Original Research Article

COMPARITIVE ANALYSIS OF THE SIGNAL STRENGTH OF TWO RADIO STATIONS IN OKENE, KOGI STATE, NIGERIA

ABSTRACT

There are significant concerns for the citizens of Okene and its surroundings; regarding the distortions experienced in radio signals due to increased attenuation, which have resulted in poor signal quality. This study carried out an assessment of radio wave propagation patterns from two radio broadcast stations in Okene, Kogi State, Nigeria, using a field strength meter. The study involved measuring the strength and quality of radio signals at six selected locations in Okene and its environs for each radio station. Additionally, the distances between the transmitting and receiving antennas were determined, and the signal wavelengths and free space path-loss of signals were calculated at fourteen different locations. The results indicated an inverse relationship between the measured signal strengths and the free space path-loss, as well as the approximate distances between the antennas. The study examined various factors contributing to signal attenuations, such as reflections caused by buildings, mountains, and vegetation cover, as well as refractions resulting from rivers, streams, rainfall, and absorption by the human abdomen. Based on the findings, suitable areas for locating FM radio stations were identified, and approximate distances from the stations for receiving news as part of emergency security measures were suggested. To improve the quality and strength of the signals, it is recommended to construct booster stations approximately 70km away from the main stations. These booster stations can effectively enhance the signal, leading to better signal quality and improved strength.

Keywords: Radio waves; attenuation; impedance mismatch; path loss; EM fields; EM Spectrum; propagation pattern

1. INTRODUCTION

Radio waves are a combination of electric and magnetic fields that are generated by the oscillation of electrons in an aerial. They encompass a wide range of strengths and are primarily utilized for communication purposes [1]. An essential characteristic of radio waves is their ability to be refracted by the ionosphere at specific angles of incidence. Very high frequency (VHF) radio waves are not significantly refracted by the ionosphere, which exhibits different refractive indices for different frequencies [2, 3]. Typically, radio waves are directed at specific angles and secondary transmission stations receive and retransmit them. Despite audio frequencies being much lower than radio frequencies, audio frequency information is carried by radio waves through a process known as modulation [4]. In amplitude modulation (AM), the amplitude of the radio wave (carrier wave) is modified to correspond to the low-frequency audio wave. In frequency modulation (FM), the frequency of the radio wave is varied. A radio receiver picks up the radio wave and, through demodulation, extracts the audio frequency information [3, 5]. Electromagnetic radiation, which comprises the energy in electromagnetic waves, is emitted radially and results from the combined

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vibration of the electric and magnetic fields. Unlike sound, which requires a medium like air for propagation, electromagnetic waves can travel through the vacuum of space.

The electric and magnetic fields of an electromagnetic wave are perpendicular to each other and to the direction of wave propagation, and they travel at the speed of light until they encounter significant objects that may hinder their propagation, such as concrete or metal [1]. According to Saroj and Smruti [6], electromagnetic interference occurs when electromagnetic fields interfere with each other, leading to distortion in both fields. This is commonly observed in radios when switching between frequencies and channels, resulting in noise, as well as in over-the-air television where the picture becomes distorted due to signal distortion. A radio frequency field (RF field) refers to an alternating current that, when applied to an antenna, generates an electromagnetic field called a radio frequency field. This field propagates through space to enable wireless broadcasting or communication. The radio frequency field covers a significant portion of the electromagnetic radiation spectrum. Sources such as mobile radio communication transmissions, radio and television broadcasting, radar, and cell phones produce RF fields [7], also referred to as radio waves. Ellingson [8] described radio propagation as the transmission of radio signals from one point to another within the Earth's atmosphere. As electromagnetic waves, radio signals exhibit properties such as reflection, refraction, diffraction, absorption, polarization, and scattering. Radio propagation is inherently unpredictable, and strong probabilistic concepts are employed in transmission. Various protocols have been developed over the years for the propagation of radio waves, with the mode to be adopted determined by the distance between the transmitter and the receiver [9]. Radio signals are greatly influenced by objects in their path and the propagation medium, making the strength of radio signal transmission crucial in the design and operation of radio systems [10].

The security of lives and properties is a paramount concern when undertaking any development initiatives by governments, individuals, or corporate organizations, particularly if the aim is to ensure long-term sustainability [11, 12]. A secure environment provides the necessary foundation for proper planning, establishment, and management of human and material resources required for successful business operations [12]. Recognizing this, the Nigerian federal government allocates a significant portion of its annual budget to security investments. Regrettably, insecurity in Nigeria has been escalating at an alarming rate, manifesting in the form of armed banditry, kidnapping, and terrorism [13]. In many instances, people become victims due to ineffective communication systems caused by poor reception of radio signals from transmitting stations. This paper aims to evaluate the strength and quality of radio signals from two radio stations in Okene, Kogi State, Nigeria, with the objective of proposing measures to enhance the signals for more effective and efficient communication, particularly concerning security matters in remote areas, thus contributing to sustainable development. The study will assist in identifying suitable locations for the establishment of radio stations to ensure better signal quality and reception within the locality.

2. MATERIALS AND METHOD

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2.1 Materials

For the assessment of radio wave propagation patterns from various radio stations in Okene, Kogi State, Nigeria, several materials and their specifications were utilized. These materials include: Hand-held field strength meter; Spectral V5 hand-held RF power meter; 8VSB (ATSC) modulator meter; and a Hand-held GPS device.

2.1.1 The Field Strength Meter

In Figure 1, a typical field-strength meter employed in this study is depicted. This meter operates based on a straightforward passive (unpowered) circuit design. In this design, the antenna intercepts radio frequency (RF) energy, which is then rectified to direct current (DC). The rectified DC is utilized to directly drive the meter, indicating the strength of the received RF signal. The maximum sensitivity of this circuit is influenced by several key factors, including:

- Gain of the antenna: how much of the intercepted RF signal is effectively received;
- Sensitivity of the meter movement;
- Battery capacity.

Fig. 1: High Resistance/Low Conductance Field Strength Meter

2.2 Methods

2.2.1 Area of Study

Okene, a strategically positioned town, is located at latitude 7.550° North and longitude 6.240° East, with an elevation of 384km above sea level. It encompasses three local government areas: Adavi, Okehi, and Okene. The town stretches along two highways, covering an area of 328km². According to the 2006 census, it has a population of 325,623, making it the largest city in Kogi State. Okene is situated in the South Central region of Nigeria and serves as a major intersection for roads from Lokoja, Kabba, Ikare, Ajaokuta, and Auchi. Originally founded on a hill, it is now situated in the Valley of the Ubo River, a minor tributary of the Niger River. Okene operates on the West Africa Time (WAT) zone.

The town's economy thrives on various businesses, including hotels, filling stations, schools, civil service works, supermarkets, and approximately 75% of the population engages in farming. Notable radio stations in Okene include Kogi Radio on 93.5 FM, situated on a hill in the Okene Bar area. It operates with a transmitter power of 10kW but broadcasts only 3kW for public consumption. Another radio station, TAO FM, operates on 100.9 FM and is located in Kuroko, Okehi. It has a combined transmitter power of 2kW and broadcasts the full 2kW for public consumption. Figure 2 displays a map of Okene, indicating the locations of these two radio stations.

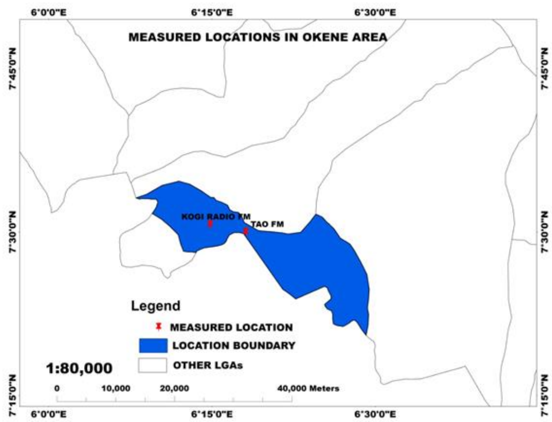

Fig. 2: Map of Okene showing locations of the radio stations

2.2.2 Method of Determining Signal Strength

The field strength meter was activated and set to the radio frequency mode, specifically tuned to the FM mode to capture only frequencies within that range. The antenna was adjusted to ensure it could capture signals from various directions. The scanning process commenced, and the screen readings were continuously monitored for approximately two minutes. As the readings fluctuated up and down, the peak value within this period was recorded. The distance between the location of the receiving antenna and the transmitting antenna of the radio channel was also noted. To minimize potential interference from external factors such as vegetation cover, trees, and buildings, the readings were taken in an open space. The data collection period spanned from August 19th to September 3rd, 2019, totaling sixteen days. During this period, rainy days were avoided due to the equipment's sensitivity to water. Cloudy days were also excluded to ensure better reception and signal quality. It should be noted that the readings obtained at the radio stations would have minimal or negligible distances from the transmitters, effectively making the distances approximately zero at those specific locations.

At six specific locations in Okene town, labeled as points 02 to 07, the strengths of the two radio signals (Kogi Radio and TAO FM) were measured. These locations were situated several kilometers away from the transmitting antenna. Additionally, the signal strengths of the two radio channels were measured at each of the radio stations, labeled as 01A and 01B, and compared with their strengths at the six selected locations. The approximate distances between the radio channels and the selected locations were also recorded. Data regarding the available transmitter powers and the powers being transmitted by the radio stations were obtained from the FM stations. The selection of the positions for measurement was based on geographic sampling, considering the northern, eastern, and western parts of Okene town. This approach aimed to capture a representative coverage area. Each location's Global Positioning System (GPS) coordinates were recorded, and corresponding codes were assigned to each point. Table 1 presents the details of these locations and their respective codes.

Table 1: Codes for the selected locations and their GPS points

Locations	Codes	GPS Locations

Kogi Radio Station	OK1A	Lat.N7033'3.52116" & Long.E6013'59.38392"
TAO FM Station	OK1B	Lat.N7033'7.78788" & Long.E6014'16.208"
Obehira/Okenwe Junction, Okene	OK2	Lat.N7032'54.69" & Long.E6012'13.81788"
Check Point, Okene	OK3	Lat.N7031'37.32168" & Long.E6015'18.03816"
FC/Lokoja Road, Okene	OK4	Lat.N7036'35.09568" & Long.E6015'41.24988"
Kabba/Obajana Junction, Lokoja	OK5	Lat.N70449'32.37852" & Long.E6034'57.9666"
Felele, Lokoja	OK6	Lat.N7050'43.2132" & Long.E6044'53.007"
Ganaja Village, Jimgbe, Lokoja	OK7	Lat.N7042'52.06428" & Long.E6044'25.3986"

2.2.3 Method of Calculating Wavelength

The wavelength (λ) of the wave, which represents the linear displacement between two consecutive crests or troughs, was calculated using the following expression:

$$\lambda = \frac{c}{f} \quad (1)$$

Where: λ represents the wavelength, v denotes the velocity of the wave; given as $3 \times 10^{8} ms^{-1}$, and f represents the frequency of the wave.

2.2.4 Method of Calculating Free Space Path Loss

The free space path loss (FSPL) refers to the reduction in radio energy as it travels across distances between the feed points of two antennas, namely the transmitting antenna at the radio stations and the receiving antennas of the field strength meter. To calculate the FSPL at each of the selected locations, the following equation was employed:

$$FSPL = \left\{\frac{4\pi d}{\lambda}\right\}^{2} \quad (2)$$

Where, d is the distance between the antennas, λ is the calculated wavelength from equation 1, and 4π is a constant.

3. RESULTS

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3.1 Signal Strength

Tables 2 and 3 present the results of the signal strength measurements and the estimated distances from the radio channel, as recorded at each of the FM radio stations. However, it should be noted that at certain remote locations far from the transmitter, no signals were detected on the meter due to the attenuation of the signals. As the signals travel over long distances, they gradually weaken and experience attenuation. This phenomenon was predominantly observed when taking readings from the distant area in Lokoja.

Table 2: Data from Kogi radio at Okene Bar Area, Okene

Positions	Signal Strengths (dBμV)	Approximate distance btw the antennas x10^3 (m)	Frequency of the signal (MHz)
OK1A	100.9	0.0	93.5
OK2A	74.4	5.0	93.5
OK3A	59.1	5.5	93.5
OK4A	45.2	10.0	93.5
OK5A	30.3	71.0	93.5
OK6A	37.5	73.0	93.5
OK7A	Nil	75.0	93.5

From the data in Table 2, the signal strength at location 01A is quite strong, measuring 100.9dBμV. In fact, the signal even registered a response without connecting the equipment's antenna. Furthermore, the distance between the antennas at this location is approximately 0.0m, indicating close proximity. Conversely, location 07A does not receive any signal, which can be attributed to various factors such as signal fading due to the considerable distance between the antennas (approximately 75,000m) and potential obstructions causing reflection, refraction, or diffraction of the signals. Location 02A, with an approximate distance of 5,000m, exhibits a signal strength of 74.4dBμV. Overall, it can be inferred from the table that the signal strengths are directly proportional to the distance between the transmitting and receiving antennas.

Table 3: Data from TAO FM, at Kuroko, Okehi

Positions	Signal Strengths (dBμV)	Approximate distance btw the antennas x10^3 (m)	Frequency of the signal (MHz)
OK1B	102.2	0.0	101.9
OK2B	64.4	4.0	101.9
OK3B	42.9	5.0	101.9
OK4B	46.7	5.0	101.9
OK5B	36.4	69.0	101.9
OK6B	Nil	72.0	101.9
OK7B	Nil	73.0	101.9

Based on the data presented in Table 3, it can be observed that location 01B, which corresponds to the radio channel location, registered a signal strength of 102.2dBμV. The approximate distance between the antennas at this location is 0.0m, indicating close proximity. However, locations 06B and 07B did not detect any signals; and this could be attributed to fading, which occurs as signals traverse different media over longer distances, such as the 72,000m and 73,000m distances in these respective locations. In addition to fading, the absence of signals could be attributed to other factors such as reflection, refraction, and diffraction caused by obstacles along the paths of signal propagation.

3.2 Wavelength

Using Tables 2 and 3, the wavelengths (λ) for each of the FM radio stations was determined using equation 1. The results of these calculations are presented in Table 4. In this context, it is important to note that both the frequency of the signal and the wavelength are directly related to the velocity of the electromagnetic wave, which is essentially a constant with an approximate value of $3x10^8$m/s, representing the speed of light.

Table 4: Calculated values of the wavelengths

Radio Stations	Frequency (MHz)	Velocity (ms^{-1})	Wavelength (m)
Kogi Radio	93.50	$3.00x10^8$	3.21
TAO FM	109.50	$3.00x10^8$	2.94

From Table 4, it is clear that higher frequency electromagnetic signals, characterized by smaller wavelengths, tend to experience faster attenuation compared to lower frequency signals with larger wavelengths. As a result, it can be inferred that TAO FM, which operates at a higher frequency, is expected to attenuate more rapidly than Kogi Radio when passing through different physical mediums such as brick walls and vegetation.

3.3 Free Space Path Loss

Using Tables 2, 3 and 4 the free path loss of the signals in each of the selected locations were obtained using equation 2 and are presented in Tables 5 and 6.

Table 5: Calculated free space path loss for Radio Kogi

Location/ Measured Values	Signal Strengths (dBμV)	Approximate distance btw the antennas $x10^3$ (m)	Wavelength (m)	Free Space Path Loss
OK1A	100.90	0.00	3.21	0.00
OK2A	74.40	5.00	3.21	$3.84x10^{-4}$
OK3A	59.10	5.50	3.21	$4.64x10^{-4}$
OK4A	45.20	10.00	3.21	$1.53x10^{-3}$
OK5A	30.30	71.00	3.21	0.077
OK6A	37.50	73.00	3.21	0.08
OK7A	Nil	75.00	3.21	0.09

Table 6: Calculated free space path loss for TAO FM

Location/ Measured Values	Signal Strengths (dBμV)	Approximate distance btw the antennas $x10^3$ (m)	Wavelength (m)	Free Space Path Loss
OK1B	102.20	0.00	2.94	0.00
OK2B	64.40	4.00	2.94	$2.92x10^{-4}$
OK3B	42.90	5.00	2.94	$4.56x10^{-4}$
OK4B	46.70	5.00	2.94	$4.56x10^{-4}$
OK5B	36.40	69.00	2.94	0.087

OK6B	Nil	72.00	2.94	0.095
OK7B	Nil	73.00	2.94	0.097

From Tables 5 and 6, it is evident that; in terms of free path loss, the properties of frequency and wavelength of the RF signal do not directly cause attenuation. The primary factor contributing to signal attenuation is the distance traveled by the signal through the atmosphere. As the signal propagates, it gradually weakens to amplitudes below the sensitivity threshold of the receiving radio. Consequently, the signal reaches the receiver but is too weak to be detected. Figures 3 and 4 further illustrate the relationship between signal strength, distance, and free space path loss for both Kogi Radio and TAO FM.

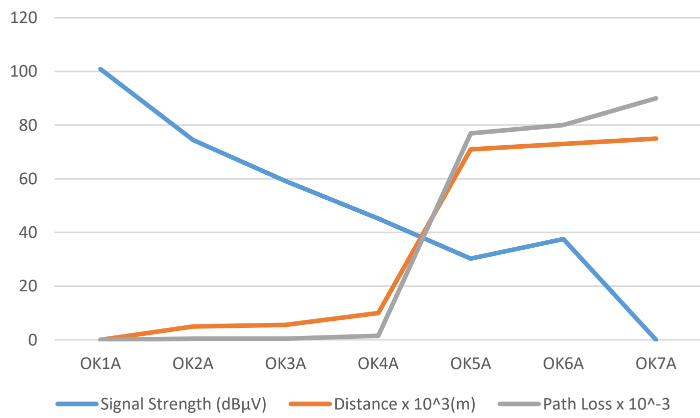

Fig. 3: Relationship between signal strength, distance and path loss for radio Kogi

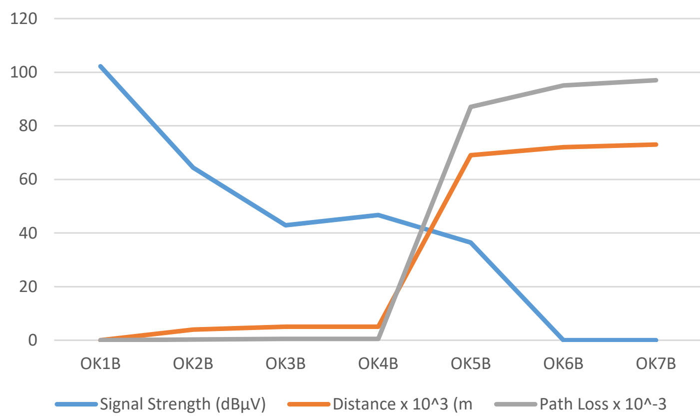

Fig. 4: Relationship between signal strength, distance and path loss for TAO FM

4. DISCUSSION

Findings indicate an inverse relationship between the wavelength and frequency of the signal. Higher frequency channels exhibit shorter wavelengths. The free space path loss depends on the distance between transmitting and receiving antennas. However, at the radio stations, the path loss is minimal and approaches zero due to the short distances between the antennas. Distance directly affects path loss and inversely affects signal strength. Larger distances result in greater path loss. The strong radio signals at the stations are attributed to their proximity to the transmitters. Signal losses occur due to obstacles like vegetation, hills, mountains, trees, water bodies, bushes, and buildings that obstruct signal propagation. Refractions, diffractions, and reflections from such obstacles impact signal quality, as observed with TAO FM at Ganaja, Jimgbe, Felele, and Kogi radio at Ganaja, Jimgbe. Previous studies by Meng, Lee, Ng [14], Gökhan, Lavent [15], and Aguirre et al. [16] support these findings regarding signal loss and the influence of human bodies on transmitted signals. At close ranges, signal weakness is observed in densely populated areas due to human presence. The body's impact on signal strength is confirmed by studies analyzing dosimetry evaluations. These losses are more significant in the abdomen region compared to the knee due to greater mass and liquid content. Comparing path loss with measured signal strengths reveals an inverse relationship. Higher signal strengths correspond to lower path loss, while lower signal strengths result in higher free space path loss.

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5. CONCLUSION

In conclusion, despite the radio stations transmitting at a minimum of 2kW from elevated locations, factors such as forests, vegetation, buildings, hills, human presence, and bodies of water have limited the coverage of their signals. The results obtained clearly indicate the areas where optimal signal reception can be expected based on the measured signal strengths. It is evident that the quality of radio signals is greatly influenced by these factors. Moreover, the results demonstrate an inverse relationship between signal strengths and the calculated free space path loss at most locations. Higher path loss corresponds to lower signal strengths. To improve signal coverage, it is recommended for the radio stations to consider installing booster stations approximately 70km away from the main stations, taking into account the locations of their target audiences. Additionally, prospective radio stations can use these findings as a guide for selecting suitable locations to establish their own stations.

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