$$\psi_{a,b}(t)=\frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right) \qquad (14)$$

Where a is the positive number which defines the scales and b is the real number that defines the shift in (14) sometimes called child wavelets derived from mother wavelet. Full wavelet decomposition (FWD) of (14) gives (15)

$$y=a_x(J,k)\,\psi_0(J,k)+\sum_{k=1}^{j}d_x(j,k)\,\psi_0(j,k) \qquad (15)$$

y is decomposed using Haar at level 5,which means that the approximated part of the signal can be seen on a J upper scale and the detail part of the signal on j lower scale as shown in Figure 4. Haar is chosen for the decomposition because of the following reasons; physical appearance of the experimental data, the wavelet Haar has a coefficient of correlation approximately equal to that of experimental data and the wave's energy is almost the same. However, the ideal wavelength (l) of propagation of the study area may be obtained as $l=C/f$; where C is the speed of the propagated wave and it can be evaluated by $C=z/t$; where z is the distance between the BS and the MU and, may be calculated using $z^2=\sqrt{z_{BS}{}^2-z_{MU}{}^2}$. Haven known the total amount of the power received in the study area using expression (16).

$$\sum_{i=1}^{n}P_i(dBm) \qquad (16)$$

Where P is the power received in the study area. Comparing the approximated signal and the signal received in the study area after the filtering, shows that the signal suffers high attenuation and, the find the average ratio of the signal received to the approximated signal as $P_i(dBm)/P_d(dBm)$ which is calculated as 5:1 respectively. This is evident that the frequency of the signal received fades 5 times [11] and wavelength becomes $l=C/Kf$ greater than the normal wavelength of the propagation due to the obstacles between the BS and the MU.K is the attenuation factor and P_d is the filtered signal. In addition, the factor that may attribute to the cause of the attenuation is the fact that the study area is close to the river Dnepr. Therefore, to determine the propagation error, the mean square error between the approximated signal and the received signal is obtained, using expression (17).

$$MSE=\sum_{i}^{n}\left(\sqrt{\frac{(P-P_a)^2}{n}}\right) \qquad (17)$$

where n and P_a is the number of the empirical data and the approximated signal respectively. Figure 4, shows the wavelet decomposition of the detail and approximated signals. d_1, d_2, d_3, d_4 and d_5 present the detail part of signal on low scale with high frequencies and a_5 presents the approximated part of the signal on high scale with low frequencies.

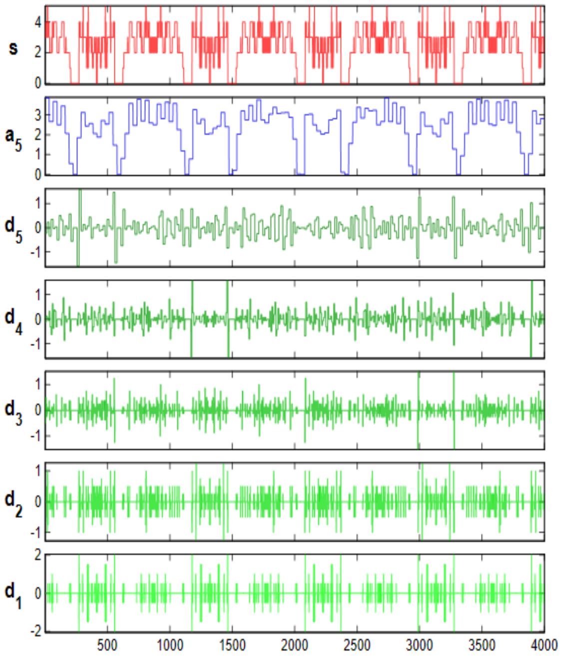

Figure 4: Detail and Approximated signals in octave

2.3 Clustering

Clustering simply means grouping elements together based on their properties, appearance contains and other features. The signal received is trained using neural network clustering, the network learned about the signal received and produced clusters of the power measured. As shown clearly in Figure 5, the signal is grouped into six different groups, -75dBm appeared more frequent, followed by -85dBm, then -65dBm and –95dBm, -105dBm and -55dBm are least signal received.

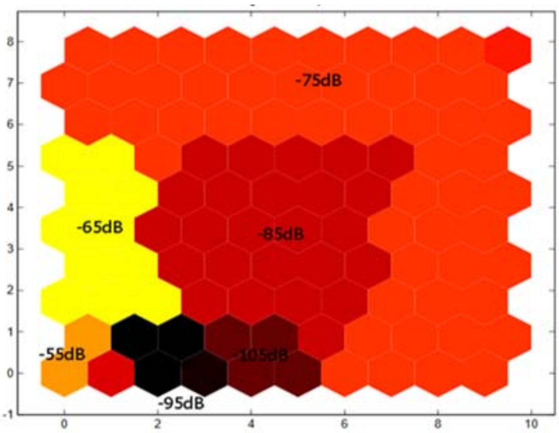

Figure 5: Clusters of the signal strength received

3. Results and Discussion

Figure 6 presents the measured path loss and the reference models; the red color graph represents the COST 231-Hata model, the green color graph presents the Okumura-Hata model and the blue color graph presents the measured path loss. It seems Okumura-Hata model best fits the study environment. Even though, both the models need modification.

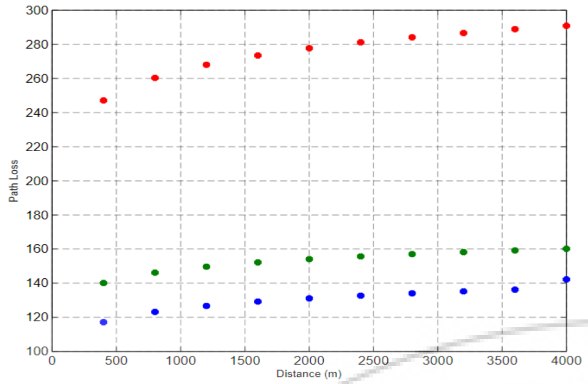

Figure 6: Path loss measured and the reference models

The MSE values are used to modify the reference models. Perhaps, both MSE values fall within the acceptable range of maximum 6dB [5]. The expressions in (18) and (19) present the new modified models using the MSE value of the neural network prediction. The modified COST 231-Hata model is given in (18) and the modified Okumura-Hata model is given in (19) respectively.

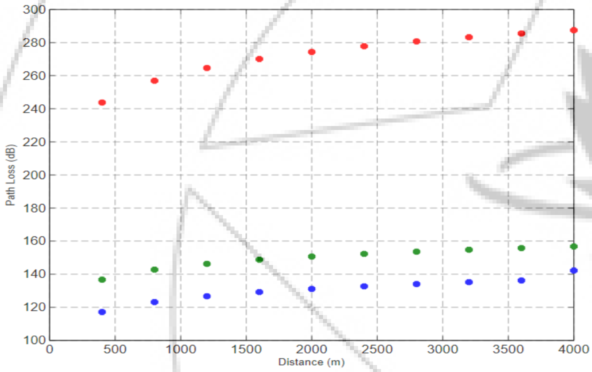

Figure 7: Measured path loss and modified models using neural network

$$L_0 = 43.6252 + 33.9\log f_c - 13.82\log h_B - a(h_m) + \log d\ (44.9 - 6.55\log h_m) + C_H \quad (18)$$

$$L_{50} = \gamma_0 - 2.6748 + a(f,d) - G_B - G_M - G_E \quad (19)$$

Figure 8 presents the path loss measured and the modified models using the neural network MSE value, the red color is the COST 231-Hata, blue color is the modified COST 231-Hata, green color is the Okumura-Hata, and blue color is the modified Okumura-Hata model. The modified Okumura-Hata model seems to best fits the path loss model of the study environment [12], despite the fact that it changes slowly with the new environment, while the COST-231 Hata model failed to fit the study environment may be due to the environmental characteristics that influence the prediction.

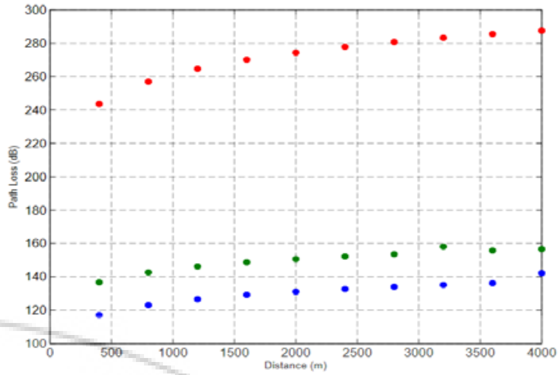

Figure 8: Path losses for all the models

4. Conclusion

Path loss is an important parameter that one needs to know before undertaking design or improving the existing radio frequency communication path. In this work, a nonlinear autoregressive neural network and a wavelet based methods were used to the predict path loss (error) in the study area. The neural network and the wavelet based method predicted that the GSM signal strength is attenuated with MSE of 3.397dB and 3.428dB, then these values were used to modify the reference models adopted and also, used neural network to group the signal strength received in the study area. This revealed that, mostly weak signal is received in order of -75dBm, -85dBm, -95dBm. This work demonstrated that nonlinear autoregressive neural network has better performance of 3.02% over the wavelet based method. However, the two methods are good tools for path loss prediction.

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