Expert Talk

Modern Counter Drone Systems – A Technology Review

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Introduction

Until recently, Drones and UAVs which were just a matter of curiosity, have fast become a critical part of military missions and low-enforcement operations. We are also witnessing commercialization of drones, as they are expanding their reach to oil and gas companies, news agencies, Survey Agencies, Land and Water resources protection agencies etc. However, the diminishing cost of drones and its easy access to public has resulted in a number of drones related incidents across the globe.

The ever-evolving electronics and communication technologies have made drones smaller and light-weight, while increasing their efficiency in terms of payload capacity, speed, guidance and navigation, manoeuvrability, and range. These developments, though in many ways beneficial, also pose several threats, not only to public safety but also to security of critical infrastructures, defence establishments and installations, communication network and law & order institutions. Anti-social elements and insurgent groups use advanced drones to carry out terror missions, smuggling, aerial surveillance at restricted/secured zones and public gatherings like sporting events, political rallies, etc. UAV swarm attack is another potential threat, wherein the formation makes it extremely challenging for security agencies to deter them in a arduous environment.

Law Enforcement and security agencies in our country strive to regulate and prevent these potential threats by adopting several measures. However, because of diverse frequency signature of drones and unavailability of an open source library for drone frequencies, it is a challenge to detect and neutralize these unmanned aerial vehicles effectively and efficiently.

Incidents that call for Attention!

Last couple of years witnessed a growing number of drone related incidents worldwide. Let's look at some of these critical incidents reported,

- **UK:** Following the reports of drone sightings close to the runway of Gatwick Airport, more than 1,000 flights were either cancelled or disrupted between 19th and 21st December 2018 impacting 140,000 passengers.
- **Saudi Arabia:** The world's largest oil processing facility and oil-field was set on fire by a drone attack. The raids led to the interruption in the production of an estimated 5.7 million barrels of crude, which is about half of the country's total production.
- **France:** Drones flew over the French Nuclear Power Facility in Normandy and dropped smoke canisters on the roof creating panic.
- **USA:** A mysterious swarm of 17 to 30 large drones were spotted in the skies of Colorado and Nebraska, consecutively for several nights creating uncertainty among people and local authorities.
- **India:** Arms & Ammunitions dropping incidents have been frequently reported at the northern borders using Drones
- **Spain:** Flights were disrupted for over an hour at Madrid International Airport after reports of drone sighting in Airport zone.
- **Germany:** Drone sightings at Frankfurt Airport resulted in suspension and diversion of several flights in May 2019 and March 2020.

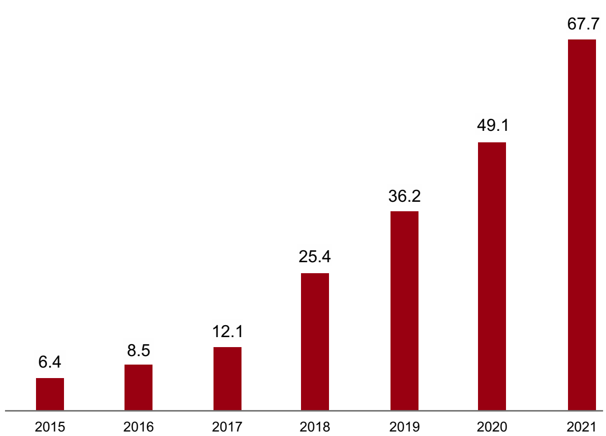


Figure 1 : Growth of Drones over the years

Moreover, as shown in Figure-1, the worldwide shipments of consumer Drones have steadily increased over the past five to six years. In 2021, these numbers are expected to hit 67.7 Million and eventually by 2025 it is expected to be 4.1 Billion. With the rise in Drone population, the adverse incidents are also bound to exponentially increase, and it is paramount for any government to protect its borders, assets and people from these potential threats. If gone unchecked, these threats may result in loss of many lives and immense financial implications to the state.

All the above discussed factors call for advanced C-UASs (Counter-Unmanned Aerial System) with rapid detection capabilities and sophisticated jamming and neutralizing technologies.

Counter-Drone Systems - Key Technologies

Counter-Drone Systems, also sometimes known as Anti-Drone systems or C-UAS, can be passive (simply looking or listening) or active (sending a signal out and analysing what comes back) and can perform several functions including,

- Detection
- Identification and Classification
- Locating and Tracking
- Generate Alerts and/or Trigger a Jamming System

All the above functions do not occur or trigger at the same time, however, these are a chain of functions that perform almost in real-time once a drone is detected.

There are several technologies that help detect a drone based on its distance, altitude, type, etc., the most common being Radars, optical sensors and acoustic sensors. These systems not only detect drones in the area of surveillance, but also detects birds, kites, other flying/floating objects and moving objects on ground. This is where Identification and Classification of objects come into picture. The system identifies various objects and classifies drones from the large clutter. Advanced C-UAS systems go one step further to even identify the drone detected by capturing its model, make, digital fingerprint, Radar signature, MAC Address (Media Access Control) etc. making it easy to trigger or deploy an appropriate counter-measure.

It is great to detect, identify and classify a drone, however knowing its exact location enables the system to deploy effective counter measures. Advanced C-UAS systems can not only locate the drones with precision, but also provides information such as speed, flight direction and help track them in real-time.

Drones have low Radar Cross Section (RCS) and relatively low speed - these characteristics make the task of detection challenging, and thereafter, identification and localization even more so. Several approaches can be adopted to detect these aerial systems. These methods or technologies can broadly be classified as:

- Radio Frequency (RF) Analysers
- Radars
- Video / Electro-optical (EO) Sensors (Cameras) and
- Audio / Acoustic Sensors (Microphones)

None of the above by itself can effectively detect a drone reliably. An effective drone detection system needs to be designed based on the coverage range, angle and the surrounding environment.
A multiple array of sensors with an overlapping coverage area in a layered architecture is the best and effective way of detecting the drones. Due to the rapidly evolving drone technologies, most military agencies are now embracing this multi-layered counter-measure approach, which offer higher detection ratios compared to the traditional systems.

RADIO FREQUENCY (RF) ANALYSERS

Almost all drones use radio signals for communication, command and control. They receive commands from the remote controller and send data such as video, images, telemetry (GPS/GNSS location, battery status) etc. back to the remote control/ground station.
RF Analysers consist of one or multiple antennas to receive signals and a processor to analyse the RF spectrum. They can be used in any type of environment, such as urban, hilly, noisy, forests, coastal, etc. to enhance and ensure airspace security. These RF sub-systems are designed to detect radio communication between a drone and its ground controller. Some RF Analysers can identify the drone make and model by analysing the waveform signature while some can even identify the MAC addresses of the drone and controller if they communicate over WIFI.
Advanced RF Analysers can also facilitate real-time mapping of drones and the remote controller.

There are several benefits of using RF Analyzers such as, relatively low cost, detects multiple drones at a time, identifies the drone signature, and importantly works in real-time. By deploying multiple RF Analyzers simultaneously, the user can triangulate drones and its controllers. Since they are passive equipment, no license is warranted by law-enforcement authorities.

Figure 2 : Radio Frequency Sensors

RF Analyzers have certain demerits though. If a drone is not using an RF sub-system (for instance, operating over 4G/5G mobile network or autonomous / pre-programmed drones), it will be totally invisible to an RF Analyzer. Moreover, RF Analyzers may also detect various other RF devices, such as WIFI routers, smart home appliances, industrial grade transmitters, etc. in the vicinity, making them less effective in crowded RF zones. Hence, RF Sensors alone may not be a reliable solution for drone detection.

RADARS

RADAR is another popular technology for the detection of drones. Currently, various C-UAS use 2D as well as 3D RADARS for accurate detection and location of drones.

2D RADARS are quite good and can detect most types of drones in the market. However, they cannot provide information about altitude of the target. In real life scenario, real-time tracking, accurate classification, and precise cueing of other sensors/sub-systems on the target is a challenge without the altitude information. For example, a 2D RADAR can probably detect a drone which is 500m away and 15 deg on left, but it might be a drone or another moving object on ground. On the other hand, a 3D RADAR could provide the very crucial altitude information as well. Hence the data from a 3D RADAR is more legible and usable. In addition, a 3D RADARS can also precisely cue the Camera or a Jammer towards the detected drone.

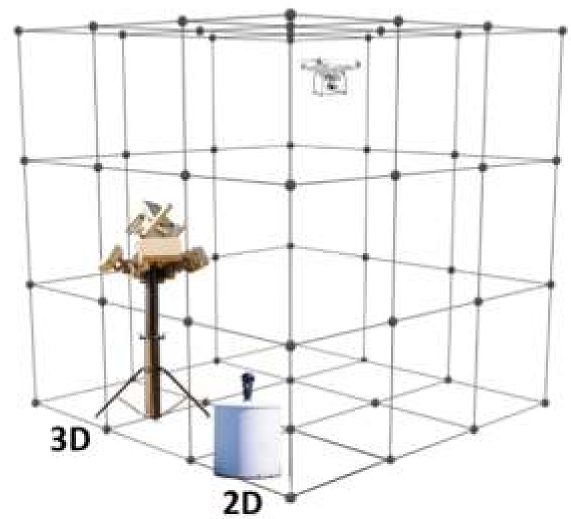


Figure 3 : Difference between 2D & 3D Radars

Active Electronically Scanned Array (AESA) Radars are a type of phased array radars which use multiple antennas in a two-dimensional array to transmit the same phase-shifted waveform, using the principle of beamforming. These AESA RADARS works more like a human eye, where you must sweep retina from one corner to the other to observe the entire picture. Multiple Input Multiple Output (MIMO) RADARS, on the other hand, can transmit different waveforms on all the antennas thereby working more like an eye of a fly, where you get the whole picture at once without any need of sweep. MIMO RADARS give amazing refresh rate, which dramatically improves detection and tracking, including swarms. It also helps in effective ground clutter removal.

Figure 4 : MIMO & AESA Radars

One of the challenges of using RADARS is that drone's low altitude, flight velocity, and very small Radar Cross Section (RCS) make them extremely difficult to distinguish from the noise or clutter. This can be overcome by deploying other sensors in the C-UAS.

VISUAL SENSORS & IMAGE PROCESSING

The Electro-Optical (EO) sensor (Bullet / PTZ / Thermal / Day-Night) Cameras combined with

Artificial Intelligence (AI) based image processing software enable the visual detection & classification of drones. Based on the number and types of cameras, EO sensor can cover a Field of View (FoV) from 30 deg to 360 deg. The EO-based systems provide dedicated cameras for detection, classification and tracking. EO sensors provide a visual evidence of drone's presence in the coverage region. These systems can be made fully autonomous, but their range is usually limited by the focal length and optical zoom capabilities of the camera's lens. Currently, cameras in the market provide a detection range of up to 2-3 Km, which may further reduce based on climatic conditions such as cloud, dust, rain or fog.

Figure 5: EO Sensor for Drone Detection

ACOUSTIC SENSORS

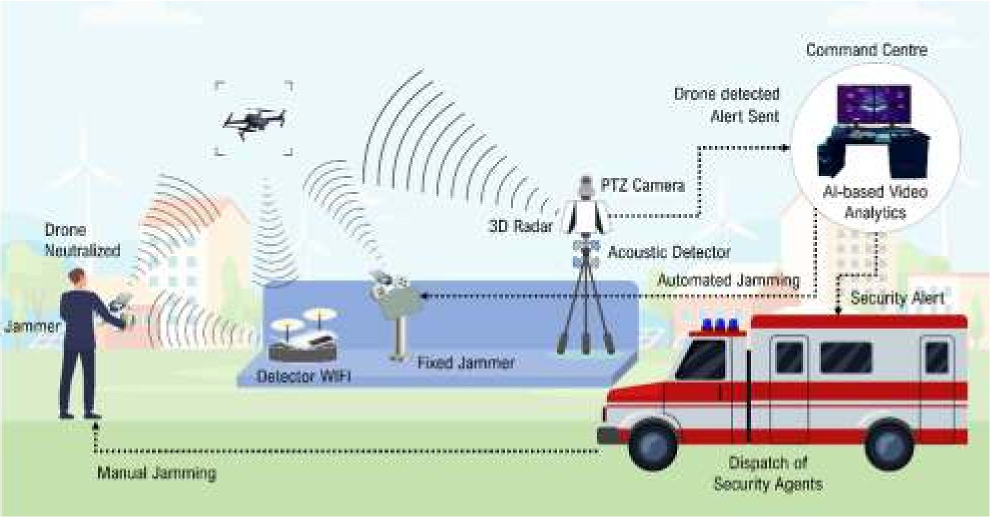
Acoustic Sensors are a microphone or an array of microphones, which detect the sound made by drone and calculate its direction. These sensors can be used whenever the radars line of sight is obstructed. The acoustic sensors cost relatively less, which makes it economically feasible.

Figure 6 : Types of Acoustic Sensors
(Photo Credit – APS & Squarehead Technologies)

Several arrays of microphones can be used for rough triangulation of the target. The acoustic sensors may not be ideal to locate the target, however, they can provide the direction of drone. They have several other limitations such as, inefficiency in noisy environmental conditions and short detection range (Max 300 - 500 meters), etc.

Conclusion

An effective and reliable Counter-Drone system needs to have all-weather detection, identification, classification, localization, tracking and countermeasure technologies along with an open C2 software, which allows integration of a wide variety of 3rd party sensors. The introduction of Artificial Intelligence is greatly enabling drone detection systems by increasing efficiency and reducing false alarms. Further, AI Algorithms provide the required intelligence for autonomous operation, thus reducing the dependency on humans to trigger a counter measure. An advanced C-UAS must have a minimum detection range of 10 kms, a combination of multiple sensors that include EO Cameras, Radar, RF Analyser, WIFI Detectors, Acoustic Sensors & Jammers, an extensive library of Drone Signatures, C2 Software integrable with the COTS sensors, along with continuous autonomous operation.



Counter Drone System Representation

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