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Effect of Temperature on Downlink Satellite Signal Attenuation in Nasarawa Broadcasting Service (NBS) Lafia, Nigeria

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Abstract: *Downlinks consist of a Satellite, transmitted waves, a free-space path and a ground based receiver. Satellites employ wireless transmission of waves and are very important because they are used for weather monitoring, Television broadcasting, internet services, Global Positioning System (GPS) navigation and even mobile phone communications. Radio waves can be affected by either the Earth's atmosphere, Earth's system, Earth's curvature or sometimes the prevailing conditions of the atmosphere. This work investigated the effect of temperature on Downlink Satellite signal attenuation in Nasarawa Broadcasting Service (NBS). Hourly data of temperature and signal quality for the hours of 8.00 to 16.00 for a period of four weeks and for temperatures ranging from 45 ℃ to 65 ℃ were collected and the average value was calculated and used for the analysis. The obtained data is reasonably symmetrical and shows a strong positive correlation between temperature and signal quality (r = 0.988, p = 0.000). It also shows that the higher the temperature, the better the signal quality at N.B.S Lafia. The satellite signal quality was found to be better at higher temperatures because moisture reduces and the air is drier resulting in reduced water vapour interference with microwave signals. Satellite signal attenuation is therefore minimised and its quality improves though there could be scintillation for some communication frequencies. The satellite signal quality improves steadily with rises in temperature between the hours of 8.00 and 12.00, though at 13.00 there was a 23 % decrease in signal quality. The signal quality improved again at 14.00 and was almost doubled to 4.0 % at 16.00. Thus at NBS Lafia, radio waves signal quality are better on warmer days.*

Keywords: *Satellite, Downlink, Radio waves, Microwaves, wireless transmission*

I. Introduction

Satellites receive electromagnetic waves typically Radio waves and Microwaves through space, process and amplify them before returning them to a receiving station such as a dish antenna referred to as a downlink [1]. The downlink on receiving the signals, data, voice or video, from the orbiting Satellite, routes them to a receiving ground station or dish antenna [2]. Downlinks are made up of a Satellite, transmitted waves, a free-space path and finally a ground based receiver. Satellites are very important because they are used for weather monitoring. Furthermore Television broadcasting, internet services and Global Positioning System (GPS) navigation and even mobile phone communications all employ wireless transmission of waves

[3]. In wireless transmission, waves do not require a material medium for their transmission however, Radiowaves can be affected by the Earth's atmosphere and the Earth's system properties [4,5,6]. The Earth's curvature or prevailing conditions of the atmosphere can influence how the electromagnetic waves from the satellite get refracted towards or away from the Earth's surface [7]. There are concerns however about how Radio waves or signals get propagated through the atmosphere as it has been reported that they actually get perturbed by gases such as Oxygen and even water vapour found in the atmosphere [8,9]. Furthermore, rain drop size and its falling rate as well as weather conditions such as cloud, and Harmattan have also been reported to affect the transmission of radio waves as it travels through space [10, 11,12] and there have been studies on the extent to which these happen.

Radiowaves have frequencies in the range 300 GHz – 3kHz with wavelengths ranging from 1 mm to 100 km and though Harmattan attenuates these waves, temperatures a little above 25 °C also attenuates radio signals [12]. Many indoor and outdoor systems use wireless communication technology and since radiowaves travel through space, it is necessary to know how their signals can be affected or attenuated [11].

While the measurements locations may remain fixed, weather conditions can cause variations in ambient temperature resulting in diurnal and seasonal changes. In some instances, higher temperatures can raise thermal noise which can in turn degrade signal quality [12].The effect of Weather variations can be minimised by investigating the extent to which prevailing weather conditions influence radio signal quality and strength at any given time.

Recent studies have shown that the ionosphere limits Satellite communication and higher frequency radio waves get attenuated by the free electrons, atmospheric gases, rains, clouds and even noise temperature when they travel through the ionosphere.[13]. At microwave and millimeter's frequencies, atmospheric gases do attenuate radio waves because of oxygen and water vapour absorption [14,15] and absorption lines at 22.2 GHz and 183.3 GHz have been reported. Signals at frequencies ranging from 20 GHz – 50 GHz are also good and immune to ionosphere effects.[16]

Though the atmosphere influences the propagation of Radiowaves because of the oxygen and water vapour it contains, Precipitation and clouds have also been reported to attenuate Satellite signals and radio waves at frequencies above 10GHz are particularly susceptible to attenuation due to molecular absorption [17,18,19].

Presently, there are not enough researches on the attenuation of radio signals by weather conditions and while some think temperature could be a major factor affecting Radio Frequency strength, others think it could be , humidity, precipitation or clouds [20,21,22]. This study only investigated the role of temperature on Radio signals attenuation in Nasarawa State broadcasting Station, Lafia, Nigeria and to achieve that hourly changes of temperature and its effect on Radio signal strength at Nasarawa Broadcasting Station over a period of nine (9) hours daily for four weeks was studied and obtained average values were evaluated statistically.

II. Methodology

The chosen study area for this work is Lafia which is South –West of Abuja, Nigeria at Latitude 8.5° N and Longitude 8.5 ° East . Digital thermometer and spectrum analyser (R & S FSW) were used for the study. Hourly changes of temperature and its corresponding satellite signal quality for a period of nine hours daily for four weeks were studied. The Data acquired from this study are secondary data obtained from Nasarawa Broadcasting Station, Lafia for the hours of 8.00 to 16.00 for a period of four weeks and for temperatures ranging from 45 °C to 65 °C. The average value of the signal strength was calculated and used for the analysis. The obtained data was analysed statistically and results derived are here presented.

III. Results and discussions

Table 1: Signal quality at hourly interval and its variation with Temperature

Time	Temperature (°C)	Average Signal Quality(%)
8.00	45.00	2.80
9.00	40.00	2.40
10.00	46.00	3.00
11.00	50.00	3.20
12.00	55.00	3.50
13.00	45.00	2.70
14.00	45.00	2.80
15.00	60.00	3.70
16.00	65.00	4.00

From table 1, and between the hours of 8.00 and 12.00, the satellite signal quality increased steadily with temperature increases and at 13.00 there was a 23 % decrease in signal quality and the signal quality was found to improve at 14.00 as it almost doubled to 4.0 % at 16.00

Table 2: Descriptive Statistics Table

Variables	N	Mean	Std. Deviation	Skewness	
	Statistic	Statistic	Statistic	Statistic	Std. Error
Time of Day	9	5.00	2.739	0.000	0.717
Temperature (°C)	9	50.11	8.223	0.833	0.717
Signal Quality (%)	9	3.122	0.5215	0.457	0.717

Table 2 shows that the temperature was 50.11°C with moderate standard deviation (SD = 8.223), and the signal quality was 3.122% with little standard deviation (SD = 0.5215). The skewness values are low, indicating that the data is reasonably symmetrical and suitable for analysis.

Table 3: Correlations Table

		Time of Day	Temperature (°C)	Signal Quality (%)
Time of Day	Pearson Correlation	1	0.738*	0.683*
	Sig. (2-tailed)		0.023	0.043
	N	9	9	9
Temperature (°C)	Pearson Correlation	0.738*	1	0.988**
	Sig. (2-tailed)	0.023		<0.001
	N	9	9	9
Signal Quality (%)	Pearson Correlation	0.683*	0.988**	1
	Sig. (2-tailed)	0.043	<0.001	
	N	9	9	9

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The time of day was moderately correlated with temperature (r = 0.738, p = 0.023) and signal quality (r = 0.683, p = 0.043), suggesting that both increased with time of day.
The most important result is that the correlation of temperature and signal quality is very strong (r = 0.988, p = 0.000) which implies that the higher the temperature the better signal quality at N.B.S Lafia.

Table 4: Simple Regression Model Summary Table

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.988[a]	0.975	0.972	0.0876
a. Predictors: (Constant), Temperature (°C)				
b. Dependent Variable: Signal Quality (%)				

The temperature was a very good indicator of the quality of the signals. The R square value of 0.975 indicates that 97.5% of the variation in signal quality is explained by the temperature alone. Predictions are likely to be within ±0.09 percentage points of the true value 97.5% of the time.

Table 5: Simple Regression Analysis ANOVA Table

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.122	1	2.122	276.746	<0.001[b]
	Residual	0.054	7	0.008		
	Total	2.176	8			
a. Dependent Variable: Signal Quality (%)						
b. Predictors: (Constant), Temperature (°C)						

The F-statistic is 276.746 at a probability level of <0.001, which means that the regression model is highly significant, and the correlation between temperature and signal quality is not coincidental.

Table 6: Multiple Regression Model Summary Table

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.990[a]	0.980	0.973	0.0850
a. Predictors: (Constant), Temperature (°C), Time of Day				
b. Dependent Variable: Signal Quality (%)				

R square was slightly improved to 0.980 when time of day was added to temperature. But, only 2.5% of the remaining variation could be accounted for by time, further supporting the conclusion that temperature is the most important factor.

Table 7: Table of Multiple Regression ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.132	2	1.066	147.488	<0.001[b]
	Residual	0.043	6	0.007		
	Total	2.176	8			
a. Dependent Variable: Signal Quality (%)						
b. Predictors: (Constant), Temperature (°C), Time of Day						

In the combined model temperature was still very significant (F = 147.488, p = <0.001), and the slight improvement over the simple model further strengthens the findings that temperature is the most practical predictor of the quality of the signals at this location.

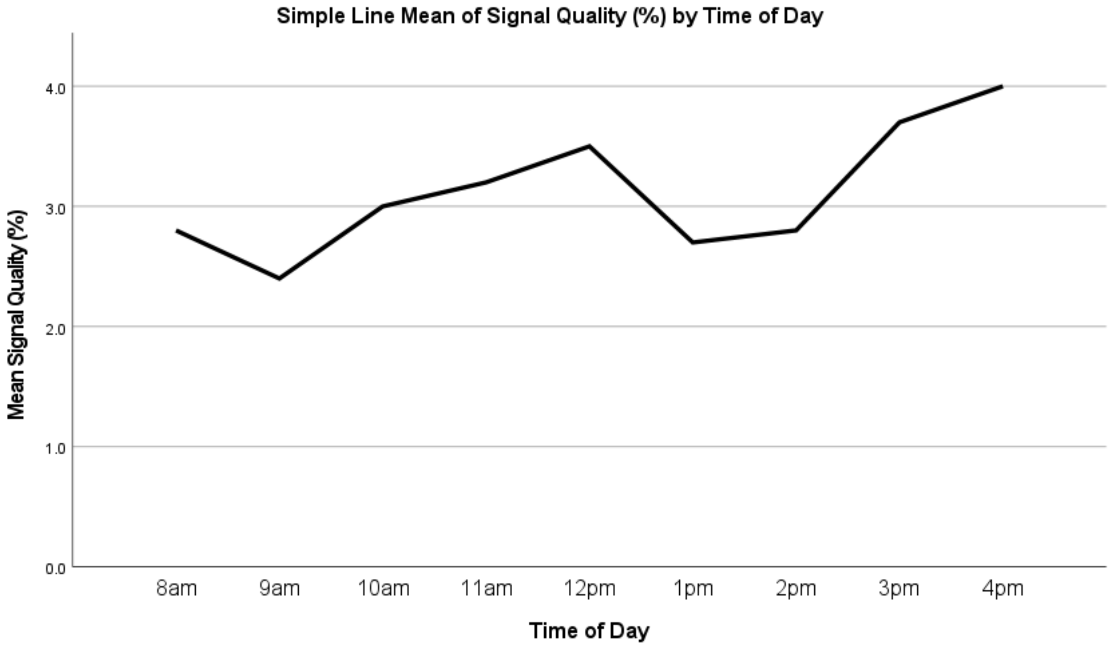

Figure 1: Mean of Signal Quality (%) over Time of Day (Simple Line)

The line graph illustrates the variation in the quality of the signals during the day at N.B.S Lafia. The signal quality began at 2.8 % at 8 am, but reduced to a minimum of 2.4 % at 9 am before rising throughout the rest of the day. The signal quality dropped significantly around 1pm, down to 2.7 %, but improved and steadily increased until it reached its highest level of 4.0 % at 4 pm. The trend indicates that signal strength is best during the warmer portions of the day, especially in the late afternoon when probably there is minimal refraction of the signals coming from the Satellite. There are however some variations within the day.

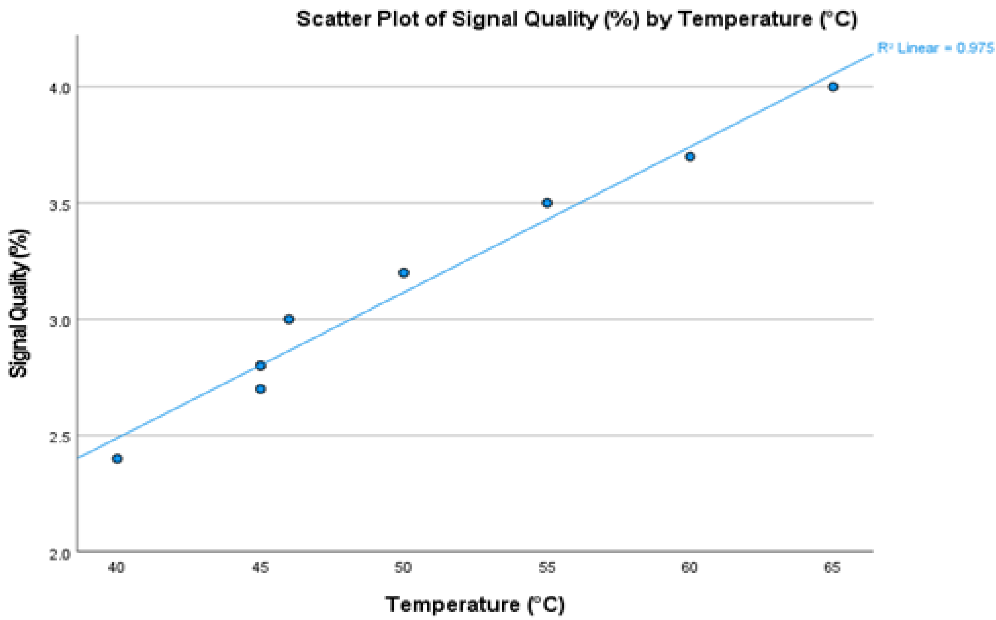

Figure 2: Scatter Plot of Signal Quality (%) by Temperature (°C)

There is a strong positive linear relationship between temperature and signal quality as illustrated in the scatter plot. As temperature increases, so does the signal quality. For temperature increases from 40 °C to 65 °C, the satellite signal quality increased from 2.4 % to 4.0 %. All the data points are very tightly grouped around the straight regression line, and the R^2 is 0.975, which indicates that signal quality is explained by temperature alone with 97.5% accuracy. This visualization is an excellent graphical illustration of the statistical result that indicates that increased temperature correlates with improved network signal quality at the study site.
The satellite signal quality is better at higher temperatures because as moisture reduces, the air is drier as water vapour rises while the thick clouds absorb what would have scattered the microwave signals. Satellite signal attenuation is minimised and its quality improves though there may be scintillation for some communication frequencies.

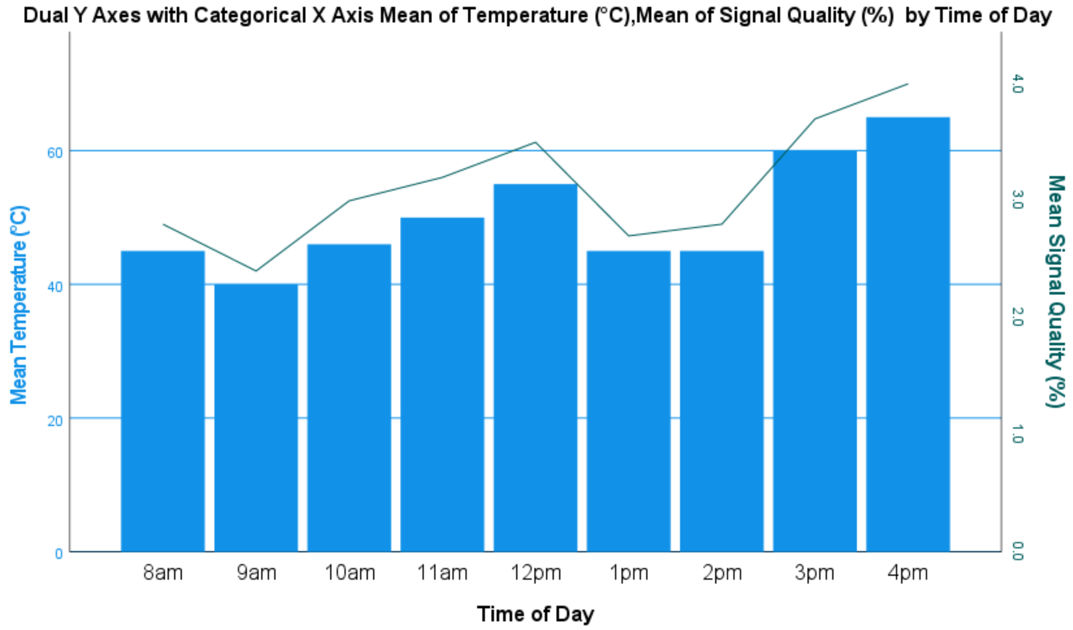

Figure 3: Dual Y Axes with Categorical X Axis

The dual axis chart shows temperature (in blue bars) and signal quality (in green line) for various times of the day. This visualization helps to observe the relationship between the two variables. The signal quality line is also better when the temperature bars are higher, which is the case at 12pm, 3pm and 4pm. On the other hand, if the temperature drops at 9 am and 1 pm, the quality of the signal will also become poor. The correlation between temperature and signal quality is visually apparent as time passes during the day, demonstrating strong positive correlation through the statistical analysis.

IV. Conclusion

This work studied the effect of Temperature on the Downlink satellite signal attenuation in Nasarawa State Broadcasting service. The signal quality line is better when the temperature bars are higher, which is the case at 12pm, 3pm and 4pm. There is a strong positive correlation between Temperature and Signal quality(r = 0.988, p = 0.000). The satellite signal quality increased steadily with temperature increases between the hours of 8.00 and 12.00, and at 13.00 there was a 23 % decrease in signal quality but the signal quality improved at 14.00 and almost doubled to 4.0 % at 16.00.

At NBS Lafia therefore, a drop in temperature leads to poorer signal quality. Satellite Signal strength is best during the warmer periods of the day when there is reduced moisture and absence of some cloud effects that could have influenced Satellite communications. Within the day however, some slight signal quality variations occurred and at NBS the higher the temperature, the better the signal quality.

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