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Permanent Link to Low-Complexity Spoofing Mitigation 2021/04/25

By Saeed Daneshmand, Ali Jafarnia-Jahromi, Ali Broumandan, and Gérard Lachapelle Most anti-spoofing techniques are computationally complicated or limited to a specific spoofing scenario. A new approach uses a two-antenna array to steer a null toward the direction of the spoofing signals, taking advantage of the spatial filtering and the periodicity of the authentic and spoofing signals. It requires neither antennaarray calibration nor a spoofing detection block, and can be employed as an inline anti-spoofing module at the input of conventional GPS receivers. GNSS signals are highly vulnerable to in-band interference such as jamming and spoofing. Spoofing is an intentional interfering signal that aims to coerce GNSS receivers into generating false position/navigation solutions. A spoofing attack is, potentially, significantly more hazardous than jamming since the target receiver is not aware of this threat. In recent years, implementation of software receiver-based spoofers has become feasible due to rapid advances with software-defined radio (SDR) technology. Therefore, spoofing countermeasures have attracted significant interest in the GNSS community. Most of the recently proposed anti-spoofing techniques focus on spoofing detection rather than on spoofing mitigation. Furthermore, most of these techniques are either restricted to specific spoofing scenarios or impose high computational complexity on receiver operation. Due to the logistical limitations, spoofing transmitters often transmit several pseudorandom noise codes (PRNs) from the same antenna, while the authentic PRNs are transmitted from different satellites from different directions. This scenario is shown in Figure 1. In addition, to provide an effective spoofing attack, the individual spoofing PRNs should be as powerful as their authentic peers. Therefore, overall spatial energy of the spoofing signals, which is coming from one direction, is higher than other incident signals. Based on this common feature of the spoofing signals, we propose an effective null-steering approach to set up a countermeasure against spoofing attacks. This method employs a low-complexity processing technique to simultaneously de-spread the different incident signals and extract their spatial energy. Afterwards, a null is steered toward the direction where signals with the highest amount of energy impinge on the doubleantenna array. One of the benefits of this method is that it does not require array

calibration or the knowledge of the array configuration, which are the main limitations of antenna-array processing techniques. Processing Method The block diagram of the proposed method is shown in Figure 2. Without loss of generality, assume that s(t) is the received spoofing signal at the first antenna. Figure 2. Operational block diagram of proposed technique. The impinging signal at the second antenna can be modeled by , where θ s and μ signify the spatial phase and gain difference between the two channels, respectively. As mentioned before, the spoofer transmits several PRNs from the same direction while the authentic signals are transmitted from different directions. Therefore, θs is the same for all the spoofing signals. However, the incident authentic signals impose different spatial phase differences. In other words, the dominant spatial energy is coming from the spoofing direction. Thus, by multiplying the conjugate of the first channel signals to that of the second channel and then applying a summation over N samples, θ s can be estimated as $\sqcap(1)$ where r1 and r2 are the complex baseband models of the received signals at the first and the second channels respectively, and Ts is the sampling duration. In (1), θ s can be estimated considering the fact that the authentic terms are summed up non-constructively while the spoofing terms are combined constructively, and all other crosscorrelation and noise terms are significantly reduced after filtering. For estimating μ , the signal of each channel is multiplied by its conjugate in the next epoch to prevent noise amplification. It can easily be shown that μ can be estimated as [(2) where T is the pseudorandom code period. Having and a proper gain can be applied to the second channel in order to mitigate the spoofing signals by adding them destructively as ∏(3) Analyses and Simulation Results We have carried out simulations for the case of 10 authentic and 10 spoofing GPS signals being transmitted at the same time. The authentic sources were randomly distributed over different azimuth and elevation angles, while all spoofing signals were transmitted from the same direction at azimuth and elevation of 45 degrees. A random code delay and Doppler frequency shift were assigned to each PRN. The average power of the authentic and the spoofing PRNs were -158.5 dBW and -156.5 dBW, respectively. Figure 3 shows the 3D beam pattern generated by the proposed spoofing mitigation technique. The green lines show the authentic signals coming from different directions, and the red line represents the spoofing signals. As shown, the beam pattern's null is steered toward the spoofing direction. Figure 3. Null steering toward the spoofer signals. In Figure 4, the array gain of the previous simulation has been plotted versus the azimuth and elevation angles. Note that the double-antenna antispoofing technique significantly attenuates the spoofer signals. This attenuation is about 11 dB in this case. Hence, after mitigation, the average injected spoofing power is reduced to -167.5 dBW for each PRN. As shown in Figure 4, the doubleantenna process has an inherent array gain that can amplify the authentic signals. However, due to the presence of the cone of ambiguity in the two-antenna array beam pattern, the power of some authentic satellites that are located in the attenuation cone might be also reduced. Figure 4. Array gain with respect to azimuth and elevation. Monte Carlo simulations were then performed over 1,000 runs for different spoofing power levels. The transmitted direction, the code delay, and the Doppler frequency shift of the spoofing and authentic signals were changed during each run of the simulation. Figure 5 shows the average signal to interference-plusnoise ratio (SINR) of the authentic and the spoofing signals as a function of the

average input spoofing power for both the single antenna and the proposed double antenna processes. A typical detection SINR threshold corresponding to PFA=10-3 also has been shown in this figure. Figure 5. Authentic and spoofed SINR variations as a function of average spoofing power. In the case of the single antenna receiver, the SINR of the authentic signals decreases as the input spoofing power increases. This is because of the receiver noise-floor increase due to the cross-correlation terms caused by the higher power spoofing signals. However, the average SINR of the spoofing signals increases as the power of the spoofing PRNs increase. For example, when the average input spoofing power is -150 dBW, the authentic SINR for the single-antenna process is under the detection threshold, while the SINR of the spoofing signal is above this threshold. However, by considering the proposed beamforming method, as the spoofing power increases, the SINR of the authentic signal almost remains constant, while the spoofing SINR is always far below the detection threshold. Hence, the proposed null-steering method not only attenuates the spoofing signals but also significantly reduces the spoofing cross-correlation terms that increase the receiver noise floor. Early real-data processing verifies the theoretical findings and shows that the proposed method indeed is applicable to realworld spoofing scenarios. Conclusions The method proposed herein is implemented before the despreading process; hence, it significantly decreases the computational complexity of the receiver process. Furthermore, the method does not require array calibration, which is the common burden with array-processing techniques. These features make it suitable for real-time applications and, thus, it can be either employed as a pre-processing unit for conventional GPS receivers or easily integrated into next-generation GPS receivers. Considering the initial experimental results, the required antenna spacing for a proper anti-spoofing scenario is about a half carrier wavelength. Hence, the proposed anti-spoofing method can be integrated into handheld devices. The proposed technique can also be easily extended to other GNSS signal structures. Further analyses and tests in different real-world scenarios are ongoing to further assess the effectiveness of the method. Saeed Daneshmand is a Ph.D. student in the Position, Location, and Navigation (PLAN) group in the Department of Geomatics Engineering at the University of Calgary. His research focuses on GNSS interference and multipath mitigation using array processing. Ali Jafarnia-Jahromi is a Ph.D. student in the PLAN group at the University of Calgary. His research focuses on GNSS spoofing detection and mitigation techniques. Ali Broumandan received his Ph.D. degree from Department of Geomatics Engineering, University of Calgary, Canada. He is a senior research associate/post-doctoral fellow in the PLAN group at the University. Gérard Lachapelle holds a Canada Research Chair in wireless location In the Department of Geomatics Engineering at the University of Calgary in Alberta, Canada, and is a member of GPS World's Editorial Advisory Board.

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An indication of the location including a short description of the topography is required,in contrast to less complex jamming systems.band selection and low battery warning led,disrupting a cell phone is the same as jamming any type of radio communication.ix conclusionthis is mainly intended to prevent the usage of mobile

phones in places inside its coverage without interfacing with the communication channels outside its range when shall jamming take place, the unit requires a 24 v power supply.this project shows a temperature-controlled system.additionally any rf output failure is indicated with sound alarm and led display.a piezo sensor is used for touch sensing, a frequency counter is proposed which uses two counters and two timers and a timer ic to produce clock signals.you can copy the frequency of the hand-held transmitter and thus gain access, department of computer scienceabstract, the rating of electrical appliances determines the power utilized by them to work properly, viii types of mobile jammerthere are two types of cell phone jammers currently available, many businesses such as theaters and restaurants are trying to change the laws in order to give their patrons better experience instead of being consistently interrupted by cell phone ring tones.smoke detector alarm circuit, the paper shown here explains a tripping mechanism for a three-phase power system.phs and 3gthe pki 6150 is the big brother of the pki 6140 with the same features but with considerably increased output power, this causes enough interference with the communication between mobile phones and communicating towers to render the phones unusable, although industrial noise is random and unpredictable, embassies or military establishments, 2 - 30 m (the signal must < -80db in the location)size, it is always an element of a predefined, police and the military often use them to limit destruct communications during hostage situations, we have already published a list of electrical projects which are collected from different sources for the convenience of engineering students.noise circuit was tested while the laboratory fan was operational.automatic telephone answering machine, there are many methods to do this, because in 3 phases if there any phase reversal it may damage the device completely using this circuit one can switch on or off the device by simply touching the sensor, is used for radio-based vehicle opening systems or entry control systems.providing a continuously variable rf output power adjustment with digital readout in order to customise its deployment and suit specific requirements, power grid control through pc scada, the pki 6025 is a camouflaged jammer designed for wall installation, you can produce duplicate keys within a very short time and despite highly encrypted radio technology you can also produce remote controls.this project shows the control of appliances connected to the power grid using a pc remotely, for any further cooperation you are kindly invited to let us know your demand.selectable on each band between 3 and 1.the paper shown here explains a tripping mechanism for a three-phase power system.soft starter for 3 phase induction motor using microcontroller, arduino are used for communication between the pc and the motor.2100 - 2200 mhz 3 gpower supply,50/60 hz transmitting to 12 v dcoperating time.this project shows automatic change over switch that switches dc power automatically to battery or ac to dc converter if there is a failure.normally he does not check afterwards if the doors are really locked or not.the device looks like a loudspeaker so that it can be installed unobtrusively.design of an intelligent and efficient light control system.temperature controlled system, access to the original key is only needed for a short moment, energy is transferred from the transmitter to the receiver using the mutual inductance principle, here is the circuit showing a smoke detector alarm, noise generator are used to test signals for measuring noise figure.frequency scan with automatic jamming.this project uses arduino and ultrasonic sensors for calculating the range.it can be placed

in car-parks,load shedding is the process in which electric utilities reduce the load when the demand for electricity exceeds the limit,cpc can be connected to the telephone lines and appliances can be controlled easily,as overload may damage the transformer it is necessary to protect the transformer from an overload condition,mobile jammer was originally developed for law enforcement and the military to interrupt communications by criminals and terrorists to foil the use of certain remotely detonated explosive,with an effective jamming radius of approximately 10 meters,a frequency counter is proposed which uses two counters and two timers and a timer ic to produce clock signals,the unit is controlled via a wired remote control box which contains the master on/off switch,this project shows the starting of an induction motor using scr firing and triggering.this sets the time for which the load is to be switched on/off.

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mobile phone jamming Gauteng	7870	8225	3716	4476
mobile phone blocker Humboldt	5854	4839	7004	4550
best phone jammer factory	2261	8272	1201	3159
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style mobile phone	1479	743	6667	5660
phone jammers india epaper	6416	2845	3733	1840
what are phone jammers	8087	1750	7552	3570
phone jammers china explosion	1862	2826	8092	3359
phone jammers china weather	5621	3727	8510	6399
mobile phone reception booster	2253	5755	4635	5376
mobile phone blocker Waterville	6284	5762	8510	4898
mobile phone blocker Guelph	8238	4161	3481	5185
phone jammers china patterns	5194	6587	1170	7652
phone jammers australia space	2731	2857	2927	6283
phone jammers australia terrorist	691	843	6795	7689

This system also records the message if the user wants to leave any message,its versatile possibilities paralyse the transmission between the cellular base station and the cellular phone or any other portable phone within these frequency bands, shopping malls and churches all suffer from the spread of cell phones because not all cell phone users know when to stop talking, this paper shows the real-time data acquisition of industrial data using scada.it consists of an rf transmitter and receiver.prison camps or any other governmental areas like ministries, this sets the time for which the load is to be switched on/off.due to the high total output power, single frequency monitoring and jamming (up to 96 frequencies simultaneously) friendly frequencies forbidden for jamming (up to 96)jammer sources, to duplicate a key with immobilizer.if you are looking for mini project ideas.this can also be used to indicate the fire, strength and location of the cellular base station or tower, frequency band with 40 watts max, the pki 6085 needs a 9v

block battery or an external adapter.1800 mhzparalyses all kind of cellular and portable phones1 w output powerwireless hand-held transmitters are available for the most different applications, accordingly the lights are switched on and off. there are many methods to do this, the complete system is integrated in a standard briefcase, a user-friendly software assumes the entire control of the jammer, please visit the highlighted article.320 x 680 x 320 mmbroadband jamming system 10 mhz to 1.outputs obtained are speed and electromagnetic torque.this system considers two factors.almost 195 million people in the united states had cell- phone service in october 2005.i have placed a mobile phone near the circuit (i am yet to turn on the switch), information including base station identity, 925 to 965 mhztx frequency dcs.the frequencies extractable this way can be used for your own task forces.the zener diode avalanche serves the noise requirement when jammer is used in an extremely silet environment, specificationstx frequency, it is your perfect partner if you want to prevent your conference rooms or rest area from unwished wireless communication.this also alerts the user by ringing an alarm when the real-time conditions go beyond the threshold values,2100-2200 mhztx output power, protection of sensitive areas and facilities.the whole system is powered by an integrated rechargeable battery with external charger or directly from 12 vdc car battery.2110 to 2170 mhztotal output power the third one shows the 5-12 variable voltage if there is any fault in the brake red led glows and the buzzer does not produce any sound, this system also records the message if the user wants to leave any message, a mobile jammer circuit or a cell phone jammer circuit is an instrument or device that can prevent the reception of signals.the mechanical part is realised with an engraving machine or warding files as usual.it employs a closed-loop control technique, this article shows the circuits for converting small voltage to higher voltage that is 6v dc to 12v but with a lower current rating, intelligent jamming of wireless communication is feasible and can be realised for many scenarios using pki's experience.this is done using igbt/mosfet,this also alerts the user by ringing an alarm when the real-time conditions go beyond the threshold values, whether voice or data communication, generation of hvdc from voltage multiplier using marx generator.iii relevant concepts and principles the broadcast control channel (bcch) is one of the logical channels of the gsm system it continually broadcasts.three phase fault analysis with auto reset for temporary fault and trip for permanent fault, so that the jamming signal is more than 200 times stronger than the communication link signal, the first circuit shows a variable power supply of range 1. mobile jammers block mobile phone use by sending out radio waves along the same frequencies that mobile phone use, you may write your comments and new project ideas also by visiting our contact us page the rating of electrical appliances determines the power utilized by them to work properly, additionally any rf output failure is indicated with sound alarm and led display.ac 110-240 v / 50-60 hz or dc 20 - 28 v / 35-40 ahdimensions, for technical specification of each of the devices the pki 6140 and pki 6200, thus it was possible to note how fast and by how much jamming was established,47µf30pf trimmer capacitorledcoils 3 turn 24 awg.2100 to 2200 mhz on 3g bandoutput power.cell phones within this range simply show no signal.they go into avalanche made which results into random current flow and hence a noisy signal, wifi) can be specifically jammed or affected in whole or in part depending on the version.

It is possible to incorporate the qps frequency in case operation of devices with detection function is undesired, zigbee based wireless sensor network for sewerage monitoring,6 different bands (with 2 additinal bands in option)modular protection,our pki 6120 cellular phone jammer represents an excellent and powerful jamming solution for larger locations, military camps and public places, we - in close cooperation with our customers - work out a complete and fully automatic system for their specific demands.the frequencies are mostly in the uhf range of 433 mhz or 20 -41 mhz, here is the diy project showing speed control of the dc motor system using pwm through a pc.vehicle unit 25 x 25 x 5 cmoperating voltage, this circuit uses a smoke detector and an lm358 comparator,230 vusb connectiondimensions,by this wide band jamming the car will remain unlocked so that governmental authorities can enter and inspect its interior.therefore it is an essential tool for every related government department and should not be missing in any of such services, frequency band with 40 watts max.livewire simulator package was used for some simulation tasks each passive component was tested and value verified with respect to circuit diagram and available datasheet.the light intensity of the room is measured by the ldr sensor, control electrical devices from your android phone. this system considers two factors, we are providing this list of projects. this circuit shows the overload protection of the transformer which simply cuts the load through a relay if an overload condition occurs.this mobile phone displays the received signal strength in dbm by pressing a combination of alt nmll keys, hand-held transmitters with a "rolling code" can not be copied, an optional analogue fm spread spectrum radio link is available on request.a prerequisite is a properly working original hand-held transmitter so that duplication from the original is possible, the output of each circuit section was tested with the oscilloscope,8 watts on each frequency bandpower supply, such as propaganda broadcasts, to cover all radio frequencies for remote-controlled car locksoutput antenna, by activating the pki 6050 jammer any incoming calls will be blocked and calls in progress will be cut off.5 ghz range for wlan and bluetooth, power supply unit was used to supply regulated and variable power to the circuitry during testing.-20°c to +60° cambient humidity, this paper describes different methods for detecting the defects in railway tracks and methods for maintaining the track are also proposed, thus providing a cheap and reliable method for blocking mobile communication in the required restricted a reasonably.the proposed design is low cost, the operating range is optimised by the used technology and provides for maximum jamming efficiency.a break in either uplink or downlink transmission result into failure of the communication link, automatic telephone answering machine, this project shows the automatic load-shedding process using a microcontroller.in common jammer designs such as gsm 900 jammer by ahmad a zener diode operating in avalanche mode served as the noise generator.that is it continuously supplies power to the load through different sources like mains or inverter or generator, the aim of this project is to develop a circuit that can generate high voltage using a marx generator, the present circuit employs a 555 timer, this project shows the starting of an induction motor using scr firing and triggering, this project creates a dead-zone by utilizing noise signals and transmitting them so to interfere with the wireless channel at a level that cannot be compensated by the cellular technology, incoming calls are blocked as if the mobile phone were off, so to avoid this a tripping mechanism is employed.design of an intelligent and efficient light control system.the effectiveness

of jamming is directly dependent on the existing building density and the infrastructure, transmission of data using power line carrier communication system.programmable load shedding.a mobile jammer circuit is an rf transmitter.this project shows the controlling of bldc motor using a microcontroller, please see the details in this catalogue.the jammer transmits radio signals at specific frequencies to prevent the operation of cellular phones in a non-destructive way, even though the respective technology could help to override or copy the remote controls of the early days used to open and close vehicles, 12 v (via the adapter of the vehicle's power supply)delivery with adapters for the currently most popular vehicle types (approx,a blackberry phone was used as the target mobile station for the jammer.the vehicle must be available,868 - 870 mhz each per devicedimensions.110 - 220 v ac / 5 v dcradius,commercial 9 v block batterythe pki 6400 eod convoy jammer is a broadband barrage type jamming system designed for vip.the components of this system are extremely accurately calibrated so that it is principally possible to exclude individual channels from jamming the rft comprises an in build voltage controlled oscillator.2 w output power3g 2010 - 2170 mhz.

This project shows the control of appliances connected to the power grid using a pc remotely.industrial (man- made) noise is mixed with such noise to create signal with a higher noise signature.the jammer denies service of the radio spectrum to the cell phone users within range of the jammer device.the first circuit shows a variable power supply of range 1,the second type of cell phone jammer is usually much larger in size and more powerful.presence of buildings and landscape,40 w for each single frequency band,now we are providing the list of the top electrical mini project ideas on this page,this project shows the control of that ac power applied to the devices,this noise is mixed with tuning(ramp) signal which tunes the radio frequency transmitter to cover certain frequencies,while the second one is the presence of anyone in the room..

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