TECHNIQUES IN PERFORMANCE IMPROVEMENT OF MOBILE WIRELESS COMMUNICATION SYSTEMS – A REVIEW

Agubor, C. K., Nosiri, O. C., Ononiwu, G. C., Atimati, E. E & [1]Onyishi, D. U.
Department of Electrical and Electronic Engineering
Federal University of Technology Owerri, **NIGERIA**
[1]Federal University of Petroleum Resources Effurun, **NIGERIA**

ABSTRACT

Mobile wireless communication providers are expected by their numerous subscribers to provide network that can allow higher data rates, and good voice quality. However, this may be restricted due to some technical problems such as limited availability of radio frequency spectrum, bandwidth, channel capacity, geographical areas and transmission problems caused by various factors like fading and multipath distortion. All these lead to overall system performance degradation. This has led to various studies on how improvement on the performance of wireless communication can be realized using different techniques. This paper is a review of some scholarly works on this subject. To achieve this some recent scholarly articles were accessed online and their findings were highlighted. It was observed that all the articles reviewed had results drawn only from theoretical analysis. Based on this, one of the recommendations is that theoretical analysis should be supported with data obtained from carrying out RF measurements in the field where possible.

Keywords: MIMO-OFDM, STBC, Diversity, MRC, Wireless-communication.

INTRODUCTION

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 face 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 paper discusses these techniques and other relevant areas that have been highlighted as methods of performance improvement in wireless communications.

RELATED LITERATURE

Performance Analysis of MIMO-OFDM 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 16 QAM (Quadrature Amplitude Modulation 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.

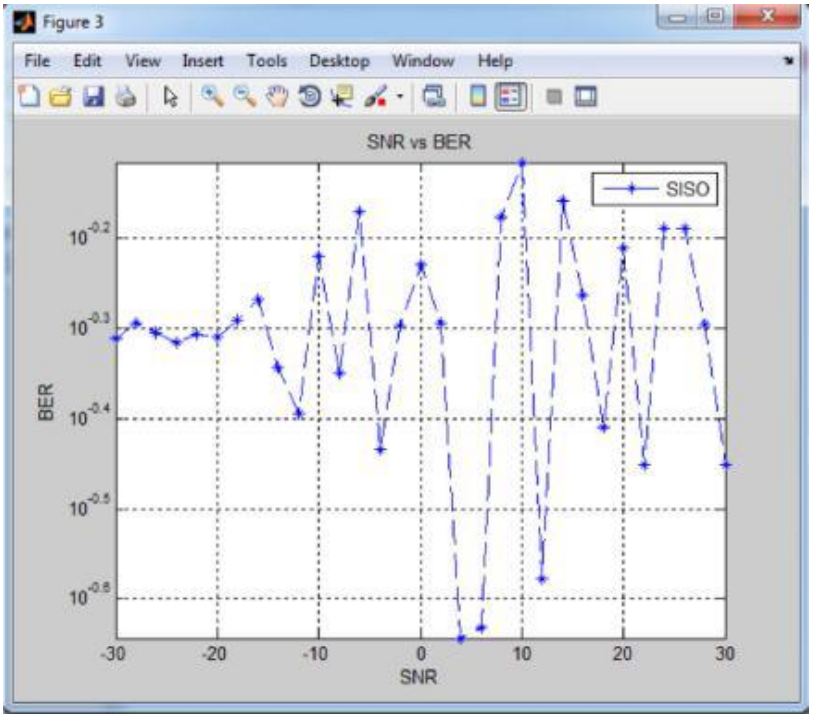

Fig.1 BER VS SNR for SISO system

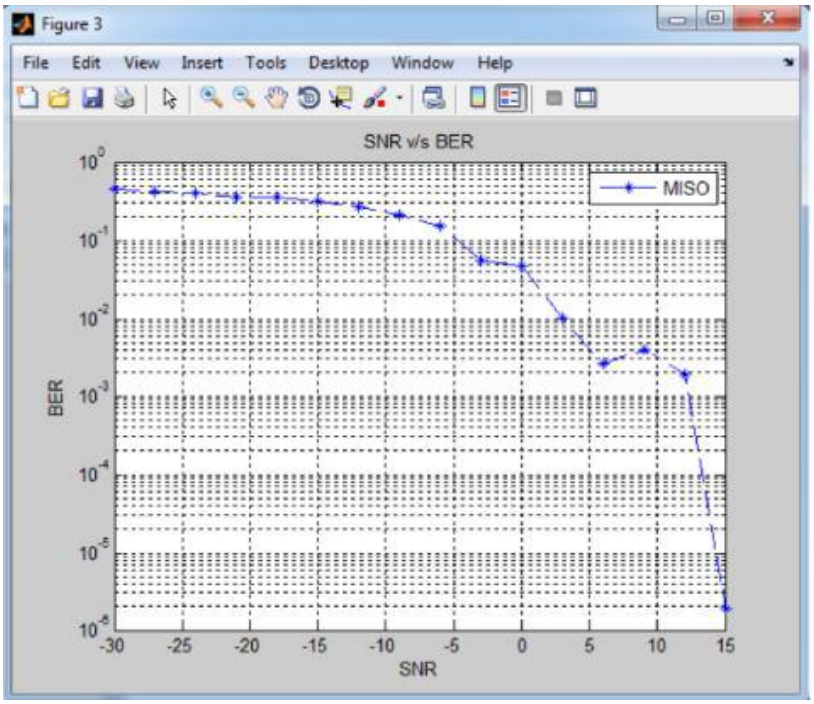

Fig.2 BER VS SNR for MISO system

It was observed from Figures 1, 2 and 3 that at 10 SNR, the BER of MIMO-OFDM system is significantly lower ($10^{-4.8}$) as compared to MISO-OFDM system ($10^{-2.6}$) and SISO-OFDM system ($10^{-0.2}$)

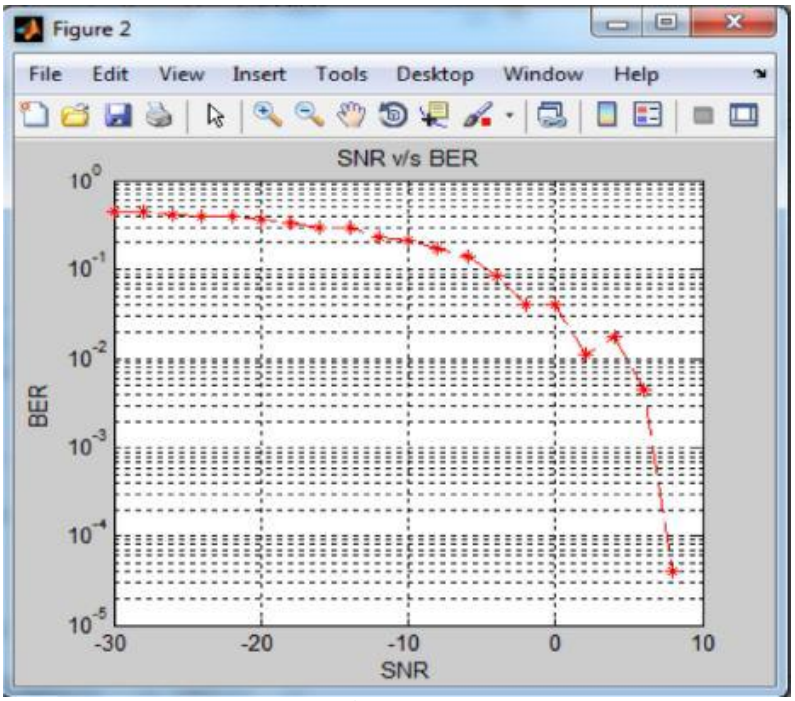

Fig.3 BER VS SNR for MIMO (2X2) system

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 BER and SNR in MIMO Antenna for Optimum Performance

Vaishali & Chopade (2014) investigated on new techniques for improving BER and SNR in wireless communication. They considered intersymbol 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, Figure 4 was obtained which shows the BER performance of ZF, MMSE and MRC techniques.

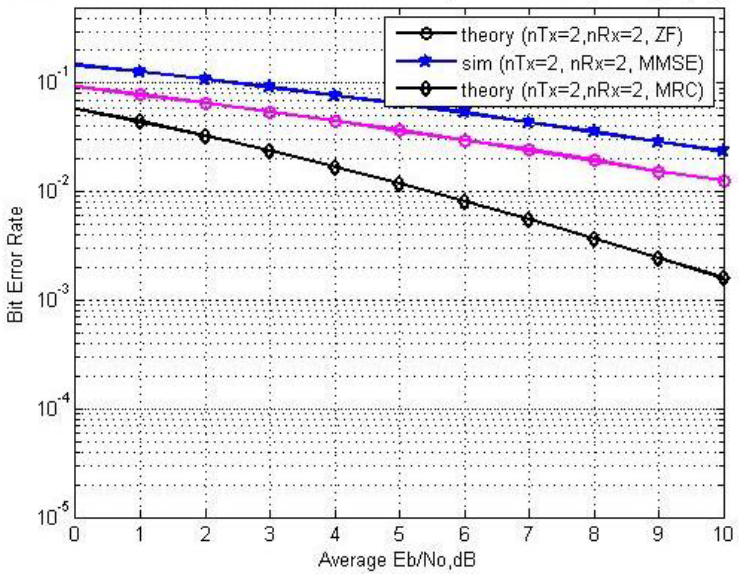

Fig.4 BER plot for BPSK modulation for MMSE, MRC and ZF Equalizer for (2×2) MIMO system

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 MIMO-OFDM 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 antenna 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 N as the spreading factor, different values were obtained for N and $\frac{E_b}{N_o}$ (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 ciphertext was converted into binary messages. The transmitted bits were channel encoded by a convolutional encoder of rate $r = \frac{1}{2}$, 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 intercarrier 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 pairwise 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. Using the STFBC the code-word for MIMO-OFDM was obtained (Su & Xi, 2005) as

$$x_m = \begin{bmatrix} x_1(0) \dots \dots \dots \dots \dots x_2(0) \\ x_1(0) \dots \dots \dots \dots \dots x_2(0) \\ \vdots \\ x_1(k-1) \dots \dots x_2(k-1) \end{bmatrix}$$

Where x_m and k are the transmit signal and desired carrier respectively.

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 $\frac{E_b}{N_o}$ ranges between $-10dB$ and $0dB$ in steps of $1dB$. The BER was calculated by performing 10,000 trials at each $\frac{E_b}{N_o}$ 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 centred 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-AntennaTechniques 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 transmit/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 seperate transmitting and receiving antenna arrays optimizes the space-time coding such that the receiving antennas are protected from the transmited 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 n 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.

DISCUSSION ON METHODOLOGICAL ISSUES

It is noted in the reviewed works that receiver combining techniques have been mostly considered in which MRC was preferred to other diversity combiners. Pravin & Badjale (2013), Srivastara (2013) and Zafeiro (2010), concentrated on diversity combining methods only as a means of improving system reliability. As seen in these studies, diversity combiners are mostly located at the receiver.

For a wholesome study, the transmitting end of the link should have been considered also. Although the importance of spatial diversity technique was mentioned as a method of improving reliability in wireless communication, they did not go further to show how this can be achieved using the necessary antenna structure.

Another method in improving reliability in wireless communication systems using the BLAST technique was by Jayalakshmy et al. (2010), which centred on exploitation rather than mitigation of multipath effect. That is using BLAST, the scattering characteristics of the propagation environment is used to enhance transmission accuracy by treating the multiplicity of scattering paths as separate parallel sub channels. This method is similar to

virtual diversity technique which is at the network layer rather than the physical layer of the network (Agubor et al, 2011).

The limitation of the BLAST technique like virtual diversity technique is that, the gain advantage comes at the price of extra bandwidth (Ozdemir et al., 2008). This is in variance with spatial diversity technique, mostly used in MIMO channels where diversity gain can be achieved without additional bandwidth or increase in transmit power (Abdul et al., 2010).
Other areas explored are CDMA (Rem & Martin, 2004), MIMO-OFDM (Niharika & Subhakhanta, 2013; Tanmeet et al 2013; Jitendra et al, 2013; Rao & Malavika 2014). The former is for 3G communication network without diversity. It uses coding technique as a way of improving system performance while the later is for 4G (Fourth Generation) communication network. It has the advantage of spectral efficiency and uses spatial diversity in the form of a 2x2 system.

On a New Subcarrier Mapping scheme, Idris et al. (2011) did not describe the method of diversity technique used. Comparison was based on frequency offset (FO) and inter-carrier interference (ICI) effects and not on antenna point of view. In Tanmeet et al (2013), the type of diversity technique was not specified and reliability improvement of the system was based on reduction of overall fading and not actually using diversity technique.

All the work reviewed were based on theoretical analysis, no real time experiment was carried out to compare with simulated results.

SUGGESTIONS

Working on improving signal reliability, it is important to consider the wireless link as a full duplex system where both the transmitting and receiving ends are considered. Therefore, future works of similar nature should consider performance level of existing networks by carrying out RF measurements and investigate some network parameters such as signal strength, level of interference and signal-to-noise ratio.

Network evaluation tools such as Drive Test or Intelligent Optimization (Chitranshi, Kushwaha, & Pancholy**,** 2012), should be used to determine the performance of existing network to justify the necessity for any improvement or comparison with proposed technique. These tools provide methods of measuring and assessing the coverage, capacity and Quality of Service (QoS) of a mobile radio network (Amaldi, Capone, Malucelli, 2008). The dataset collected during drive testing field measurements can include information such as signal intensity, signal quality and interference. Results obtained from these field measurements can be used to further authenticate theoretical results.

CONCLUSION

Performance improvement techniques used in wireless communication has been reviewed. The areas covered include diversity combiners, MIMO antenna structures, equalization methods and OFDM. Computer simulation was the research method used by the researchers.
Future works of similar nature should consider real time measurements made in the field. This will cover the performance level of existing networks. Theoretical results obtained from computer simulation and field measurement results can then be analyzed.

REFERENCES

Abdul W. & Ain A.A. (2010) Peak to Average Power Ratio Reduction in OFDM Systems using Selected Mapping and Statistical Redistribution, J.Eng Technol Res., 2, 189-194.

Agubor C.K., Opara F.K. & Eze G.N. (2013) A Review of Diversity Techniques for Wireless Communiation Systems. Academic Research International, 4,157.

Amaldi, A., Capone & Malucelli, F. (2008) Radio Planning and Coverage Optimization of 3G Cellular Networks. Journal of Wireless Networks, 14, 435–447.

Bliss, D.W. (2008) *Multiple-Antenna Techniques for Wireless Communications, Communications Office, MIT Lincoln laboratory*, [Accessed 30th March 2011] Available from World Wide Web: http://www.11.mit.edu

Chitranshi, R., Kushwaha, J. & Pancholy, P. (2012) Intelligent Optimization of GSM Network. International Journal of Engineering Science and Innovative Technology, 1, 9.

Idris, A. et al., (2011) Diversity Techinque for Multiple-Input Multiple-Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) System Using a New Sub Carrier Mapping Scheme. International Journal of the Physical Sciences, 6, 3879-3884.

Jayalakshmy, S. et al.,(2011) Performance, Analysis and Efficient Transmission over Multiple Wireless Channels using V-Blast Architecture. CIS Journal, 2, Special issue, 11.

Jintendra, K.D. et al., (2013) Performance Analysis with Space-Time Coding in MIMO-OFDM Systems with Multiple Antennas. International Journal of Advanced Computer Research, 3.

Manish, R. & Inderpret K. (2011) Performance Improvement of DS-CDMA Wireless Communication Network with Convulationally Encoded OQPSK Modulation Scheme. International Journal of Advances in Engineering and Technology.

Mohankumar, N.M., Swetha & Devaraju, J.T. (2012) Performance Evaluation of Multi-antenna Techniques in LTE. International Journal of Mobile Network Communication & Telematics, 2,4.

Naveen, V.J., Krishna, K.M. & Rajeswari, K.R. (2010) Performance Analysis of Equalization Techniques for MIMO Systems in Wireless Communication. International Journal of Smart Home, 4.

Niharika, S. & Subhakanta, (2013) BER Analysis of MIMO-OFDM System in Different Fading Channel. IJAIEM, 2.

Ozdemir O. & Tarlak M. (2008) Opportunistic Beamforming over Rayleigh Channels with Partial Side Information, IEEE Trans. on Wireless Communications, 7, 3417-3427.

Pravin, W.R. & Badjate, S.L. (2013) Diversity Technique For Wireless Communication. International Journal of Advanced Research in Engineering and Technology, 4, 144-160.

Rao,V. & Malavika, T., (2014) Performance Analysis of MIMO-OFDM for Multiple Antennas. International Journal of Advanced Research in Electrical, Electronic and Instrumentation Engineering.

RemVanDar, H &. Marten, K. (2004) Improving the Performance of Third Generation Wireless Communication Systems. Applied Probabilty Trust.

Srabanty, A. S. & Sazzad, F. (2013) Performance Analysis for Alamouti's STBC Encoded MRC Wireless Communication System over Raleigh Fading Channel. International Journal of Scientific and Research Publications, 3.

Srivastara, N. (2011) Diversity Schemes for Wireless Communication –A Short Review. Journal of Theoretical and Applied Information Technology, 15, 2.

Su, W. & Xi, H-G. (2005) Two Generalized Complex Orthogonal Space-Time Block Codes of Rates 7/11 and 3/5 for 5 and 6 Transmit Antennas. IEEE Trans. Inf. Theory, 49, 313-316.

Tanmeet, K., Balwinder, S. D. & Sandeep, S.G. (2013) Performance Evaluation of MIMO Systems with Varying Number of Transmitting Antennas. Journal of Innovative Research in Electrical, Electronic, Information and Control Engineering, 1.

Vaishali ,W.S. & Chopade, N.B. (2014) Techniques for Improving BER and SNR in MIMO Antenna for Optimum Performance**.** SSRG-International Journal of Electrical and Electronics Engineering.

Vaishali, W.S. & Chopade, N.B. (2014) Techniques for Improving BER and SNR in MIMO Antenna for Optimum Performance. SSRG International Journal of Electrical and Electronics Engineering, 1,3.

Zafeiro, G.P. (2010) Performance Analysis of Wireless Single-Input Multiple-Output systems (SIMO) in Correlated Weibull Fading Channels; zefipap@hotmail.com