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Journal of Wireless Communication and Simulation

Aims and Scope

Journal of Wireless Communication and Simulation has become very important with the ever increasing demands of the software development to serve the millions of applications across various disciplines. For large software projects, innovative software development approaches are of vital importance. In order to gain higher software standards and efficiency, software process adaptation must be derived from social behavior, planning, strategy, intelligent computing, etc., based on various factors. This Journal addresses the state of the art of all aspects of software engineering, highlighting the all tools and techniques for the software development process.

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Contents

Performance Evaluation ofan MIMO Array for Wireless Communications Systems

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A B S T R A C T

Wepresent in this papera MIMO array to operate at the frequency of 2. 6GHz Long Term Evolution (LTE) band for wireless communication systems. The array consists of four miniaturized patch antennas on a dielectric substrate with total dimensions of 125 mm x62. 5 mm x1. 27mm. Modifications on the ground plane along with systematic placement and orientation (rotation) of each antenna on top of the substrate plays a key role to reduce the mutual coupling which normally degrades the MIMO arrays performance. The performance of this proposed MIMO array has been evaluated through simulations and measurements of the scattering parameters, radiation patterns, and correlation coefficients. The isolation obtained is over 25dB between all the antennas, and the maximum achieved gain of a single antenna is 3. 14dBi with other antennas terminated with appropriate loads (50-ohms).

Keywords— Antenna array, characteristic modes, correlation, multiple-input multiple-output (MIMO) systems, mutual coupling, radiation pattern.

I. INTRODUCTION

The antenna arrays with MIMO system are techniques that allows to increase the data transmission rate and link reliability when operating in environments with high scattering. The MIMO array technique normally generates low-correlation and parallel sub-channels between elements of the array, thus achieving increment in the system capacity (bit/s/Hz) by several orders of magnitude [1].

A factor that affects drastically the MIMO array performance is the mutual coupling between antennas of the array. A high level of the mutual coupling can cause increment in spatial correlation between the received signals by each antenna, which in return, reduces the number of independent parallel sub-channels [2]. Therefore, the high performance that MIMO system can offer is basically depends on: 1) the multipath characteristic of the propagation channel, and 2) the mutual coupling between antennas of the array. Modifying the propagation channel might not be easy to achieve; however reduction is the mutual coupling is still feasible.

There exist different techniques to reduce the mutual coupling between the elements of an array; one way is to increase the spacing between antenna elements of the array. This technique is feasible when the antenna array is located on base stations where the spacing can be increased; however, if the antenna array is built within small mobile phones, expanding the spacing is very difficult and requires complex work. This introduces new challenges for antenna designers, as spacing between antennas in the array becomes a strong constraint.

Several antenna designs have been proposed to reduce the mutual coupling of MIMO arrays in small mobile phones. In [3], and [4], several slot techniques was presented to achieve high isolation. These techniques work as a low wave structure, which can decrease the wavelength of the signal in the vicinity of the antennas and thus increase the electrical separation between antennas of the array [3]. Other methods uses Tshaped ground slot has been used to reduce the mutual coupling between antennas in [5]. In [6], T-shaped and dual inverted-L-shaped ground branches were inserted to reduce the mutual coupling. Additionally, Neutralization techniques have also been shown to increase the port-to-port isolation between two closely placed antennas through a transmission line connected between the antennas of the array. This technique has been used on PIFA antennas [7], on printed monopole antennas [8].

There have been some efforts using electromagnetic band gap (EBG) structures, which can suppress surface waves and thus reduce the mutual coupling between antennas [10]. The use of defected wall structure (WAS) was proposed in [11] along with slits in the ground plane, which separate two microstrip patch antennas and can provide isolation of 56dB. All these techniques and others [12], and [13] have been used to meet the required specifications for MIMO systems.

Although these techniques allow high level of isolation and thus very low level of spatial correlation, it is evident in many instances that considering the characteristic and influence of the printed circuit board (PCB/dielectric substrate) or mobile chassis becomes a critical factor in MIMO array performance. It seems that this type of consideration has not been rigorously analyzed in literature. In addition, the complexity of the design and fabrication deserve more attention and consideration.

An interesting and appealing technique to understand the role of the mobile chassis is through physical-based analysis modal, namely, Characteristic Mode (CM) analysis.

This model analysis provides physical insight into the potential resonant characteristic of a structure by finding and rigorously examining the natural modes of the structure.

The theory of CM was introduced by Garbacz in [14], and later redefined by Harrington and Mautz in [15]. Basically, CM's are real currents modes that must be computed numerically for structures of arbitrary shape. These CM's form a complete set of orthogonal currents on the structure, as well as a set of orthogonal radiation patterns. This property allows us to use the theory of CM to design a MIMO antenna array is built within small mobile phones, expanding the spacing is very difficult and requires complex work. This introduces new challenges for antenna designers, as spacing between antennas in the array becomes a strong constraint.

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The CM-based approach considers the chassis as a fundamental structure, and by examining the set of characteristic currents in the dielectric substrate, allows the designer to define the position of each antenna of the MIMO array. Another version of this theory is called, Network Characteristic Modes (NCM), where the modes are only considered at set of ports on the structure under study. In this work, we propose a novel MIMO array designed to operate at the 2. 6GHz (4G-LTE). The antenna array consists of four compact patch antennas on a PCB. Modification of the ground plane with slots along with a systematic placement and orientation of each antenna on top of the dielectric substrate plays a key role to increase the isolation and thus reduces the correlation between antennas. The modifications of the ground plane, placement, and orientation of each antenna on the array was done based on the insights provided by the theory of CM.

II. DESIGNED MIMO ARRAY

The goal in this work is to build an array with a substantial number of antennas within a compact mobile chassis and, in return, have a high isolation between the antennas. Initial design of single antenna was done such that the antenna operates at 2. 6GHz (AWS frequency band of LTE), thanks to the miniaturization techniques, which allowed us to design such antenna in small size using some slot insertion ideas, as can be seen in Fig. 1.

The next step is to place four antennas similar to the one in Fig. 1 on the substrate and try to achieve low mutual coupling between them. To do so, a systematic procedure of modifying the ground plane and antenna locations is performed. Each step of this procedure is explained clearly in the following sections.

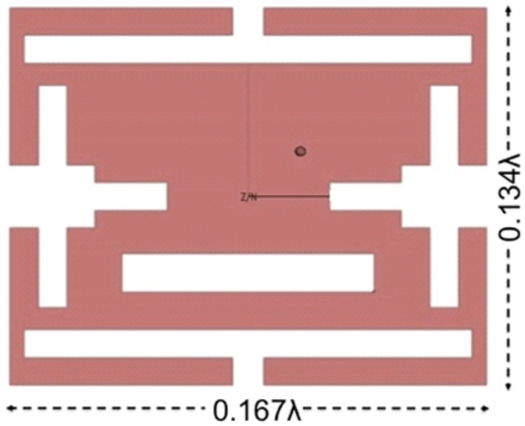


Figure 1. Design of the miniaturized Patch antenna using slots to operate at 2. 6GHz.

A. Eduardo Rodríguez et al

We start with a baseline structure; the four antennas have the same orientations and spacing as shows in the Fig. 2. Yet, no-modified is performed on the ground plane of the substrate. By starting modifying the structure aiming to reduce the mutual coupling, a slot design is introduced on the ground plane. These slots helped to reduce the effect from surface waves excited in the substrate. This systematic insertion of the slots on the ground plane allows us to select the final ground plane structure taking into considering the position of each slot as well as the spacing between antennas. To compares the total current distribution at 2. 6GHz for the baseline structure (Fig. 3a), and the ground plane with straight slots (no corrugated). It observes how the total current distribution decreases substantially when the slots are introduced. This means that there is less interaction between the antennas and a reduction in mutual coupling between them. Further modification is performed by introducing of some corrugations (small rectangles of 5mm x2. 5mm) in the slots to achieve greater reduction of the mutual coupling between antennas of the array how we can see in the Fig. 3c.

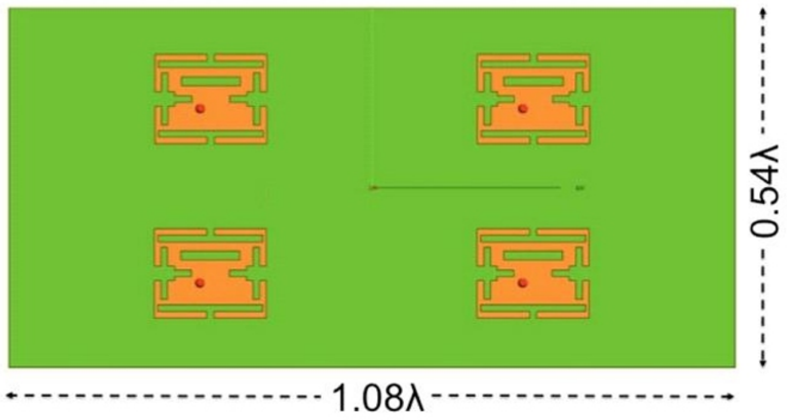
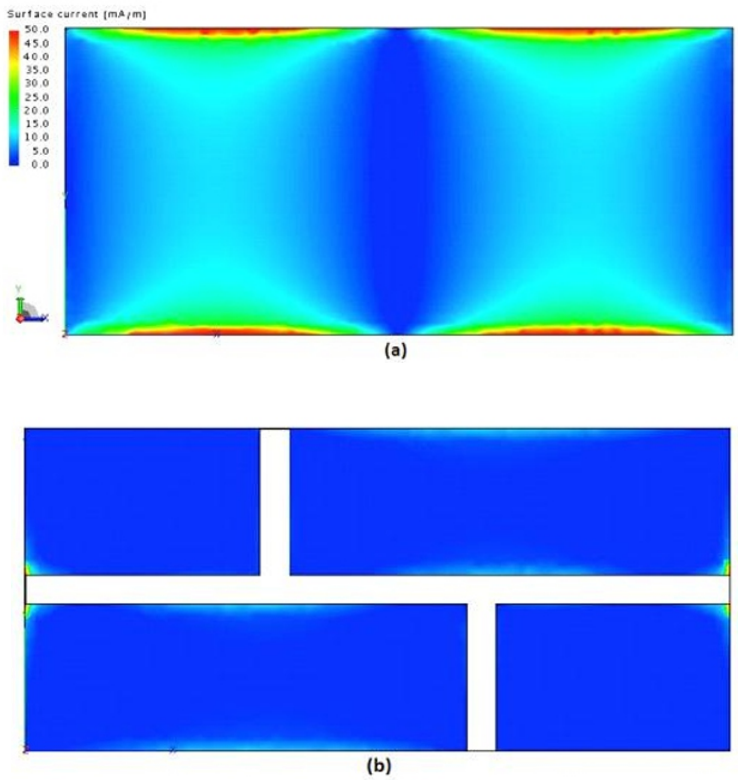
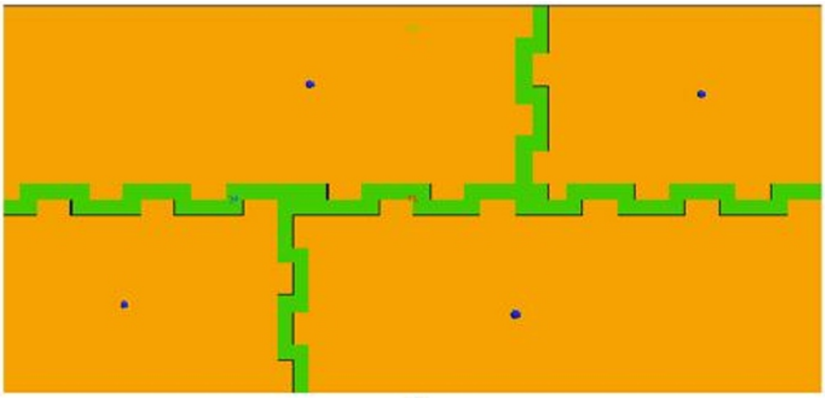


Figure 2: The Baseline structure of the 4-element antennas at 2. 6GHz.





(c)

Figure 3: Total current distribution at 2. 6GHz of (a) baseline ground plane, (b) modified ground plane with straight slots, and (c) modified ground plane with small rectangles (corrugations).

B. The Placement and Orientation of the Antennnas

Additional modifications are necessary to obtain a better performance, i. e. more reduction in the correlation. The first modification is to modify the location of each antenna on top of the substrate. Initially, each antenna is centered in the corresponding ground plane, then; further modification related to the antenna orientation is performed. It was observed that specific rotation helps improving polarization diversity so that the correlation between the signals reaching to each antenna of the array is reduced.

One way to obtain the optimum orientation of each antenna on the array by using the analysis that CM provides. The NCM eigenvalue spectrum for the four antennas of the array with corrugated slots in the ground plane and each antenna located in the center of the corresponding ground plane can be seen in Fig. 4a. The spectrum shows the dominant mode corresponding to each antenna. It can be seen the behavior of corresponding.

The modes to the antennas #1 and #2 show a good resonance near 2. 6 GHz. The results of these modifications can be seen in Fig. 4b and 4d. The latter shows that all antennas are well matched at 2. 6GHz. Note that a more detailed CM analysis was performed to obtain these results.

Fig. 5 shows the final arrangement of each antenna on top of the dielectric, and the geometry of the ground plane. Four miniaturized patch antennas are printed on top of substrate (r=4. 5 and tan=0. 002) with total dimensions of 125 mm 62. 5 mm 1. 27mm. The ground plane structure, modified with slots along the large dimensions of the ground plane and two perpendicular corrugated slots dividing the ground plane.

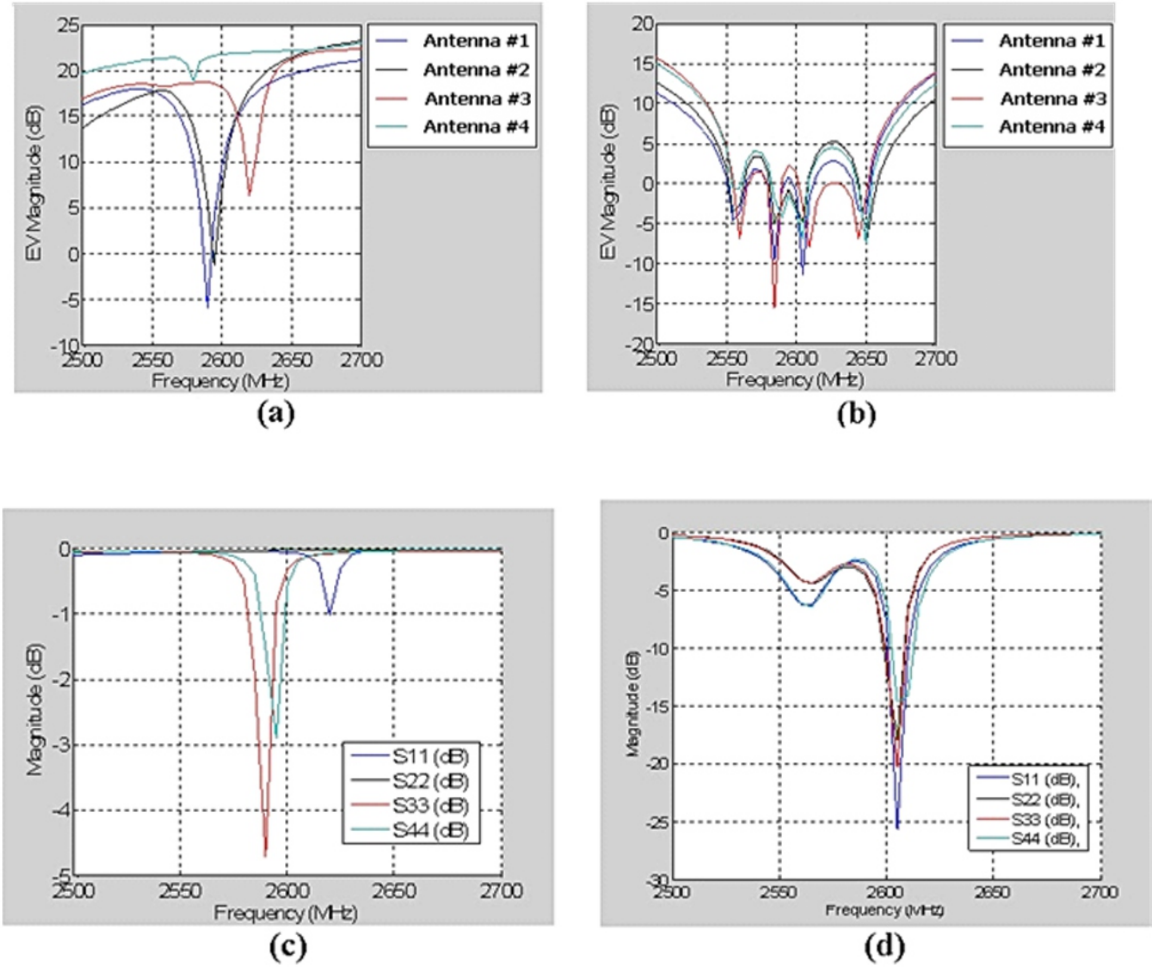


Figure 4: NCM eigenvalue spectrum of the dominant mode for each antenna at 2. 6GHz. (a) Eigenvalue before, and (b) after using rotations, (c) simulated return loss of each antenna before, and (d) after rotations (see Fig. 5).

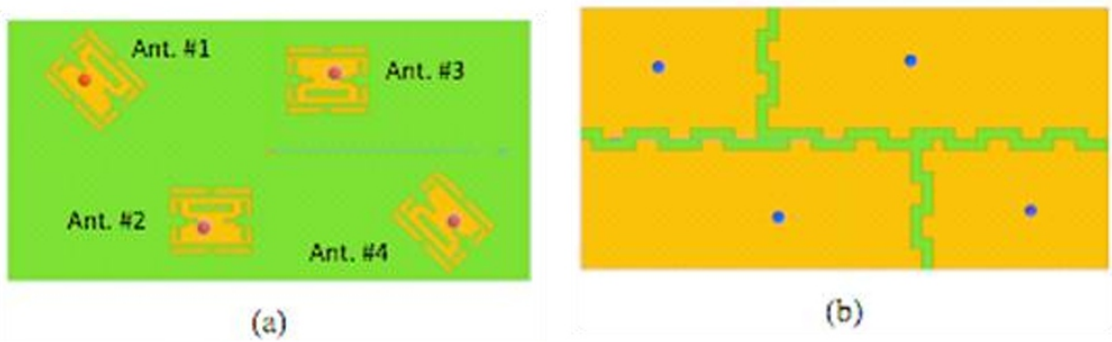


Figure 5: The designed four-antenna array for LTE-MIMO. (a) The antennas on top of the dielectric substrate, and (b) the modified ground plane.

III. RESULTS

The results from simulations and measurements to evaluate the performance of the proposed MIMO array arepresented for Scattering parameters, mutual coupling, radiation patterns, and enveloped correlation at a frequency of 2. 6 Ghz.

A. Scattering Parameters and Mutual Coupling.

Fig. 6 shows the results of the simulated and measured S-parameters with respect to 50-ohm reference for all antennas on the substrate. Note that the S-parameters are measured while all other antennas are terminated to 50-ohm loads. The return loss values (Sii) show a good agreement between simulated and measured. The measured mutual coupling (Sij, i j) between antennas remain below -28dB as shown in Fig. 6b.

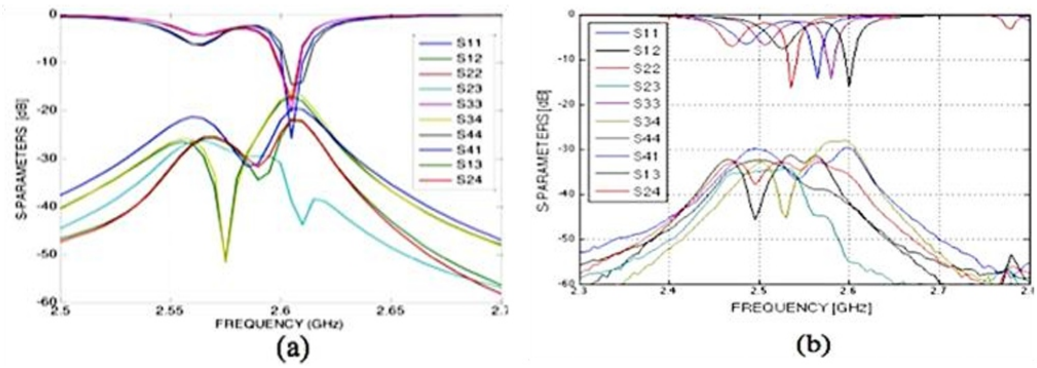
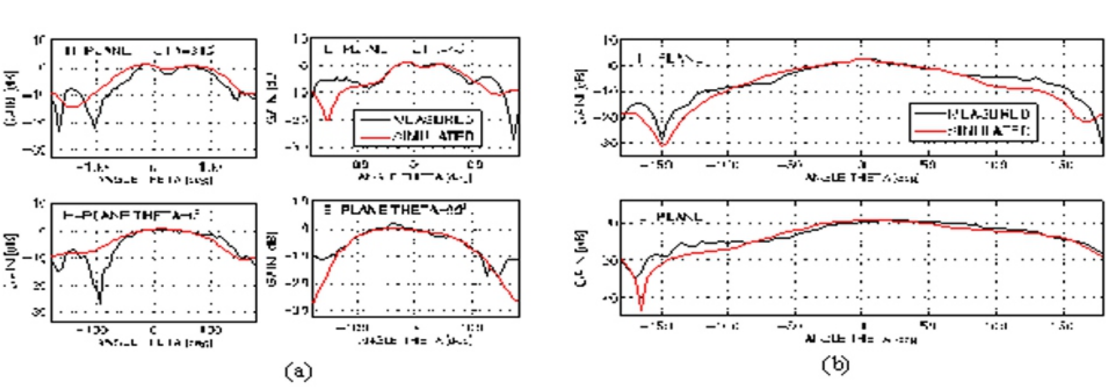


Figure 6: The S-parameters of the proposed MIMO antenna array. (a) Simulated, and (b) measured.

B. Radiation Pattern and Pattern Diversity

The simulated and measured radiation patterns at 2. 6GHz of each antenna of the array are plotted in the Fig. 7. It can be noticed that each antenna shows a different radiation pattern (pattern diversity); this favorable property helps reduce the envelope correlation because the received multipath distribution in each antenna will be different. Furthermore, the simulated and measured radiation patterns show a good agreement, and with a maximum achieved gain of 3. 14dBi. The measurement was performed by exciting one antenna while the others antennas were terminated by 50ohm load.



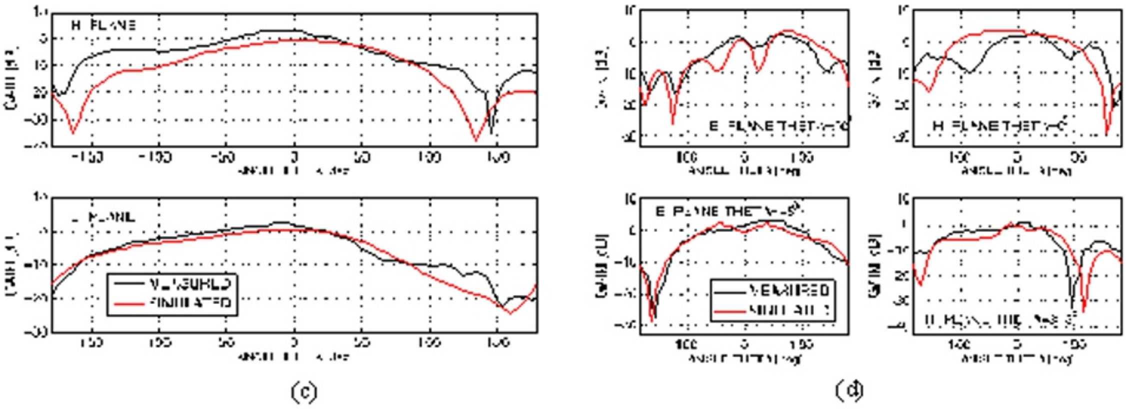


Figure 7: Measured (black line) and simulated (red line) radiation patterns of each antenna of the MIMO array. (a) Antenna #1. (b) Antenna #2. (c) Antenna #3. (d) Antenna #4.

C. Enveloped Correlation Evaluation.

One metric that provides very important information about the performance of the array for MIMO systems is the correlation. This enveloped correlation coefficient between signals received by the antennas of the array can be computed through the Sparameters with the assumption that the incoming signals are uniformly distributed, I. e. the direction of arrival of each multipath component has equal probability, and for a lossless MIMO Antenna [15].

The correlation coefficient between any two elements of the array is given as:

$$\rho_{ij} = \frac{\left|S_{ii}^{*}S_{ij} + S_{ji}^{*}S_{jj}\right|}{(1-\left|S_{ii}\right|^{2}-\left|S_{ji}\right|^{2})(1-\left|S_{jj}\right|^{2}-\left|S_{ij}\right|^{2})} \quad (1)$$

For an array of N-antennas, the correlation coefficients can be calculated as [16]:

$$\rho_{ij,n} = \frac{\left|\sum_{n=1}^{N} S_{i,n}^{*}S_{n,j}\right|}{\prod_{k=(i,j)} \left|1-\sum_{n=1}^{N} S_{i,n}^{*}S_{n,k}\right|} \quad (2)$$

The results of the correlation coefficients calculated through the measured Sparameters are plotted in the Fig. 8. The results are much less than 0. 000015 at 2. 6 GHz; these very low values can potentially enable the generation of more independent and parallel sub-channels producing high performance wireless communication systems with MIMO arrays.

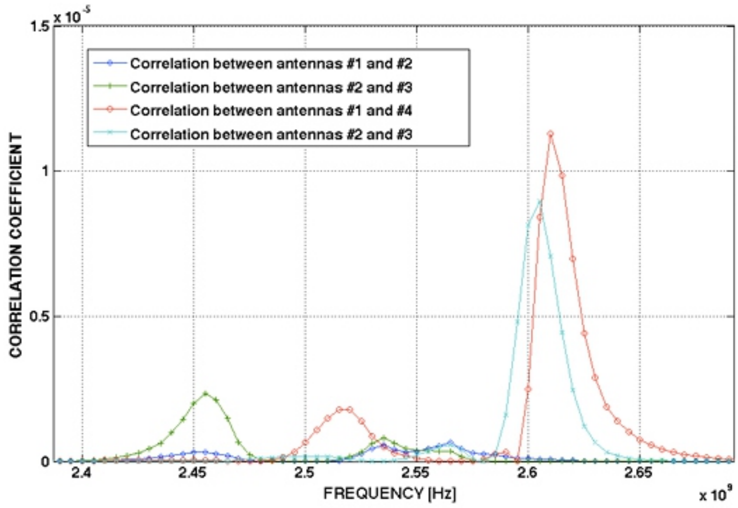


Figure 8: Enveloped Correlation coefficients calculated through the measured Sparameters with base at (2), and for losslees MIMO antenna.

III. CONCLUSION

The designed array with miniaturized antennas was shown to be suitable for use in wireless communication with MIMO systems at 2. 6 GHz (AWS band of LTE/4G). The modification of the ground plane with corrugated slots (with small rectangles) along with a systematic location and orientation/rotation (space and polarization diversity) of the antennas elements using the insight provided by the theory of Characteristic Modes (Cms), it was possible to build an MIMO antenna array with very high isolation and very low correlation coefficients. This allowed us to achieve a MIMO system with high performance. Furthermore, the radiation characteristics observed in the proposed array havethe ability to overcome channel problems as multipath fading because these patterns provide diversity in shape.

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The Development of a Mobile Application for Passenger Fare Guide for the City of Cagayan de Oro

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A B S T R A C T

This study stemmed from the need for the public to be aware of the exact amount of fares when riding a Public Utility Jeepney (PUJ), the most common public utility vehicle used by majority of commuters in Cagayan de Oro(CDO) City. However, until now, the city still used traditional information dissemination and free access to digital fare matrix with routing guides remains unavailable for commuters as far as Information Technology aspect is concerned. Thus, the researchers developed a mobile application named "CDO Fair Fare" in coordination with the information and formulas given by the Land Transportation Franchising Regulatory Board in Region-X. The researchers installed an Admin System on a personal computer (with Windows Operating System) to update fare and route information, thus creating the "CDO Fair Fare" Mobile Application. The beta application underwent human-testing and overall survey result yielded a rate of 37.52 percent from the respondents, which is equivalent to an "agree" respond when it comes to the application's efficiency. Therefore, the developed system CDO Fair Fare mobile application was can be deemed effective to the commuters if this will be put to actual use, with recommendations that this application can be upgraded or improved by future researchers/developers.

Key Words: Land Transportation Franchising Regulatory Board, Colorum, Public Utility Jeepneys. Commuters, Routing Guide, Mobile Application.

1.0 INTRODUCTION

In the continuing evolution of innovation, everybody lives in a fast-paced technology era wherein a wide range of internet resources arebecoming dependent to touchscreen mobile "smart" devices run mostly by Android Operating Systems. An example of this will be the Smart Phones that has introduced new possibilities in human lifestyle. This software can help the mobile phone be more useful to the user. In Tagbilaran City, Bohol the LTFRB regional office warned the drivers and operators of PUJsto give discount to students and senior citizens. Failure to do will mean drivers and operators will be slapped with severe penalties, said regional director Ahmed Cuizon. Cuizon urged those who are not given this privilege to report to the authorities concerned erring drivers for failure to honor the law providing for discounted fares. The Expanded Senior Citizens Act of 2010 also known as Republic Act No.9994, as amended, provides tax privileges. A senior citizen or elderly under the law refers to any resident citizen of the Philippines at least 60 years old. By that, this application will provide the exact fare for jeepneys, and passengers will be informed to avoid future conflict with PUJ drivers because the application details were based from the LTFRB data.

The problem states that based on the current state, the city's fare matrix with routing guides was not available for an easy and understandable reference for the commuters in Cagayan de Oro City, as far as digital technology or Information Technology is concerned.

Thestudy aims to develop a mobile application that will give the city's fare matrix information with routing guide for the commuters of Cagayan de Oro City. Specifically, the study aims to design a fare matrix mobile application with mapping and routing guides, to develop and implement a fare matrix mobile application that contain routing guides, and to conduct user testing to identify if the system helps commuters in Cagayan de Oro City about fare and maps.

2.0 Methodology

2.1 Design of the System

2.1.1 Use Case Diagram

In Figure 1, shows the passenger can view the calculated fare from his/her source and destination, can view the map and be able to know the details of his route. The passenger can be able to view the routes from the LTFRB copy.

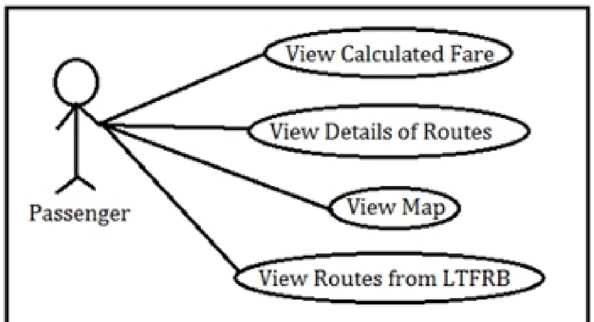

Figure 1. CDO Fair Fare: A Mobile Application

2.1.2 Implementation

CDO Fair Fare Mobile Application was designed using Java programming language and SQLite Database.

The passenger will type an input of his/her starting point and destination. The passenger can use the application even without an internet connection. The SQLite database will give a response if the starting point and destination's input will match. It will show the calculated fare, its route, how many rides to the passenger's destination, and it will also suggest the shortest route in order to arrive at the desired destination faster after the entered inputs of the user matched route in the SQLite database.

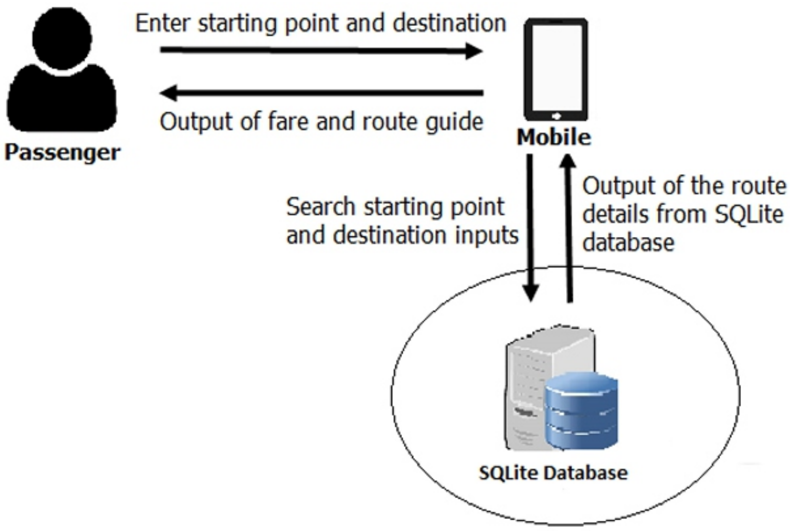

Figure 2. CDO Fair Fare System Architecture.

2.2 Testing

The researchers conducted a preliminary testing by doing assumptions for beta testers that have android phones because the CDO Fair Fare application required an Android OS smart phone to work.

The researchers chose the BSIT first year level students of Mindanao University of Science and Technology because most of the first year students are new for traveling around Cagayan de Oro City. There are 9 sections with 40 students in each, comprising the first year class under the BSIT program. From there, the researchers chose seven respondents from BSIT-1R2 who were willing to participate in the orientation conducted by the researchers. During the testing the researchers guided the beta testers on how to install the Google Play Services (to be able to use the google map which is in the application) and the CDO Fair Fare application. After the installations were completed, the researchers let the respondents to use and find the vulnerabilities of CDO Fair Fare mobile app. After five minutes, the researchers conducted three tests which were asked to the respondents to input the source and destination. The test was conducted in order to know the effectiveness and the accuracy of the mobile application.

3.0 Results and Discussion

The calculated percentage in each table of the tests conducted was from (n/35)*100 where n was a number of votes in the survey and the 35 (7 multiplied by 5) where 7 is the number of respondents and 5 where the number of questions in each test category, multiplied by 100 and came up with the total percentage. Results show that 37.52 percent agree on the effectiveness of the system.

Table 1: Overall Result Survey

		Strongly Agree	Agree	Fair	Disagree	Strongly Disagree
I.	Usefulness	37%	24%	11%	5%	0%
II.	Ease of Use	25.71%	48.57%	28.57%	0%	0%
III.	Satisfaction	42.86%	40%	17.14%	2.86%	0%
	Total	**35.19%**	**37.52%**	**18.90%**	**2.62%**	**0%**

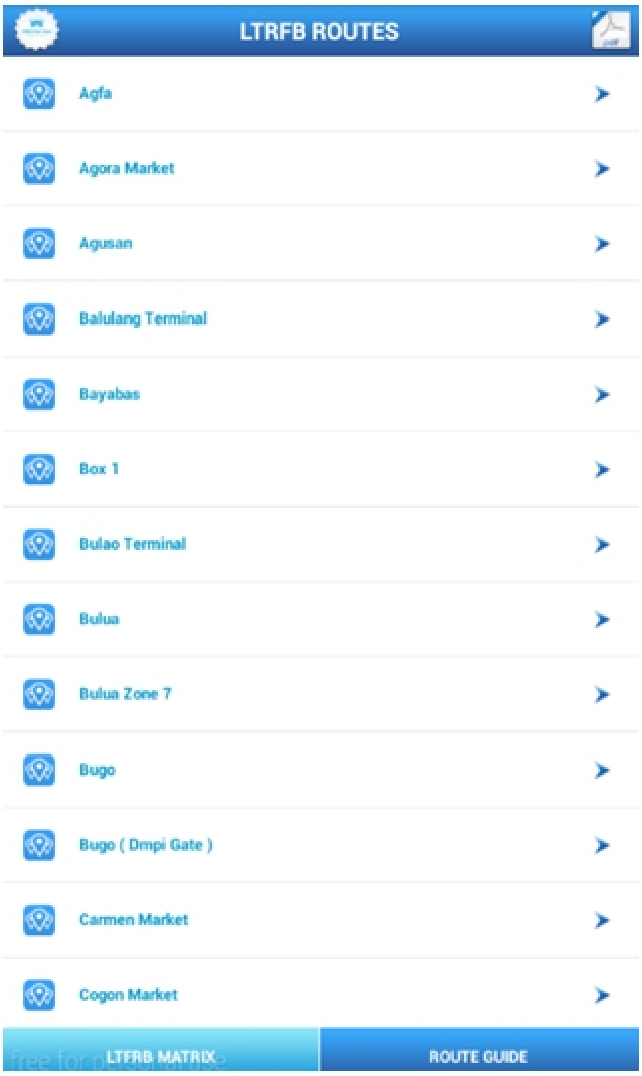

Figure 4: Land Transportation Franchising Regulatory Board Routes.

Figure 4shows the route information provided by the LTFRB.

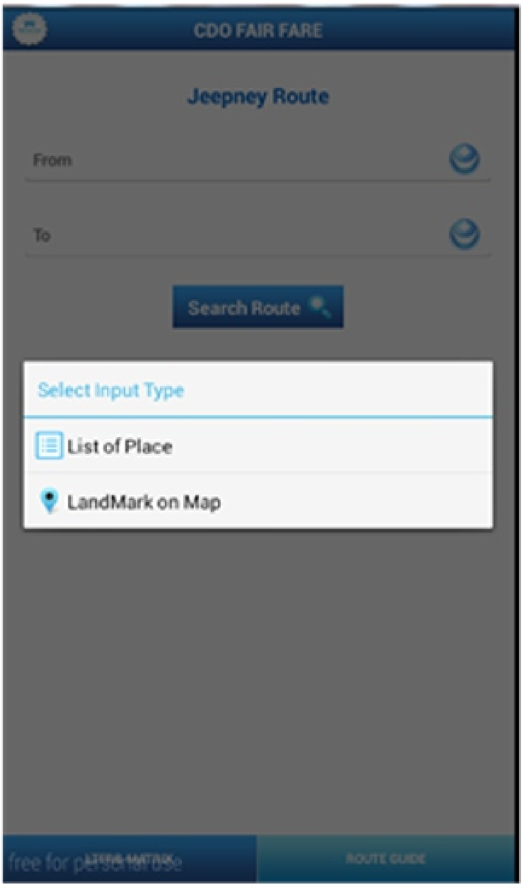

Figure 5: Route Guide Selector.

Figure 5 shows the options of choosing the areas in CDO. The land mark on map is for the tourists that do not know where the particular area is.

Figure 6: LandMark.

Figure 6 shows the landmarks in the map. Tap the location indicators (pin-like shapes) to know the name of the place. It is also for choosing the source and destination of the commuters.

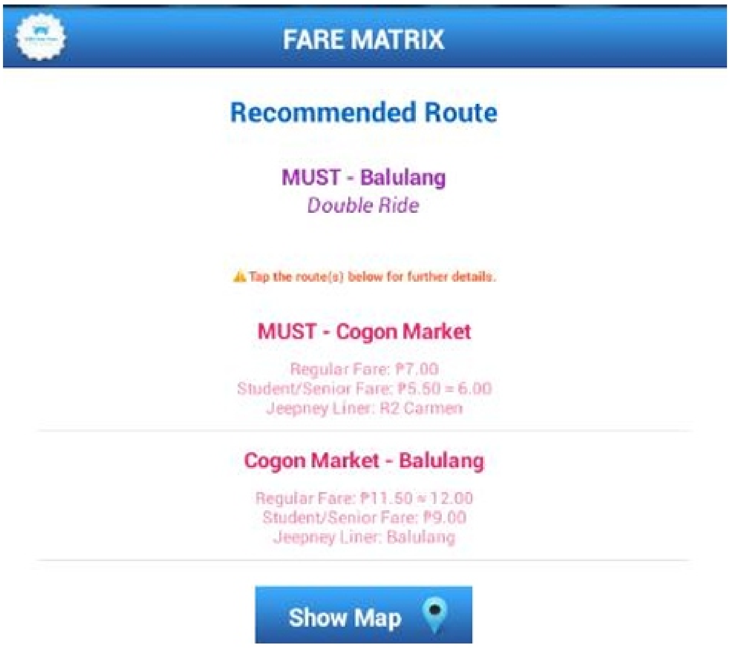

Figure 7: Route Details.

Figure 7 shows the chosen route example, from MUST going to Balulang. After the search route button was tapped, it displayed the recommended routes showing the regular fare, the jeep liners that must be taken, and the seniors/students/disabled privilege fares. It also showed how many rides the commuter must take (single and double-rides only). The commuter can tap the route for further details.

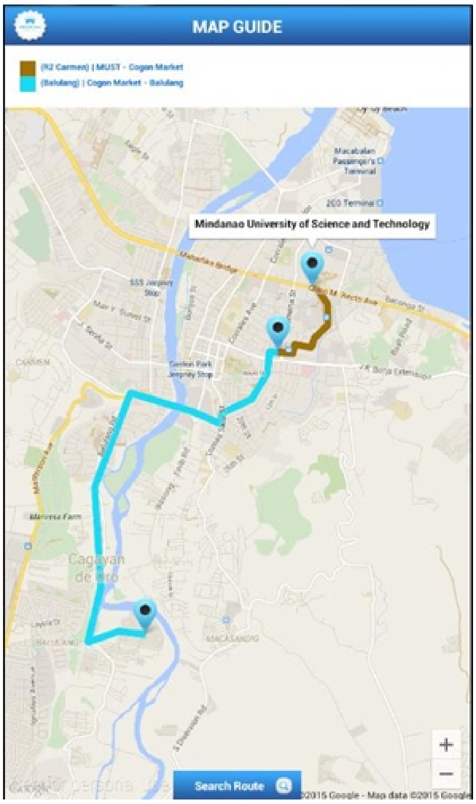

Figure 8: Map Guide.

Figure 8 shows the mapping guide of the user's source and destination.

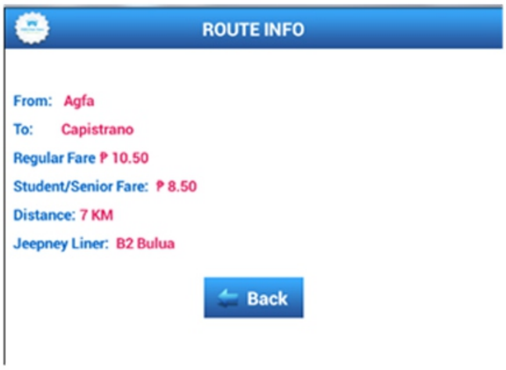

Figure 9: Route Information.

Figure 9 shows the all details of the chosen routes. It contains the regular and discounted fare, the distance from the source and destination and the jeep liner to be taken.

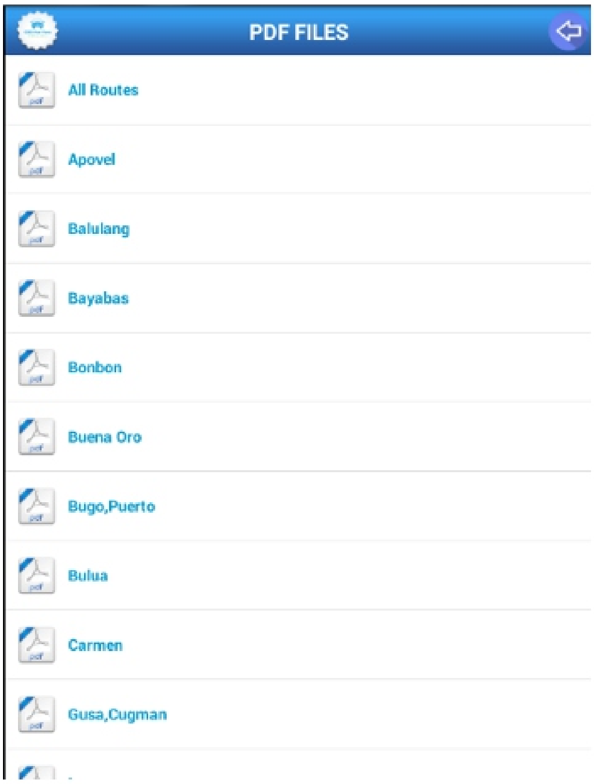

Figure 10: PDF Files

Figure 10 shows the route information from the LTFRB in a PDF format.

4.0 Conclusion and Recommendations

CDO Fare Fair system showed that there is a strong probability it can help the commuters in riding the jeepneys within Cagayan de Oro city. The result of the overall survey preference of the system is agreeable having 37.52 percent under the usefulness, ease of use, and satisfaction questionnaires. This resulted on the reference of the commuters in the city's jeepney fare matrix deemed as more convenient. Graphs of the jeepney routing paths will be the passenger's destination guide. Shortest paths of the jeepneys destination route will lessen the passenger's transportation time.

The researchers recommend the following:

First, the CDO Fair Fare Android mobile application can be extended to support other Operating Systems like iOS in order to serve more the passengers who used smart phones with different OS in Cagayan de Oro City. Second, you can improve the application to triple-rides or more. Third, you can add new features to the application, such as a hotline number or email address to LTFRB that can directly cater the complaints of the passengers in the fare matrix.

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Energy Optimization In Wireless Sensor Networks Using Leach Protocol

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A B S T R A C T

Wireless Sensor Networks are created by using connected wireless sensor nodes that each node is compact and has the ability of sensing, storing and processing the environmental information as well as communicating with other nodes. Strong adaptability, High fault tolerance, and comprehensive sensing coverage are the main merits. These are some of the features which allow wireless sensor networks to be applied to a diverse range of applications, e.g. environmental monitoring, home, health care, battlefield surveillance, and so on. In recent times, WSNs have become a crucial space for research. In wireless sensor networks during communication process between the sensors nodes more amount of energy is consumed.

Keywords: Energy efficiency, Cluster head, Lifetime, Wireless sensor network.

Introduction:

Recent promotions in Electronic and wireless communication industries, has created the ability of designing tiny size, minimum price, low consumption and multi applications sensors. These small sensors have the ability of receiving, processing and sending the environmental data and have created an idea for development of networks that are named Wireless Sensor Networks [9]. The sensor networks architecture performance is so that the sensors distributed randomly and consistently in a region to detect and control the processed events, and then they send the information to the base Station [10]. These sensors have high performance and they have some restrictions while developing in high scale. The sensors limits can be classified into some categories such as band width restriction, no battery replacement short radio broadcast and low energy consumption conditions in most cases. Every sensor node is usually equipped with a battery, microcontroller and transceiver. Sensor nodes are generally set with communication and processing capability. In wireless sensor networks efficiency of energy is an important issue. Hierarchical routing is a professional way to minimize the energy consumption within a cluster. However, because the cluster heads (CHs) closer to the sink node are burdened with heavy traffic, they drain much faster than other Chs.

Some features of sensor network make it dissimilar from other traditional and wireless networks. These features are:

• High density of node distribution in operating region
• Failure talent of the nodes
• Data oriented network
• Memory
• Dynamic and periodic topological changes
• Hardware including size restrictions, power supply, process power and capacity
• Using the broadcast communication method instead of peer to peer method

Protocols and sensor network algorithms should have capability of self-organizing. Thus, routing protocols design should increase network lifetime and utilize maximum node energy, also WSN routing networks should be simple with few calculation's, little delay in data transferring from nodes to the Sink, minimum energy consumption. In this view, so many protocols and algorithms have been designed. One of the methods is hierarchical method. By this method, lots of data aggregation methods could be done in every cluster. Clustering methods have a few advantages. The first one is that they split network to some different regions and each region is managed by a Cluster-Head. The second one is to decrease data redundancy because of data aggregation by the Cluster-Head (CH). Sensor networks organization in the clustered architecture lead to several clustering algorithms at recent years [4].In fact ClusterHeads can aggregate, process and filter the data send by cluster members, then reducing network bandwidth. Clustering saves energy power. Many applications are required for wireless sensor networks (WSN) to self-organization of a network into clusters. Cluster creates a hierarchical structure over a flat network. In this paper we have present a clustering algorithm that has clustering network and sending data by the CH in each cluster. Thus decrease energy consumption and increase network lifetime. Also in this the data of each cluster is send to BS via a single method [4].

RELATED WORK:

Bagheri et al. [12] proposed a protocol in which GPS system is used to activate the nodes. Cluster head is selected to construct multi-path routes between nodes. If the path selected is failed, cluster head will choose another path. Quynh et al. [13] have suggested an event-based multipath clustering protocol. Nodes will be activated if an event is identified in their close proximity. One among the activated nodes with maximum energy is elected as cluster head. The other activated nodes form a cluster by connecting to the cluster head. Mazaheri et al. [14] have proposed a QoS based multipath hierarchical routing protocol. The nodes elected as a cluster head within its range r based on the remaining energy and the distance to the sink. In multipath construction a set of clusters are elected by the cluster head in its range R based on the distance to the sink, residual energy, signal to the noise ratio and remaining buffer size. Jin et al. [15] explained the Passive Cluster based Multipath Protocol. In this protocol, the node will be close to the event waits for a certain time to become the candidate cluster head. If it does not get any cluster head announcement, it becomes the cluster head and broadcasts the advertisement on its range R. The nodes inside the range R/2 joins the cluster and remaining nodes follow the same procedure for cluster formation and also the nodes within the range R become the candidate cluster head. Branch aware flooding method is employed to construct the multipath between the sources and sink node. For the next time if any source detected the identical event, the same sets of clusters were used, however a contemporary set of multipath is needed for data transmission. In existing protocols higher-energy consumption is there because of additional management packet overhead. It directly affects the lifetime of the network. These protocols provide additional stress on reliability through the multipath but neglect some QoS parameters like as end-to-end delay, control overhead and network lifetime. Zaman et al. [16] have planned a protocol whenever the network is split into levels. One cluster head is selected in each and every level. The cluster head gathers the data from all the nodes of that level and send it to the lowerlevel cluster head using directional flooding technique. Almalkawi et al. [17] have planned a cross layer clustered multipath routing. The nodes are randomly deployed and heterogeneous. The sink initiated the cluster formation by broadcasting the control packet and supported received signal strength, the powerful nodes become the cluster heads. The cluster heads are classified into different levels. They send the information through the higher level cluster head. An analysis based clustering and multipath routing is proposed [17]. For cluster formation, the base station chooses a specific number of candidate cluster heads randomly on certain probability. The candidate cluster head checks for the faulty status of each other. Once the faulty node is detected, it is eliminated from the network. The neighboring node having the highest residual energy will become a cluster head and the remaining nodes join the nearby cluster head and form the cluster. For multipath construction, the cluster head is chosen within the range 2R having the minimum distance from the sink. The protocols which do not have a proper path, they have the information regarding their neighbor nodes. They have to select a node from the neighboring record without knowing their current residual energy or connectivity with the other nodes. It minimizes the reliability of a network. Wang et al. [18] explained a hierarchical multipath routing protocol is hierarchical. To allocate the distance between the source and sink each node has a hop count value. The node will be selected the parent and alternate parent node based on the hop count value to make the multipath [3]. The network with the sink as the root node it looks like a tree. Using hierarchical structure, it reduces some amount of energy consumption and data traffic [3].

PROPOSED WORK:

The core operation of a WSN is to be gathered and convey the collected information to a distant BS for their processing and analysis. Gathering data from a WSN in an energy effective manner is an important way to extend its network life time. These calls are used for an appropriate routing protocol to ensure that the efficient data transmission is done through the network. The sensor nodes are occasionally switch to their sensors, sense the environment and transmit data at constant time intervals. They provide a snapshot for the relevant attributes at regular intervals. At later the sensor nodes should react immediately when the changes are to be happened at a certain event [5].

The proposed LEACH routing protocol ensures that the elected cluster-heads will be distributed regularly over the network and there is no possibility that all cluster-heads will be concentrated at an individual part of the network.

The performance of the proposed LEACH protocol is evaluated mainly based on the following metrics:

Average Energy utilization: The average energy consumption of a sensor nodes are measured at equal intervals [5].

The total sensor field is segregated into equal sub-regions. The choice of the cluster head from each sub-region is determined by the energy of the sensor node. Following is the algorithm for the LEACH protocol.

ALGORITHM:

Algorithm for cluster head selection:

$E[\#CH] = \sum_{i=1}^{N} P_i(t) * 1 = K$

$K/N\text{-}k * (r \bmod N/k) : C_i(t) = 1$

$P_i(t) = \{$

$0 : C_i(t) = 0$

$E\left[\sum_{i=1}^{N} C_i(t)\right] = N\text{-}K * (r \bmod N/K)$

$E[\#CH] = \sum_{i=1}^{N} P_i(t) * 1$

$= (N\text{-}K * (r \bmod N/K)) * k/N\text{-}k * (r \bmod N/k)$

$= K$

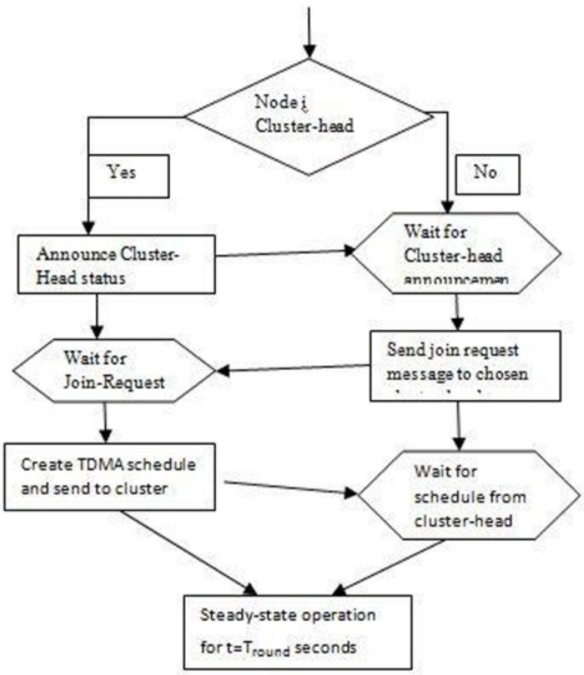

Figure 1: Flowchart of the distributed cluster formation algorithm for LEACH

SIMULATION:

Simulation Parameters

Table 1: Parameters for simulation

Parameter	Value
Network Size	200*200
Number of Nodes	200
Base Station Location	100,100 m
Initial Energy	2j
Packet size	100 KB
Transmission Range	120 m

Results and Analysis:

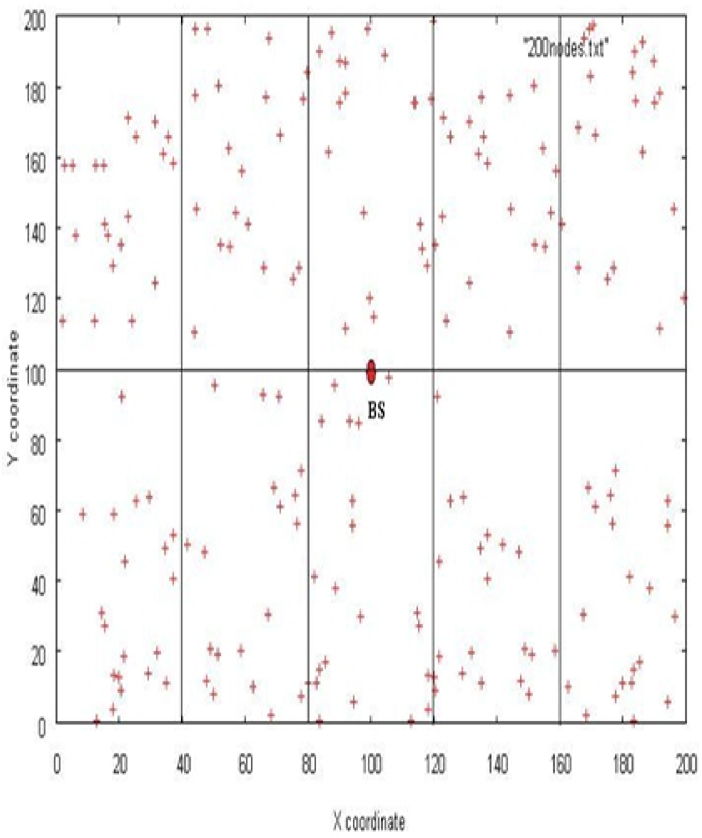

Figure 2: Sensor network topology for 200 nodes with base station at (100,100)

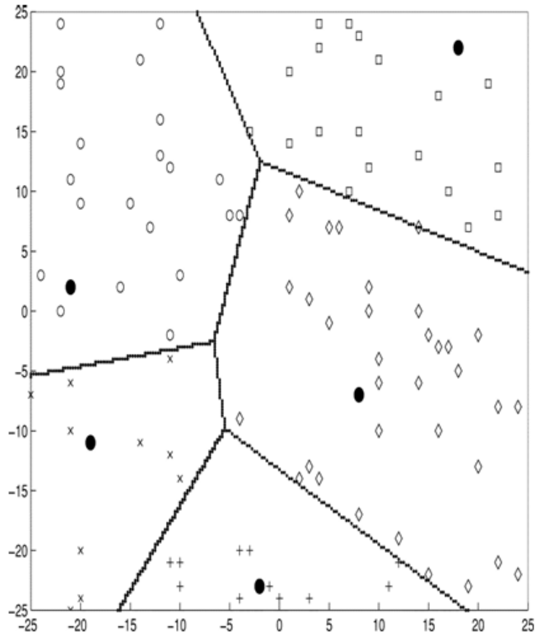

Figure 3: Dynamic cluster formation

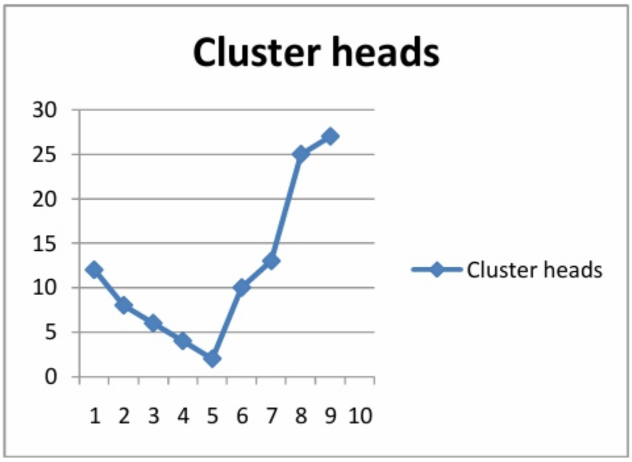

Figure 4: Average energy consumption under different cluster header number

From this we can view that the energy consumption is minimum when the number of cluster heads are five, and LEACH simulation is done in the following aspects for respective five and six cluster heads in order to verify that the LEACH protocol under optimal number of cluster-heads can improve its network performance [6].

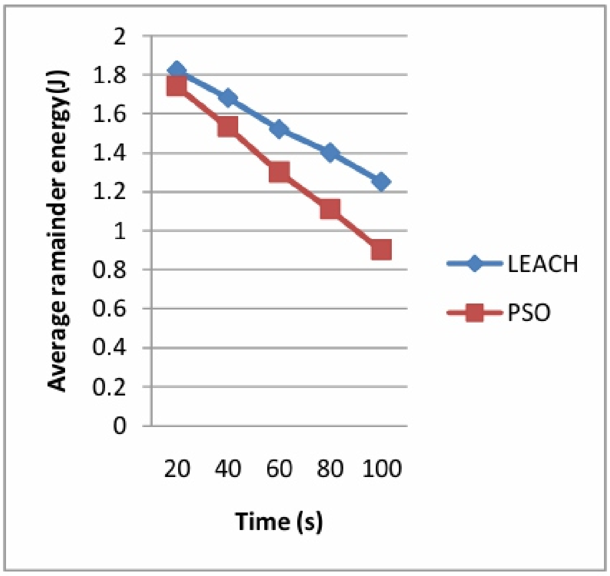

Figure 5: Average remain energy of 200 sensor nodes

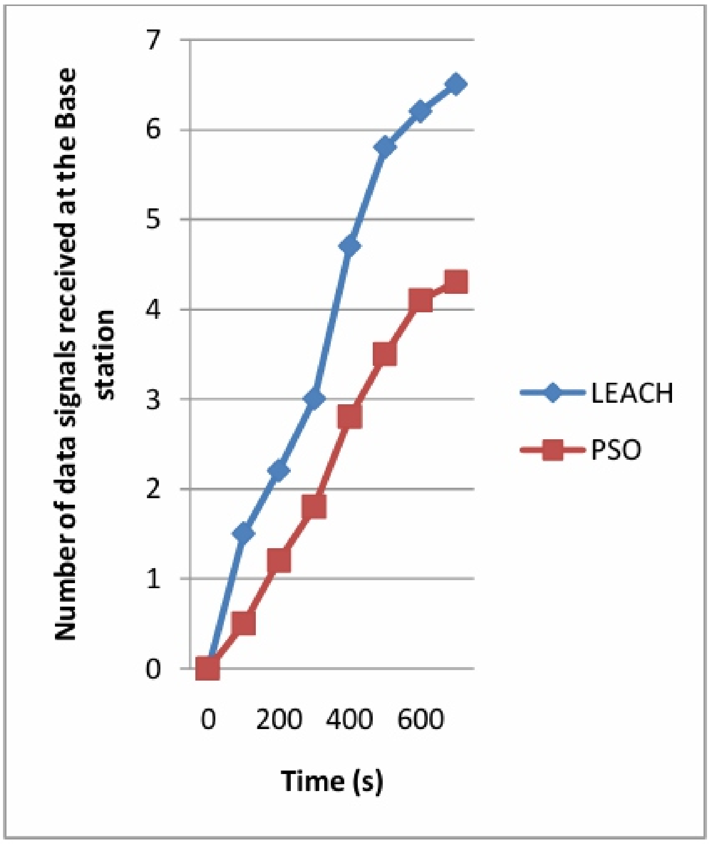

Figure 6: Total amount of data received at BS over time

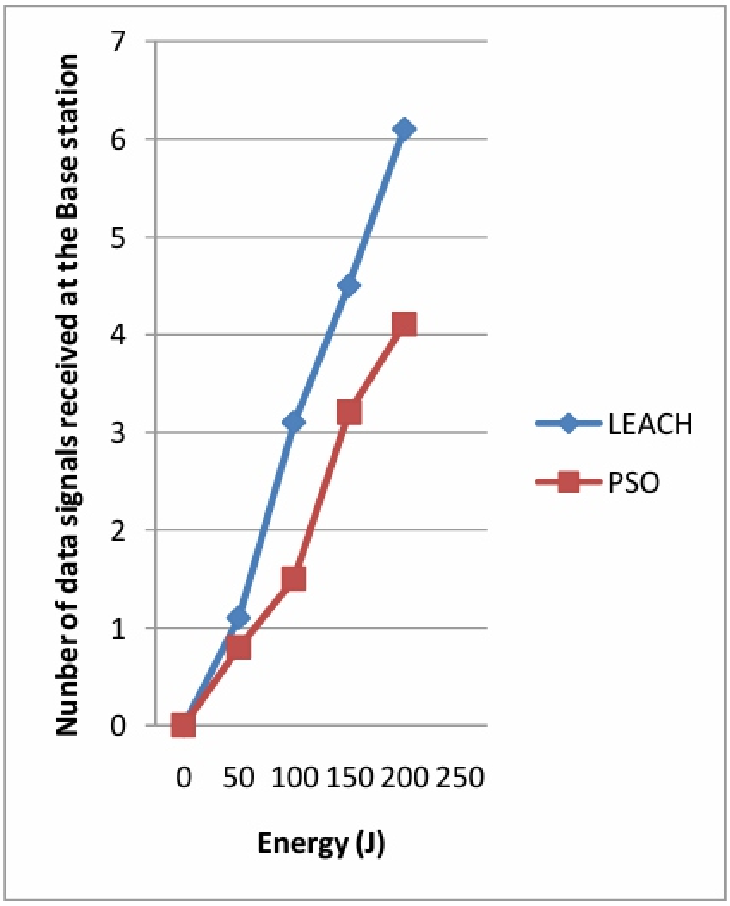

Figure 7: Total amount of data received at BS per given amount of energy

The cluster head of mth cluster aggregates the data received from another sensor nodes, transmits to the next hop cluster head with its own data which is nearer to the base station based on the cluster formation and the shortest distance among the cluster head and the BS [6]. At every transmission or repetition made, energy decrease occurs for every node; to prolong the lifetime of the WSN the cluster head rotation was utilized.

We observed that the first node dies during a non-hierarchical cluster creation. Since all nodes tend to send the captured data via one randomly chosen cluster head per round to the base station [5]. The elected cluster heads during the round of simulation significantly reduced the CHs' energy over a short period.

CONCLUSION:

This paper proposed an energy efficient routing scheme using the clustering and multipath technique. The workloads of the sensor nodes are alleviated by giving more responsibility to the base station. The multipath gives more reliability to the network, and it increases the throughput and decreases latency. In addition to that, cluster based data collection reduces the traffic and energy consumption and also increases the lifetime of the network. The simulation results show that the proposed protocol is outperformed.

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Performance and Comparative Analysis of SISO, SIMO, MISO, MIMO

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ABSTRACT

In the present world, due to rapid growth in communication (over broader distance) has increased; therefore there is a need to improve the transmission of the data over wireless media so as to achieve the demand of fast and feasible communication. To meet the above, it is required to have better and improved throughput, data rates, BER and quality of signals received at the receiving end of the system, in the advanced wireless communication. The parameter (like throughput, data rates, BER) mainly depends on the antennas used in transmitting and receiving end of transmitter and also on the external disturbances introduced in the form of noise in the system. The antenna that can attain all the parameters values at optimum level is MIMO antenna. Apart of MIMO we also have SISO, SIMO, MISO antennas available for communication over radio channels. Among all the four mentioned (SISO, SIMO, MISO, MIMO) MIMO gives the best diversity gain of the signals received at the receiving end also it has got the ability to handle the external noise effect in the most appropriate manner than other so as to reconstruct the same signal at the receiving end. In this article we will analyze all the four types of antennas theoretically and practically (with respect to OFDM) to have an clear view regarding how the signals are processed in all the four types and what are the advantages and limitations of using each of them and what all are the limitations in SISO, SIMO and MISO which makes the MIMO technique the most suitable among the four. In this article we have compare all of them practically using BER (comparison parameter) to support the analysis. Based on the analysis obtained we can derive that MIMO is the best suitable for advanced digital wireless communication.

Keywords: SISO, SIMO, MISO, MIMO, OFDM (Orthogonal Frequency Division Multiplexing), BER, LAN, WAN, MAN

1. INTRODUCTION

During the past few years (especially the last decade), the communication industry has experienced an exponential growth which has led people use this pace of advancement in communication industry at the highest level. Mobile communication has reached to 4G from 2G, here the data rate for 2G was around 12kbps and then 2Mbps in 3G and followed by 100Mbps downlink speed and 50 Mbps uplink speed in 4G-LTE [2].

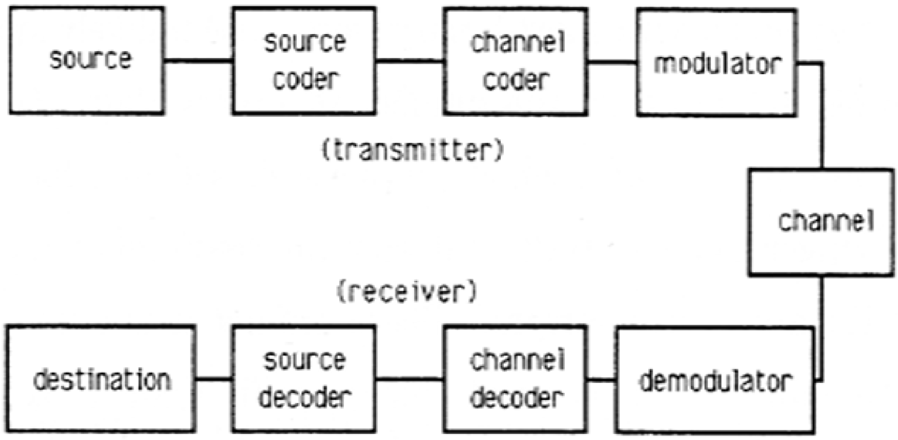


Fig. 1: Block Diagram of wireless digital communication system [2].

The above block diagram indicates how the signals are transmitted and received in radio channels. In the above diagram, the transmitting antenna is located at after the modulator to pass the modulated signal to receiving antenna via radio channels. The quality of the signals received at the receiver end depends on the channel, since many unwanted signals may get introduced in the original signal when the data is getting processed from transmitter end to receiver end. For transmitting of the signals antennas are located at both the ends and the channel capacity is maintained by the different types of antennas used in the system [1].

As of now, there has been a tremendous increase in the wireless communication globally, which has led down an increased demand to have better communication over radio channels in wireless media with minimal or negligible (if possible) data loss, proper SNR value to give fast and effective communication. As it depends mainly on the types of antennas used, we will now study each of them in detail. As discussed earlier we have four types of antennas available viz. SISO, SIMO, MISO and MIMO. The criterion that classifies any antenna in any of the four types is number of antennas at input side and number of antennas at output side.

II. MODULATION TECHNIQUE(S)

There are many types of modulation techniques available which can be used, some of the techniques available are – PSK, BPSK, DPSK, DEPSK, QPSK, MPSK, BFSK, MFSK, QASK / QAM, MSK.

Here we have analyzed all the antennas using BPSK (Binary Phase Shift Keying) since modulating a digital signal is easier in BPSK comparatively with other techniques. In BPSK, when the data is at one level then one of the two phases is fixed while the other phase is at a phase difference of 180 degree [1]. It consists of a bit synchronizer to detect the end of one signal and the start of other so as to change the phase of the system. The BPSK signal transmission in time domain is as shown below.

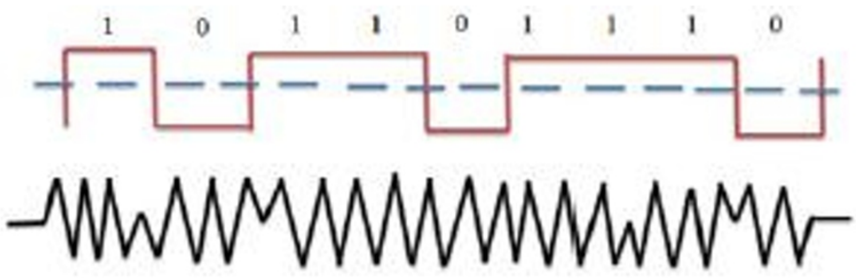


Fig. 2: BPSK signal modulation.

I. TYPES OF ANTENNAS

1. SISO (Single Input Single Output)
2. SIMO (Single Input Multiple Output)
3. MISO (Multiple Input Single Output)
4. MIMO (Multiple Input Multiple Output)

1. SISO (Single Input Single Output)

In SISO type of antenna, there is only one transmitting at the transmitter end and one receiving antenna at the receiver end. This makes SISO the simplest to implement and easiest to design amongst all the four types of antennas available. Following is the block diagram of SISO system.

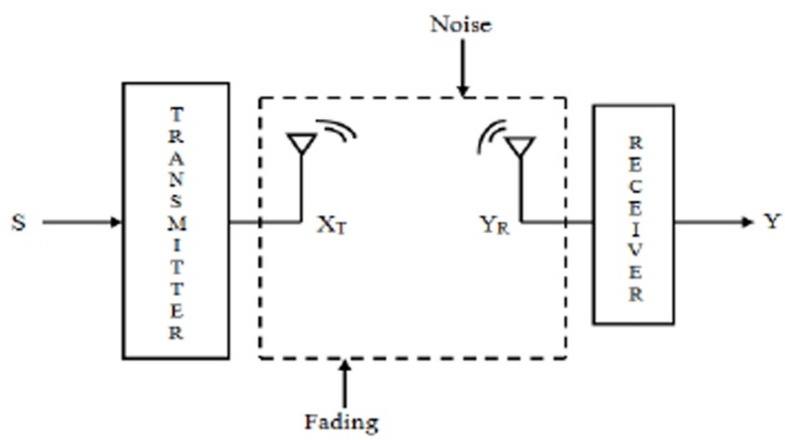


Fig. 3: SISO system.

In the above diagram, S: input, Y: output, XT: Transmitting antenna, YR: Receiving antenna

The noise is introduced in the system when the signal is processing from XT to YR (and the signal fads in this region while it is processed) as shown in diag. above. The channel capacity of the SISO system is given as [1]:

$$C_{(SISO)} = B \log_2\left(1 + \frac{S}{N}\right) \quad (1)$$

Where C is the capacity, B is Bandwidth of the signal and S/N is the signal to noise ratio [1].

The channel bandwidth of SISO is limited by Shannon's law which states that, theoretical maximum rate at which error-free digits can be transmitted over a bandwidth-limited channel in the presence of noise. The only advantage of using SISO system is that it is very simple in design and cheap that all the other types of systems. SISO system has found out its applications in Wi Fi, TV, radio Broadcasting, etc [2].

2. SIMO (Single Input Multiple Output)

In SIMO technique, there is only one transmitting antenna and multiple receiving antennas at receiving end; this helps to increase the receiving diversity at the receiving end as compared with SISO [2]. Following is the block diagram of SIMOsystem with one transmitting antenna and two receiving antenna at the receiving end for analysis (in this case only two, more than two also possible).

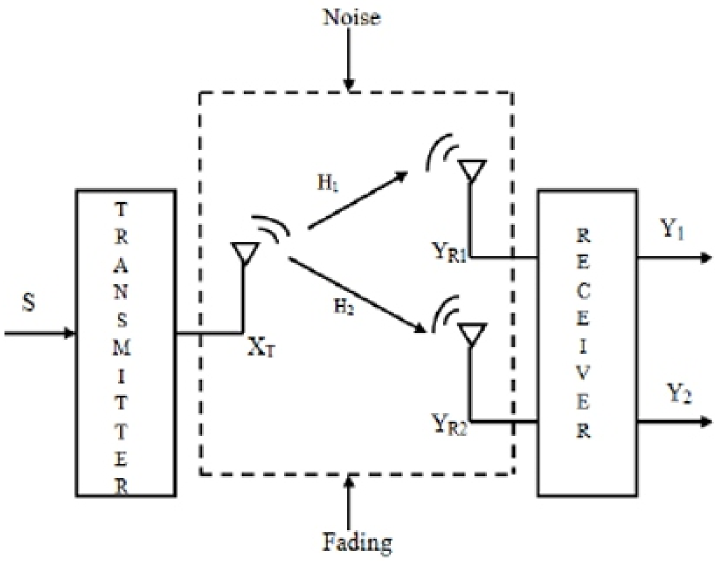


Fig. 4: SIMO system.

In the above diagram, S: input, Y1 & Y2: two outputs from two receiving antennas, XT: Transmitting antenna, YR1 & YR2: two receiving antenna (both the receiving antennas will have different fading coefficients).

In the receiving scheme of SIMO, since there are multiple receiving antennas many type of signal receiving techniques can be used like RAKE receiver (as discussed above). SIMO helps in improving the receiving diversity of the antenna as it gives stronger diversity than SISO, but there is no increase observer in channel capacity [1].

The channel capacity of the SISO system is given as [1]:

$$C_{(SIMO)} = M_r B \log_2\left(1 + \frac{S}{N}\right) \quad (2)$$

Where C is the capacity, Mr is the number of antennas used at receiver side, B is Bandwidth of the signal and S/N is the signal to noise ratio [1]. SIMO has found out his applications in encountering the effects of ionosphere fading for listening and receiving short waves. The advantage of SIMO over SISO is that it gives improve diversity than SISO and due to this SIMO can give a better BER analysis than SISO we will see this in results section further. In SIMO, the receiving antennas are mostly placed in devices like mobile phone and due to this the performance of the systems will be restricted the some of the physical parameters of the mobile used like battery, shape and size, etc [2].

3. MISO (Multiple Input Single Output)

In MISO, there can be multiple transmitting antennas from which the signal can be sent, and there I only one receiving antenna to receive the signals coming from multiple transmitting antenna, which means there are different sources available but there is only one destination available [2]. Following is the block diagram of MISO system with two (in this case only two, more than two also possible) transmitting antenna and one receiving antenna at the receiving end for analysis.

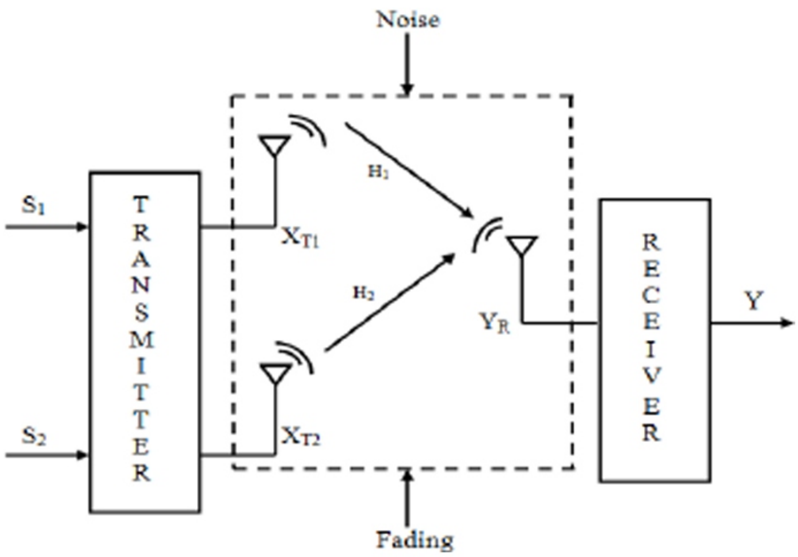


Fig 5: MISO system.

In the above diagram, S1 & S2: two inputs from two transmitting antennas, Y1 & Y2: outputs from, XT1 & XT2: two transmitting antenna (both the transmitting antennas will have different fading coefficients), YR: two receiving antenna.

This scheme of antenna helps to recover original signal at receiving end with lesser path loss than SISO and SIMO, and also the effect of multipath fading is observed to be less that the above two techniques since there are two antennas at the transmission end [2]. Since two signals needs to be transmitted the channel capacity has still not increased but it is better than the other two (SISO & SIMO), the channel capacity of the SISO system is given as [1].

$$C_{(MISO)} = M_t B \log_2\left(1 + \frac{S}{N}\right) \quad (3)$$

Where C is the capacity, Mt is the number of antennas used at transmitter side, B is

Bandwidth of the signal and S/N is the signal to noise ratio [1].

MISO has got wide range of applications (due to high diversity gain) like W-Lans and Digital TV. The advantage of using MISO over SISO is that if the receiving antenna is placed in mobile phone that multiple signals may get received with different time delay and this can be completely overcome by using MISO since there is only one receiving antenna and therefore a complete signal will be received at the receiver, this is due to the reason that the coding redundancy is moved from receiver to transmitter. Also it does have any impact from the physical parameters of mobiles phones as is it is in SIMO [2].

4. MIMO (Multiple Input Multiple Output)

In MIMO, there can be multiple transmitting antennas from which the signal can be sent, and also there are multiple receiving antennas through which the signal can be received. In MIMO, since there can be multiple transmitting antennas the signal can be transmitted by any antenna and therefore the signal can follow any path to reach to receiving end and this path followed by the signal depends on the position of the antenna i.e. if we move the antenna by small position the path will get change [2]. The fading introduced in the signal from multiple paths can be termed as multipath fading. Following is the block diagram of MIMO system with N(in this case only two considered for practical analysis, more than two also possible) transmitting antenna and M (in this case only two considered for practical analysis, more than two also possible) receiving antenna at the receiving end for analysis.

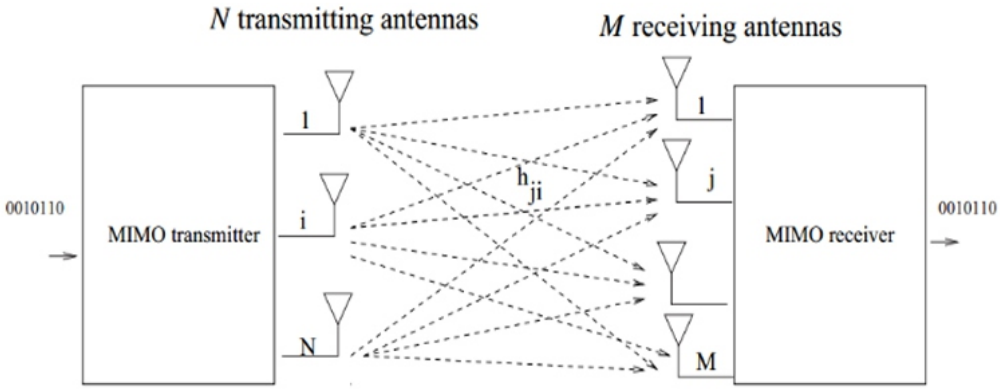


Fig. 6: MIMO System

In the above fig., there is one digital input given at the transmitter of MIMO which goes through multiple path to receiver and at receiver the signal received from all the receiving antennas are combined using RAKE receiver to reconstruct the original signal back at the receive end. The requirement to have better throughput, increased data rates and optimized spectral efficiency can be achieved by using MIMO [1]. In MIMO multiple channels are available, therefore the MMO channel can be represented as a N×M:

$$\begin{bmatrix} h_{11}\ h_{12} & \cdots & h_{(1N)} \\ h_{21}\ h_{22} & \cdots & h_{(2N)} \\ \cdot\quad\ \cdot & & \cdot \\ \cdot\quad\ \cdot & & \cdot \\ \cdot\quad\ \cdot & & \cdot \\ h_{(M_1)}\ h_{(M_2)} & \cdots & h_{(MN)} \end{bmatrix}$$

Let the above matrix be of format H, where h11, h12, etc are the variables of fading gain between the transmitting and receiving antenna [1]. If the data rate has been increased for single user using MIMO then it is called as SU – MMIO (Single User - MIMO) whereas for multiple users it is MU – MIMO (Multiple User - MIMO) [1].

The input and output relation for the MIMO antenna can be given by the equation:

$$output\left[y(t)\right] = \sum\nolimits^{N}_{(j=1)} h_{(NM)} S_{(M)}(t) \tag{4}$$

Here SM(t) is the signal received at Mth antenna which was transmitted by jth antenna [1].

The capacity of MIMO system is given as [1]:

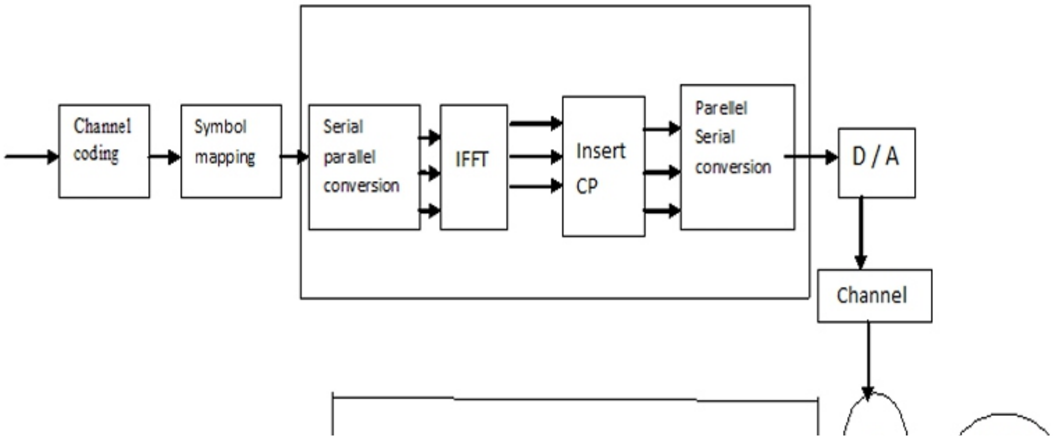
$$C = NMB \log_2\left(1 + \frac{S}{N}\right) \tag{5}$$

Where C is the capacity of MIMO system, N is the number of transmitting antennas, M is the number of receiving antennas and S/N is the signal to noise ratio [1]. As MIMO system gives the best capacity amongst all the four its has got wide range of applications like in MIMO signals can be transmitted via different spatial domains by employing Spatial Multiplexing using MIMO, MIMO is used in almost all the advanced wireless communication systems like LAN, WAM, MAN, 3G (OFDM - CDMA), 4G (OFDM – IDMA / LTE) [2]. The advantage of using MIMO is that it can give the best results when compared with the rest three since it has got the best throughput and efficiency of signals transmissions by the using multiple antennas

III. OFDM (ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING)

In most of the advanced communication methods OFDM is used due to its advantage of using the channel in the most optimized manner as compared with other communication techniques. Here, in this article we have used OFDM system to analysis all the above four types of antennas practically i.e. we will observe the BER plot of OFDM system with all four types of antennas to study the practical aspects of a four of them.

Following is the basic block diagram of OFDM system.



Sr. No.	Parameters	SISO	SIMO	MISO	MIMO
1	BER	It gives the lowest BER value due to only one antenna.	The value is better than SISO due to multiple antennas at receiving end.	Better than SIMO since loss of signal is less.	Optimized value of BER is observed, due to multiple antennas at both the ends.

Fig. 7: OFDM System [3]

IV. BER (BIT ERROR RATE)

The BER of any system is defined as the ratio of number of error bits received to the total number of bits transmitted [3]. The error may get introduced by the fading effect while using different types of antennas. Mathematically, BER is given as:

$$\text{BER} = \text{No. of errors} / \text{Total number of bits}$$

V. THEORITICAL COMPARISION OF SISO, SIMO, MISO, MIMO

Table 1: Comparison of SISO, SIMO, MISO & MIMO

Sr. No.	Parameters	SISO	SIMO	MISO	MIMO
1	BER	It gives the lowest BER value due to only one antenna.	The value is better than SISO due to multiple antennas at receiving end.	Better than SIMO since loss of signal is less.	Optimized value of BER is observed, due to multiple antennas at both the ends.

2	Throughput	It is observed to be very less than all the others.	Even though there are multiple antennas at receiving end, it is observed to be less due to the complexities at receiver end due having multiple antennas.	Slightly better than MISO since there is only one receiving antenna.	It is observed to have the best capacity amongst all, which allows MIMO to have a wide range of applications.
3	Transmitting (Processing) of signals from Tx to Rx and	Since there is only one antenna at Tx & Rx end, the signal is transmitted from one end and received at another end.	Here, the signals are received by multiple antennas and they are then combined by the technique of Maximum Ratio Combining (MRC) and Equal Gain Combining [4].	The signals are transmitted using transmit beam forge and space time coding, there is only one receiving and multiple transmitting antenna [5].	Here transmit receive diversity is used where multiple antennas are present at both Tx &Rx end.
4	Quality of signal received at the output.	The quality of signal is quite weak as there is only one transmitting & receiving antenna.	It uses the concept of switched diversity (selection diversity) for implementation, where the receiver can choose the stronger antenna for receiving the signal.	It is implemented by Space Time Coding (STC) technique where signal can be transmitted in both time & space i.e. data can be transmitted by multiple antennas; this increases the gain & signal quality [5].	Signal can be transmitted using Spatial Multiplexing which allows the signal to be transmitted across different spatial domain, therefore it gives the best signal quality and diversity gain.

VI. RESULTS, ANALYSIS AND DISCUSSIONS

In this article, we have implemented SISO, SIMO, MISO and MIMO with respect to OFDM. In the above sections we have analytically studied all the four types of antennas and here in this section we have carried out the practical analysis of all four of them to satisfy the above theoretical analysis practically. For practical analysis we have plotted the BER curve against SNR for all the four antennas.

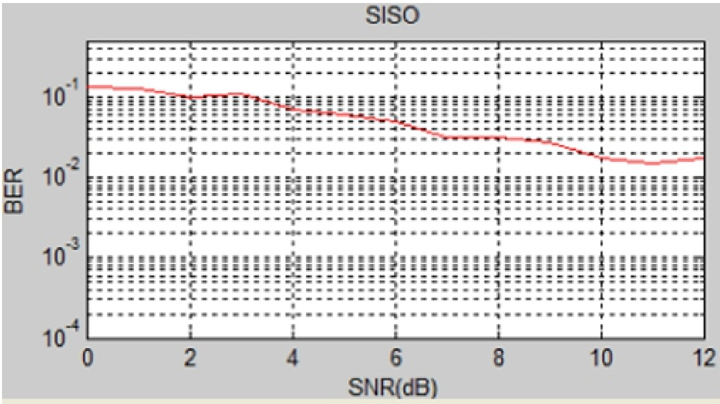


Fig. 8: BER response of SISO System.

In the above curve we can observe that, as the SNR increases the value of BER is decreasing, which shows that SISO system is getting affected the noise signal and the original signal will be faded.

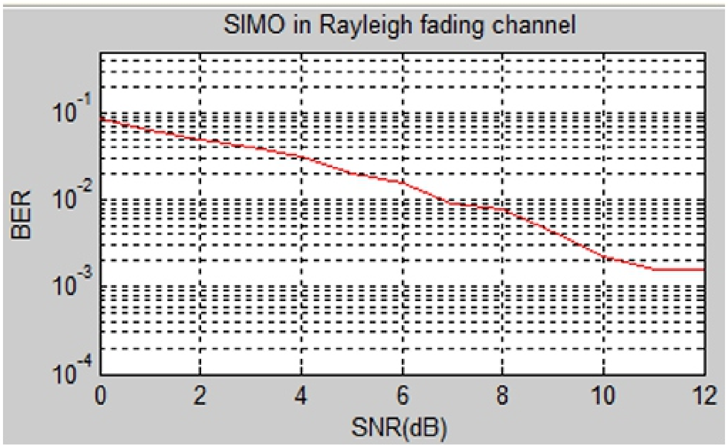


Fig. 9: BER response of SIMO System.

In SIMO, it is observed that the BER value has increased as compared to SISO since there are multiple receiving antennas and it employs techniques like transmit beam forge and space time coding for signal transmission.

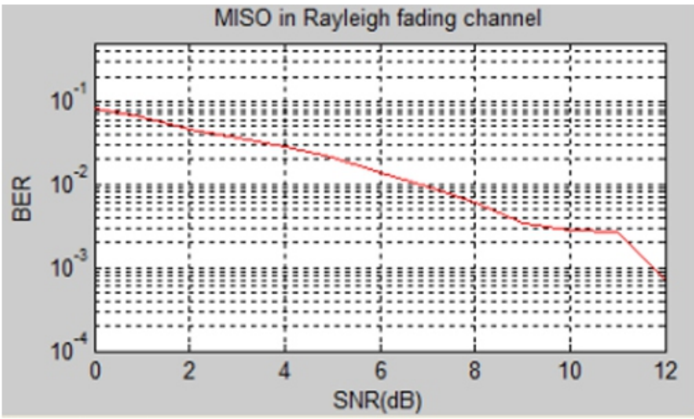


Fig. 10: BER response of MISO System.

Here in MISO, the BER value is a bit better than SIMO. It uses RAKE receiver at the receiver to combines the multiple signal received. In this case, as there is only one receiving antenna and if in a case the number of transmitting antenna increases then the time required by the RAKE receiver will be more, therefore we have gone to MIMO system to overcome the drawbacks all MISO and the above two systems.

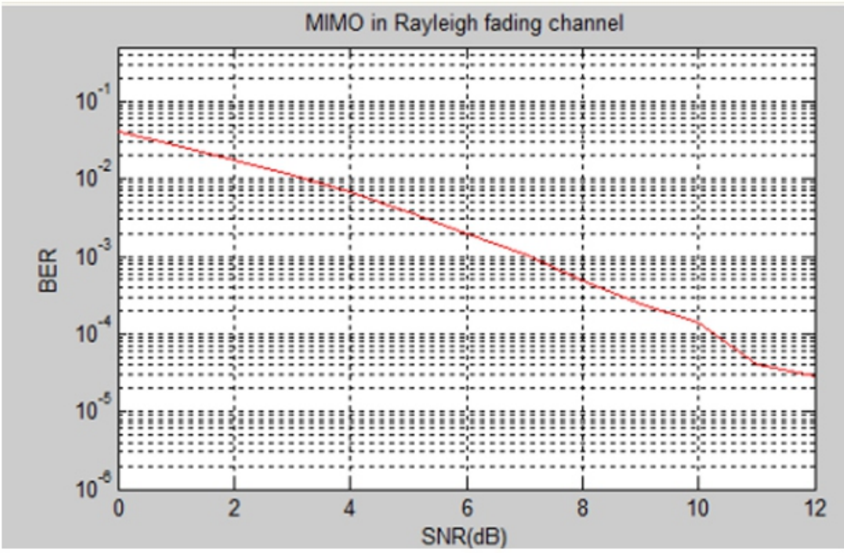


Fig. 11: BER response of MIMO System.

The above curve of MIMO gives the optimum result amongst all the four which and be observed from the above graph.

The following table gives the comparative analysis of BER results obtained for all the above four types of antennas and using the below table we will be able to compare the above graphs on the basis of practical analysis. The practical analysis obtained in the below table also matches the theoretical analysis of for all the four antennas and therefore it can be stated that MIMO gives the best possible output when compared with the other three and also MIMO has found out its applications in higher order digital communication techniques like CDMA, OFMD & IDMA.

Table 2: Practical Comparison of SISO, SIMO, MISO & MIMO.

BER / SNR (In dB)	SISO	SIMO	MISO	MIMO
0	0.145	0.0844	0.081	**0.04048**
2	0.112	0.0499	0.0469	**0.01787**
4	0.077	0.0308	0.0252	**0.006693**
6	0.063	0.0154	0.0136	**0.001984**
8	0.03	0.008	0.006	**0.00049**
10	0.022	0.0023	0.0028	**0.000138**

VII. CONCLUSION

The key idea behind this article was to have a comparison of SISO, SIMO, MISO & MIMO (both theoretically & practically) so that we can reach out to a conclusion that which of the antenna will play an important role in future wireless communication. Based on the above analysis what we have found out is SIMO is better than SISO, since due to better throughput value it give a good BER value whereas MISO is found to be even better that SIMO sine it avoids there is only one receiving antenna but the time rehired here for combining the signal may get increased in case of more number of transmitting antenna and since we are looking to have such an antenna which can be used in digital communication therefore time is one of the major factor here, so we have reached to MIMO were the signal can be transmitted in Spatial domain and it gives the optimum BER values which is clearly observed from table 2.

Therefore, we can definitely conclude that from all of the analysis done above both theoretical & practical we can make out that MIMO system is the one which can be used in future wireless communication for transmitting the signals with least fading, within optimized time with best throughput and this will led down the transformation in advanced wireless communication giving maximum data rate to all the users.

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Investigation of the Effect of Receiving Antenna Height on Cell Coverage Area

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ABSTRACT

In this work we study the effect of receiving antenna high on average cell coverage percentages. First of all, the received signal for two received antenna heights [1 m and 3.5 m] were measured and simplified path loss models parameters are developed. The cell coverage percentage is calculated for the two receive antenna height propagation model. The result shows that at the higher receive antenna height the coverage percentage is always better due to less shadowing fading.

Keywords: Simplified path loss model, propagation model, receive antenna height, cell coverage percentages. Shadowing fading.

1. INTRODUCTION

Since the deployment of the first generation cellular mobile communication systems four decade ago, this industry poses a great progress in term of system capacity, coverage, applications supports, level of services and quality of services as well [13]. The main factors determine the cellular system network performances are capacity design and coverage design. Cellular system capacity design of the network /or network segment decide the maximum number of customers that can be served by the hole network /or network segment at given time[4, 5]. On the other hand call coverage planning and design determines quality of service and the level of service provided by the network in given area. A network with excellent coverage planning is going to have less dark areas (areas under deep shadowing fading) inside the system which consequently leads to less ongoing calls and connections drop. To improve the network coverage, excellent understanding of signal propagation in the cellular system is required. In the literature, a lot of work for large scale signal propagation determination were proposed [5-9] . These works statistically determine the effects of signal attenuation due to path loss and shadowing as a function of the distance between the transmitter and receiver. Given the recent advancement in the area of multiple antenna and OFDM technologies which leads to progressively increase in the number of bits transmitted per Hertz /esc[10], better understanding of shadowing effect as function of receive antenna height becomes crucial[11]. In this work, we study the effect of receiving antenna height to the cell coverage percentages profile.

The reset of this work is organized as follows: section 2, introduces a theoretical background on simplified path loss model and shadowing. Section 3 summarizes the theoretical background on cell coverage percentages. Section 4, describes the received signal measurement , channel model parameters calculation and the results. Section 5 concludes the paper.

2. Simplified Path Loss Model and Shadowing Fading

The complexity of signal propagation makes it difficult to obtain a single model that characterizes path loss accurately across a range of different environments. Accurate path loss models can be obtained from complex analytical models or empirical measurements when tight system specifications must be met or the best locations for base stations or access point layouts must be determined. However, for general tradeoff analysis of various system designs, it is sometimes best to use a simple model that captures the essence of signal propagation without resorting to complicated path loss models, which are only approximations to the real channel. Thus, the simplified path loss model developed in [8] is used in this paper as a reference to calculate path loss as a function of the distance between the transmitter and receiver in urban communication environment.

$$P_r = P_t K\left[\frac{d_o}{d}\right]^{\gamma} \quad (1)$$

Equation (1) can be written in dB as:

$$P_r(dBm) = P_t(dBm) + K(dBm) - 10\gamma\log_{10}\left[\frac{d}{d_o}\right] \quad (2)$$

So the dB path loss is given by:

$$P_L(dB) = 10\gamma\log_{10}\left[\frac{d}{d_o}\right] - K(dB) \quad (3)$$

Where, d_0 is the reference distance for the antenna far-field, γ is the path loss

exponent, d is the transmission distances (the distance between the transmitter and the receiver), and K unit less constant. The value of the constant Kis calculated from the equation (4) as follows:

$$K(dB) = 20\log_{10}[\lambda / 4\pi d_o] \quad (4)$$

The value of for more complex environments can be obtained via equation (5) which represents a Minimum Mean Square Error (MMSE) fit to an empirical measurement of the received signal loss.

$$F(\gamma) = \sum_{i=1}^{n}\left[P_{measured}(d_i) - P_{model}(d_i)\right]^2 \quad (5)$$

Where,) (I measured d P is the path loss measured at distance i d , and I el d P (mod) is the Path loss calculated from the model at the distance i d .

Shadow fading (SF), also called slow fading or log-normal shadowing is defined as the random variation in average received power at a given distance due obstacles in signal path such as buildings and trees. This log-normally distributed parameter is generally independent of path loss and it modeled by:

$$P(\Psi) = \frac{\xi}{\sqrt{2\pi}\sigma_{\Psi dB}} \exp\left[-\frac{(10\log_{10}\Psi - \mu_{\Psi dB})^2}{2\sigma_{\Psi dB}^2}\right] \quad (6)$$

And the distribution of the dB value of Ψis Gaussian with mean μΨ and standard deviation σΨ is given by equation (7) as follows[12]:

$$P(\Psi)_{dB} = \frac{1}{\sqrt{2\pi}\sigma_{\Psi dB}} \exp\left[-\frac{(\Psi_{dB} - \mu_{\Psi dB})^2}{2\sigma_{\Psi dB}^2}\right] \quad (6)$$

Where, Ψ is the Gauss-distributed random variable with (0 - σ 2 Ψ), ξ = 10/ ln 10, is the mean of the random variable μΨ, is the standard deviation of the random variable Ψ and σΨ 2 is the variance of the random variable . In fact, Shadow fading is correlated. It is correlated with distance, which means that shadow fading value changes slowly with movement of the subscriber (receiver). This distance is referred to as a de-correlation distance is typically tens of meters in urban areas and a few 100 meters in suburban and rural areas. This distance describes the size of the clutter that obstructs the path to the receiver. Individual buildings may be the main component of the clutter in urban areas, whereas city blocks or terrain changes may be the clutter in suburban areas[13]. The variance of signal due to shadowing can be calculated from the equation

$$\sigma_{\Psi}^2 \text{dB} = \frac{1}{n}\sum_{i=1}^{n}\left[P_{measured}(d_i) - P_{model}(d_i)\right]^2 \quad (7)$$

3 Cell Coverage Area

The cell coverage area in a cellular system is defined as the expected percentage of area within a cell that receives power above a given minimum power min P required for system operation [4, 12, 13]. In the practical system design, the transmit power is planned for an average received power at the cell boundary. Thus, transmitting at different power levels leads to different coverage area percentages. Note that, all users within a cell require some minimum received Signal to Noise Ratio (SNR) for any predefined acceptable performance.

In practice, cellular communication system coverage is designed based on an average received power r P at the cell boundary with cell radius R and thus, the cell coverage area is the fraction of cell area where the received power is above a given level min P , which is also referred as receiver sensitivity. The cell coverage area c can be calculated from the following expression[13].

$$c = Q(a) + \exp(\frac{2-2ab}{b^2})Q(\frac{2-ab}{b}) \quad (8)$$

Where, the Q-function is defined as the probability that a Gaussian random variable X with mean 0 and variance 1 is greater than z. This expression can be evaluated as:

$$Q(z) = prob(X \geq z) = \frac{1}{\sqrt{2\pi}}\int_z^{\infty} \exp(-\frac{x^2}{2})\,dx \quad (9)$$

The values of a and b in the equation (8) are calculated from equations (10) and (11) respectively as reported in[13].

$$a = \frac{P_{\min} - P_r}{\sigma_\psi} \quad (10)$$

$$b = \frac{10\gamma \log_{10} e}{\sigma_\psi} \quad (11)$$

Where, min P is the minimum received power or system sensitivity and r P
Average received power at distance R (cell boundary).

The Received Signal Measurement and Results

To understand the effect on receiving antenna height on the average received signal due to path loss and shadowing, the received signal is measured at 33 points around a base station of antenna height of 30 m. At each point two measurements at 1 m and 3.5 m are taken. The path loss was calculated from the expression given by (12).

$$P_{measured}\mathrm{dB} = P_t dB - P_r dB \quad (12)$$

Where, measured P P r dB (12) Measured path loss, t P = 38.5 dBm (measured at the transmitter), P r is received power . The model parameters are calculated using equation s (5) and (7) for the two receive antenna heights as shown in table (1):

Table 1: channel models for the two receive antenna heights

Propagation model	Model Parameter values	
	at 3.5m height	at 1 m height
$PL = k + 10\gamma log_{10}(d) + \xi[dB]$ $\xi \sim \mathbb{N}(0, \sigma^2), d\ in\ meters$	$k = -64.8, \gamma = 4.326,$ $\sigma = 5.675$	$k = -64, \gamma = 4.79$ $, \sigma = 6.72$

Figure 1: shows the compression between measured path loss (scattered measurement) and model path loss (calculated from the developed model as reported in table 1). There is a small different between measured and model path loss.

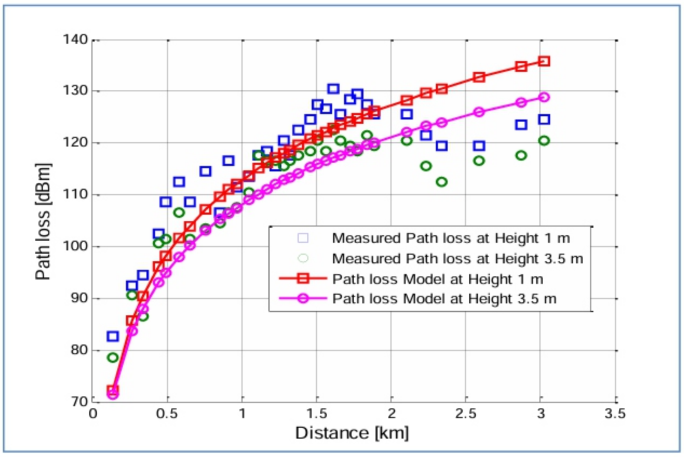

Figure 1: Compression between measured scattered path loss and model path loss In figure 2, a range of distances between base station and receiver from 1 Km -to-5 km is considered to calculate and plot the cell coverage percentage under system sensitivity of min = -95 dBm and making use of both height path loss model parameters (1 m parameters [γ 4.7989 and σ = 6.72] and 3.5 m parameters [4.326 and = 5.675]) . The figure shows the cell area coverage percentage curve for two heights verses the transmission distance. For height 3.5 m we have acquired excellent coverage values when the cell radius approximately less than or equal 3.5 km. While the lowest value we get greater than .6 at cell radius equal 5 km, which mean we have low coverage value, and thus make customer unsatisfied. So the theoretical value of cell radius leads to excellent coverage. For height 1 m (black color) we have acquired excellent coverage values when the cell radius approximately less than or equal 2.5 km. and the lowest value we get is 0.4 at cell radius approximately equal 4.5 km, this value is unacceptable and impractical.

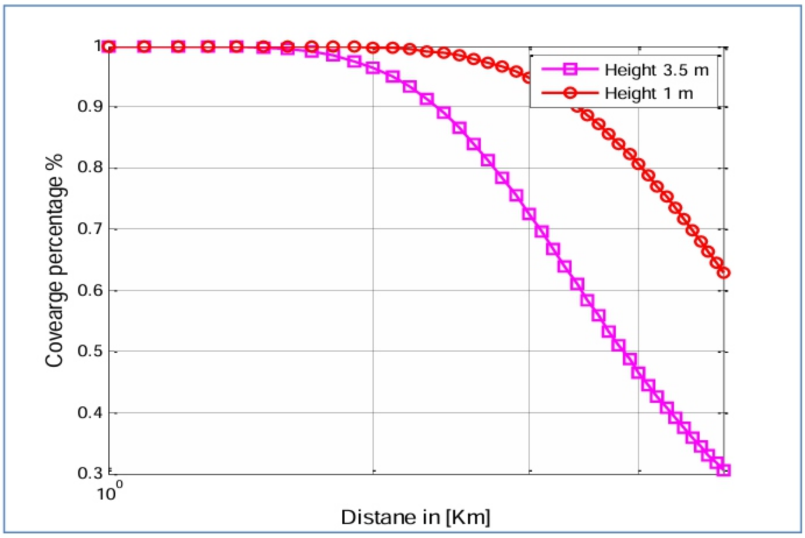

Figure 2: Cell coverage in different cell Radius

In figure 3, we consider a range of Pmin takes discrete values from -87 to -105 dBm, is considered to calculate and plot the cell coverage percentage at a distance of R= 3 km and making use of both height path loss model parameters (1 m parameters [4.7989 and = 6.72] and 3.5 m parameters [4.326 and = 5.675]) . The height 3.5 m shows excellent coverage percentage when the minimum received power is equal or less than -93 dBm, and the lowest value at min P= -87, which is equal 0.7, and it means good coverage.

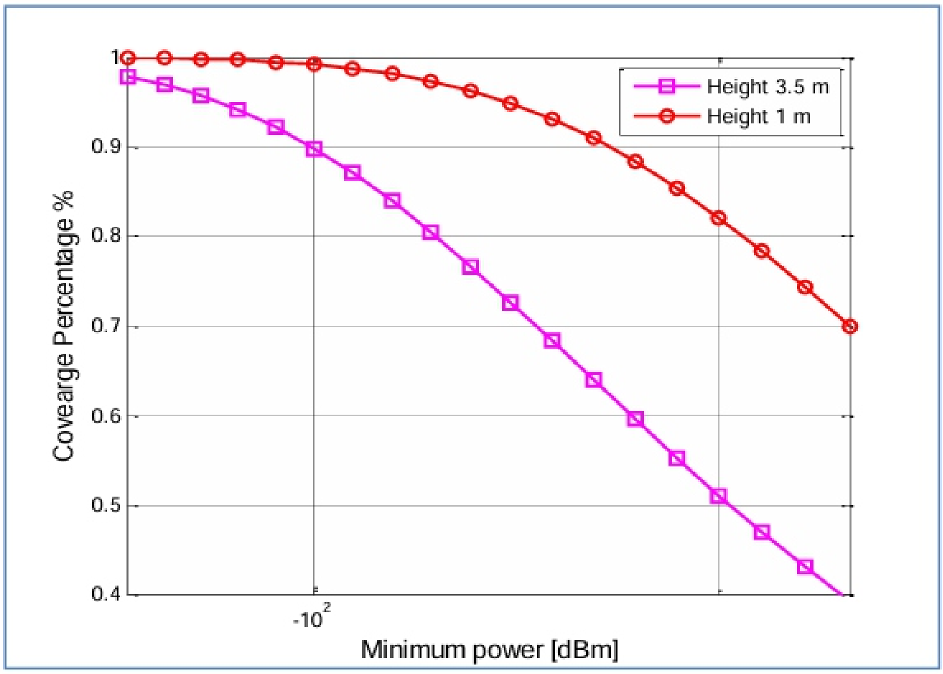

Figure 3: Cell coverage in case of different minimum received power

CONCLUSION

In this paper, received signal loss measurements at two receive antenna heights is reported and two simplified path loss models are developed from the set of measurement. The developed models are further used to calculate and plot the cell converge percentage verses distance and system sensitivity respectively. A P compression between the two receive antenna heights clearly shows that the height 3.5 m always gives better coverage area at the same minimum received power, for example at min = -95 dBm the cell coverage percentage in height 3.5 is 0.95 and in height 1 m is 0.73, this mean the height 3.5 m gives excellent coverage percentage and the value of coverage percentage will decrease when the receive antenna height decrease.

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