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IMPROVING SIGNAL RECEPTION IN 4G NETWORK USING CHANNEL EQUALIZER

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Abstract
The efficiency of signal reception in 4G networks is critical for ensuring reliable and high-quality communication. However, challenges such as signal fading, multipath interference, and noise significantly impact network performance. This research explores the potential of channel equalizers to improve signal reception in 4G networks. Channel equalizers mitigate distortions introduced by the communication channel by adapting to changing channel conditions and restoring the transmitted signal to its original form. This study analyzes the effectiveness of equalization techniques such as linear equalizers, decision feedback equalizers, and adaptive equalizers in combating issues like inter-symbol interference (ISI) and multipath fading. Using MATLAB-based simulations and real-world signal analysis, the performance of various equalization algorithms is evaluated in terms of metrics such as bit error rate (BER), signal-to-noise ratio (SNR), and throughput. Results demonstrate that the implementation of adaptive equalizers, particularly those using least mean squares (LMS) or recursive least squares (RLS) algorithms, significantly enhances the robustness of 4G signal reception in diverse network conditions. This research concludes by recommending the integration of advanced channel equalizers into 4G network infrastructures to optimize performance and pave the way for smoother transitions to next-generation technologies like 5G.

Keywords: 4G Network, MTN base station, GSM Network, Channel equalizer, Radio Channel, Radio Transmission.

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). 4G allows the integration of available heterogeneous and homogeneous networks into a single platform capable of supporting user roaming between them while not interrupting active communications. 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). The design target for radio performance is to achieve a scalable capacity from 100 Mbps high speeds and above compared to the 3G best performances of 14.4 Mbps using HSDPA and other 3G technologies (Kuboye, 2014).

The Long-Term Evolution (LTE) belongs to the family of 4G or next generation wireless communication. 4G wireless technology allow an immediate access to services that offer information on demand at a very high data communication speed because it was designed to provide 3 times faster speed than 3G (Kuboye, 2014).LTE uses MIMO technology to send data, thereby, minimizing noise effect, increase throughput, and spectrum utilization (Kuboye, 2014). The basic idea of MIMO is to use multiple smart antennas at the receiver end and use multiple transmitters when sending the data. LTE is the technological path followed to achieve 4G network speeds. In carrying out this research on improving signal reception in 4G-Network using channel equalizer, the researcher aims to study the nature of drawbacks inherent in 4G-Network's signal reception, causes and to find a way to negate the effects of the drawbacks.

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 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 channel equalizer is to study the nature of interferences in a communication channel, the causes of these interferences and find out a way to improve 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 channel equalizer. The specific objectives include:

1. To characterize 4G network under study hence determines reception signal strength of it.

2. To design a channel equalizer and develop an algorithm for the equalizer.
3. To design software to make the equalizer channel.
4. To develop a MATLAB model to boost attenuated signal in 4G network under study using channel 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 channel 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 they can communicate on the network without interruption.
2. The digital communication technology will be greatly improved and will give good results to economic growth of the nation.

Scope of the Study

This research work presents channel 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.

LITERATURE REVIEW

Wireless communication systems are playing very important role in the world today. Initially, wireless systems were mainly designed for voice communication. Later it was used to transfer low data-rate. Today, higher data rates of 300Mbps (down link) and 75Mbps (uplink) are possible (Mohankumar, Swetha & Devaraju, 2012). Wireless communication systems have gained popularity because of their ease of use and mobility. All wireless technology faces the challenges of signal fading, multipath propagation, interference and limited spectrum. The channel through which the signal is propagated may consist of reflectors which will lead to multipath propagation causing multiple copies of the transmitted signal to arrive at the receiver after reflecting from the objects present in the channel. It results to constructive or destructive interference. This is a major problem in wireless communication as the end result is signal distortion (Agubor, Opara & Eze, 2013). To combat the effect of multipath propagation, interference or fading, etc, many techniques have been proposed, much of which have been the antenna part of the radio system such as the use of multiple antennas at both the transmitter and receiver ends (Mohankumar et al.2012). Combining methods such as selective, switching and maximal combining techniques (Srivastara, 2010) have also attracted significant interest as methods of improving system performance. This chapter discusses these techniques and other relevant areas that have been highlighted as methods of performance improvement in wireless communications.

Conceptual Framework

In 4G LTE networks, signal reception is a critical aspect that impacts data quality, speed, and overall user experience. However, impairments such as multipath fading, Inter-Symbol Interference (ISI), and additive noise, degrade the signal quality during transmission. Channel equalizers are employed to counteract these impairments and improve the reception of the signal at the receiver. The conceptual framework outlined here explores the components, relationships, and key factors influencing signal reception improvements in a 4G network channel equalizer. The key factors and their relationship between them include:

Channel Impairments and Signal Reception: The channel introduces impairments such as multipath fading, ISI, and AWGN, which degrade the quality of the received signal. This relationship negatively impacts the Signal-to-Noise Ratio (SNR) and increases the Bit Error Rate (BER).

Adaptive Equalization and Channel Impairments: Adaptive equalization dynamically adjusts its filter parameters in response to real-time channel variations. It mitigates the effects of multipath fading and ISI by updating its coefficients using algorithms like LMS and RLS. This adaptation reduces ISI and enhances the received signal quality.

Frequency-Domain Equalization (FDE) and Frequency-Selective Fading: FDE transforms the signal into the frequency domain, allowing the equalizer to handle different frequency components separately. This technique is particularly effective for channels exhibiting frequency-selective fading and significantly improves signal reception.

MIMO Equalization and Spatial Diversity: MIMO technology improves signal reception by leveraging multiple antennas, providing spatial diversity. MIMO equalizers (e.g., Zero-Forcing MIMO and MMSE MIMO) separate the signals transmitted over different antennas, reducing interference and improving throughput and BER.

Neural Networks and Complex Channel Conditions: Neural network-based equalization offers a modern solution for handling nonlinear and highly dynamic channel conditions. By learning from large datasets, these networks can adapt to changes in the channel environment more effectively, further minimizing BER and improving SNR compared to traditional equalizers.

Channel Estimation and Equalization Performance: Accurate channel estimation is essential for the effective performance of equalizers. Techniques like pilot-assisted estimation and Kalman filtering provide real-time channel information, which helps the equalizer apply the correct compensation, reducing errors and improving signal reception.

This conceptual framework provides a comprehensive understanding of how different channel equalization techniques improve signal reception in 4G networks. By addressing various impairments such as ISI, fading, and noise, these equalizers play a critical role in ensuring high-quality communication and data transmission. Adaptive techniques, frequency-domain equalization, MIMO, and neural network-based approaches form the basis for future advancements in equalizer design, paving the way for more reliable and efficient 4G network performance.

Theoretical Framework

Signal reception in a 4G network is often affected by impairments such as multipath fading, inter-symbol interference (ISI), and noise, which degrade the quality of the received signal. To address these issues, channel equalization techniques are used to mitigate the effects of signal distortion, improving overall reception and communication quality. This theoretical framework aims to explain the key concepts, models, and theories underpinning the improvement of signal reception in 4G networks using channel equalizers.

Channel equalization in 4G Network refers to the process of reversing the effects of signal distortion caused by the transmission channel. In 4G networks, which rely heavily on Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input Multiple Output (MIMO) technologies, equalization is crucial for reducing multipath fading, minimizing noise, and improving data throughput.

- **Theoretical Models Underpinning Channel Equalization**

Multipath Fading Model: In wireless communication, the transmitted signal reflects off multiple objects, causing it to arrive at the receiver at different times and with varying amplitudes. This phenomenon is known as multipath fading. Multipath fading leads to inter-symbol interference (ISI), where symbols overlap and create distortion at the receiver. To mitigate these effects, equalization techniques are applied.

- **Inter-Symbol Interference (ISI) Model**

Inter-symbol interference arises when adjacent symbols overlap due to the channel's time-varying nature or bandwidth limitations. ISI is mathematically expressed as:y(t) = \sum_{k} s(k) h(t-kT) + n(t).

Where T is the symbol period, and

s(k) is the kth transmitted symbol.

The aim of channel equalizers is to minimize ISI by estimating and inverting the channel's distortion effect.

- **Additive White Gaussian Noise (AWGN) Model**

Noise in wireless channels is typically modeled as Additive White Gaussian Noise (AWGN), characterized by a zero-mean Gaussian distribution with variance (sigma). Equalizers attempt to reduce the impact of noise on signal reception by enhancing the signal-to-noise ratio (SNR).

4G Technology

Accessing information anywhere, anytime, with a seamless connection to a wide range of information and services, and receiving a large volume of information, data, pictures, video, and on, are the keys of the 4G infrastructures. The future 4G infrastructures will consist of a set of various networks using IP (Internet protocol) as a common protocol so that users are in control because they will be able to choose every application and environment. Based on the developing trends of mobile communication, 4G will have broader bandwidth, higher data rate, and smoother and quicker handoff and will focus on ensuring seamless service across a multitude of wireless systems and networks (Jayalakshmy, 2011).

Application adaptability and being highly dynamic are the main features of 4G services of interest to users. These features mean services can be delivered and be available to the persona preference of different users and support the users traffic, air interfaces, radio environment, and quality of service. Connection with the network applications can be transferred into various forms and levels correctly and efficiently. The dominant methods of access to this pool of information will be the mobile telephone, PDA, and laptop to seamlessly access the voice communication, high-speed information services, and entertainment broadcast services. The fourth generation will encompass all systems from various networks, public to private; operator-driven broadband networks to personal areas; and ad hoc networks.

The 4G systems will interoperate with 2G and 3G systems, as well as with digital (broadband) broadcasting systems. In addition, 4G systems will be fully IP-based wireless Internet. This all-encompassing integrated perspective shows the broad range of systems that the fourth generation intends to integrate, from satellite broadband to high altitude platform to cellular 3G and 3G systems to Wireless Local Loop and Fixed Wireless Access to Wireless Local Area Network and Personal Area Network, all with IP as the integrating mechanism. With 4G, a range of new services and models will be available. These services and models need to be further examined for their interface with the design of 4G systems. The features of 4G network includes:

- Support for interactive multimedia, voice, streaming video, Internet, and other Broad band services
- IP based mobile system
- High speed, high capacity, and low cost-per-bit
- Global access, service portability, and scalable mobile services
- Seamless switching, and a variety of Quality of Service-driven services
- Better scheduling and call-admission-control techniques
- Ad-hoc and multi-hop networks (the strict delay requirements of voice Make multi-hop network service a difficult problem)
- Better spectral efficiency
- Seamless network of multiple protocols and air interfaces (since 4G will be all-IP, look for 4G systems to be compatible with all common networks**.** Technologies including 802.11, WCDMA, Bluetooth, and Hyper LAN).
- An infrastructure to handle pre-existing 3G systems along with other wireless Technologies, some of which are currently under development.

The goal of 4G is to replace the current core mobile networks with a single worldwide core network standard, based on IP for control, video, packet data, and voice. This will provide uniform video, voice, and data services to the mobile host, based entirely on IP.

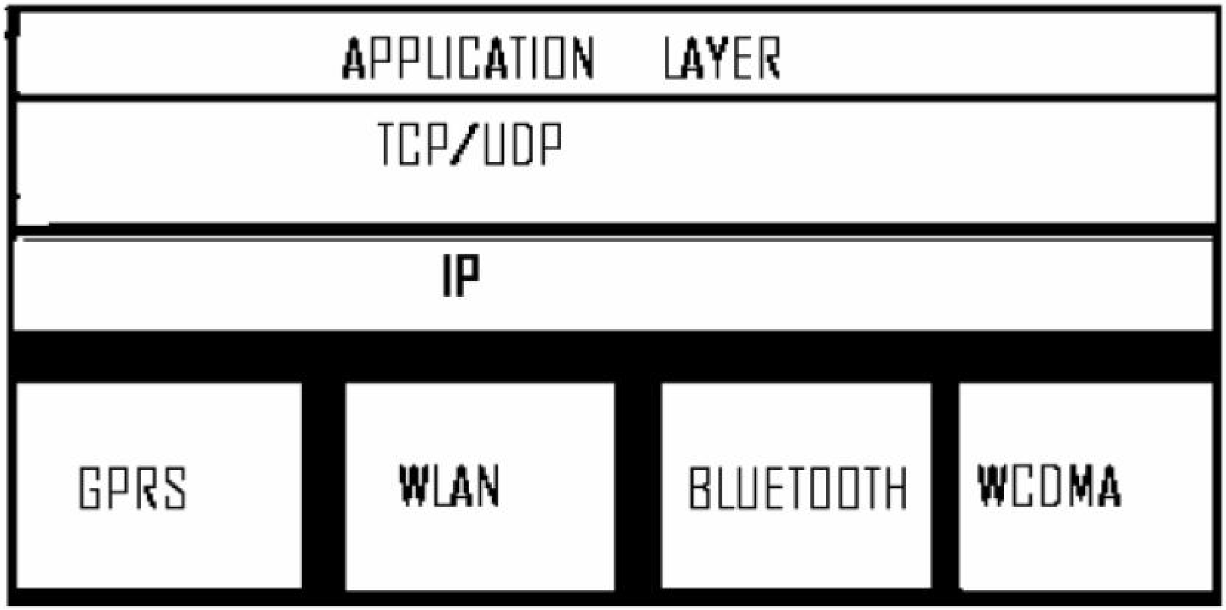

Fig. 1.0: 4G Wireless Systems (Jayalakshmy, 2011)

IP is assumed to act as an adhesive for providing global connectivity and mobility among networks. An all IP-based 4G wireless network has inherent advantages over its predecessors. It is compatible with, and independent of the underlying radio access technology.

An IP wireless network replaces the old Signaling System 7 telecommunications protocol, which is considered massively redundant. This is because SS7 signal transmission consumes a larger part of network bandwidth even when there is no signaling traffic for the simple reason that it uses a call setup mechanism to reserve bandwidth, rather time/frequency slots in the radio waves.

IP networks, on the other hand, are connectionless and use the slots only when they have data to send. Hence there is optimum usage of the available bandwidth. Today, wireless communications are heavily biased toward voice, even though studies indicate that growth in wireless data traffic is rising exponentially relative to demand for voice traffic. Because an all IP core layer is easily scalable, it is ideally suited to meet this challenge. The goal is a merged data/voice/multimedia network.

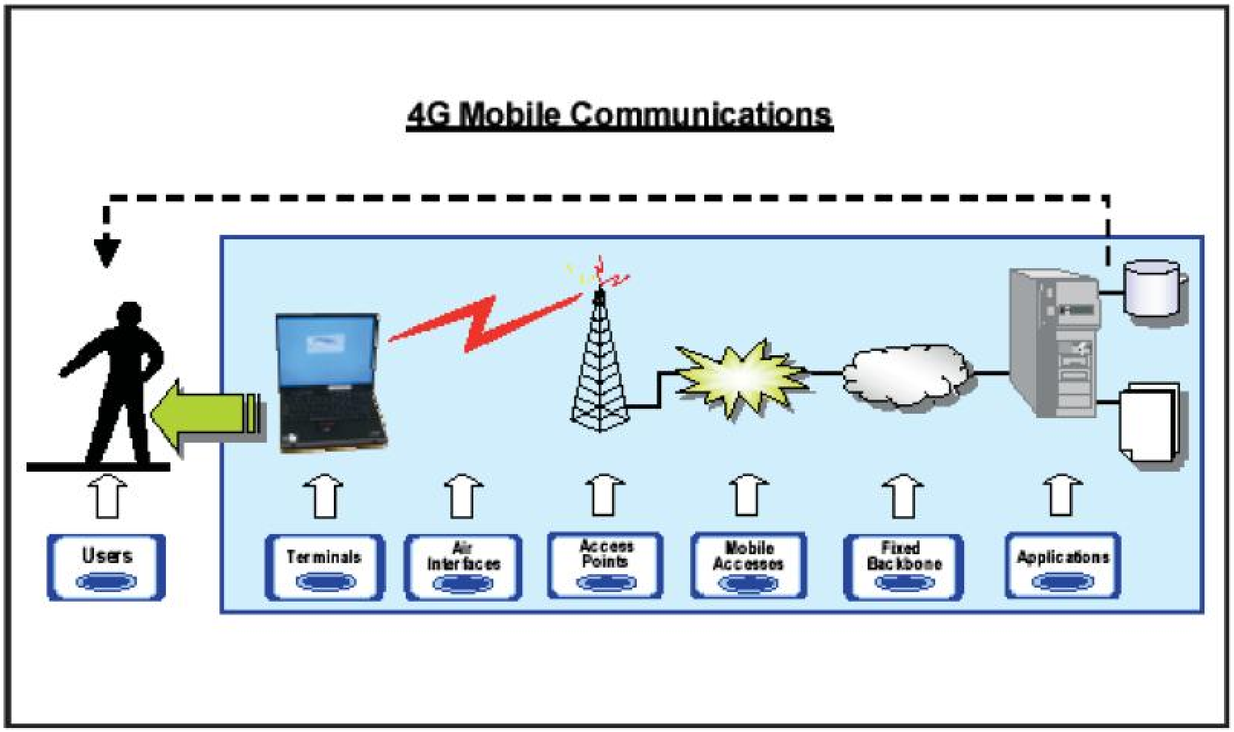

Fig. 1.1: 4G Mobile Communications (Jayalakshmy, 2011)

RELATED LITERATURE

Performance Analysis of Multiple Input Multiple Output-Orthogonal Frequency Division Multiplexing for Multiple Antennas

Rao & Malavika (2014), in their work used MIMO-OFDM (Orthogonal Frequency Division Multiplexing) as a means of increasing the performance of a wireless communication system by having multiple transmit and receive antennas. They suggested that the performance of wireless communication in which the channel quality fluctuates, the receiver should be provided with multiple received signals generated by the same underlying data. These suggestions were referred to as diversity which exists in different forms such as temporal diversity, frequency diversity and antenna diversity. The study made use of Space Time Block Codes (STBC) based on Quadrature Amplitude Modulation (16 QAM) over Raleigh channels. Computer simulation was used to simulate in MATLAB the reference model obtained. BER (bit-error-rate) and SNR (signal-to-noise ratio) performance of the multiple-input multiple-output orthogonal frequency division multiplexing (MIMO-OFDM) technique was compared to that of multiple-input single-output (MISO) OFDM and single-input single-output (SISO) OFDM. The work concluded that, MIMO–OFDM model as demonstrated in the study can be used for real time data transmission such as multimedia and high-speed internet applications especially in low SNR areas as compared to MISO-OFDM and SISO-OFDM.

Techniques for Improving Bit Error Rate (BER) and Signal to Noise Ratio (SNR) in Multiple Input Multiple Output (MIMO) Antenna for Optimum Performance

Vaishali & Chopade (2014) investigated on new techniques for improving BER and SNR in wireless communication. They considered Inter Symbol Interference (ISI) as a major limitation which can be removed by including equalization at the receiver end. Two popular equalization algorithms - zero forcing (ZF) equalizer and minimum mean square error (MMSE) equalizer, were used. Maximum ratio combining (MRC) was also included in the work as a combining network because of the fact that it maximizes the correct reception and reduces ISI. Using MATLAB, result was obtained which shows the BER performance of ZF, MMSE and MRC techniques. With BER for the theoretical MRC as 0.0581, simulated MMSE as 0.0925 and theoretical ZF as 0.1464, they concluded that MRC has a lower BER as compared to MMSE in every case.

Performance Analysis with Space-Time Coding in Multiple Input Multiple Output-Orthogonal Frequency Division Multiplexing System with Multiple Antennas

Jitendra et al, (2013), discussed several aspects in the direction of Space-time coding in MIMO-OFDM systems with multiple antennas. In this study, two types of space time coding techniques were discussed, Space Time Block Codes (STBC) and Space Time Trellis Codes (STTC). The paper also highlighted a recent work on space time coding techniques as it relates to improving link reliability by ensuring low BER performance. The work presented STBC as a technique for diversity gain, with very low decoding complexity, whereas STTC provide both diversity and coding gain at the cost of higher decoding complexity. The diversity gain results to improved signal at the receiver. To provide coding gain, STBC must be concatenated with an outer code. Concatenating STBC with Trellis Coded Modulation (TCM) creates a bandwidth efficient system with coding gain which further improves system reliability. The paper concluded that increasing the number of antennas has better transmission performance.

Performance Evaluation of MIMO Systems with Varying Number of Transmitting Antennas

In this work, Tanmeet, Balwinder, & Sandeep, (2013) evaluated the BER performance of MIMO systems. The main objective of the study was to design MIMO systems to reduce fading and increase diversity gain which will result to improvement of system performance. To achieve this, channel estimation technique was used with maximum likelihood decoder at the receiver end. The channel fading coefficients were estimated by inserting pilot frequencies in the transmitted signals.

Simulations were done in MATLAB using Raleigh fading channel. From the result obtained, it was observed that with increased SNR, BER decreased. Considering the two channels used in the study, it was concluded that the lower the fading in the channel, the better the channel estimation.

BER Analysis of MIMO-OFDM System in Different Fading Channel

In investigating how a mobile wireless communication can be improved by overcoming fading effects, Niharika & Subhakhanta (2013) worked on BER analysis of BPSK (Binary Phase-Shift Keying) signal in MIMO and MIMO-OFDM systems. MIMO system was used in this work to achieve full diversity using OSTBC (Orthogonal Space-Time Block Coding) encoder, to overcome fading effect of the channel.

They suggested that by using OFDM, inter-symbol interference (ISI) can be reduced with higher data rate and higher spectral efficiency, thus improving the overall reliability of the system. To carry out the analysis, computer simulation method was used to simulate MIMO-OFDM (2x2) system in a Raleigh and Rician channel. The result obtained indicated BER performance of Raleigh channel in MIMO system was much better than that of Rician channel. They also showed that BER performance of MIMO system is better than that of MIMO-OFDM whereas in terms of spectral efficiency MIMO-OFDM is better than MIMO system. The conclusion was that in a Raleigh channel there is improved signal transmission with low BER in a MIMO system.

Diversity for Wireless Communication

Pravin and Badjale (2013) carried out a study to show that diversity techniques can be useful methods in reducing fading problems in wireless communications. The work explained that using diversity technique the receiver is supplied multiple replicas of transmitting signals instead of one signal that has passed over different fading channels. The study pointed out that fading means the loss of propagation experienced by the radio signal on forward and reverse links. Diversity as a method of improving wireless communication performance was classified under three domains, namely, temporal diversity, frequency diversity and spatial diversity. Among these, spatial diversity with multiple transmitting and receiving antennas is most popular due to its efficiency in terms of system resource usage (no extra power and bandwidth utilization necessary).

The work also analyzed improvement in wireless communication using diversity combining techniques such as:

- Maximal ratio combining (MRC)
- Equal gain combining (EGC)
- Selection combining (SC)

- Switching combining (SWC)
- Periodic switching method
- Phase sweeping method

The method of research was based on computer simulation which was used to determine the performance of the above combining methods. It was concluded that system performance with MRC is better than when using any of the other combining methods.

Performance Improvement of DS-CDMA Wireless Communication Network with Convulationally Encoded OQPSK Modulation Scheme

In this study, Manish & Inderpret (2013) considered the bit-error probability analysis of Direct-Sequence Code Division Multiple Access (DS-CDMA) system in which a statistical characterization of the decision variable at the transmitter and receiver was obtained. The effect of Multiple-Access Interference (MAI) on the bit error performance of the single user correlation receiver was considered. The problem of MAI was examined in the context of OQPSK (Offset Quadrature Phase Shift-Keying) spreading, which is more applicable to the third-generation (3G) CDMA standards. In the evaluation of error performance for the DS-CDMA with offset quadrature modulation scheme, the study made use of Standard Gaussian Approximation (SGA). The system model developed included that of the transmitter, multipath-channel and receiver. With as the spreading factor, different values were obtained for and (bit-energy to noise power spectral density ratio) that provided for the simulation. The result showed that in terms of probability of error (Pe), using OQPSK there was a 90 improvement with coding as against 80 without coding. The work concluded that similar work can be done for BPSK modulation.

Performance Analysis for Alamouti's STBC Encoded MRC Wireless Communication System over Raleigh Fading Channel

In this work, Srabanty & Sazzad (2013) investigated the performance of wireless communication using various forms of digital modulation techniques. Their study was based on a double-transmit and multiple-receive antenna supported wireless communication system that employs single user Alamouti's STBC and MRC scheme on secured text message transmission. The encoded Alamouti MRC transmission under investigation implements cryptographic algorithm and deploys various multi-level digital modulations (16 PSK, 16 DPSK and 16 QAM) techniques over an Additive White Gaussian Noise (AWGN) and Raleigh Fading Channels. A MIMO wireless communication system was used in which a single user transmitted secured text messages. For the secret message transmission, a public-key cryptosystem was used.

After encryption of the plaintext, the cipher text was converted into binary messages. The transmitted bits were channel encoded by a convolutional encoder of rate, interleaved for minimization of burst errors and then converted to M-ary signal. This M-ary signal was modulated using various types of multi-level digital modulation techniques such as quadrature amplitude modulation (QAM), phase shift keying (PSK) and differential phase shift keying (DPSK). Computer simulation method was used to evaluate the BER performance of the encoded secured multi-user STBC MIMO wireless communication system. The simulation covered the multi-level digital modulations (16 PSK, 16 DPSK and 16 QAM) technique over an AWGN and Raleigh Fading Channel. The result showed that there was an improvement in the wireless communication system with the adaptation of 16 QAM compared to 16 DPSK and 16 PSK.

Diversity Technique for MIMO-OFDM System Using a New Subcarrier Mapping Scheme

Idris et al (2011) proposed a new subcarrier scheme inter carrier interference self-cancellation (ICI-SC) technique using data allocation in space time frequency block codes (STFBC) MIMO-OFDM system. The technique was designed to achieve maximum diversity order and to compensate integrated effect of frequency offset (FO) for ICI reduction in the system. The method made use of theoretical derivation of the pair wise error probability (PEP). A simulation model was then used to compare with adjacent and symmetric subcarrier mapping scheme with FO. The results showed that the ICI contained in the received signals can be effectively reduced using a new subcarrier mapping scheme. Thus, the proposed method in using STFBC outperforms existing subcarrier mapping by approximately reducing the ICI with maximum diversity order in MIMO-OFDM system.

Performance Analysis and Efficient Transmission over Multiple Wireless Channels Using V-BLAST Architecture.

Jayalakshmy et al., (2011) carried out a study on wireless communication systems which uses multiple antennas at both transmitting and receiving ends of the link. The study presented an overview of MIMO system and its channel model. It explained the evolution of V-BLAST (Vertical Bell-Labs Layered Space–Time) structure and its architectural functions as well as some of the detection algorithm employed in MIMO systems. BLAST was defined as an extraordinary bandwidth-efficient approach to wireless communication which takes advantage of spatial dimension by emitting and detecting a number of independent co-channel data streams using multiple, essentially co-located antennas. Mathematical analysis was done to show the principles of V-BLAST detection algorithm. Computer simulation was used in the analysis. The simulation result obtained was for a (M,N)=(8,12) system with 16-QAM and used ranges between and in steps of . The BER was calculated by performing 10,000 trials at each point.

The result showed that V-BLAST, a wireless architecture is capable of realizing extraordinary spectral efficiencies over the rich scattering wireless channel. The study concluded that implementing BLAST approach may eventually lead to significantly improved signal reliability by way of improved spectral efficiencies in wireless systems.

Diversity Schemes for Wireless Communication

Srivastara (2011), discussed the characteristics of fading channels and a broad classification of various diversity techniques. The work centered on how to overcome the effect of fading by using various combining techniques at the receiver to get good signal for improving the overall performance of the communication system.

Very simple mathematics and schematics were used to demonstrate the workings of the diversity under discussion. The study concluded that diversity techniques are used to improve the performance of radio channel without any increase in the transmitted power. As higher as the received signal replicas are de-correlated, as much as the diversity gains can be achieved. The work finally suggested that much research is required to improve the performance in terms of fading in the next generation wireless networks.

Performance Analysis of Wireless Single Input Multiple Output System in Correlated Weibull Fading Channel

In Zafeiro (2010), the statistical characteristics of the trivariate and quadrivariate Weibull fading distribution with arbitrary correlation, non-identical fading parameters and average powers are analytically presented. The study investigated the effect of signal fading or interference which results in fluctuation of the received signal's amplitude, phase and angle of arrival. The study suggested the use of diversity reception technique as a means of improving reliability by employing more than one antenna at the receiver. These antennas are to receive multiple copies of the transmitted signal which are combined in order to satisfy network administrator demands. Mathematical expressions based on moment-generating probability distribution function (PDF) and moment-generating function (MGF), were developed. Computer simulation was the method adopted in the research. The result showed the performance of selection combining (SC) and maximal-ratio combining (MRC) as good receivers with multiple antennas.

Performance Analysis of Equalization Techniques for MIMO Systems in Wireless Communication

In this work, Naveen et al (2010) investigated how improvement of wireless communication can be achieved using equalization techniques in a 2 transmit 2 receive antenna case (2x2 MIMO channel). The ultimate goal in their study was to provide universal personal and multimedia communication without regard to mobility or location with high data rates.

To achieve this objective, they worked on the following equalization techniques:

- Zero Forcing (ZF) equalizer

- Minimum Mean Square Error (MMSE) equalization
- Zero Forcing equalization with Successive Interference Cancellation (ZF-SIC)
- ZF-SIC with Optional Ordering, and
- MIMO with MMSE SIC and Optional Ordering

Simulation process was used for the study. Observing the simulation results, they concluded that by using MMSE with SIC Optional Ordering, interference can be cancelled at optimum level. In this way system performance is improved even in mobile fading channel.

Multiple-Antenna Techniques for Wireless Communication

Multiple-antenna techniques are presented in Bliss (2008). The study was done in Lincoln Laboratory and was on improving the robustness and performance of wireless links using MIMO techniques. The two techniques discussed are advanced receiver techniques and joint transmitter/receiver arrays. For advanced receiver techniques, the Laboratory has developed and demonstrated techniques that enable communication in the presence of interference and jamming without significant degradation in link performance. The diversity provided by multiple transmitting antennas allow the system to avoid signal interference, and the multiple receiving antennas allow the system to mitigate the effect of interference.

Mitigation is achieved by subtracting the jamming and interference components of the signal seen at one receiving antenna from signals received at other antennas. Without using multiple-antenna mitigation techniques, a typical communication link would simply fail or at best be forced to reduce its data rate by factors of thousands to millions, making the links effectively useless. The Laboratory has also extended its MIMO research to include the adaptive use of joint transmitting and receiving antenna arrays. In order to do this, the transmitter must have an estimate of the channel, i.e, the environment between the transmitting antenna array and the receiving antenna array. Given this estimate of the channel, the transmitter can make intelligent decisions that improve performance of the intended link while simultaneously reducing interference to other communication links.

Extreme examples of joint transmission and receiver adaptation have been demonstrated theoretically and experimentally as reported in Bliss et al., (2007). In one of the examples, a node with separate transmitting and receiving antenna arrays optimizes the space-time coding such that the receiving antennas are protected from the transmitted energy. The residual self-interference signal power is mitigated using advanced receiver techniques such as space-time adaptive processing (STAP) and temporal-interference mitigation (TIM). The study concluded that by combining these techniques with a mechanical design that provides natural transmitter-to-receiver isolation, it may be possible to build full-duplex nodes that simultaneously transmit and receive at the same time.

Improving the Performance of Third Generation Wireless Communication System

RemVanDar & Martin (2004), studied the performance of Third Generation (3G) mobile communication system which is based on a technique called Code-Division Multiple Access (CDMA). They started by explaining the mathematical description of CDMA systems from which expressions showing the functions of a Matched Filter (MF) was derived as one used in 3G systems. They also explained the multiuser detection system called Hard-Decision Parallel Interference Cancellation (HD-PIC). It is an advanced algorithm in which estimation of the interfering signals are used to improve the quality of the signal of the desired user. Comparison was done between HD-PIC with MF in a simple case, where the only two parameters are the number of users and the length of the coding sequences.

The study used exponential-rate as a performance measure. It stated that the bit-error probability is mainly characterized by its exponential rate, and a small increase of the exponential rate for large code length leads to a large decrease of the bit-error probability. They suggested that the exponential-rate of the bit-error probability is a convenient measure of performance. That, one can compare the performance in two systems by comparing the exponential rates of their bit-error probabilities. In concluding, they stated that with HD-PIC, there is an improvement in the quality of signal transmitted. Hence, more users can transmit without errors than in MF systems.

NOISE CANCELLATION TECHNIQUES

Transmission of information in real world communication system is mostly affected by noise thus data quality gets degraded. Error control coding is a practical option for improving the data quality. Again, adaptive filters have the ability to change their own parameters automatically and their design requires little or no knowledge of noise and signal characteristics (Haykin, 2009). Real-time adaptive filtering algorithms and error correction coding techniques are essential components of most present-day communications in both wired and wireless forms. In this research, the researcher explores certain methods of noise cancellation using error correction coding as well as adaptive filter trained with Least Mean Square (LMS), Normalized Least Mean Square (NLMS) and Recursive Least Square (RLS) algorithm. The experiments performed show satisfactory results in severely faded Sakagami-M channels. The work formulates a methodology for developing certain insight into the use of error control coding and adaptive filtering to fight fading in wireless channel.

Error Control Coding

Error control coding is a technique used for controlling errors in data transmission over noisy communication channel. A predetermined algorithm is used for adding redundancy to the transmitted information and this is how forward error correction is accomplished.

Adaptive Filter

An adaptive filter comprises of two basic components (Haykin, 1991), these are a digital filter and an adaptive algorithm. The digital filter produces an output in response to an input signal and the adaptive algorithm is responsible for adjusting the coefficients of the digital filter. The block of an adaptive filter is shown in figure 2.4. The signal d (n) is called the desired signal. The input and the output of the filter are denoted by x (n) and y (n) respectively. The signal e (n) is called the estimation error and is defined by e (n) =d (n)-y (n). The error signal contributes some objective function and the adaptive algorithm aims to minimize those functions.

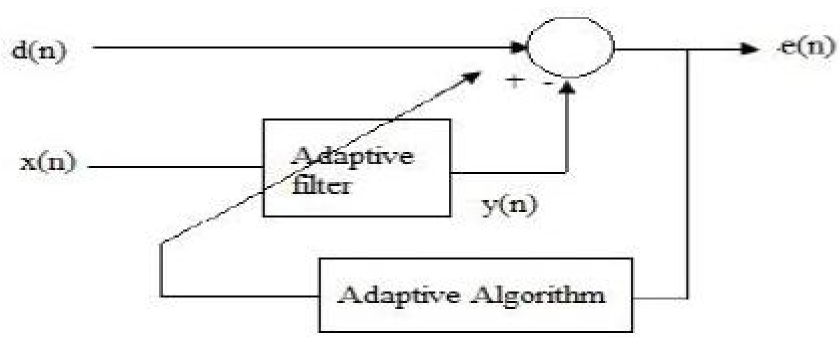

Fig 1.2: Adaptive Filter Block Diagram (Haykin, 1991)

Adaptive Noise Cancellation

The block diagram of a dual input adaptive noise canceller is shown in Figure 2.4. The adaptive noise canceller mainly consists of two sensors: primary sensor, which intends to supply a desired signal along with noise and a reference sensor which is responsible for supplying noise alone. The signal and noise at the output of the primary sensor are uncorrelated and the noise at the output of the reference sensor is correlated with the noise component of the primary-sensor output. The adaptive filter operates on the reference sensor output and thus produces an estimate of the noise and this is subtracted from the primary sensor output (Haykin, 2009). The adjustments applied to the tap weights in the adaptive filter are controlled with the aid of the overall output of the adaptive noise canceller. The adaptive canceller tends to minimize the mean-square error (MSE) value of the overall output, thereby causing the output to be the best estimate of the desired signal in the minimum-mean-square error sense (Kaur, 2011).

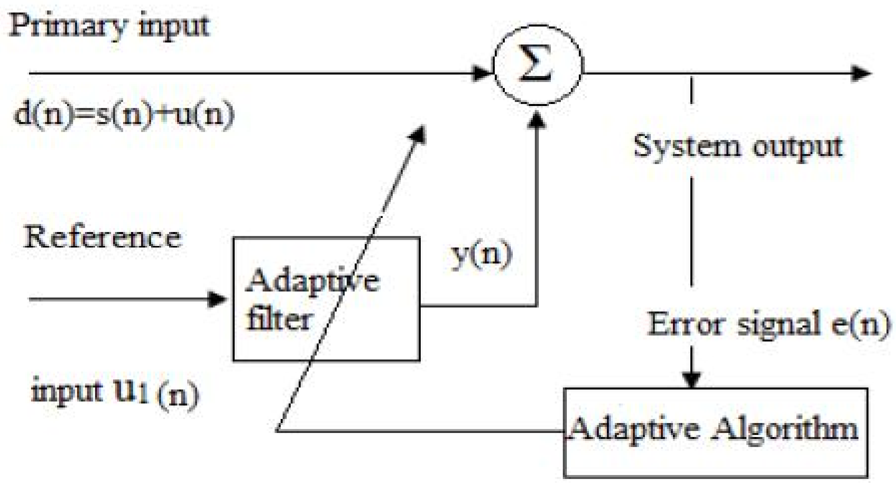

Fig 1.3: Dual input Adaptive Noise Canceller (Kaur, 2011)

There are two criteria on which the design of an adaptive filter depends. It mainly designs itself based on the characteristics of the input signal to the filter and also on a signal that represents the desired behavior of the filter on its input.

Adaptive Algorithms

Adaptive algorithms can be broadly classified as under Stochastic Gradient Algorithms and Recursive Least Square Algorithms. The LMS algorithm is a stochastic gradient algorithm; it iterates each tap weight of a transversal filter in the direction of the gradient of the squared magnitude of the error signal with respect the tap weight (Kaur, 2011). The main demerit of the LMS algorithm is that it is sensitive to the scaling of its input. The stability of the LMS algorithm is guaranteed by a learning rate μ, which is not easily chosen due to its sensitivity. This problem can be solved with the help of the Normalized Least Mean Square Algorithm (NLMS), which is a variant of the LMS algorithm, by normalizing with the power of the input. Further, slow convergence and high sensitivity to the Eigen value spread are some of the problems associated with the LMS algorithm which can be solved by using the RLS algorithm. The RLS algorithm represents increased complexity, computational cost and fidelity (Kaur, 2011).

OTHER RELATED REVIEW

Channel equalization is fundamental to mitigating the degradation of signal quality due to the wireless channel. Equalizers aim to reverse the distortions introduced by the channel, particularly by compensating for multipath fading, ISI, and noise. Proakis (2001) describes equalizers as a key solution to improving wireless communication quality by adjusting the received signal to its original transmitted form. In 4G networks, where complex modulation schemes such as Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input Multiple Output (MIMO) are used, channel equalization is essential for improving performance.

Multipath fading occurs when signals arrive at the receiver via multiple paths with different delays, causing constructive and destructive interference. Rappaport (2002), highlights that multipath fading is a major issue in wireless networks, particularly in dense urban environments. To counteract multipath fading, techniques like adaptive and decision feedback equalization are widely applied.

Adaptive equalization dynamically adjusts the filter coefficients to minimize the error between the received signal and the desired signal. The Least Mean Squares (LMS) algorithm, one of the most widely used adaptive algorithms. LMS updates the equalizer coefficients iteratively based on the error signal, making it effective for time-varying channels. However, its convergence speed is relatively slow, prompting the development of faster algorithms like Recursive Least Squares (RLS). Frequency-domain equalization is particularly effective in 4G networks that use OFDM modulation. Li & Stuber (2006) present FDE as an approach to handle frequency-selective fading channels, which are common in OFDM-based systems. By transforming the received signal into the frequency domain using the Fast Fourier Transform (FFT), the equalizer can operate on different frequency components independently. In their study, Li & Stuber (2006) demonstrate that FDE significantly reduces ISI and improves the bit error rate (BER) in 4G networks. The use of frequency-domain techniques is critical for combating frequency-selective fading, ensuring that the receiver can reconstruct the transmitted signal more accurately.

Recent advancements in machine learning have introduced neural network-based equalization techniques. Farsad et al. (2018) discuss how deep learning models can be used to improve equalization in wireless communication systems. Neural networks can learn complex, nonlinear channel characteristics and adapt to dynamic environments more effectively than traditional equalizers. The study by Farsad et al. (2018) shows that neural network-based equalizers out perform conventional adaptive algorithms in rapidly changing channels. These models can handle non-linearities and unpredictable channel conditions, making them a promising solution for improving signal reception in 4G and future 5G networks.

The literature on improving signal reception in 4G networks through channel equalization reveals a broad range of techniques aimed at mitigating the effects of multipath fading, ISI, and noise. Adaptive algorithms such as LMS and RLS provide flexible solutions for time-varying channels, while frequency-domain and decision feedback equalizers offer effective methods for reducing ISI and enhancing signal quality. MIMO and neural network-based equalizers introduce further advancements in handling complex channel conditions, with channel estimation playing a vital role in optimizing performance. These studies underscore the importance of continuous advancements in equalization techniques to improve signal reception and network performance in modern wireless communication systems.

RESEARCH GAP

From the previous literature, most of the work has challenges like a situation where simulations consider only static channels, or diversity combiners are mostly located at the receiver while the transmitting end of the link was not considered, or that each equalizer must be trained separately thereby taking much time during the iterations. Also, all the work reviewed were based on theoretical analysis, no real time experiment was carried out to compare with simulated results. So, this research work tends to cover the research gap identified by implementing the equalizer at both the transmitting and receiver end of the 4G network.

Research Methodology

The major aim of this research work is to improve signal reception in 4G network using channel 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 stations 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, a channel 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).

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.

8591E Agilent Spectrum Analyzer equipment was used in performing the experiment. The measurement step is as follows:

1. Input the frequency of the 4G MTN base station onto the spectrum analyzer that is hand held.
2. Travel a distance to a location
3. Press a calculate button on the spectrum analyzer to test the service performance on the Base Transceiver Station (BTS)

This operation will show a result on the screen of spectrum analyzer in the form of distance in (km) from cell site (A) (BTS) to the location point B, and the co-ordinates in terms of latitude and longitude of the location point B. This test experiment is carried out up to 7km distance from the base transceiver station, and various values of the received signal strength are obtained.
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 1.1.

Table 1.1 : 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)

To design a channel equalizer and develop an algorithm for the equalizer

Signals in almost every application are non-stationary. Processing non-stationary processes in blocks, over approximately stationary intervals is limited in its effectiveness for several reasons. For rapidly varying processes, the interval over which a process may be assumed to be stationary may be too small to allow for sufficient accuracy or resolution in the estimation of the relevant parameters. This approach would not easily accommodate step changes within the analysis intervals. This solution imposes an incorrect model on the data, i.e. piecewise stationary. So, a better approach is a non-stationary assumption at the outset. For non-stationary signals, the filter should be able to adapt to the changing statistics and "track" the solution as it evolves in time.

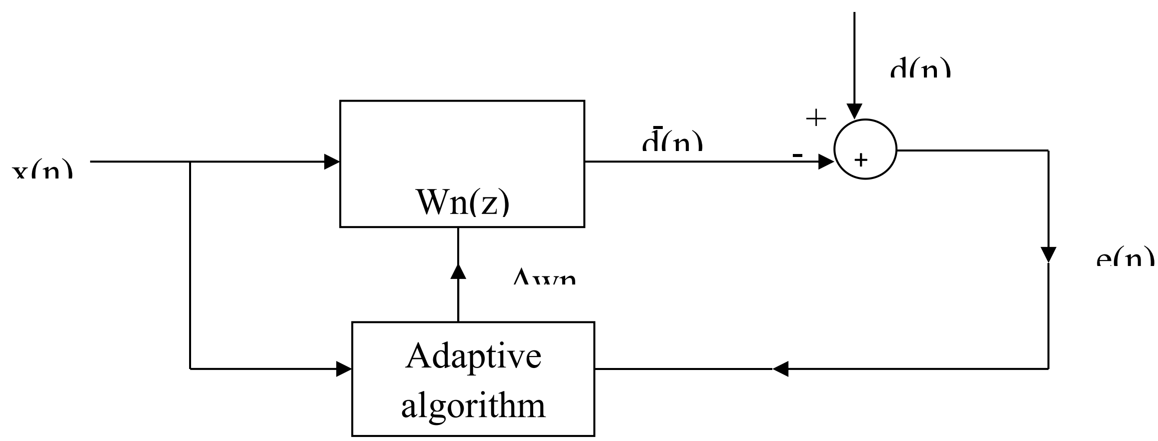

Fig. 1.4: Design of a channel equalizer

Figure 1.4 consist of a shift-varying filter Wn(z) and an adaptive algorithm for updating the filter coefficients wn(k).

x(n) = obtained signal

d(n) = desired signal

d(n)= noise

e(n) = error

x(*n*) = *d*(*n*) + *v*(*n*) (1)

Minimizing E{e^2(n)} is equivalent to minimizing *E{[d(n)* — y(n)]^2},the error between *d(n)* and the output of the channel equalizer, *w(n)* . Thus, the output of the channel equalizer is *d(n).*

The efficiency of the channel equalizer and its performance in estimating *d(n)* will depend on a number of factors including the type of filter (FIR or 1IR), the filter structure (direct form, parallel, etc.), and the way in which the performance measure is defined. There is a wide variety of applications in which channel equalizer have been successfully used such as linear prediction, echo cancellation, channel equalization, interference cancellation, adaptive notch filtering, adaptive control, system identification, and array processing.

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 channel 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
```

Channel equalizer Flowchart

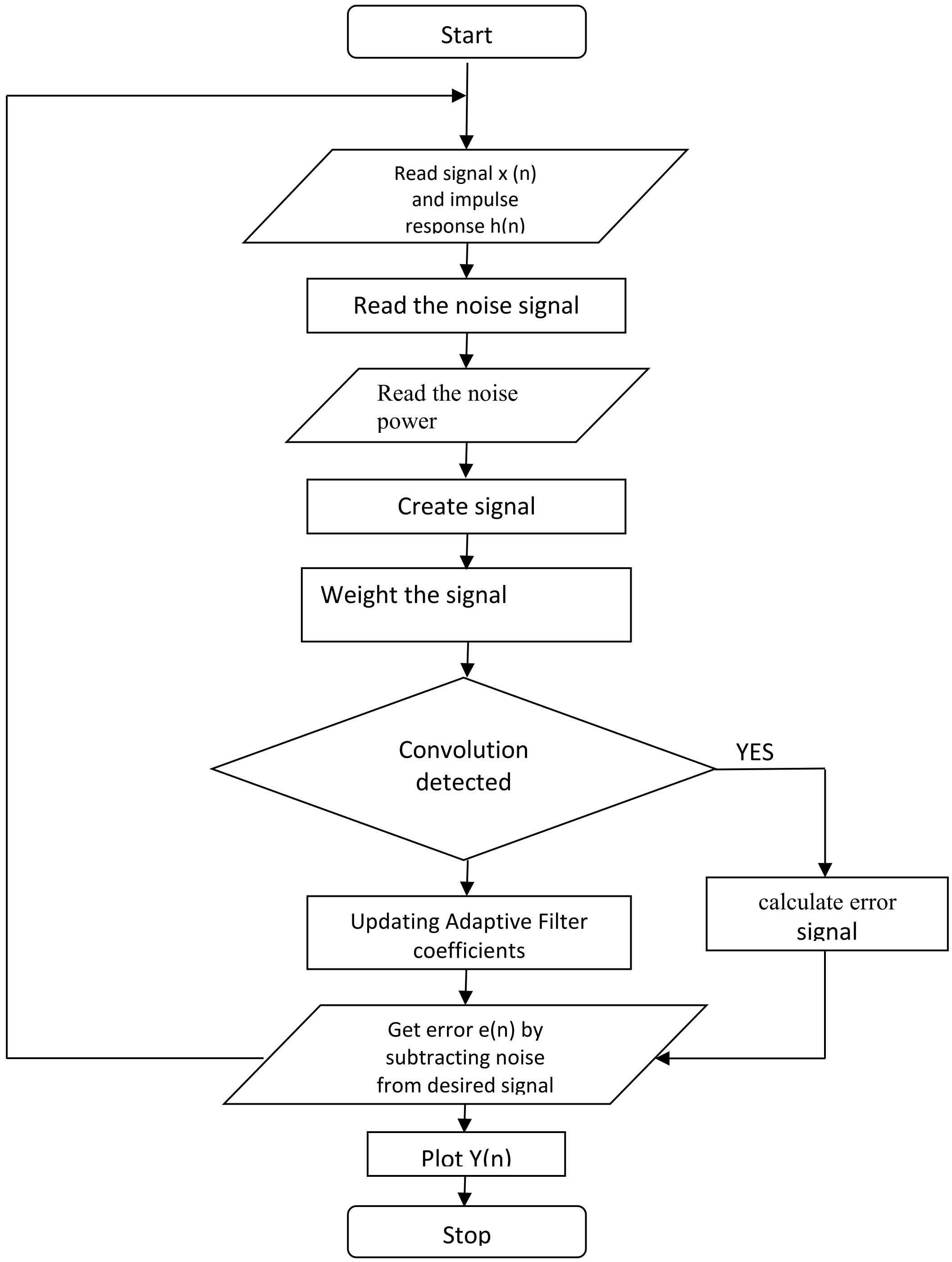

Fig. 1.5: flowchart for the software to make the equalizer adaptive

To develop a MATLAB model to boost attenuated signal in 4G network under study using channel equalizer algorithms.

Since telecommunication signals are facing dynamic interference and distortion, channel equalization is one of the widest application fields for adaptive filters. As the name suggests, channel equalizer is a type of device that uses a coefficient update procedure to counteract the unwanted effects of the environment. To compensate for the varying characteristics of the channel, an adaptive system should react to the change quickly enough. This property of the equalizer is called tracking, and it mainly depends on the type of adaptive algorithm. Knowledge of the initially transmitted data is also quite limited, thus different techniques are used to guide the convergence of the system. Basic transmission scheme with channel equalizer is shown in figure 1.5.

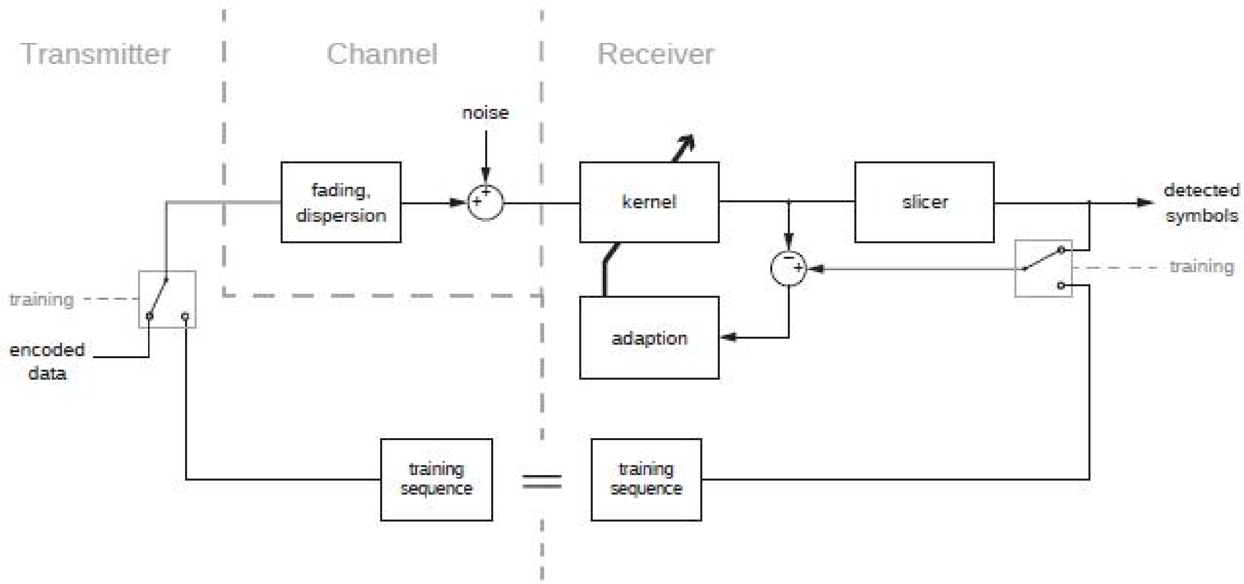

Fig. 1.5: Channel equalizer

As can be seen in figure 1.5, the communication model consists of three basic segments: transmitter, receiver, and channel. Channel parameters such as distortion and fading are modeled as a time-varying transfer function applied to the signal; noise and other interference are additive. In this particular example, modulation and demodulation procedures are omitted by speculating that channel characteristics would ultimately have some effect on the transmitted symbols after demodulation has been done. Equalization of a down-converted signal is known as the baseband equalization.
On the receiver side, equalizer attempts to improve the obtained baseband signal by compensating the channel imperfections using an appropriate impulse response (kernel). Equalized signal then is fed into the slicer, a threshold device used to approximate mapped symbols from the input samples. Adaptation algorithm adjusts the input filter's coefficients according to the error value, provided by the receiver firmware.

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 Channel 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 labeled gain control that implements gain control for the received signal using channel equalizer.
vi. An Embedded MATLAB Function block labeled 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.

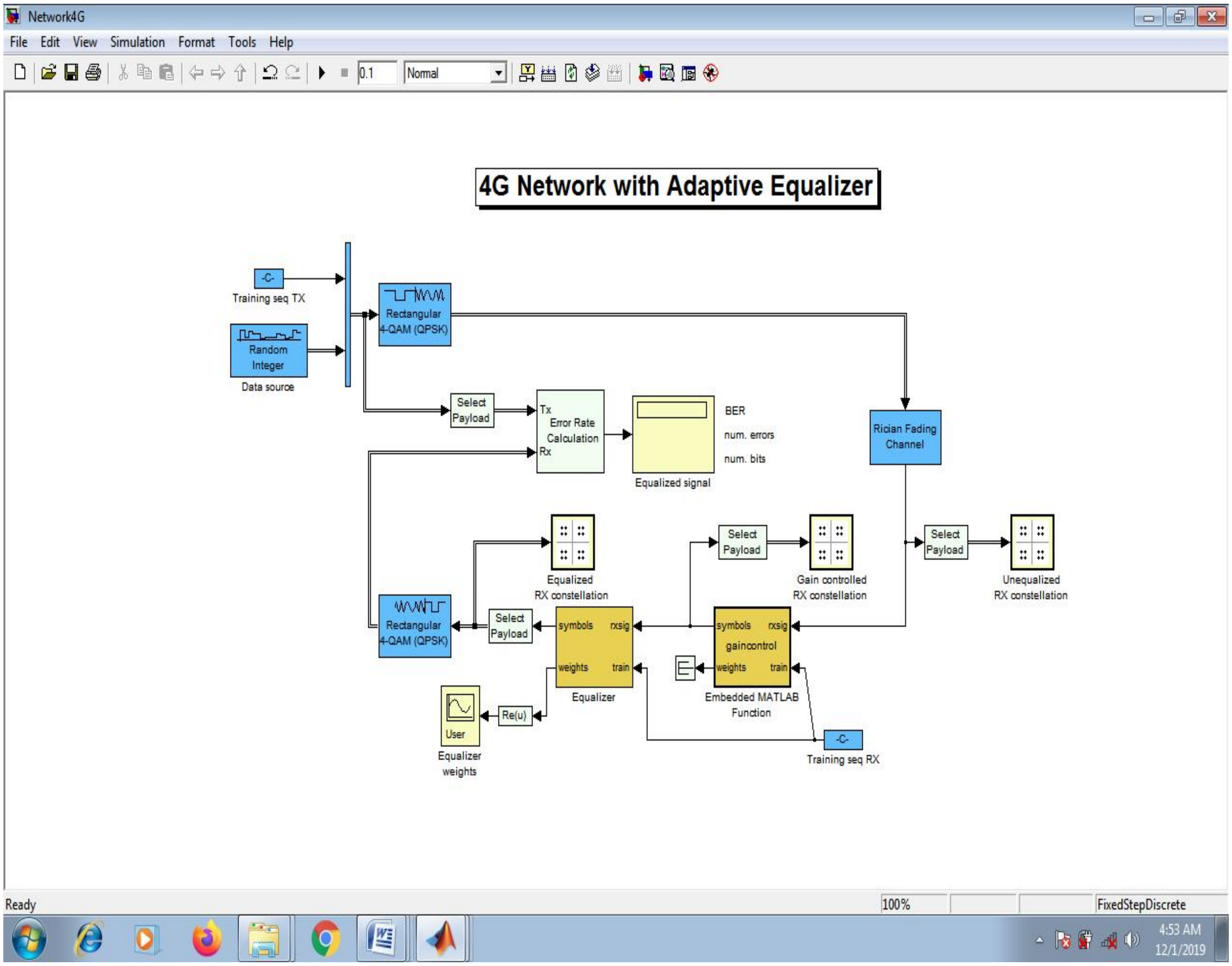

Fig. 1.6: MATLAB Model of Channel equalizer

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 3.4 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 emulate 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.

DATA PRESENTATION AND ANALYSIS

Data Measurement Techniques

The implementation for improving signal reception in 4G network was carried out using Adaptive Equalizer 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 1.2 shows the simulation parameters.

Table 1.2: Simulation Parameters

Parameter	Value
Design Method	Adaptive Equalizer
Equalization Algorithm	
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
Adaptive Equalizer step 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 Adaptive. 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)

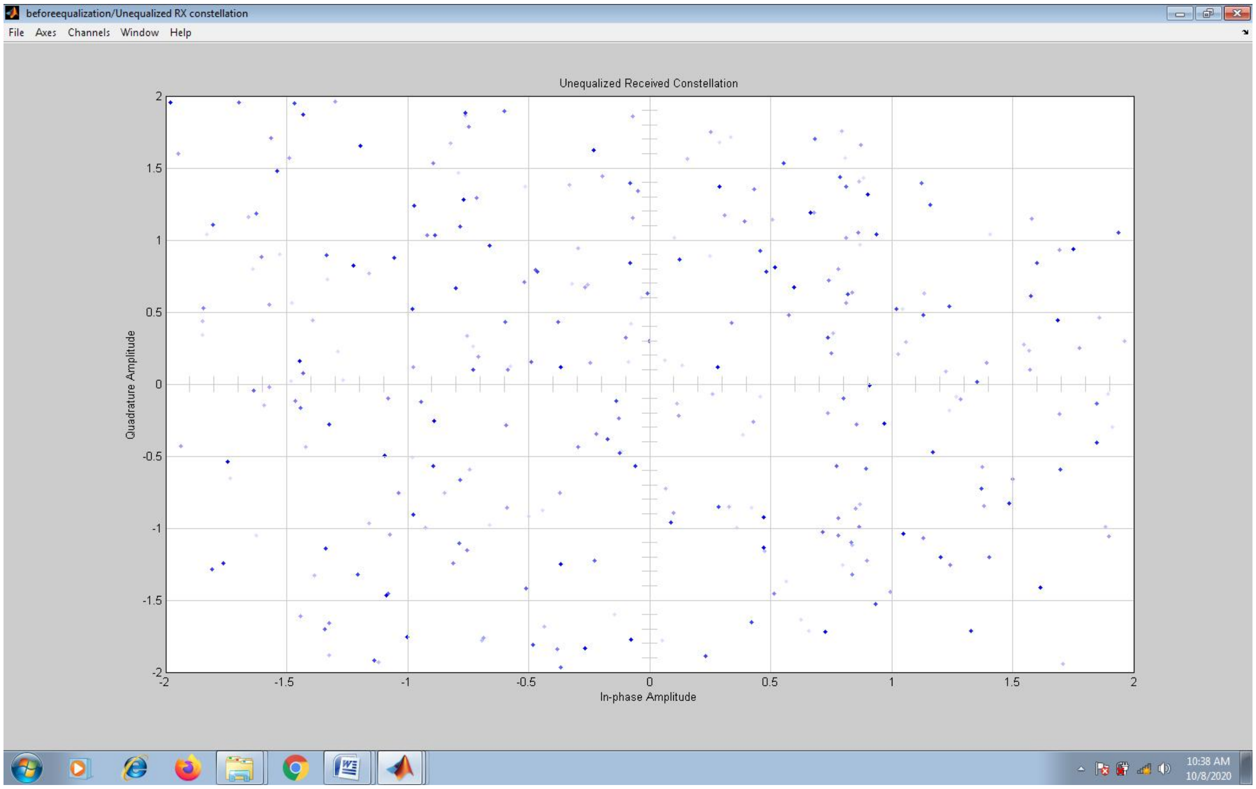

Fig 1.7: Channel scatter plot showing the Un-equalized Received Constellation

Table 1.3: Power Received (without Adaptive 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

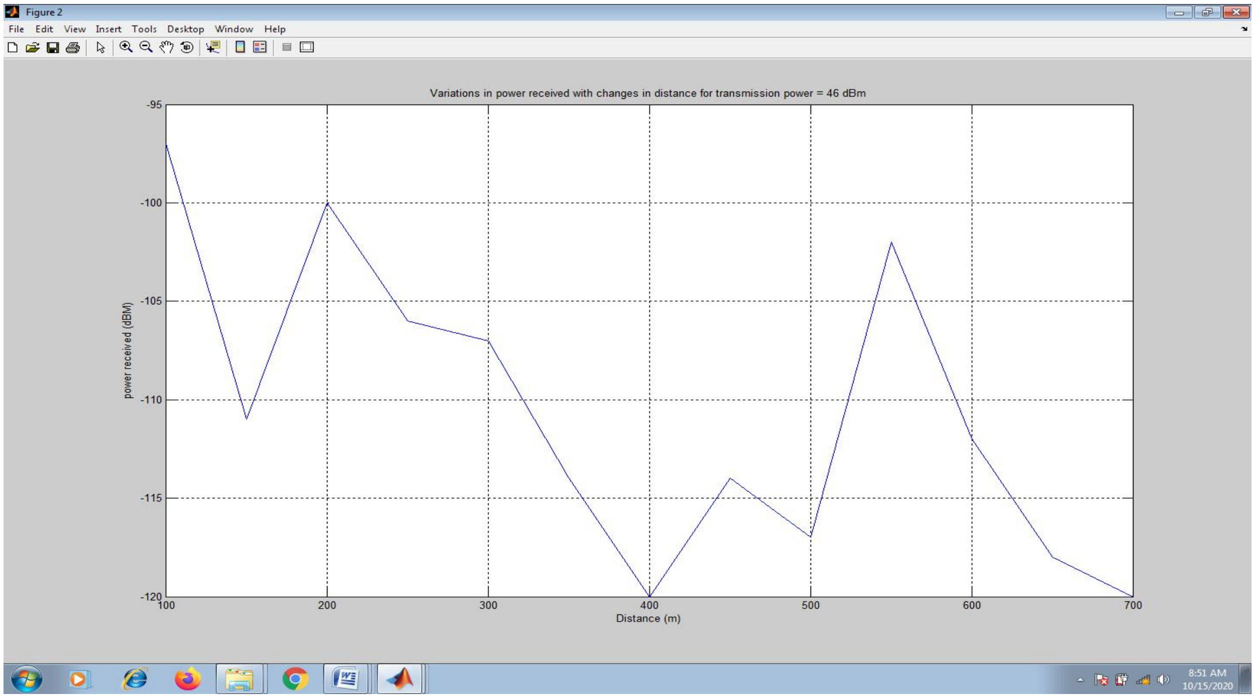

Fig 1.7: Variations in power received with changes in distance for MS transmission power = 46 dBm without Adaptive equalizer

In figure 1.7, 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 1.7, it is observed that the angle of the antenna affects the power received. As shown in Figure 1.7, 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 midrange 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 `Adaptive` Equalizer)

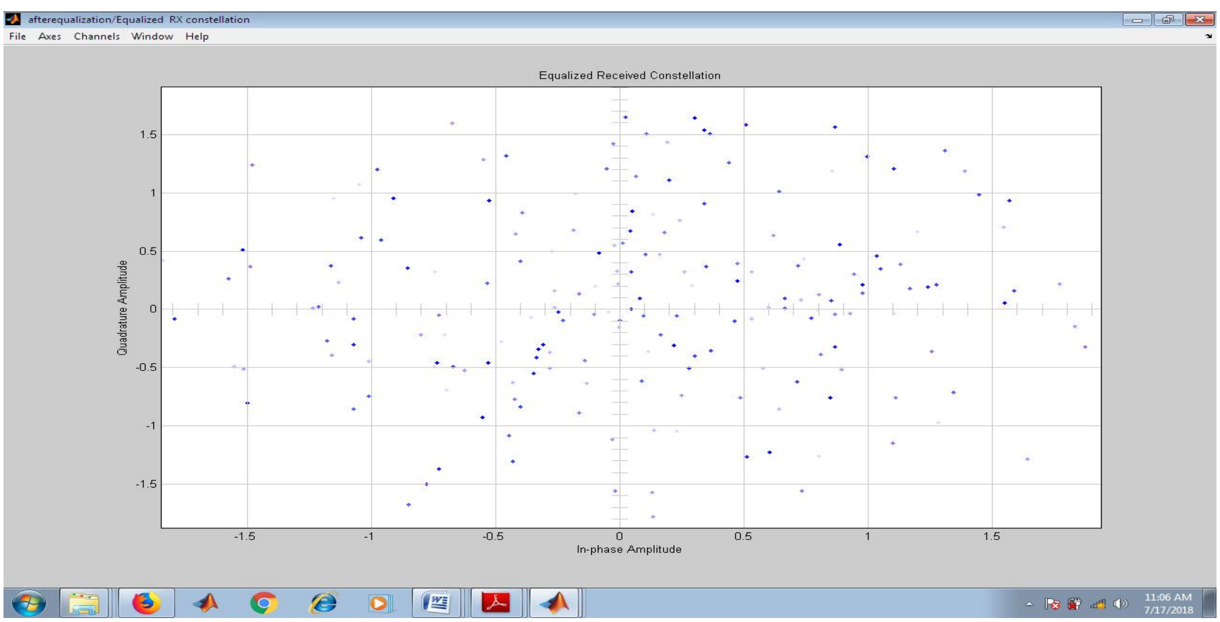

Fig 1.8: The scatter plot shows the equalized Received Constellation after the channel equalization

Table 1.4:Power received (With Adaptive 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

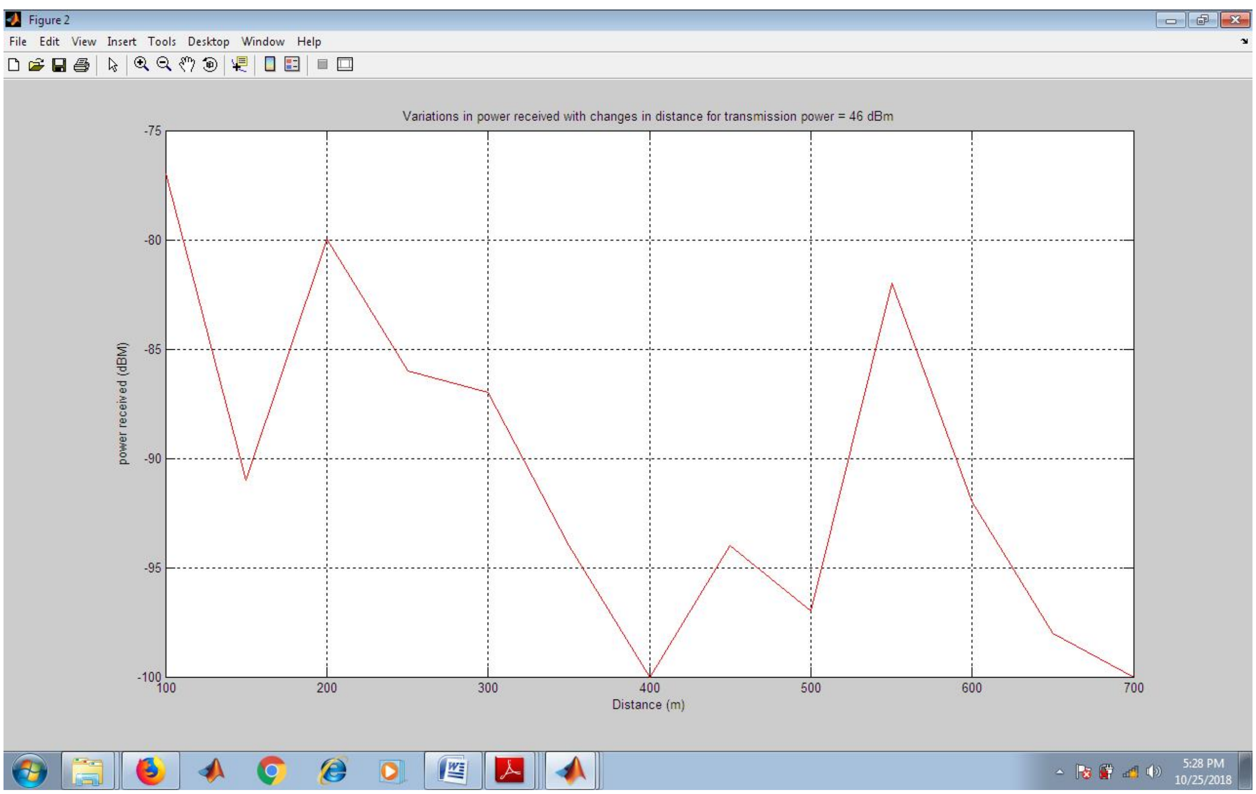

Fig 1.9: Variations in power received with changes in distance for MS transmission power = 46 dBm with adaptive equalizer

The adaptive equalizer plays an important role in the result obtained. In figure 4.4, 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 Adaptive 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 1.5: Comparison of Power received

Distance (m)	RSSI (dBm) Without Adaptive Equalizer	RSSI (dBm) With Adaptive 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

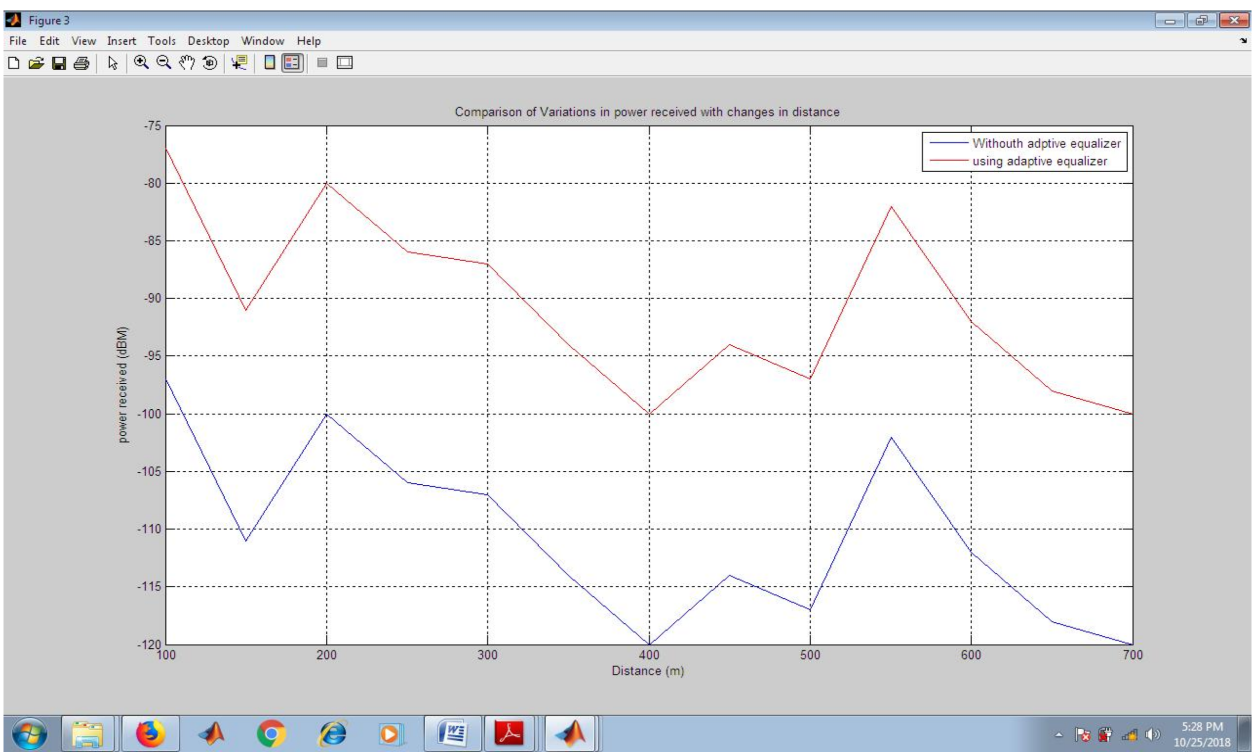

Fig. 2.0: Comparison of measured and simulated values of RSSI Variations with changes in distance for MS transmission power = 46 dBm with and without Adaptive equalizer

As shown in Figure 2.0, 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 Adaptive 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.

Discussions

The implementation and simulation of signal reception optimization using Adaptive equalization have been done using MATLAB environment and the simulation result was shown in figures 1.6, 1.7, 1.8, 1.9 and 2.0. The comparison on the Adaptive equalization algorithms has been carried out based on their RSSI.
As shown in Figure 1.6, it is observed that the angle of the antenna affects the power received. As shown in Figure 1.6, 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 midrange distances the expected significant degradation of the resulting RSSI values could not be observed. However, distances beyond 700 m suddenly produced 100 % packet loss rate.

In figure 1.9, with the adaptive 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. This has proved that Adaptive equalizer helps in optimization of signal reception in 4G network.

MATLAB Simulation Code

For the MATLAB simulation code, see appendix A.

CONCLUSION AND RECOMMENDATIONS

Summary

The problem of poor signal reception is mainly caused in dispersive channels such as, telephone and Radio channels. In a dispersive channel an Adaptive equalizer can be placed to "Equalize" the channel, i.e. to provide a frequency and phase response in the signal pass band which is the inverse or reciprocal of that of the channel itself, and thus compensate for dispersion. For wireless, (Radio) transmission, such as in mobile cellular communications, the multipath propagation of transmitted signal results in severe ISI. Equalizers are the devices widely used to mitigate the effects of ISI. With the advent of new technologies in mobile cellular communication, and in general, in the field of communications, Adaptive equalizers have really proved to be very powerful in combating ISI effect.

The cost functions to be minimized are not convex, but convergence to optimal gain scan be ensured by employing small step-size parameters in adaptation loops and initializing the equalizer reference gain to any large enough value, typically in the order of two when the equalizer input energy is normalized to that of the data symbol constellation. Practically, data receivers are usually equipped with an automatic gain control circuit, so that the equalizer initialization should not be a critical problem. Simulations 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.

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

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.

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, 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.

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