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RAYLEIGH FADING - SHADOWING OF OUTDOOR CHANNELS ANALYSIS BASED ON SNR-PDF MODEL

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ABSTRACT

The outdoor transmission channels condition in multiple wireless signals systems changes continuously due to signals transfer path characteristics. The path loss, multiple reflected rays Rayleigh fading and shadowing presents an important factor that effects inconsistent with signals propagation through the wireless channels of communication systems. The solutions for these effects will contribute to minimize the error probability of transferred data and maximize the data rate in high speed systems. This paper deals with the analysis of error probability using Probability density function (PDF) model of Signal to Noise ratio (SNR) for different values of transmitted signals power at outdoor receiver of multi users systems. The proposed approach use Rayleigh fading channels, 2GHz carrier frequency, (0-30) dB SNR, (0.1,0.2,0.3), (1,2,3) and (10,20,30) PW. The relationship between error probability and SNR has been studied to determine efficient transmission channels. The proposed channel model has been simulated and analyzed using MATLAB R2012b software under different users power signals values. The obtained results have showed accuracy as well as efficiency of the proposed method where the error probability is decrease when the SNR increase and the error probability decrease when decrease in the transmitted power signal.

KEYWORDS: Rayleigh fading–shadowing, lognormal distribution, error probability.

1. INTRODUCTION

The performance improvement in wireless communications environment is paramount important due to increase use in mobile phones, internet services, intranet and Bluetooth. These systems require high transmission data rate, reliability, quality of service (QoS), minimize bit error rate (BER), spectral efficiency, and diversity gain.

A measure of the wireless communication systems performance through transmission channels depends on important factors such as the multipath, Rayleigh fading, multiple reflections rays, path loss, and shadowing effects (Chen et al., 2009; Wang and Cao, 2015; Bhis and Khot, 2016; Ilter and Altunbas, 2012; Ren et al., 2011). The treatment of these challenges provide other potential advantages such as increase the system capacity and power reducing due to decrease the transmit power and co- channel interference (Lee et al., 2012). The multipath fading can be represented by small scale fading that produce rapid and random variations in signal strength at receive antennas. On other hand the shadowing effects present by large scale fading due to large structures. Large and small scale fading have been modeled using (Rayleigh, Nakagami, Rice distribution) and (lognormal distribution) respectively (Alam and Annamalai, 2012).

The state of indoor multi input multi output (MIMO) channel has variant dynamically caused by movements reorientation of the human body shadowing effect that can be presented by the rays arrived from all direction in the room. The indoor environment characterized can be modeled by the non-line–of–sight (NLoS) radio propagation with Rayleigh distributed small scale fading and lognormal shadowing. The propagation analysis deals with two important parameters: the angle of arrival (AoA) and time of arrival (TOA) (Saito et al., 2012; Torre et al., 2012). Also the radio on free space optics (RoFSO) technology of worldwide interoperability for microwave access (WiMAX) has path loss, shadowing, and Rayleigh fading problems in optical wireless channels. Therefore, the relationship between the outage probability and symbol error rate (SER) of the WiMAX link can be analyzed to compute the laser transmitter gain (Vaiopoulos et al., 2012).

There are many schemes of relay selection protocols has been used in wireless communication system for multipath and shadowing side information such as best-worse channel selection schemes, best-harmonic-mean selection schemes, nearest-neighbor selection schemes, reactive-relay selection, and partial relay selection schemes. These schemes are operating in wireless millimeter wave (60 GHz or above) frequencies. Therefore, the data transmission will be increase cause by relay protocols can faster over time (Yilmaz and Alouini, 2011; Dziri et al., 2012).

Two dimensional model for auto-correlation filter algorithm and site-to-site cross correlation of shadow fading has been used with linear interpolation scheme that is decrease the computational complexity of wireless system simulation (Zhang et al., 2012). Highest shadowing coefficient between a transmitter and receiver has been obtained at transmit antenna selection (TAS) when single transmit antenna is selected (Yilmaz et al., 2013). In indoor received signal strength indication (RSSI) ranging was used to study the effects of shadow and fading at change of distance value (Wanhee et al., 2012).

Error probability in shadowing mobile channel has been evaluated by analytical model for signal modulation formats: Non coherent M-array frequency shift keying (NCMFSK) , M-array coherent phase shift keying (MCPSK) and M-array coherent quadrature amplitude modulation (MCQAM) and transmitted in the presence of Nakagami / Ricean fading (Hadzialic et al., 2008).

The rest of this paper is organized as follow. In the next section, the Rayleigh fading- shadowing of outdoor wireless mobile communication channels will be described using PDF model. In section two, the simulation results of the outdoor channel performance for error probability is presented. Finally, the conclusions will be presented in section four.

2. MODELING OF RAYLEIGH FADING - SHADOWING CHANNEL

This section is dedicated to derivation of mathematical model for Rayleigh fading – shadowing lognormal distribution used in wireless mobile communication system as shown in Fig. 1. Uniform channel environment can be realized by assumed that equally Rayleigh fading - shadowing effects in all direction and constant time intervals.

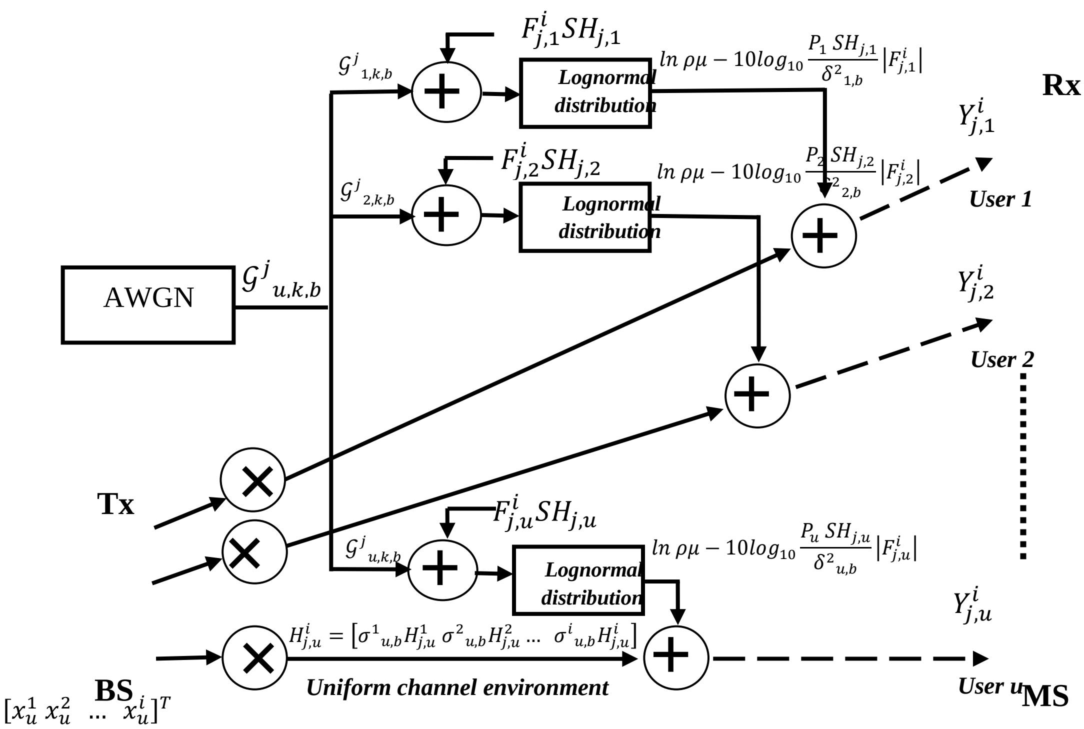

Fig. 1. Multi-users mobile wireless Rayleigh fading shadowing system model.

The error probability parameters of rays are analyzed using PDF model. As shown in Fig. 1, there is a multi- users wireless mobile communication system, Tx presents the transmit antennas and Rx presents the receive antennas which are denoted by the base station (BS) and mobile station (MS) respectively. Rayleigh fading - shadowing effects between the Tx and Rx antennas has been approximated using variant range value of (0-30) dB SNR. The main characteristics of these effects can be described in the following. The received signal of an k subcarrier multiuser system with U users and b subband at mobile station is given by (Chen et al., 2009; Wang and Cao, 2015; Dziri et al., 2012):

$$Y^i_{j,U,k,b} = \sqrt{P_U}\,\sigma^i_{U,b}\,[H^i_{j,U,b}]^T x^i_{k,b} + \mathcal{G}^j{}_{U,k,b} \qquad 1$$

Where the P_U is the transmit power for uth user , $\sigma^i_{U,b}$ is the distance that the path loss and the shadowing effect relying on it , $H^i_{j,U}$ presents the Tx × Rx channel matrix of Rayleigh fading coefficients matrix between ith and jth transmit and receive antennas respectively. $x^i_{k,b}$ is the transmitted symbols vector as $x^i_{k,b} = [x^1_{k,b}\ x^2_{k,b}\ \dots\ x^i_{k,b}]^T$, T denotes the transpose . $\mathcal{G}^j{}_{U,k,b}$ is the complex additive white gaussian noise (AWGN) vector at each jth receive antenna that independent of Tx (Alam and Annamalai, 2012). $H^i_{j,U,b} = [\sigma^1{}_{U,b}h^1_{j,U,b}\ \ \sigma^2{}_{U,b}h^2_{j,U,b}\ \dots\ \sigma^i{}_{U,b}h^i_{j,U,b}\ ]$ represent total frequency channel vector between the ith transmit antenna and jth receive antenna. .

$$h^i_{j,U,b} = F^i_{j,U,b}\sqrt{L_{j,U,b}SH_{j,U,b}} \qquad 2$$

Where $F^i_{j,U,b}$ is the Rayleigh fading effect of the *jth* receive antenna. Path loss and shadowing are given by $L_{j,U,b}SH_{j,u,b}$ respectively. The path loss $L_{j,U,b}$ can be modeled as (Trigui et al., 2009; Mailaender, 2012; Palaios et al, 2012).

The *K Tx* ×*K Rx* total complex channel gain matrix for *uth* users is provided by (Fu et al., 2008).

$$H^i_{j,U,b} = \begin{vmatrix} F^0_{0,U,b}\sqrt{L_{0,U,b}SH_{0,U,b}} & F^0_{1,U,b}\sqrt{L_{1,U,b}SH_{1,U,b}} & \cdots & F^0_{(Rx-1),U,b}\sqrt{L_{(Rx-1),U,b}SH_{(Rx-1),U,b}} \\ F^1_{0,U,b}\sqrt{L_{0,U,b}SH_{0,U,b}} & F^1_{1,U,b}\sqrt{L_{1,U,b}SH_{1,U,b}} & & F^1_{(Rx-1),U,b}\sqrt{L_{(Rx-1),U,b}SH_{(Rx-1),U,b}} \\ \vdots & & \ddots & \vdots \\ F^{(Tx-1)}_{0,U,b}\sqrt{L_{0,U,b}SH_{0,U,b}} & F^{(Tx-1)}_{1,U,b}\sqrt{L_{1,U,b}SH_{1,U,b}} & \cdots & F^{(Tx-1)}_{(Rx-1),U,b}\sqrt{L_{(Rx-1),U,b}SH_{(Rx-1),U,b}} \end{vmatrix} \qquad 3$$

$F^{i}_{j,U,b}\sqrt{L_{j,U,b}SH_{j,U,b}}$ represent the channel coefficients between the ith and jth transmit and receive antennas respectively as a function of Rayleigh fading –shadowing and path loss as (Chen et al., 2009; Wang and Cao, 2015; Bhis and Khot, 2016; Ilter and Altunbas, 2012; Ren et al., 2011; Lee et al., 2012; Alam and Annamalai, 2012; Saito et al., 2012; Torre et al., 2012).

$$L_{j,U,b} = P_U D_U \left(\frac{ds}{dtr}\right)^{\gamma_U} \qquad 4$$

where D_U is the dimensionless and deal with the antenna characteristics, ds represent the far-field antenna reference distance, dtr is the distance between the ith and jth transmit and receive antennas respectively. $\gamma_{U,b}$ is the propagation path loss exponent.

In this paper the path loss $L_{j,U,b}$ is assumed to have 0 dB in calculation of shadowing and fading effects only.

The PDF Rayleigh fading with standard deviation $\delta^2_{\mu,U,b}$ (dB) at $\mu \geq 0$ can be expressed as (Torre et al., 2012).

$$F^{i}_{j,U,b}(\mu) = \frac{1}{2\delta^2_{\mu,U,b}} \exp\left(-\frac{\mu}{2\delta^2_{\mu,U,b}}\right) \qquad 5$$

where $\delta\ (dB) = 10log_{10}\mu$. Consider that the $2\delta^2_{\mu,U,b} = \varepsilon$. The $F^{i}_{j,U}(\mu)$ can be written as $\frac{1}{\varepsilon}\exp\left(-\frac{\mu}{\varepsilon}\right)$.The shadowing has been assumed to be lognormal distributed with standard deviation $\delta^2_{\rho}(dB)$. Where $\delta_{U,b}\ (dB) = 10log_{10}\,\rho_{U,b}$, at $\rho \geq 0$ (Torre et al., 2012).

$$SH_{j,U,b}(\rho) = \frac{\frac{10}{\ln 10}}{\rho_{U,b}\sqrt{2\pi\delta^2_{ln\rho,U,b}}}\, exp\left(-\frac{\left(10\, log_{10}\,\rho_{U,b}\right)^2}{2\delta^2_{\rho,U,b}}\right) \qquad 6$$

The approximate PDF form computed by adding eq. (5) with eq. (6) as (Mailaender, 2012).

$$PDF_{j,U,b}(\rho\mu) = \int_0^\infty SH_{j,U,b}(\rho)\, F^{i}_{j,U,b}(\mu) d\rho \qquad 7$$

$$PDF_{j,U,b}(\rho\mu) = \int_0^\infty \frac{\frac{10}{\ln 10}}{\varepsilon\sqrt{2\pi\delta^2_{ln\rho,U,b}}}\, exp\left\{-\frac{\left(10\, log_{10}\,\rho_{U,b}\right)^2}{2\delta^2_{\rho,U,b}}\right\}\frac{1}{\varepsilon}\exp\left(-\frac{\mu}{\varepsilon}\right) d\varepsilon \qquad 8$$

The accurately approximate of lognormal distribution for high values of δ_ρ ($\delta_\rho \geq 6$ dB) can be written as (Torre et al., 2012).

$$PDF_{j,U,b}(\rho\mu) = \frac{\frac{10}{\ln 10}}{\rho\mu\sqrt{2\pi\delta^2_{ln\rho,U,b}}} \exp\left(-\frac{10\log_{10}\rho\mu - \left(\frac{ln10}{10}\right)10log_{10}\left(2\delta^2_{\mu,U,b}\right) - 2.5\, dB)}{2\left(\sqrt{\delta^2_{\rho,U,b} + 5.57^2\mathrm{dB}}\right)^2}\right) \qquad 9$$

where ε denoted to Rayleigh distribution of signal amplitude variations, ξ denoted to the shadowing lognormally distribution. Eq (9) can be approximated as (Torre et al., 2012):

$$PDF_{j,U,b}(\delta) = \frac{1}{\rho_{U,b}\mu\sqrt{2\pi\delta^2_{ln\rho\mu,U,b}}}\exp\left(-\frac{\left(ln\,\rho\mu-\left(\frac{ln10}{10}\right)10log_{10}(\varepsilon)-2.5\,dB\right)}{2\xi^2_{\ln\rho\mu}}\right) \quad 10$$

By considering the $SNR_{j,U,k,b}$ is a function of the Rayleigh fading and lognormal shadowing distribution at the jth receive antenna (Chen et al., 2009):

$$SNR_{j,U,k,b} = \frac{P_u\,SH_{j,U,b}}{\delta^2_{U,b}}\left|F^i_{j,U,b}\right| \quad 11$$

Substitute eq. (9) in eq.(8) to derive the $PDF_{j,U}(\delta)$ as a function of $SNR_{j,U}$

$$PDF_{j,U,k,b}(SNR) = \frac{1}{\rho_{U,b}\mu\sqrt{2\pi\delta^2_{ln\rho\mu,U,b}}}\exp\left(-\frac{\left(ln\,\rho\mu-10log_{10}\frac{P_U\,SH_{j,U}}{\delta^2{}_{u,b}}\left|F^i_{j,u}\right|\right)}{2[\left(\frac{ln10}{10}\right)\,\delta\rho,U,b]^2}\right) \quad 12$$

Eq.(12) is applied to calculate the PDF of $\frac{P_U\,SH_{j,U,b}}{\delta^2_{U,b}}\left|F^i_{j,U,b}\right|$ for multi users at mobile station based on different range of SNR in dB . Then the received signal of jth receive antenna at the mobile station for U users , b sub band , k subcarrier and $PDF_{j,U,k,b}(SNR)$ complex noise can be illustrated in eq.(13) . The complex noise vector $\mathcal{G}^j{}_{U,k,b}(n)$ in eq.(13) can be presented as fading and shadowing effects that responsible of bits error production.

$$\underbrace{\begin{bmatrix} Y^0_{j,U,k,b}(n) \\ \vdots \\ y^{N_R-1}_{j,U,b,s}(n) \end{bmatrix}}_{y^i_{U,b,s}(n)} = \sqrt{P_U}\sigma^i_{U,b}$$

$$\underbrace{\begin{bmatrix} F^0_{0,U,b}\sqrt{L_{0,U,b}SH_{0,U,b}} & F^0_{1,U,b}\sqrt{L_{1,U,b}SH_{1,U,b}} & \cdots & F^0_{(Rx-1),U,b}\sqrt{L_{(Rx-1),U,b}SH_{(Rx-1),U,b}} \\ F^1_{0,U,b}\sqrt{L_{0,U,b}SH_{0,U,b}} & F^1_{1,U,b}\sqrt{L_{1,U,b}SH_{1,U,b}} & & F^1_{(Rx-1),U,b}\sqrt{L_{(Rx-1),U,b}SH_{(Rx-1),U,b}} \\ \vdots & & \ddots & \vdots \\ F^{(Tx-1)}_{0,U,b}\sqrt{L_{0,U,b}SH_{0,U,b}} & F^{(Tx-1)}_{1,U,b}\sqrt{L_{1,U,b}SH_{1,U,b}} & \cdots & F^{(Tx-1)}_{(Rx-1),U,b}\sqrt{L_{(Rx-1),U,b}SH_{(Rx-1),U,b}} \end{bmatrix}}_{h^i_{j,U,b}(n)}.$$

$$\underbrace{\begin{bmatrix} x^0_{b,s}(n) \\ \vdots \\ x^{(N_T-1)}_{b,s}(n) \end{bmatrix}}_{x^j_{b,s}(n)} + \underbrace{\begin{bmatrix} PDF_{j,U,k,b}(SNR)(n) \\ \vdots \\ PDF_{j,U,k,b}(SNR)(n) \end{bmatrix}}_{\mathcal{G}^j{}_{U,k,b}(n)}$$

13

The error probability of composite fading and shadowing can be calculated by (Trigui et al., 2009).

$$EP_{j,U,k,b,} = \int_0^{\delta th} PDF_{j,U,b}(\delta)\,\mathrm{d}\,\delta. \quad 14$$

Where $PDF_{j,u,b}(\delta)$the pdf of the SNR is, δth is the system protection ratio that can be related with receiver properties.

3. SIMULATION RESULTS

The obtained simulation results represent the error probability analysis using approximate PDF form based on SNR related to Rayleigh fading-shadowing channel in multi-users wireless mobile communication systems. The 2GHz carrier frequency at $\delta = 2.2dB$ and (0-25) dB SNR under different levels of transmitted signals power were used in validation of the proposed method. The performance of the wireless mobile communication system has also been studied by comparing the error probabilities results using preceding shadowing - fading system for SNR range (0-25) is shown in Fig. 2. Also This Figure shows that references results for fading–shadowing error probability with and without interference signals at $\delta = 2.9dB$. It is clear that the simulation result is closer to reference results especially when the signal power equal to 1

and 2 which is equivalent to 30 and 33.010299957 dBm respectively which are used in the 3G wireless universal mobile telecommunication system (UMTS) and global system for mobile communications (GSM). The approximate PDF provide low values of error probability in fading - shadowing effects used in wireless mobile communication systems applications. The error probability decreases as the SNR increase until reach to 4.203 ×10-4 at 25 dB SNR.

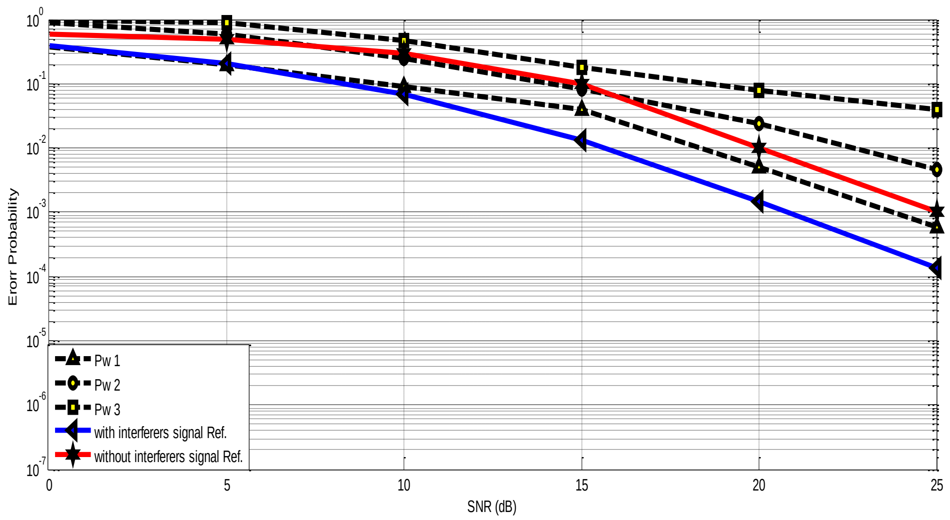

Fig. 2. Error probability at standard deviation $\delta = 2.2dB$, 2 GHz carrier frequency and error probability with and without interferers Ref. at standard deviation $\delta = 2.9\,dB$ for SNR 0-25 dB.

Fig. 3 shows the error probability at lower power values of wireless LAN (WLAN) transmitted signals power equal to (0.1, 0.2, 0.3) at $\delta = 2.2dB$, 2 GHz carrier frequency and SNR (0-30) dB. The error probability of all received signals decreases with SNR increases but the zero error probability has been occurred when the transmitted signals has power equal to (0.1,0.2,0.3) at SNR equal to (5, 10, 15) dB respectively. It is clear from this Figure. that is (5) dB gains can be realized at (10-6, 10-7, 10-8, 10-9) of error probability. Error probabilities compression of different power values such as (1, 2, 3) w which are used in UMTS and GSM systems and (0.1, 0.2, 0.3) dBm that can be operated in wireless LAN wide channels and Bluetooth systems are shown in the Fig. 4 at standard deviation $\delta = 2.2dB$, 2 GHz carrier frequency with SNR (0- 30) dB . The error probability of (1, 2, 3) Pw has been approximated for SNR variant from (0 to 25) dB. While the SNR increases from (25 to 30) dB the error probability of 1w transmitted signal decreases suddenly to reach 10-9. There is 15 dB gain of SNR values has been illustrated between the (1, 2, 3) Pw and (0.1, 0.2, 0.3) Pw. The error probability decreases when the transmitted signal power decreases.

Fig. 5 illustrates the error probability compression for different values of power signals that operated in Typical power line carrier (PLC) transmit power, GSM, UMTS, WLAN systems, and Bluetooth. In general, the error probability of each received signal decreases when SNR increases. From this results it can be noted that the maximum error probability is one that occurs at power signal equal to (44.771, 43.01 ,40) dBm for wireless PLC carries data on a conductor that is also used for AC electric power transmission or electric power distribution to consumers. It can be noted that the one error probability of transmitted signal power (44.771, 43.01, 40) dBm has been occurred at SNR range (0-20) dB, (0-15) dB and (0-10) dB respectively. Then the error probability decreases to (0.441, 0.2, 0.06773) respectively at SNR equal to 30 dB. For Power dBm (34.771, 33.0102, 30) the error probability decreases with increase of SNR from 0 to 30 dB. The transmitted signal power (30) dBm only decreases until reach to zero at SNR equal to (30) dB. While the transmitted power (24.7, 23, 20) dBm rapidly decrease to reach zero probability at SNR equal to (15, 10, 5) dB. Fig. 5 illustrate the effect of transmitted signal power decreases. The error probability can be decreases when transmitted signal power decreases.

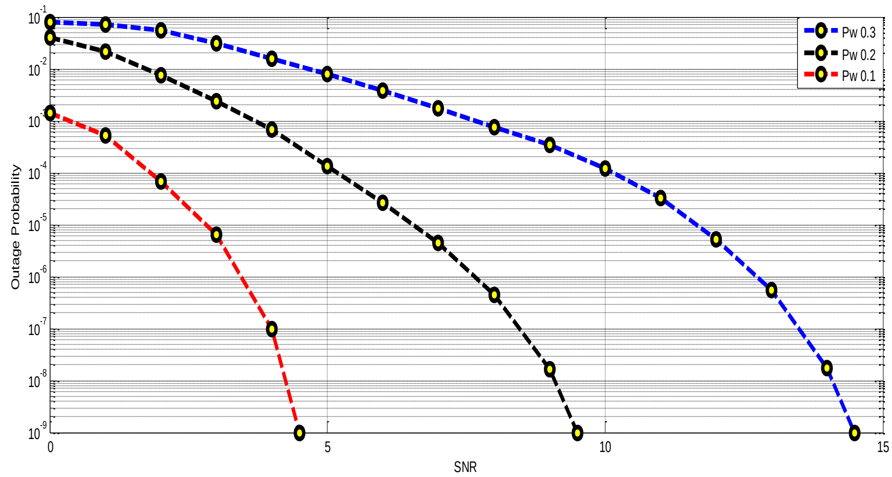

Fig. 3. Error probability of low power values Pw 0.3, 0.2, 0.1 using in wireless LAN wide channels at standard deviation $\delta = 2.2dB$, 2 GHz carrier frequency with SNR. (0- 15) dB

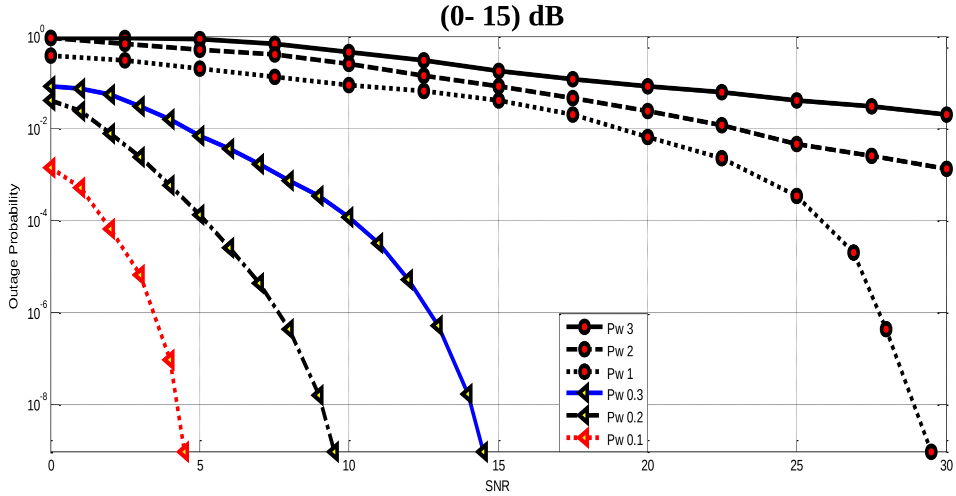

Fig. 4. Error probability compression of different power values using in wireless LAN wide channels ISM band , and Bluetooth at standard deviation $\delta = 2.2dB$, 2 GHz carrier frequency with SNR (0- 30) dB.

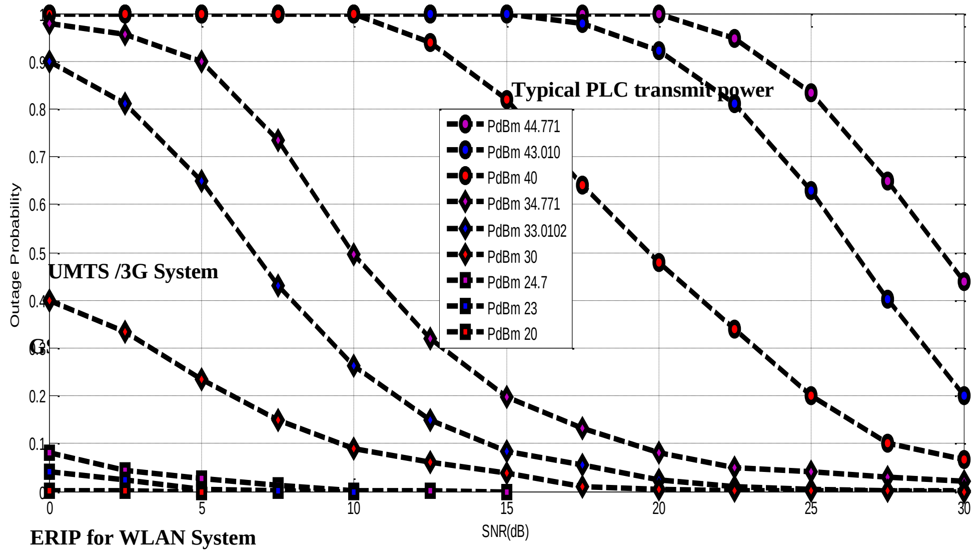

Fig. 5. Simulation Error Probability Comparison of typical PLC ,GSM , UMTS /3G systems, ERIP for WLAN systems , and Bluetooth at standard deviation at $\delta = 2.2dB$, 2 GHz carrier frequency SNR 0-30 dB.

4. CONCLUSIONS

This paper presents an approach to analyze of the error probability performance related to lognormal Rayleigh fading-shadowing effects in the wireless mobile communication systems based on approximate PDF form. Different SNR values have been used to calculate the approximate PDF form. The proposed approach provides accurate and low computational complexity in error probability calculation. The simulation results have shown that the compensation of shadowing - Rayleigh fading scheme based on SNR can provide low error probability value. Furthermore, the error probability is decrease when SNR increase. Also, the error probability can be improved by decreasing the transmitted signal power.

Finally, lower error probability can be included in multi–users wireless mobile communication systems when using the approximate PDF.

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