Results of VHF Radiowave Propagation Experiment in a Tropical Climate

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Citation

Abstract
Field strength measurements at a frequency of 100.5 MHz were conducted on a 200 km path in a tropical location in Nigeria as part of a measurement campaign to further enhance knowledge of the radiowave propagation characteristics in this region. Statistical analysis has been undertaken of the field strength behavior to identify the received field strength values at various percentages of time. The results obtained from the analysis demonstrate that the received field strength values were remarkably high during the dry months of November to March, as well as in the early morning and night time whereas smaller values were recorded during the wet months of April to October. The wet month of July recorded the lowest value of field strength while the dry month of March recorded the highest. The high field strength values, obtained, are attributed to anomalous propagation effects such as ducting and super-refractivity which are rampant in the West African tropical sub-region.

1. Introduction

The earth’s atmosphere in juxtaposition with the ground (or sea) surface, as a radiowave propagation medium, has been the subject of numerous experimental and theoretical studies over the years [1-27]. Many of these studies were conducted so as to better enrich the understanding of radiowave propagation characteristics in different climatic regions of the world. These investigations have, in the case of frequencies less than 50 MHz, provided a considerable knowledge of the propagation properties of the atmosphere and also of the effects of the known inhomogeneities or boundaries, such as the ionospheric regions and the earth’s surface. Such a knowledge, which depends very largely on a vast store of accumulated statistical information, allows fairly accurate predictions of the propagation characteristics of low- and medium-frequency systems to be made in practice. For frequencies greater than 50 MHz, investigations have shown that inhomogeneities due to the ionospheric regions are of little or no consequence and that wave propagation are restricted to the region of earth’s atmosphere known as the troposphere. The troposphere is the nearest region of the atmosphere to earth, and experiences conditions of continual motion [10, 24, 28].

In the very high frequency (VHF) band (i.e. frequency range 30-300 MHz), a radio broadcasting service is normally planned so that a satisfactory service would be provided within a defined coverage zone. The intended coverage zone might typically be a town and its immediate surroundings. A satisfactory service may be defined by specifying that the received field strength be equal to, or greater than, a certain value at a given percentage of locations within the intended coverage area, for a specified percentage of the time. It then implies that any interfering signals at the same frequency would be acceptable if they had lower field strength within the wanted coverage area, or are
received for less than 1% of the time and at less than 50% of the locations within the wanted coverage area.

The signals from a desired transmitter would usually propagate over paths of less than 50 km so as to ensure that an acceptable service is achieved, in accordance with specifications, whereas signals from interfering stations would travel to far greater distances. Therefore for most of the time, the potentially interfering signals would not be heard due to the large distances involved. Moreover, there are certain times when radiometeorological conditions cause a signal to propagate to much larger distances than normal and thus show up in another service area with enough strength to result in interference [29]. For example, radiowave propagation in the VHF band is extremely influenced by the meteorological conditions in the troposphere [2, 5, 8, 10, 28]; there are occasions when inversion layers and ducts are formed which then enable a signal to travel to far greater distances well beyond the normal radio horizon. An illustration of these anomalous radiowave propagation mechanisms is shown in Fig. 1. These anomalous propagation effects are frequently prevalent in the West African tropical sub-region [12, 16, 20, 31], and are major source of interference between stations.

This paper presents the results of transhorizon propagation measurements, in the VHF band, carried out in a tropical location in West Africa as part of a measurement campaign to further enhance knowledge of the radiowave propagation characteristics in this region.

2. Experimental Setup

2.1. Overview

The radio broadcasting station, used in this experiment, is located at Lagos within latitude 6°27'N and longitude 3°24'E, whereas the measurement site at Ile-Ife is located between latitudes 7°0'N and 7°35'N, longitudes 4°20'E and 4°45'E. These transmitting and receiving sites are both in the south west region of Nigeria; the link of propagation is basically a land path. The parameters of this experiment are provided in Table I. Nigeria has a tropical climate with two main seasons; the dry season (around November to March) and the rainy season (around April to October). The experiment was initiated in September 1998, and was intended to be carried out for at least two years. This paper presents the analyses of the data acquired between September 1998 and August 1999. There was a failure of the receiver in December 1998, and therefore no data were acquired during this month.

![Image](https://via.placeholder.com/150)

*Figure 1. An illustration of anomalous radiowave propagation mechanisms [30].*

<table>
<thead>
<tr>
<th>Table I. Details of the Experiment</th>
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<tbody>
<tr>
<td>Frequency</td>
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<tr>
<td>Receiver antenna height</td>
</tr>
<tr>
<td>Transmitter effective radiated power (ERP)</td>
</tr>
<tr>
<td>Path distance</td>
</tr>
</tbody>
</table>

2.2. Data Processing

A field strength meter, and data logger, was used to measure the signal level resulting from the radio transmitter. This field strength meter was connected to a personal computer which has been programmed to sample the received signal level, continuously, at about once every minute. The received signal levels, as voltage values, were later changed to field strength values and then subsequently analysed by computer programs. Extra caution was taken in arranging the data for monthly and diurnal variations, and in changing from signal level, dB (µV), to field strength, dB (µV/m).
The field strength, $E$ dB ($\mu$V/m), induced at the receiving antenna is related to the signal level, $V$ dB ($\mu$V), by [29]

$$E = V + L - G + 20 \log f - 32,$$

where, for a 50 $\Omega$ characteristic impedance;
$G$ is the gain in dB of the receiving antenna reference to a $\lambda/2$ dipole,
$f$ is the frequency in MHz,
$E$ is the field strength, dB ($\mu$V/m),
$V$ is the measured signal level, dB ($\mu$V),
$L$ is the loss in dB of the feeder between the field strength meter and the antenna.

The antenna gain at the receiving site is 12 dB while the feeder loss in the measurement setup is estimated to be -0.84 dB. The frequency of operation is 100.5 MHz (i.e. in the VHF band). After substituting the parameters of the experiment into (1); the field strength, $E$ dB ($\mu$V/m), is eventually derived as

$$E = V - 4.8 \text{ dB}.$$

Taking into consideration the likelihood of variations in the transmitted power as well as the characteristics of the receiving equipment, it is estimated that the total error in the values of field strength is about $\pm 4 \text{ dB}$.

The field strength distribution over the entire database of measurements has been computed to show the field strength at various percentages of the total measurement. Field strength distributions were also computed to show the monthly values for seasonal variations, as well as to show diurnal variations.

3. Data Analysis and Discussions

3.1. Total Field Strength Distribution

Fig. 2 shows the total field strength distribution, for the 10-month period from September 1998 to August 1999, and at various percentages of the entire database of measurement. The time of measurements is from 0h to 23h59 (excluding the periods of equipment failure and power blackouts). The field strength value with the greatest percentage is 38 dB ($\mu$V/m); received for 5.6 % of the entire database of measurement.

Furthermore, as observed in Fig. 2, high field strength values were received for low percentages of the measurement. These high field strength values are several dBs more than the median value of 49 dB ($\mu$V/m). For instance, 70dB ($\mu$V/m) and 73 dB ($\mu$V/m) were received for 0.4 % of the entire field strength distribution. At more than 1 % of the database, field strength values of 61 dB ($\mu$V/m), 62 dB ($\mu$V/m), and 64 dB ($\mu$V/m) were also received. These high field strength values are indications of interfering signals associated with small time percentages, which are attributed to the anomalous propagation effects in the region.

3.2. Monthly Field Strength Distribution

In order to obtain a more comprehensive examination of the field strength values that have been received, monthly distributions of the field strength have been computed; the median values are tabulated in Table II while the distributions are illustrated in Figs. 3-12.
Figure 5. Field strength distribution for the November 1998.

Figure 6. Field strength distribution for January 1999.

Figure 7. Field strength distribution for February 1999.

Figure 8. Field strength distribution for March 1999.

Figure 9. Field strength distribution for April 1999.

Figure 10. Field strength distribution for May 1999.

Figure 11. Field strength distribution for July 1999.

Figure 12. Field strength distribution for August 1999.
From Table II, it can be observed that the month with the lowest median value is July, i.e. 39 dB (µV/m), whereas March recorded the highest value, i.e. 51 dB (µV/m). This seasonal variation in the received field strength is as a result of the prevailing meteorology. The greatest value recorded in March, which tallies with the dry season in Nigeria, is affiliated to the incidence of anomalous propagation effects such as ducting and super-refractivity.

Table II. Monthly Field Strength Variation

<table>
<thead>
<tr>
<th>Month</th>
<th>Median field strength</th>
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<tr>
<td>September 1998</td>
<td>44 dB (µV/m)</td>
</tr>
<tr>
<td>October 1998</td>
<td>45.5 dB (µV/m)</td>
</tr>
<tr>
<td>November 1998</td>
<td>46.5 dB (µV/m)</td>
</tr>
<tr>
<td>January 1999</td>
<td>50 dB (µV/m)</td>
</tr>
<tr>
<td>February 1999</td>
<td>50.5 dB (µV/m)</td>
</tr>
<tr>
<td>March 1999</td>
<td>51 dB (µV/m)</td>
</tr>
<tr>
<td>April 1999</td>
<td>48 dB (µV/m)</td>
</tr>
<tr>
<td>May 1999</td>
<td>48 dB (µV/m)</td>
</tr>
<tr>
<td>July 1999</td>
<td>39 dB (µV/m)</td>
</tr>
<tr>
<td>August 1999</td>
<td>45.5 dB (µV/m)</td>
</tr>
</tbody>
</table>

At small time percentages, high values of field strength were received in the dry months. These high field strength values are again several dBs more than the median value. For example at 0.4 % of the measurement period in February 1999, the measured field strength values were 78 dB (µV/m) and 79 dB (µV/m). At more than 1 %, field strength values of 70-73 dB (µV/m) were also received. The median value for this month is 50.5 dB (µV/m). These deviations of the received field strength from their median values, by many dBs during the dry months, are again evidences of the incidence of interfering signals affiliated with small time percentages.

3.3. Diurnal Field Strength Variation

To examine the diurnal variations, field strength distributions have been derived over a whole day (i.e. 0h to 23h59). The daily median field strength values, for some representative days within the wet and dry months, are shown in Table III. These representative days were picked from months with very low and high median field strength values. The diurnal variations are shown in Figs. 13-16.

Table III. Field Strength Variation on Typical Days

<table>
<thead>
<tr>
<th>Day</th>
<th>Median field strength</th>
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<tbody>
<tr>
<td>February 9, 1999</td>
<td>56 dB (µV/m)</td>
</tr>
<tr>
<td>March 15, 1999</td>
<td>48.5 dB (µV/m)</td>
</tr>
<tr>
<td>May 30, 1999</td>
<td>46 dB (µV/m)</td>
</tr>
<tr>
<td>July 13, 1999</td>
<td>39 dB (µV/m)</td>
</tr>
</tbody>
</table>

Figure 13. Diurnal field strength variation for February 9, 1999.
Figure 14. Diurnal field strength variation for March 15, 1999.

Figure 15. Diurnal field strength variation for May 30, 1999.
Table III shows that the daily median field strength is highest on a representative day within the dry month, i.e. February 9, while the smallest value is observed in the wet month, i.e. July 13. Strong diurnal effects are also seen on February 9 and March 15, as shown in Figs. 13 (a) and 14 (a) respectively. The greatest signal strength occurs during the early morning and night hours whereas the smallest value happens in the daytime. Additionally, February 9 recorded the highest prevalence of interfering signals affiliated with low time percentages, whereas July 13 recorded the smallest. These are shown in Figs. 13 (b & c) and 16 (b & c) respectively.

The strong diurnal effects, observed, are attributed to the prevailing meteorological conditions of the atmosphere. In the daytime, the sun heats the earth’s surface. Moreover after sunset, the upper air cools, as does the surface temperature, but at different rates; consequently resulting in a rise (rather than the normal decrease) in temperature with height in the lower troposphere. This causes the forming of an inversion layer and ducting. In the following morning after sunrise, the inversion layer is spifflicated because of solar heating and the signal strength therefore decreases.

As observed in Figs. 13 (a) and 14 (a), a full day in the dry month can be generally split into three distinct periods. First, a time of signal enhancement often with short duration fades and frequent deeps. Second, a time of reduced signal strength, and finally a time of signal strengthening usually with the same properties as the first time period. These three distinct time periods are, however, not seen on the representative days in the wet month shown in Figs. 15 (a) and 16 (a). Small signal strength was observed, generally, in these wet months. The reduced signal strength observed at this time, for example on July 13, may be attributed primarily to the high occurrence of rain in the wet months. The received field strength also often exhibits relatively short duration fades as well as strong frequent deeps due to attenuation by obstructions such as hills or buildings.

4. Conclusions

The data acquired from a 10-month period of long-distance radiowave propagation experiment in the VHF band, carried out in a tropical climate, have been analysed in this paper. The results obtained show that low values of signal strength were recorded during the wet months of April to October while high values were received during the dry months of November to March. The greatest median field strength was recorded in March. The high values of field strength recorded in the dry months could pose serious implications for planning of VHF radio broadcasting services in the area, since it is likely that the prevalence of interfering signals affiliated with small time percentages, such as 10 % to 0.1 %, will be high. Consequently, careful planning is required so as to minimise interference problems.

Acknowledgment

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References


Biography

Olusegun A. Aboaba received the BSc and MSc degrees in electronic and electrical engineering in 1995 and 2000 respectively from Obafemi Awolowo University, Ile-Ife, Nigeria. He received the PhD degree in electrical and computer engineering from Curtin University, Perth, Western Australia. Dr. Aboaba is a member of the Institute of Electrical and Electronics Engineers (IEEE) and the Nigerian Society of Engineers (NSE). He is a former Associate of the Abdus-Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy. He received the Best Paper Award at the 12th Asia-Pacific Conference on Communications (APCC), Busan, South Korea.