SC-FDMA Performance over Various Fading Channels

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***Abstract*: As the demand for high data rate and speed is increasing day by day in the area of mobile communication, there is immense need of new technology which would satisfy the never ending demands of mobile subscribers. The evolution of mobile communication generation from the 1st generation analog communication to the most advanced 3rdgeneration (CDMA, HSUPA) has shown a drastic change in terms of data rate and accessing speed. Various techniques for uplink and downlink communication have also undergone a significant change. In this paper we are going to discuss about the 4th generation i.e. 3GPP-LTE technology which utilizes SCFDMA for uplink communication and OFDM for downlink communication.We are going to study the basics of OFDM in the initial half and then proceed towards SCFDMA because SCFDMA is the pre-coded version of OFDM.In our paper we are going to compare the BER performance of SFDMA over various fading channels like Rayleigh and Ricean channel models.Currently we are working on the physical layer and verifying the results of SCFDMA using BPSK modulation technique.**

I. INTRODUCTION

Before starting with the actual theory of OFDMA and SCFDMA lets have a glimpse at the evolution of mobile generation's. First generation was successful in introducing the mobile voice service whereas 2G increased the capacity and coverage area. Followed by the 3G which significantly quest the demand of high data rate and high speed which opened the gate for mobile broadband service.4G came up with new feature as VoIP and data rateup to 100Mbps, extending the bandwidth up to 40 MHz It promises to provide Mobile TV in our hand with stream less video and net access with zero buffering. As we are going to discuss on SC-FDMA used in LTE technology in our paper, in which we are basically working on the physical layer and comparing the behavior of the different modulation scheme used at physical layer by considering various parameters, so let's have a glance on the diagram showing basic features of 4G.

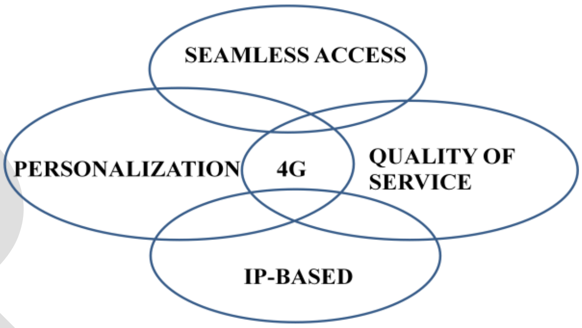

Fig.1.Features of 4G technology

Let us now have a look on the specifications of 4G:

- Peak Uplink speed: 50Mbps (QPSK) and 86 Mbps (64QAM).
- Peak Downlink speed: 100Mbps.
- Data Type: Packet Switched.
- Channel Bandwidth: 1.4,3,5,10,15 and 20 in MHz
- Duplex schemes:FDD and TDD.
- Latency: Less than 100ms.
- Modulation Types supported:QPSK,16QAM, 64QAM(Uplink and Downlink)
- Standard subcarrier spacing: 15 KHz.
- Standard length of cyclic prefix: 4.69µs.
- Standard symbol length: 66.7µs.

In our paper we will be discussing the performance of SC-FDMA using BPSK and QPSK modulation techniques over different ITU channels [2] and compare the BER [4] for different values of K[4] by deploying two equalizers MMSE [4] and Zero forcing[4] also we will see results for various value of sub-carrier.

SC-FDMA performance over Ricean channel is already studied in [6]. The channels used in simulation are VB and PA channels, which are specified by ITU-R M-1255. It is observed that BER performance of SC-FDMA with MMSE equalization is improved by increasing Rice factor K and increasing number of allocated subcarriers. Independent subcarrier BER performance with ZF equalization is independent on Rice factor K.

II. CHANNEL MODEL

As we are dealing with mobile wireless communication we are aware of the fact that unlike the wired media like cable where the signal travels through a single path, in case of wireless media the signal undergoes reflection from n number of objects and splits into multiple number of components that follow multiple paths.

Constructive interference occurs when the multipath components arrive in phase whereas destructive interference occurs when the multipath components arrive out of phase.

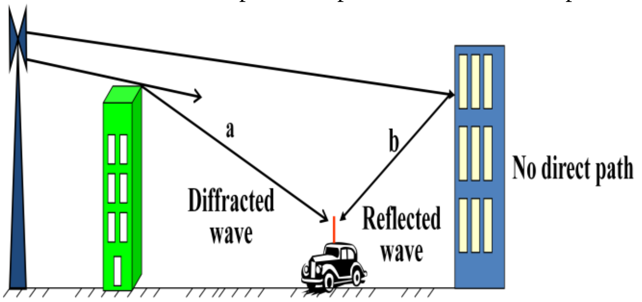

Fig.2. Multipath propagation model [8]

In the above figure1 signal a undergoes diffraction[7] after getting reflected from a denser object like building. The signal b undergoes reflection[7] and arrives at the receiver antenna of the car. However if signals a and b arrive in phasei.e. the relative phase difference between the two signals is 0 then the constructive interference[7] phenomenon is said to occur and the signals get added constructively at the receiver side. But if the relative phase difference between the signals is π radians then destructive interference[7] is said to have occurred. Complete fading occurs when 2πd/λ is equal to nπ radians, where d is the path difference.

Fading represents change in amplitude of the propagating signal over a distance. In flat fading, the coherence bandwidth of the channel is larger than the bandwidth of the signal. Therefore, all frequency components of the signal will experience the same magnitude of fading. In frequency selective fading, the coherence bandwidth of the channel is smaller than the bandwidth of the signal. Different frequency components of the signal therefore experience uncorrelated fading.

Since we are working on multi-Carrier modulation where we have advantage of flat fading since coherence bandwidth is larger than that of signal bandwidth.

A. Rayleigh Fading Channel

It basically assumes that the amplitude of the transmitted signal deteriorates or fades after covering a specific amount of distance. The transmitted signal follows the Rayleigh distribution pattern. Rayleigh propagation is not applicable for dominant propagation along line of sight. The PDF of Rayleigh distribution is as follows:

$P_r(r)= (2r/\Omega)e^{-r2/\Omega}$, $r\geq 0$. Where $\Omega=E\,(R^2)$……………..(1)

Rayleigh fading model contains N number of reflective components and no dominant line of sight signal. For Rayleigh fading channel thefactor 'K' [4] is ideally considered to be zero. Here the in phase and quadrature components of complex fading gain are complex and involves zero mean Gaussian processes.

B. Ricean Fading Channel

Rice fading channel is modeled with dominant line of sight propagation. This means that there is N number of reflective components or signals along with a dominant line of sight strong signal. Here the in phase and quadrature components of complex fading gain are complex and possesses zero mean Gaussian processes. The Rice distribution is given as:

$$F(X) = \frac{2(K+1)x}{\Omega} exp\left(-K - \frac{(K+1)x^2}{\Omega}\right) I0 \qquad …………(2)$$

Where 'K' is the rice factor and is ideally considered to be infinite and I_0 is the zerothorder modified Bessel function of the first kind.

C. Additive White Gaussian Noise

The simplest radioenvironment in which a wireless communications system or a local positioning system or proximity detector based on Time of- flight will have to operate is the Additive-White Gaussian Noise (AWGN) environment. Additive white Gaussian noise (AWGN) is the commonly used to transmit signal while signals travel from the channel and simulate background noise of channel. The mathematical expression in received signal r(t) = s(t) + n(t) that passed through the AWGN channel where s(t) is transmitted signal and n(t) is background noise.

An AWGN channel adds white Gaussian noise to the signal that passes through it. It is the basic communication channel model and used as a standard channel model. Thetransmitted signal gets disturbed by a simple additive white Gaussian noise process.

III. SYSTEM MODEL

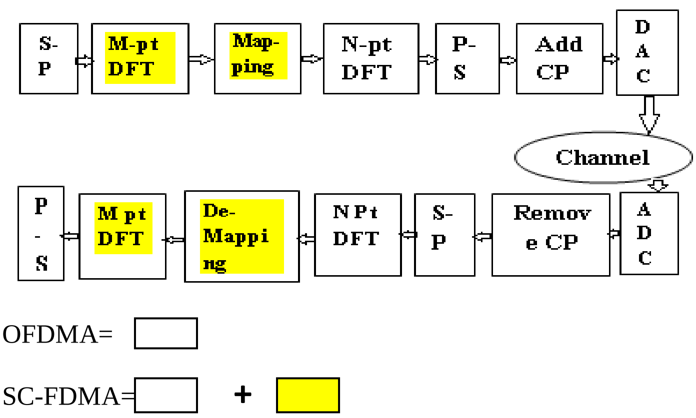

Fig.3.Block Diagram of SC-FDMA

es which can transmit several signals simultaneously, as similar to all orthogonal frequency division techniques it employs a discrete set of the orthogonal subcarriers distributed across the system bandwidth. It includes discrete transforms to move signals between the time domain and frequency domain. To transmit several signals simultaneously the multiple access techniques assign the signals to mutually exclusive sets of subcarriers. Because broadband channels experience frequency-selective fading, the FDMA techniques can employ channel dependent scheduling to achieve multi-user diversity, and because the fading characteristics of the terminals in different locations are statistically independent, the scheduling techniques can assign each terminal to subcarriers with favorable transmission characteristics at the location of the terminal. [1].

In case of other high rate cellular system like WiMAX they utilize OFDMA for both uplink and downlink due to its high robustness, but one drawback of OFDMA is its high PAPR (Peak to Average power ratio). And during uplink the transmitter is basically our mobile devices which have got limitation on the power as it is battery operated so 3GPP prescribes OFDMA for downlink transmission and SC-FDMA for uplink transmission in the long term evolution (LTE) of cellular systems in order to make the mobile terminal power-efficient.

In case of OFDMA which is a multi-carrier technique and it is most robust one utilizing bandwidth to the fullest. But we have issue of the PAPR in OFDMA. PAPR is variation in power w.r.t average power. Ideally it should be low, as high PAPR causes distortions and saturation of linear amplifier which is caused due the IFFT block which is used for complex orthogonal subcarrier modulation. So SC-FDMA technique uses an M-point FFT and sub carrier mapping before IFFT to achieve low PAPR. Here value of M<N and N is number of sub-carrier.

In the localized subcarrier mapping mode, the modulation symbols are assigned to M adjacent subcarriers. In the distributed mode, the symbols are equally spaced across the entire channel bandwidth. In both modes, the IDFT in the transmitter assigns zero amplitude to the N − M unoccupied subcarriers. We refer to the localized subcarrier mapping mode of SC-FDMA as localized FDMA (LFDMA) and distributed subcarrier mapping mode of SC-FDMA as distributed FDMA (DFDMA). The case of N = Q *M for the distributed mode with equidistance between occupied subcarriers is referred to as Interleaved FDMA (IFDMA). IFDMA is a special case of SC-FMDA and it is very efficient in that the transmitter can modulate the signal strictly in the time domain without the use of DFT and IDFT.

IV. TABLES

From below mentioned information we can observe the variation in the signal power level at different delay intervals when it is passed through different channels. Thus, in short Power Delay Profile (PDP)[5] of a signal defines the intensity of a signal received through a multipath channel as a function of time delay. Where time delay is the difference in travel time between multipath arrivals. Power profile of received signal can be obtained by convolving power profile of the transmitted signal with the impulse response of the channel. The above mentioned channels are defined by ITU [2]We have mainly used Pedestrian A and Indoor Office channel model.

Table 2:PDP of Pedestrian A channel model

Relative Delay(ns)	0	110	190	410
Relative Power(dB)	0.0	-9.7	-19.2	-22.8

The Indoor Office A channel modeled for different delays is as follows:

Table 3:PDP of Indoor Office A channel model

Relative Delay(ns)	0	50	110	170	290	310
Relative Power (dB)	0	-3.0	-10.0	-18.0	-26.0	-32.0

V. SIMULATION RESULTS AND DISCUSSION:

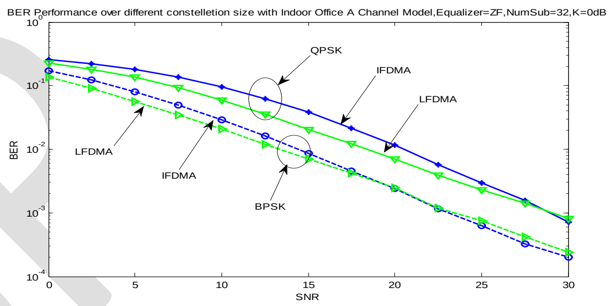

Fig.4. BER Performance for different constellation size with Indoor Office A Channel Model,Equalizer=ZF,K=0dB,NumSub-Carrier=32

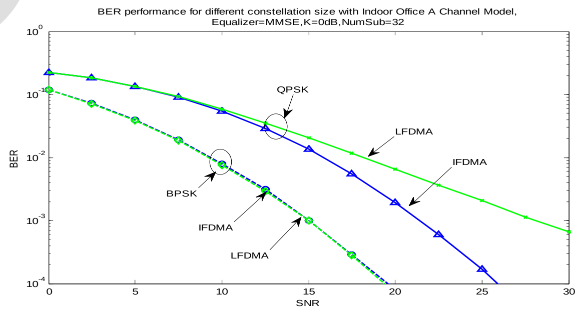

Fig.5.BER Performance for different constellation size with Indoor Office A Channel Model,Equalizer=MMSE,K=0dB,NumSub-Carrier=32

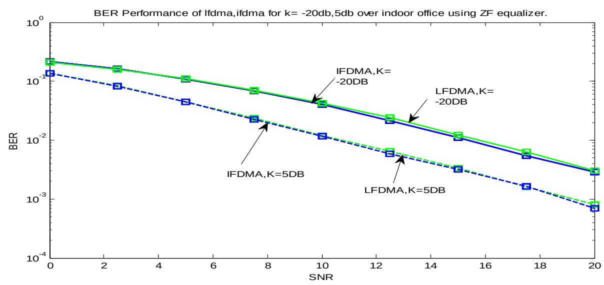

Fig.6.BER Performance for different Rice Factor with Indoor Office A Channel Model,EqualizerZF,NumSub-Carrier=32,BPSK Modulation

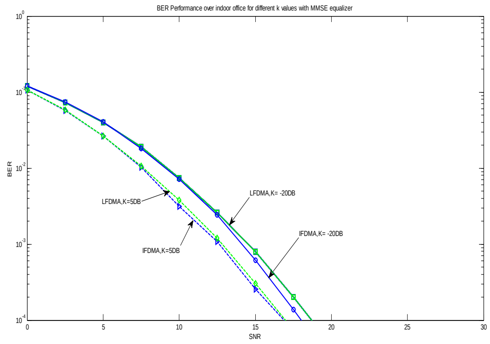

Fig.7.BER Performance for different Rice Factor with Indoor Office A Channel Model,Equalizer MMSE,NumSub-Carrier=32,BPSK Modulation

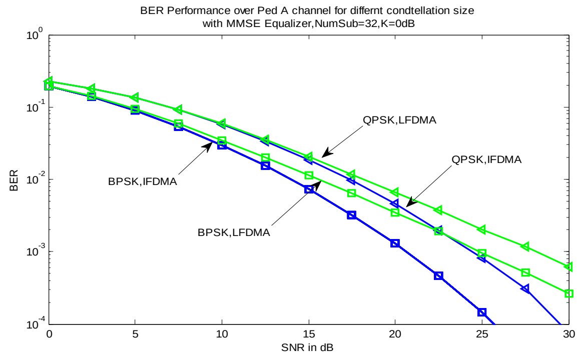

Fig.11.BER Performance for different size of Constellation with Outdoor Office Ped A Channel Model,Equalizer MMSE,K=0dB,NumSub-Carrier=32

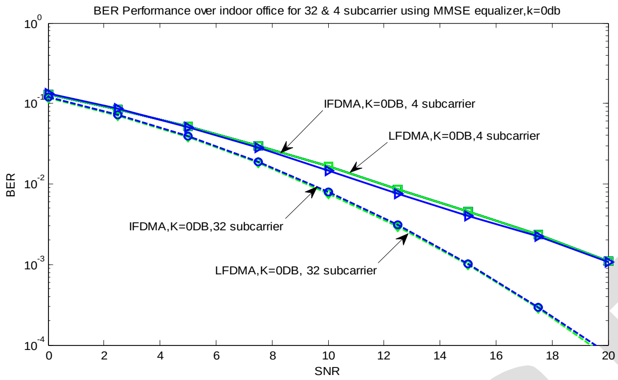

Fig.8.BER Performance for different number of Subcarrier with Indoor Office A Channel Model,Equalizer MMSE,K=0dB,BPSK Modulation

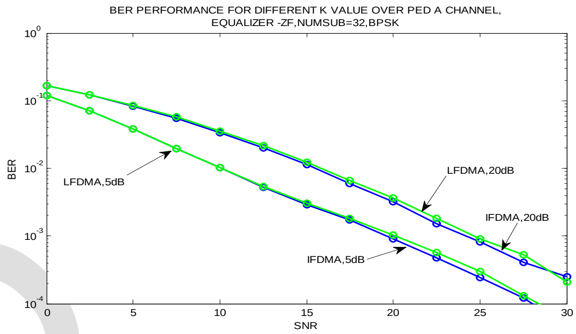

Fig.12.BER Performance for different Rice Factor with Outdoor Office Ped A Channel Model,Equalizer ZF,Modulation-BPSK,NumSub-Carrier=32

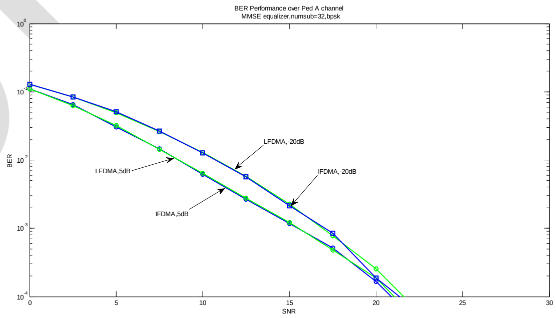

Fig.13.BER Performance for different Rice Factor with Ped A Channel Model,Equalizer MMSE,Modulation-BPSK,NumSub-Carrier=32

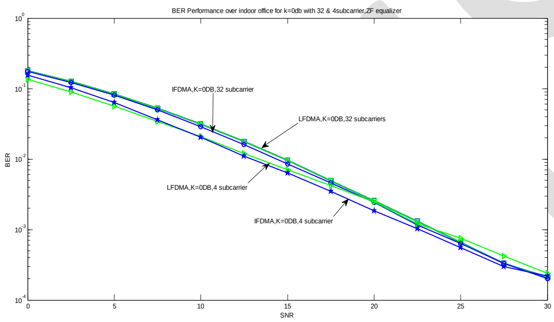

Fig.9.BER Performance for different number of Subcarrier with Indoor Office A Channel Model,Equalizer ZF,K=0dB,BPSK Modulation

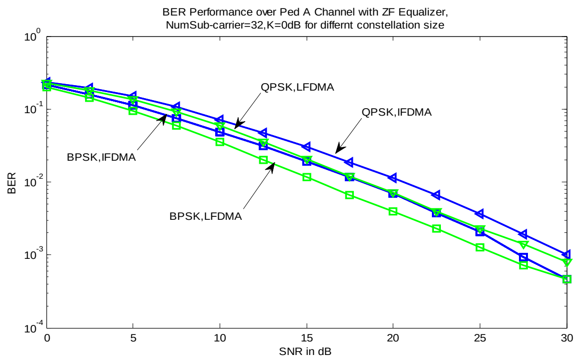

Fig.10.BER Performance for different size of Constellation with Outdoor Office Ped A Channel Model,Equalizer ZF,K=0dB,NumSub-Carrier=32

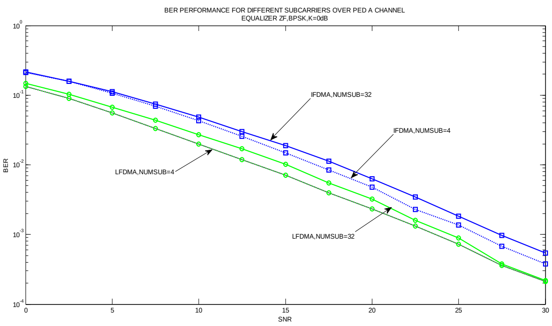

Fig.14.BER Performance for different Number of SubCarrier with Outdoor Office Ped A Channel Model,Equalizer ZF,K=0dB,Modulation-BPSK

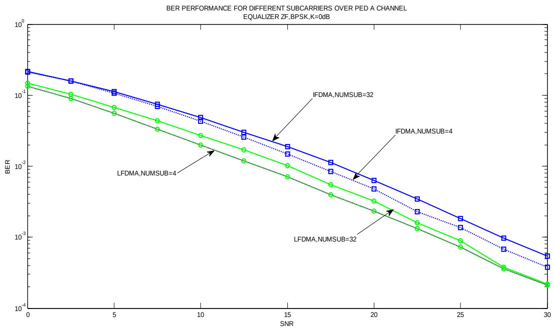

Fig.15.BER Performance for different Number of Sub-Carrier with Outdoor Office Ped A Channel Model,Equalizer ZF,K=0dB,Modulation-BPSK

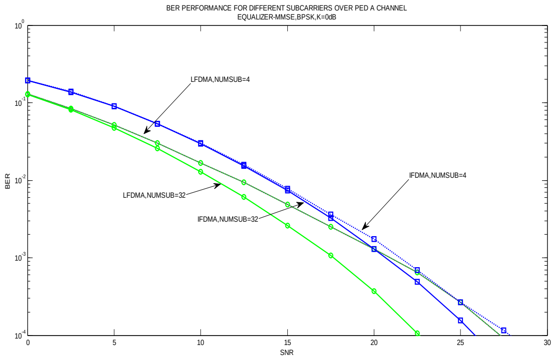

Fig.16.BER Performance for different number of Subcarrier with Indoor Office A Channel Model,Equalizer MMSE,K=0dB,BPSK Modulation

From Fig.5 and 6 it is observed that QPSK has higher BER since as we increase constellation size the number of bits in the symbol increases and hence symbols will come closer and will result in to interference and noise. Also with MMSE equalizer the performance of IFDMA improves as MMSE takes care of the channel nulls and noise introduced but this is completely neglected by ZF equalizer. Fig 7 and 8 shows BER performance for different Rice Factor as rice factor increases it means we have strong LOS component and hence BER reduces. Hence more positive the value of K better is the performance. And from Fig.9 and 10 it is observed that as we increase the value of Sub Carrier it means we are adding more number of channels and hence multi user interference induces noise in the channel. Now if the equalizer used is ZF then since it will not consider the effect of noise so performance will degrade but for MMSE the BER reduces for increased number of Sub-Carrier.

Coherence Bandwidth of Indoor Office A channel model is higher than that of the Outdoor Office A channel. Hence if we compare, with ZF equalizer the Indoor channel will show better result but MMSE equalizer will work well with the outdoor channel model. Hence Fig 11 onwards which is for Outdoor channel shows similar result as that of the Indoor channel with little variations.

V. CONCLUSIONS AND FUTURE SCOPE

SC-FDMA performance over Indoor Office A and Outdoor Pedestrian A test channel model is studied. It is observed that BER performance of SC-FDMA with MMSE equalization is improved by increasing Rice factor K and increasing number of allocated subcarriers. As the constellation size is increased the BER increases irrespective of other factors. In ideal condition the behavior of the IFDMA is best but for Zero forcing equalizer the Localized SCFDMA shows better result since noise cancellation is not done in case of ZF equalization.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge and express their deep indebtedness towards the support provided bySinhgad Institute of Technology, Lonavala for giving us platform to work and express their gratitude to Prof.Jyoti.R.Ganganefor her incredible guidance and support throughout the successful completion of our project.

REFERENCES

[1] H. G. Myung, J. Lim, and D. Goodman, “Single Carrier FDMA for Uplink Wireless Transmission,” IEEE Vehicular Technology Mag., vol. 1, no. 3, pp.30-38, Sep. 2006.

[2] “Recommendation ITU-R M-1255; Guidelines for Evaluation of Radio Transmission Technologies for IMT-2000,” International Telecommunication Union (ITU), Tech.Rep.1997.

[3] ”Evolution of Mobile Communication “,International Journal of Electronics and Communication Technology by Amit Kumar, www.iject.org

[4] MIMO OFDM wireless Communication with MATLAB by Yong Soo Cho Chung-Ang University, Republic of Korea;Jaekwon Kim Yonsei ;Won Young Yang Chung-AngChung G. Kang Korea University, Republic of Korea,WileyPub.IEEEPRESS

[5] “SC-FDMAPerformance over Ricean Channel” ,J.R. Gangane, M.C. Aguayo-Torres, J.J. Sánchez-Sánchez and U. Fernández-Plazaola, Proceedings of the 6th International Conference on Broadband Communications & Biomedical Applications, November 21 - 24, 2011, Melbourne, Australia.

[6] “Software Implementation and Comprehensive Performance of Uplink channel on Mobile 4th Generation Technology”,MayadaFarishGhanim,MdFaizLiew Abdullah, AwsZuheerYonish; International Journal of Smart Phone Vol.7.No.3,May.2013.

[7] T. S. Rappaport. Wireless Communications – Principles and Practice. Prentice Hall, New Jersey, 1999.

[8] ‘Fading’ – Online Article in Wikipedia en.wikipedia.org/wiki/Fading