APPRAISAL OF TROPOSPHERIC RESEARCH ON COMMUNICATION IN NIGERIA

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Abstract

The knowledge of the past is a treasure for the present towards accurate and reliable plan and design that can lead to economic, scientific and technological advancement and self-reliance. This paper discusses the present status of tropospheric researches in Nigeria. It reports on rainfall rate, raindrop size distribution, conductivity, field strength, refractivity, water vapour density, rain height, intersystem interference and attenuation. Appraisals of the quality of the tropospheric researches reveal that measurements and evaluations works are of high standard and quality. However, measurements of atmospheric parameters in Nigeria are inadequate and discontinuous. Consequently, prediction models, based on the local data that will properly characterize the pattern and behaviour of transmitted signal, are grossly insufficient. Equipment for studies is in short supply; and most times, unavailable, thus inhibiting comprehensive research works. Areas requiring urgent attention toward rapid national growth and healthy competition in the 21st century are addressed.

Keywords: *Rain intensity, attenuation, refractivity, conductivity, refractive index,*

Introduction

A nation without appropriate communication design and plan is in a wrong lane that leads to self- slavery and disrespect. In this information age, a nation that solely relies on imported data and information for her growth and development will remain in the backyard of development. Surely, poverty shall be her portion perpetually. Communications, be it sound, vision and video, are potent weapon of unity at local, national and international levels. Broadcasting and telecommunications are imperative and invaluable tools of socio-economic growth, political and cultural creativity and integration (Olumuyiwa, 1978; Scott-Emuakpor, 1978).

The lower part of the atmosphere is the troposphere that extends from the surface of the earth surface up to a height of 8 to 10 km at polar latitudes, 10 to 12 km at the moderate latitudes, and 16 to 18 km at the equator (Bean and Dutton, 1968).

Particles and gases in varying proportions are found in the troposphere. The percentage composition of dry air (Nitrogen, 78.09%, Oxygen, 20.95%, Argon, 0.93%) does not vary with height but remains practically the same as it is at the surface. The temperature of the troposphere, like that of the mesosphere, decreases with height owing to the fact that the troposphere is almost transparent to the sun rays, and also due to the uneven heating of the earth's surface. When temperature decreases with height, a positive lapse rate condition occurs.

Another characteristic of the troposphere is that there is large-scale vertical mixing caused by convection currents. Consequently, transportation of particles of various shapes and sizes, as well as gaseous products, to the top of the troposphere is actualised within a short period of time. We should not forget that in the absence of large-scale vertical mixing, diffusive equilibrium occurs; that is, lighter gases being present in greater ratio at higher altitudes than heavier gases. Also, another effect of this is that the partial pressure (in kPa) of each constituent gas decreases at a separate rate.

Following this region is the stratosphere, then the mesosphere and the ionosphere. In the troposphere, several attempts have been made in Nigeria to provide useful information and data on radio wave propagations for both terrestrial and earth-space radio links. Atmospheric parameters could be simulated in the laboratory and /or measured directly on the field. Through measured atmospheric parameters such as rain rate, raindrop size distribution, field strength and attenuation, the actual influence of these parameters on transmitted radio signals can be ascertained. Correlation of measured values with predicted values often yield better models for characterizing the propagating medium for good quality signal reception. Some of the research efforts in the troposphere are presented and appraised with a view to understanding how far we have gone and what the future holds for the most populous nation in Africa. Discussions are restricted to the troposphere in areas of measurements and predictions made with existing models for radio propagations in Nigeria.

Rain Rate

Rainfall intensity could be measured with rainguages. In the absence of measured data, it could be evaluated. Rainguages with short integration time, to account for fluctuations and variation of rainfall in a short time interval, are often used [Ajayi et al., 1996]. In Nigeria, Ofoche (1982) measured rainfall intensity with electronic rapid response rainguage with ten seconds integration time at the then University of Ife, now Obafemi Awolowo University. The data analysed covered a period of three years, 1979 to 1981. It was found that there is a greater incidence of high rainfall intensity (as high as 180 mm/h) at Ile-Ife (7.5°N, 4.5°E), a tropical site than in the temperate zone. It was further noted that the rainfall intensity could continuously be exceeded for 20 seconds with returns periods ranging from three minutes to twenty minutes. Adimula et al. (1995) measured rain rate at Ilorin (8.5°N, 4.5°E) from 1989 to 1992 and reported that convective rain dominates 70% of the total rainfall observed. The mean rainfall rate for 0.01% of time is 100mm/h. The year-to-year variability exhibited by the data indicated that 1989, being a year of exceptional incidence of convective rainfall, consistently has the greatest rain rates when compared with the other three years. The worst month statistics are invaluable to system engineers in that they assist in determining the month(s) in a year when signal degradation is greatest. The worst month for Ilorin vary between September and October. The month of May was found to have appreciable rainfall close to the worst month, indicating possible two periods in a year at Ilorin. The dependence of rain rate statistics on integration time has been investigated. Ajayi et al., (1996) generated a power law relation that could be used for conversion from available long rate to short integration times. Ajayi and Ezekpo (1988) produced a contour map of rainfall intensity exceeded for 0.01% of the year for Nigeria. The long-term precipitation data gotten from 37 Nigeria weather stations for over 30 years were converted to 1 minute integration time rainfall rates with Rice-Holmberg technique (Ajayi et al., 1996). Currently, there are over 37 weather stations in Nigeria. Table 1,from Kolawole (1980) and arranged according to increasing latitude shows the name, altitude and geographical coordinate of a great deal of weather stations in Nigeria.

Table 1: Some weather stations in Nigeria

S/N	Station Name	Altitude (m)	Geographical Latitude (°N)	Coordinates Longitude
1.	Abobiri	6	04 37	06 19
2.	Bonny	2	04 38	07 03
3.	Portharcourt	18	04 51	07 01
4.	Calabar	63	04 58	08 21
5.	Obio Akpa	30	04 59	07 47
6.	Elele	15	05 06	06 48
7.	Kwa Falls	122	05 08	08 31
8.	Umudike	122	05 29	07 33
9.	Warri	2	05 31	05 44
10	Effurum	9	05 31	05 47
11.	Abia	116	05 57	08 54
12.	Sapoba	76	06 04	05 52
13.	Asaba	91	06 12	06 45
14.	Benin	78	06 19	05 36
15.	Abakaliki	107	06 20	08 07
16.	Obudu	1585	06 23	09 24
17.	Ajali Oghe	305	06 25	07 19
18.	Lagos	13	06 27	03 24
19.	Enugu	137	06 28	07 33
20.	Ikeja	37	06 35	03 20
21.	Irrua	183	06 44	06 13
22.	Nsukka	396	06 52	07 23
23.	Ijebu-Igbo	137	06 59	04 10
24.	Ondo	289	07 06	04 50
25	Akure	375	07 17	05 14
26.	Yandev	122	07 23	09 01
27.	Ibadan	228	07 26	03 54
28.	Okene	396	07 34	06 23
29.	Iwo	244	07 38	04 12
30.	Ilesa	366	07 38	04 45
31.	Makurdi	97	07 41	08 37
32.	Osogbo	305	07 47	04 29
33.	Ilora	250	07 48	03 50
34.	Lokoja	62	07 47	06 44
35.	Oyo	229	07 54	03 43
36.	Ibi	111	08 11	09 45
37.	Ilorin	307	08 29	04 35
38.	Shendam	168	08 39	09 40
39.	Bacita	107	09 04	04 56
40.	Badeggi	70	09 05	06 07
41.	Bida	142	09 06	06 01

42.	Yola	186	09 14	12 28
43.	Mokwa	152	09 18	05 04
44.	Minna	258	09 37	06 32
45.	Vom	1265	09 44	08 47
46.	Zondwa	841	09 45	08 23
47.	Jos	1285	09 52	08 54
48.	Toro	1067	10 03	09 04
49.	Bauchi	609	10 17	09 49
50.	Kontagora	396	10 21	05 28
51.	Kaduna	646	10 36	07 27
52.	Yelwa	244	10 53	04 45
53.	Zaria	652	11 05	07 43
54.	Daudawa	640	11 38	07 09
55.	Potiskum	415	11 42	11 02
56.	Maiduguri	354	11 51	13 05
57.	Kano	476	12 03	08 32
58.	Gusau	468	12 10	06 42
59.	Kafinsoli	549	12 32	07 45
60.	Kasarawa	351	12 51	05 12
61.	Nguru	343	12 53	10 28
62.	Sokoto	302	13 01	05 15
63.	Katisina	517	13 01	07 41
64.	Daura	428	13 02	08 13
65.	Yau	305	13 33	13 15

Raindrop Size Distribution

Ajayi and Olsen (1985) measured drop spectra at Ile-Ife with an automatic recording distrometer using a sampling time of 1 minute. The results of this effort produced the celebrated lognormal model or Ajayi-Olsen (A-O) model, as it is otherwise called, and other useful empirical relationships (Ajayi and Olsen, 1985). Ajayi (1984) compared drop size measured for West African thundersquall system over Ile-Ife on 16th April, 1982 with the West African monsoon rainfall of 7th September, 1981, and found that both rainfall types are usually characterized by high rainfall rates. The squall line was made up of intense convective cells. The Monsoon event on the other hand, was principally due to stratiform clouds. The variability of number of drop per unit volume per diameter interval, N(D) was noticed to be greater in number of large diameter drops at the onset of the thunderstorm than at the middle of the storm. The differences have been attributed to uneven terminal velocities and differences in the updraft velocities in the different parts of the storm. Empirical relationships for the slope, Ë and intercept, N_o of the negative exponential distribution were obtained. With the measurements of drop size at two additional sites in Nigeria, Zaria and Calabar, Adimula and Ajayi (1996) reported the geographical variations of drizzle rain and obtained new relationship for N_o.

Conductivity

Ground waves are influenced by the inhomogenity of the surface terrains, electric permittivity, ε and ground conductivity, σ . Both conductivity and permittivity had been measured at certain locations in Nigeria. At Ibadan, Ajayi and Owolabi (1981) measured σ, using ground wave attenuation method. The medium wave propagation curves, which could find use in evaluating optimum radiated power condition for a given area coverage, were produced. The strong dependence of field strength on ó rather than on σ

was reported. Ajewole and Arogunjo (2000) also measured ground electrical conductivity around six medium frequency radio transmitters, and the depth of penetration, using vertical electrical sounding technique based on the Wenner Array geophysical prospecting method. Ajayi (2001) reported ground electrical conductivity measurements for a coverage area of about 9 x 10^5 km in Nigeria, using Wenner arrangement of the probe methods of ground resistivity. The study spanned a period of three years (1998-2000) for 85 towns and villages that spread around the country. Ten different types of soils were investigated during rainy season. The results showed that above 20.0ms/m accompanied areas of very moist sandy loam and silt loam soil types, while dry sandy soil areas recorded 1.0 ms/m. He also generated four ground conductivity zones of high, medium, low and very low for Nigeria. Besides, medium frequency propagation curves and ground electrical conductivity map were produced. This study is the most comprehensive and nation-wide study so far on ground electrical conductivity measurements in Nigeria.

Refractivity

Kolawole (1980) investigated the variation of surface radio refractivity, N_s in Nigeria in terms of a reduced-to-sea-level form of the index N_o that gives a significantly more accurate description of the refractive index variations than the non-reduced form. The monthly mean values of surface pressure, temperature and relative humidity from 65 weather stations for 1964 65 formed the data base. He found that N_o varies from about 390 N-units at the coastal stations to about 290 N-units in the northern part of Nigeria during the dry season. During the rainy season N_o values are generally high (370-390 N-units) throughout the nation with no significant variation in N_o from the coastal area to the north. A contour map of N_o was produced accompanied by an empirical relationship which could be used to estimate N_o to an accuracy of about 10% from the N_o contours.

Kolawole and Owonubi (1982) study of N_s over Africa yielded four key refractivity patterns along the major climatic regions of the continent: the equatorial region (5°N-5°S of the equator) where N_0 has all-time high values ranging from about 370 to 400 N-Units; the tropical continental region (extending to about 20° North and south of the equator) where N_0 exhibits marked seasonal variations with very high annual ranges (70-110 Nunits) throughout the year; the hot desert climatic region (20°-30°N) where the values of N_0 are fairly low at the hinterland; range for Aswan being 280 310 N-units; and the warm temperate region (prevalent most of South Africa and Northern most part of the continent) with moderate values of N_0 (300-350 N-units) and low annual range of about 5 N-units. Babalola (1996) studied the vertical radio refractive index gradient at the ground level for three radiosonde stations in Nigeria. The surface layer in the southern part of Nigeria is super-refractive, while that of the northern part is sub-refractive. The probability of occurrence of ducting is high often in the south. It is greater than 60% during the rainy season and 10% lower during the dry season. On the other hand, ducting probability in the north is low, only about 13% and 3% respectively during rainy and dry seasons. Large lapse rate of vapour pressure with height rather than temperature inversion was discovered by Babalola to be responsible for ducting. Further investigations of refractivity gradient and its modified form, M (N-unit) have also taken place. Falodun and Kolawole (2000) observed seasonal and geographical variations of refractivity and modified refractivity from south to the north. Oyedum and Gambo (1994) computed N_S for three stations: Jos (8.56°N, 8.30°E), Katsina (12.3°N, 6.50°E) and Sokoto (12.35°N, 4.35°E) in northern Nigeria with monthly mean data for eight consecutive years, 1971 1978. They reported that N_S, on a long-term basis, varies between 288 and 359 N-units. A good correlation between measured field strength and seasonal variation of N_S was obtained.

Water Vapour Density

Water Vapour Concentration evaluation at Ondo and Minna Stations using 10 years monthly mean meteorological data and Liebe model had been reported (Adenugba, 1999). The peak vapour density of 24.83g/m^3 was reported for the month of June while January has the least value of 4.24g/m^3. The diurnal, seasonal and geographical variations of water vapour density have also been reported for other sites. With hourly temperature and relative humidity data from three meteorological stations, Ibadan (7.2^{0}N, 3.59^{0}E); Ilorin (8.26^{0}N, 4.29^{0}E) and Kano (12^{0}N, 8.31^{0}E), Adeyemi and Adenugba (2003) computed water vapour density, WVD. The latitudinal distribution of WVD which decreases from low latitude to high latitude regions was observed to be acute during the dry season. Adenugba et al.(2003) presented some statistical properties of WVD in Nigeria, using three models: ITUR, Liebe and Garcia Muller et al. models. Monthly mean data from seventeen weather stations were employed, and the results comprised seasonal and diurnal variation of WVD. The percentage difference between the models was found not to be more than 2%, indicating that any of the models could be used without any significant difference in results.

Field Strength, Rain Height and Intersystem Interference

Relative field strength measurement on Bauchi (10.25^{0}N, 9.75^{0}E) FM broadcasting station, transmitting at 94.57 MHz and 20kW, was conducted using field strength meter. Five routes were considered at 10km regular interval from Bauchi FM broadcasting station. A comparison of the calculated and measured field strengths shows that the calculated values at 60 and 70km distance overestimate the field strength at all the routes [Alao and Akande, 2000].

The effective rain height, h_R is needed for the prediction of attenuation due to rain on earth-satellite path. Ajayi (1996) and Ajayi et al. (1996) studied the characteristics of the 0°C isotherm height during rain, h_{FR} with radiosonde data at Oshodi, Minna and Kano. Comparisons were made with other tropical and temperate regions. These efforts produced useful relations for the computation of effective rain height.

Ajewole et al. (2000) studies the effects of intersystem interference on system planning and availability in Nigeria using mean annual and worst month cumulative distributions of point rainfall rate measured at Ile-Ife. Vertical polarized signal, satellite antenna gain of 56dB and terrestrial antenna gain of 35-55dB in the frequency range of 4-30GHz, were assumed in the transmission loss characteristics computation. It was found that transmission loss (interference) depends on the position of the common volume formed by the intersection of the beams. Also, increasing terrestrial antenna gain results in decreasing transmission loss over a given outage margin.

Attenuation

Propagated signals diminish in strength with increasing distance. This could be as a result of the effect of gases and hydrometeors on the signal. Earth-space attenuation measurement was carried out at Ile-Ife for a period of two years. The radiometer employed for this work was supplied by INTELSAT and COMSAT, while the local financial support came from Nigerian Telecommunication Ltd (NITEL) [Ajayi, 1996]. The measured attenuation at Ile-Ife was found to be higher than the value predicted with ITUR prediction technique. This was also found to be true for Douala and Nairobi sites. Therefore, the ITUR prediction model underestimates attenuation at tropical sites, probably due to insufficient consideration given to the vertical non-uniformity of rain in the tropical regions [Ajayi, 1996].Gaseous attenuation due to oxygen and water vapour was evaluated for Nigeria in the frequency range of 3350 GHz with Liebe model. Ajayi and Kolawole (1984) found that gaseous attenuation is generally higher at Ile-Ife, a tropical site than at temperate zones.

Considering four other sites, Adenugba (2000) reported seasonal and geographical variations of specific gaseous attenuation and spectral lines of oxygen and water vapour. Lagos was found to have the highest attenuation value, while Kano has the least values. During the wet season the gaseous attenuation is higher than the dry season. Also, the attenuation is generally higher for the tropical sites than the temperate zone. The oxygen isolated resonant absorption line was obtained at 118 GHz with series of closed lines at 54 66 GHz. On the other hand, water vapour three resonant absorptions spectral were obtained at 22, 184 and 326 GHz.

Yesufu (1998) presented a mathematical basis for the fold over effect associated with the ITU-R rainfall attenuation prediction model. He clearly showed that specific attenuation, rather than the reduction factor, should be held responsible for the ITU-R model problem.

Appraisal and Recommendations

Measurements of atmospheric parameters have tremendous merits. Indeed, they reveal true and actual pictures of situations and provide data and information for modelling. To set up an experiment, expert and fund requirements cannot be overlooked. These may be threatened initially, but the end results, often than not, yield stunning benefits to the immediate environment and humanity in general. There are extremely few measurements on short integration time rain fall rates which are suitable for communication prediction in Nigeria. However, long term rain intensity measurements data taken with long rainguage integration times are available at over 40 meteorological stations in Nigeria. In the absence of the short-time rain rates, the conversion factor for conversion of available integration time rain rate to the required one has to be used. Rainguages with short integration time, preferably 1 minute, arranged to form a network will reliably provide data and information on spatial distribution of rain intensity and rain attenuation. The growing need for channel capacity for communication requires that research should also be extended to higher frequency bands.

Apart from the measurement of rain height by Ajayi, it is doubtful if any researcher has done so again in Nigeria, at least not to our knowledge. More so, measurements of attenuation due to rainfall are few and none for gaseous attenuation yet. In Nigeria, it is observed that measurements of atmospheric parameters are made intermittently and for a very short period. The 3-year data analysed by most researchers are grossly inadequate, seven years short of the recommended period by the ITU-R. This discontinuous pattern of measurement has certain grave setbacks. The consistent and continuous investigation of a parameter over a long period of time that can yield reliable and precise prediction model(s) and actual data is denied. Long-term continuous data, it should be noted, give a true representation of the behaviour and pattern of the parameter under consideration. Scientists and engineers that should have been kept busy together to rub minds to produce enhanced and improved techniques, equipment and atmospheric models are isolated and under-utilized. Lack of continuity in measurements may be attributed to insufficient funds, un-coordinated activities of researchers in the nation and constant drift of investigators to find greener pastures.

The immediate solution to this is to set up three standard atmospheric laboratories in Nigeria, preferably in the Universities where serious research works can be embarked upon. By establishing one laboratory in the north, east and west, extensive radio parameters can be gleaned simultaneously. By standard laboratories we mean laboratories thoroughly-equipped with modern equipment and facilities; manned by atmospheric scientists of note and staffed to the teeth with seasoned scientists and engineers who are appointed not by selection but strictly on academic merits. A laboratory that is not autonomous and has no sure and reasonable source of fund will soon become moribund and gradually become a living dead through fund starvation and unnecessary external interference(s). Against this backdrop, substantial amount of money should be set aside in the annual budget for research. The greatness of a nation as well as its technological and economic advancement depends on research, which has focus on measurements of its immediate environmental. Comparison of measured local parameter(s) with values from other locations around the world will manifest similarities and differences.

Ground conductivity measurements had yielded quality data and information for planning and designing of radio communication systems. However, continuous measurements of ground conductivity in all towns and villages for both dry and wet seasons are required in order to produce all-encompassing ground conductivity maps and all-embracing medium frequency propagation curves.

There are few sporadic measurements of field strength. These efforts clearly are grossly inadequate to provide lucid patterns, facts and figures on medium wave propagations. Extension of the current coverage areas with better equipment on continuous basis will reverse the present ugly situation. For complete characterization of medium wave propagation predicted values should be correlated with measured values. The need to use artificial ground screen where there are existing mast has been noted [Ajewole and Arogunjo, 2000], as this will increase signal reception and enhance system performance that is less dependent on weather conditions.

No radar measurements of rain parameters have been reported in Nigeria; neither is there any report on network measurement of rain intensity. This may be due to lack of equipment to employ for measurement rather than lack of experts to carry out the measurements. Availability of modern equipment, no doubt, will provoke researches into hitherto un-measured atmospheric parameters like gaseous attenuation; and additionally, young Nigerians will be wooed to consider research career in atmospheric research and communication. To generate more models and empirical relations that will really represent the true nature and pattern of atmospheric parameters, more measurements are required and on continuous basis. The mean data values used by investigators cannot provide complete picture of gaseous absorption pattern characteristic. This indicates the need for wide-range of data on daily basis for the entire seasonal periods prevalent in the nation; Liebe model used was developed with temperate data. Tropical model generated with tropical data will give a better prediction than the temperate models currently used. Measurements of attenuation due to oxygen and water vapour are thus required for modelling. Needless to mention that extension of the sites from five so far studied is certainly going to produce widespread statistics on gaseous attenuation and generate gaseous attenuation map that can be employed for both centimeter and millimeter waves planning and prediction. NITEL financial support is commendable. Support from other companies, organizations and agencies will advance research, especially in area of modern equipment acquisition and /or donations.

Software applications for atmospheric parameters estimation are scarce. This area deserves attention, as availability of software packages will enhance research works.

Some tropospheric studies in Nigeria for communication have been reported and appraised. We observed that most of the research works in the troposphere on communication were carried out in the Western part of the country. This is by no means exhaustive; all the same, what has been reported indicated some areas so far covered and sections deserving attention. We find that quality research works are conducted to provide data and information on radio waves propagation in the troposphere.

Measurements of atmospheric parameters of interest to radio engineers, apart from being grossly insufficient, are done in a discontinuous manner and for a very short time. Proper design and planning require continuous long-term high quality data. Lack of adequate funds and equipment inhibit long-term research efforts. With the level of what had been done, Nigeria is not a push over. But to actually achieve its deserved greatness, there is the need to: establish well-equipped and well-funded laboratories; raise the morale of those currently on the job through various incentives and living wages; recruit additional adept hands; set long-term measurement targets for the nation and encourage team and coordinated research work.

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