Research Article

International Journal of Advanced Computer Research, Vol 7(31)
ISSN (Print): 2249-7277 ISSN (Online): 2277-7970
http://dx.doi.org/10.19101/IJACR.2017.731005

Optimal thresholds for discrete power levels using adaptive modulation in presence of imperfect channel state information

Reza Mahin Zaeem[1*], Mina Naeimi[2], Soroosh Tayebi Arasteh[3] and Houda Chihi[4]
Department of Electrical Engineering, University of Isfahan, Isfahan, Iran[1]
Department of Electrical Engineering, Urmia University, Urmia, Iran[2]
Department of Electrical Engineering, Bu-Ali Sina University, Hamedan, Iran[3]
Innov'COM, SUP'COM, Tunis, Tunisia [4]

Received: 17-March-2017; Revised: 01-June-2017; Accepted: 05-June-2017

Abstract
The continuous power scheme was the choice of many researchers towards power allocation. However, continuous power application is not very suitable following hardware complexity. For this discrete power is efficient, especially in cellular systems as it could reduce the feedback rate. On the other hand, receiver mobility implies transmission thresholds and power level alternation determination which leads to reduction in system's spectral efficiency (SE). Consequently, a method based on adaptive modulation (AM) has been introduced and some power discrete levels while all information of channel state wasn't considered. Computer results highlight that the proposed scheme provides better efficiency in comparison to other adaptation schemes but with less feedback rate.

Keywords
Adaptive modulation, Continuous and discrete power, Feedback rate, Imperfect channel state information.

1.Introduction
Adaptive modulation application in link adaptation (LA) is a promising tool for improving the spectral efficiency (SE) (bit per second per hertz) in flat fading channels. Indeed, this approach is extensively applied to wireless systems [1]. LA ensures transmission rate and transmit power varies. Furthermore, the transmission mode selection depends on the channel state information. It should be also mentioned that the variable rate and variable power provide better performance in SE[1]. Furthermore, determining the suitable transmission thresholds fitting to link status, variability is very significant to find the spectral efficiency optimal rate. Authors in [2] show the importance of thresholds characterization and analysis its effect on SE. In fact, SE could be reduced if a receiver changes position or with a wrong estimation channel status. Note that instantaneous transmission power justification based on channel status requires more feedback rate from receiver to transmitter that would be impractical to implement [3-5]. In this regard, some discrete levels are used to determine the transmission power more easily. However, these levels can remarkably reduce the processing load for feedback rate. Impact of imperfect channel state information (CSI) during the use of adaptive modulation was analyzed in [6-7]. The optimal method for determining rate, adaptive power and transmission thresholds, given that not all information regarding channel state is accessible, was introduced in[8]. In [9][10] assuming channel state information availability, some algorithms proposed to calculate transmission thresholds in discrete adaptive power pattern. Thresholds and adaptive power determination based on perfect channel information for Rayleigh fading provided in [11] in which the feedback rate determined regarding channel parameters and thresholds. In [12] a new scheme introduced to the allocaterate, according to Marcum model wherein a noticeable part of throughput could be lost. In [13] we examined energy efficiency (EE) through adaptive rate modulation and packet error rate investigation. In addition, in our work [14] we investigate EE following a cross-layer design through modulation and coding scheme (MCS).

In this paper, we focus on offering an optimal method to characterize the exact transmission thresholds and discrete power levels based on channel state imperfect information of Nakagami-m fading. Then,

*Author for correspondence

it will be shown that the obtained transmission thresholds in this approach can be even applied to the particular state in which perfect information of channel state is available. Hence, based on this method we can achieve the exact determination of thresholds and transmission power.

This paper is organized following. Section 2 presents system model and problem formulation. In section 3, we present the proposed approach wherein we consider a comparison between variable power and continuous power levels. Numerical results are presented in section 4 by considering a wide range of channel behaviors. Finally, the conclusion will be drawn in the section 5.

2.System modeling and problem formulation

In this section we introduce the system model; further the problem will be formulated.

A. System model

We consider a single input single output communication system over a fading channel which is depicted in *Figure 1*. Besides, we consider a channel time variant gain $h[i]$, where i is a frame time index. The channel gain is modeled as an independent and identically distributed (i.i.d) stationary random process. Indeed, following stationary assumption frame time index can be omitted. The channel gain is normalized in the way that $E\{|h|^2\} = 1$. Furthermore, transmitted signal suffers from flat fading with additive white Gaussian noise (AWGN). The signal average transmitted power and noise are respectively denoted by $\bar{S}$ and N_0. Therefore instantaneous SNR at the receiver is expressed by $\gamma = \frac{\bar{S}|h|^2}{N_0 B}$, where B is the received signal bandwidth. By this way the estimated received SNR is expressed by: $\hat{\gamma} = \frac{\bar{S}|\hat{h}|^2}{N_0 B}$.

The main reason to consider Nakagami fading is that it covers all types of fading channel. In particular, $m = 1$ and $m = 1.8$ represent Rayleigh and Rician channels respectively.

We consider, the same correlation coefficient for the two SNRs (γ and $\hat{\gamma}$) in conditional distribution probability density function (PDF) representation. Assuming a channel with Nakagami flat fading of order m [14], PDF could be written as [15]:

$$p_{\gamma|\hat{\gamma}}(\gamma|\hat{\gamma}) = \frac{1}{(1-\rho)\Gamma} I_{m-1}\left(2\frac{\sqrt{\rho}}{(1-\rho)}\sqrt{\frac{\gamma\hat{\gamma}}{\Gamma\hat{\Gamma}}}\right)\left(\frac{\gamma}{\rho\hat{\gamma}}\right)^{\frac{m-1}{2}} \exp\left(-\frac{\gamma}{(1-\rho)\Gamma} - \frac{\hat{\gamma}\rho}{(1-\rho)\hat{\Gamma}}\right) \quad (1)$$

Otherwise the distribution functions of γ and $\hat{\gamma}$ are respectively represented by:

$$p_{\gamma}(\gamma) = \frac{m^m \gamma^{m-1}}{\Gamma(m)\Gamma^m}\exp\left(-\frac{m\gamma}{\Gamma}\right)$$

$$p_{\hat{\gamma}}(\hat{\gamma}) = \frac{m^m \hat{\gamma}^{m-1}}{\Gamma(m)\hat{\Gamma}}\exp\left(-\frac{m\hat{\gamma}}{\hat{\Gamma}}\right) \quad (2)$$

Where:

- Γ and $\hat{\Gamma}$ represent respectively the average SNRs ($E\{\gamma\} = \Gamma$ and $E\{\hat{\gamma}\} = \hat{\Gamma}$).
- $\Gamma(m)$ denotes Gamma function.
- $\rho = \frac{cov(\gamma,\hat{\gamma})}{\sqrt{var(\gamma).var(\hat{\gamma})}}$ quantifies the correlation coefficient between γ and $\hat{\gamma}$. It was shown that this parameter depends on feedback delay and Doppler frequency [7].

B. Problem formulation

In this section, the problem is defined based on some preliminaries. In fact, $\boldsymbol{\mathcal{M}} = \{M_i\}_{i=1}^{N}$ and $\boldsymbol{\mathcal{P}} = \{P_i\}_{i=1}^{N}$ represent respectively the set of modulation schemes and transmitted discrete power levels. N describes the number of modulation levels. Besides, BER is defined following:

$$BER(\gamma,\hat{\gamma}) \leq c_1 \exp\left(-c_2 \frac{\gamma}{\mathcal{M}_i - 1}\mathcal{P}_i\right) \quad (3)$$

Where constants c_1 and c_2 are provided in [1] and considered for any type of modulation. Note that, we are only interested on discrete rates. Indeed, if we consider $\mathcal{M}$ the set of available constellations, the spectral efficiency is defined by:

$$k_i = log_2 M_i \quad (4)$$

It is also assumed that k_i is used when estimated SNR ($\hat{\gamma}$) ranges between $\hat{\gamma}_i \leq \hat{\gamma} \leq \hat{\gamma}_{i+1}$. In addition, there is no transmission while $\hat{\gamma} \leq \hat{\gamma}_1$. The other assumption is $\hat{\gamma}_{N+1} = \infty$. SE is defined as the ratio of the average transmitted rate of bandwidth. On the other hand, authors in [1]-[7] show that average SE for $\mathcal{M}$-dimensional modulation is $log_2\mathcal{M}$. The problem can be formulated as:

$$ASE = \max E\{\log_2 \boldsymbol{\mathcal{M}}\} \quad (5)$$

$$s.t \quad \begin{cases} C(1): E_{\hat{\gamma}}\{\boldsymbol{\mathcal{P}}\} \leq 1 \\ C(2): BER(\hat{\gamma}) \leq B_0 \end{cases} \quad (6)$$

Where ASE represents the average spectral efficiency. Applying some similar explanations like in [1], (5) could be written as:

$$ASE = \sum_{i=1}^{N} k_i \int_{\hat{\gamma}_i}^{\hat{\gamma}_{i+1}} p_{\hat{\gamma}}(\hat{\gamma}) d\hat{\gamma} \quad (7)$$

Furthermore, according to the instantaneous error rate in (3), using (1) with the consideration of:

$$BER(\hat{\gamma}) = \int_0^{\infty} BER(\gamma, \hat{\gamma})\, p_{\gamma|\hat{\gamma}}(\gamma|\hat{\gamma}) d\gamma \quad (8)$$

Consequently we obtain:

$$BER(\hat{\gamma}) \leq c_1(\boldsymbol{\mathcal{F}})^m \exp\left(-\frac{m\rho\hat{\gamma}}{(1-\rho)\hat{\Gamma}}(1-\boldsymbol{\mathcal{F}})\right) \quad (9)$$

where $\mathcal{F} = \frac{1}{1+c_2(1-\rho)\Gamma\frac{\mathcal{P}}{\mathcal{M}-1}}$. It is proved that while $C(1)$ is replaced in (6), the instantaneous error rate would be $C(2)$ expressed in (9). According to this equation, a closed-form expression of $\boldsymbol{\mathcal{F}}$ cannot be obtained to compute discrete power levels based on instantaneous SNR. As a result, the optimal instantaneous power allocation can be determined by solving (9). In fact, the benefit of power allocation in discrete levels is complexity reduction.

3.Problem resolution

At first, we try to solve the problem in continuous power mode.

A. Optimal continuous power levels and transmission threshold determination

In this section, (6) will be solved assuming continuous transmission of power depending on the instantaneous SNR. Additionally, following the Nakagami fading approach in [7] we have:

$$\mathcal{L} = ASE - \lambda(E\{P\} - 1) = \sum_{i=1}^{N} k_i \int_{\hat{\gamma}_i}^{\hat{\gamma}_{i+1}} p_{\hat{\gamma}}(\hat{\gamma}) d\hat{\gamma} - \lambda\left(\sum_{i=1}^{N} \int_{\hat{\gamma}_i}^{\hat{\gamma}_{i+1}} P_{\hat{\gamma}}(\hat{\gamma}) p_{\hat{\gamma}}(\hat{\gamma}) d\hat{\gamma} - 1\right) \quad (10)$$

Where P denotes continuous power, λ is Lagrangian coefficient. Therefore, if we replace $\mathcal{P}_i$ in (3) by the continuous power policy $P_{\hat{\gamma}}(\hat{\gamma})$ and if we consider $\frac{\partial \mathcal{L}}{\partial \hat{\gamma}_i} = 0$ we obtain:

$$\hat{\gamma}_i = \frac{(1-\rho)\hat{\Gamma}}{\rho}\left(\frac{\ln(\frac{\frac{c_1}{B_0}}{m}) + \ln\left(\frac{k_i - k_{i-1}}{\lambda}\right)}{1+\left(\frac{k_i - k_{i-1}}{\lambda}\right)}\right), 1 \leq i \leq N \quad (11)$$

where $k_0 = 0$. It can be proved that $\frac{\partial^2 \mathcal{L}}{\partial \hat{\gamma}^2_i} \leq 0$ $where$ $1 \leq i \leq N,$ by this way the obtained response is optimal[18]. Instantaneous power is determined with the help of (9) and (11) where SNR ranges between $[\hat{\gamma}_i, \hat{\gamma}_{i+1})$. Complexity problems could be met whenever the channel state varies. For this we need to solve (9).

B. Optimal allocation in discrete levels of power and determining transmission thresholds

Note that $\boldsymbol{\mathcal{F}}$ and $\boldsymbol{\mathcal{M}}$ determination is based on (5) and (6) resolution. Indeed, each of these vectors is composed of N values. The objective is to optimize average SE following (7). The relation between instantaneous SNR ($\hat{\gamma}$) and discrete power levels can be determined as below:

$$\hat{\gamma} \leq \frac{(1-\rho)\hat{\Gamma}}{\rho}\left(\frac{\ln\left(\frac{c_1}{B_0}\right) + \ln(\mathcal{F})}{1-\mathcal{F}}\right) \quad (12)$$

According to discrete power level approach, P_i determination follows the range of $\hat{\gamma}_i \leq \hat{\gamma} \leq \hat{\gamma}_{i+1}$ (12). Correspondly, transmission thresholds are defined based on discrete levels power as below:

$$\hat{\gamma}_i = \frac{(1-\rho)\hat{\Gamma}}{\rho}\left(\frac{ln\left(\frac{c_1}{B_0}\right) + ln(\mathcal{F}_i)}{1-\mathcal{F}_i}\right) \quad (13)$$

Being $\mathcal{F}_i = \frac{1}{1+c_2(1-\rho)\Gamma\frac{\mathcal{P}_i}{\mathcal{M}_i-1}}$. Otherwise, once we have perfect channel state information (13) could be written as:

$$\hat{\gamma}_i = \frac{M_i - 1}{P_i}\left(\frac{ln\left(\frac{c_1}{B_0}\right)}{c_2}\right) \quad (2)$$

We must mention that the proof of (2) determination is provided in Appendix. In other side, we apply Lagrangian method to determine the maximum value of SE [17].

$$\mathcal{L} = ASE - \lambda(E\{\boldsymbol{\mathcal{P}}\} - 1) = \sum_{i=1}^{N} k_i \int_{\hat{\gamma}_i}^{\hat{\gamma}_{i+1}} p_{\hat{\gamma}}(\hat{\gamma})\, d\hat{\gamma} - \lambda\left(\sum_{i=1}^{N} P_i \int_{\hat{\gamma}_i}^{\hat{\gamma}_{i+1}} p_{\hat{\gamma}}(\hat{\gamma}) d\hat{\gamma} - 1\right) \quad (3)$$

Yields,

$$\frac{\partial \mathcal{L}}{\partial \hat{\gamma}_i} = 0 \Longrightarrow k_i - k_{i-1} = \lambda(P_i - P_{i-1}) \quad (4)$$

and $k_0 = P_0 = 0$, lied to:

$$P_i = \frac{k_i}{\lambda} \quad (5)$$

Optimal response for average SE could be determined considering power allocation in (5) and the relation between transmission thresholds and discrete power levels in (13). Based on the following equalities $\mathcal{P}=\{P_i\}_{i=1}^{N}$ and $\{\hat{\gamma}_i\}_{i=1}^{N}$, $C(1)$ which is defined in (6) , we can consider discrete levels as equalities. Transmission thresholds can be rewritten according to (13) and as a function of discrete power levels. Otherwise, we apply bisection method to determine λ.

Note that the repeated number of levels applied for power quantizing, increases the feedback rate. Thus, if we assume that the number of quantized levels in continuous rate approach is infinite and considering [18] and [19], feedback rate will be infinite too.

$$\mu = 2\sum_{i=1}^{N} N_i \tag{6}$$

Where μ defined as a feedback rate and $N_i = \sqrt{2\pi} f_d (\frac{m^{m-\frac{1}{2}}}{\Gamma(m)})(\frac{\gamma_i}{\bar{\gamma}})^{m-\frac{1}{2}}.\exp(-m\frac{\gamma_i}{\bar{\gamma}})$ discrete levels of feedback rate. It should be noticed that increasing N together with transmission thresholds causes enhancement in feedback rate, and further, the processing load on the system will increase.

4.Numerical results

In this section, we focus on some methods to achieve the value of spectral efficiency (in all of the figures we assume $\Gamma = \hat{\Gamma}$):

- ASE_{pro} can be introduced as obtained SE that is achieved from the mentioned approach for discrete power levels where thresholds and power are computed based on (13) and (5), respectively.
- ASE_{up} is the SE obtained from continuous power approach where rate and power are calculated based on (9) and (11), respectively.
- According to (6), μ_{pro} and μ_{up} correspond respectively to the feedback rate in discrete power levels and continuous power method.

In addition, we consider all our results $B_0 = 10^{-3}$ in comparison to[8],[15-17].

The simulation results are shown as follows:

- *Figure 2* illustrates the ratio of discrete power method to continuous power based on SNR and ρ variability (selecting 7 modulation levels, $\mathrm{k_i} = \{\mathrm{BPSK}, 4\mathrm{QAM}, \dots, 128\mathrm{QAM}\}$). The obtained results show a gain of 30% compared to continuous power approach due to high feedback rate.
- *Figure 3* shows a performance comparison between the proposed approach and the method based on continuous power, according to correlation coefficient $= 0.95$ ($\frac{ASE_{pro}}{ASE_{up}}|_{\rho=0.95}$). We deduce from the obtained results in *Figure 2* and *Figure 3* that changing all of the channel parameters (average SNR), fading parameter (m) and correlation parameter (ρ), keep ASE_{pro} in a close performance to ASE_{up}.
- *Figure 4* shows that although the applied sub-optimal method in [7],[14]-[16] based on continuous power, the obtained results show weaker performance. It is obvious that the introduced approach for discrete power shows better performance and it is not limited to Rayleigh fading compared to continuous power levels in [7].
- *Figure 5* compares the ratio of the feedback rate in discrete and continuous approaches with average changes based on SNR and ρ. In continuous power scheme, it is assumed that the numbers of quantized levels are equal to 100. In this figure feedback rate for continuous power scheme is too much greater than discrete power approach. When parameter ρ increases reach one, the ratio of continuous power's feedback rate of feedback rate of discrete power increases. Hence, this ratio increases while enhancement in this parameter occurs. On the other hand, it can be similarly concluded that the increase in average SNR causes an increase in the ratio of feedback rate.

5.Conclusion

In this paper, we focused on a method using discrete power in Nakagami-m fading considering imperfect information about the channel. It was shown that the high value of feedback rate is required for continuous power approach. Performance improvement is based on good regulation of thresholds and power. The proposed method shows a performance close to continuous power adaptation for the high SNR regime. However, in low SNR regime the performance is acceptable due to the low computational complexity. In addition, higher values of fading parameters cannot diminish the performance.

6.Future work

In this contribution, adaptive approach has been adopted to enhance throughput performance, undoubtedly these ideas cannot be limited to the below mentioned items:

- This paper can be extended to MIMO systems as in [15,16] and[20].

- Recently, a new scheme was proposed in [5] for constant power with full CSI which can be extended to the optimum set of modes.
- Further applications, consider multiuser proposition.

Appendix

Based on perfect CSI, $\rho \to 1$ and $\hat{\Gamma} \to \Gamma$, so (13) would be:

$$\lim_{\rho \to 1} \lim_{\hat{\Gamma} \to \Gamma} \hat{\gamma}_i =$$

$$\lim_{\rho \to 1} \frac{(1-\rho)\Gamma}{\rho} \left(\frac{ln\left(\frac{c_1}{B_0}\right) + ln\left(\frac{1}{1+c_2(1-\rho)\Gamma\frac{\mathcal{P}_i}{\mathcal{M}_i - 1}}\right)}{1 - \frac{1}{1+c_2(1-\rho)\Gamma\frac{\mathcal{P}_i}{\mathcal{M}_i - 1}}} \right) \tag{7}$$

So, $\lim_{\rho \to 1} ln\left(\frac{1}{1+c_2(1-\rho)\Gamma\frac{\mathcal{P}_i}{\mathcal{M}_i - 1}}\right) = 0$, therefore (2) can be obtained.

Acknowledgment

None.

Conflicts of interest

The authors have no conflicts of interest to declare.

References

[1] Liu Q, Zhou S, Giannakis GB. Cross-layer combining of adaptive modulation and coding with truncated ARQ over wireless links. IEEE Transactions on Wireless Communications. 2004; 3(5):1746-55.

[2] Chung ST, Goldsmith AJ. Degrees of freedom in adaptive modulation: a unified view. IEEE Transactions on Communications. 2001; 49(9):1561-71.

[3] Torrance JM, Hanzo L. Optimisation of switching levels for adaptive modulation in slow Rayleigh fading. Electronics Letters. 1996; 32(13):1167-9.

[4] Kuang Q, Leung SH, Yu X. Adaptive modulation and joint temporal spatial power allocation for OSTBC MIMO systems with imperfect CSI. IEEE Transactions on Communications. 2012; 60(7):1914-24.

[5] Taki M, Zaeem RM. How to select an optimum set of modes for a link adaptive transmission. In international symposium on telecommunications 2016 (pp. 256-60). IEEE.

[6] Falahati S, Svensson A, Ekman T, Sternad M. Adaptive modulation systems for predicted wireless channels. IEEE Transactions on Communications. 2004; 52(2):307-16.

[7] Basar E, Aygolu U, Panayirci E, Poor HV. Performance of spatial modulation in the presence of channel estimation errors. IEEE Communications Letters. 2012; 16(2):176-9.

[8] Olfat A, Shikh-Bahaei M. Optimum power and rate adaptation for MQAM in Rayleigh flat fading with imperfect channel estimation. IEEE Transactions on Vehicular Technology. 2008; 57(4):2622-7.

[9] Wang D, Xu X, Chen X, Tao X, Yin Y, Haas H. Discrete power allocation via ant colony optimization for multi-cell OFDM systems. In vehicular technology conference (VTC Fall) 2012 (pp. 1-5). IEEE.

[10] Hwang JW, Shikh-Bahaei M. Packet error rate-based adaptive rate optimisation with selective-repeat automatic repeat request for convolutionally-coded M-ary quadrature amplitude modulation systems. IET Communications. 2014; 8(6):878-84.

[11] Paris JF, del Carmen Aguayo-Torres M, Entrambasaguas JT. Optimum discrete-power adaptive QAM scheme for Rayleigh fading channels. IEEE Communications Letters. 2001; 5(7):281-3.

[12] Taki M, Zaeem RM, Heshmati M. Throughput optimized error-free transmission using optimum combination of AMC and ARQ based on imperfect CSI. In international conference on information and communication technology research 2015 (pp. 182-5). IEEE.

[13] Chihi H, Zaeem R, Bouallegue R, Innov'Com T. Energy expenditure per bit minimization into MB-OFDM UWB systems. International Journal of Digital Information and Wireless Communications. 2017;7(1):42-8.

[14] Chihi H, Zaeem RM, Bouallegue R. Energy minimization by selecting appropriate modulation and coding scheme for MB-OFDM UWB systems. In international conference on advanced information networking and applications 2016 (pp. 247-52). IEEE.

[15] Yin X, Yu X, Liu Y, Tan W, Chen X. Performance analysis of multiuser MIMO system with adaptive modulation and imperfect CSI. IET international conference on information and communications technologies. 2013 (pp. 571 – 6). IETICT.

[16] Zhou T, Yu X, Li Y, Jiao Y. Cross-layer design with feedback delay over MIMO Nakagami-m fading channels. In IEEE international conference on communication technology 2010 (pp. 1369-72). IEEE.

[17] Dong ZC, Fan PZ, Lei XF, Panayirci E. Power and rate adaptation based on CSI and velocity variation for OFDM systems under doubly selective fading channels. IEEE Access. 2016; 4:6833-45.

[18] Boyd S, Vandenberghe L. Convex optimization. Cambridge University Press; 2004.

[19] Yacoub MD, Bautista JV, de Rezende Guedes LG. On higher order statistics of the Nakagami-m distribution. IEEE Transactions on Vehicular Technology. 1999; 48(3):790-4.

[20] Zeng H, Shi Y, Hou YT, Lou W, Sherali HD, Zhu R, et al. A scheduling algorithm for MIMO DoF allocation in multi-hop networks. IEEE Transactions on Mobile Computing. 2016; 15(2):264-77.

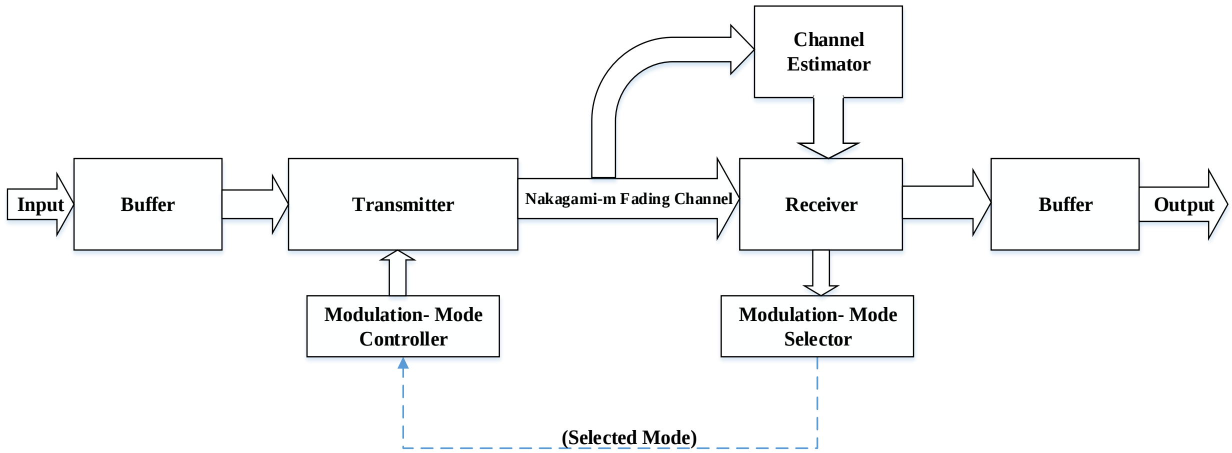


Figure 1 System model

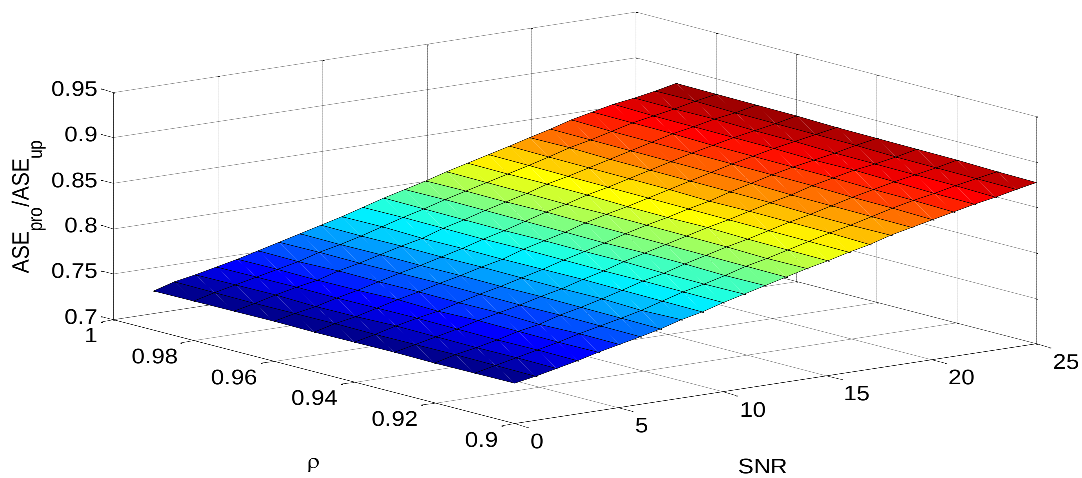


Figure 2 The ratio of ASE with two different power approaches for correlation parameter and SNR changes

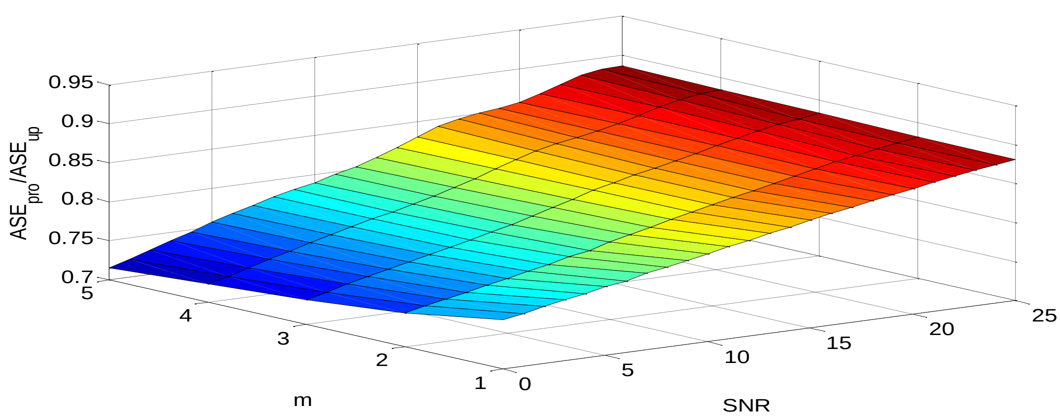


Figure 3 The ratio of ASE with two different power approaches for fading parameter and SNR changes

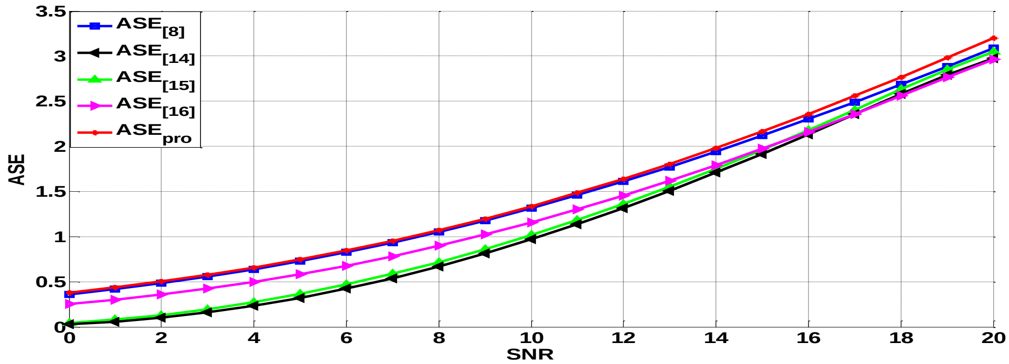


Figure 4 Comparison between proposed approach, [7],[14],[16] for power adaptation parameter and SNR changes when fading parameter is $m = 2$

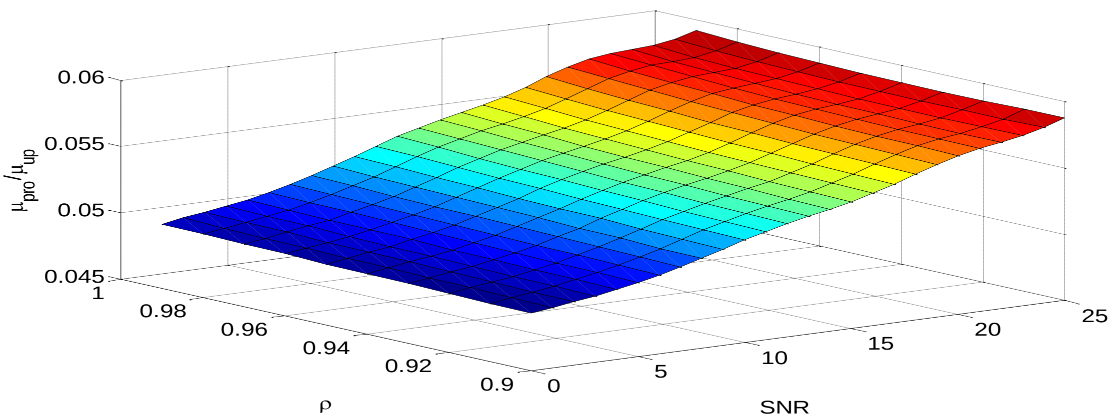
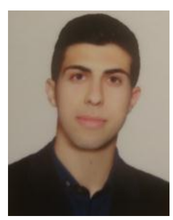


Figure 5 The ratio of feedback rates for two discrete and continuous power approaches

Reza Mahin Zaeem was born in 1989. He received his Bachelor and Master in Electrical engineering and telecommunication engineering from Islamic Azad University Karaj branch and University of Isfahan in 2012 and 2015, respectively. From 2015, he focuses on “In-Building Solutions and Telecommunication Infrastructures". His research interests include “Cross Layer Design, Linear Coding, Multi-Hop Relaying and MIMO systems”.

Email: Reza.zaeem@gmail.com

Mina Naeimi was born in 1991. She received her Bachelor degree in Electrical engineering-telecommunication from Urmia University of Iran in 2015. She is currently a Master student of control engineering at Sapienza university of Rome. Her research interests are “Cross layers and optimization problems” and moreover “general cases of control and robotics as humanoid, manipulators and so on” which are related to her current study major in control domain.



Soroosh Tayebi Arasteh was born in 1995. He is currently pursuing his B.Sc. in Electrical Engineering at Bu-Ali Sina University, Hamedan, Iran. His research interests include Wireless Communications, Wireless Networks, Digital Signal Processing, as well as Information Theory and Coding.