Spread Spectrum Jamming

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ABSTRACT

Direct-sequence spread spectrum (DSSS) is a modulation technique that has been used in many telecommunication devices. Unlike the case of a single frequency carrier, the modulated signal in DSSS occupies a much wider bandwidth in order to reduce the possible interferences with narrow band communication signals. Considering the fact that spread spectrum is generally used to resist jamming, there are very few documented techniques or methods on jamming spread spectrum signals

In this project, we attempt to jam a remote control (RC) car (manufactured by Traxxas) that employs DSSS. The multichannel transmitter of a Sony camera is used as a jammer. Experimental results show that our attempt is successful in a limited range of distance. A directional antenna can be added to improve the range of jamming for future works. It is expected that this method can be further applied to jam mini unmanned aerial vehicles (UAVs) that may potentially be used as explosive or biological weapons targeted at civilian populations.

LIST OF TABLE AND FIGURES

I. INTRODUCTION

Scenario

Within the last few years, there have been advancements in wireless technology. Products are being designed with spread spectrum to minimize any signal interference for reliability and safety. Remote controlled aircrafts fall under such category; it has become increasingly difficult to detect these mini unmanned aerial vehicles (UAVs). These same UAVs could potentially be used to target explosive or biological weapons at civilian populations, whether at range or upon impact. There need to be a countermeasure to detect the UAV and jam it, to prevent it from reaching its targeted site and a possible tragedy from occurring.

Client

Our client is Raytheon, a major defense contractor and industrial corporation. It has a core manufacturing concentration in weapons, and military and commercial electronics. Raytheon produces aircraft radar systems, weapon sights and targeting systems, communication and battle-management systems, and satellite components. It is the world's largest producer of guided missiles and has been around for roughly 90 years while currently employing over 70,000 employees worldwide.

Project Summary

While working with a UAV would be ideal, we decided to scale it down for better mobility and efficiency. During winter and spring quarter, we attempted to jam a remote controlled (RC) car that employs similar spread spectrum signals as a UAV. The car employs a 2.4 GHZ radio system equipped with Direct Sequence Spread Spectrum (DSSS). The RC car was developed and created by Traxxas, a company that specializes in high-end RC cars.

II. REQUIREMENTS

The requirements for this senior project would be to:

- Build/acquire equipment to determine the frequencies the control system is using
- Determine the power needed to jam the car
- Jam the spread spectrum RC car with minimal power at a specified frequency

By jamming the spread spectrum RC car, the receiver would be stopped from receiving any signal from the transmitter, thus rendering the car uncontrollable. This would prevent any communication between the transmitter and receiver of the car. By successfully jamming the RC car, we would be able to take what we learn and possibly apply it to a UAV, therefore preventing a potential dangerous situation in the future.

III. DESIGN

To properly understand the procedure undertaken by this project, three theories need to be understood: spread spectrum, pulse-width modulation, and jamming. Jamming encompasses the entire project and is the main goal, while understanding spread spectrum and pulse-width modulation were key parts in accomplishing the goal.

What is Jamming?

Jamming is a deliberate attempt to disrupt communication between the transmitter and the receiver. A jamming device can often override the signal at the receiver if it is tuned to the same frequency and with enough power. When jammed, a device can no longer receive information from the transmitter and most often remains inert.

What is Spread Spectrum?

Originally developed for the military purposes of securing radio transmissions, spread spectrum is now used pervasively in most wireless products. It uses wide band, noise-like signals, which make it difficult to detect and jam compared to narrowband signals. Since spread spectrum signals are wide, they transmit at a much lower spectral power density, making it less likely to interfere with narrowband communications. Spread spectrum signals are hard to detect on narrow band equipment because the signal's energy is spread over a bandwidth of about 100 times. It trades a wider signal bandwidth for a better signal to noise ratio. Two major types of spread spectrum today are direct sequence and frequency hopping.

Frequency hopping continuously switches or "hops" frequencies during radio transmissions to minimize interference or jamming possibilities. The transmitter hops between available frequencies

according to a specified algorithm. The algorithm can be completely random or preplanned. The transmitter operates in synchronization with a receiver, which remains tuned to the same center frequency as the transmitter (the receiver changes as the transmitter changes). For every burst of data transmitted both the transmitter and receiver change frequencies. Bursts of data can range from fraction of bits to multiple bytes. Because of how it operates, frequency hopping requires a much wider bandwidth to send the same information than a signal only using one carrier frequency.

Direct sequence uses a locally generated pseudo noise code to encode digital data to be prepared for transmission. It breaks the data into small pieces and spreads them across the frequency domain. A data signal at the point of transmission is combined with a higher data-rate bit sequence that divides the data according to a spreading ratio. This enables the original data to be recovered if data bits are damaged during transmission. By dividing the data and spreading it across multiple frequencies, there is a greater resistance to any interference. In contrast to frequency hopping, direct sequence is more reliable, but is more expensive and requires more power.

What is Pulse-width Modulation?

Pulse –width modulation is used commonly to control power to inertial electrical devices such as RC cars. The average value of voltage fed to the load is controlled by turning the switch between supply and load on and off at a fast pace. The longer the switch is on compared to the off periods, the higher the power supplied to the load is. The greatest advantage of pulse-width modulation is that the power loss in the switching devices is very low.

IV. TEST PLANS

The initial test plans were to collect data on the RC car's transmitter and receiver and on how they functioned and synchronized. The spectrum analyzer was connected via the antenna of the transmitter (Traxxas link, high output 2.4GHz). For the initial test, the receiver and transmitter were off to collect a baseline. The spectrum analyzer was concentrated on frequencies between 2.3 GHz and 2.5 GHz since those are near the frequencies the transmitter sends data. Figure 1 displays the initial baseline for the spectrum analyzer with both the receiver and transmitter off.

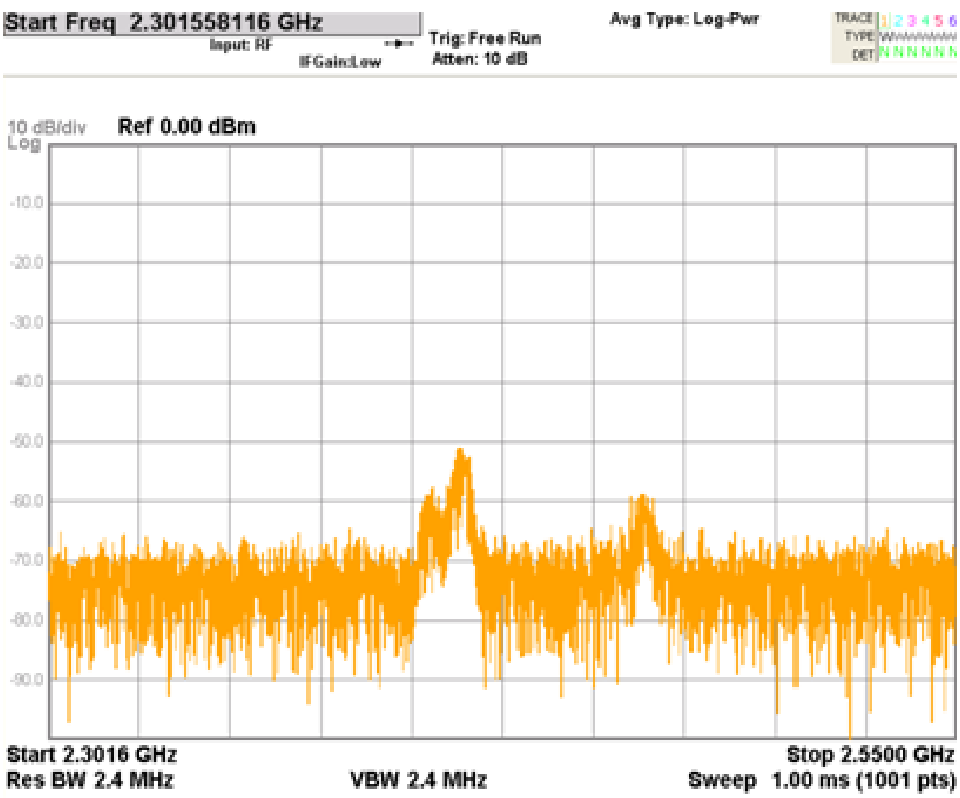

Figure 1: Typical Baseline of Spectrum Analyzer

From the baseline display, it was noticed that without anything connected, there were still some minor spikes at approximately 2.413 and 2.46 GHz. It was determined that the spikes close to 2.4 GHz

were most likely due to cell phone communication. The highest spike at 2.41 GHz was measured to be - 40dBm.

Transmitter Spectrum Testing

The spectrum analyzer was connected to the antenna of the transmitter to measure and display its frequency spectrum (Traxxas link, high output 2.4GHz). The ground wire from spectrum analyzer was attached to the negative rail (0V) and the other wire to the antenna of the transmitter.

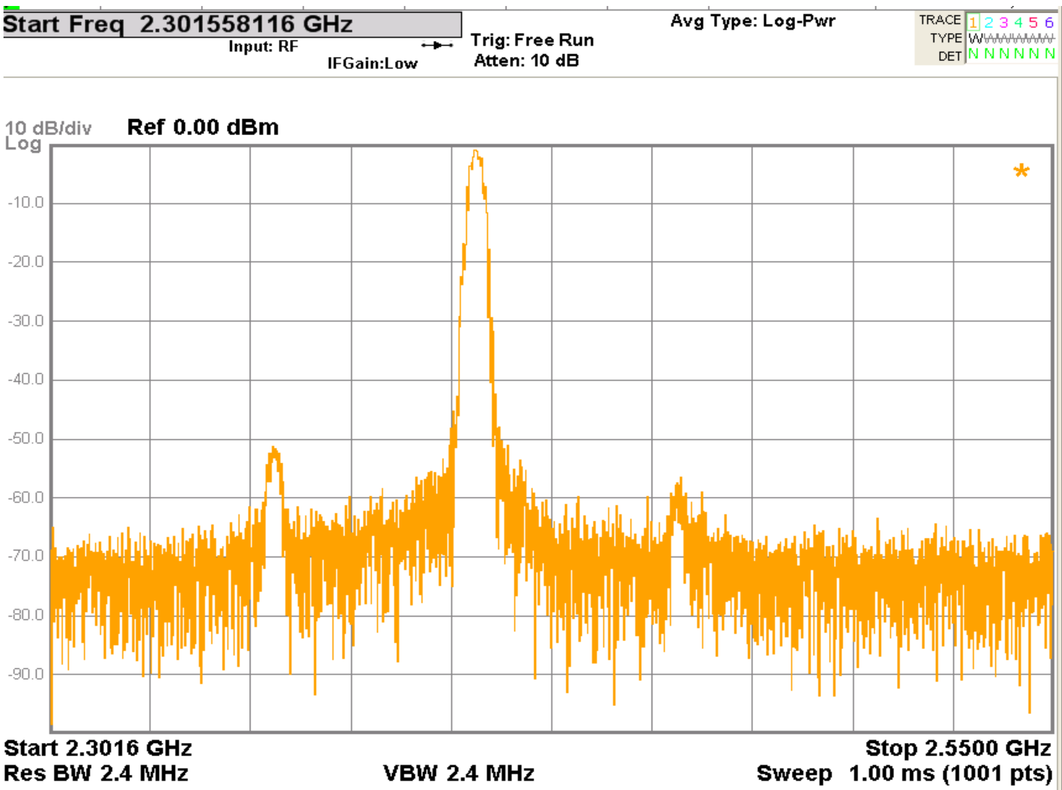

Figure 2: Spectrum Analyzer connected to transmitter antenna

It was noticed that the spike at 2.41 GHz seen in Figure 2 increased dramatically from -40dBm (baseline value) to 0dBm. However, this same spike was inconsistent and appeared sporadically on the spectrum display. From the same display, the average spike was found to surpass -20dBm. Utilizing this

average, the detector was set to trigger when the spike peaked above -30dBm to minimize any false positives. This ascertains that the transmitter is on when it triggers.

Comparing Baseline and Activated Transmitter Spectrum

The comparison was performed with a max hold function on the spectrum analyzer: the highest power was held at each specific frequency. There were noticeable differences between the baseline and transmitter, particularly around 2.406 GHz, shown with marker 5 in Figure 3.

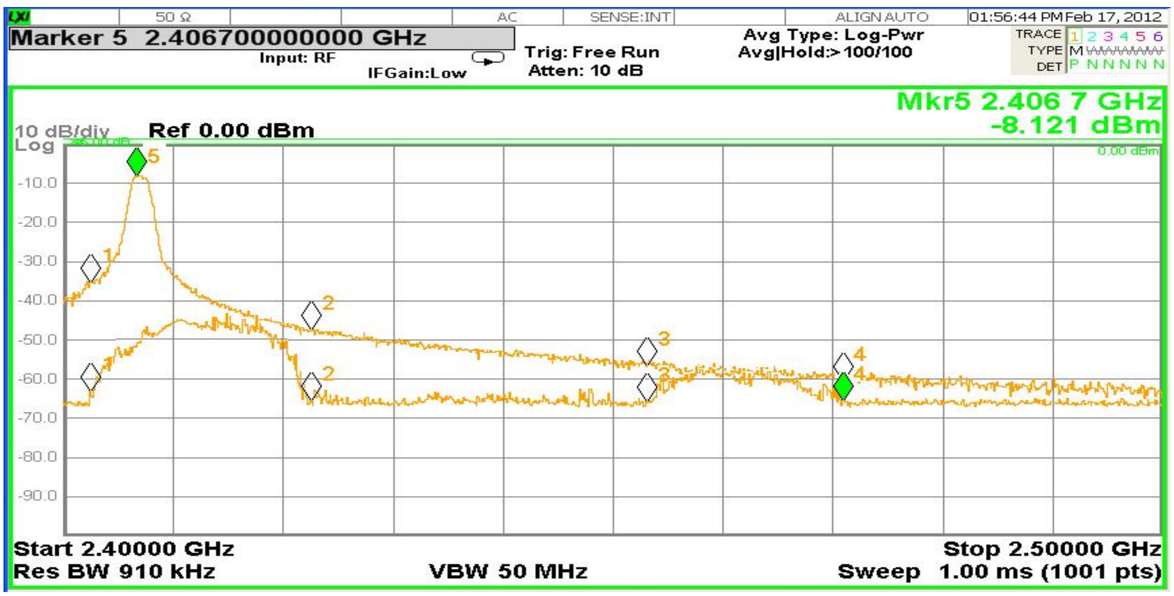

Figure 3: Spectrum comparison between baseline and the transmitter on

Linking Up

The next step was to see if there would be any changes or patterns to the transmitter's frequency spectrum when the linking process between the transmitter and receiver was being executed**.** Any noticeable patterns would provide a method of knowing when the transmitter and receiver were communicating. While observing the spectrum analyzer, the transmitter and car were simultaneously activated. Unfortunately, the spectrum analyzer failed to display any spectral patterns: this meant the linking process would have to be manually analyzed for detection.

Analyzing the Receiver

In order to fully analyze the receiver (shown in Figure 4), each of the pins were probed to determine their function. The receiver only utilized channel 2 and both of the channel 1 slots. After testing the various probes, the receiver was found to run on 6 volts DC and the channel 1 slots affected the steering of the car. Channel 2 was unable to be directly tested because once disconnected, the receiver lost power.

Channels 3-5 were not used

---> (Seemed to control power)
---> Channel 1A
---> Channel 1B
(Both controlled steering)

Figure 4: 5 channel receiver of RC car (there are two channel 1s)

Pulse-width modulation (PWM) signals were observed when connected to the channel 1 pins on the receiver. The PWM signals varied when the car was steered in different directions. The frequency of the signal was 100 Hz while the duty cycle changed depending on its direction. The PWM signal is shown in Figure 5 and the data collected from probing channel 1 slots are shown in Table I and II. The data was taken and compared by steering the car left and right, throttling, and at rest**.** The information was taken in case the jamming does not pertain to the antenna, but instead to the wires or other hardware of the car.

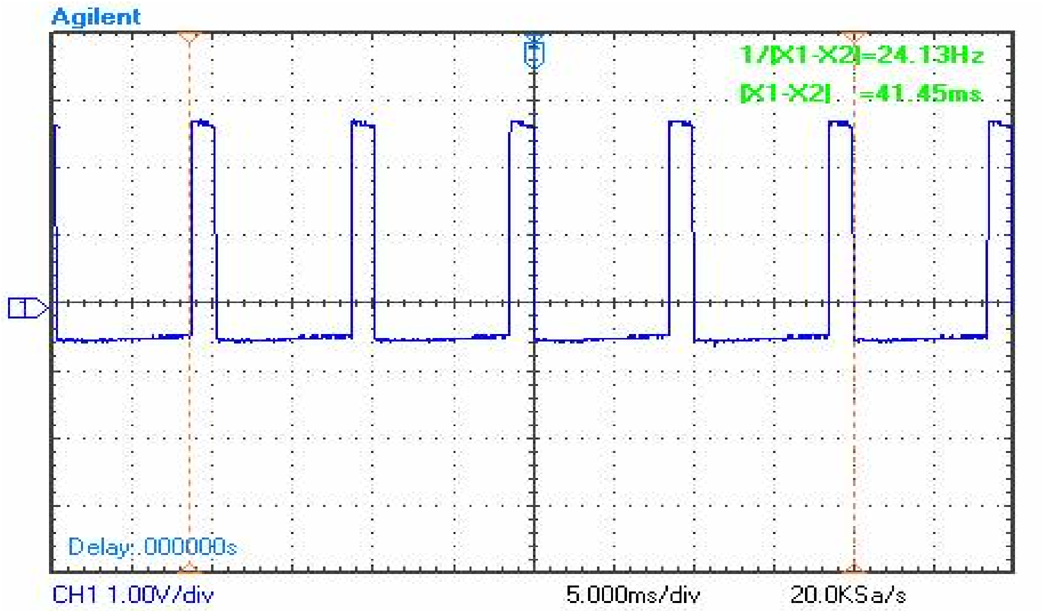

Figure 5: PWM signal found on channel 1 slot

Table I: DATA FROM PROBING CHANNEL 1A PINS

Channel 1A Pins				
	no turn(baseline)	turn left	turn right	Throttle
Vpp (V)	3.281	3.241	3.281	3.321
Vmax (V)	2.721	2.841	2.601	2.721
Duty Cycle	15.10%	10.60%	19.20%	15.20%
Freq (Hz)	100.5	100.5	101	101

Table II: DATA FROM PROBING CHANNEL 1B PINS

Channel 1B Pins				
	no turn(baseline)	turn left	turn right	Throttle
Vpp (V)	3.361	3.321	3.321	3.361
Vmax (V)	2.761	2.881	2.601	2.761
Duty Cycle	15.60%	10.60%	19.70%	15.60%
Freq (Hz)	100.5	101	101	100.5

Emulating a Jammed Car

Previously, Chad Amonn, a graduate student contact of ours, had observed that the car jammed when the transmitter of a Sony camera (900MHZ 1500mW Tx/Rx & 1/3-inch CCD Camera PAL 420TVL) was turned on. He made this observation working with the same RC car as ours prior to us. In order to replicate this jamming scenario, the same camera was ordered. The signal spectrum of the camera needed to be analyzed for the particular frequencies responsible for jamming the car. This provided a major stepping stone for the project.

Camera Transmitter Characteristics

The first step was to find any constraints and ensure the camera's safety while working with it. Any losses would be costly both money and time wise. It was found that the voltage for the camera should not be any higher than its rated 12 volts DC.

The camera transmitter was then examined on the spectrum analyzer. The transmitter consisted of 4 channels ranging from channel 0 to channel 3. Chad informed our group that he had managed to jam his car with the transmitter on three channels: 0, 1, and 2. The spectrum of each of the 4 channels are shown in Figures 6-9.

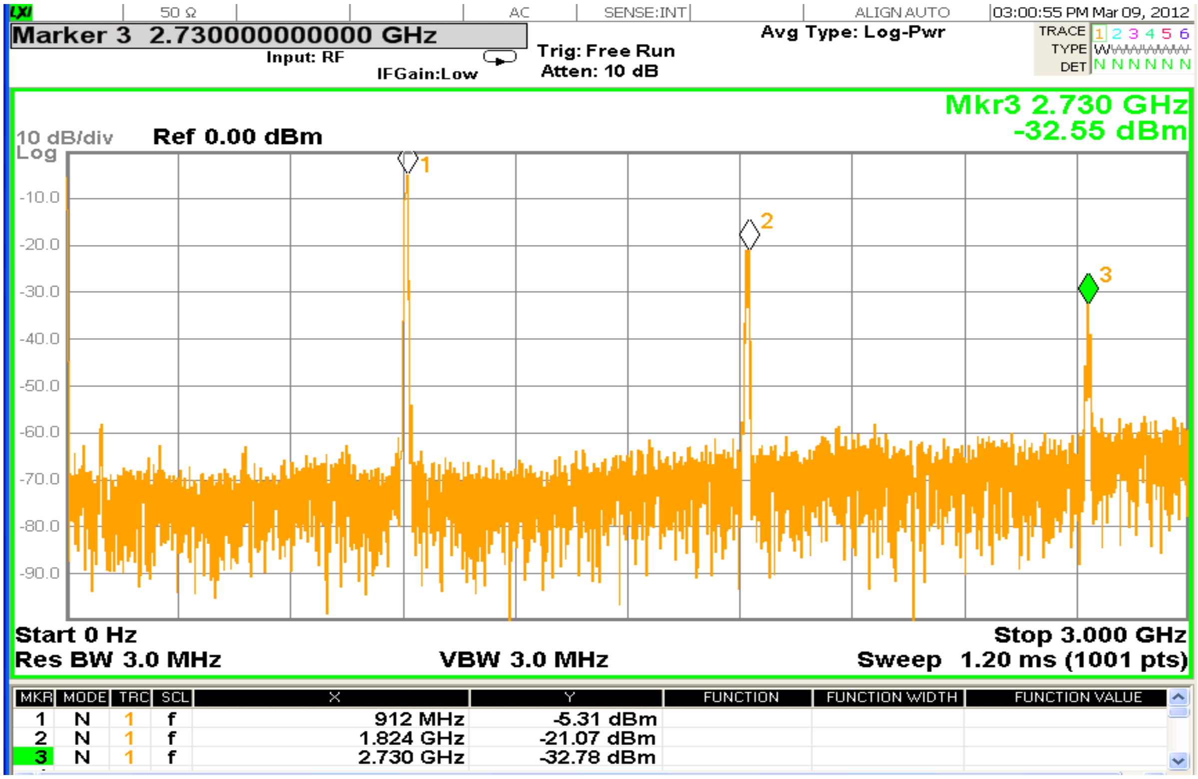

Figure 6: Spectrum of Camera Channel 0

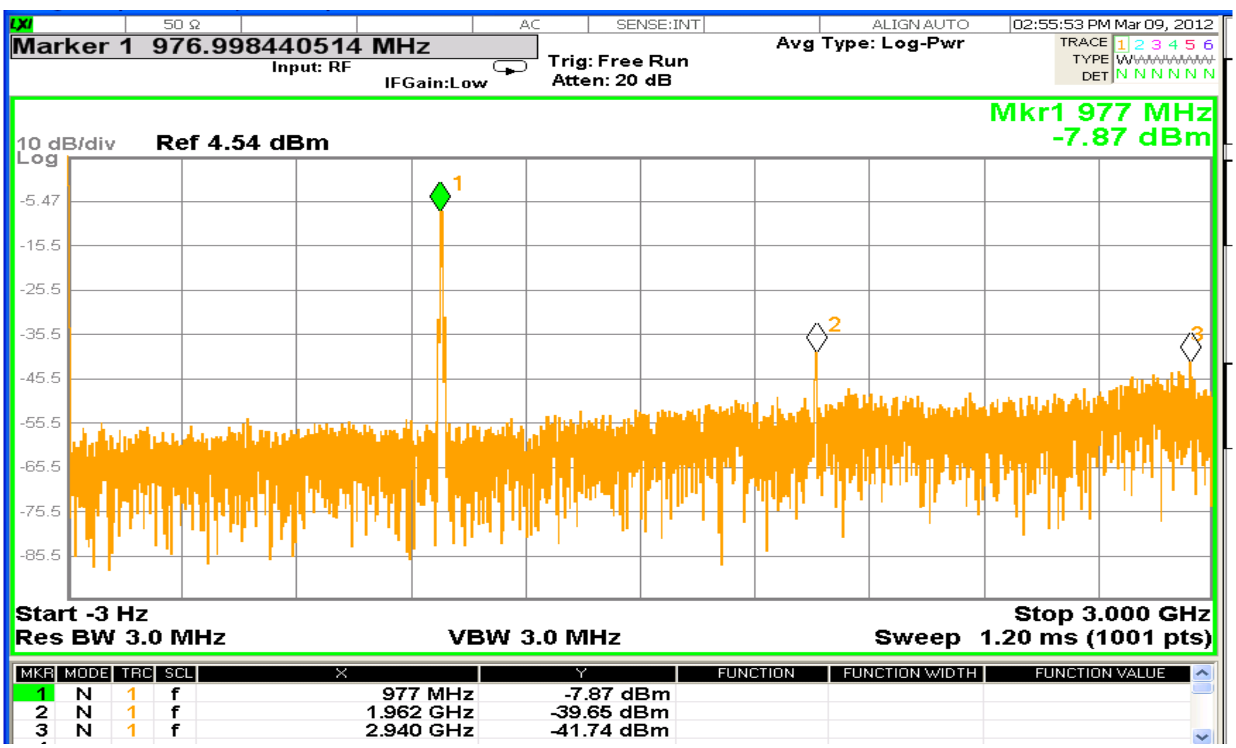

Figure 7: Spectrum of Camera Channel 1

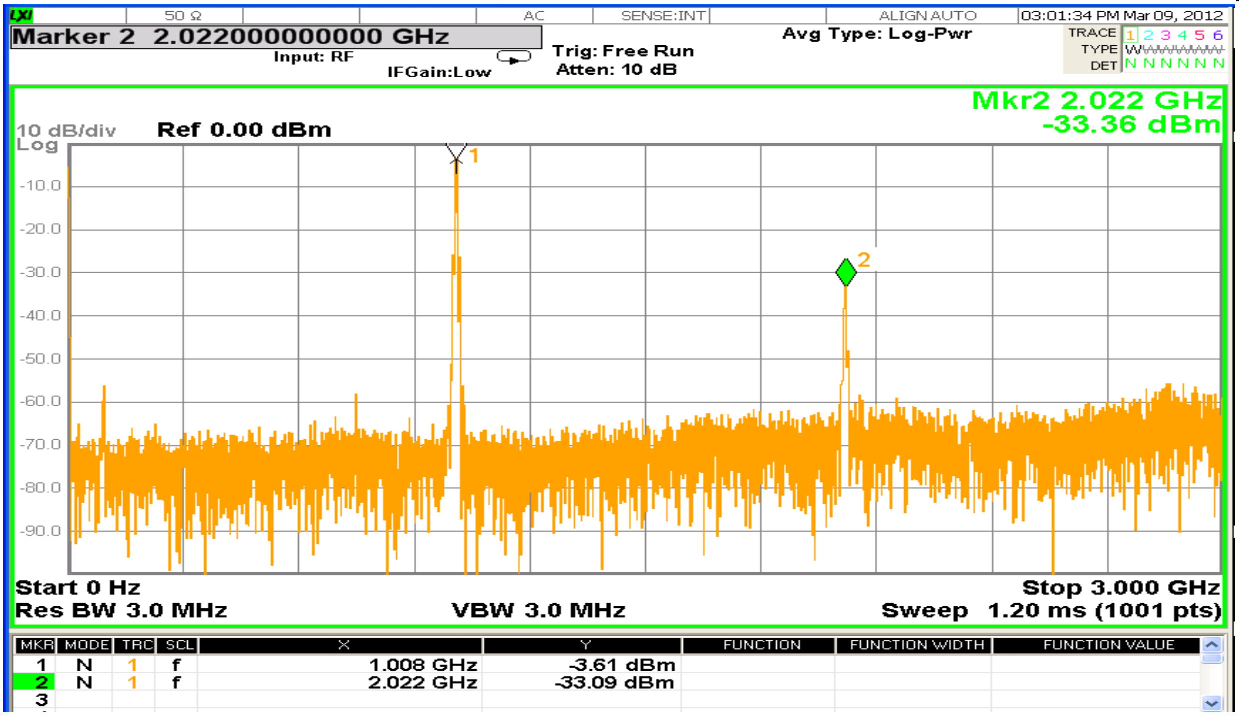

Figure 8: Spectrum of Camera Channel 2

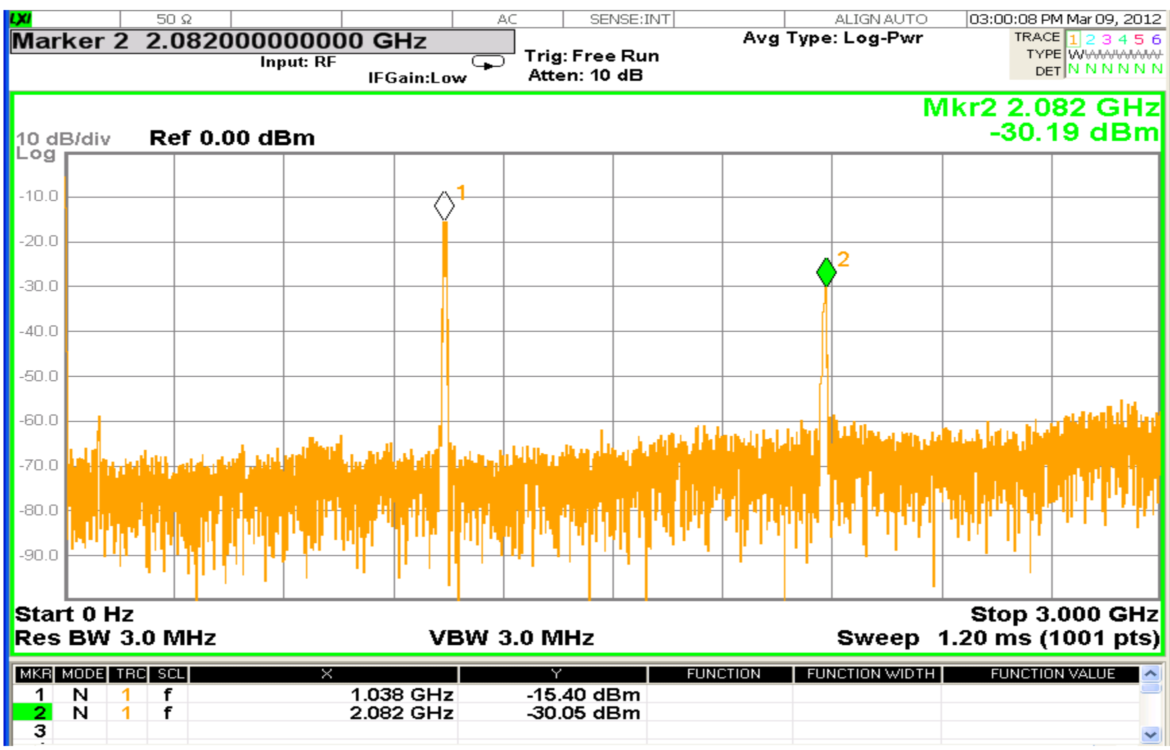

Figure 9: Spectrum of Camera Channel 3

These figures demonstrate that the 900 MHz camera has harmonics close to 2.4 GHz, which could potentially lead to jamming the signal. Notice that these were the only signals observed by the spectrum analyzer without a direct connection, and therefore this only shows the strongest signals. Table III displays the main harmonics.

Table III: MAIN HARMONICS OF CAMERA CHANNELS (the first harmonics are all larger than -10dBm)

	Channel 0			Channel 1			Channel 2		Channel 3	
Frequencies (GHz)	0.912	1.824	2.73	0.977	1.962	2.94	1.008	2.022	1.038	2.082

Camera Transmitter Jamming

To test for jamming, an antenna was attached to the camera transmitter and placed in the vicinity of the car's antenna. The transmitter managed to jam the RC car on all channels (0-3). However, in order for it to jam, the antenna of the transmitter needed to be extremely close, within an inch, to the antenna of the car. It was hypothesized that the harmonic of the camera closest to the 2.4 GHz range was jamming the signal. While the camera transmitter jammed the car, once it was moved away from the car's antenna, the car accelerated rapidly.

Probing Channel 2

A small part of the wires for channel 2 probes were stripped to accurately gauge and measure them. The red wire was measured to be 6V and the black wire was 0V. The wires to the probes are shown in Figure 10. The white wire carried a pulse width modulation signal with specifications shown in Table IV**.** The notches in the wires shown in Figure 10 are the parts that were stripped and connected for measurements.

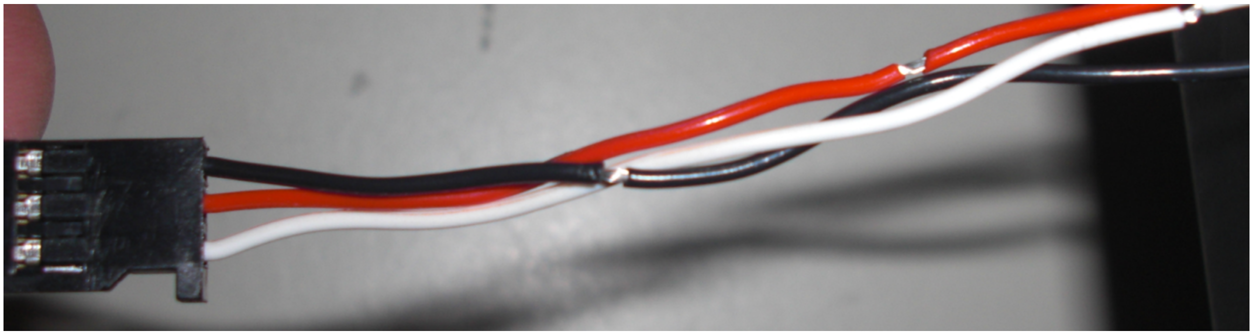

Figure 10: Three wires connected to the probes for Channel 2

Table IV: CHANNEL 2 WIRES PWM SIGNALS

Duty Cycle	Frequency	Amplitude	Peak to Peak	Maximum	Minimum
15 %	100.67Hz	3.26	3.38	3.26	-.12V

There was no change in the 15% duty cycle PWM when the transmitter was linked and the car was steered in a direction without any throttle. When the car was throttled, the duty cycle was shown to be 15.4%. When the car was put in reverse, the duty cycle decreased to 14.6%

Filtering the Signal

The signal received from the camera transmitter that jammed the RC car is shown in Figure 11.

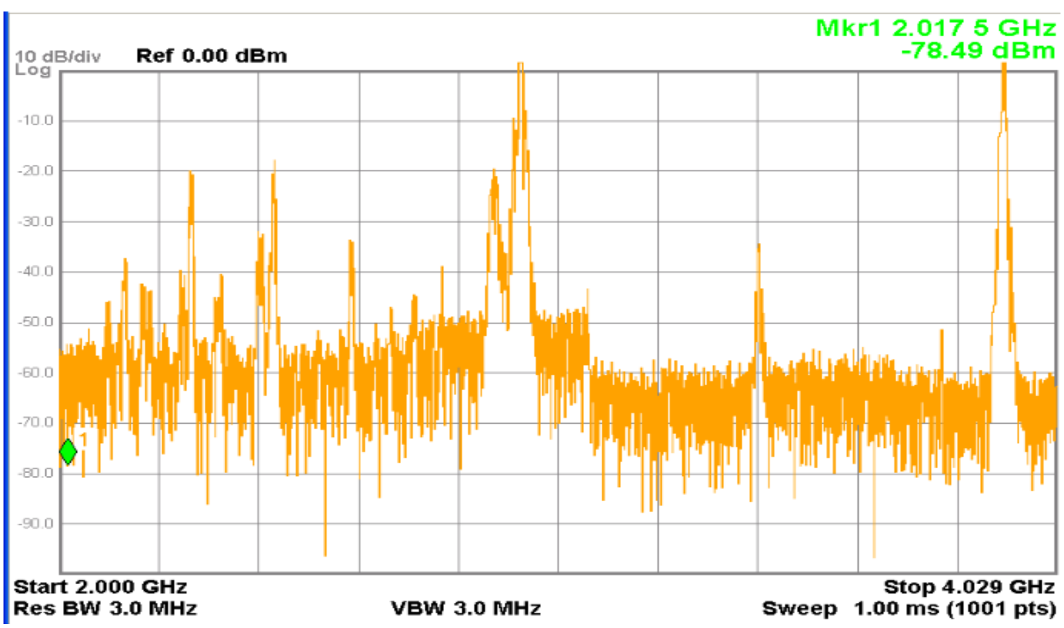

Figure 11: Camera Transmitter Signal Spectrum

It was necessary to filter the signal to determine the correct and exact frequency range which would properly jam the car. Using this frequency range, a signal generator could be used to disrupt the transmitter signal, thus jamming the car.

V. CONSTRUCTION AND TESTING

Simple RC Filter

A first order high-pass filter with a 2.5 GHz cutoff frequency was constructed to pass high-frequency signals, but attenuate signals with frequencies lower than 2.5GHz. To calculate the capacitance, an equation was employed: **frequency =** $\frac{\mathbf{1}}{\mathbf{2\pi RC}}$. The filter consisted of a resistor (4.5Ω) and a capacitor in the pico-farad range. It was found that this cutoff frequency still jammed the car. The placement of the filter in connection to the camera and camera antenna is shown in Figure 12. This means that the jamming frequency is above 2.5GHz or there was not enough attenuation to the jamming frequency

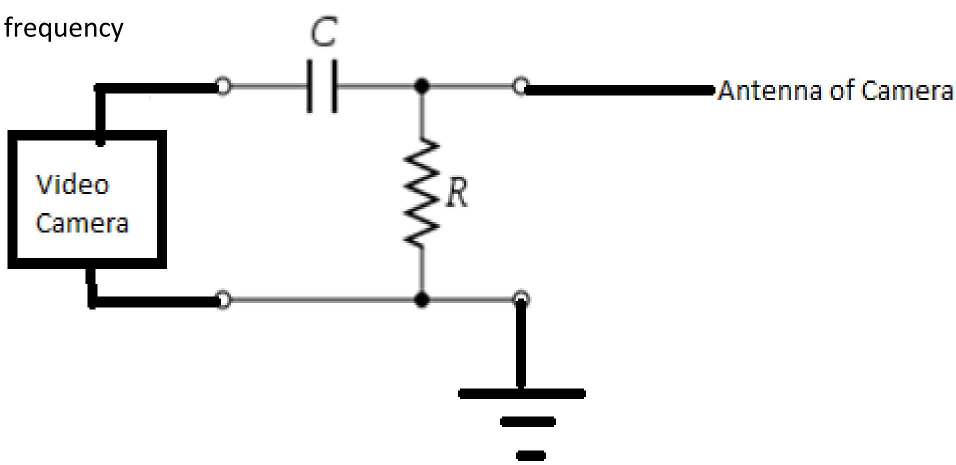

Figure 12: First-Order High-Pass Filter

Low-Pass 160 MHz Filter

A 160 MHz low –pass filter was constructed to confirm that the car would not jam without its high frequencies. The filter was applied between the camera transmitter and the antenna. This filter worked successfully, by preventing the camera transmitter from jamming the R/C car.

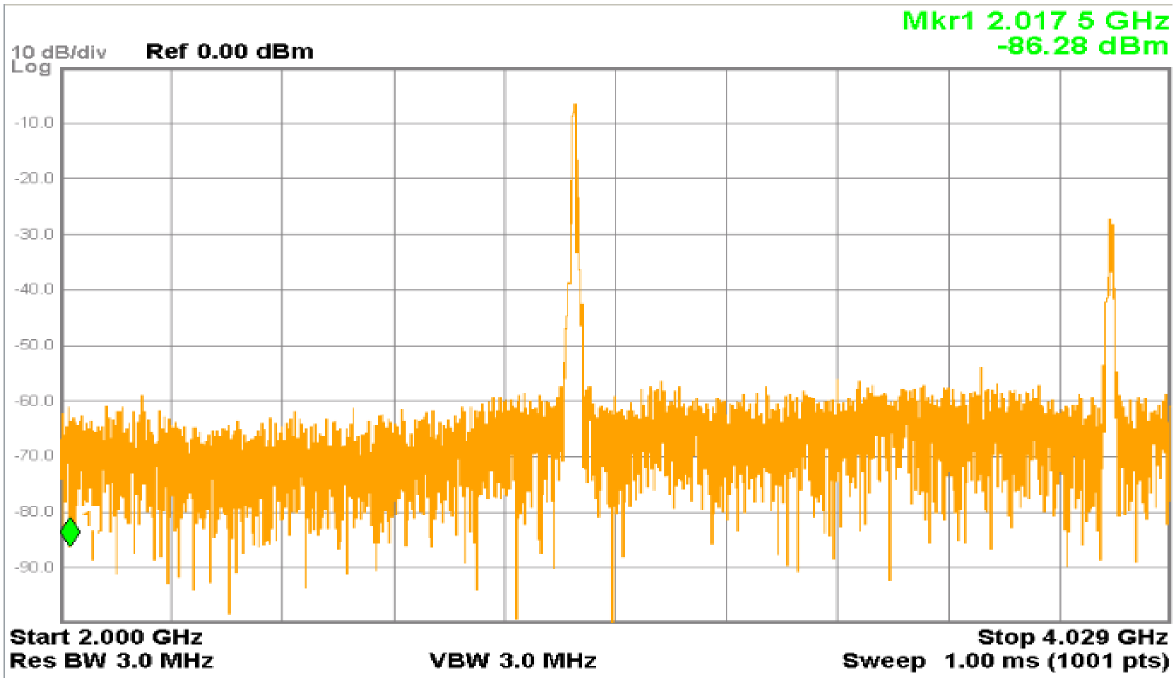

Figure 13: 160 MHz Low-Pass Filter Signal

Varying Filters

As seen from **Figure 13** much of the signal originally peaking (**Figure 11)** was attenuated. This set a definite jamming range from 160MHz to 2.5GHz. However, such a range was too large and needed to be narrowed. This was accomplished by various filters with different cutoff frequencies. To vary the frequency, the capacitor values were altered by placing more capacitors in parallel with the original capacitor. Unfortunately, this method did not work and resulted in a lack of finding the correct jamming frequency range. First-order filters did not offer enough attenuation; therefore higher order filters with inductance were necessary.

Calculating the capacitance and inductance values would cost too much time especially for high order filters; a program, Elsie, was used instead to design the filter. Elsie is a computer design tool that can design many types of analog filters. It provides options for different filters such as Bessel or Chebyshev, and allows the user to input the corner frequency. Using the inputted data as well as filter

choice, it produces a schematic of the filter along with the capacitance and inductance values necessary. These capacitances and inductances can be slightly adjusted to better fit a user's needs: if a capacitance was too small, it could be increased; however, this would change inductance values. The inductances and capacitances for this project's filters turned out to be very small (the inductance was always in nano-Henrys and the capacitance was always in pico-Farads).

A fifth order filter was built to ascertain the jamming range. The schematic with the inductance and capacitance values is shown in Figure 14. It was attempted to make the inductance as close of a value as shown.

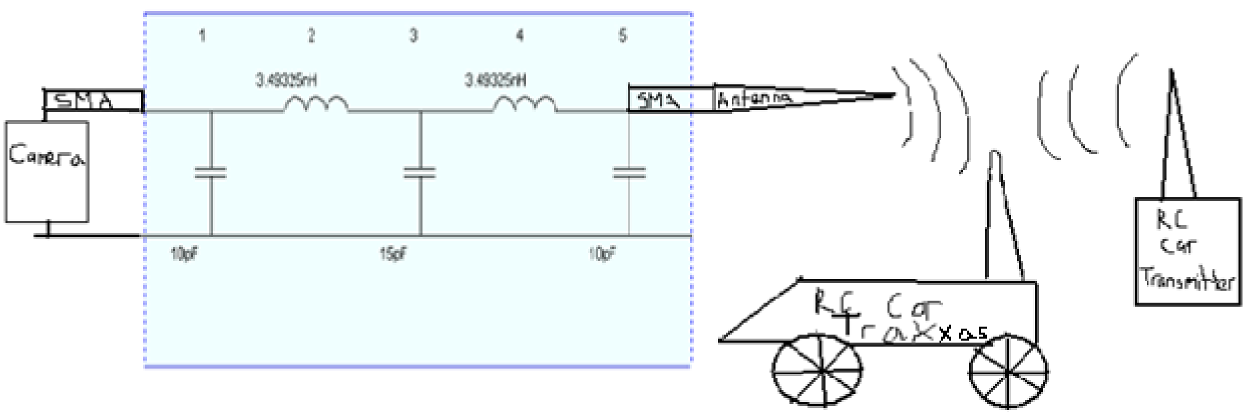

Figure 14: Fifth-Order Filter Schematic

A Chebyshev filter was chosen because of its fast transition region characteristic. This means that it has a fast roll off, after meeting its cutoff frequency (not many frequencies in the transition region). With a fast transition region, it is easier to pinpoint the frequencies that could be jamming the RC car. The filter in Figure 14 was built as a template for various fifth order filters. The same configuration was used for other fifth order filters while the inductance and capacitance were changed

based on what was being tested. The input and output stayed constant no matter what filter was being used.

Using a network analyzer, the magnitude response of the fifth order filter was displayed as shown in Figure 15. The magnitude response demonstrates a large amount of attenuation roughly between frequencies 10 MHz and 1.3 GHz with a magnitude of at least 38.397 dB. The magnitude at 2.409 GHz still has an attenuation of 23.9 dB. This caused the camera transmitter to be unable to jam the RC car. This Chebyshev fifth-order filter attenuates too much of the signal from the camera transmitter. It was speculated that a filter with less attenuation between 1 GHz and 2 GHz may allow the camera to jam the car.

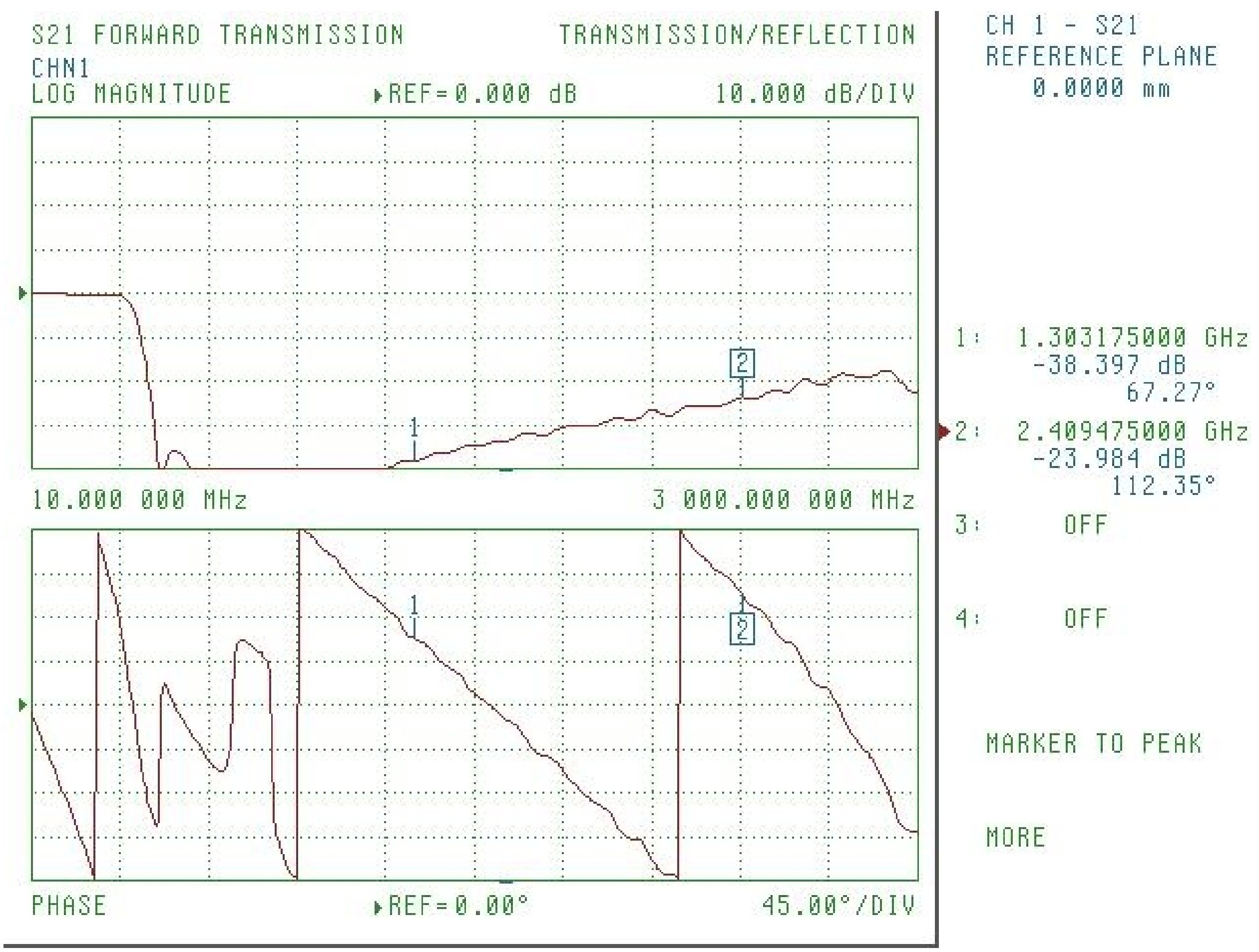

Figure 15: Magnitude Response with Fifth-Order Filter using Network Analyzer

The next fifth-order filter allowed the camera transmitter to jam the RC car. The magnitude response is shown in Figure 16**.** The largest attenuations are located at 1.303 GHZ and 2.409 GHz with magnitudes of 20.457 dB and 20.306 dB respectfully. Between these two frequencies, there was at least an attenuation of 10 dB except for the frequency around 1.8 GHz where the attenuation was at least 5 dB. This filter demonstrated that the frequencies between 1GHz and 2.4 GHz are most likely responsible for jamming the RC car.

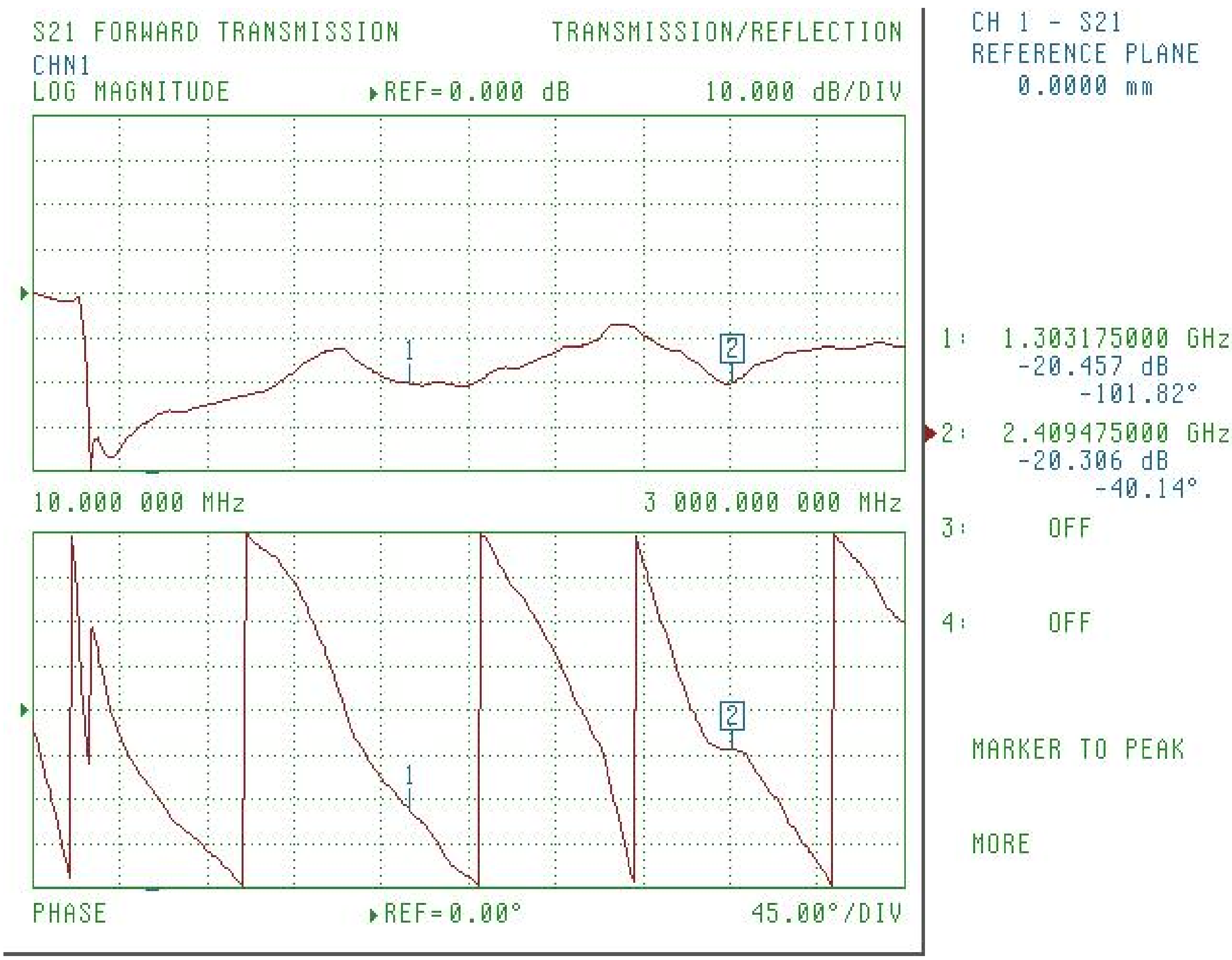

Figure 16: Second Fifth-Order Filter Magnitude Response

In order to properly compare the two fifth order filters, the responses were overlapped as seen in Figure 17. The upper magnitude response corresponds to the filter that enabled jamming, while the lower magnitude response corresponds to the filter that prevented jamming. While there are differences in attenuation between the two filters, there are also similarities. These similarities can be seen at very low frequencies and very high frequencies: the magnitudes at these frequencies are close for the two filters. This shows that very low frequencies do not jam the RC car and at the same time the probable frequencies enabling the jamming are between 1 GHz and 2.4 GHz. The filters provided a much narrower and definite frequency range to work with.

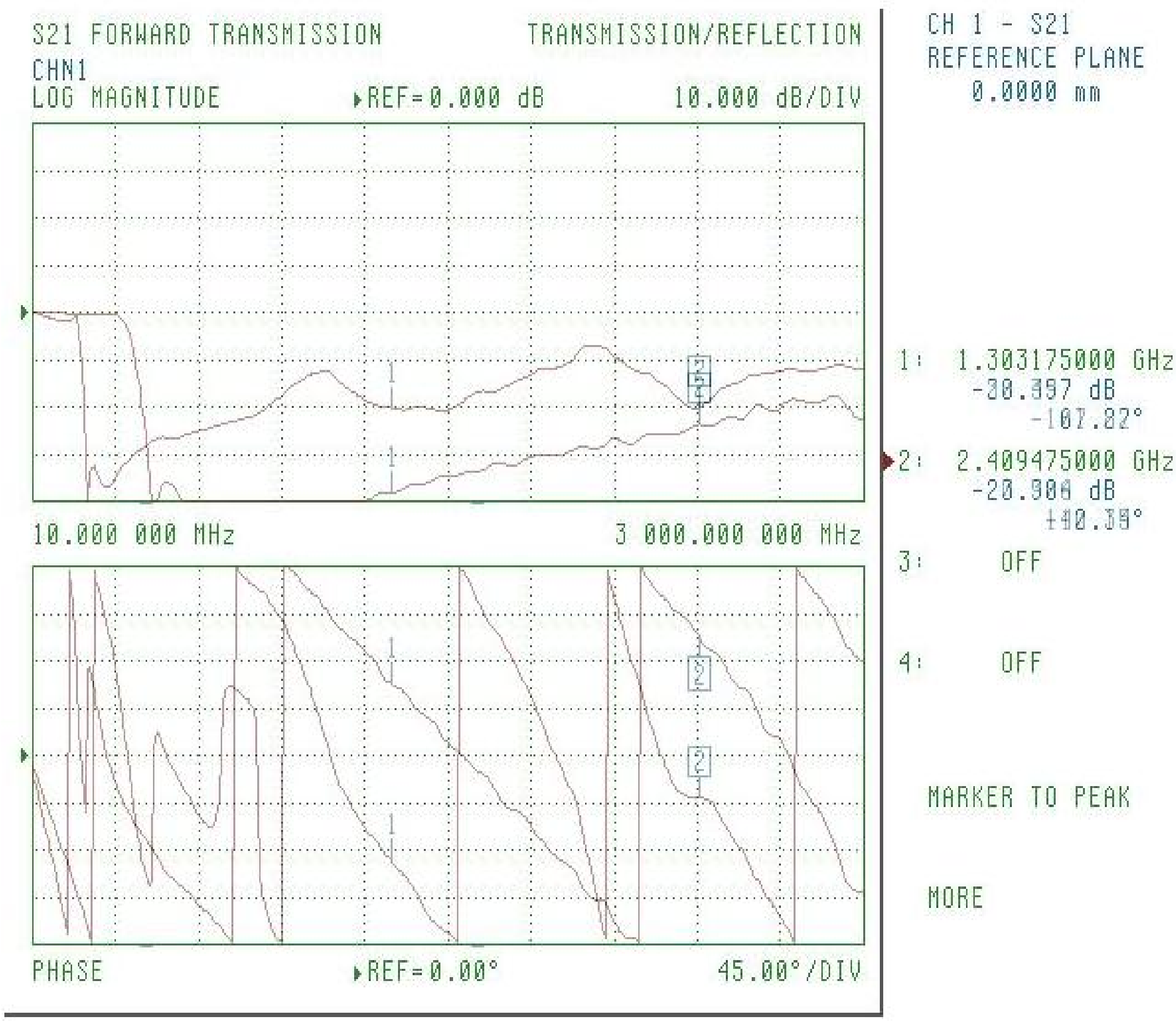

Figure 17: Comparison of the Two Fifth-Order Filters

Tunable Filter: Quarter Wave Cavity Resonator

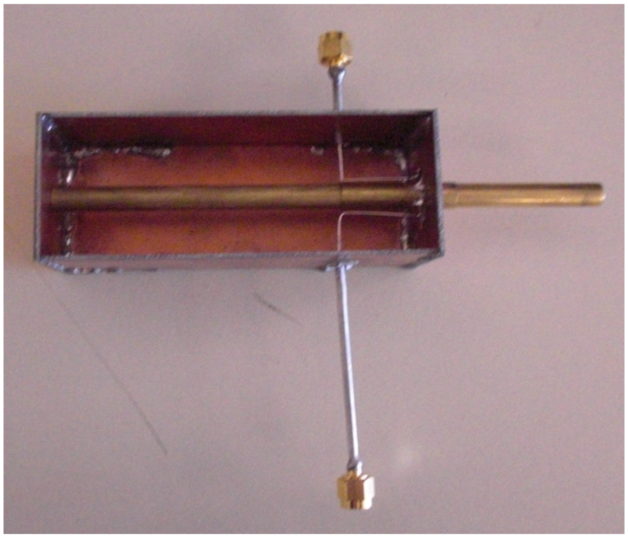

Figure 18: Tunable Filter Original

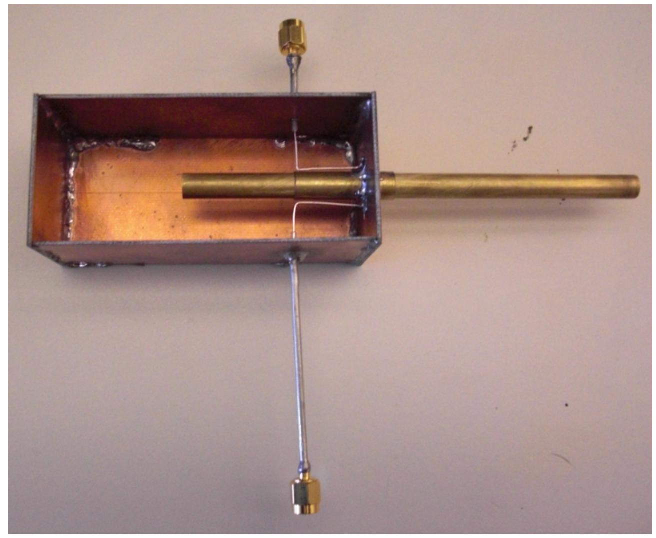

Figure 19: Tunable Filter Adjusted

This tunable filter can easily change or "tune" the band-pass frequency by adjusting the cylindrical length of copper. The copper length can be seen within the box and moved in Figures 18 and 19**.** The length can be decreased by pulling the copper out as seen in the transition from Figure 18 to Figure 19**.** The longer the length of copper is in the box, the lower the band-pass frequency. At the same time the shorter the length, the higher the band-pass frequency.   This is the easiest filter to use once it is created since no discrete components such as inductors, capacitors, or resistors needed to be added or changed.

The output of the camera transmitter was put through this tunable filter. The copper length of the filter was then decreased starting from maximum length until the transmitter is no longer able to jam the RC car. This narrowed the frequencies that were responsible for jamming the car and reduced the need to construct multiple filters, thus saving time. Figure 20 shows the lower frequency limit that prevents jamming is roughly 1.108 GHz.

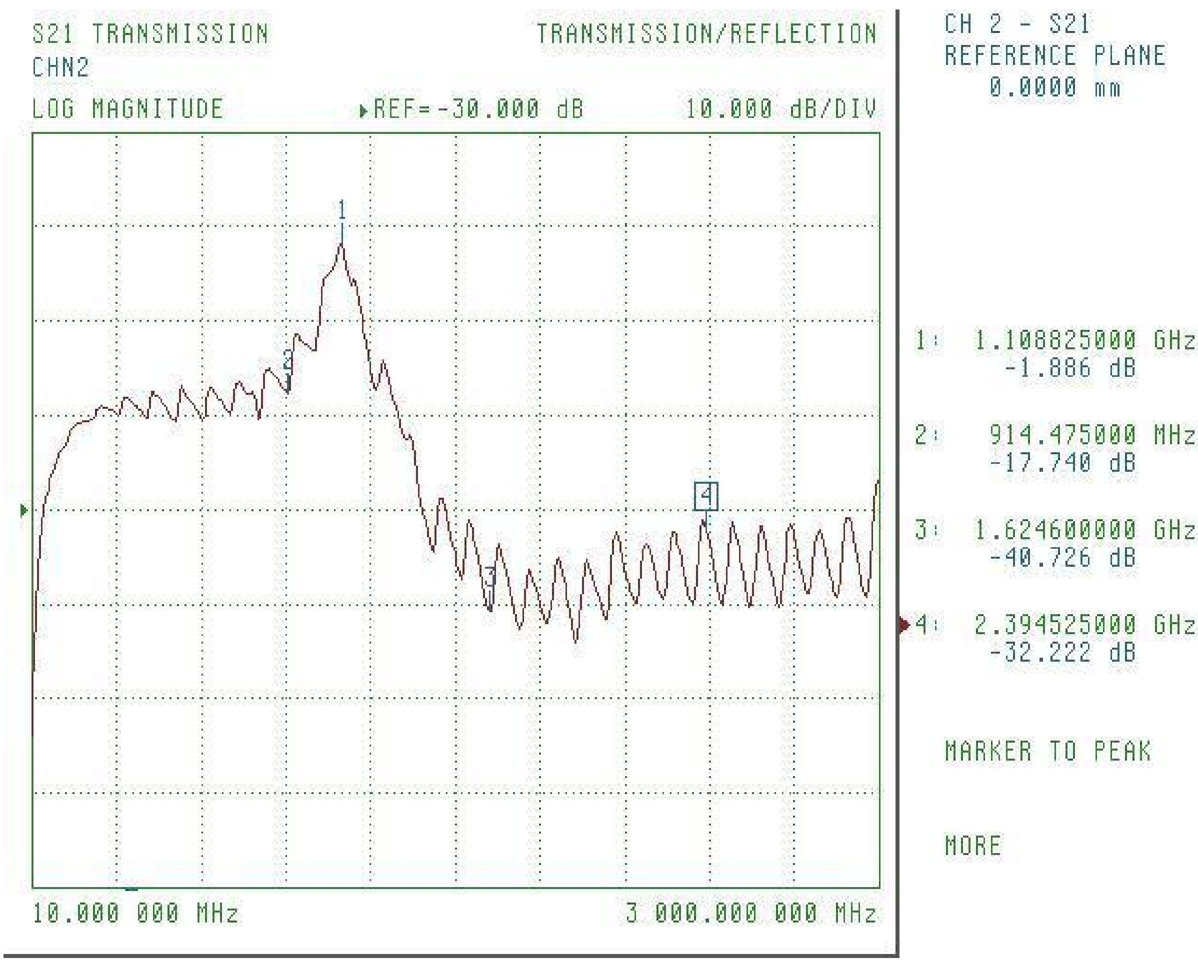

Figure 20: Lower Bound of the Tunable Cavity Filter

The copper length of the filter was adjusted again to find the upper limits. The frequency of the upper limit was found to be 1.14 GHz as shown in Figure 21. This frequency also prevents the transmitter from jamming the RC car. The signal that the camera transmitter uses to jam the RC car was attenuated by the filter.

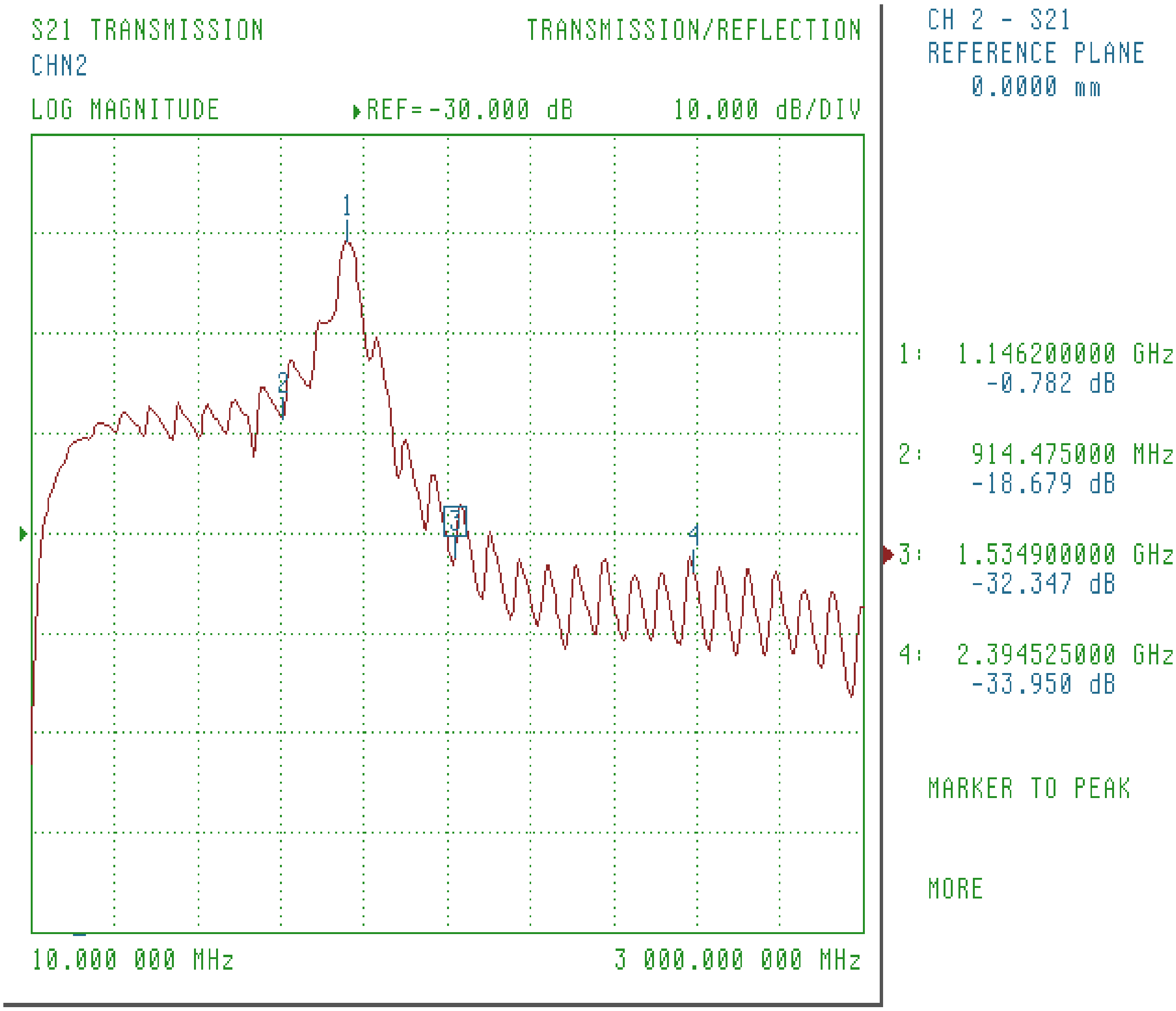

Figure 21: Upper Bound of Tunable Cavity Filter

To verify the frequencies that jammed the RC car, the camera transmitter spectrum was passed through the tunable filter with the same jamming frequencies and displayed on the spectrum analyzer as shown in Figure 22. The center frequency was roughly 1.039 GHz as shown by marker 2 in Figure 22**.** It was necessary to mimic this signal with a signal generator: this would provide a signal, independent of the camera, which would successfully jam the RC car accomplishing the goal of the project.

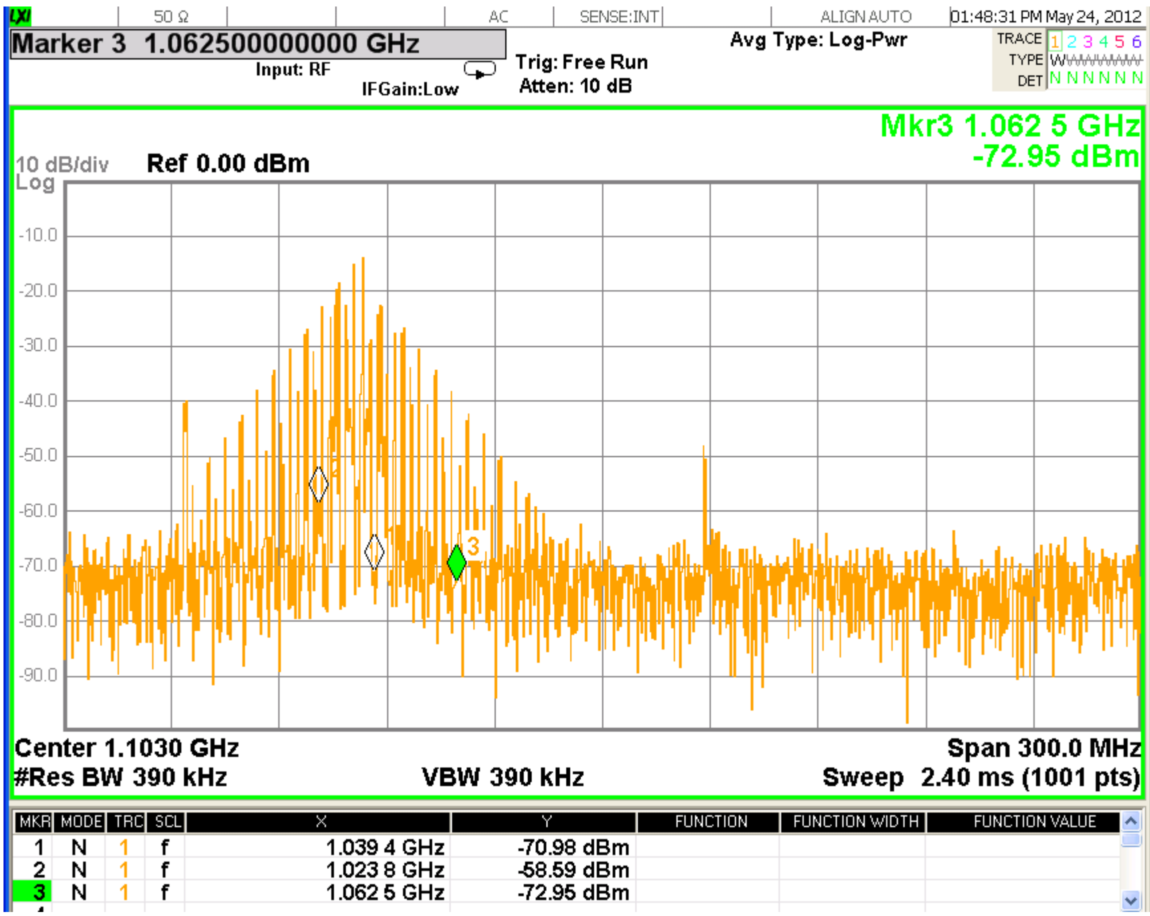

Figure 22: Signal from the camera's transmitter after being filtered

Using the center frequency of 1.039 GHz, a single pulse was generated at this frequency with the signal generator. However, this failed to jam the RC car and it was decided that the signal would be modulated with a square wave to widen the signal bandwidth as shown in Figure 23. The square wave provided the extra peaks to the left and right of the original pulse signal at 1.039 GHz. The modulated signal transmitted from the signal generator was able to jam the RC car. However, a more precise and narrow signal option was explored.

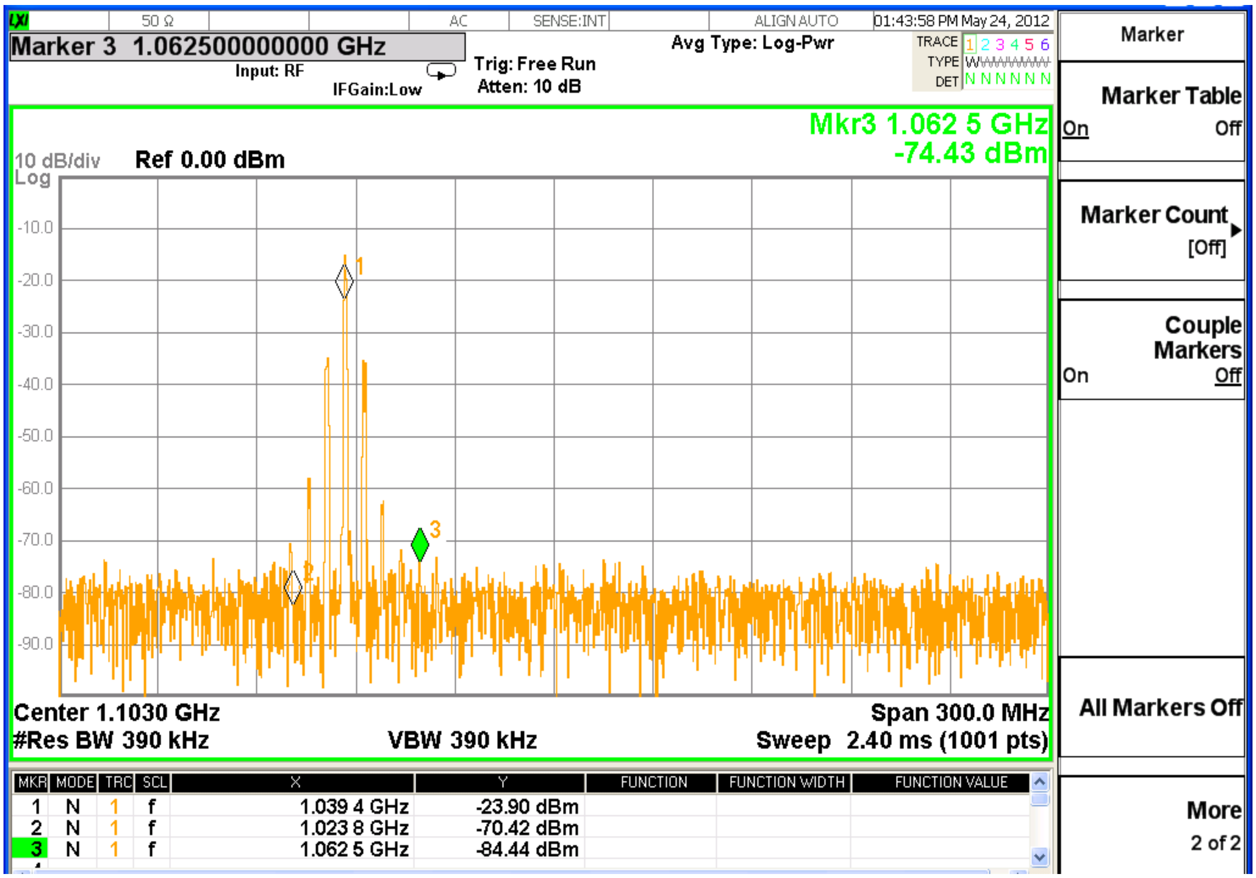

Figure 23: Square Wave Modulated Signal

To narrow the signal from Figure 23**,** the signal was unmodulated and the signal generator was set to 20 dBm with a center frequency of 1.02 GHZ. This frequency would be the main lobe. The side lobes are shown to be roughly 1.01 GHz and 1.03 GHz. These frequencies are able to successfully jam the car. The final spectrum used to jam the RC car can be seen in Figure 24.

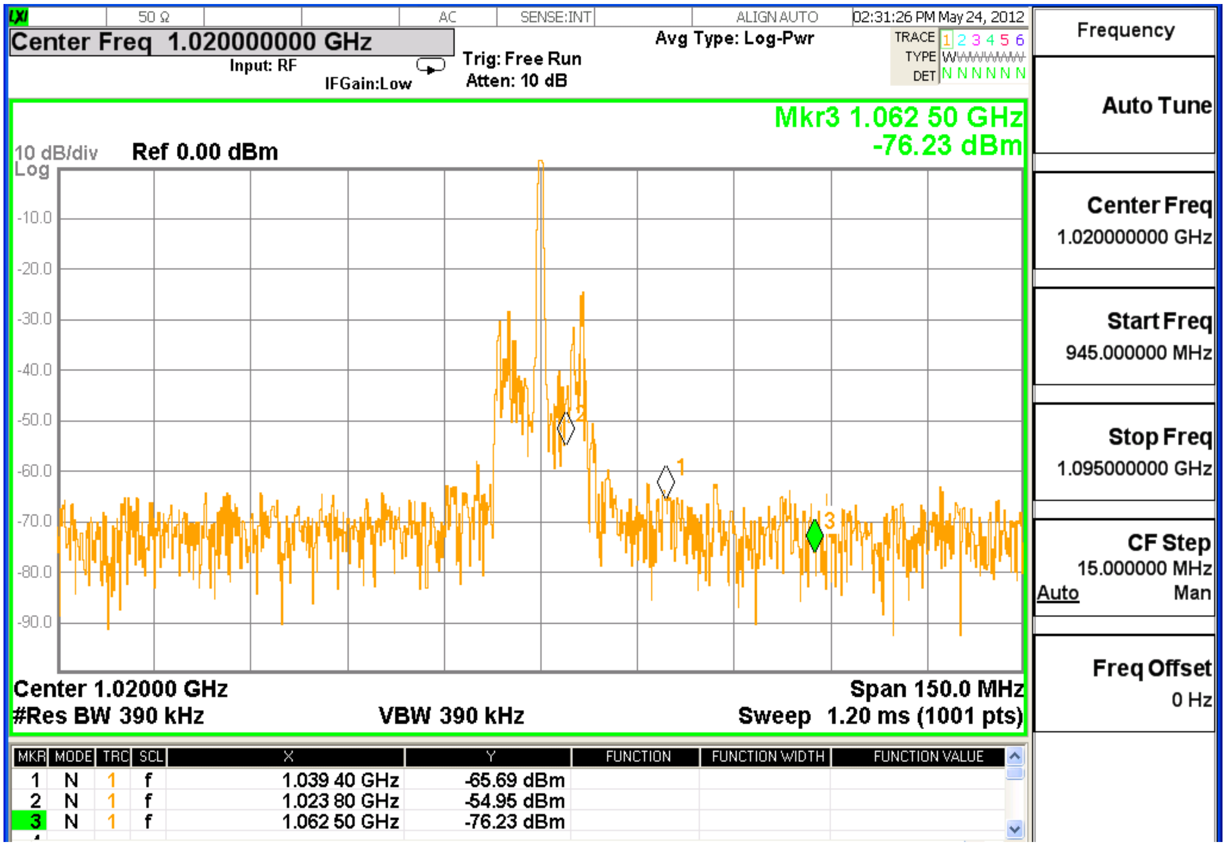

Figure 24: Final Spectrum using Signal Generator with Center Frequency of 1.02 GHz

This spectrum is similar to that of the camera transmitter. The main frequency was concentrated at 1.02 GHz and the side lobes were at roughly 1.0175 GHz and 1.025GHz. This signal generator successfully jammed the car without the use of the camera transmitter.

VI. CONCLUSION

Overall, the project involved many hours of hands on work and testing. The final result was successful due to isolation of frequencies that contributed specifically to jamming the car. The principal jamming ranges were from roughly 970 MHz to 1.07 GHz. A power of at least 18dBm was required to jam the car along these frequencies. The bandwidth for these signals was a reasonable 20 MHz. The particular frequencies that jam the RC car are interesting in the fact that none of them are harmonics of the original signal sent by the transmitter. Some internal hardware within the receiving device for the car is jammed when these signals are transmitted.

A disappointing aspect of this project was the range of the jamming. The antenna connected to the signal generator needed to be within inches of the RC car receiver in order to jam the car. However, it is possible that the range of jamming could be increased by using a power amplifier and a directional antenna. This could increase the overall power delivered through the antenna and thus dramatically increase the range of the jamming signal. This method would be more useful for instances when the jamming device needs to be hundreds of feet or more from the receiver. This would apply more to UAV or other devices used at large ranges that could potentially endanger civilians.

The same method used on the direct sequence spread spectrum (DSSS) RC car for this project could be implemented with an unmanned aerial vehicle (UAV). The first attempt would be to find a broadband jammer that could be filtered and have its frequencies isolated. The tuning cavity filter was an extremely convenient filter and most likely the optimal candidate for isolating frequencies. The isolated frequencies can then independently be sent to the receiver and attempt to jam the communication.

The project provided experience of everything, including wireless devices communicate, how processing down converts a particular high frequency signal, and how to create accurate analog filters. A possible addition to the project could be creating a detector to detect the usage of the RC car. This would provide an alert that a wireless device was in use and motion. This would allow for automated detection and jamming of the car and could be used to prevent the need for manual approach.

While analyzing the various signals, creating multiple filters, and trying to isolate the frequency range took much time and resources, the success of jamming the DSSS RC car exceeds the hardships experienced along the process.

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APPENDIX A

Senior Project Analysis

Project Title: Spread Spectrum Jamming

Student Names: Edward Hwang

Karl Sanders

Advisor Name: Helen Yu

Summary of Functional Requirements

The project was aimed to have the capability of jamming a spread spectrum RC vehicle. It was hoped that once this was done, it could be applied on a larger scale: to other spread spectrum devices such as unmanned aerial vehicles.

Primary Constraints

Spread spectrum in itself was one of the main obstacles of this project. The concept of spread spectrum was meant to prevent and mitigate any jamming. However, this was the challenge that we were aiming to overcome. Another limitation was the equipment for the project. In order to study the spread spectrum, a signal analyzer was required. However, the frequency for the spread spectrum RC car was 2.4 GHz; this meant that the signal analyzer needed to be able to reach such frequency. There were very few signal analyzers on campus that reached such a high frequency and those that could were unavailable most of the time. No oscilloscopes would even go close to 2.4GHz so a real time view of the transmitter was never observed. The remaining hindrance dealt with time constraints: the parts that

needed to be shipped took time to arrive. Unfortunately sometimes progress could only be made when the parts arrived.

Economic

Final Bill:

ITEM	PRICE	QTY	SHIPPING	TOTAL
RC Car with Transmitter	519.99	1	25	544.99
Sony Camera/Transmitter/Antennas	99.99	1	20.94	120.93
EZ-Peak Plus Battery Charger	119.99	1	15	134.99
RC Car Transmitter and Receiver only	150	1	5	155
Antenna caps/spool	8	4	1	9
Antenna crimp nuts	4	1	2	6
Antenna tube	4	4	2	6
Total				976.91

The cost of the project included buying the targeted device, which in this case was the RC car. The other main cost would be obtaining equipment that would measure high frequency. We were able to find such a signal analyzer in Cal Poly's Computer Network and Communications lab. Luckily for us, the project was being sponsored by Raytheon, which covered any of the project's costs.

Spread spectrum jamming would not have such a large impact economic wise. It would mainly be marketed to defense contractors and the military. In reality, it is not a commercial product that an average consumer would purchase. It is a countermeasure against potential threats. The main people who would profit monetarily from this would be defense contractors; however, at the same time the civilians would profit from this safety-wise. This countermeasure can be used to protect citizens from any attacks.

This type of project was not done in mind to generate billions in revenue; it was construed to be a safety measure against dangerous devices that utilized spread spectrum.

Environmental

There will not be any major environmental impacts, considering how much of the work deals with signals rather than physical products. The equipment needed only consist of those that can detect and measure signals.

Manufacturability

The main issue would be creating a device to detect such a high frequency and to transmit a similar frequency. The equipment such as a spectrum analyzer can be manufactured and a greater scale, but such equipment is still costly.

Sustainability

The system would only require a transmitter and detector so the main issue would be maintaining these equipment. There would not be any effects to natural resources and ecosystems. It would also not affect any other species. In contrast, the system would prevent potential destruction if used properly.

Ethical

The main ethical implications would be if someone decided to use the information from the project to illegally jam signals. This includes any forms of public communication or even possibly military.

Health and Safety

The only health and safety concerns would be setting up the system, and even then the concerns would be very minor. The equipment would need to be manufactured properly for there to be no malfunctions. The largest risk would be not being able to jam a dangerous incoming UAV.

Social and Political

The project's only impact on stakeholders would be if it successfully worked and jammed the targeted the device. It is a countermeasure meant to prevent any harm not to cause it. Other than its function, the project has few impacts on people.

Development

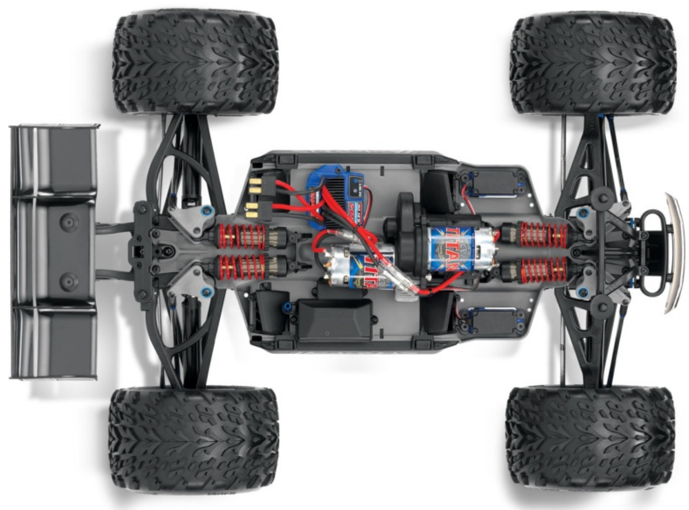
The project provided the opportunity for a much greater study and in depth look at spread spectrum. It allowed for analysis of direct sequence spread spectrum as well as the equipment necessary to examine it. This includes spectrum analyzers, oscillators, modulators, and various filters. Through this project, various filters were studied and designed including low pass, high pass, and band pass. To measure the inductance, a network analyzer was employed.

APPENDIX B:

PARTS LIST

<u>RC Car Components</u>

E-Revo Traxxas RC Car (#5603)

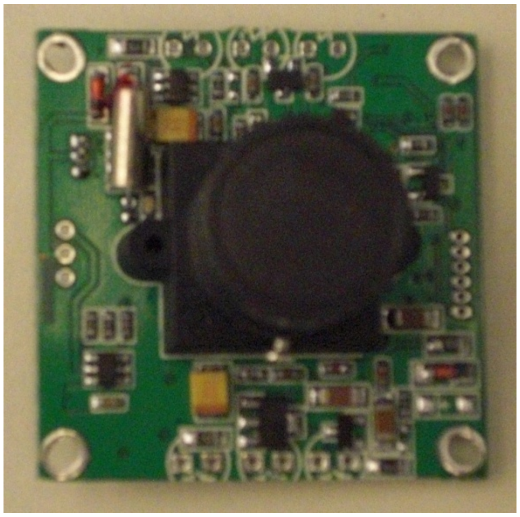


Traxxas TQ 2.4 GHz Transmitter

EZ-Peak Plus Battery Charger for Car

<u>Camera Components</u>

SONY CCD 1/3 inch Camera



900 MHz 8 Channel Video Transmitter (1500 mW)

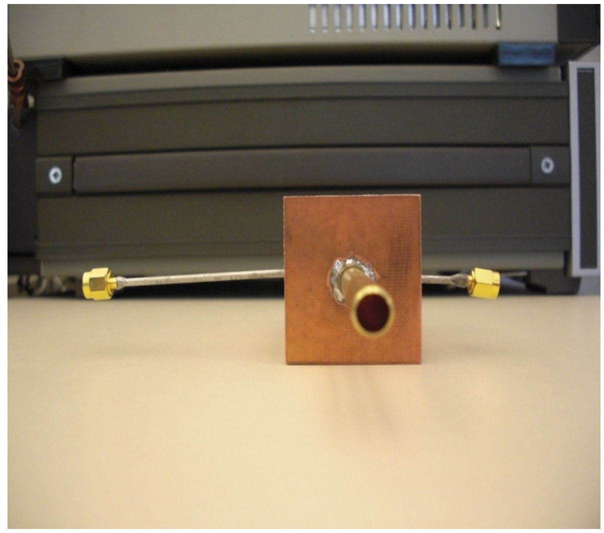
900 MHz 12 Channel Video Receiver

2 Antennas

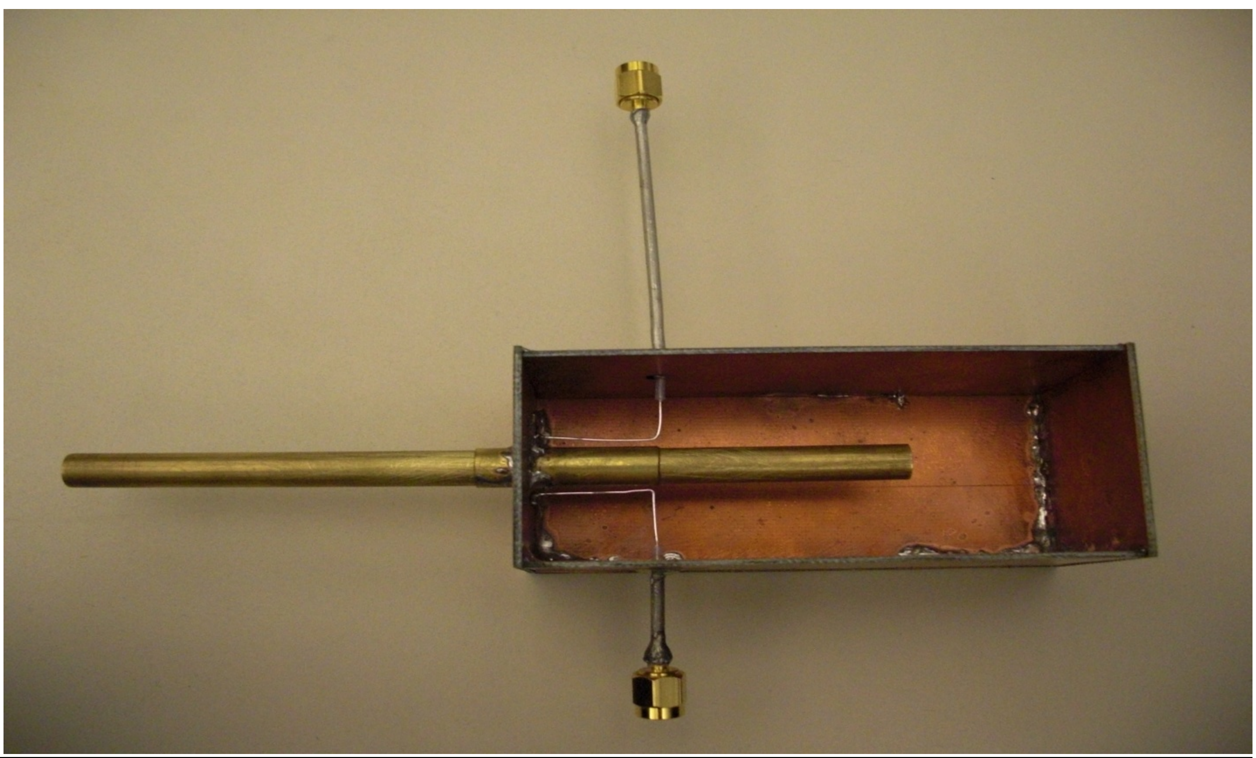
Tunable Filter for the Camera

Side view of filter

Front view of Filter



Top view of Filter

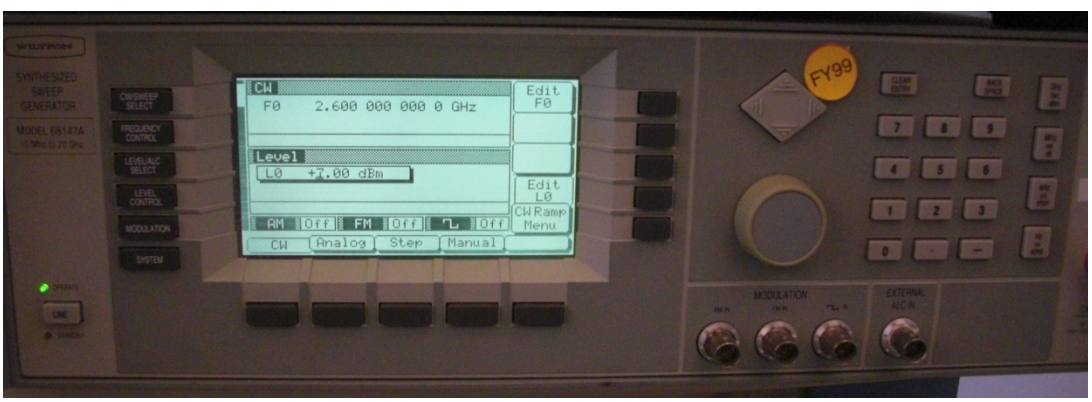


Equipment Used in Cal Poly SLO Communications Lab

Signal Analyzer: 9 KHz-7.5 GHz Agilent

Network Analyzer

Signal Generator



APPENDIX C

TIME ALLOCATION:

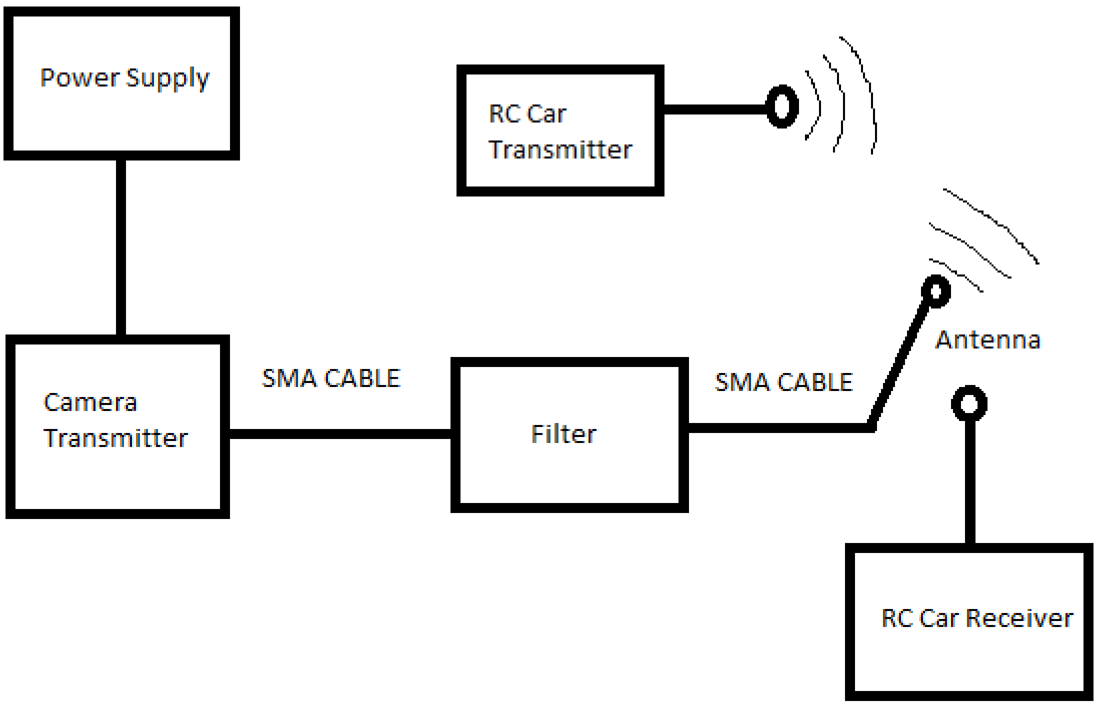
		WINTER QUARTER									
Start 1/3/2012	Activity	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
	Research of Spread Spectrum	■	■								
	Awaiting Order of Sony Camera	■	■								
	Awaiting Order of Traxxas RC car	■	■								
	Finding Baseline of Spectrum Analyzer			■	■	■					
	Analyzing the Baseline			■	■	■	■				
	Finding Transmitter Spectrum						■	■	■		
	Comparing Transmitter to Baseline						■	■	■		
	Compiling the Spectrum Data received						■	■	■	■	■
End: 3/15/2012											

		SPRING QUARTER									
Start: 3/26/2012	Activity	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
	Research Jamming Techniques	■	■	■							
	Analyzing Camera Transmitter Characteristics	■	■								
	Testing if the Camera Jammed the RC car		■	■							
	Probing the wires of the receiver			■	■						
	Designing Filters to specify jamming frequency range					■	■	■	■	■	
	Testing the filters						■	■	■	■	
	Testing Specified Frequency for jamming									■	
	Finalizing Senior Project Report							■	■	■	
End: 5/25/2012											

APPENDIX D

SCHEMATICS

Camera Transmitter Fed Through Filter



Signal Generator as Independent Transmitter to Jam RC Car (Receiver)