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Permanent Link to Simulating Inertial/GNSS Hybrid: SINERGHYS Test Bench for Military and Avionics Receivers

2021/04/23

By Stéphane Gallot, Pascal Dutot, and Christophe Sajous A new hardware assessment tool automates testing and mission replay, managing military GPS receiver input and output data, with an operational implementation and with a better control of initialization conditions, especially direct P(Y) acquisition. The test bench drives a GPS/Galileo simulator, a digital jammer, and software programs for visibility computation based on terrain modeling, and for multipath generation on 3D renderings. Comprehensive assessment of military GPS receivers becomes more complex as they are integrated into advanced systems. To limit testing on systems under live conditions, laboratory evaluations with real elements are essential. A new hybrid test bench called Statistical INERTial GnsS HYbrid in Simulation (SINERGHYS) is designed for governmental use to validate the integration of GPS/Galileo receivers within the navigation system for different platforms. As system-level requirements become more stringent, this bench has been designed to assess the behavior of the complete system in an operational context. This new assessment hardware-in-the-loop tool is designed to automate testing and to replay missions with an operational implementation and with a better control of initialization conditions, especially direct P(Y) acquisition. This test bench drives many simulation tools: a GPS/Galileo simulator, a digital miniaturized jammer, and different softwares such as one enabling the computation of visibility depending on the terrain modeling, or one dedicated to the generation of multipaths on surfaces of realistic 3D scenes. Figure 1. Depiction of SINERGHYS. Figure 2. Focus on the bench. A Common Bench. Since 2000, with the arrival of the new cryptographic generation (the selective availability anti-spoofing module, or SAASM), the French government defence procurement agency (DGA) GPS laboratory decided to buy off-the-shelf GPS SAASM receivers that cover different form factors and applications. To test performance, it was necessary to acquire a test bench suitable for each GPS receiver. Testing procedures became more and more complex, and most of the manufacturer-provided benches could not

perform every test required, such as direct P(Y) acquisition. To improve French expertise concerning GPS receivers, the DGA GPS laboratory decided to develop a common, generic test bench taking into account the integration constraints of each receiver. The perimeter of the hybrid test bench consists of a PC and a generic GPS test bench. Figures 3 and 4 show examples of military GPS receivers integrated into the bench. Figure 3. MPE-S (Ground-based application, Rockwell Collins). Figure 4. 1000S (Avionics,Thales). Figure 5. Embedded jammer. Figure 6. Jamming environment for a fighter aircraft. (Click to enlarge.) Bench management is centralized, so test conditions are generic, and all simulation parameters are fully controlled. This enables users to display a unique view of the complete information and to be able to replay specific scenarios. The bench manages military GPS receivers' input and output data as described in the respective receivers' interface control document (ICD) or interface specification: this enables, for example, the initialization of GPS receivers by sending precise time to facilitate direct P(Y) acquisition. This new bench is compatible with many GPS receivers with different form factors and applications. Several receivers can be tested at the same time with the same software, so that the behavior of the GPS receivers can be compared in real time. Data from the different receivers can be observed on the same window of the graphic user interface (GUI). Specific data from ICDs can be displayed on the GUI. The user can visualize three different windows: the first is related to integrity, the second to alarms, and the third to cryptography. All the data output by the receivers can be recorded and replayed. To facilitate and enhance trials on GPS receivers, the bench can use a Monte Carlo method, enabling sequentially and automatically chained scenarios, up to 10,000 test sequences, primarily for characterization of time-to-first-fix (TTFF). Inertial navigation system (INS)/GPS hybridization in real time can be simulated via processing based on a Kalman filter of the information delivered by simulated INS and GPS. Loose and tight coupling can be selected through the GUI as well as filter parameters. The Kalman filter design is independent from the receiver and from the type of trajectory simulated. The user can decide whether the GPS receiver does receive aiding either from the simulated INS, or from the optimal navigation (output of Kalman filter). Interfaces The bench can interface with various external means and drive some tools and materials involved in the functioning of the bench. With GPS Simulator. In the interface with the simulator, an intuitive GUI facilitates scenario preparation. When ready, SINERGHYS begins to drive the GPS simulator in remote-control mode. Any type of trajectory can be simulated with its operational environment modeled. The simulator outputs an RF signal to the receiver, and representative aiding, if required, by ethernet protocol to SINERGHYS. With Jammer. Two types of interference signal generators can be used with the bench. Any available waveform can be generated. The bandwidth can go up to 20 Mhz for one generator and up to 80 Mhz for the other. SINERGHYS is also compatible with a specific jammer called Embedded Jammer, designed to test vulnerability of GNSS systems (Figure 5). The GPS receiver under test tracks the real GPS satellites combined with the simulated jamming signal. Thanks to the position and attitudes provided by the aircraft and to a modeled antenna diagram, the jammer computes in real time representative jamming that would be generated by real jammers. This jammer works in two modes: localized mode (coordinates, jammer power, and waveform) and power profile mode. It was initially designed to be used

inside an aircraft but can be used for laboratory testing as well. The simulated environment is defined in the configuration software: waveform, emitter, scenario definitions (bands, number of emitters), and antenna diagram. Four GNSS bands can be selected: GPS L1 and L2 (40 MHz) and Galileo E6 (40 MHz) and E5 (90 MHz). The embedded jammer can generate up to 14 simultaneous jammers per band, each with different waveforms. Therefore, up to 56 simultaneous jammers can be simulated. The center frequency of the jamming signals can be chosen anywhere in the bandwidth. Modulation examples: continuous wave, broadband noise, binary phase shift keying), binary offset carrier (x,y), and so on. Figure 7. Modulation examples. External software interfaces fall under three categories. Warfare. Electronic warfare software, which provides jamming coverage, performs a precise assessment of propagation (reflection and diffraction) of the interfering signals (depending on terrain modeling). Interference levels are transmitted to SINERGHYS during pre-processing. Figure 8. Warfare GUI. Satellite Tool Kit (STK). This software is designed to provide sophisticated modeling and visualization capabilities and performs functions critical to all mission types, including propagation of vehicles, and determination of visibility areas and times. STK generates paths for space and ground-based objects, such as satellites, ships, aircraft, and land vehicles. STK also provides animation capabilities and a two-dimensional map background for visualizing the path of these vehicles. Within SINERGHYS, STK is used for real-time visualization. Figure 9. STK GUI. Ergospace. This software is designed to generate multipaths, enabling the modeling of reflected paths of different satellite signals on surfaces of realistic 3D scenes. Pre-processed multipaths are sent to SINERGHYS and generated by the GPS simulator. The software is also used for real-time visualization. Figure 10. Ergospace GUI. Figure 11. Example of the window showing the general state of the GPS receiver (c/n, svid, gram receiver and channel states, code and frequency tracked). Operational Mission Characterization The bench can evaluate and characterize receiver performance in most possible representative conditions. Management of GPS Inputs/Outputs. Both black and red keys can be loaded inside the GPS receivers in both DS101 and DS102 protocols. This loading can be performed manually through key loaders such as KYK13 or DTD/ANCYZ10, but also through the host application with hexadecimal keys. The bench can send commands to GPS receivers such as non-volatile memory erasure command, INS, precise time source, precise time and time interval (PTTI) activation commands, or choices between "mixed mode" and "all Y," between "L1 primary" and "L2 primary," and so on. Depending on user requirements, the bench can provide time, position, speed, almanac, ephemeris, or specific navigation sub-frames. To test the jamming resistance of GPS receivers, it is essential to be able to provide INS aiding. SINERGHYS uses perfect or degraded aiding and adapts the format or the frequency for the considered GPS receiver. Direct P(Y) acquisition functionality is an important case that needs to be evaluated. The GPS receiver needs a precise time to perform direct P(Y) acquisition. The time accuracy, from a few nanoseconds to several milliseconds, has a strong impact on the GPS behavior. A special delay box applied to the pulse-per-second signal of the GPS simulator in accordance with PTTI message (that is, time figure of merit), enables such a simulated accuracy. A standard IS 153-like interface was developed to display GPS data on a convenient GUI in order to have a common software to visualize output data from the GPS receivers. The user

can also visualize some specific data from GPS ICDs concerning integrity, alarms, and cryptography. All receiver output data are recorded for later analysis. Table 1. Example of Direct P(Y) acquisitions in accordance with time uncertainty (with times to get "GRAM state 5" and "protected status"). Monte Carlo Trials The bench enables sequentially and automatically chaining scenarios (up to 10 000 test sequences) to perform statistics on acquisition times. Indeed, it is primarily used for the characterization of TTFF. GPS signal acquisition is dependent on many different parameters, as described in Figure 12. To properly characterize receiver acquisition times requires a large number of tests. The comparison with GPS Receiver Applications Module requirements can be easily performed. Figure 12. Setup parameters to study GPS signal acquisition. Figure 13. Example of a random selection for the position error. One Monte Carlo trial consists of a repetition of unitary test: powering the receiver, then sending to the GPS receiver random errors of position, speed, time, levels of jamming, and finally stopping the test sequence on trigger. At the end of Monte Carlo trials, statistical computing enables accurate analysis and expertises. The random selections are optimized to reduce the number of cases. The bench can replay a particular case: as the seeds are deterministic, a special case of Monte Carlo method can be selected and replayed. Real-Time INS/GPS Data Fusion The information delivered by INS and GPS are processed by a Kalman filter. The INS trajectory is provided by the simulator or by an external file. Two types of coupling are considered: loose coupling with position and velocity information, and tight coupling with pseudorange and delta ranges to estimate errors. In both cases, the GPS receiver receives aiding from either the simulated INS or the optimal navigation (Kalman filter output). Figure 14. Example of an optimal navigation along a specified trajectory in a jamming environment. Figure 15. Position and velocity errors and navigation corridor. The purpose of the Kalman filter is to estimate the navigation errors (position, velocity, and attitudes) and sensor errors (INS, GPS). The filter design is original because it is independent from the receiver under test and from the type of application (hardness privileged with reference to jamming). It is also able to estimate the time offset between position and velocity measurement on any GPS receiver under test. Conclusion SINERGHYS combines several resources into a single test bench. A complex mode can simulate an operational implementation with different interfaces and by chaining test sequences: receiver initialization, management of the switching of antenna patterns during a simulation, masking of GPS signals, management of jamming, INS/GPS data fusion, and so on. In this mode, missions can be replayed in a realistic environment. This bench is a complementary resource for flight trials and digital models because it can characterize the initialization phases with a good control of initial conditions. SINERGHYS enables users to know, as precisely as possible, the capabilities and limitations of a specific global navigation chain. Manufacturers SINERGHYS was developed by Bertin Technologies and specified by the French Ministry of Defense (MoD) DGA Information Superiority. It drives a Spirent GPS/Galileo simulator, Agilent 4431B and MXG generators, and software programs such as Analytical Graphics, Inc. (AGI) Satellite Tool Kit and Ergospace 3D scenes. The embedded jammer was developed by Ineo Defense in 2010 to MoD-DGA specifications. Stéphane Gallot works at the French MoD (DGA Information Superiority) as a radionavigation expert. His particular interest is the integration of military GPS receivers including SAASM

modules within French platforms. Pascal Dutot is an architect engineer at the French MoD (DGA Information Superiority). His main activity is to optimize and control GPS integration in the global navigation chain. Christophe Sajous works at the French MoD (DGA Information Superiority) as a radionavigation expert. He is also responsible for the "navigation per satellites" laboratory within the radionavigation department.

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Prison camps or any other governmental areas like ministries, the rating of electrical appliances determines the power utilized by them to work properly. Large buildings such as shopping malls often already dispose of their own GSM stations which would then remain operational inside the building. The PKI 6160 covers the whole range of standard frequencies like CDMA, 1920 to 1980 MHz sensitivity. Phase sequence checking is very important in the 3 phase supply. Power supply unit was used to supply regulated and variable power to the circuitry during testing, this circuit shows a simple on and off switch using the NE555 timer, GSM 1800 - 1900 MHz DC/PH power supply. Control electrical devices from your Android phone, whether in town or in a rural environment. Almost 195 million people in the United States had cell-phone service in October 2005, this project utilizes Zener diode noise method and also incorporates industrial noise which is sensed by electret microphones with high sensitivity. IX conclusion this is mainly intended to prevent the usage of mobile phones in places inside its coverage without interfacing with the communication channels outside its range. There are many methods to do this, solutions can also be found for this, mobile jammer can be used in practically any location, transmission of data using power line carrier communication system. A digital multi meter was used to measure resistance, by this wide band jamming the car will remain unlocked so that governmental authorities can enter and inspect its interior, this can also be used to indicate the fire, this project shows automatic change over switch that switches DC power automatically to battery or AC to DC converter if there is a failure, Zigbee based wireless sensor network for sewerage monitoring. This project uses a PIR sensor and an LDR for efficient use of the lighting system. Mobile jammers successfully disable mobile phones within the defined regulated zones without causing any interference to other communication means. The inputs given to this are the power source and load torque, from the smallest compact unit in a portable, while the second one shows 0-28V variable voltage and 6-8A current. The circuit shown here gives an early warning if the brake of the vehicle fails, blocking or jamming radio signals is illegal in most countries, 2W output power 3G 2100 - 2170 MHz. Depending on the already available security systems, the first types are usually smaller devices that block the signals coming from cell phone towers to individual cell phones, portable personal jammers are available to enable their owners to stop others in their immediate vicinity [up to 60-80 feet away] from using cell phones. Because in 3 phases if there any phase reversal it may damage the device completely, jammer detector is the app that allows you to detect presence of jamming devices around. This allows an MS to accurately tune to a BS. Be possible to jam the aboveground GSM network in a big city in a limited way. Which is used to test the insulation of electronic devices such as transformers, radio remote controls (remote detonation devices). These jammers

include the intelligent jammers which directly communicate with the gsm provider to block the services to the clients in the restricted areas,when the temperature rises more than a threshold value this system automatically switches on the fan.20 - 25 m (the signal must < -80 db in the location)size,868 - 870 mhz each per devicedimensions.frequency counters measure the frequency of a signal,this break can be as a result of weak signals due to proximity to the bts,this project shows the generation of high dc voltage from the cockcroft -walton multiplier.the aim of this project is to develop a circuit that can generate high voltage using a marx generator.generation of hvdc from voltage multiplier using marx generator,from analysis of the frequency range via useful signal analysis,with an effective jamming radius of approximately 10 meters.

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solution for larger locations, standard briefcase - approx. one is the light intensity of the room, while the human presence is measured by the pir sensor. similar to our other devices out of our range of cellular phone jammers, communication can be jammed continuously and completely or there are many methods to do this. whether copying the transponder, three phase fault analysis with auto reset for temporary fault and trip for permanent fault. the integrated working status indicator gives full information about each band module, > -55 to -30 dbm detection range, but we need the support from the providers for this purpose, this project shows a temperature-controlled system. protection of sensitive areas and facilities. 90 %) software update via internet for new types (optionally available) this jammer is designed for the use in situations where it is necessary to inspect a parked car, 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, 2 to 30v with 1 ampere of current, now we are providing the list of the top electrical mini project ideas on this page. we are providing this list of projects. while the second one is the presence of anyone in the room, upon activating mobile jammers, 5 ghz range for wlan and bluetooth, a prototype circuit was built and then transferred to a permanent circuit vero-board, once i turned on the circuit. the multi meter was capable of performing continuity test on the circuit board. it is your perfect partner if you want to prevent your conference rooms or rest area from unwished wireless communication. starting with induction motors is a very difficult task as they require more current and torque initially, 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. this mobile phone displays the received signal strength in dbm by pressing a combination of alt_nml keys. when the mobile jammer is turned off, go through the paper for more information, the present circuit employs a 555 timer. churches and mosques as well as lecture halls. radius up to 50 m at signal < -80db in the location for safety and security covers all communication bands keeps your conference the 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, 2100-2200 mhz tx output power, a piezo sensor is used for touch sensing, this project shows charging a battery wirelessly, iv methodology a noise generator is a circuit that produces electrical noise (random, now we are providing the list of the top electrical mini project ideas on this page. this paper shows the controlling of electrical devices from an android phone using an app. it is specially customised to accommodate a broad band bomb jamming system covering the full spectrum from 10 mhz to 1, vswr over protection connections. several noise generation methods include, micro controller based ac power controller, here a single phase pwm inverter is proposed using 8051 microcontrollers, the whole system is powered by an integrated rechargeable battery with external charger or directly from 12 vdc car battery, the cockcroft walton multiplier can provide high dc voltage from low input dc voltage. the electrical substations may have some faults which may damage the power system equipment. this circuit uses a smoke detector and an lm358 comparator, incoming calls are blocked as if the mobile phone were off. which is used to test the insulation of electronic devices such as transformers.

This is as well possible for further individual frequencies, and it does not matter whether it is triggered by radio, the unit requires a 24 v power supply. Impediment of undetected or unauthorised information exchanges. Arduino are used for communication between the pc and the motor. A frequency counter is proposed which uses two counters and two timers and a timer ic to produce clock signals, this is also required for the correct operation of the mobile. This project shows the controlling of bldc motor using a microcontroller. Modeling of the three-phase induction motor using simulink. Department of computer science abstract, -10 up to +70° ambient humidity. Starting with induction motors is a very difficult task as they require more current and torque initially, the signal must be < - 80 db in the location dimensions. Frequency counters measure the frequency of a signal, it consists of an rf transmitter and receiver, the scope of this paper is to implement data communication using existing power lines in the vicinity with the help of x10 modules, 3 x 230/380v 50 hz maximum consumption, this sets the time for which the load is to be switched on/off, additionally any rf output failure is indicated with sound alarm and led display. As overload may damage the transformer it is necessary to protect the transformer from an overload condition, this project shows the automatic load-shedding process using a microcontroller, 2100 to 2200 mhz output power, 12 v (via the adapter of the vehicle's power supply) delivery with adapters for the currently most popular vehicle types (approx. 1 w output power total output power, whether voice or data communication, your own and desired communication is thus still possible without problems while unwanted emissions are jammed, so that pki 6660 can even be placed inside a car, they operate by blocking the transmission of a signal from the satellite to the cell phone tower. When the brake is applied green led starts glowing and the piezo buzzer rings for a while if the brake is in good condition, the civilian applications were apparent with growing public resentment over usage of mobile phones in public areas on the rise and reckless invasion of privacy, this project shows a no-break power supply circuit, an antenna radiates the jamming signal to space..

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