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Field strength intensity measurement of a Radio station for Frequency and coverage range inferences and human exposure index

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ABSTRACT

In this research, the measurements of the field strength intensity of a radio station (ORISUN FM 89.5 MHZ) and its nearby locations within its coverage area were taken. This was taken to determine the frequency range, coverage area, field strength and power density measurements of the frequency modulation (FM) station and to ascertain whether its propagating frequency is within the radiofrequency (RF) protection guidelines. The result revealed that the frequency of the FM station did not reach all expected coverage areas in Ile-Ife and also that no mutual interference existed within the coverage areas. It also indicated that the RF propagation is within the protection guidelines of broadcasting stations and not dangerous to residents. The radiofrequency safety recommendations for the field strength and power density were not exceeded in all the locations covered. The highest values could be linked with other antennas. However, this research study provided radio station operators with information on environmental RF fields that will help ensure the prudent and safe operation of amateur facilities.

Keywords: Field strength, radio station, coverage area, propagating frequency, radiofrequency

1. INTRODUCTION

Telecommunication is communication at a distance by high-tech means, mostly electromagnetic signals and waves. This modern equipment for lengthy-distance communication generally involves electromagnetic technologies like mobile phones, networks, radio, microwave transmission, fiber optics, and communications satellites. A radio transmitter's performance is a function of actions of the intensity of the electromagnetic field of the radio wave produced by the transmitter. This action includes differences in the electric field intensity propagation, which determines its transmission profile and coverage area, which are both related (Morris and William, 1973; Yaghjian et al., 1986; Seybold, 2005; Igbonoba et al., 2023). These two properties have their unique usefulness and play balancing roles in the performance of radio transmitter. Likewise, there is also the

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risk of exposure of humans to radiofrequency (RF) electromagnetic fields due to transmission from the transmitter (Ashwin, 2015; Holloway et al., 2001).

In Nigeria, more than 2000 licensed radio operators exist, and several others exist all over the world. Because of its responsibilities under the terms of the NBC and the NESDRA, it is necessary to ensure that the transmissions from these stations do not expose and render the community residents to high intensities of radiofrequency, which is not accepted by the regulating agencies and guidelines. The propagation profile (2 or 3 dimensions), which shows the relationship between distance, electric field and coordinates, gives the coverage of the landmass essentially by the transmitter (Akinbolatia et al., 2016; Gumusay et al., 2007; Deminco, 2000).

The exposure of humans to RF has been considered by some researchers as one of the major environmental factors to evaluate the potential impact from transmission and suggested guidelines for the evaluation of this exposure to RF energy. So, measurements of electromagnetic fields at a selected radio station in Ile-Ife, Osun State in July 2014 were taken in order to examine the potential impact of the transmission from the radio station. This data will help the regulating agencies in achieving their compliance mandate on radio station transmission in the future. The Orisun FM station was chosen for this study on the basis of accessibility of the workers, antennas and equipment range, approachability of the station transmitting site, and its proximity to the center of the city. Though, no two radio stations can be identical since they have several allocations of frequency bands between 1.8 MHz and 250 GHz and a 1500 watts peak cover power (Cleveland and Mantiply, 1991; ITU-R, 1992).

The signal quality and coverage area are very essential factors that attract high patronage from listeners. Thus, there is a need to carefully determine the rate of decay of electric field intensity alongside the propagation path because an amplified electric field strength and distance provide more signal clarity and reliability coupled with distance propagation (Akinsanmi, 2007; Ajewole et al., 2014; Akinbolati et al., 2016). In some literature, either one of the coverage area or profile of propagation were used to give details of the electric field strength variations near the transmitter and vice versa in radio and television stations in Nigeria, while some used propagation profiles to investigate the UHF and VHF signal strength variations (Ajewole et al., 2013; Oluwafemi and Femi-Jemilohun, 2017). Akinbolati et al., (2017) carried out some research work on UHF TV signal (source to destination) and concluded that the signal strength of UHF signal is seriously affected by the elevation pattern of its coverage. Ajewole et al., (2013) worked on spatial coverage of FM radio transmitters using the propagation of radio waves in the frequency-modulated (FM) band and relief on the very high frequency (VHF) band of the electromagnetic spectrum (30MHZ-300MHZ).

He concluded that the FM radio transmitter in Niger State does not give optimum coverage in the state. Phontus and Chotigo, (2008) proposed a humility correction factor of positive DC breakdown voltage of the sphere-sphere gap at h/δ lower than 13 g/m3. Their results showed that the voltage measurement by means of standard air gaps which enables them to recognize the effects of electric barriers to the electric field of rod plane air gap. Calvente et al., (2016), Elder, (2003) and Ismail et al., (2010) investigations attempted to determine a correlation between non-ionizing radio frequency (RF) radiation and diverse health effects due to the intense increase in the use of wireless communication devices as well an increase in concerns about potential health risks.

Thus, the aim of the study is to investigate the relationship between the propagation profile and coverage area from the transmitter of a radio broadcasting station and the probable degrees of RF radiation exposure to the public (operators, and residents in the immediate vicinity of the station). The study will deduce the field intensity around the FM transmitting station's coverage area and provide data relating to the coverage area to avoid frequency channel interference. The study's objectives will classify the station's coverage area and determine the transmitted signal's intensity at the clarified coverage area. It will also investigate the radio station's compliance in accordance with NBC since all transmitting stations have their expected coverage area in order for their signal strength not to constitute interference with others.

Theoretical Background

The electric field intensity at a point can be obtained from the power provided to the transmitting antenna, its geometry, and radiation resistance. Consider an example of a center-fed half-wave dipole antenna in free space where the total length, L, is equal to one-half wavelengths ($\lambda/2$) (Figure 1). Assuming it is made of thin conductors, the current distribution is basically sinusoidal and the radiating electric field is given equation 1:

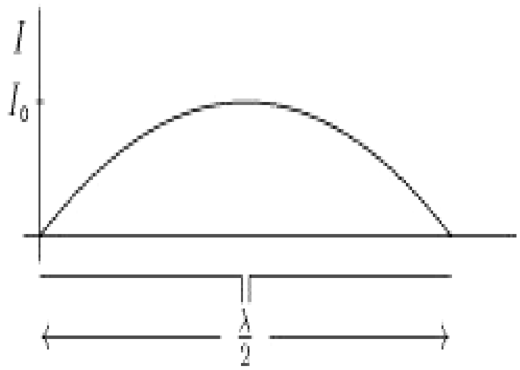

Figure 1 Distribution of current on length L of antennae equal to one half-wavelength (λ/2).

$$E_\theta(r) = \frac{-jI_o}{2\pi\varepsilon_o cr}\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}e^{j(\omega t-kr)} \quad 1$$

Where θ= angle between the antenna axis and the vector to the observation point

I_o=peak current at the feed-point

εo=the permittivity of free-space

c=the speed of light in a vacuum

r=the distance to the antenna in meters.

When the antenna is viewed broadside ($\theta = \pi/2$) the electric field is maximum and it is given by:

$$|E_{\pi/2}(r)| = \frac{I_o}{2\pi\varepsilon_o c r} \quad 2$$

Solving equation 2 gives:

$$I_o = 2\pi\varepsilon_o c r|E_{\pi/2}(r) \quad 3$$

Thus, the average power of the antenna is given by:

$$P_{avg} = \frac{1}{2}R_a I_o^2 \quad 4$$

where Ra=73.13 Ω which is the center-fed half-wave antenna's radiation resistance. Substituting the formula for Io into equation 4 and solving for the maximum electric field. This gives:

$$|E_{\pi/2}(r)| = \frac{1}{\pi\varepsilon_o c r}\sqrt{\frac{P_{avg}}{2R_a}} = \frac{9.91}{r}\sqrt{P_{avg}} \quad (L = \lambda/2) \quad 5$$

So, if the average power to a half-wave dipole antenna is 1mW, then the maximum electric field at 313 m (1027 ft) is 1 mV/m (60 dBμ). For a short dipole where L≪ λ/2, the current distribution is nearly triangular and for this instance the electric field and radiation resistance are:

$$E_\theta(r) = \frac{-jI_o\sin\theta}{4\varepsilon_o cr}\frac{L}{\lambda}e^{j(\omega t-kr)} \quad 6$$

$$R_a = 20\pi^2\left(\frac{L}{\lambda}\right)^2 \quad 7$$

Applying a technique related to the above, the maximum electric field for a center-fed short dipole is given by equation 8:

$$|E_{\pi/2}(r)| = \frac{1}{\pi\varepsilon_o c r}\sqrt{\frac{P_{avg}}{160}} = \frac{9.48}{r}\sqrt{P_{avg}} \quad (L \ll \lambda/2) \quad 8$$

2. METHODOLOGY

Measurements were made using an Industry Model EFS-1 field intensity meter at 1-2m above the ground surface at different distances from the station's antenna and also within the premises of the stations and operators building. The measurements of the electric field strength were obtained alongside the coordinates using the meter and a handheld GPS receiver with a total of seven routes around the radio transmitter. The radios transmitter limits and specifications are given in (Table 1).

The data were processed into contour map and profiles for proper visualization and interpretations. The values of the electromagnetic field intensity were adjusted for standardization inaccuracy and rounded off. Field strength meter is test meter equipment used to measure the strength or level of a radio frequency signal; it provides an indication of the presence of radio frequency (RF) energy. It is frequency sensitive and useful for both indication for a change in level and the actual strength of the signal indicated, it responds to signal at any selected frequency under its range.

Table 1 Standard Frequency Band Range

Frequency Band	Lowest Strength (dBμv/m)	Notes
Band 1	48	
Band 2	70	Large areas
Band 3	55	
Band 4	65	
Band 5	70	Large areas
Band 6	48	Rural areas
Band 7	60	Urban areas

In an ideal open space, the electric field intensity created by a transmitter with isotropic space heater is estimated by equation 9 as:

$$\mathrm{E} = \frac{\sqrt{30 \cdot P}}{d} \tag{9}$$

Where E =electric field strength (V/m), P= transmitter power output (W), D= distance from the radiator (m).

From equation 9 it is obvious that the electric field strength and the distance are inversely proportional between the receiver and transmitter. Nevertheless, this relationship is applied for computing the electric field strength created on terrestrial transmitters in which reflections and attenuation caused by objects around the transmitter or receiver may affect the electrical field strength measured. The field strength of an antenna radiation at a given point in space is equal to the amount of voltage induced in a wire antenna 1m long located at that given point. This field strength is affected by a number of conditions such as the time of day, atmospheric conditions and distance from the transmitter.

3. RESULTS AND DISCUSSION

The parameters obtained from the work were used to determine the coverage areas of the FM radio signal carried out in Ile-Ife Osun State and the impact of the RF exposure to the public. The measurement was taken at the base of the transmitter which sends signal to the antenna. The parameter of the transmitter in which it sends signal to the antenna from the antenna to the receiving end is given in (Table 2).

Table 2 Transmitter Readings of Orisun FM (89.5MHZ)

Transmitter	Parameter
Name of station	Orisun FM
Frequency	89.5MHZ
Maximum transmitter power operating	
Antenna Height Above Sea Level	450m
Location	Ife
Geographical Coordinates	7oN and 4oE
Forward Power	0.9-1.1w
Deviation	197KHZ
Inlet Air temperature	26oc
VPA	42.6V

IPA	3.0A
Reflected Power	0W
Power Output	5KW
Heat Sink Temperature	31oC

The electric field strength of the station was measured with a digitalized level meter over the range of 30-120dbμv within the hours of 9:00am and 4:00pm local time every day in the month of April 2014. Measurements were obtained at every neighboring town and village and at every location. The intensity meter will be switched on when the aerial on it is being elevated to a required level and it served as an antenna so that the meter can pick up the transmitting of the transmitter when the meter is switched on so it immediately begins to read the frequency of the programmed frequency from the based station. The resulting field data report is given in Table 3 which shows the location of each town and their respective frequency.

Table 3 Summary of field strength measurement

Location	Frequency (dBμv)	Latitude	Longitude	No of satellite	GPS Accuracy (m)
Main station	112.4	N7 29.1221	E4 33.6822	11	16.97
Ife round about	51.2	N7 30.5519	E4 26.745	5	101.19
Omi-Okun	75.8	N7 27.9597	E4 33.6822	8	17.89
Ifelodun	68.0	N7 27.522	E4 33.3479	9	17.89
Ita Osa	52.0	N7 25.8120	E4 34.932	11	13.42
Iyanfoworogi	39.4	N7 22.6812	E4 34.41	11	81.42
Ajibamidele village	31.0	N7 19.8546	E4 8344	11	8.49
Ayekoka	No signal	N7 7798	E4 36.2778	5	71.55
Modakeke	80.3	N7 27.8891	E4 32.7012	10	16.97
OAU gate	64.1	N7 29.7707	E4 31.2330	10	10.00
To gate (Ile-Ife)	56.0	N7 29.6364	E4 29.5536	9	14.42
Roundabout	44.3	N7 29.8271	E4 27.2418	9	10.00
Akinola Junction	53.5	N7 29.8287	E4 26.9455	8	14.42
OAU Teaching Hospital	70.0	N7 30.1637	E4 34.3158	11	13.42
Lagere Junction	70.0	N7 31.3331	E4 34.4730	11	50.60
Ile-funfun	62.0	N7 35.1692	E4 34.6529	9	16.97
Osu Ilesa road	42.0	N7 35.1692	E4 37.4634	9	10.00
Ibodi Ilesa road	35.0	N7 35.6114	E4 39.3509	8	20.00
Ilesa	No signal	N7 35.6114	E4 39.6114	9	17.89
Kajola Ede road	54.0	N7 30.6407	E4 29.6303	8	14.42
Moro Junction	46.6	N7 32.3789	E4 27.6432	8	17.89
Edun Abon	37.3	N7 32.7323	E4 27.3311	10	20.00

The measurements were obtained at the beginning of rainy season. The contour map was obtained for the coverage areas for Orisun FM (89.5MHZ) radio signals to give a pictorial view of the coverage areas of the radio stations and to determine optimum coverage areas for the station based on the primary coverage area, secondary coverage area and fringe coverage area respectively (Figure 2). At the base station, the measured signal strength was averagely 112.4dbμv which was the highest across Ile-Ife and environs.

The signal level reduced from the base station. This conforms to the inverse square law (*P1* is the power density and r is the distance from the transmitter). The signal dropped to about half of its base value around Ile-Ife round about. This sharp drop could be linked to the terrestrial factors on the signal path-tress, buildings and low-level area and around this place which caused attenuation in the signal's strength. Higher signal level was also measured and recorded at some distant locations such as the case at Omi-Okun, Ifelodun than expected as shown in the propagation profile across Ile-Ife and environs (Figure 3).

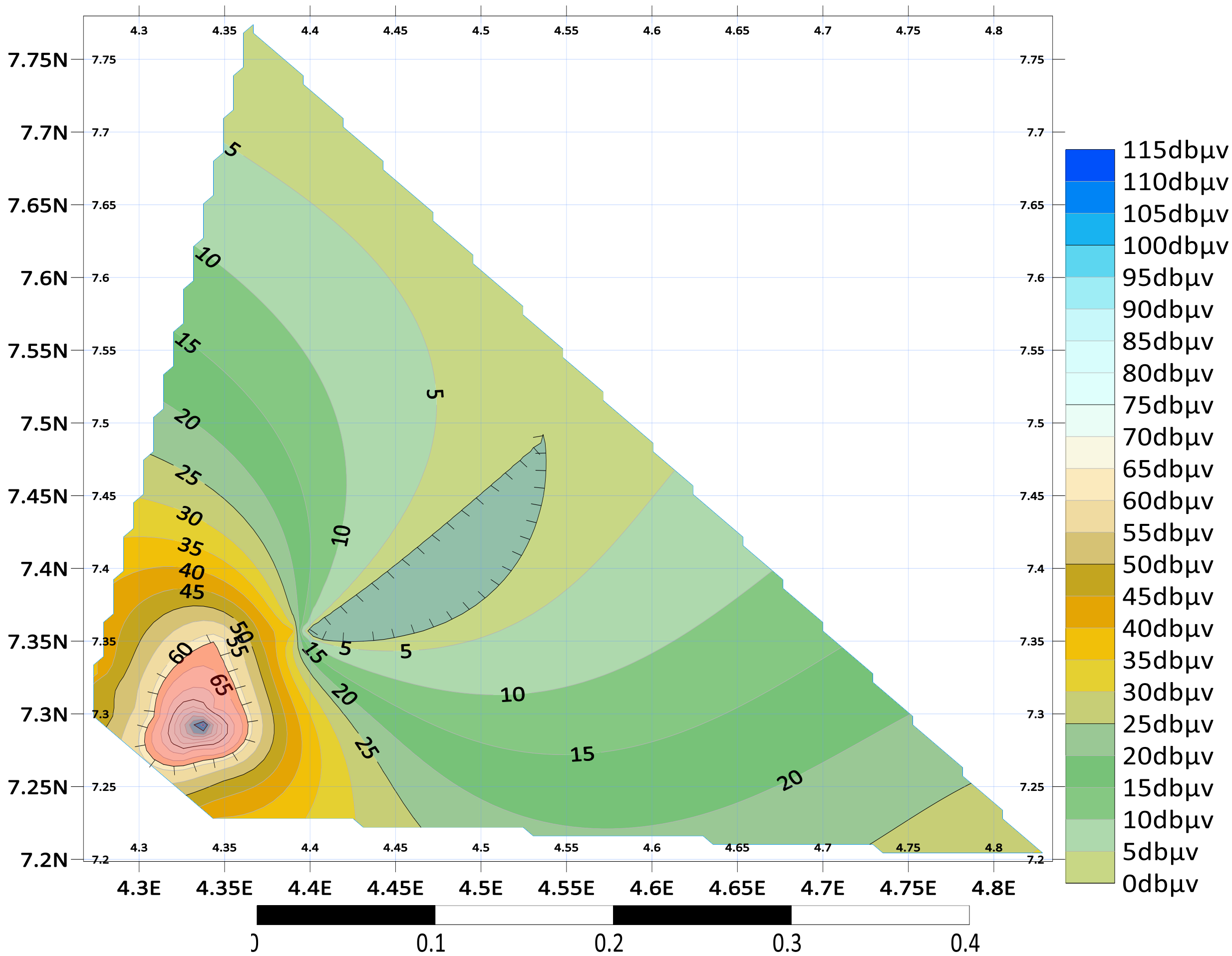

Figure 2 Frequency distribution contour of the study area

Also, the signal dropped drastically at Ita-Osa, Foworiji areas which could have been caused by trees and low-level area. The signal strength at Ajibandele village and Ayekoka along Ondo Road was very poor perhaps low signal, due to the distance the transmitter was able to cover and could be linked to some terrestrial factors on the signal path. The propagation profile of some signals is along Ibadan Road. It was observed that places along Ibadan, Ife and environs do not receive signals from the FM radio station. There are places along Ibadan Road that enjoys Grade A service quality from FM radio station (Orisun 89.5MHZ) simultaneously.

However, a few places enjoy Grade B quality of service from the station. The signal enhancement in these locations can be attributed to the increased impact of space waves as the elevations of these places are more significant than that of the neighboring towns. The propagation profile of some signal along Ilesa, Moro and Edunabon revealed that signals along this route are grade C but occasionally moves to grade B, because of the changes in the troposphere around there and these changes can influence the way in which radio waves propagates from one point to another (Figure 3).

However, the signal strength of Orisun FM (89.5MHZ) Ife, as expected, varied significantly with distance from the transmitting antenna. This is due to the fact that the strength of the electric field of radio signals decreases with increase in distance from the transmitting antenna due to free space loss and attenuation by atmospheric condition. Attenuation due to free space loss is greater in these environments as a result of their respective distance from the transmitting antenna. Moro junction, Osu Ilesa Road, Akinlalu, Ile funfun areas may be shielded from the FM radio signals by the high-lands in the area as observed from the propagation profile.

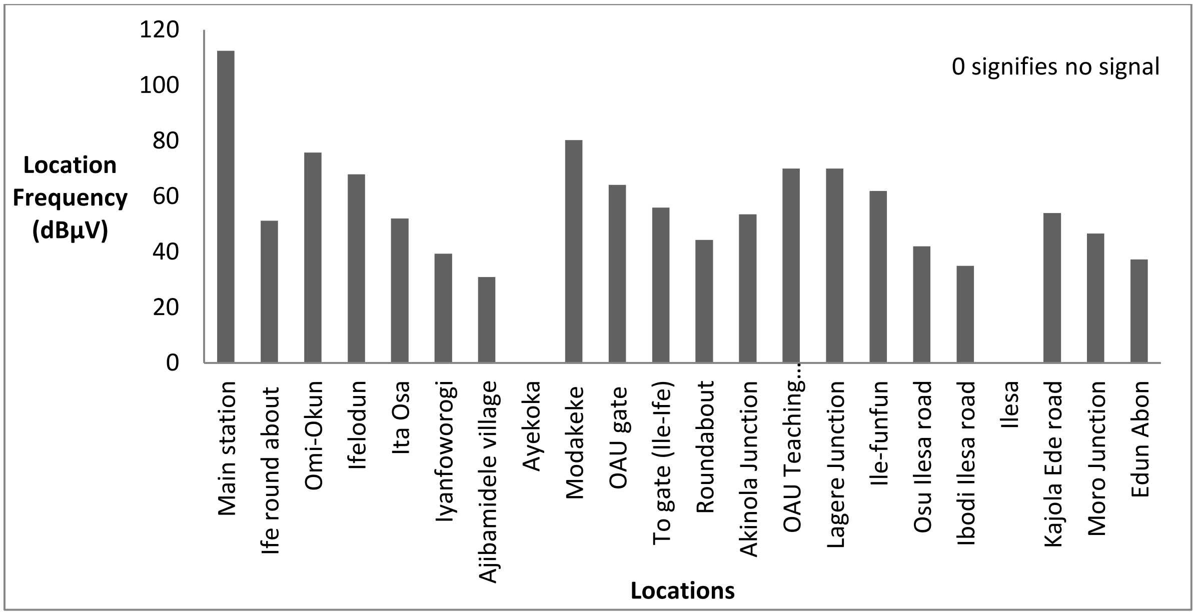

Figure 3 Variations of the frequency obtained from each location of the study area

It is also observed from the propagation profile of some signals along Ibadan Road that there is shrinkage of the coverage area. This can be attributed to the effect of obstacles on the propagation path. The terrain over switch over which signals travel significantly affects the signal. The steepness of the highlands in these areas and the chain of hills in the region combine to shield the signal from the receiver, which is seen in the 3-D map distribution (Figure 4). The generated electromagnetic frequency from and near the antennas and transmitter of Orisun radio does not exceed recommended limits for human exposure from the data acquired likewise the radiofrequency protection and power density were not surpassed in all the accessible areas during this study (ANSI, 1992; NCRP, 1986; IRPA, 1988; ITU-R, 1992). Though at greater power intensities, greater exposure intensities cannot be completely overruled and this study only represents a minor sampling of many likely radio facilities.

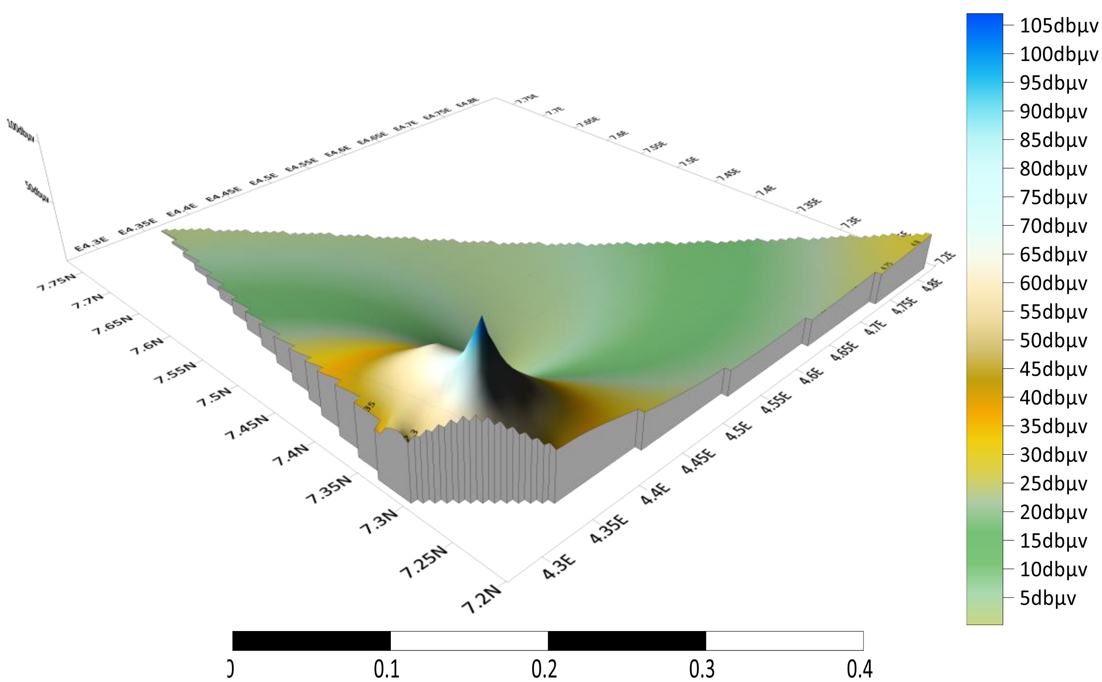

Figure 4 3D map of frequency distribution of study area

4. CONCLUSION

The inverse square rule has been correct in some instances, but there were some exemptions due to high altitudes since the radio signal decreases as a line of sight (distance) increases from the transmitter. The signal is stronger and can travel better during the dry season than other seasons due to the low moisture level in the troposphere. At the source, high transmitter power with high antenna gain and high antenna will ensure signal coverage. At the receiving end, the higher the antenna height and the altitude of the location, the better the reception, and the active antenna will also enhance reception.

The configuration of FM radio transmitters in Ife Osun state does not give optimum coverage in the neighboring town and environs, few towns and villages areas receive grade A quality of service such areas and towns with this coverage area are Omo Okun (75.8dbμv), Ifelodun (68.0dbμv), Modakeke (80.3dbμv), O.A.U main campus (64.1 dbμv), Teaching Hospital O.A.U (70.0 dbμv), Ilefunfun (62.0dbμv) although some areas or towns fall in the range of Grade B, such areas and towns within this coverage area are Osu (42.0dbμv), Ibodi (35.0dbμv), Kajola Akile Ede road (54.0dbμv), Moro Junction (46.6dbμv), Edunabon (37.3dbμv), Ife Roundabout (51.2 dbμv), Ita osa (52.0dbμv), Iyanfaworogi town (39.4dbμv), Bamidele village (31.0dbμv), to gate Ife (56.0dbμv), Ipetumodu (44.3dbμv), Akinola Junction (53.5dbμv), Akinlalu Junction (49.3dbμv), Oduduwa University (51.2dbμv) while Aye koka falls within the Grade C range because the frequency (0 dbμv) is zero indicating no signal.

The signal strength is seriously affected by the elevation pattern of its coverage. The Orisun FM station does not cause interference to other FM radio stations in nearby states so it is in compliance with the regulation of Nigeria Broadcasting Commission (NBC) on harmful from neighboring radio. In view of the political and socio-economic religious importance of radio stations to the populace, management of broadcast stations should ensure optimum signal level within their expected coverage areas, this means that listeners could receive clear signal without the use of active antenna or atmospheric weather conditions. This could be achieved by the height of the mast (antenna) because when the reflected power from the antenna is low, the output of the transmitter becomes more effective.

This could also be achieved by ensuring high transmitter power of the main station. Further studies needed to be done on measuring field strength intensity of FM stations in Osun state to aid their compliance with the Nigerian Broadcasting Commission (NBC) regulation and their hazardous effect on the populace, if any. As a general precaution, measures should be put in place to stop the exposure of workers and the public to RF intensities in excess of the safety recommendations. Measures like application of minimum power required for transmission; reduction in transmission time; erection of antennas at a distant height above the ground level etc. It is also recommended that a further study and research be done to measure and categorize RF field emission from substandard transmitters so as to curb any exposure of the public to unnecessary radiation hazards.

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Author's Contribution

SOS developed the concept, design, analysis and interpretation of the data as well as writing and editing of the manuscript.

Informed Consent

The author has read and approved the manuscript the publication

Ethical approval

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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Data and materials availability

All data associated with this study are present in the paper.

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