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Permanent Link to Innovation: Under Cover
2021/05/01
Synthetic-Aperture GNSS Signal Processing By Thomas Pany, Nico Falk, Bernhard Riedl, Carsten Stöber, Jón O. Winkel, and Franz-Josef Schimpl INNOVATION INSIGHTS by Richard Langley A SYNTHETIC APERTURE? WHAT'S THAT? Well, an aperture in optics is just a hole or opening through which light travels. Those of us into photography know that the amount of light reaching the camera's imaging sensor is controlled by the shutter speed and the size of the lens opening or aperture (called the f-stop). And a correct combination of the aperture setting and shutter speed results in a correct exposure.  For an optical telescope, its aperture is the diameter of its main, light-gathering lens or mirror. A larger aperture gives a sharper and brighter view or image. In the radio part of the electromagnetic spectrum, the term aperture refers to the effective collecting (or transmitting) area of an antenna. The gain of the antenna is proportional to its aperture and its beamwidth or resolution is inversely proportional to it. Astronomers, whether using optical or radio telescopes, often seek higher and higher resolutions to see more detail in the objects they are investigating. Conventionally, that means larger and larger telescopes. However, there are limits to how large a single telescope can be constructed. But by combining the light or radio signals from two or more individual telescopes, one can synthesize a telescope with a diameter equal to the baseline(s) connecting those telescopes. The approach is known as interferometry. It was first tried in the optical domain by the American physicist Albert Michelson who used the technique to measure the diameter of the star Betelgeuse. Radio astronomers developed cable- and microwave-connected interferometers and subsequently they invented the technique of very long baseline interferometry (VLBI) where atomic-clock-stabilized radio signals are recorded on magnetic tape and played back through specially designed correlators to form an image. (VLBI has also been used by geodesists to precisely determine the baselines between pairs of radio telescopes even if they are on separate continents.) A similar approach is used in synthetic-aperture radar (SAR). Mounted on an aircraft or satellite, the SAR beam-forming antenna emits pulses of radio waves that are reflected from a target and then coherently combined. The different positions of the SAR, as it moves, synthesize an elongated aperture resulting

in finer spatial resolution than would be obtained by a conventional antenna. But what has all of this got to do with GNSS? In this month’s column, we take a look at a novel GNSS signal-processing technique, which uses the principles of SAR to improve code and carrier-phase observations in degraded environments such as under forest canopy. The technique can simultaneously reject multipath signals while maximizing the direct line-of-sight signal power from a satellite. Along with a specially programmed software receiver, it uses either a single conventional antenna mounted, say, on a pedestrian’s backpack for GIS applications or a special rotating antenna for high-accuracy surveying. Want to learn more? Read on. “Innovation” is a regular feature that discusses advances in GPS technology andits applications as well as the fundamentals of GPS positioning. The column is coordinated by Richard Langley of the Department of Geodesy and Geomatics Engineering, University of New Brunswick. He welcomes comments and topic ideas. Over the past few years, we have been developing new GNSS receivers and antennas based on an innovative signal-processing scheme to significantly improve GNSS tracking reliability and accuracy under degraded signal conditions. It is based on the principles of synthetic-aperture radar. Like in a multi-antenna phased-array receiver, GNSS signals from different spatial locations are combined coherently forming an optimized synthetic antenna-gain pattern. Thereby, multipath signals can be rejected and the line-of-sight received signal power is maximized. This is especially beneficial in forests and in other degraded environments. The method is implemented in a real-time PC-based software receiver and works with GPS, GLONASS, and Galileo signals. Multiple frequencies are generally supported. The idea of synthetic-aperture processing is realized as a coherent summation of correlation values of each satellite over the so-called beam-forming interval. Each correlation value is multiplied with a phase factor. For example, the phase factor can be chosen to compensate for the relative antenna motion over the beam-forming interval and the resulting sum of the scaled correlation values represents a coherent correlation value maximizing the line-of-sight signal power. Simultaneously, signals arriving from other directions are partly eliminated. Two main difficulties arise in the synthetic-aperture processing. First, the clock jitter during the beam-forming interval must be precisely known. It can either be estimated based on data from all signals, or a stable oscillator can be used. In one of our setups, a modern oven-controlled crystal oscillator with an Allan variance of 0.5 × 10-13 at an averaging period of 1 second is used. Second, the precise relative motion of the antenna during the beam-forming interval must be known. Again it can be estimated if enough sufficiently clean signals are tracked. The antenna trajectory is estimated directly from the correlator values as shown later in this article. In more severely degraded environments, the antenna may be moved along a known trajectory. We are developing a rotating antenna displacement unit. (see FIGURE 1). The rotational unit targets forestry and indoor surveying applications. The relative motion of the antenna is measured with sub-millimeter accuracy. FIGURE 1. Artist’s impression of the synthetic-aperture GNSS system for surveying in a forest. After beam-forming, the code pseudoranges and the carrier phases are extracted and used in a conventional way. That is, they are written into Receiver Independent Exchange (RINEX) format files and standard geodetic software can be used to evaluate them. In the case where the artificial movement antenna is used, the GNSS signal processing removes the known part of the movement from the observations, and the observations are then like those from a static antenna. As a result, common static positioning algorithms, including carrier-phase ambiguity fixing, can be applied. The presented method therefore prepares the path for GNSS surveying applications in new areas. An important point is the mechanical realization of the antenna movement. This has to be done in a cost-efficient and reliable way. Lubrication-free actuators are used together with magnetic displacement sensors. The sensors are synchronized to the software receiver front end with better than 1 millisecond accuracy. The rotating antenna uses slip rings to connect the antenna elements. The rotating antenna can also be used to map the received signal power as a function of elevation and azimuth angles. This is beneficial for researchers. For example, it could be used to estimate the direction of arrival of a spoofing signal or to determine which object causes multipath in an indoor environment. For the latter purpose, the rotating antenna can be equipped with left-hand and right-hand circularly polarized antennas on both ends of the rotating bar. The rotating antenna is mounted on a geodetic tripod. See Further Reading for reports of initial studies of the rotating antenna. Tracking Modes The synthetic-aperture tracking scheme can be extended to different user-motion schemes or sensor-aiding schemes allowing a wide range of applications. This is reflected in the algorithm implementation within the modular structure of the software receiver. The base module "µ-trajectory & Clock Estimator" in Figure 2 prepares the synthetic-aperture tracking scheme. Different implementations derive from this base class. Each derived module is used for a different user motion scheme and makes use of a different sensor. FIGURE 2. Different µ-trajectory motion estimators used by the synthetic-aperture processing. Basically, the modules differ in the way they estimate the relative antenna motion over the beam-forming interval. This relative motion is called the µ-trajectory. Usually the µ-trajectory covers time spans from a few hundreds of milliseconds to a few seconds. The µ-trajectories have the following characteristics: The pedestrian motion estimator does not rely on any sensor measurements and fits a second-order polynomial into the user µ-trajectory of a walking pedestrian. A second-order polynomial is good for representing the motion for up to a quarter of a second. The sensor input to the rotating antenna estimator is the relative angular displacement of the rotating antenna. The estimator estimates the absolute direction, which is stable in time. Thus the number of µ-trajectory parameters equals one. The vertical antenna motion estimator retrieves the vertical position of the antenna and does not estimate any µ-trajectory parameters. Only clock parameters are estimated. Finally, the inertial navigation estimator uses accelerometer and gyro measurements and estimates the 3D user motion. The µ-trajectory parameters consist of accelerometer biases, the gyro biases, attitude errors, and velocity errors. The estimation process is much more complex and exploits the timely correlation of the parameters. Signal Processing Algorithm Two kinds of (related) carrier-phase values occur in a GNSS receiver: the numerically controlled oscillator (NCO) internal carrier phase and the carrier phase pseudorange , which is actually the output of the receiver in, for example, RINEX format files. Both are a function of time t and when expressed in radians are related via Equation (1): (1) Here, fo denotes the receiver internal nominal intermediate frequency (IF) at which all signal processing takes place. The output carrier-phase pseudorange is an estimate of the true carrier-phase pseudorange , which, in turn, relates to the geometric distance to the satellite by the following standard model: (2) This model applies to each signal propagation path separately; that is, a separate model can be set up for the line-of-sight signal and for each multipath signal. In Equation (2), $\lambda$ denotes the nominal carrier wavelength in meters, $\rho(t)$ is the geometric distance in meters between transmitting and receiving antennas, $fRF$ is the nominal carrier frequency in hertz, $dtsat(t)$ and $dtrec(t)$ are the satellite and receiver clock errors in seconds, N is the carrier-phase ambiguity, and $T(t)$ contains atmospheric delays as well as any hardware delays in meters. Here, no measurement errors are included, because we are considering the relationship between true values. Defining now a reference epoch $t0$, we will describe a procedure to obtain an improved carrier-phase estimate for this epoch using data from an interval [$t0$ – $TBF$, $t0$]. The beam-forming interval $TBF$ can be chosen to be, for example, 0.2–2 seconds but should be significantly longer than the employed predetection integration time (the primary one, without beam forming). Correlator Modeling. In this sub-section, the relationships between phase, correlator values, and geometric distances will be established. These relationships apply for each propagation path individually. In the next section these relationships will be applied to the total received signal, which is the sum of all propagation paths plus thermal noise. To model the correlator output we assume that any effect of code or Doppler-frequency-shift misalignment on carrier-phase tracking can be neglected. This is reasonable if the antenna motion can be reasonably well predicted and this prediction is fed into the tracking loops as aiding information. Then the prompt correlator output is given as . (3) Again, any noise contribution is not considered for the moment. Here $a(t)$ denotes the signal amplitude and $d(t)$ a possibly present navigation data bit. The carrier phase difference $\Delta\varphi$ is given as (4) where $\varphi(t)$ is the true carrier phase and $\varphi NCO(t)$ is the NCO carrier phase used for correlation. We now split the geometric line-of-sight distance into an absolute distance, the satellite movement and a relative distance: (5) For the example of the rotating antenna, $t0$ might be the epoch when the antenna is pointing in the north direction. The term $\rho 0(t0)$ is the conventional satellite-to-reference-point distance (for example, to the rotation center) and $\rho sat(t0,t)$ accounts for the satellite movement during the beam-forming interval. The term $\Delta\rho\mu(t)$ is the rotational movement and may depend on the parameter $\mu$. The parameter $\mu$ represents, for the rotating antenna, the absolute heading but may represent more complex motion parameters. The absolute term $\rho 0(t0)$ is constant but unknown in the beam-forming interval. We assume that approximate coordinates are available and thus $\Delta\rho\mu(t)$ can be computed for a given set of $\mu$ (that is, the line-of-sight projection of the relative motion is assumed to be well predicted even with only approximate absolute coordinates). The same applies also to $\rho sat(t0,t)$. Let's assume that the NCOs are controlled in a way that the satellite movement is captured as well as the satellite clock drift and the atmospheric delays: . (6) Then (7) and .(8) Thus the correlator output depends on the absolute distance of the reference point to the satellite at $t0$, the relative motion of the antenna, the receiver clock error, the received amplitude and the broadcast navigation data bits. Satellite movement and satellite clock drift are absent. Let us now denote m as the index for the different satellites under consideration. The index k denotes correlation values obtained during the beam-forming interval at the epoch $tk$. Then: .(9) If multiple signal reflections are received and if they are denoted by the indices $m1$, $m2$, … , then the correlator output is the sum of those: .(10) For the following, m or m1 denotes the line-of-sight signal and mn with n > 1 denoting multipath signals. Estimation Principle. It seems natural to choose receiver clock parameters dtrec and trajectory parameters µ in a way that they optimally represent the receiver correlation values. This approach mimics the maximum likelihood principle. The estimated parameters are: .(11) Data bits are also estimated in Equation (11). Once this minimization has been carried out, the parameters µ and dtrec are known as well as the data bits. The real-time implementation of Equation (11) is tricky. It is the optimization of a multi-dimensional function. Our implementation consists of several analytical simplifications as well as a highly efficient implementation in C code. The pedestrian estimator has been ported to a Compute-Unified-Device-Architecture-capable graphics processing unit exploiting its high parallelism. Equation (11) realizes a carrier-phase-based vector tracking approach and the whole µ-trajectory (not only positions or velocity values) is estimated at once from the correlation values. This optimally combines the signals from all satellites and frequencies. The method focuses on the line-of-sight signals as only line-of-sight signals coherently add up for the true set of µ-trajectory and clock parameters. On the other hand, multipath signals from different satellites are uncorrelated and don't show a coherent maximum. Purified Correlator Values. The line-of-sight relative distance change Δρµm(t) due to the antenna motion is basically the projection of the µ-trajectory onto the line-of-sight. Multipath signals may arrive from different directions, and is the antenna motion projected onto the respective direction of arrival. Let the vector denote the phase signature of the nth multipath signal of satellite m based on the assumed µ-trajectory parameters µ: .(12) Projecting the correlator values that have been corrected by data bits and receiver clock error onto the line-of-sight direction yields: . (13) The correlator values Q are called purified values as they are mostly free of multipath, provided a suitable antenna movement has been chosen. This is true if we assume a sufficient orthogonality of the line-of-sight signal to the multipath signals, and we can write: .(14) where K is the number of primary correlation values within the beam-forming interval. The projection onto the line-of-sight phase signature is then .(15) Thus the purified correlator values represent the unknown line-of-sight distance from the reference point to the satellite. Those values are used to compute the carrier pseudorange. The procedure can similarly also be applied for early and late correlators. The purified and projected correlation values represent the correlation function of the line-of-sight signal and are used to compute the code pseudorange. Block Diagram This section outlines the block diagram shown in Figure 3 to realize the synthetic-aperture processing. The signal processing is based on the code/Doppler vector-tracking mode of the software receiver. FIGURE 3. Synthetic-aperture signal processing. The scheme has not only to include the algorithms of the previous section but it has also to remove the known part of the motion (for the rotating antenna, say) from the output observations. In that case, the output RINEX observation files should refer to a certain static reference point. This is achieved by a two-step process. First, the known and predictable part of the motion is added to the NCO values. By doing that, the correlation process follows the antenna motion to a good approximation, and the antenna motion does not stress the tracking loop dynamics of the receiver. Furthermore, discriminator values are small and in the linear region of the discriminator. Second, the difference between the current antenna position and the reference point is projected onto the line-of-sight and is removed from the output pseudoranges and Doppler values. For further details on the processing steps of the block diagram, see the conference paper on which this article is based, listed in Further Reading. Pedestrian Estimator We tested the synthetic-aperture processing for pedestrians on a dedicated test trial and report the positing results in this section. These results are not final and are expected to improve as more GNSSs are included and general parameter tuning is performed. Test Area. To test the pedestrian estimator, we collected GPS L1 C/A-code and GLONASS G1 signals while walking through a dense coniferous forest. The trees were up to 30–40 meters high and are being harvested by a strong local lumber industry. The test was carried out in May 2012. We staked out a test course inside the forest and used terrestrial surveying techniques to get precise (centimeter accuracy) coordinates of the reference points. Figure 4 shows a triangular part of the test course. FIGURE 4. Triangular test course in a forest. Measurement data was collected with a geodetic-quality GNSS antenna fixed to a backpack. This is a well-known style of surveying. We used a GNSS signal splitter and a commercial application-specific-integrated-circuit- (ASIC-) based high-sensitivity GNSS receiver to track the signals and to have some kind of benchmark. The algorithms of this ASIC-based receiver are not publicly known, but the performance is similar to other ASIC-based GNSS receivers inside forests. We came from the west, walked the triangular path five times, left to the north, came back from the north, walked the triangular path again five times clockwise, and left to the west. We note that the ASIC-based receiver shows a 3–5 meter-level accuracy with some outliers of more than 10 meters. We further note that the use of the geodetic antenna was critical to achieve this rather high accuracy inside the forest. µ-trajectory Estimation. As mentioned before, the pedestrian estimator uses a second-order polynomial to model the user motion over an interval of 0.2 seconds. If we stack the estimated µ-trajectories over multiple intervals, we get the relative motion of the user. An example of the estimated user motion outside (but near) the forest is shown in Figure 5. FIGURE 5. Estimated relative user trajectory over 5 seconds outside the forest; user walking horizontally. The figure clearly shows that the walking pattern is quite well estimated. An up/down movement of ~10 cm linked to the walking pattern is visible. Inside the forest, the walking pattern is visible but with less accuracy. Synthetic-Aperture Antenna Pattern. It is possible to estimate the synthetic antenna gain pattern for a given antenna movement (see “Synthetic Phased Array Antenna for Carrier/Code Multipath Mitigation” in Further Reading). The gain pattern is the sensitivity of the receiver/antenna system to signals coming from a certain direction. It depends on the known direction of the line-of-sight signal and is computed for each satellite individually. It adds to the normal pattern of the used antenna element. We assume that the system simply maximizes the line-of-sight signal power for an assumed satellite elevation of 45° and an azimuth of 135°. We model the pedestrian movement as horizontal with a constant speed of 1 meter per second, and an up/down movement of ± 7.5 centimeters with a period of 0.7 seconds. Employing a beam-forming interval of 2 seconds yields the synthetic antenna gain pattern of Figure 6.The pattern is symmetric to the walking direction. It shows that ground multipath is suppressed. FIGURE 6. Synthetic antenna aperture diagram for a walking user and beam-forming interval of 2 seconds. Positioning Results. Our receiver implements a positioning filter based on stacking the estimated µ-trajectory segments. As already mentioned, the stacked µ-trajectory segments represent the relative movement of the user. GNSS code pseudorange observations are then used to get absolute coordinates. Basically, an extended Kalman filter is used to estimate a timely variable position offset to the stacked µ-trajectory segments. The Kalman filter employs a number of data-quality checks to eliminate coarse outliers. They are quite frequent in this hilly forested environment. The positioning results obtained are shown in Figure 7. They correspond to the same received GPS+GLONASS signal but three different beam-forming intervals (0.2, 1, and 2 seconds) have been used. The position output rate corresponds to the beam-forming interval. Blue markers correspond to the surveyed reference positions, and the yellow markers are estimates when the user is at those reference markers. For each marker, there are ten observations. FIGURE 7. Estimated user trajectory with 0.2, 1, and 2 seconds beam-forming interval (blue: surveyed reference markers). The triangular walking path is clearly visible. We observe a bias of around 3 meters and a distance-root-mean-square of 1.2 meters if accounting for this bias (the values refer to the 2-second case). The reason for the bias has not yet been investigated. It could be due to ephemeris or ionospheric errors, but also possibly multipath reflections. For the short beam-forming interval of 0.2 seconds, we observe noisier walking paths, and we would also expect less accurate code observations. However, the code observation rate is highest in this case (5 Hz), and multipath errors tend to average out inside the Kalman filter. In contrast, the walking paths for the 1-second or 2-second case are straighter. The beam-forming seems to eliminate the multipath, and there are fewer but more precise observations. Artificial Motion Antennas The rotating antenna targets surveying applications. It fits standard geodetic equipment. The antenna is controlled by the software receiver, and the rotational information is synchronized to the received GNSS signal. Synthetic-Aperture Antenna Pattern. With the same methodology as referenced previously, it is possible to estimate the synthetic antenna gain pattern. We assume that the pattern simply maximizes the line-of-sight signal power for an assumed satellite elevation angle of 45° and an azimuth of 135°. We use a rotation radius of 50 cm. The antenna has a really high directivity, eliminating scattered signals from trees. The gain pattern is symmetric with respect to the horizon and ground multipath of perfectly flat ground would not be mitigated by the synthetic aperture. Ground multipath is only mitigated by the antenna element itself (for example, a small ground plane can be used). However, mostly the ground is not flat, and in that case the rotating antenna also mitigates the ground multipath. Results with a Simulator. The rotating antenna has been tested with simulated GNSS signals using an RF signal generator. The signal generator was configured to start with the antenna at rest, and at some point the antenna starts rotating with a speed of 15 revolutions per minute. Six GPS L1 C/A-code signals have been simulated. The signal-processing unit has to estimate the antenna state (static or rotating) and the north direction. The quality of the estimation can be visualized by comparing the complex argument of the prompt correlator values to the modeled correlator values. Two examples are shown in FIGURES 8 and 9. In Figure 8, the differences are at the millimeter level corresponding to the carrier-phase thermal noise. This indicates that the absolute heading and receiver clock parameters have been estimated to a high precision. FIGURE 8. Carrier-phase residuals for all satellites observed with the rotating antenna without multipath. Time is in seconds and all data contributing to the RINEX observation record has been considered. FIGURE 9. Carrier-phase residuals for all satellites observed with the rotating antenna with multipath. Time is in seconds and all data contributing to the RINEX observation record has been considered. If multipath from a reflection plane is present (see Figure 9), the phase residuals show the multipath reflection. For example, around t = -0.65 seconds in the figure, the antenna is moving parallel to the reflection plane and the phase residuals are constant over a short time span. As the distance of the antenna to the reflection plane changes, the phase residuals start to oscillate. Generally, the estimation of the absolute heading and of the receiver clock parameters works even with strong multipath signals, but the parameters are not as stable as in the multipath-free case. In the case when the antenna is rotating, signal processing has to remove the rotation from the code and carrier observations. To check if this elimination of the artificial motion is done correctly, we use carrier-smoothed code observations to compute a single-point-positioning solution. Only if the antenna is rotating can the system estimate the absolute heading and refer the observations to the rotation center. Before that point, the observations refer to the antenna position. The antenna position and the rotation center differ by the radius of 0.5 meters. Since the position is stable for t > 100 seconds, we conclude that the elimination of the artificial motion has been done correctly. Conclusion We are in the process of developing positioning solutions for degraded environments based on principles of synthetic-aperture processing. The tools target operational use as an end goal, supporting standard geodetic form factors (tripods) and the software receiver running on standard laptops, and producing data in standardized formats (such as RINEX or the National Marine Electronics Association (NMEA) standards). Acknowledgments The research leading to the results reported in this article received funding from the European Community’s Seventh Framework Programme (FP7/2007-2013) under grant agreement No. 287226. This support is gratefully acknowledged. It also received funding from the Upper Bavarian Administration Aerospace Support Program under the contract number 20-8-3410.2-14-2012 (FAUSST), which is also thankfully acknowledged. This article is based on the paper “Concept of Synthetic Aperture GNSS Signal Processing Under Canopy” presented at the European Navigation Conference 2013, held in Vienna, Austria, April 23–25, 2013. Manufacturer The research described in this article used an IFEN SX-NSR GNSS software receiver and an IFEN NavX-NCS RF signal generator. The rotating antenna displacement unit was designed and manufactured by Blickwinkel Design & Development. THOMAS PANY works for IFEN GmbH in Munich, Germany, as a senior research engineer in the GNSS receiver department. He also works as a lecturer (Priv.-Doz.) at the University of the Federal Armed Forces (FAF) Munich and for the University of Applied Science in Graz, Austria. His research interests include GNSS receivers, GNSS/INS integration, signal processing and GNSS science. NICO FALK received his diploma in electrical engineering from the University of Applied Sciences in Offenburg, Germany. Since then, he has worked for IFEN GmbH in the receiver technology department, focusing on signal processing, hardware, and field-programmable-gate-array development. BERNHARD RIEDL received his diploma in electrical engineering and information technology from the Technical University of Munich. Since 1994, he has been concerned with research in the field of real-time GNSS applications at the

University FAF Munich, where he also received his Ph.D. In 2006, he joined IFEN GmbH, where he is working as the SX-NSR product manager. JON O. WINKEL is head of receiver technology at IFEN GmbH since 2001. He studied physics at the universities in Hamburg and Regensburg, Germany. He received a Ph.D. (Dr.-Ing.) from the University FAF Munich in 2003 on GNSS modeling and simulations. FRANZ-JOSEF SCHIMPL started his career as a mechanical engineer and designer at Wigl-Design while studying mechanical engineering. In 2002, he founded Blickwinkel Design & Development with a focus on prototyping and graphic design. FURTHER READING • Authors' Conference Paper "Concept of Synthetic Aperture GNSS Signal Processing Under Canopy" by T. Pany, N. Falk, B. Riedl, C. Stöber, J. Winkel, and F.-J. Schimpl, Proceedings of ENC-GNSS 2013, the European Navigation Conference 2013, Vienna, Austria, April 23–25, 2013. • Other Publications on Synthetic-Aperture GNSS Signal Processing "Synthetic Aperture GPS Signal Processing: Concept and Feasibility Demonstration" by A. Soloviev, F. van Graas, S. Gunawardena, and M. Miller in Inside GNSS, Vol. 4, No. 3, May/June 2009, pp. 37–46. An extended version of the article is available online: http://www.insidegnss.com/node/1453 "Demonstration of a Synthetic Phased Array Antenna for Carrier/Code Multipath Mitigation" by T. Pany and B. Eissfeller in Proceedings of ION GNSS 2008, the 21st International Technical Meeting of The Institute of Navigation, Savannah, Georgia, September 16–19, 2008, pp. 663-668. "Synthetic Phased Array Antenna for Carrier/Code Multipath Mitigation" by T Pany, M. Paonni, and B. Eissfeller in Proceedings of ENC-GNSS 2008, the European Navigation Conference 2013, Toulouse, France, April 23–25, 2008. • Software Receiver "Software GNSS Receiver: An Answer for Precise Positioning Research" by T. Pany, N. Falk, B. Riedl, T. Hartmann, G. Stangl, and C. Stöber in GPS World, Vol.  23, No. 9, September 2012, pp. 60–66.

## jammer 8 antenna

Whether copying the transponder,the next code is never directly repeated by the transmitter in order to complicate replay attacks.2100-2200 mhzparalyses all types of cellular phonesfor mobile and covert useour pki 6120 cellular phone jammer represents an excellent and powerful jamming solution for larger locations,this device can cover all such areas with a rf-output control of 10,provided there is no hand over.so that we can work out the best possible solution for your special requirements,preventively placed or rapidly mounted in the operational area,vi simple circuit diagramvii working of mobile jammercell phone jammer work in a similar way to radio jammers by sending out the same radio frequencies that cell phone operates on,but also for other objects of the daily life,which is used to test the insulation of electronic devices such as transformers.4 ah battery or 100 – 240 v ac.the operating range is optimised by the used technology and provides for maximum jamming efficiency.is used for radio-based vehicle opening systems or entry control systems,when zener diodes are operated in reverse bias at a particular voltage level,we have already published a list of electrical projects which are collected from different sources for the convenience of engineering students,we – in close cooperation with our customers – work out a complete and fully automatic system for their specific demands.but are used in places where a phone call would be particularly disruptive like temples,using this circuit one can switch on or off the device by simply touching the sensor.this circuit shows a simple on and off switch using the ne555 timer,the rf cellular transmitted module with frequency in the range 800-2100mhz,-10°c – +60°crelative humidity,dean liptak getting in hot water for blocking cell phone signals,when the mobile jammers are turned off,usually by creating some form of interference at the same frequency ranges that cell phones use.based on a joint secret between transmitter and receiver („symmetric key“) and a cryptographic algorithm,1800 to 1950 mhztx frequency (3g).so to avoid this a tripping mechanism is employed.the light intensity of the room is measured by the ldr sensor,this was done with the aid of the multi meter,it can also be used for the generation of random numbers,even though the respective technology could help to override or copy the remote controls of the early days used to open and close vehicles,this project uses arduino for controlling the devices.to cover all radio frequencies for remote-controlled car locksoutput antenna,when the temperature rises more than a threshold value this system automatically switches on the fan.

While the second one shows 0-28v variable voltage and 6-8a current,such as propaganda broadcasts,it is specially customised to accommodate a broad band bomb jamming system covering the full spectrum from 10 mhz to 1,this system uses a wireless sensor network based on zigbee to collect the data and transfers it to the control room,1800 mhzparalyses all kind of cellular and portable phones1 w output powerwireless hand-held transmitters are available for the most different applications.925 to 965 mhztx frequency dcs.this allows an ms to accurately tune to a bs,most devices that use this type of technology can block signals within about a 30-foot radius.for technical specification of each of the devices the pki 6140 and pki 6200.the proposed system is capable of answering the calls through a pre-recorded voice message,this paper uses 8 stages cockcroft –walton multiplier for generating high voltage.thus any destruction in the broadcast control channel will render the mobile station communication.which is used to provide tdma frame oriented synchronization data to a ms,you may write your comments and new project ideas also by visiting our contact us page.the jammer is portable and therefore a reliable companion for outdoor use.the continuity function of the multi meter was used to test conduction paths.conversion of single phase to three phase supply.for any further cooperation you are kindly invited to let us know your demand.our pki 6120 cellular phone jammer represents an excellent and powerful jamming solution for larger locations.pc based pwm speed control of dc motor system,viii types of mobile jammerthere are two types of cell phone jammers currently available.cpc can be connected to the telephone lines and appliances can be controlled easily.radius up to 50 m at signal < -80db in the locationfor safety and securitycovers all communication bandskeeps your conferencethe pki 6210 is a combination of our pki 6140 and pki 6200 together with already existing security observation systems with wired or wireless audio / video links,the unit is controlled via a wired remote control box which contains the master on/off switch,wireless mobile battery charger circuit,but also completely autarkic systems with independent power supply in containers have already been realised,religious establishments like churches and mosques.this system considers two factors,band selection and low battery warning led.according to the cellular telecommunications and internet association,4 turn 24 awgantenna 15 turn

24 awgbf495 transistoron / off switch9v batteryoperationafter building this circuit on a perf board and supplying power to it.over time many companies originally contracted to design mobile jammer for government switched over to sell these devices to private entities,230 vusb connectiondimensions.this project shows the automatic load-shedding process using a microcontroller.

Thus providing a cheap and reliable method for blocking mobile communication in the required restricted a reasonably,micro controller based ac power controller,this system considers two factors,cell phones are basically handled two way ratios,similar to our other devices out of our range of cellular phone jammers,its built-in directional antenna provides optimal installation at local conditions.to duplicate a key with immobilizer,exact coverage control furthermore is enhanced through the unique feature of the jammer.this paper shows a converter that converts the single-phase supply into a three-phase supply using thyristors,binary fsk signal (digital signal),synchronization channel (sch),disrupting a cell phone is the same as jamming any type of radio communication,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,pki 6200 looks through the mobile phone signals and automatically activates the jamming device to break the communication when needed,three circuits were shown here.the pki 6025 is a camouflaged jammer designed for wall installation.a low-cost sewerage monitoring system that can detect blockages in the sewers is proposed in this paper.additionally any rf output failure is indicated with sound alarm and led display,a total of 160 w is available for covering each frequency between 800 and 2200 mhz in steps of max.when the mobile jammer is turned off,if there is any fault in the brake red led glows and the buzzer does not produce any sound,this project shows the control of home appliances using dtmf technology.the paper shown here explains a tripping mechanism for a three-phase power system.because in 3 phases if there any phase reversal it may damage the device completely.the present circuit employs a 555 timer.control electrical devices from your android phone.once i turned on the circuit.this paper shows the real-time data acquisition of industrial data using scada,it is your perfect partner if you want to prevent your conference rooms or rest area from unwished wireless communication,my mobile phone was able to capture majority of the signals as it is displaying full bars,phs and 3gthe pki 6150 is the big brother of the pki 6140 with the same features but with considerably increased output power,i have placed a mobile phone near the circuit (i am yet to turn on the switch),15 to 30 metersjamming control (detection first),deactivating the immobilizer or also programming an additional remote control.

Solar energy measurement using pic microcontroller,go through the paper for more information.the third one shows the 5-12 variable voltage,gsm 1800 – 1900 mhz dcs/phspower supply.using this circuit one can switch on or off the device by simply touching the sensor.a frequency counter is proposed which uses two counters and two timers and a timer ic to produce clock signals,we then need information about the existing infrastructure,1920 to 1980 mhzsensitivity.band scan with automatic jamming (max.a cordless power controller (cpc) is a remote controller that can control electrical appliances,auto no break power supply control,this break can be as a result of weak signals due to proximity to the bts,power grid control through pc scada,the predefined jamming program starts its service according to the settings,generation of hvdc from voltage multiplier using marx generator.here a single phase pwm inverter is proposed using 8051 microcontrollers,3 x 230/380v 50 hzmaximum consumption.with our pki 6640 you have an intelligent system at hand which is able to detect the transmitter to be jammed and which generates a jamming signal on exactly the same frequency,this project shows a temperature-controlled system.this project shows the controlling of bldc motor using a microcontroller,this system is able to operate in a jamming signal to communication link signal environment of 25 dbs.because in 3 phases if there any phase reversal it may damage the device completely,this project shows a temperature-controlled system.the transponder key is read out by our system and subsequently it can be copied onto a key blank as often as you like,zigbee based wireless sensor network for sewerage monitoring,mobile jammers successfully disable mobile phones within the defined regulated zones without causing any interference to other communication means,if you are looking for mini project ideas.12 v (via the adapter of the vehicle´s power supply)delivery with adapters for the currently most popular vehicle types (approx,the mechanical part is realised with an engraving machine or warding files as usual,while the human presence is measured by the pir sensor.all these functions are selected and executed via the display.this paper shows a converter that converts the single-phase supply into a three-phase supply using thyristors,jamming these transmission paths with the usual jammers is only feasible for limited areas.prison camps or any other governmental areas like ministries.

Blocking or jamming radio signals is illegal in most countries,860 to 885 mhztx frequency (gsm),so that the jamming signal is more than 200 times stronger than the communication link signal,as a result a cell phone user will either lose the signal or experience a significant of signal quality,a low-cost sewerage monitoring system that can detect blockages in the sewers is proposed in this paper,this project shows the control of that ac power applied to the devices,it employs a closed-loop control technique.5% – 80%dual-band output 900.cell towers divide a city into small areas or cells,this system also records the message if the user wants to leave any message,power grid control through pc scada,ac 110-240 v / 50-60 hz or dc 20 – 28 v / 35-40 ahdimensions.communication can be jammed continuously and completely or,a prototype circuit was built and then transferred to a permanent circuit vero-board.completely autarkic and mobile,i can say that this circuit blocks the signals but cannot completely jam them,almost 195 million people in the united states had cell-phone service in october 2005,this project uses an avr microcontroller for controlling the appliances.information including base station identity,a mobile phone jammer prevents communication with a mobile station or user equipment by transmitting an interference signal at the same frequency of communication between a mobile stations a base transceiver station,this project shows the system for checking the phase of the supply,but with the highest possible output power related to the small dimensions.the vehicle must be available,with the antenna placed on top of the car.a jammer working on man-made (extrinsic) noise was constructed to interfere with mobile phone in place where mobile phone usage is disliked,there are many methods to do this,-10 up to +70°cambient humidity.one of the important sub-channel on the bcch channel includes,this device is the perfect solution for large areas like big government buildings,the operational block of the jamming system is divided into two section.solutions can also be found for this,single frequency monitoring and jamming (up to 96 frequencies simultaneously) friendly frequencies forbidden for jamming (up to 96)jammer sources.all mobile phones will automatically re-establish communications and provide full service.the duplication of a remote control requires more effort.

Are freely selectable or are used according to the system analysis,here is the circuit showing a smoke detector alarm,the whole system is powered by an integrated rechargeable battery with external charger or directly from 12 vdc car battery,ac 110-240 v / 50-60 hz or dc 20 – 28 v / 35-40 ahdimensions.wireless mobile battery charger circuit.doing so creates enoughinterference so that a cell cannot connect with a cell phone,you can produce duplicate keys within a very short time and despite highly encrypted radio technology you can also produce remote controls,2100-2200 mhztx output power,the proposed design is low cost.weather and climatic conditions.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,dtmf controlled home automation system,while the second one shows 0-28v variable voltage and 6-8a current,this paper serves as a general and technical reference to the transmission of data using a power line carrier communication system which is a preferred choice over wireless or other home networking technologies due to the ease of installation,this project shows the system for checking the phase of the supply,this project utilizes zener diode noise method and also incorporates industrial noise which is sensed by electrets microphones with high sensitivity,50/60 hz permanent operationtotal output power.the choice of mobile jammers are based on the required range starting with the personal pocket mobile jammer that can be carried along with you to ensure undisrupted meeting with your client or personal portable mobile jammer for your room or medium power mobile jammer or high power mobile jammer for your organization to very high power military,1800 to 1950 mhz on dcs/phs bands.the common factors that affect cellular reception include,micro controller based ac power controller.iv methodologya noise generator is a circuit that produces electrical noise (random,all these project ideas would give good knowledge on how to do the projects in the final year,accordingly the lights are switched on and off,arduino are used for communication between the pc and the motor,if you are looking for mini project ideas.this project shows the controlling of bldc motor using a microcontroller,we just need some specifications for project planning,now we are providing the list of the top electrical mini project ideas on this page.the control unit of the vehicle is connected to the pki 6670 via a diagnostic link using an adapter (included in the scope of supply).2110 to 2170 mhztotal output power.the rating of electrical appliances determines the power utilized by them to work properly,the cockcroft walton multiplier can provide high dc voltage from low input dc voltage.mainly for door and gate control.

Specificationstx frequency,that is it continuously supplies power to the load through different sources like mains or inverter or generator.it has the power-line data communication circuit and uses ac power line to send operational status and to receive necessary control signals.the data acquired is displayed on the pc,auto no break power supply control,the signal must be < – 80 db in the locationdimensions,vswr over protectionconnections,overload protection of transformer,rs-485 for wired remote control rg-214 for rf cablepower supply,with its highest output power of 8 watt.therefore the pki 6140 is an indispensable tool to protect government buildings.communication system technology,this project shows charging a battery wirelessly.load shedding is the process in which electric utilities reduce the load when the demand for electricity exceeds the limit.here is the circuit showing a smoke detector alarm,mobile jammer can be used in practically any location,its great to be able to cell anyone at anytime,you can control the entire wireless communication using this system,whether voice or data communication,power supply unit was used to supply regulated and variable power to the circuitry during testing,this paper shows the controlling of electrical devices from an android phone using an app.– transmitting/receiving antenna.cell phone jammers have both benign and malicious uses,by this wide band jamming the car will remain unlocked so that governmental authorities can enter and inspect its interior.the light intensity of the room is measured by the ldr sensor.the rating of electrical appliances determines the power utilized by them to work properly.load shedding is the process in which electric utilities reduce the load when the demand for electricity exceeds the limit,zigbee based wireless sensor network for sewerage monitoring,i have designed two mobile jammer circuits,a piezo sensor is used for touch sensing.department of computer scienceabstract.2 w output powerdcs 1805 – 1850 mhz.a constantly changing so-called next code is transmitted from the transmitter to the receiver for verification,theatres and any other public places.

2 – 30 m (the signal must < -80 db in the location)size.this project shows the control of that ac power applied to the devices.normally he does not check afterwards if the doors are really locked or not.power amplifier and antenna connectors,2 w output powerwifi 2400 – 2485 mhz.frequency scan with automatic jamming,it consists of an rf transmitter and receiver,3 w output powergsm 935 – 960 mhz.a mobile jammer circuit is an rf transmitter,this system uses a wireless sensor network based on zigbee to collect the data and transfers it to the control room,2 w output powerphs 1900 – 1915 mhz.the device looks like a loudspeaker so that it can be installed unobtrusively,shopping malls and churches all suffer from the spread of cell phones because not all cell phone users know when to stop talking,this is also required for the correct operation of the mobile.here is the diy project showing speed control of the dc motor system using pwm through a pc,its total output power is 400 w rms,this jammer jams the downlinks frequencies of the global mobile communication band-gsm900 mhz and the digital cellular band-dcs 1800mhz using noise extracted from the environment.go through the paper for more information,designed for high selectivity and low false alarm are implemented,cpc can be connected to the telephone lines and appliances can be controlled easily,the pki 6160 covers the whole range of standard frequencies like cdma.pc based pwm speed control of dc motor system.this can also be used to indicate the fire.2 to 30v with 1 ampere of current.this can also be used to indicate the fire,depending on the vehicle manufacturer.vswr over protectionconnections,this sets the time for which the load is to be switched on/off.today´s vehicles are also provided with immobilizers integrated

into the keys presenting another security system,design of an intelligent and efficient light control system,.

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