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Wavelet Based Indoor Prediction of Global System for Mobile Communication (GSM) Signal Strength Attenuation

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Abstract—**In this work, we monitored GSM signal strength (power) in an indoor environment and measured samples of the GSM signal strength on a mobile equipment (ME). We also, used one-dimensional multilevel wavelet to predict the fading phenomenon of the GSM signal measured and neural network clustering to determine the average power received in the study area. The wavelet prediction revealed that the GSM signal attenuation is a fast fading phenomenon which fades about 7 times faster than the radio wavelength while the neural network clustering determined that -75dBm appeared more frequently followed -85dBm. The work revealed that significant part of the signal measured is dominated by weak signal and the signal followed more of Rayleigh than a Gaussian distribution. This confirmed the wavelet prediction.**

Index Terms—**Decomposition, clustering, propagation, model and spectral efficiency.**

I. INTRODUCTION

The demand for GSM service is rapidly growing in the entire world, as the number of subscribers of GSM mobile equipment user increases; the spectral efficiency becomes a so essential. This is because; the frequency allocation is a limited resource. Greater capacity or excellent quality of service is achieved as a result of less frequency reuse [4]. High spectral efficiency can be realized by reusing frequency in a dense or complex environment such as outdoor or indoor areas; thick forest, high buildings, large water surface, other geographical features, area consist of walls, furniture's and floors which may scatter the signal. Subscribers, experienced call difficulties more especially, in the indoor environments such as; frequent call drop, poor intra and inter connectivity, cross talk in call conversation. This prompted us to study the behavior of the GSM strength attenuation in an indoor environment. However, the work did categorically choose any specific component that attributes to the attenuation of the GSM signal strength, but in this work, fast or slow fading phenomenon is the central focus. In [2], the authors used one dimensional multilevel wavelet to detect the signal attenuation with reference to multipath and shadow fading, but did not group and predict the average power received in their study area, while in this work, we used neural network clustering to ascertain the average power received from our study environment. In [3], a simple approach to a statistical path loss model for indoor communications was developed using power law. The work concluded that the model can be used to obtain basic information on how to estimate the power budget of communication system in a given environment. Also, the work extracted some vital information about the signal fading, but did not classify the characteristics of the signal fading in terms of the fast or slow phenomenon. In [5], a research was conducted on measuring and characterizing the indoor channel for IEEE 802.11 for a WLAN at 2.4GHz, the measurement was conducted in close and open corridors. The authors observed that the signal fading is normally distributed at 5% significant level, while some works were carried out on the measurement of signal strength to predict the effect of walls, office partition, floors and building layout on a specify frequency range 914MHz. The work revealed that floors attenuate the signal strength more than the other factors [6].

In this work, we propose to use one-dimension multilevel wavelet techniques to predict the GSM signal strength attenuation in terms of slow or fast fading in an indoor environment. We will also use neural network clustering technology to determine the average amount of the signal strength received by the mobile equipment (ME) in the study area in decibels, to enable us to predict the signal strength received more frequent in the study area.

II. PROPAGATION MODEL

The model incorporates the following parameters as given in Equation (1)

$$P_0 = \chi + 10\gamma\log(d) + \varphi_0 + \phi_0 = NL + wW \text{ [dB]} \quad (1)$$

Where $\chi =$ unit loss, $\gamma =$ power delay index, $d =$ distance between the transmitter and the mobile equipment, φ_0 = fast fading phenomenon (Rayleigh distribution), ϕ_0 = slow fading phenomenon (Gaussian distribution), $N =$ number of the floors, $L =$ loss per floor, $w =$ number of walls and $W =$ loss per wall. The power delay index factor can be evaluated from the experimental data measured using Equation (2)

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$$\gamma = I\sum_{i=1}^{I}\log(d.x) - \frac{\left(\sum_{i=1}^{I}\log d\right)\left(\sum_{i=1}^{I}\log x\right)}{I\sum_{i=1}^{I}(\log d)^2 - \left(\sum_{i=1}^{I}\log d\right)^2} \quad (2)$$

$I =$ is the number of the experimental data measured. Usually, the fast fading phenomenon follows the Rayleigh distribution given by

$$\varphi_0(x,\sigma) = \frac{x}{\sigma^2}e^{-\frac{x^2}{2\sigma^2}} \quad (3)$$

Where $\sigma =$ the mode of the experimental data measured, x is the GSM signal received. The mean and the variance of the fast fading power received, can be evaluated using expression (4) and (5)

$$\mu(x) = 1.253\sigma \quad (4)$$

$$Var(x) = 0.429\sigma^2 \quad (5)$$

Fast fading phenomenon is characterized by reflection of local objects or movement of ME around these objects which can cause fast fluctuation of the signal amplitude, for example, signal reflected by the large water surface, glasses, or vehicle movement. While the slow fading follows a Gaussian distribution given by

$$\phi_0(x,\sigma) = \frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{(x-\mu)^2}{2\sigma^2}} \quad (6)$$

Slow fading phenomenon usually occurs due to the diffraction and large reflection from building, mountains, etc.

III. STUDY AREA AND METHOD OF DATA COLLECTION

The data are collected on the ground floor of a three storey building in a room measuring 14 x 14 fts size, the room contains; furniture's like table, chairs, bed, clothes hang on the wall, boxes, standing mirror and other materials. The GSM signal is monitored in terms of network bars on a ME, samples of the GSM signal strength were collected in every 5s. Thus, network bars on the ME range from 0 to 5 bars, the lowest bar is 0 and is the weakest signal, if the signal strength increases as the number of the bars increase, which means the strongest signal is 5 bars. Usually, GSM signal strength is measured in -dBm; that is, the power measured (dB) multiple by the distance between the transmitter and ME receiver. The useful range is between -50dBm to -110dBm in a frequency range of 900MHz to 1800MHz or 1900MHz depending on the environmental requirements. The smaller the number of the dB received by the ME the worse the reception or QoS. Therefore, -50dBm is much better than -110dBm. In this work, we assigned 0 (no bar) to -105dBm, subsequently, 1bar = -95dBm, 2bars = -85dBm, 3bars = -75dBm, 4bars = -65dBm and 5bars = -55dBm. The transmitter is located almost 2000m from the ME.

IV. WAVELET DECOMPOSITION AND PREDICTION ALGORITHM

Here we use, wavelet transforms to decompose the attenuated signal measured in terms of fast or slow fading phenomenon. Full wavelet decomposition of the attenuated signal measured usually provides information about the time and the frequency of the signal at numerous scales. Thus, the signal can be seen in detail and approximated form both on the octave axis (j, J) respectively as shown in the experimental Fig. 1. Where the approximated signal is situated on the upper scale ranging from $1 \leq J \leq J_n$ while the details on the lower scale ranging from $1 \leq j \leq J_n$. The wavelet coefficients $a_x(J,k)$, $d_x(j,k)$ are derived from the relation below after full decomposition.

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right) \quad (7)$$

Where a is the positive number which defines the scales and b is the real number that defines the shift. Equation (7) sometimes called child wavelets derived from the mother wavelet. But full wavelet decomposition (CWD) is composed of the combine wavelet coefficients of the approximated and the details signal as given by

$$y = a_x(J,k)\,\psi_0(J,k) + \sum_{k=1}^{j} d_x(j,k)\,\psi_0(j,k) \quad (8)$$

y is decomposed using Haar at level 4, this means that n = 4. Haar is chosen for the decomposition because of the following; physical appearance of the experimental data and the wavelet Haar, coefficient of correlation is approximately equal and the wave's energy almost the same. Ideal propagation means equal propagation in all directions. Unfortunately, in real life situation, it is impossible because of some certain factors that hamper effectiveness of the propagation between the GSM base station (BS) and the ME. The ideal wavelength (λ) of propagation of the study area may be obtained as $\lambda = C / f$; where C is the speed of the propagated wave and it can be evaluated by $C = d / t$; where d is the distance between the BS and the ME. Haven obtained the total amount of the power received in the study area from expression (9).

$$\sum_{i=1}^{n} P_i(dBm) \quad (9)$$

Where P is power received in the study area. Comparing with the approximated power (P_a) after de-noising, the ratio P/P_a is equal to 7:1, this means that the frequency of the power received fades 7 times and the wavelength becomes $\lambda = 7C / f$ more than the normal wavelength of the propagation. Therefore, we can deduced that since the ratio of the signal approximated at level 4 fades about 7 times the wavelength of the propagation. It is worth to say that the signal received corresponds to the fast fading scale as shown in Fig. 1.

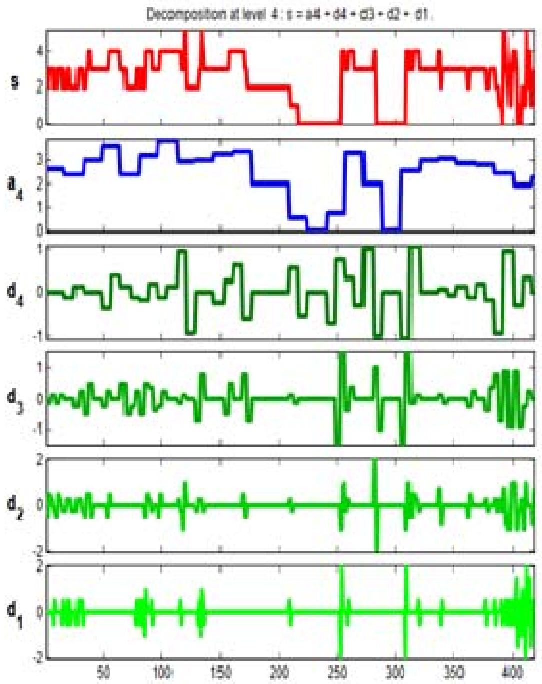

Fig. 1. Wavelet prediction of the signal received showing the signal details and the approximation

Therefore, to determine the propagation error, we obtained the root mean square error between the approximated signal and the received signal, using expression (9) as 5.482dB

$$RMSE = \sum_{i}^{n} \left(\sqrt{\frac{(P - P_a)^2}{n}} \right) \quad (10)$$

where n and P_a is the number of the empirical data and the approximated signal respectively.

V. CLUSTERING OF THE VARIATION OF SIGNAL STRENGTH RECEIVED

Clustering simply means grouping elements together based on their properties, appearance contains and other features. We trained the experimental data collected using neural network clustering, the network learned about the data and produced clusters of the power measured. As we can see clearly 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.

As described in the model Equation (1), we further went ahead to validate our wavelet prediction using probability distribution function (PDF) of the experimental data in terms of the Rayleigh and the Gaussian distribution as shown in Fig. 3. As we can see the signal follows more of Rayleigh than Gaussian distribution with the likelihood of 649.272 and little variation of 0.000037066, contrary to most information in the literature [7]. This confirmed that the signal received experienced fast fading phenomenon.

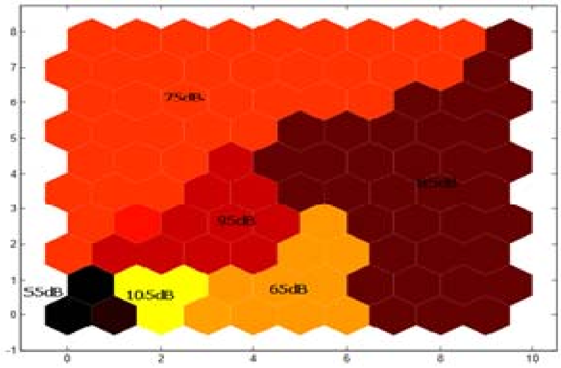

Fig. 2. Clusters of power received (signal strength)

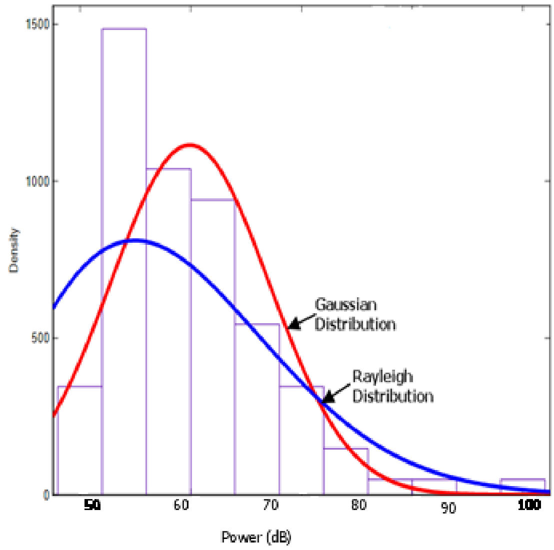

Fig. 3. Probability density functions of the experimental data

VI. CONCLUSION

In this work, we used one-dimensional multilevel wavelet to predict the GSM signal attenuation in an indoor environment in terms of fast fading phenomenon and used neural network to determine the clusters of the power received in the study area. The work revealed that the signal is attenuated by the fast fading phenomenon and the average power received in the study area range from -95dBm to -75dBm, this means significant part of the signal received is a weak signal.

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