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Estimation of the effects of Secondary Radioclimatic Variables on signal propagation in Bauchi metropolis, Nigeria

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Abstract: *This research paper estimates the effects of secondary Radioclimatic variables on signal propagation in Bauchi, Nigeria. Radio Refractivity, refractive index, k-Factor (effective Earth's radius), Geoclimatic factor and Saturated vapour pressure are important radioclimatic parameters that influence radio wave propagation. The impact of these variables depends on the variation of the measured data of the primary radioclimatic parameters (temperature, relative humidity and atmospheric pressure). The data obtained from Bauchi airport based automatic weather station located between latitudes $9^0 3'$ and $12^0 3'$ north of the equator. The primary Radioclimatic data used in this study includes temperature, Relative humidity and atmospheric pressure while the Secondary radioclimatic variables includes k-Factor(K), Geoclimatic factor (K_G), Refractivity (N), refractive index (n) and Saturated vapour pressure (e). The estimated values of K-factor referred to as effective earth radius is less than the global value of (1.333). The closest value obtained was 1.2582 for the year (2020), these values are of indication that Super-refraction effects are possible in the study area and this may lead to possible interference of wireless communication signals. Hence all networks that rely on radio frequency will have distortion of communication within the study area.*

Keywords: Radioclimatic variables, Geoclimatic factor, K-factor,

I. INTRODUCTION

The atmosphere is mainly characterized by temperature, pressure, humidity and vapour pressure. These parameters affect the propagation of electromagnetic waves in the lower parts of the atmosphere (Troposphere). To quantify this effect, an index named radio refractive index (n) is used [1]. Thus the knowledge of the index, n, is very important to the design of the communication links

Many communication systems rely on Radio Frequency (RF) propagation through the atmosphere. Thus modeling atmospheric effects on RF propagation is an important element of system design and performance prediction. For the purpose of propagation modeling, the atmosphere can be divided into three regions: troposphere, stratosphere, and tropopause. The troposphere is the lowest region of the atmosphere where temperature tends to decrease with height and where weather occurs [1]

Since the late 1950's Microwaves Radio Frequencies have become the dominant form of communication for TV's, Cell Phones, Weather Stations, and a host of others. Each of these communication companies having millions of subscribers, satellite transmitters and Earth antennas, transmit Ultra high frequency (UHF) and higher microwave frequencies all over the planet [2].

It has been established that a good knowledge of secondary radioclimatic variables especially the surface refractivity as well as the diurnal and seasonal variability amongst other factors, are useful tools in planning terrestrial radio links mainly because of multi-path fading and interference effects. Tropospheric surface refractivity poses a major setback to the phenomenon of communication globally. Research carried out by [3] indicates that the interaction between some tropospheric factors and radio frequencies > 30 Mhz, exposes the signals to important propagation characteristics which often degrades communication links especially at higher frequencies.

Bauchi is located between latitudes 9° 3' to 12° 3' north and longitudes 8° 50' to 11° east Nigeria. The period of investigation spans across the two major seasons (wet and dry) in Bauchi, Nigeria. This research aims to investigate the effects of Radioclimatic variables on signals propagation in Bauchi, with a view to provide adequate information about the effects of secondary radioclimatic variables on communication signals in order to improve radio communication on their reception in the study area.

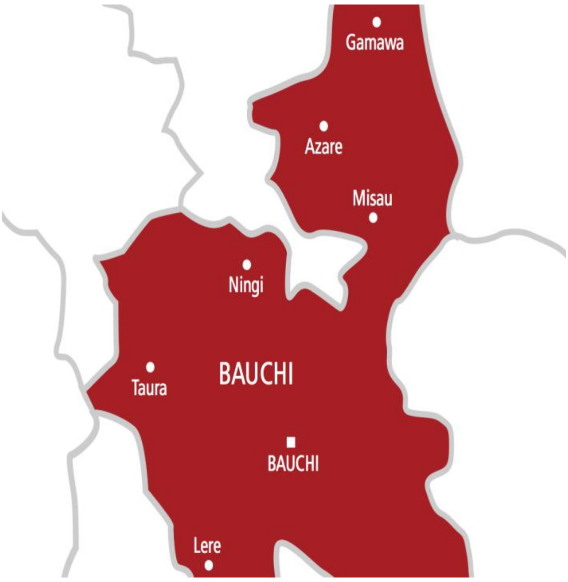

Figure 1: Geographical Location of Bauchi, in Bauchi State, Nigeria

II. THEORY

A recent effort by the international community to update the radioclimatological data base for tropospheric propagation predictions has led to an increase in the number of meteorological stations, the introduction of new potential prediction variables and improved mapping and other presentation procedures [4]. This research therefore focuses on the estimation of secondary radioclimatic variables on radio signals propagation of Bauchi metropolis.

[5]. Stated that over the years, wireless communication networks have grown to become the dominant communication technology across the globe. In the design and planning of wireless communication networks, the vertical profile of some radioclimatic parameters is required. Among such parameters is the radio refractive index, radio refractivity and vapour pressure among others at the lower part of the atmosphere (troposphere).

The electromagnetic waves that are propagated in the lower atmosphere are mainly influenced by the different components which affect atmospheric temperature, atmospheric pressure and relative humidity [6].

Radio signal propagation in the lower atmosphere is affected by primary and secondary weather parameters. The primary weather parameters include; atmospheric pressure, temperature and water vapour. The variation of these parameters are associated with change in weather condition at different seasons of the year and these changes result in the variations of secondary weather parameters; radio refractivity, refractive index, Geoclimatic factor, vapour pressure and k-factor [7].

III. ATMOSPHERIC REFRACTION

Refraction and scattering effects of the atmosphere include:

- ✓ Refraction on horizontal paths resulting in alteration of the radio horizon due to ray curvature.
- ✓ *Troposcatter*, from localized fluctuations in the atmospheric refractive
- ✓ *Temperature inversion*, abrupt changes in the refractive index with height causing reflection.
- ✓ *Ducting*, where the refractive index is such that electromagnetic waves tend to follow the curvature of the earth.

These effects vary widely with altitude, geographic location, and weather conditions. The effects can permit beyond-the-horizon communication, or produce blockage and diffraction from terrain that appears to be below the line of sight and multipath fading.

IV. THE RADIO HORIZON

Gradual changes in the refractive index with height cause electromagnetic (EM) waves to bend in the atmosphere. If the atmosphere were homogeneous, the waves (rays) would travel in a straight line and the physical and RF horizons would coincide. The rate of change of the refractive index with height can be approximated as being constant in the first kilometer above sea level [8].This rate of change increases the apparent distance to the horizon, by bending the nearly horizontal rays downward. This is illustrated in Figure 2, where a horizontal ray is bent downward and sees a radio horizon that is beyond the straight line-of-sight (LOS) horizon. Antenna height is h

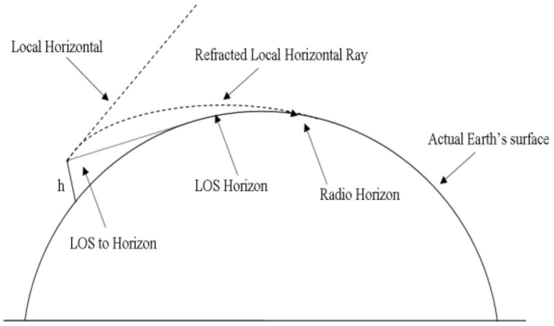

Figure 2: Effect of atmospheric refraction on the distance to the horizon

By replacing the model of the earth's surface with one that has a radius of 4/3 of the earth's radius (for a standard reference atmosphere), the curved ray becomes straight. This is shown in Figure 3.0 where the horizon appears at the point where a straight ray emanating from the source intersects the 4/3 *Re* spherical surface. The 4/3 earth radius approximation is derived based on a standard atmosphere at sea level and is therefore not universally applicable.

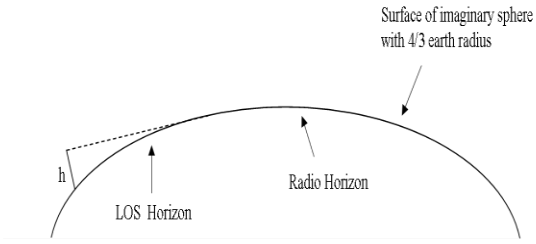

Figure 3: Equivalent radio horizon with 4/3 earth radius model

Nonetheless, it is very widely used and often treated as if it were universal. It is interesting to note that the ray that reaches the radio horizon is not the same ray that is directed at the LOS horizon, it leaves the source at a slightly greater elevation angle. In the case of very narrow beam width antennas, it is possible that the departure angle of the radio horizon ray is outside of the beam width of the antenna. If this occurs, then the effect of the refraction can be a reduction in communication distance rather than an increase since the ray leaving the source at the center of the antenna beam width will be bent toward the ground and the peak of the transmitted signal will not be directed at the intended receiver.

The energy that reaches the receiver will be a combination of off-axis radiation from the antenna and any diffraction from intervening terrain that blocks the bore-sight radiation. For this reason, it is important to verify antenna aiming at different times over a period of days [1]. If aiming is only done once and happens to be done during a period of significant refraction, then under nominal conditions the link margin will be below the design level, reducing the link margin and availability.

V. LAYERS OF THE ATMOSPHERE

The Earth's atmosphere is broadly divided into five different layers which includes: Troposphere (0 – 10 km), stratosphere, (10 km to 30 km), mesosphere (30 km to 50 km), Thermosphere (50 km to 400 km), and the magnetosphere or exosphere, 400 km to 900 km [1]. However, for the purpose of this research, the activities within the troposphere was investigated.

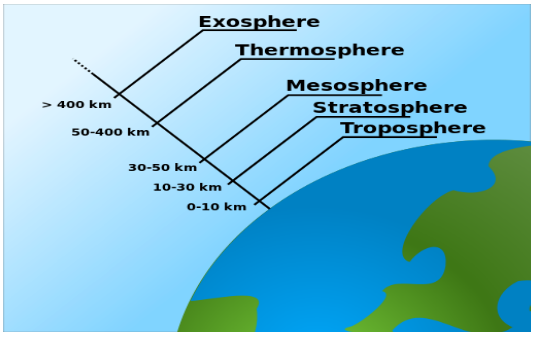

Figure 4: Display of the position of the troposphere

VI. AIR PRESSURE AND ALTITUDE

Air is all around us, but we cannot see it gravity from the Earth pulls air down - this is called air pressure. We don't feel this pressure because our bodies push an equal amount of pressure outward[9].The graph below shows how air density and air pressure changes with altitude (the distance above sea level). The variation of air density and air pressure with altitude is shown in figure 5 below.

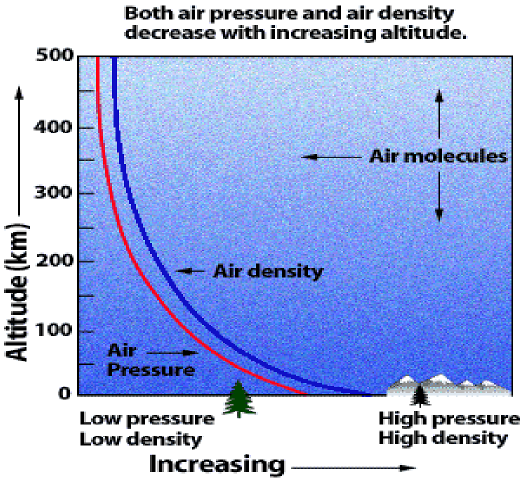

Figure 5: Display of the variation of air pressure and air density

VII. RADIOCLIMATIC

Radioclimatic had been derived from Radio and climate. The meaning of the acronyms RADIO stands for Remote Audio Discrete Integrated Oscillations; Radio is a way of sending electromagnetic signals over a long distance, to deliver information from one place to another. A machine that sends radio signals is called a transmitter, while a machine that "picks up" the signals is called a receiver or antenna [10].

VIII. CLIMATE

Climate is the average weather in a given area over a long period of time or climate simply means the usual condition of the temperature, humidity, atmospheric pressure, wind, rainfall, and other meteorological elements in an area of the Earth's surface for a long time, [11].

Hence, Radioclimatic signify the role of climate in propagation and transmission of radio signals. Due to the variation in the climatic condition of a given place over a period of time, tends to attenuate the intensity of the shortwave electromagnetic spectra known as radiowave.

IX. ATMOSPHERIC REFRACTION

Atmospheric refraction is simply the deviation of light or other electromagnetic waves from a straight line as it travel through the atmosphere as a result of the variation of air density with altitude [12]. Typical consequences of atmospheric refraction are commonly observed as mirage [12]. In general, the magnitude of atmospheric refraction depends on temperature, relative humidity, and pressure [8].The consequence of atmospheric refraction can be more damaging especially under the conditions of inhomogeneous atmosphere e.g. when there is turbulence in the air [12]. It has been established that such condition is mostly the cause of twinkling of the stars and deformation of the shape of the sun at sunset and at sunrise [13].

X. REFRACTIVE INDEX OF THE TROPOSPHERE

The refractive index (n) is defined as:

$$n = (\varepsilon\mu)^{0.5} = \sqrt{\varepsilon_r} = \frac{C}{\upsilon_p} \qquad (1)$$

Where ε_r is the dielectric constant of the troposphere, C is the speed of light, υ_p is the phase velocity of the wave in the medium, ε is the permitivity, and μ is the relative permeability of the medium. The difference between the value of refractive index in the troposphere (n≈1.00003), and in free space (n=1.0) is not much and hence the variation is more conveniently defined by a new parameter called "refractivity, N", according to [8].

$$N = (n-1) \times 10^6 \qquad (2)$$

Equation (2) is the excess over unity of refractive index expressed in millionths, hence at the surface where n=1.000314, the value of N is 314 N-unit [8]. [14] noted that the "radio refractivity N, is a measure of deviation of refractive index (n) of air from unity which is scaled-up in parts per million to obtain more amenable figures.

XI. THE FORMULA FOR RADIO REFRACTIVITY INDEX (N)

The atmospheric radio refractive index, n, can be computed by the following formula:

$$n = 1 + N \times 10^{-6} \qquad (3)$$

where the radio refractivity, N, is:

$$N = N_{dry} + N_{wet} \quad \text{(N-units)} \qquad (4)$$

where the dry and wet term of radio refractivity is as follows:

$$\left.\begin{aligned} N_{dry} &= 77.6\frac{P_d}{T} \\ \mathrm{N_{wet}} &= 72\frac{\mathrm{e}}{\mathrm{T}} + 3.732 \times 10^5 \frac{e}{T^2} \end{aligned}\right\} \qquad (5)$$

Substituting equation (5) in (4) ⇒

$$N = 77.6\frac{P_d}{T} + 72\frac{e}{T} + 3.732 \times 10^5 \frac{e}{T^2} \qquad (6)$$

Since

$P_d = p - e$, equation (4) can rewritten as:

$$N = 77.6\frac{P}{T} - 5.6\frac{e}{T} + 3.732 \times 10^5 \frac{e}{T^2} \qquad (7)$$

where:

P_d = dry atmospheric pressure (mb)
P = total atmospheric pressure (mb) = P_d + e
e = water vapour pressure (mb)
T = absolute temperature in Kelvin (K)

Equation (7) may be approximated with reduced accuracy as:

$$N = \frac{77.6}{T}\left(P + 4810\frac{e}{T}\right) \quad [15] \qquad (8)$$

Equation (8) yields values of N within 0.02 percent of the value obtained from equation (7).

XII.WATER VAPOUR PRESSURE

The vapour pressure of water (e) is the pressure at which water vapour is in thermodynamic equilibrium with its condensed state [16]. At higher pressures water would condense and the water vapour pressure is the partial pressure of water vapour in any gas mixture in equilibrium with solid or liquid water [16].

The relationship between water vapour pressure (e), saturated vapour pressure (e_s) and relative humidity (H) is given by [15] as follows:

$$e = \frac{He_s}{100} \qquad (9a)$$

with

$$e_s = ae^{(\frac{bt}{t+c})}$$

(9b)

where:

e= water vapour pressure in (mb)

H= relative humidity in percentage (%)

t= Celsius temperature Celsius (^{0}C)

e_s=saturated vapour pressure in (mb) at t (^{0}C) and the coefficients a, b and c are constants given below:

Water	Ice
a=6.1121	a=6.1115
b=17.5020	b = 22.4500
c=240.9700	c=272.5500

Valid between -20^{0}C to +50^{0}C, with an accuracy of ±0.20% (Water)

Valid between –50° to 0°C with an accuracy of ±0.20% (Ice)

Thus,

$$\square e_s = 6.1121 Exp(\frac{17.502T}{T+240.97}) \qquad [17]$$

(10)

XIII. THE K-FACTOR

The k-factor also known as effective Earth's radius is the radius of a hypothetical spherical Earth without sphere for which propagation paths follow straight lines, the heights and ground distances being the same as for the actual Earth in an atmosphere with a constant vertical gradient of refractivity [18].

The k-factor can be derived from the vertical refractivity gradient, ΔN, in the first kilometer above the ground. It is obtained from two refractive values, N_2, refractivity at maximum temperature (T_{max}), and N_1, refractivity at minimum temperature (T_{min}). Since data at exact heights are not available, the following equation will be used according to [19]:

$$\Delta N = \frac{N_2 - N_1}{h_2 - h_1}$$

(11)

where h_1 is the point nearest to 1 km height and ΔN is calculated only if 900m < h_1< 1100m [15], and

N_2 = Radio refractivity at maximum temperature (T_{max}),

N_1 = Radio refractivity at minimum temperature (T_{min}),

h_2 = Bauchi altitude = 616m (NiMet) and

h_1 = 450m (900m < h_1< 1100m)

The k-factor can be calculated from the following formula according to [20]

$$K = \frac{1}{\left(1+a\left({}^{dn}/_{dh}\right)\right)} \quad \text{or} \quad K = \frac{1}{(1+0.006371\mathit{\Delta N})} \quad \text{or}$$
$$K = \frac{157}{(157-\mathit{\Delta N})}$$

(12)

Where a is the actual Earth's radius (a=6371km), and dn/dh is the rate of change of refractive index with height h.

$$\Rightarrow \frac{dn}{dh} = \frac{dN}{dh} \times 10^{-6} \quad \text{(From eq. 2)}$$

(13)

Alternatively, k-factor may also be calculated using ΔN as follows [17].

$$k = \frac{157}{157-\Delta N} \text{ or } K = \frac{1}{(1+0.006371\Delta N)}$$

(14)

Although, a typical design value of 4/3 is often assigned for k-factor in the line of sight link design, especially where information about the actual value of k-factor for that location is not available ITU-R (P.452-12).

However, recent study revealed that k-factor is location dependent and should not be assumed constant in any location under study [21].

XIV. GEOCLIMATIC FACTOR

Geoclimatic factor is another important secondary radioclimatic variables that affect electromagnetic signals. Geoclimatic factor (k_G) is a measure of climatic and geophysical condition of a terrain and is given as [22].

$$K_G = 10^{-4.2-0.0029\times({}^{dN_{Pt}}/_{dh})}$$

(18)

where dN_{pt}/dh is the point refractivity gradient in the lowest 65m of the atmosphere not exceeded for 1% of the average year [15].

$$\frac{dN_{Pt}}{dh}(2016, \ldots, 2020) = \frac{N_{av}(T_{max}) - N_{av}(T_{min})}{h_2 - h_1}$$

Where

N_{av} (T_{max})= average Radio refractivity at maximum temperature,

N_{av} (T_{min})= average Radio refractivity at minimum temperature and

h_2 will be = 0m, h_1=65m, since (60 m < h_1< 70 m) according to [15].

XV. RESEARCH METHODOLOGY

The materials used are the primary Radioclimatic data of Temperature, Pressure and relative humidity were collected at Bauchi state airport based automatic weather station for the period of five years (Jan. 2016 – Dec. 2020). The secondary radioclimatic parameters were determined as follows:

1) Refractive index (n) were determine using equation (3).
2) Radio refractivity (N) were determine using equation (8).
3) water vapour pressure (e) were determine using equation (9a)
4) K – factor (k) were determine using equation (12) and
5) Geoclimatic factor (K_G) were determine using equation (18).

VI. RESULTS AND DISCUSSION

The primary radioclimatic variables were obtained from Bauchi state airport automatic weather station (BAAWS) and Nigerian Meteorological (NiMet) Agency. The average values of the primary radioclimatic variables and the estimated values of the secondary radioclimatic parameters (refractive index, Refractivity, water vapour pressure, k-Factor, and Geoclimatic factor) were obtained. Finally, the data were analyzed using the software XLSTAT Pro. 6.1 The results are tabulated as follows:

Table 1 – 12 contains the average of the primary radioclimatic variables and the secondary radioclimatic variables for the period of the study.

Table 1: Shows the values of vapour pressure (e) and average Radio refractivity (N) for the year 2016

Months	e(mb)	N_{av}
January	3.2814	278.9089
February	3.9776	286.2709
March	15.053	318.3605
April	22.591	347.6320
May	23.902	351.6941
June	10.463	299.6115
July	24.120	358.4352
August	23.862	362.5020
September	23.708	356.4389
October	22.703	351.3046
November	8.4809	297.7945
December	8.5558	297.1976

Table 2: Shows the values K – Factor, Bauchi altitude in km and Refractive index for the year 2016

Months	K	Altitude	n_{av}
January	1.459354	0.051	1.000279
February	1.659735	0.102	1.000286
March	1.928754	0.153	1.000318
April	1.592567	0.204	1.000348
May	3.012415	0.255	1.000352
June	2.466089	0.306	1.000299
July	-7.25722	0.357	1.000358
August	-1.14259	0.408	1.000363
September	0.067644	0.459	1.000356
October	0.349019	0.510	1.000351
November	0.479621	0.561	1.000298
December	0.560260	0.612	1.000297

Table 3: Shows the values of vapour pressure (e) and Average Radio refractivity (N) for the year 2017

Months	e(mb)	N_{av}
January	3.71697	277.9973
February	2.92016	270.9888
March	4.9909	276.6996
April	16.0429	313.3093
May	20.3688	339.2744
June	19.9958	334.0277
July	24.1204	354.063
August	24.7574	358.1491
September	23.2455	351.4232
October	23.7637	350.0755
November	8.0761	290.733
December	9.68262	300.4386

Table 4: shows the values of K – Factor and Refractive index for the year 2017

K	n (T_{max})	n (T_{mix})	n (T_{av})
1.1747	1.000273	1.000283	1.000278
1.2189	1.000266	1.000276	1.000271
1.2637	1.000272	1.000282	1.000277
1.3621	1.000308	1.000318	1.000313
1.1568	1.000337	1.000341	1.000339
1.5557	1.000330	1.000338	1.000334
2.2531	1.000350	1.000358	1.000354
-1.6776	1.000353	1.000363	1.000358
0.1214	1.000346	1.000357	1.000351
0.4813	1.000345	1.000355	1.000350

0.6862	1.000287	1.000295	1.000291
0.7501	1.000296	1.000305	1.000300

Table 5: shows the values of vapour pressure (e) and average Radio refractivity (N) for the year 2018

Months	e(mb)	N_{av}
January	4.623752	280.5217
February	5.870838	274.8377
March	8.561639	287.1608
April	4.993901	273.3036
May	21.09717	331.3107
June	21.03717	337.1924
July	16.62693	331.0069
August	30.56842	377.7176
September	24.22781	362.2754
October	20.08782	334.9909
November	5.480638	279.8805
December	5.934006	287.4563

Table 6: shows the values of K – Factor and Refractive index for the year 2018

K	$n (T_{av})$
1.1456	1.000281
1.2002	1.000275
1.1693	1.000287
1.2078	1.000273
1.5273	1.000331
1.4955	1.000337
1.5754	1.000331
-1.6570	1.000378
0.1863	1.000362
0.5173	1.000335
0.7151	1.000280
0.7898	1.000287

Table 7: shows the values of vapour pressure (e) and average Radio refractivity (N) for the year 2019

Months	e(mb)	N_{av}
January	05.2859	285.0337
February	04.7762	281.7656
March	05.8953	278.9265
April	19.4244	327.9404
May	19.6655	329.4768
June	22.4323	349.2059
July	24.4340	369.5199
August	24.4701	362.6446
September	24.5908	364.6941
October	25.0382	362.9316
November	12.6182	307.3853
December	06.4924	287.1729

Table 8: shows the values of K – Factor, and Refractive index for the year 2019

K	n_{av}
01.1510	1.000285
01.1599	1.000282
01.1593	1.000279
01.2534	1.000328
01.3089	1.000329
01.3440	1.000349
01.1227	1.000370
-19.2190	1.000363
00.1678	1.000365
00.5495	1.000363
00.7122	1.000307
00.7773	1.000287

Table 9: shows the values of vapour pressure (e) and average Radio refractivity (N_{av}) for the year 2020

Months	e(mb)	N_{av}
January	08.8000	297.3494
February	07.3772	290.8211
March	05.1675	274.3489
April	22.4222	343.2801
May	23.4834	346.3005
June	21.8541	343.1693
July	25.9383	368.4502
August	24.0128	365.7752
September	23.8176	358.6612
October	23.3107	354.0943
November	10.2506	302.2830
December	07.8926	289.6099

Table 10: shows the values K – Factor (k) and Refractive index (n) for the year 2020

K	$n (T_{max})$	$n (T_{mix})$	$n (T_{av})$
1.1649	1.000293	1.000302	1.000297
1.1984	1.000286	1.000295	1.000291
1.1964	1.000271	1.000278	1.000274

1.2503	1.000339	1.000347	1.000343
1.3434	1.000342	1.000350	1.000346
1.5954	1.000339	1.000347	1.000343
1.6126	1.000366	1.000371	1.000368
3.4995	1.000363	1.000368	1.000366
0.1713	1.000355	1.000362	1.000359
0.5853	1.000351	1.000357	1.000354
0.7181	1.000299	1.000306	1.000302
0.7625	1.000286	1.000294	1.000290

Table 11: shows the values of Geoclimatic factor for five years (2016 – 2020)

Years	Geoclimatic factor, K_G
2016	0.000472
2017	0.000170
2018	0.000150
2019	0.000133
2020	0.000143

Table 12: shows the average values of k-factor (k) for five years (2016 – 2020)

Years	k	ITU Value
2016	0.4313	
2017	0.8622	
2018	0.8227	1.333
2019	-0.7094	
2020	1.2582	

XVII. DISCUSSION

The yearly data of the primary radioclimatic variables for the period of five years (2016 –2020) for the Bauchi metropolis was carried out from the monthly data values collected and the result are tabulated in tables 1 – 12.

Table 11 also shows that the values of Geoclimatic factor increases with increase point refractivity gradient the year 2019 has the lowest value of 0.000133 which is an indication that the point refractivity gradient has less negative value than the other years (2017 – 2018 and 2020) of the study

Table 12 shows the obtained values of k – factor which is referred to as the effective earth radius. The results shows that the obtained value is less than the global value (1.333) for the first four years (2016 – 2019) of the study but had a little improvement in year 2020. The negative sign in the year 2019 is attributed to the change in temperature which is the major factor that influences most of the secondary radio climatic variables.

Fig. 6 – 8 shows the variation of Radio refractivity (N), Radio refractive index (n) and vapour pressure (e) with months of the years (2016 – 2020) of the study

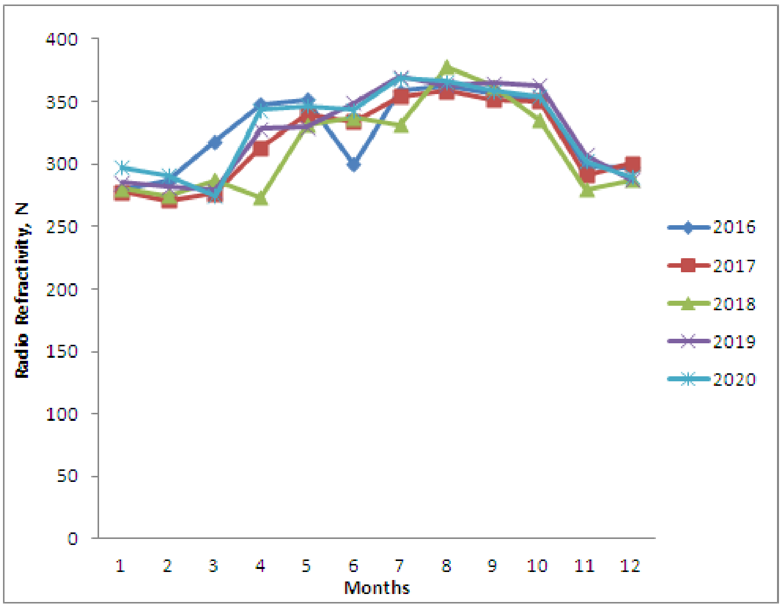

Figure 6: Variation of Radio refractivity with months of the years 2016 – 2020

Figure 6 shows the Variation of Radio refractivity with months of the years of study. The plots indicates month/year of May (2016), August (2017), July (2019) and September (2020) has the highest value the radio refractivity while the months/years of December (2016), November (2017), November (2018), December (2019) and December (2020) has the lowest value of the estimated radio refractivity. This means that the radio refractivity has the highest value between the months May to September of the years (2016 – 2020) while it has the lowest value between November and December of same years of study. Hence , the result shows that all network that rely on radio frequency (John, S.S., 2005) has low interference between the months of May and September during the five years of study while high interference occurs between November and December of the years of study within Bauchi metropolis.

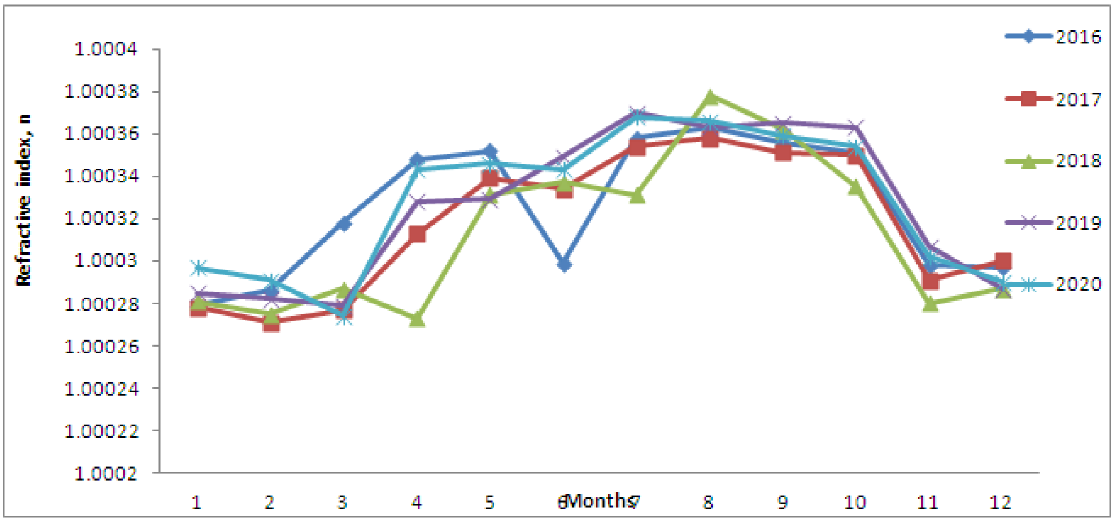

Figure 7: Variation of refractive index with months of the years 2016 – 2020

Fig.7 shows the variation of refractive index with months of the years of study, the plots indicates that the refractive index (n) has it highest value at the months/years of August (2016), August (2017), August (2018), July (2019) and July (2020) while the lowest value occur at November (2016), November (2017), November (2018), December (2019) and December (2020). This means that all networks that rely of radio frequency (John, S.S., 2005) has low interference effects between July and August while high interference effects had taken place between November and December of the years (2016 – 2020) within Bauchi metropolis.

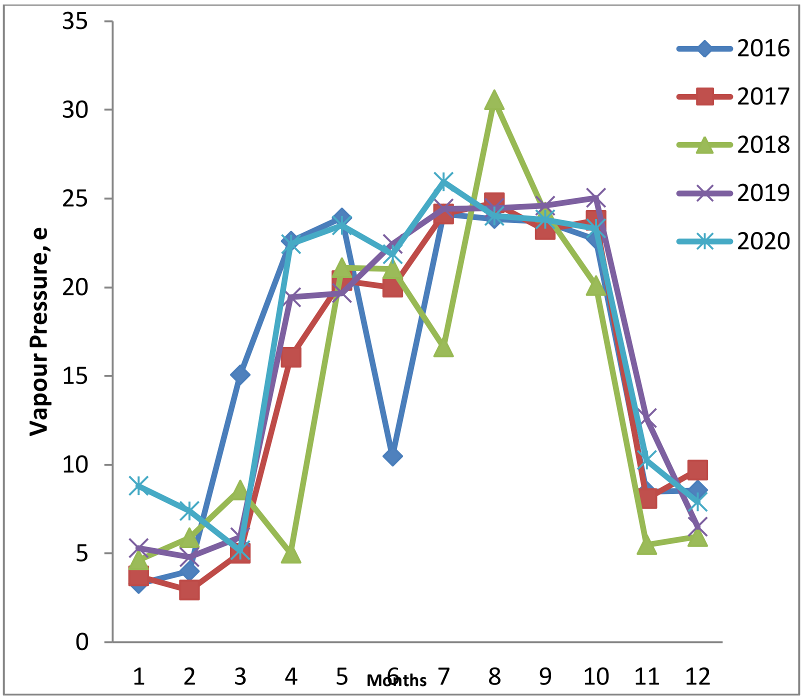

Figure 8: Variation of vapour pressure with months of the years 2016 – 2020

Fig.8. Shows the variation of vapour pressure with months of the years of study, the highest value was estimated at May (2016), October (2017), August (2018), October (2019) and July (2020). The lowest value obtained at June (2016), November (2017), January (2018), December (2019) and December (2020). The variation shows scatter behaviour with months of the years of study. This behaviour was attributed to the prevailing seasons and weather conditions in the study area.

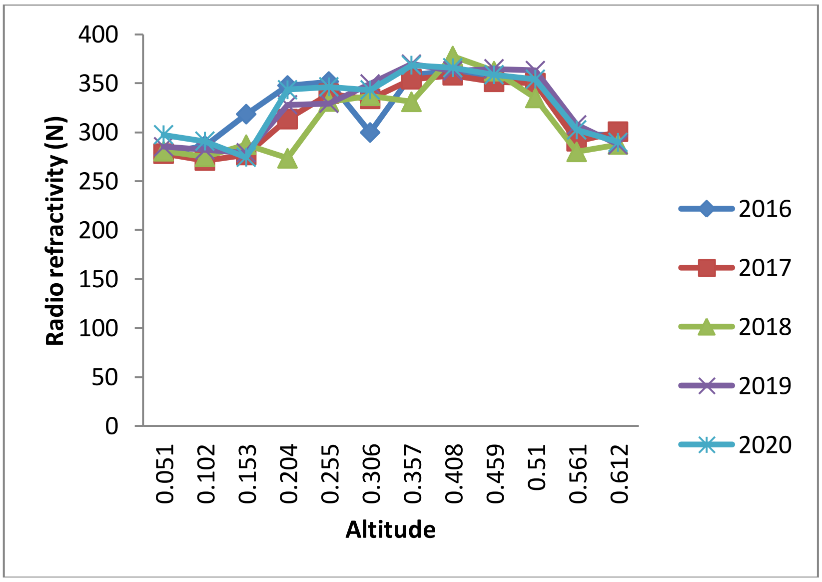

Figure 9: Variation of Radio refractivity with altitude

Fig.9. shows the variation of Radio refractivity (N) with altitude. The plots shows that the highest value for the radio refractivity occurs at an altitude of 0.408 km and the lowest value occur at 0.561 km. This means that the higher the refractivity (N) the lower the altitude and the faster wireless communication may be transmitted from place to place within the study area. Hence, all networks that rely on radio frequency will travel faster.

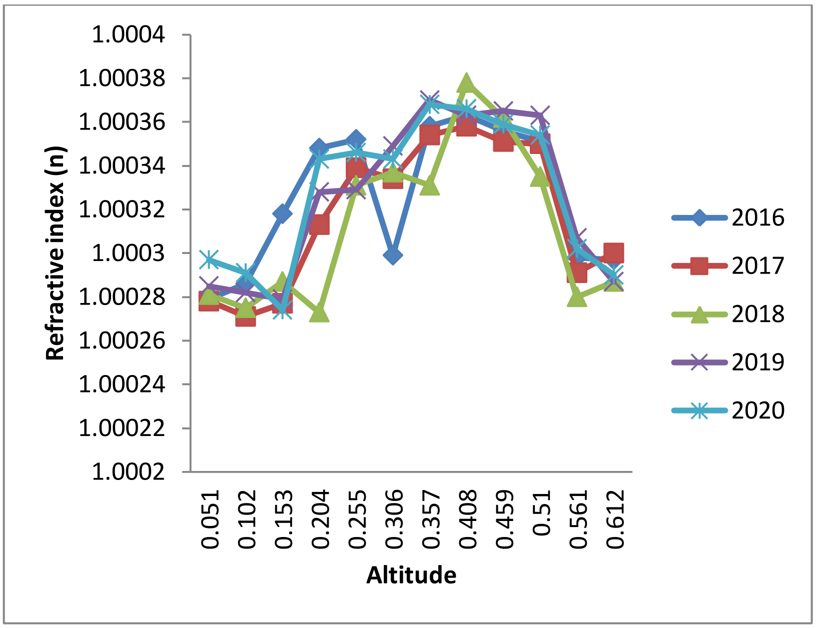

Figure 10: Variation of refractive index (n) with altitude

Fig.10. shows the variation of refractive index (n) with altitude. The plots shows that the highest value of (n) for the years of study 2016 is 1.000360 (0.408 km), for 2017 is 1.000350 (0.408 km), for 2018 is 1.000380 (0.408 km), for 2019 is 1.000364 (0.408 km) and 2020 is 1.000365 (0.408 km). Similarly the lowest value for the period of study i.e. 2016 to 2020 occur at altitude of 0.561 km. This implies that the higher the altitude the lower the refractive index (n) and when (n) is very small electromagnetic waves travel faster.

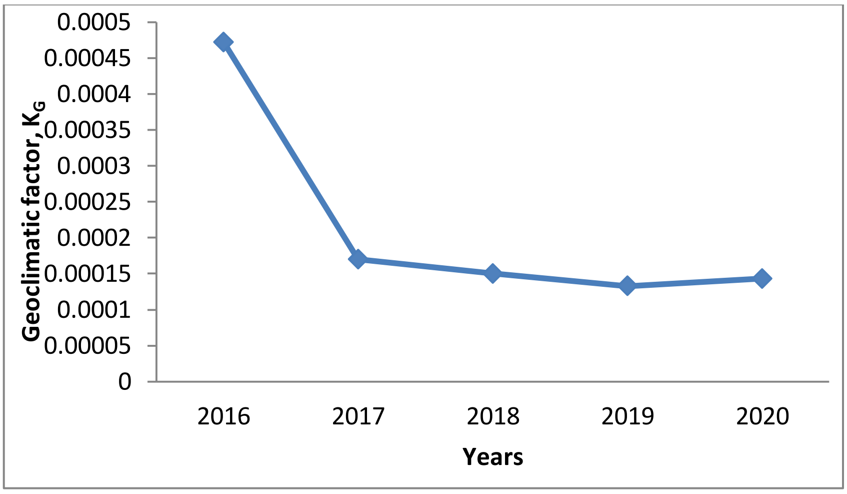

Figure 11: Variation of Geoclimatic factor (K_G) with years (2016 – 2020)

Fig.11. shows the variation of Geoclimatic factor (K_G) with years of study. The figure indicates that 2016 has the highest value of 0.000455 with 2019 which has the lowest (0.00015), both the values are greater than the global value of 0.000111. This shows that all networks that rely on radio frequency are affected with interference. High interference occurs when the value of (K_G) is lower than 0.000111. Hence, the result of (K_G) shows that the interference is low within the study area.

XVIII. CONCLUSION

An estimation of radioclimatic variables on signal propagation in Bauchi metropolis, Nigeria has been investigated. The result also shows that there is sub-refractivity in the study area which is a situation where by the atmosphere is such that the refractivity increases with height, resulting in refractivity gradient that is more positive than the standard refractivity gradient. The radio wave bends upwards away from the Earth and this tends to shorten the radio horizon.

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