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ORIGINAL RESEARCH

EFFECT OF RAINFALL ON DIGITAL / ANALOG TELEVISION SIGNALS

Frank Onaifo[1] | Alexander Akpofure Okandeji*[2] | Ayodeji Akinsoji Okubanjo[1] | Abdulsalam Khadeejah[2] | Peter Alao[1]

[1] Dept. of Electrical and Electronics Engineering, Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Nigeria

[2] Dept. of Electrical and Electronics Engineering, University of Lagos, Akoka, Yaba, Lagos, Nigeria

Correspondence

*Alexander Akpofure Okandeji, Department of Electrical and Electronics Engineering, University of Lagos, Akoka, Yaba, Lagos, NigeriaEmail: aokandeji@unilag.edu.ng

Present Address

Dept. of Electrical and Electronic Engineering, University of Lagos, Lagos, Nigeria

Abstract

Rainfall has a strong negative impact on television (TV) signals, most especially at the receivers' end. This is due to the propagation effect caused by atmospheric rain absorption of the wave signal. Television signals may reach the TV receiver unstable due to interferences caused by heavy rainfall, which creates undesirable poor-quality reception and noise. The effect of rain-induced attenuation on television signal reception is not enviable, especially when it is heavy. Consequently, this work aims to analyze the correlation between received signal strength and frequency of transmission during rainfall. The received signal strength measurements and rainfall data were collected concurrently during dry days and rainy days to achieve this aim. These readings were taken with a signal strength meter and other mobile phone software such as the rain gauge app, compass, etc.). The results show that rain leads to a noticeable degradation in the quality of received signals. Specifically, the data obtained were simulated, and it was observed that attenuations increase sharply as the rain rate increases. In particular, when the frequency is about 1080 GHz and the wavelength is low, there tends to be a disturbance between the drops of rainfall, which causes attenuation and results in low signal strength. In conclusion, this work proposes a possible solution favorable to all TV subscribers during rainfall.

KEYWORDS:

Signal Strength, Rainfall, TV Signals, Absorption, Atmospheric Rain, Frequency of Transmission.

1 | INTRODUCTION

Climate-environment relationships and impacts on human activities are predicted to change dramatically if global warming accelerates at the rates currently proposed. One such impact is on the distortions of the satellite television (TV) signal and the quality and clarity of the video[1]. Changes in weather conditions affect the quality of TV signal reception, though this occurs rarely and lasts only a short period [2]. For most users, heavy rain can attenuate signal enough to result in a noticeable degradation of image quality. In extreme cases, the reception of TV signals can be effectively disrupted. In general, the level of concern about the possibility of signal degradation/loss in a particular area depends on regional yearly rainfall figures, satellite footprint locations, and satellite height above the horizon [3]. The rain pattern experienced in a place has many effects on the satellite television system [3]. Yet, microwave attenuation due to rainfall in tropical regions has not been widely studied [4].

1.1 | RELATED WORKS

According to Nweke [2], fading in TV signals occurs more at the peak of heavy dry and heavy rainy seasons in Nigeria. Chandra et al. [3], Siddique et al. [4], Dutta and Kaur [5] reiterated that rainfall causes severe degradation of the received signal level above 10GHz, and generally, this degradation is directly proportional to the frequency of radio waves. Each particular raindrop contributes to the attenuation of the wanted signal. Several propagation mechanisms affect the earth-space and terrestrial communications performances, but attenuation due to rain is the most severe [4].

Rain-caused attenuation has been a major inhibitor in radar and communication systems operating at millimetric and microwave frequencies for a long time. The attenuation of microwave line-of-sight signals due to precipitation (rainfall, in particular) limits the propagation path length of line-of-sight communication systems. The actual amount of fading is dependent on the frequency of the signal and the size of the raindrop [4]. The two main causes of rain fading are scattering and absorption.

Rainfall is a critical factor of water cycle dynamics as it is a vector for energy exchange between the atmosphere, sea, and land. Television signal transmission in the ultrahigh-frequency (UHF) and very high-frequency (VHF) bands is highly affected by rainfall as such signals are susceptible to high levels of attenuation. Television signal transmission is an important communication area as many individuals seek clear reception in their received TV signals. Transmission and reception involve the components of a TV system that generate, transmit, and utilize the TV signal waveform. A lens focuses the scene to be televised on an image sensor within the camera. This produces the picture signal, and the synchronization and blanking pulses are then added, establishing the complete composite video waveform. The composite video and sound signals are then imposed on a carrier wave of a specific allocated frequency and transmitted over the air or a cable network. After passing through a receiving antenna or cable input at the TV receiver, they are shifted back to their original frequencies and applied to the receiver's display and loudspeaker [6, 7]. Undoubtedly, poor TV signal reception is observed during rainfall [8]. This action bridges the decimation of information by scrambling the received signal. Rain has been seen as a major source of interference on signal propagated for TV communication [9]. In Akobre et al. [10], other than rainfall, the effect of harmattan, sunshine, and cloudy weather was investigated on the UHF and VHF band for the TV system. It was shown that of all the adverse weather conditions, rainfall remains the greatest source of attenuation on signal propagation. Investigation into the impact of rain on satellite TV transmission is necessary for service providers to ensure adequate signal transmission during poor weather conditions [11]. Rainfall can affect the transmission of electromagnetic signals in several ways: system noise increase, signal attenuations, miss alignment loss, ionospheric losses, fixed atmospheric loss, etc. In Lee and Winkler [12], an investigation on the impact of rainfall on the signal quality of a high-speed link for video streaming activity was performed on the UHF and VHF bands. The results showed that rain attenuation was not peculiar to the UHF and VHF bands alone.

Television transmission involves the passage of radio waves in the space between transmitting and receiving stations. The transmission process uses satellites to relay television programs. Recent advances in satellite transmissions based on digital television systems have led to a drastic increase in the utilization of UHF and VHF band frequency in many ways, including direct-to-home broadcast arrangements [13]. Communication satellites receive communication signals from a transmitting ground station, amplify the signal, and possibly process it. The satellite further transmits the signal back to Earth for reception by one or more receiving ground stations. In the television transmission principle, the satellite microwave systems transmit signals between directional parabolic receiving antennae.

Meanwhile, it has been shown that wireless sensor systems functioning outdoors are open to changing weather conditions, which may result in serious dilapidation in the performance of the radio broadcasting system. Thus, it is important to discover the elements affecting radio link quality to lessen their effect and adjust to erratic conditions. The impact of rain not only causes the attenuation of satellite signals but also affects the cost of signal propagation from the transmission station. This is because there will be a need to increase the equipment's transmitting power in compensation flowers caused by rain. Research also shows that rain attenuation causes a greater power requirement from the transmitting units, resulting in a higher cost per bit of ht 

FIGURE 1 Signal strength meter.

transmission[14]. Investigation has also shown that at high frequencies, the wavelength becomes significantly shorter; these short wavelengths are easily absorbed and scattered as they pass through raindrops[15]. This is principally the major reason rainfall causes deterioration of the received signal. The impact of rain as part of losses encountered in the transmission system can also be estimated from statistical data. Thus, this study analyzes the impact of rain, specifically on the UHF and VHF frequency bands for TV transmission. In particular, this study aims to determine the rain rate against attenuations and measure signal strength at different periods or ranges of time.

2 | MATERIAL AND METHOD

2.1 | Study area.

This study was conducted in the College of Engineering and Environmental Technology, Olabisi Onabanjo University. Olabisi Onabanjo University is a state (owned and operated) multi-campus University in Ogun State, Nigeria. The College of Engineering is situated in Ibogun community, Ifo local government of Ogun State, Nigeria, on longitude 3.18594400004 and latitude 6.81203483508.

2.2 | Experimental setup.

The measurement setup comprises tools, including a signal strength meter, the thermometer app (which can be used on an Android phone), the rain gauge app, and the compass App (also on an Android phone).

2.3 | The signal strength meter.

The signal strength meter is shown in Fig 1 ; it is used throughout the study to determine the dead zone or areas with inadequate cellular coverage. It was used in this research work to take readings to compare the time, temperature, and signal strength on sunny and rainy days. The readings are measured in dBm.

2.4 | Installation program.

A dialog box is displayed on the screen of the signal strength meter and the option to click on the satellite selections is selected. The chosen television satellite was ROCKTV, with a frequency range of 1080-2650GHz. A dialog box appears showing the signal picture quality and signal strength, which was taken with percentage value and , in turn, changed to decibel (dBm)

2.5 | The Thermometer.

The thermometer was installed on an Android phone. The main use of the thermometer was to take temperature readings when taking adequate signal strength variations on the system software. The readings were measured in (°C).

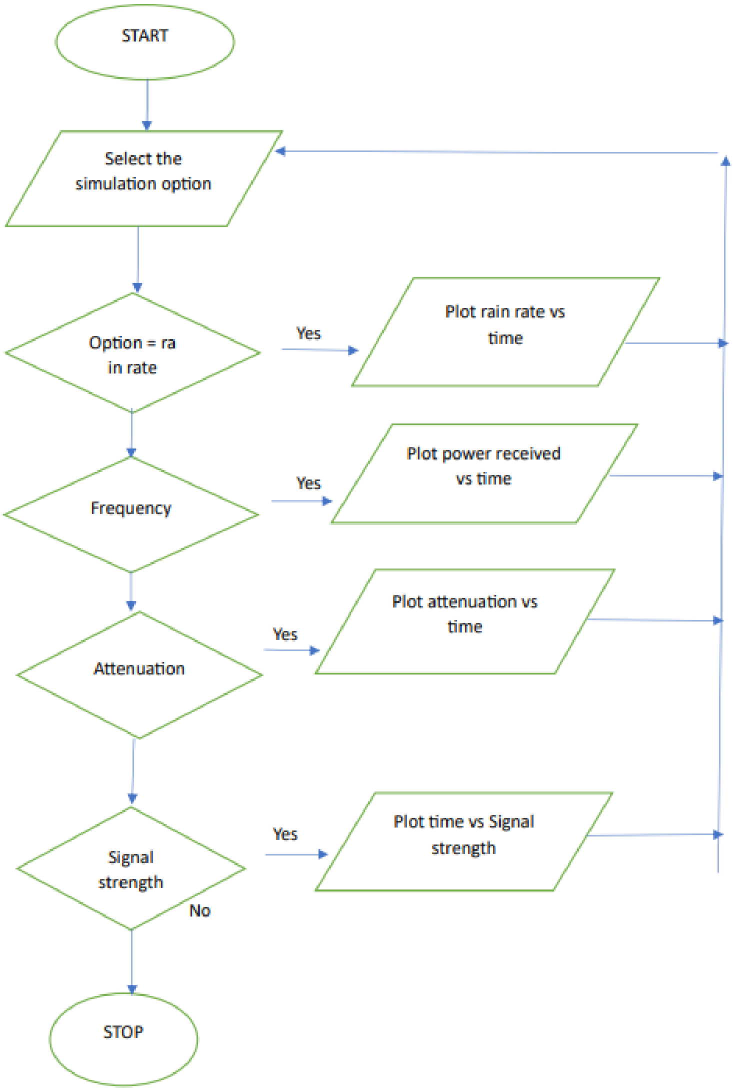

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FIGURE 2 The algorithm for the simulation of the various weather conditions.

2.6 | The rain gauge.

The rain gauge app measured the intensity of raindrops around the area where the experiment was conducted.

2.7 | The compass.

The compass was used to determine the real positioning of the particular satellite dish used for the study. The compass was used to determine the position and direction of the dish while the TV signal strength and quality content were concurrently monitored concerning rainfall intensity. Other connections for monitoring, such as spectrum analyzers and TV encoders, were set up inside the monitoring control room. The rainfall rate was then utilized to determine the rainfall attenuation suffered by the signal per the ITU-R global model for σ attenuation. The ITU-R model calculates specific attenuation as follows:

$$Y_R = K R^{\alpha} \tag{1}$$

Where Y is the specific attenuation due to rainfall, R is the rain rate (mm/h) in the given region. Also, K and α, respectively, denote the regression coefficient, which is dependent on frequency and temperature. The value of K was calculated using the

TABLE 1 The average data recorded during dry season.

Time) (Mins)	Received signal strength (dBm)	Time (Mins)	Received signal strength (dBm)
5	-59	60	-58
10	-50	65	-56
15	-58	70	-49
20	-56	75	-49
25	-71	80	-65
30	-58	85	-65
35	-59	90	-48
40	-52	95	-61
45	-58	100	-61
50	-51	105	-60
55	-52	120	-53

TABLE 2 The measured data of rainfall intensity against signal Level during heavy rainfall.

Rain Intensity (mm/hr)	Received Signal Level (dBm)	Rain Intensity (mm/hr)	Received Signal Level (dBm)
2.04	-75	5.40	-78
2.24	-77	5.50	-80
2.30	-76	6.32	-74
2.32	-79	7.30	-73
2.50	-75	9.10	-70
2.50	-78	10.9	-68
2.50	-81	11.10	-67
3.01	-80	11.40	-75
3.23	-82	11.50	-73
3.32	-85	11.90	-67
3.60	-83	12.10	-79
4.20	-78	12.20	-89
4.27	-68	13.23	-88
5.30	-67	14.10	-87
5.30	-79	14.40	-86

ITU-R recommendation. Equation 1 links specific attenuation directly to frequency and rainfall rate. The rain gauge was placed in an open area without obstacles. The algorithm shown in Figure 2 was developed to simulate the various weather conditions.

3 | RESULTS AND DISCUSSION

The transmission frequency was 10.85GHZ at the onset of rain during the experiments. The received signal (Rs) was monitored and recorded, as well as the picture quality. As the rainfall intensity increases, the signal strength starts fluctuating. The measurements were taken at 10-minute intervals each during the period for better resolution of rain rates. The received signal strength value collected from all the measurements was combined and sorted according to rainfall intensity scenarios to represent the average effect of the condition (rainfall) on signal strength. Temporal variations in the received signal were analyzed and presented using MATLAB. The signal level at the receiver from the transmitted signal was determined by developing a propagation model equation as shown below:

$$PRX = PTX + GTX + GRX - LFSRL - ARAIN \tag{2}$$

Where:
PRX = Received Power (dB)
PTX = Transmit Power (dB) PowerX = Transmit gain (dBi)
GRX = Received gain (dBi)
ARAIN = Rain attenuation dB

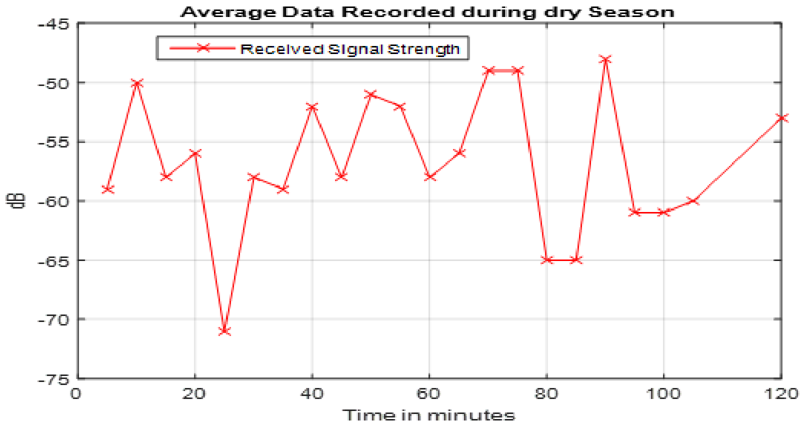

FIGURE 3 Plot of the graph of received signal level against time during the dry period.

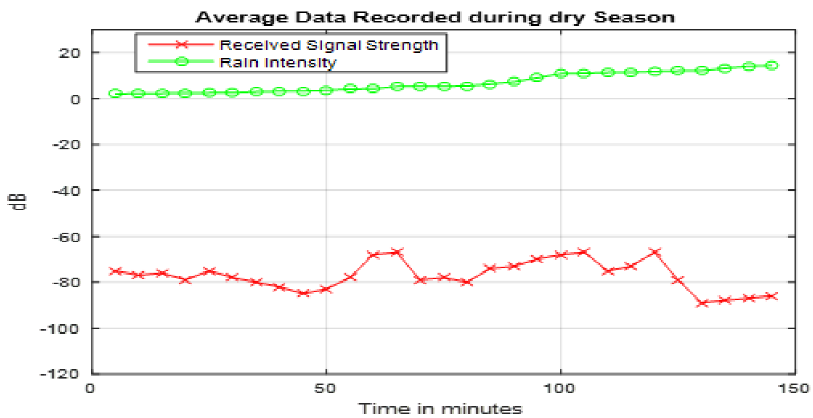

FIGURE 4 Plot of rainfall intensity, received signal strength against time during heavy rainfall.

LFSRL = 32.44db+ 20log10 (F) + 20log10 (d) in dB

Link budget analysis was used to compute the rain attenuation for different rain intensities at a distance of 25km. The rain attenuation was computed using Eq. 3:

$$ARAIN = YRd \tag{3}$$

Received signal strength was measured at different weather conditions (dry and rainfall) concerning time in minutes as shown in Tables 1 and 2 . Figures 3 and 4 show the graph of the received signal level during the dry period and the rainfall intensity against signal level during heavy rainfall, respectively. Information from Table 1 shows that the received signal has a good reception.

It could be observed from Figure 4 that signal fluctuations were more frequent during heavy rain. It shows that the more the rain intensity increases, the weaker the received signal strength, which may result in signal interruption and sometimes total loss of signal. It could also be observed from Figure 4 that the received signal has a good reception.

The received signal strength and rain intensity were measured at different rainfall rates concerning time in minutes. Table 3 shows the average recorded data without frequency hopping, while Figure 5 shows the graph of signal attenuation rainfall against time (min) without frequency hopping under rainy conditions.

TABLE 3 The average data recorded without frequency hopping under rainfall conditions.

Time (mins)	Rain Intensity (mm/H)	Received Signal Strength (dBm)
10	0.0	-68.0
20	0.1	-66.6
30	0.5	-65.5
40	0.7	-62.5
50	1.2	-68.6
60	2.0	-79.5
70	2.5	-78.8
80	13.2	-85.0
90	12.8	-80.0
100	2.5	-77.5
110	1.5	-68.4
120	0.8	-60.5
100	2.5	-77.5
110	1.5	-68.4
120	0.8	-60.5

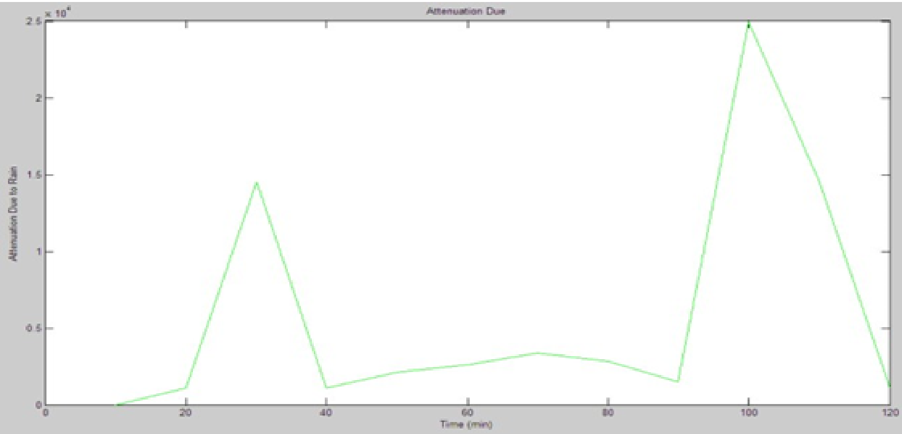

FIGURE 5 Attenuation due to rain.

TABLE 4 The average data recorded with frequency hopping under rainfall conditions.

Time (mins)	Rain Intensity (mm/H)	Received Signal Strength (dBm)
10	0.0	-55.0
20	0.1	-45.2
30	0.5	-50.5
40	0.7	-58.0
50	1.2	-53.5
60	2.0	-56.5
70	2.5	-48.5
80	13.2	-55.0
90	12.8	-50.0
100	2.5	-47.5
110	1.5	-48.4
120	0.8	-40.5
100	2.5	-54.5
110	1.5	-48.4
120	0.8	-40.5

The average received signal (ARS) was calculated by substituting the measured values into equation 2. Observation from the graph shows that the signal strength (dBm), which indicates the amount of signal, follows a fluctuating pattern of rainfall rate within the period under investigation. Also, the received signal strength and rain intensity were measured at different rainfall rates concerning time in minutes with frequency hopping, as shown in Table 4 .

Figure 6 shows the signal attenuation graph due to rainfall conditions. From Figure 6 a, it is observed that although the signal strength shows some signs of fluctuation, it was not as repeated as that of figure 5 where there is no frequency hopping (FH). The frequency hopping model was used to evaluate the effect of rain on received signal modulations and compare the performance with the situation without frequency hopping. Performance evaluation is based on received signal strength values under two situations (with and without FH) versus normalized signal-to-noise ratio (SNR) measured by Eb/N0 values of the channel. From Figure 7 , the red line indicates the signal performance during the hopping process, while the green color indicates the signal performance without the hopping process.

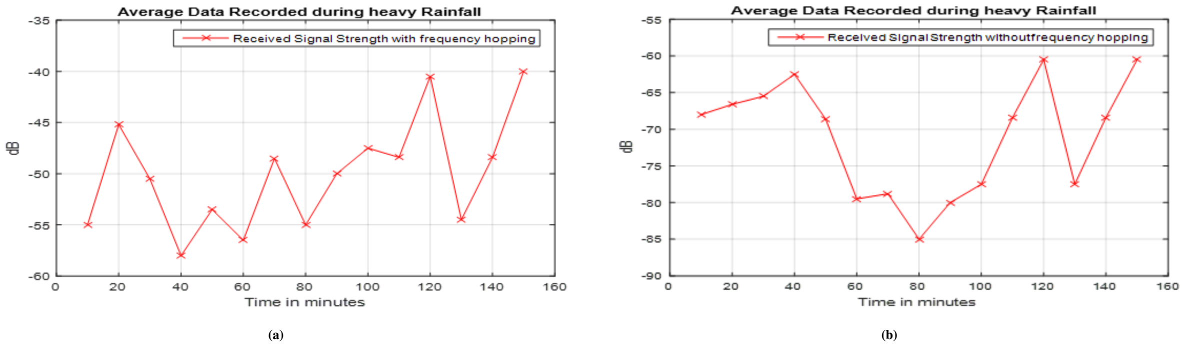

FIGURE 6 (a) Received power against time (min) with frequency Powerng under rainfall; (b) received signal strength against time (min) without frequency hopping under rainfall conditions.

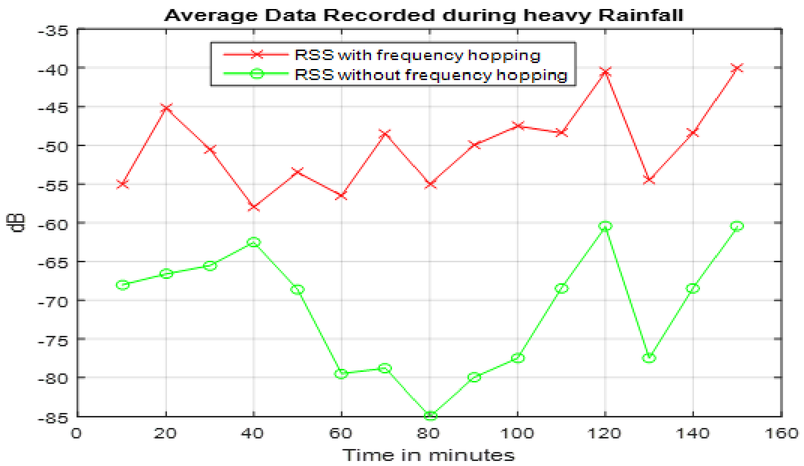

FIGURE 7 Comparing received signal strength against time (min) with and without frequency hopping under rainfall conditions.

Observation from Figure 7 shows that the attenuated received signal stabilizes as the frequency hops along with increased rainfall intensity. Also, Figure 7 presents the frequency hopping spectrum showing improved signals during the hopping process to reduce the effect of rainfall on television signals. The frequency hopped from one frequency to another, using the frequency with a strong signal for the received signal. Tables 5 and 6 , respectively, show data recorded with temperature difference during dry and rainy days at 950-2150 MHz frequency.

TABLE 5 The data recorded with temperature difference during the dry day with a stable frequency of 950 to 2150 (MHz)

Time (mins)	Signal Strength (dBm)	Picture Quality	Temperature (° C)	Direction
10	91	63	25	N30°E
20	87	61	27	N30°E
30	90	60	29	N30°E
40	87	57	20	N30°E
50	95	60	21	N30°E
60	98	65	28	N30°E
70	81	60	26	N30°E
80	79	50	27	N30°E
90	88	69	24	N30°E
100	87	71	25	N30°E
110	94	77	26	N30°E
120	98	78	24	N30°E

TABLE 6 Readings recorded concerning temperature during rainy day.

Time (mins)	Signal Strength (dBm)	Picture Quality	Temperature (° C)	Direction
10	60	44	19	N30°E
20	61	40	18	N30°E
30	64	51	16	N30°E
40	57	39	13	N30°E
50	48	22	14	N30°E
60	49	18	12	N30°E
70	55	27	17	N30°E
80	52	31	14	N30°E
90	58	38	15	N30°E
100	54	37	17	N30°E
110	50	48	16	N30°E
120	45	29	13	N30°E

4 | CONCLUSION

This work focused on improving signal reception during adverse weather conditions. It used available readings to compare and contrast and developed a suitable frequency during the rainy season. Results from the measurements showed that rain degradation of the received signal was due to increased rainfall intensity, which can cause total signal loss or make the picture quality freeze or flicker. In addition, results showed that signal fluctuations occur more frequently during heavy rain. Thus, an increase in the intensity of the rain induces a weak received signal strength, which may result in signal interruption and sometimes total loss of signal. A recommendation for futuristic research is to consider how increasing rain intensity cannot affect signal strength.

5 | RECOMMENDATIONS

The graphical result from this study shows the effect. It has been proven that when there is high rainfall in a particular geographical region, the high frequency has a smaller wavelength, which makes it easy for the raindrop to affect the wavelength because of the intensity. This study clarifies that the wavelength is higher at low frequencies, so the rainfall does not impact the signal strength. Therefore, when the frequency is high, there is a low wavelength, which causes signal attenuation. This research, therefore, recommends the incorporation of low-frequency signals into today's transmission system. The use of low frequency guarantees a high wavelength strong enough to withstand rainfall. Thus, television subscribers can enjoy viewing even on rainy days.

CREDIT

Frank Onaifo: Conceptualization, Methodology, Resources, Data Curation, Writing - Original Draft, and Visualization. **Alexander Akpofure Okandeji:** Methodology, Validation, Writing - Review & Editing, and Supervision. **Ayodeji Akinsoji Okubanjo:** Validation, Investigation, and Formal Analysis. **Abdulsalam Khadeejah:** Validation, Investigation, Review & Editing, and Formal Analysis. **Peter Alao:** Validation, Investigation, Review & Editing, and Formal Analysis.

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