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# Inhibition Systems for First-Person View Unmanned Aircraft

***Abstract*—Current anti-drone systems face rapid obsolescence. Commercial drones like DJI, with each new generation, integrate advanced video systems (e.g., OcuSync 4), making them undetectable to existing technology. Furthermore, custom-built First-Person View (FPV) unmanned aerial vehicles with analog video transmission are particularly difficult to jam and detect. These FPV systems not only evade current radars and jamming systems due to their high speed and agility but also make their location impossible to detect. Given these challenges, the use of Software Defined Radios (SDR) emerges as a viable solution for FPV drone detection and jamming. Although SDR devices with variable detection ranges exist (e.g., more economical ones operate between 25 MHz and 1.7 GHz without transmission capability, which is limited for the 900 MHz and 2.4 GHz dual control systems currently used in drones), others like the MicroPhase E200 (AD9363 versions from 325 MHz-3.8 GHz and AD9361 from 70 MHz-6 GHz) and the HackRF One (1 MHz-6 GHz) offer the necessary frequency ranges for effective detection and the possibility of transmission for jamming.**

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**Keywords—anti-drone, first-person view, jamming, security, software defined radio, unmanned aerial vehicle.**

## I. INTRODUCTION

There is a wide variety of First-Person View unmanned aerial vehicles, in this case, the focus is on quadcopter-type aircraft, known as FPV drones. Unmanned aerial vehicles of this type and fixed-wing aircraft are completely changing our perspective on geopolitical, social, and military issues. A drone costing between $2000 to $4000 dollars, or even less, can save many lives or cause a catastrophe. In Mexico and many Latin American countries, there is no regulation for these aircraft, although this is quite a complex issue as it is difficult to determine who owns such an aircraft. This is because FPV drones are open source, which is great for amateur pilots interested in the hobby, but dangerous for people with malicious intentions. These aircraft are composed of:

- Brushless motors
- ESC (Electronic Speed Controllers)
- FC (Flight Controller)
- Receiver (ELRS, TBS Crossfire, Immersion RC, among others…)
- VTX (Video Transmitter)
- 2.4GHz and 5.8GHz Antennas
- Analog Camera
- Lithium battery (3S, 4S, 6S)

Some FPV drones have GPS and can be controlled from anywhere in the world using the open-source Ardupilot firmware.

In the state of Michoacán, there are more attacks with DJI drones by criminal groups than in any other state in Mexico. These commercial drones are modified to carry release mechanisms for explosive devices, causing terrorist acts. Sooner or later, these criminal groups will get their hands on FPV drones, turning them into kamikaze aircraft. Authorities are trying to counteract these attacks using anti-drones, as shown in Figure 1.0; however, they still lack the necessary capacity to prevent these attacks. They also use some DJI brand drones and fixed-wing drones.

Therefore, it is necessary to have these types of systems to prevent these terrorist events in Mexico and anywhere else in the world.

Figure 1.0. Michoacán State Civil Guard element carrying an anti-drone weapon.

## II. TYPES OF COMMERCIAL ANTI-DRONES

### *A.* ANTI-DRONE WEAPON

Portable anti-drone systems mostly feature an omnidirectional detection system, usually focusing on 2.4GHz and sometimes 5.8GHz frequencies, designed to force DJI drones to land by jamming their GPS. They have a unidirectional attack to determine which drone to exploit. An example is shown in Figure 1.1.

Figure 1.1. ND-BD003 Handheld Anti-Drone System.

### *B.* FIXED ANTI-DRONE SYSTEMS

These are designed to be placed on a tripod or in a vehicle. They feature an omnidirectional detection and jamming system, some covering ranges of 800MHz - 1400MHz, 2.4GHz, and 5.8GHz. Many have better power due to having more antennas and radiofrequency amplifiers, see Figure 1.2.

Figure 1.2. Anti-Drone System SC-P8000

## III. SOFTWARE DEFINIED RADIOS

The fundamental component for any radar and anti-drone system to function is Software Defined Radios. These are tools used by amateur radio enthusiasts and cybersecurity experts.

SDRs have multiple applications such as receiving images from satellites using SSTV (Slow Scan Television), simulating Bluetooth devices, replay attacks on 433MHz radio frequencies, transmitting Morse code, generating random passwords using white noise, slow sweep radio frequency scanning, aircraft detection at 1090MHz, among many other applications.

### *A.* NESDR SMART

These devices are the most basic and affordable. They have a reception range from 25MHz to 1.7GHz; however, they are better receivers than other more expensive SDRs. Figure 1.3 shows the schematic, and Figure 1.4 shows the connection to a computer.

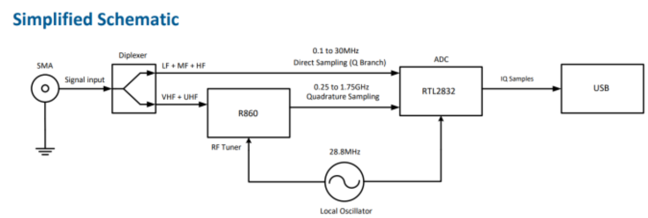


Figure 1.3. NESDR SMART device schematic.

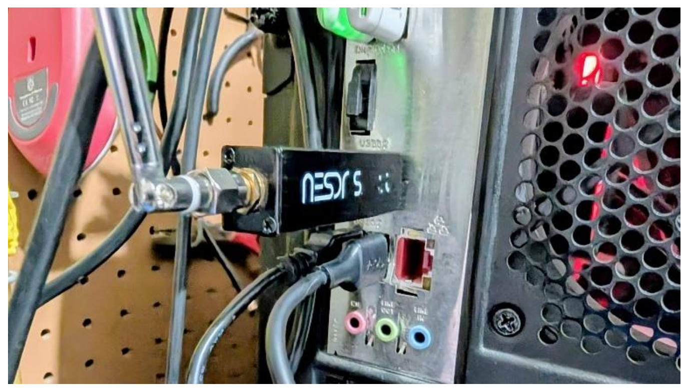

Figure 1.4. NESDR SMART connected to a computer and a 20cm extensible antenna.

This device is not capable of transmitting; however, it is useful for receiving the 900MHz frequency, which is useful for detecting some aircraft, and costs approximately $45. It has a sample rate of 3.2MHz, as shown in Figure 1.5.

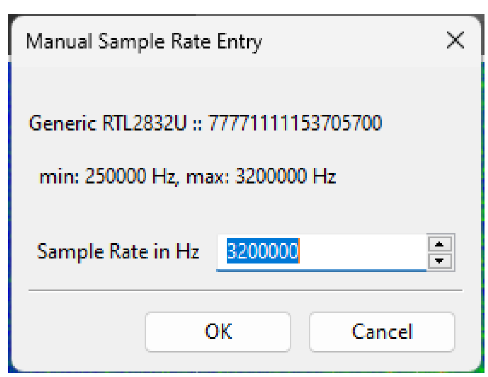

Figure 1.5. Maximum sample rate of the NESDR SMART device.

Using the CubicSDR software, Figure 1.6 shows the spectrum detection at 900MHz.

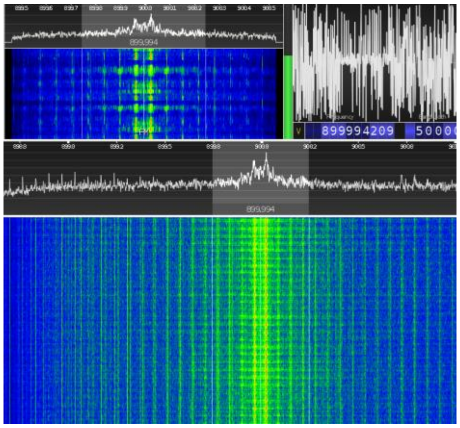


Figure 1.6. CubicSDR software using the NESDR SMART device detecting 900MHz.

*B.* HACKRF ONE

This open-source device is capable of detecting or transmitting from 1MHz to 6GHz. Having only one SMA port, it can only perform detection or transmission, not both simultaneously. It has two other ports called CLKIN and CLKOUT, very useful for synchronizing with other HackRFs or connecting a clock. It has very low transmission power but is very useful for this project, costing approximately $100.
By being able to detect the entire radiofrequency communication spectrum, it is possible to detect 900MHz, 2.4GHz, or 5.8GHz. Figure 1.7 shows the board.


Figure 1.7. HackRF ONE board.

It has the capacity to have a sample rate of 20MHz, as shown in Figure 1.8, which is quite good for wider reception or transmission.

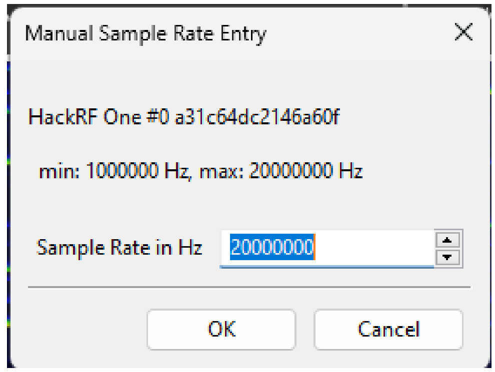


Figure 1.8. Maximum sample rate of the HackRF ONE device.

*C.* PORTAPACK H2+

This device is an add-on for the HackRF ONE board, consisting of a board that connects to all the pins on the top of the SDR, with a touch screen, a potentiometer, 5 buttons, a 3.7v 2500mAh lithium battery, and a metal case. This transforms the SDR into a portable and enhanced device with all the tools that can be used without the need for a computer. As shown in Figure 1.9, it is equipment protected against interference.


Figure 1.9. HackRF PORTAPACK H2+.

This device uses an open-source firmware called PORTAPACK Mayhem and has a wide variety of tools, including NRF for decoding common drone signals. There are also signal peak detection tools, perfect for detecting 2.4GHz and 5.8GHz frequencies. It costs approximately $200.

### *D.* MICROPHASE SDR E200 AD9363

This device features 2 receivers and 2 transmitters, with reception and transmission from 325MHz to 3.8GHz. It is considered a high-end SDR, as seen in Figure 2.0, it has an AMD/Xilinx ZYNQ7020 FPGA (Field Programmable Gate Array). Figure 2.1 shows the board.

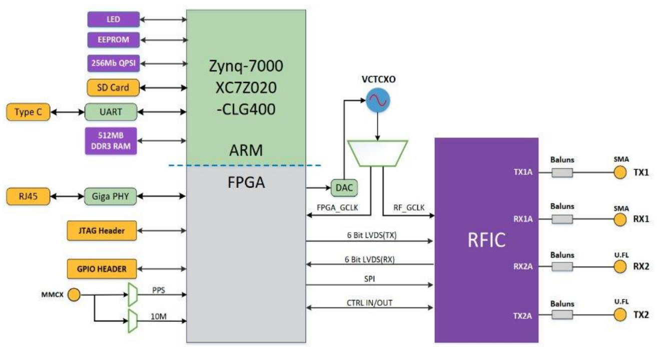


Figure 2.0. E200 AD9363 SDR diagram.

Figure 2.1. E200 9363 SDR board, usually enclosed in a metal case to prevent interference.

This device does not communicate via the conventional USB port like the previous SDRs; it uses a serial port connection via Ethernet cable. This is more complex to use as it requires a Linux operating system for easier monitoring, although it is possible to install some drivers on Windows, but it is more tedious.

## IV. DETECTION AND JAMMING

Both the PORTAPACK H2+ and the SDR E200 AD9363 are perfect for detecting unmanned aerial vehicles, but only one can detect analog video and even interfere with analog video. The PORTAPACK has this capability despite the disadvantage that it can only transmit or receive.

### *A.* JAMMING AND DETECTION WITH THE PORTAPACK H2+ FROM 5.8GHZ TO 5.9GHZ

All FPV systems with analog video transmission range from 5.3GHz to 5.9GHz. These have a determined number of channels, as shown in Figure 2.2, the VTX table for analog systems. This table is really important for knowing which channel the aircraft is on.

| Banda | CH 1 | CH 2 | CH 3 | CH 4 | CH 5 | CH 6 | CH 7 | CH 8 |
|---|---|---|---|---|---|---|---|---|
| A | 5865 | 5845 | 5825 | 5805 | 5785 | 5765 | 5745 | 5725 |
| B | 5733 | 5752 | 5771 | 5790 | 5809 | 5828 | 5847 | 5866 |
| E | 5705 | 5685 | 5665 | 5645 | 5885 | 5905 | 5925 | 5945 |
| F | 5740 | 5760 | 5780 | 5800 | 5820 | 5840 | 5860 | 5880 |
| R | 5658 | 5695 | 5732 | 5769 | 5806 | 5843 | 5880 | 5917 |
| D | 5362 | 5399 | 5436 | 5473 | 5510 | 5547 | 5584 | 5621 |
| U | 5325 | 5348 | 5366 | 5384 | 5402 | 5420 | 5438 | 5456 |
| O | 5474 | 5492 | 5510 | 5528 | 5546 | 5564 | 5582 | 5600 |
| L | 5333 | 5373 | 5413 | 5453 | 5493 | 5533 | 5573 | 5613 |
| H | 5653 | 5693 | 5733 | 5773 | 5813 | 5853 | 5893 | 5933 |

Figure 2.2. Channel table for analog video systems.

The bands correspond to different types of analog transmissions:

- Band A: BlackSheep (TBS), RangeVideo, SpyHawk, FlyCamOne USA equipment
- Band B: FlyCamOne Europe
- Band R: Banda used in racing competitions
- Band E: HobbyKing, Foxtech
- Band F: ImmersionRC, Iftron
- Band D: Diatona

The remaining bands are for other rarer protocols; however, this makes them more dangerous as current radars only detect 5.8GHz, but not frequencies like 5.3GHz, and this is truly crucial. Current VTXs make it easy to switch between Bands and channels without needing to open the drone; modification is possible from a visual menu, helping to quickly change channels if there is jamming on one channel. Analog systems have a bandwidth of 30MHz.

Using the Search tool and scanning from 5600MHz - 5700MHz, 5700MHz - 5800MHz, and 5800MHz - 5980MHz with a slow sweep and turning on a 3-inch propeller diameter FPV drone, with the plan to determine which channel it is transmitting on and confirming that there is an aircraft near our location, a unidirectional antenna was used, as shown in Figure 2.3.


Figure 2.3. 3-inch propeller diameter FPV CineWhoop drone being detected on RaceBand R CH 8.

Now, to detect it at a considerable distance, it is necessary to use input amplifiers and multiple unidirectional and omnidirectional antennas. This radiofrequency range has no other use, only for commercial and armed FPV unmanned aerial vehicles; therefore, there will be no false positives, as long as no jammer is active. As shown in Figure 2.4, the SDR has a 40dB input amplifier.


Figure 2.4. 1.7-inch Whoop drone being detected using a 10MHz to 6GHz input amplifier at 48dB.

With this, we can now determine if there are unmanned aerial vehicles. Now, to jam an FPV drone, once the frequency at which its analog video is operating is detected, it is necessary to connect the PORTAPACK H2+ to a computer, even an Nvidia Jetson Nano or Raspberry Pi 5 can be used (the Raspberry Pi 4 does not work very well). Once connected, the SDRangel software, dedicated to SDR transmission and reception, is used. It also helps us open windows to do multiple things using several SDRs simultaneously. In this case, the SDR is initialized to attack an aircraft that is on RaceBand R CH8 at 5917MHz. Then the ATV Modulator window is opened, and the MW variables are modified to maximum, VGA to 47dB, and then the figure to be transmitted is determined, in this case, it will be a chessboard, but an image, video, or even a webcam can be connected for transmission. Once these configurations are made, the command is executed to the SDR as shown in Figure 2.5. The screen shows the data it is receiving from the computer and that it is transmitting (it is important to have the antenna connected when transmitting; if there is no antenna, an overload in the chip may occur and burn the PORTAPACK).


Figure 2.5. On-screen visualization of the PORTAPACK H2+ connected to a computer receiving commands to transmit at a frequency of 5917MHz.

As shown in Figure 2.6, this is how the software looks, and in Figure 2.7, it is observed on the FPV goggle screens that something is transmitting on that channel. In Figure 2.8, the type of goggles used can be seen.

Figure 2.6. SDRangel software in transmission mode.

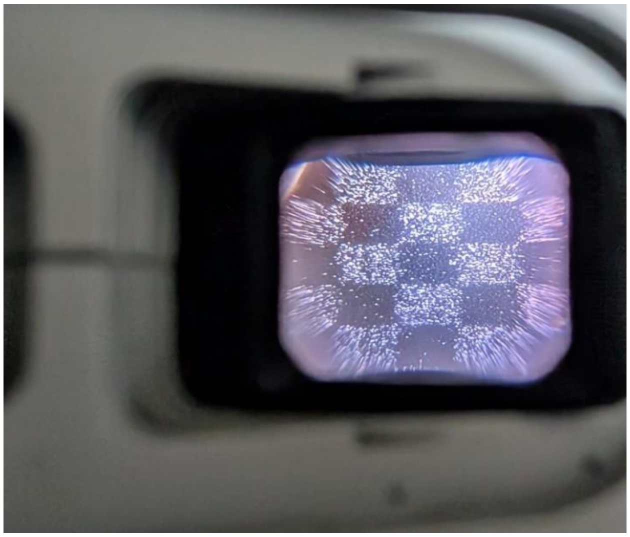

Figure 2.7. Analog video reception visualized on FPV goggle screens.


Figure 2.8. Goggles for unmanned aerial vehicles with analog transmission systems.

## *B.* CONCLUSION

The PORTAPACK H2+ and the E200 9363 have low transmission power. To be more powerful than a drone video transmitter, amplifiers are necessary. It should also be added that these devices can be programmed in Python; in this case, programs were used, but it is better to do programming or even use GNU Radio and use several SDRs, a computer like an Nvidia Jetson Nano, separate the transmission from the reception, and make this equipment portable or fixed depending on its intended use. For FPV drones that have a fiber optic transmission system, this is no longer possible, but for digital video systems that use less advanced protocols than Ocusync 4, they can be detected with the E200 9363. There are also other high-end SDRs that have similar capabilities and are equally useful for this purpose.

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