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Application Specific Embedded Board Development Interfaced with GPS/IRNSS Receiver for Environmental Monitoring

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Abstract*: A forest fire is the most dangerous natural disaster that occurs in all countries and is a dominant factor for the destruction of vegetation and wildlife. Wildlife includes non-domesticated animal species. Wildlife is affected by human activities. Environmental Monitoring (EM) is a process for monitoring the changes that occur in the environment. Wildlife monitoring systems and Forest fire monitoring systems are an example for Environment Monitoring. This paper proposed with an environment monitoring system based on Wireless Sensor Networks (WSNs) which have spatially distributed autonomous sensors to monitor environmental conditions, give a good solution for continuous data collection. This WSN has integrated with a navigation system which consists of GPS/IRNSS receiver. Use of navigation system enables to predict the accurate location of Forest fire and animal movement. Integration of this proposed system done through an embedded board. This system helps in detecting the forest fire as well monitoring the wild life.

***Index Terms*: Embedded System, Disaster Monitoring.**

I. INTRODUCTION

Forest fire and Wildlife monitoring system will take advantage of recent advances in sensor network technologies. Depending on the nature, size, and speed of spreading, forest fires can be classified into four types are surface fires, underground fires, ground fires, and crown fires. Surface fires: it is the most common forest fire that burns small vegetation on the forest floor is an example of surface fire [1].

Fig.1 Surface Fire

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Underground fires are also called as Muck fires. These fires are caused by the organic matter present on the top of the soil. Ground fires: these fires generally burn the herbs on the forest floor and also the organic matter layer. This fire causes more damage than surface fires and they may destroy vegetation completely [3].

Fig.2. Ground Fire

Crown fires: Fig. 1. Shows an example of crown fire and it is an unpredictable form of fire that burns the top of trees. The forest fire may occur by some human activities or by natural causes. For early detection of forest fires, a Wireless Sensor Network-based forest fire detection system is employed. The Wildlife includes non-domesticated animal species [7]. Deserts, forests, plains, and grasslands all have distinct forms of wildlife. Wildlife Monitoring is the technique used to monitor, track, and locate different types of wildlife. This wildlife monitoring is consisting of tracking the animals and transmitting information to a remote server. The proposed system establishes a wireless sensor network (WSN) gateway model prior to the back-end server for diverse environmental monitoring applications [4] [5]. The design catalogs different sensor data with transmission load balance to incorporate heterogeneity of sensor signals, the stability of data transportation, and expenditure of mobile communication. The proposed system introduces an open-source wireless mesh network (WMN) module, which integrates the functions of network discovery, automatic routing control, and transmission scheduling [6]. In addition, this design is open source in order to promote the use of wireless mesh networking for environmental monitoring applications.

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Wireless sensor networks (WSN) are well suited for long-term environmental data acquisition for IoT representation [9]. The design is based on the Fire Weather Index (FWI) System. Since the lifetime of sensors in active mode is much shorter than even a fraction of one season, sensor deployment is assumed to be relatively dense such that each sensor is active only during a short period of time and the monitoring task is rotated among all sensors to achieve the target network lifetime. A hierarchical wireless sensor network (WSN) capable of transmitting and storing this information has to be developed [11]. For the efficient management of disasters in India, a Decision Support Centre (DSC) has been established. A system called "Indian Forest Fire Response and Assessment System" (INFFRAS) is operated under DSC since 2005 for the management of forest fires [10]. INFFRAS is designed to work at three different levels:

- Planning for fire control in the pre-fire stage.
- Detection and monitoring during the fire stage.
- Damage assessment in the post-fire stage.

The different wildlife monitoring techniques implemented in India i.e., for monitoring the movement of lions, a radio collar is fitted on them. This was a technique adopted by Wildlife Institute of India (WII), in association with Gujarat Forest Department. WII is using radio collars on tigers to track their movement in Sariska Tiger Reserve and Panna Tiger Reserve. This is a joint venture between National Tiger Conservation Authority (NTCA) and State governments of Rajasthan and Madhya Pradesh [12].The objective of this paper is to develop Wireless Sensor Network to detect and locate the focus of the fire and to establish a proper communication channel by including GPS and NavIC receiver [2][8]. In wildlife monitoring system sensors are used to detect the presence of an animal.

II. METHODOLOGY

In this paper, Wireless Sensor Networks and NavIC receivers are used for identifying the exact location of forest fire and wildlife. Wireless Sensor Networks has a large number of sensors, equipped with wireless transceivers to send the sensed data to the server and a microcontroller that is programmed to perform these tasks. For environment monitoring, the sensors are spread across the environment in large numbers. The Wireless Sensor Network in short consists of two parts such as data acquisition network and data distribution network. Mainly in this paper has three parts such as the Wireless Sensor Network, the Communications Network, and the Reception Centre which consists of sensors, transceivers, GPS module and Raspberry Pi. In the forest fire monitoring, the following sensors are used - Temperature; Relative humidity; Carbon monoxide (CO); Carbon Dioxide (CO2); Moisture; Smoke Sensor. In the wildlife monitoring, the sensors are used for tracking motion detection. This module is used to check the movement of animals based on its location change. The location information is obtained by using Global Positioning System (GPS). The sensors used are Ultrasonic Sensor; Infra Radar Sensor; Doppler Radar Sensor. An overview of the Wireless Sensor Network is shown in Fig.3.

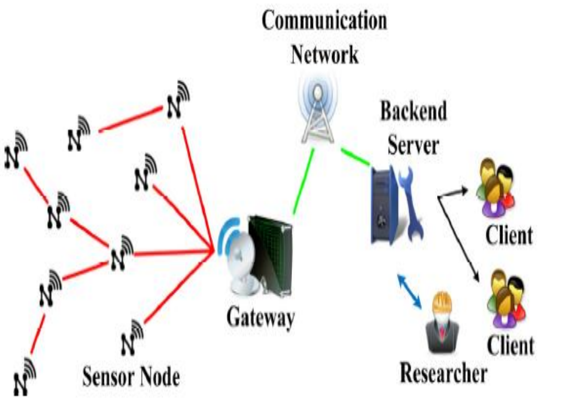

Fig.3. Overview of the Wireless Sensor Network

III. SOFTWARE AND HARDWARE TOOLS

The following sets of sensors are used for monitoring forest fire and also wildlife. Also following are the different types of tools required for the implementation of the proposed system: Raspberry Pi; Moisture Sensor; Temperature Sensor; Humidity Sensor; Smoke Sensor; Carbon dioxide Sensor; Ultrasonic Sensor; IR Sensor; Battery; Global Positioning Satellite system; NavIC Receiver.

IV. FIELD SURVEY AND NAVIGATION

The objective of the survey was to study about altitude variations and position errors, interferences, etc and also to calculate GDOP, HDOP, DOP, TOP. These calculations enable to estimate the location of a forest fire. Observation of different signals from NavIC receiver in the order of several magnitudes was done. The survey was scheduled from Achalu (Kanakpura) which is a village in the southern state of Kanakapura, India and located in the Kanakapura taluk of Bangalore Rural district. Different signal interferences and readings were noted. The setup was done with respect to antenna location, NavIC receiver location and then started journey towards Achalu Hills (Fig.4). Different signal Interferences were observed due to vegetation and the same readings for L5 and S1 bands were collected.

Fig.4. NavIC Receiver connection

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In order to estimate the accurate position, the signals from space vehicle are multiplied by GDOP term. There are various GDOP terms that can be computed by using the covariance matrix of navigation that is not independent of each other. They different components are;

* PDOP: Position Dilution of Precision or Spherical DOP.
* HDOP: Horizontal Dilution of Precision (Latitude, Longitude).
* VDOP: Vertical Dilution of Precision (Height).
* TDOP: Time Dilution of Precision (Time).

PDOP indicates the uncertainty in three-dimensional position of the navigation solution. HDOP gives uncertainty in horizontal position i.e. longitude and latitude of the navigation solution. VDOP is a measure of uncertainty in the altitude or vertical position of the navigation solution. TDOP indicates uncertainty in receiver clock.The accuracy of a GPS positioning is affected by measurement errors and also by the satellite geometry. The measurement errors can be represented by using User Equivalent Range Error (UERE) which is the square root of the sum of the squares of different errors. Multiplying UERE with GDOP gives the position accuracy i.e,

GPS Position Accuracy = UERE ×GDOP ...(1)

Let x, y, z be the position of the receiver and xi, yi, zi be the position of the satellite. Then,

$$R_i = \sqrt{(x_i - x)^2 + (y_i - y)^2 + (z_i - z)^2} \quad ...(2)$$

σ is the total User Equivalent Range Error which can be used to find covariance matrix. The covariance matrix is given by,

$$cov(x) = (A^T.A)^{-1} = \begin{bmatrix} \sigma_x^2 & \sigma_{xy} & \sigma_{xz} & \sigma_{xt} \\ \sigma_{yx} & \sigma_y^2 & \sigma_{yz} & \sigma_{yt} \\ \sigma_{zx} & \sigma_{zy} & \sigma_z^2 & \sigma_{zt} \\ \sigma_{xt} & \sigma_{yt} & \sigma_{zt} & \sigma_t^2 \end{bmatrix} \quad ...(3)$$

The expressions for GDOP, TDOP, HDOP, PDOP, and VDOP are given by

$$GDOP = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2 + \sigma_t^2} \quad ...(4)$$

$$TDOP = \sqrt{\sigma_t^2}$$

...(5)

$$PDOP = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2} \quad ...(6)$$

$$HDOP = \sqrt{\sigma_x^2 + \sigma_y^2}$$

...(7)

$$GDOP = \sqrt{\sigma_z^2}$$

...(8)

Fig.5 shows the various observations made by NavIC receivers in the form of sky plot including GPS, IRNSS SBAS types of different receivers. It will provide us an accurate near real time positioning services in and around India (extended up to 1500 km). There are three satellites in geostationary orbit, four satellites in geosynchronous orbit which are 36000 km above the earth surface.

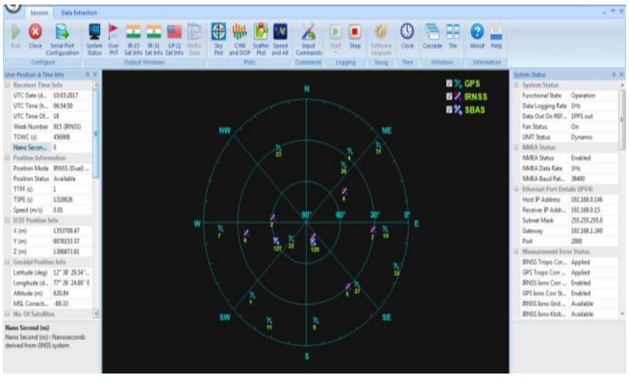

Fig.5. Sky-plot of Various location of NavIC/GPS/SBAS satellites by NavIC receiver

Fig.5-7 shows skyplot for NavIC Receivers and GPS Receivers one at a time respectively. It will find out the location which is considered to be most useful in several orders of magnitudes.

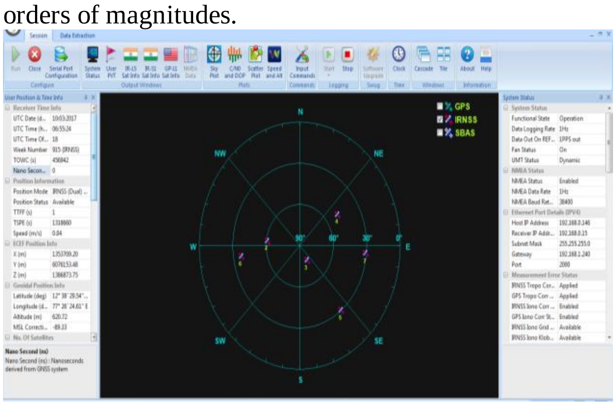

Fig.6. Skyplot of Various location by NavIC receiver

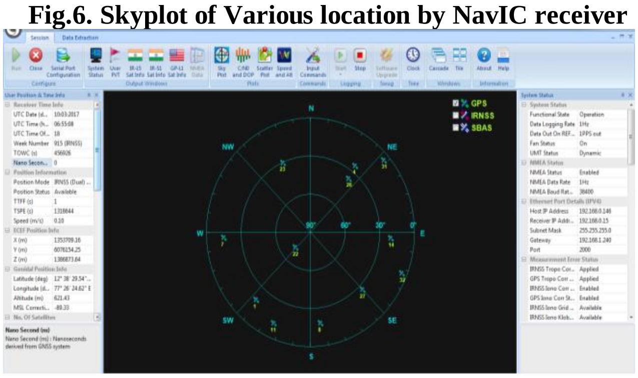

Fig.7. Skyplot of Various location by NavIC receiver

Fig.8 represents Carrier to Noise (C/N_0) ratio of various signals observed from NavIC receiver. The representation of carrier to noise ratio helps to determine signal strength and therefore plays an important role. Signals are considered to be essential elements for the variation. Top row C/N_0 for GPS and SBAS and below shown for IRNSS L5 and S1 band. Fig. 9 represents various pattern of the signals observed from NavIC receiver with respect to TOWC v/s altitude variations. Fig.10 represents real time data collection of L5 band and Fig.11 for GPS signals real time data collection.

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Fig.8. Signals from NavIC Receiver

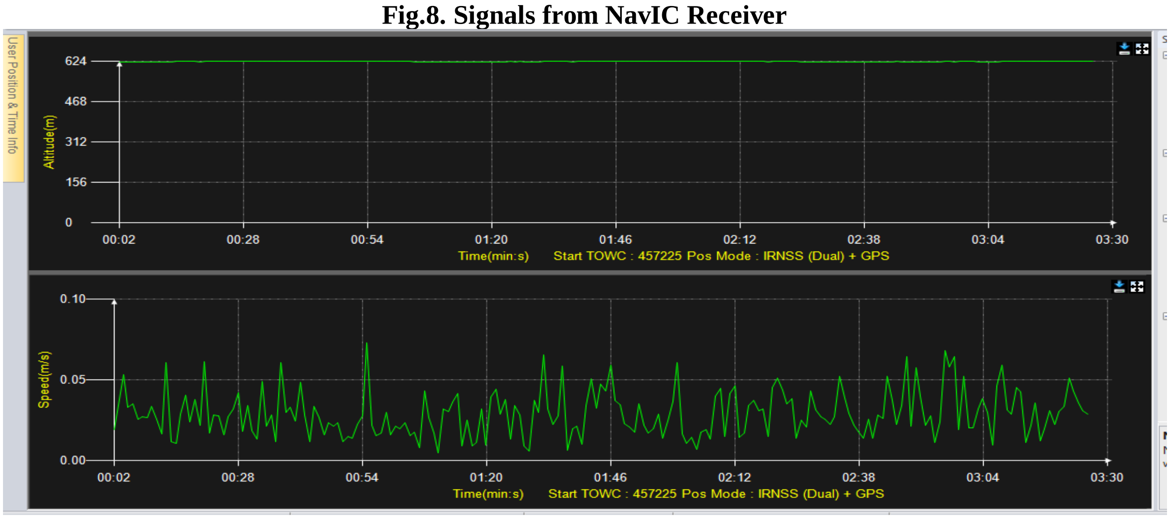

Fig.9 Signals from NavIC Receiver

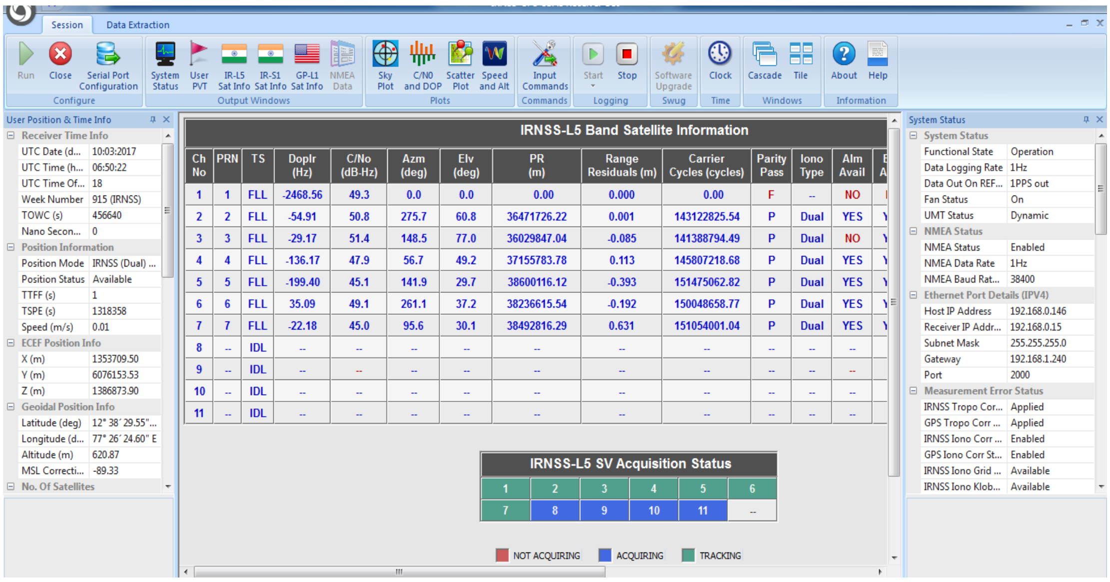

Fig.10 Data collection from NavIC Receiver

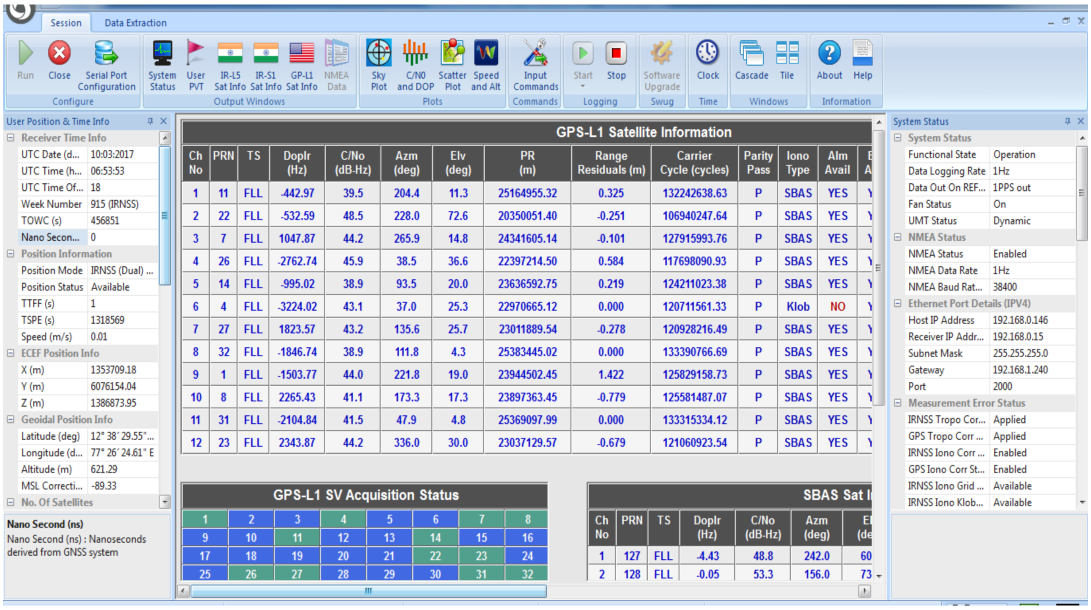

Fig.11 Data collection from NavIC Receiver

V. IMPLEMENTATION

This paper segmented with three parts such as Sensor Modules, the Communication Network, and Navigation Receiver. The Reception Centre which consists of sensors, transceivers, GPS module and Raspberry Pi. Fig.12. shows proposed model for the forest fire and wildlife detection system in presence of various sensors, server, Raspberry pi board and Navigation system. The sensor in Fig. 12 used to determine the various parameters which can be measured in remote location. Usually the sensor output will be normal which is recorded for the deployed environment. If there is a fire which is detected by these sensors the values will record beyond the threshold in following sensors: Temperature Sensor, Smoke Sensor, CO Sensor and Humidity Sensor. Whenever there is movement of any animal in the surrounding which will interfere with signals of following sensors: Optical Sensor, IR Sensor, and Ultrasonic Sensor.

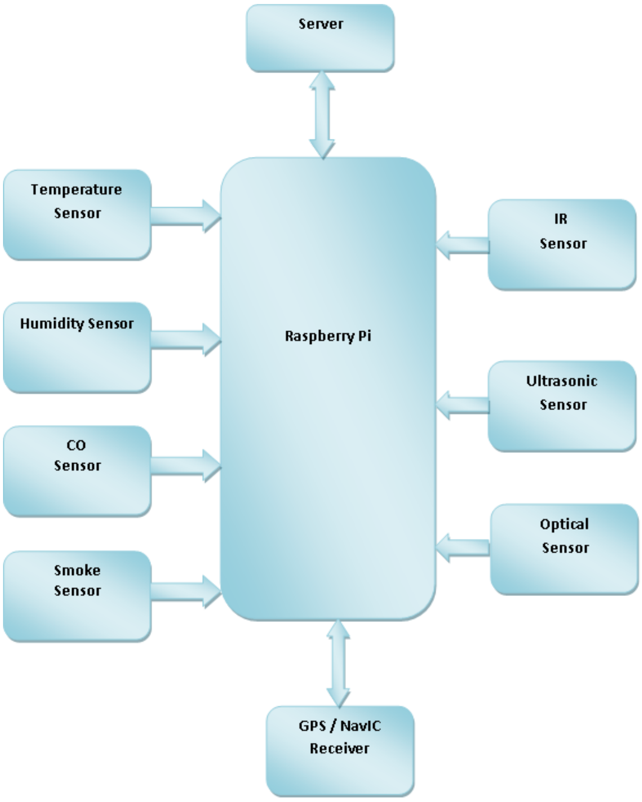

Fig.12 shows proposed model

The field setup was done with respect to antenna location, NavIC receiver location and then started journey towards Achalu Hills. Different signal Interferences were observed. The reading for L5 and S1 Bands were collected. Fig.13. shows the survey set up with antenna and NavIC receiver.

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Fig. 13(a) Antenna and NavIC receiver setup for field survey

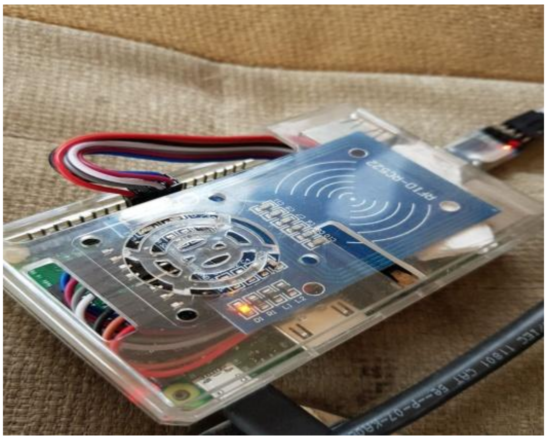

Fig. 13(b) Antenna and NavIC receiver setup for field survey

By using the above setup different signal Interferences were observed. Fig.14 shows the data received by testing of sensors with Raspberri Pi board. Current position map of the experiment area can be seen in portable device display Pi board.

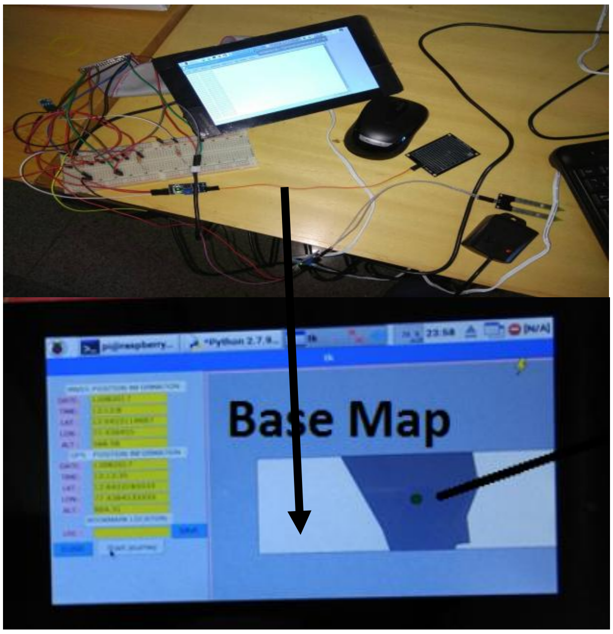

Fig.14 Testing of sensors with Raspberri Pi board

The power strategy for sensor nodes that will be deployed in the forest will be tagged with a powerbank which is connected to solar power backup. It is a great resource for our system to survive for the longer duration. So that, the system life time will be increased.

VI. RESULTS AND DISCUSSION

The monitoring system is designed for forest fire and wildlife. Forest fire affects both wildlife and vegetation. The main concern of the natural resource management agencies in the last decade is the effect of roads on wildlife populations.

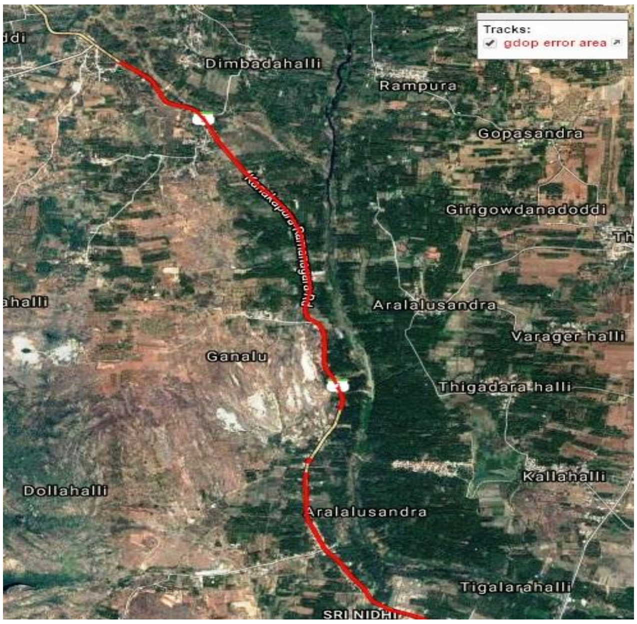

Fig. 15 Vegetation area in hills

Fig.16 Position map of Achalu hills

Roads affect wildlife populations in numerous ways, from habitat loss, barriers to animal movement, and wildlife mortality. Fig. 15 path contains more vegetation area and 16 show the path for the hill region are the two different sites selected for our experiment survey.

Accidents with wildlife are becoming a major safety concern. The monitoring system uses sensors like moisture sensor, Doppler sensor, temperature sensor, humidity sensor, ultrasonic sensor and IR sensors which are connected to the Raspberry Pi. GPS along with NavIC receiver is used for Navigation. The navigation system was used to get the exact location of the forest fire. This enables the position estimation. But in the navigation system, there can be few errors which are unavoidable. The Fig. 16 illustrates the position map of Achalu forest which is situated in Ramnagara district in Bangalore utilizing NavIC receiver and the same have been plotted in Lat v/s Long graph shown in Fig.17. It specifies the additional multiplicative effect of navigation satellite geometry on positional measurement precision. The position data varies due to the foliage loss.

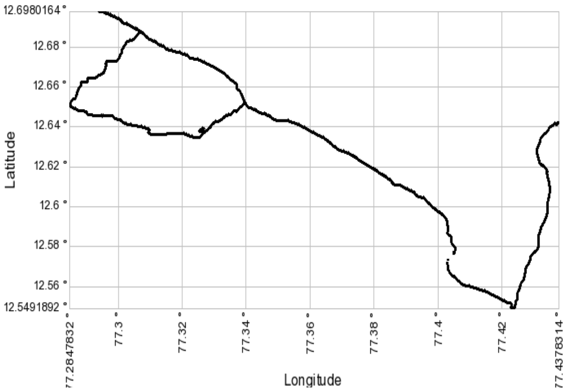

Fig.17 Position accuracy

The Fig. 18 illustrates the altitude variations from Jain University campus to Achalu hills. In the position accuracy, the variations in the positions are being calculated. In the case of GPS, it may have less error compared to NavIC position error. The altitude dropped to 0 in some places, due to vegetated area signals dropped.

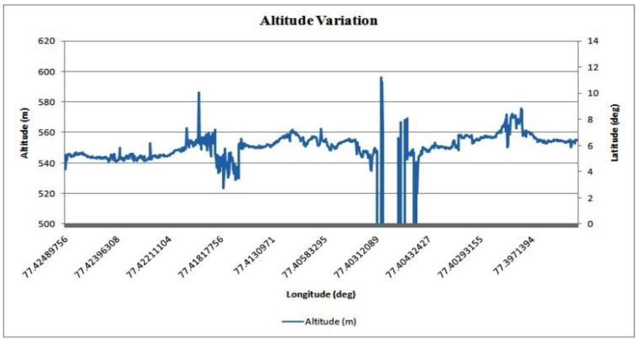

Fig.18. Plot of Altitude Variation

Altitude variation is another parameter used for the Navigation and positioning by satellite. It deals with the height and is important in indicating the position of a forest fire.

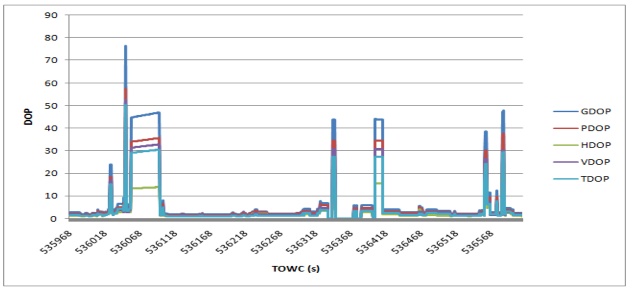

Fig.19. Dilution of precision values

Dilution of precision values plays most important role in the Navigation. Geometric Dilution of Precision, Position dilution of precision, vertical dilution of precision, horizontal dilution of precision and Time dilution of precision are its various types plotted with respect to TOWC shown in Fig.19.

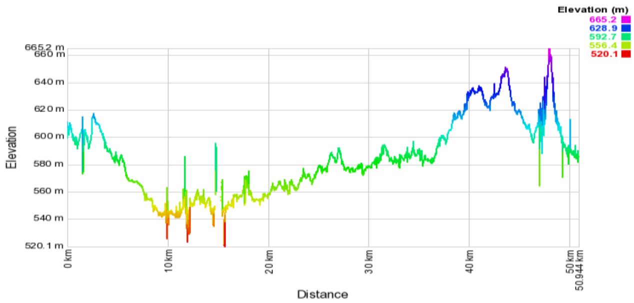

Fig.20 Elevation graph

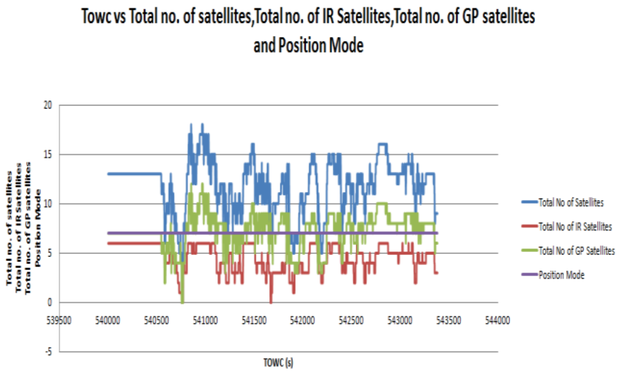

Fig.21 Total number of satellite present

Fig.20 illustrates the graph of elevation with respect to distance of the experiment survey and Fig.21. represents total number of satellite present and total number of visibility of satellites during survey period. Thus, total number of satellites and visibility of satellites plays vital role for the navigation and positioning.Ionosphere scintillation significantly affects the performance of navigation systems such as GPS and IRNSS. Signal fading is caused by amplitude and phase scintillation of the signal and may result in fluctuations of carrier to noise ratio. The signal will be undetected if the signal fading exceeds fade margin of the receiver. Further signal distortion, data loss, and loss of lock on the signal are some of the degrading effects. Experiment survey have been taken in 3 stages are single frequency i.e., L5 band and S1 band separately and dual frequency.

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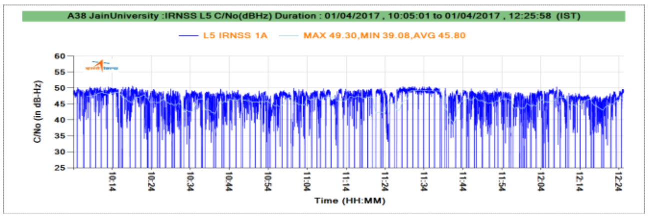


Fig.22 C/No Plot of L5 IRNSS 1A

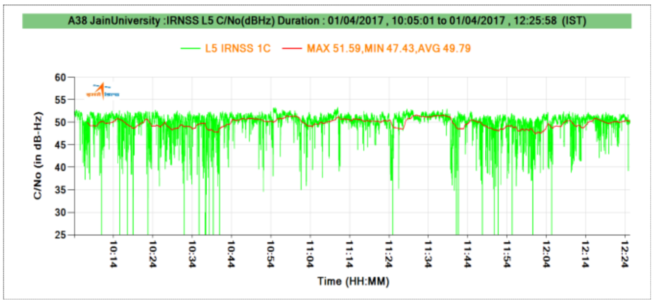


Fig.23 C/No Plot of L5 IRNSS 1C

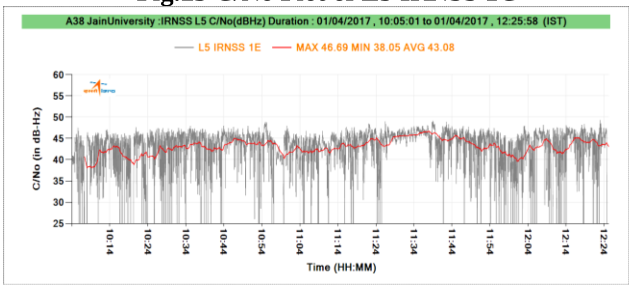


Fig.24. C/No Plot of L5 IRNSS 1E

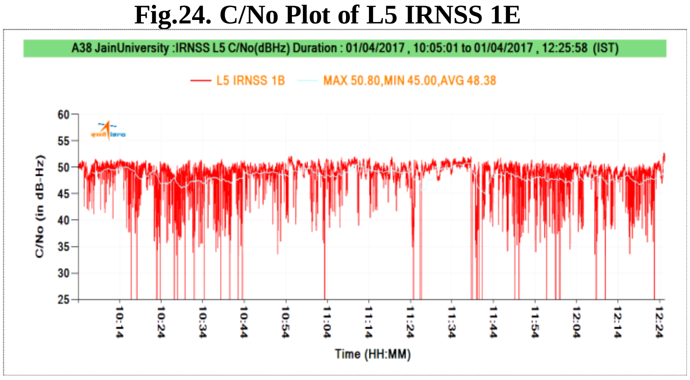


Fig.25. C/No Plot of L5 IRNSS 1B

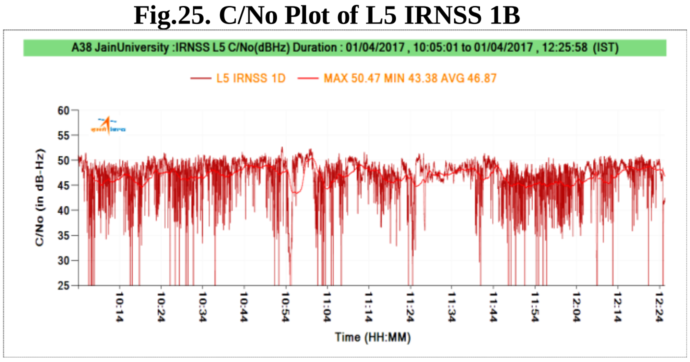


Fig.26. C/No Plot of L5 IRNSS 1D

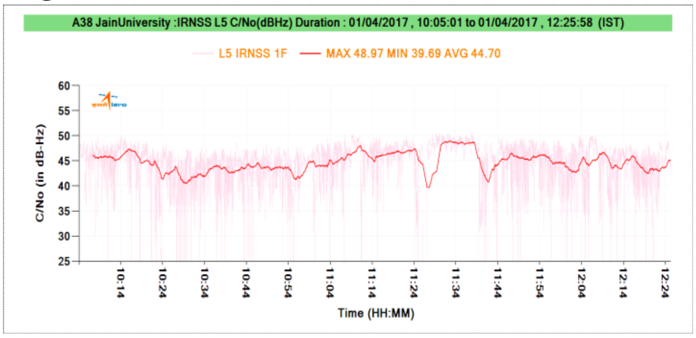


Fig.27. C/No Plot of L5 IRNSS 1F

From Fig. 22 to 27 shows the carrier to noise ratio v/s time taken to complete our experiment survey and the same plotted for all the IRNSS/NavIC satellites of L5 band frequency.

S Band C/No Plots

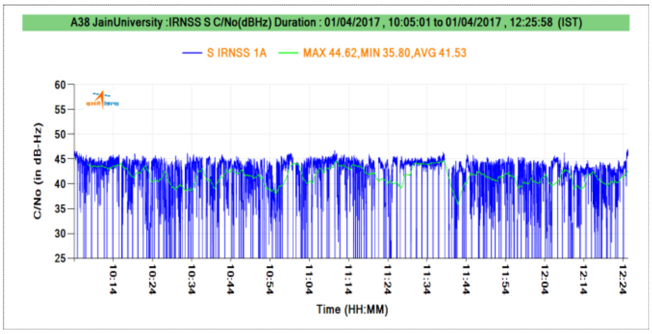


Fig.28. C/No Plot of S Band IRNSS 1A

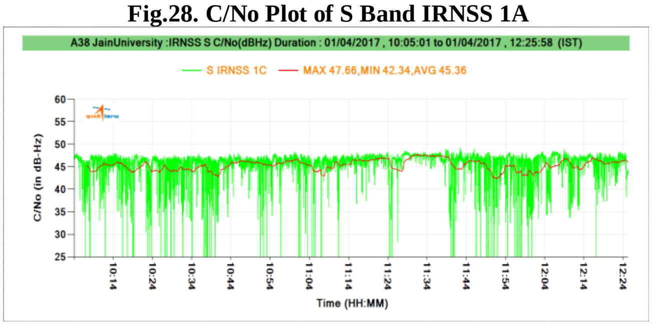


Fig.29 C/No Plot of S Band IRNSS 1C

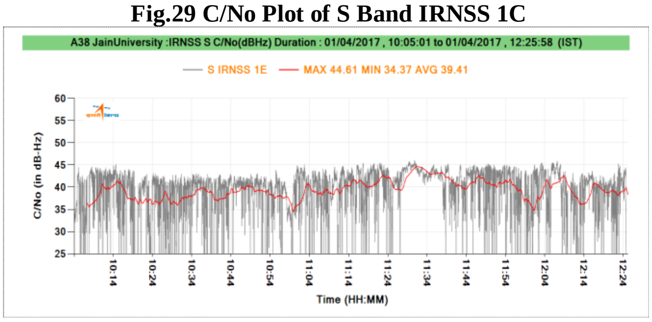


Fig.30. C/No Plot of S Band IRNSS 1E

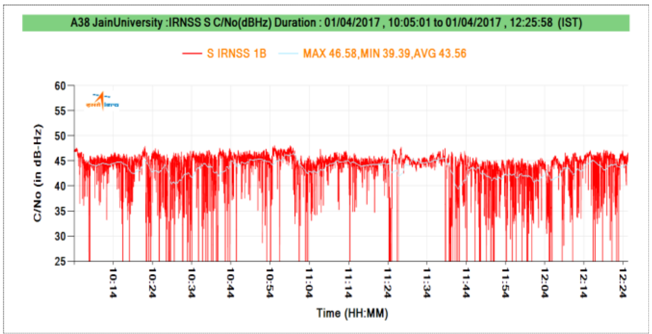


Fig.31. C/No Plot of S Band IRNSS 1B

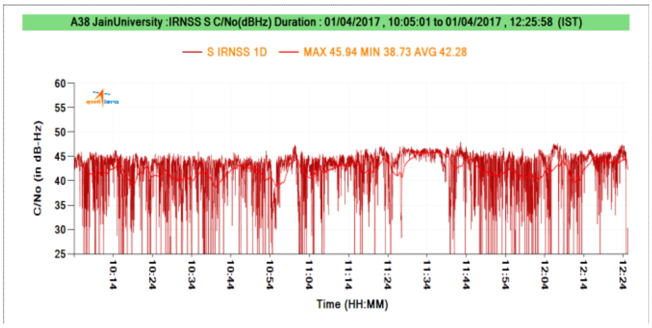


Fig.32. C/No Plot of S Band IRNSS 1D

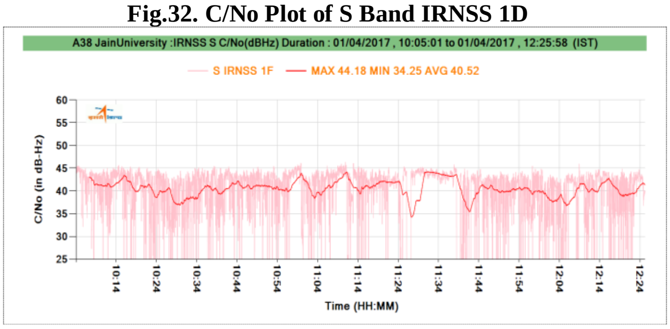


Fig.33. C/No Plot of S Band IRNSS 1F

Same experiment was repeated for the S1 band frequency and the same is represented from Fig. 28 to 33 i.e., the carrier to noise ratio v/s time taken to complete our experiment survey.

L5 and S1 Band C/No Plots

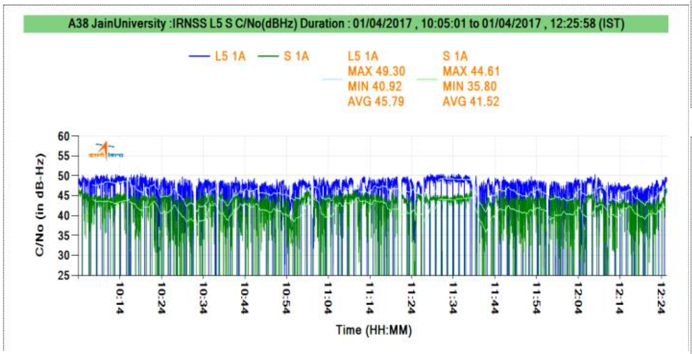
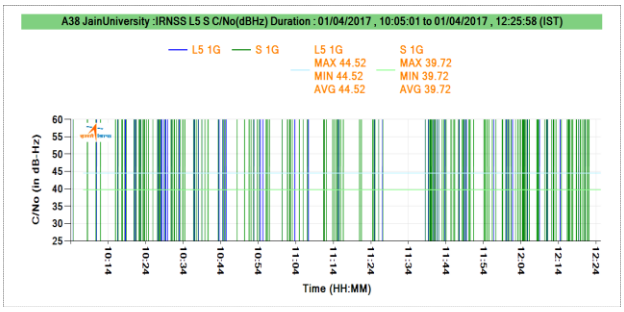


Fig.34 C/No Plot of L5 1A and S 1A



Lastly same experiment was repeated for dual frequencies (L5+S1) observation i.e., both L5 band (represented in blue colour) and S1 band (represented in green colour) frequency active and the same is represented from Fig. 34 to 37 i.e., the carrier to noise ratio v/s time taken to complete our experiment survey. Few places signals dropped below 25 dB-Hz are the places where vegetation is more in hill region. Table.1 shows the data collected at the time of survey from all 7 IRNSS satellites.

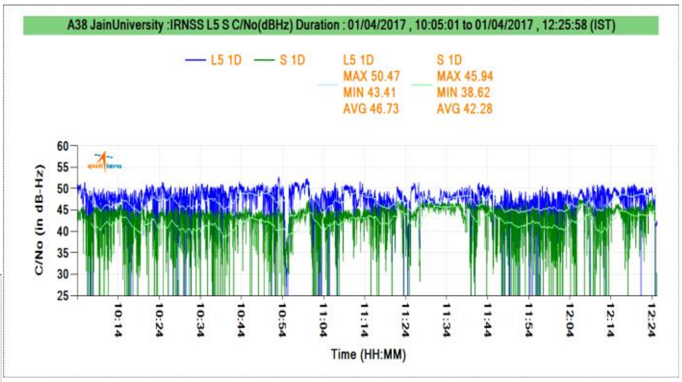


Fig.36 C/No Plot of L5 1D and S 1D

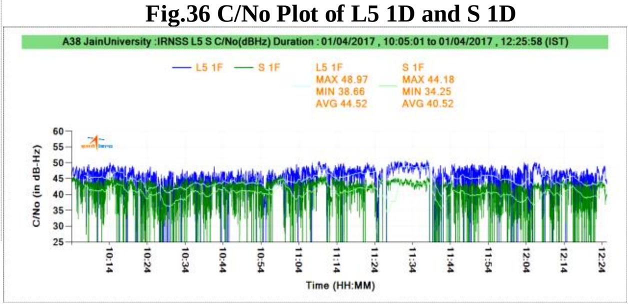


Fig.37 C/No Plot of L5 1F and S 1F

Fig.35 C/No Plot of L5 1G and S 1G

Table 1 Survey data collected for dual frequency mode

TOWC (s)	C/NO-1 (dB-Hz)	C/NO-2 (dB-Hz)	C/NO-3 (dB-Hz)	C/NO-4 (dB-Hz)	C/NO-5 (dB-Hz)	C/NO-6 (dB-Hz)	C/NO-7 (dB-Hz)
534901	47.97113	49.87846	52.22389	50.06029	41.8382	46.98639	47.43104
534902	49.02091	50.22685	52.24359	51.11217	41.72825	46.65748	47.23532
534903	47.77511	49.83763	52.00746	50.37508	40.89351	46.20042	47.34572
534904	48.15793	50.27586	51.84542	50.81337	41.00301	45.96288	47.46586
534905	48.75196	50.18191	51.76257	49.8339	40.54168	45.71936	47.24326
534906	47.74607	50.11422	51.70848	50.22115	40.44373	46.28293	47.69520
534907	48.32000	50.12532	52.03658	50.01874	40.61040	45.97566	47.28921
534908	48.45869	50.08176	51.90377	49.97793	40.10987	46.24662	46.98721
534909	48.10479	49.86895	51.56900	50.16776	38.88779	46.55403	46.92675

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VII. CONCLUSION

Integrated Sensor Modules and NavIC receiver were used for identifying the exact location of forest fire and wildlife monitoring in real time. Wireless Sensor Networks had a large number of sensors, equipped with wireless transceivers to send the sensed data to the server and Raspberry Pi that is programmed to perform these tasks. For environment monitoring, the sensors were spread across the environment in large numbers. This paper discussed about the navigation concepts of NavIC/GPS along with its real time performance. This proposed system gathers data in all weather conditions and for a quite long time. The different parameters related to the monitoring was collected in real time were analysed. The unique feature of this system is that it is cost effective and energy efficient. This sensor module has integrated with a navigation system which consists of GPS/IRNSS receiver. This navigation system enables to predict the accurate location of Forest fire and animal movement in the forest area. Integration of this proposed system done through an embedded board Raspberry Pi. This system helps in detecting the forest fire as well monitoring the wild life in real time and communicates to the server.

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