



RADIO REFRACTIVITY STUDY IN AKURE-OWO DIGITAL MICROWAVE LINK IN SOUTH WESTERN NIGERIA

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ABSTRACT

This work is a study of radio refractivity in Akure-Owo Digital Microwave Link in South Western Nigeria. Meteorological data of air temperature, atmospheric pressure, relative humidity, and water vapour pressure were measured between January and December 2006 at the observatory centre of the Nigerian meteorological agency (NIMET) situated at Akure Airport. The meteorological data collected were computed to obtain the refractivity, refractivity gradient and earth radius factor. The results of the study show that the refractivity gradient was greater than zero and vary slightly throughout the months of the year 2006. The highest value of refractivity gradient was in April and lowest value in September, the effective earth radius factor was observed to be less than one which implies that there is sub-refraction in the link. Sub refraction is a situation in which the radio signal beam is refracted upwards in the link thereby resulting in microwave link loss.

Keywords: effective earth radius factor, refractivity, refractivity gradient microwave link, sub-refraction

1. INTRODUCTION

The troposphere is the lowest region of the atmosphere and it extends from the earth's surface to an altitude of about 10km at the middle latitudes, 6km at the poles and up to 18km at the equator [1,2]. The basic parameters that describe the troposphere region are pressure, temperature and relative humidity. Variations in these conditions within the troposphere cause changes in the refractive index of air and large scale changes of refractive index with height cause radio waves to be refracted and the effect can be quite significant at all frequencies [3,4].

Propagation of waves in a microwave link is through the troposphere which is the non-ionized lowest portion of the atmosphere [5]. The refractive index is defined as [5].

$$n = \sqrt{\epsilon_r} = \frac{c}{v} \quad (1)$$

Where ϵ_r is the dielectric constant of the troposphere C is the speed of light and V is the phase velocity of the wave in the medium. The refractive index is always greater than unity but for a radio wave travelling in air, it is only a small fraction greater than unity. For example the average ground refractive index (n) is 1.000315 which is an inconvenient number and hence radio refractivity N is defined as [6].

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

Substituting the value for the ground refractive index (n = 1.000315 into equation (2) yields a value for N as 315 units. The radio refractivity for links below 100 GHz is given as [6].

$$N = 77.6 \frac{P}{T} + 3.733 \times 10^5 \frac{e}{T^2} \quad (3)$$

where P is the atmospheric pressure, T is the absolute temperature in degree Kelvin and e is the partial pressure due to water vapour in millibars.

The value of N varies with altitude since pressure; temperature and humidity normally decrease exponentially with height.

A radio link designer should not be so much interested in the absolute level of refractivity but in the change in the value over the microwave front. It is thus the gradient of refractivity that is of interest [6]. The refractivity gradient is thus defined as:

$$G = \frac{\Delta N}{\Delta h} \quad (4)$$

Refractivity gradients change with time leading to anomalous propagation conditions. There is a convenient artifice which is used to account for the problem of refraction when the path profile is plotted. This is called the effective earth radius factor "k" [6].

The K-factor is related to the refractivity gradient as [6, 7].

$$K = \frac{1}{1 + \frac{adn}{dh}} \tag{5}$$

If the radio refractivity index “N” defined in equation (2) is rearranged, we get;

$$N = N \times 10^6 + 1 \tag{6}$$

To obtain the gradient there is need to differentiate equation (6) with respect to height.

$$\frac{dn}{dh} = 10^{-6} \frac{dN}{dh} = 10^{-6} G \tag{7}$$

Substituting this ratio equation (5) yields

$$K = \frac{1}{1 + 0.006371G} \tag{8}$$

Using eqn (8) some commonly referred values of K to G can be obtained as shown in Table 1:

Table 1: Comparison of K – factor versus Gradient in the troposphere

| Earth radius factor (K) | Radio refractivity gradient (G) | Atmospheric Refraction |
|-------------------------|---------------------------------|------------------------|
| 1 | 0 | Standard refraction |
| $\frac{4}{3}$ | -39 units/km | Standard refraction |
| ∞ (infinity) | -157units/km | Ducting refraction |
| < 1 | > 0 | Sub-refraction |

Hence when the gradient of refractivity (G) = -39 units/km (or K = 4/3) it is called standard refraction, when the gradient becomes positive, it is known as sub-refraction and can cause diffraction loss. When the gradient becomes more negative than G = 100 N units/km it is called super – refraction and results in multipath fading, when the gradient becomes more negative than G = -157units/km, ducting conditions occur resulting in severe multipath, beam spreading and even blackout conditions [8,9].

2. METHODOLOGY

The meteorological data used in this work such as air temperature, atmospheric pressure, relative humidity and water vapour pressure were obtained from the observatory centre of the Nigeria Meteorological Agency (NIMET) at Akure Airport which is situated on the Akure – Owo microwave link.

Akure lies on latitude 071509.30N and longitude 0051142.60E and Owo lies on latitude 071220.00N and longitude 0053402.00E. The path length of the link is 41.42km. The link was chosen because it has a

meteorological station (Akure Airport) situated on the link where meteorological parameters can be measured.

At the NIMET observatory centre at Akure Airport, temperature was measured with a dry bulb thermometer, atmospheric pressure was measured with a kew pattern barometer. Vapour pressure was measured with the psychrometer (which is a combination of dry and wet bulb thermometers). The readings from the dry and wet bulb thermometer were computed to get the relative humidity in percent and water vapour in millibars. The meteorological readings were recorded over a twenty four hours period daily for four weeks in the months of January to December 2006. The weekly total for the months were divided by number of hours multiplied by total number of days in the month as illustrated in equation (9).

$$\text{Average meteorological readings} = \frac{\Sigma \text{ weekly total meteorological readings}}{\Sigma \text{ total no of hours x total no of days}} \tag{9}$$

3. RESULTS AND DISCUSSION

The computed average monthly meteorological data in the link are shown in Table 2

Table 2: Average monthly meteorological data in Akure-Owo digital microwave link for year 2006

| Month | Temperature °C | Relative Humidity (%) | Vapour Pressure (mb) | Atmospheric Pressure (mb) |
|-----------|----------------|-----------------------|----------------------|---------------------------|
| January | 29.2 | 92.5 | 28.0 | 1004.5 |
| February | 29.6 | 82.6 | 32.1 | 1003.8 |
| March | 29.2 | 81.3 | 31.8 | 1005.3 |
| April | 29.0 | 88.2 | 32.5 | 1004.3 |
| May | 27.4 | 86.3 | 30.8 | 1005.5 |
| June | 27.1 | 86.6 | 30.4 | 1007.8 |
| July | 25.3 | 91.0 | 29.8 | 1007.6 |
| August | 25.6 | 90.0 | 28.6 | 1007.6 |
| September | 26.0 | 92.3 | 29.9 | 1006.4 |
| October | 27.2 | 89.8 | 29.7 | 1006.5 |
| November | 28.7 | 65.6 | 32.1 | 1005.5 |
| December | 28.4 | 57.0 | 30.8 | 1004.2 |

4. ANALYSIS OF RESULTS

(i) *Computation of refractivity gradient* - The values obtained in Table 2 were computed using equation (3), (4) and (5) to get Table 3. The computations are illustrated as:

$$N = 77.6 \frac{P}{T} + 3.733 \times 10^5 \frac{e}{T^2} \tag{10}$$

Where P is the atmospheric pressure in millibars, T is the air temperature in Kelvin and e is the water

vapour pressure in millibars. If we substitute the values of P, T and e from Table 2 we get N.

$$G = \frac{dN}{dh} \tag{11}$$

If we substitute the value of N and h we get G, the height (h) is taken as 90 meters from the link budget of Akure-Owo digital microwave link [10]. From:

$$K = \frac{1}{1 + 0.006371G} \tag{12}$$

If we substitute the value of G we get K. The results of computation are shown in Table 3.

Table 3: Refractivity, refractivity gradient and earth radius factor for Year 2006

| Month | Refractivity (N) | Refractivity Gradient (G) | Earth Radius Factor (K) |
|-----------|------------------|---------------------------|-------------------------|
| January | 373 | 4.14 | 0.973 |
| February | 388 | 4.31 | 0.973 |
| March | 389 | 4.32 | 0.973 |
| April | 391 | 4.34 | 0.973 |
| May | 387 | 4.30 | 0.973 |
| June | 387 | 4.30 | 0.973 |
| July | 387 | 4.30 | 0.973 |
| August | 382 | 4.24 | 0.974 |
| September | 374 | 4.16 | 0.974 |
| October | 383 | 4.26 | 0.973 |
| November | 390 | 4.33 | 0.974 |
| December | 386 | 4.29 | 0.973 |

Table 4: Table showing refractivity gradient versus months for Year 2006

| Month | Refractivity Gradient |
|-----------|-----------------------|
| January | 4.14 |
| February | 4.31 |
| March | 4.32 |
| April | 4.34 |
| May | 4.30 |
| June | 4.30 |
| July | 4.30 |
| August | 4.24 |
| September | 4.16 |
| October | 4.26 |
| November | 4.33 |
| December | 4.29 |

(ii) From Table 4, it can be deduced that refractivity gradient lies between 4.14 to 4.34 units and the effective earth radius factor is 0.973 and 0.974 throughout the year. Hence, it can be stated that the refractive gradient of the link is greater than zero and the earth radius factor is less than one. This condition is called sub-refraction. A sub-refraction condition is a situation in which the radio beam travelling in the link is refracted upward and hence the portion of the wave front that is received at the distant end will travel close to the ground than usual. This situation leads to signal degradation (attenuation).

It can also be deduced from the Table 4., that refractivity gradient is highest in April and lowest in January leading to an attenuation of -2.0dbm in April and -0.97 in January [3]. Thus, it is expected that signal reception on the Akure-Owo digital microwave link will degrade more in April and good reception is more likely in January.

5. CONCLUSION

In this study of radio refractivity in Akure-Owo digital microwave link, the result of the study allows us to conclude as follows:

- (i) The effective earth radius factor was computed as 0.973 and 0.974 respectively. This enables one to conclude that there is sub refraction in the link.
- (ii) The refractivity gradient vary, slightly throughout the months of the year, it has its lowest value in January and highest value in April in year 2006.

Finally, this study is intended to serve as a database for the prediction of microwave communication impairment in South Western Nigeria.

6. REFERENCES

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