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Impact of Atmospheric Variables, Radio Resource Control and Call Drop on Radio Frequency Signals Attenuation in Wireless Communication Networks

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Abstract: In our increasingly interconnected society, wireless communication networks are essential for facilitating smooth data transfer and communication across long distances. Radio frequency signals are used in communication networks for flawless message delivery, whether you're calling, texting, or streaming video. The quality of these signals, however, can be impacted by variables like temperature, precipitation, relative humidity, and others, which can result in attenuation, deterioration, and subpar network performance. The impact of temperature and humidity on RF signal attenuation is the main emphasis of this research, even if other atmospheric conditions also contribute to signal attenuation. In this paper Radio resource control, call drop, temperature and relative humidity data were sourced from Globacom communication and Nimet, north central office in Nigeria. The results indicated clearly that relative humidity contributed largely to signal attenuation while temperature, RRC and call drop parameters closely follows for the period evaluated.

Keywords: Radio resource control, call drop, temperature, relative humidity

1. Introduction

Radio Frequency (RF) channels, has become an integral part of our daily lives, in today's interconnected wireless communication systems, enabling seamless connectivity and information exchange. A strong and stable signal allows for uninterrupted communication between devices and networks. A weaker signal can result in data loss or corruption, leading to disruptions in voice and video calls, slow internet speeds, and delayed or failed network access [1]. a well-maintained RF signal minimizes the occurrence of transmission errors, reducing the need for retransmissions. This, in turn, enhances the networking capabilities, leading to faster data transfers, reduced latency, and improved user experience. It is evident that a variety of parameters, including propagation and transmit power, affect how well an RF energy harvesting system performs [2].

It is essential to look at the things that can make a signal less effective as we depend more on it for voice, data, and multimedia communication. These elements have the potential to greatly affect the caliber and dependability of our priceless relationships. As fundamental climatic factors, temperature and humidity can have a direct impact on signal coverage and quality attenuation. The impact of temperature and relative humidity on RF signal attenuation is the main topic of this thesis, which employs the north central (FCT) Nigerian environment as a case study. However, a thorough knowledge and accurate measurement of how these variables affect transmitted signal intensity or induce its attenuation are still lacking. This paper aims to present a thorough empirical analysis of the effects of humidity and temperature on RF signal attenuation in wireless communication networks by investigating the relationship between humidity and temperature in relation to the transmission of radio frequency signals in wireless networks.

Transmission interference is one important issue that might affect the quality of the transmission. The disruption or deterioration of the signal brought on by outside influences is referred to as signal interference. Environmental settings, physical barriers, electrical gadgets, and meteorological variables like humidity and temperature are a few examples of these influences [3]. There are various types of signal interference, such as adjacent channel interference, co-channel interference, and multipath interference. Signal distortion results from multipath interference, which occurs when signal waves bounce off obstructions and travel via several routes before reaching the receiver. When several devices use the same frequency, co-channel interference happens, resulting in signal overlap. Signals sent on adjacent frequency bands can interfere with one another, causing adjacent channel interference [4].

Temperature alters several important characteristics of RF signal attenuation. The atomic mobility in the atmosphere increases with temperature, leading to a rise in molecular collisions. RF signals are absorbed and scattered as a result of these collisions, which eventually results in their attenuation. As the temperature rises, the loss gradually but marginally decreases [5]. The presence of moisture causes a number of issues for our radio frequency signals because water molecules have a tendency to absorb radio frequency energy. As humidity levels rise, these water molecules begin to absorb the RF signals, which weakens and attenuates them. It's as if our wireless communications are engaged in a conflict with the unseen forces of moisture. Temperature and relative humidity have an inverse relationship with signal strength, but their combined effects are much more pronounced in harmattan than during the rainy season [6].

[7] examines how air temperature affects the intensity of the signals produced by FM transmitters in Imo State, Nigeria. Investigating how air temperature affects FM transmitter signal strength in Imo State, Nigeria, was the main goal of Bassey D.'s study. The study measured the variations in signal strength under various temperature circumstances using statistical analysis and empirical data collection. The findings showed a strong relationship between signal strength and air temperature. The work is relevant to our understanding of how temperature affects FM transmission, particularly in areas with varying climates. [8] studied the impact of rain-induced signal fluctuations and attenuation.

2. Materials and methods

the ITU-R water vapor-based suggested model is used to analyze the effects of temperature and humidity on signal attenuation. It has been provided by equation (1)

$$g(f, f_i) = 1 + \left(\frac{f - f_i}{f + f_i}\right)^2 \tag{1}$$

where:

f =Transmission frequency (GHz) f_i = Varied Transmission frequency (GHz)

ρ = water-vapour density (g/m^3), p = pressure (hPa)

$r_p = p / 1013$, $r_t = 288/(273 + t)$, t =temperature (°C).

This study included a quantitative research methodology and secondary data collection approaches. The atmospheric data, which included temperature and relative humidity readings, was supplied by the Nigerian Meteorological Agency (NIMET) north central office, Nigeria.

Furthermore, the Globacom (GLO) north central office provided the cell report data for LTE. Precisely, the LTE data provided are from the federal Capital Territory, Abuja (fig. 1). To assess the operation of the local LTE network, metrics such as dropped call rates and Radio Resource Control (RRC) were incorporated into the data.

Atmospheric and cell report data were collected twice a month, respectively, the data collection period ran from January to December 2019. The data was then preprocessed and analyzed using

Matlab (R2024a) tools.

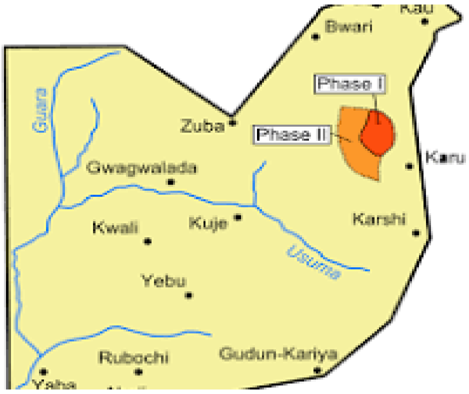

Fig. 1: Map of FCT, North central Nigeria.

Abuja is situated in central Nigeria on a grass hill at an elevation of about 1,180 feet. The land area is located on 7 E longitude and 9 15' latitude. A straight line is projected westward to a point on the Kemi River just north of Lefu; a line is then projected southward along 6 47½' E, passing near the villages of Semasu, Zui, and Bassa, down to a point just west of Ebagi; from there, a line is projected parallel to 8 27½' North latitude to Ahinza village 7' E (on Kanama River); then draw a line northward connecting the villages of Odu, Karshi, and Karu; after that, project a straight line to Bugu village at 8 30' North latitude and 7 20' E longitude. From Karu, the line should follow the border between Benue-Plateau (Nassarawa) and North-West States as far as Karu; from there, it should follow the border between North Central (Kaduna) and Northwestern (Niger) States until it reaches the area immediately north of Bwari village; from there, it should continue straight to Zuba village; and finally, it should continue straight to Izom.

3. Result and discussion

Temperature variations can have noticeable effects on RF signal strength and quality. As temperatures rise, the refractive index of the atmosphere changes, causing RF signals to bend and scatter. This bending, known as refraction, can result in signal losses, increased interference, and reduced coverage. Similarly, colder temperatures can also affect signal performance. Low temperatures can cause equipment malfunctions, such as frozen components or condensation buildup, leading to signal degradation [5]. As humidity increases, RF signals tend to experience higher levels of attenuation or signal loss. This attenuation occurs because the water molecules in the air absorb and scatter the RF waves, weakening the signal as it travels through the atmosphere. Higher humidity levels can result in a decrease in signal strength and coverage. This can lead to dropped calls, slower data speeds, and reduced signal quality for mobile users. Consequently, network operators need to take into account the effects of humidity when planning and optimizing their cellular networks [8]. disturbance in signal transmission of wireless communication can impact the overall quality of service delivered by the network operator [10].

Figure 2, shows the specific attenuation of temperature and relative humidity. As the temperature and relative humidity increases along the distance, there is increase in attenuation leading to disruption in signal transmission.

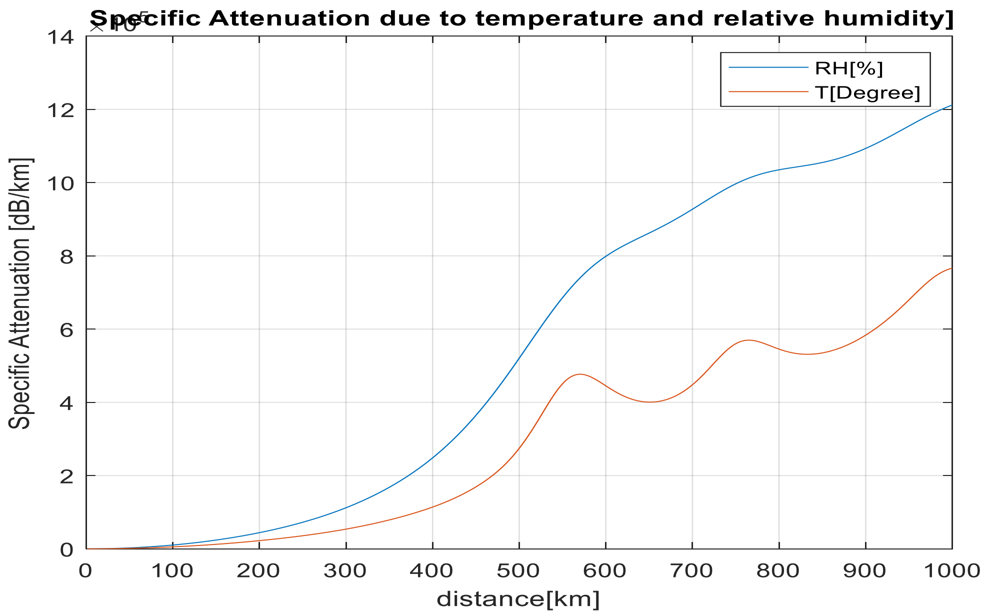

Fig 2: Specific antennation due to temperature and relative humidity.

From figure 2, as the relative humidity increases, the specific attenuation increases as well. It is observed from the figure, that there is more specific attenuation due to relative humidity compare to temperature. This implies that, for this specific period, relative humidity contributed more to signal degradation than the temperature factor. For instance, at a distance of 800km, the specific attenuation due to relative humidity is about $10.5 x 10^5$ dB/km while that of temperature is around $5.3 x 10^5$ dB/km.

In order to ensure the smooth operation of mobile networks, radio resource control (RRC) is essential. It is vital for managing how and when devices access network resources, which directly impacts the quality-of-service users experience. Without effective RRC, networks would experience congestion, which would result in dropped calls and slow data speeds. RRC optimizes resource allocation, ensuring that each device gets the necessary bandwidth and minimizes interference with other devices, which is especially important in densely populated areas where many devices are competing for the same resources. Without RRC, mobile devices would find it difficult to establish and maintain efficient connections.

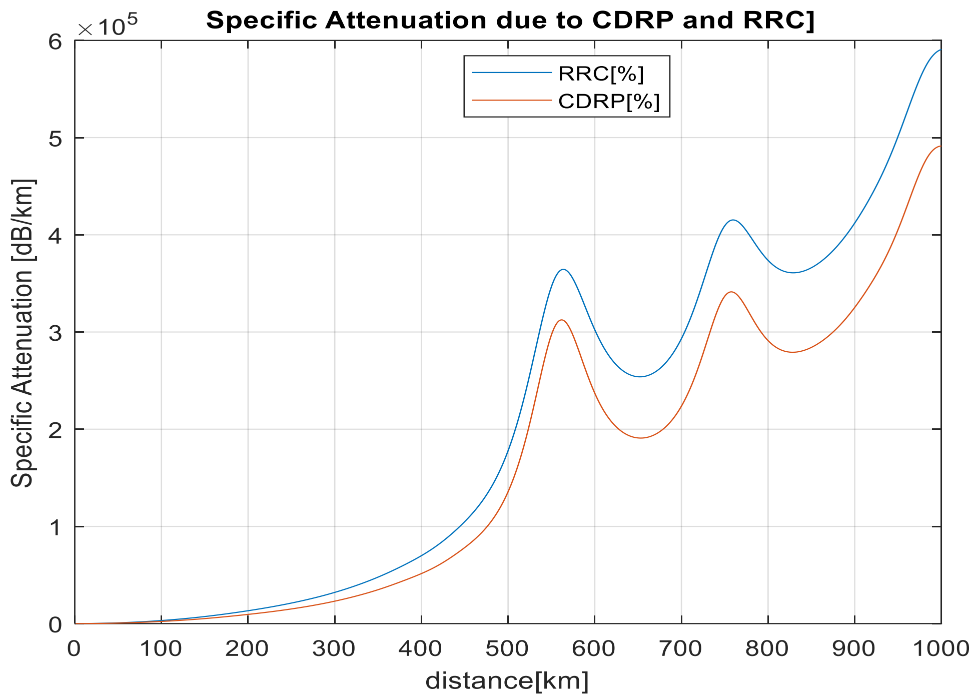

Fig.3: specific attenuation due to radio resource control (RRC) and call drop (CDRP).

In figure 3, the relationship between RRC and CDRP is linear as seen from the graph. It is noticed also that, at a distance of 800km, the specific attenuation due to RRC is about $3.8\text{x}10^5$dB/km while that of call drop is approximately $2.9\text{x}10^5$dB/km. implying that at that particular distance of 800km, there is more signal attenuation occurring due to RRC than that of call drop. Once there is a percentage increase in RRC, the call drop increases as well this is also evident in figure 4.

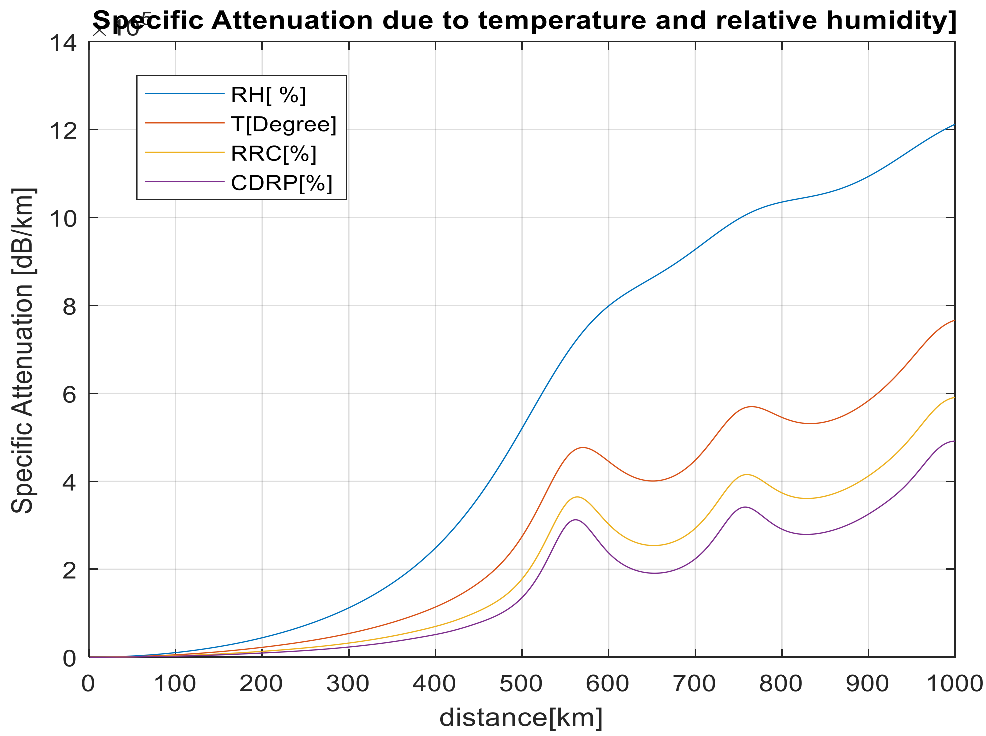

Fig.4: specific attenuation due to LTE and some atmospheric parameters.

Figure 4, shows clearly the relationship between the variables considered in the paper. Relative humidity contributed largely to signal attenuation while temperature, RRC and call drop parameters closely follows.

4. Conclusion

The study examined the relationship between temperature, relative humidity, radio resource control and call drop and their effects call drops on signal attenuation in FCT North-Central Nigeria. the study demonstrates a correlation between RRC performance and temperature and relative humidity, meaning that as these metrological factors rise, RRC performance may likely rise as well. However, there is a clear relationship between these factors (temperature and relative humidity) and call drop rates, indicating that higher relative humidity and temperatures may probably lead to higher signal attenuations.

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