International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

# Detection of Drones using SDR as a RADAR

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**Abstract**
With the evolution of technology, the application of drones in Fourth Generation Warfare has increased manifolds. Drones offer many advantages as they are inexpensive to operate, can fly for longer periods, and are less vulnerable to enemy fire. This makes them an ideal, inconspicuous, and low-cost weapon for both conventional and non-state actors to carry out targeted attacks on valuable targets. Detection of drones is a major challenge as they offer minimum Radio signature and low Radar cross-section. A credible method to detect incoming drones is by employing Software Defined Radio as a RADAR.

**Keywords:** Drone, RADAR, SDR

**Introduction**
The first major use of drones in combat was in the Gulf War. The United States used the Predator drone to carry out successful surveillance and to strike targets. Since the Gulf War, drones have become increasingly common in the military domain. They have been extensively used by the Saudi-led coalition in the Yemeni Civil War, which began in 2015. The drones have been used to strike targets belonging to the Houthi rebels.

**Indian Context**. India shares a 3,323 Km long international boundary with its western neighbour. This boundary traverses along the Himalayan mountain ranges, through the plains of Punjab, and moves southward towards Rann of Kutch via the Thar desert. The first such kind of drone-related terror activity was carried out in RS Pura Sector in Jammu and Kashmir in 2022. The drone threat is being further exploited for smuggling weapons and narcotics in the plains of Punjab. According to the Border Security Force (BSF), there have been 254 drone incursions along the India-Pakistan border in Punjab since January 1, 2022, which is a four-fold increase from the 67 drone incursions reported in 2021. The majority of these incursions have been detected in the Tarn Taran, Fazilka, and Amritsar sectors of the border.

**Figure 1 : Contraband captured by Border Security Force**

The use of drones in warfare is a complex issue with no easy answers, and with the evolution of VLSI design, there is no doubt that drones are evolving as a powerful new weapon that will have a significant impact on the future of warfare. Thus detection of Drones is the need of the hour to prevent their use as a weapon which is detrimental to the security of the nation.

**RADAR Basics**

- The foundations for the development of radar were laid by Heinrich Hertz in 1886. However, the first practical radar system was not invented until 1935 by the British physicist Sir Robert Watson-Watt. Radar was used extensively by the British military during World War II to detect and track enemy aircraft and ships. It was also used by the United States military, and by other allied countries and played a critical role in the victory of the Allies during the war.
- RADAR is an acronym for **Radio Detection and Ranging System** that uses radio waves to **determine the distance, angle, and speed of objects. It is an active sensor, meaning that it emits its own energy to detect objects.** RADAR systems typically consist of a transmitter, an antenna, a receiver, and a processor. The transmitter sends out a pulse of radio waves. The antenna then reflects the waves off of the object and back to the receiver. The receiver measures the time it takes for the waves to travel to the object and back. This information is used to calculate the distance to the object.

**Doppler Effect**

- The Doppler effect is used to calculate the range of the object from the transmitter to the flying object and is explained in the following paragraphs:
  The Doppler effect is the apparent change in the frequency of a wave in relation to an observer moving relative to the wave source. It is named after the Austrian physicist Christian Doppler, who described the phenomenon in 1842. The Doppler effect can be observed for any wave, including sound waves, light waves, and radio waves.
- The Doppler effect occurs because the wave crests emitted by the source are closer together when the source is moving toward the observer and further apart when the source is moving away from the observer. This is because the source is emitting the waves at a constant rate, but the observer is moving relative to the source. The formula for the Doppler effect is

$$f' = f * (v + u)/ (v - u)$$

where,
$f'$ = Observed frequency
$f$ = Emitted frequency
$v$ = Speed of the wave
$u$ = Speed of the observer relative to the source

**Beat Frequency** RADAR can also calculate the speed of an object with the concept of **Beat Frequency**. Beat frequency is the difference between the frequencies of two waves. It is the frequency at which the waves interfere with each other and produce a noticeable signal.
Beat frequency can be observed when two waves of slightly different frequencies are mixed together.
For example, if two waves with frequencies of 100 Hz and 102 Hz are mixed together, the beat frequency will be 2 Hz. This means that the waves will interfere with each other twice per second, creating a noticeable signal.
The same is illustrated with the figure given below:-

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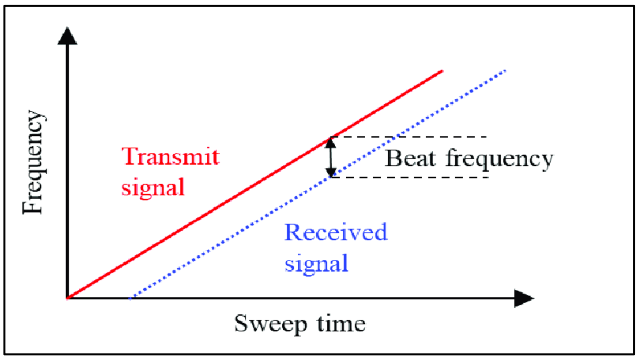


**Fig 2: Beat Frequency**

$f_b = |f2 - f1|$

where fb = beat frequency
f2 = Received frequency
f1 = transmitted frequency

**Calculation of velocity** The calculation of velocity "v" can be carried out with the help of beat frequency :

v = f x b / c

where f = Tx frequency
b = Beat Frequency
c = Speed of light

## 5. Software Defined Radio as a RADAR

**Introduction: SDR**

- Software-defined radios are transmitter-receiver systems that work primarily with radio software. They use only basic equipment that needs to work on the RF chain and propagate the signal. A typical SDR architecture has two main components: a radio front end (RFE) and a digital back end. The RFE includes receiver (Rx) and transmitter (Tx) functions and operates over a wide tuning range, typically DC to 18 GHz. Instantaneous bandwidth is also important for defining an immediately identifiable spectrum.
- The radio's processing functions can be reprogrammed and adjusted without the need for hardware modification. Thus, a single unit essentially can be completely repurposed for a different function without component replacement or physical knob tweaking.
- The FPGA-based architecture enables the SDR to be completely reconfigured and upgraded to support the latest radio protocols and DSP algorithms, which significantly extend the service life of radio equipment. SDRs also contain multiple independent RF channels with dedicated analog-to-digital and digital-to-analog converters (ADCs/DACs).
- The multichannel operation combines with the parallel computing capabilities of the FPGA to enable simultaneous transmission and reception of multiple signals with very low latency while still maintaining phase coherency and stability.

**GNU Radio**

- To implement the functionality of SDR, GNU radio forms the backbone of SDR implementation. It provides the libraries, that can be implemented for SDR functionality. GNU Radio is a free, open-source software development tool that provides signalling building blocks for implementing software-defined radio and signalling functions. It can be used with other radio frequency (RF) hardware or without hardware in a simulation-like environment to create software-defined radios. It is widely used in amateur, academic and commercial settings to support communication science and real-world publishing.
- GNU Radio is a powerful tool that can be used to create a wide variety of software-defined radios and signal-processing applications. It is a popular choice for both hobbyists and professionals, and it is constantly being updated with new features and capabilities. Certain benefits of using GNU Radio are as follows:
- **Free and open-source.** GNU Radio is free to use and distribute, and its source code is available for anyone to inspect and modify.
- **Modular.** GNU Radio is modular, which means that it is made up of a collection of independent blocks that can be connected together to form a signal processing flowgraph. This makes it easy to create custom signal processing applications.
- **Widely supported.** GNU Radio is widely supported by a community of developers and users. There are many resources available to help users learn about GNU Radio and to develop their own applications.
- **Cross-platform.** GNU Radio is available for a variety of platforms, including Linux, Windows, and macOS. This makes it a versatile tool that can be used on a wide range of systems.

**SDR : RADAR**

- Conventional RADAR systems suffer from a fatal limitation in the modern world – as they lack flexibility and adaptability. In the current scenario, with smart software-based systems dominating electronic warfare (EW) and signals intelligence, radars must keep up with the fast technological development to properly detect targets and protect themselves against EW attacks.
- Software-defined radio (SDR) can be used as a RADAR because it is a flexible and versatile platform that can be used to implement a variety of RADAR techniques. SDRs are typically equipped with a wide range of frequency bands, which allows them to be used for a variety of RADAR applications. By integrating high-performance SDRs in the RADAR architecture, designers can take advantage of Software-based functions that can be easily and remotely changed, tuned, updated, and upgraded via on-the-fly programming; there's no hardware modification and minimal human intervention.
- Moreover, dynamic adaptations can be programmed to work automatically, including frequency-hopping techniques to prevent jamming and beamforming to avoid clutter. SDRs can provide a very stable and deterministic clock signal too, which is crucial for synchronization and time reference while also being capable of receiving external clocks from 10-MHz crystals to synchronize with other equipment in the architecture.
- In terms of basic RF characteristics, SDRs can significantly improve the performance of radar systems, especially considering the very precise RFEs typically implemented in high-end SDRs. Firstly, multiple-input, multiple-output (MIMO) SDRs are fundamental for phased-array radars—typically implemented in beamforming/beam steering techniques—and radars implementing multiple antennas for different ranges.

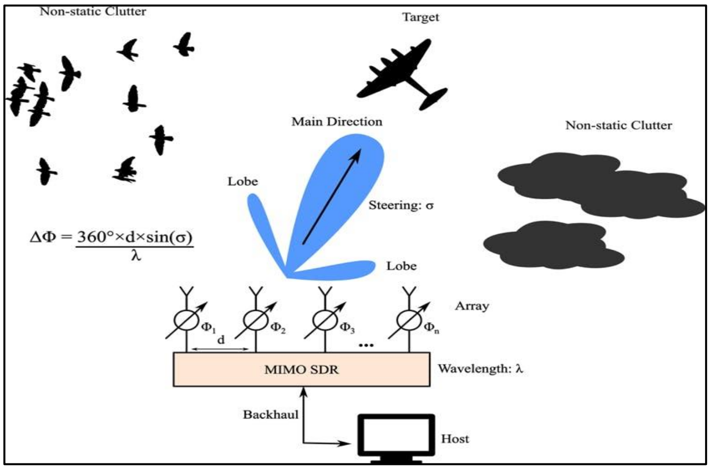


**Fig 3: Schematics of SDR as a RADAR**

**Advantages of using SDR as RADAR**. SDR offers the following advantages for RADAR applications:

**Flexibility**. SDR is software-defined. This means that RADAR signal processing can be implemented in software. This gives SDRs greater flexibility by allowing RADAR signal processing to be changed to suit the specific requirements of the application.

**Versatility**. SDR can be used to implement a variety of RADAR technologies, including pulsed radar, continuous wave radar, Doppler RADAR, synthetic aperture RADAR, and retrosynthetic aperture RADAR. This makes SDR a versatile platform that can be used for a variety of RADAR applications.

**Cost-effective**. SDRs are relatively inexpensive, making them a cost-effective option for RADAR applications.

**Portability**. SDRs are typically small and lightweight, making them portable and easy to deploy. This makes it a good option for applications where the radar must be mobile, such as military applications.

**Freq Bands of operation**. To select the type of SDR required for RADAR applications, there is a need to scrutinize the MM wave band to find the requisite SDR. The comparison of frequency bands is given as under:

| Band | Freq | Applications |
|---|---|---|
| UHF Band | 300 MHz - 1 GHz | • Wind Profilers in Wx Detection<br>• NATO based MEADS (Med Extended Air Def Sys) due to Long Ranges for the detection of fast moving Ballistic Msls |
| L Band | 1 GHz - 2 GHz | • Long Ranges up to 400 Km<br>• Gen used for Air Svl Radars<br>• Op with Huge Rotating Antennas |
| S Band | 2-4 GHz | • Special Airport Svl Radars,Drone Detection Radars used at Airports<br>• Position of Aircraft upto 100Km<br>• Smaller Antennas |
| C Band | 4-8 GHz | • Satl Comn, Wifi Devices, Cordless Telephones |
| X and Ku Band | 8-12 GHz | • Airborne Imaging Radars<br>• Ocean Studies and Civ Geog Mapping |
| K and Ka Band | 26.5-40 GHz | • Incr in attenuation at these freq<br>• Airfd Surface Mov Radar |

**Table 1: S Band as universally acceptable band for Drone Detection Radars**

| FEATURE | LIME SDR | ADALM PLUTO SDR | USRP B210 |
|---|---|---|---|
| Freq Response | 100 KHz – 3.8GHz | 325MHz – 3.8GHz | 70 MHz – 6 GHz |
| Stability in Tx Freq | Lowest | Better than Lime SDR | Most Stable |
| Noise Figure | 9.0dB | 4.8dB | 4.7dB |
| RF Bandwidth | 61.44MHz | 20 MHz | 61.44MHz |
| Tx Rx Ch | 2/2 | 1/1 | 2/2 |
| Cost | Rs 25,000 | Rs 1,25,000/- | Rs 1,63,000/- |

**Table 2:Performance comparison between commercially available SDRs**

**Performance metric comparison between various SDRs for RADAR applications**.
**Challenges associated with detection of UAV/Drone by RADAR**. Traditional RADAR detection techniques rely on reflected signals from the target of interest, which has a significant metallic component. However, there is an issue with the detection of Drones/UAVs which use carbon fibre material as their major components. Some of the challenges of UAV detection using RADAR:
**Small size and low radar cross-section (RCS)**. UAVs are typically small and have a low RCS, which makes them difficult to detect using radar.
**Clutter**. Radar signals can be cluttered by other objects in the environment, such as buildings, trees, and birds. This can make it difficult to distinguish between UAVs and other objects.
**False alarms**. Radar systems can produce false alarms, which can make it difficult to identify real UAVs.

## Conclusion

The document discusses the advantages of employing **SDRs** as a **RADAR** for the **detection of UAVs/Drones**. It highlights the evolution of a **Fourth Generation Weapon – UAV/Drone** as a credible weapon system that is being exploited by Armies all over the world.
The paper also brings out the versatility of the SDR, when employed as a RADAR, can detect the range, velocity, and angle of arrival of an incoming flying object. It also highlights the challenges posed by a small flying object with minimal or no metallic parts for detection and the challenges faced in their detection. The paper also brings out the various bands of employment of RADARs and summarises the best range of frequencies that can be employed for the detection of drones. The paper compares various SDRs available in the commercial market and highlights the SDR most suitable for RADAR-based applications.

## References

1. www.cs.princeton.edu/courses/archive/spring18/cos463/labs/lab5_preview.html

2. Drone Detection Sensor With Continuous 2.4 GHz ISM Band Coverage Based on Cost-Effective SDR Platform Przemys Flak Institute of Automatic Control, Faculty of Automatic Control, Electronics and Computer Science, Ph.D. School, Silesian University of Technology, IEEE Access, date of publication August 13, 2021.
3. Design and Development of RADAR for detection of Drones and UAVs, Sirish Deshmukh Dept. of Electronic Systems Engg. Indian Institute of Science, 2022 IEEE Microwaves, Antennas, and Propagation Conference (MAPCON).
4. D. Santos, P. Sebastiao and N. Souto," Low-cost SDR based FMCW radar for UAV localization," 2019 22nd International Symposium on Wireless Personal Multimedia Communications.
5. S. Zulkifli and A. Balleri, "Design and Development of K-Band FMCW Radar for Nano-Drone Detection," 2020 **IEEE Radar Conference (Radar- Conf20)**.
6. S. Sundaresan, C. Anjana, T. Zacharia, and R. Gandhiraj, "Real time impl of fmcw radar for target detection using gnu radio and usrp," in 2015 International Conference on Communications and Signal Processing (ICCSP), pp. 1530–1534, IEEE, 2015.
7. https://www.gnuradio.org/grcon/grcon20/
8. www.tutorialspoint.com/radarsystems=radarsystems ,"Radar systems overview."
9. www.mathworks.com/help/phased/examples/automotiveadaptive- cruise-control-using-fmcw-technology.html.
10. Two-Dimensional Superresolution Radar Imaging Using the MUSIC Algorithm **J.** W. Odendaal, **E.** Barnard, and C. W. **I.** Pistorius, ***Member, ZEEE.***
11. Studies on Ultra Wideband Triangular Patch Antennas for Imaging Applications Vijayashree T. Bhat Research Student Department of Electrical Communication Engineering Indian Institute of Science Bangalore, India.
12. kb.ettus.com/index.php?title=Open_Architecture_For_Radar_and_EW_Research
13. https://hackaday.com/2017/10/11/homemade-6ghz-radar-v3/#comments
14. www.mwrf.com/technologies/embedded/systems/article/21264379/per-vices-corp-how-softwaredefined-radio-is-advancing-radar-systems.
15. https://www.rtl-sdr.com/hackrf-vs-bladerf-vs-usrp/
16. Design of a Radio Direction Finder for Search and Rescue Operations: Estimation, Sonification and Virtual Prototyping by David Poirier-Quinot.
17. https://www.ndtv.com/india-news/border-forces-recover-drone-carrying-3-packets-of-drugs-in-punjab-5152496