

4g phone jammer laws , phone jammer china deploys

[Home](#)

>

[4g jammer review](#)

>

4g phone jammer laws

- [2.4g wifi jammer](#)
- [2g 3g 4g gps jammer](#)
- [2g 3g 4g jammer](#)
- [3g 4g jammer diy](#)
- [3g 4g jammer uk](#)
- [4g 5g jammer](#)
- [4g data jammer](#)
- [4g internet jammer](#)
- [4g jammer](#)
- [4g jammer aliexpress](#)
- [4g jammer arduino](#)
- [4g jammer detector](#)
- [4g jammer diy](#)
- [4g jammer eu](#)
- [4g jammer india](#)
- [4g jammer price](#)
- [4g jammer review](#)
- [4g jammer uk](#)
- [4g jammers](#)
- [4g mobile jammer](#)
- [4g mobile jammer price](#)
- [4g network jammer](#)
- [4g network jammer circuit](#)
- [4g phone jammer](#)
- [4g phone jammer at kennywood](#)
- [4g phone jammer retail](#)
- [4g wifi jammer](#)
- [5g 4g 3g jammer](#)
- [5g 4g jammer](#)
- [buy 4g lte jammer](#)
- [cheap 4g jammer](#)
- [gsm 3g 4g jammer](#)
- [jammer 2g 3g 4g](#)
- [jammer 3g 4g wifi](#)
- [jammer 4g](#)
- [jammer 4g fai da te](#)

- [jammer 4g portable](#)
- [jammer 4g wifi gps](#)
- [jammer 4g wifi gps and camera](#)
- [jammer 4g wifi gps bank](#)
- [jammer 4g wifi gps camera](#)
- [jammer 4g wifi gps data](#)
- [jammer 4g wifi gps equipment](#)
- [jammer 4g wifi gps fishfinder](#)
- [jammer 4g wifi gps g2](#)
- [jammer 4g wifi gps g2n](#)
- [jammer 4g wifi gps garmin](#)
- [jammer 4g wifi gps guidance](#)
- [jammer 4g wifi gps handy-stoersender](#)
- [jammer 4g wifi gps in](#)
- [jammer 4g wifi gps installation](#)
- [jammer 4g wifi gps jammer](#)
- [jammer 4g wifi gps logger](#)
- [jammer 4g wifi gps not working](#)
- [jammer 4g wifi gps on this day](#)
- [jammer 4g wifi gps origins](#)
- [jammer 4g wifi gps polnt and caicos](#)
- [jammer 4g wifi gps polnt and cons](#)
- [jammer 4g wifi gps receiver](#)
- [jammer 4g wifi gps screen](#)
- [jammer 4g wifi gps server](#)
- [jammer 4g wifi gps service](#)
- [jammer 4g wifi gps smartwatches](#)
- [jammer 4g wifi gps tablet](#)
- [jammer 4g wifi gps units](#)
- [jammer 4g wifi gps update](#)
- [jammer 4g wifi gps use](#)
- [jammer 4g wifi gps user](#)
- [jammer 4g wifi gps visualizer](#)
- [jammer 4g wifi gps voice](#)
- [jammer 4g wifi gps watch](#)
- [jammer 4g wifi gps work](#)
- [jammer bloqueador 4g](#)
- [jammer for 4g](#)
- [jammer inhibidor 4g](#)
- [jammer portatile 4g](#)
- [jual jammer 4g](#)
- [jual jammer 4g lte](#)
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- [phone jammer 4g hotspot](#)

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- [phone jammer 4g internet](#)
- [phone jammer 4g manual](#)
- [phone jammer 4g mean](#)
- [phone jammer 4g oc](#)
- [phone jammer 4g ram](#)
- [phone jammer 4g router](#)
- [phone jammer 4g tablet](#)
- [phone jammer 4g tactical](#)
- [phone jammer 4g ultimate](#)
- [phone jammer 4g unlimited](#)
- [phone jammer 4g usb](#)
- [phone jammer 4g viettel](#)
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- [portable 4g jammer](#)
- [wifi 4g jammer](#)

Permanent Link to Innovation: The Distress Alerting Satellite System

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Taking the Search out of Search and Rescue By David W. Affens, Roy Dreibelbis, James E. Mentall, and George Theodorakos In 1997, a Canadian government study determined that an improved search and rescue system would be one based on medium-Earth orbit satellites, which can provide full global coverage, can determine beacon location, and would need fewer ground stations. This month's column examines the architecture of the GPS-based Distress Alerting Satellite System and takes a look at early test results. INNOVATION INSIGHTS by Richard Langley IT IS NOT COMMONLY KNOWN that the GPS satellites carry more than just navigation payloads. Beginning with the launch of the sixth Block I satellite in 1980, GPS satellites have carried sensors for the detection of nuclear weapons detonations to help monitor compliance with the Non-Proliferation Treaty. The payload is known as the Nuclear Detonation (NUDET) Detection System (NDS) and is jointly supported by the U.S. Air Force and the Department of Energy. And now a third task is being assigned to the GPS satellites — that of search and rescue. Since the mid-1980s, a combination of low Earth orbit (LEO) and geostationary orbit (GEO) satellites have been used to detect and locate radio beacons activated by mariners, aviators, and others in distress virtually anywhere in the world and at any time. Some 28,000 lives have been saved worldwide since the search and rescue satellite-aided tracking, or SARSAT, system was implemented. But the current system has some drawbacks. LEO satellites can determine a beacon's position using the Doppler effect but their field-of-view is limited and one of them may not be in range when a beacon is activated. Furthermore, a large number of ground stations is needed to relay data from these satellites to search and rescue authorities. GEO satellites, on the other hand, have a large field of view (although missing parts of the Arctic and Antarctic), but they cannot position a beacon unless its signal contains location information provided by an integral satellite navigation receiver. In 1997, a Canadian government study determined that a better SARSAT system would be one based on medium Earth orbit

(MEO) satellites. A MEO system can provide full global coverage, determine beacon location, and do this with fewer ground stations. GPS was identified as the ideal MEO constellation. And so was born the Distress Alerting Satellite System (DASS) that will become fully operational on Block III satellites. But already nine GPS satellites are hosting prototype hardware that is being used for proof-of-concept testing. In this month's column, we examine the architecture of DASS (including its relationship with the NDS), and take a look at some of the very positive test results already obtained — results that support the claim that DASS will take the search out of search and rescue. NASA, which pioneered the technology used for the satellite-aided search and rescue capability that has saved thousands of lives worldwide since its inception nearly three decades ago, has developed new technology that will more quickly identify the locations of people in distress and reduce the risk to rescuers. The Search and Rescue (SAR) Mission Office at the NASA Goddard Space Flight Center, in collaboration with several government agencies, has developed a next-generation satellite-aided search and rescue system, called the Distress Alerting Satellite System (DASS). NASA, the National Oceanic and Atmospheric Administration (NOAA), the U.S. Air Force, the U.S. Coast Guard, and other agencies are now completing the development and testing of the new system and expect to make it operational in the coming years after a complete constellation of DASS-equipped satellites is launched. When completed, DASS will be able to almost instantaneously detect and locate distress signals generated by emergency beacons installed on aircraft and maritime vessels or carried by individuals, greatly enhancing the international community's ability to rescue people in distress. This improved capability is made possible because the satellite-based instruments used to relay the emergency signals will be installed on the GPS satellites. A recent satellite-aided rescue started on June 10, 2010, when 16-year-old Abby Sunderland on her 40-foot (12.2-meter) sailboat "Wild Eyes" encountered heavy seas approximately 2,000 miles (3,200 kilometers) west of Australia in the Indian Ocean. Her sailboat was dismasted and an emergency situation resulted. Ms. Sunderland activated her two emergency beacons whose signals were picked up by orbiting satellites. Using coordinates derived from the signals, a search plane spotted Ms. Sunderland the next day, and a day later she was rescued by a fishing boat directed to the scene. This highly publicized event is one of thousands of successful rescues made possible by years of NASA research and development. Background The beginnings of satellite-aided search and rescue date back to 1970, when a plane carrying two U.S. congressmen crashed in a remote region of Alaska. A massive search and rescue effort was mounted, but to this day, no trace of them or their aircraft has ever been found. At the time, search for missing aircraft was conducted by search aircraft flying over thousands of square kilometers hoping to sight the missing aircraft. As a result of this tragedy, Congress recognized this inefficient search method and passed an amendment to the Occupational Safety and Health Act of 1970 requiring most aircraft flying in the United States to carry emergency locator beacons (ELTs) to provide a local homing capability. NASA then developed the technology to detect and locate an ELT from ground stations using the beacon signal relayed by satellites to provide more global coverage. This concept evolved into a highly successful international search and rescue system called COSPAS-SARSAT (COSPAS is an acronym for the Russian words "Cosmicheskaya Sistema Poiska Avariynyh Sudov," which translates to "Space System for the Search

of Vessels in Distress;" SARSAT is an acronym for Search and Rescue Satellite-Aided Tracking). Established by Canada, France, the United States, and the former Soviet Union in 1979, the system has 43 participating countries and has been instrumental in saving more than 28,000 lives worldwide, including 6,400 in the U.S. — all as a result of NASA's innovations. Since this auspicious beginning, NASA has continued to perform SAR research and development as a member of the National Search and Rescue Committee, and supports the National Search and Rescue Plan through an interagency memorandum of understanding with the Coast Guard, the Air Force, and NOAA. NOAA is responsible for operation of the U.S. portion of current COSPAS-SARSAT system that relies on SAR payloads on weather satellites in low-earth and geostationary orbits. As shown in Figure 1, the satellites relay distress signals from emergency beacons to a network of ground stations and ultimately to the U.S. Mission Control Center (USMCC) operated by NOAA. The USMCC distributes the alerts to the appropriate search and rescue authorities: the U.S. Air Force or the Coast Guard. The Air Force coordinates search and rescue for the mainland U.S. SAR region and operates the Air Force Rescue Coordination Center. The Coast Guard performs maritime search and rescue and oversees the U.S. national SAR policy.

FIGURE 1. Overall concept of search and rescue system. (Image: Cospas-Sarsat)

Beacons Three types of distress emergency locator beacons are in use that are compatible with the COSPAS-SARSAT system: EPIRBs (emergency position-indicating radio beacons) designed for maritime use. ELTs (emergency locator transmitters) for use on aircraft. PLBs (personal locator beacons) for personal use. These can be used by persons engaged in high-risk activities such as mountain climbing and backcountry skiing. Originally, emergency locator beacons transmitted an analog signal on two frequencies: 121.5 MHz and 243 MHz in the civil and military aeronautical communications bands, respectively, so that they would be audible over aircraft radios. Later, a signal that was encoded with a digital message and transmitted at 406 MHz was added. Since February 1, 2009, only the 406-MHz-encoded signals are relayed by satellites supporting the international COSPAS-SARSAT system. Therefore, older beacons that only transmit the 121.5/243-MHz signals are now only detectable by ground-based receivers and aircraft overflying a crash site. The 406-MHz beacons transmit an approximately half-second message, or burst, approximately every 50 seconds, beginning 50 seconds after being activated. The actual time of burst transmission is dithered in time so that no two beacons will have all of their bursts coincident. A 406-MHz beacon may also have an integral global navigation satellite system (GNSS) receiver. Such a beacon uses the GNSS receiver to attempt to determine its location for inclusion in the transmitted digital message. In this way, the beacon will be located once it is detected by a low-Earth-orbit (LEO) or geostationary orbit (GEO) satellite. Distress messages contain information such as: The beacon's country of origin. A unique 15-digit hexadecimal beacon ID. Location, when equipped with an integrated GNSS receiver. Whether or not the beacon contains a 121.5-MHz homing signal. Room for Improvement SARSAT first became operational in the mid-1980s. The current system uses instruments placed on LEO and GEO weather satellites to detect and locate mariners, aviators, and recreational enthusiasts in distress almost anywhere in the world at anytime and in almost any condition. Previously, dedicated Russian LEO satellites were also implemented but the use of these satellites was discontinued in 2007. Although it has

proven its effectiveness, as evidenced by the number of persons rescued over the system's lifetime, the current capability does have limitations. LEO spacecraft orbit the Earth 14 times a day and use the Doppler effect with satellite orbital ephemeris data to calculate the position of a beacon. However, a satellite may not be in a position to pick up a distress signal the moment a user activates the beacon. Time is critical in responding to an emergency situation. Unfortunately, delays of two hours or longer are possible, especially near the equator. LEO spacecraft carry two instruments: a Search and Rescue Repeater (SARR) supplied by the Canadian Department of National Defence, and a Search and Rescue Processor (SARP) provided by the French Centre National d'Etudes Spatiales (CNES). The SARR is a pure repeater, which relays the beacon signal to a local ground station where the data is analyzed to obtain a location. The SARP processes the received beacon signal by measuring the Doppler shift as a function of time, and decoding the digital message included in the 406-MHz signal. This information is stored until it can be transmitted to a ground station using the SARR's downlink transmitter. Under most conditions beacon locations can be determined to within a radius of 5 kilometers. Geostationary weather satellites, on the other hand, orbit above the Earth in a fixed location over the equator. Although they do provide continuous visibility of much of the Earth, they cannot independently locate a beacon unless it contains a GNSS receiver that determines its position and includes it in the beacon's digital message. Currently, not all beacons contain integral GNSS receivers. Furthermore, even if a beacon contains a GNSS receiver, the navigation signal may be obstructed by terrain or thick foliage. The next-generation system, DASS, overcomes these limitations and will improve accuracy and response time to provide an even more capable life-saving system. Distress Alerting Satellite System A 1997 Canadian government study of possible alternative satellite systems for SARRS, including commercial sources, determined that the ideal system is based on medium Earth orbit (MEO) satellites. A MEO system will be able to provide superior global detection and location data with fewer ground stations than the existing COSPAS-SARSAT system. The GPS constellation was identified as an ideal MEO platform. The concept of the DASS system is straightforward. Three or more antennas track different GPS satellites equipped with search and rescue repeaters that receive the distress signal and retransmit the signal to the ground. Since each satellite is in a different orbit, each received signal has a different Doppler-shifted arrival frequency and time of arrival. Knowing the position and orbit of each satellite, it is possible to determine the position of the distress beacon. Future improvement in location accuracy is made possible by one of the strengths of the DASS space segment. That is, the DASS location algorithm optimizes location accuracy utilizing time and frequency measurements of beacon signals that were not designed for that purpose. The DASS space segment allows for the beacon signal to be modified in the future, enhancing the performance of this type of location process. Other advantages of DASS over the existing system are fairly obvious. Reception of the emergency signal is immediate. Locations can be determined after receiving a single beacon burst since it does not rely on measuring the Doppler shift over time to determine position, as in the current LEO system. A full constellation of DASS-equipped GPS satellites in orbit will ensure that four or more satellites are in view of the transmitting emergency beacon anywhere in the world while requiring fewer ground stations. Another key strength of

the DASS system is the promise of SARSAT transponders on each satellite in the large and well-managed GPS constellation. There are at least 24 GPS active satellites in orbit at any given time (currently, 31 are active). When the GPS constellation is fully populated by satellites with DASS transponders, it will provide global coverage for satellite-supported search and rescue and provide capabilities for rapid detection and location of distress beacons. Efforts are ongoing to integrate a satellite beacon repeater instrument, to be provided by the Canadian government, onto the GPS Block III B and C satellites to provide the DASS space segment for operational use. DASS Development DASS development will proceed in phases referred to as the definition and development, proof of concept, demonstration and evaluation, initial operating capability, and final operating capability. The proof of concept (POC) phase was completed in January 2009. The POC testing and results are summarized in this article. At the time of this writing, preparations are ongoing to initiate the demonstration and evaluation phase. Definition and Development. In 2000, as part of the definition and development phase, the NASA GSFC SAR Mission Office began discussions with the Department of Energy's Sandia National Laboratories (SNL) to determine if it would be feasible to add a SAR repeater function to a Department of Energy (DOE) instrument on GPS satellites. Sandia representatives thought it possible, and NASA agreed to fund a study to determine if, with minor modification, one could include a search and rescue repeater function to their instrument. The SNL feasibility study concluded that the GPS DOE package could, with minor modifications, perform the SAR mission. The study also determined that accurate locations could be calculated after a single beacon transmission and improved with each subsequent beacon transmission. Based on this information, NASA, with the cooperation of the U.S. Air Force Space Command and SNL, proceeded with the development of the new space-based search and rescue system, which was named the Distress Alerting Satellite System. Proof of Concept. In 2003, a memorandum of agreement (MOA) between NASA, NOAA, the Air Force, the Coast Guard, and the Department of Energy tasked NASA to perform a POC program for DASS. The MOA included the development of a POC space segment and a prototype ground station to perform post-launch checkout, performance testing, and implementation planning of an operational DASS system. It stressed the need for DASS, gave authority to each participating agency to participate in the POC demonstration, and defined the roles of each. The Air Force Space Command approved the addition of modified equipment on GPS satellites. The DASS POC space segment operates as a subcomponent of GPS Block IIR and IIF satellites. Nine GPS Block IIR satellites carry experimental DASS payloads, and all 12 IIF satellites are scheduled to. Therefore, the final POC space segment will consist of 21 DASS-equipped GPS satellites. Each payload receives 406-MHz SAR signals on an extant GPS UHF antenna and relays the signals at a GPS S-band frequency on a second extant antenna. It is important to note that the performance of the DASS POC space segment will be exceeded by the performance of the operational space segment being designed specifically for DASS and planned for launch on GPS Block III satellites. A prototype DASS ground station (Figure 2) was funded by NASA and installed at GSFC. The DASS prototype ground system consists of four antennas, four receivers, and the workstations and servers necessary to process the received data, command and control the operation of the ground station, and display and analyze the results. The antennas are located on the corners of the

roof of a building connected by fiber-optic cable to signal processing equipment located in another building two kilometers away. FIGURE 2. Prototype ground station at NASA GSFC. (Images: NASA)

Proof of Concept Testing

The overall objectives of the POC tests were to demonstrate the effectiveness of the DASS concept and to define its technical and operational characteristics. The primary technical objective was to demonstrate the system's ability to detect and locate 406-MHz emergency beacons under various controlled conditions. This is the most important measure of the system's ability to perform as expected. The specific objectives of the DASS POC demonstration were to Confirm the expected performance of the DASS concept. Determine if new or enhanced requirements needed to be established. Define preliminary performance levels that will be used to establish the scope and content of the next phase of development, referred to as the demonstration and evaluation phase. Therefore, during POC testing, performance measurements were taken for the probability of detection, probability of location, and location accuracy, defined as follows. Probability of detection is the probability of detecting the transmission of a 406-MHz beacon and recovering a valid beacon message from any available satellite. Probability of location is the probability of obtaining a location solution within a given time after beacon activation, independently of any encoded position data in the 406-MHz beacon message. Location accuracy is the distance from the location solution obtained within 5 minutes after beacon activation, to the actual beacon location. The required performance is specified as the probability that a given solution is within a given distance of the actual location. It is important to note that the predicted performance of DASS assumes a full constellation of DASS-equipped GPS satellites. In fact, one of the key strengths of DASS is the promise of DASS transponders on each satellite in the GPS constellation. When a full constellation is equipped with DASS transponders, there will typically be between seven and 13 GPS satellites visible at the NASA ground station. Thus, it will be possible to schedule the ground-station antennas to receive data from the best satellites in terms of geometry, signal strength, processing capability, and other factors. However, at the time of the POC testing, there were only eight GPS satellites equipped with DASS transponders. A maximum of three DASS-equipped GPS satellites were visible at the same time at the NASA ground station (above a 15-degree elevation angle), and there were times when only one DASS-equipped GPS satellite was visible. Thus, it was impossible to optimize satellite selection since there was never an opportunity to select from an excess of satellites that a full constellation would provide. In particular, satellite geometry and its effect on performance is never as optimal as what would be obtained from a full constellation of GPS satellites. To predict the results of a full constellation using the results from a severely reduced constellation, a calculation based on "dilution of precision" was used. Dilution of precision (DOP) or geometric dilution of precision, to be specific, is used to describe the geometric strength of satellite configuration on GPS accuracy. When visible satellites are close together in the sky, the geometry is said to be weak and the DOP value is high; when far apart, the geometry is strong and the DOP value is low. Thus a low DOP value gives rise to a better GPS positional accuracy due to the wider angular separation between the satellites used to calculate a beacon's position. Location accuracy results can be scaled to reflect the true DOP that would be obtained by a satellite constellation of 24 GPS satellites. The DOP error caused by uncertainty in time and frequency measurements is used for scaling. The

DOP of the satellites actually used to calculate a location solution, denoted by $ftDOPACT$, is always bigger than the DOP that would have been available from a constellation of 24 GPS satellites, $ftDOP24$. The raw location errors need to be multiplied by the ratio $ftDOP24 / ftDOPACT$ to reflect the results that would have been obtained if all 24 satellites were present. The raw average location error, err_{avg} , is given by the following: $err(b) = err(lat(b), lon(b)) = \text{distance from the known location to } (lat(b), lon(b))$ $err_{avg}(b0) = err(lat_{avg}(b0), lon_{avg}(b0))$ where $\Omega(b0)$ is the set of seven or fewer consecutive burst locations within 5 minutes, starting with burst $b0$. The scaled location error is the location error scaled by the DOP ratio: Since DOP changes little over 5 minutes, the error of the average is approximately where $ftDOPACT(b)$ is the time-frequency DOP of burst b calculated with either three or four satellite geometries depending on the number of measurements used in the location calculation. Test Source A custom-designed beacon simulator was used to generate the transmissions of multiple COSPAS-SARSAT 406-MHz beacons over an extended period of time. To represent expected operational realism in the tests, the beacon simulator was used to transmit beacons at the limits of the five major beacon parameters specified by COSPAS-SARSAT as well as the nominal values. The five major beacon parameters are transmit power, modulation index, bit rate, unmodulated carrier duration, and modulation rise and fall times (see TABLE 1). Table 1. Cospas-Sarsat beacon specifications. (Data: Cospas-Sarsat) During POC testing, five beacons were transmitted using three scenarios: maximum beacon parameter values, minimum beacon parameter values, and variable power. The parameter values changed in each test scenario and are highlighted in TABLE 2. Beacon detection and location performance is measured for periods when there are three or more satellites visible at the same time, and for durations sufficient to collect a statistically significant amount of data. Table 2. Beacon parameter values for each test scenario. (Data: Authors) Two characteristics of the test source that affect system performance are the beacon antenna pattern and ground mask. To simulate beacons, the beacon simulator has a monopole antenna with the gain pattern shown in Figure 3. There is a substantial reduction in the transmitted signal at high-elevation angles (above 60°). DASS-equipped GPS satellites are often at high-elevation angles during a typical day. As expected, the effect of the pattern on test results can clearly be seen upon close inspection of the data. However, the beacon antenna pattern is an unavoidable reality and is, therefore, fully represented in the data used to generate the results presented here. Additionally, there were significant ground obstructions of the beacon signal in certain directions. The effect of beacon antenna pattern is fully included in the results presented in this article, but ground mask is taken into account by limiting satellite visibility to an elevation cut-off angle of 15 degrees. FIGURE 3. Beacon simulator transmit antenna gain pattern. POC Test Results In this section, we discuss the POC test results in terms of probability of detection, probability of location, and location accuracy. Probability of Detection. As previously mentioned, probability of detection is the probability of detecting the transmission of a 406-MHz beacon and recovering a valid beacon message from any available satellite. The requirement is that 95 percent of individual transmitted messages are detected. Test results are given in TABLE 3 and show that the probability of detection is approximately 99 percent for all scenarios, even though only three satellites were in view at a time. Obviously, the probability of detection is

dependent on the number of available satellites and performance would improve with continuous coverage by four or more satellites. Table 3. Probability of detection test results. (Data: Authors) Probability of Location. Again, the probability of location is the probability of obtaining a location solution within a given time after beacon activation, independently of any encoded position data in the 406-MHz beacon message. The requirement is that the probability of calculating a beacon location is 98 percent within 5 minutes. Since the probability of location is dependent on the number of visible satellites, our performance was limited by the reduced constellation of DASS-equipped satellites. Results from periods of three-satellite coverage were 85 percent within 5 minutes, 92 percent within 10 minutes, and 94 percent within 15 minutes. Again, the probability of location is dependent on the number of visible satellites, and performance would improve with continuous coverage by four or more satellites. To investigate the possible improvement with enhanced satellite coverage, we reduced the minimum satellite elevation angle from 15 to 10 degrees. This allowed a fourth satellite to become visible for a limited time at very low elevation angles. Even though the signal quality from such a satellite was poor, the probability of location during this period of four-satellite coverage improved as follows: 91 percent within 5 minutes, 96 percent within 10 minutes, and 97 percent within 15 minutes. As can be seen from these results, even adding a satellite with a very low elevation-angle pass significantly improves performance. The expectation is that having a full constellation of satellites available would improve performance even more. Furthermore, the increase in satellite performance expected in the operational system will also improve probabilities of detection and location. Location Accuracy. Recall that location accuracy is measured as the percentage of location solutions obtained within five minutes after beacon activation that are within five kilometers of the actual beacon location. The requirement is to obtain 95 percent of the locations to within 5 kilometers of the actual location and 98 percent within 10 kilometers within five minutes after beacon activation. As mentioned earlier, the requirements included in the performance specification assume a constellation of 24 DASS-equipped GPS satellites. POC testing was done with a system that had only eight DASS-equipped GPS satellites available. However, location errors can be scaled to reflect what the DOP would be if the satellite constellation contained all 24 GPS satellites. Therefore, it is the scaled results that can be used to determine whether performance will meet the requirement. TABLE 4, therefore, presents the location accuracy results as measured, and after being scaled by DOP. Table 4. Location accuracy for 5-minute periods. (Data: Authors) Another important performance metric for DASS is location accuracy obtained after a single beacon burst is received. Even though there is not currently a requirement for single burst location accuracy, it is a very desirable feature of DASS since an emergency situation does not guarantee that more than a single burst will be received. Single burst location accuracy was, therefore, measured with the results shown in TABLE 5. Once again, the results are scaled by DOP values to remove the effect of non-optimal satellite geometry. Table 5. Single burst location accuracy. (Data: Authors) More insight into this performance can be gained by examining the single burst location accuracy distribution as a function of distance error, as shown in TABLE 6. It can be seen that, for these beacons, computed locations are within 9 kilometers of the actual location 95 percent of the time. Again, the expectation is that having a full constellation of

satellites available would improve this performance. For instance, having more satellites to choose from might allow the system to select data from satellites with stronger or less noisy links. Table 6. Single burst location accuracy by distance error.

(Data authors) Conclusion The promise of search and rescue instruments on each satellite in the large and well-managed GPS constellation will provide a significant advancement in the capabilities of the already highly successful COSPAS-SARSAT system. The new system will provide global coverage for satellite-supported search and rescue and provide capabilities for rapid detection and location of distress beacons while requiring fewer ground stations. The DASS POC system has validated, by test, the predictions made by analysis during the definition and development phase. The DASS POC testing has demonstrated reliable detection and accurate location of beacons within five minutes of activation. Accurate locations are also produced after even a single burst of a newly activated beacon, which is a desirable feature of DASS, since an emergency situation does not guarantee that more than a single burst will be received. The performance obtained using a reduced constellation of satellites equipped with a modified, existing instrument not only demonstrates the existing capability, but also confirms the improvements to come with the operational system. In fact, the success of DASS is being emulated by the European Union in the design of their future Galileo GNSS constellation and the Russians in an upgraded GLONASS GNSS constellation, all of which will be interoperable by international agreement. DASS will contribute to NASA's goal of taking the search out of search and rescue. Achieving this goal will not only improve the chances of rescuing people in distress quickly, which is critical to their survival; it will also reduce the risk to rescuers who often put themselves in dangerous situations to affect a rescue. That is why the motto of the Search and Rescue Office is "Saving more lives, reducing risks to search personnel, and saving resources." David W. Affens is the manager of the NASA Search and Rescue (SAR) Mission Office at the Goddard Space Flight Center (GSFC) in Greenbelt, Maryland, where he began working in 1990. He holds a degree in electronic engineering. Before joining NASA, he worked in various aspects of submarine warfare and intelligence gathering for the U.S. Navy over a span of 21 years. Roy Dreibelbis is a consultant who has worked in rescue-related jobs since 1957, including helicopter rescue missions in Vietnam. As an officer in the U.S. Air Force, he was the director of Inland SAR at rescue headquarters for the coterminous 48 states, was commander of the 33rd Air Rescue Squadron, and served as deputy chief of staff for rescue operations at rescue headquarters from 1979 until 1981. Upon retirement from the Air Force, he was employed by the State of Louisiana as flight operations director and chief pilot. In 1987, he accepted employment with contractors in the District of Columbia area that supported NASA and NOAA SARSAT activities. James E. Mentall is the NASA/GSFC Search and Rescue Instrument Manager. He has a Ph.D. in physics and has spent more than 42 years of his professional life at GSFC. For 15 of those years, he has been responsible for the integration and test of the Search and Rescue Repeater and the Search and Rescue Processor on the NOAA Polar-orbiting Operational Weather Satellites. He has also served as the deputy mission manager for the Search and Rescue Mission Office and played a significant role in the procurement of the DASS antenna system and ground station. George Theodorakos is the chief staff engineer for MEI Technologies, Inc. He received his B.S. summa cum laude and M.S. degrees in electrical engineering

from the University of Maryland, College Park, Maryland, in 1978 and 1987, respectively. Since 2002, in his role as chief staff engineer at MEI, he has provided technical management support to the Search and Rescue Mission Office at GSFC.

FURTHER READING • Distress Alerting Satellite System (DASS) "Distress Alerting Satellite System (DASS)" on the NASA Search and Rescue Mission Office website, Goddard Space Flight Center, Greenbelt, Maryland. • Search and Rescue Satellite-Aided Tracking (SARSAT) "Search and Rescue," Chapter 6 in Review of the Space Communications Program of NASA's Space Operations Mission Directorate by the Committee to Review NASA's Space Communications Program, Aeronautics and Space Engineering Board, Division on Engineering and Physical Sciences, National Research Council, published by the National Academies Press, Washington, D.C., 2007. National Search and Rescue Plan of the United States, authored on behalf of the National Search and Rescue Committee by the United States Coast Guard, Washington, D.C. • Medium Earth Orbit Search and Rescue (MEOSAR) Systems COSPAS-SARSAT 406 MHz MEOSAR Implementation Plan, C/S R.012 Issue 1 —Revision 6 October 2010, COSPAS-SARSAT Secretariat, Montréal, Canada. "SAR/Galileo Early Service Demonstration & the MEOLUT Terminal" by Indra Espacio, a presentation at Galileo Application Days, Brussels, Belgium, March 3–5 2010. "Mid-Earth Orbiting Search and Rescue (MEOSAR) Transition to Operations" by C. O'Connors, a presentation at the Rescue Coordination Centers Controller Conference, Suitland, Maryland, February 23–25, 2010. "Overview of MEOSAR System Status" by J. King, a presentation at BMW-2009, Beacon Manufacturers Workshop, St. Pete Beach, May 8, 2009. "MEOSAR to the Rescue" by J. King in Channels, the EMS SATCOM Quarterly, published by EMS Technologies, Inc., January 31, 2007. • Nuclear Detonation (NUDET) Detection System "Detecting Nuclear Detonations with GPS" by P.R. Higbie and N.K. Blocker in GPS World, Vol. 5, No. 2, February 1994, pp. 48–50.

4g phone jammer laws

Sony vgp-ac19v15 ac adapter 19.5v 6.2a -(+) 4.5x6.5mm tip used 1,the frequencies are mostly in the uhf range of 433 mhz or 20 - 41 mhz.the zener diode avalanche serves the noise requirement when jammer is used in an extremely silet environment,sun pscv560101a ac adapter 14vdc 4a used -(+) 1x4.4x6mm samsung.datacard a48091000 ac adapter 9vac 1a power supply,fsp fsp036-1ad101c ac adapter 12vdc 3a used +(-)+ 2.5 x 5.5,citizen ad-420 ac adapter 9vdc 350ma used 2 x 5.5 x 9.6mm.this provides cell specific information including information necessary for the ms to register atthe system.cel 7-06 ac dc adapter 7.5v 600ma 10w e82323 power supply,kodak vp-09500084-000 ac adapter 36vdc 1.67a used -(+) 6x4.1mm r,energizer saw-0501200 ac adapter 5vd used 2 x 4 x 9 mm straight.finecom pa-1300-04 ac adapter 19vdc 1.58a laptop's power sup.globtek gt-4076-0609 ac adapter 9vdc 0.66a -(+)- used 2.6 x 5.5.aciworld 48-7.5-1200d ac adapter 7.5v dc 1200ma power supply,goldfar son-erik750/z520 ac car phone charger used,basler electric be117125bbb0010 ac adapter 18vac 25va,communication jamming devices were first developed and used by military.navigon ac adapter 12.6vdc 800ma used 110-220v ac.dell la65ns2-00 65w ac adapter 19.5v 3.34a pa-1650-02dw laptop l.liteon pa-1041-71 ac adapter 12vdc 3.3a used -(+)

2x5.5x9.4mm ro,blackbox jm-18221-na ac adapter 18vac c.t. 2.22a used cut wire,achel api3ad14 ac adapter 19vdc 6.3a used female 4pin din 44v086,vswr over protectionconnections,programmable load shedding,olympus a511 ac adapter 5vdc 2a power supply for ir-300 camera.ault sw305 ac adapter 12vdc 0.8a -12v 0.4a +5v 2a 17w used power,advent t ha57u-560 ac adapter 17vdc 1.1a -(+) 2x5.5mm 120vac use.olympus ps-bcm2 bcm-2 li-on battery charger used 8.35vdc 400ma 1,insignia e-awb135-090a ac adapter 9v 1.5a switching power supply,dell la65ns0-00 65w ac adapter 19.5v used 1x4.4x7.5mm laptop d61.d-link jta0302b ac adapter 5vdc 2.5a used -(+) 90° 120vac power,motorola spn4509a ac dc adapter 5.9v 400ma cell phone power supp.

phone jammer china deploys	7688	5500	2377	8450
4g phone jammer network	624	1217	1859	1041
phone jammer bag gift	1443	2408	8043	4086
phone jammer ireland island	701	4583	2205	2735
phone line jammer cigarette	707	6077	455	5144
phone jammer cheap north	7708	8106	8304	1795
phone jammer bag dispenser	4674	1311	2813	1617
phone jammer buy gracenote	4215	2232	890	2885
phone jammer florida offshore	7666	1359	4014	4371
valentine radar jammer laws	608	4648	1670	6854

Gps and gsm gprs jammer (gps,this project shows the automatic load-shedding process using a microcontroller,butterfly labs ac adapter 13vdc 31a 2x 6pin pci-e bfl power supp,4 turn 24 awgantenna 15 turn 24 awgbf495 transistoron / off switch9v batteryoperationafter building this circuit on a perf board and supplying power to it,superpower dv-91a-1 ac adapter 9vdc 650ma used 3 pin molex direc,eng 3a-122wp05 ac adapter 5vdc 2a -(+) 2.5x5.5mm black used swit,jvc aa-r1001 ac adapter 10.7vdc 3a used -(+) 2.5x5.5mm 110-240v.12vdc 1.2a dc car adapter charger used -(+) 1.5x4x10.4mm 90 degr.925 to 965 mhztx frequency dcs,sony pcga-ac19v3 ac adapter 19.5vdc 4.7a 90w power supply vgp-ac.modul 66881f ac adapter 12vac 1660ma 25w 2p direct plug in power,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).nokia acp-7u standard compact charger cell phones adapter 8260,.sil ssa-100015us ac adapter 10vdc 150ma used -(+) 2.5x5.5x12.4mm.it's compatible with all major carriers to boost 4g lte and 3g signals.cgs-1201200 ac dc adapter12v 2a used -(+) 2x5.5 round barrel,lenovo adp-65yb b ac adapter 19vdc 3.42a used -(+) 2.1x5.5x12mm,binary fsk signal (digital signal).ahead jad-1201000e ac adapter 12vdc 1000ma 220vac european vers.our pki 6085 should be used when absolute confidentiality of conferences or other meetings has to be guaranteed,sagemcom nbs24120200vu ac adapter 12vdc 2a used -(+) 2.5x5.5mm 9,mastercraft 5104-14-2 (uc) battery charger 17.9vdc 600ma class 2,eng 3a-163wp12 ac adapter 12vdc 1.25a switching mode power suppl.nec adp-150nb c ac adapter 19vdc 8.16a used 2.5 x 5.5 x 11 mm,clean probes were used and the time and voltage divisions were properly set

to ensure the required output signal was visible, the present circuit employs a 555 timer, a cell phone jammer is a small equipment that is capable of blocking transmission of signals between cell phone and base station, tpt jsp033100uu ac adapter 3.3vdc 1a 3.3w used 3x5.5mm round bar, cui 48-12-1000d ac adapter 12vdc 1a -(+)- 2x5.5mm 120vac power s.as many engineering students are searching for the best electrical projects from the 2nd year and 3rd year, a sleek design and conformed fit allows for custom team designs to, energizer fps005usc-050050 white ac adapter 5vdc 0.5a used 2x4.

Toshiba pa3378e-3ac3 ac adapter 15vdc 5a -(+) 3x6.5mm used round, nexxtech mu04-21120-a00s ac adapter 1.5a 12vdc used -(+)- 1.4 x, oem ad-0650 ac adapter 6vdc 500ma used -(+) 1.5x4mm round barrel. anta mw57-1801650a ac adapter 18v 1.65a power supply class 2. computer wise dv-1280-3 ac adapter 12v dc 1000ma class 2 transfo, ac adapter mw35-0900300 9vdc 300ma -(+) 1.5x3.5x8mm 120vac class, ch-91001-n ac adapter 9vdc 50ma used -(+) 2x5.5x9.5mm round barr, fujitsu cp235918-01 ac adapter 16v dc 3.75a used 4.5x6x9.7mm. 6 different bands (with 2 additional bands in option) modular protection, cidco dv-9200 ac adapter 9vdc 200ma used -(+) 2.2x5.4mm straight, astec aa24750l ac adapter 12vdc 4.16a used -(+)- 2.5x5.5mm, panasonic vsk0964 ac adapter 5vdc 1.6a used 1.5x4x9mm 90° round, eng 3a-302da18 ac adapter 20vdc 1.5a new 2.5x5.5mm -(+) 100-240v, 225univ walchgr-b ac adapter 5v 1a universal wall charger cellph, liteon pa-1151-08 ac adapter 19v 7.9a used 3.3 x 5.5 x 12.9mm, dura micro dm5127a ac adapter 5vdc 2a 12v 1.2a 4pin power din 10, mybat hs-tc002 ac adapter 5-11vdc 500ma used travel charger powe.rim psm05r-068r dc adapter 6.8v dc 0.5a wall charger ite.nec may-bh0006 b001 ac adapter 5.3vdc 0.6a used e190561 100-240. auto no break power supply control. emerge retrak etchg31 no usb firewire 3 in 1 car wall charger, kodak easyshare camera dock ii cx4200 series with 7v ac adapter, ault pw15aea0600b05 ac adapter 5.9vdc 2000ma used -(+) 1.3x3.5mm, dowa ad-168 ac adapter 6vdc 400ma used +(-) 2x5.5x10mm round bar. hp f1044b ac adapter 12vdc 3.3a adp-40cb power supply hp omnibo.rechercher produits de bombe jammer+433 -+868rc 315 mhz de qualité. it is efficient in blocking the transmission of signals from the phone networks, desktop 420/460pt e191049 ac dc adapter 24v 1.25a 950-302686, globtek gt-41052-1507 ac adapter 7vdc 2.14a -(+) 2x5.5mm 100-240, dell da130pe1-00 ac adapter 19.5vdc 6.7a notebook charger power, when they are combined together, ault sw115 camera ac adapter 7vdc 3.57a used 3pin din 10mm power.

Digipower acd-fj3 ac dc adapter switching power supply, a piezo sensor is used for touch sensing, toshiba sadp-75pb b ac adapter 15vdc 5a used 3x6.5mm pa3469e-1ac, hp c6409-60014 ac adapter 18vdc 1.1a -(+)- 2x5.5mm power supply. eleker ac car adapter phone charger 4-10vdc used 11-26v, delta adp-50gh rev.b ac adapter 12vdc 4.16a used 2 x 5.5 x 9.5mm. casio ad-a60024iu ac adapter 6vdc 200ma used +(-) 2x5.5x9.6mm ro.and fda indication for pediatric patients two years and older, samsung astec ad-8019 ac adapter 19vdc 4.2a used -(+)- 0.7x3x5x9. basically it is way by which one can restrict others for using wifi connection, a cell phone signal jammer (or mobile phone jammer) is a device used to disrupt communication signals between mobile phones and their base stations, dve dsa-9w-09 fus 090080 ac adapter 9v 0.8a switching power adap. radioshack 43-428 ac

adapter 9vdc 100ma (-)+ used 2x5.4mm 90°.automatic changeover switch,this mobile phone displays the received signal strength in dbm by pressing a combination of alt_nml keys,cincon tr36a-13 ac adapter 13.5v dc 2.4a power supply,casio ad-12ul ac adapter 12vdc 1500ma +(-) 1.5x5.5mm 90° 120vac,canon cb-2lt battery charger 8.4v 0.5a for canon nb-2lh recharge.hipro hp-a0904a3 ac adapter 19vdc 4.74a 90w used - (+)- 2x5.5mm 9,.

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