Viewshed Analysis of Campus Radio (Search FM 92.3Mhz) of Federal University of Technology, Minna, Niger State, Nigeria

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Abstract

A Geographic Information System (GIS) viewshed is the result of a function that determines, given a terrain model, which areas on a map can be seen from a given point(s), line or area. In the communications industry, this function has been used to model radio wave coverage and to site transceiver towers for cellular phones. The aim of this research is to demonstrate the use of viewshed analysis in improving Frequency Modulated (FM) Radio signal reception in Minna Metropolis, Niger State, Nigeria. The map covering the study area was scanned and saved into the computer. Global Position System (GPS) coordinates acquired from the field were used for geo-referencing and digitization was performed using AutoCAD Land Development and Arc GIS 9.2 version, which gave the digital map showing the location of the Radio mast. In this work, measurement of electric field strength of FM radio signals from 92.3MHZ was carried out along streets Route A to Route E in Minna Metropolis. A Digital Signal Level Meter, GE-5499, covering the signal range of 30-120 dBμV, was used to measure the signals. The Easting, Northings, Altitude (E, N, and H) and also distance from the reference point (i.e., location of the Transmitting Antenna) were measured at every location using a GPS receiver. The parameters obtained were used to map the coverage areas of the Search FM radio signals in Minna Metropolis. It was observed that FM signal strength and speed are good and fast mainly around the mast, while other areas of considerable long distances have poor or no signal reception (Inverse Square Law). The results also showed that viewpoints on high peaks produce better visibility and signal reception than on lowlands in the line of sight analysis. Based on the analysis, it is recommended that radio masts should be installed at locations of high peaks where the line of sight will not be obstructed.

Keywords: *Viewshed Analysis, Radio Signal coverage map, Optimization*.

Analyse du champ de vision de la radio de campus (Search FM 92,3 Mhz) de l'Université fédérale de technologie, Minna, État du Niger, Nigéria

Résumé

Un champ de vision du système d'information géographique (SIG) est le résultat d'une fonction qui détermine, étant donné un modèle de terrain, quelles zones sur une carte peuvent être vues à partir d'un ou de plusieurs points, lignes ou zones donnés. Dans l'industrie des communications, cette fonction a été utilisée pour modéliser la couverture des ondes radio et pour implanter des tours d'émetteurs-récepteurs pour les téléphones cellulaires. Le but de cette recherche est de démontrer l'utilisation de l'analyse du champ de vision pour améliorer la réception du signal radio modulé en fréquence (FM) dans la métropole de Minna, dans l'État du Niger, au Nigéria. La carte couvrant la zone d'étude a été scannée et enregistrée dans l'ordinateur. Les coordonnées du système de positionnement global (GPS) acquises sur le terrain ont été utilisées pour le géoréférencement et la numérisation a été effectuée à l'aide d'AutoCAD Land Development et de la version Arc SIG 9.2, qui a donné la carte numérique indiquant l'emplacement du mât radio. Dans ce travail, la mesure de l'intensité du champ électrique des signaux radio FM de 92,3 MHz a été effectuée le long des rues Route A à Route E à Minna Metropolis. Un mesureur de niveau de signal numérique, GE-5499, couvrant la plage de signal de 30 à 120 dBμV, a été utilisé pour mesurer les signaux. L'abscisse, l'ordonnée, l'altitude (E, N et H) ainsi que la distance par rapport au point de référence (c'est-à-dire l'emplacement de l'antenne émettrice) ont été mesurés à chaque emplacement à l'aide d'un récepteur GPS. Les paramètres obtenus ont été utilisés pour cartographier les zones de couverture des signaux

radio Search FM à Minna Metropolis. Il a été observé que la force et la vitesse du signal FM sont bonnes et rapides principalement autour du mât, tandis que d'autres zones de distances considérables ont une réception de signal médiocre ou inexistante (loi du carré inverse). Les résultats ont également montré que les points de vue sur les hauts sommets produisent une meilleure visibilité et une meilleure réception du signal que sur les basses terres dans l'analyse de la ligne de visée. Sur la base de l'analyse, il est recommandé d'installer des mâts radio aux emplacements des pics élevés où la ligne de visée ne sera pas obstruée.

Mots-clés : analyse du champ de vision, carte de couverture du signal radio, optimisation.

عرض نظام المعلومات الجغرافية هو نتيجة وظيفة التي تحدد نظرًا لنموذج التضاريس، يمكن رؤية المناطق الموجودة على الخريطة من نقطة معينة في مجال أو منطقة في صناعة الاتصالات، استُخدمت هذه الوظيفة لنموذج تغطية الموجات اللاسلكية وموقع أبراج أجهزة الإرسال والاستقبال للهواتف الخلوية الهدف من هذا البحث هو إظهار استخدام تحليل المشاهدة في تحسين الترددات المعدلة (FM) في مدينة مينا ولاية نيجر في نيجيريا تم مسح الخريطة التي تغطي منطقة الدراسة وحفظها في الكمبيوتر. استُخدمت إحداثيات النظام العالمي لتحديد المواقع التي تم الحصول عليها من الميدان لإعداد المراجع الجغرافية وأجريت الرقمنة باستخدام برنامج AutoCAD لتطوير الأراضي وطبعة Arc GIS 9.2 التي أعطت الخريطة الرقمية التي توضح موقع صاري الراديو، في هذا العمل، قياس قوة المجال الكهربائي لإشارات الراديو FM من 92.3MHZ على طول الشوارع من الطريق أ إلى الطريق ح في مدينة مينا عداد مستوى الإشارة الرقمية،GE-5499 تغطي نطاق الإشارات 30-120 dBµV لقياس الإشار إرتفاع الشرق والشمال (E, N, and H) وكذلك المسافة من النقطة المرجعية تم قياس موقع هوائي الإرسال في كل موقع باستخدام جهاز استقبال GPS.تم استخدام البارامترات التي تم الحصول عليها لرسم خريطة لمجالات تغطية إشارات الراديو FM في مدينة مينا لوحظ أن قوة إشارة FM والسرعة جيدة وسريعة بشكل أساسي حول الصاري في حين أن المناطق الأخرى ذات المسافات الطويلة الكبيرة تعاني من ضعف أو عدم وجود إشارة استقبال أظهرت النتائج أيضًا أن وجهات النظر حول القمم المرتفعة تنتج رؤية وإشارة أفضل أكثر من الأراضي المنخفضة في خط تحليل البصر. بناءً على التحليل،ويوصى بتركيب صواري لاسلكية في مواقع القمم العالية.حيث لن يتم عرقلة خط الرؤية.

Introduction

Radio signal obeys the law of rectilinear propagation and this needs unobstructed visibility to get to the intended destination with optimal strength. This requires careful network design and planning from site to guarantee inter-visibility and hence communication (Musa, 2009; Young-Hoon, Sanja, and Stere, 2004; Sotiroudis & Siakavara, 2015).Global System for Mobile Communication (GSM) Telecommunication and Frequency Modulated (FM) Radio signals can be affected by a number of factors such as: temperature, humidity, pressure, scattering, refraction etc. Geographic features such as topography, buildings, mountains and peak with undulating terrain between transmitters and receivers are some of the main barriers to signal propagation (Young-Hoon, K. Sanja, R and Stere, W. (2004); Xolani and Elisha, 2018; Faruk, Adediran, & Ayeni, 2013;Oseni, Popoola, Enumah, & Gordian, 2014; Sotiroudis & Katherine Siakavara, 2015)

Two points are said to be inter-visible only if straight line can be drawn between the points without intersecting with any path of terrain surface between them (Davin,2006; Musa, 2009)

Line of sight (LOS) is the process of determining visibility between an observer point and a target while viewshed analysis is the process of determining the region of visibility observable from one or more viewpoints (Musa, 2009; Bakare, 2019; Nigatu, and Biadgilgn, 2017 Popoola *et al.,* 2018;).

However, as population grew, expansion increased and Physical development

intensified in the immediate environment, many of the newly developed suburbs fell within the black spots of the radio station, coupled with the mountainous nature of the area under investigation.

The planning and siting of radio station at G/K campus of FUTMINNA was based on Theoretical Mathematical Modeling to determine the effective coverage of its broadcasts. This Mathematical Models were based on rough estimates of signal quality in the presence of approximated terrain and interference levels. They do not accurately account for many factors that affect the signal, including receiver performance, multipath fading, attenuation from man- made obstructions and interference [6]. These poised some parts of the town to have difficulty in signal reception, hence, the need to analyze the effective physical coverage by geospatial techniques in the study area (Davin, 2006); Thomas and Shelley,2008; De Peiris, 2016; Edan, Idowu, and Zango, 2013; Bakare, 2019)

The lack of proper reconnaissance and mapping of the radio station; terrain geography resulting to reflection, diffraction and scattering of radio waves posed a great challenge to effective radio signal coverage**.** Planning and siting of Search FM 92.3MHz at Gidan- Kwano campus of FUTMINNA was based on theoretical mathematical model based on rough estimates of signal quality in the presence of approximated Terrain and interference levels. They do not accurately account for many factors that affect the signal penetration, including receiver performance, multipath fading, attenuation from Man-made obstructions (buildings), land use/ land cover, environmental factors, increased population, physical development in the suburbs etc. (Davin, 2006); Thomas and Shelley,(2008); De Peiris, (2016); Edan, Idowu, and Zango, I.S (2013).

The desire to meet the communication needs of increased number of listeners in the suburbs; complaint of signal loss; difficulty in signal reception; limitations due to transmission power, tower height and antenna gain, interferences, deserves special attention in improving the radio wave coverage for optimal transmission. Therefore, this paper tends to provide solutions to alleviate the geographical barrier by incorporating Geographic Information System technologies with respect to the spatial coverage of radio waves.

The aim is to determine the signal coverage of the Search FM92.3mhz campus radio in Minna metropolis with the following objectives:

1. To determine the spatial location and signal coverage of the transmitting station within Minna metropolis.

2. To conduct a viewshed analysis in order to map out the existing effective signal coverage of the FM radio transmission.

3. To optimize the effective coverage of radio signals in the study area.

One of the major stumbling blocks in this endeavour has been the absence of accurate maps detailing the current signal coverage of search FM92.3MHz, campus radio in Minna metropolis. In order to visualize the installed network and assist in planning future expansion the spatial coverage of the wireless network , its exact extent, its performance, and coverage area delineation , using viewshed analysis or visibility analysis tool of ArcGIS. This work demonstrated how a precise map of signal coverage was accomplished and provide helpful information to the information services for wireless management in the campus, which was lacking prior to this research.

Study Area

The search FM 92.3mhz is at Gidan-Kwano Campus of FUT Minna , located along Minna – Bida Road, in Bosso Local Government Area of Niger State, Nigeria. The Campus is located at 09^0 32' 30.46”N, $06^0$26'14.37"E at the top left, 09^0 31'15.84"N, $06^0$27' 20.67"E at

the bottom of the longitude and latitude respectively.

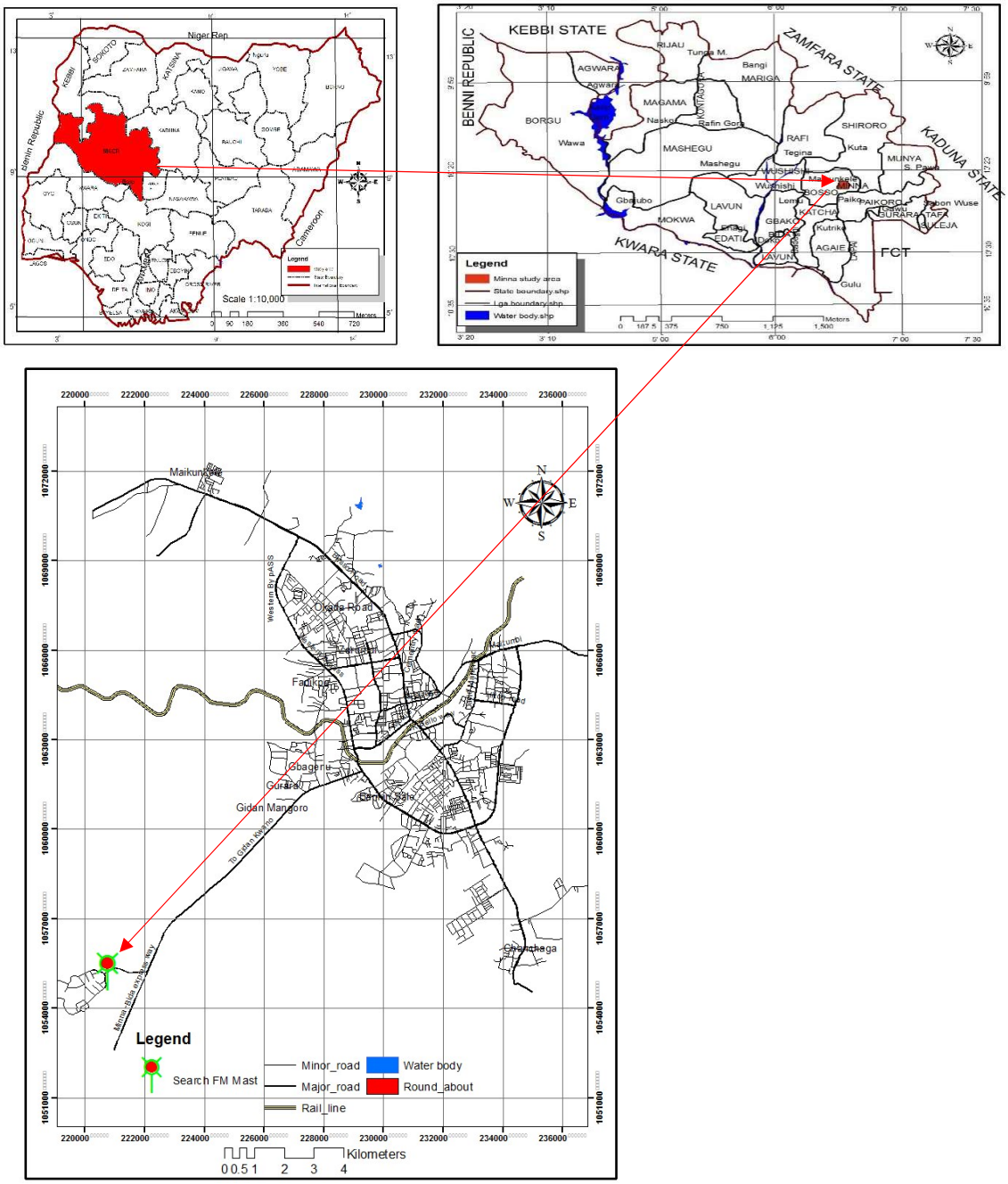


Figure 1.1**: Map of the study area (Author's Laboratory work, 2022)**

Materials and Methods

Using ESRI's ArcGIS 9.10 version and other relevant GIS Packages in conjunction with a generated DEM of the study area, satellite image of the area was draped on the DEM to give a 3D view of the area. The generated (ASTER DEM was exported to ArcGIS where viewshed analysis was performed. Viewshed analysis was run based on the location of the existing radio mast/tower (FM 92.3MHz) and on a digitally proposed new location for effective coverage and to determine the line of sight (areas in view / not inview) along the

routes within the study area (Minna Metropolis).

Data:

Table 1: Data Used

S/N	Data Type	Scale	Source
1	Quick bird image 2017		From Image GeoEye.(Google Image)
2.	ASTER DEM	1: 125000	www.Earthexplorer.usgs.gov.
3.	GPS coordinates of Transmitting Radio masts& locations with their signal strengths(strength meter readings)	UTM Coordinates/ dBµV	Author's fieldwork, 2022
4	Contour Map of Minna Metropolis Derived from ASTER DEM.	1:125000	WWW.Earthexplorer.usgs.gov.
5	Map of Minna Metropolis,(Street Guide map)	1:10000	From Surveying and Geoinformatics Department, FUTMINNA.

(Source: Author's Research 2022)

Table 2: Parameter of Search FM 92.3MHZ

Altitude	Frequency	Easting(m)	Northing(m)	Transmitter output power FM92.3MHz	Antenna Height above ground level
243m (msl)	92.3 MHz	220750 .00E	1055227.00N	44-46Volts	52m

(Source: Field survey, 2022).
Note: msl = mean sea level

Methodology

The method adopted in carrying out this investigation is such that requires the physical presence of the investigator in the various locations (all the points and locations) where the signal is expected to be received. This was done by measuring the Eastings and Northings coordinates of the place, the elevation above sea level, the line of sight distance of the place to the transmitter base and the field strength of the radio signal. The electric field strength of the transmitted FM signal for different locations with their corresponding distances (LOS) from the base station and was recorded. The data so collected were tabulated for easy computation / analysis and used to plot the contour map of the coverage area using surfer 8 with coordinates (Eastings, Northings, Signal strength). The procedure was repeated in all the Drive routes (Routes A-E) in Minna Metropolis.

Spatial location of Transmitting Station/mast(Search FM92.3MHz)

Using the coordinate of the existing mast A (220750.00E, 1055227.00N), a point shapefile was created.

Viewshed Analysis

Two viewports were used (ie FM92.3 Radio Mast and a new proposed site) to measure signal coverage along some selected routes in Minna Metropolis. Viewshed analysis was done twice. Firstly, the analysis was done to identify areas in view/not in view based on the present location of the transmitting mast,and secondly, another one was done after digitally shifting the transmitting mast to a presumed better location (optimization). A viewshed map was produced depicting the radio signal coverage for the study area; Minna Metropolis.

Results and Analysis

Spatial Location of the Existing Search Fm92.3mhz Mast and The New Digitally Proposed Radio Mast Station

ASTER DEM was generated depicting the spatial location of Search FM92.3MHZ and the proposed new site of the radio mast.

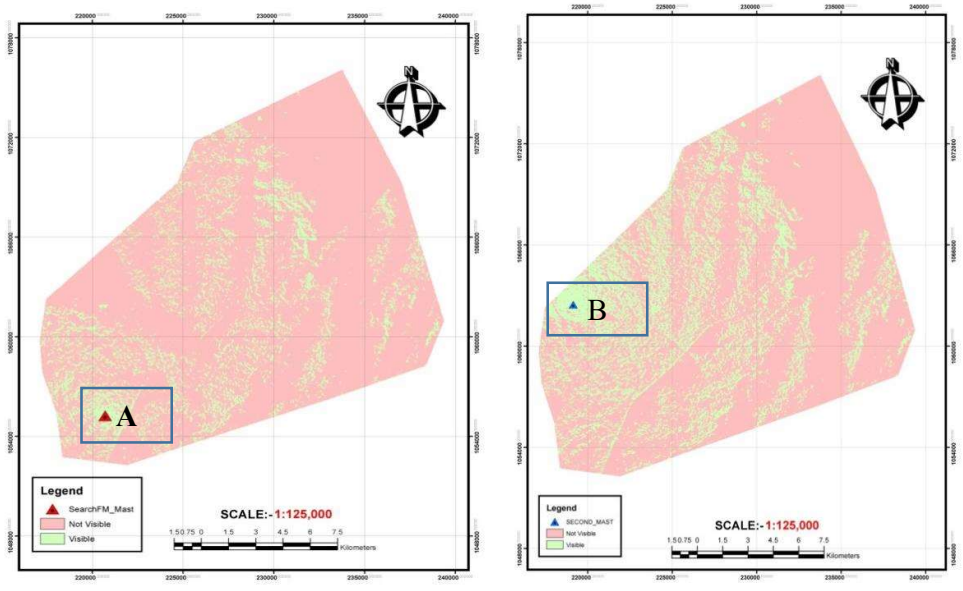
Viewshed Analysis (Optimization) for effective Radio signal coverage of Search FM in Minna Metropolis is shown on Table3;

Table 3: Optimized coverage of the campus radio (Search FM92.3MHz), covering Minna Metropolis

Location	Eastings (m)	Northings (m)	Mast Height mast (m)	Viewshed Analysis; Visible Areas(Hectares)	Viewshed Analysis; Not Visible Areas(Hectares)	Remarks
A (Existing Mast)	220750.00	1055227.00	52	4079.504Ha	28820.29615Ha	Fair coverage (12%)
A (Existing Mast)	220750.00	1055227.00	80	6421.945674Ha	26477.85433Ha	Fair coverage (20%)
B (New proposed Mast)	219144.00	1062460.00	52	6002.88563Ha	26896.91437Ha	Fair coverage (18%)
B (New proposed Mast)	219144.00	1062460.00	80	7158.512913Ha	24741.28709Ha	Good coverage (22%)

(Source: Author's Research 2022)

Viewshed Map based on the existing Radio Mast and the proposed Radio mast (Search FM92.3MHz) in Minna Meteroplis



(A) (B)

Figure 3: Viewshed map of existing radio mast at a height of 52m (Left) and the proposed radio mast at a height of 80m (Right). (Source**:** Author's Research, 2022.)

Spatial Coverage of Search FM92.3MHZ (Contour Map of Radio signal coverage)

The contour Signal map of Search FM (92.3 MHz), Campus Radio, was overlaid on the DTM map of Minna Metropolis to determine areas that receive signals from the FM radio station, as shown below;

Coverage classification

Table 4: Coverage Classification (%) within Minna metropolis

Coverage	Area(Hectares)	Percentage (%)
Primary Coverage Area (40dBμV≤/E/≤82dBμV)	8800Ha	23%
Secondary Coverage Area (20dBμV≤/E/≤39dBμV)	20,100Ha	51%
Fringe Coverage Areas (15dBμV≤/E/≤19dBμV)	10,200Ha	26%
Total	39,100Ha	100%

Source: Author s Fieldwork, 2022

The configuration of the Search FM92.3mhz radio transmitter in Minna Metropolis does not give optimum coverage in the Study area. It was observed from table 4, that 23% of 8800Ha received primary signal coverage, while 51% of 20100Ha received secondary signal coverage and 26% of 10200Ha was categorized on fringe coverage out of the total Area of 39100Ha. This implies that grade "**A**" signal applies to locations close to the transmitting station which obeys the inverse square law of signal propagations.

However, in Bosso campus, secondary coverage was experienced and interference from Prestige FM 91.7MHz, due to its proximity to Bosso campus. The DTM of the Study area depicts a hill (Maitunbi hills) as an obstruction to rectilinear propagation of the radio signal. This blockage resulted into non line of sight propagation (NLOS) causing multipath, diffractions, reflections and non-coherence propagation.

Conclusion and Recommendations

This study reveals the spatial coverage of the electric field strength of the Search FM92.3MHz transmitter in Minna Metropolis within **a total area of 32899.80 Hectares.** The viewshed analysis has shown that the present location of Search FM 92.3MHz mast is not a suitable platform for extensive signal coverage within the study area.

Recommendations

Based on this study, it is recommended that:

1. Viewshed analysis should be used as a tool for the determination of optimal site and outreach for other telecommunication networks such as Airtel, Glo, MTN,TV, and radio stations.
2. Optimization of the Transmitter Height and Location of Search FM 92.3MHZ:

At the FM frequencies, the radio waves follow line-of-sight propagation, which is rectilinear. Therefore, increasing the height of the radio tower from 52m to 80m will also improve the signal coverage in its current region by raising it further above trees, buildings or hills that may cause obstruction with the signal. This will enhance the current signal's region and also increase the maximum distance of the signal coverage in the metropolis.

3. Mast should be installed at locations (B) where unobstructed line of sight exists between optimal sites and visible boundaries of the study area to increase signal coverage. However, location B (**219144.00E, 1062460.00N)** which was digitally determined at a distance of 2.973km with a bearing of **347º 28' 52"**away from the existing tower proves to provide feasible improvement for effective signal coverage of search FM campus radio as has been presented in this study.

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