Project Report

RFID Object Tracking System

Submitted by

Gaurav Gupta

Team members:

Shiv Prakash
Gouri Shankar

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1. RFID Object Tracking System

1.1 Introduction

Object tracking using RFID has grown very popular these days. Its wide applications including object identification, predicting location, assets tracking makes it significant in enhancing security and personnel comfort. Tracking of assets like tools in workshop holds significant advantages. By making tracking process automatic, we can make process faster and can achieve significant savings in human effort.

When the number of assets to be tracked are very large this system has proved its usefulness. Because of its long range wireless nature it can be used in indoor as well as in outdoor environments even with presence of other stray (in sense not to be tracked or obstacle) objects. This system of tracking is widely appreciated because of its mobile nature i.e. both receivers as well as tags can have dynamic locations. That is why this system can be applied for personnel also. These RFID tags are very small in size and light weight which make them handy as far as personnel are concerned and have very low power consumption which makes them long lasting.

A basic RFID tracking system consists of a receiver, an operating system and tags. Tags are small wireless transmitters which transmits unique identification code which can be identified by receiver when enquired. The quantity of receivers can be more than one and they are connected to generally a central server which takes care of these receivers and data management. These receivers are connected to a server through wired network and recorded information can be accessed remotely.

System Overview

The block diagram for RFID Object Tracking System is shown in fig. 1.1. It consists of mainly three components namely Environment, server and remote GUI running setup.

The environment can be indoor or outdoor. The receiver and tags are placed in an environment first and their locations are marked and measured. The RFID receiver keep track on tags and send information to server.

The server is connected to the receiver present inside environment. At the server end, unique ID's send by receiver are collected and stored in a database. A MySQL database server keeps the record.

The recorded information can be accessed remotely. A Graphical Viewer Application GUI running on remote computer provides a real-time graphical representation of tags and receiver locations in an environment.

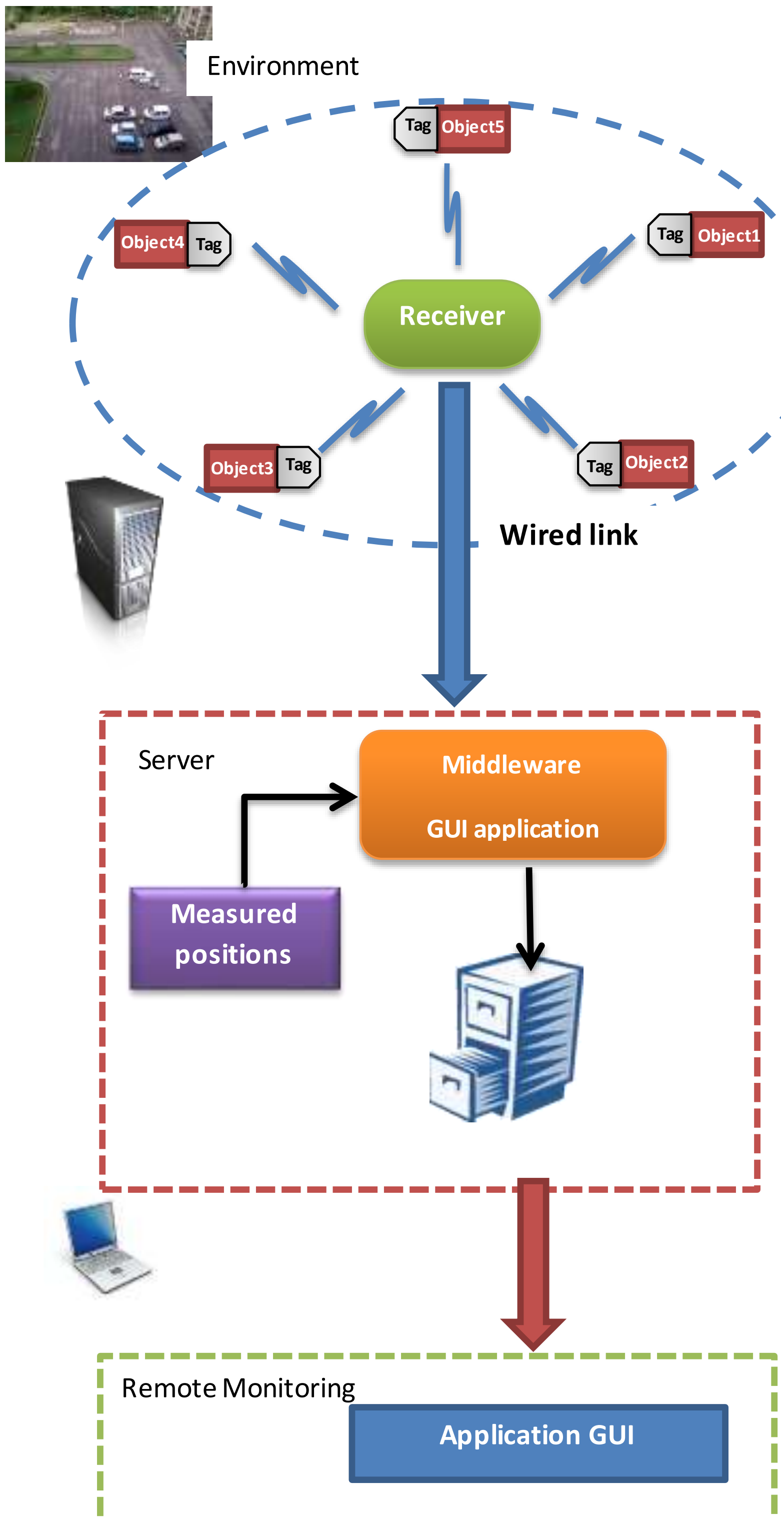


Fig. 1.1 block diagram of process

The following sections elaborate in detail on the components of RFID Object tracking system namely environment, the server, and the object tracking application GUI.

1.2 Environment

Fig. 1.2 shows the diagram for an environment used in experimenting receiver and tags detection. Environment can be indoor or outdoor. The experiment begins with selection of environment and placement of reader and tags on it. For experiment purpose certain points on map (environment) are marked first and their co-ordinates are noted in suitable units with respect to an origin chosen suitably in a rectangular co-ordinate system. After marking the map, placement of receiver and tags begins on marked points.

This environment consists of our assets which we want to track using our system and may be some obstacles which interfere in doing so. The receivers are generally placed at sufficient height so that they can cover a large area for detection. Tags are generally very small as compared to assets which we are tracking and generally attached to highest point available on asset. The tags used are active tags (i.e. they transmit their own signal) therefore detection is approximately completely dependent upon their transmission power. Tags transmission behavior can vary according to environment.

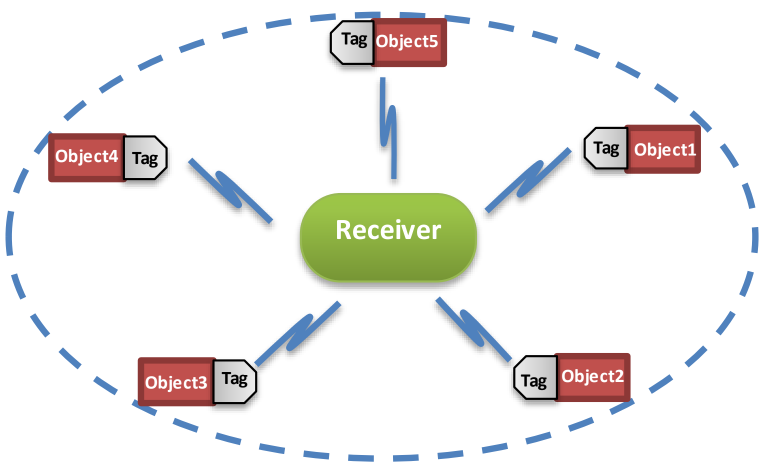


Fig. 1.2 Arrangement in an environment

Before describing placement and selection of environment, let us describe the components of RFID object tracking system.

Sapphire Vision V652 Tag Reader

Sapphire VISION reader as shown in fig. 1.3 is a single receiver used for tag detection; tag localization requires a Sapphire DART RTLS System (minimum system for localization requires 4 receivers, a reference tag, cabling and a processing hub).

Each Sapphire tag repeatedly sends out a packet burst consisting of a short train of UWB pulses, each pulse having an instantaneous bandwidth of 1GHz. Since individual tags are not

Fig. 1.3 Sapphire Vision Reader

synchronous, and the packet bursts are of extremely short duration, the probability of tag packet collision is very small allowing for the simultaneous processing of hundreds to thousands of tags in a local area. Each Sapphire VISION reader uses a highly sensitive, very high speed, short pulse detector to measure tag packet arrival at its antenna. For specification details see Appendix.

Sapphire Vision reader is connected to a computer via Ethernet cable and its network parameters can be modified on existing network by using configurator as shown in fig. 1.4. This configurator can be started by opening a web browser and entering IP address. It requires java plugin to be installed as pre-requisite in web browser. After changing the IP settings, currents changes can be saved by pressing save button.

Fig. 1.4 Reader Configuration Menu

After configuration is done reader is ready to operate and it starts detecting tags (explained in later section) when "Tag Reader" is pressed as shown in fig 1.5. JAVA client provided displays list of tags unique identification code read along with their last seen date and time. It also shows current battery level of tags read and their blinking rate.

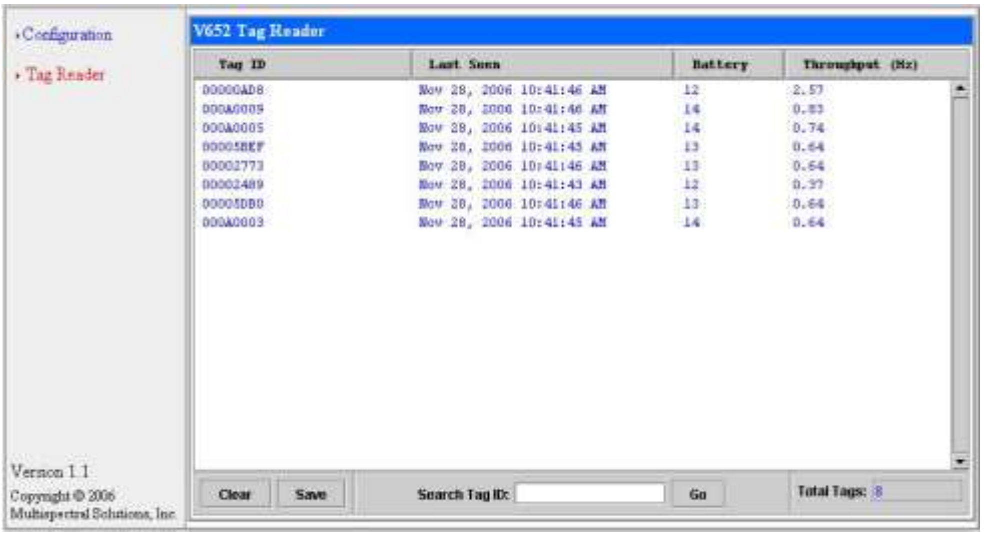


Fig. 1.5 JAVA applet for displaying list of tags read

Sapphire Tags

Sapphire Tags are UWB transmit only devices that communicate to the receivers wirelessly.
They have a nominal center frequency of 6.35 GHz with a peak and average power compliant with FCC Part 15 regulations. Tags are powered with a 3V battery with a life expectancy proportional to the size of the battery. The tags currently used for experiments are of three kinds namely

1. T651-1x1 as shown in fig.1.6 (i) for assets tracking.
2. T651-BDG as shown in fig.1.6 (ii) for personnel tracking.
3. T651-MIC as shown in fig.1.6 (iii) for assets tracking.

(i) **(ii)** **(iii)**

Fig. 1.6 Sapphire tags

Although these tags have very long battery life but these tags have capability to be switch on/off to further save power when not in use. Sapphire tags transmit their unique identification code over channel continuously at certain rate which is known as blinking rate which can be changed by using a Dart Wand module.

DartWand module

DartWand module as shown in fig. 1.7 is used to configure and manage thousands of tags. The DartWand Module transmits LF instructional messages to the DartTags and in turn can receive UWB validation from the DartTags for validation and inventorying purposes. The DartWand module is capable of configuring any tag within its LF range, up to 100 tags at once. It can configure their present power status (on/off) as well as their blinking rate.

Fig. 1.7 DartWand Module

DartWand module is provided with its operating application as shown in fig. 1.8. This application starts as soon as it detects the presence of hardware connection to system. Tags on whom we want to apply changes are to be placed near module. After pressing “Find tags…” button it gives list of all tags near to it and changes selected from available menus can be applied by pressing “Go” button.

2. Reader Application GUI

Reader application GUI is a graphical user interface created by us as shown in fig. 2.1 to read data send by receiver, and sending it to server for storing in MySQL database. Reader application connects to the receiver via opening a TCP/IP port over a network. The number of tags using and their unique Tag ID is entered in MySQL database before carrying out a particular

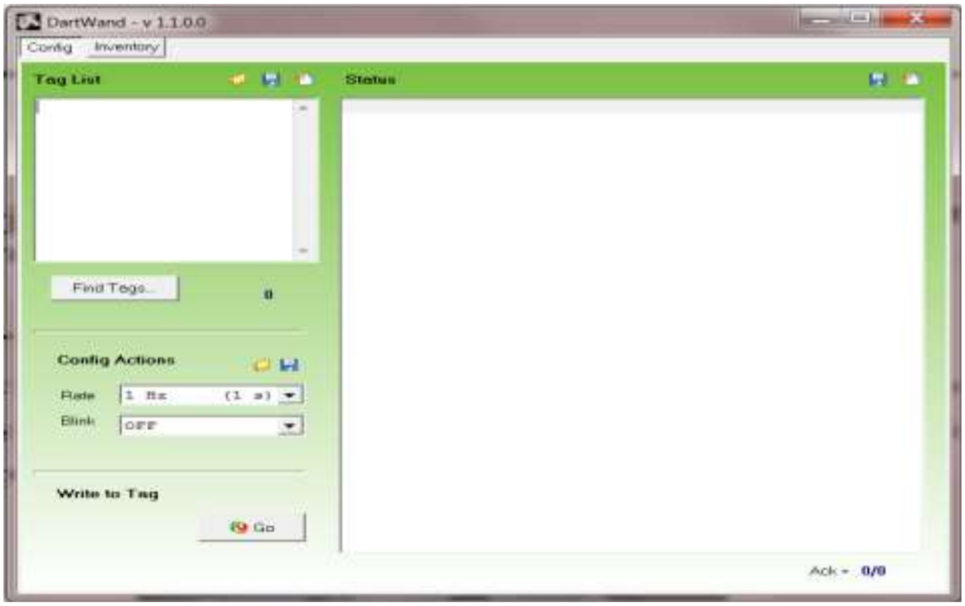


Fig. 1.8 Application for DartWand module

experiment. Reader application before opening connects to database for enquiring available tags for experiment and gives list of that tags along with their Id's as shown.

For connecting to database server it requires username and password provided by user at time of starting or can be saved in password vault inside itself.

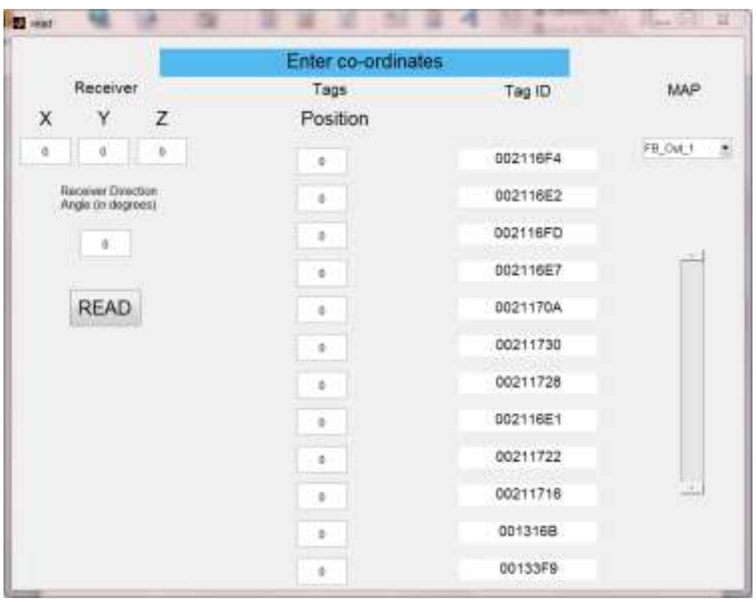


Fig. 2.1 Reader Application GUI

2.1 Functionalities:

1. Receiver

Receiver section is provided to enter co-ordinates in rectangular co-ordinate system along with orientation of receiver specified in terms of angle in degrees with respect to origin as described in fig. 2.2. The angle can be positive or negative with positive implies counterclockwise direction and negative implies clockwise direction.

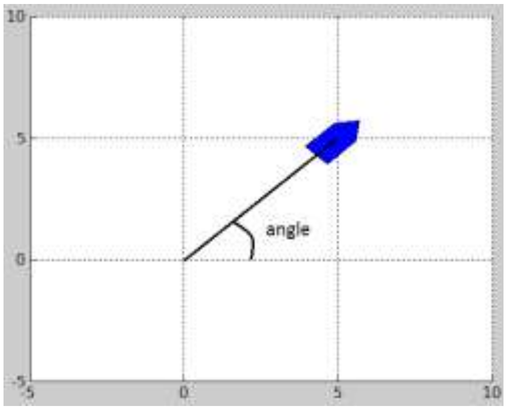


Fig. 2.2 Receiver symbol

2. Tags and Tag ID

Tags section is used to designate position occupied by a tag with corresponding Tag Id on a map. Positions as stated above are measured earlier on a map with their co-ordinates saved in database.

3. Map

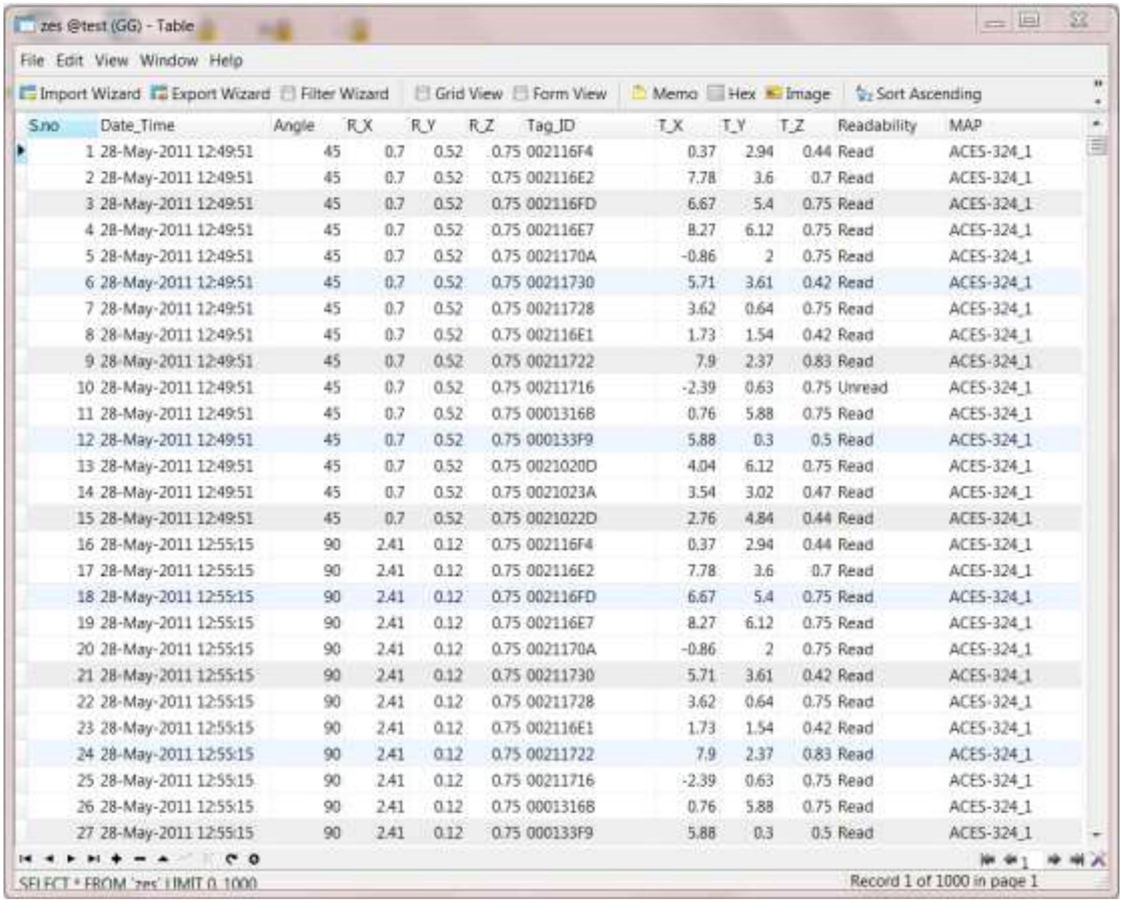
Reader application is provided with a popup menu used to select particular map on which experiment is currently being performed from list of maps.

4. READ

The "READ" button is to be press to store all details contained by GUI which includes receiver and Tags positions, map name, current date and time and tags read by receiver to database server.

Some other details related to Reader Application are:

- The database table formed by Reader Application has format as shown in fig. 2.3. It consists of columns namely, Date & time, Angle of receiver with respect to origin, Receiver and tags co-ordinates, Read status of tags and Map name.
- The status of current task is displayed on top of Application and it also displays instructions for next task. For example while making connection to database server if connection fails it displays "Connection to database not established".



zes @test (GG) - Table

File Edit View Window Help

Import Wizard Export Wizard Filter Wizard Grid View Form View Memo Hex Image Sort Ascending

S.no	Date_Time	Angle	R_X	R_Y	R_Z	Tag_ID	T_X	T_Y	T_Z	Readability	MAP
1	28-May-2011 12:49:51	45	0.7	0.52	0.75	002116F4	0.37	2.94	0.44	Read	ACES-324_1
2	28-May-2011 12:49:51	45	0.7	0.52	0.75	002116E2	7.78	3.6	0.7	Read	ACES-324_1
3	28-May-2011 12:49:51	45	0.7	0.52	0.75	002116FD	6.67	5.4	0.75	Read	ACES-324_1
4	28-May-2011 12:49:51	45	0.7	0.52	0.75	002116E7	8.27	6.12	0.75	Read	ACES-324_1
5	28-May-2011 12:49:51	45	0.7	0.52	0.75	0021170A	-0.86	2	0.75	Read	ACES-324_1
6	28-May-2011 12:49:51	45	0.7	0.52	0.75	00211730	5.71	3.61	0.42	Read	ACES-324_1
7	28-May-2011 12:49:51	45	0.7	0.52	0.75	00211728	3.62	0.64	0.75	Read	ACES-324_1
8	28-May-2011 12:49:51	45	0.7	0.52	0.75	002116E1	1.73	1.54	0.42	Read	ACES-324_1
9	28-May-2011 12:49:51	45	0.7	0.52	0.75	00211722	7.9	2.37	0.83	Read	ACES-324_1
10	28-May-2011 12:49:51	45	0.7	0.52	0.75	00211716	-2.39	0.63	0.75	Unread	ACES-324_1
11	28-May-2011 12:49:51	45	0.7	0.52	0.75	0001316B	0.76	5.88	0.75	Read	ACES-324_1
12	28-May-2011 12:49:51	45	0.7	0.52	0.75	000133F9	5.88	0.3	0.5	Read	ACES-324_1
13	28-May-2011 12:49:51	45	0.7	0.52	0.75	0021020D	4.04	6.12	0.75	Read	ACES-324_1
14	28-May-2011 12:49:51	45	0.7	0.52	0.75	0021023A	3.54	3.02	0.47	Read	ACES-324_1
15	28-May-2011 12:49:51	45	0.7	0.52	0.75	0021022D	2.76	4.84	0.44	Read	ACES-324_1
16	28-May-2011 12:55:15	90	2.41	0.12	0.75	002116F4	0.37	2.94	0.44	Read	ACES-324_1
17	28-May-2011 12:55:15	90	2.41	0.12	0.75	002116E2	7.78	3.6	0.7	Read	ACES-324_1
18	28-May-2011 12:55:15	90	2.41	0.12	0.75	002116FD	6.67	5.4	0.75	Read	ACES-324_1
19	28-May-2011 12:55:15	90	2.41	0.12	0.75	002116E7	8.27	6.12	0.75	Read	ACES-324_1
20	28-May-2011 12:55:15	90	2.41	0.12	0.75	0021170A	-0.86	2	0.75	Read	ACES-324_1
21	28-May-2011 12:55:15	90	2.41	0.12	0.75	00211730	5.71	3.61	0.42	Read	ACES-324_1
22	28-May-2011 12:55:15	90	2.41	0.12	0.75	00211728	3.62	0.64	0.75	Read	ACES-324_1
23	28-May-2011 12:55:15	90	2.41	0.12	0.75	002116E1	1.73	1.54	0.42	Read	ACES-324_1
24	28-May-2011 12:55:15	90	2.41	0.12	0.75	00211722	7.9	2.37	0.83	Read	ACES-324_1
25	28-May-2011 12:55:15	90	2.41	0.12	0.75	00211716	-2.39	0.63	0.75	Read	ACES-324_1
26	28-May-2011 12:55:15	90	2.41	0.12	0.75	0001316B	0.76	5.88	0.75	Read	ACES-324_1
27	28-May-2011 12:55:15	90	2.41	0.12	0.75	000133F9	5.88	0.3	0.5	Read	ACES-324_1

SELECT * FROM 'zes' LIMIT 0, 1000   Record 1 of 1000 in page 1

Fig. 2.3 database entries

Fig. 2.4 GUI after "READ" is pressed

After getting information from receiver and storing it in to MySQL database, current status changes as shown in fig 2.4 stating that data is stored successfully. For taking further readings

“OK” is to be pressed which resets the current status of tags to blank allowing user to read the tags again.

3. Graphical Viewer Application GUI

Graphical Viewer application GUI aims to display data (receiver and tags location in an environment here) in better, understandable way as shown in fig. 3.1. It is made to be used on remotely connected systems to server for accessing data and representing them in graphical way. Graphical Viewer GUI connects to database server through network by providing IP of server and login details of MySQL database.

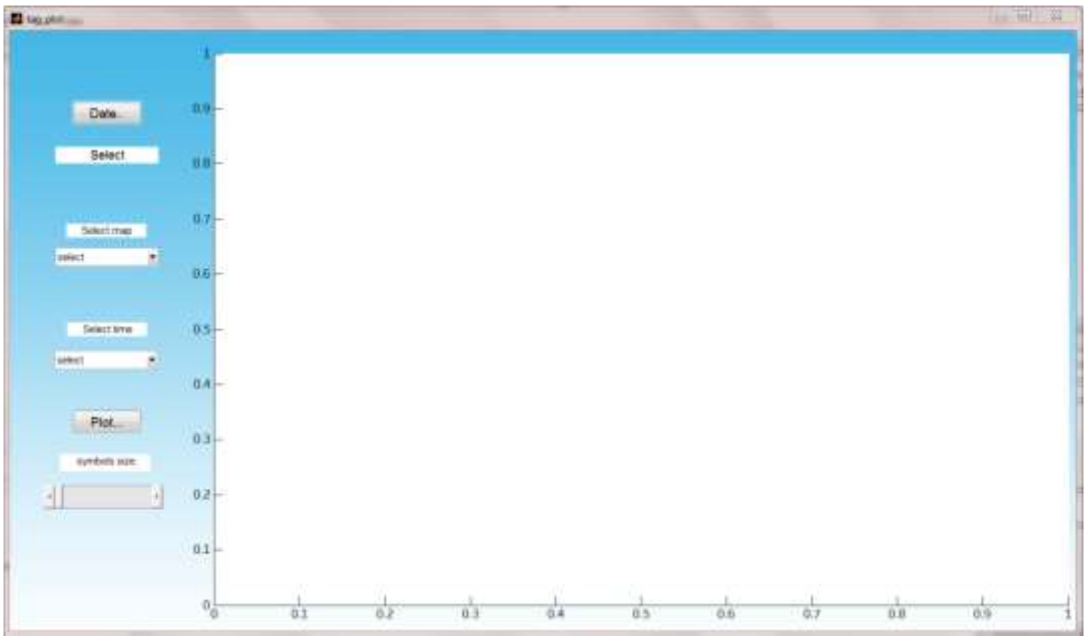


Fig. 3.1 Graphical Viewer Application GUI

3.1 Functionalities:

This application connects to database as soon as date button is pressed. All steps below are to be carried out in sequence listed only. On pressing date it access all entries in database and save it to remote computer, as user proceed through each step filtering of data to require one takes place.

1. Date

It is provided with Date button clicking on it opens a calendar as shown in fig. 3.2 from which date of experiment can be selected data of which we want to see. Only dates on which data was recorded can be selected and others are de-activated to prevent their selection by user.

2. Map

After selecting date this application give list of all maps available on that particular date as popup menu. User can select desired map from list to condense data further.

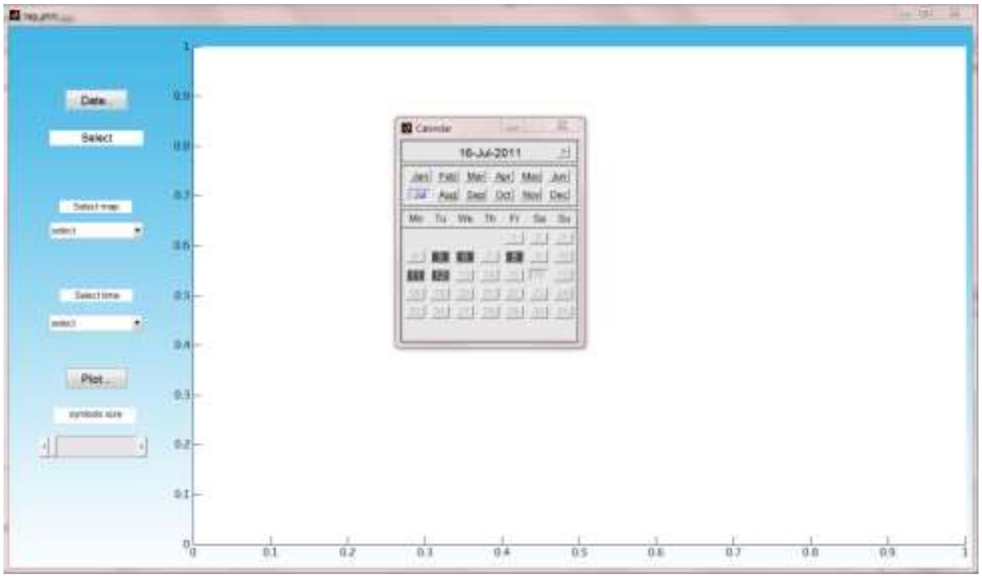


Fig. 3.2 GUI with calendar open

3. Map

For a particular map selected, this gives list of all timings at which readings were taken during the time of experiment. User should select a particular time to get a particular set of reading.

After selecting all parameters finally plot button is to be pressed to represent data selected from database in graphical form. In bottom part of GUI a slider is there which can be slide to adjust size of symbols appear on screen provided within GUI itself. The symbols appear on screen denotes receiver and tags with background image containing rough plot of map selected.
The blue directed arrow denotes receiver with its direction as direction of receiver placed on map with respect to origin as shown in fig. 3.3
For tags representation following convention is used

- T651-MIC tags are represented as round shape
- T651-BDG tags are represented as square shape
- T651-1x1 tags are represented as triangle shape symbols

The colors of symbols denote their read status with green represents tag was read at that position and red represents tag was not read.
Since we are dealing with 2-D representation of map (which actually is 3-D) certain conventions are employed for representation of third dimension (height) of tags and receiver position which are listed below

- If two or more tags are at same 2-D position but at different heights, then the one tag with least height represented in usual way and other tags are represented at that position only with concentric circles (or square, triangle depending upon tag type) with tag of largest height as largest radius and so on.
- If two or more reading sets are found for same position of a tag, then it is represented by unfilled round (or square, triangle depending upon tag type) bigger symbol.

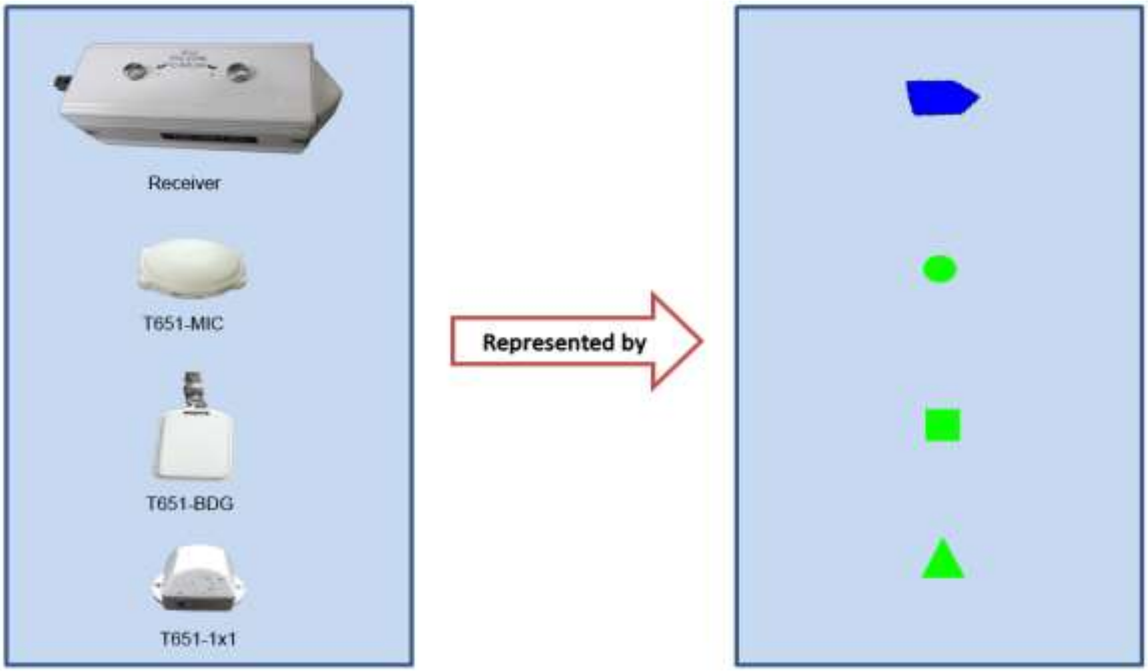


Fig. 3.3 convention for tags and receiver

4. Placement of Tags

4.1 Indoor

The experiment begins with the placement of tags in an environment. Environment selected for testing of tags in initial stage is indoor place which is sufficiently large. Tags are placed on available blocks like tables, chairs. The receiver is placed at various positions including on chair, on table, on top of shelf to give maximum height available inside. Chairs orientation are used to block tags as far as possible. Tags are placed at various heights for testing like on ground, on chairs, tables. Three kinds of tags are used in this experiment namely T651-MIC, T651-BDG and T651-1x1. The tags are placed in room as shown in fig. 4.1.

Fig. 4.1 tags placed inside room

The chair and tables acts as obstacle for tags while reading by receiver. The basic dimension of chair used by us in this experiment is shown in fig.4.2.

Fig. 4.2 dimension of chair used

The back of chair generally acts as an obstacle if tags are placed on seat and back comes between receiver and tags.
After placement of tags and receiver Reader application GUI described above is used for reading data from receiver and entering positions to database. Tags and receiver positions are measured initially in rectangular co-ordinate system with co-ordinates as distance from origin chosen suitably in meters.

<u>Experiments:</u>

Indoor

Data taken inside room is represented by below figures in graphical way.

- Four positions of receiver are shown respectively.
- The unit of measurement of distance is in meter.
- Co-ordinates are noted in rectangular co-ordinate system with respect to an origin chosen suitably.

The purpose of doing this indoor experiment is to observe the interaction of tags with other objects like wall, small obstacles like chair, certain metal boxes etc. before going to field testing. Walls are represented in usual way with closed boxes like obstacles as shaded rectangles. Chairs are represented as squares with dark line at one side to represent its back. All above readings are taken in same room but by changing chairs positions.

Following inferences are made after doing this experiment.

- ➢ Walls have definitely negative behavior for tags detection by receiver if comes in between them.
- ➢ Presence of small opening in walls like doors or windows allow RF leakage and gives possibility to read tags even inside.
- ➢ T651-MIC and T651-1x1 shows approximately same behavior in their detection by receiver but T651-BDG has very less range of detection.

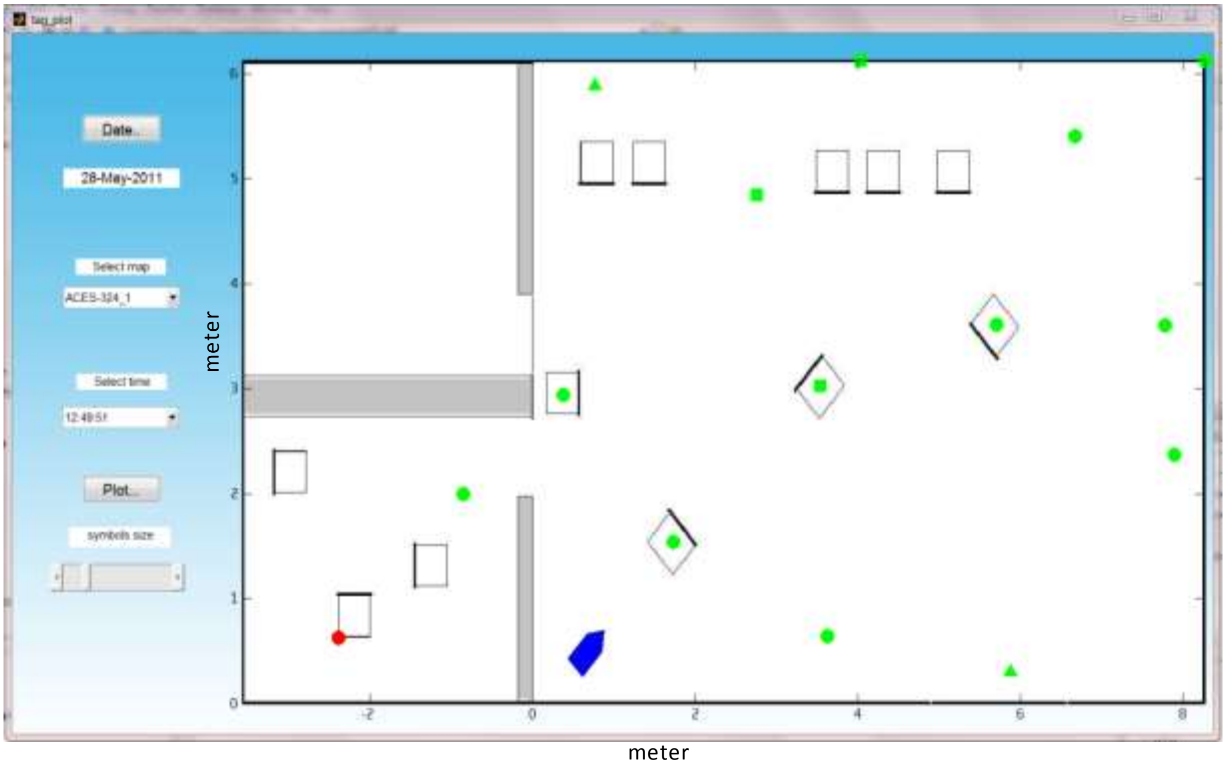


Fig. 4.3 (i) Indoor Experiment

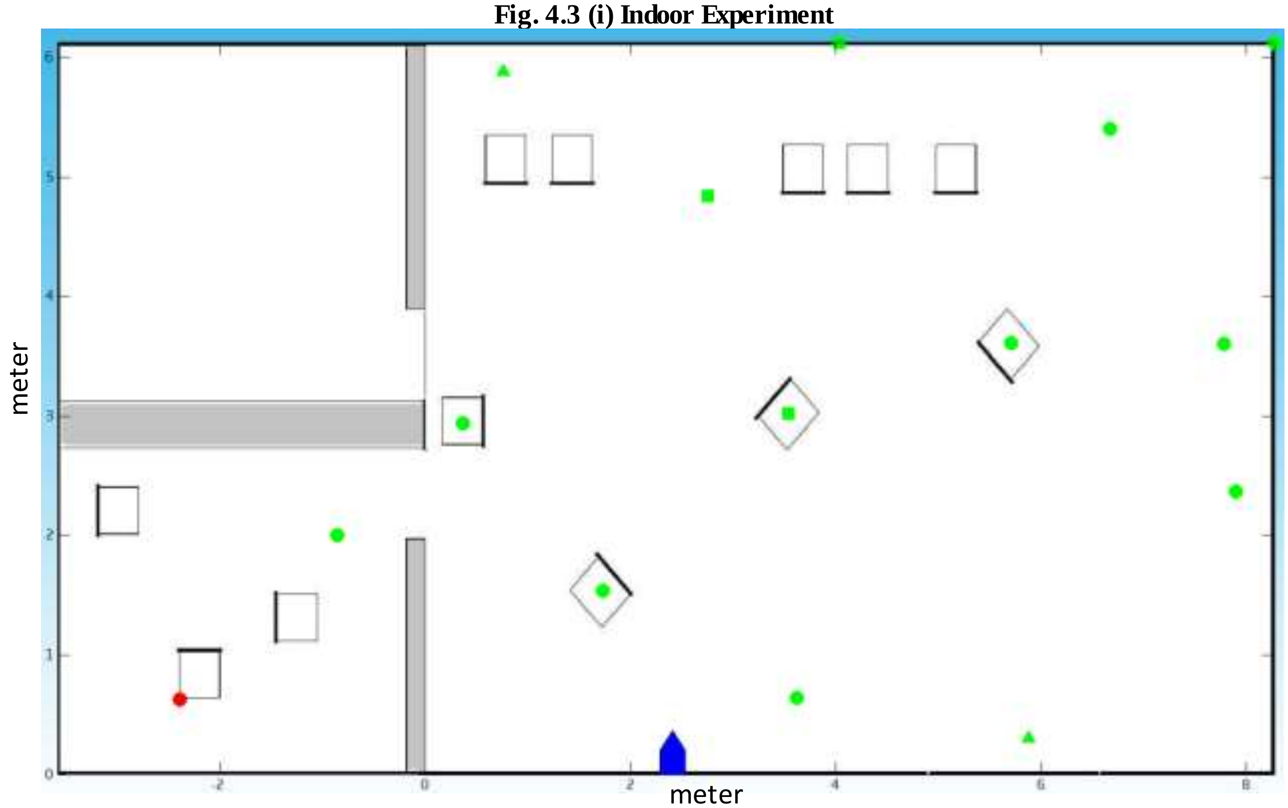


Fig. 4.3 (ii) Indoor Experiment

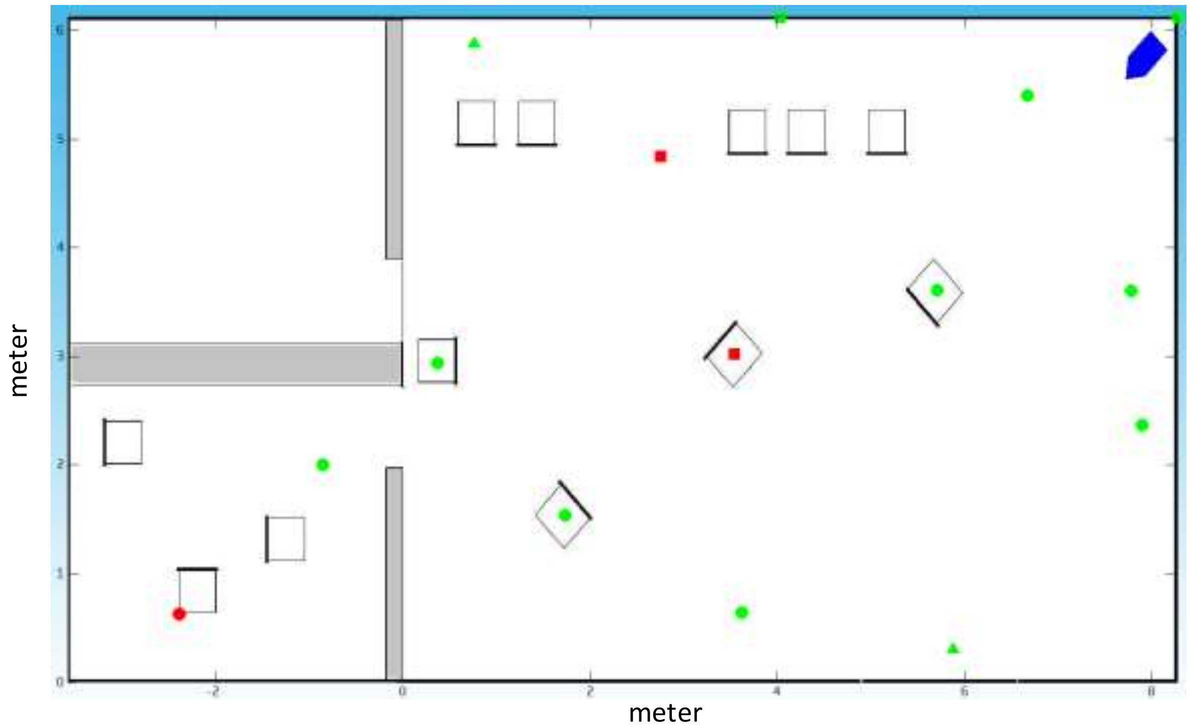


Fig. 4.3 (iii) Indoor Experiment

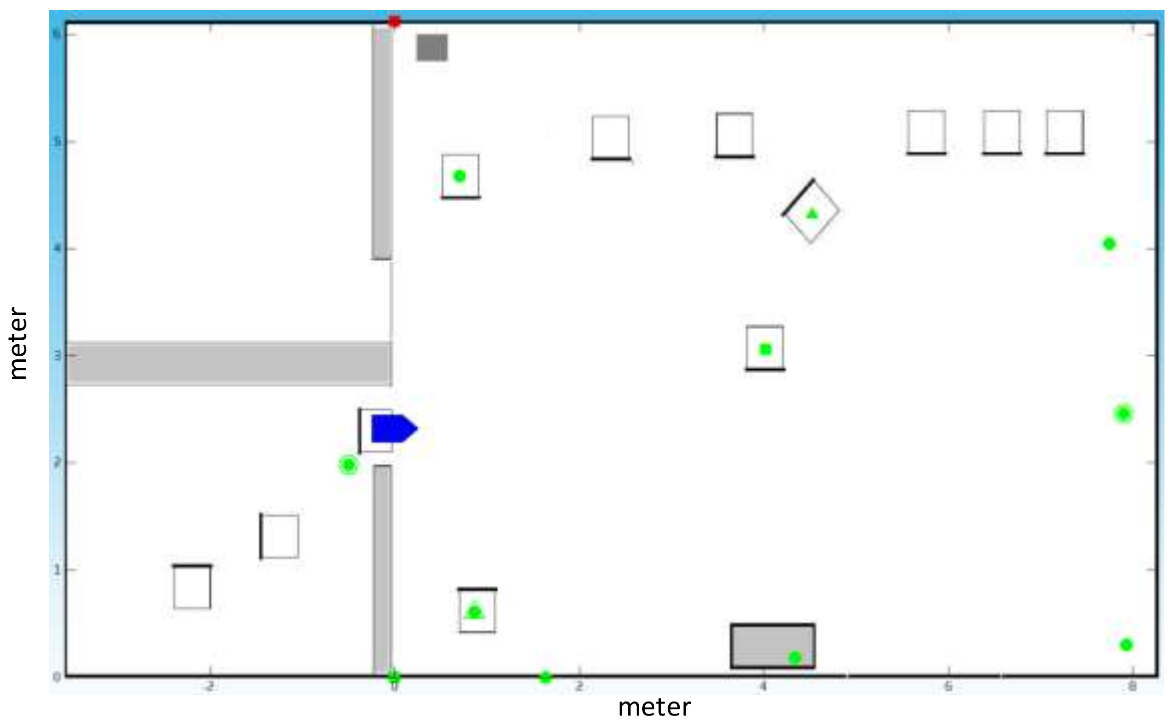


Fig. 4.3 (iv) Indoor Experiment

Tags comparison experiment

To confirm last observation of previous experiment, another experiment is carried out in other bigger room than current room. Since T651-MIC and T651-1x1tags shows same behavior one of the T651-MIC tag and one of the T651-BDG tag is taken for comparing their detection. To make their detection by receiver unbiased these two tags are placed side by side as shown in fig. 4.4 so that their location can be approximated as same with respect to some origin of rectangular co-ordinate system.

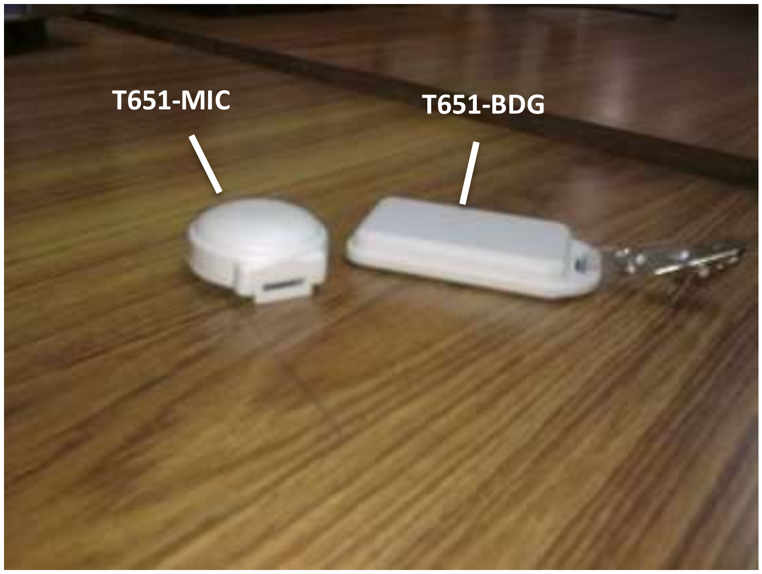


Fig. 4.4 tags placement style (side by side)

The graphical representations of results are shown in fig. 4.5.

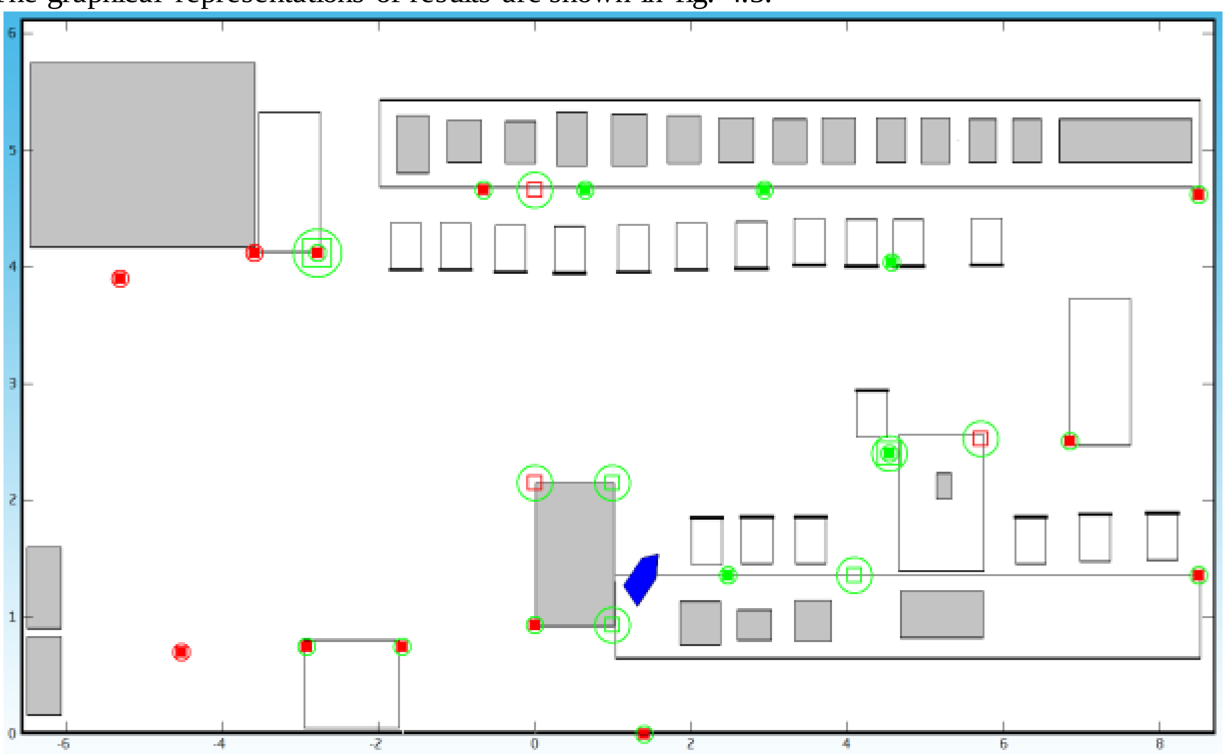


Fig. 4.5 (i) tags comparison experiment

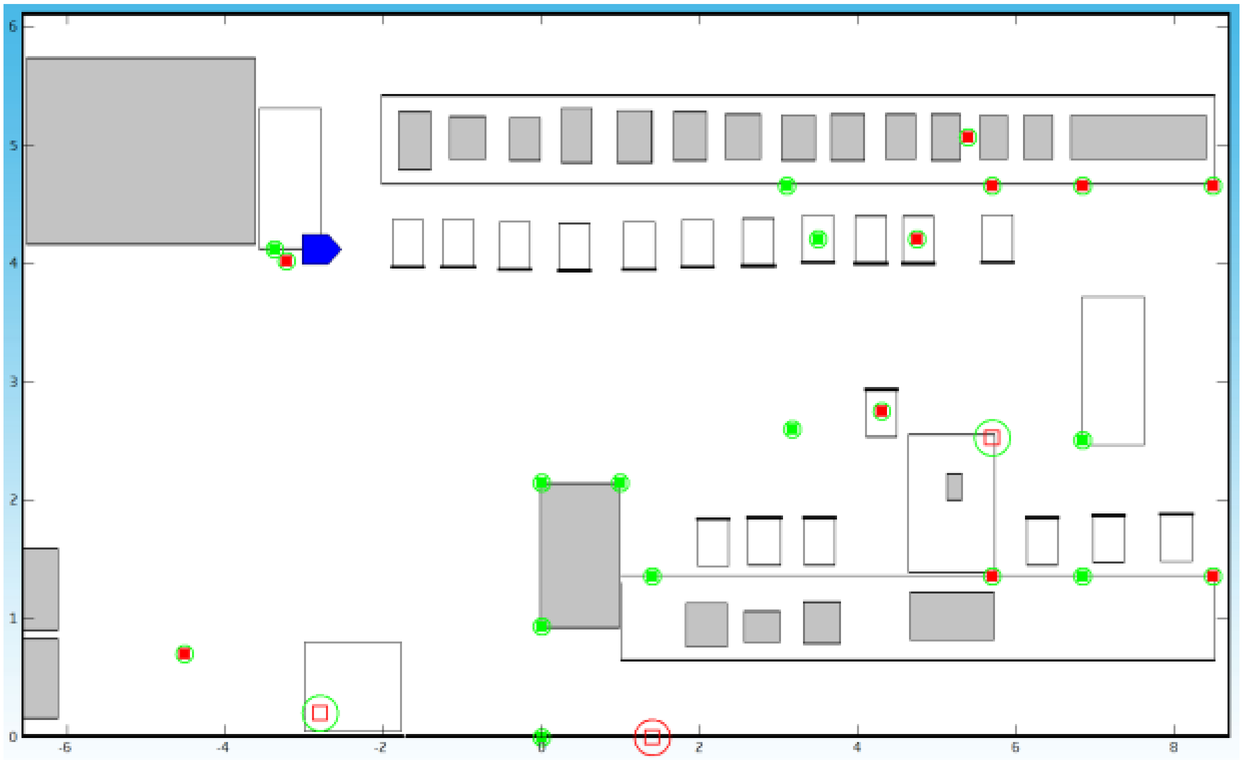


Fig. 4.5 (ii) tags comparison experiment

Interpretation

- T651-BDG tag has very poor obstacle overcoming capability as compared to T651-MIC tag.
- The signal transmitted by BDG tag dies out very earlier than MIC tag.

The comparison between these two tags is shown on fig. 4.6 where direct distance between tags and receiver is plotted vs read status with 1 denoting read and 0 denoting not read. The T651-BDG dies out when distance is increased but T651-MIC goes longer.

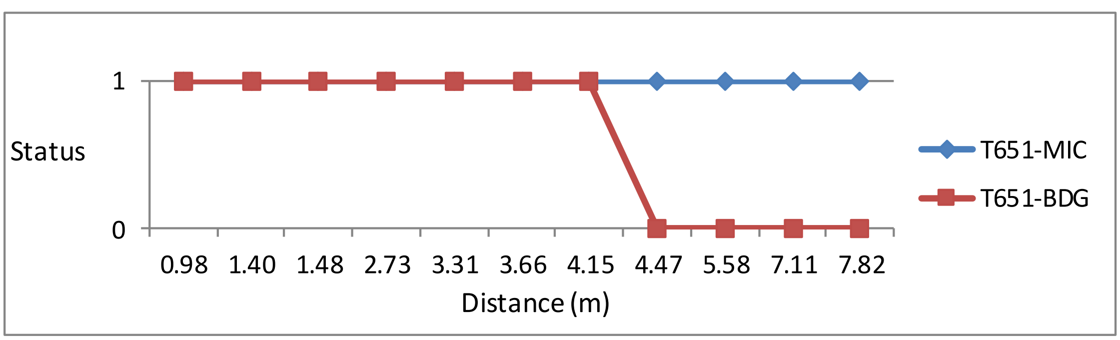


Fig. 4.6 comparison chart for tags

Therefore T651-BDG tags cannot be used for assets tracking but can be used for personnel tracking very well.

Outdoor

For field testing we will be using only T651-MIC and T651-1x1 tag since their performance is very much better than T651-BDG for detection purpose. But specifically for this case we have used T651-BDG tags also to see their behavior in outdoor environment. In field testing obstacles encountered generally are trees, cars, wall of nearby buildings etc. These obstacles are pretty large as compared to ones we deal in inside testing. Here we had opportunity to place tags at far points from receiver. Initial site selected for testing is shown in fig. 4.7. Here we have two facing walls on opposite sides, cars and trees as obstacles. These cars can be approximated as metal boxes (ignoring RF leakage which is very less from bottom of cars).

Fig. 4.7 field testing site

The readings obtained for this experiment are shown in figures below graphically

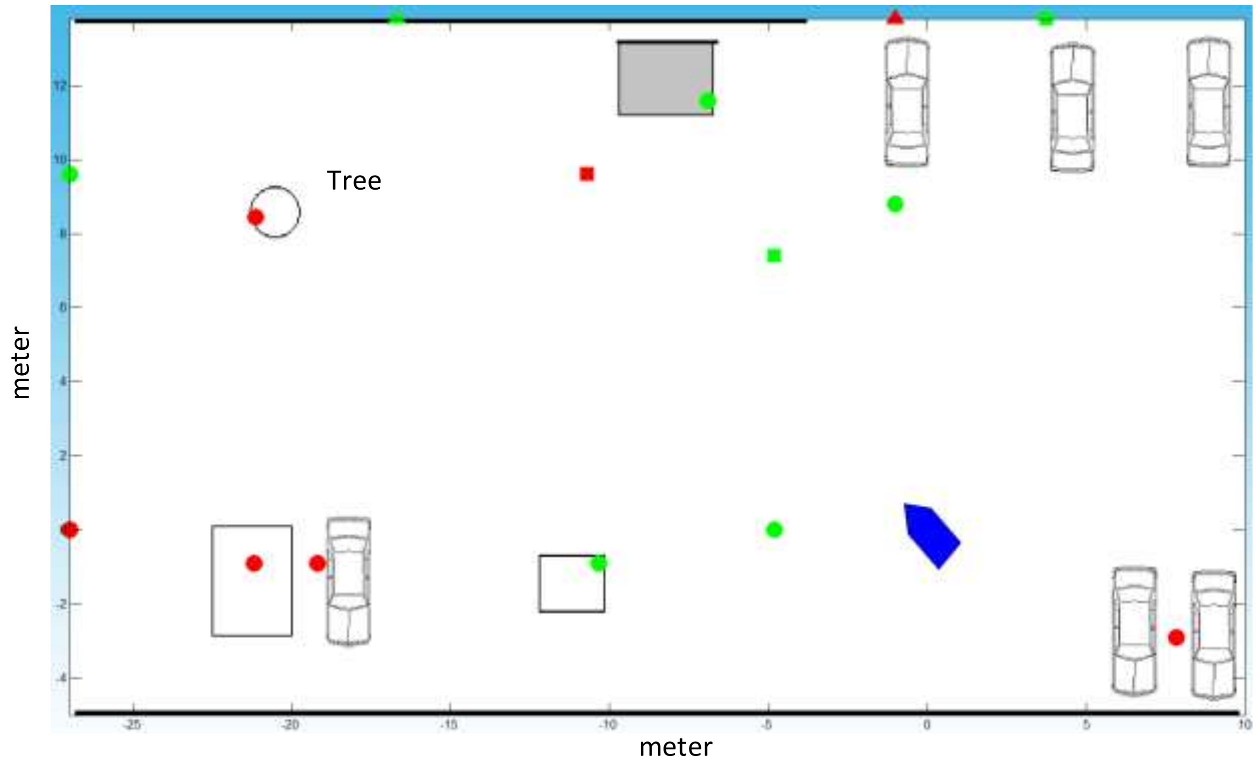
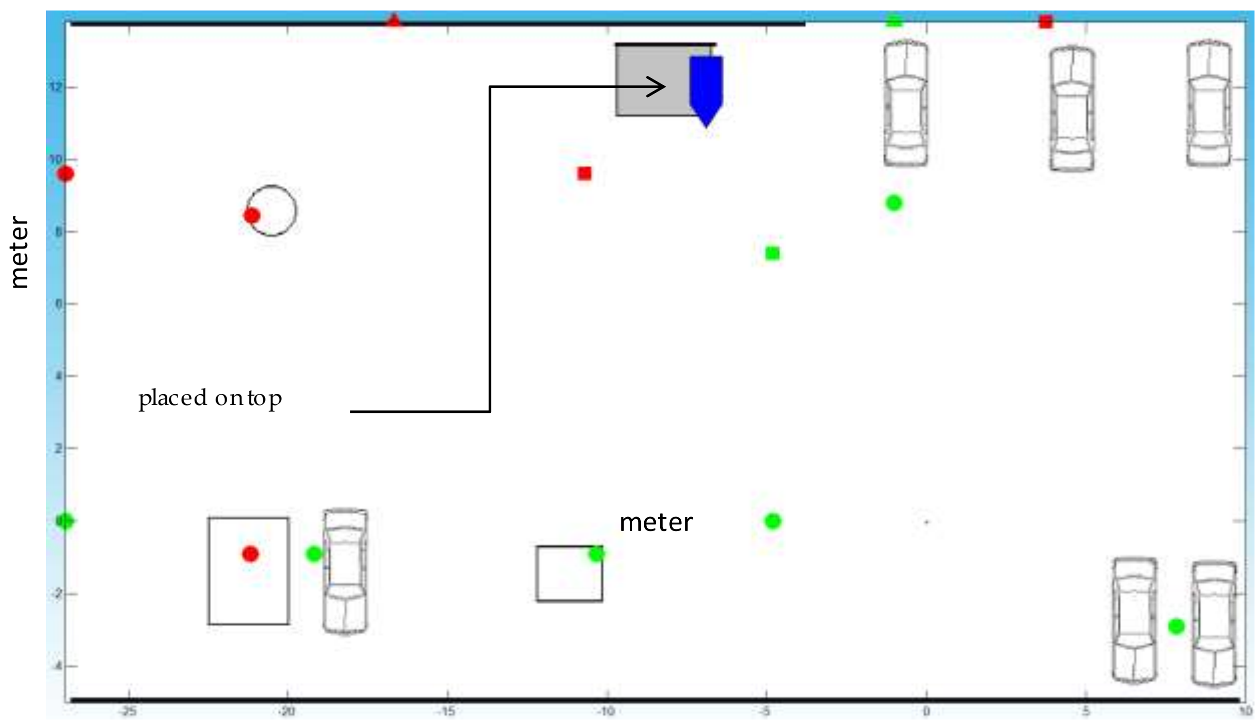
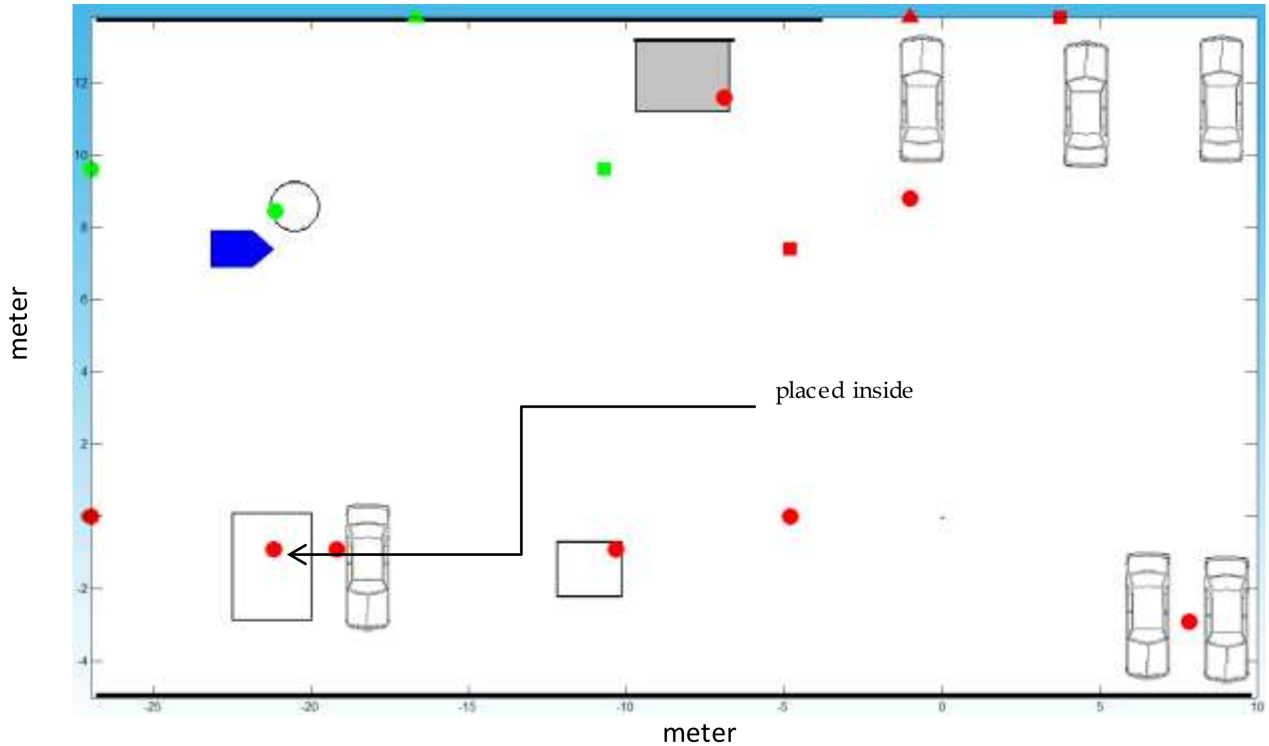


Fig. 4.8 (i) filed testing graphical representation





This experiment shows same result as we have got earlier for T651-BDG tags, and hence we will not be using these tags further for field testing. As expected, cars have shown behavior as an obstacle for tag detection by receiver. If a tag is placed on ground then car completely blocks tag transmission if it comes between tag and receiver. The tags still read in corners of map this suggest need for bigger map which we will present in next section.

Filed testing with more obstacles

A larger map than previous one is selected with more obstacles like cars. A car parking place suits this condition as shown in fig. 4.9. This place has sufficiently large space for placing tags and receiver. Some trees are also there which interfere with tags transmission. Presence of walls in nearby can make reflections for RF signals and allow tags to be read.

The graphical representation of data collected in this map is shown in fig. 4.10

Although in presence of cars, nearby tags are read because receiver is placed at sufficient height which overcomes blocking effect of cars. To get a good picture of tags status in locations around receiver, number of tags at particular receiver position is increased as shown in fig. 4.11.

- It is clear from above figures that receiver back position is not a good place to track assets by attaching tags.

Fig. 4.9 field testing in parking place

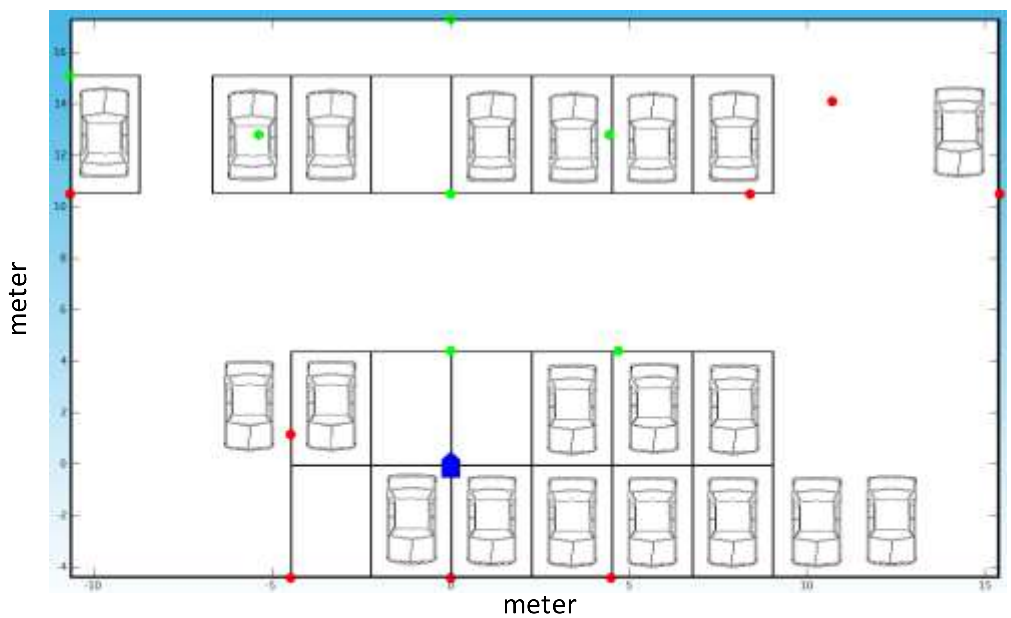


Fig. 4.10 field testing

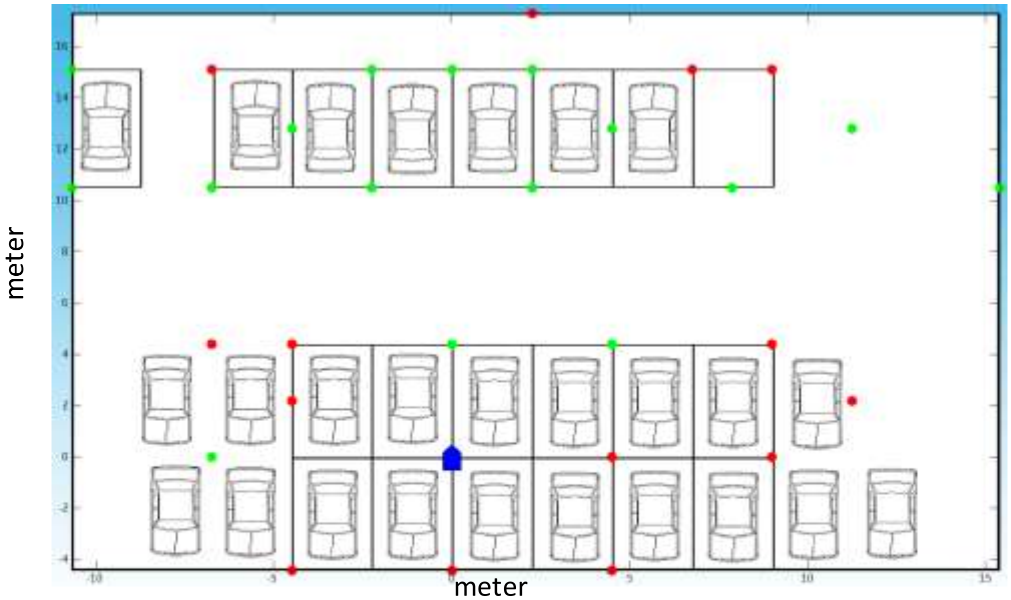


Fig. 4.11 field testing with increased number of tags

To compare tags at different height

Cars blocks tags detection significantly when tags are placed at ground but there is possibility of their detection when they are placed at certain height. To test this and compare their detection behavior an experiment is performed in which two set of readings are taken on same map with same receiver position but tags are placed on ground in first and at a height higher than cars in second. Representing both sets on same map we have graphical picture as shown in fig. 4.12.

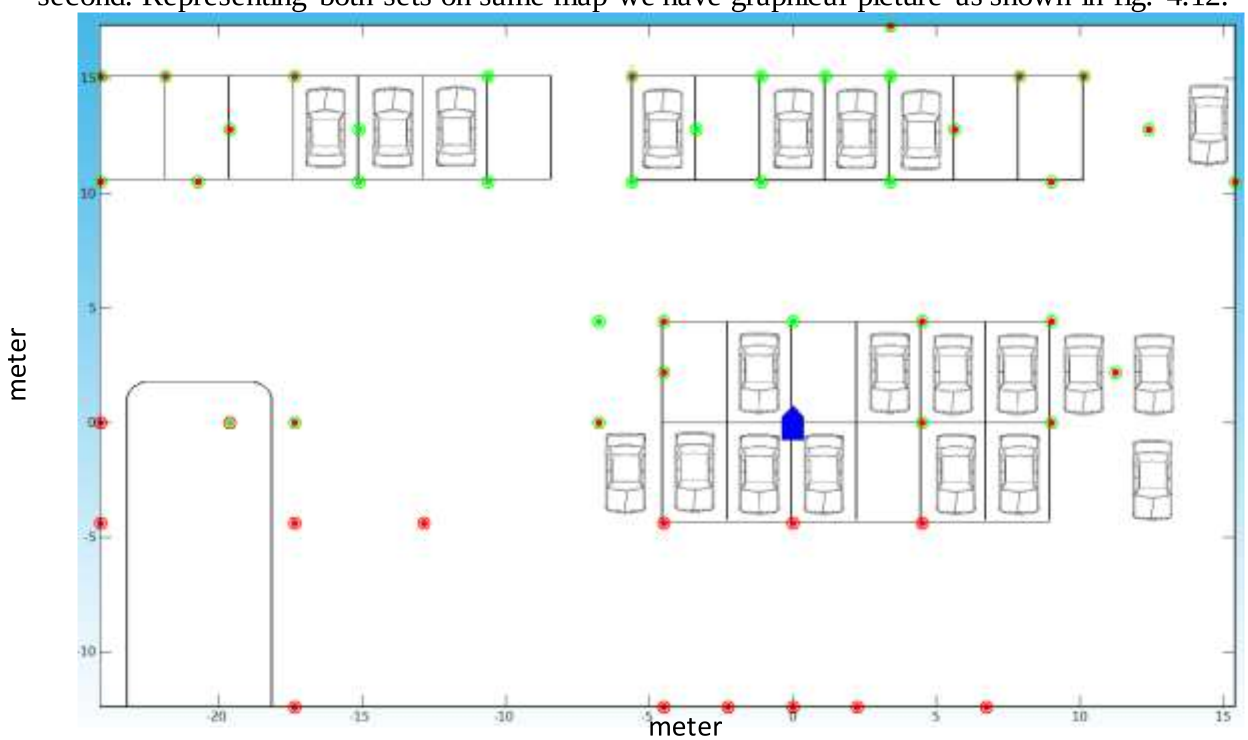


Fig. 4.12 comparison of tags at different heights

The figure establishes following result

- Tags placed at height comparable to blocks are approximately not disturbed by their interference.

This experiment suggests attaching tags to assets at highest point available on them.

To see further range up to which receiver can read tags map is extended to large area.

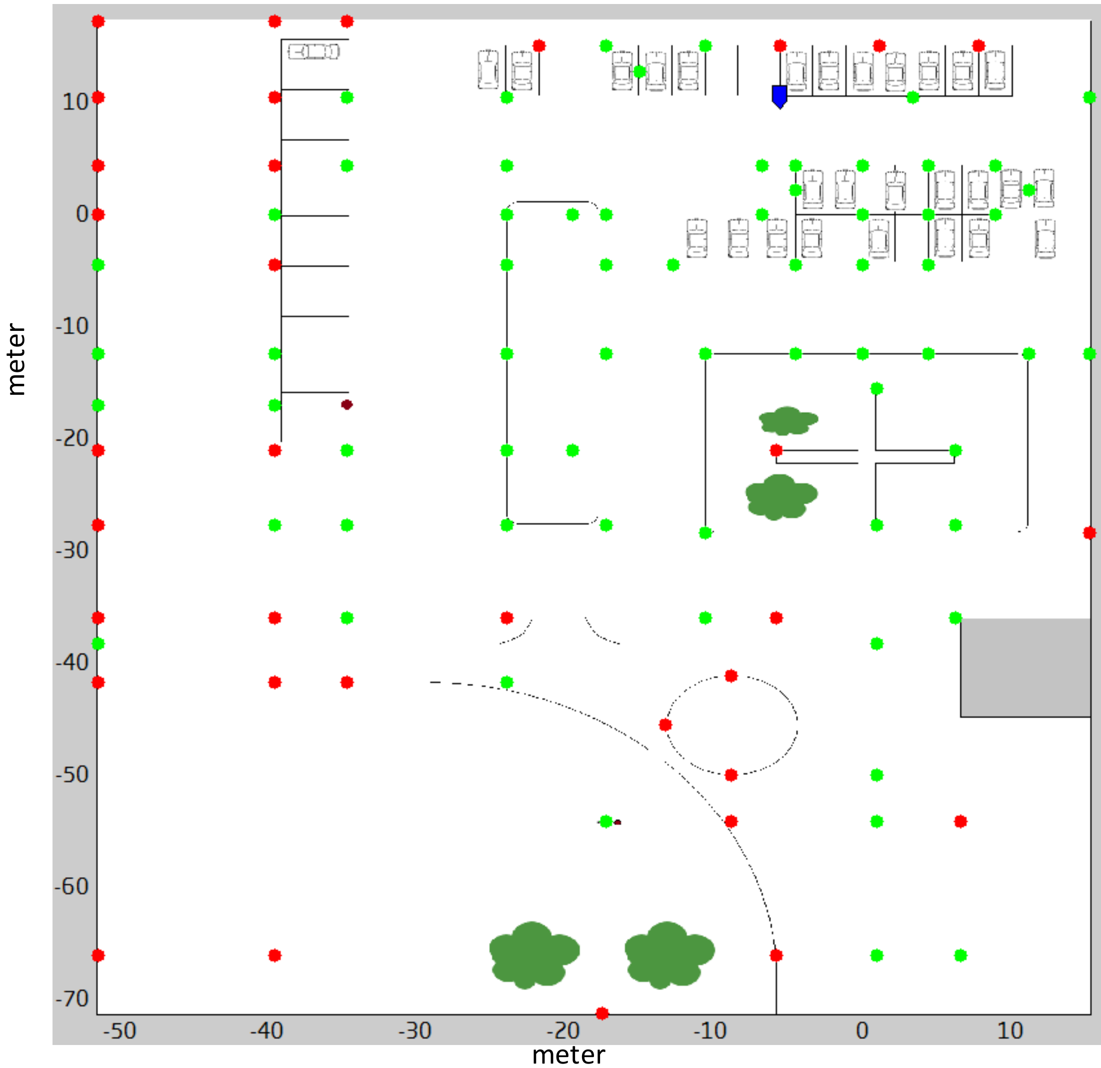


Fig. 4.13(i) field testing to estimate range of detection

Fig. 4.13(i) and (ii) are readings on same map with same locations of tags and receiver but at different time. It is to be note that some tags at back of receiver are read because of presence of wall behind receiver. As we move farther from receiver tag detection fades from read to unread. Presence of tree interferes in tag detection significantly which is noticeable from figures.

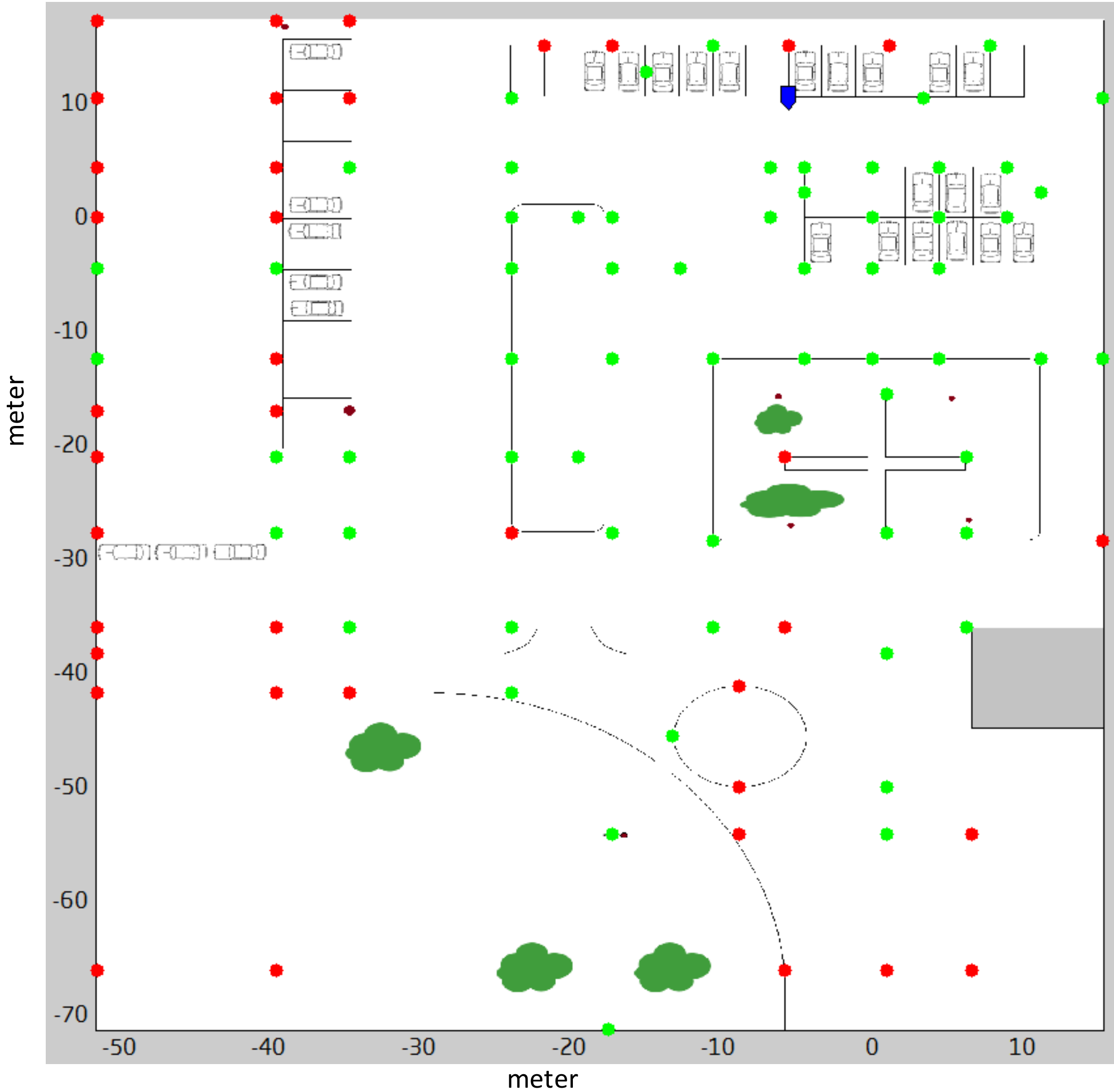


Fig 4.13 (ii) field testing to estimate range of detection

Appendix

Specifications:

Sapphire *VISION* Reader (V652)

Physical Specifications	
Dimensions	6.5” x 2.5” x 2.5”
Weight	15 ounces
Operating Voltage (DC)	5 – 12VDC
Communications	
Data Rate	100Mbps
Maximum 1Hz tags per second	5000
Antenna Options	
V652-O (Omni-directional antenna)	2.5 dBi
V652-MG (Mid-gain antenna)	8 dBi
V652-HG (High gain antenna)	12 dBi

Dart tags

	Dart Tag	Dart Tag Badge
Port Number		
Standard	UWT-1100-A-00AA	UWT-1200-A-00AA
ATEX	UWT-1100-A-0AAA	UWT-1200-0AAA
Pre-programmed Blink Rate		
Blink rate (Hz)	Programmable from 0.01 to 200 Hz	
Performance		
Frequency Range	6.35 – 6.75 GHz	
Typical Battery Life	7 years @ 1 Hz	
Locate, Indoors		
Typical Range	50 m (164 ft)	
Read (Presence), Indoors		
Typical Range	100 m (328 ft)	
Environmental/Physical/Power		
Operating Temperature	-40°C to 70° (-40°F to 158°F)	
Environmental Rating	IP67	
Length	ϕ4.0 cm (1.57 in)	4.22 cm (1.66 in)
Width		0.71 cm (0.28 in)
Height	2.0 cm (0.78 in)	7.42 cm (2.92 in)
Power	20 gm (0.70 oz)	18 gm (0.63 oz)

Software used:

1. Mathworks MATLAB 2011a
   http://www.mathworks.com

References:

1. Microsoft .Net framework 4.0
   http://www.microsoft.com/download/en/details.aspx?id=17851

2. http://www.zebra.com/id/zebra/na/en/index/products/location/ultra_wideband.html