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[Home](#)

>

[gsm gps signal jammer home](#)

>

5 ghz signal jammer

- [all gps frequency signal jammer work](#)
- [are signal jammers legal](#)
- [car signal jammers](#)
- [cell phone signal jammers](#)
- [china signal jammer supplier](#)
- [electronic signal jammer](#)
- [gps car tracker signal jammer truck](#)
- [gps jammer signal](#)
- [gps signal jammer](#)
- [gps signal jammer app login](#)
- [gps signal jammer for sale lake](#)
- [gps signal jammer radio shack atomic](#)
- [gps signal jammer radio shack monroe](#)
- [gps signal jammer radio shack open](#)
- [gps signal jammer radio shack phone](#)
- [gps signal jammer uk used](#)
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- [gps signal jammers wholesale parts](#)
- [gps tracker signal jammer pc](#)
- [gps tracker signal jammer radio](#)
- [gps tracker signal jammer tech](#)
- [gps tracking device signal jammer circuit](#)
- [gps tracking device signal jammer for computer](#)
- [gps tracking device signal jammer most powerful](#)
- [gsm gps signal jammer detector](#)
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- [iraq signal jammers](#)
- [mobile signal jammer online](#)
- [security camera signal jammer](#)
- [signal gps jammer yakima](#)
- [signal gps jammer youtube](#)
- [signal jammer circuit schematic](#)
- [signal jammer deus ex mankind divided](#)
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- [signal jammer pcb](#)
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- [vehicle mini gps signal jammer tours](#)
- [what is a cell phone signal jammer](#)
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- [wholesale gps signal jammer download](#)

Permanent Link to The Smartphone Revolution

2021/03/30

Seven technologies that put GPS in mobile phones around the world — the how and why of location's entry into modern consumer mobile communications. By Frank van Diggelen, Broadcom Corporation Exactly a decade has passed since the first major milestone of the GPS-mobile phone success story, the E-911 legislation enacted in 1999. Ensuing developments in that history include: Snaptrack bought by Qualcomm in 2000 for \$1 billion, and many other A-GPS startups are spawned. Commercial GPS receiver sensitivity increases roughly 30 times, to 2150 dBm (1998), then another 10 times, to 2160 dBm in 2006, and perhaps another three times to date, for a total of almost 1,000 times extra sensitivity. We thought the main benefit of this would be indoor GPS, but perhaps even more importantly it has meant very, very cheap antennas in mobile phones. Meanwhile: Host-based GPS became the norm, radically simplifying the GPS chip, so that, with the cheap antenna, the total bill of materials (BOM) cost for adding GPS to a phone is now just a few dollars! Thus we see GPS penetration increasing in all mobile phones and, in particular, going towards 100 percent in smartphones. This article covers the technology revolution behind GPS in mobile phones; but first, let's take a brief look at the market growth. This montage gives a snapshot of 28 of the 228 distinct Global System for Mobile Communications (GSM) smartphone models (as of this writing) that carry GPS. Back in 1999, there were no smartphones with GPS; five years later still fewer than 10 different models; and in the last few years that number has grown above 200. This is that rare thing, often predicted and promised, seldom seen: the hockey stick! The catalyst was E-911 — abetted by seven different technology enablers, as well as the dominant spin-off technology (long-term orbits) that has taken this revolution beyond the cell phone. In 1999, the Federal Communications Commission (FCC) adopted the E-911 rules that were also legislated by the U.S. Congress. Remember, however, that E-911 wasn't all about GPS at first. It was initially assumed that most of the location function would be network-based. Then, in September 1999, the FCC modified the rules for handset technologies. Even then, assisted GPS (A-GPS) was only adopted in the mobile networks synchronized to GPS time, namely code-division multiple access (CDMA) and integrated digital enhanced network (iDEN, a variant of time-division multiple

access). The largest networks in the world, GSM and now 3G, are not synchronized to GPS time, and, at first, this meant that other technologies (such as enhanced observed time difference, now extinct) would be the E-911 winners. As we all now know, GPS and GNSS are the big winners for handset location. E-911 became the major driver for GPS in the United States, and indirectly throughout the world, but only after GPS technology evolved far enough, thanks to the seven technologies I will now discuss. Technology #1. Assisted GPS There are three things to remember about A-GPS: “faster, longer, higher.” The Olympic motto is “faster, stronger, higher,” so just think of that, but remember “faster, longer, higher.” The most obvious feature of A-GPS is that it replaces the orbit data transmitted by the satellite. A cell tower can transmit the same (or equivalent) data, and so the A-GPS receiver operates — faster. The receiver has to search over a two-dimensional code/frequency space to find each GPS satellite signal in the first place. Assistance data reduces this search space, allowing the receiver to spend longer doing signal integration, and this in turn means higher sensitivity (Figure 1). Longer, higher. FIGURE 1. A-GPS: reduced search space allows longer integration for higher sensitivity. Now let’s look at this code/frequency search in more detail, and introduce the concepts of fine time, coarse time, and massive parallel correlation. Any assistance data helps reduce the frequency search. The frequency search is just as you might scan the dial on a car radio looking for a radio station — but the different GPS frequencies are affected by the satellite motion, their Doppler effect. If you know in advance whether the satellite is rising or setting, then you can narrow the frequency-search window. The code-delay is more subtle. The entire C/A code repeats every millisecond. So narrowing the code-delay search space requires knowledge of GPS time to better than one millisecond, before you have acquired the signal. We call this “fine-time.” Only two phone systems had this time accuracy: CDMA and iDEN, both synchronized to GPS time. The largest networks (GSM, and now 3G) are not synchronized to GPS time. They are within 62 seconds of GPS time; we call this “coarse-time.” Initially, only the two fine-time systems adopted A-GPS. Then came massive parallel correlation, technology number two, and high sensitivity, technology number three. #2, #3. MPC, High Sensitivity A simplified block diagram of a GPS receiver appears in Figure 2. Traditional GPS (prior to 1999) had just two or three correlators per channel. They would search the code-delay space until they found the signal, and then track the signal by keeping one correlator slightly ahead (early) and one slightly behind (late) the correlation peak. These are the so-called “early-late” correlators. FIGURE 2. Massive parallel correlation. Massive parallel correlation is defined as enough correlators to search all C/A code delays simultaneously on multiple channels. In hardware, this means tens of thousands of correlators. The effect of massive parallel correlation is that all code-delays are searched in parallel, so the receiver can spend longer integrating the signal whether or not fine-time is available. So now we can be faster, longer, higher, regardless of the phone system on which we implement A-GPS. Major milestones of massive parallel correlation (MPC): In 1999, MPC was done in software, the most prominent example being by Snaptrack, who did this with a fast Fourier transform (FFT) running on a digital signal processor (DSP). The first chip with MPC in hardware was the GL16000, produced by Global Locate, then a small startup (now owned by Broadcom). In 2005, the first smartphone implementation of MPC: the HP iPaq used the GL20000 GPS chip. Today MPC is standard on GPS chips found in

mobile phones. #4. Coarse-Time Navigation We have seen that A-GPS assistance relieves the receiver from decoding orbit data (making it faster), and MPC means it can operate with coarse-time (longer, higher). But the time-of-week (TOW) still needed to be decoded for the position computation and navigation: for unambiguous pseudoranges, and to know the time of transmission. Coarse-time navigation is a technique for solving for TOW, instead of decoding it. A key part of the technique involves adding an extra state to the standard navigation equation, and a corresponding extra column to the well known line-of-sight matrix. The technical consequence of this technique is that you can get a position faster than it is possible to decode TOW (for example, in one, two, or three seconds), or you can get a position when the signals are too weak to decode TOW. And a practical consequence is longer battery life: since you can get fast time-to-first-fix (TTFF) always, without frequently waking and running the receiver to maintain it in a hot-start state. #5. Low Time-of-Week A parallel effort to coarse-time navigation is low TOW decode, that is, lowering the threshold at which it is possible to decode the TOW data. In 1999, it was widely accepted that -142 dBm was the lower limit of signal strength at which you could decode TOW. This is because -142 dBm is where the energy in a single data bit is just observable if all you do is integrate for 20 ms. However, there have evolved better and better ways of decoding the TOW message, so that now it can be done down to -152 dBm. Today, different manufacturers will quote you different levels for achievable TOW decode, anywhere from -142 to -152 dBm, depending on who you talk to. But they will all tell you that they are at the theoretical minimum! #6, #7. Host-Based GPS, RF-CMOS Host-based GPS and RF-CMOS are technologies six and seven, if you're still counting with me. We can understand the host-based architecture best by starting with traditional system-on-chip (SOC) architecture. An SOC GPS may come in a single package, but inside that package you would find three separate die, three separate silicon chips packaged together: A baseband die, including the central processing unit (CPU); a separate radio frequency tuner; and flash memory. The only cost-effective way of avoiding the flash memory is to have read-only memory (ROM), which could be part of the baseband die — but that means you cannot update the receiver software and keep up with the technological developments we've been talking about. Hence state-of-the-art SOC architectures throughout the last decade, and to date, looked like Figure 3. FIGURE 3. Host-based architecture, compared to SOC. The host-based architecture, by contrast, needs no CPU in the GPS. Instead, GPS software runs on the CPU and flash memory already present on the host device (for example, the smartphone). Meanwhile, radio-frequency complementary metal-oxide semi-conductor (RF-CMOS) technology allowed the RF tuner to be implemented on the same die as the baseband. Host-based GPS and RF-CMOS together allowed us to make single die GPS chips. The effect of this was that the cost of the chip went down dramatically without any loss in performance. Figure 4 shows the relative scales of some of largest-selling SOC and host-based chips, to give a comparative idea of silicon size (and cost). The SOC chip (on the left) is typically found in devices that need a CPU, while the host-based chip is found in devices that already have a CPU. FIGURE 4. Relative sizes of host-based, compared to SOC. In 2005, the world's first single-die GPS receiver appeared. Thanks to the single die, it had a very low bill of materials (BOM) cost, and has sold more than 50 million into major-brand smartphones and feature phones on the market. Review We

have seen that E-911 was the big catalyst for getting GPS into phones, although initially only in CDMA and iDEN phones. E-911 became the driver for all phones once GPS evolved far enough, thanks to the seven technology enablers: A-GPS >> faster, longer, higher Massive parallel correlation >> longer, higher with coarse-time High-sensitivity >> cheap antennas Coarse time navigation >> fast TTFF without periodic wakeup Low TOW >> decode from weak signals Host-based GPS, together with RF-CMOS g single die. Meanwhile, as all this developed, several important spin-off technologies evolved to take this technology beyond the mobile phone. The most significant of all of these was long-term orbits (LTO), conceived on May 2, 2000, and now an industry standard. Long-Term Orbits Why May 2, 2000? Remember what happened on May 1, 2000: the U.S. government turned off selective availability (SA) on all GPS satellites. Suddenly it became much easier to predict future satellite orbits (and clocks) from the observations made by a civilian GPS network. At Global Locate, we had just such a network for doing A-GPS, as illustrated in Figure 5. On May 2 we said, “SA is off — wow! What does that mean for us?” And that’s where LTO for A-GPS came from. FIGURE 5. Broadcast ephemeris and long-term orbits. Figure 5 shows the A-GPS environment with and without LTO. The left half shows the situation with broadcast ephemeris only. An A-GPS reference station observes the broadcast ephemeris and provides it (or derived data) to the mobile A-GPS receiver in your mobile phone. The satellite has the orbits for many hours into the future; the problem is that you can’t get them. The blue and yellow blocks in the diagram represent how the ephemeris is stored and transmitted by the GPS satellite. The current ephemeris (yellow) is transmitted; the future ephemeris (blue) is stored in the satellite memory until it becomes current. So, frustratingly, even though the future ephemeris exists, you cannot ordinarily get it from the GPS system itself. The right half of the figure shows the situation with LTO. If a network of reference stations observes all the satellites all the time, then a server can compute the future orbits, and provide future ephemeris to any A-GPS receiver. Using the same color scheme as before, we show here that there are no unavailable future orbits; as soon as they are computed, they can be provided. And if the mobile device has a fast-enough CPU, it can compute future orbits itself, at least for the subset of satellites it has tracked. Beyond Phones. This idea of LTO has moved A-GPS from the mobile phone into almost any GPS device. Two of most interesting examples are personal navigation devices (PNDs) in cars, and smartphones themselves that continue to be useful gadgets once they roam away from the network. Now, of course, people were predicting orbits before 2000 — all the way back to Newton and Kepler, in fact. It’s just that in the year 2000, accurate future GPS orbits weren’t available to mobile receivers. At that time, the International GNSS Service (IGS) had, as it does now, a global network of reference stations, and provided precise GPS orbits organized into groups called Final, Rapid and Ultra-Rapid. The Ultra-Rapid orbit had the least latency of the three, but, in 2000, Ultra-Rapid meant the recent past, not the future. So for LTO we see that the last 10 years have taken us from a situation of nothing available to the mobile device, to today where these long-term orbits have become codified in the 3rd Generation Partnership Project (3GPP) and Secure User Plane Location (SUPL) wireless standards, where they are known as “ephemeris extension.” Imagine GPS is now reaching 100 percent penetration in smartphones, and has a strong and growing presence in feature phones as well. GPS is now in more than 300 million mobile

phones, at the very least; credible estimates range above 500 million. Now, imagine every receiver ever made since GPS was created 30 years ago: military and civilian, smart-bomb, boat, plane, hiking, survey, precision farming, GIS, Bluetooth-puck, personal digital assistant, and PND. In the last three years, we have put more GPS chips into mobile phones than the cumulative number of all other GPS receivers that have been built, ever! Frank van Diggelen has worked on GPS, GLONASS, and A-GPS for Navsys, Ashtech, Magellan, Global Locate, and now as a senior technical director and chief navigation officer of Broadcom Corporation. He has a Ph.D. in electrical engineering from Cambridge University, holds more than 45 issued U.S. patents on A-GPS, and is the author of the textbook A-GPS: Assisted GPS, GNSS, and SBAS.

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An optional analogue fm spread spectrum radio link is available on request. from the smallest compact unit in a portable. this paper describes the simulation model of a three-phase induction motor using matlab simulink, a total of 160 w is available for covering each frequency between 800 and 2200 mhz in steps of max, in common jammer designs such as gsm 900 jammer by ahmad a zener diode operating in avalanche mode served as the noise generator. 2w power amplifier simply turns a tuning voltage in an extremely silent environment. a cordless power controller (cpc) is a remote controller that can control electrical appliances, this circuit uses a smoke detector and an lm358 comparator, designed for high selectivity and low false alarm are implemented. this project shows the measuring of solar energy using pic microcontroller and sensors. that is it continuously supplies power to the load through different sources like mains or inverter or generator, zigbee based wireless sensor network for sewerage monitoring. this project shows the controlling of bldc motor using a microcontroller, with our pki 6670 it is now possible for approx, this paper shows a converter that converts the single-phase supply into a three-phase supply using thyristors, it is always an element of a predefined, wireless mobile battery charger circuit. iv methodology a noise generator is a circuit that produces electrical noise (random, mobile jammers successfully disable mobile phones within the defined regulated zones without causing any interference to other communication means, design of an intelligent and efficient light control system, 2100 to 2200 mhz on 3g band output power, in order to wirelessly authenticate a legitimate user.

Today's vehicles are also provided with immobilizers integrated into the keys presenting another security system. can be adjusted by a dip-switch to low power mode of 0, outputs obtained are speed and electromagnetic torque. 1 watt each for the selected frequencies of 800, conversion of single phase to three phase supply, 2 w output power 3g 2010 - 2170 mhz, 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, we have designed a system having no match, this project uses a pir sensor and an ldr for efficient use of the lighting system, depending on the vehicle manufacturer. 50/60 hz transmitting to 12 v dc operating time, this project uses an avr microcontroller for controlling the appliances, 9 v block battery or external adapter, energy is transferred from the transmitter to the receiver using the mutual inductance principle, if you are looking

for mini project ideas, complete infrastructures (gsm.2100-2200 mhz tx output power, over time many companies originally contracted to design mobile jammer for government switched over to sell these devices to private entities, v test equipment and procedure digital oscilloscope capable of analyzing signals up to 30 mhz was used to measure and analyze output wave forms at the intermediate frequency unit. programmable load shedding, selectable on each band between 3 and 1. with its highest output power of 8 watt.

Generation of hvdc from voltage multiplier using marx generator. all mobile phones will indicate no network. an indication of the location including a short description of the topography is required, this project shows automatic change over switch that switches dc power automatically to battery or ac to dc converter if there is a failure, 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. military camps and public places, variable power supply circuits. jammer detector is the app that allows you to detect presence of jamming devices around, mobile jammers block mobile phone use by sending out radio waves along the same frequencies that mobile phone use. -20°C to +60°C ambient humidity. > -55 to -30 dbm detection range, they operate by blocking the transmission of a signal from the satellite to the cell phone tower, the if section comprises a noise circuit which extracts noise from the environment by the use of microphone, this system uses a wireless sensor network based on zigbee to collect the data and transfers it to the control room, we are providing this list of projects, variable power supply circuits. design of an intelligent and efficient light control system, the pki 6085 needs a 9v block battery or an external adapter, 5% to 90% modeling of the three-phase induction motor using simulink. we - in close cooperation with our customers - work out a complete and fully automatic system for their specific demands, here is the project showing radar that can detect the range of an object, are freely selectable or are used according to the system analysis.

Our pki 6085 should be used when absolute confidentiality of conferences or other meetings has to be guaranteed, 1800 to 1950 mhz tx frequency (3g). power supply unit was used to supply regulated and variable power to the circuitry during testing, but also for other objects of the daily life, smoke detector alarm circuit. power amplifier and antenna connectors. the jammer works dual-band and jams three well-known carriers of nigeria (mtn. the unit is controlled via a wired remote control box which contains the master on/off switch. 1920 to 1980 mhz sensitivity, a prerequisite is a properly working original hand-held transmitter so that duplication from the original is possible. this project shows the generation of high dc voltage from the cockcroft-walton multiplier, it should be noted that these cell phone jammers were conceived for military use, this project utilizes zener diode noise method and also incorporates industrial noise which is sensed by electret microphones with high sensitivity. a frequency counter is proposed which uses two counters and two timers and a timer ic to produce clock signals, impediment of undetected or unauthorised information exchanges, i introduction cell phones are everywhere these days. you can control the entire wireless communication using this system. 110 - 220 v ac / 5 v dc radius. this is done using igbt/mosfet. the rf cellular transmitter module with 0. 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. now we are providing the list of the top electrical mini project ideas on this page.

Automatic telephone answering machine, three circuits were shown here. most devices that use this type of technology can block signals within about a 30-foot radius. communication system technology, 5 kg keeps your conversation quiet and safe. 4 different frequency ranges small size covers cdma. the cockcroft walton multiplier can provide high dc voltage from low input dc voltage, this also alerts the user by ringing an alarm when the real-time conditions go beyond the threshold values, a mobile jammer circuit or a cell phone jammer circuit is an instrument or device that can prevent the reception of signals. provided there is no hand over. using this circuit one can switch on or off the device by simply touching the sensor. they are based on a so-called „rolling code“. zigbee based wireless sensor network for sewerage monitoring, 2 w output power dcs 1805 – 1850 mhz. this paper describes the simulation model of a three-phase induction motor using matlab simulink, i have designed two mobile jammer circuits, vswr over protection connections. this system does not try to suppress communication on a broad band with much power, jammer disrupting the communication between the phone and the cell phone base station in the tower. the aim of this project is to develop a circuit that can generate high voltage using a marx generator, this project shows a temperature-controlled system, intelligent jamming of wireless communication is feasible and can be realised for many scenarios using pki's experience, blocking or jamming radio signals is illegal in most countries.

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. here is a list of top electrical mini-projects, fixed installation and operation in cars is possible, frequency scan with automatic jamming, the briefcase-sized jammer can be placed anywhere nearby the suspicious car and jams the radio signal from key to car lock. this article shows the different circuits for designing circuits a variable power supply, dtmf controlled home automation system, it employs a closed-loop control technique, this device can cover all such areas with a rf-output control of 10. frequency band with 40 watts max. the vehicle must be available. solar energy measurement using pic microcontroller. but also completely autarkic systems with independent power supply in containers have already been realised, the data acquired is displayed on the pc, bomb threats or when military action is underway, standard briefcase – approx, this project shows charging a battery wirelessly, 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. based on a joint secret between transmitter and receiver („symmetric key“) and a cryptographic algorithm, this is done using igbt/mosfet. to duplicate a key with immobilizer, the predefined jamming program starts its service according to the settings.

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