Senior Design Project Progress Report

EE 492 Senior Design Project Planning

Jam Guard

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Acknowledgments

Thank you to Dr. Salem and Chris Stewart.

Abstract - A

GPS signals are naturally very weak by the time they reach the ground, which makes them vulnerable to interference from low cost jamming devices. In the past few years, several major incidents have shown how easily GPS service can be disrupted, affecting shipping, aviation, and public safety operations. Our project, Jam Guard, aims to provide a practical way to protect GPS receivers from this type of interference.

Jam Guard replaces a regular GPS antenna with a compact system that can detect when a jammer is active and automatically adjust its antenna pattern to reduce the unwanted signal. It uses a simple phased antenna array to steer a null toward the jammer, allowing the actual GPS signal to remain usable. Simulation work helped us understand how the array behaves, evaluate different phase settings, and create a fast lookup table that allows the system to respond quickly in real time. This approach offers a realistic and affordable method for improving GPS reliability, and it forms the foundation for upcoming hardware testing and continued development.

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1. Problem Statement

We are exploring the problem of GPS signal jamming by low-cost wideband (noise) jammers. GPS signals are vulnerable to simple, low cost jammers that create wideband noise masking the signal into the noise floor and preventing the GPS receiver from acquiring or maintaining a lock-on. This leaves people dependent on GPS without the ability to accurately determine and share their location.

2. Introduction

GPS devices can be affected by many types of jamming, including broadband noise jamming, narrowband jamming, sweep jamming, and spoofing. Spoofing is especially dangerous because it sends fake GPS signals that can trick a receiver into reporting an incorrect location. When GPS signals are jammed, it can cause serious problems for systems that rely on accurate positioning, such as ships, airplanes, emergency responders, and law enforcement. Since GPS is used almost everywhere today, these vulnerabilities can impact people on land, at sea, and in the air.

Although it would be ideal to protect against all types of GPS jamming, this is not realistic within the time and budget limits of this project. Because of this, our team chose to focus on the most common and accessible form of jamming: broadband noise jamming. Broadband jammers are inexpensive and easy to use, yet they are very effective at disrupting GPS signals by overpowering them with noise.

This project is mainly intended as a research project, since most commercial anti-jamming GPS systems are designed for military or law-enforcement use. Our goal is to design a system that includes the key components needed to reduce the effects of broadband GPS jamming, while also being adaptable to different types of GPS devices. Through this project, we aim to better understand GPS jamming and explore practical ways to mitigate it.

3. **Literature Review and Previous Works (Must be 1.5-2 pages)**

GPS signals are very weak when they reach a receiver, which makes them easy to jam. Over the years, many different anti-jamming solutions have been created to deal with this problem. Most of these solutions fall into two main categories: spatial filtering and temporal filtering. The majority of effective anti-jamming systems are designed for military or government use, which makes them expensive and hard to access for civilian or academic projects. There are several existing anti-jamming products that show how this problem is currently handled. One example is the TUALAJ 4200 Mini GPS/GNSS Anti-Jam CRPA System [1]. This system uses multiple antennas and phase control to detect where a jammer is coming from and suppress it. While this method is very effective, it is considered military grade, requires a price quote, and is not realistic for low-cost or student projects. Another product is the infiniDome GPSdome-SunStone [2], which is a compact dual-band GNSS anti-jamming device priced around $2700. This system is smaller and easier to deploy, but the internal processing is proprietary and still too expensive for widespread use. The Orolia GPSdome 1.02B Anti-Jammer follows a similar approach and relies mainly on spatial filtering, but it also requires special approval to purchase and is intended for government or industrial users. Most of these systems rely heavily on spatial filtering techniques. Spatial filtering uses multiple antenna elements and controls the phase of each element to separate signals based on the direction they come from. Beamforming is one method where the antenna gain is focused toward GPS satellites while reducing interference from other directions. A more direct approach is null-steering, which creates deep nulls in the direction of a jammer to suppress interference before it reaches the GPS receiver. This method is especially effective against broadband noise jamming and is commonly used in CRPA-based systems. Another approach to anti-jamming is temporal filtering, which processes signals based on time or frequency instead of direction. Pre-correlation filtering removes interference before the GPS signal is processed, helping reduce broadband noise. Post-correlation filtering is applied after processing to clean up any remaining noise. While temporal filtering is easier and cheaper to implement, it is generally less effective against strong or directional jammers and is often used together with spatial filtering instead of on its own. The approach used in this project focuses on a simpler and more affordable version of spatial filtering. Instead of using expensive hardware that performs real-time adaptive processing, this project uses MATLAB to pre-compute beamforming weights and store them in a lookup table. These weights are then implemented on a microcontroller to create nulls at specific jammer locations. While this system is not meant to compete with military-grade solutions, it allows us to study and demonstrate broadband GPS anti-jamming techniques in a practical and accessible way.

4. Methodology

Our team will solve the problem of GPS jamming by developing an Anti Jamming GPS Solution that can be adapted to different types of GPS devices. The system we are designing creates a null at the jammer's location for any direction within 0–360° azimuth and 0–90° elevation. This is done using a lookup table generated in MATLAB that provides the beamforming weights needed to null interference from each possible jammer position. To generate this lookup table, we first built a mathematical array that simulates multiple elements arranged in two dimensions. This model captures how the array responds to signals arriving from different angles. Using this model, we implemented a genetic algorithm that searches for the lowest magnitude within each 5° × 5° angular region across the entire section. For every region, the algorithm outputs a set of amplitude and phase weights that minimizes the array's gain in the direction of the jammer. These optimized weights are stored and indexed by their corresponding azimuth and elevation angles, forming the complete lookup table. The next stage involved implementing these MATLAB-generated weights onto hardware. To do this, we exported the lookup table as a .c header file and accompanying .c source file, making the data directly usable on an embedded microcontroller. This allows the system to quickly select and apply the correct weights during operation based on the detected jammer location. Our initial testing focuses on validating how closely the MATLAB-generated weights match the weights applied on the microcontroller. We will demonstrate this using a circuit that accepts a chosen jammer location as input and outputs the corresponding four-element phase values. These outputs will be compared directly to the entries in the exported lookup table to ensure the microcontroller implementation is accurate and consistent with the MATLAB results.

5. Challenges and Risks

A large challenge with our project is knowledge gathering. A large part of this project consists of entirely new concepts to us. We do not know what we do not know at this point. Research will be an extremely crucial part of this project and we will need to make sure that we understand this subsection of the RF world in order to even be able to complete a project.

PCB is also another tremendous undertaking for our project. The cost and turnaround time for a single PCB can sink this project before serious testing can even begin. We must be diligent in learning and executing PCB design.

Lastly, real world testing of our project is a concern. Operating a jammer is not legal, and thus is subject to fines of $100,000. Finding the proper environment to be able to test is always a concern in the GPS jamming space.

6. **Project Requirements**

Marketing Requirements (MR)

1. ***MR1:***Device shall reliably detect GPS broadband jamming
2. ***MR2***:The device must maintain usable GPS under broadband jamming
3. ***MR3:***The device must integrate easily with existing GPS receivers
4. ***MR4:***The device must be compact and portable
5. ***MR5:***The device must operate efficiently on limited power
6. ***MR6:***The device must be easy to monitor and operate

Engineering Requirements (ER)

1. ***ER1.1:*** Detect jamming with ≥ 95% probability at Jamming Signal Ratio ≥ 3 dB.
2. ***ER1.2:*** Trigger jamming alert in < 500 ms
3. ***ER2:*** Provide ≥ 20 dB null-forming suppression at 1,575.42 MHz ± 15.34 MHz
4. ***ER3.1:*** RF output impedance ~50 Ω ±10%

5. ***ER3.2:*** Support L1 (1,575.42 MHz ± 7.5 MHz)

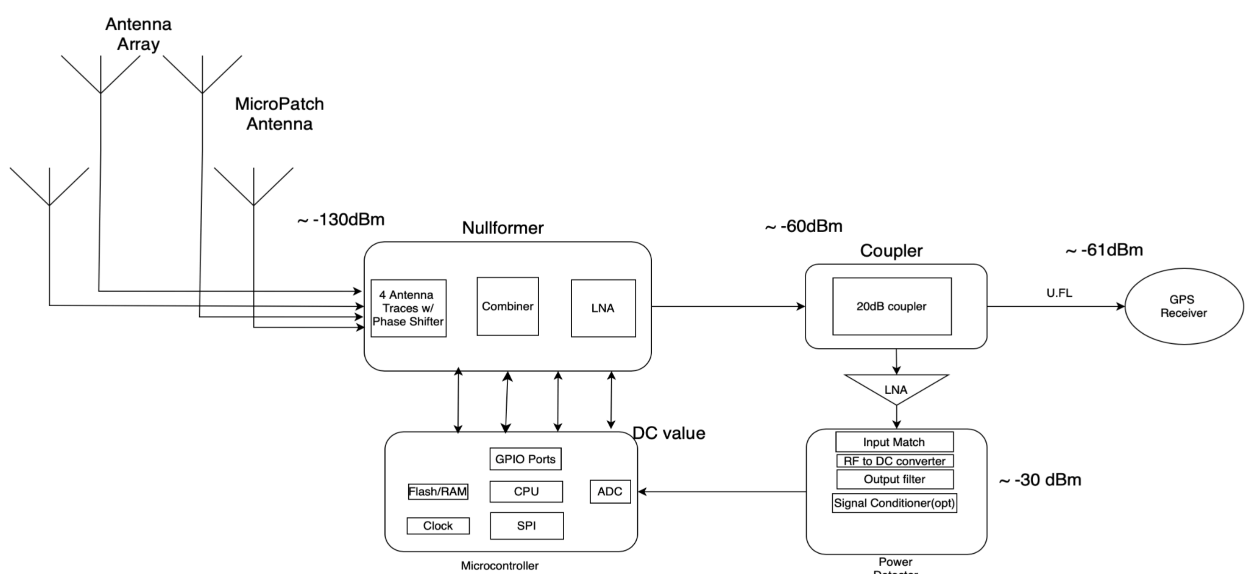
6. ***ER4:*** PCB footprint ≤ 15 × 15 cm and weigh less than 600 g

7. ***ER5:*** Total power consumption ≤ 25 W

8. ***ER6:*** Directional Arrow Indicator points in jam direction with 95% accuracy

7. **Implementation**

We are implementing a replacement for a standard passive antenna. This will go upstream of the GPS receiver and will be an antenna and anti-jamming device simultaneously.



8. Budget/Parts List

We have broken down our system into 4 key blocks, with the expected parts noted in each one. The main four blocks are the Nullformer, Coupler, power detector and microcontroller. There are other components but they do not have subcomponents. This is primarily the antennas and GPS receiver. Our primary budget considerations are noted but there is likely to be more as we progress through the project.

Component	Quantity	Price
Nullformer		~$100
Phase shifter	4	$16 per($64 total)
Combiner	1	~$5
LNA	2	~$2 per(~$4 total)
Coupler		~$15
Coupler	1	$7
LNA	2	~$2 per(~$4 total)
Power Detector		$6
LNA	2	~$2 per(~$4 total)
RF to DC	1	$2
MicroController		$20
ESP32	1	~$20
GPS Receiver		$120(already owned)
Raspberry Pi	1	$120
PCB	1	$60
MicroPatch Antennas	4	$2 per ($8 total)
Total		**~$320**

9. Project Schedule

The first semester of our project will be primarily focused on research and development of our algorithm. This will allow us to dive into the conceptual side of the project and build a strong foundation in order to get the most out of our project.

Winter break will primarily focus on creating the PCB and the spring semester will focus on testing and refinement of the design.

					SEP				OCT				NOV				
					Week				Week				Week				
	TASK TITLE	START DATE	DUE DATE	EST. DAYS	1	2	3	4	1	2	3	4	1	2	3	4	1
1	Project Research and Simulation																
1.1	Initial Research	9/15/25	10/7/25	22													
1.2	Project Selection	10/7/25	10/7/25	5													
1.3	Deeper RF research	10/7/25	Open	NA													
1.4	Advisor Form 1	10/15/25	10/15/25	1													
1.41	High Level Block Diagram	10/15/25	11/3/25	17													
1.42	Initial MatLab programming	10/15/25	11/3/25	17													
1.5	Customer Meeting	10/21/25	10/21/25	1													
1.6	Eval Boards Schematic creation	10/25/25	11/24/25	30													
1.7	First Department Presentation	11/19/25	11/19/25	1													
1.8	Use Suggestions for Improvements	11/19/25	12/5/25	16													
1.9	492 Final Presentation	12/5/25	12/5/25	1													

Figure 1: Current Gantt Chart

10. Ethics of the Engineering Profession and Our Project

There are no notable ethics concerns with our project. The carbon footprint is fairly minimal as it is consistent with designing and creating a PCB module and using a battery to power it. When this device stops working it can simply be turned on again with a fresh battery. If it needs to be scrapped, the entire module size is roughly 15 x 15 cm so it is also very low profile.

Anti jamming GPS systems provide clear societal benefits by improving the reliability of navigation and timing services that many people depend on every day. They help protect public safety by reducing the risk of accidents in aviation, maritime operations, and emergency response when GPS interference occurs. Making these systems more affordable and accessible allows civilian users and critical infrastructure to better withstand intentional or accidental disruptions. Overall, anti jamming technology supports safer transportation, more resilient infrastructure, and greater trust in essential navigation systems.

This device is essentially just plug and play for the user so it works equally for users that are disabled as well. The only consideration point would be replacing the battery. Elsewise, it is meant to not need a lot of user interaction. This product does not generate any signals so that is also not a concern for the user of this product.

11- Updated Report

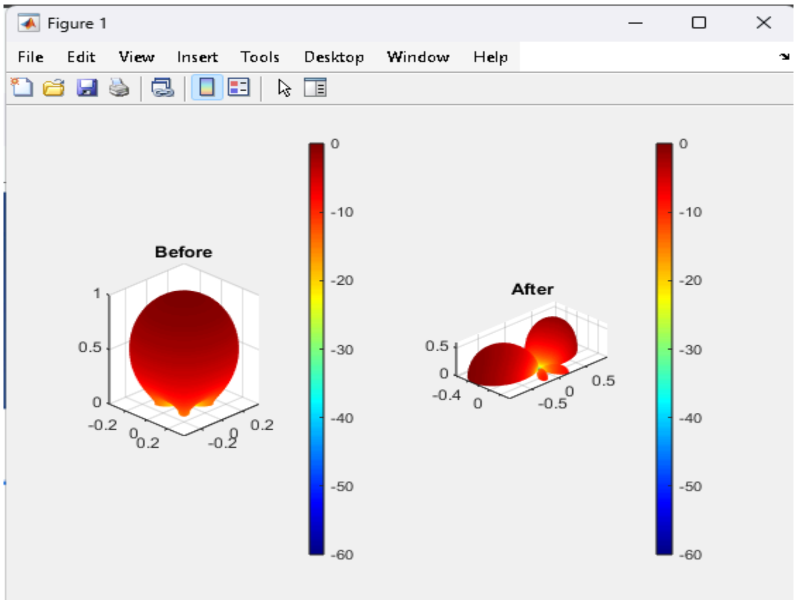
11.1 Theoretical Design vs. Practical Implementation

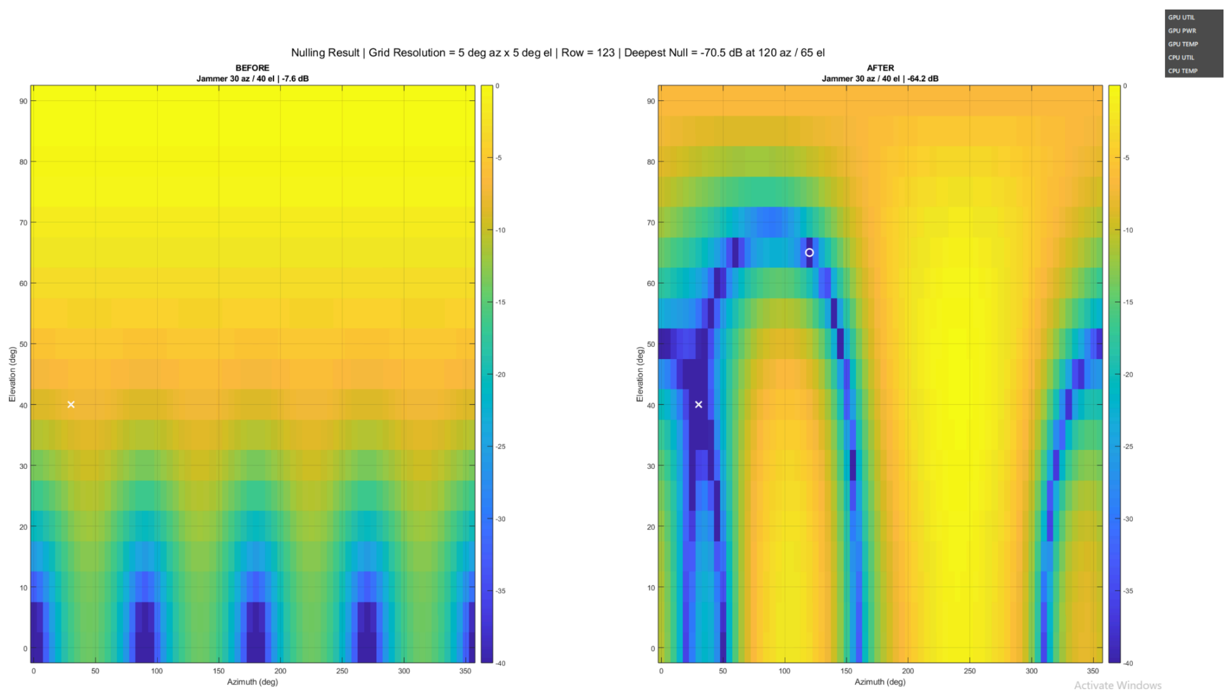
The theoretical foundation of this project was based on phased antenna arrays and null-steering. In simulation, the system behaved as expected, successfully generating nulls in specified directions using optimized phase weights based on the PE44820 Phase shifter's datasheet.

However, translating this theory into hardware revealed several challenges. The physical implementation of the system introduced several non-ideal factors that were not accounted for in the simulation. The effectiveness of the null-steering algorithm is highly dependent on accurate phase control, which in hardware is influenced by multiple factors. These include the precision of the phase shifters, variations in component performance, and the physical length of the coplanar transmission lines on the PCB. Even small deviations in trace length can introduce unintended phase shifts, significantly affecting the overall array performance. In addition, real RF systems inherently introduce noise, electromagnetic coupling between components, and impedance mismatches. These effects were not modeled in the simulation but play a critical role in system performance. Given that GPS signals are extremely weak, typically in the level of picowatts at the receiver, even minor sources of noise or interference can degrade signal quality and reduce the effectiveness of interference suppression techniques. Furthermore, at the GPS L1 frequency of 1.575 GHz, phase accuracy becomes extremely sensitive to small physical variations. Miniscule differences in PCB layout, connector tolerances, or component placement can lead to measurable phase errors, which in turn reduce the depth and accuracy of the generated nulls.

Overall, while the simulation results validated the theoretical approach, the transition to hardware revealed that achieving precise control in a real-world RF environment is significantly more challenging.

The images below show the simulation results as well as what was expected with implementation. The first image shows a before and after null radiation pattern in which you input a known jammer location. The second image shows the depth of the null, corresponding row, and angular resolution using a heat map.





11.2 Manufacturing and PCB Design Challenges

RF PCB design proved to be significantly more complex than initially anticipated. At the beginning of the project, it was assumed that transitioning from simulation to physical PCB layout would be a relatively straightforward process, similar to prior low-frequency or digital designs. However, once working in the GHz frequency range, it became clear that PCB traces could no longer be treated as simple electrical connections. Instead, they behave as transmission lines, meaning their physical dimensions and the properties of the PCB substrate directly affect signal behavior. One of the major challenges was designing controlled-impedance transmission lines, typically at 50 Ω, to ensure proper matching between components. Achieving this required careful consideration of trace width, dielectric constant, substrate thickness, and copper properties. In addition, ground plane design became critical, as RF signals rely on well-defined return paths. Any discontinuities in the ground plane or poor via placement introduced unwanted inductance and noise. Signal isolation also emerged as a key concern, since high-frequency signals are prone to electromagnetic coupling, leading to crosstalk and interference between adjacent traces. Another important realization was the strong impact of parasitic effects at high frequencies. Small layout features such as trace bends, pad sizes, and component placement introduced unintended capacitance and inductance that could significantly alter circuit performance. These effects often caused deviations from simulated results, requiring multiple iterations of redesign and further research. As a result, the PCB layout process became highly iterative rather than a one-step implementation. This unexpected complexity delayed the project timeline by approximately one month and reduced the time available for hardware testing and debugging. Overall, the experience demonstrated that RF PCB design is a specialized skill that requires dedicated study and practical experience, and it should be allocated sufficient time in future project planning.

11.3 Manufacturing Cost and Time Constraints

Although the project aimed to be low-cost compared to commercial products produced by the government, manufacturing introduced constraints, our design was supposed to be a low cost implementation in comparison to the solutions on the market. The amount of time given to us to implement this project led to a limited number of iteration cycles. This project highlighted the scaling cost in components and any mistake in the design would have led to a full redesign and re-fabrication which unfortunately we could not afford or have the time to do. Due to the limitations in time, this led to an extensive amount of research as well as verification which increased the time it took to send to manufacturing, as well as reduced our testing time.

11.4 Knowledge Gaps and Learning Curve

A major factor influencing project progress was our limited prior experience in RF system design. Our project required us to teach ourselves about RF before our fellow classmates, this led to us having to start research into a subject we wouldn't have learned until the following semester. In terms of designing the algorithm, there was an extensive amount of research into radiation patterns, phased antenna arrays, RF signal integrity and interference as well as high frequency PCB layout techniques. We are still learning about our project as of now and will continue to learn more about it as we progress with our careers or

Key areas where additional knowledge was required included:

- Antenna array behavior in real environments
- RF signal integrity and interference
- High-frequency PCB layout techniques

- Hardware debugging at GHz frequencies

This led to:

- Underestimation of project complexity early on
- Increased time spent on research rather than implementation
- Delays in transitioning from simulation to hardware

This aligns with the Dunning-Kruger effect, where initial confidence did not match the true complexity of the system.

11.5 Testing Constraints and Limitations

Testing the system presented both technical and legal challenges.

Legal Constraints:

- GPS jamming is illegal and can result in fines up to $100,000
- This prevented real-world testing with actual jammers

Technical Constraints:

- Lack of controlled RF testing environment (e.g., anechoic chamber)
- Difficulty generating safe and realistic interference signals
- Limited access to RF measurement equipment

Planned Testing (Not Fully Achieved):

- Directional jammer simulation using signal generators
- Validation of null depth using antenna measurements
- Real-time system response testing

Actual Testing Achieved:

- Verification of lookup table implementation on microcontroller
- Validation of phase output matching MATLAB results

11.6 Key Engineering Takeaways

Despite the system not being fully realized, the project provided critical insights:

- Simulation success does not guarantee hardware success
- RF systems require careful co-design of hardware and algorithms
- Testing strategy must be planned early, especially for restricted signals
- Project scope must match team experience and available resources

Initial Research/Concepts	PCB/Code Development	Testing/Optimization	Documentation
Ideal: September 2025 **Actual: Mid November 2025**	**Ideal: Early February 2026** **Actual: Mid March 2026**	**Ideal: Early April 2026** **Actual: Ongoing**	**Ideal: Ongoing** **Actual: Ongoing**
Develop understanding of fundamentals and begin to start developing first blocks (conceptual layout/early code)	Get finalized forms of both PCB and Code for first implementation	Complete robust testing for use-cases and applications of JamGuard	Complete documentation of project
Key Issue: Dunning-Kruger	Key Issue: Lack of KiCAD experience	Key Issue: Late Dev of PCB and manufacturing/exporting issues	