



# Impact of Maritime Environmental Factors on the Deployment of Long-Term Evolution (LTE) Networks: A Case Study of the Forcados-Ogulagha Region of Delta State, Nigeria

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## Authors' contributions

*This work was carried out in collaboration among all authors. Authors URN and ZJT designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors OEP and SOS managed the analyses of the study and managed the literature searches as well. All authors read and approved the final manuscript.*

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## ABSTRACT

This study investigates the impact of maritime environmental factors on the deployment of Long-Term Evolution (LTE) networks, focusing on the Forcados-Ogulagha region of Delta State, Nigeria. The research examines how different environmental conditions, such as sea state, atmospheric conditions, and terrain, affect LTE signal propagation. Data were collected over 18 months using Cluster Drive Testing (CDT) to capture various seasons and weather patterns. The results highlight the significant influence of environmental factors on LTE pathloss, with clear air conditions over freshwater showing the least attenuation, while wet air over saltwater presents the most challenging conditions for signal propagation. The combination of high humidity and the reflective nature of saltwater in the study location led to increased path-loss and reduced signal strength, making it the most challenging scenario for LTE network deployment either the saltwater surface causes multipath propagation, potentially affecting signal quality. This study provides valuable insights for optimizing LTE network deployment in maritime environments

*Keywords: LTE pathloss; maritime environment; signal propagation and network deployment.*

## 1. INTRODUCTION

The deployment of Long-Term Evolution (LTE) networks in maritime environments presents unique challenges, primarily due to the impact of environmental factors on signal propagation. LTE networks are designed to deliver high-speed internet and voice services, which depend heavily on accurate pathloss modelling. Pathloss, the attenuation of signal strength as it travels through space, is influenced by various environmental factors such as sea state, atmospheric conditions, and terrain [1]. Maritime environments, with their dynamic sea surface, high humidity, and variable atmospheric conditions, introduce additional difficulties to LTE network deployment [2] Zhimwang et al., 2022).

It has been noticed that water acts as an obstruction to radio wave transmission. When water is in the transmission path, the radio wave will be redirected, reflected, and re-transmitted. These processes cause attenuation of the radio wave by absorbing its energy, and this behavior is most prominent in the VHF and UHF bands [3, 4]. However, for frequencies higher than 900 MHz, the direct absorption of energy by water molecules is already significant. This water absorption factor leads to infinite path loss at certain frequencies. This is caused by the behavior of water molecules as dipoles when subjected to electromagnetic waves, which causes them to collide and rotate in sync with the frequency of the electromagnetic field [5,3]. The rotation of the molecules heats the water. If the frequency increases, the dipole rotation behavior becomes faster, resulting in higher energy absorption. Oxygen molecules also follow the electromagnetic wave field and similarly absorb

energy from water molecules [6]. This entire water absorption mechanism leads to path loss for radio waves at specific frequencies where the behavior of water and oxygen molecules becomes resonant. According to ITU in Recommendation ITU-R P.841-8: "The mobile radio wave can propagate above the water surface when the received field strength over the water is greater than that over reflecting land for the same distance from the transmitter." This is because there is less absorption above the water surface than the path across water Igbekele et al., 2020; Zhimwang et al., [7].

Additionally, reflection, which causes signal pathloss in the maritime terrain, is the process of incident energy impinging on a water surface and then being scattered in many different directions. This occurs from a water surface because of the different refractive indices of air and water. The Fresnel laws give the amount of energy reflected and transmitted at an interface and the angle at which the reflection occurs [8,9,3,4].

The Forcados-Ogulagha region in Delta State has faced network interference over the years, resulting in various network challenges and a decline in user experience quality. This environment is a stretch of river that runs through Sagbama in Bayelsa State, Nigeria. It is part of the larger Niger and rises in the swampy lowlands that empty into the Gulf of Guinea. It is an important transportation route for the Niger Delta, connecting the region to the nearby port city of Warri. The river is one of the centers of offshore oil exploration activities and maritime fishing. These economic activities demand effective communication services to aid reliable communication between ship-to-ship, ship-to-

shore, and person-to-person communication applications. However, the performance of the present broadband communication system in this region has not been fully optimized for maritime applications. One major setback is the signal interference due to ship movement and the presence of a path mixture of trees and water bodies. This interference from the terrain's heterogeneous nature, ship's movement, sea state, and atmospheric parameters such as humidity, temperature, atmospheric air pressure, and wind speed in no small measure has caused signal path loss in the region [10,9,7].

## 2. MATERIALS AND METHODS

### 2.1 Experimental Sites

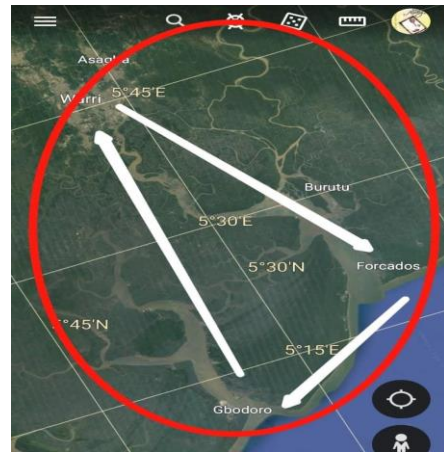
The Forcados-Ogulagha River and the Escravos water in Delta State are the experimental sites for this study. To measure the signal strength, a total of eighty base transmission sites were surveyed, four maritime sites were chosen to symbolize a typical mixed-path ecosystem. The Warri-Burutu River is position number one, the Forcados-Ogulagha River is location number two, the Yokri-Ogidigbe River is location three, and the Escravos-Okerenkoko River is site four. The surroundings included shipyards, islands, extensive mangrove forests, freshwater and saltwater, and linear communities.



**Picture 1. Fresh water and saltwater surveyed area**

The survey was conducted in the Old Forcados River, covering a total distance of 172 km and an area of 1,542 km<sup>2</sup> bounded by latitude 50.151N and longitude 50.451E. The surveyed area is outlined in Pic 1, and the direction of the survey is depicted by arrows in pic 2. Pic 1 also shows the regions covered by freshwater (red area) and

salt water (yellow area). These areas are of interest due to their economic value and unique geographical and environmental conditions, which may impact network performance.



**Picture 2. Map of the direction of the surveyed routes**

### 2.2 Experimental Setup and Data Collection

LTE signal receiving equipment, high gain directional antenna, a base station, and data logging devices for the recording of the received signal strength were used at each selected measurement location at every 0.02km along the river surface. Both the measuring instruments and the materials used for the study were organized to achieve a comprehensive experimental setup that enabled an efficient signal survey. This setup had two categories; the setup for signal propagation and the setup for the Drive Test (DT).

Data were gathered over 18 months to capture various seasons and weather patterns, including wet and clear air, using Cluster Drive Testing (CDT). The data collection period spanned from July 2022 to November 2023. The CDT survey took into account fluctuations in atmospheric parameters such as temperature, relative humidity, wind speed, and pressure. These atmospheric parameters, combined with the Received Signal Reference Power (RSRP), were measured based on the parameters in Table 1 at different times of the day (morning, afternoon, and evening). The study also factored in sea conditions by collecting data during strong and mild winds, which indicated rough and calm waters, in both freshwater and saltwater environments.

**Table 1. Network test bed parameters**

Parameters	Values
Frequency (MHz)	800
Transmitter power ( $P_t$ ) (dBm)	22
Antenna transmitter gain ( $G_t$ ) (dBi)	40.81
Cable/connecting loss ( $C_l$ ) (dB)	5
Shadow fading ( $S_f$ ) (dB)	5.4
Thermal fade margin (dB)	32.46
Base station antenna height (m)	34
Height of mobile station (m)	1.2
EIRP <sub>dry air</sub> (dBm)	33.81
EIRP <sub>wet air</sub> (dBm)	22

From the measured RSRP, signal loss values were calculated using [1,10,11,12]:

$$PL(\text{dB}) = \text{EIRP}(\text{dBm}) - \text{RSRP}(\text{dBm}) \quad (1)$$

where EIRP is the effective isotropic radiated power given as [13,14,15,16];

$$\text{EIRP} = P_t + G_r + G_t - L_t - L_r \quad (2)$$

where  $G_r$  and  $G_t$  are the receiver and transmitter antenna gains,  $L_t$  and  $L_r$  are transmitter and receiver cable losses in dB and  $P_t$  is transmitter power.

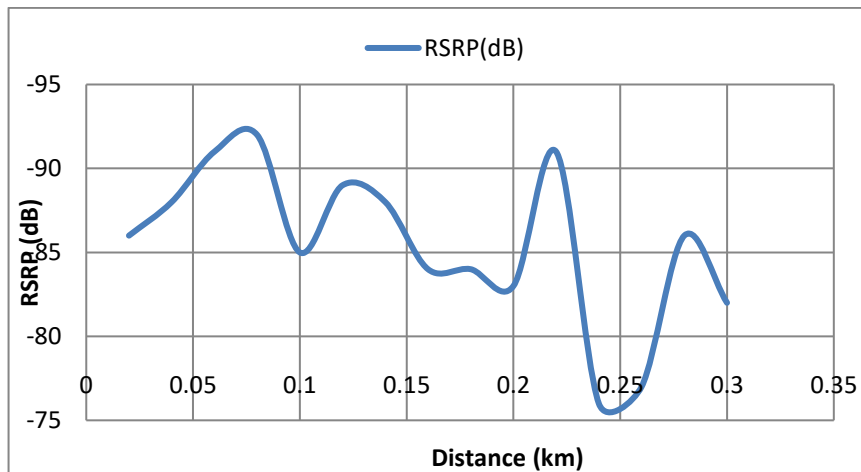
### 3. RESULTS AND DISCUSSION

Results were obtained under various maritime environmental factors such as fresh water clear air, fresh water wet air, salt water clear air and

salt water wet air. This is to estimate how LTE network varies under such conditions.

Figs 1, 2, 3, and 4 show the effects of various maritime environment factors on LTE pathloss. Fig. 1 illustrates the signal strength and pathloss characteristics of an LTE network operating over freshwater lakes under clear atmospheric circumstances. The absence of moisture and other meteorological disturbances may have resulted in low signal attenuation, resulting in improved network performance.

Fig. 2 is for the LTE network received under fresh water wet air factor. This figure represents the LTE network performance over freshwater with high humidity or damp air conditions. Moisture in the air increases signal attenuation, resulting in higher path loss compared to clear air conditions. This resulted in a decrease in signal strength compared to Fig. 1.



**Fig. 1. LTE Network received under Fresh water-clear air factor**

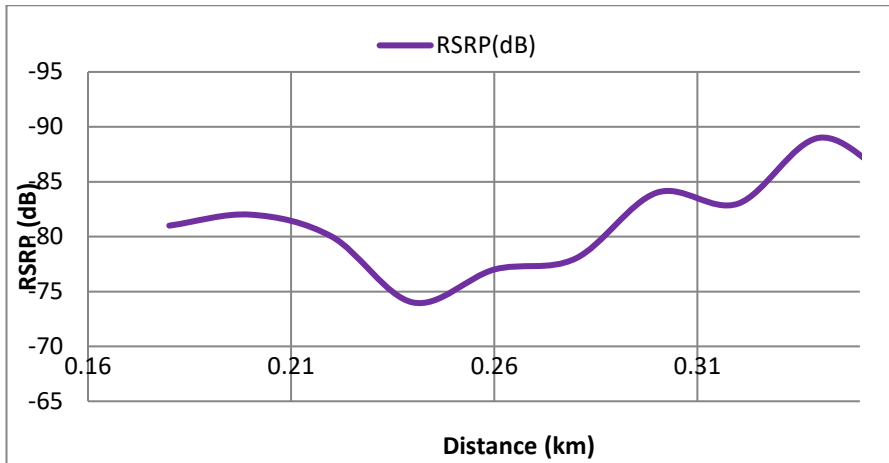


Fig. 2. LTE Network received under Fresh water wet air factor

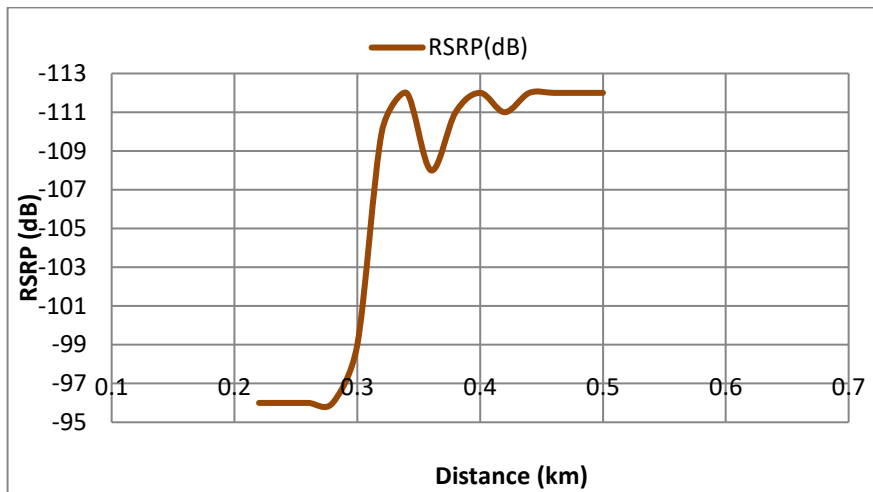


Fig. 3. LTE Network received under Salt water clear air factor

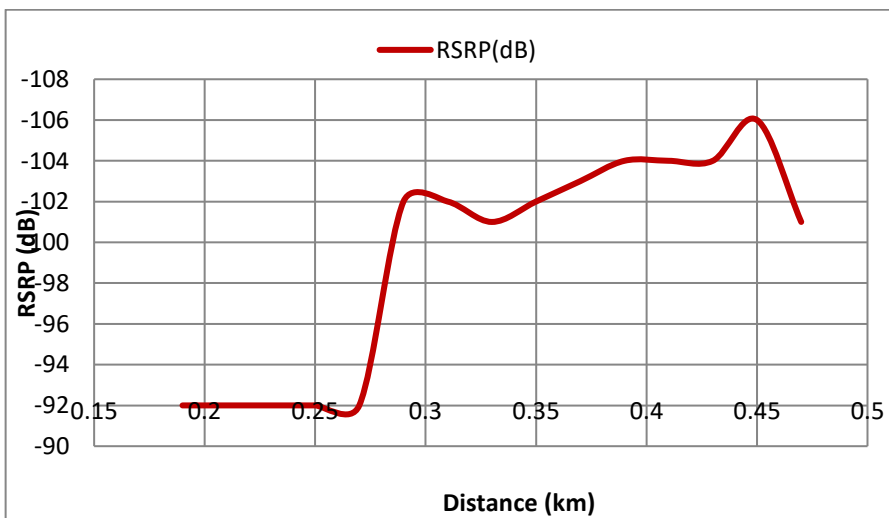


Fig. 4. LTE Network received under salt water wet air factor

Fig. 3 is for LTE Network received under salt water with clear air factor. This demonstrates the unique challenges posed by the reflective and refractive properties of saltwater. While the air is clear, the saltwater surface can cause multipath propagation, potentially affecting signal quality.

Fig. 4 is for the LTE Network received under the Saltwater wet air factor. This combines the effects of saltwater and wet air, which can significantly impact signal propagation. The combination of high humidity and the reflective nature of saltwater can lead to increased path and reduced signal strength, making it the most challenging scenario for LTE network deployment

#### 4. CONCLUSION

The study found that marine environmental factors have a considerable impact on LTE network performance, with different effects depending on the kind of water and meteorological conditions. Freshwater locations with clean air provide the best conditions for LTE signal transmission, whereas saltwater situations with damp air provide the biggest impediments. These findings highlight the need of taking into account environmental conditions when designing and deploying LTE networks in marine environments. Future research should concentrate on constructing adaptive models that account for these characteristics in order to improve network reliability and performance in such demanding conditions.

#### DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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