Hack-a-Thon:BB-RC Jammer

MAE 4344 Final Report

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Introduction and Problem Statement

Drones, also known as unmanned aerial vehicles, are aircrafts that fly autonomously through programmed software or are controlled by a person through remote control. These drones now pose a threat to the United States' national security, as enemy drones are used to scout enemy positions, film propaganda videos, and drop dangerous objects below. For example, in recent years ISIS has been caught attaching explosives to the drones and then flying them into US held cities. However, on a domestic level, drones have also become a growing issue in the state of Oklahoma's jail system. A growing number of criminals have been using drones to fly drugs into state penitentiaries. In an attempt to combat this security risk, we will create a system to defeat the target drone by disabling or hacking. There are a few current defeat systems available on the market ranging from drone based nets to using combat trained hawks.



Figure 1: Drone based net

Figure 2: Guard hawk

These current methods have seen limited success, and in order to improve upon their success our group has created a new system that utilizes EM waves to disrupt communication between the drone and the controller. Our system will consist of a ground operator holding an electromagnetic jammer. The electromagnetic jammer will flood the 2.4 GHz bandwidth, preventing the enemy pilot from communicating with his drone. For testing purposes we will be attempting to stop a standard 3DR IRIS+ Solo Quadcopter, which is a very prototypical drone that criminals use.



Figure 3:: 2.4 GHz spectrum channels.

Project Requirements and Deliverables

This project requires us to build an electrical or mechanical system to hack, disable and or track an enemy controlled drone. The effectiveness of the system will be tested in the Hack-A-Thon competition as outlined by Dr Jacob.

Testing of the system will take place in The Colvin Annex or the Sherman Smith Training Center and two scenarios will take place.



Figure 4: Colvin Annex



Figure 5: Sherman Smith Training Center

First, the enemy drone will travel at a moderate speed and will keep a constant path towards the target. Next, the enemy drone will actively avoid the defense system we created. Points will be awarded based on where the enemy drone is disabled, relative to the red zone. Additionally, bonus points will be given based on level of damage to enemy drone. A scoring matrix is shown below.



Figure 6: Scoring Matrix

Plan of Attack

When given this problem our team began debating between a number of designs. After talking with Dr. Jacob it became clear that our group should lean towards a design that is focused around more the electrical side of things by utilizing EM waves. After reviewing our options our group elected to begin work on a design that was focused around an Electromagnetic Pulse (EMP) generating device. Our idea was to attach the EMP generator to a relatively cheap drone and then fly our disposable drone towards the enemy drone. Shortly before collision occurs we planned to set the EMP off, which then would destroy all electrical systems within a short range.



Figure 7: Initial Concept of Drone with EMP generator

Unfortunately, after more research we found two main issues with our EMP idea. The first issue we encountered is that EMP's require a large amount of electrical energy in order to be generated. In order to generate a reasonably sized EMP from our drone we would have to increase the carrying capacity of our drone, which requires a larger drone, thus our plan was no longer financially feasible. The second major issue with the EMP based plans was that EMP generation is actually a felony according to the U.S. government. Generating EMP's can lead to jail time and fines.

Due to the negative findings we encountered with the EMP plan our group decided against using EM waves via EMP, but yet we still wanted to find a method that utilized EM to disable the enemy drone. Our team began to evaluate how the drone and controller communicated. After research we saw there was a potential weakness with the drone's built in fail safes that could be exploited. The 3DR IRIS+ has a few built failsafe's that dictate that when the drone and controller lose connection one of the following options must occur: 1) the drone hovers in place until either the battery is exhausted, or the connection is reestablished. 2) the drone makes an emergency landing and lands directly below where it is currently positioned. 3) the drone will return to "home", which is the same location the drone took off from.

Moving forward with this plan to disrupt the communication between the drone and controller our team began to investigate the best way to achieve our goal. We discovered that the best method appeared to be flooding the 2.4 Ghz band in order to block all communication attempts.

Detailed Description of Work and Key Decisions Made

Our group initially intended to utilize small, relatively cheap drone with a small EMP (electromagnetic pulse) generator attached. These drones were going to be manually flown at the target drone and briefly before impact we planned to initiate the EMP device. Once the EMP was generated, all electronic devices in a small radius around our drone, such as the target drone, would have been forced off.

Further research into the legality of generating EMPs led to the discovery that EMP generators are both illegal and very easily tracked by the authorities. Detonating an EMP is punishable with a \$16,000 fine and the possibility of jail time. Additionally, it would be very difficult to shield our drone from the EMP and the risk of potentially damaging unintended targets in a destructive manner was too high. In an effort to mitigate these issues, we decided to pursue an EM Jammer instead of the EMP.

An EM jammer will disrupt communication with the controller, but will not necessarily take down the drone. In order to take down the drone, a physical takedown method is also needed.

In addition to a jammer, we considered designing a ground based system to launch a net at the drone, however a shotgun shell is already on the market that will be much more practical. We decided to mount our system on a shotgun, and equip the wielder with said shotgun shells.

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Figure 8: Rendering of our attachable jammer concept

The decision to mount our system on a shotgun was made for several reasons. Currently, warfighters often carry more than 90 lbs of equipment. Most fire teams already have at least one shotgun. Our system would simply be a lightweight attachment to this shotgun instead of two additional systems (jammer and net launcher). Furthermore, by mounting the jammer on the takedown weapon, both steps of the takedown can be simultaneously accomplished by one person.

Detailed Description of the Final Design

We decided that an EMP was not the best option to accomplish our task. The size an EMP would need to be in order to reliably take down a drone would also likely damage other nearby electrical equipment. This, coupled with the fact that large EMPs are not legal to detonate, we decided to go in a different direction.

After ruling out an EMP we decided to go with an EM jammer. A jammer with a directional antenna will be much more reliable than a one shot EMP and also much simpler than a mechanical defeat system. According to the manufacturer's data, a 3DR IRIS+ Solo Quadcopter transmits signals from its controller to the drone over the 2.4 GHz wifi spectrum. The 2.4 GHz spectrum has 11 channels over which data can be transmitted. The drone and controllers are built so that if they lose connection on one wifi channel they will begin bouncing from channel to channel until they are able to re-establish a link.



Figure 9: 2.4 GHz spectrum channels.

All 3DR IRIS+ Solo Quadcopters have a series of built in default commands when the controller and the drone lose contract. The reason these safeguards exist is to help prevent the drone from crashing simply because the controller runs out of battery or some interference occurs. The three built in commands for the Solo are hover in place, land, and return to take-off point.

The key components to the jammer are four 2.4 GHz radio transmitters and 2.4 GHZ 8dB patch antennas. The jammer will work by flooding specific channels with noise. The radio

transmitters selected are able to flood the specified channel, as well as the channels above and below said channel. After all four radio transmitters are activated, the entire 2.4 GHz spectrum will be flooded to the point where no other signals can be transmitted within range of the jammer's transmitters. Thus, once the drone enters the transmitters' range it will lose contact with the controller and begin channel hopping in an effort to reconnect with its controller. The drone will be unable to re-establish connection with the controller and the target drone will be forced into one of its failsafe mechanisms.



Figure 10: 2.4 GHz spectrum channels flooded by four transmitters.

We chose to use patch antennas because their power drop off is much lower than an omni directional antenna. Also, the conical gain pattern of patch antennas will allow us to 'aim' the jammer at the target. aiming will help us avoid accidentally interfering with nearby Wi-Fi communications.



Figure 11: Gain pattern of 8 dB patch antenna.

Evaluation of Final Design

On April 7th, 2017 we tested the BBRC Jammer on a IRIS SOLO Quadcopter and the device did not work due to the type of radio transmitters we ordered. We tested the radio transmitters prior to testing and confirmed that they did flood one channel with signal, but not the channels above and below its set channel like we anticipated. That is to say, there was very little signal spilling into adjacent channels. This meant that we would either need many more radios, or radios with looser tuning. We decided to use four 500 mW radios with looser tuning. We also compared the signal strength of the transmitters with a patch antenna and an omnidirectional antenna and could not tell a significant difference. We decided to test anyway to confirm that these 2 radio transmitters were not enough to flood the entire 2.4 GHz spectrum. When we turned on the BBRC Jammer the test drone did not lose communication with the controller and was still able to proceed to the target.

The new radios we ordered have not yet arrived. Based on the tests and observations from UAS 1--who have a similar design--our new design should work. By mounting our system on a shotgun, we allow for both jamming and takedown to be performed by a single operator. The operator first jams the enemy, making it a much easier target, and then shoots it down.

Overall, this is a good step in the right direction. Although still and early prototype, this hybrid of electrical and mechanical techniques allows for a reliable and compact drone defense package.

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Recommendations for Future Work

This project is a good step in the right direction, but it is far from perfect. Future improvements must be made for this to be a truly viable system. Currently, our system is only equipped to counter targets operating on the 2.4 GHz bands. In order to increase the effectiveness of our system, we implement the ability to also jam the 5.8 GHz bands. These are by far the most popular channels for commercial drones.

This could be accomplished fairly easily by adding more transmitters to the system, or by replacing the current transmitters with signal generators capable of producing a much wider range of frequencies. The antennas currently in place on our system are dual band antennas and are capable of effectively transmitting both 2.4 and 5.8 GHz signals. If more signals than these are desired, new antennas should be selected.

Material, Equipment, and Facilities Requirements

The key components of our jammer are radio transmitters, Wi-Fi antennas and a power source. The radios we selected are 500mW, 16 channel 2.4GHz transmitters, purchased from "hobby king". The antennas we selected are ALFA networks APA-M25 Dual band patch antennas. The power source has yet to be selected, a multitude are available at the USRI and will be selected once we receive our radios.



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Figure 12: Alfa APA-M25 dual band 2.4GHz/5GHz 10dBi high gain directional indoor panel antenna

Figure 13: TBS Unify 2.4GHz 500mV Wireless Radio Transmitter

These components will be mounted on a shotgun using a system of our own design. THe body of this mount is primarily comprised of PVC pipes. Two concentric pipes--one connected to the shotgun and one connected to the jammer--are connected to one another by a springs and damping pads. This spring/damper system vastly lessens the acceleration felt by the antennas when the gun is fired.

The third key piece of our system is the physical projectile we plan to use to take down the jammed drones. These are commercially available, we selected SkyNet Drone Defense shells.

Revised Budget

Our maximum budget for this project is 1000 USD. We are currently on track to be well within this budget. Specific costs are shown below.

4-2.4 GHz Transmitters	\$200
4-Dual band patch antennas	\$80
Power source	Provided
Construction Components (mount)	\$50
Excess	~\$670

Figure 14: Finalized Budget

Revised Gantt Chart

Hack-A-Thon Senior Design Project

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Work Plan

