Grenze International Journal of Engineering and Technology, January Issue

Wireless Communication Prototyping for GPS Signal using Software Defined Radio

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***Abstract*—DGPS, with its ground-based reference stations, significantly improves GNSS positional accuracy by correcting satellite-derived data. Real-time DGPS, constantly transmitting corrections, achieves pinpoint accuracy of one to two meters. Geostationary satellites relay correctional data, further enhancing GPS precision. SDRs, adaptable transceivers, modernize GPS by supporting various applications, including differential correction techniques. Integrating DGPS with energy efficient SDRs narrows the margin of error to two to three centimeters. Standardized data formats like NMEA protocol ensure seamless interoperability among GPS receivers, fostering widespread adoption and enhanced navigational accuracy in real-time and post-processing scenarios.**

***Index Terms*—DGPS, SDRs, accuracy enhancement, interoperability, NMEA protocol.**

I. INTRODUCTION

With the useful resource of the global positioning gadget (GPS), users can verify their particular vicinity through the use of pseudo tiers to at the least 4 satellites. The positional statistics furnished by means of international navigation satellite systems (GNSSs) is superior by means of differential international positioning structures (DGPS).

GPS refers to any constellation of satellites transmitting at L1, L2, and L5 provider frequencies and the usage of trilateration to measure distances as it should be. It operates the usage of satellites orbiting the earth, allowing customers to pinpoint their region when in line of sight of three or extra of the 31 strategically located satellites. GPS, GLONASS, BeiDou, and Galileo satellites function through inter-component verbal exchange. GPS includes 3 additives: the space segment, the manipulate section, and the receivers, making sure accurate transmission of navigational, timing, and positional information.

DGPS measures and records the differences between real-time positions and the coordinates indicated by using GPS signals, presenting more accuracy than GPS. It makes use of a reference receiver and a rover receiver to accurate positional measurements, enhancing region precision and being utilized in land surveys. SDRs, characterised by using their adaptability, enhance DGPS by supporting various wi-fi communications with out hardware modifications, accomplishing exceptional precision and narrowing the margin of blunders to about five meters.

DGPS is greater accurate than traditional GPS devices like Total Stations, offering millimeter-level upgrades. Its adaptability lets in operation in numerous environments, making certain reliable overall performance. DGPS excels in speed and efficiency, surpassing conventional survey gadget.

Grenze ID: 01.GIJET.11.1.501_1

The real-time functionality of DGPS entails base stations continuously computing and broadcasting corrections, enabling roving receivers to modify positions correctly within one to 2 meters. Geostationary satellites further decorate accuracy by means of relaying correctional records from a couple of reference stations. Standardized facts formats like NMEA protocols foster interoperability among GPS receivers and simplify software improvement, contributing to DGPS's large adoption. SDRs use software for sign modulation and demodulation, providing powerful sign processing abilties. They are vital for mobile services, coping with multiple dynamic radio protocols in real time. SDRs usually include a superheterodyne RF front end and analog-to-digital and virtual-to-analog converters for sign processing. They offer flexibility, permitting dynamic configuration modifications for uses consisting of mobile telephones, wi-fi net devices, and GPS receivers. SDRs permit quick function integration thru over-the-air updates and enhance verbal exchange with multicasting and multichannel listening. They aid the development of cognitive radios (CRs) and are vital for developing and checking out new wireless technology, together with GPS satellite structures.
Therefore, integrating DGPS with SDRs represents a paradigm shift in GPS technology, reaching remarkable accuracy and reliability. Leveraging ground-based reference stations, actual-time correctional facts, and standardized protocols, DGPS and SDRs beautify navigational accuracy in real-time and submit-processing situations. This integration expands GPS packages and sets a new preferred for precision navigation in the current generation.

II. Literature Survey

- Lu et al. (2023) addresses a class of nonconvex complex quadratic programming (CQP) problems with applications in signal processing. The paper presents an enhanced semidefinite relaxation (SDR) algorithm for solving CQP problems, along with an efficient branch-and-bound algorithm. Through simulations, the study demonstrates the efficacy of the proposed algorithm in solving various signal processing problems, surpassing existing methods in terms of tightness and computational efficiency.
- Tian and Dong (2022) propose an improved algorithm for train positioning using GNSS single-frequency observations. The paper addresses the challenges of differential GPS (DGPS) implementation along the Qinghai-Tibet Railway and presents a novel single-frequency algorithm based on the divergence-free Hatch filter. By incorporating a sliding ionospheric variation fitting window and employing the Kalman filter for continuous positioning accuracy, the algorithm achieves sub-meter level accuracy in static and kinematic field tests, demonstrating its effectiveness in railway applications.
- Mpimis et al. (2022) focus on enhancing land vehicle positioning accuracy in Intelligent Transportation Systems (ITS) using low-cost GNSS receivers. The paper introduces a novel vehicle ranking and selection methodology for cooperative positioning (CP), aiming to maximize the benefits of low-cost GNSS receivers in safety-critical vehicular applications. Through Multi-attribute Decision-Making (MADM) theory and simulations with real experimental data, the study validates the effectiveness of the proposed methodology in improving positioning accuracy and reliability.
- The paper by Kuter and Kuter (2020) focuses on comparing the accuracy of GPS and DGPS through a field study conducted at the Middle East Technical University (METU) campus in Ankara. The study aims to elucidate the differences between these commonly used technologies by evaluating their horizontal and vertical accuracy in real-time measurements. It highlights the superior performance of DGPS over GPS in terms of both horizontal and vertical accuracy, underscoring the significance of DGPS in enhancing positional accuracy.
- Stateczny (2020) delves into the realm of hydrographic surveys, particularly addressing the accuracy requirements set out by the International Hydrographic Organization (IHO) S-44 standard. The paper discusses the utilization of GNSS/INS systems supported by DGPS and Real-Time Kinematic (RTK) receivers in hydrographic surveys, aiming to determine their effectiveness in meeting the stringent accuracy requirements of different survey orders. Through experimentation and statistical analyses, the study confirms the suitability of RTK systems for meeting IHO order requirements and demonstrates the potential of DGPS systems to fulfill the most stringent accuracy criteria.
- Spravil et al. (2020) tackle the issue of maritime GPS spoofing attacks, emphasizing the vulnerability of high-precision GNSS receivers to malicious manipulations. The paper introduces Maritime Nmea-based Anomaly detection (MANA), a cost-effective framework for detecting GPS spoofing attacks by monitoring NMEA-0183 data. Through simulations and real-world experiments, the study evaluates the efficacy of MANA in detecting spoofing attacks and underscores the importance of reliable detection methods to mitigate the risks posed by such attacks in maritime settings.

Using NEO-6M GPS modules, ESP32 microcontrollers, and RTL-SDR for DGPS implementation provides a cost-effective solution compared to traditional high-end GNSS receivers. The affordability of these components makes advanced GPS technology accessible for educational purposes, hobbyists, and small-scale projects. Incorporating Advanced Positioning Algorithms showcases the innovative aspect, integrating research into practical, low-cost GPS solutions. Leveraging open-source components and tools fosters collaboration within the community, allowing for continuous improvement and the sharing of enhancements. The system's versatility allows it to be used in various applications, including agriculture, autonomous vehicles, and environmental monitoring, where high accuracy is crucial.

III. METHODOLOGY

Two ESP32 modules are used in the implementation of a low-cost DGPS system, acting as reference stations and rovers. The stations are spaced 25–40 meters apart and connect with each other via Wi-Fi. Both stations receive latitude, longitude, and a timestamp from the GPS data. The Haversine formula is used by the reference station to process data from both its antenna and the rover station, correcting for positional errors. The rover station receives the updated data via Wi-Fi, and it uses that information to update its GPS coordinates. This methodology shows how to implement DGPS systems with readily available hardware and open-source software in a practical way, improving GPS accuracy for uses like marine navigation and precision agriculture. Furthermore, RTL-SDR v3 makes it easier to analyze and experiment with GPS signals, and real-time kinematics (RTK) corrects errors between reference and rover stations to increase accuracy to centimetre levels.
Retrieving satellite signals in order to ascertain precise position and timing information requires multiple crucial steps in the GPS signal processing process:

- Signal Acquisition: By looking for the known code or carrier frequency, the receiver locates and locks onto satellite signals.
- Signal tracking: The receiver continuously monitors each satellite signal's phase and code after it has been acquired.
- Data Decoding: The satellite's position, velocity, and clock correction are extracted by the receiver after it has decoded the satellite's navigation message.
- Error Correction: To improve accuracy, a variety of errors are corrected, such as atmospheric effects, clock errors, and satellite orbit errors.
- Position Calculation: Using methods like multilateration or trilateration, the receiver processes measurements from several satellites to determine its position and velocity.

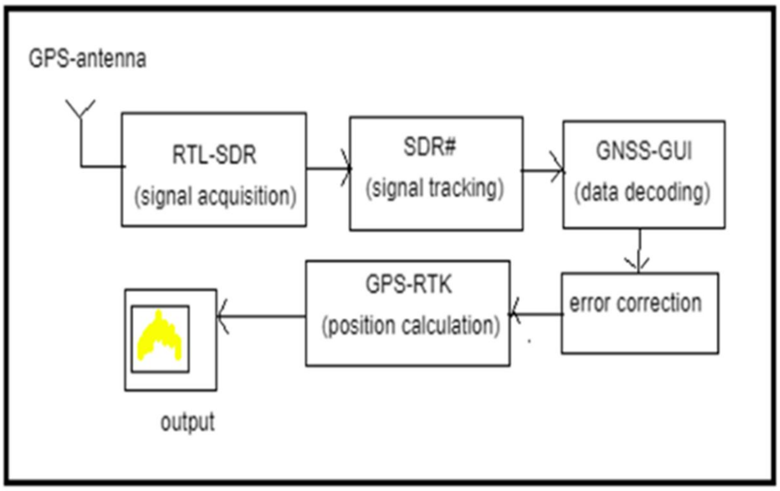


Fig 3.1: Block diagram for Decoding GPS signals using Differential RTK Technique

Differential Real-Time Kinematics (RTK) decoding of GPS signals entails comparing data from a mobile (rover) and stationary (base station) receiver. Signal differences allow the rover to make extremely precise position corrections, which is crucial for tasks like precision farming and surveying.
The Reference Station and the Rover, each with a NEO-6M GPS module for location data, are the two primary parts of the system.

A. Reference Station Algorithm

- Setup: Initializing variables and libraries. ESP32 microcontroller set up with preset credentials to function as an access point. WiFi client communication was started by the WiFi server. The NEO-6M GPS module and I have established serial communication.
- Loop: Checks for client connections continuously. every thirty seconds, reads GPS data. retrieves longitude and latitude. Reads client data if the client is connected. Retrieves the coordinates of the rover if the client data begins with "RoverLat:". computes and sends corrected data (distance, differences in latitude and longitude) to the client using the Haversine formula.

B. Rover Algorithm

- Setup: Variable and library initialization. NEO-6M GPS module serial communication. attaches to the designated access point. Establishes connection with Reference Station using IP address and port.
- Loop: Checks GPS data availability. Reads latitude and longitude from GPS module. Sends GPS data to Reference Station every 5 seconds. Receives correction data from Reference Station. Extracts and converts correction data to float. Applies correction to rover coordinates. Calculates difference and checks if within threshold percentage. Sends feedback to Reference Station.

C. Overall Functionality

- Reference Station periodically obtains GPS coordinates and awaits rover's data.
- Upon receiving rover's data, it calculates correction data based on the coordinates difference.
- Rover adjusts its GPS coordinates according to correction data to enhance accuracy.
- This iterative communication ensures precise positioning for applications like navigation and tracking.

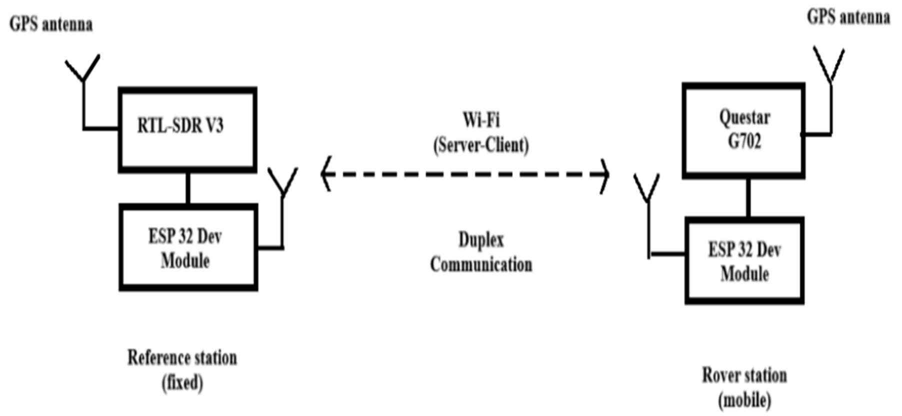


Fig 3.2 Block diagram of DGPS

The system operates in a closed-loop architecture as depicted in a block diagram. The Reference Station acquires own its GPS coordinates periodically. Upon receiving the rover's data, it computes correction data based on the positional variance. The Rover, upon receiving this correction data, adjusts its GPS coordinates. This iterative communication loop ensures synchronized and accurate positioning using the Reference Station and the Rover. This synchronization facilitates various applications like navigation, tracking, and geolocation-based services, enhancing overall system performance and reliability.

Haversine formula (used in reference station)

- dlon = lon2_rad - lon1_rad
- dlat = lat2_rad - lat1_rad
- a = sin(dlat/2)^2 + cos(lat1_rad) * cos(lat2_rad) * sin(dlon/2))^2
- c = 2 * a* tan2(sqrt(a),sqrt(1 - a))
- distance = R * c

Were,

- dlon, dlat = difference between two latitudes and longitudes.
- lat2_rad, lon2_rad = latitude and longitude of the rover.
- lat1_rad, lon1_rad = latitude and longitude of the reference station.

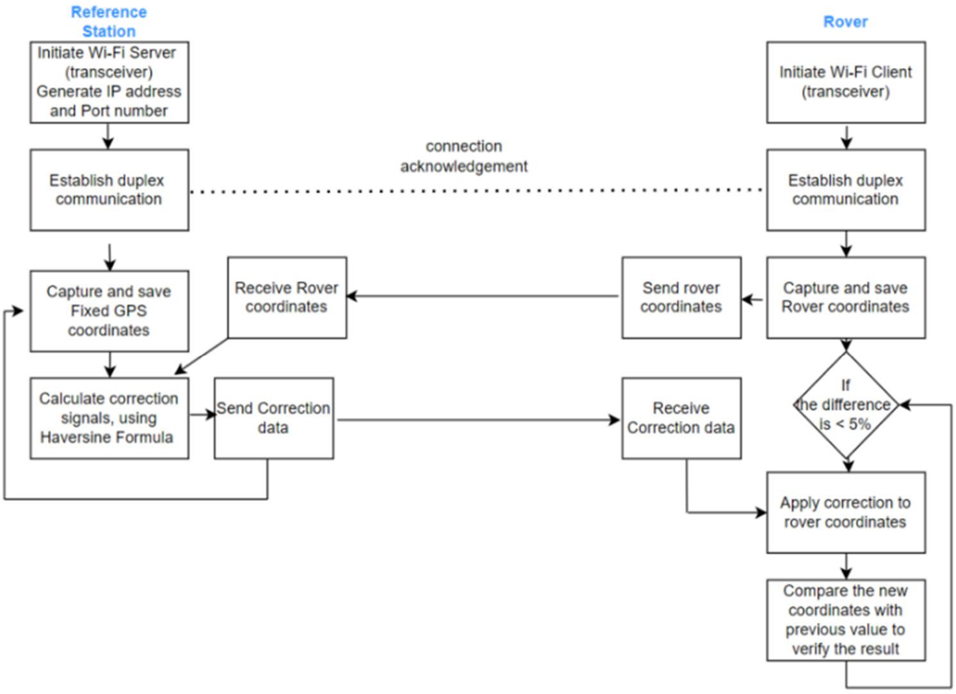
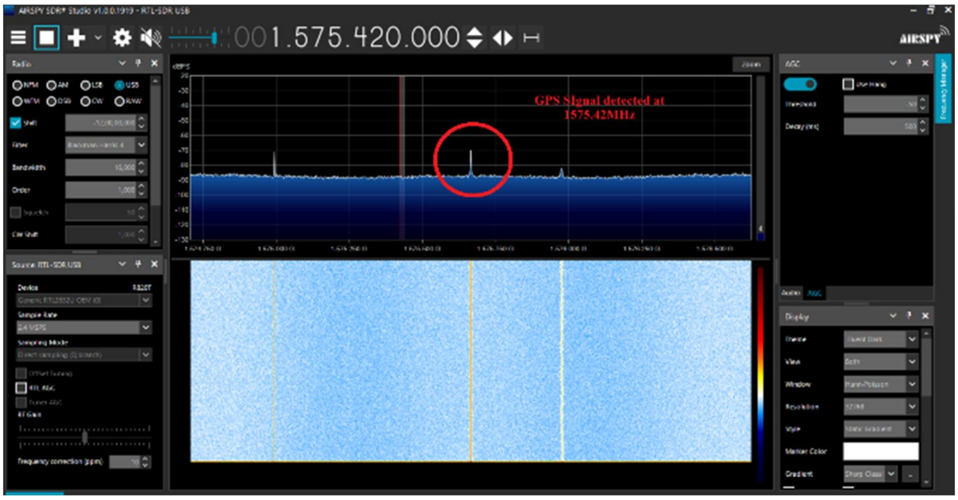


Fig 3.3 Flowchart

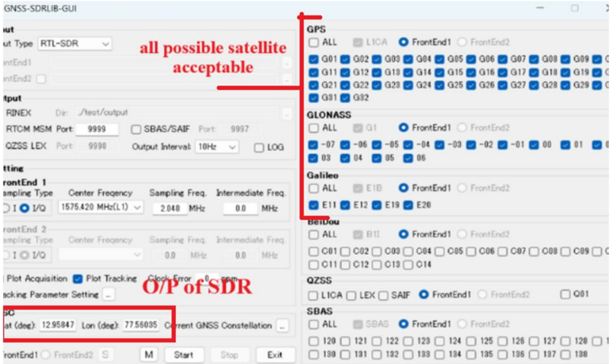
The flowchart depicts the process of calculating correction signals for rover coordinates using the Haversine formula. It involves establishing a Wi-Fi connection between a transceiver acting as a server and another acting as a client. Once connected, the client generates an IP address and port number, and duplex communication is established between the two devices. The server then captures and saves fixed GPS coordinates. On the client side, rover coordinates are captured and sent to the server. The server calculates correction signals using the Haversine formula, and transmits them back to the client. The client then applies these corrections to the rover coordinates and compares them with the previous value to validate the results.

IV. RESULTS

Signal acquisition by SDR



This figure indicates GNSS-SDRLIB-GUI software, a tool designed for satellite tv for pc navigation sign processing and analysis. In this case, the selected satellite represents the particular satellite tv for pc constellation from which the software program desires to acquire signals.



From a variety of constellations, such as GPS, GLONASS, Galileo, or BeiDou, which are each represented by a different symbol, users can choose individual satellites.

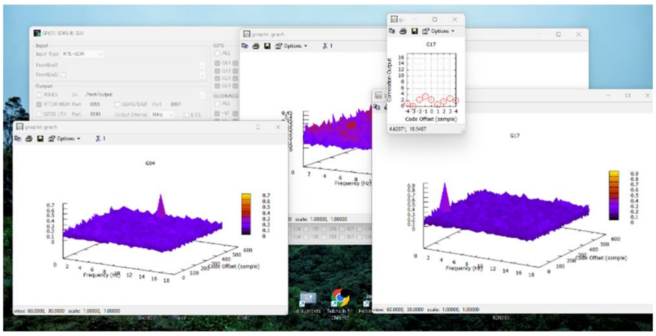


Figure 4.3: GPS output from SDR

It gives important insights into how satellites function within the GNSS constellation by visualizing signal properties like frequency shift, intensity, and code shift. These results address various factors such as atmospheric effects, receiver clock errors, and satellite motion, which aid in performance evaluation and accuracy assurance.
Users can then record, navigate, or record signals for use in timekeeping. To accommodate user needs, the software provides programmable signal processing and analysis features like time synchronization and sensitivity adjustment. Accurate signals must be obtained by adjusting frequency offsets; stronger signals correspond to higher power levels, which enhance reliability and resolution.

Differential GPS

The figure shows a comparison of two sets of GPS data: one obtained from a fixed station and the other from a mobile rover. The purpose of the comparison is to evaluate the consistency and accuracy of GPS location in these two cases.

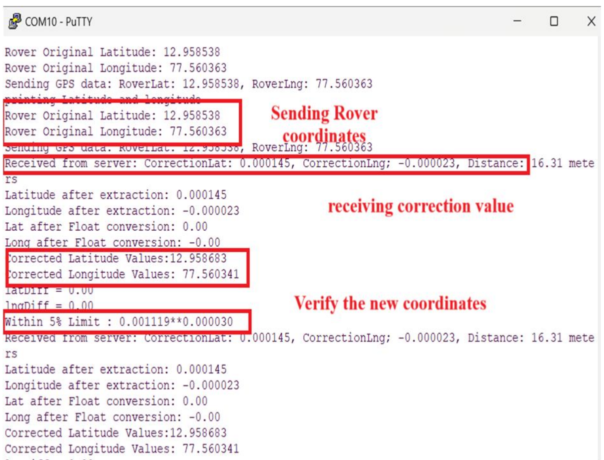


Figure 4.4: DGPS rover

This information usually provides clear lines of coordination of receiver stability for several satellites and allows location to be determined.

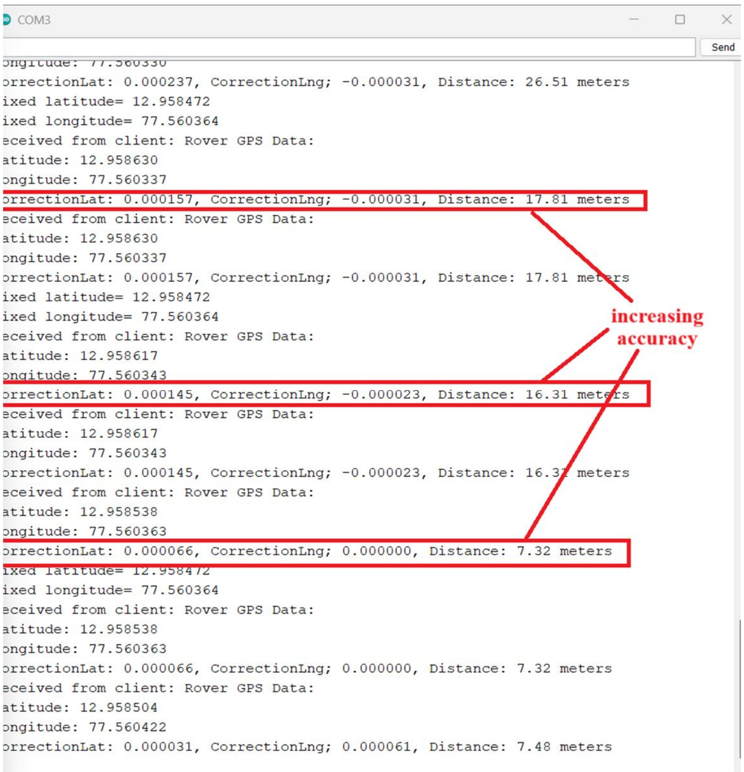


Figure 4.5: DGPS reference station

This provides information about the operation of various situations. Seeing the difference between fixed data and the rover can indicate the location of errors or inaccuracies in the GPS position (for example, multiple interference, signal degradation, or receiver Wireless prototyping for GPS signals using Software Defined Radio inaccuracy).

V. Conclusion and Future Work

In conclusion, our challenge explores the usage of ESP32 modules to enhance GPS accuracy in dynamic environments. By comparing signals from a reference station with the ones from a shifting rover ready with ESP32, we evaluated our correction method's effectiveness. Using the Haversine components and accuracy calculations, we assessed our gadget's precision. The rover station constantly gets GPS records, sends it to the bottom station for correction, and affords the refined statistics to the person. Our findings show promising effects in improving GPS accuracy, specially in eventualities needing regular correction because of motion. While no longer utilizing SDR technology, our ESP32-based technique offers a value-powerful alternative for enhancing GPS accuracy in cell programs.

Future paintings entails in addition refining and trying out our device for integration into numerous industries, offering dependable positioning solutions for transportation, logistics, and outdoor navigation. We also goal to growth GPS accuracy in indoor settings, addressing challenges like sign blocking off and reflections. By mitigating signal interference and improving facts processing algorithms, we will adapt our ESP32-based totally machine for indoor programs, such as warehouse logistics and navigation in big complexes. Additionally, we are committed to decreasing device latency. While our present day gadget operates on the facts level, destiny paintings will attention on the service stage the usage of RTK concepts to minimize latency. By optimizing conversation protocols and information processing mechanisms, we intention to obtain near-immediate updates, making sure users receive correct place facts with out important put off.

Overall, the future of our mission includes extending its attain into indoor environments and enhancing overall performance for extra precision and responsiveness, paving the way for enormous adoption throughout industries.

REFERENCES

[1] Kuter, Nazan, and Semih Kuter. "Accuracy comparison between GPS and DGPS: A field study at METU campus." In IEEE access Italian Journal of Remote Sensing, vol 7, pp: 1123(2020)

[2] Stateczny, Andrzej, "Study on the positioning accuracy of GNSS/INS systems supported by DGPS and RTK receivers for hydrographic surveys." Energies in IEEE access, vol 5, pp: 1267

[3] Spravil, Julian, et al. "Detecting maritime gps spoofing attacks based on nmea sentence integrity monitoring." in IEEE ACCESS, vol.6, pp.1123, 2020

[4] R. Tian and X. Dong, "An Improved Divergence-Free Hatch Filter Algorithm Toward Sub-Meter Train Positioning with GNSS Single- Frequency Observations Only," in IEEE Access, vol. 8, pp. 112027-112040, 2022.

[5] T. Mpimis, T. T. Kapsis, V. Gikas and A. D. Panagopoulos, "Dynamic Optimal Vehicle Selection for Cooperative Positioning Using Low-Cost GNSS Receivers," in IEEE Access, vol. 11, pp. 134146-134154, 2022

[6] C. Lu, Y. -F. Liu and J. Zhou, "An Enhanced SDR Based Global Algorithm for Nonconvex Complex Quadratic Programs with Signal Processing Applications," in IEEE Open Journal of Signal Processing, vol. 1, pp. 120-134, 2023

[7] Bakuła, M. Uradziński, and K. Krasuski, “Performance of DGPS smartphone positioning with the use of P(L1) vs. P(L5) pseudorange measurements,” MDPI, 14-Feb-2022.

[8] Krasuski, D. Popielarczyk, A. Ciećko, and J. Ćwiklak, “A new strategy for improving the accuracy of aircraft positioning using DGPS technique in aerial navigation,” MDPI, 22-Jul-2021.

[9] Specht, “Consistency of the empirical distributions of navigation positioning system errors with theoretical distributions-comparative analysis of the DGPS and Egnos Systems in the years 2006 and 2014,” MDPI, 23-Dec-2020.

[10] Deng, R. He, L. Yan, X. Wang, X. Han, and X. Fang, “IEEE 802.11be Wi-Fi 7: New challenges and opportunities | IEEE Journals & Magazine | IEEE Xplore,” IEEE 802.11be Wi-Fi 7: New Challenges and Opportunities.

[11] E. Khorov, I. Levitsky, and I. F. Akyildiz, Current Status and Directions of IEEE 802.11be, the Future Wi-Fi 7, 08-May-2020.

[12] F. Arena, G. Pau, and A. Severino, “A review on IEEE 802.11p for Intelligent Transportation Systems,” MDPI, 26-Apr-2020.