Spatial Coverage of FM Radio Transmitters in Niger State, Nigeria

M O Ajewole[1], O D Oyedum[2], A T Adediji[3], J O Eichie[4] and A S Moses[5]

In the VHF band (30 MHz-300 MHz), radio propagation is usually by space waves, which consist of direct wave and ground-reflected wave. These radio signals are affected by the electrical parameters of the ground, curvature of the earth surface, height of the antenna above earth's surface and weather conditions in the troposphere. The electric field strength of radio signals decreases with increase in distance from the transmitting antenna. In this work, measurement of electric field strength of Frequency Modulated (FM) radio signals from Crystal FM, Minna, on 91.2 MHz and Power FM, Bida, on 100.5 MHz in Niger State Nigeria, was carried out in all the 25 Local Government Areas of the state. A Digital Signal Level Meter, GE-5499, covering the signal range of 30-120 dBμV, was used to measure the signals. The longitude, latitude, altitude and also distance from the reference point (i.e., location of the transmitting antenna) were measured at every location using a handheld Global Positioning System (GPS) receiver. The parameters obtained were used to determine the coverage areas of the two FM radio signals studied in Niger State. The results obtained showed that the configuration of FM radio transmitters in Niger State does not give optimum coverage of the State.

Keywords: Radio signal, Electric field strength, Propagation

Introduction

The propagation of radio waves in the Frequency Modulated (FM) band, relies on the Very High Frequency (VHF) band of the electromagnetic spectrum (30 MHz-300 MHz). FM signals use frequencies ranging from 87.5 MHz to 108.0 MHz (Morris and William, 1973) and propagation is usually by space waves which consist of direct wave and ground-reflected wave. These waves are propagated in all directions within the troposphere from the transmitting antenna. Due to free space loss caused by spreading, the strength of the field created by these waves weakens and it is inversely proportional to the square of the distance from the transmitting antenna (Boithias,

[1] Professor, Department of Physics, Federal University of Technology, Akure, Nigeria. E-mail: oludareajewole61@yahoo.com

[2] Professor, Department of Physics, Federal University of Technology, Minna, Nigeria. E-mail: oyedumod@yahoo.com

[3] Senior Lecturer, Department of Physics, Federal University of Technology, Akure, Nigeria. E-mail: kunleadediji2002@yahoo.co.uk

[4] Lecturer, Department of Physics, Federal University of Technology, Minna, Nigeria; and is the corresponding author. E-mail: julichie@yahoo.com

[5] Lecturer, Department of Physics, Federal University of Technology, Minna, Nigeria. E-mail: hisgracemakesit@yahoo.com

1987). Radio signals are affected by the electrical parameters of the ground, curvature of the earth's surface, height of the antenna above the earth's surface and weather conditions in the troposphere (Hall and Barclay, 1991).

In the troposphere, changes in temperature, pressure and humidity, as well as clouds and rain, influence the way in which radio waves propagate from one point to another (Bean and Dutton, 1968). In normal atmospheric condition, temperature decreases with altitude in the troposphere and as a result, warm air near the surface of the earth readily rises, being less dense than the colder air above it. Such vertical movement or convection of air generates clouds and ultimately rain from the moisture within the air, and gives rise to variation in atmospheric refractive index and much of the weather which we experience. Sometimes, the temperature does not decrease with height in the troposphere, but increases. Such a situation is known as temperature inversion (Hall, 1979). Temperature inversion may be caused by evaporation, advection, nighttime ground cooling by radiation, and subsidence of air, causing a good amount of water vapor to be trapped below the inversion layer (Oyedum *et al.*, 2011). Temperature inversion can result to tropospheric ducting, a situation in which radio waves are trapped resulting in the signals following the curvature of the earth and experiencing low-loss propagation over long distance.

Radio signals consist of the electric and magnetic field components. The electric field component is measured in terms of the change of potential over a given distance, such as volts per meter, and this is known as the electric field strength (Morris and William, 1973). This measure is often used in measuring the strength or intensity of radio signals (electromagnetic waves) at points to determine the signal coverage area. The electric field strength of radio signals at VHF and higher frequency bands generally vary in the troposphere due to variations in the ground constants and in the refractivity conditions of the air, which in turn depend on variations in temperature, pressure and water vapor pressure. These variations show climatic, seasonal and diurnal trends (Hall, 1979).

Coverage areas of broadcast stations can be classified into primary, secondary and fringe areas. The size of each of these coverage areas depends on the transmitter power, the directivity of the antenna, the height of antenna above the earth's surface, the ground electrical conductivity and the frequency of propagation. The coverage areas decrease with increase in frequency and reduction in the ground conductivity (Ajayi and Owolabi, 1979).

The primary coverage area is a region about a transmitting station, in which the signal strength is adequate to override ordinary interference in the locality at all times. The region has signal level value of Grade A, with signal level values greater than or equal to 60 dBμV.

The secondary coverage area is a region where the field strength is often sufficient to be useful, but is insufficient to completely overcome interference at all times. This

region has signal level value of Grade B, with signal level values greater than 30 dBμV but less than 60 dBμV.

The Fringe Coverage Area can be regarded as a region in which the signal strength can be useful for some periods, but its service can neither be guaranteed nor protected against interference. This region has signal level value of Grade C, with signal level greater than 0 dBμV but less than or equal to 30 dBμV.

Data Collection

The study was carried out for the two FM radio stations in Niger State (Figure 1), situated in the Middle Belt region of Nigeria. The parameters of the two broadcasting stations considered in this study are shown in Table 1.

Figure 1: Map of Niger State Showing the Local Government Areas, Some Towns, and the Locations of the Two FM Transmitting Stations

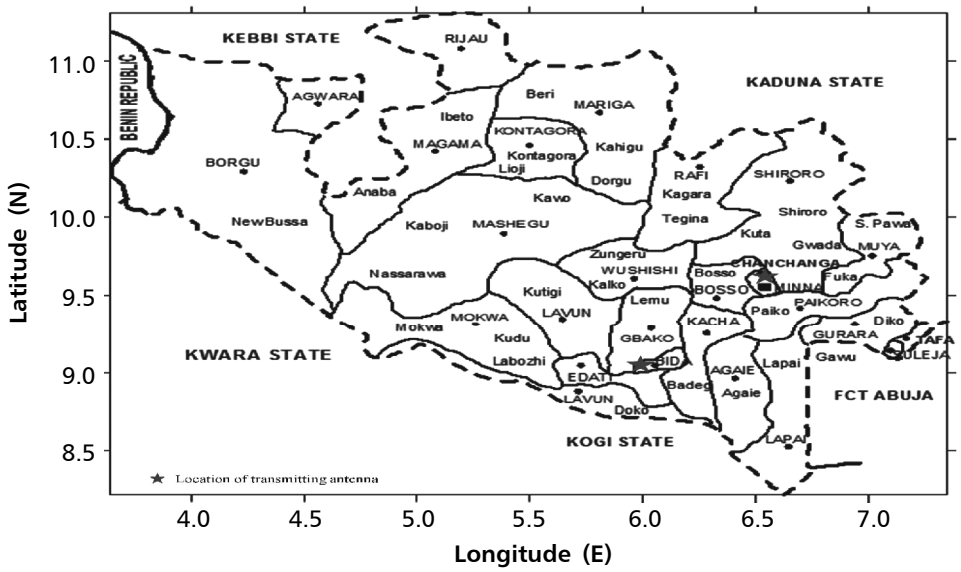
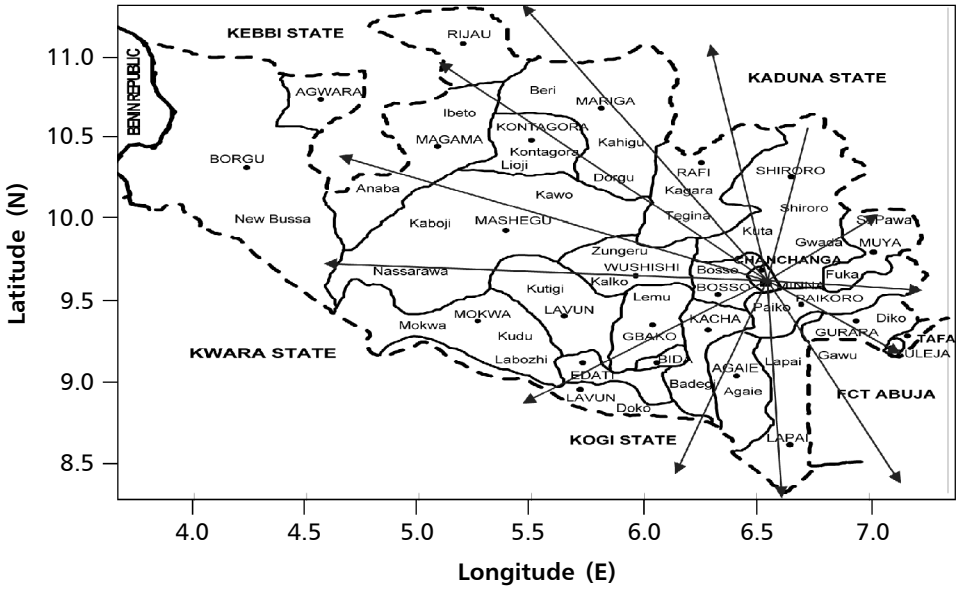


Table 1: Parameters of the Two FM Transmitting Stations in Niger State

Name of Station	Crystal FM	Power FM
Frequency	91.2 MHz	100.5 MHz
Maximum Transmitter Power	35 kW	20 kW
Operating Transmitter Power	18.2 kW	9.12 kW
Antenna Height Above Sea Level	450 m	540 m
Location	Minna	Bida
Geographical Coordinates	9.64° North and 6.59° East	9.09° North and 6.04° East

Electric Field strength of Crystal FM (91.2 MHz), Minna, and Power FM (100.5 MHz), Bida, radio signals were taken using a Digital Signal Level meter covering the range 30-120 dBμV. The measurements were taken at the base of the transmitting antennas, and at major towns and villages in the local government areas of Niger State, as far as accessibility by the major and minor road networks permitted and along radial routes shown in Figures 2 and 3 with the transmitting antenna at focus. The measurements were also taken at neighboring villages in the Federal Capital Territory, Abuja. The longitude, latitude, altitude and distance from the reference point (i.e., location of the transmitting antennas) were also noted at every location using a handheld Global Positioning System (GPS) receiver, GPS-72 (www8.garmin.com/manuals/GPS72_OwnersManual.pdf). The measurements were carried out between 8.30 am and 5.00 pm Local Time (LT) everyday in the month of May 2010, being the onset of wet season in this geographic zone of the country.

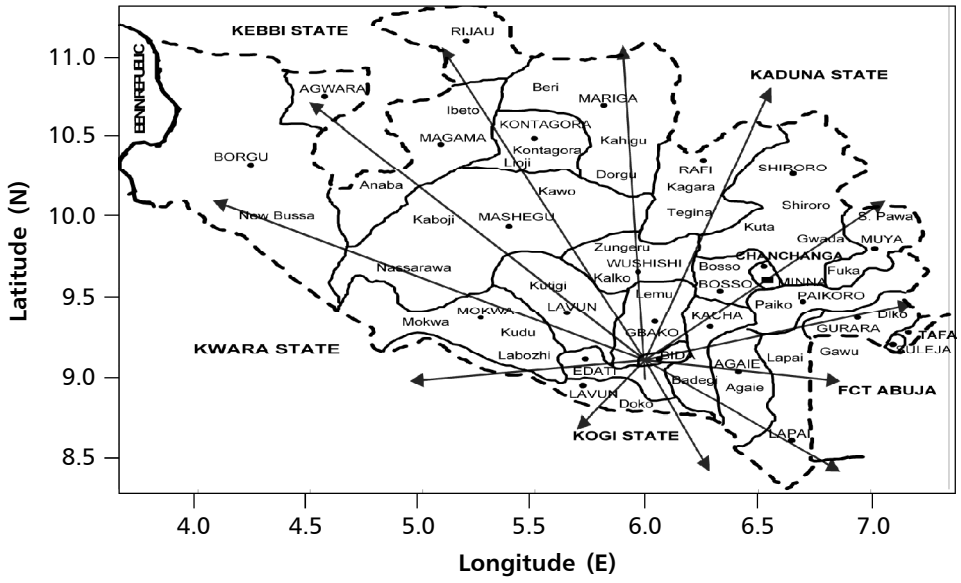
Figure 2: Radial Routes for Crystal FM-91.2 MHz Minna with the Transmitting Antenna in Focus



Results and Discussion

The coordinates of the various locations and the signal level measured at the onset of wet season were used in Surfer8 application software to draw contour maps of coverage areas for Crystal FM (91.2 MHz) and Power FM (100.5 MHz) radio signals. These contour maps were overlaid on the map of Niger State to give a pictorial view of the coverage areas of the two radio stations so as to determine optimum coverage areas for the stations based on the primary coverage area, secondary coverage area and fringe coverage area respectively.

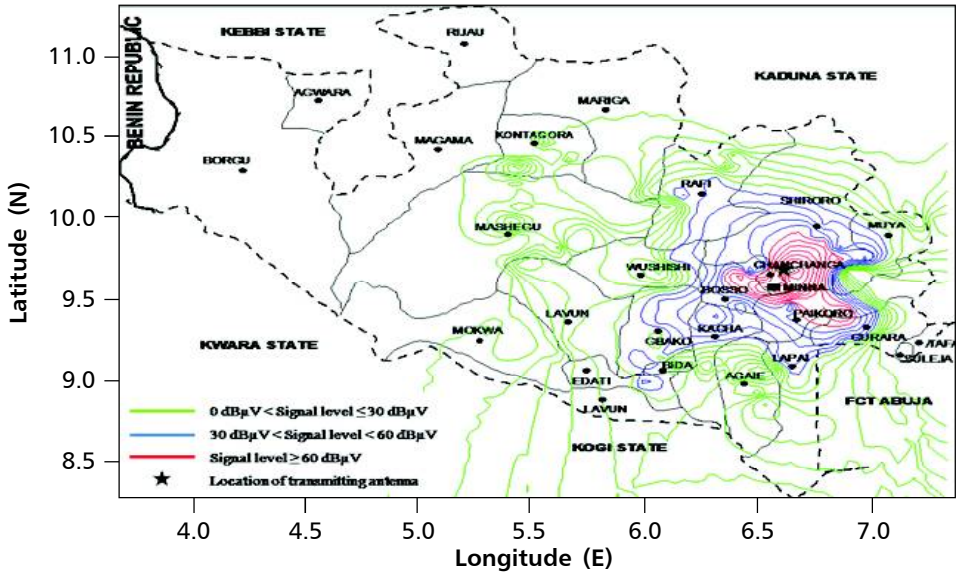
Figure 3: Radial Routes for Power FM-100.5 MHz, Bida with the Transmitting Antenna in Focus



Coverage Areas of Crystal FM (91.2 MHz), Minna, Radio Signals

A contour of the electric field strength of the Crystal FM (91.2 MHz) radio signals at the onset of the wet season, was overlaid on the map of Niger State, as shown

Figure 4: Contours of Coverage Area for Crystal FM (91.2 MHz) in Niger State at the Onset of the Wet Season



in Figure 4, while Table 2 captures the coverage area in terms of primary, secondary and fringe zones.

Table 2: Coverage Areas of Crystal FM (91.2 MHz), Niger State

Type of Coverage	Towns Within Coverage	Name of Local Government Area
Primary	Maitumbi, Minna, Tunga	Chanchanga
	Bosso, Tundun Fulani, Kpakungu	Bosso
	Pago, Farindoki, Tanu	Paikoro
	Gunu, Gwada, Mutundaya	Shiroro
Secondary	Sudigi, Nagenu	Agaie
	Sabondaga, Kampala, Rafinrianshi, Maikunkele, Garatu	Bosso
	Magim, Tuwagi, Emmaru, Lemu	Gbako
	Lufa	Gurara
	Matachibu, Tunga Wawa	Kontagora
	Kataerigi, Maraya, Gadaerigi, Kakakpangi, Badegi	Kutcha
	Kawo, Takalafia, Barshe, Lapai	Lapai
	Gini, Suaka	Muya
	Gabadan, Kwakuti, Tunga Malam, Paiko	Paikoro
	Kagara, Ushiba,Yakila, Makangara	Rafi
	Mutundaya, Kuta, Shiroro, Asha, Zumba, Chiri	Shiroro
	Kalko, Wushishi, Zungeru	Wushishi
Fringe	Rukwagi, Shipo, Jipo, Takagi Alashe	Agaie
	Patinda, Bida	Bida
	Dikko Enagi, Kusodu, Lokosananja	Edati
	Lambata, Izom, Malam Karo	Gurara
	Uzange, Rafingora, Lamba, Mangu, Kontagora	Kontagora
	Badegi, Essa	Kutcha
	Saminaka, Lapai	Lapai
	Batati, Danchitagi, Duguhawa, Jima, Kutigi, Lanle	Lavun
	Kahigu, Kwana Mariga	Mariga
	Kagara, Bakwai Bakwai, Karamai Rami	Mashegu
	Kpaki, Mokwa	Mokwa
	Kuchi, Kwana Mangoro	Muya
	Garun Gabas, Tash Kadi Pandogaei	Rafi
	Tangwagi	Wushishi

The approximate percentages of the Local Government Areas of Niger State that fall within the three service areas at the onset of the wet season are shown in Table 3.

Table 3: Percentage of Each Local Government Area Within Grades A, B and C Service Areas of Crystal FM (91.2 MHz)

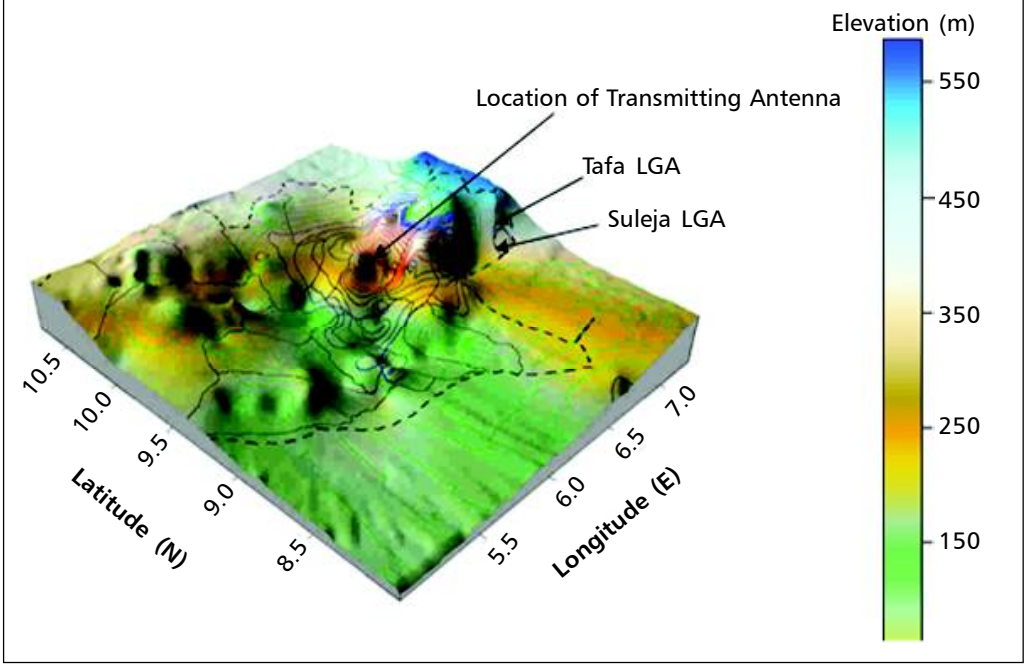
Local Government Area	% of LGA Within Grade A	% of LGA Within Grade B	% of LGA Within Grade C	Total % of LGA Covered
Agaie	0	3	97	**100**
Agwara	0	0	0	**0**
Bida	0	15	85	**100**
Borgu	0	0	0	**0**
Bosso	60	40	0	**100**
Chanchanga	100	0	0	**100**
Edati	0	10	90	**100**
Gbako	0	50	50	**100**
Gurara	5	35	35	**75**
Katcha	0	45	55	**100**
Kontagora	0	0	60	**60**
Lapai	4	16	80	**100**
Lavun	0	0	100	**100**
Magama	0	0	5	**5**
Mariga	0	0	40	**40**
Mashegu	0	0	50	**50**
Mokwa	0	0	40	**40**
Muya	0	25	68	**93**
Paikoro	30	35	20	**85**
Rafi	0	25	65	**90**
Rijau	0	0	0	**0**
Shiroro	20	40	30	**90**
Suleja	0	0	0	**0**
Tafa	0	0	0	**0**
Wushishi	0	20	80	**100**
Total	**24**	**52**	**72**	**80**

The signal strength of Crystal FM (91.2 MHz), Minna as expected, varied significantly with distance from the transmitting antenna. This was because the electric field strength of radio signals decreases with increase in distance from the transmitting antenna due to free space loss and attenuation by atmospheric conditions (Hall, 1979).

Borgu, Agwara, Suleja, Tafa and Rijau Local Government Areas, as shown in Figure 4, are completely out of the coverage areas of Crystal FM (91.2 MHz), Minna. Rijau, Borgu and Agwara Local Government Areas are more than 200 km line of sight distance from the transmitting antenna of Crystal FM (91.2 MHz) in Minna. Attenuation due to free space loss is greater in these local governments as a result of their respective great distance from the transmitting antenna. Suleja and Tafa may be shielded from the FM radio signals by the highlands in the area, as observed from Figure 5, showing overlay of coverage contour map on surface map.

It is also observed from Figure 4 that there is shrinkage of the coverage area towards the eastern part of Minna (that is, south west of Muya Local Government Area and north east of Paikoro Local Government Area). This can be attributed to the effect of obstacles on the propagation path. The terrain over which signals travel has significant effect on the signal. The steepness of the highlands in these areas and also the chain of hills in the region, as shown in Figure 5, combine to shield the signal from the receiver.

Figure 5: Overlay of Coverage Area Map of Crystal FM (91.2 MHz), Minna at the Onset of the Wet Season on Surface Map



Coverage Areas of Power FM (100.5 MHz), Bida Radio Signals

A contour of the electric field strength of the Power FM (100.5 MHz), Bida, radio signals at onset of the wet season was overlaid on the map of Niger State, as shown in Figure 6, while Table 4 gives a summary of the coverage areas in terms of the three service areas.

Figure 6: Contour of Coverage Areas for Power FM (100.5 MHz) in Niger State at the Onset of the Wet Season

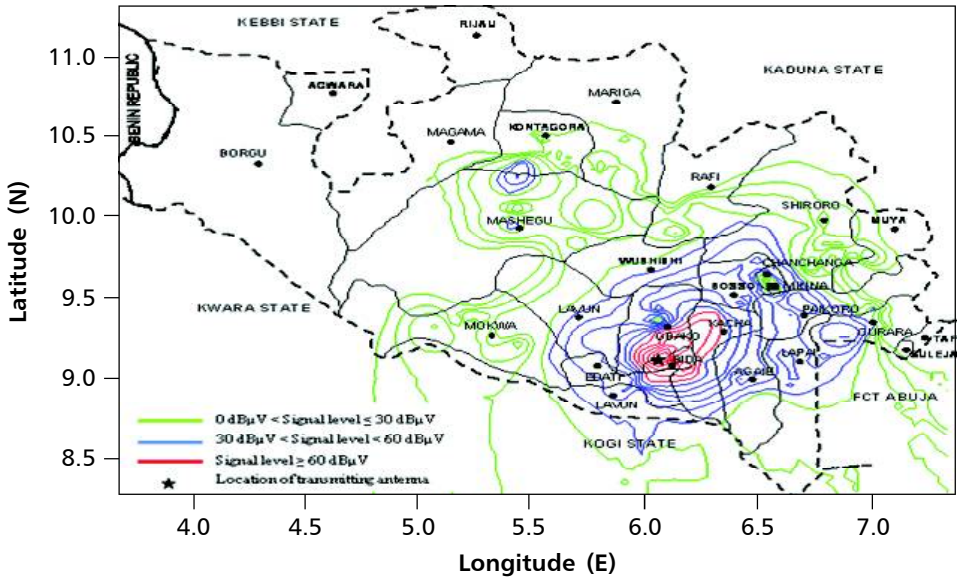


Table 4: Coverage Areas of Power FM (100.5 MHz), Niger State

Type of Coverage	Towns Within Coverage	Name of Local Government Area
Primary	Bida, Patinda	Bida
	Vunchi, Zanchita	Edati
	Tuwagi	Gbako
	Kataerigi, Maraya, Kakakpangi	Kutcha
Secondary	Shipo, Rukwagi, Jipo, Agaie	Agaie
	Garatu, Bosso, Maikunkele, Gussase	Bosso
	Chanchanga, Maitumbi	Chanchanga
	Lokosananja	Edati
	Emmaru, Lemu, Magim	Gbako
	Lambata, Lufa	Gurara

Table 4 (Cont.)

Type of Coverage	Towns Within Coverage	Name of Local Government Area
	Rafingora, Matachibu	Kontagora
	Gadaerigi	Kutcha
	Lapai, Saminaka, Barshe	Lapai
	Ekota, Kutigi, Batati, Wayakanti	Lavun
	Kagara, Babban Rani, Karamai	Mashegu
	Tanu, Pago, Kwakuti, Farindoki	Paikoro
	Yakila, Tasha Kadi	Rafi
	Gwada	Shiroro
	Kalko, Zungeru, Wushishi, Tankwagi	Wushishi
Fringe	Takagi	Agaie
	Chanchanga, Maitumbi	Chanchanga
	Kusodu, Dikko Enagi	Edati
	Magim	Gbako
	Izom, Malam Karo	Gurara
	Tunga Wawa, Baba Lamba, Tudun Fulani	Kontagora
	Kawo	Lapai
	Duguhawa, Maniki	Lavun
	Danauta, Dorgu, Kanpini-Bobi	Mariga
	Kawo, Malamawa, Sabon Rami	Mashegu
	Bokani	Mokwa
	Gini, Suaka	Muya
	Chimbi, Muye	Paikoro
	Kusherki, Ushiba	Rafi
	Gunu, Chiri, Aligali	Shiroro
	Diko, Maje, Suleja	Suleja
	Tafa	Tafa
	Wushishi, Zungeru, Maito	Wushishi

The approximate percentages of the Local Government Areas of Niger State within the three service areas at the onset of the wet season are shown in Table 5.

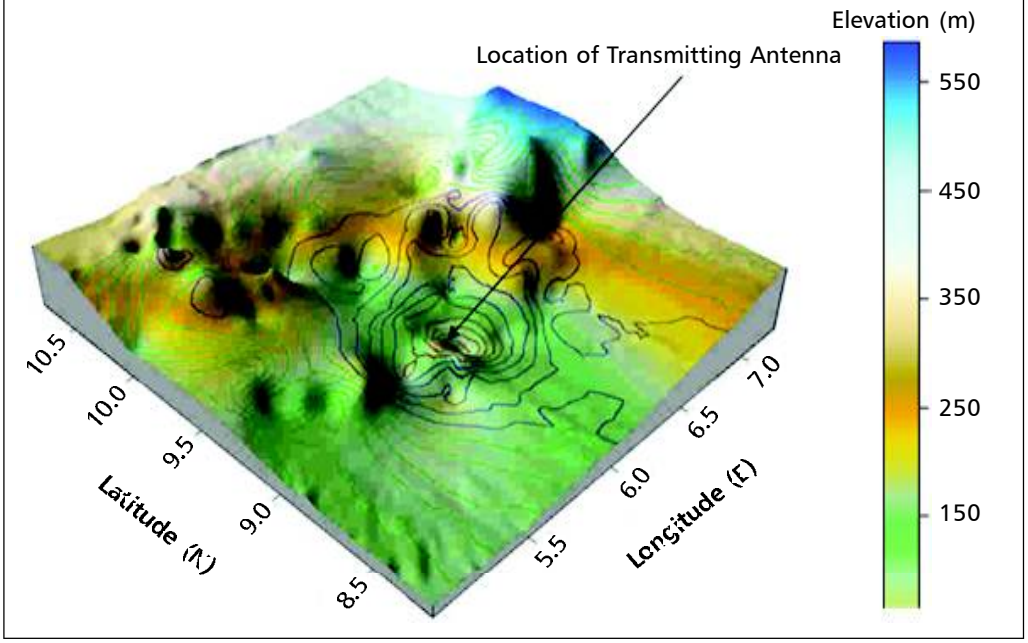
Table 5: Percentage of Each Local Government Area Within Grades A, B and C Service Areas of Power FM (100.5 MHz)				
Local Government Area	**% of LGA Within Grade A**	**% of LGA Within Grade B**	**% of LGA Within Grade C**	**Total % of LGA Covered**
Agaie	0	50	50	**100**
Agwara	0	0	0	**0**
Bida	100	0	0	**100**
Borgu	0	0	0	**0**
Bosso	0	100	0	**100**
Chanchanga	0	20	80	**100**
Edati	10	90	0	**100**
Gbako	40	54	4	**98**
Gurara	0	45	30	**75**
Katcha	40	60	0	**100**
Kontagora	0	5	50	**55**
Lapai	0	10	90	**100**
Lavun	0	50	50	**100**
Magama	0	0	10	**10**
Mariga	0	0	25	**25**
Mashegu	0	4	50	**54**
Mokwa	0	0	80	**80**
Muya	0	0	70	**70**
Paikoro	0	40	30	**70**
Rafi	0	0	50	**50**
Rijau	0	0	0	**0**
Shiroro	0	5	80	**85**
Suleja	0	0	5	**5**
Tafa	0	0	0	**0**
Wushishi	0	10	90	**100**
Total	**16**	**56**	**68**	**84**

Figure 6 reveals that Borgu, Agwara and Rijau Local Government Areas are completely out of the coverage area of Power FM (100.5 MHz), Bida. Borgu and Agwara Local Government Areas were not part of the old Niger State, as explained

earlier. Rijau, Borgu and Agwara Local Government Areas are more than 200 km line of sight distance from the transmitting antenna of the Power FM (100.5 MHz) in Bida. Attenuation due to free space loss and ground effect is greater in these local governments as a result of their respective great distance from the transmitting antenna.

It is also observed from Figure 6 that some villages in Kontagora (Matachibu and Rafingora) and Mashegu (Babann Rami, Kagara and Karamai Rami) Local Government Areas receive Grade B quality of service, while the neighboring towns receive Grade C quality of service. The signal enhancement in these locations can be attributed to increased impact of space wave as the elevations of these towns are greater than that of the neighboring towns, as shown in Figure 7.

Figure 7: Overlay of Contour Map of Power FM (100.5 MHz), Bida at the Onset of the Wet Season on Surface Map

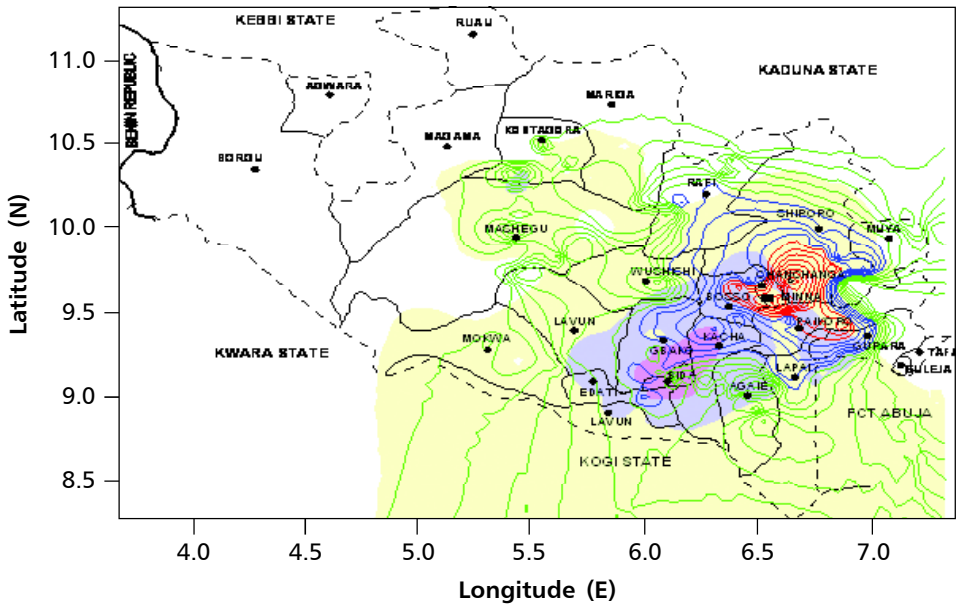


Furthermore, the strength of Power FM (100.5 MHz), Bida, signal received in some busy areas in Minna, the capital city of Niger State, was of Grade C quality of service, while neighboring locations received Grade B quality of service at the onset of wet season. This can be attributed to the fact that urban areas are more prone to multipath interference resulting from diffraction due to closely built-up environment, vehicle and human traffic. In other words, FM receivers in these areas may pick a signal of Grade B quality, but also as a result of several reflections coming from various directions. These reflections arrive at the receiver out-of-phase and tend to blur the original signal, resulting in multipath fading of the radio signal in these locations.

Overlap of Crystal FM (91.2 MHz), Minna and Power FM (100.5 MHz), Bida Coverage Areas

The contour map of Crystal FM (91.2 MHz), Minna was overlaid on that of the Power FM (100.5 MHz), Bida to determine areas of the state that receive signals from the two FM radio stations, as shown in Figure 8.

Figure 8: Coverage Areas of Crystal FM (91.2 MHz), Minna and Power FM (100.5 MHz), Bida at Onset of the Wet Season



It is observed that towns and villages such as New Bussa, Rijau, Sabon Gari, Kali, and Karunji in Borgu, Agwara and Rijau Local Government Areas do not receive signals from either of the FM radio stations in the State. There is no town or village that enjoys Grade A service quality from both FM radio stations simultaneously. However, a few towns and villages enjoy Grade A quality of service from either of the FM stations and Grade B quality of service from the others simultaneously. Some of these towns are Minna, Bosso, Paiko, Bida, Lemu, Chanchanga, Gidan Kwanu, Patinda, and Alashe. Less than 50% of Niger State enjoys service of at least Grade B quality from either of the FM stations.

Conclusion

The configuration of the FM radio transmitters in Niger State does not give optimum coverage in the State. For Power FM, 16% of the Local Government Areas receive Grade A quality of service, 56% receive Grade B quality of service, while 68% receive Grade C quality of service. For Crystal FM, 24% of the Local Government Areas receive

Grade A quality of service, 52% receive Grade B quality of service, while 72% receive Grade C quality of service. And 12% of the Local Government Areas (i.e., Borgu, Rijau and Agwara) are completely out of the coverage areas of Niger State FM radio signals, 48% of the Local Government Areas receive Grade B quality of service from both Power FM and Crystal FM, while 52% of the Local Government Areas receive Grade C quality of service from both Power FM and Crystal FM. For optimum coverage, there is need for relay stations for both Crystal FM (91.2 MHz) and Power FM (100.5 MHz) in Kontagora and Borgu Local Government Areas of Niger State. The FM radio stations in Niger State are, however, not sources of interference to FM radio stations in neighboring states. Hence, they are in compliance with the regulations of Nigeria Broadcasting Commissions (NBC) on harmful interference from neighboring radio and television stations.

References

1. Ajayi G O and Owolabi I E (1979), "Coverage Area of the 10 kw, 702 kHz Medium Wave Transmitter at Minna and Feasibility Studies for Full Radio Coverage of Niger State", pp. 1-8, Electrical Communication Consultancy Unit (ECCU), Department of Electrical and Electronics Engineering, University of Ife, Nigeria.
2. Bean B R and Dutton E J (1968), *Radio Meteorology,* pp. 1-22, Dover Publications Inc., New York.
3. Boithias L (1987), *Radio Wave Propagation*, pp. 20-43, Translated by David Beeson, McGraw-Hill, New York.
4. Hall M P M (1979), *Effects of the Troposphere on Radio Communication*, pp. 160-161, Peter Peregrinus Ltd., London, United Kingdom.
5. Hall M P M and Barclay L W (1991), *Radio Wave Propagation,* pp. 23-60, Peter Peregrinus Ltd., London, United Kingdom.
6. Morris S and William O (1973), *Essentials of Communication Electronics*, pp. 2-4, McGraw-Hill.
7. Oyedum O D, Ibrahim S O, Eichie J O, Igwe K C and Moses A S (2011), "Seasonal Variation of Coastal Refractivity Gradients in a Tropical Environment", *International Journal of Scientific Research*, Vol. 1, No. 1, pp. 43-54.
8. www8.garmin.com/manuals/GPS72_OwnersManual.pdf

Reference # 70J-2012-11-01-01