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High Level Noise Impact on Image Data of Yagi Antenna Smart TV Transmitting at 18- 24 Ghz

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Abstract
Noise had been known to have great impact on the quality of service (QoS) in digital Television transmission network and in wireless communication systems during data communication. This is because noise reduces Signal to Noise ratio (SNR) in Wi-Fi and cellular networks, and in television and radio broadcasting systems. Yagi antenna had been in use on Television network and in wireless systems, because it provides focused coverage and minimize interference especially in location where signal strength is weak. The effect of high impact noise at very close range on microwave signal have not been investigated to include non-convectional sources of noise such as a high-noise source (≥80 dB). The measurement of high level noise impact on digital TV transmission at microwave frequency with Yagi antenna transmission at microwave frequency up links (18 - 24 GHz) and downlink (474 to 842 MHz) band was taken using Digital Transmission Television (DST) equipment, a GOTV decoder, a Yagi antenna, a high-noise source (≥80 dB), a power source, a smart television monitor, and a sound meter. Twenty stations within the microwave frequency range were selected for the study. The results indicated that signal loss caused by excessive environmental noise adversely affected signal quality on the Smart TV. It was concluded that high noise level greater than 80 dB may have detrimental effect leading to decrease in signal quality (loss of picture) during evening hours and on rainy days.

Keywords: SNR, Digital TV, Environmental noise, Microwave Frequencies, QoS

1.0 Introduction

In early 20th-century research on television systems, and by the 1920s, TV viewing had made significant progress in number [1, 2]. The most common home electronics item in the world without a doubt is the television receiver. According to the International Telecommunications Union- Radio (ITU-R), television sets in use worldwide is of significant increase over the number of fixed telephones (0.787 billion), cellular phones (0.75 billion), or personal computers (0.277 billion) [3]. For television reception Yagi-Uda antenna- a directional antenna is widely utilised.

Many nations have already begun the switchover to Digital Television (DTV) from analog television. Still the utilization of Yagi-antenna for TV reception increases. The quality of Service QoS of the TV signal, the quality of the image has to be maintained. The effect of noise impedes the quality of image on TV. Also, the use of Yagi antenna in radio broadcasting reception in suburban and rural areas where signal strength is relatively weak can also be affected by high environmental noise. This study tends to investigate the degree of effect of high impact noise on Yagi antenna transmitting and receiving DTV signal in order to enhance performance at any level of signal exposed to noise. This is also paving the way for the smooth integration with other communication systems, computer networks, and digital media, enabling datacasting and multimedia interactive services [4, 5, 6].

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2.0 Literature Review

The implementation of digital television broadcasting standards has enabled the delivery of high-definition video and audio broadcasts to TVs and smartphones over the air at greater bandwidths in ultrahigh-frequency bands. Large payloads of data are now being wirelessly sent at ultrahigh-frequency (UHF) bands as a result of the introduction of digital broadcasting standards for the transmission of TV signals over the air (ATSC, DVB-T, and ISDB-T) since the 1990s. Orthogonal frequency-division multiplexing (OFDM), which transmits audio and video streams at digitally modulated closely spaced carrier orthogonal frequency-division multiplexing (COFDM) frequencies, allows for transmission of a significantly improved picture quality without suffering from ghosting and multi-path effects common with analog [7, 11,22].

There are currently numerous terrestrial digital TV (DTV) networks operating all over the world that adhere to various standards, including Advanced Television Systems committee (ATSC) [8]. Digital Video Broadcasting - Terrestrial (DVB-T), integrated services digital broadcasting - terrestrial (ISDB-T), and Sistema Brasileiro de Televisao Digital (SBTVD). Additionally, some of them are already being replaced by next-generation systems, such as ATSC and DVB-T, which are both being replaced by ATSC 3.0 [10].

A signal's amplitude or power is reduced as it moves across a communication network, which is known as attenuation. It happens frequently in both wired and wireless communication systems. Attenuation is a significant factor that affects the performance of communication networks. It can be caused by a variety of factors, including distance, obstacles, and atmospheric conditions. The impact of attenuation can include signal degradation, reduced range, interference, and increased costs [11]. Radio Frequency Interference (RFI) is the presence of unwanted electromagnetic radiation in the frequency range of interest. It can occur naturally or due to man-made sources and can affect the performance of communication systems, such as wireless networks, satellite communications, and radar systems [12, 21,22]. The RFI can cause degradation of signal quality, reduced data throughput, and loss of connectivity. The RFI can be caused by natural sources such as lightning, solar flares, and cosmic radiation. Man-made sources of RFI include power lines, motors, electric fences, electronic devices, and even LED lighting. The increasing use of wireless devices and the proliferation of wireless networks has made RFI a more significant problem in recent years.

Additionally, the growing number of unmanned aerial vehicles (UAVs) and other wireless systems have contributed to RFI. The RFI can have a range of effects on communication systems. It can cause signal distortion, noise, and interference that degrade the quality of the signal. This can lead to reduced data throughput, increased latency, and loss of connectivity. In severe cases, RFI can cause complete system failure, resulting in significant downtime and lost productivity.

The effects of RFI can be especially problematic for critical systems such as air traffic control, military communications, and emergency services. Various spectrum sensing techniques have been proposed for RFI monitoring in Cognitive Radios (CR). These include Cyclo-Stationary Feature Detection (CFD) [13, 14], Energy Detection (ED) [13], and matched filtering-based detection [16, 17]. Among these techniques, CFD [13] stands out as it can identify the Signal of Interest (SoI) amidst interference and noise, even in low Signal-to-Noise Ratio (SNR) scenarios. However, its implementation is computationally complex [18].

In its most basic form, signal noise refers to any unwanted interference that weakens a communication signal. Digital transmissions can be affected by signal noise, but it takes far more noise to damage a digital signal. This is due to the fact that digital signals utilize discrete electrical pulses as a means of communication to transmit digital. Signal noise introduced into electrical transmission will decrease the predicted signal value.

A Yagi-Uda antenna, transmits signals mostly in one direction. The Yagi antenna is most sensitive to incoming electromagnetic field energy arriving from the same direction that the electromagnetic field energy is traveling from the driven element toward the director(s). The forward gain and length of the antenna increase as the number of directors in a Yagi increases. Although television reception has made this form of antenna particularly popular, it is also employed in a variety of other residential and commercial applications where an RF antenna with high gain and directivity is needed.

This digital transmission uses microwave for long-distance transmission between ground stations and satellites, but the importance of radio frequency interference (RFI) especially environmental noise—on microwave in achieving high-quality radio links, television signals, sound, and image production cannot be understated. Additionally, the use of Yagi antennas to improve the quality of picture and sound during digital transmission has recently grown in popularity due to their wide range, affordability, and ease of construction; however, their high sensitivity to frequency encourages the predominance of RFI on their performance to the point that environmental disturbance can disrupt their frequency efficiency.

Therefore, it is important to undertake thorough measurements on operational microwave links in order to be able to assess the link performances, identify and reduce RFI in the channels. It may be possible to improve digital transmission at microwave frequency with reduced RFI by measuring the impact of external radio frequency interference, such as high level noise, on Yagi antenna.

3.0 Materials and Method

3.1 Experimental set-up

To investigate the high level noise impact on digital TV transmission at microwave frequency with Yagi antenna. Materials such as Digital Transmission Television (DST), (GOTV decoder), Yagi antenna, Source of high noise (≥80 dB), Power source, a monitor (Smart Television) and Sound meter were used to perform test on twenty station within a microwave frequency links operating at the range of 474 to 842MHz bands. The Yagi antenna was selected on a Digital Transmission Television (DST). The selection of the stations were based on the National and International stations that are available on GOTV transmission on microwave frequency on approximately ratio 1:2. That is eleven selected stations were national stations while nine were international station.

The selected stations were labelled station 1 to 20 (S1-S20). Table 3.1 shows the selected stations, status and their respective Frequencies. The high noise source of (≥80 dB) was generated from a 12.5 kVa power generating set. This was placed beside the Yagi antenna to serve as the environmental source of noise. The smart television was used to monitor the picture quality and the variation in the picture quality with frequency and signal strength and signal quality. Sound meter was used to measure the level of noise before the introduction of environmental noise and after the introduction of the environmental noise.

The period before the introduction of the environmental noise was called quiet period while the period of the introduction of the environmental noise was called disturbed period The signal variation according to the season (may be raining or sunny) and time of the day was also considered and Smart TV was also used to monitor the picture quality and the variation in the picture quality with frequency and signal strength and signal quality.

A noise of (≥80 dB), was selected because it has been confirmed that a microwave frequency transmission could only be affected by environmental noise (≥80 dB) [4, 5, 6].

Table 1 Selected stations, status and frequencies

STATIONS	FREQUENCY (MHz)	STATUS
1	117.5	S(N) National
2	205.4	S(N) National
3	212.5	S(N) National
4	474	S(N) National
5	522	S(N) National
6	634	S(I) International
7	642	S(I) International
8	658	S(I) International
9	666	S(I) International
10	674	S(N) National
11	690	S(I) International
12	706	S(I) International
13	714	S(I) International
14	722	S(I) International
15	786	S(I) International
16	794	S(I) International
17	802	S(I) International
18	802	S(I) International
19	834	S(I) International
20	842	S(I) International

3.2 Methodology

In order to investigate high level noise impact on digital TV transmission at microwave frequency with Yagi antenna the signal-to-noise power ratio was conducted for twenty selected station for twenty days. The twenty days comprises of 14 bright days and 6 raining days. The experiment was conducted three times a day—morning, afternoon, and night—over a period of 20 days. Within these twenty days, there were 14 days during the morning period before sunrise, characterized by a very low ionization rate.

Additionally, there were 6 days of cloudy and rainy mornings, which combined environmental noise, rainfall, and low ionization. The afternoons were sunny, representing the peak ionization period, while the evenings were cloudy after sunset. This variation was necessary to assess the impact of seasonal changes and environmental noise on digital TV transmission at microwave frequencies. The procedure was repeated for the twenty selected stations as presented in Tables 1. This measurement was recorded against each stations. The environmental noise (≥80 dB) was introduction by switching on the generating set and the noise meter to allow measurement of the highest detected noises level. This level of noise was maintained throughout the experiment. The noise level in dB was recorded, the signal strength and the signal quality were also recorded by the smart monitor TV.

Statistical analysis was performed on the measured value of the signal during Quiet period (QD) and Disturbed Period (DP). The percentage signal loss was calculated using equation (1).

$$\% Signal\ loss(dB) = \frac{Qp - Dp}{Qp} \times 100\ \% \quad (1)$$

where $Qp - Dp$ is the
QP= quiet period signal
DP= disturbed period signal

4.0 Results and Discussion

4.1 Results

In order to evaluate the signal strength variations that are related to the effect of high environmental noise, a group of percentage signal loss within the period of consideration were plotted for all selected transmitting stations of each event for easy comparison as shown in Figures 1 to 6. In all the Figures, the blue bar represents the morning % signal loss, the red bar depicts the afternoon the % signal loss variation and the grey bar represent the evening %signal loss, respectively. The combination of the three bars represents the daily variation of the % signal loss with time S1 to S20 represents the selected stations 1 to 20 as shown in Table 1.

For the analysis of the % signal loss due to the combination of the high environmental noise and weather variation for raining days of the selected days as shown in Figures 1-6. It is worthy to note that no or negative % signal loss indicates no significant impact of the environmental noise on the signal strength of the transmitting station at that particular time. Therefore, there is no significant effect of the high environmental noise on the signal quality of the station. The higher the % signal loss the lower the signal quality, this implies that the positive % signal loss depicts the degree of the effect of the high environmental noise on the stations. Figure 1 shows the variation of the % signal loss of the twenty selected stations of different frequencies with the time of the day. It could be observed from the Figure 1 that the % signal loss due to the environmental noise impact is very high in the morning time of the day in all the selected station. The % signal loss is highest in S3 (N) = 212. 5(MHz), and there is no significant % signal loss in S8 (I) =658(MHz). The % signal loss in the afternoon is lower than that of the morning period in all the observed stations except S19 and S20 but there are still significant % signal loss. The % signal loss in the evening is greater than that of the afternoon period in all the stations except S19 and S20 this may be due to the difference in the operating frequency band because signal strength depends on frequency.

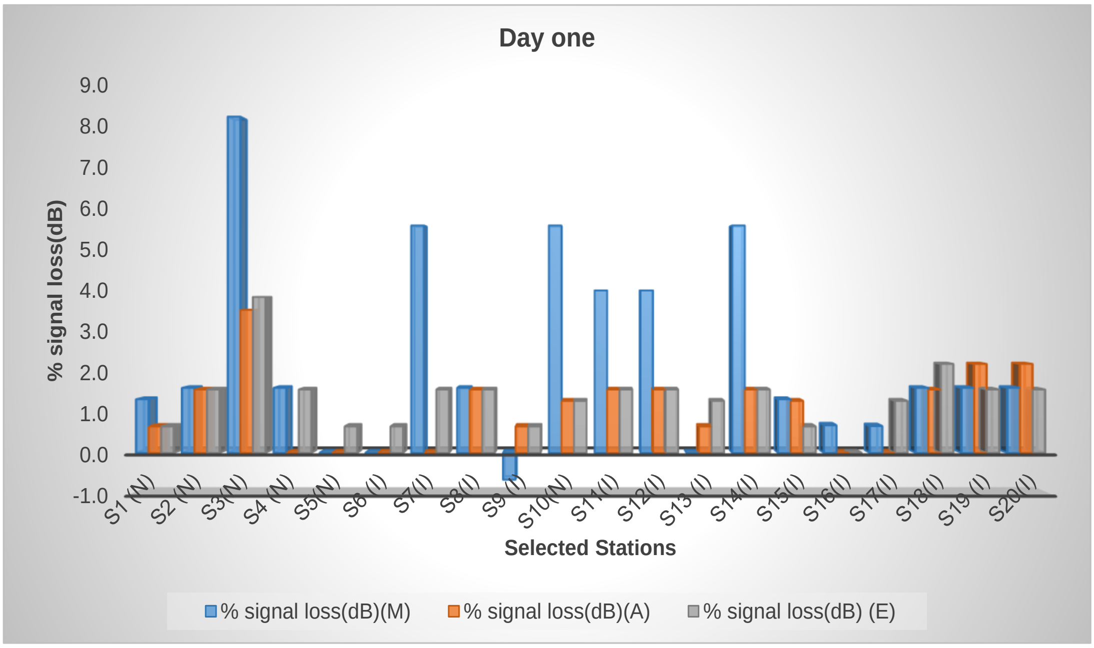

Figure 1: Plots of % signal loss against selected stations of Different Frequency for Day One

Figure 2 shows the variation of the % signal loss of the twenty selected stations of different frequencies with the time of the day. The plot showed that the % signal loss due to the environmental noise impact is very high in the Evening time of the day in all the selected station except for stations S18(I)=802 (MHz) and S20(I)=842(MHz). The morning, afternoon and evening % signal loss is highest in S3(N)= 212. 5(MHz), and there minimum % signal loss as compare with other time of the day. The high frequency band operation may account for the disparity. Moreover, the lower % signal loss recorded in the morning period may be due to intensity of the sun in the early hours of that same day.

Figure 3 depicts the variation of the % signal loss of the twenty selected stations of different frequencies with the time during the third day. It could be observed from the figure that the % signal loss due to the environmental noise impact is very high in the morning time of the day in all the selected station. The % signal loss is highest in S3 (N) = 212.5(MHz). The % signal loss in the afternoon is lower than that of the morning period in all the observed stations, but there are still significant % signal loss the % signal loss in the evening is greater than that of the afternoon period in all the stations.S3(N)= 212.5(MHz), has the highest % signal loss.

Figure 4 illustrates the bar chart of the variation of the % signal loss of the twenty selected stations of different frequencies with the time of the Day four. The figure shows that the % signal loss due to environmental noise is high in the morning period than in the evening period and minimal in the afternoon period in all the observed selected station except for S17(I)=802 (MHz), that presented no significant % signal loss. The % signal loss is more obvious in S3(N)= 212. 5(MHz).

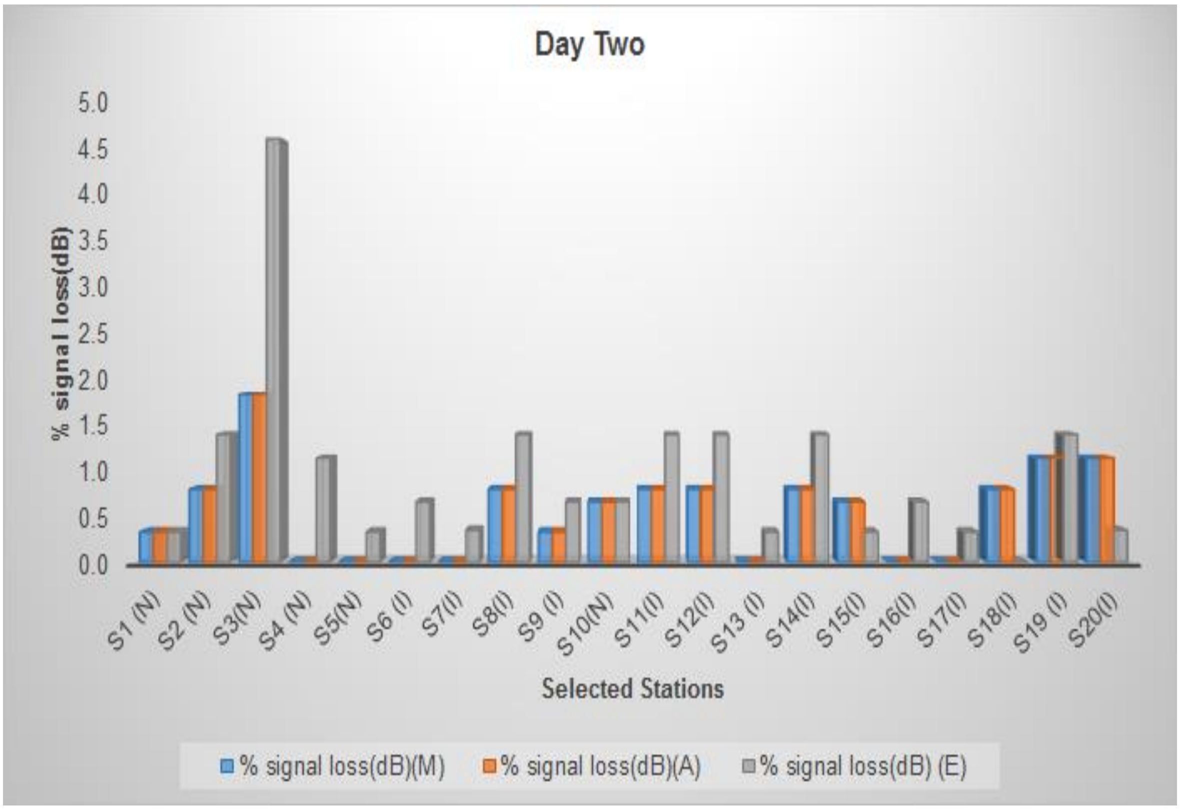

Figure 2: Plots of % signal loss against selected stations of Different Frequency for Day Two

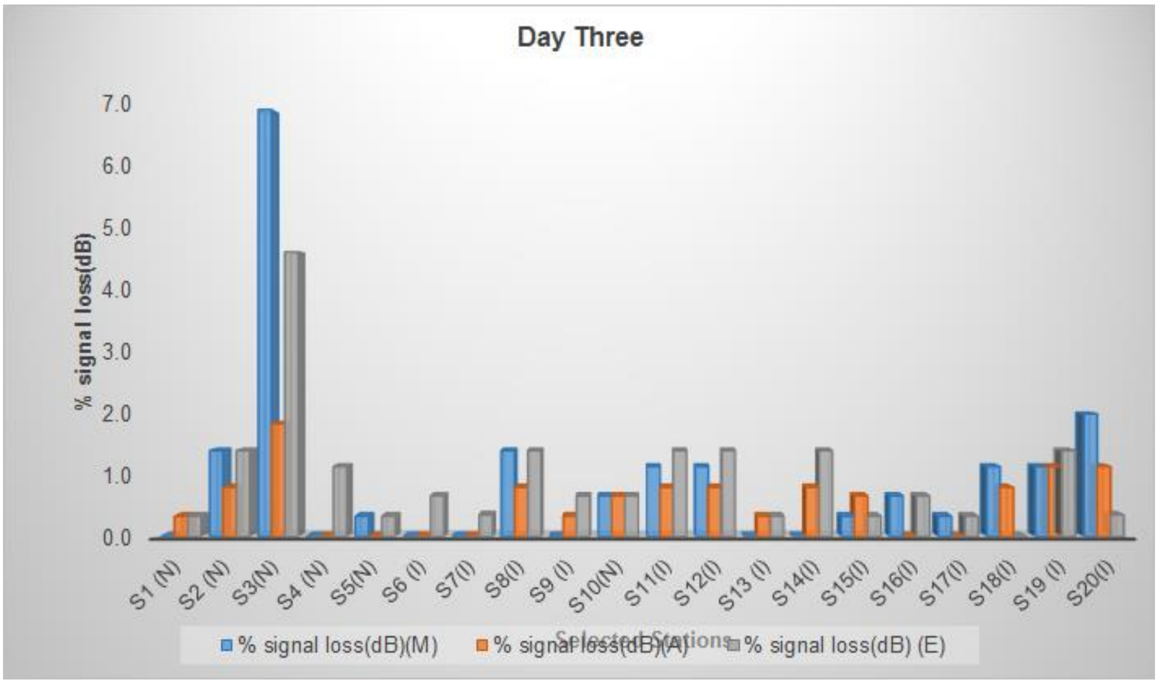

Figure 3: Plots of % signal loss against selected stations of Different Frequency for Day Three

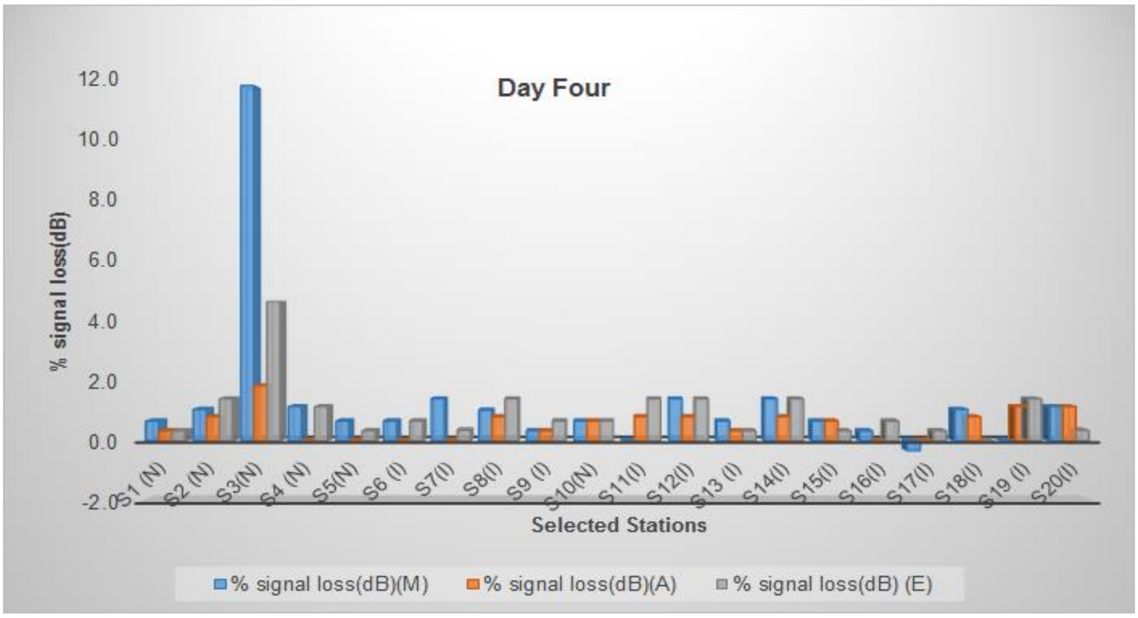

Figure 4: Plots of % signal loss against selected stations of Different Frequency for Day Four

Figure 5 shows the variation of the % signal loss due to environmental noise and rain of the twenty selected stations of different frequencies with the time of day Two It could be observed from the figure that the % signal loss due to the environmental noise impact and rain is very high in the evening time of the day in all the selected station. Except for S8 (I)=658(MHz), The % signal loss is highest in S3(N)= 212. 5(MHz), S12(I)=706(MHz), S15(I)=786(MHz and S19 (I)=834(MHz) that the % signal loss is greater in the morning than in the evening period and there is no significant % signal loss in the evening period of S5(N)= 522(MHz), the % signal loss in the afternoon is lower than that of the morning period in all the observed stations but there are still high significant % signal loss the % signal loss in the afternoon period of all the observed stations,

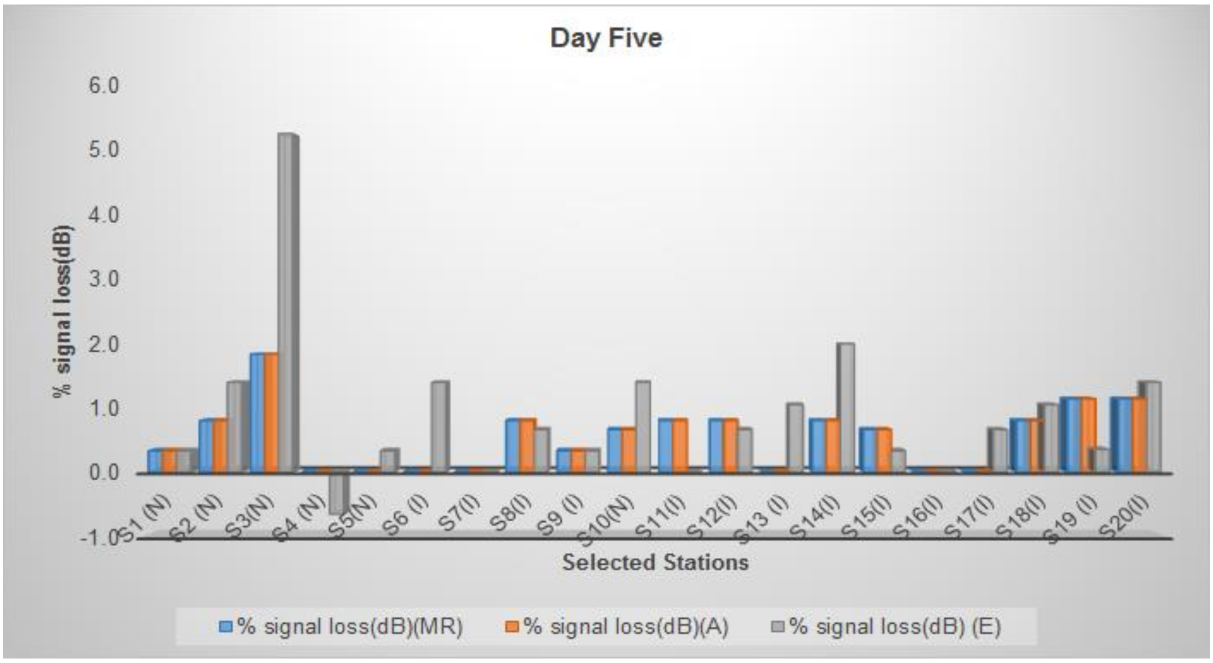

Figure 5: Plots of % signal loss against selected stations of Different Frequency for Day Five

Figure 6 shows the variation of the % signal loss due to environmental noise and rain of the twenty selected stations of different frequencies with the time of day six. It could be observed from the figure that the % signal loss due to the environmental noise impact and rain is very high in the evening time of the day in all the selected station. Except for S8 (I) = 658(MHz), The % signal loss is highest in S3 (N) = 212.5 (MHz), S12(I)=706(MHz), S15(I)=786(MHz and S19 (I)=834(MHz) that the % signal loss is greater in the morning than in the evening period and there is no significant % signal loss in the evening period of S5(N)= 522(MHz), the % signal loss in the afternoon is lower than that of the morning period in all the observed stations but there are still high significant % signal loss the % signal loss in the afternoon period of all the observed stations.

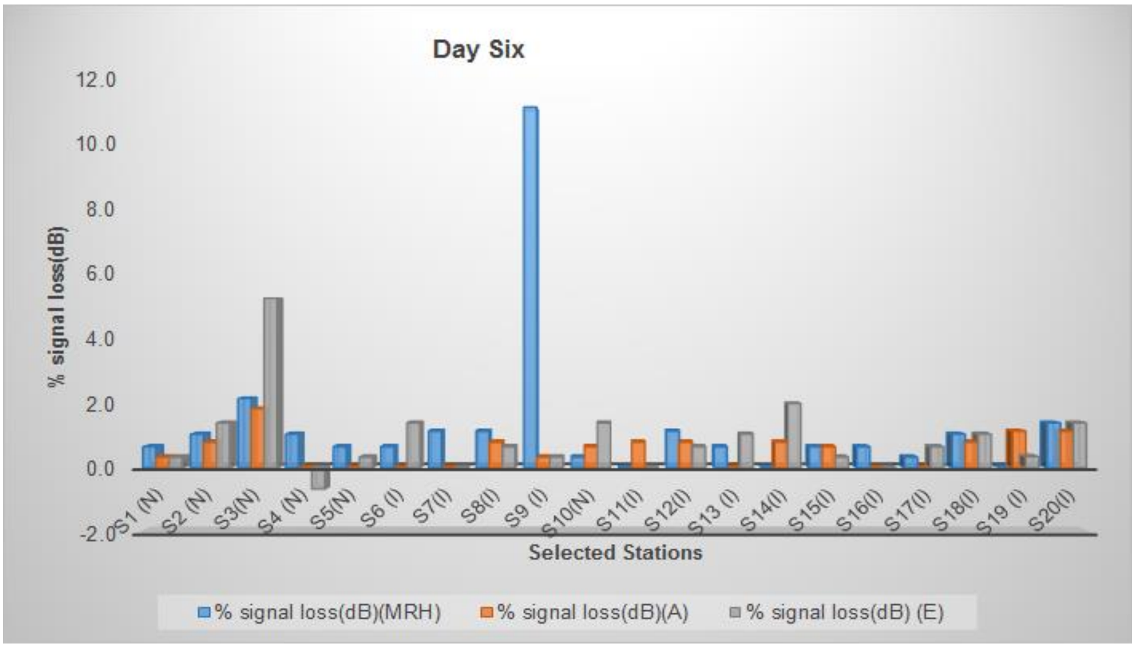

Figure 6: Plots of % signal loss against selected stations of Different Frequency for Day Six

4.2 Discussion of Results

4.2.1 The Influence of High Level Noise on Digital TV Transmission at Microwave Frequency

Many digital TV networks operating outdoors are exposed to many factors as changing weather conditions, which may cause severe degradation in system performance [12]. There were also attenuation during heavy down pour that swallow the signal thereby causing disruption in signal quality of digital television transmission but it is only peculiar to rainfall. Therefore, the high level noise impact on Digital TV transmission was determined when there is a significant % signal loss which is greater than 1%. % signal loss is up to 12% in the early and evening hours of the day in some of the selected station and greater than 1% in the afternoon period on all the station that was examined. This implies that the introduced high environmental noise (≥80 dB), has effect on the microwave frequency transmission [4, 5, 6]. This effect of the environment noise and its combination with rainfall is determined when there are significant disparity in the % signal loss between the raining days and the bright days,

Figure 7 indicated that the combination of the effect of rain and noise on Digital transmission may have adverse effect on the signal quality during the evening time and not during the downpour as the signal loss during down pour may be associated with attenuation [11]. The pictures as recorded on the monitor during the evening time of the raining days as compared with the evening time of the bright days shows total degradation.

The environmental noise affect both the national and the international stations as both respond positively to the effect of the noise through deviation in percentage loss. However, the higher frequency station has less % signal loss as compared with the stations of lower frequency this may be due to the fact that the signal strength depends on frequency. The morning period of both the national and international stations has total signal loss that make the signal quality to provide blurring pictures as compared with the afternoon period that has fading picture that may be noticed due to short time of signal restoration

Figure 7 shows the typical picture that was observed on the smart TV whenever there is loss of signal as a result of the impact of the high environmental noise, this picture depicts that there is also loss of signal quality which may be a response of the transmitting station to the loss of signal due to high environmental noise. This distortion of the process signal, that lead to inaccurate interpretation or display of a process condition by the equipment (Smart TV) may be due to signal loss that was from signal noise. It may also be as a result of an erroneous process variable results from the process signal being added to or subtracted from the transmission due to high level environmental noise [20].

Figure 7: The typical picture on the smart TV whenever there is loss of signal

5. Conclusions

This research aimed at understanding the impact of high-level noise on digital TV transmission at microwave frequencies using a Yagi antenna it was concluded that the introduction of environmental noise at a level equal to or greater than 80 dB has an effect on microwave frequency transmission. This can be attributed to the fact that signal strength is influenced by the frequency of transmission. There was also a noticeable decrease in signal quality and a total signal degradations during evening time of raining days that could be attributed to the total loss of signal on TV sensor networks due to weather conditions. Consequently, it becomes crucial to investigate the factors that influence radio link quality. Understanding these factors is essential for minimizing their impact and adapting to the changing environmental condition. For further study, it is recommended that same method may be adopted to study many more stations in different locations.

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