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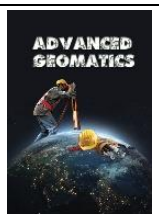

The Current State of Use of Satellite-Based Positioning Systems in Turkey

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ABSTRACT

Nowadays, the cartography sector has also been affected by the rapid developments in the field of technology. Recently, satellite-based positioning systems have been used instead of the classic land measurements made with total station and engineer's level. In this study, the general structure of satellite-based global and regional positioning systems is examined. The general usage densities of the system in the public and private sectors in Turkey and the status of the signals that can be received and the average sales prices of devices on the market have been investigated. The results were presented in the form of tables and graphs, and it was found that the most ideal device for our country is the device called Kolida K58 Pus, which can work with systems such as GPS/GLONASS/SBAS/GALILEO/QZSS/BEIDOU and receive signals from many satellites of these systems.

1. INTRODUCTION

Mankind has always wanted to improve itself in the field of communication from the very beginning of its existence. It has used a different communication method in each cycle by producing new communication systems. After a while, satellites were sent to space and satellite-based communications began. Today, satellites are widely used both for communication and for providing location data. In this study, the number of satellites seen by devices using the data of satellite-based positioning systems and the variety of signals it can receive from these satellites are presented as tables and graphs. Then, with the help of the relevant tables and graphs, recommendations were made about which brand and model could be the most suitable GNSS buyer for our country (Yılmaz et al., 2016; Mutlu & Kahveci, 2019).

Today, there are 6 satellite-based positioning systems operating at full capacity or under construction. GPS is the first satellite-based positioning system. The GPS program was initiated by the US Department of Defense in the 1970s. GLONASS is the second system to reach full capacity, operated by Russia. GLONASS's constellation consists of 24 satellites and provides global coverage. Of the 25 GLONASS satellites currently in orbit, 1 is in the testing phase, while the other 24 are operational. Galileo is a civilian system operated by the European Global Agency for Navigation Systems (GSA). The satellite set, whose first satellite was launched in 2014, is planned to be completed in 2020. The satellite set consists of 7 satellites. QZSS is a regional positioning system serving Japan and the Asia-Oceania region (Kaya et al., 2019; Konak et al., 2020). The satellite set, which currently consists of 4 satellites, will be completed to 7 after 2023 and will be able to serve as an independent system [URL-1].

In this study, first of all, the structure of satellite-based positioning systems will be introduced. Afterwards, the structure, capacity and number of satellites that can receive the signals of these GNSS systems will be presented graphically (Altuntaş & Tunalıoğlu, 2022). As a result, the most ideal satellite system for Turkey will be determined.

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2. SATELLITE BASED POSITIONING SYSTEMS STRUCTURE and COMPONENTS

2.1. GPS

The GPS system was originally designed for military requirements. Its design was partially developed in the early 1940s, after World War II. It is based on similar ground-based radio-navigation systems such as LORAN (LORAN - Long Range Navigation) and Decca Navigator, which was a solution for that period used during World War II and then used for a long time. The first use of GPS dates back to just after the Second World War. The system was designed to be used in navigation with signal receivers, in military plans and position calculations, and in the control of guided rockets. The GPS system was opened for civilian use only in the 1980s [URL-2].

2.1.1 Space Division

The space segment consists of at least 24 satellites (18 active and 6 standbys) and is the center of the system. The satellites orbit 20,000 km above the earth's surface, called "High Orbit". Satellites at such heights have a very wide field of view and are placed in such a way that a GPS receiver on Earth can always see at least 3 satellites for two-dimensional determination and at least 4 for three-dimensional determination. They run on solar energy and are designed to be used for at least 10 years. It also has backup batteries in case of solar power outages and small igniter rockets for orbit corrections [URL-2].

2.1.2 Control Section

In satellites, timing is provided by 4 atomic clocks (2 rubidium and 2 cesium). These clocks measure the oscillation of cesium and rubidium atoms, and therefore time. Small deviations in satellite orbits may occur. To calculate these deviations, the control section satellites continuously monitor the orbital information. This obtained error transmits the data to the main control center and correction messages must be uploaded to the satellites at regular intervals [URL-1].

2.2 GLONASS

GLONASS, which stands for "GLObal'naya NAvigatsionnaya Sputnikovaya Sistema (Global Navigation Satellite System)", is a space-based satellite navigation system that provides both civil and military service operated by the Russian Aerospace Defense Forces. It is planned to consist of 24 operational satellites rotating in 3 different orbital planes at an altitude of 19100 km. The system as an alternative to GPS; It is the second satellite-based navigation system with global coverage and comparable sensitivity. The development of GLONASS is somewhat delayed, but parallels GPS. The system, which started to provide military service with 12 satellites since 1993, reached full operational capability in 1995 with the completion of the main satellite set consisting of 24 satellites [URL-3].

2.2.1 GLONASS Space Division

GLONASS is a satellite-based positioning system with global coverage, whose main constellation consists of 24 medium orbiting satellites. The satellites in the GLONASS constellation are placed in 3 orbital planes close to the earth-centered circular orbit. 24 satellites are deployed in 3 orbital planes with 8 satellites in each. The orbital tilt angle of the orbital planes is 64.8 degrees. Each satellite completes one orbit in 11 hours 15 minutes 44 seconds. The track of the orbits is repeated every 17 revolutions (8 days). The chosen orbital period ensured that the satellites did not need orbit correction during their active life; Unlike GPS, it allowed the creation of a sustainable orbital system [URL-3].

2.2.2 GLONASS Control Section

The GLONASS control segment consists of a system control center, two central clock facilities and a network of command and tracking stations distributed over Russia. In the network of command and tracking stations; telemetry, tracking and command stations (TT&C), upstream data stations, unidirectional tracking stations and laser distance measuring stations (SLR). Updates are uploaded to the satellites twice a day. The system control center responsible for the planning and coordination of all ground segment components is located in Kraznosnamensk, near Moscow. The central clock consists of the main plant in Shelkovo and the supplementary plant in Komsomolsk. In each of these facilities, 4 hydrogen masers are used for the continuity of the GLONASS system time [URL-3].

2.3 GALILEO

2.3.1 GALILEO Space Division

Galileo's satellite suite, which is a positioning system with global coverage, consists of a total of 30 medium-orbiting (MEO) satellites, 24 of which are main and 6 are backup. The Galileo constellation was initially planned to consist of 27 active satellites and 3 standby satellites to meet the Safety of Life (SoL) service requirements. In 2012, these services were rearranged and it was decided to use 24 active and 6 backup satellites in the system. Satellite sequences in orbits have been changed accordingly [URL-4].

2.3.2 Galileo Control Section

Galileo control segment; It consists of 2 ground control centers and 3 different station networks with global spread. It is divided into two separate sub-segments in the Galileo control segment. The control of the satellite team is performed by the Ground Control Segment (GCS), while the service-related tasks are performed by the Ground Mission Segment (GMS). The Galileo ground segment, which is under construction, is being built in partnership with Thales-Alenia Space (France, Italy) and Airbus Defense and Space (England, France). Ground Control Segment (GCS); performs all operations related to the command and control of the satellite team. Ground Control Segment (GCS); It consists of a Ground Control Center (GCC) and Telemetry, Monitoring and Command Facilities/Stations (TTCF/TT&C) [URL-4].

2.4 BEIDOU

BeiDou means "Big Bear Constellation" in Chinese. The Ursa Major is considered to be the most important constellation that enables people to navigate in the northern hemisphere. When China decided to establish its own satellite-based navigation system, this name was chosen naturally, but the English name of the system was COMPASS for many years. Deciding to develop its own independent satellite-based positioning system in the 1980s, China planned the construction of the system in three stages. Thus, China became the third country to establish an independent satellite-based navigation system after the USA and Russia. In the second phase, called BeiDou-2, it is aimed to establish a regional satellite-based positioning system. The system, which will consist of a total of 35 satellites with 27 mid-orbit, 3 inclined geosynchronous orbits and 5 geostationary orbits, is expected to be completed approximately in 2020 [URL-5].

2.4.1 BeiDou Space Division

The BeiDou Navigation Satellite System is being developed in three phases. Three experimental positioning satellites were launched in BeiDou Phase I, which aims to demonstrate technology. Within the scope of BeiDou Phase II, a regional satellite-based positioning system was established. When these satellites reached the end of their design life, they were replaced with second generation satellites. The signals emitted by the BeiDou satellite team were named with the first letter of the system "B". BeiDou-2 regional satellite-based positioning system; It transmits navigation signals to the earth in the B1, B2 and B3 bands [5].

2.4.2 BeiDou Control Department

The components of the BeiDou ground segment, called the Operational Control Segment (OCS), are scattered over mainland China. BeiDou control segment; It consists of 1 main control station, 29 monitoring stations and 2 upstream data transmission stations. There are two types of tracking stations in the system. Type A tracking stations are used to monitor orbital and ionospheric delays. There are 7 of these stations. The remaining 22 monitoring stations are of type B. These stations are; They provide support and integration services. Data sending stations are used for time synchronization and data upload (URL-5).

2.5 QZSS

Japan, which uses GPS extensively, continues its efforts to establish a regional positioning system called the Quasi-Zenith Satellite System (QZSS) in order to solve the problems encountered during the use of GNSS in dense urban areas and to create its own satellite-based positioning capability. The main purpose of Japan to start the QZSS project is to reduce the errors caused by signal shadowing and reflection, especially during the use of GPS in cities. The Quasi-Zenith orbital set, which gives the system its name, ensures that there is always at least one satellite with an elevation angle of 60 degrees and above over Japan. The main purpose of this is to reduce the error rate due to reflection and atmospheric effects, and to increase positioning accuracy and consistency. QZSS satellites can also act as additional GPS satellites; It can work integrated with GPS. The system, the first satellite of which was launched in 2010, is expected to reach full operational capability in 2018 [URL-6].

2.5.1 QZSS Space Division

QZSS consists of 3 Quasi-Zenith orbiting (QZO) satellites and one Geostationary orbit (GEO) satellite. The geostationary satellite follows a circular orbit at an altitude of about 36000 km above the equator. The orbital period of the satellite, which has a constant speed of about 3 km / s, is about 24 hours and rotates simultaneously with the earth The orbital speed of the satellites is around 3 km/s. The orbital periods, which are about 24 hours, are synchronized with the rotation of the earth, as in the Earth-Stationary orbit. As a result, their projections on the earth during their movements draw an "8" shape. When viewed from the ground, it is seen that they follow an orbital path in the form of "8". The Quasi-Zenith orbit is set for the satellites to stay over Japan for an extended period of time [URL-6].

2.5.2 QZSS Control Section

The ground segment of QZSS consists of 2 main control stations, 7 satellite control stations and over 30 monitoring stations around the Earth. QZSS has two main ground stations. These stations, which act as control centers, are located in two different campuses. The main station from which the operation is conducted is located in Hitachi-Ota. There are 25 Precision Orbiting stations for GPS and QZSS satellites around the world. Three of these stations are in Japan. In addition, there are 10 Sub-Meter Level Support Service (SLAS) stations in Japan. For QZSS's Centimeter Level Support Service (CLAS), Japan's Continuous Employee Service with more than 1,300 stations. Reference Stations (CORS) network GEONET (GNSS Ground Observation Network System) is used [URL-6].

2.6 IRNSS

2.6.1 IRNSS Space Division

The NavIC constellation consists of 7 satellites. 3 of the satellites are in geostationary orbit and 4 of them are in inclined geosynchronous orbit. While designing the said satellite set; Attention has been paid to minimizing the loss of sensitivity (DOP value), maximizing the number of satellites that can be seen over the targeted area, using the least possible number of satellites, ensuring system sustainability in case one of the satellites fails, and orbital positions to be used are suitable. All of the satellites in the NavIC constellation are constantly visible from the Indian region [URL-7].

2.6.2 IRNSS Control Section

The ground segment is responsible for operating and maintaining the IRNSS constellation. In this context; 15 IRNSS Distance and Integrity Monitoring Stations (IRMS), 4 IRNSS CDMA Distance Measurement Stations (IRCDR), 2 IRNSS Spacecraft Control Facility (IRSCF), 1 IRNSS Network Timing Facility (IRNWT), 1 IRNSS Navigation Center (INC) was established [URL-7].

3. STRUCTURE AND COMPONENTS OF SATELLITE-BASED POSITIONING SYSTEMS

The GPS system, first developed in the early 1940s for military requirements, was developed during World War II. It is based on similar ground-based radio-navigation systems used during World War II, such as LORAN (LORAN - Long Range Navigation) and the Decca Navigator, which later became a solution for that period. The first use of GPS was intended for use in military plans and for the control of guided rockets. The GPS system was opened for civilian use only in the 1980s [URL-1, 2].

GLONASS operated by the Russian Aerospace Defense Forces, both civilian and military-service space-based satellite navigation system. Although the development of GLONASS is somewhat delayed, it has parallels with GPS [URL-3]. GALILEO's satellite team, a positioning system with global coverage, consists of a total of 30 mid-orbit (MEO) satellites, including 24 main and 6 backup ones. The GALILEO satellite team was originally planned to consist of 27 active and 3 reserve satellites in order to meet the Life Safety (SOL) service requirements [URL-4].

BeiDou means “Big Bear Team Star” in Chinese. The Big Bear is considered to be the most important star team that allows people to find direction in the northern hemisphere. Although this name was naturally chosen when China decided to create its own satellite-based navigation system, the COMPASS name was used as the English name of the system for many years [URL-5].

GPS-intensive, Japan, in dense urban areas and resolve their own problems encountered during the use of GNSS satellite-based positioning capability to create Quasi-Zenith Satellite System (QZSS) is called to establish a regional positioning system continues to work. QZSS satellites can also act as additional GPS satellites and work in an integrated way with GPS. The system, the first satellite of which was launched in 2010, is expected to reach full operational capability in 2018 [URL-6].

The NavIC satellite suite consists of 7 satellites. 3 of the satellites are in an earth-stationary orbit, and 4 are in an oblique earth-synchronous orbit. When designing the satellite set in question, attention was paid to minimizing the sensitivity loss (DOP value), maximizing the number of satellites visible over the targeted area, and using the fewest possible satellites. All of the satellites in the NavIC satellite suite are constantly visible from the Indian region [URL-7].

4. EXPERIMENTAL METHOD

The current use status of satellite-based position systems in our country, public and private sector users have been contacted by phone, website and mail to determine which of their respective devices have seen how many satellite systems and which signals they have received. The obtained results are given in Table 1.

Table 1. Current status of satellite-based position sites in Turkey

Companies	Devices	Used Satellite Systems	Monitored Signals
KAYA HARİTA MÜHENDİSLİK	e-survey E600	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC /SBAS	L1 ,L1P,L1C,L2P,L2C,L5 / G1,G2,P1,P2 / B1,B2,B3 / E1BC , E5A,E5B /L1,L2C,L5,L1C / L1 ,L5 /WAAS,EGNOS,MSAS,GAGAN
PAKSOY TEKNİK MÜHENDİSLİK	Topcon Hıper HR	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC /SBAS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6 / L5 /WAAS,EGNOS,MSAS,GAGAN
SİSTEM A.Ş.	Leica Viva GS16	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC /SBAS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6 / L5 /WAAS,EGNOS,MSAS,GAGAN
SİSTEM A.Ş.	Leica GS18 T	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC /SBAS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6 / L5 /WAAS,EGNOS,MSAS,GAGAN
BAYTEKİN MÜHENDİSLİK	Sanding Aquila T66 PRO	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC /SBAS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6 / L5 /WAAS,EGNOS,MSAS,GAGAN
GEOMATİK HİZMETLER	Geomax Zenith 40	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC /SBAS	L1,L2,L2C,L5 /L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,altboc,E6/L1,L2C,L5,L6/L5/EGNOS,WAAS,MSAS,GAGAN
SİSTEM A.Ş.	Leica GS07	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC /SBAS	L1,L2,L2C,L5/L1,L2,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2,L5,LEX / L5 /WAAS,EGNOS,MSAS,GAGAN
GEOMATİCS GROUP	Spectra Geospatial SP85	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC /SBAS	L1 C/A ,L1P,L2C,L2P,L5 / L1 C/A,L1P,L2 C/A,L2P,L3 /B1,B2 /E1,E5a,E5b/ L1 C/A,L1C,L2C,L5 / L5 / L1 C/A,L5
GEOTEKNİK MÜHENDİSLİK	Kolida K58 Pus	GPS /GLONASS /SBAS /GALİLEO /QZSS /BEİDOU	L1C/A, L1C, L2C, L2E, L2P, L5 /L1C/A, L1P, L2C/A, L2P, L3 / L1 C/A, L5 /GIOVE-A ve GIOVE-B, E1 , E5A, E58, E5AltB0C, E6 /L1C/A. SAIF, L1C, L2C, L5, LEX /B1,B2,B3
KAYA HARİTA MÜHENDİSLİK	e-survey E300 PRO	GPS/GLONASS/BeiDou/Galileo /SBAS/QZSS	L1 C/A ,L1P,L1C,L2P,L2C,L5 /G1,G2,G3 / B1L,B2L,B3L,B1C,B2A,B2B,ACEBOC /E5A, E5B, E5AltBOC, E6 /L1,L5 /L1 C/A,L1C,L2C,L5,LEX
SİSTEM A.Ş.	Leica GS18 I	GPS/GLONASS/BeiDou/Galileo /QZSS/SBAS	L1,L2,L2C,L5/L1,L2,L2C,L3/E1,E5a,E5b,AltBOC,E6/B1I,B1C,B2I,B2a,B3I/L1,L2C,L5,L6/WAAS, EGNOS,MSAS,GAGAN L-bant
GEOTEKNİK MÜHENDİSLİK	Kolida K1 PRO	GPS /GLONASS /QZSS /GALİLEO /SBAS /BEİDOU	L1C/A, L1C, L2C, L2E, L5 / L1C/A, L1P, L2C/A, L2P, L3 /L1 C/A, L5 /GIOVE-A ve GIOVE-B, E1, E5A, E5B, E5AltBOC, E6 /WAAS, MSAS, EGNOS, GAGAN /B1, B2,B3
GEOTEKNİK MÜHENDİSLİK	South Galaxy G6	GPS /GLONASS /QZSS /GALİLEO /SBAS /BEİDOU	L1C/A, L1C, L2C, L2E, L5 / L1C/A, L1P, L2C/A, L2P, L3 /L1 C/A, L5 /GIOVE-A ve GIOVE-B, E1, E5A, E5B, E5AltBOC, E6 /WAAS, MSAS, EGNOS, GAGAN /B1, B2,B3
PAKSOY TEKNİK MÜHENDİSLİK	Topcon MR-2	GPS /GLONASS /BeiDou /Galileo /SBAS /QZSS	L1 C/A , L1C,L1P,L2P,L2C,L5 / L1 C/A ,L1P,L2 C/A,L2P,L3C / E1,E5a,E5b,AltBOC /B1,B2 /WAAS,MSAS,EGNOS/L1 C/A,L1C,L2C,L5C
EKSEN TEKNİK	FOİF A90	GPS / GLONASS/ BEİDOU / GALİLEO /SBAS/QZSS	L1 C/A ,L1P , L1C ,L2P , L2C ,L5 / G1,G2,P1,P2 / B1,B2,B3 / E1BC, E5a,E5b,E5AltBOC ,E6 / L1,L5 / L1 C/A ,L2C, L5,L1C
GEOTEKNİK MÜHENDİSLİK	South Galaxy G1	GPS /GLONASS /SBAS /GALİLEO /QZSS /BEİDOU	L1C/A, L1C, L2C, L2E, L5 /L1C/A, L1P, L2C/A, L2P, L3 / L1 C/A, L5 /GIOVE-A ve GIOVE-B, E1 , E5A, E5B, E6altB0C /L1C/A, L1C, L2C, L5 /B1,B2,B3
SATLAB GEOSOLUTIONS	Satlab SLC	GPS /GLONASS /SBAS / BeiDou /GALİLEO /QZSS	L1 C/A, L1C,L2P,L5 /L1,L2 / WAAS,EGNOS,MSAS,GAGAN/B1,B2/E1,E5a,E5b,AltBOC/L1,L2C,L5,L6

Table 1 (continued).

GEOMATİCS GROUP	Spectra SP60	GPS /GLONASS /BeiDou /GALİLEO /QZSS /SBAS	L1 C/A ,L1P,L2C,L2P,L5 / L1 C/A,L1P,L2 C/A,L2P,L3 /B1,B2 /E1,E5a,E5b/ L1 C/A,L1C,L2C,L5 / L1 C/A,L5
BAYTEKİN MÜHENDİSLİK	Sanding T28	GPS /GLONASS /Galileo / BeiDou /SBAS /QZSS	L1 C/A ,L1C,L2C,L2E,L5 / L1 C/A, L1P , L2 C/A ,L2P,L3 / GİOVE-A , GİOVE-B,E1, E5A ,E5B / L1 C/A ,L5 / WAAS,EGNOS,MSAS,GAGAN/L1,L2C,L5,L6
DOĞA ELEKTRONİK	Stonex S700A	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC	L1,L2,L2C,L5/L1,L2,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2,L5,LEX / L5
DOĞA ELEKTRONİK	Stonex S850a	GPS /GLONASS /BeiDou /Galileo /QZSS /NAVIC	L1,L2,L2C,L5/L1,L2,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2,L5,LEX / L5
IFA GRUP MÜHENDİSLİK	Sokkia GCX3	GPS/GLONASS /BeiDou /Galileo /SBAS /QZSS	L1 C/A , L1C,L2P,L2C / L1 C/A , L1P , L2 , L2P / B1,B2 /E1 / L1 ,WAAS,MSAS,EGNOS,GAGAN / L1 C/A ,L1C,L2C
GNSS TEKNİK	CHCNAV İ73 İMU MİNİ	GPS /GLONASS /SBAS / BeiDou /GALİLEO /QZSS	L1,L2,L5/ L1,L2 /L1 / B1,B2,B3 / E1, E5a,E5b / L1,L2,L5
BAYTEKİN MÜHENDİSLİK	Sanding T66	GPS/GLONASS/BEİDOU/Galileo/SBAS	L1 C/A ,L1 , L1C ,L2,L2C,L2E,L5 / L1, L1 C/A ,L1P ,L2, L2 C/A ,L2P ,L3 / B1,B2,B3 / GIOVE-A,GIOVE-B,E1,E2-L1, E5A,E5B,E6-ALTBOC/WAAS,MSAS
GEOTEKNİK MÜHENDİSLİK	South Galaxy G1 Plus	GPS/GLONASS/SBAS/GALİLEO /SBAS	L1C/A, L1C, L2C, L2E, L5 / L1C/A, L1P, L2C/A, L2P, L3 / L1 , L5 / GIOVE-A ve GIOVE-B, E1, E5A, E5B, E5AltBOC, E6 / WAAS, MSAS, EGNOS, GAGAN
BAYTEKİN MÜHENDİSLİK	Gıntec G9	GPS/GLONASS/BeiDou/GALİLEO/SBAS	L1 ,L2E,L2C,L5/ L1 C/A,L1P,L2 ,L2P / B1,B2/ L1 BOC,E5A,E5B,E5 ALTBOC1 /L2 CBOC,E5A,E5B,E5 ALTBOC1 / WAAS,EGNOS,MSAS,GAGAN
BAYTEKİN MÜHENDİSLİK	Pentax G6Tİ	GPS/GLONASS/BeiDou/Galileo /SBAS	L1 ,L2E,L2C,L5 / L1 C/A,L2 , L3 CDMA / B1,B2 / E1,E5A,E5B,E5 ALTBOC / L1 C/A ,L1 SAIF,L2C,L5 / L1 C/A ,L5
SİSTEM A.Ş.	Leica viva GS18T	GPS/GLONASS/BeiDou/Galileo /QZSS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6
DOĞA ELEKTRONİK	Stonex S900	GPS/GLONASS/BeiDou/Galileo /QZSS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6
DOĞA ELEKTRONİK	Stonex S980	GPS/GLONASS/BeiDou/Galileo /QZSS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6
DOĞA ELEKTRONİK	Stonex S990	GPS/GLONASS/BeiDou/Galileo /QZSS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6
KORDİL MÜHENDİSLİK	Hemispere s321	GPS/GLONASS/GALİLEO/BeiDou/QZSS	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6/L1,L2C,L5,L6
BAYTEKİN MÜHENDİSLİK	Gıntec G10	GPS/GLONASS/BeiDou/Galileo /SBAS	L1 C/A ,L1C,L2C,L2E,L5/ L1 C/A ,L1P,L2 C/A,L2P,L3 / B1 ,B2, optinal B3/ E1,E5a,E5b/WAAS,EGNOS,MSAS,GAGAN
BAYTEKİN MÜHENDİSLİK	Pentax G6Nİ	GPS/GLONASS/BeiDou/Galileo /SBAS	L1 C/A,L1C,L2C,L2P,L5/ L1 C/A,L2C,L2P,L3,L5/B1,B2,B3/ E1,E5 ALTBOC,E5a,E5b,E6/L1 C/A,L1C,L2C,L5,L6/L1,L5
GEOMATİK HİZMETLER	Geomax Zenith 35	GPS/GLONASS/BeiDou/GALİLEO/SBAS	L1,L2,L2C,L5 /L1,L2,L3 /B1,B2,B3/E1,E5a,E5b,ALTBOC,E6 /EGNOS,WAAS,MSAS,GAGAN
SATLAB GEOSOLUTIONS	Satlab SL800	GPS/GLONASS/SBAS /GALİLEO/QZSS	L1 C/A, L1C,L2P,L5 /L1,L2 / WAAS,EGNOS,MSAS,GAGAN/E1,E5a,E5b,AltBOC/L1,L2C,L5,L6
GRAFTEK MÜHENDİSLİK	Trimble R12İ	GPS/GLONASS/SBAS/GALİLEO /BeiDou	L1 C/A ,L1C,L2C,L2E,L5 /L1 C/A ,L1P , L2 C/A ,L2P,L3 /L1 C/A ,L5 / E1,E5a,E5B /B1,B2,B3
KAYA HARİTA MÜHENDİSLİK	e-survey E300	GPS/GLONASS/BEİDOU/GALİLEO/QZSS	L1 C/A ,L1P,L1C,L2P,L2C,L5 / G1,G2,P1,P2 / B1,B2,B3 / E1BC , E5A,E5B / L1 C/A ,L5
BAYTEKİN MÜHENDİSLİK	Sanding Venus T3	GPS/GLONASS/BeiDou/Galileo /QZSS	L1 C/A ,L1C, L2C,L2E,L5 / L1 C/A , L2 C/A ,L2P / B1,B2,B3 / GIOVE-A, GIOVE-B,E1 , E5A , E5B / L1 C/A, L5
GNSS TEKNİK	CHCNAV İ70	GPS/GLONASS/SBAS / BeiDou /GALİLEO	L1 C/A ,L2C,L2E,L5 / L1 C/A ,L1P, L2 C/A ,L2P ,L3 / WAAS,EGNOS,MSAS /B1,B2 / E1,E5A,E5B
GRAFTEK MÜHENDİSLİK	Trimble R12	GPS/GLONASS/SBAS/GALİLEO /BeiDou	L1 C/A ,L1C,L2C,L2E,L5 /L1 C/A ,L1P , L2 C/A ,L2P,L3 /L1 C/A ,L5 / E1,E5a,E5B /B1,B2
GRAFTEK MÜHENDİSLİK	Trimble R8s	GPS/GLONASS/SBAS/GALİLEO /BeiDou	L1 C/A ,L1C,L2C,L2E,L5 /L1 C/A ,L1P , L2 C/A ,L2P,L3 /L1 C/A ,L5 / E1,E5a,E5B /B1,B2
ADASTEK MÜHENDİSLİK	ComNav T300 Plus	GPS/GLONASS/BeiDou/Galileo /SBAS	L1,L2,L2C,L5 /L1,L2/B1,B2,B3/E1,E5a,E5b/WAAS,EGNOS,MSAS,GAGAN
GRAFTEK MÜHENDİSLİK	Trimble R2	GPS/GLONASS/SBAS/GALİLEO /BeiDou	L1 C/A ,L1C,L2C,L2E/L1 C/A ,L1P , L2 C/A ,L2P/L1 / E1,E5a,E5B /B1,B2
GRAFTEK MÜHENDİSLİK	Trimble R9s	GPS/GLONASS/SBAS /BeiDou/GALİLEO	L1 C/A ,L2C,L2E,L5 /L1 C/A , L2 C/A ,L3 /L1 C/A ,L5 / B1,B2/ L1 CBOC,E5A,E5B,E5
SİSTEM A.Ş.	Leica Viva GS14	GPS/GLONASS/BeiDou/Galileo /SBAS	L1,L2,L2C/L1,L2/B1,B2/E1,E5b/WAAS,EGNOS,MSAS,GAGAN
SİSTEM A.Ş.	Leica Viva GS14	GPS/GLONASS/BeiDou/Galileo /SBAS	L1,L2,L2C/L1,L2/B1,B2/E1,E5b/WAAS,EGNOS,MSAS,GAGAN
GRAFTEK MÜHENDİSLİK	Trimble SPS855	GPS/GLONASS/SBAS/GALİLEO /BeiDou	L1 ,L2,L2C,L5 /L1, L2 /L1 C/A ,L5 / E1,E5a,E5B /B1,B2
GRAFTEK MÜHENDİSLİK	Trimble TDC150	GPS/GLONASS/SBAS/GALİLEO /BeiDou	L1 C/A,L1P,L2P,L2C /L1 C/A,L2 C/A, / L1 C/A /E1,E5B /B1,B2
GRAFTEK MÜHENDİSLİK	Trimble R1	GPS/GLONASS/SBAS/GALİLEO /BeiDou	L1 / G1 / 4 Kanal/E1/ L1
DOĞA ELEKTRONİK	Stonex S500	GPS/GLONASS/BeiDou/Galileo	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6
DOĞA ELEKTRONİK	Stonex S70G	GPS/GLONASS/BeiDou/Galileo	L1,L2,L2C,L5/L1,L2,L2C,L3/B1,B2,B3/E1,E5a,E5b,AltBOC,E6
GRAFTEK MÜHENDİSLİK	Trimble SPS555	GPS/GLONASS/GALİLEO/BeiDou	L1 C/A ,L2C,L2E,L5 /L1 , L2 C/A,L1 ,L2P /L1 CBOC,E5A,E5B, E5 ALTBOC /B1,B2
GNSS TEKNİK	CHCNAV İ50	GPS/GLONASS/ BeiDou /GALİLEO	L1 C/A ,L2C,L2E,L5 / L1 C/A ,L1P, L2 C/A ,L2P ,L3 /B1,B2 / E1,E5A,E5B
ADASTEK MÜHENDİSLİK	ComNAV G200	GPS/GLONASS/BeiDou/SBAS	L1 C/A ,L2C,L2P /L1 C/A, L1P,L2 C/A , L2P / B1,B2/WAAS,EGNOS,MSAS,GAGAN
ADASTEK MÜHENDİSLİK	ComNav T300	GPS/GLONASS/BeiDou/SBAS	L1 C/A, L1C,L2P,L5 /L1,L2/B1,B2,B3/WAAS,EGNOS,MSAS,GAGAN
GEOMATİK HİZMETLER	Geomax Zenith 25 Pro	GPS/GLONASS/BeiDou/SBAS	L1,L2,L2C/L1,L2/B1,B2/WAAS,EGNOS,MSAS,GAGAN
GNSS TEKNİK	CHCNAV İ90 İMU	GPS/GLONASS/GALİLEO/BeiDou	L1,L2,L5 /L1,L2 / E1,E5a,E5b /B1,B2,B3
GEOMATİCS GROUP	Spectra precision SP20	GPS/GLONASS/ BeiDou /GALİLEO	L1,L2 /L1,L2/ B1,B2 /E1,E5b
GEO TEKNİK	DJİ Matrice 300 RTK	GPS/BeiDou/GLONASS/Galileo	L1,L2 /B1,B2 /L1,L2 / E1,E5a
GNSS TEKNİK	phantom 4 RTK	GPS/BeiDou/GLONASS/Galileo	L1,L2 /B1,B2 /L1,L2 / E1,E5a

Table 1 (continued).

PAKSOY TEKNİK MÜHENDİSLİK	Topcon Hıper SR	GPS/GLONASS/QZSS	L1,L2,L2C/L1,L2,L2C/L1,L2C
LEO MÜHENDİSLİK	NV08C-CSM	GPS/GLONASS/GALİLEO	L1 C/A ,L1C, L2C,L2E,L5 / L1 C/A , L2 C/A ,L2P/E1,E5 ALTBOC,E5a,E5b,E6
GEOMATİCS GROUP	Spectra precision promark800	GPS/GLONASS/GALİLEO	L1 C/A ,L1P,L2C,L2P,L5 / L1 C/A,L1P,L2 C/A,L2P,L3 /E1,E5A,E5B
GEOMATİCS GROUP	Spectra precision promark220	GPS/GLONASS/SBAS	L1 C/A ,L1P,L2C,L2P,L5 / L1 C/A,L1P,L2 C/A,L2P,L3 / L1 C/A,L5
GEOMATİCS GROUP	Spectra precision SP80	GPS/GLONASS/BeiDou	L1 C/A ,L1P,L2C,L2P,L5 / L1 C/A,L1P,L2 C/A,L2P,L3 /B1,B2
IFA GRUP MÜHENDİSLİK	Sokkıa GRX2	GPS/GLONASS/SBAS	L1 CA,L1 , L2 P - code ,L2C/L1,L2 CA,L2P-code/WAAS,EGNOS,MSAS,QZSS
GNSS TEKNİK	CHCNAV LT600	GPS/GLONASS/ BeiDou	L1 C/A ,L2C,L2E,L5 / L1 C/A ,L1P, L2 C/A ,L2P ,L3 /B1,B2
LEO MÜHENDİSLİK	NV08C-RTK-A	GPS/GLONASS/BeiDou	L1 C/A ,L1C, L2C,L2E,L5 / L1 C/A , L2 C/A ,L2P/B1,B2,B3
SATLAB GEOSOLUTIONS	Satlab SL600	GPS/GLONASS/SBAS	L1 C/A, L1C,L2P,L5 /L1,L2 / WAAS,EGNOS,MSAS,GAGAN
GRAFTEK MÜHENDİSLİK	Trimble Geo 7X	GPS/GLONASS/SBAS	L1 C/A ,L2C,L2E / L1 C/A,L1P,L2 C/A / L1 C/A
GRAFTEK MÜHENDİSLİK	Trimble SPS461	GPS/SBAS	L1 C/A,L1-L2 / 4 Kanal

Figure 1. Number of Satellite systems and signals used (The number of signals it sees, the number of satellites it has seen)

Using Table 1, a ranking was made from the device that sees the least satellite system and signal to the maximum and a visual graph was created (Figure 1). As a result, it has become easier to examine the device that receives the most signals and sees the most satellite systems via the corresponding table. Accordingly, it has been seen that the most ideal device for our country is the Kolida K58 Pus device, which can work with systems such as GPS /GLONASS /SBAS / GALILEO / QZSS / BEIDOU and receive signals from many satellites of these systems (Figure 1).

Author contributions

The authors contributed equally.

Conflicts of interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

This study complies with the rules of research and publication ethics.

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