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Improving Signal Reception in 4G Network using Adaptive Equalizer

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Abstract:

In this thesis, the major concerns in 4G network which is poor quality of service rendered to the subscribers by the network providers due to poor signal reception is addressed. Data communication has become increasingly in high demand in carrying out day to day activities. The need for reliable data communication-system for internet access cannot be over emphasized as 4G network users still experience poor network services such as poor internet access, weak signal reception and other forms of interference. This motivated in carrying out this research on improving Signal reception in 4G-network using adaptive equalizer. This thesis characterize 4G Network under study and developed a model to boost attenuated signal in 4G network under study using adaptive equalizer algorithms. The simulation was carried out using MATLAB SIMULINK. Simulations results have shown that the algorithms used in this project are extremely robust with respect to the channel distortions. For short, midrange and long distances the expected significant degradation of the resulting RSSI values could not be observed significantly. This has proved that adaptive equalizer helps in optimization of signal reception in 4G network.

Keywords — **Transmitted Signal, Receiving Signal, Traffic Session, 4G Networks, and GSM.**

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I. INTRODUCTION

A lot of people across the nation have adopted mobile broadband as their primary means of accessing Internet, voice communication, entertainment services and text messages. Therefore, the demand for mobile broadband services increases every time. The improvement in digital signal processing, radio transmission technologies as well as digital computing have contributed for the introduction of a wide range of mobile wireless communication services. In the 90's, the introduction of second generation (2G) mobile communication system such as GSM provides a reliable narrowband – communication medium mostly for voice and short message service (SMS) with high mobility and high transmission rate WLAN such on WI-FI and Bluetooth. However due to expansion and dynamism in the global market where information communication has become increasing in high demand in early life activities the third generation (3G) mobile Network was introduced to allow users to have larger amount of bandwidth that will enable them to access internet services, retrieve text messages, Image, Video and other multimedia services. Despite the gains of 3G- Networks over 2G-Network and other analog communication systems there still exist a number of challenges facing the 3G-Network quality of services delivery to the end-users, these challenges ranges from network congestion, call-drops, poor/No Signal reception to poor internet access. The third generation (3G) network brought the quest for data at higher speeds and opened the gates for mobile broadband experience which was further realized by the fourth generation (4G).

The Fourth generation (4G) provides access to wide range of telecommunication services such as voice, data and video (Ozovehe, 2015).

The 4G is driven by low cost, high-speed data, application ubiquity, high degree of personalization and synchronization between various user appliances. 3G is based on two parallel infrastructures consisting of circuit switched and packet switched network nodes respectively, while 4G is based on packet switching only. It consists of end-to-end IP solution with better quality data, video and sound services due to high bandwidth, and convergence of networks services such as enterprise, fixed and cellular (Kuboye, 2014).

Motivation / Justification of the Research Work

In most recent time, data communication has become increasingly in high demand in carrying out day to day activities. Most importantly, in 9th Mile Enugu, the need for reliable data communication-system for internet access cannot be over emphasized, the area is sited on Landmass of about 1000 hectares and the land space is being surrendered by six communication cell base stations belonging to three different telecommunication network providers. Despite the location of these various network cell-base stations, users still experience poor network services such as poor internet access, weak signal reception and other forms of interferences.

Thus, my motivation in carrying out this research on Signal reception optimization in 4G-network using adaptive equalizer is to study the nature of interferences in a communication channel, the causes of these interferences and find out a way to negate the effect of these channel interferences so as to optimize signal reception which will in turn improve the quality of service in communication system.

Problem Statement

The development in the number of wireless devices and applications has led to a crowding of the wireless spectrum and more stringent requirements for receiver designs. Radio frequency interference continues to be a persistent problem in many digital communication systems and will potentially exacerbate as the unused wireless spectrum continues to shrink. The poor quality of service is as a result of the faded signal, interference, attenuation and reflections. These have greatly affected businesses that rely on the network for data transmission. Poor quality of service, data loss due to call drops, mix-up in transmitted signal due to interference are all witnessed in the wireless networks resulting to users not getting much needed value for the money paid. These constituted the research problems that this research work is to solve.

Aim and Objectives

The aim of the research work is to improve signal reception in 4G network using adaptive equalizer. The specific objectives include:

1. To characterize 4G Network under study hence determines reception signal strength of 4G network.
2. To design an adaptive equalizer and develop an algorithm for the equalizer
3. To design software to make the equalizer adaptive
4. To develop a Matlab model to boost attenuated signal in 4G network under study using adaptive equalizer algorithms.
5. To simulate the above model using MATLAB SIMULINK.
6. To compare the performance of the developed system against the measured reception signal strength of 4G network

Significance of the research

The research work will be beneficial to communication industries and the masses as it will among other things:

1. The adaptive equalizer will help reduce the channel degradation experienced in digital communication due to noise and hence improve the quality of service in the network which will be beneficial to the masses as the can communicate on the network without interruption.
2. The digital communication technology will be greatly improved and results to economic growth of the nation

Scope of the Study

This research work presents adaptive solutions to equalize the received signal of a 4G network where scrambling has been applied to the transmitted signal.

The transmitted signal is subjected to frequency- and time-selective Rayleigh fading and AWGN noise. The research work derive the optimal equalizer and give the signal to interference plus noise ratio (SINR) expression so as to eliminate noise which degrades digital communication signals.

II. MATERIALS AND METHODS

Research Methodology

The major aim of this research work is to improve signal reception in 4G network using adaptive equalizer. To achieve this, there is need to determine the parameters responsible network signal reception challenges. To this effect the 4G network was characterized. This was done by undergoing a drive test for a period of time and also collecting MTN Network Management Statistical data for their base station at Okpara Avenue, Enugu. This is to ensure that data collected were sufficient enough to prove the existence of poor signal reception, discover their causes, and proffered solutions.

The 4G network was characterized using Spectrum Analyzer equipment. Such characteristics include Received signal strength (Rxlev) and signal to noise ratio (SNR). Having observed the causes of the poor network signal reception, an adaptive equalizer was designed to improve the signal reception in 4G network. So, a digital communication model with adaptive filtering and without filtering is modeled. The design criteria of filters at transmitter (Tx) and receiver (Rx) is carefully designed using MATLAB environment with the requirements of reducing inter-symbol interference (ISI).

Material

The materials used for this project include;

i. Computer System
ii. MATLAB& Simulink software
iii. Spectrum Analyzer.

To characterize 4G Network under study hence determine reception signal strength of 4G network

An experiment was carried out to measure the signal strength, Rx level, Rx quality, speech quality to know their impact on the network. To achieve these, a system was designed for the process; a telecom device (mobile phones) performs a task to meet a particular requirement. It focuses basically on the process the mobile phone initiates and terminates a traffic session (voice or data).

To conduct Voice and Data measurement of 4G network, a cluster drive test was done using a DT tool version TEMS Investigation 15.0 with Discovery 10.0 installed in a laptop. Two Mobile stations (MS1, MS2) were connected to the laptop to get the network parameters of 4G data respectively.

During a traffic session, the user equipment (UE) or mobile station (MS) which is made up of the Subscriber Identity Module (SIM) and International Mobile Equipment Identity (IMEI) interfaces with the BTS or Node B through the air interface. For the user equipment which is a signal receptor (input device) to get radio resource, a quality of service testing software (TEMS) was installed in it. The MS was connected to the laptop which served as an output device that displayed the perceived radio environment and the system which response during a traffic session.

The experiment is carried out at designated position/location within the Enugu Metropolis using the MTN base station located at Okpara Avenue, Enugu as a reference point. The mode of mobility is vehicular for quicker and easier accessibility to various points. It took the researcher two (2) weeks to round off various points/location to conclude the experiment. The parameters supplied to the researcher by the MTN Site Engineer include:

(a) Antenna tilt in radius
(b) Transmitter Power in decibel
(c) Frequency in hertz
(d) Base Transceiver Station Co-ordinates (Latitude and Longitude) in degrees.
(e) Site identification number.

The essence of the test carried out is to ascertain the Received Signal strength level of the Reference base station understudy at various locations or distance. The result obtained is as shown in table 1.

Table 1: **GSM network characterization result Measured Data from BTS T4668 (Okpara Avenue, Enugu)**

Time	Date	Rxlev	SNR
09:30:07 am	03-09-2019	-105.8	29.2
09:52:27 am	03-09-2019	-95.8	29.2
11:01:05 am	03-09-2019	-110.3	19.7
11:21:15 am	03-09-2019	-75.3	19.7
04:10:17 pm	03-09-2019	-105.8	0.8
04:22:21 pm	03-09-2019	-109.8	3.8
06:01:00 pm	03-09-2019	-55.3	39.7
06:21:17 pm	07-10-2019	-100.0	25
08:30:01 am	07-10-2019	-105.5	0.6
09:12:27 am	07-10-2019	-98.8	3.8
10:21:00 am	07-10-2019	-99.3	39.7
11:00:15 am	07-10-2019	-102.0	25
03:10:12 pm	15-10-2019	-101.8	0.5
04:02:00 pm	15-10-2019	-97.8	3.8
05:21:05 pm	15-10-2019	-115.3	39.7
06:00:21 pm	15-10-2019	-110.0	0.4

(*Source*: Researcher, 2019)

III. DESIGN SOFTWARE TO MAKE THE EQUALIZER ADAPTIVE

The software code for making the equalizer adaptive using Matlab is as follows.

```
clear all
N=1000; % number of sample is 1000
np = 0.01; % noise power is 0.01
sp = 1; % signal power is 1 which implies SNR =
20dB
h=[1 2]; % unknown impulse response
x = sqrt(sp).*randn(1,N);
d = conv(x,h);
d = d(1:N) + sqrt(np).*randn(1,N);
w0(1) = 0; % initial filter weights are 0
w1(1) = 0;
mu = 0.005; % step size is fixed at 0.005
y(1) = w0(1)*x(1); % iteration at “n=0”
e(1) = d(1) - y(1); % separate because “x(0)” is
not defined
w0(2) = w0(1) + 2*mu*e(1)*x(1);
w1(2) = w1(1);
for n=2:N % the adaptive equalizer algorithm
y(n) = w0(n)*x(n) + w1(n)*x(n-1);
e(n) = d(n) - y(n);
w0(n+1) = w0(n) + 2*mu*e(n)*x(n);
w1(n+1) = w1(n) + 2*mu*e(n)*x(n-1);end
n = 1:N+1;
subplot(2,1,1)
plot(n,w0) % plot filter weight estimate versus
time
axis([1 1000 0 1.2])
subplot(2,1,2)
plot(n,w1)
axis([1 1000 0 2.2])
figure(2)
subplot(1,1,1)
n = 1:N;
semilogy (n,e.*e); % plot square error versus time
```

Adaptive Equalizer Flowchart

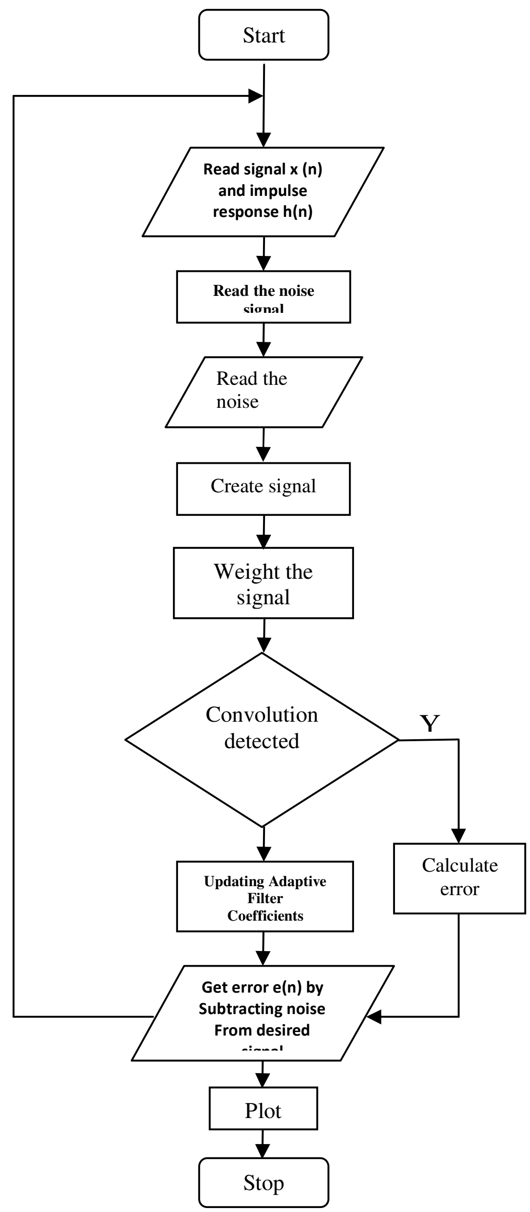

Fig. 1: flowchart for the software to make the equalizer adaptive

To simulate the above model using MATLAB SIMULINK

This Matlab model illustrates how to use blocks that contain embedded MATLAB code describing a communications algorithm. The model uses the Embedded MATLAB Function block in Simulink to construct Adaptive equalizers. When implementing an algorithm within your own models, you can choose a MATLAB approach or a block diagram approach, whichever seems better suited to the problem. The communications link in this model includes these components:

i. A source of random data.
ii. A source of a constant training sequence.
iii. A modulator that modulates the data and the training sequence. Each frame comprises 200 data symbols and 50 training symbols.
iv. A subsystem that models a multipath Rician channel with additive white Gaussian noise.
v. An Embedded MATLAB Function block labelled gain control that implements gain control for the received signal using adaptive equalizer.
vi. An Embedded MATLAB Function block labelled Equalizer that implements a multiple-tap equalizer. Before you run the simulation, you can change the equalizer's adaptive algorithm, number of tap weights, or reference tap.
vii. A demodulator.

Several Select Payload blocks in the model select the data symbols from each frame for visualization and error rate calculation purposes. Figure 3.4 shows a model with the adaptive equalization for interference cancellation.

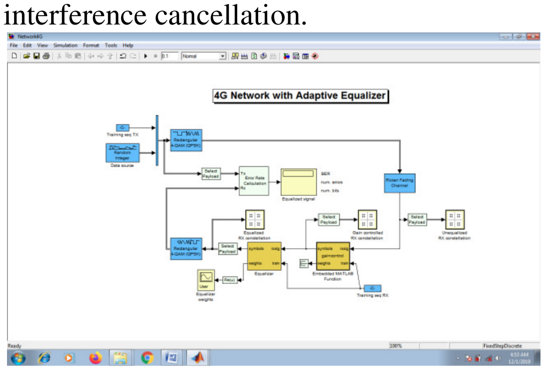

Fig. 2: Matlab Model of Adaptive Equalizer

Simulation of the transmission procedure is carried out in the data flow-based environment Simulink. It is quite versatile software in terms of visual planning, data analysis and model complexity. Simulink models are presented to the user as a combination of functional units in a block diagram. Figure 2 illustrates the digital transmission chain model implemented for this project.

As can be seen from the block diagram, the test data sequence is obtained from the random integer generator block and modulated using the 16-QAM scheme. Transmission channel effects are reproduced by additional processing of the complex baseband signal. Equalizer subsystem block attempts to recover the initial complex signal based on the "clean" reference which is provided separately. In this configuration, the equalizer algorithm is assessed in conditions of a constant training sequence.

Baseband output of the equalizer is demodulated and the recovered symbols are given to the complex scatter plot. As a means to evaluate the convergence of the algorithm, the magnitude of obtained error vector is logged with the scope block. Bit error rates for raw and equalized signals are compared by using additional error calculation block that individually demodulates each signal and compares the obtained bits.

In order to replicate continuous processes, Simulink evaluates the mathematical model of each functional block based on a discrete time steps, specified in the simulation settings. This also allows to locally emulating the digital sampling by using decimation, given that the sampling rate of the block is a multiple of the fundamental simulation step. In this particular model, the discrete step is set to 10 microseconds.

IV. RESULTS AND ANALYSIS

Data Measurement Techniques

The implementation for improving signal reception in 4G networks was carried out using Least Mean Square Equalizer (LMS) algorithm and simulation carryout out in MATLAB environment and their responses have been studied. The comparison on the equalization algorithms has been carried out based on their RSSI. Table 1 shows the simulation parameters.

Table 2: **Simulation Parameters**

Parameter	Value
Design Method	Least Mean Square Equalizer (LMS)
Equalization Algorithm	LMS
Sampling Frequency (F_s)	2Hz
Transmitter power (PT_X)	46Watt
Antenna gain G(MS)	10db
Transmitter gain	10db
Threshold value	-75dBm
SNR	60dB
Roll off factor (α)	0.9
Variable integer delay	2 samples
Symbol Constellation	QAM
Filter length	40
LMS Equalizerstep size (μ)	0.01
Frequency offset	50 Hz
Symbol Duration	1s
Channel	Rician Fading Channel

Source: (Farhang-Boroujeny, 2008)

Simulated Data and Result

Deep channel fades and path loss can cause the equalizer input signal level to be much less than the desired output signal level and result in acceptably long equalizer convergence time. At the beginning of the simulation, if the number of symbol errors for a given frame exceeds a preset threshold, the threshold is set to 10 for this model. The equalizer mode control block gets feedback on the number of errors and decides based on this information, whether the equalizer should be trained or decision directed. The Error Rate Calculation block generates the error rate data needed by the equalizer mode control. Running the simulation produces these figures:

- A constellation diagram of the signal before the receive filter
- A constellation diagram of the signal after equalization with signal quality measurements shown
- An equalizer error plot
- The power received

For the plots shown here the equalizer algorithm selected is LMS. Monitoring these figures, you can see that the received signal quality fluctuates as simulation time progresses. If the error threshold is exceeded, the equalizer reenters training mode. Throughout the simulation, the signal before equalization deviates noticeably from a QAM signal constellation. At the start of the simulation, the equalizer weights have not converged and constellation after equalization is poor.

Simulated Result for Power Received (without LMS Equalizer)

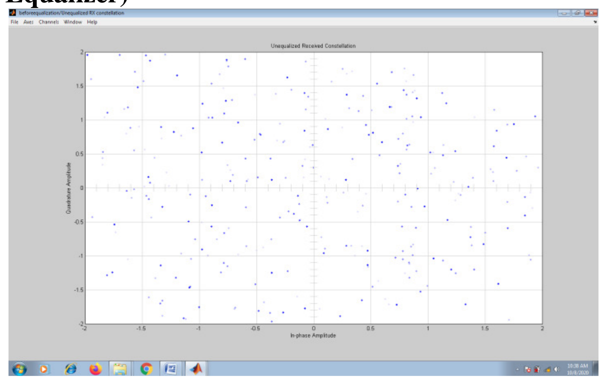

Fig 3: Channel scatter plot showing the Un-equalized Received Constellation

Table 3: **Power Received (without LMS Equalizer)**

Distance (m)	RSSI (dBm)
100	-97
150	-111
200	-100
250	-106
300	-107
350	-114
400	-120
450	-114
500	-117
550	-102
600	-112
650	-118
700	-120

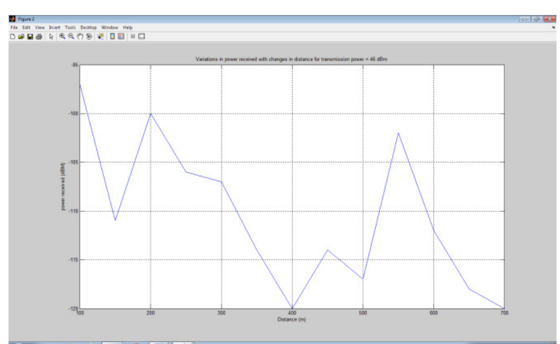

Fig 4: Variations in power received with changes in distance for MS transmission power = 46 dBm without LMS equalizer

In figure 4, this correction allows us to compute the transmitter-receiver distance from measured RSSI values. The measured values follow the progression of the function graphs. In figure 4, it is observed that the angle of the antenna affects the power received. As shown in Figure 4, the received signal strength varies continuously with the change in location. That is to say, the changes in location lead to the variation for RSSI with a power = 46 dBm. At the distance above 700m, the RSSI weakened and the signal reception in 4G network became poor. For short and mid range distances the expected significant degradation of the resulting RSSI values could not be observed. However, distances beyond 700m suddenly produced 100 % packet loss rate.

Simulated Result for Power Received (with LMS Equalizer)

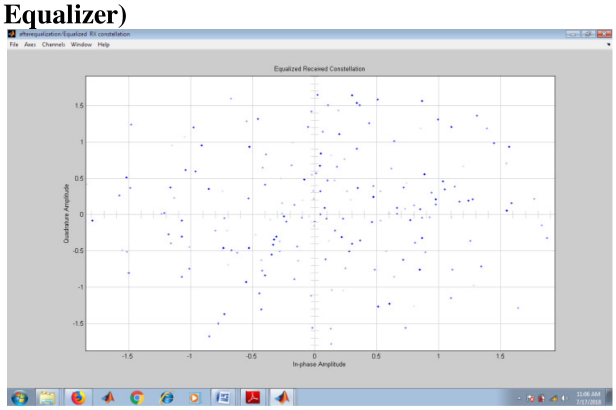

Fig 5: The scatter plot shows the equalized Received Constellation after the channel equalization

Table 4: **Power received (With LMS Equalizer)**

Distance (m)	RSSI (dBm)
100	-77
150	-91
200	-80
250	-86
300	-87
350	-94
400	-100
450	-94
500	-97
550	-82
600	-92
650	-98
700	-100

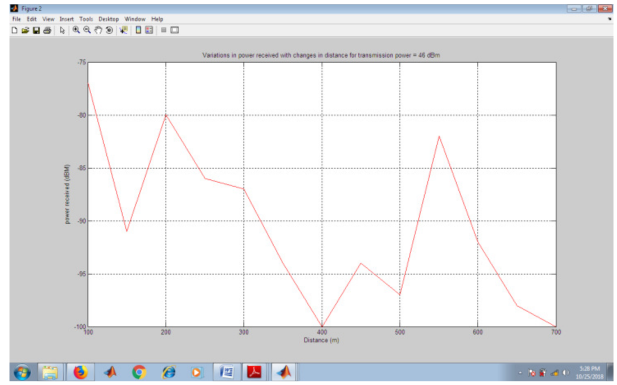

Fig 6: Variations in power received with changes in distance for MS transmission power = 46 dBm with adaptive equalizer

The adaptive equalizer plays an important role in the result obtained. In figure 6, it is observed that the location affects the power received. The received signal strength varies continuously with the change of location. That is to say, the changes in location lead to variation for RSSI with a power = 46 dBm. With the LMS equalizer, it was noticed that the RSSI increased across the varied location. At the distance above 700m, the RSSI was still strong and the signal reception in 3G network was strong. For short, midrange and long distances the expected significant degradation of the resulting RSSI values could not be observed significantly.

Table 5: **Comparison of Power received**

Distance (m)	RSSI (dBm) Without LMS Equalizer	RSSI (dBm) With LMS Equalizer
100	-97	-77
150	-111	-91
200	-100	-80
250	-106	-86
300	-107	-87
350	-114	-94
400	-120	-100
450	-114	-94
500	-117	-97
550	-102	-82
600	-112	-92
650	-118	-98
700	-120	-100

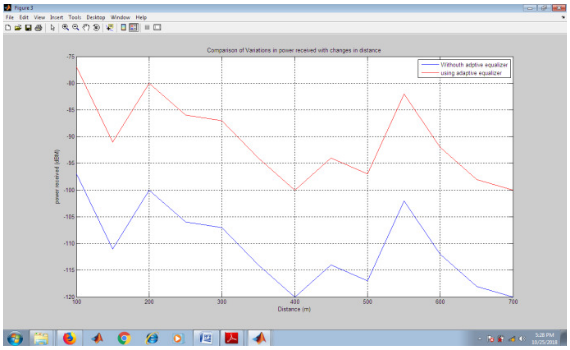

Fig. 7: Comparison of measured and simulated values of RSSI Variations with changes in distance for MS transmission power = 46 dBm with and without LMS equalizer

As shown in Figure 7, the received signal strength varies continuously with the change of location. That is to say, the changes in location lead to the variation for RSSI with a power = 46 dBm. At the distance above 700m for model without LMS equalizer, the RSSI weakened and the signal reception in 4G network became poor. But the LMS equalizer plays an important role in the result obtained. With the LMS equalizer, it was noticed that the RSSI increased across the varied distances. At the distance above 700m, the RSSI was still strong and the signal reception in 4G network was strong. For short, midrange and long distances the expected significant degradation of the resulting RSSI values could not be observed significantly.

V. CONCLUSIONS AND RECOMMENDATIONS

Conclusion

In this project, the research summarized the theoretical basics of a propagation model for radio signals at free space. We also described our corresponding real-world tested in detail before presenting and analyzing the RSSI measurement series. By choosing suitable parameters, the outdoor experiments closely follow the theoretical free space propagation model with ground reflection. Simulations have shown that the algorithms used in this project are extremely robust with respect to the channel distortions. For short, mid range and long distances the expected significant degradation of the resulting RSSI values could not be observed significantly. This has proved that Adaptive equalizer helps in optimization of signal reception in 4G network.

Recommendations for Further Research

The antenna used in this current project is directional. To optimization the current signal reception problem with multi directional antenna can have better result which may reduce the computational complexity of the higher degree of the polynomial. Hence it is recommended that further research be carried out in this area using multi directional antenna.

Contributions to Knowledge

This research work opens a new chapter in the area of signal reception optimization in 4G network. The research work was very extensive that it has contributed immensely to improving reader's knowledge in the following areas.

1. The research work exposed the 4G network characteristics and parameters that contributes to poor signal reception in a given locality.
2. The modeling carried out in Matlab will help readers learn how to model digital communication system using Matlab
3. This work can also serve as a resource material for further research in the field of wireless network

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