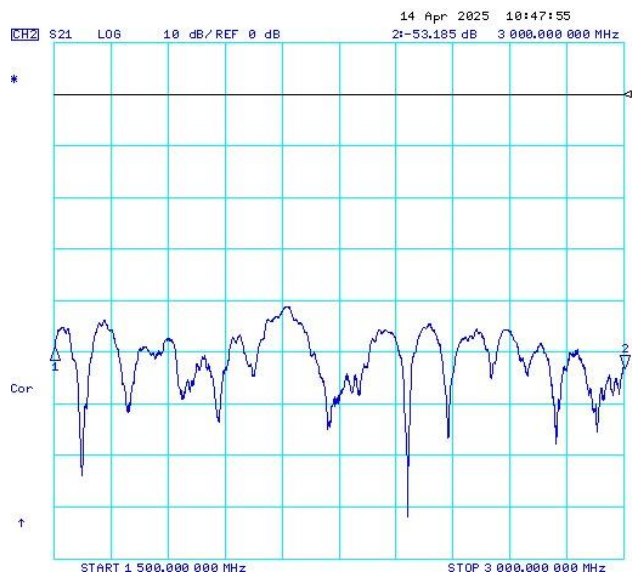
### d) Presence of mechanical and environmental constraints on the system dimensions.

The electrical characteristics described in the previous section must be implemented on antennas integrated into a system that meets specific mechanical and environmental constraints, particularly in the case of vehicular or even portable installations. It is not uncommon, in fact, that the electrical design of the radiating elements used in a given counter-drone system must start from considerations related to size, weight, and resistance to thermal cycling and vibrations.

### e) Integration into a multi-antenna structure that also houses the electronic subsystem.

Instead of using separate antennas mounted on a single mechanical support with exposed cabling, the current trend is to develop an integrated system within a single radome, containing both the antennas — whether omnidirectional or sector — and the RF and control electronics, along with the associated cabling.

In addition to greater mechanical reliability, the possibility of integrating all the system antennas into a purpose-designed structure allows optimization of their electrical characteristics that cannot be achieved with a system made up of discrete elements. It is therefore clear that a counter-drone system of this type also requires significant mechanical engineering work, in addition to the electrical design.



**Figure 5**

*Isolation between two adjacent sectors of a multi-sector DF/jammer system, in the 1.5–3 GHz sub-band: only through a purpose-designed integrated approach is it possible to achieve such high isolation levels.*

## 5. Advantages of a custom solution

The design of antennas for counter-drone jammers is a complex process that cannot be approached with a standardized methodology. There is no universal solution suitable for every operational scenario: each application presents unique variables that require a custom design in order to achieve maximum performance.

As in the development of any innovative industrial product, the design of custom antennas also requires the ability to adapt to the Customer’s requirements, both in terms of the initial design specifications and in anticipating potential issues that may arise throughout the entire operational life of the product.

The design of counter-drone antenna systems is characterized by a strong interdisciplinary component: it is necessary to take into account both the electrical specifications and the mechanical ones, related to the integration of the radiating system into a purpose-designed structure.

These two aspects are strongly interdependent, and therefore these custom products should be considered true integrated antennas, similar to those used in IoT devices. Compared to the latter, however, the electrical performance required for counter-drone systems is far more precise and demanding, and therefore the mechanical structure that houses them must be specifically designed for the application.

It can indeed be said that **in IoT systems the device houses the antenna**, whereas **in counter-drone systems it is the antenna that houses the device**.

For this reason, it is essential to rely on a company capable of handling both aspects of the project — electromagnetic and mechanical — with a centralized and unified product development process, unlike what often happens today in many interdisciplinary projects (**Figure 6**).

In fact, the analysis of mechanical and dimensional constraints leads to an initial outline of the system structure, providing the basis for identifying the radiating element configuration best suited to meet the electrical requirements across the entire operational frequency range. In particular, the accurate definition of radiation characteristics (beamwidth in the principal planes, side lobe suppression, and optimization of the front-to-back ratio) is essential to avoid unwanted interference and ensure maximum accuracy in targeting the jamming signal.

The mechanical design of the antenna therefore plays a key role in improving overall performance. For example, a customized structure can be designed to minimize radiation lobes in unwanted directions or to optimize isolation between different radiating elements, thereby reducing the risk of undesired signals and ensuring clean and effective operation.

From the experience gained through direct interaction with our Customers, it clearly emerges that attempting to implement jammer systems based on standard antennas rarely produces satisfactory results. Although they may represent a temporary or compromise solution, such antennas rarely guarantee the level of performance and reliability required in professional applications. Only a purpose-designed antenna allows the optimization of every technical and structural parameter, ensuring maximum control over system performance.

## 6. Conclusions.

Technological evolution has made drones increasingly widespread and versatile tools, with applications ranging from industry to security. However, their improper or malicious use represents a real threat to the protection of critical infrastructure, public safety, and information security. In this scenario, the adoption of effective defense measures has become a priority.

**Counter-drone jammer systems** offer a reliable solution to neutralize UAV threats by disrupting communications between the drone and its operator through **jamming and spoofing** techniques. While jamming degrades or blocks control and navigation signals, spoofing manipulates GPS coordinates, causing the drone to deviate from its intended route.

The effectiveness of these systems largely depends on the quality and design of the antennas used. A counter-drone jammer system requires antennas with highly precise technical specifications, which must be optimized according to operating conditions, frequency bands, and threat mitigation objectives. Factors such as beamwidth, side lobe suppression, isolation between radiating elements, and maximum power handling play a crucial role in the system's ability to ensure consistent and effective performance.

Given the complexity of these requirements, the use of **custom antennas** represents a strategic choice for obtaining tailor-made solutions capable of perfectly adapting to each operational scenario. Only through dedicated design is it possible to maximize the efficiency of the jamming signal, minimize unwanted interference, and ensure optimal integration with C-UAS platforms.



**Figure 6**  
*Final assembly stage of a custom wideband integrated multi-sector system.*



*All the information and experiences presented in this article are the result of the design, development, and production of custom professional antennas carried out by **ElettroMagnetic Services Srl** using the **AntennaCustomizer** method.*

*For questions, clarifications, or further information on this or other topics related to professional antennas, please contact [bollini@elettromagneticservices.com](mailto:bollini@elettromagneticservices.com).*

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