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Design and Development of RF Propagation Map and Antenna Coverage Map for Optimal Placement of Paging System in Caraga State University (CSU) – Main Campus

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Abstract: *This study aimed to design and development of a Radio Frequency (RF) Propagation Map and an Antenna Coverage Map to optimize the deployment of a public address (PA) or paging system to be installed at Caraga State University (CSU) – Main Campus. The main objective is to ensure robust and continuous signal coverage in all critical university zones to facilitate reliable communication during emergencies, routine operations and important events. MATLAB was used to simulate RF signal behavior; incorporating variables such as antenna height, transmission power, frequency, and environmental obstructions including vegetation and other infrastructures present in the campus. The RF Propagation Map shows signal distribution and identifies potential dead zones, while the Antenna Coverage Map shows proposed optimal placement of transmitters to maximize coverage efficiency. Simulation results confirm that strategic antenna positioning significantly enhances signal reach and system performance. The developed system offers a scalable, cost-effective reference model for implementing similar communication systems in institutional and large-area settings.*

Keywords: Paging System, RF Propagation, Antenna Coverage, Signal Mapping, Optimization

1. INTRODUCTION

Reliable communication infrastructure serves as the backbone for operational efficiency, safety protocols, and emergency responsiveness in large-scale institutional settings [1][2], with particular criticality in academic environments like Caraga State University (CSU) - Main Campus where the daily movement of thousands of students, faculty, and staff necessitates robust information dissemination systems. Among the most vital components of such infrastructure are public address (PA) systems [3], which provide essential one-way broadcasting capabilities for both routine announcements and critical emergency alerts across campus grounds encompassing multiple buildings, open spaces, and varied terrain [4]. While these systems have evolved significantly from their analog predecessors [5], contemporary implementations continue to face substantial technical challenges including signal degradation, coverage inconsistencies, and intelligibility reduction - problems intensified by the complex propagation environment created by architectural structures, dense vegetation, and the campus's unique topographic features [6]. These limitations not only compromise daily operations but could prove particularly consequential during emergency situations where clear, reliable communication becomes a matter of safety. To systematically address these challenges, this research proposes an innovative technical solution through the development of a comprehensive Radio Frequency (RF) Propagation Map and corresponding Antenna Coverage Map, employing advanced computational modeling techniques in MATLAB to simulate and analyze signal behavior with high precision. The simulation framework incorporates multiple critical parameters including but not limited to transmitter power output, antenna radiation patterns, operating frequency characteristics, elevation data, and detailed obstruction profiles, while geospatial datasets sourced from OpenStreetMap and enhanced through topographical analysis tools like CalcMaps

provide the necessary environmental context to ensure modeling accuracy. The resulting RF Propagation Map delivers a granular visualization of signal strength distribution across the entire campus, enabling identification of problematic interference zones and coverage gaps, while the complementary Antenna Coverage Map translates these insights into actionable recommendations for optimal hardware placement that maximizes effective coverage area while minimizing redundant overlap and eliminating dead zones [7],[8]. This dual-mapping approach, grounded in established antenna theory and refined through linear optimization techniques [9], serves multiple objectives: first, to create a scientifically-validated planning tool for current PA system enhancements; second, to establish a testing framework for evaluating proposed configurations prior to physical implementation; and third, to develop a replicable methodology that can be adapted by other institutions facing similar communication challenges. Beyond the immediate benefits to CSU's operational infrastructure, this study contributes to the broader field of RF system design by demonstrating the practical application of computational propagation and pathloss modeling in real-world institutional environments [10]-[14], while also providing a case study in cost-effective infrastructure optimization that balances technical performance with budgetary constraints [15]. The research methodology further incorporates validation phases involving field measurements and comparative analysis to assess the real-world effectiveness of the modeled solutions, ensuring that theoretical predictions translate into tangible improvements in campus communication reliability, clarity, and coverage consistency.

2. METHODS AND MATERIALS

This section presents the research design, instrumentation, software tools, modeling techniques, and algorithmic framework developed to construct an

optimal RF propagation and antenna coverage map for a wireless public address (PA) paging system deployed across Caraga State University (CSU) – Main Campus.

2.1 Research Locale

The study was conducted at CSU–Main Campus, which features diverse topographical characteristics including academic buildings, administrative zones, open fields, and vegetation. These physical elements were extracted from OSM data and incorporated into the modeling process as sources of attenuation and signal blockage.

2.2 Methodology Overview

The methodology seen in Figure 1 consists of five key stages: (1) Data Collection, (2) Path Loss Modeling, (3) RF Propagation Simulation, (4) Antenna Coverage Mapping, and (5) Optimization via Linear Programming. A visual summary of the methodology is illustrated below.

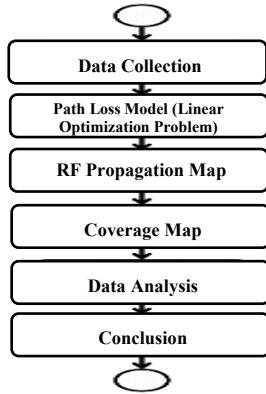


Fig. 1 Methodology Overview and Flow

2.3 Path Loss and Propagation Modeling

The proposed framework integrates the Free Space Path Loss (FSPL) model with empirically derived attenuation factors to account for environmental obstructions such as buildings and trees. The signal strength at each receiver node is computed by evaluating the path loss between transmitter and receiver locations and incorporating additional loss due to terrain and structural interference. This hybrid modeling approach serves as the analytical foundation for the subsequent antenna placement optimization and coverage assessment methodology.

To quantify the expected signal strength over distance in the absence of obstacles, we apply the standard free-space path loss model:

$$\text{FSPL (dB)} = 32.44 + 20 \log_{10}(f) + 20 \log_{10}(d) \quad (1)$$

where $f = 108.25 \text{ MHz}$ is the operating frequency, d is the distance in kilometers between the transmitter and receiver, and $B = 70 \text{ dB}$ models the estimated building attenuation. Total path loss is then calculated:

$$\text{Path Loss (dB)} = \text{FSPL} + B \quad (2)$$

Coverage is determined by the received power:

$$P_r = P_t - \text{Path Loss} \quad (3)$$

Using the received power $P_{r_{\min}} = -90 \text{ dBm}$ the placement is covered if the received power meets or exceeds the minimum receiver sensitivity

$$P_r \geq P_{\min} = -90 \text{ dBm} \quad (4)$$

To account for Earth curvature in campus-scale modeling, the Haversine formula was applied to compute distances between antenna sites and target coverage points. The

potential antenna placements and target coverage areas are defined in terms of latitude and longitude coordinates, geodesic distance computation is necessary to ensure precise signal loss estimation.

The Haversine formula is derived from spherical trigonometry and provides a reliable method to estimate the shortest path over the Earth's surface. It begins by computing an intermediate value α , which represents the square of half the chord length between two points:

$$\alpha = \sin^2\left(\frac{\Delta\phi}{2}\right) + \cos(\phi_1) \cdot \cos(\phi_2) \cdot \sin^2\left(\frac{\Delta\lambda}{2}\right) \quad (5)$$

The next step involves converting the angular displacement into a central angle c , measured in radians

$$c = 2 \cdot \text{atan2}(\sqrt{\alpha}, \sqrt{1-\alpha}) \quad (6)$$

The geodesic distance d between the transmitter and receiver nodes is computed by multiplying the central angle c by the mean radius of the Earth \mathcal{R} , typically taken as 6,371 kilometers

$$d = \mathcal{R} \cdot c \quad (7)$$

A binary integer linear programming (BILP) formulation was used to determine the minimum number of antennas needed to achieve full coverage. The binary decision variable x_i indicates antenna placement, and a binary coverage matrix \mathbf{A} derived from received signal strength defines node coverage:

We define a binary variable $x_i \in \{0,1\}$ for each candidate node location i , where:

$$x_i = \begin{cases} 1, & \text{if an antenna is placed at candidate location } i \\ 0, & \text{otherwise} \end{cases}$$

Let $a_{ij} \in \{0,1\}$ be a binary indicator such that:

$$a_{ij} = \begin{cases} 1, & \text{if placing an antenna at location } i \text{ provides coverage to node } j \\ 0, & \text{otherwise} \end{cases}$$

This yields a binary **coverage matrix** $\mathbf{A} \in \{0,1\}^{9 \times 9}$, derived from received power calculations. Each row i of \mathbf{A} corresponds to a transmitter at node i , and each column j indicates whether node j is covered.

The full coverage matrix $\mathbf{A} \in \mathbb{Z}^{9 \times 9}$ be defined as:

$$\mathbf{A} = \begin{bmatrix} 1 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 1 & 0 & 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 1 & 0 & 1 & 0 & 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \end{bmatrix}$$

The objective is to minimize the total number of active antennas:

$$\text{Minimize } Z = \sum_{i=1}^9 x_i \quad (8)$$

subject to the constraint that each node j must be covered by at least one active antenna:

$$\sum_{i=1}^9 a_{ij} \cdot x_i \geq 1, \quad \forall j \in \{1, 2, \dots, 9\} \quad (9)$$

This can be compactly written in matrix form:

$$\mathbf{A}x \geq \mathbf{1}_{9 \times 1} \quad (10)$$

where

$x \in \{0,1\}^9$ is the antenna placement decision vector

$\mathbf{A} \in \{0,1\}^{9 \times 9}$ is the binary coverage matrix

$\mathbf{1}$ is a 9-dimensional column vector of ones

3. RESULTS AND DISCUSSION

This section presents the simulation outcomes and optimization results based on the developed RF propagation and antenna placement framework. The results include visualizations of signal coverage, identification of dead zones, and evaluation of antenna

deployment efficiency across the Caraga State University Main Campus. All simulations were executed in MATLAB using real-world geospatial data sourced from OpenStreetMap. The performance of the antenna placement algorithm is analyzed in terms of coverage accuracy, computational efficiency, and compliance with the coverage threshold constraints defined in the propagation model. The comparisons between baseline propagation scenarios and optimized configurations highlight the benefits of incorporating environmental factors and linear programming techniques in campus-scale wireless communication planning.

3.1 Binary Linear Programming

The optimal antenna placement problem was implemented and solved using MATLAB's *intlinprog* function, a built-in solver designed for binary integer linear programming (BILP). With the coverage matrix established, the final step involved formulating and solving the antenna placement problem as a BILP. The objective function, given by Equation (8), seeks to minimize the total number of antennas required. Simultaneously, the optimization process enforces the constraint that every target node must be covered by at least one active transmitter, as expressed in Equation (9). The *intlinprog* function was used to solve this constrained integer optimization problem efficiently. The output of the solver yielded a minimal set of node indices where antennas should be deployed to guarantee full coverage of the target area under the modeled RF propagation conditions.

3.2 Optimization and Solution

We solve the resulting binary integer program using MATLAB's *intlinprog* solver and the optimal solution is:

$$x^* = [1 \ 1 \ 0 \ 0 \ 0 \ 0 \ 0 \ 1 \ 0]^T$$

This solution indicates that antennas should be placed at nodes 1, 2, and 8 to ensure full coverage across all nodes while minimizing infrastructure cost.

3.3 Coverage

To confirm that this solution indeed covers all nodes, we select the rows from matrix **A** corresponding to $x_i = 1$, forming the submatrix:

$$A_{selected} = \begin{bmatrix} 1 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 & 1 & 1 & 1 \end{bmatrix}$$

Computing the logical OR (maximum per column) across the rows gives:

$$\max(A_{selected}, axis = 0) = [1 \ 1 \ 1 \ 1 \ 1 \ 1 \ 1 \ 1 \ 1]$$

indicating that all 10 nodes are indeed covered by the selected antennas.

This computational pipeline ensures a mathematically rigorous and practically reliable approach to determining optimal antenna placements, balancing spatial precision with computational efficiency. The integration of accurate geodesic distance metrics, realistic propagation models, and integer linear programming ensures that the resulting configuration is not only theoretically optimal but also viable for real-world deployment on the Caraga State University Main Campus.

3.4 MATLAB Simulated Results

In this discussion, the researchers evaluated the behavior of wireless signal propagation from a central base station transmitting at 30 dBm to multiple node locations across

a designated area. The theoretical propagation characteristics, calculated using the Free-Space Path Loss (FSPL) model and compared the results obtained from a simulation environment under different configurations: base station only, and scenarios where base station with three auxiliary antennas (Antenna 1, Antenna 2, and Antenna 3). Table 4.1 presented the coordinates, building names and their total path loss (in dB) from the simulated signal behavior at each building under different antenna configurations.

Table 1. Summary of Path Loss in Different Locations in Simulated Environment

COORDINATES	BUILDING	Main Transmitter (Admin Building)	Base Station with Antenna 1	Base Station with Antenna 1 and 2	Base Station with Antenna 1, 2 and 3
8.95723, 125.598	ADMIN	-	-	-	-
8.95321, 125.597	COFES	0	0	98.5859	46.4702
8.9552, 125.598	CEIT	93.0991	93.099	90.2771	89.5727
8.95614, 125.598	KINAADMAN	87.6617	87.217	85.8161	85.8833
8.95558, 125.597	OLD CAS	101.871	96.231	43.3067	46.3067
8.95622, 125.596	GYM	102.927	94.180	89.8264	89.9414
8.95783, 125.596	LIBRARY	89.5133	45.173	45.173	45.0924
8.95828, 125.598	BATOK	87.1959	82.109	82.109	82.109
8.95926, 125.597	CED	103.518	84.394	84.3946	84.3664
8.95888, 125.596	CAA	104.919	93.043	93.1255	92.963

The College of Forestry and Environmental Science (COFES) has received simulation results indicating a received signal strength of 0 dBm for both the base-only and Base + Antennal configurations, signifying that the simulation environment detected no viable signal due to likely obstructions or significant attenuation.

COORDINATES	BUILDING	d (km)	FSPL (dB)	PL (dB)	PR (dBm)
8.95723, 125.598	ADMIN	-	-	-	-
8.95321, 125.597	COFES	0.46	66.36	96.36	-66.36
8.9552, 125.598	CEIT	0.22	59.96	89.96	-59.96
8.95614, 125.598	KINAADMAN	0.12	54.69	84.69	-54.69
8.95558, 125.597	OLD CAS	0.21	59.55	89.55	-59.55
8.95622, 125.596	GYM	0.25	61.07	91.07	-61.07
8.95783, 125.596	LIBRARY	0.23	60.34	90.34	-60.34
8.95828, 125.598	BATOK	0.12	54.69	84.69	-54.69
8.95926, 125.597	CED	0.25	61.07	91.07	-61.07
8.95888, 125.596	CAA	0.29	62.36	92.36	-62.36

Table 2. Admin Transmitter to All Locations with Transmit Power of 30 dBm

Table 2 displays the signal propagation analysis was conducted with the Admin building, located at coordinates (8.95723, 125.598), designated as the base transmitter of the system. The evaluation aimed to assess the received power across various node locations using a consistent set of physical and environmental parameters. The transmission frequency was set at 108 MHz and commonly characterized by moderate diffraction and better penetration through obstructions compared to higher frequencies. The base station was configured to transmit at a power of 30 dBm, with a transmitting antenna mounted at a height of 21.5 meters. The maximum receiver sensitivity threshold was established at -90 dBm, implying that any received power above this level would render the signal undetectable or unusable at the receiving node.

Table 3 demonstrated that the Library building, located at coordinates (8.95783, 125.596) was configured to function as a signal repeater or secondary transmitter for extending coverage to surrounding node locations. This Table 3. Repeater 1 (Library) to All Locations with Transmit Power of 36 dBm

COORDINATES	BUILDING	d (km)	FSPL (dB)	PL (dB)	PR (dBm)
8.95723, 125.598	ADMIN	-	-	-	-
8.95321, 125.597	COFES	0.52	67.43	97.43	-61.43
8.9552, 125.598	CEIT	0.36	64.23	94.23	-58.23
8.95614, 125.598	KINAADMAN	0.29	62.36	92.36	-56.36
8.95558, 125.597	OLD CAS	0.27	61.74	91.74	-55.74
8.95622, 125.596	GYM	0.18	58.21	88.21	-52.21
8.95783, 125.596	LIBRARY	0.0010	13.11	43.11	-7.11
8.95828, 125.598	BATOK	0.23	60.34	90.34	-54.34
8.95926, 125.597	CED	0.19	58.68	88.68	-52.68
8.95888, 125.596	CAA	0.12	54.69	84.69	-48.69

scenario was designed to assess the feasibility and effectiveness of a repeater system in improving network connectivity across the area. The transmitter in the Library was configured to operate at a frequency of 108 MHz and a transmit power of 36 dBm, representing a moderate power increase compared to the main base station. The antenna was installed at a height of 16.5 meters to achieve the line-of-sight (LOS) deployment suitable for a repeater setup within an academic or urban campus.

The increased transmit power in this scenario and the strategic placement of the repeater at the Library location provided improved coverage to certain buildings, particularly those obstructed or poorly served by the main base station. This scenario validates the practical utility of deploying localized repeaters in areas where direct line-of-sight or main signal paths are blocked, thereby enhancing signal reach and ensuring reliable connectivity across complex environments.

Table 4. Repeater 2 (Old CAS) to All Locations with Transmit Power of 36 dBm

COORDINATES	BUILDING	d (km)	FSPL (dB)	PL (dB)	PR (dBm)
8.95723, 125.598	ADMIN	-	-	-	-
8.95321, 125.597	COFES	0.26	61.41	91.41	-55.41
8.9552, 125.598	CEIT	0.12	54.69	84.69	-48.69
8.95614, 125.598	KINAADMAN	0.13	55.39	85.39	-49.39
8.95558, 125.597	OLD CAS	0.0010	13.11	43.11	-7.11
8.95622, 125.596	GYM	0.13	55.39	85.39	-49.39
8.95783, 125.596	LIBRARY	0.27	61.74	91.74	-55.74
8.95828, 125.598	BATOK	0.32	63.21	93.21	-57.21
8.95926, 125.597	CED	0.41	65.36	95.36	-59.36
8.95888, 125.596	CAA	0.38	64.70	94.70	-58.70

Table 4 discussed that the College of Arts and Sciences (Old CAS) building, located at coordinates (8.95558, 125.597) was configured to function as another repeater antenna capable of transmitting signals to other buildings within the area. This deployment was analyzed to assess how a mid-point repeater could enhance signal distribution, particularly in zones with partial or no coverage from the main base station. The repeater was set to operate at a frequency of 108 MHz with an elevated transmit power of 36 dBm, facilitating broader signal dissemination. The antenna was mounted at a height of 18.5 meters, chosen to optimize coverage without exceeding typical campus infrastructure constraints.

Table 5. Repeater 3 (COFES) with Transmit Power of 36 dBm

COORDINATES	BUILDING	d (km)	FSPL (dB)	PL (dB)	PR (dBm)
8.95321, 125.597	COFES	0.0010	13.11	43.11	-7.11

Simulation results in Table 5 for the College of Forestry and Environmental Science (COFES), located within the campus coverage area, reveal that signal reception from the main transmitter alone yields a received signal strength of 0 dBm. This value, within the context of the simulation framework, is used to denote no viable signal detected. The result suggests that the location is subjected to heavy attenuation or obstruction, possibly due to surrounding buildings, dense vegetation, and especially the distance from the base transmitter that disrupts direct line-of-sight (LOS) signal propagation.

To address this coverage gap, COFES is identified as a strategic location for repeater placement. Unlike increasing the transmission power which can result in interference or regulatory violations, placing a repeater at COFES provides a localized signal source, enabling the node to receive, amplify, and rebroadcast signals from the main base station or nearby antennas. The antenna was set to operate at a frequency of 108 MHz with a transmit power of 36 dBm, facilitating broader signal dissemination and addressing the dense vegetation of the area. The antenna was mounted at a height of 21.5 meters to optimize coverage without exceeding typical campus infrastructure constraints. Once a repeater is installed at this position, the coverage simulation reports a significant improvement in received signal strength, falling well within operational limits thus validating the effectiveness of the approach. The recommendation to deploy a repeater at COFES aligns with efficient network planning principles, which emphasize coverage densification in shadowed zones.

3.5 Antenna Coverage Map

The antenna coverage map in Figure 2 outlines the area around the antenna where its signal can reach. It shows a circular boundary that represents the maximum distance the signal can travel in open conditions. Based on the map, the current location is optimal because it covers the central parts of the campus where communication is most important. The placement ensures that key buildings and common areas are within reach. Since antennas can cover large distances, placing them in high, open areas with fewer obstructions gives the best results.

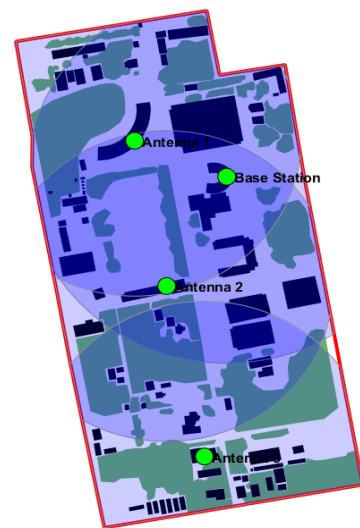


Fig. 2 Antenna Coverage Map

3.6 Outdoor Speakers Coverage Map

The outdoor speakers' coverage map seen in Figure 3 also shows the boundary of the area that each speaker can reach. Since speakers are placed at a lower height and have less power compared to antennas, their coverage zones are smaller. The map helped determine the optimal speaker positions by ensuring that their ranges slightly overlap, avoiding dead zones while also preventing unnecessary signal repetition. Areas near hallways, open spaces, and paths with frequent foot traffic were prioritized to maximize the usefulness of the speakers.

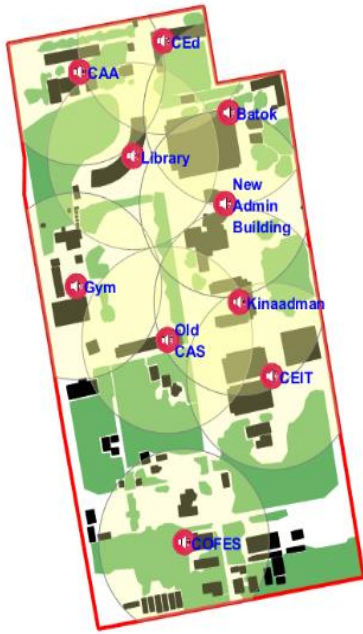


Fig 3 Outdoor Speakers Coverage Map

3.7 RF Propagation Map

RF propagation map in Figure 4 show how the signal behaves as it travels across different parts of the campus. These maps visualize how the signal strength decreases over distance and is affected by obstacles such as buildings and trees. They offer a more detailed view of the quality of coverage in various areas. To generate these maps, OSM data was again utilized to model real-world environmental features. A path loss algorithm was used to simulate the effects of signal attenuation based on distance and environmental factors. Furthermore, a linear optimization approach helped in determining the optimal placement of nodes by evaluating multiple possible positions and selecting those that provided the most reliable signal distribution across the campus. This combination of accurate geographic modeling and strategic placement algorithms allowed for realistic and reliable RF simulation results.

The map for the antenna shows the areas with stronger and weaker signals. It highlights how the signal gradually fades as it travels farther from the antenna. It also shows how some areas, like behind buildings or trees, may have reduced signal strength due to interference or obstacles. The map confirms this is an optimal spot because it offers the widest strong-signal area with the fewest obstructions.

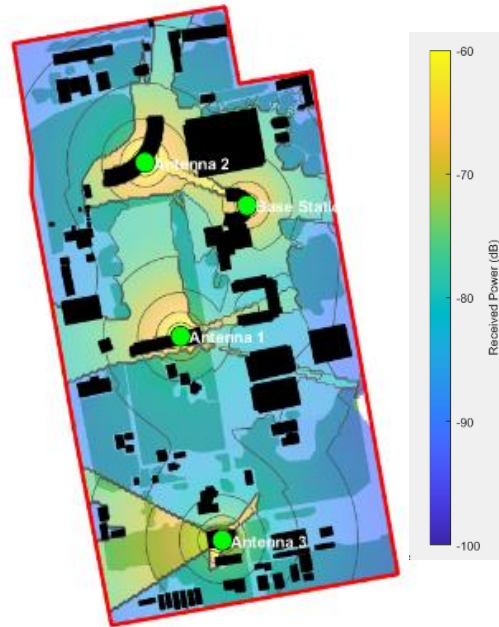


Fig. 4 Antenna RF Propagation Map

3.8 Actual Testing

To validate the simulation results in Figure 5, actual field testing was conducted using a mock base station located at the CEGS Building, utilizing a different transmitter (7W FM Transmitter from FMUSER, provided by the CRAFT office). The simulation parameters were adjusted to match the specifications of the FMUSER transmitter. Testing was carried out at three different campus locations, selected to represent varying distances from the simulated antenna site, to evaluate the reliability and accuracy of the generated map. A tinySA spectrum analyzer was used during testing to measure and verify the received signal strength at each location.

Mock Base Station: 8.955005, 125.597748 (Hinang Hall)

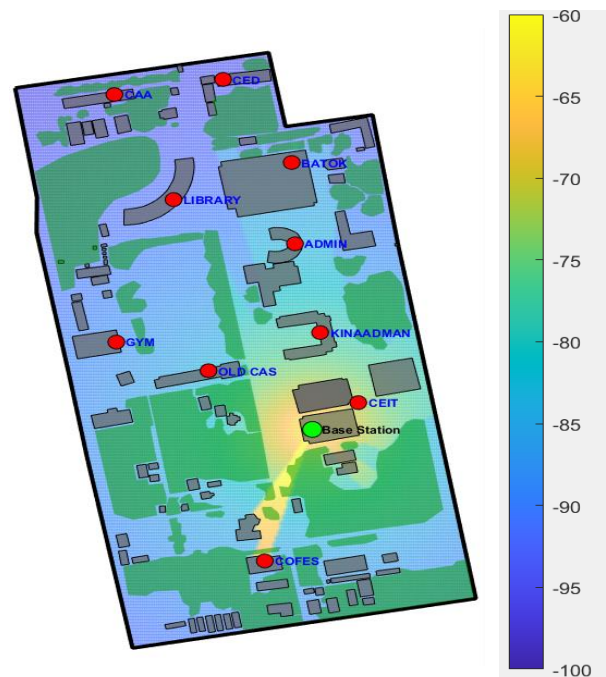


Fig. 5 Simulated Map for the Mock Base Station

Table 6. Summary of Average Actual Testing Values, Simulated Values and Calculation Values

RECEIVER LOCATION	ACTUAL TESTING POWER AVERAGE (dBm)	SIMULATED (dBm)	CALCULATIONS (dBm)
ADMIN	-84.74	-83.597	-91.53
COFES	-88.60	-85.457	-92.64
CEIT	-75.92	-72.301	-70.70
KINAADMAN	-86.98	-77.875	-84.68
OLD CAS	-84.89	-83.846	-86.26
GYM	-89.00	-88.222	-92.64
LIBRARY	-89.54	-91.082	-95.80
CAA	-88.52	-94.605	-97.93
CED	-90.74	-94.368	-97.93
BATOK	-86.85	-86.859	-95.31

Table 6 compares the average RF signal strengths (in dBm) at various campus receiver locations using actual field measurements, simulation results, and theoretical calculations. Overall, the actual values generally fall between the simulated and calculated results, suggesting that the simulation model provides a closer approximation to real-world conditions than basic theoretical formulas. Locations like CEIT show strong signals across all methods, likely due to proximity to the transmitter or minimal obstructions, while CED and CAA exhibit weaker signals, possibly due to distance or building interference. The close match at BATOK between actual and simulated values indicates a well-modeled environment there. These variations highlight the importance of accurate environmental modeling in RF simulation, and the data could be used to further refine prediction models.

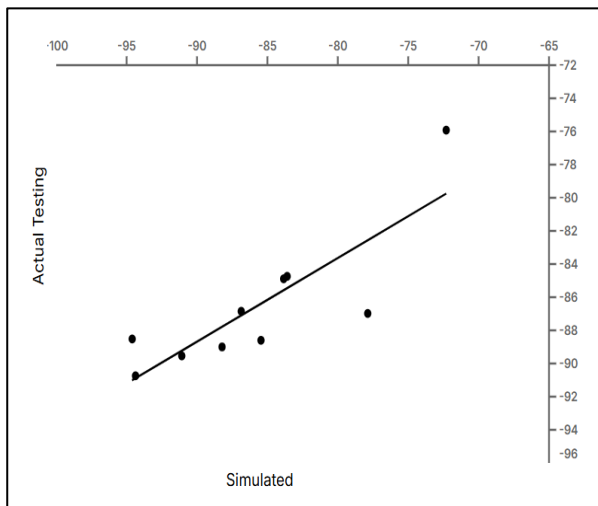


Fig. 6 Linear Regression Analysis of Averaged Actual Testing Value and Simulated Values

Table 7. Summary of Regression Analysis for Averaged Actual Testing Values and Simulation Values

Metric	Interpretation
$R^2 = 0.7005$	70% of variance explained — good fit
P-value = 0.0025	Model is statistically significant
Slope > 0	Positive correlation between simulated and actual
Equation	Predicts actual based on simulation: $Y = 0.5047 * X - 43.26$

The linear regression in Figure 6 yields the equation $Y = 0.5047X - 43.26$, where X is the simulated value and Y is the predicted actual value. This suggests that each 1 dB increase in simulation corresponds to a 0.5047 dB increase in actual values. The model shows a good fit ($R^2 = 0.7005$) and strong statistical significance ($P = 0.0025$, $F = 18.71$), with a 95% confidence interval for the slope (0.2357 to 0.7738). The standard error of 2.446 dB indicates low average prediction error.

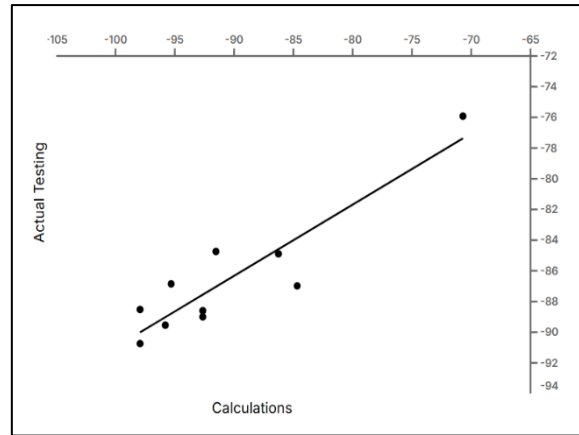


Fig. 7 Linear Regression Analysis of Averaged Actual Testing Value and Calculated Values

Table 8. Summary of Regression Analysis for Averaged Actual Testing Values and Calculated Values

Metric	Interpretation
$R^2 = 0.8299$	82.99% of the variation in actual values is explained by the simulated values.
P-value = 0.0002	The model is statistically significant ($P < 0.05$), indicating a reliable fit.
Slope > 0	The positive slope confirms a strong positive correlation between X and Y.
Equation	Predicts actual based on simulation: $Y = 0.4642X - 44.55$

Linear regression in Figure 7 shows a strong, significant link between simulated and actual values, with the equation $Y = 0.4642X - 44.55$. Each 1 dB increase in simulation predicts a 0.4642 dB rise in actual values. The model fits well ($R^2 = 0.8299$, standard error = 1.844 dB) and is statistically robust ($P = 0.0002$, $F = 39.03$). The 95% confidence interval for the slope (0.2928 to 0.6356) excludes zero. A scatter plot confirms the strong correlation, showing data clustering around the regression line.

4. CONCLUSION

This study successfully designed and developed an RF Propagation Map and an Antenna Coverage Map to help find the best locations for placing a wireless public address paging system at Caraga State University (CSU) – Main Campus. Using MATLAB software and data from OpenStreetMap (OSM), the signal strength across the campus was simulated by applying the Free-Space Path Loss (FSPL) model, along with simple adjustments for obstacles like buildings and trees. This made the simulation closer to real-world conditions. The study used a method called binary integer linear programming to choose the best spots for antennas and speakers. As a result, the number of antennas needed was reduced from the original 12 to just 3, while the number of speakers was also reduced from 12 to 10, still covering the whole

campus. This helped make the system more cost-effective and practical without losing the quality of communication. To check if the simulation was accurate, actual field testing was done using a 7W FM transmitter from FMUSER, located at the CEGS Building. The tinySA signal analyzer was used to measure the real signal strength at three different locations on campus. The test results were very close to the simulated values, showing only small differences of about ± 1 to ± 8 dBm. This proved that the simulation was reliable and the generated coverage maps were accurate. The study showed that with careful planning, simple modeling, and basic testing, it is possible to design an effective paging system for a large area like a university campus. It also showed that using fewer antennas and speakers, but placing them in the right locations, can still provide good signal coverage while saving costs. The maps and methods developed in this study can help CSU improve its communication system and can also be used as a guide for similar projects in other schools or institutions. With this foundation, future improvements and expansions can be made easily, ensuring that the university's communication needs are met for years to come.

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