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Global Navigation Satellite System: A Survey

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ABSTRACT: Global navigation satellite systems (GNSS), involving satellites, ground reference station infrastructure and user equipment to determine positions anywhere on earth, have revolutionized the mapping, surveying and tracking industry. These systems allow small electronic devices to determine their location (longitude, latitude and altitude) in within a few meters using time signals transmitted along a line of sight from orbiting satellites. The past decade has seen tremendous growth in the use of these systems across many areas of the society. Among the currently used GNSS, the global positioning system (GPS) from the USA is the only fully operational satellite navigation system. Russia also operates its GNSS called GLONASS, which became fully operational by 2010. Fuelling growth in the coming decade, several next generation GNSS (Galileo, GLONASS, and Enhanced GPS etc.) are currently being developed. In this paper we present a survey on basic design, performance, applications, and what technological improvements will these next generation GNSS incorporate in order to deliver better accuracy, reliability and availability to the spatial information industry.

KEYWORDS: GNSS, GPS, GLONASS, GALILEO, Design system, Antennas.

I. INTRODUCTION

1.1 General:

Global navigation satellite system (GNSS) is a general term describing any satellite constellation that provides positioning, navigation, and timing services on a global or regional basis. Global Navigation Satellite Systems (GNSS) include constellations of Earth-orbiting satellites that broadcast their locations in space and time, of networks of ground control stations, and of receivers that calculate ground positions by trilateration. GNSS are used in all forms of transportation: space stations, aviation, maritime, rail, road and mass transit. Positioning, navigation and timing play a critical role in telecommunications, land surveying, law enforcement, emergency response, precision agriculture, mining, finance, scientific research and so on. They are used to control computer networks, air traffic, power grids and more. Thus the specific objectives of the implementation of the GNSS education curriculum are the demonstration and understanding of GNSS signals, codes, biases and practical applications, and the implications of prospective modernization.

1.2 Objectives:

1. To study what is global navigation satellite system.
2. To study technological improvements of GNSS in future years.
3. To make a detail report including all above factor for people who doesn’t have any idea about GNSS.

II. METHODOLOGY

Global Navigation Satellite System (GNSS) receivers, using the GPS, GLONASS, Galileo or BeiDou system, are used in many applications. The first systems were developed in the 20th century, mainly to help military personnel find their way, but location awareness soon found many civilian applications.

In this paper, a review of binary spreading sequence generation methods for use in satellite navigation systems is presented. Sequence generation methods for the existing GNSS like GPS, GLONASS, GALILEO, BEIDOU, IRNSS and QZSS are considered. Also, recently proposed binary sequences for satellite navigation systems are discussed. It is found that the sequences of different lengths which are multiple of fundamental on-board frequency are commonly used in GNSS.

Surveyors are increasingly leaving behind their theodolite and using the Global Navigation Satellite System (GNSS) for most of the surveys they undertake. Surveys such as: land development, cadastral surveying, engineering surveying, topographic surveying, construction surveying and set out, urban design and planning, hydrographic surveying, mining surveying, land administration, geodesy.

III. RESULT AND DISCUSSION

3.1. GLOBAL NAVIGATION SATELLITE SYSTEMS:

Satellite navigation systems have become integral part of all applications where mobility plays an important role. These functions will be at the heart of the mobile phone, third-generation (3G) networks such as the UMTS. In transportation systems, the presence of receivers will become as common as seat belts or airbags, with all car manufacturers equipping their entry-level vehicles with these devices. As for the past developments, GPS launched a variety of techniques, products and, consequently, applications and services. The milestone of satellite navigation is the real time positioning and time synchronization. GNSS is one of the best example of it.

GNSS are used in all forms of transportation: space stations, aviation, maritime, rail, road and mass transit. Positioning, navigation and timing play a critical role in telecommunications, land surveying, law enforcement, Emergency response, precision agriculture, mining, finance, scientific research and so on. They are used to Control computer networks, air traffic, power grids and more. For developing countries, GNSS applications offer a cost-effective way of pursuing sustainable economic Growth while protecting the environment.

Global navigation satellite systems (GNSS), involving satellites, ground reference station infrastructure and user equipment to determine positions anywhere on earth. This has revolutionized the mapping, surveying and tracking industry. These systems allow small electronic devices to determine their location (longitude, latitude and altitude) in within a few meters using time signals transmitted along a line of sight from orbiting satellites

There are currently two Global Navigation Satellite Systems in operation: the U.S. Global Positioning System (GPS) and the Russian Global Navigation Satellite System (GLONASS). A third system, Galileo, is currently under development in Europe. All the three systems will be Interoperable. Combined use of Galileo and GPS will provide unprecedented increase in the availability of Positioning.

Fig. 1 GNSS Basics

GNSS Components:-

The GNSS consist of three main satellite technologies: GPS, GLONASS and Galileo. Each of them consists mainly of three segments: (a) space segment, (b) control segment and (c) user segment. These segments are almost similar in the three satellite technologies, which are all together make Up the GNSS.

3.1.1 Global Positioning System (GPS):

The United States Department of Defence has developed the Navistar GPS, which is an all-weather, space based navigation system to meet the needs of the USA military forces and accurately determine their position, velocity, and time in a common reference system, anywhere on or near the Earth on a continuous basis. GPS has made a considerable impact on almost all positioning, navigation, timing and Monitoring applications. It provides particularly coded satellite signals that can be processed in a GPS receiver, allowing the receiver to estimate position, velocity and time.

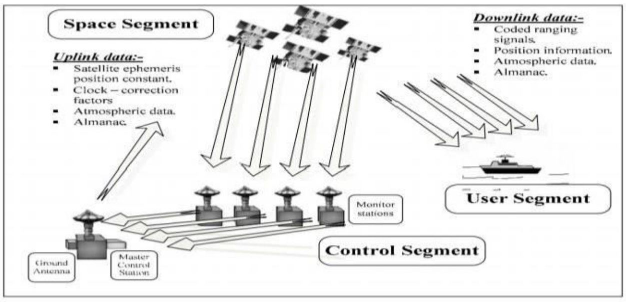

Fig. 2 GPS Segments

3.1.2 GLONASS:

The GLONASS (Global Navigation Satellite System) is nearly identical to GPS. Gleans satellite-based radio-navigation system provides the positioning and timing information to users. It is operated by the Ministry of Defence of the Russian Federation (GLONASS-ICD, 2002). GLONASS space segment is consist of 24 satellites, equally distributed in 3 orbit separated by o 120 in the equatorial plane. Satellite orbital altitude is about 19,130 km above the ground surface. The future of GLONASS seems uncertain due to economic problems facing the Russian Federation. The number of operational satellites was steadily decreasing over the past few years. The launch of three new GLONASS satellites in December 1998 was the first launch after a lapse of 3 years. As of January 2006, a total of 10 GLONASS satellites are operational.

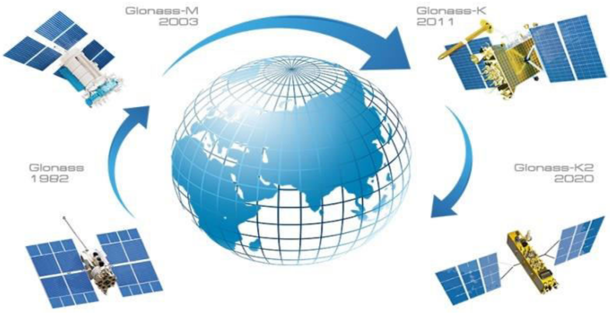

Fig. 3 GLONASS

3.1.3 GALILEO:

GALILEO is Europe’s initiative for a state-of-the-art global navigation satellite system, providing a highly accurate, guaranteed global positioning service under civilian control. Galileo will be not too different from the other GNSS parts (modernized GPS and GLONASS (Salgado et Al., 2001). It will provide autonomous navigation and positioning services, but at the same time will be interoperable with the two other global satellite navigation systems; the GPS and GLONASS. A user will be able to take a position with the same receiver from any of the Satellites in any combination. By providing dual frequencies as standard, however, GALILEO will deliver real-time positioning accuracy down to the meter range. It will guarantee availability of the service under all, but the most extreme circumstances and will inform users within seconds of a failure of any satellite. This will make it appropriate for applications where safety is vital, such as running trains, guiding cars and landing aircraft. The combined use of GALILEO and Other GNSS systems can offer much improved performance for all kinds of users worldwide. GALILEO came in operation by the year 2008. The first satellite of Galileo system (GIOVE A) has been lunched in 27th December 2005.

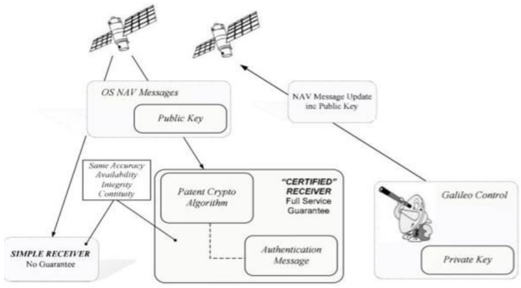

Fig. 4 Galileo System Architecture

3.2 DESIGN AND PERFORMANCE OF GLOBAL NAVIGATION SATELLITE SYSTEM:

3.2.1 Design –

Emetic algorithms are mostly considered to represent the primary class of evolutionary methods that operate by combining solutions to produce better ones. These systems are used to determine the geographical positions of unknown points on and above the earth and its oceans using suitable satellite receiving equipment. When related to satellite technology, a surveying network can be defined as a number of points which are co-ordinated by a series of observation sessions. These sessions are formed by placing receivers on the points of the network. An observation session can be defined as a period of time during which two or more receivers simultaneously record satellite signals. Thus, the schedule of receivers is a sequence of sessions to be observed consecutively. The goal is to select the best order in which these sessions can be organised to give the best possible solution at minimal cost. Several real space-based satellites surveying networks have been used to assess the performance of the proposed technique in terms of the solution quality and computational effort.

In order to process the L-band signals transmitted by the satellites and compute a navigation solution, GNSS receivers can be designed to target different applications, markets, and solutions. From single or multi-frequency, single or multi-constellation, to survey or automotive applications, system design details extend through a broad range of decisions and trade-offs, in order to achieve the target performance.

Besides these blocks, other common receiver components are the power unit (e.g. batteries). These components are designed and dimensioned to match each specific target application (e.g. a receiver designed for road applications may have less stringent power requirements than a receiver designed for outdoor environments). At system design level, the receiver is designed to take full advantage of the characteristics of the targeted GNSS signals: in fact, each architectural block is dimensioned to cope with the targeted signal bandwidth, modulation and code rate, in order to maximize performance.

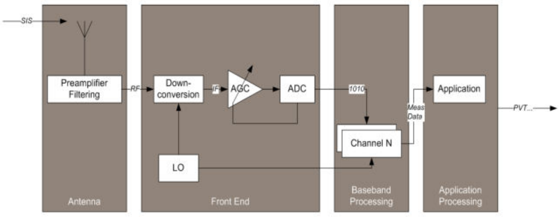

Fig. 5 Design of GNSS

3.2.2 Antennas:

GNSS antennas are Right Hand Circularly Polarized (RHCP) and aim at capturing GNSS signals in the L-band, with the associated amplification and filtering. It is the entry point from the space segment to the user segment, as it receives the L-band signals to pre-process and feed as an analog electrical signal to the front end (still as a 1.2 - 1.6 GHz range RF signal).

When designing a GNSS antenna, the main objective is to maximize the antenna gain towards emitting satellites above a given elevation angle, while rejecting multipath signals (usually at lower elevation angles) and interference. The design of the antenna has to survive with the environmental conditions of the target application, while respecting mobility, power and size limitation. Usually GNSS antennas present hemispherical radiation patterns that can reject multipath coming from low elevation angles.

As far as interference is concerned, antenna arrays can be used to modify the radiation pattern so as to reject signals coming from the direction of the interferer. In addition, beam steering techniques are often employed to "follow" the signal from a given satellite with maximum gain. Another important parameter is phase stability and repeatability in applications that use carrier phase measurements to provide a navigation solution

3.2.3 Baseband Processor:

The baseband processing block is responsible for the signal processing tasks, such as addition and tracking of each signal. The input of this block is typically a down-converted digital signal.

Receivers guarantee several channels that process each signal (e.g. a given frequency from a given satellite), which are usually independent from each other. The main objective is to track code delay and carrier phase measurements in order to produce observables like code pseudo range, carrier phase measurements, and Doppler frequency. For that purpose, each channel ensures at least two lock loops: Delay Lock Loop (DLL) and Phase Lock Loop (PLL), to track code and phase delays respectively.

Depending on the target application, the baseband processing block will also accommodate any dedicated algorithms, e.g. for multipath mitigation. The design of the tracking loops is far from bearing a single solution, and receivers may use several lock loops and use their information at will: for example, some receivers will aid the DLL with the PLL outputs. In addition, some receivers can be "smart enough" to dynamically change the configuration parameters of the loops, e.g. increase the PLL bandwidth when in high receiver dynamics conditions in order to avoid lock losses.

3.2.4 Performance:

In an era of significant air traffic expansion characterized by a rising congestion of the radiofrequency spectrum and a widespread introduction of Unmanned Aircraft Systems (UAS), Global Navigation Satellite Systems (GNSS) are being exposed to a variety of threats including signal interferences, adverse propagation effects and challenging platform-satellite relative dynamics. Thus, there is a need to characterize GNSS signal degradations and assess the effects of interfering sources on the performance of avionics GNSS receivers and augmentation systems used for an increasing number of mission-essential and safety-critical aviation tasks (e.g., experimental flight testing, flight inspection/certification of ground-based radio navigation aids, wide area navigation and precision approach).

GNSS signal deteriorations typically occur due to antenna obscuration caused by natural and man-made obstructions present in the environment (e.g., elevated terrain and tall buildings when flying at low altitude) or by the aircraft itself during manoeuvring (e.g., aircraft wings and empennage masking the on-board GNSS antenna), ionosphere scintillation, Doppler shift, multipath, jamming and spurious satellite transmissions. Anyone of these phenomena can result in partial to total loss of tracking and possible tracking errors, depending on the severity of the effect and the receiver characteristics. After designing GNSS performance threats, the various augmentation strategies adopted in the Communication, Navigation, Surveillance/Air Traffic Management and Avionics (CNS + A) context are addressed in detail. GNSS augmentation can take many forms but all strategies share the same fundamental principle of providing supplementary information whose objective is improving the performance and/or trustworthiness of the system. Hence it is of paramount importance to consider the synergies offered by different augmentation strategies including Space Based Augmentation System (SBAS), Ground Based Augmentation System (GBAS), Aircraft Based Augmentation System (ABAS) and Receiver Autonomous Integrity Monitoring (RAIM). Furthermore, by employing multi-GNSS constellations and multi-sensor data fusion techniques, improvements in availability and continuity can be obtained. SBAS is designed to improve GNSS system integrity and accuracy for aircraft navigation and landing, while an alternative approach to GNSS augmentation is to transmit integrity and differential correction messages from ground-based augmentation systems (GBAS). In addition to existing space and ground based augmentation systems, GNSS augmentation may take the form of additional information being provided by other on-board avionics systems, such as in ABAS. As these on-board systems normally operate via separate principles than GNSS, they are not subject to the same sources of error or interference. Using suitable data link and data processing technologies on the ground, a certified ABAS capability could be a core element of a future GNSS Space-Ground-Aircraft Augmentation Network (SGAAN). Although current augmentation systems can provide significant improvement of GNSS navigation performance, a properly designed and flight-certified SGAAN could play a key role in trusted autonomous system and cyber-physical system applications such as UAS Sense-and-Avoid (SAA).

3.3 REFERENCE SYSTEM

3.3.1 Coordinate System:

The definition of reference coordinate system is crucial for the description of Satellite motion, the modelling of observable and the interpretation of results. Reference coordinate system in satellite geodesy is global and geocentric by Nature since satellite motion refers to the centre of mass of the earth.

In satellite geodesy, two reference systems are required: (a) space-fixed, inertial Reference system for the description of satellite motion, and (b) earth-fixed, terrestrial reference system for the positions of the observation stations and for the description of results from satellite geodesy.

The positioning with using GNSS depends mainly on knowing the satellite Coordinates. The position of the receiver is calculated with respect to the instant Position of the satellite. By considering the range vector relation between satellite and receiver, the coordinate of the satellite and receiver should be expressed in the same coordinate system.

In satellite geodesy, the two systems are used and the transformation parameters Between the space fixed and earth fixed are well known and used directly in the LGNSS receiver and post processing software to compute the position of the Receivers in the earth fixed system.

Terrestrial reference system is defined by convention with three axes, where Z-axis coincides with the earth rotation axis as defined by the Conventional International Origin (CIO). The X-axes is associated with the mean Greenwich Meridian, and the Y-axis is orthogonal to both Z and X axes and it completes the Right-handed coordinate system, one example of the terrestrial reference System is the WGS84. GPS has used the WGS84 as a reference system, and with WGS84 associated a geocentric equipotential ellipsoid of Revolution. The basic idea, in geodesy, behind using the reference ellipsoids is that they fit the real shape of the earth.

Another example of terrestrial reference frame is the International Terrestrial Reference Frame (ITRF), which is established by Central Bureau of the International Earth Rotation Service (IERS). The ITRF is regularly updated and is more accurate than WGS84, but the difference Between WGS84 and ITRF is now in the order of a few centimetres. This difference is mainly Due to the difference between the reference stations used by each system when it is realized. Both systems are geocentric and the transformation parameters between them are regularly published by IERS.

The representation of position in geocentric Cartesian coordinates (X, Y and Z) has less Significance in navigation. Hence, the ellipsoidal representation (longitude, latitude and height above the ellipsoid) are more commonly used for coordinate representation.

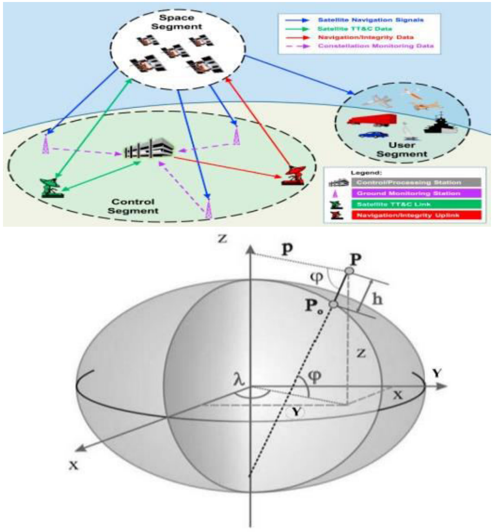

Fig. 6 ECEF Co-ordinate System & Ellipsoidal Co-ordinate

3.3.2 Time Reference Frame:

There are many time reference systems used and they are based on various periodic processes Such as the earth rotation. The major types of these systems are shown in Table 1. The conversion between time systems is accomplished by well-known formulas. In GNSS (e.g. GPS), instead of the dynamic time system itself, the atomic time system serves as reference.

GLONASS satellite clock is moved according to UTC (SU). The Galileo System Time (GST) will be a continuous coordinate time scale directed towards the International Atomic Time (ITA) with an offset of less than 33 nanoseconds. The GST limits, expressed as a time offset relative to ITA. The Difference between GST and ITA and between GST and UTC shall be broadcast to the users using the signal-in-space of each Galileo service. The Galileo ground segment will monitor the offset of the GST with respect to the GPS system time and eventually broadcast the offset to Users.

3.4 ANTENNAS FOR GNSS

The upcoming availability of so many satellites, and over such a wide frequency range, in GNSS constellations, as well as the move toward more unified code-division multiple-access (CDMA) approach, in the near future will offer superior performance and lower life-cycle cost, as well as new features and capabilities in GNSS. These game-changing events are also enabled by newly available low-cost software-defined radio (SDR) technologies and the unprecedented global economy. To meet the anticipated market needs, GNSS receivers covering two or more GNSS systems have been developed and deployed at fairly low costs. While GNSS antennas will be pivotal in enabling superior performance, lower life-cycle cost, and new features and capabilities of new SDR receivers**.**

3.4.1 Radio frequency Performance of GNSS antennas:

The impact of the fundamental changes from GPS to GNSS has been recognized and taken advantage of by receiver manufacturers. Several GNSS receivers have recently showed up in the marketplace; and they can easily adapt to large future changes in GNSS waveforms since they are based on SDR technology. These GNSS receivers readily benefit from the fairly mature and low-cost SDR technology, which has been under continuous multibillion dollar development programs funded by the U.S. Government since 1980 as the SPEAKEASY programs, which were transitioned around 2000 to the Joint Tactical Radio System (JTRS) programs. In the commercial world, SDR Development and application have been growing rapidly since about 2000.

Since the receivers will be increasingly more able to cover the entire GNSS spectrum, and take advantage of it, it is desirable and sometimes necessary that their antennas' operating frequencies and bandwidths be consistent with those of the SDR receivers. Additionally, large bandwidths are needed to reduce detuning due to changes in antenna's installation environment. In practical applications, there is also a growing trend for GNSS antennas toward multifunction that covers not only GNSS but also some satellite communications such as satellite radio, Iridium, etc.

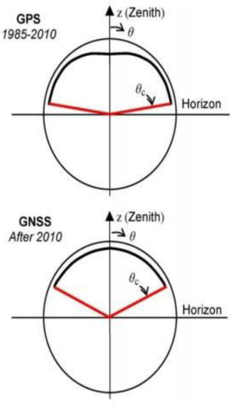

Fig. 7 Ideal Antennas Gain Pattern for GPS Antennas & GNSS Antennas

3.4.2 Classification of GNSS Antennas and there characteristics from user's perspective based on installation platform:

It is demonstrated that a GNSS antenna's platform (in a broad sense including its environment) drives and constrains its design. The broader the bandwidth, the greater the difficulty is; and the smaller the platform, the greater the difficulty becomes. Thus, most of the design criteria and challenges are rooted in the platform. Accordingly, it is reasonable to classify GNSS antennas first by their intended platforms. A review of the numerous products in GPS World in the Annual survey of GNSS antenna manufacturers confirms the need for a more readable classification. It proposes a simple top-level classification, dividing GNSS Antennas into four types based on their intended platform: Large, medium, small, and handheld platforms. Conventional application-based classifications are used as second-tier Sub classifications (similar to how auto tires are classified).

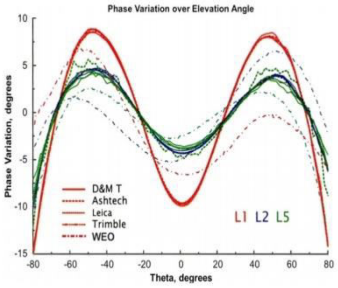

Fig. 8 Comparison of Measured Phase Variation of 5 high Performance GNSS Antennas

3.4.3 High Performance GNSS Antennas:

High-performance GNSS antennas will clearly be the first to respond to changes in the marketplace. Their growth Path will reflect the state of the art and cost structure of relevant GNSS antenna technologies, monitored by government agencies, with data available on their websites. The use of choke rings and other software and hardware techniques in geodetic GNSS antennas tends to mask the inherent merits and shortcomings of the basic antennas. Simpler overview from a pure Antenna is shown. Two key performance issues in long-term evolution of GNSS antennas, as discussed, are their potential to adapt to Ag requirements of broadened bandwidth and elevated.

3.5 APPLICATIONS

Due to advance design, performance & antennas function of GNSS, it has vast scope in various fields. GNSS can be used effectively in various fields as mentioned below:

- GNSS technology has been adopted by the consumer market, in an ever-increasing range of products. GNSS receivers are now routinely integrated into smartphones, to support applications that display maps showing the location of and best route to stores and restaurants.
- Automobiles can be equipped with GNSS receiver at the factory or aftermarket equipment. It helps to display moving maps & information about location, speed, direction, etc.
- Boats and ships can use GNSS to navigate all of the world's lakes, seas & oceans.
- Using GNSS, shipping hubs can improve their operating efficiency by tracking movement and placement of containers about their yards.

- In the Canadian city of Calgary, paying for on street parking has become automated. Customers pay for parking at street side terminals or using their smartphone and monitoring of the parked vehicles is done from a vehicle equipped with cameras and GNSS receiver.
- GNSS technology is being integrated into equipment such as bulldozers, excavators, graders, pavers and farm machinery to enhance productivity in the real time operation of this equipment, and to provide situational awareness information to the equipment operator. The adoption of GNSS-based machine control is similar in its impact to the earlier adoption of hydraulics technology in machinery, which has had a profound effect on productivity and reliability.
- GNSS system can be also used in field of geophysics, geology & archeology.
- GNSS information can be used in agriculture to position the cutting edge of a blade (on a bulldozer or grader, for example) or a bucket (excavator), and to compare this position against a 3D digital design to compute cut/fill amounts. “Indicate systems” provide the operator with visual cut/fill information, via a display or light bar, and the operator manually moves the machine’s blade or bucket to get to grade.
- GNSS functionality can be used by emergency services to locate cell phones, as it has ability to locate phone required in the US by E911 emergency services legislature.
- GNSS information is being used to efficiently manage the mining of an ore body and the movement of waste material.
- GNSS-based surveying reduces the amount of equipment and labor required to determine the position of points on the surface of the Earth, when compared with previous surveying techniques. Using GNSS, it is possible for a single surveyor to accomplish in one day what might have taken a survey crew of three people a week to complete.
- Measurement of atmospheric bending of GNSS satellite signals by specialized GNSS receivers in orbital satellites can be used to determine atmospheric conditions such as air density, temperature, moisture and electron density. Such information from a set of six micro-satellites, launched in April 2006, called the Constellation of Observing System for Meteorology, Ionosphere and Climate has been proven to improve the accuracy of weather prediction models.
- Some market research companies have combined GIS systems and survey based research to help companies to decide where to open new branches, and to target their advertising according to the usage patterns of roads and the socio-demographic attributes of residential zones.
- Satellite communications systems use a directional antenna pointed at a satellite. The antenna on a moving ship or train, for example, must be pointed based on its current location. Modern antenna controllers usually incorporate a GNSS receiver to provide this information.

IV. CONCLUSION

So hereby we can conclude that study of Global Navigation Satellite involving satellites, ground reference station infrastructure and user equipment to determine positions anywhere on earth, have revolutionized the mapping, surveying and tracking industry. This technology has become vital to many applications that range from city planning engineering and zoning to military applications. It has been widely accepted globally by governments and organizations. The impressive progress in wireless communications and networks has played great role in increasing interest in GNSS and providing enabling methodologies and mechanisms.

Thus, this can give you clear idea & basic knowledge regarding design, performance, antennas & application of GNSS in various fields. Also adapting this technology with combination of different techniques can help to develop the developing countries in many fields.

V. FUTURE SCOPE

1. This paper can help to give basic knowledge of GNSS & plan how we can develop this system in maximum countries
2. Study how we can improve the design of GNSS system and antennas for its advance performance.
3. Make use of GNSS in maximum sectors for their smooth working.
4. Study of reference system & antennas in detail allows understanding how GNSS work, its function & what changes to be maid so that GNSS can become one of the most developed effective technique.

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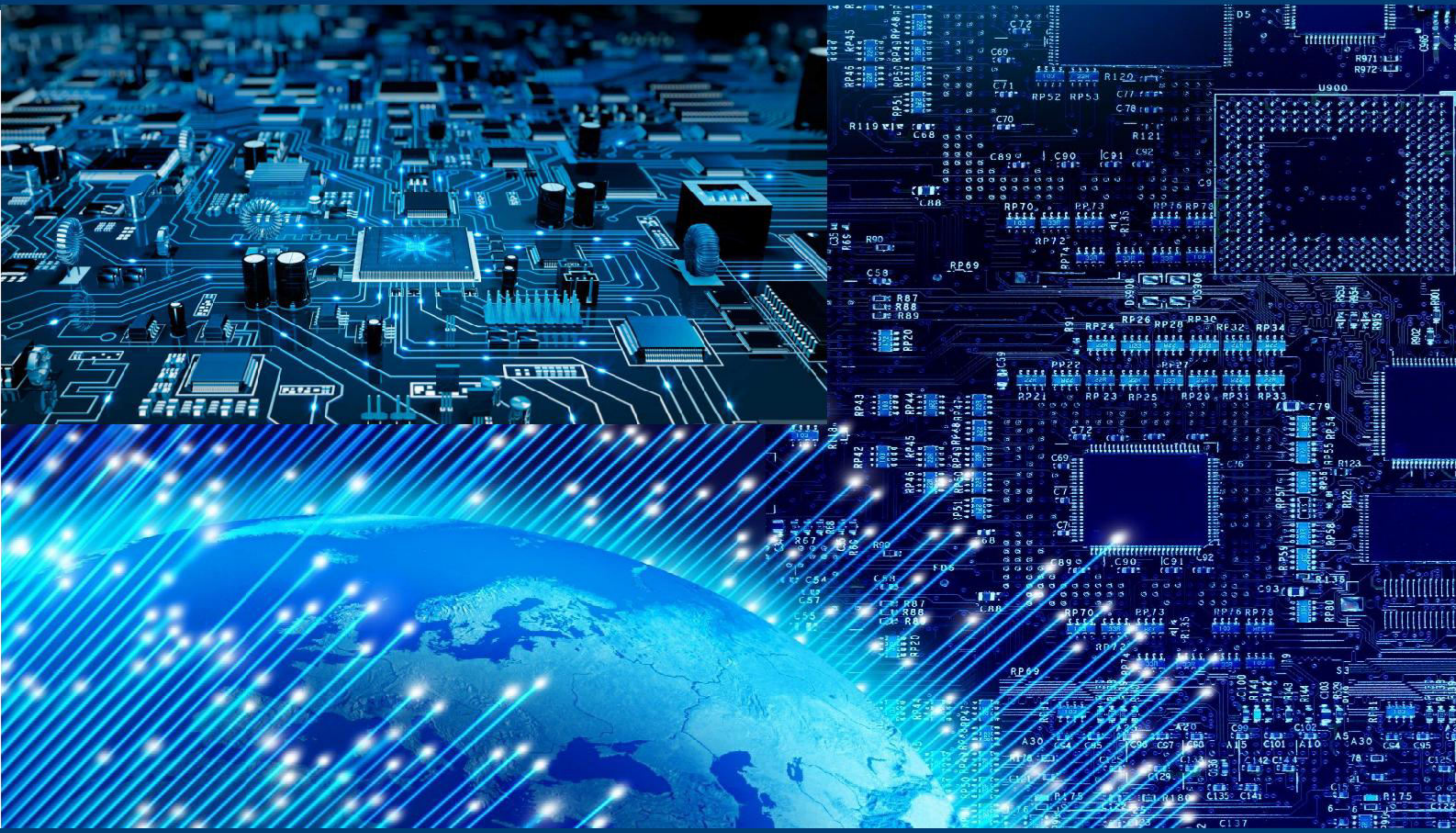

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