GEO FENCING FOR LOW FLYING OBJECTS

MENTORS:

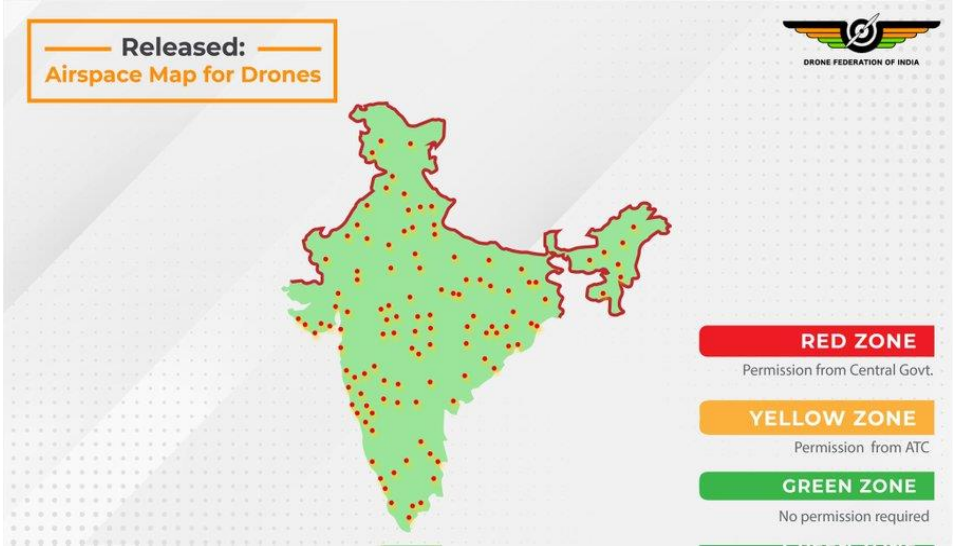
Dr. Manish Kumar Bajpai
Dr. Trivesh Kumar

TEAM:

B. Chandra Haas	***20BEC030***
B. Rakesh	***20BEC026***
B. Sharath Naik	***20BEC028***
S. Sri Harsha	***20BEC100***
P. Rohith	***20BCS153***

INTRODUCTION

In this ever-evolving world, low flying such as drones, UAVs have become a global threat. During their initial stages of development low flying objects were extremely expensive and were not available to public. As technology caught up, drones become dirt cheap and are easily available to the public. Anyone with enough financial resources can buy them off the shelf. This has become a global threat as these drones are tiny and can not be easily counter acted, they are used for malicious and threatening activities around the globe. This is a major security and privacy threat to the nation as well as the public. In 2015, a recreational drone flew into one of the most secure places, the White house. One of the Defense personnel said, *"The Defense Department typically scrambles fighter aircraft for aerial threats over Washington, but when it gets to a toy, that's not something the military typically addresses."*[1] This has also raised questions about this unethical usage of drones across sensitive areas around the world , international borders being a major concern. There already have been many incidents reported of drones crossing the borders illegally.[2] Also there have also been increased doubts of privacy among the people.[3]So a drone counteracting system is the need of the hour. As the world is moving towards technological warfare, drones become an essential and threating part for reconnaissance and stealth operations. If fallen into the wrong hands, they can be used for destruction and terrorism.



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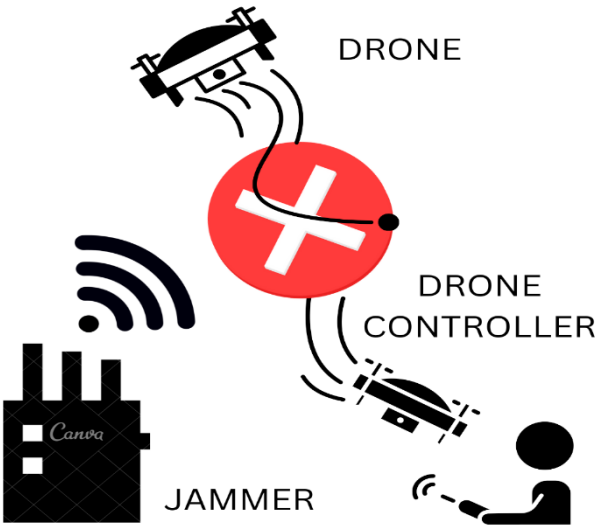
[1] *(A Drone, Too Small for Radar to Detect, Rattles the White House - The New York Times (nytimes.com)*
[2] *BSF says it shot down 7 out of 191 cross-border drones from Pakistan (medianama.com)*
[3] Eyes In The Sky: The Public Has Privacy Concerns About Drones (forbes.com)
[4] ***Drone federation of India (Via Twitter)***

FIELD STUDY & ANALYSIS

To make drone jamming system that will restrict the passage of drones into restricted airspaces, there for will act as a fence, we need to understand the working of drone. A to the today's world is an unmanned aerial vehicle or UAV that is either operated by human from remote location or it can work autonomously as per set mode. The drone has a pilot controller, a human that controls the drone using a remote and the drone itself that acts a receiver. Some drones have inbuilt features that will send the drone back to a specified location if the communication link between the drone and the pilot controller is broken. As a result, our motto would be to break or disrupt this communication channel between the drone and its pilot controller. To disrupt this channel, we need to the details of the channel. Most of the drones use 3 communication channel bands i.e., 433Mhz, 2.4Ghz & 5.8Ghz. As we would be making a student grade prototype, we would be needing to choose the most used frequency band to make an efficient jamming system. Hence, we have done market research and we concluded as follows[5]:



Manufacturer	Frequency
DJI Phantom	2.4 GHz / 5.8 GHz
Futaba	2.4 GHz
Spektrum	2.4 GHz
JR	2.4 GHz

[5] https://digital.wpi.edu/pdfviewer/r781wj76b

Hitec	2.4 GHz
Graupner	2.4 GHz
Yuneec	2.4 GHz
Parrot AR2	2.4 GHz
Immersion	433 MHz

Hence, we can clearly observe that 2.4Ghz frequency band is the most used to communicate from drone-to-drone pilot controller. However more advanced and pricey drones send a video feed to the controller that helps the controller to check out the environment in the drone's airspace. This causes a greater threat as it would not only be used for illegal payload delivery, but also a recon and surveillance drone. Hence, further research was done to know the video feed frequency of drones.

Manufacturer	**Frequency**
DJI	2.4 GHz
Immersion	2.4 GHz
Yuneec	5.8 GHz
Connex	5.8 GHz
Boscam	5.8 GHz

Further investigating & with the suggestion of our mentors, it got into out notice that DJI Matrice 300 Commercial Quadcopter With RTK, DJM300SPC is the most common drone found in the Indo-Pak border. Its specification is as follows:

Ideal for industrial, commercial, and rescue operations, the Matrice 300 Commercial Quadcopter with RTK from DJI features a built-in RTK (Real-Time Kinematic) module that helps the drone withstand magnetic interference from metal structures for a more stable flight. RTK support also provides the possibility of extremely accurate positioning data with an optional D-RTK 2 GNSS mobile station. The Matrice 300 RTK is also rated IP45 for rain and dust resistance, and it is engineered to withstand temperatures from -4 to 122°F.

This kind of durability can be utilized in firefighting, law enforcement, and inspection of buildings and structures. Accomplish this, the Matrice 300 RTK will need to be provided with a gimbal camera payload (not included). It supports a wide variety of Zenmuse and other third-party devices. When in flight, you can operate the Matrice 300 RTK from up to 9.3 miles away thanks to DJI's OcuSync Enterprise technology and included controller. Fly far and fast, up to 51.5 mph, for up to 55 minutes at a time on a full battery charge (battery is not included). Additional technologies are included to help with obstacle avoidance, course plotting, and more. Transmit and control the Matrice 300 RTK from up to 9.3 miles away and receive a triple-channel 1080p video feed from the gimbal. For signal stability and security, the Matrice 300 RTK supports dual-band **2.4/5 GHz** real-time auto switching signals and AES-256 data encryption. Controller is rated for 29.5 dBm (FCC) 18.5dBm (CE)18.5 dBm (SRRC); 18.5dBm (MIC).[6]

DJI Matrice 300 RTK

So, from the observations and a lot more research we have decided that 2.4Ghz frequency is used in most cost-effective drones that are used to transport drugs, aerial bombs, and other illegal items across the border. So, our target frequency will be **2.4Ghz** frequency band. A drone uses this frequency band to communicate between itself and the transmitter (drone pilot remote).

[6] *MATRICE 300 RTK - Specifications - DJI*

THEORY

To disrupt the 2.4Ghz band, our target frequency we would be generating a noisy environment that would disrupt the communication link. To know the details of the required noise, we need to know the power and gain details of the drone controller. Most common drone controller has a transmit power of 20dBm7. They come with 5dBi omni directional antenna. Hence total power required can be calculated as follows.

From Friss equation of free space transmission, we get[8]:

$$\frac{J}{S} = \frac{\frac{P_J G_J G_R \lambda^2}{(4\Pi d_J)^2}}{\frac{P_T G_T G_R \lambda^2}{(4\pi d_S)^2}}$$

$$\frac{J}{S} = \frac{P_J G_J}{P_T G_T} \frac{d_S^2}{d_J^2}$$

$$\frac{J}{S} = P_J + G_J - P_T - G_T + 20\log(d_S) - 20\log(d_J)$$

J is jammer signal power at intended receiver (dB)

S is transmitter signal power at intended receiver (dB)

P_J is jammer output power (dBW)

G_J is jammer antenna gain (dBi)

P_T is transmitter output power (dBW)

G_T is transmitter antenna gain (dBi)

d_J is distance from jammer to receiver (m)

d_s is distance from transmitter to receiver (m)

[7] *Radiolink AT10 2.4GHz 12CH RC Drone Transmitter - Robu.in | Indian Online Store | RC Hobby | Robotics*

[8] *How much J/S do you REALLY need? (cyntony.com)*

Hence from the J/S equation if we separate out the signal terms, we get 35db as the drone controller gain. In order to calculate the power loss in free space we will use Free space path loss equation (FSPL):

$$FSPL\ (dB) = 20\log(d) + 20\log(f) + 20\log(4\pi/c)$$

Where d is the distance from the receiver in Km, f is the frequency in GHz , c is the speed of light.

From this equation, by substituting values in, and subtracting this from the initial power of the drone controller we get the following observations:

Distance in meter	***Power in dBm***
10	-40.1
20	-46.1
50	-54
100	-60.1
250	-68

Power at various distances @ Drone controller

Theoretically, if the J/S ratio = 0, then the drone will be jammed. But in real world scenario, 6dB[9] J/S ratio is found to be the threshold gain difference. So, our jammer should be at least more powerful than the transmitter by 6dB. To Make the jammer, an ideal approach will be to use a 2W amplifier. The transmitter will transmit a 450mW signal. The gain will be **35 dBm** according to the product specifications. We would use 9dBi gain patch panel antenna in order to transmit our signal farther.

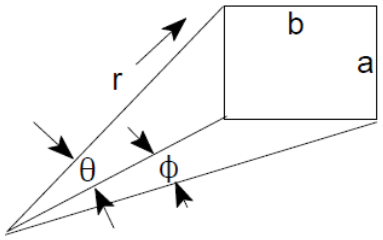
[9] *https://digital.wpi.edu/pdfviewer/r781wj76b (4.2.2 Power considerations)*

Distance in meter	*Power in dBm*
10	-16.1
20	-22.1
50	-30
100	-36.1
250	-44

We can observe that when both jamming system and the drone pilot are in line of sight, there is a difference of 19 dB, which is greater than our threshold of 6dB. Hence our jammer would work perfectly fine.

[10]In order to know our area of coverage, we need to know the beamwidths of the antenna.

Approximating the antenna pattern as a **rectangular** area:



Where θ=BW_θ, and ϕ= BW_ϕ

$$a = r \sin\theta\,, \quad b = r \sin\phi, \quad \text{area} = ab = r^2 \sin\theta \sin\phi$$

$$G = \frac{Area\ of\ Sphere}{Area\ of\ Antenna\ pattern} = \frac{4\pi r^2}{r^2 \sin\theta\ \sin\phi} = \frac{4\pi}{\sin\theta\ \sin\phi}$$

Where $BW_\phi$is Azimuth beam width in radians &BW_θ is Elevation beamwidth in radians. In the product specification we get to know that $BW_\phi = 70^0$ & $BW_\theta = 65^0$. Using this data and the above formula we get:

- Area of coverage of 53,228 Sq m at 250m from the antenna

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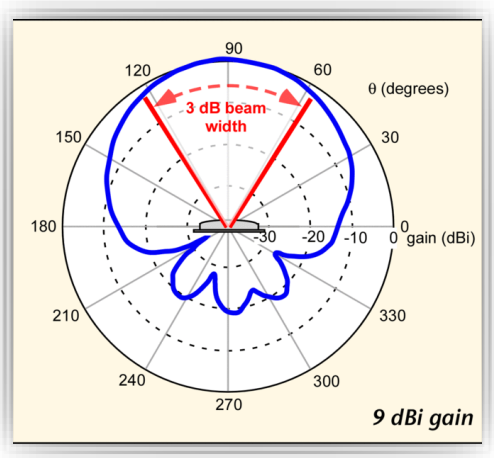
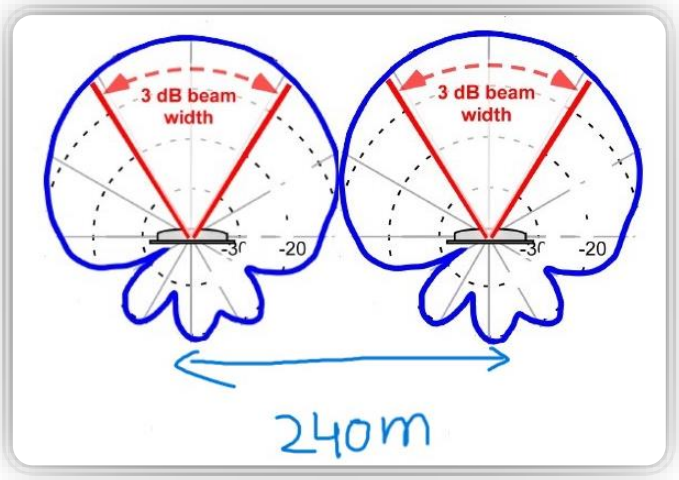
- Its vertical height of coverage would be 226 m
- Its horizontal width of coverage would be 226 m.

Now to know the optimum arrangement of the jamming systems we need to know the radiation pattern of the patch panel antenna.[11]



Hence, as the horizontal width of coverage is 240m (approx), we will arrange each jamming system 240m apart.



This would complete our jamming assembly and the arrangement of our jammer.

PART SPECIFICATIONS

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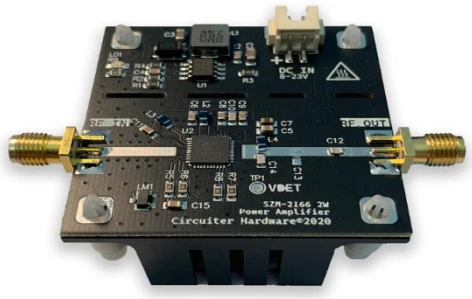
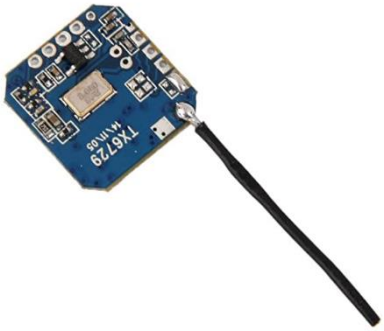
Amplifier:



RFMD's SZM-2166Z is a high linearity class AB Heterojunction Bipolar Transistor (HBT) amplifier housed in a low-cost surface-mountable plastic Q-FlexN multi-chip module package. This HBT amplifier is made with InGaP on GaAs device technology and fabricated with MOCVD for an ideal combination of low cost and high reliability. This product is specifically designed for 802.16 customer premises equipment (CPE) terminals in the 2.3GHz to 2.7GHz bands. It can run from a 3V to 6V supply. The external output match and bias adjustability allows load line optimization for other applications over narrower bands. It features an output power detector, on/off power control, and high RF overdrive robustness. A 20dB step attenuator feature can be utilized by switching the second stage Power up/down control. This product features a RoHS compliant and green package with matte finish, designated by the "Z" suffix.

A V transmitter:



2.4 G4 XLT24017 Wireless Audio Video Transmitting Module A/V Transmitter is an A/V wireless transmitter that supports 2.4 G broad band FM audio video sync transmitting. This wireless audio video module features high stability and low clutter leakage. It is great wireless audio video module that can be used in many applications. Technical Data:

Model: XL24017

Power Supply: 5V

Current: 90mA

Transmission Range: Approx. 150M (Open space)

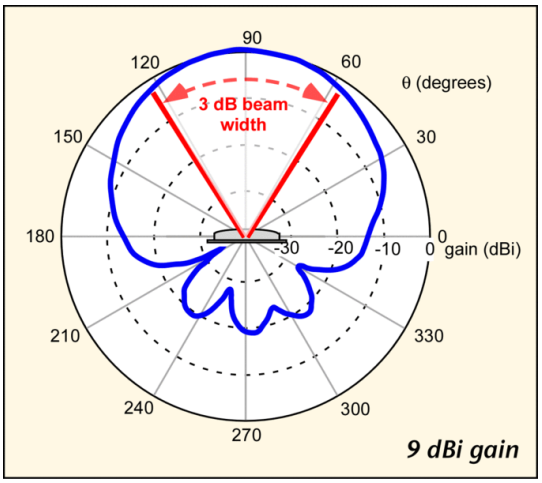
Video Input Impedance: 75 Ohm

Audio Input Impedance: 10K Ohm

Size (L x W): Approx. 18.3 x 17.6mm

Antenna:

This is a GSM external/internal antenna for GSM landline phones or GSM fixed wireless phones. Wide band patch panel antenna is high gain, premium quality, UV protected antenna, which is made from ABS material, and has a rugged structure. Wall mount GSM patch panel antenna extends your network strength in all dead regions. 9dBi Wall Mount antenna provides maximum coverage throughout indoor areas. Vertically polarized patch panel antenna operates on the wide frequency range of 698-2700MHz and has 50 Ohm impedance. Azimuthal Bandwidth is 70 deg. Vertical Bandwidth is 65 deg.



Antenna & Its radiation

Battery:

Orange 5200mAh 3S 40C/80C Lithium polymer battery Pack (LiPo) batteries are known for performance, reliability, and price. It is no surprise to us that Orange Lithium polymer packs are the go-to pack for those aware. Orange batteries deliver the full rated capacity at a price everyone can afford.

Orange 5200mAh 3S 40C/80C Lithium polymer battery Pack (LiPo) batteries are equipped with heavy duty discharge leads to minimize resistance and sustain high current loads. Orange batteries stand up to the punishing extremes of aerobatic flight and RC vehicles. Each pack is equipped with gold plated connectors and JST-XH style balance connectors. All Orange Lithium Polymer batteries packs are assembled using IR matched cells.

Drone:

Tello is a small quadcopter that features a Vision Positioning System and an onboard camera. Using its Vision Positioning System and advanced flight controller, it can hover in place and is suitable for

flying indoors. Advanced features like Bounce mode, 8D Flips, and EZ Shots make using Tello fun. Tello captures 5-megapixel photos and streams 720p live video to the Tello app on a mobile device.

Its maximum flight time is approximately 13 minutes*, and its maximum flight distance is 328 ft (100 m).

Aircraft (Model: TLW004) Weight (including Propeller Guards) 87 g Max Speed 17.8 mph (28.8 kph) Max Flight Time 13 minutes (0 wind at a consistent 9mph (15 kph)) Operating Temperature Range 32° to 104° F (0° to 40° C) Operating **Frequency Range 2.4 to 2.4835 GHz Transmitter (EIRP) 20 dBm (FCC) 19 dBm (CE) 19 dBm (SRRC)** Camera Max Image Size 2592×1936 Video Recording Modes HD: 1280×720 30p Video Format MP4 Flight Battery Capacity 1100mAh Voltage 3.8 V

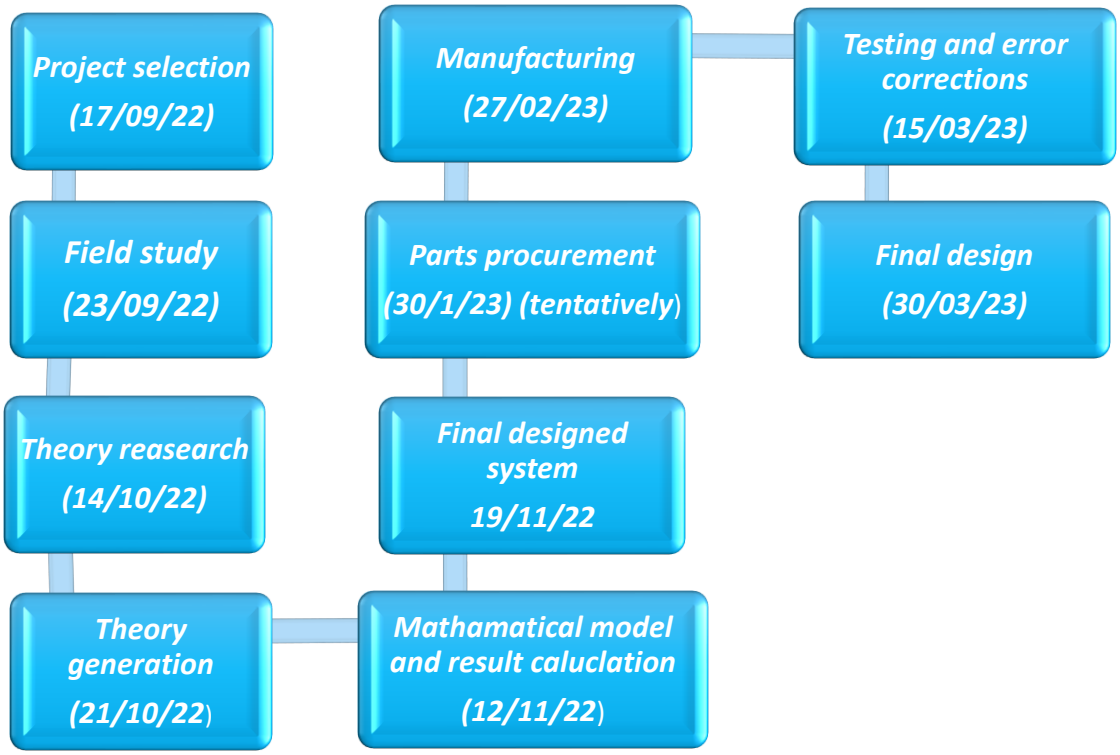
Battery Type LiPo Energy 4.18 Wh Net Weight 25±2 g Charging Temperature Range 41° to 113° F (5° to 45° C) Max Charging Power 10 W

WHY OUR MODEL?

Our model would be completely legal, off the shelf made model. There are drone jammers in the market available for public use. But they are illegal or barely legal as their power limitations exceed the permitted use without proper license[12]. The permitted input amplifier power is <10 W in India. One would require HAM radio license in order to use power beyond 10 W. Also, power amplifiers are costly and are made to order. Hence our design uses a low amplification amplifier in order to meet the cost requirements. Presently in the public market, there is no jamming system. There are only individual jammers that work separately. We have created a jamming system in order to make a fence around the restricted airspace.

[12] *http://www.niar.org/downloads/ham-downloads/Amateur-Radio-Rules.pdf (pg no 19)*

TIMELINE



COST ESTIMATES

MATERIAL	COST(INR)
AV TRANSMITTER	1985 X 4 = 7940
BATTERY	4000
PATCH PANEL ANTENNA	3500
RF AMPLIFIER	4000
DRONE	19000

TOTAL = 38,440 INR

CONCLUSION & MANUFACTURING PLAN

We have successfully completed the mathematical model of our jamming system. Our next phase would be to procure parts and start manufacturing. If successful, we would be able to make low cost-efficient jamming device. The same principle can be used for other frequencies to jam out all kinds of drones. Due to budget & time limitations we are unable to make broad band jammer that could jam all kinds of drones

THANK YOU!