# Ai Backed - Genetic Algorithm Based Electronically Reconfigurable Antenna

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## Introduction

Electronically reconfigurable antennas can deliver equal functionality of multi-antenna systems by dynamically changing their geometries and behavior to meet desired criteria. To provide a desired dynamic response, RF switches or mechanical actuators are used to enable the redistribution of the RF currents through the antenna surface. In this work we will discuss a Smart Antenna, also known as an adaptive array antenna. The antenna can find its own geometrical configurations based on an evolutionary algorithm (EA). The evolutionary algorithm follows similar conditions as stated by Darwin's Evolution theory, where separate biological traits are mixed through a "mating" algorithm and the best traits are sent to the next generation. The algorithm also introduces "mutations" in the genetic string for the antenna to better solve the entire space and limit the algorithm from being stuck at a local minima. This work also introduces an Artificial Intelligence (Ai) algorithm that runs at the highest hierarchy in the program. The Ai builds its dataset based on the information gathered from the genetic algorithm. In this work we go over the Algorithm that controls the antenna, the physical antenna, and it is concluded with a real-world test of the entire system. The algorithm will use a Network analyzer to test the performance of each generation and optimize the structure to work at desired operating frequency. The tests will conclude with the Antenna being moved over to a test bed where the power of a reconfigurable antenna is shown. The antenna will be set up in an electronic warfare/ signal jamming configuration where external attacks on the antenna will result in the Algorithm reconfiguring the antenna to different known configurations in the AI dataset to avoid this external attack and utilize the geometry to filter out the jamming signal.

## Ai-EA Algorithm

The backbone of the entire program is the genetic algorithm. Genetic algorithms have been shown in recent times [2] to be an efficient way of having a computer program solve for a desired configuration. This work used an FEM solver to test each configuration for the criteria which slowed down the solving process. This algorithm was recreated but modified and further optimized to begin with solving from a small geometry and modify the antenna outward until the desired criteria was met. This was shown with an open-source FEM solver as can be seen in Fig 1 where the antenna was asked to solve for a 5.8 GHz antenna. This allowed the EA to solve for the desired frequency point quickly as it would have forward projections of the next generations instead of randomly solving and mixing. The block chain for the algorithm in shown in Fig. 2, The EA is represented in towards the center of the algorithm, the simulation-based EA and physical device EA are identical in terms of operation, the difference being the physical device utilizes the VNA to test the fitness criteria, where as the simulation based utilizes a FEM solver. The algorithm utilizes return loss as the search criteria to determine performance. The algorithm communicates to the VNA over GPIB to acquire Return loss performance. The algorithm will is designed to be run on the system micro controller which controls the RF switch array or the system can be set up to accept inputs from a desktop PC to begin controlling the RF switches. This project utilizes the microcontroller to accept inputs from the desktop PC to the microcontroller.

## RF Switch

The device that controls the RF current distribution between each element of the antenna array is a PIN diode based RF switch. The diode is AC-coupled between each element so there is no DC current between switch which would forward/reverse bias the next switch. The schematic in Fig 3. shows the build configuration for each RF switch. There is a true RF ground and a true DC ground. Between the two grounds there is a capacitive connection to allow the RF signal on top of the DC connection in the RF switch a return path to RF ground. This build configuration allows a continuous ground plane for the antenna. The DC board is fed to the RF switch through small holes on the ground plane. This build allowing the DC traces and majority of components to be outside of the RF field.

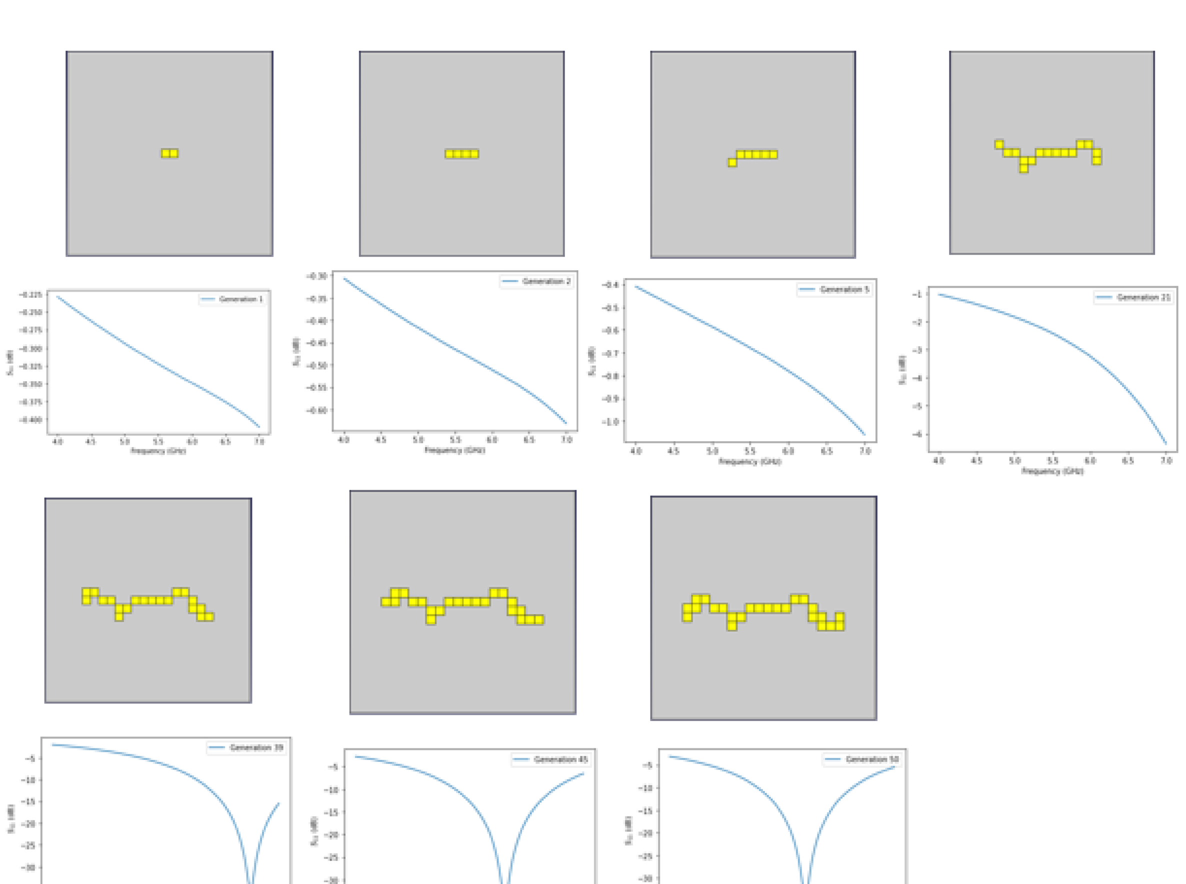

Fig. 1: The EA solving for a 5.8 GHz antenna

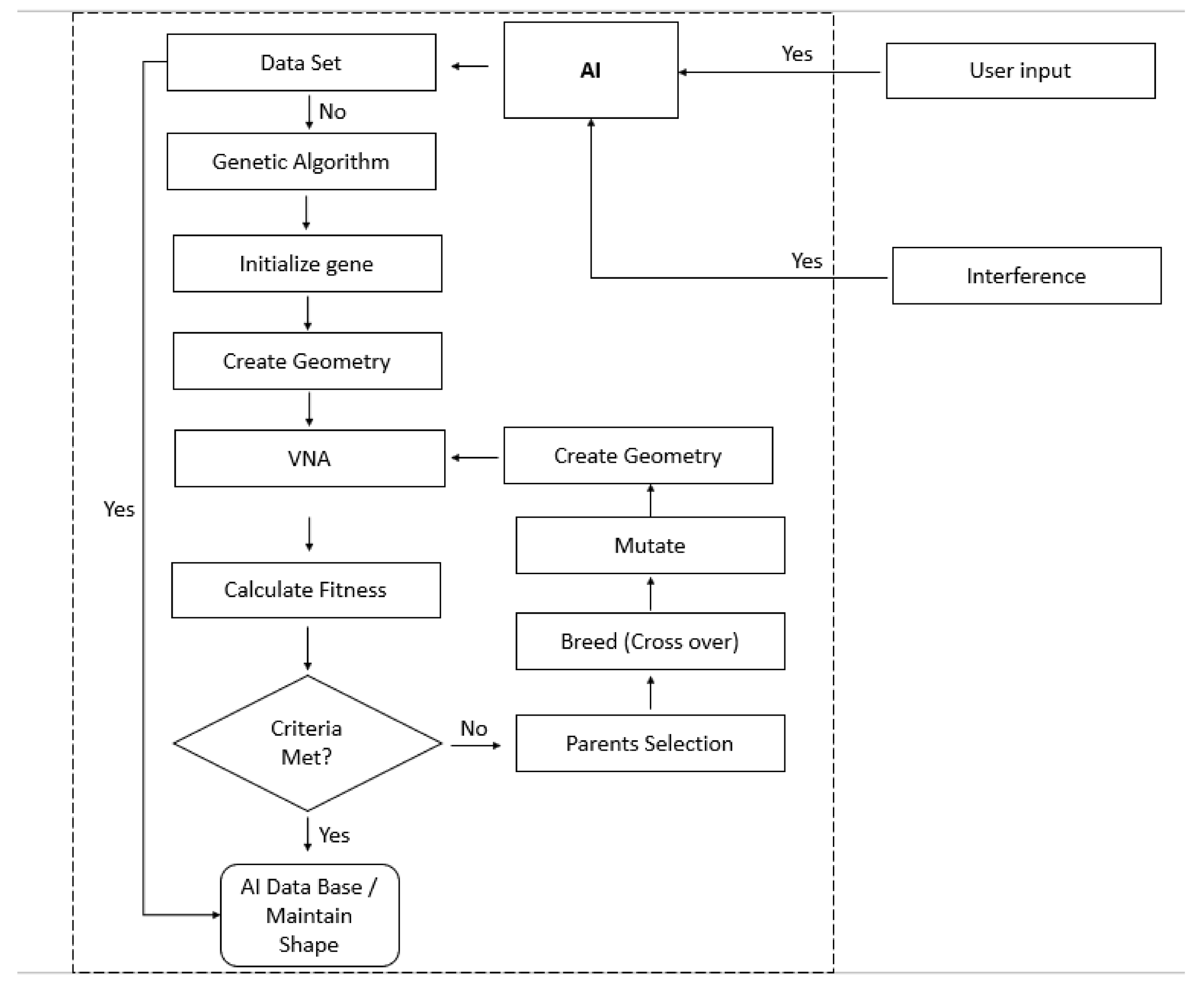


Fig. 2: Ai-EA block chain for the physical build.

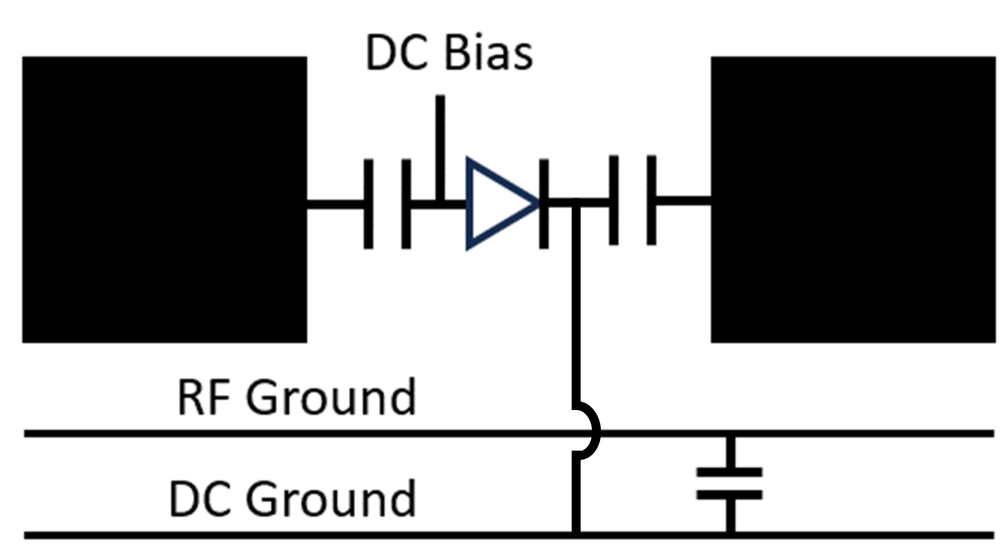


Fig. 3: Schematic for the RF between antenna pixels.

## Antenna

The antenna was designed as a five-layer board but due to fabrication limitations, the layers were split across 3 individual boards which allowed for easy prototyping at an accelerated rate. The antenna can be seen below with 3 individual boards tied together. The bottom board contains the logic board, the middle board contains the DC routing and is connected to the top board via pogo pins. The top board contains the RF circuit and RF ground. The Antenna is comprised of 64 individual pixels in an 8x8 array. Each antenna element has at minimum one inward current and outward current path to allow the Ai-EA algorithm to have a plethora of space to solve for. This also allows the antenna to both act as a transmitting and receiving antenna. Without this inward-outward current path, the inward path would face 20 dB of loss from the isolation of the RF switch. In addition, it allows the antenna to be configured into different polarization geometries. The antenna was built upon a low loss PTFE material. The DC board and logic board were built upon FR-4. The final stack up for the antenna will be PTFE-FR4-FR4 to keep production cost down.

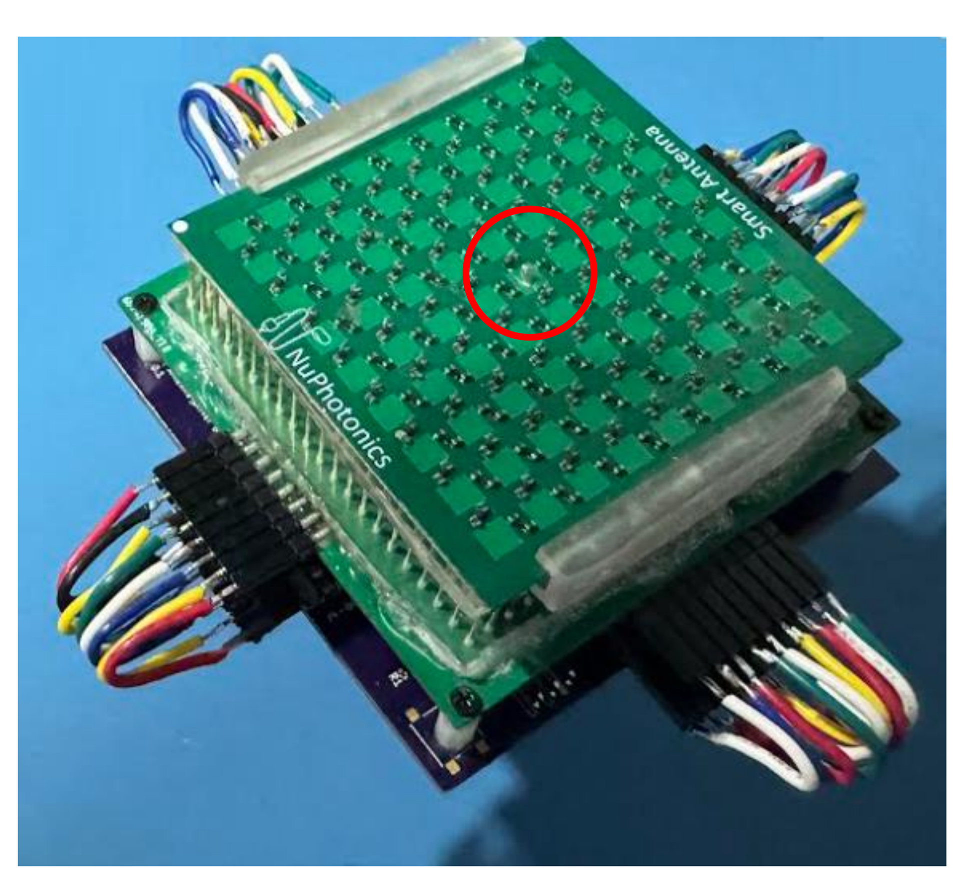


Fig. 4: Physical antenna

## Ai-EA Learning

When the antenna is first connected to a VNA, the results can be seen in Fig. 5 a.1. A feature of 9.4 GHz is noted, which is created by the center antenna pixel, circled in Fig. 4. The first solve for the antenna was for a single band operation at 5.8 GHz, the results are shown in Fig. 5 a.2. The second solve was done for multi-band operation at 5, 6.4, and 7.8 GHz, the results are shown in Fig. 5 b. The antenna solved each frequency point with a S11 < -10 dB, which was the fitness criteria. These frequency points were also solved for individual frequency points for the Ai-EA to have a data set for the signal jamming test. The final learning test was a broadband 5-8 GHz operation, the results are shown in Fig. 5 c. The solve criteria was the average S11 across the bandwidth below -10 dB. This will need improvements as it can be heavily weighted with a good impedance match at one point as it will weigh the average down. A solution to this weighted average includes taking the average across smaller portions for the entire bandwidth but that was not in the scope of this work.

## Application

The next generation of advanced front-end systems to offer advanced defense mechanism for electronic warfare and advanced wireless systems. Utilizing AI to control the device allows the user to focus on the mission at hand where the AI is monitoring the wireless network and making the appropriate changes to keep communication.

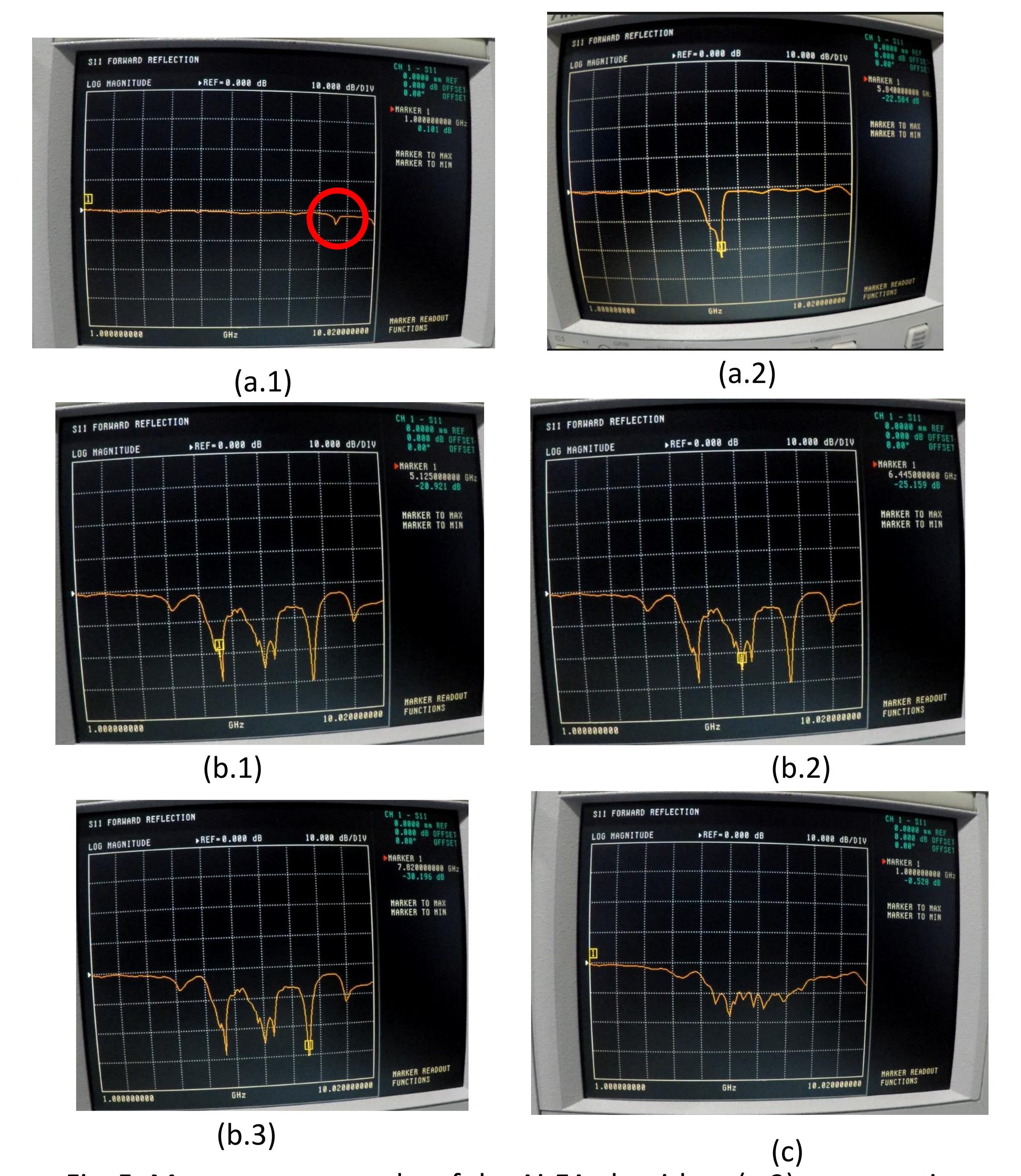


Fig. 5: Measurement results of the Ai-EA algorithm. (a.2) no operating conditions (a.2) 5.8 GHz solve. (b) results for Ai-EA solving for multi-band operation at 5 (b.1), 6.4 (b.2), and 7.8 GHz (b.3). (c) Ai-EA solving for 5-8 GHz broad band operation

## Ai-EA Adapting

The power of this technology is in the ability to reconfigure the operating frequencies when needed. A test bed was created where the AI-EA antenna was connected to a spectrum analyzer and a transmit antenna was connected to a signal generator to create a mockup communication system. A second transmit antenna was connected to a signal generator that will act as an interfering antenna that simulates an external jamming attack. This test bed is shown in Fig. 6. The Ai-EA configures the antenna for the operating frequency, it also sets the output frequency to the first generator through GPIB so the Tx and receive antenna are operating at the same frequencies. As shown in Fig. 7 the antenna was configured to operate at 5 GHz, then the second generator was turned on to output a 5 GHz signal. This caused the receive signal strength to fluctuate. This fluctuation triggered the AI to reconfigure to a state it has in its data base. As shown in Fig. 7, the antenna reconfigured to 6.4 GHz when the Ai notices an undesirable condition. The current time it takes the antenna to notice an external attack and reconfigure is about 2 seconds. As can be seen in Fig. 7, when the antenna reconfigures to the 6.4 GHz signal, the 5 GHz signal disappears as the receive signal strength is below in the noise floor. It acts as an affective way of removing a jamming signal.

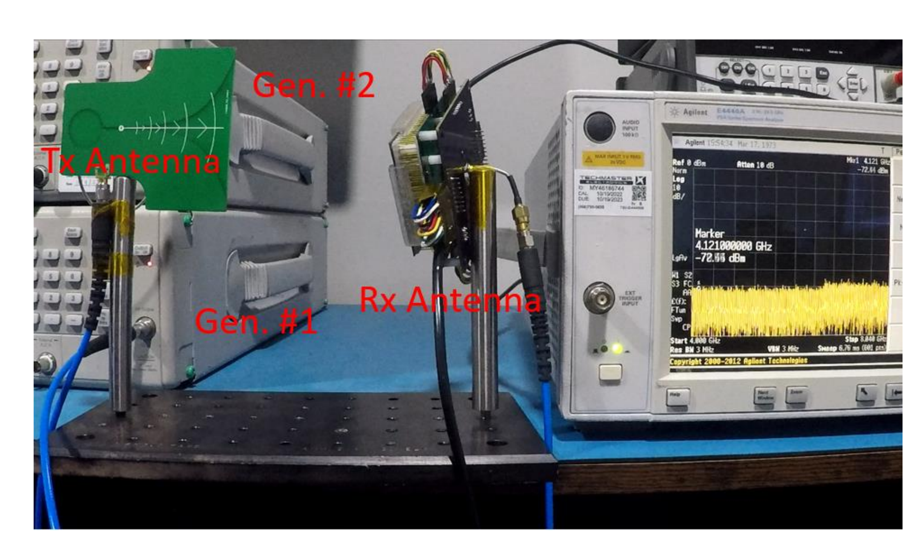


Fig. 6: Test bed.

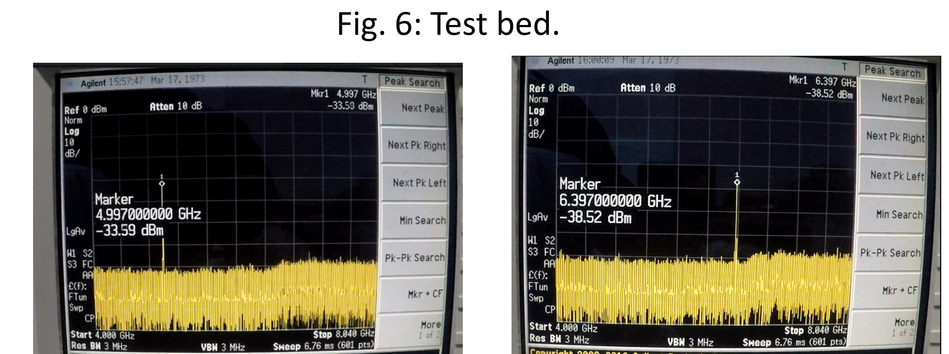

Fig. 7: The antenna at initial condition of 5 GHz followed by changing to 6.4 GHz when external signal jamming occurs

## Conclusion

This work is an exciting possibility for defense against electronic warfare. The antenna can adjust operating frequencies to utilize the geometry filter unwanted signals. It provides a powerful capability to reconfigure, in real time, without the need of human intervention. Utilizing the geometry of the antenna to filter out external signals is a cost effective way to defend against similar attacks.. There is potential for use in both civil and military applications. This work is being followed by utilizing the Ai-EA to electronically beam steer a phased array antenna. The Ai-EA will adjust the phase between the elements to steer the main lobe towards a direct line of sight.