Impacts of Weather and Environmental Conditions on Mobile Communication Signals

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Abstract

The impacts of weather and environmental conditions on mobile communication signals were determined in this study. A Glo mobile communication network operating in the 900MHz band was considered. The Glo fixed base transceiver station (BTS) location at Gloworld in Benin City was considered. A frequency-signal tracker software, version 2.5.1 was installed and configured into a notebook Intel palm top, relative parameters data were obtained from 200 meters from the Glo BTS from 28th of July to 31st of August 2016, with data obtained hourly. Morning, afternoon and evening, and dry weather, fog weather and raining conditions was based on the statistical central tendency parameters. The average refractivity gradient observed was -61.3 N/km. It was observed that dry weather, signal strength variation was within 32 dBm, fog, variation was within 34 dBm range, while the variation of rain was within 38 dBm range indicating higher variation. It was observed that the more the mobile station move away from the BTS the higher the signal loss and that temperature and refractivity gradient has 0.50 and 0.42 positive correlations. In addition, relative humidity and pressure possesses negative correlations of -0.50 and -0.44 respectively.

1. Introduction

To ensure large number of mobile subscribers are being accommodated in a mobile cellular system low-power wireless transmitters are being deployed to create cells. The transmitter power level in a cell is used to determine subscriber density and demand with in a specific region. As mobile subscribers migrate from one cell to another, their conversations channels are handed off between the cells. Transmission channels deployed in one cell can also be reused in other distance cells. Hence, larger mobile subscribers can be accommodated in a wide range of radio frequencies. The mobile stations are linked with base station communication through the uplink and down link transmission channels. The base station covering a specific geographical area called a cell is allocated with a group of radio channels. Moreover, the issue of interference of signal between close cells must be within tolerable limits (Shoewu et al., 2014).

The radio signal propagation characteristics are diffraction, reflection and scattering. These radio signal phenomenon can cause signal distortion, resulting to signal fading and propagation losses (Dalip & Kumar, 2014). In the establishment of any wireless or radio communication system, it is important to study the propagation features of the site and possible causes of signal loss. This study is aimed at analysing the impacts and ways of overcoming them. Although, the uplink and downlink are bidirectional between mobile station and base station, the system is designed to supply adequate signal strength from the base station to mobile station (Dalip & Kumar, 2014; Osahenvemwen & Omorogiuwa, 2013). The signal strength received by the mobile station depends on the distance from the base station, condition of weather and the prevailing environmental meteorology (Omorogiuwa & Okundamiya, 2015).

In the cellular system design, the signal strength plays a vital role between the mobile station and the base station. A base station is cited in such a way that it provides enough signal for the operation of a mobile station within it coverage area (Emeruwa, 2015). A crucial component of any propagation environment is the path loss.

Correct approximation of the propagation losses can enable for proper selection of the base station locations in addition to an accurate determination of the frequency plan. With the knowledge of the propagation characteristic losses, one can efficiently determine the field strength, interference and signal-to-noise ratio (Tonga et al., 2015).

The growth of mobile cellular network has witnessed a lot of development leading to a high level of reliability (Okundamiya, 2015). The ability of mobile networks to establish and maintain calls are perhaps one of the major concerns of both consumers (network users) and the network operators. Transmitted signal move through the atmosphere before getting to the mobile station, this signal has encounter with atmospheric parameters such as temperature, pressure and humidity in addition to environmental factors. Due to these atmospheric parameters and environmental factors the signal witnessed distortion and attenuation of signal level. In addition, signal variation and distortion are different from one distance to another (Ogbulezie et al., 2013, Shoewu et al., 2014; Osahenwenwen & Omorogiuwa, 2013).

2. Materials and Methods

Signal strength measurements were carried out using a software known as a Radio Frequency-Signal tracker, version 2.5.1 was installed and configured into a notebook Intel palm top. The system was used to measure and record GSM signal strength at each 200 meters from a fixed base transmitter station planted at Gloworld, at 58 Mission Road Benin City from on the 28th of July to 31st of August 2016. The measured values were used to determine activity factors for the cellular phone network. The analysed data were expressed over 12 hours showing the mobile phone traffic activity for that particular base station. Data were measured at dry weather for signal strength in every one hour of a day; this same measurement was carried out for fog and rainy day at similar time and the same locations.

The same experiment was repeated in the afternoon and evening respectively. Also the experiment was repeated for fog weather and rain weather conditions for comparison of result. Data (shown in Table 1) were analysis based on statistical central tendency parameters and using Microsoft excel software for graphical presentation; the events of rain and signal strength were also investigated at different frequencies. The collected data per km at frequencies of 10, 30, and 100GHz as a function of rain rate were determined. Refractivity gradient were obtained hourly and other atmospheric parameters collected from the Nigerian Meteorological Centre, Edo station. A computer (with RF-signal tracker software) was mounted on a vehicle to measure and record both signal and GPS position formation. The recorded signals are the control channels, which were identified as belonging to the base station. A technique (known as ray tracking) was used to find signal strength through wave propagation in the same geographical area.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Morning</th>
<th>Afternoon</th>
<th>Evening</th>
<th>Average</th>
<th>Fog</th>
<th>Rain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>-76.0</td>
<td>-73.0</td>
<td>-74.0</td>
<td>-71.0</td>
<td>-77.0</td>
<td>-84.0</td>
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<tr>
<td>Max</td>
<td>-39.0</td>
<td>-38.0</td>
<td>-41.0</td>
<td>-39.0</td>
<td>-43.0</td>
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<tr>
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<td>-56.0</td>
<td>-54.0</td>
<td>-55.0</td>
<td>-53.0</td>
<td>-57.7</td>
<td>-65.3</td>
</tr>
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<td>Median</td>
<td>-55.5</td>
<td>-53.5</td>
<td>-52.5</td>
<td>-49.0</td>
<td>-53.0</td>
<td>-66.0</td>
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<tr>
<td>Mode</td>
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<td>-54.0</td>
<td>-56.0</td>
<td>-41.0</td>
<td>-61.0</td>
<td>-</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>13.2</td>
<td>11.2</td>
<td>12.0</td>
<td>11.3</td>
<td>12.1</td>
<td>13.7</td>
</tr>
<tr>
<td>Range</td>
<td>37.0</td>
<td>35.0</td>
<td>33.0</td>
<td>32.0</td>
<td>34.0</td>
<td>38.0</td>
</tr>
</tbody>
</table>

2.1 Refractivity Gradient

An investigation on the impacts of refractivity on GSM signal operating at 900MHz and measurement of troposphere variables such as relative humidity, pressure, temperature and relative signal strength were obtained from Benin Meteorological Centre. In addition, other data obtained from the meteorological centre was weather parameters used to determine the radio refractivity, refractivity gradient, vapour pressure and effective earth radius factor. It was deduced that refractive index is a function of water vapour content, pressure and temperature. The refractivity N is determined by (1). The ideal range of refractive index (N) from (1) lies between 250 and 400 N units.

\[ N = (n - 1) \times 10^6 \]  

(1)

Radio refractivity N is given in (2) as follows:

\[ N(\rho, T, e) = N_{dry} + N_{we} = \frac{77.6\rho}{T} + 3.732 \times 10^5 \frac{e}{T^2}, \]

(2)
where, \( P \) represents the atmospheric pressure, \( e \) represents the water vapour pressure, and \( T \) represents the temperature (K). Equation (2) can be deployed for mobile radio frequencies less than or equal to 100 GHz with less than 0.5% error. The water vapour pressure (\( e \)) can be deduced using the equation:

\[
e = \frac{H_R e_s}{100}
\]

(3)

\( H_R \) is the relative humidity, \( e_s \) is the saturation vapour pressure (hPa) at a given temperature, \( t \) (°C) is deduced from the equation:

\[
e_s = a \times \exp\left(\frac{b t}{1 + c}\right).
\]

(4)

Coefficients \( a = 6.1121 \) hPa, \( b = 17.502 \) and \( c = 240.97°C \) above liquid water and above ice; \( a = 6.1115 \) hPa, \( b = 22.452 \) and \( c = 272.55 °C \). The coefficients above liquid water were used in this study.

From (2), the refractivity index \( N \) varies inversely with temperature \( T \) and is strongly dependent on water vapour pressure \( e \). \( N \) decreases exponentially in the troposphere with height as follows:

\[
N = N_s \times \exp\left[-\frac{h}{H}\right]
\]

(5)

where \( N \) is the refractivity at \( h \) (km) above the sea level where the refractivity is \( N_s \) while \( H \) is the applicable scale height. The suggested values of \( N_s \) and \( H \), at average of mid-latitude are 315 and 7.35 km respectively. Hence, \( N \) is a function of the height given in (6).

\[
N = 315e^{-0.136h}
\]

(6)

The refractivity gradient from (5) is given by:

\[
\frac{dN}{dh} = -\frac{N_s}{H} \exp\left[-\frac{h}{H}\right]
\]

(7)

The ideal refractivity gradient is given as -39N units/km with the condition of \( b < 1 \) km, were \( dN/db \) is used to determine the ray path or the curvature of the radio wave. The effective earth radius factor \( (k) \) can be used to characterise refractive conditions as normal refraction, sub-refraction, super-refraction and ducting, which can be expressed in terms of refractivity gradient as follows:

\[
k = 1 + \left(\frac{dN}{dh}\right)/157\]

(8)

The near earth’s surface, \( k = 4/3 \) is referred to as standard atmosphere or normal refraction. Under this condition, radio signals travel on a straight line path along the earth’s surface and go out to space unobstructed.

3. Results and Discussion

The impacts of these environmental factors relative to the geographical position, using mobile phone and the fluctuations in weather on the measurement signal strength investigated from 28th of July to 31st of August 2016 are presented in Figures 1 – 5. It was observed that the level of signal varies considerably among severe allocations, but remains similar across same location with different times for the study. Diurnal variation of mobile signal strength is presented in Figure 2. From the average signal strength at different weather as being plotted in Figure 3, at dry weather, signal strength variation was within 32dBm range and fluctuations were not that pronounced compared to the case of rain or fog.

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**Figure 1**: Signal strength observed across different locations (dry weather)
During the period of fog, the variation was within 34dBm range; indicating higher range compared to that at dry weather. Also, during the period of rain, the variation was within 38dBm range indicating higher variation and thus more attenuation compared to dry and fog weather. The observed low signal from a distance of 1.4 km from the BTS was due to increase in rain rate. Therefore, the dry weather has lesser signal attenuation compared to fog and rain weather. Moreover, the more the mobile station move away from the BTS the higher the signal loss.
In Figure 4, the observed signal attenuation in decibels per km at frequencies of 10, 30, and 100GHz are in the function of rain rate. At 10GHz and below, the attenuation due to rain was relatively small since typical line-of-sight to large paths is 20 to 30km in length. Attenuation rates of 1dB or more per km can lead to a large decrease in signal strength. The refractivity gradient is mostly used to determine the weather impact on the signals shown in Figure 5. It was observed that refractivity gradient obtained is not linear, and there was a decrease in the morning hour at 10.00 hours to a value of -79.4N/km and then it begins to rise to -41.2N/km at about 4.00 pm.

![Figure 5: Average refractivity gradient (dN/dh) values for the entire measurement](image)

The -61.3N/km was the average value obtained from the seven days hourly record. Both positive correlation obtained for temperature and refractivity gradient are 0.50 and 0.42 respectively. Negative correlation for temperature and refractivity gradient are -0.50 and -0.44 respectively. Based on obtained result, it was observed that the location under investigation has an impact of environmental factor on the received signal strength.

The coverage measurement of signal strength was based on the receiver’s power and variations from one location to another was due to the obstacles along the way. The signal strength received by the mobile phone depends on the distance from the base station and the environment between the mobile stations. Signal strength experienced behind the hill, trees and houses in the path between the base station and mobile station result to reduced signal strength. At a constant rain rate, GSM signal attenuation is directly proportional to frequency, increase in frequency lead to increase in attenuations.

4. Conclusion

The impact of weather and environmental conditions on mobile communication signals was determined in this study. The dry weather, signal strength variation was within 32dBm range and fluctuations were not that pronounced compared to the periods of rain or fog. During fog, the variation was within 34dBm range; indicating higher range compared to dry weather. Similarly, the variation was within 38dBm range, during rainy periods, indicating higher variation and thus more attenuation compared to dry and fog weather.

Vertical space diversity should be incorporated to overcome fading. This involves the use of two vertically separated antennas at the transmitter and a signal comparator at the receiver. Signal booster (repeater station) should be installed at strategic positions or either the antenna gain or the transmitter power should be increased in other to boost the signal strength. Antenna gain or transmitter power should be increased to minimise attenuation problems. Telecom Engineers should always have in mind that the coverage area of a mast should not be too far, else more repeater stations will need to be installed along the path of the mast to correct the problems of poor signal and to amplify signal more in other to be reached by various subscribers within the network.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.
References


