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Signal Strength Dependence on Atmospheric Particulates

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Abstract

Our research examines the effect of rain on signal strength dependence on atmospheric particulates. A series of meteorological and signal strength measurements were taken before and after heavy downpour. From the result, marked improvement in propagation signal strength corresponding to clear-sky condition was measured. This study suggests that clear-sky refractivity response is a useful indicator of signal profile traversing the atmosphere and its fluctuations determining nominal signal degradation.

Keywords: Clear sky, signal field strength meter, modified refractivity, atmospheric particulates

Introduction

The ionosphere and the neutral atmosphere induce propagation delays. In the neutral atmosphere, delays are induced by refractivity of gases, hydrometeors, and other particulates, depending on their permittivity and concentration, and forward scattering from hydrometeors and other particulates. Changes in temperature, moisture, and pressure in the atmospheric column cause a change in atmospheric density, which in turn causes variations in the intensity of waves in both the vertical and horizontal. The delays can be subdivided into dry hydrostatic delay (N_D) and wet hydrostatic delay (N_w), which are quantifiable using the modified refractivity (M [in N-unit]) expression accounting for the curvature of the earth [1]:

$$M = N_D + N_w + \frac{z}{r_g} \tag{1}$$

where the dry and wet hydrostatic delays are represented by [2] [3]:

$$N_D = k_1 \frac{P}{T} \tag{2}$$

$$N_w = k_2 \frac{e}{T} + k_3 \frac{e}{T^2} \tag{3}$$

T is temperature [in kelvin, K], *e* is the water vapour [hPa] and P is the hydrostatic atmospheric pressure [hPa]. The constants k_1, k_2 and k_3 have values 77.6848, 71.2952 and 375463 respectively [4]. The water vapour is derived from the relative humidity H [%] and temperature *t* [deg C] using the expression [5]

$$e = 0.061121 H \exp\left\{\frac{17.502t}{t + 240.97}\right\} \tag{4}$$

Also, z is the atmospheric altitude (km) and r_g is the geometric radius due to the elliptical nature of the Earth's orbit (in km) given by [6]

$$r_g \approx r_e\left(0.99832 + 0.001684\cos 2\theta_{lat} - 0.000004\cos 4\theta_{lat}\cdots\right) \tag{5}$$

where r_e is the radius of the earth at the equator [km] and θ_{Lat} is the location latitude [degree].

Dry particulates including aerosols vary in time and in space and could impact atmospheric radiactive properties and signal propagation physics. Under normal circumstances, the majority of aerosols form a thin haze in the lower atmosphere (troposphere), where they are washed out of the air by rain about a week [7]. Human activities increase daily and build up in aerosols and particulates also increase. As such most dry hydrostatic components would be washed during rain. Our research examines the effect of rain on signal strength dependence on atmospheric particulates.

Measurement

Akure, in Ondo State of Nigeria, is used as the study area. It is situated in the tropics at Lat 7.25^{o}N, Long 5.2^{o}E, altitude 420m above sea level; an agricultural trade centre with light industries and is minimally influenced by industrial pollutants or aerosols. A series of readings of television broadcast signal strength were carried out in the UHF band (470 - 862 MHz) using Yagi array antenna coupled through a 50-ohm feeder to the UNAOHM model EP742A field strength meter, during the dry periods and after heavy downpour. In addition, dry and wet temperature, saturated water vapour and relative humidity measurements were collected of selected open spaces. This series of measurements allows us to study the atmospheric effect before and post rain, particularly effect of hydrometeors and particulates on radio signals.

Result

Refractivity values of the pre-rain (dry) period and after downpour (post-rain) periods were derived and compared with broadcast signal strength measurements. Plots of pre-rain period and post-rain period are, respectively, shown in Figures 1 and 2.

Signal strengths' statistical means of 36.54dB and 55.25dB, and standard deviations of 2.98 dB and 7.70 dB, were respectively estimated for dry and after downpour. An average of 18dB gain in signal strength after heavy downpours, which could be considered clear-sky, points to washing away significant atmospheric particulates as well as hydrometeors. In contrast, there is a small difference between the average saturated water vapour in both periods: 31.96 ± 0.84 hPa for dry period and 29.94 ± 1.20 hPa for post rain period. This study shows that there is correlation between the signal link measurements and atmospheric refractivity gauges.

The Least square regression analysis of our measurements establishes the following relationships between signal link measurement, S [dB] and refractivity, M [N-unit], for the pre-and post-rain periods, as well as their correlation coefficients, R^2:

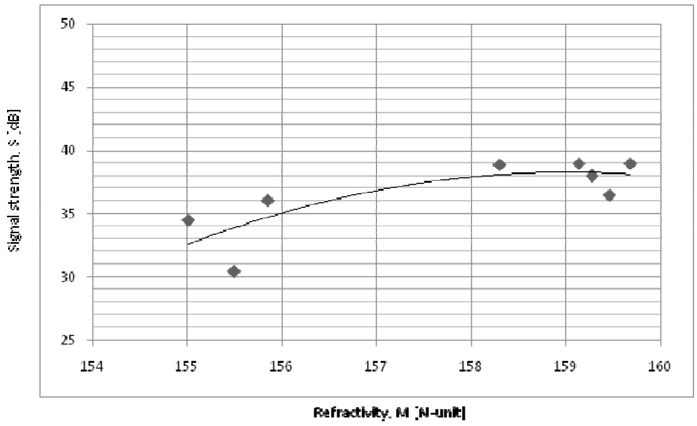

Figure 1: Dry hydrostatic response.

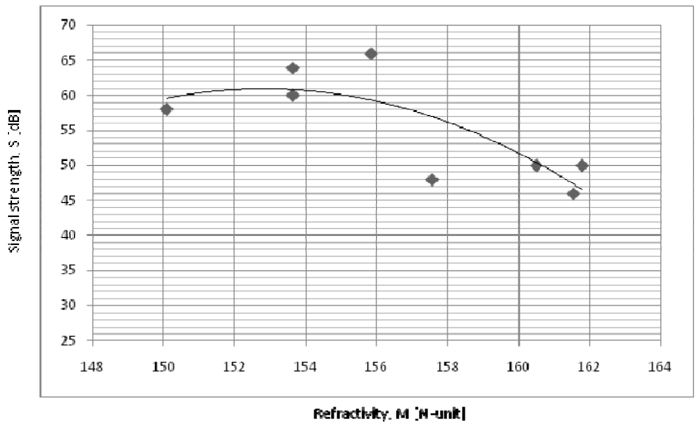

Figure 2: Clear-sky hydrostatic response.

Pre-rain (dry condition)

$$S_{pr} = -8873 + 112.0 M_{pr} + 0.352 M_{pr}^2 \; R^2 = 0.640 \qquad (1)$$

Post rain (clear-sky condition)

$$S_{po} = -4144 + 55.03 M_{po} + 0.180 M_{po}^2 \; R^2 = 0.634 \qquad (2)$$

where subscripts “pr” and “po” denote ‘pre-rain’ and ‘post-rain’.

The study suggests that the clear-sky refractivity response provides a window to the behavioural pattern of signal traversing the atmosphere, including the signal links’ degradation.

Conclusion

The study has demonstrated the dependence of refractivity on the physical structure of the atmosphere implying that changing meteorological conditions can lead to changes in radio wave propagation. The study suggests that clear-sky refractivity response can be used for radio-link planning for anticipating nominal level of signal degradation.

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