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IMPROVE RECEIVED SIGNAL STRENGTH USING DIRECTIONAL ANTENNA IN INDOOR POSITIONING SYSTEM

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Abstract: *In radio equipment an antenna plays a vital role for Trans receiving the signals. The transmitter antenna sends high frequency energy into space while the receiver antenna receives this energy and converts it into electricity. Radio location using signal strength is a popular method. RSS-based systems are easy implement, but the accuracy is dependent on environment and distance.*

Localization is a fundamental thing in mobile robot navigation. An indoor location sensing radio frequency identification (RFID) is a wireless communication technique which determines the position of a mobile robot by analysis of sensory data. In such system directional antennas can be used to boost the capacity of wireless networks.

Directional antenna can concentrate its transmitting or receiving capabilities to its desired direction rather than an Omni directional antenna which radiates or receives equally in all directions. By comparing Omni-directional antennas with directional antennas, directional antenna have many advantages such as less interference, decreased Power requirement, yearn transmission range, improved spatial reuse and network capacity. Difficulty raised in single directional antenna if the transponder was not stationary.

Index Terms: *Antennas; Radiation Patterns; Gain; Radio Frequency Identification (RFID); Indoor Localization Techniques; RSS*

I. INTRODUCTION

Nowadays, wireless networks have a various applications. These various applications can categorize into two types:

- *Indoor wireless networks*
- *Outdoor wireless networks*

From last few decades indoor positioning systems become more popular. Researchers are interested to work on these systems. These systems can provide navigation, tracking, or monitoring services. Indoor wireless networks include wireless networks which usually have shorter links than outdoor wireless networks.

In indoor localizing system an indoor location sensing radio frequency identification (RFID), is used to locate and track an object in dynamically changing environment. Localization of an object is takes just a moment to determine the position, and other hand to track an object require a continuous recording of an object's motion.

In indoor environments usually require extra challenges than that in outdoor environments for accurate and efficient localization, in case of interference and obstacles in communication channels.

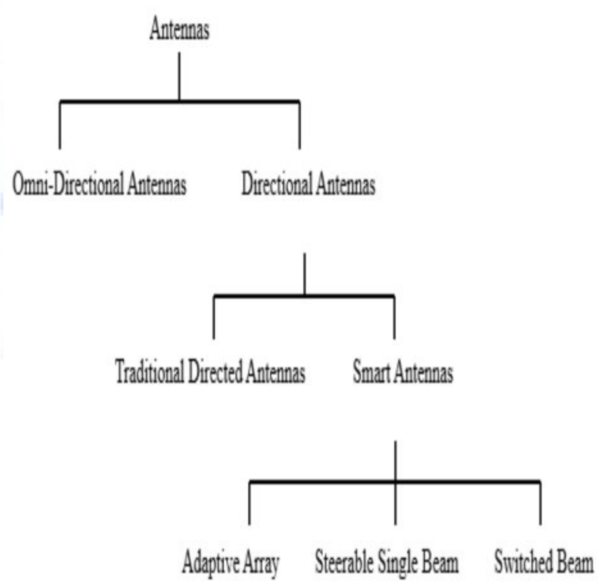

Figure 1: Classification of Antenna

Depending upon the technology used different antennas has been considered for radio frequency (RF) localization systems. There are two main types that are Omni directional antenna and directional antenna. The Omni-Directional antennas are commonly used in wireless networks. One hypothetical Omni-directional antenna, called isotropic. It radiates its signals in all directions equally. A half-wave dipole is a practical Omni-directional antenna, which has a circular radiation pattern in the azimuth plane or in the elevation plane. The Directional Antenna which can radiate or receive radio signals more effectively in some directions than in others. There are two types of directional antennas Traditional Directed Antennas and Smart Antenna. The classification of various antennas is shown in Figure 1.

In Traditional Antenna the beam formed by these antennas is fixed or adjusted to point to a desired direction by rotation. This antenna includes Helix, Yagi-Uda, patch antennas, etc. Compared with traditional directed antennas, smart antennas have large capabilities of directional beam forming, diversity processing, spatial reusing, etc. Smart antennas include phased array, intelligent antennas, digital beam forming adaptive, spatial processing, antenna systems etc. Smart antennas can be categorized as shown in figure. In switched Beam shifting every signal phase of antenna elements the antenna beam patterns are predetermined. According to weights for antenna elements the desired beam pattern can be saved in memory. In Steerable Single Beam Antenna the beam patterns are formed on the fly. This technique can have large signal to interference and noise ratio and an adaptive antenna is type of smart antenna also called as MIMO.

Wireless networks using Omni-directional antennas called as WON*s* and wireless networks using directional antennas called as DAWN*s*. Generally DAWNs have higher network capacity than WONs.

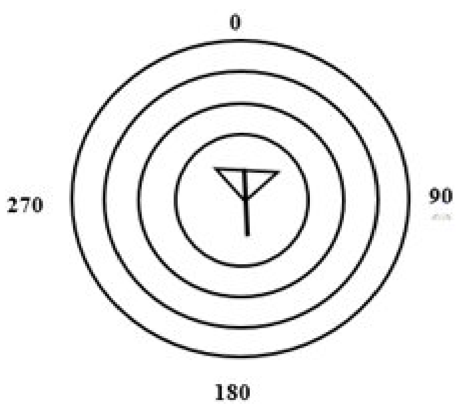

Figure 2: Isotropic Pattern

The WONs antennas spread radio signals equally in all directions. Hence the capacity of these networks limited because of high interference and the low spatial reuse. Compared with an Omni-directional antenna, a directional antenna can consider its transmitting or receiving signals to a certain direction. Thus it leads to less interference.

Figure 2 shows an “Omni-directional” wave where the wave is travelling from the antenna equally in all directions and Figure 3 shows “Directional” wave where the wave is travelling from the antenna in a defined direction.

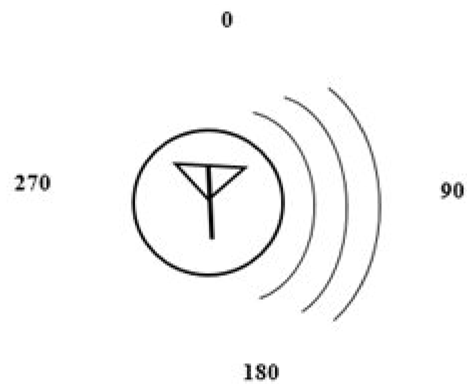

Figure 3: Directional Pattern

In localization systems, some fundamental things that one must be aware of an antenna and position of an object which are used throughout in this paper. These fundamental things are shortly consider in section 2. In section 3 existing technology for directional antenna with their improvement are presented. Next section 4 describes the methodology of proposed system with system flow and also includes the simulation platform, which will use for performance evaluation. In section 5, the simulation results are presented and section 6 includes the concluding remarks.

Fundamental Background:

In general, an antenna is a device which is used for radiating/collecting electromagnetic energy (radio signals) into/from space.

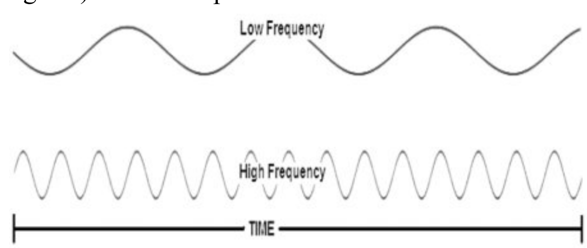

Figure 4: Wave Frequency

The electromagnetic energy waves which are radiated from the antenna is measured at a defined Amplitude, Angle and Frequency. If the wave is smaller it indicate that the frequency is high. If the wave is longer then we can say that frequency is low. Figure shows the wave frequency with time.

A) Angle: Angle is the direction of the wave that is traveling antenna. Understanding angle in relation to an antenna pattern is a key factor. Using this knowledge is beneficial for selecting the type of antenna needed to achieve the coverage you desire.

B) Azimuth and Elevation Angle: Azimuth is the left or right angle from reference plane. This angle defined as the horizontal angle measured clockwise from north and ranges from 0° to 360°.

Elevation is the "Up" and "Down" angle from a reference plane. This angle which is lifted above the horizontal plane and ranges from -90° (straight down or nadir) to +90° (straight up or zenith).

C) Phase: Phase is an important factor to antenna placement and require little understanding. Graphically phase looks like a sine wave or sinusoid that wave has a start and a finish. It start from 0 degree and end with 360 degree. From start to finish length representing one wavelength. The wavelength is identified by this symbol "λ" known as Lambda.

In figure 5 the wavelength is segmented into four equal sections. The four points represent 0°, 90°, 180°, 270°, and 360° in phase. It shows 90° as a ¼ wavelength, 180° as a ½ wavelength, 270° as a ¾ wavelength, and 360° as one full wavelength

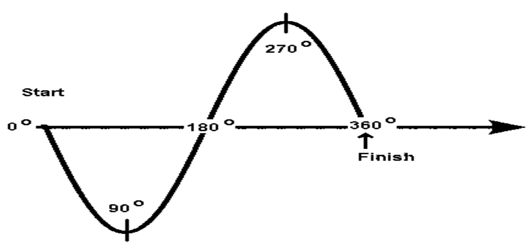

Figure 5: Wave length

D) Gain: The gain of an antenna is a relative measure of strong signal which is received or transmitted. An antenna adds this gain to a radio frequency (RF) signal.

E) Decibel (dB): It is the unit of measure of loss or gain. Gain has a positive value, loss has a negative value, and is equal to 10*log (Pout/Pin)

F) Direction: Direction of an antenna is the form of the transmission radiation pattern. The gain of a directional antenna increases with decrease in angle of radiation. As gain increases it gives a larger coverage distance, but it reduced coverage angle. Figure 6 shows radiation pattern with high gain and figure 7 shows radiation pattern with wide angle

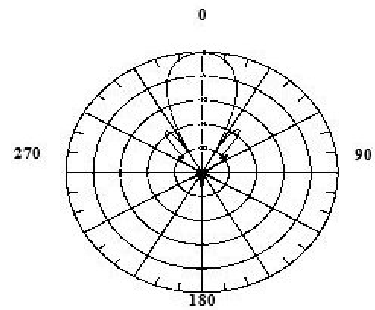

Figure 6: Radiation Pattern with High Gain

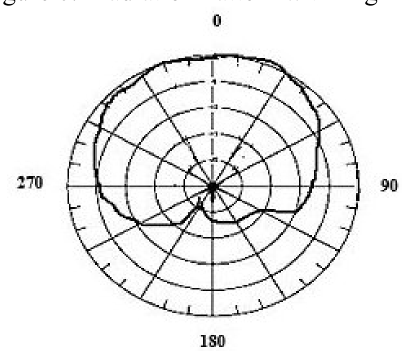

Figure 7: Radiation Pattern with Wide Angle

G) Polarization: An antenna generates an electromagnetic wave that increases in time when it travels through space. The polarization of an antenna is the relative position of this electromagnetic wave of that is radiated from wireless signal component.

When we used a pair of antennas to get maximum signal transfer then it is necessary that they are mounted with the same polarization. If one antenna is mounted vertically then the receiving antenna should also be mounted vertically. If the polarization of both antennas does not match then there will be a lot of loss in capturing the radio waves.

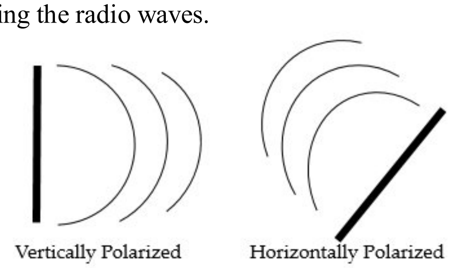

Figure 8: Polarity Mismatched Antennas

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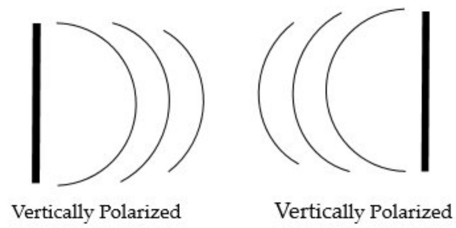

Figure 9: Polarity Matched Antennas

To get the highest signal strength rotate one antenna along with the axis between the two antennas till the two antennas are in the same polarization. Figure 8 and 9 shows polarity mismatched and matched antennas respectively.

H) Horizontally polarized waves and vertically polarized waves: The polarization of an antenna is an electromagnetic wave that travels through space and increases in time. If radio waves radiated form antenna increases "up and down" with the electric field in time then that wave is called vertically polarized. This radiated radio waves are vertical to the ground. If radio waves radiated form antenna increases "left and right" with the electric field in time then that wave is called horizontally polarized. This radiated radio waves are horizontal to the ground. Figure 10 shows the vertically polarized and Figure11 shows horizontally polarized waves.

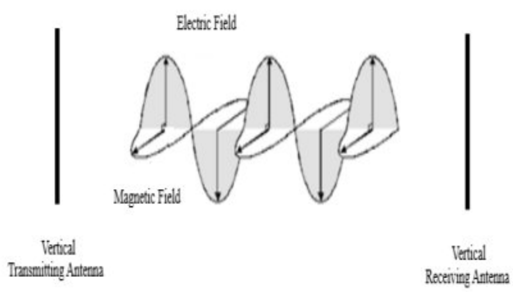

Figure 10: Vertically Polarized Waves

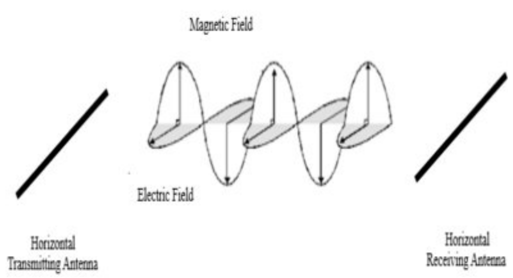

Figure 11: Horizontally Polarized Waves

I) The Antenna Radiation Pattern:

The radiation pattern is measured in degrees .It is a graphical representation of the gain values in each direction in space. This Radiation Pattern includes a main beam of peak gain and side beams of smaller gain. The radiation Pattern Plot is usually presented in a Polar style plot or Rectangular style plot shown. Figure 12 Shows the Radiation Pattern for Directional Antenna.

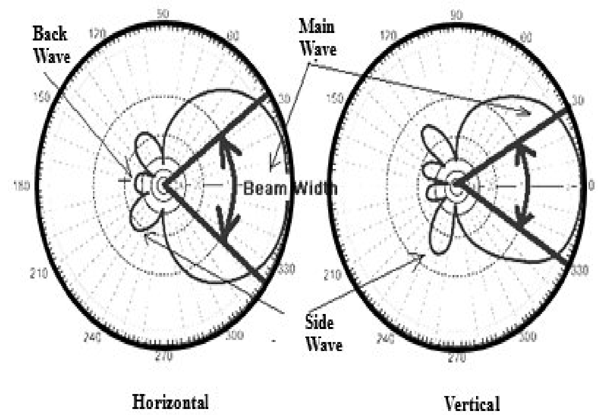

Figure 12: Horizontal and Vertical Radiation Patterns

J) Beam width: Radiation Pattern angles are measured in degrees is called beam widths. Antenna beam width is the angle on the main lobe at which the power gets down to half of its peak power in the radiation pattern of the antenna. As the gain of the antenna increases, the beam width decreases due to focus radio waves into a narrow beam. Beam widths are defined in horizontal and as well as in vertical plane.

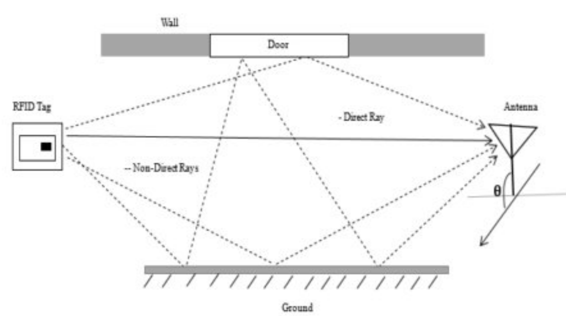

Figure 13: Multipath Interference in RF Signal

K) Multipath Interference in RF Signal: Multipath Interference is an interference generated by signals reflection on the walls or on any other obstacles at the receiver at different times. In indoor environment multipath interferences are mostly observed. Errors are increased with distorted RF signals. Multipath interference in RF signals is illustrated in figure 13.

L) Path loss: As a signal radiates through the air it have some loss. This loss is called as path loss. This loss is occurred due to signal radiates out over a wider area from the source antenna and to some of them signal being absorbed by the air itself.

II. LITERATURE REVIEW

Indoor localization systems can be categorized as token or token-less according to whether or not the mobile unit carries or not any device used for the localization process. Token-less systems are the Smart Floor and the Easy Living based on vision localization techniques. Token localization systems have been implemented based on several technologies: infrared (IR), Bluetooth, radio-frequency identification (RFID), wireless local area networks (WLAN), Ultra-wideband (UWB), ultra-sound, magnetic positioning, and audible sounds.

There are many RFID based localization system are proposed to understand the concepts and techniques thus Mathieu Bouet and Aldri L. dos Santos[1] proposed survey on 'RFID Tags: Positioning Principles and Localization Techniques'.

The indoor localization algorithms classified in three main techniques:

- *Distance Estimation,*
- *Scene Analysis,*
- *Proximity based*

i) Distance Estimation: These techniques are based on triangles property to calculate the location. This technique includes two methods: The triangulation method consists in calculating the angle of arrival also known as AOA. It requires at least two reference points to calculate location of an object. The appraisal position define by the intersection of the lines defined by the angles. Another approach is Lateration, the Lateration approach calculates the position of an object by evaluating its distances from at least three reference points. Received Signal Strength (RSS), Received Signal Phase (RSP), Time Difference Of Arrival (TDOA), Time Of Arrival (TOA) any of these techniques are used for distance measurements.

ii) Scenes Analysis: Two different steps are used in these approaches. In First step collection of all information regarding to the environment that is fingerprint. Then next step is find out the object's location by matching set of fingerprints. There are two main fingerprinting based methods:

- ***K-nearestneighbor (kNN) Method:*** *It is a RSS based method. In this method RSS at known locations are considered.*
- ***Probabilistic Method:*** *In this method the highest probability location is considered.*

iii) Proximity: Implementation of this approach is very easy and simple. In this method the gain arrangement of antenna is considered. The case where only one antenna is considered to locate an object, its location is same as its receiver. In another case where more than one antenna locate an object, then that object is selected with the one of the receiver which receives the strongest signal.

The Xiaofeng Lu, Fletcher Wicker, Ian Leung, Pietro Li`o, Zhang Xiong[3] proposed a 'Location Prediction Algorithm for Directional Communication'. The proposed algorithm is used in Ad hoc networks to determine the post location of a mobile node where nodes use directional antennas for communication. This algorithm derived from mobility characteristic and efficient up to 95.3%. The future work for researchers is to consider communication with mobile nodes, different transmission strategies and security aspects of the algorithm for efficiency.

The existing system 'Effective Beam Width of Directional Antennas in Wireless Ad Hoc Networks' is proposed by Jialiang Zhang and Soung-Chang Liew[5]. The system introduced the concept of the effective beam width that is the boosting capability of directional antennas. The effective beam width defined by considering effects of three factor - antenna pattern, active-node distribution, and channel characteristics rather than an isolated characteristics alone. This system used the effective beam width properties to analyse the effectiveness of complex directional antenna pattern with multi-user interference. Experimentally the result shows that in an Aloha-like network a phased array antenna with N elements can boost transport capacity.

In 1 JANUARY 2009, Myungsik Kimand Nak Young Chong [7] developed 'Direction Sensing RFID Reader for Mobile Robot Navigation' system. The dual-directional antenna calculates the signals radiated from tag using DOA (direction of arrival) by the ratio of the received signal strengths between two adjoin antennas. In most cases path loss is face in a cluttered environment. But this problem can be overcome by the direction correction algorithm. The algorithm is proposed to triangulate the location of the tag at the three recent DOA estimates with intervals of the robot movement and the received signal strengths. Defined algorithm is estimate the mobile robot position with obstacles. The 'Performance of Ad Hoc Networks with Beam forming Antennas' presented by Ram Ramanathan [2]. The system introduced in a broad way the potential that can be provide by beam forming antenna to achieve the longer ranges with less interference. The simulated results improve up to 28% to 118% in beam forming antenna and factor-of-28 reduction in delay.

In 5 September 2012, 'Genetic-Based Approach for Efficient RFID Reader Antenna Positioning' proposed by Nazish Irfan, Mustapha C. E. Yagoub, and Khelifa Hettak [4]. The proposed genetic algorithm is used to get the optimal antenna beam position for longer reader coverage. In the algorithm two types of angles are considered, one is tilt and another is orientation angle. In tilt angle RFID reader is placed on certain height of tag and in the oriented angle both are in same level. As per the simulation results, the longer reader coverage can be achieved by the optimal beam angle. The 'Adaptive Radiation Pattern Optimization for Antenna Arrays by Phase using a Taguchi Optimization Method' developed by A.Smida, R. Ghayoula, H.Trabelsi and A. Gharsallah[6]. This system illustrates an optimal radiation pattern formed by a linear antenna array using Taguchi's Optimization method. The optimized phase shift weights is used to maximize the gain of the main wave at any desired direction. To calculate the phase shift weights, fitness function is used. In international journal of communication systems Hong-Ning Dai, Kam-Wing Ng, Minglu Li and Min-You Wu worked on 'An Overview of Using Directional Antennas in Wireless Networks' [8]. The research issues arise in different network layers on directional antenna wireless network are classified. The issues on DAWNs into the following different network layers are:

A) Benefits of Directional Antenna:

Compared with Omni-directional antennas, directional antenna has the following benefits

- ***Less Interference***- *Less Interference because a directional antenna concentrates transmitting signals to desired direction*
- ***Improved Spatial Reuse***- *Directional antennas improve spatial reuse by making more concurrent transmissions.*
- ***Yearn Transmission Range -*** *To get a longer transmission range it requires higher antenna gain and directional antenna achieve this gain by radiating radio signals to a certain direction.*
- ***Decreased Power Requirement***- *Directional antennas have higher antenna gains than Omni-directional antennas require minimum transmission power that is inversely proportional to the product of the antenna gains of both the transmitter and the receiver.*

III. OVERVIEW OF METHODOLOGY

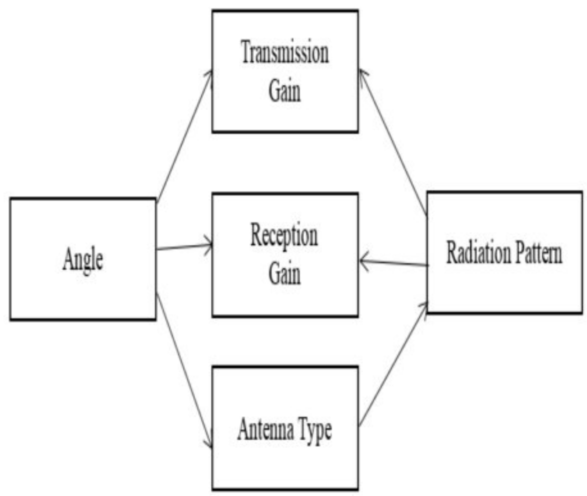

Figure 14: Existing System Flow Diagram for RSS of Directional Antenna.

Angle: It converts angle from radian to degree.

Antenna Type: This Checks the valid and invalid antenna type between Type0 to Type8.

Reception Gain: It calculates the maximum Reception Gain.

Transmission Gain: This evaluates the maximum Transmission Gain

Radiation Pattern: According to valid radiation pattern type initialize gain for that angle

A) Methodology:

1) Function to Calculate Angle

Angle ← atan2(y,x)
Angle ← angle*180/M_PI
End Calculate Angle

2) Function to Calculate Reception Gain

If Type equal to zero then
// multiply the gain with the ratio of the solid angles
Solid Angle Ratio ←
2/(1 - cos(M_PI*Width_/360))

```
        Gain ← Gr*solidAngleRatio
    Else
gain ← (gainVals[((int)diff_angle)%360]
+gainVals[(((int)diff_angle)+1)%360])/2.0;
        Gain ← pow(10.0,gain/10),
    End If
End Calculate Reception Gain
```

3) Function Calculate Transmission Gain

```
    If Type equal to zero then
        solidAngleRatio ←
2/(1 - cos(M_PI*Width_/360))
        Gain ← Gt*solidAngleRatio
    Else
gain← (gainVals[((int)diff_angle)%360] +
    gainVals[(((int)diff_angle)+1)%360])/2.0;
        Gain ← pow(10.0,gain/10)
End Calculate Transmission Gain
```

4) Function Calculate Antenna Type

```
    If Type > 8 || Type < 0 Then
     Invalid Type
    If Type != 0 Then
    Call  Initialize_Radiation_Pattern
End Calculate Antenna Type
```

5) Function Initialize_Radiation_Pattern

```
   If type+1 == Type Then
   gainVals[angle] ← gain
End initialize_radiation_pattern
```

B) Problem Formulation

1) Antenna Calculation

Input - {X1, X2, Y1, Y2, Z1, Z2, Lambda1, Lambda2}
Methodology – {Convert angle from radian to degree}
Output - {Angle1, Angle2}

2) Transmission Gain

Input - {Angle1, Angle2, Type0}
Methodology – {Calculate Maximum Transmission Gain}
Output - {Transmission Gain}

3) Reception Gain

Input - {Angle1, Angle2, Type0}
Methodology – {Calculate Maximum Reception Gain}
Output - {Reception Gain}

4) Angle Type

Input - {Type0, Type1, Type2, Type3, Type4, Type5, Type6, Type7, Type8}
Methodology – {Check Valid and Invalid Angle Type}
Output - {Valid Angle Type}

5) Initialize Radiation Pattern

Input - {Angle, Valid Type, Gain}
Methodology – {According to Valid Type, Define Maximum Gain for Angle}
Output - {Angle, Gain}

IV. SIMULATION RESULTS

A) Simulation Environment:

The ns-2 simulation environment is a flexible tool to network researcher to examine various protocols and their topologies. The ns-2 framework is useful for RFID systems. NS-2 stands for Network Simulator version 2. It is a discrete event simulator for networking research. This simulator Simulates wired and wireless network. It use OTCL and C++ to write a program. Ns-2Provide support to simulate various protocols like TCP, UDP, FTP, HTTP and DSR. Generally NS-2 used to -

- *To compute the performance of existing network protocols.*
- *To examine new network protocols before use.*
- *To experiment on large scale which is not possible in reality?*
- *To simulate a various IP networks*

Many other network simulation tools are available for network simulation. The other network simulation tools are:

OMNet++ is a public-source simulation environment used simulation of communication networks. OMNet++ modules are structured by an own network definition language NED, while the functionality is coded by using C++ classes. OMNet++ is available for Unix-Systems as well as for Windows supporting Visual C++ 6.0, Visual Studio .NET 2003 and CygWin.

Ns3 like ns-2 is an open source, discrete-event network simulator. ns-3 it does not have an OTcl API. It is written in C++ language and python.NS-3 network simulations can be implemented in pure C++, while some parts of the simulation can also be written using Python.

QualNet is the first commercial simulator. It is based on GloMoSim .GloMoSim uses the Parallel Simulation Environment for Complex Systems. QualNet is a network simulator used for wireless solutions and also support for wired networks. It uses primarily Java for the GUI hence it is available for Linux as well as for Windows.

SimPy is an extension for the script language Python for easy discrete event simulation. This simulator released under the GNU public license, which enables every one free use of the package. Since SimPy used an extension for Python, it is available on every system, which includes Linux and Windows.

Enterprise Dynamics has a very nice GUI for developing the model but it is only available for Windows. The core modules can be extended by using the own scripting language 4DScript. It is not focus on network simulation because of that it does not provide good performance.

Simulated Results

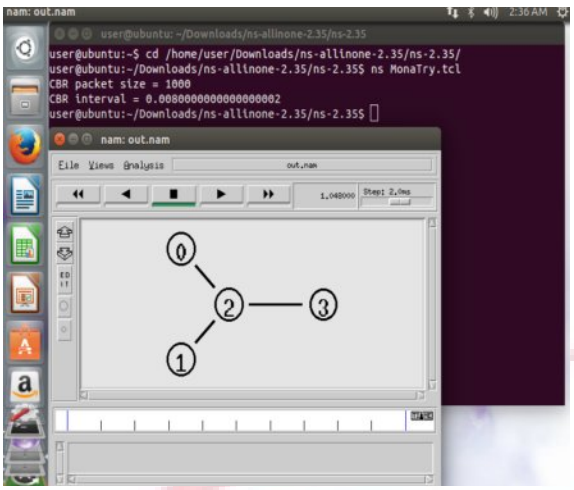

Figure 15: Simulation Result before 1.0ms.

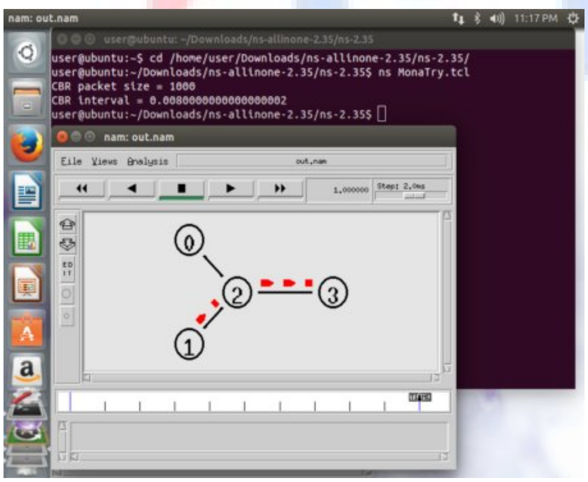

Figure 16: Simulation Result after 1.0ms.

Any Logic is the only simulator which supports discrete, continuous and hybrid simulation methods. This simulator is only available for Windows. Any Logic is based on Java. So possibility to be enhanced by custom Java functions.

V. CONCLUSION

Directional antennas can give great value for indoor applications. Directional antennas used for the indoors which requires lower gain. Thus it results in ability to reduce the interference signals received from directions outside the primary lobe area. This problem can be overcome by considering three factors - the antenna pattern, active-node distribution and channel characteristics. The directional antennas can concentrate its energy in a desired direction that overcome multipath but multipath reduces the focusing power of a directional antenna. The number of multipath at a long distance observed by a user can be much more. This problem can be avoided by using beam forming antenna to achieve the longer ranges as well as to reduce the interference. Hence, the directional antenna has ability to reduce interference. It can be used for longer communication range.

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The focus of his research in the last decade has been to explore problems at Near Field Communication and it's various application In particular, he is interested in applications of Mobile computing, wireless technology, near field communication, Image Processing and Parallel Computing. He has register patents like Indoor Localization System for Mobile Device Using RFID & Wireless Technology, RFID Based Vehicle Identification System and Access Control into Parking, A Standalone RFID and NFC Based Healthcare System. He has recently completed a book entitled Artificial Intelligence, Operating System, and Intelligent System. He has been an active scientific collaborator with ESDS, Carrot Technology, Techno vision and Research Lab including NVIDIA CUDA, USA. He is a member of CSI, ISTE, and IACSIT.

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