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AN ASSESSMENT OF COVERAGE AREAS OF SOME AM RADIO TRANSMITTERS IN NIGERIA

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Abstract

This study presents the result of the assessment of the useful coverage areas of some amplitude modulated (AM) transmitters over Nigeria landmass and the investigation of some factors impairing the signal integrity. This is motivated by the decline in the number of AM radio transmitters operating in Nigeria. Electric field strengths of the radio signals were measured along some routes around the transmitters during the rainy and dry seasons. The results obtained were interpolated to generate primary, secondary and fringe coverage areas but only the secondary coverage was geo-referenced on the maps of the owner states because it is the region where the signals are useful. The influences of ambient radio noise, seasonal variation, distance from transmitter, vegetation absorption, ground conductivity and antenna height on the service coverage were deduced. Results reveal that the percentage of landmass of the State outside useful service coverage within the State is greater for all the station except around Voice of Ekiti and Kano radios.

***Keywords*:** coverage areas, radio noise, vegetation absorption, electric field strength.

1.0 Introduction

Radio broadcasting is a way of reaching large number of people and communities with information within a short time through radio wave propagation. Broadcasting at FM, VHF and UHF provide signals with high noise immunity compared to AM thus leading to decline in the number of AM transmitters operating in Nigeria. The electromagnetic wave is a self-propagating transverse oscillating wave of electric and magnetic components. Propagation at the Medium Frequency is by ground and sky wave. The electric component of the wave results from the voltage changes that occur as the antenna element is excited by the alternating waveform. The lines of force in the electric field run along the same axis as the antenna, but spreading out as they move away from it. The electric component or field is measured in terms of the change of potential over a given distance in Volts per meter (Vm^{-1}) and this is known as electric field strength of the wave [1, 2]. The service areas of transmitter are classified into primary, secondary and fringe service areas. The value of field strength for the various qualities of service depends on atmospheric and man-made noise in the locality. The ranges of values; $E_p \geq 1.0\, mV/m$, $0.5\, mV/m \geq E_s \leq 1.0\, mV/m$ and $0.25\, mV/m \leq E_f \geq 0.5 mV/m$ were adopted for primary, secondary and fringe service areas respectively [3]. The primary service area is the region about the transmitters in which the signal strength is sufficient to suppress interference at all times. The region where the signal strength is useful but not sufficient to overcome interference at all time is the secondary service area. The fringe service area is regarded as the region in which the signal can be useful for some periods but the service can neither be guaranteed nor protected against interference. The boundary of the secondary service coverage is usually considered limit of useful service. Factors which influence the usefulness of the signals at AM include radio noise, vegetation absorption, frequency, ground electrical conductivity, transmitter power, receiving distance, digital or analogue signal and antenna heights.

1.1 Frequency

Frequency of the radio signal is one of the major determining factors as reduction in electric field strength rise with increasing frequency [4]. The increase in frequency also reduces the coverage area of the transmitter.

1.2 Ground Electrical Conductivity

The surface wave is also dependent on the electrical parameter of the ground over which the signal travels [4, 5]. Ground conductivity affects the signal propagation but dielectric constant has no effect. Electric field strength increases with ground

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electrical conductivity. If the conductivity is high the attenuation will be less. The depth of penetration of the surface wave is inversely proportional to the frequency and the ground electrical conductivity. If the ground conductivity is higher, the energy is channeled within a region located just above the surface; little energy penetrates deeper into the ground. This effect allows the signal to be detected at large distances. In contrast, when the ground electrical conductivity is low, wave penetrates deeper into the ground and the distance from the transmitter at which the signal can be detected is less than that associated with high conducting medium.

1.3 Vegetation Absorption

Air/treetop interface guides the propagating wave much as the air/ground interface guides the ground wave [6]. As the wave travels, the vegetation contributes to the reduction in the strength of the wave. Through vegetation path loss has many models but the Fitted ITU [7] is considered most suitable for the study and is given as [8, 9]

$$L_{FITU}(dB) = 0.37 f^{0.18} d^{0.59} \qquad (1a)$$

out-of-leaf condition

$$L_{FITU}(dB) = 0.39 f^{0.39} d^{0.25} \qquad (1b)$$

in-leaf condition.

where *f* is frequency in MHz and *d* is distance in metre the signal travelled within vegetation.

1.4 Transmitter Power

The transmitter power is the measure of the strength with which the transmitter pushes the signal into space. The greater this power the more the range covered by the signal. Greater transmitter power results in greater coverage area [10, 11].

1.5 Distance

Due to free space loss caused by spreading, the electric filed strength of the signal reduces with distance. All electromagnetic waves obey the inverse-square law. This means that its power density is proportional to the inverse of the square of the distance from the source. If the distance from a transmitter is doubled, the power density of the signal at the new location reduced to one-quarter of its previous value [2, 4, 12].

1.6 Antenna Height

The heights of the transmitting and receiving antennae are supposed to be above obstructions along the propagation path. In medium wave propagation, signal diffracts around the earth curvature and obstacles along its path. Increasing antenna height reduces path loss and vice versa [13]. Antenna height gain is given as [8, 14]

$$G_a(dB) = -12 - 4log_{10}(f) + 20log_{10}(h_t) + 20log_{10}(h_r) \qquad (2)$$

1.7 Radio Noise

Radio noise is a time-varying electromagnetic phenomenon having components in the radio-frequency range; apparently not conveying the desired information and which may be superimposed on, or combined with, the wanted signal [15]. The ambient radio noise environment consists of two parts: the irreducible residual ambient noise, which is more or less constant in any particular location and the incidental noise from local man-made sources [11] which include passing automobile with noisy exhaust. In an AM wave, the signal is the amplitude variations of the carrier. All natural and man-made noises are made up of electrical amplitude disturbances. The radio receiver cannot distinguish between amplitude variations containing noise and those containing the desired signal, hence the reception generally contains noises [16]. Radio noise must be taken into consideration because it sets a limit to the performance of the radio system but digitizing the signals reduces the level of radio noise superimposed on the desired signal. This is because the digital signals propagate as discrete pulses which are less affected by radio noise interference. The noise increases the signal strength and reduces the audio quality. The field strength due to man-made noise is given by [15, 17].

$$E_{ne} = F + 20\log f_{MHz} + 10\log h - 95.5 \quad (dB\mu V/m) \qquad (3)$$

h = 9 *kHz*, the bandwidth at the broadcasting frequency and *f* is frequency.

According to [15, 17, 18], a business zone is any area where the predominant usage throughout the area is for any type of business such as stores and offices, industrial parks, large shopping centres, main streets or highways lined with various business enterprises, etc. A residential zone is any area used predominantly for single or multiple family dwellings with a density of at least five single family units per hectare and no large or busy highways. Rural zone is an area where dwellings are no more than one every two hectares. Quiet rural zone is a place that is isolated where the activities are predominantly that of low noise animals or an individual in about five hectares of land. The radio noise in an environment is a function of the land use and/or land-cover pattern. The urban land use pattern of an environment can be used to categorize the radio noise level coming from the different sections of the environment.

2.0 MATERIAL AND METHODS

This study is focused on the measurement electric field strength of surface wave radiated from seven transmitters whose parameters and locations are presented in Table 1 and Figure 1 respectively. Data were collected in both seasons around the transmitters of Oyo Radio, Radio Kwara, Voice of Ekiti (VOE) Radio and Federal Radio Cooperation of Nigeria (FRCN) Kaduna while measurements around the transmitters of Kano Radio, Radio Jigawa and Radio Benue took place only in the dry because of insecurity situation in Nigeria. The instruments used for the study are Potomac field strength meter FIM – 21, Garmin 38 Global Positioning System (GPS) and HP mini laptop. The field strength meter is a radio receiver equipped with an inbuilt loop antenna. The field strength meter was used to measure the electric field strength along some routes around the transmitters. The GPS registered the coordinates of the points of measurements along the routes [19, 20]. The measured field strength weas interpolated using kriging technique to generate primary, secondary and fringe coverage areas. The secondary coverage areas were contoured for all the stations with the aid of Surfer software and geo-referenced on maps of Nigeria in arcmap. Along each route, the point of measurement ranges from 5-10 km so that rapid change in the contours of electric field strengths can be recognized. This is important in identifying regions where change in electric field strength is caused by a change in the ground electrical conductivity [5]. The measurements were taken between the hours of 9:00 am and 5:00 pm to avoid measuring the electric field strength of space wave. Since the value of ground electrical conductivity is related to wetness of the ground [21] and consequently that of electric field strength, the measurements were done during wet and dry seasons. The field strength meter was mounted on a car with a height not far from the ground surface. The coordinates of points of measurement were recorded in universal transverse mercator (UTM) projection system which is useful in the surfer and armap. Kriging interpolation technique was used for contouring the coverage areas of the transmitters. According to [22, 23], kriging has some advantages over other interpolation techniques which make it more suitable for contouring the service coverage of radio transmitters. The range electric field strength for secondary coverage adopted for this study is $0.5\, mV/m \geq E_s \leq 1.0\, mV/m.$ In arcmap, the surface areas of the coverage areas were calculated using the field calculator [24]. This is done by clicking along the perimeter of the polygon after selecting the field area calculator and the desired unit of measurement. The coverage areas created in surfer were imported into arcmap in shapefile format and then their surface areas were estimated using the field calculator.

NigerSat 1 image of landmass around the transmitters was classified into vegetation, built-up, rock and bare soil. From these, the distances travelled by the signal within vegetation in wet season were determined and these were used to calculate the vegetation absorption level. The built-up could not categorised into city/business, residential, rural and quiet zones because the land-use land-cover acts are not enforced in infrastructural development and therefore there exist no demarcation. Therefore the maximum and minimum vegetation absorptions for each zone were calculated based on the [17]. The levels of vegetation absorption, antenna height gain and radio noise influencing the signal were determine using equations 1, 2 and 3 respectively.

3.0 RESULTS AND DISCUSSION

The outer boundary of secondary coverage area is the limit of the region where the signal strength is considered useful. It demarcates regions where useful signal can be received as well as where degrading interference occur. The useful coverage areas for the transmitters assessed in both wet and dry seasons are presented in Figures 2 and 3 respectively. The percentages of landmass outside the useful coverage areas are general greater except in Ekiti State in wet season and in the State of Jigawa, Kano and Ekiti in dry season. The percentages of landmass of owner States within and outside the useful coverage area in the wet and the dry seasons are presented in Figures 4 and 5 respectively. In wet season, there is the likelihood of overlapping of coverage and interference of signals between the Kwara Radio and Voice of Ekiti Radio because the boundaries of their useful coverage areas are in contact as shown in Figure 2. In the dry season, there is an overlapping of coverage areas between the transmitters of Kano Radio and Radio Jigawa. The overlapping engulfed 6,972.44 km^2 of the coverage areas because the transmitters are located at approximately 78.78 km apart. The signal strength and coverage areas of both transmitters will be greater in wet season. Therefore the overlapping of coverage areas of the two transmitters will be greater than what was obtained in dry season. This will lead to serious degrading in the quality of the signals due to interference. Radio Jigawa should be repositioned to the centre of the State to reduce this effect. The propagation curves presented in Figure 6 for a route each around four of the transmitters in both seasons, reveal that the field strength reduce as the distance from the transmitter increases. The three dimensional plot of Figure 7 show the influence of the ground electrical conductivity on the electric field strength. The contour of the ground conductivity and field strength are presented in blue and red colours respectively. Increase in ground conductivity leads to increase in the field strength. The antenna height gain increases the field strength while vegetation absorption and radio noise degrade the signal quality. The antenna height gain and vegetation absorption are represented in Figure 8, the gain (dB) for each transmitter far outweighs vegetation absorption, and therefore the effect of vegetation absorption is negligible. The residual ambient radio noise is generally negligible but it is more in business zone, follow by residential zone and least is in quiet zones. As presented in Figure 9, there is no distinct difference between the radio noise in rural and quiet zones around the transmitters of Kano, Kwara, Oyo, Benue and Jigawa Radio. As notice during the measurement campaign, the effect of incidental radio noise results in serious reduction in signal fidelity. This was experienced as vehicles with faulty exhaust passed by during the measurement.

4.0 CONCLUSION

This study assesses the useful coverage areas of some AM transmitters currently operating in Nigeria and the factors inhibiting their coverage areas. For most of the transmitters, larger portion of the state they licensed to cover are not reach with useful service coverage. Ground conductivity and antenna height gain enhance the signal strength while vegetation absorption and radio noise which reduce signal fidelity has minimal influence on the signals. Since signal strength reduces with distance, booster station will be required to extend useful service coverage to those portions of each State outside useful service.

Table 1: Assessed Broadcasting Organizations

Name	State	Frequency (MHz)	Transmitter Power (kW)
Voice of Ekiti (VOE) Radio	Ekiti	0.549	5.0
Federal Radio Cooperation of Nigeria (FRCN) Kaduna	Kaduna	0.594	50.0
Radio Kwara	Kwara	0.612	50.0
Kano Radio	Kano	0.729	50.0
Oyo Radio	Oyo	0.756	50.0
Radio Benue	Benue	0.918	50.0
Radio Jigawa	Jigawa	1.026	25.0

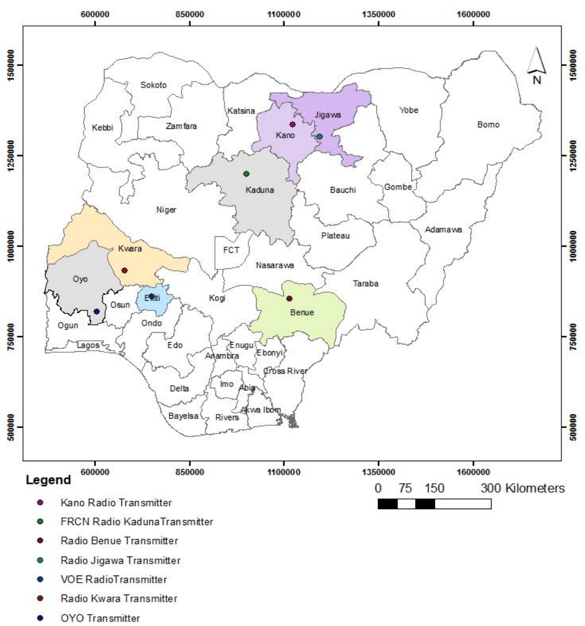

Figure 1: Map of Nigeria showing location of AM transmitters

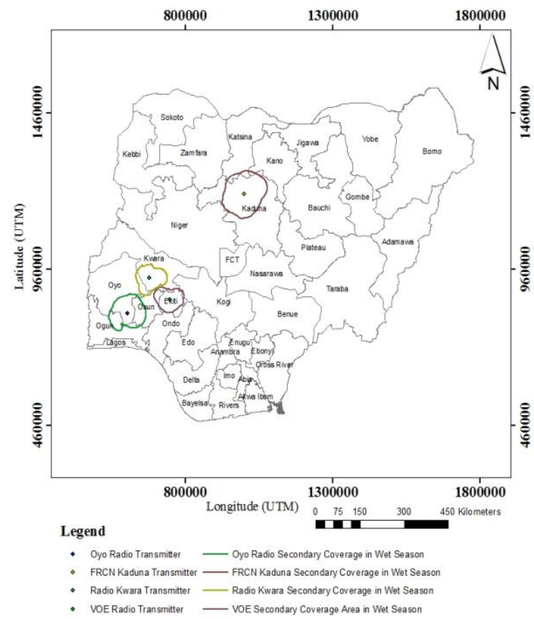

Figure 2: Coverage Areas in Wet Season

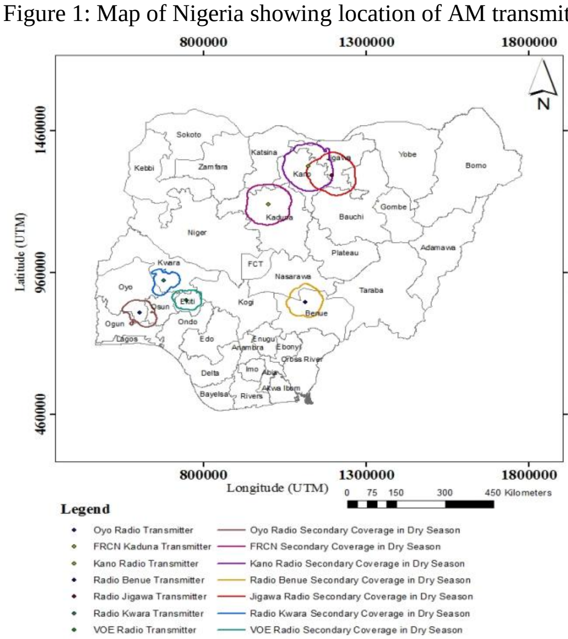

Figure 3: Coverage Areas in Dry Season

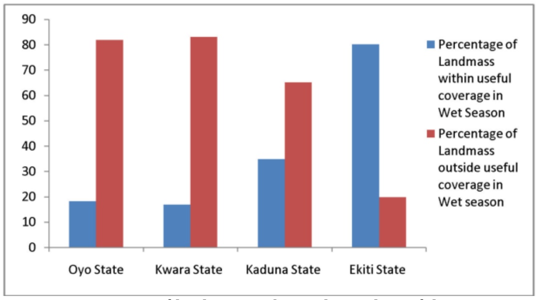

Figure 4: Percentage of landmass within and outside useful coverage in Wet Season

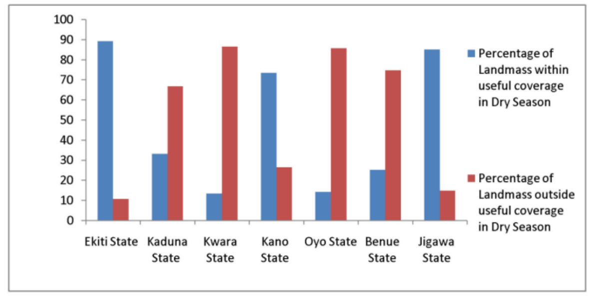

Figure 5: Percentage of landmass within and outside useful coverage in Dry Season

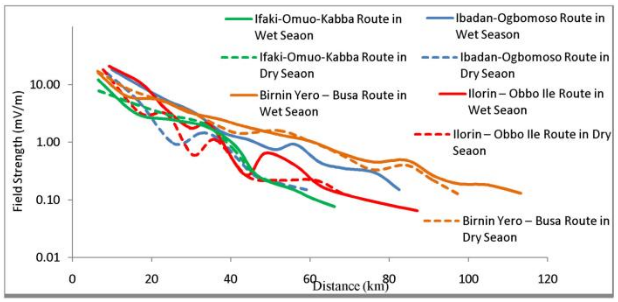

Figure 6: Propagation Curves of some of the Radio Transmitters assessed.

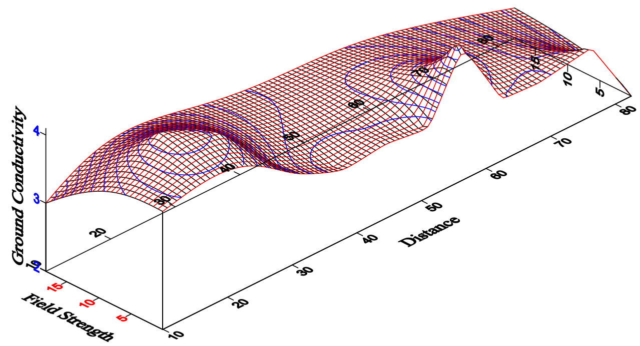

Figure 7: Influence of Ground Conductivity on Field Strength

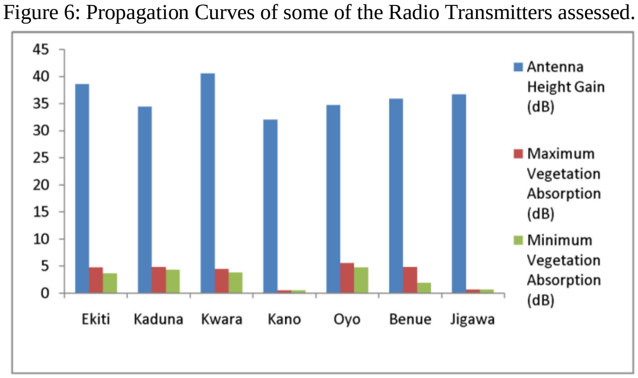

Figure 8: A plot of Antenna Gain and Vegetation Absorption

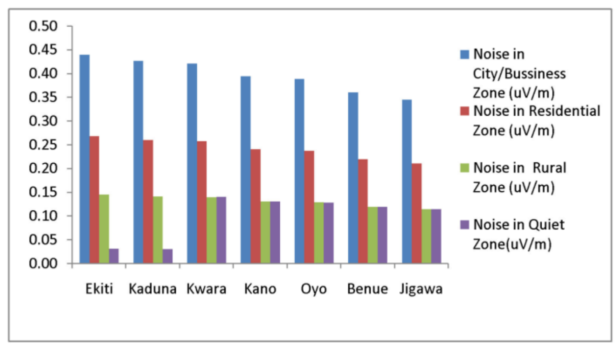

Figure 9: A Plot of Noise Level at the different zones

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