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Factors Affecting Performance of GPS Receiver and Solutions for Sustainable Signal

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Abstract-

This study deals with the factors that affects the functionality of GPS receivers. It intends to give an overview of the potential sources that are causing interference to the GPS signal on the receiver side. It also focuses on the techniques that make an impact in reducing interference level or make them apart. The study procures a quantitative comprehension of the impact of major types of interference. Most of the interfering sources are going to be analyzed with their technical characteristics and the rejection requirements to make them isolated and to keep the good performance of the receiver. Superior methods and circuit designs for GPS signal processing are included which eliminate interference.

Keywords- Global Navigation Satellite System (GNSS); Global Positioning System (GPS); Interferences; Jamming; Universal Software Radio Peripheral (USRP); Earth Centered Earth Fixed (ECEF); Signal Control Unit (SCU)

I. INTRODUCTION

GNSS is basically a network of satellites which orbit around the earth. It uses triangulation to determine a user's position. The current GNSS constellation is supported by 31 active satellites revolving around the earth in six different orbits, with minimum of four satellites in each orbit. The GPS system which is a part of GNSS makes sure that the earth based GPS devices and GPS servers receive signals from five or more satellites round the clock even though a GPS device can function with signals from four satellites, to enhance the accuracy of GPS device [1].

These satellites are located 20,000 km above us and are moving at a speed of approximately 14,000 km/hr. All Navigation satellites broadcasts a pseudo random string of 0s and 1s which is known only to the receiver. By figuring the delay between broadcasted and the received signal, the distance from the satellite can be calculated by multiplying it by the speed of light. This is usually done with 4 satellites and the position of the GPS receiver can be figured out in 3 dimensional (latitude, longitude and altitude).

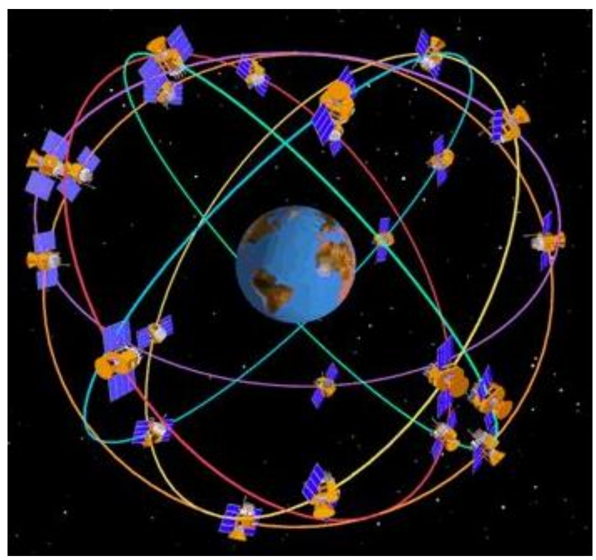

Fig 1.1: Navigation Satellites moving around Earth in 6 orbital planes

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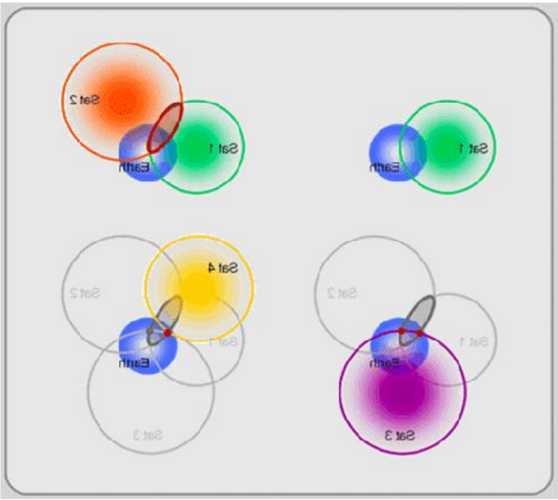

Fig 1.2 Global location of the user achieved by four satellites in 3 Dimensional Plane

The Global Positioning System (GPS) can be described in terms of three principal segments:

- Space Segment
- Control Segment
- User Segment

The Space Segment:

Space segment is comprised of orbiting GPS satellites each one carrying atomic clocks. There are minimum of four satellites in each of six orbital planes which are inclined at 55 degrees with respect to earth's equatorial plane, distributed so that from any point on the earth, four or more satellites are almost always above the local horizon. Satellites are tied to the clocks that act as timing signals which are transmitted from each satellite. The sequences of events in space are characterized by positions and times of transmission.

The Control Segment:

This segment is comprised of a master command station (MCS) with

- Different master control place,
- 4 dedicated surface antennas and
- 6 monitor areas.

A number of ground-based monitoring stations are present which continuously gather information from satellites. The data collected are sent to a Master Control Station where it analyzes the constellation and projects the ephemerides of satellites and clock behavior forward. This information is then uploaded into the satellites for retransmission to GPS users.

The User Segment (GPS Receiver):

User segment is a worldwide network of ground based GPS systems. It basically consists of GPS enabled users who receives signals transmitted from the satellites. They are able to determine their position, velocity, with their time on their local clocks.

Clock timings in the GPS are synchronized with the Earth Centered Inertial frame, in which self-consistency can be achieved. GPS systems are meant to be accurate within 5 to 8 meters. If you consider the speed of light (i.e. 3*10^8 m/s) which means it translates to a time accuracy of 20 to 30 ns. Even though a nanosecond is a billionth of a second, it matters when it comes to GPS. Satellite ephemerides in a model earth-centered, earth-fixed, reference frame (ECEF frame) rotates about a fixed axis with a defined rotation rate equal to 7.2921151467 × 10^-5 rad/s.

Any navigation shown by a GPS receiver is based on the computation of its distance to a set of satellites, by means of extracting the propagation time of the incoming signals traveling through space approximately at the speed of light. GPS receivers attempts to acquire all signals that are transmitting from satellites, generating the Pseudo-Random number (PRN) codes for all satellites. The ideal pseudo range for each satellite is calculated using the following equation:

$$\rho_j = c\left(t_{AU,j} - t_{TS,j}\right) \quad \text{eq(1)}$$

Where 'c' is the speed of light,

' tAU j' is the true time of the signal arrival at the user

'tTS,j', is the true time of the signal transmission from the satellite[2].

The GPS signal consists of three components: carrier wave, ranging codes, and navigation message. A smartphone can download the almanac from the server, reducing the number of satellites to be acquired from 31 to 8-12. As GPS is a power consumption application, power spent on searching for fewer satellites will improve energy efficiency. Searching can terminate early, once it detects the satellites that are in line of sight position contributing information. By considering satellites are always in motion, previous to obtaining the navigation data, the satellite's signal is detected and tracked.

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The receiver's functional device that perform these tasks are the antenna, the front-end and the baseband signal processing They are responsible for acquiring and tracking the signal.

Once the signal is acquired and tracked, the receiver application decodes the navigation data and estimates the user position. The navigation data includes:

- Ephemeris parameters (needed to compute the satellite's coordinate).
- Time parameters and Clock Corrections (to compute satellite clock offsets and time conversions).
- Service Parameters with satellite performance information.
- Ionosphere parameters model (needed for single frequency receivers).
- Almanacs (which allow computing the position of all satellites but with a lower accuracy than the ephemeris [3].

Special Relativity

In simple words, Special Relativity tells us that 'the faster we go, time slows down'. The satellites are in orbital velocities of 14,000 km/hr. Although this is extremely low value when compared to the speed of light, this makes the clock on the satellite tick 7 micro seconds slower than a clock on earth per day.

General Relativity

General Relativity states that 'closer you are to a massive object, time slows down'. The GPS receiver is much closer to Earth (massive object) than the satellite. Now this makes the Earth Clock tick 45 microseconds slower per day than the satellite clock.

Taking both relativities into consideration,

The total delay is 45-7=38 microseconds.

It means the satellite clock is always 38 microseconds ahead of the Earth clock per day [4].

Interference

The interference can be defined as jumbling of radio signals caused by the reception of undesired ones. Millions of GPS users across the world are dependent on the signals sent by GNSS network in the sky to achieve certain tasks that include determining their location, navigation, tracking something or someone, mapping areas are some among the many other applications of GPS. The accuracy of GPS depends on the GPS signal strength that may degrade due to several reasons. At this moment, GPS signal is divided into two categories, for civilians and for military. Accordingly, it send signals at L level frequencies. L1 for civilians and L2 for military purpose. L2 is highly encrypted and made stronger to increase the accuracy of GPS for military.

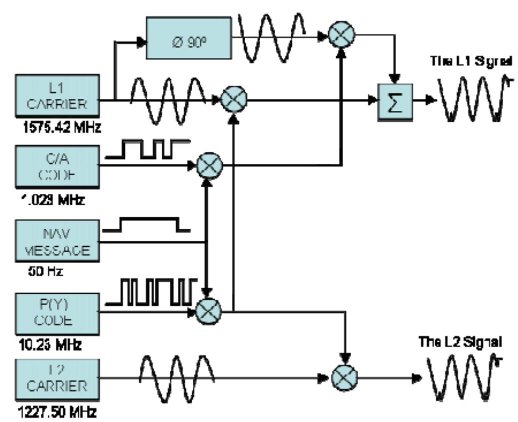

Figure 1.3: Composition of the signals from GPS satellites system [2].

GPS	GLONASS	Galileo
L1 1575.42 MHz	L1 1602.00 MHz	E1 1575.42 MHz
L2 1227.6 MHz	L2 1246.00 MHz	E5A 1176.45 MHz
L5 1176.45 MHz		E5 1191.795 MHz
		E5B 1207.14 MHz
		E6 1278.75 MHz

Table 1: GNSS RF Carrier Frequencies [5]

Types of Interference

There are many interferences that poses a threat to the GPS signals. They can be mainly classified into three categories –

A) Receiver System Noise
B) Man Made Interference
C) Environmental Interference

II. LITERATURE REVIEW

A) Receiver System Noise

It is a kind of interference which we get physically from any system. In this context, the interference made by GPS receivers is considered as system interference. GPS receivers are always subjected to some level of noise that contaminates the data and observations. In radio-based communication and navigation systems like GPS, noise originate from various sources like the equipment itself. These sources play a major role in determining receiver performance. They are sorted into following types.

Thermal Noise:

It is the most basic kind of electrical noise produced by the random movement of electrons in any conductor with a temperature above absolute zero (0 K or 273.16 °C). If we measure the voltage, we would see that it fluctuates rapidly, alternating in polarity sign, such that the mean or average voltage is zero. Yet the power associated with it is proportional to the integral of the square of the voltage. This available noise power, it turns out to be proportional to the conductor's absolute temperature. The noise occupies a broad frequency spectrum, and its power in a given pass band is independent of the passband's center frequency. We refer to such noise as white noise. In analogy to white light, which consists of more or less equal contributions of different colors. We can express the relationship between power, temperature and bandwidth as

$$P = kTB \qquad \text{eq(2)}$$

Where ‘p’ is the thermal noise power
‘k’ is Boltzmann 's constant (1.380662 X 10^-23 joules)
‘T’ is temperature in kelvin
‘B’ is the bandwidth in hertz

If we are considering a resistor at room temperature (T = 290 K), the available power from the noise voltage in one MHz bandwidth is

P(noise) =1.38 X 10^-23 X 290 X 10^6 = 4 X 10^-15 watts. eq(3)

Even though the value is small indeed but considering the possible noise effect on signal use, we must compare the noise power with the available signal power. The power from a received radio signal generates at an antenna's terminal can be quite small. For example, the GPS C/ A-code signal generate only about 10^-16 watts which acts as noise [3].

Antenna Noise:

The electron randomly moving in a conductor produce not only thermal noise (voltage) but also electromagnetic radiations. In fact, all objects at temperatures above absolute zero radiate electromagnetic waves and may also absorb or reflect incident radiation. A perfect absorber is called a black body. It absorbs all incident radiation at all frequencies. The radiation energy heats the body to a particular temperature that is dependent on the radiation frequency. A black body is also a perfect radiator. It emits a continuous radiation spectrum, with a brightness in the radio wavelength region given by

b=2f^2kT/c^2 eq(4)

Where ‘f’ is frequency,
‘k’ is Boltzmann's constant,
‘T’ is body's temperature and
‘c’ is the vacuum speed of light.

If we could build a black body in the form of a box and place an antenna in it, the antenna would absorb the radiation emitted by the box walls and generate a noise with bandwidth equal to ‘kT’. The same amount generated at the terminals of a resistor at temperature T. So, we can use the black body concept to characterize any electromagnetic radiation intercepted by an antenna in terms of the temperature of the black body that would have produced the same noise power [6].

Electromagnetic radiation:

GPS receiver antenna like that of any radio receiver, picks up a certain amount of noise in the form of naturally

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produced electromagnetic radiation. This radiation comes from the sky, the ground and the objects in antenna's vicinity. The sky noise has two main components. The first one is cosmic noise caused by the random electromagnetic radiation emitted by the sun, the Milky Way galaxy and other discrete cosmic objects. Radiation left over from the Big Bang also contributes little to this noise which is called by the earth's atmosphere. The radiation from these sources is not confined to a narrow range of frequencies but extends over a large portions of the radio spectrum.

While the ephemeris data is transmitted every 30 seconds, the information itself may be up to two hours old. Variability in solar radiation pressure has an indirect effect on GPS accuracy due to its effect on ephemeris errors. If a fast time to first fix (TTFF) is needed, it is possible to upload a valid ephemeris to a receiver, and in addition to setting the time, a position fix can be obtained in under ten seconds. It is feasible to put such ephemeris data on the web so it can be loaded into mobile GPS devices.

Clock error:

The satellite's atomic clocks experience noise and clock drift errors. The navigation data contains corrections for these errors and estimates of the accuracy of the atomic clock. However, they are based on observations and may not indicate the clock's current state. These problems tend to be very small, but may add up to a few meters (tens of feet) of inaccuracy in calculating user's position.

For very precise positioning, these effects can be eliminated by differential GPS. It is the simultaneous use of two or more receivers at several survey points [7].

B) Man Made Interference

It is the interference created by the machinery developed by various organizations for their individual purposes. The interference can also be from the people who are seeking navigation assistance. Some of the major interferences caused to a GPS signal are from

- Aircraft Navigation Systems
- Television Broadcasting
- Radio Signals
- Telecommunication

Aircraft Navigation Systems

The signals used by the aircraft agencies to communicate with their aircrafts can cause interference to the GPS signal. Some of the agencies use jammers for purposes like security and breaching. A jammer is a device that blocks transmissions by creating interference. The jamming techniques they use are mechanical jamming and electronic jamming.

Mechanical Jamming

It is caused by mechanical devices which reflect or re-reflect radio signals back to the source to produce false data on the operator's device. Some of the mechanical jamming devices are chaff, corner reflectors, and decoys.

Electronic jamming

It is a form of electronic warfare where jammers radiate interfering signals towards an enemy's radar, blocking the operator (GPS receiver) with highly concentrated energy signals. The two main techniques used are noise techniques (spot jamming, sweep jamming, barrage jamming, base jamming, and pulse jamming) and repeater techniques. Repeater technique is also called as 'Digital Radio Frequency Memory Jamming (DRFM)' is a technique that manipulates received data from the signal and retransmits it to change the identification in the radar. This technique can change the range, velocity and angle of the radar by causing false targets.

Television Broadcasting

There are three types of transmission to broadcast a channel on a television. They are by cable, by antenna and by satellite. When a television program is broadcasted, the varying electrical signals are amplified and are used to modulate a carrier wave. Then modulated carrier is usually given to an antenna, where it is converted to electromagnetic waves and broadcasted over a large region. The broadcasted waves are sensed by antennas connected to television receivers. Although, the frequencies at which the television channels are broadcasting does not imply a major threat in interfering with GPS signal, some of the countries like Western Europe, Greenland, most countries in Asia and Africa uses ultra-high frequencies for broadcasting which may interfere and cause GPS receiver to lose track of the signals coming from satellites[9].

Radio Signals

The number of systems that make use of the radio magnetic spectrum has increased a lot over the last decades with the number of users increasing daily. This development has crowded the radio frequency spectrum significantly. When two systems use the same frequencies or frequencies close to each other, this can cause interfere for both systems. These two systems can both be navigation systems such as GPS and Galileo, but interference of completely different systems can also be encountered and can even be much more severe. For a GNSS receiver, degraded performance can result in less accurate range and phase measurements leading to a less accurate position. Because modern GNSS applications demand increasingly high accuracy, this makes the subject of interference very important [10].

Telecommunication

Most of them owns a cellular phone in their hands. As per the statistics in manufacturing and purchasing of mobile phones, it says each person will be having two phones by the year 2020. If that is the case, there will be tremendous increase in electromagnetic radiation within the segments of the spectrum in which these systems operate. These emissions have the potential to interfere with the normal operation and function of GPS. Many cellular mobiles use Frequency Modulated Signals in the frequency range around 1800 MHz for GSM Systems.

Example: Light Squared is a company that sought to develop a wholesale 4G LTE wireless broadband communications network integrated with satellite coverage across the United States. It controls a block of the united spectrum (1525-1559 MHz) in the L-Band. The spectrum allocated for the GPS "L1" signal is 1559 to 1610 MHz [11].

C) Environmental Interference

It is the interference caused by the environment around us. Some of the interferences that are considered are

Solar Activity

It is a consequence of the behavior of the Sun, the nature of the Earth's magnetic field and our location in the solar system. Space Weather events such as solar flares, coronal mass ejections and solar radio bursts can have major effects on GPS. Solar flares and CMEs induce geomagnetic storms that make the ionosphere unstable, resulting in rapid changes. Ionosphere has practical importance because it influences radio wave propagation between space and earth.

CME (Coronal Mass Ejections) are a giant cloud of solar plasma drenched with magnetic field lines that are blown away from the sun during strong, long-duration solar flares. They are the most threatening of solar events [12] [13].

Geomagnetic Storms

The increase in the solar wind pressure initially compresses the magnetosphere (the region surrounding the earth in which the magnetic field is effective). The solar wind's magnetic field interacts with the Earth's magnetic field and transfers an increased energy into the magnetosphere. Interactions cause an increase in plasma movement through the magnetosphere driven by increased electric fields.

Scintillation is a rapid variation in the intensity of the satellite signal that can cause a GPS receiver to lose lock on the signal.

Dense Materials

The term refers to the high rise concrete buildings and skyscrapers that do not allow the signals to pass through them. These urban structures either totally block the radio signals sent by the satellites or alter their path so that they never reach the GPS servers or GPS device. Even if the signals are able to get through the buildings, they become so weak that it makes GPS receiver difficult to interpret the signal. Several factors interfere with a GPS signal: dense clouds, dust particles, mountains. If the GPS devices are being used underwater such as in submarines, the depth becomes too long for the radio signals to retain their strength. The density of ocean water also contributes to the weakening of the radio signals [15] [16].

Problem Statements

- Signal processing methods that will enhance the quality of GPS signal? Analyze them and finding the most effective method?

- Is there any unique circuit designs that act as filter for GPS receivers to eliminate particular type of interference? (like system noises)

- What are the steps to follow through (In case of emergency) while receiving GPS signal to reduce an environmental interference?

III. METHODOLOGY

IMPACT OF NARROW BAND INTERFERENCES

The interference is measured by receiver's signal-to-noise ratio. The signal received by GPS receiver is degraded more when narrowband interference frequency is located at band center. It is degraded even more when narrowband interference is at frequencies away from center band which affects code tracking accuracy even if the interference having the same power at band center [24]. The typical $C/N0$ value of an ideal GPS receiver ranges from 37 to 45 dB-Hz [28].

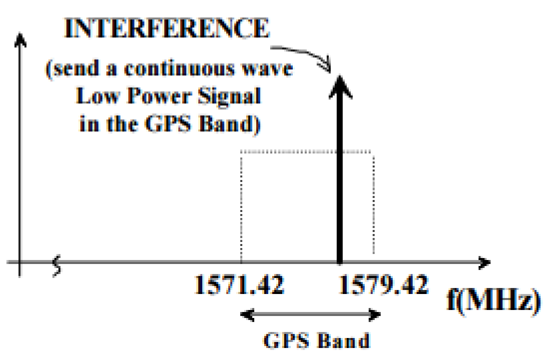

Fig 3.1 Interference in GPS Band [17]

SIGNAL PROCESSING METHODS

KALMAN FILTER:

It is a digital signal processing technique used for smoothening the data received from GPS receivers and accelerometer. It is a multiple input-output digital filter which have the capacity to highly estimate in real time, the states of a system based on its noisy outputs. It is used where you have inconsistent information about some dynamic systems. They are ideal for the systems which continuously change the positions. The main advantages of this filter are that they are light on memory and are very fast which makes them well suited for real time problems and embedded systems [19].

As majority of people uses Smartphones for GPS navigation and smartphones do not come with a Kalman filtering solution from the factory, it is important to take into consideration.

Basic working Principle-

- Taking a least squares fit approach which will just use positional information from GPS.
- Takes velocities into account from accelerometer [19].

When the Pseudo Random codes from satellite and GPS receiver match each other, the receiver is put on to sync and determines its distance from the satellites.

In accomplishing the tasks, the filter knows how to best use for given set of sensors for modeling a system by providing the current estimates of receiver variables like position coordinates. It also determines up-to-date uncertainties of the estimates for real-time quality assessments or for off-line system design purposes. It uses statistical models to weigh each new measurement relative to past information [20] [21].

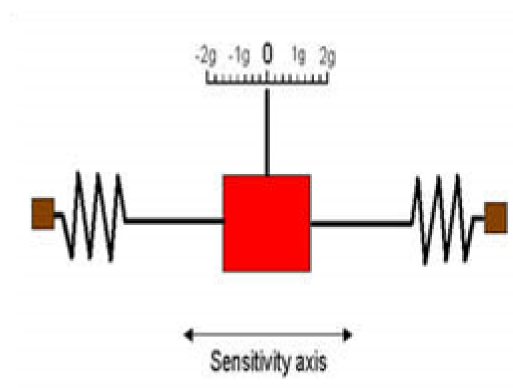

Fig 3.2. Basic schematic structure of Accelerometer

MATHEMATICS INVOLVED IN KALMAN FILTERING

The Kalman filter assumes system states vector which evolves as

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- $x_{k+1} = \mathbf{F}_k x_k + w_k$

With the measurement vector given by

- $z_k = \mathbf{H}_k x_k + v_k$

Where x_k is system state vector

x_0, w_k, and v_k are mutually uncorrelated vectors

The later occurring two are white noise sequences with means of $\mathbf{m}_0$, 0, and 0 which are non-negative definite covariance's of S_0, Q_k, and R_k respectively.

The vector Xk/j is the optimal estimate of X at time t_k based on measurements up to t_j, and $P_{k/j}$ is the corresponding best estimation error covariance matrix when the applied filter model matches the real-world system which is generating data actually.

Minimizing the generalized mean square error, E[etk/jAek/j],

where ek/j[xk – xk/j] and A is any positive semi definite weighting matrix, If results in the equations respective of all variables and noises are Gaussian.

The filter works by the recursive algorithm which is shown in figure 3.3 corresponding to the Figure 3.4.

The algorithm involves four steps

– Gain Computation
– State Estimate Update
– Covariance Update
– Prediction

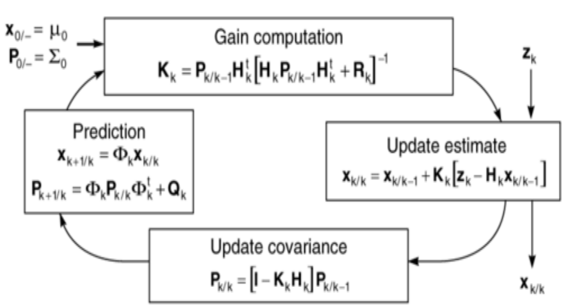

Fig: 3.3 Steps followed by Kalman Filter

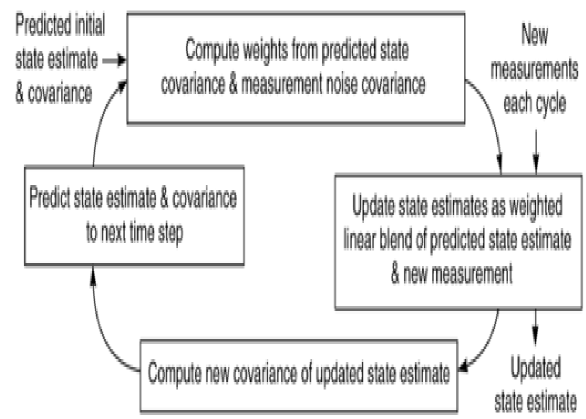

Fig: 3.4 at each cycle, the state estimate is updated by combining new measurements with state estimates from previous measurements

In non-Gaussian cases, an additional restriction is put forward. There should be linear relationship between state measurements, state estimate and the predicted state [21].

GPS Signal Simulator with USRP

Embedded GPS receivers have become popular with the rapid increase in usage of GPS navigation systems into all human-machine interfaces [23]. As more production companies embed low cost GPS receivers into their products, the need for low-cost GPS signal simulators has also grown. Controlled virtual testing is important in ensuring the system execution.

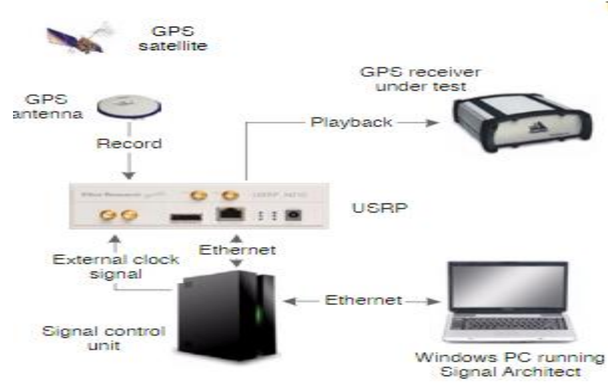

Fig: 3.5 GPS Signal Simulator Hardware

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The signal simulation toolbox uses a universal software radio peripheral which simulates the effect of signal degradation for GPS receiver which uses MATLAB software. It also simulates the effect of carrier tracking loops like losing lock or cycle slipping. It also has additional features to read GPS almanacs and ephemerides which compute ECEF and straight line vectors to GPS satellites as a function of user's location and time. Universal Software Radio Peripheral (USRP) records and play back the legacy signals (L1 C/A) at the L1 band (1575.42 MHz). The legacy signals are usually transmitted with acquisition code rate at 1Mbps which implies 1ms [25].

The Signal Control Unit (SCU) and USRP were connected to a GPS L1 antenna. The GPS signal will split between GPS receiver and USRP to allow operator to monitor the GPS receiver while the USRP records GPS signal. When recording, the I/Q data is written from the USRP to a file on SCU. In testing, the data is read from the file by the USRP to generate the RF signal. The RF signals are made as output to the GPS receiver through an external variable attenuator. The attenuator allows operator to adjust power of the signal going to GPS receiver as multiple lengths of antenna cable are added or the signal is split to other GPS receivers. As the data is analyzed, the C/N0 ratio was 1–2 dB lower in playback mode when compared to the data collected from the GPS antenna [22].

Post Processing Technique:

It is a technique which can increase GPS accuracy in the form of Differential GPS (DGPS) that is used to correct the received data set by shifting the data relative to a known location. It processes the data collected from data set and corrects it by calculating from multiple fixed GPS receivers.

It uses Vincenty's formulae for calculating distance between two points. A co-ordinate translation is used to shift all the latitudes and longitudes of receivers within the two fixed clusters to fix to a single point. Later a filtering technique called moving average filer (MA) is used to smooth the averaged coordinates. The combination of these two techniques gives the post processing algorithm.

Fig 3.6: Two clusters holding multiple GPS receivers

Proposed Post Processing Algorithm:

A post processing algorithm increases the precision of distance measurement between two clusters and the location co-ordinates can be used in assisting other GPS receivers. The distance between central points of two clusters is baseline distance. It is an efficient approach to increase baseline distance accuracy while lowering receiver noise at the same time. To increase the accuracy of calculated baseline to a desired level, the MA filter is selected to reduce the random variations of a data set. The MA filter works efficiently on time domain data and executes latitudes and longitudes and executes quickly. It works similar to low pass filter that removes high frequency noise and smoothens short term fluctuations [29].

CIRCUIT DESIGNS
(FOR ELIMINATION OF INTERFERENCE)

Cross Interferences-

It is a phenomenon occurred when a signal is transmitted on circuit or channel creates an unwanted effect in another circuit or channel.

For example, if we consider a combinations of cellular phone and Standard Positioning system (SPS) receiver, the transmissions from the cellular phone generate strong interference which reduces the performance of the SPS receiver.

Some of the current approaches that have been made on overcoming the cross-interference involve the use of complex filters or high dynamic range circuits on top of the SPS receiver to limit the interference-band to acceptable area. These approaches require usage of complex circuitry which directly increases the cost and power consumption of the system. One approachable method of reducing the cross-

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interference in the combination cellular/SPS receiver is to use several bandpass filters in the front end of RF section of the GPS transmitter to eliminate the RF interference from the cellular transmitter [26].

To reduce low level signal contamination from the nearby digital circuitry and to acquire the highest quality GPS signals at the front end, the receiver uses a front end Application Specific Integrated Circuit (ASIC) to convert the GPS signals to a suitable IF, followed by an Field Programmable Gate Array (FPGA) to perform the base-band processing functions.

The RF front end ASIC contains

1) An RF amplifier
2) Mixing of L1 signal (1575.42MHz) to an IF which Filters and eliminates out-of-band signals.
3) A base band processor which samples the Obtained IF and gives a high quality signal.

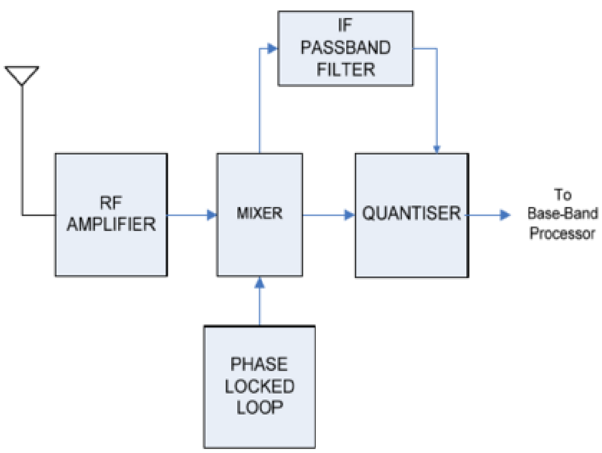

Fig 3.7: Front end Architecture of GPS

PRECAUTIONS
(TO REDUCE ENVIRONMENTAL INTERFERENCE)

Some of the ways where you can reduce the impact of environmental interference are staying away from

Big magnets:

It creates huge magnetic field around it which interfere with radio waves.

Tinted windows:

It is coated with metals which obstruct some power of the signal.

OTHER TYPES OF RECEIVERS NEAR YOU:

The systems or devices near your location that are acting as receivers may absorb the signal if the hardware of it is designed to receive the range of frequency used by your device.

If GPS antenna is placed in the signal path of radar (inline vertical), it will get forged and damages the antenna if exists for more time.

AM signals were found to be more damaging than FM signals. An AM signal of 20 dB more than the GPS signal will prevent successful acquisition.

Suppose the operating frequencies of GPS and radar have a good isolation distance (1.5GHz and 2.5GHz) and they are continuously operating. When the material heats up, it absorbs radiation of its frequency so it will probably absorb it at GPS frequencies too.

Shielding:

By placing metal shield around the GPS RF front end components, some of the tracks and inductors in the RF circuit act as effective antennas which are capable of picking up undesired signals at similar frequencies and creates a barrier for radiated noise. Thus, shielding reduces both FPGA and outside interference [27].

IV. RESULTS

- The recent structure of navigation system has been introduced in this paper
- The types of interferences that affect the performance of received signal of the GPS system are best classified as system noise, man-made and environmental interferences
- The most of the filtering methods for the GPS signal are analyzed and the best solution is presented in the paper (Kalman Filter)
- Kalman Filter – working principle, usage, algorithm, steps involved
- USRP- A signal simulation process to prevent the degradation of the GPS signal

- Post Processing Technique (algorithm approach , moving average filter, accuracy determination, average estimates of latitude and longitude)
- Elimination of cross interference (circuit design, RF section, usage of bandpass filters, FPGA)

V. Discussion

- From the research and observation, Software based GPS receivers allow flexibility in dealing with noise excision when compared to hardware GPS receivers.
- Kalman Filter is the best fit for usage in the GPS receivers and other systems that has most degree of uncertainty from time to time.
- USRP is an ideal low cost signal simulation tool than can be used in cases where there is more attenuation for GPS signal (L1).
- The post processing technique can be used when there is necessity of accuracy in the presence of some amount of noise.
- If there is need for hardware modification, an ASIC with RF amplifier can be used which can be affordable by many people.

VI. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

- In filtering techniques that can be used to eliminate interference caused to the GPS received signal, we find kalman filter is most efficient and capable of handling uncertainties in estimation of location co-ordinates of the user
- Usage of certain band pass filters in the front end RF section of GPS transmitters eliminates cross interferences
- In future, we want to work on Implementation of kalman filter to gain the maximum accuracy of GPS systems that are fit to use in mostly dense urban cities.

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