A TEST OF THE RELATIONSHIP BETWEEN REFRACTIVITY AND RADIO SIGNAL PROPAGATION FOR DRY PARTICULATES

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Abstract

Radio waves or radio signals propagate through the atmosphere in wireless communication. They are affected mostly by variability in radio refractivity which leads to a decrease in their speed or rate of propagation which eventually cause propagation delay or attenuation in the troposphere.The hourly averages of radio refractivity for dry particulates during dry season (January) were calculated from the data obtained from the Nigeria Meteorological Agency (NIMET) when UHF broadcast signal measurement was also taken for each hour throughout the whole day in Akure, Ondo state, Nigeria. However, the statistical correlation (with a correlation coefficient of -0.97) reveals that at different points when the refractivity was high (most especially at night and in the morning when the humidity was high) the signal strength was low and at the points when the refractivity was low (most especially during the day when the humidity was low due to high temperature) the signal strength was higher. Therefore, the higher the refractivity the lesser the signal strength at the point of observation in the troposphere i.e. they are inversely proportional to each other.

Key words: Radio Signal, Refractivity, Troposphere, Dry particulates

I. INTRODUCTION

In wireless communication, Radio signal propagation through atmosphere is a major concern. The atmospheric radio refractive index depends on air temperature, humidity, atmospheric pressure and water vapour pressure. Multipath effects also occur as a result of large scale variations in atmospheric radio refractive index, such as different horizontal layers having different refractivity. This effect occurs most often, when the same radio wave signals follow different paths thereby having different time of arrivals to its targeted point. This may result to interference of the radio wave signals with each other during propagation through the troposphere.Consequently, the large scale variation in the atmospheric refractive index is that radio waves propagating through the atmosphere become progressively curved towards the earth. Thus, the range of the radio waves is determined by the height dependence of the refractivity. Thus, the refractivity of the atmosphere will not only vary as the height changes but also affect radio signal. It is an established fact that electromagnetic signals propagated through the neutral atmosphere are affected by the constituent gasses. The fact that their combined refractive index is slightly greater than unity gives rise to a decrease in the signal's velocity. This increases the time taken for the signal to reach the receiver's antenna, also increasing the equivalent path length. Both effects are often referred to as the "Delay". Refraction also bends the raypath and thereby lengthens it, thus further increasing the delay [1]. Because the bulk of the delay occurs within the troposphere, the whole delay is often referred to solely as the "Tropospheric Delay".

(Adediji A. T., Ajewole M. O., 2008) [2] reported that radio wave propagation is determined by changes in the refractive index of air in the troposphere. Changes in the value of the troposphere radio refractive index can curve the path of the propagating radio wave. At standard atmosphere conditions near the Earth's surface, the radio refractive index is equal to approximately 1.0003
[3]. Since the value of refractive index is very close to unity, then the refractive index of air in the troposphere is often measured by a quantity called the radio-refractivity N, which is related to refractive index, n as:

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

As the conditions of propagation in the atmosphere vary, the interference of radio wave propagation is observed. Such interferences are incident with some meteorological parameters (inversion of temperature, high evaporation and humidity, passing of the cold air over the warm surface and conversely), [4].

The quality of radio wave signal reception and probability of the failure in radio wave propagations are largely governed by radio refractivity index gradient which is a function of meteorological parameters changing in lower atmosphere such as temperature, pressure and humidity. It was established that the propagation media affects radio signals at all frequencies and causes refraction with a time delay of the arriving signal [5]. Focus is made on these propagation media encompassing the ionosphere and troposphere.The atmospheric radio refractive index depends on air temperature, humidity, atmospheric pressure and water vapour pressure. Subsequently, meteorological parameters depend on the height at a point above the ground surface. Variation in any of these meteorological parameters can make a significant variation on radio wave propagation, because radio signals can be refracted over whole signal path [6].

II. Research Methodology

The meteorological parameters collected from Nigeria Metrological Agency (NIMET) were used to calculate radio refractivity. Hourly variations of meteorological parameters for the particular dry day for five minute (5min) interval were recorded for the day in Akure. The average variation of each hour per day was calculated from the recorded data. On hourly basis, UHF broadcast signal strength was taken throughout the dry day at the same point of observation (3.7km line-of-sight with GPS) using a Yagi array antenna coupled through a 50-ohm feeder to the UNAOHM model EP742A field strength meter. For each hour, the calculated refractivity was plotted against the corresponding measured signal strength and statistical correlation was observed.As obtained from Willoughby, et al, 2002 [7]The partial pressure of water e was determined from the equation as follow:

$$e = e_s H \quad (2)$$

where H is the relative humidity, and e_s is the saturation vapour pressure determined by Clausius-Clapeyron equation given as:

$$e_s = 6.11 \exp\left[\frac{17.26(T - 273.16)}{T - 35.87}\right] \quad (3)$$

In relation with the measured meteorological parameters such as the temperature, pressure and relative humidity radio refractivity was calculated using:

$$N = 77.6\frac{P}{T} + 3.37 \times \frac{10^5 e}{T^2} \qquad (4)$$

where
P = atmospheric pressure (hPa)
e = water vapour pressure (hPa)
T = absolute temperature (K)
Equation (4) may be employed for the propagation of radio frequencies up to 100GHz. The error associated with the application of the above formula is less than 0.5% (ITU-R, 2003).

III. Results and Discussion

The hourly calculated refractivity and corresponding measured signal strength for the dry day is as shown in Table 1. The plot of refractivity against measured signal strength is shown in Figure 1.

Hour (hr)	Signal Strength (mV/m)	Refractivity Value (N)
1	64.01	273.04
2	63.08	269.12
3	62.85	267.31
4	64.37	265.06
5	65.92	262.17
6	67.07	260.09
7	68.03	259.11
8	67.58	260.20
9	66.73	261.01
10	61.87	264.02
11	62.54	266.13
12	65.84	262.22
13	67.56	260.23
14	70.15	256.31
15	69.89	257.01
16	68.01	259.02
17	66.75	261.11
18	63.50	268.01
19	61.72	275.06
20	60.84	277.08
21	61.51	275.17
22	61.73	274.21
23	61.74	274.85
24	63.20	272.1

Table 1: Hourly Refractivity values with Corresponding Measured Signal Strength for Dry day

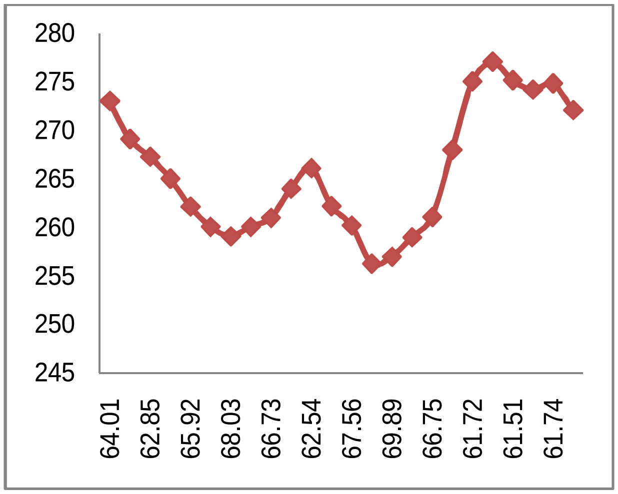

Figure 1: Relationship between Refractivity and Measured Signal Strength

Akure is situated in the tropics at Lat 7.250N, Long 5.20E, altitude 420m above sea level; an agricultural trade centre with light industries and is minimally influenced by industrial pollutants or aerosols. The hourly average values of radio refractivity plotted at 1-hour interval were observed to posses similar characteristics. Radio refractivity were observed to fall from the midnight hours (between 1:00-6:00hrs) owing to the decrease in humidity within that period of the day. Between 8:00-21:00hrs, radio refractivity wereobserved to almost increase at a constant rate while the signal strength decreases becauseof the presence of fog noticed in the early hours of theday during the period which causes humidity to varyresulting also to change in radio refractivity. At about20:00hr, radio refractivity was found to increase to apeak value while the signal strength decreased and between 22:00-24:00hrs it decreasedagain to a lower value resulting fall in refractivity with a rise in measured signal strength.

Statistical correlation was performed on the calculated refractivity and measured signal strength for the dry day using equation 5.

$$\text{Correlation}(r) = \left[N\sum XY - \frac{(\sum X)(\sum Y)}{\sqrt{([N\sum X^2 - (\sum X)\hat{}2][N\sum Y^2 - (\sum Y)\hat{}2])}}\right] \qquad (5)$$

Where

- N = Number of hours in the day
- X = Hourly Measured Signal Strength
- Y = Hourly Refractivity Value
- $\sum XY$ = sum of the product of hourly measured signal strength and refractivity value
- $\sum X$ = sum of the hourly measured signal strength
- $\sum Y$ = sum of the hourly refractivity value
- $\sum X^2$ = sum of square hourly measured signal strength
- $\sum Y^2$ = sum of square hourly refractivity value

The correlation coefficient gives–0.97. This means as refractivity value gets larger the measured signal strength gets smaller which implies inverse correlation.The result of this research work ascertained the inverse proportional relationship that exists between refractivity and signal propagation as contained in the Willoughby et al (2002) [7].

CONCLUSION

This paper examines the relationship that exists between refractivity and radio signal propagation. Hourly refractivity values were calculated from hourly meteorological parameters obtained from NIMET (Nigeria Meteorological Agency) and UHF signal strength measurements was taken for each hour of refractivity calculation was made. Statistical correlation revealed inverse relationship between refractivity and radio signal propagation i. e. as refractivity gets bigger the measured signal strength gets smaller and vice versa.

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