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AnIoTbasedSmartPositioningandDecisionManagementApplicationwithRealTime Kinematics Information

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ABSTRACT

An IoT based smart positioning measures are useful to the society for accurate mapping of boundaries and to do the localization of geo graphical area. The existing approach uses GNSS technologies, and the boundary values can be improved further by applying advanced technique. In this paper, a novel approach for optimization of the positioning technique is proposed. A digitalclassificationandoptimizationofareamapping,enhancementofcorrelationdata,analysis through expert system and clustering of delineation zones using machine learning algorithm is implemented as part of the solution. The precision accuracy optimization is achieved by error correction of zonal map boundaries obtained through GNSS satellite system. The real time kinematicstechniqueisappliedtoachievethebetteraccuracy.Theexperimentiscarriedoutatin real time at Nagamangala region and real time data received from the radio frequency sensors, satellites areanalysed, calibrated, and improved further to obtain the precision accuracy up to 99.9% with the accuracy of 2mm.The proposed solution is useful in real time sectors to manage the data related to real time tracking, safety critical applications, health care, military, mining, geological surveys, and agricultural applications.

Keywords:

RealTimeKinematics,IoTApplication,SmartPositioningandManagement,Sensor,RFID, Real Time Navigation, Localization,Geo Data, Precision Decision Making

1. Introduction

The Satellite Geo spatial data is obtained from the remote sensing device that has the raw GNSS data in WG84 based format [1]. The raw GNSS data is humungous, and data is generated dynamicallywithin a milli second. The extraction ofNGS CORS data from the generated data is challenging and requires optimal algorithm [2,3]. After the data acquisition, data processing and data transformation is to be performed further by using ML/DL based algorithms [4,5, and 6]. Precisionagricultureneedsaccuracyinthecreationofmanagementzones[7].Kriging interpolation methos though gives the solution, precision accuracy is still a challenge in agriculture, Land Survey, and other field specific applications [8].Real Time Kinetics (RTK) is the mechanism usedfor deriving positioning accuracyin anyarea orzones [9, 10]. Theproposed solution in this paper uses the RTK based solution to determine the accuracy of GNSS positioning.

Considering the diversion of the points of projections, one needs map the directions across the dimensions of coordinate systems. The spectral difference between the coordinate points interprets the accuracy level of the projection points [11]. Point level fusion mapping can bedonetoextractthecoherentinformationofcoordinatesandthenbyapplyingthedecision rulesto obtainnewcoordinateprojectionspace[12].RealTimeKineticscan beusedin IoTapplications such as Smart Cities, Agriculture, Environment, Robotics, and Autonomous Vehicles etc. [13]. Real Time Kinetics gives the positioning references using reference station that is fixed and movable station [14]. Real Time Kinetics works with dual frequency, and it mitigates the positioning errors bydifferentiating the positions between reference station and movable station. In Vietnam and other European country, dual frequency based real time kinetic measurement technique is used [15, 16]. With optimized real time kinetics protocol implementation through GNSS receiver and NTRIP caster framework, it is possibleto obtain theprecision accuracy[17]. The similar approach is incorporated in this paper with optimization in real time kinetics.

Trajectory Planning method is used in Unmanned Aerial Vehicle delineation. A Trust Region Filtered Sequential Convex Programming is proposed to build UAV trajectories [18]. The image fusion space with geo plots needs projection mapping calculations and involves complicated computations [19]. Mixed Integer Linear Programming. To solve the trajectory planning, Random Tree Exploration and Informatics interpretation can be used [20]. The computation methods and algorithms logics increase the complexities for plotting the trajectories [21].Convex programming methods are suggested for improving the trajectory generation [12 and22]. Comprehensive Analysis is needed to achieve geo fencing through China’s BDS-3 based carrier shift methods for range specific GNSS data [23]. Tukey and K-Means methods are suggested by Massimiliano et al. to implement Single Point Positioning on GIS applications [24].Determining spatial differentiation of geographical area using Ecological Redline Area is proposed by Deng Sui Chen et.al [25]. To develop tractable simulations trial and error-based methods arefollowed in actual model scalinganalysis [26].A polynomial modelis the common method for correction in geometric. The order of the polynomial and remote sensing is not co related andhencemachinelearningalgorithmssuchasENVIdeeplearningmodelisproposedby Weicheng Xu et. al. [27].Imperative areas are detected through down sampled GlobalNighttime Light using multi source spatial variables as proposed by Yang Ye et al. [28].

Multi spectrum Instrument based satellite positioning data on the land area was studied and solution to spatial variability is discussed in the paper of Mortz K. Lehmann et al. [29]. Monitoring forest area based on multi sourceremote sensing byobserving phenological surfaces of the environment is studied by Yali Zhang et. al [30]. A sequence of extraction of points using GatedRecurrentUnitframeworkandneighbornetworkhoodalgorithmisproposedbyYiheet al. [31]. Horizontal coordinate points for the transformation of points in longitudinal axis of the original coordinate system can be computed by using gradient component derivation method as proposedbyAndreasA.Beckertet.al.[32].Satelliteimagesareanalyzedthrough remotesensing computations using optimized algorithm was suggested by Hu et. al. [33].High powered trajectory optimization to provide tri axis commands and attitude control approach is proposedby Mazinan et. al [34]. However, scale dependent spatial pattern quantification is challengingand needs power law predictions as proposed by Qun Ma et. al [35]. With back trackingthe traces of encroachment space patterns across Southern Great Plain, a threshold value for accuracy assessment was studied by Xuebin et al. [36]. It is proven that utilization of GIS based methodologies are needed in various regions, zones and tracking etc, [37]. The delineation of land area may not be accurate at all locations [17, 38]. BumairiyemuMaimaiti et.al suggested to do mapping of classifications, expansion scaling and relevant parameter calculations done through ArcGIS software [39].Diversified land zones and mapping of the areas through consistent characterization with an accuracy of 4.77m is implemented by Yang, F. and Zeng, Z [40]. Intense investigation is done by Shreshtha et al., in the mountain region of Asia where complexities are high due to unstable slopes. However, positioning accuracy is still a challenge and requires research.

Precision accuracy for Galileo constellation positioning can be determined by single frequency modeling and computation as proposed by Bahadur, B [13]. Post Processing Kinematics andReal Time Kinematics are the methods suggested to achieve accuracy in unmanned vehicles and the outcome shows that Root Mean Square of 0.0189m is achieved by Nicola et.al and team. [14]. In urban areas, GlobalUrbanNet based framework is useful as proposed by Yanfei Zhonget. al and team in their work [41].Taddia, Y et al., proposed Network RTK and DJI Phantom RTK modes to achieve GNSS accuracy and have achieved 5cm offset with vertical residuals [42]. In our paper, a similar approach is adapted to achieve an offset accuracy of 2mm. The proposed IoT application is useful in use cases such as agriculture precision management, real time object tracking management and in safety critical applications and management.

2. Methodology

DataFormat

The Smart positioning application makes use of the dynamic data generated by active satellites and is represented in the format called NGS CORS data. The raw data received fromthe satellite constellations are managed by real time kinematics technology, RFID sensor and Geo Informatics approaches. The positional data parameters such as Longitude, Latitude, Altitude, time, mode of fixing the position, accuracy data in 2D and 3D and live satellite information etc.A sample ofdata formatreceived through the simulation softwareis represented in Fig. 1.

Fig.1DataFormat

The real challenge of engineering a complex system is to aggregate the electric, electronic, mechanical, and computing elements. The tool simulations or modeling is needed to study and analyze the behavior and performance of the elements. The signaling strength, gain and better impedance with low cost was needed for deriving delineation solution at its first place.The optimization technique needed to improve the harmonic response and analysis of antenna to be performed. A monopole antenna is analyzed, and mitigations are proposed by Jadon et al. [43] and Chand P S P etal[44]. The hardware module of RTK consists of RTK basestation and RTK Rover station along with the fabrication of patch antenna designed exclusively for the proposed IoT device.

PatternAnalysisoftheAntennas

The design, fabrication, and patternanalysis of the antennassuch as Pifaantenna, Microstrip element Antenna, Patch Microstrip inset Antenna, Patch Microstrip Circular Antenna etc. are performed in real time to achieve better accuracy. The elevation and pattern analysis of Patchand Pifa antenna is depicted in Fig.2 and Fig.3.

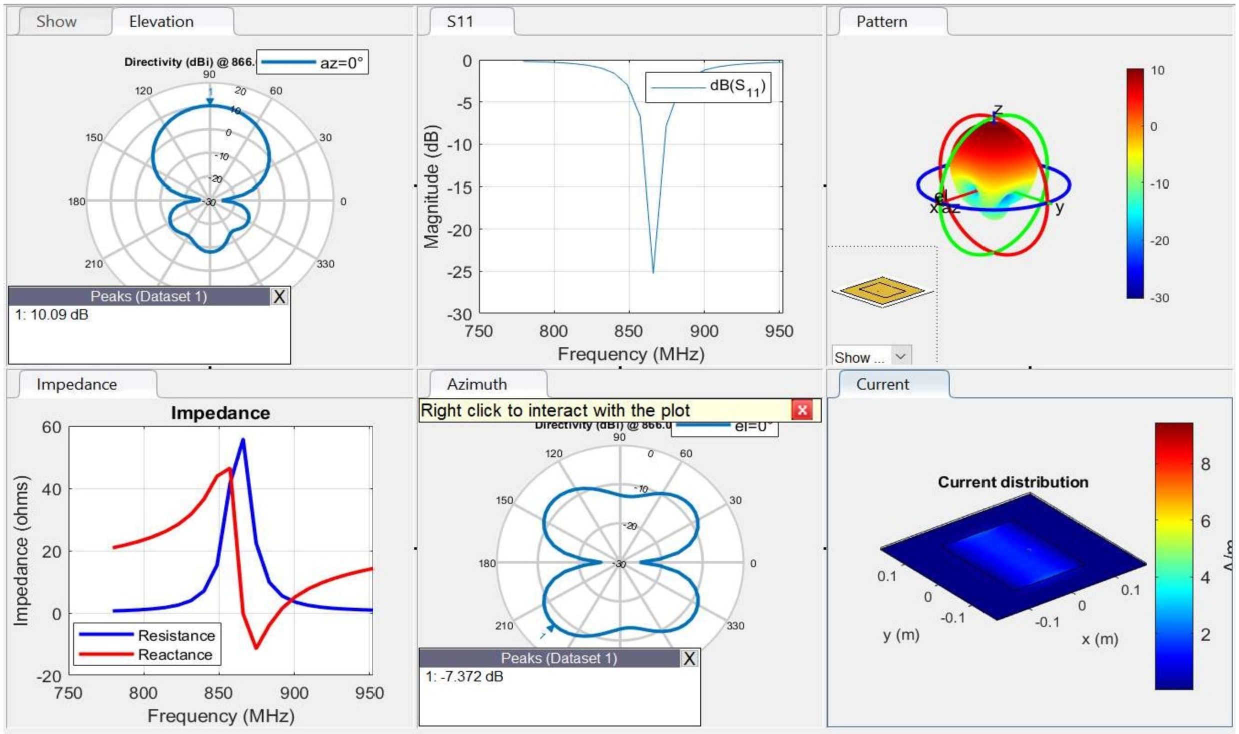


Fig2.PatternofPatchMicrostripelementAntennawith155mm×155mmdimension

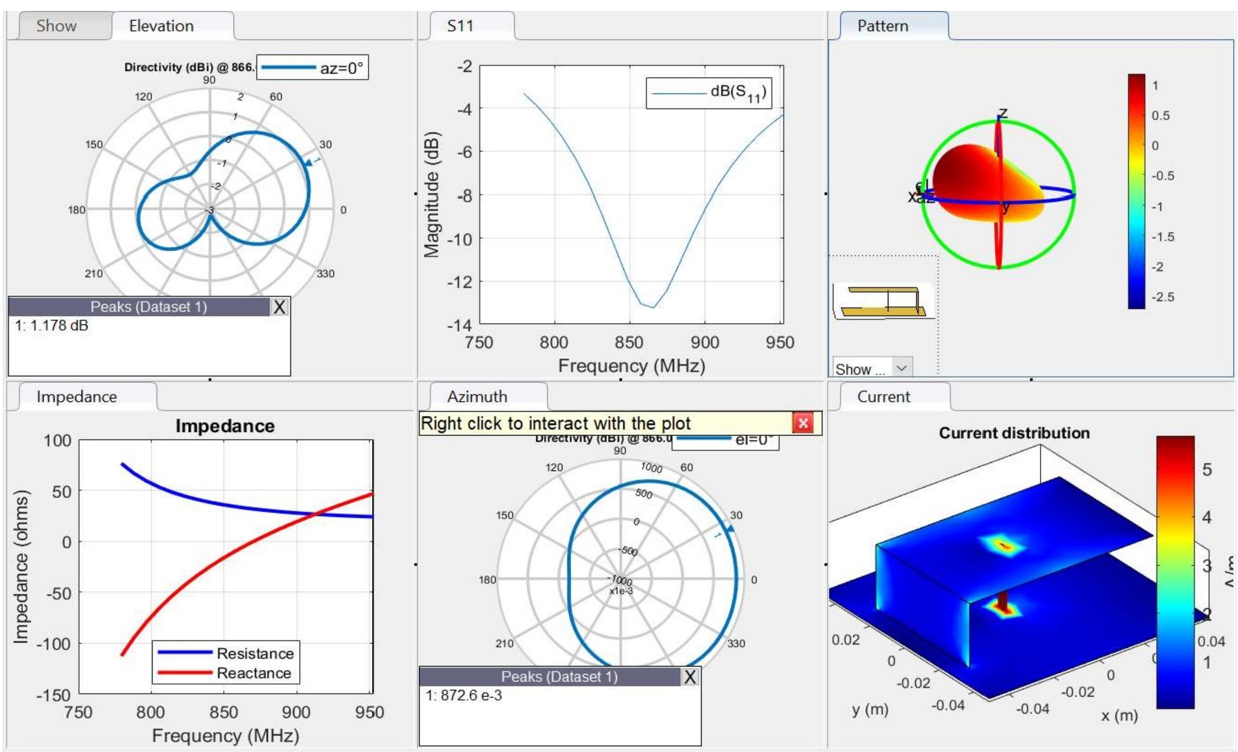


Fig.3PatternofPifaAntennawith45mm(x-axis)×50mm(y-axis)×20mm(z-axis)

Patch Antennawith Micro strip element is designed and manufactured further to improve the gainofsignals.Diploeantenna,Fractalantenna,Helix,loopandspiralantennaaredesigned,and itisverifiedthatinsetfedantennagivesthebetterresultincomparisontootherantennasas depicted in Figs. 4 to 7.

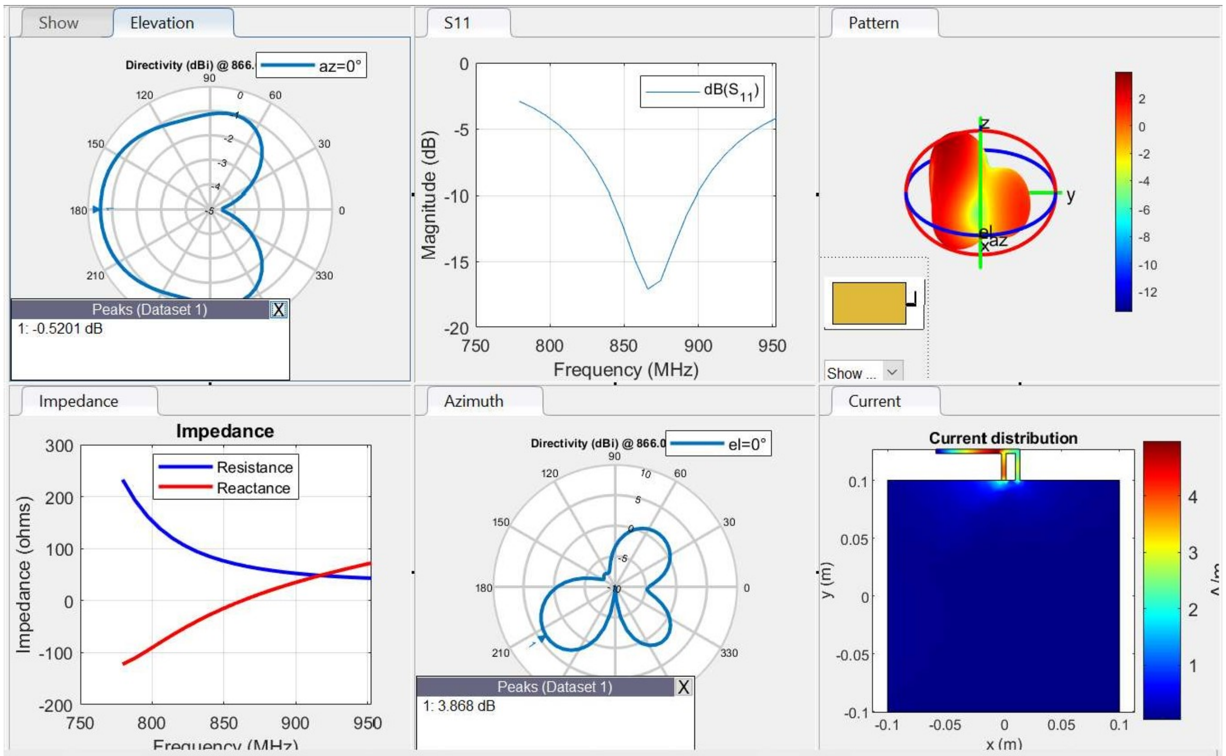


Fig.4PatternofInvertedFcoplanarAntennawith100mm×100mmdimension

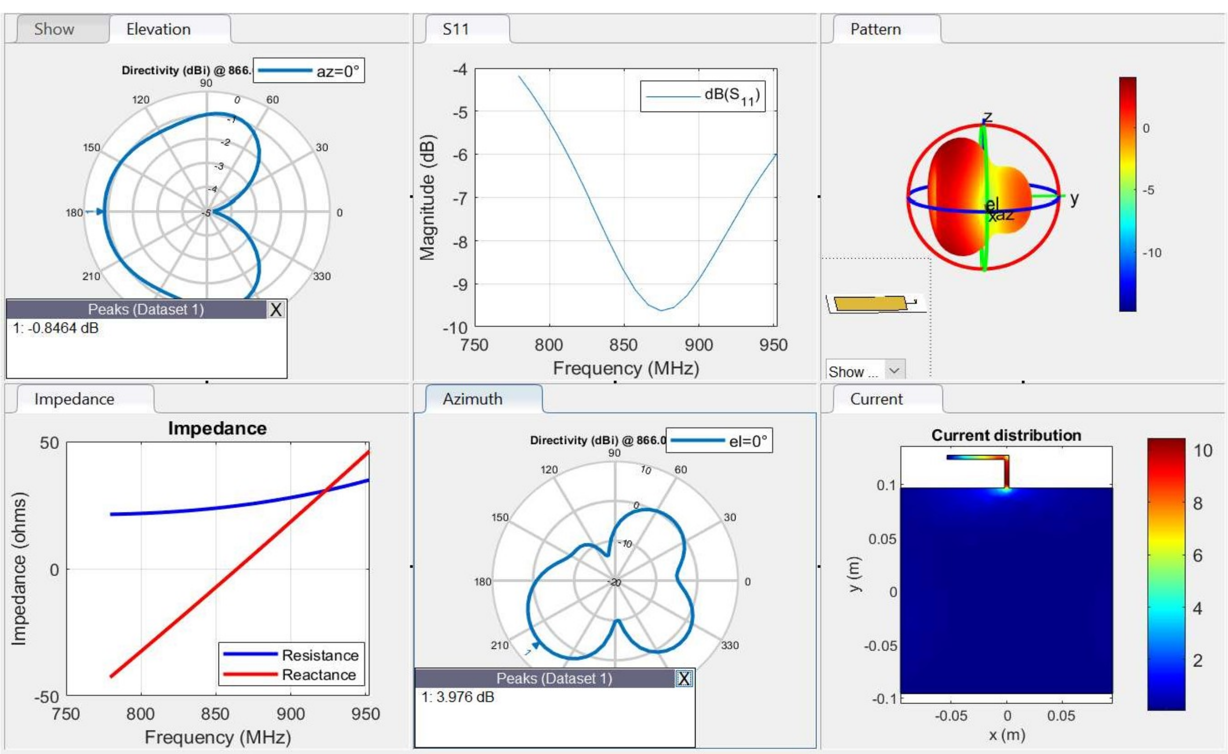


Fig.5PatternofInvertedLcoplanarantennawith100mm×100mmdimension

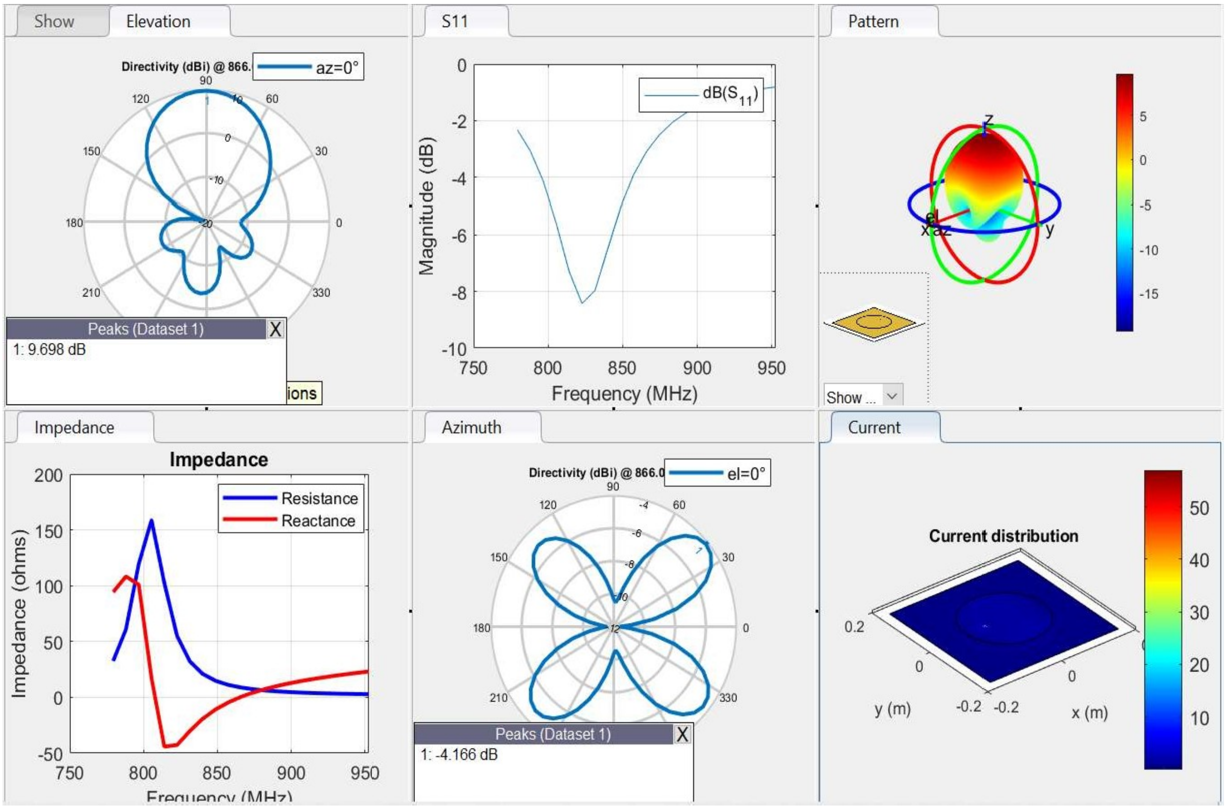


Fig.6PatternofPatchMicrostripcircularantennawith155mm×155mmdimension

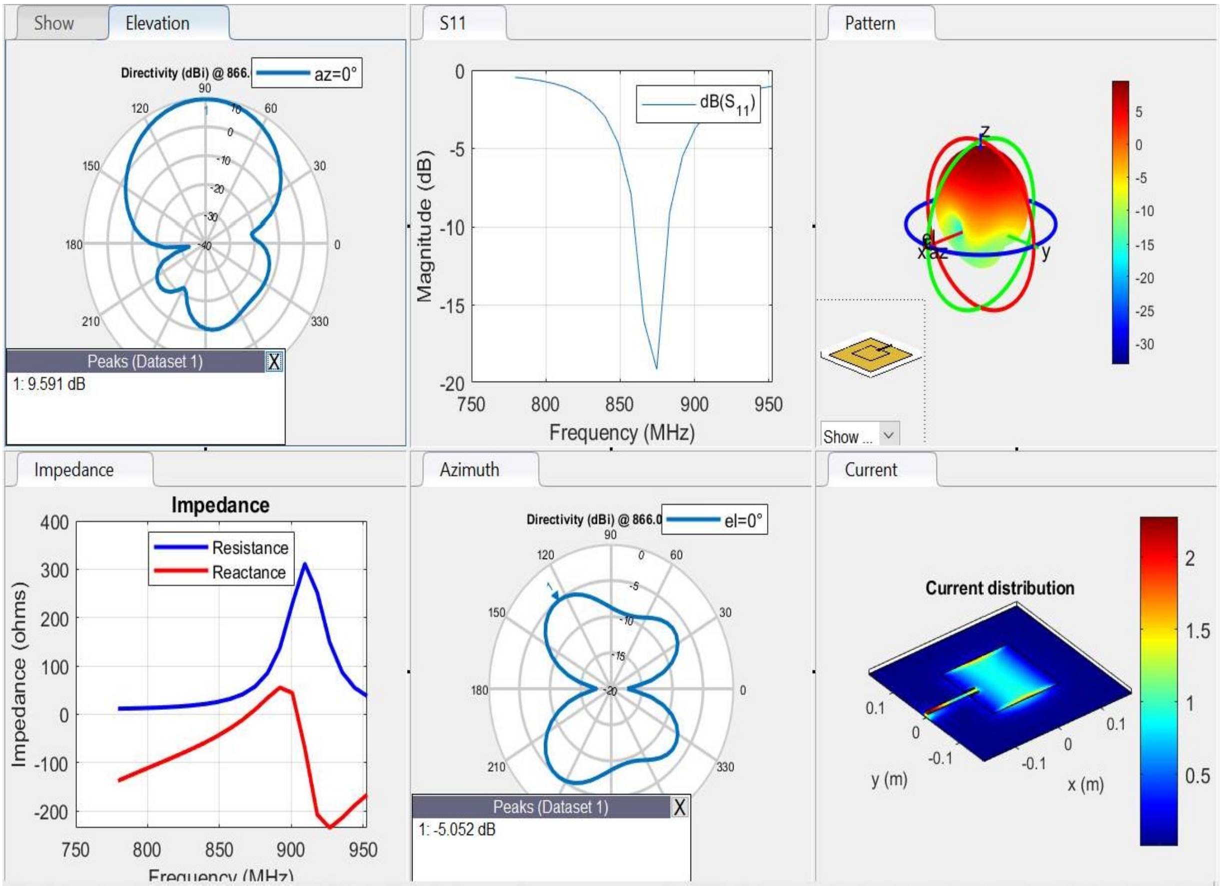


Fig7.Patternofpatchmicrostripinsetfedantennawith155mm×155mmdimension

Itisevidentfromthepatternanalysisthatthemicrostripantennawithpatchinsetfedantennais efficient and can be used in the proposed system to improve the accuracy. The comparative analysis of the antenna is shown in Table 1.

Table1

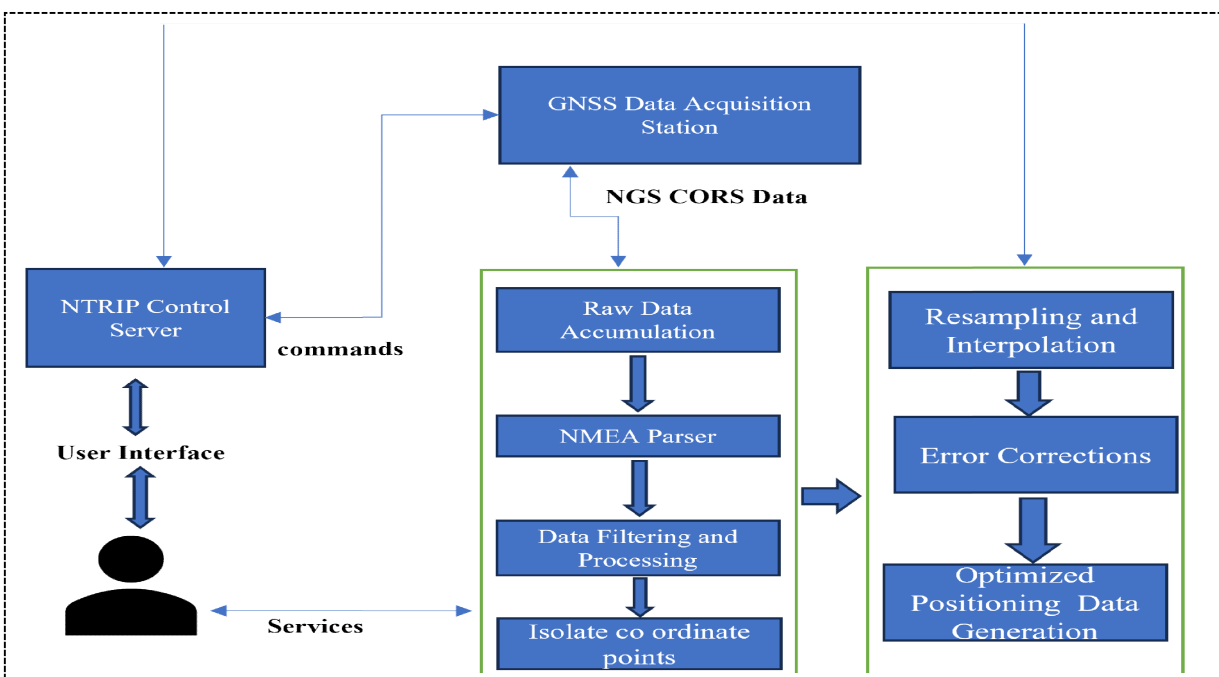
PatternAnalysisofAntennas

AntennaTypes	Dimension	Impedance @950 MHz	S11 Frequency @ 865 MHz	Distri bution
PatchMicrostrip element	155*155mm	-20to+60	25dB	high
PifaAntenna	50*20mm	-100to +100	13dB	low
InvertedFCoPlanar	100*100mm	-100to +200	16dB	low

InvertedLCoPlanar	100* 100mm	-50to+50	9dB	low
PatchMicroStrip Circular	155*1 55mm	-50 to +150	8dB	low
PatchMicroStrip Insetfed	155*1 55mm	-200to +400	25dB	High

FrameworkforDecisionMakingandInformationManagement

Theprocessframeworkusedinthispaperforobtainingtheprecisionaccuracyisrepresentedin Fig.8.ThemodelconsistsofCLIdrivencontrolserver,DataAcquisitionstation,andUser Services. The processing activities at the services interface consists of parsing logic with optimization, Isolation of coordinate points, Interpretations, Corrections, Generation of new coordinatepointsandfinallydistributionofdata.RealTimeKinematicsbasedpositioningisa techniquethatperformspositioningcomputation.Thehardwareintegratesgeodatareceiver comprising Rover and Ranger stations and is communicated through the server. The IoT system is deployed on the locality identified and obtains data from satellite. The received raw data is finetuned further and is optimized dynamically at the edge server. The satellite response generatedis extractedautomaticallyonceevery4 millisecondsandis displayedonmobiledevice through android application. A wireless sensor testbed to record the metadata and calibrate the timestampaccordingtotherecordeddatasegmentisusefulasdefaultgateway[50].Theprocess



frameworkusedinthispaperforobtainingtheprecisionaccuracyisrepresentedinFig.8.

Fig.8DataProcessingFramework

The model consists of CLI driven control server, Data Acquisition station, and User Services. The processing activities at the services interface consists of parsing logic with optimization, Isolation of coordinate points, Interpretations, Corrections, Generation of new coordinate points and finally distribution of data. Finally, data processing and decision is performed through thedata processing logic.

Let us gather the data with distance record. After recording distance every 4 seconds thereafter record the elapsed time, t and distance, dist(t) until the final distancevalue 1 cm. Let us consider exponential function as shown in Eq. (1)

$$dist(t)=Ee^{-pt} \quad (1)$$

where,**E**and**p**arethepositiveconstantsrepresentingerrorcorrectionvalue.Let $\mathbf{E_r}$bethe exponential spatial threshold value. Then, the Eqn. 1 is updated as shown in Eq. (2)

$$dist(t)= Ee^{-pt} \qquad +E_r \quad (2)$$

Theinitialrecordeddistancevalueisdist(0).ThenthedeviationiscalculatedasperEq.(3)

$$dist(t)=(dist(0)-E_r)e^{-pt} \qquad +E_r \quad (3)$$

If the function fits all of the data, then any of the ordered pair should satisfy the function. For example, use pair (d/2, t/2) from the recorded data and the value of error correction constant p can be set with 0.01. Then, the distance amount can be derived as per Eq.(4).

$$dist(t)=(d_0)e^{-0.01t} \qquad +d_1 \quad (4)$$

Thesteptoberepeatedtofindtheconstantpfor all thepairs.Oncethedistanceis determined, the time(t) vector can be determined as per the Eq. (5).

$$time(t)=2\pi\div\sqrt{E_r}\times dist_t \qquad (5)$$

Duringperiod,time(t),thecorrelationvariationpertimeisobtainedasshowninEq.(6)

$$2\pi\times \frac{dist(t)}{time(t)} \qquad (6)$$

Distortioncorrectioncanbedonebyusingfirstorderlinearequation.Thecoordinationsystem points (x,y) are related by mapping functions obtained from CORS data set, (u,v) as given in

Eq.(7).

$$u=f(x,y) \quad and v=g(x,y) (7)$$

wherefandgarepolynomial.

Thetranslationduetodistortionisrepresentedby 1^{st}degreepolynomial.Thenewvaluenthvalue of u and v for n^{th} order coordinate sets $\{a_n,b_n\}$is given by Eqn. 8

$$u_n=a_0+a_1x+a_2y+..a_{n-1}x+a_ny$$
$$v_n=b_0+b_1x+b_2y+\cdots+b_{n-1}x+b_ny \quad (8)$$

The new coordinate system may not have one to one mapping with actual points. The actual to new coordinate difference can be calibrated and is dependent on the degree of the polynomial used in the mapping function and average mapping range is (n+1) (n+2)/2. With resampling and interpolation one can correct the misalignment and distortion. Furthermore, error correction and modelingcanbedonewiththeoptimizedcomputationalprocedureortechnique.Several contiguouscoordinateframedataareresampled,interpolatedandmodelledtoachieve approximation values needed for accuracy [52]. The projection of coordinate system and the distortion angle along x and y varies.Precision rate with respect to inclination of coordinate system deviation is represented as shown in Fig. 9.

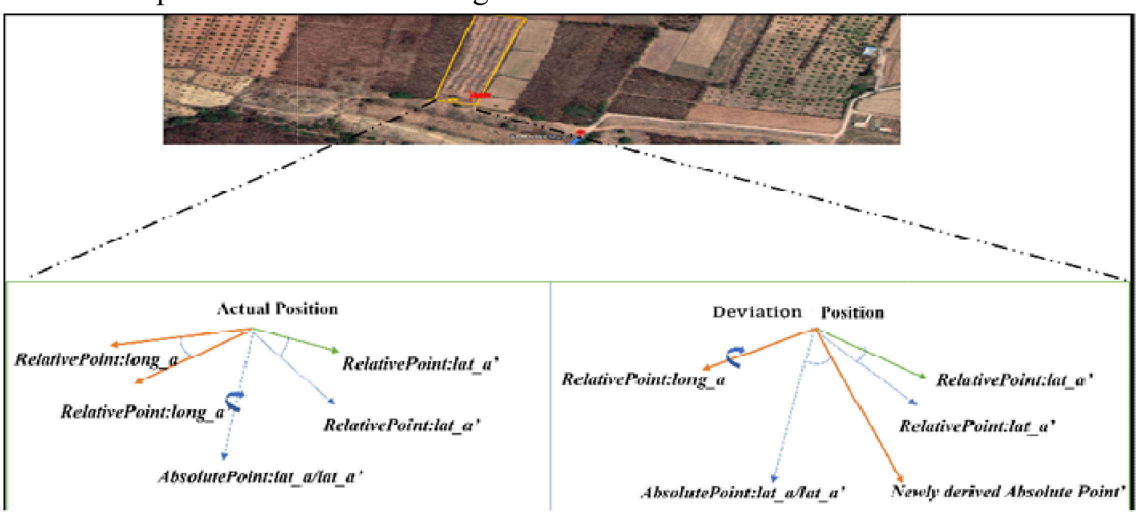


Fig.9.CoordinationSystemDelineationandDeviationCorrection

LetthedisplacementbeΔ⁄andisrepresentedasshowninEq.(9)

$$\Delta⁄=\frac{360}{(\text{Correction}*\text{Noofderivations})}\times time(t) (9)$$

Theconsecutivedataiscalibratedtogetcompletedeviationanalysis.Theperiodicrepetition parameter Q can be designated as per Eq. (10).

$$Q=1+\frac{K}{(N)}\times\Delta\acute{\lambda}(10)$$

where, Krepresents distortions observed and N represents numberof repetitions. Theration K/N represents successive deviation parameter. The back propagation based neural network method with optimized Artificial Bee Colony algorithm is used in this paper to optimize the parameter and dynamic threshold technique is used to predict the future approximation of location points.

3. Results

IntheproposedIoTsystem, thebooththestationsareplaced atthedistance of40kmsas shownin Fig.10.Fortesting,theRTKbasestationandRTKRoverstationissetupattwodifferent locationswiththedistanceofupto40km.Oncethestationisready,theGNSSreceiversstart collecting the data via Bluetooth.

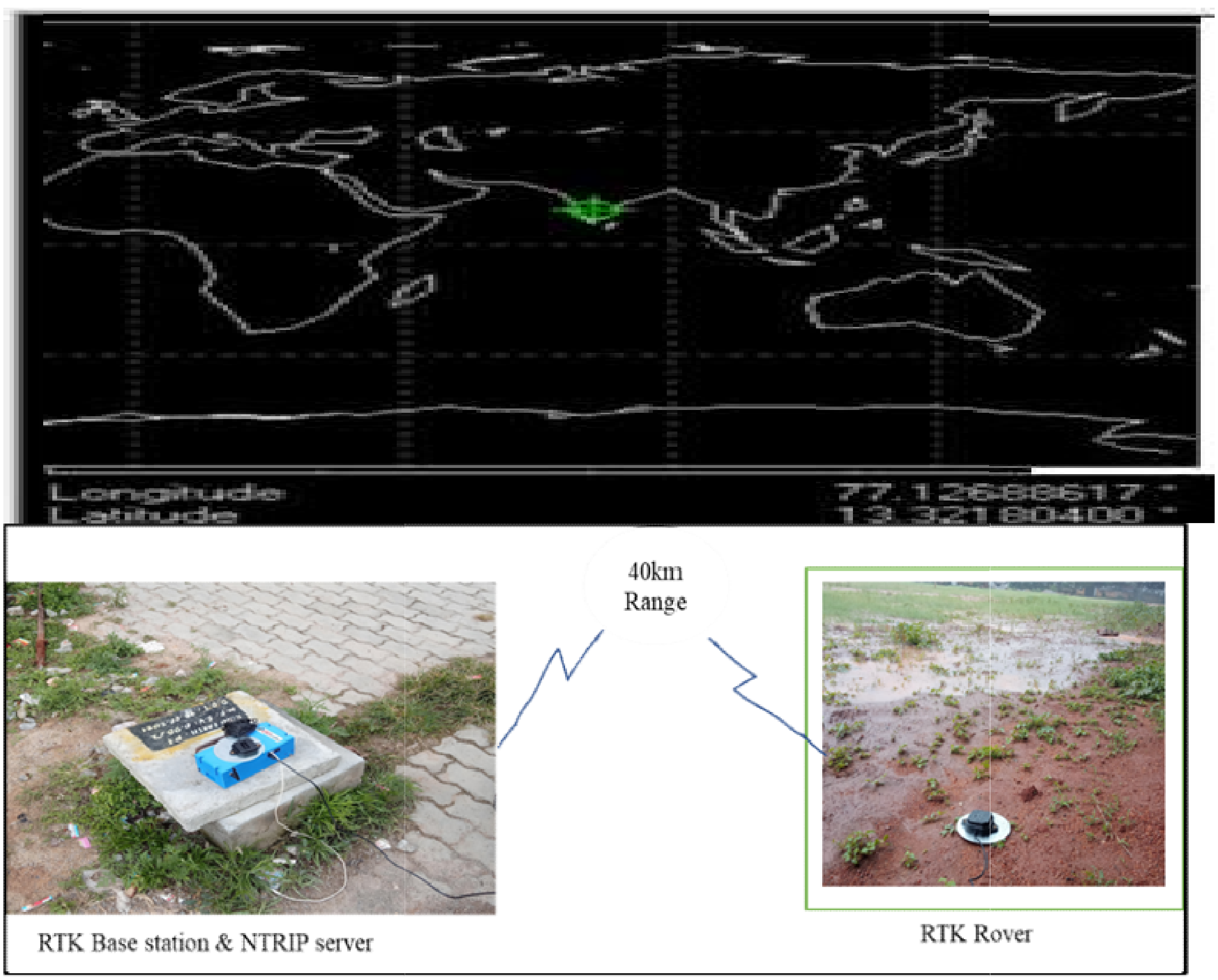


Fig.10SetupofRTKBasestationandRTKRoverwith40kmdistanceasshowninDigital Satellite Map

The GPS log is captured in text file and is preprocessed before classification process is applied. The region where the internet facility is not available, the instrumentation profiles are obtained directlyfromthesatellitethroughGNSSreceiver.TheconstellationscapturedasshowninFig. 11.The Geo raw data is collected in the console from the active satellites and smart delineation line in yellow with 2mm accuracy.

Fig.11ResultoftheSmartPositioningwithdelineationdigitalmarking

Theresultofthepositioningistrackedfromtheremotelocationandprecisionaccuracydeviation in mm is depicted in the testing area at the remote server as shown in Fig. 12.

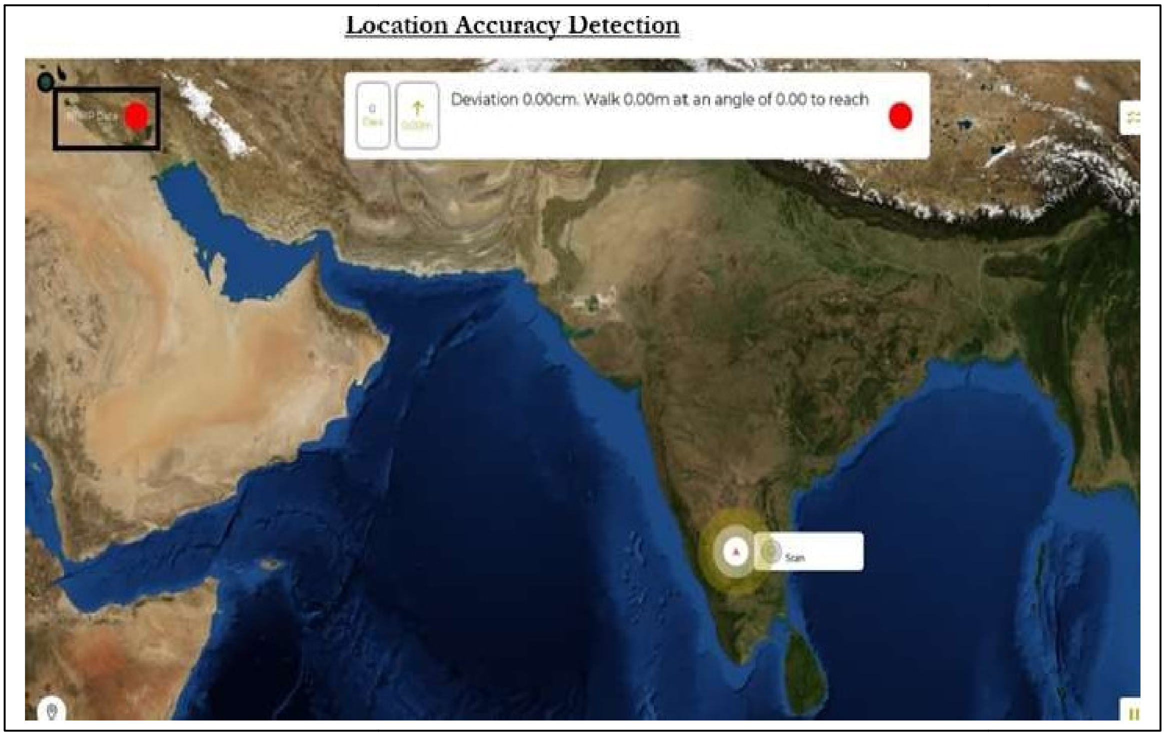
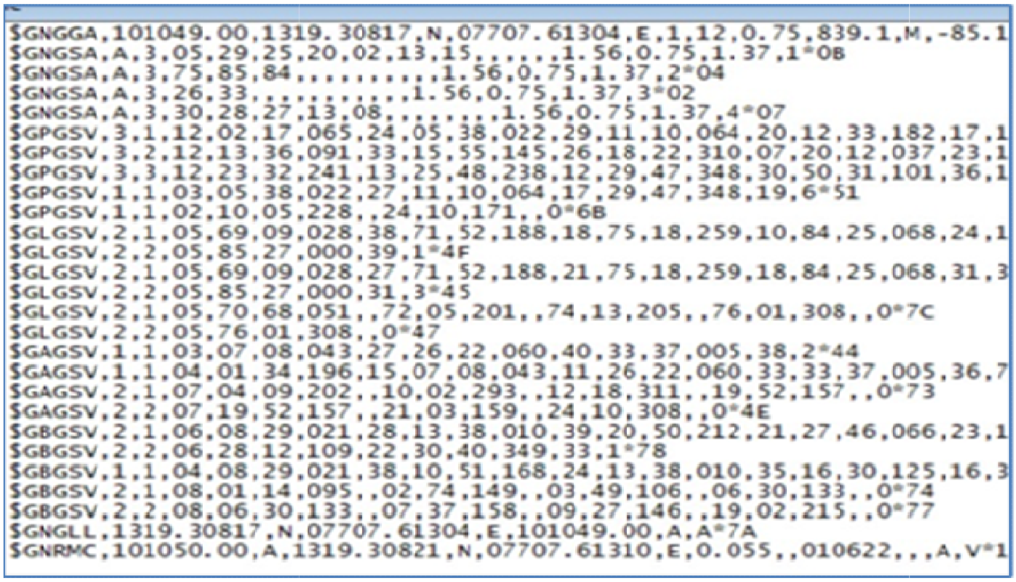


Fig. 12 PositioningAccuracyat 2mm precision and trackingfrom remote location awayat 40 km

The experiment carried out using Real Time Kinetics proves that the location accuracy up to centimeter level is achievable and it is easy to carry out land survey in the area without Internet. The results of parameter simulations and it is proven that fractal boundary antenna is suitable for all satellite application. The data is calibrated once every 4 seconds and each time dynamically the optimization logic is applied. The deviation chart depicts that 100 percent of the data are corrected and positioning accuracy is achieved. The distortions observed are analyzed and as shown in Fig. 13, the location deviations variations are captured and 4% of the location data distortions are observed.



$GNGGA,101049.00,1319.30817,N,07707.61304,E,1,12,0.75,839.1,M,-85.1
$GNGSA,A,3,05,29,25,20,02,13,15,,,,,,1.56,0.75,1.37,1*0B
$GNGSA,A,3,75,85,84,,,,,,,,,,1.56,0.75,1.37,2*04
$GNGSA,A,3,26,33,,,,,,,,,,,1.56,0.75,1.37,3*02
$GNGSA,A,3,30,28,27,13,08,,,,,,,,1.56,0.75,1.37,4*07
$GPGSV,3,1,12,02,17,065,24,05,38,022,29,11,10,064,20,12,33,182,17,1
$GPGSV,3,2,12,13,36,091,33,15,55,145,26,18,22,310,07,20,12,037,23,1
$GPGSV,3,3,12,23,32,241,13,25,48,238,12,29,47,348,30,50,31,101,36,1
$GPGSV,1,1,03,05,38,022,27,11,10,064,17,29,47,348,19,6*51
$GPGSV,1,1,02,10,05,228,,24,10,171,,0*6B
$GLGSV,2,1,05,69,09,028,38,71,52,188,18,75,18,259,10,84,25,068,24,1
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$GBGSV,2,2,08,06,30,133,,07,37,158,,09,27,146,,19,02,215,,0*77
$GNGLL,1319.30817,N,07707.61304,E,101049.00,A,A*7A
$GNRMC,101050.00,A,1319.30821,N,07707.61310,E,0.055,,010622,,,A,V*1

Fig.13. RecordofGNSSliveandrawdatafetchedatthetestingarea

Therelativepointcorrectionistobedoneonaltitudeandrelativepointcoordinates.Theamount of relative point corrected is shown in Fig. 14

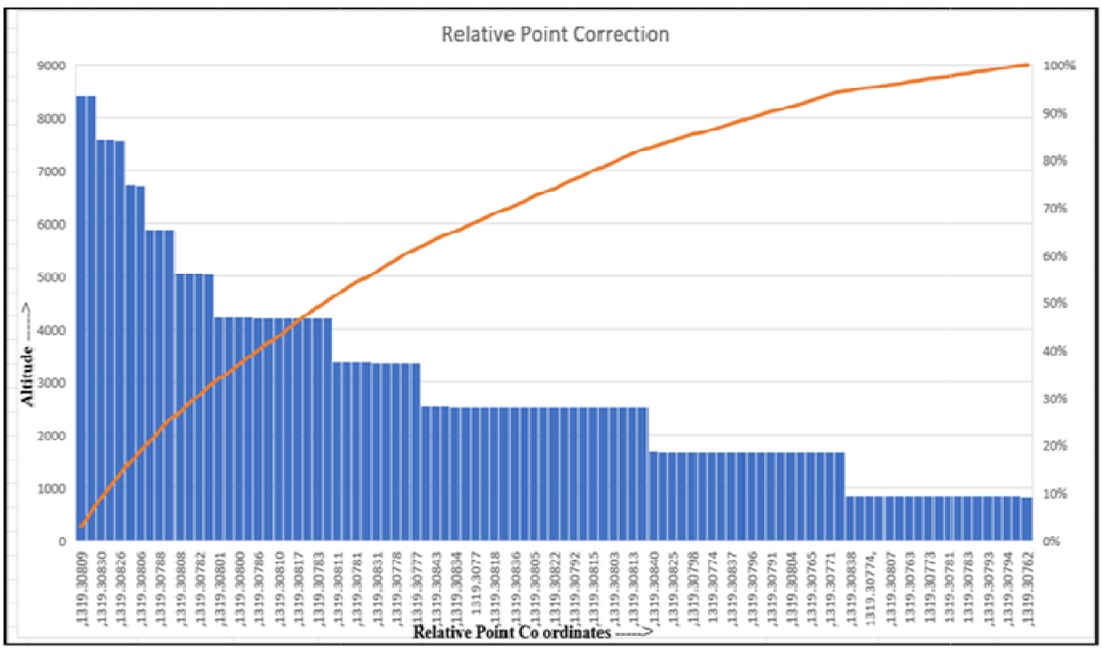

Fig.14RelativePointCorrectionStatistics

It is observed that all the relative point coordinates and the relative points are corrected with the optimizationalgorithmto achieveaccuracyof2mmatthetesting area. Thenumberofdistortions observed across the coordinate system is shown in Fig. 15.

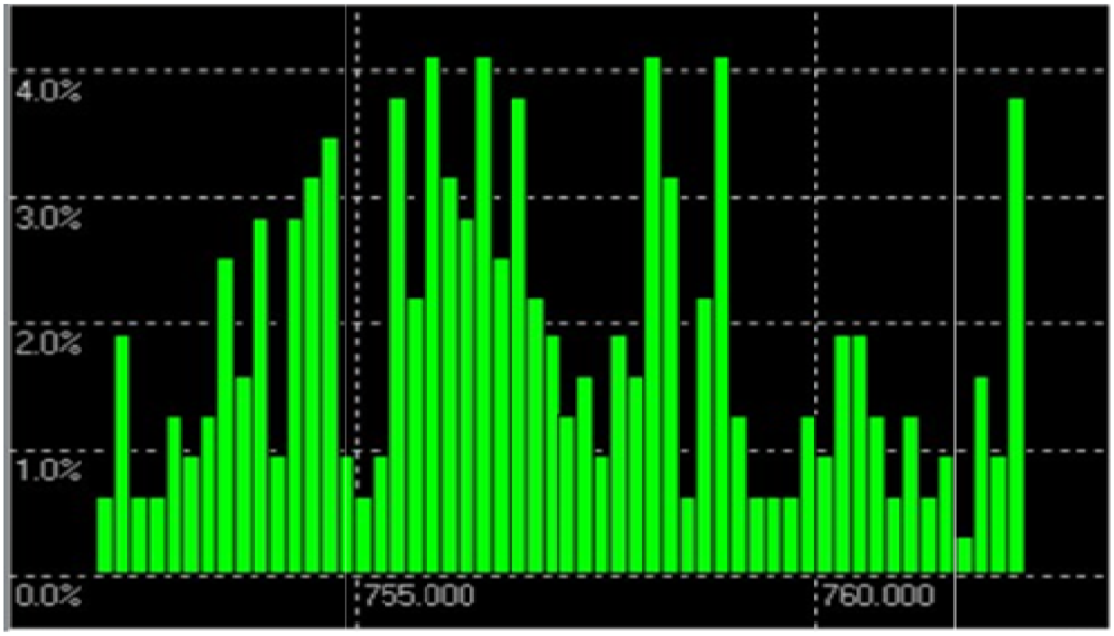

Fig.15Distortionsfetchedwhileparsingthepositioningdata

4. Conclusions

ManyIoTapplicationsusedinthefieldofPrecisionAgriculture,LandSurvey,Surveillance Systems,AutonomousVehicles,HumantoMachineandMachinetoMachineinteraction requireslivetrackingofrealtimedataonthegroundandundertheground.UsingGPSbased geofencingmethod,thoughit ispossibletofetchthenearbylocation,an accuracyupto centimetreandthenuptomillimetrelevelisnotpossible.Suchrequirementneedsextended technologysuchasRealTime Kinetics.GNSSbasedaccuracyusingReal TimeKineticsis efficientintrackingandmanagingtheIoTassets.Inthispaper,anoptimizedrealtimekinetics frameworkthatgivestheresultofupto2mmaccuracyisillustrated.The GNSSrawdata sampledandispre-processedfurtherwiththefinetuningofpatchantenna. Theresearchis carried out at Nagamangala area to demonstrate the precision accuracy and 99.9% of accuracyresult is achieved.

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DataAvailabilityStatement

None

ConflictsofInterest

Theauthordeclaresthattheyhavenoknowncompetingfinancialinterestsorpersonal relationshipsthatcouldhaveappearedtoinfluencetheworkreportedinthispaper.

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