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Channel Capacity Analysis For *L*-Mrc Receiver Over *Η-μ* Fading Channel

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ABSTRACT:

In this paper we used η-μ fading channel as a fading model and maximal ratio combiner (MRC) which is one of the diversity combining technique considered at the receiver. Closed-form expressions for the capacity of maximal-ratio combining (MRC) diversity systems over η-μ fading channel are obtained and analyzed for an arbitrary number of input branches. Channel capacity for adaptive transmission techniques: Constant power with optimum rate adaptation (ORA), Channel inversion with fixed rate (CIFR) and Truncated channel inversion with fixed rate (TIFR) are derived. The effect of diversity order and fading parameters on the channel capacity with different adaptive transmission schemes has been studied.

Keywords: *η-μ distribution, MRC receiver, Optimum rate adaptation (ORA), Truncated channel inversion with fixed rate (TIFR), Channel inversion with fixed rate (CIFR)*

INTRODUCTION

Capacity analysis of fading channels makes important role in designing and implementation of wireless communication systems and to improve spectrum efficiency and service quality thereby providing useful information [1]. For small scale fading phenomena where there is no line of sight component, η-μ channel model is used. Besides others commonly used fading models such as Rayleigh, Nakagami-m, Nakagami-q etc., can be realized as the special case of η-μ channel model [2].Mohamed-Slim Alouini el. at [3] studied the Shannon capacity of adaptive transmission techniques in conjunction with diversity combining. This capacity provides an upper bound on spectral efficiency using these techniques. Closed-form solutions for the Rayleigh fading channel capacity under three adaptive policies: optimal power and rate adaptation, constant power with optimal rate adaptation, and channel inversion with fixed rate are obtained. Performance of an L branch maximal ratio combining (MRC) receiver are analyzed in equally correlated η-μ fading channels. Mathematical expressions for the PDF, moments, outage probability and ABER for binary, coherent and non-coherent modulations are presented in [4]. In paper [5], a number of new closed-formexpressions for the η-μ fading channels involving the joint statistics of the envelope, phase, and their time derivatives are obtained. A number of new exact second order statistics for the η-μ fading channels are derived. The rest of this paper is organized as follows. In Section II, the introduction of η-μ distribution is given and in Section III the capacity of MRC combiner system is discussed. In Section IV, numerical analysis and result have been given. Finally, the paper is concluded in Section V

THE η-μ DISTRIBUTION

2.The η-μ distribution is a general fading distribution that can be used to better represent the small-scale variation of the fading signal in a non-line-of-sight condition which may appear in two different formats. However, in mathematical terms, one format can be obtained from another by the relation: $\eta_{Format2} = \frac{1-\eta_{Format1}}{1+\eta_{Format1}}$

Where 0 << ∞ is the parameter η in Format 1, and -1 << 1 is the parameter η in Format 2. $\eta_{Format1}$

2.1 η -μ Distribution: Format 1

In Format 1, 0 < η < ∞ is the scattered-wave power ratio between the in-phase and quadrature components.

In such case, $h = \frac{2+\eta^{-1}+\eta}{4}$ and $H = \frac{\eta^{-1}-\eta}{4}$. It is noted that within 0 <η ≤1, we have H ≥ 0. On the other hand, within 0 <η^{-1} ≤ 1, we have H ≤ 0. Because $I_v(-z) = (-1)^v I_v(z)$,the distribution yields identical values within these two intervals, i.e., it is symmetrical around η =1. Therefore, as far as the envelope (or power) distribution is concerned, it suffices to consider η only within one of the ranges. We note that in Format 1, $H/h = (1-\eta)/(1+\eta)$.

2.1 η -μ Distribution: Format 2

In Format 2, -1 $<\eta<$1 is the correlation coefficient between the scattered-wave in-phase and quadrature components of each cluster of multipath.

In such a case, $h=\dfrac{1}{1-\eta^2}$ and $H=\dfrac{\eta}{1-\eta^2}$.

We note that within $0 \le \eta < 1$, we have $H \ge 0$. On the other hand, within $-1 < \eta \le 0$, we have $H \le 0$. Because $I_\nu(-z)=(-1)^\nu I_\nu(z)$, the distribution yields identical values within these two intervals, i.e. it is symmetrical around η = 0. Therefore, as far as the envelope (or power) distribution is concerned, it suffices to consider η only within one of the ranges. We note that in Format 2, H/h = η.

3. CAPACITY OF MRC COMBINER SYSTEM

Initially, consider the physical model for the η-μ distribution Format 1. The envelope R, can be written in terms of the in-phase and quadrature components of the fading signal as

$$R^2=\sum_{i=1}^{l}(X_i^2+Y_i^2)$$

where X_i and Y_i are mutually independent Gaussian processes with, $E(X_i)=E(Y_i)=0$, $E(X_i^2)=\sigma_X{}^2$, and $E(Y_i^2)=\sigma_Y{}^2$,and n is the number of clusters of multipath. Now so that $R^2=(X_i^2+Y_i^2)$. $R^2=\sum_{i=1}^{n}R_i^2$

Using this channel model the PDF of output SNR for L-MRC receiver is obtained which is given by

$$f_\gamma(\gamma)=\left[\frac{(1-\rho)}{(1+(L-1)\rho)}\right]^{2\mu}\left[\frac{\mu(1+\eta)}{\overline{\gamma}(1-\rho)\sqrt{\eta}}\right]^{2L\mu}\sum_{t_1,t_2=0}^{\infty}\frac{(\mu)_{t_1}}{t_1!}$$
$$\times\left[\frac{L\rho\mu(1+\eta)}{\overline{\gamma}(1-\rho)(1+(L-1)\rho)}\right]^{\lambda}\frac{(\mu)_{t_2}\,e^{-\frac{\mu(1+\eta)}{\overline{\gamma}(1-\rho)}\gamma}}{t_2!\,\eta^{t_1}\Gamma(2L\mu+\lambda)}$$
$$\times\gamma^{2L\mu+\lambda-1}\,{}_1F_1\left(L\mu+t_1;2L\mu+\lambda;\frac{\mu(\eta^2-1)}{\eta(1-\rho)\overline{\gamma}}\gamma\right) \qquad (3)$$

Where $\lambda \,@ t_1+t_2$ and $\Gamma(\cdot)$ is the gamma function, ${}_1F_1(.;.;.)$ is the confluent hypergeometric function [6] and $(x)_a=\dfrac{\Gamma(x+a)}{\Gamma(x)}$ is the Pochhammer's symbol [8,(6.1.22)].Writing the hypergeometric function in terms of infinite series, we have

$$f_\gamma(\gamma)=\left[\frac{(1-\rho)}{(1+(L-1)\rho)}\right]^{2\mu}\left[\frac{\mu(1+\eta)}{\bar{\gamma}(1-\rho)\sqrt{\eta}}\right]^{2L\mu}\sum_{t_1,t_2,t_3=0}^{\infty}\frac{(\mu)_{t_1}(\mu)_{t_2}(L\mu+t_1)_{t_3}}{t_1!t_2!t_3!\eta^{t_1}\Gamma(2L\mu+\lambda)}\times$$

$$\left[\frac{L\rho\mu(1+\eta)}{\bar{\gamma}(1-\rho)(1+(L-1)\rho)}\right]^{\lambda}\times\left[\frac{\mu(\eta^2-1)}{\eta(1-\rho)\bar{\gamma}}\right]^{t_3}\frac{1}{(2L\mu+\lambda)_{t_3}}\gamma^{2L\mu+\lambda+t_3-1}e^{-\frac{\mu(1+\eta)}{\bar{\gamma}(1-\rho)}\gamma} \qquad (4)$$

Where

$${}_1F_1(\mu L+t_1;2\mu L+t_1+t_2;\frac{\mu(\eta^2-1)}{\eta(1-\rho)\bar{\gamma}}\gamma)=\sum_{t_3=0}^{\infty}\frac{(\mu L+t_1)_{t_3}}{(2\mu L+t_1+t_2)_{t_3}}$$

$$\times\left[\frac{\mu(\eta^2-1)}{\eta(1-\rho)\bar{\gamma}}\right]^{t_3}\frac{1}{t_3!}$$

3.1 Constant Power with optimum rate adaptation

The formula for ORA is given by [7]

$$C_{ORA}=B\int_0^{\infty}\log_2(1+\gamma)f_\gamma(\gamma)d\gamma \qquad (5)$$

By putting the values of $f_\gamma(\gamma)$ in the formula we obtain

$$C_{ORA}=\left[\frac{(1-\rho)}{(1+(L-1)\rho)}\right]^{2\mu}\left[\frac{\mu(1+\eta)}{\bar{\gamma}(1-\rho)\sqrt{\eta}}\right]^{2L\mu}\times\sum_{t_1,t_2,t_3=0}^{\infty}\frac{(\mu)_{t_1}(\mu)_{t_2}}{t_1!t_2!t_3!}$$

$$\times\frac{(L\mu+t_1)_{t_3}}{\eta^{t_1}\Gamma(2L\mu+\lambda)(2L\mu+\lambda)_{t_3}}\times\left[\frac{L\rho\mu(1+\eta)}{\bar{\gamma}(1-\rho)(1+(L-1)\rho)}\right]^{\lambda}$$

$$\times\left[\frac{\mu(\eta^2-1)}{\eta(1-\rho)\bar{\gamma}}\right]^{t_3}\times\int_0^{\infty}\log_2(1+\gamma)\gamma^{2L\mu+\lambda+t_3-1}e^{-\frac{\mu(1+\eta)}{\bar{\gamma}(1-\rho)}\gamma}d\gamma \qquad (6)$$

Rearranging the equation we can write it as

$$C_{ORA}=\left[\frac{(1-\rho)}{(1+(L-1)\rho)}\right]^{2\mu}\left[\frac{\mu(1+\eta)}{\bar{\gamma}(1-\rho)\sqrt{\eta}}\right]^{2L\mu}\times\sum_{t_1,t_2,t_3=0}^{\infty}\frac{(\mu)_{t_1}(\mu)_{t_2}}{t_1!t_2!t_3!}$$

$$\times\frac{\log_2 e(L\mu+t_1)_{t_3}}{\eta^{t_1}\Gamma(2L\mu+\lambda)(2L\mu+\lambda)_{t_3}}\times\left[\frac{L\rho\mu(1+\eta)}{\bar{\gamma}(1-\rho)(1+(L-1)\rho)}\right]^{\lambda}$$

$$\times\left[\frac{\mu(\eta^2-1)}{\eta(1-\rho)\bar{\gamma}}\right]^{t_3}\times I_{2L\mu+\lambda+t_3}\left(\frac{\mu(1+\eta)}{\bar{\gamma}(1-\rho)}\right) \qquad (7)$$

$$I_n(\mu)=\int_0^{\infty}t^{n-1}\ln(1+t)e^{-\mu t}dt$$

Where and its evaluation given in the Appendix A.

The value is given by $I_n(\mu)=(n-1)!\dot{e}^{\mu}\sum_{k=1}^{n}\frac{\Gamma(-n+k,\mu)}{\mu^K}$

Putting the above value of in (7) and rearranging the equation, we have

$$C_{ORA}=\left[\frac{(1-\rho)}{(1+(L-1)\rho)}\right]^{2\mu}\left[\frac{\mu(1+\eta)}{\bar{\gamma}(1-\rho)\sqrt{\eta}}\right]^{2L\mu}$$
$$\times\sum_{t_1,t_2,t_3=0}^{\infty}\frac{(\mu)_{t_1}(\mu)_{t_2}}{t_1!t_2!t_3!}\times\frac{\log_2 e\left(L\mu+t_1\right)_{t_3}(2L\mu+\lambda+t_3-1)!}{\eta^{t_1}\Gamma(2L\mu+\lambda)\left(2L\mu+\lambda\right)_{t_3}}$$
$$\times\left[\frac{L\rho\mu(1+\eta)}{\bar{\gamma}(1-\rho)(1+(L-1)\rho)}\right]^{\lambda}\times\left[\frac{\mu(\eta^2-1)}{\eta(1-\rho)\bar{\gamma}}\right]^{t_3}$$

3.2 Truncated channel inversion with fixed rate

The capacity for this scheme is given by

$$C_{tifr}=B\log_2\left(1+\frac{1}{R_{tifr}}\right)(1-P_{out}(\gamma_0)) \qquad (9)$$

Where $R_{tifr}=\int_{\gamma_0}^{\infty}\left(\frac{1}{\gamma}\right)f_{\gamma}(\gamma)d\gamma$ and $P_{out}(\gamma_0)=\int_{0}^{\gamma_0}f_{\gamma}(\gamma)d\gamma$

For this, a solution to the integral in R_{tifr} and $P_{out}(\gamma_0)$ in [7] is given. Using (3), this can be obtained by solving the resulting integral using [8, (3.381.3)]. The expression for R_{tifr} can be found out in the following manner. By putting the value of $f_{\gamma}(\gamma)$ in (9), we have

$$R_{tifr}=\left[\frac{(1-\rho)}{(1+(L-1)\rho)}\right]^{2\mu}\left[\frac{\mu(1+\eta)}{\bar{\gamma}(1-\rho)\sqrt{\eta}}\right]^{2L\mu}$$
$$\times\sum_{t_1,t_2,t_3=0}^{\infty}\frac{(\mu)_{t_1}(\mu)_{t_2}(L\mu+t_1)_{t_3}}{t_1!t_2!t_3!\eta^{t_1}\Gamma(2L\mu+\lambda)}\times\left[\frac{L\rho\mu(1+\eta)}{\bar{\gamma}(1-\rho)(1+(L-1)\rho)}\right]^{\lambda}$$
$$\times\left[\frac{\mu(\eta^2-1)}{\eta(1-\rho)\bar{\gamma}}\right]^{t_3}\frac{1}{(2L\mu+\lambda)_{t_3}}\times\int_{\gamma_0}^{\infty}\gamma^{(2L\mu+\lambda+t_3-1)-1}e^{-\frac{\mu(1+\eta)}{\bar{\gamma}(1-\rho)}\gamma}d\gamma \qquad (10)$$

The above expression can be expressed as

$$R_{tifr}=\left[\frac{(1-\rho)}{(1+(L-1)\rho)}\right]^{2\mu}\left[\frac{\mu(1+\eta)}{\bar{\gamma}(1-\rho)\sqrt{\eta}}\right]^{2L\mu}\sum_{t_1,t_2,t_3=0}^{\infty}$$
$$\frac{(\mu)_{t_1}(\mu)_{t_2}(L\mu+t_1)_{t_3}}{t_1!t_2!t_3!\eta^{t_1}\Gamma(2L\mu+\lambda)}\left[\frac{L\rho\mu(1+\eta)}{\bar{\gamma}(1-\rho)(1+(L-1)\rho)}\right]^{\lambda}$$
$$\times\left[\frac{\mu(\eta^2-1)}{\eta(1-\rho)\bar{\gamma}}\right]^{t_3}\frac{1}{(2L\mu+\lambda)_{t_3}}\left(\frac{\bar{\gamma}(1-\rho)}{\mu(1+\eta)}\right)^{2L\mu+\lambda+t_3-1}$$
$$\Gamma\left(2L\mu+\lambda+t_3-1,\frac{\mu(1+\eta)}{\bar{\gamma}(1-\rho)}\gamma_0\right) \tag{11}$$

We have $\int_u^{\infty} x^{v-1}e^{-\mu x}dx=\mu^{-v}\Gamma(v,\mu u) \qquad [u>0,\operatorname{Re}\mu>0]$

The final expression after simplification for R_{tifr} can be given as

$$R_{tifr}=\left[\frac{(1-\rho)}{(1+(L-1)\rho)}\right]^{2\mu}\left[\frac{1}{\sqrt{\eta}}\right]^{2L\mu}\frac{\mu(1+\eta)}{\bar{\gamma}(1-\rho)}$$
$$\sum_{t_1,t_2,t_3=0}^{\infty}\frac{(\mu)_{t_1}(\mu)_{t_2}(L\mu+t_1)_{t_3}}{t_1!t_2!t_3!\eta^{t_1}\Gamma(2L\mu+\lambda)}\left[\frac{L\rho}{(1+(L-1)\rho)}\right]^{\lambda}\left[\frac{(\eta-1)}{\eta}\right]^{t_3}$$
$$\times\frac{1}{(2L\mu+\lambda)_{t_3}}\Gamma\left(2L\mu+\lambda+t_3-1,\frac{\mu(1+\eta)}{\bar{\gamma}(1-\rho)}\gamma_0\right) \tag{12}$$

Outage probability can be defined as $p_{out}=\int_0^{\gamma_{th}} f_{\gamma_{mrc}}(\gamma_{mrc})\,d\gamma_{mrc}$, where γ_{th} is a threshold value of the output SNR [7]. Using (9), the resulting integral can be solved by expressing the hypergeometric function in infinite series and using [8, (3.381.1)]. The final expression for the outage probability is given as

$$P_{out}=\frac{1}{\eta^{\mu L}}\left[\frac{1-\rho}{(1+(L-1)\rho)}\right]^{2\mu}\sum_{t_1,t_2,t_3=0}^{\infty}\frac{(\mu)_{t_1}(\mu)_{t_2}}{t_1!t_2!t_3!\eta^{t_1+t_3}}$$
$$\times\frac{(L\mu+t_1)_{t_3}(\eta-1)^{t_3}}{\Gamma(2L\mu+\lambda+t_3)}\left(\frac{L\rho}{1+(L-1)\rho}\right)^{t_1+t_2}$$
$$\times g\left(2L\mu+\lambda+t_3,\frac{\mu(1+\eta)}{(1-\rho)\bar{\gamma}_N}\right) \tag{13}$$

Where $\lambda\, @\, t_1+t_2$, and $g(a,x)=\int_0^x e^{-t}t^{a-1}dt$ is the incomplete gamma function [5, (6.5.2)] and $\bar{\gamma}_N\, @\, \frac{\bar{\gamma}}{\gamma_{th}}$ is the normalized average branch SNR. The final expression after simplification can be given as

$$p_{out} = \frac{1}{\eta^{\mu L}} \left[\frac{1-\rho}{(1+(L-1)\rho)} \right]^{2\mu} \sum_{t_1,t_2,t_3=0}^{\infty} \frac{(\mu)_{t_1} (\mu)_{t_2} (L\mu + t_1)_{t_3}}{t_1!t_2!t_3!\eta^{t_1}\Gamma(2L\mu+\lambda+t_3)}$$
$$\left(\frac{L\rho}{1+(L-1)\rho} \right)^{\lambda} \left(\frac{\eta-1}{\eta} \right)^{t_3} \times \Gamma(2L\mu+\lambda+t_3) -$$
$$\Gamma\left(2L\mu+\lambda+t_3, \frac{\mu(1+\eta)\gamma_0}{\bar{\gamma}(1-\rho)} \right) \quad (14)$$

The final expression for capacity for TIFR scheme can be obtained by putting the values of R_{tifr} and $P_{out}(\gamma_0)$.

3.3 Channel inversion with fixed rate

The capacity for this scheme is given by

$$C_{cifr} = B \log_2 \left(1 + \frac{1}{R_{cifr}} \right) \quad (15)$$

For this scheme requirement to find a solution to the integral R_{cifr}. It can be solved by putting (3) and then solving the resulting integral using [8, (7.621.4)]. The procedure is shown below.

The formula for R_{cifr} is given by $R_{cifr} = \int_{\gamma_o}^{\infty} \frac{1}{\gamma} f_{\gamma}(\gamma) d\gamma$.Putting (3) in this formula we have

$$R_{cifr} = \left[\frac{(1-\rho)}{(1+(L-1)\rho)} \right]^{2\mu} \left[\frac{\mu(1+\eta)}{\bar{\gamma}(1-\rho)\sqrt{\eta}} \right]^{2L\mu} \times \sum_{t_1,t_2=0}^{\infty} \frac{(\mu)_{t_1}}{t_1!}$$
$$\times \left[\frac{L\rho\mu(1+\eta)}{\bar{\gamma}(1-\rho)(1+(L-1)\rho)} \right]^{\lambda} \times \frac{(\mu)_{t_2}}{t_2!\eta^{t_1}\Gamma(2L\mu+\lambda)} \int_0^{\infty} \gamma^{2L\mu+\lambda-1-1} e^{-\frac{\mu(1+\eta)}{\bar{\gamma}(1-\rho)}\gamma}$$
$$\times {}_1F_1\left(L\mu+t_1; 2L\mu+\lambda; \frac{\mu(\eta^2-1)}{\eta(1-\rho)\bar{\gamma}}\gamma \right) d\gamma \quad (16)$$

Using the formula [8, (7.621.4)]

$$\int_0^{\infty} e^{-st} t^{b-1} {}_1F_1(a;c;kt) dt = \Gamma(b) s^{-b} \times {}_2F_1(a;b;c;ks^{-1})$$
$$[|s| > |k|]$$

The given integral can be solved as

Where ${}_2F_1(a,b;c;z)$ is the hypergeometric function. The expression after algebraic manipulation and simplification can be given as

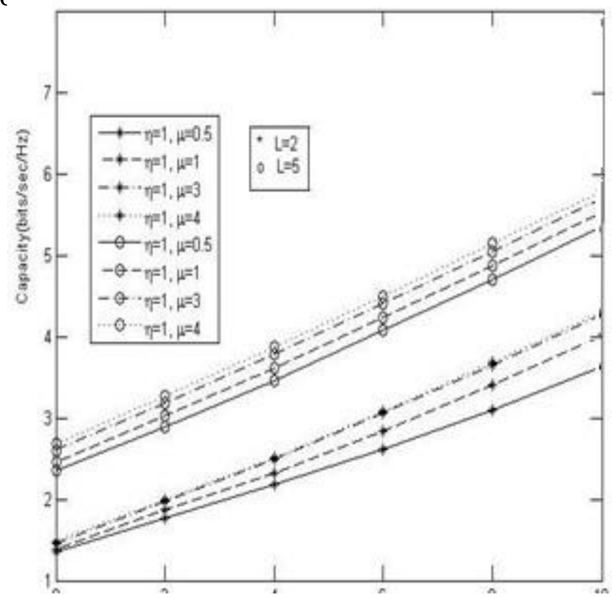
$$R_{cifr} = \left[\frac{(1-\rho)}{(1+(L-1)\rho)}\right]^{2\mu} \frac{\mu(1+\eta)}{\overline{\gamma}(1-\rho)} \sum_{t_1,t_2=0}^{\infty} \frac{(\mu)_{t_1}}{t_1!}$$
$$\times\left[\frac{L\rho}{(1+(L-1)\rho)}\right]^{\lambda} \frac{(\mu)_{t_2}\,\Gamma(2L\mu+\lambda-1)}{t_2!\,\eta^{t_1}\Gamma(2L\mu+\lambda)}$$
$$\times{}_2F_1\left(L\mu+t_1, 2L\mu+\lambda-1; 2L\mu+\lambda; \frac{(\eta-1)}{\eta}\right) \qquad (18)$$

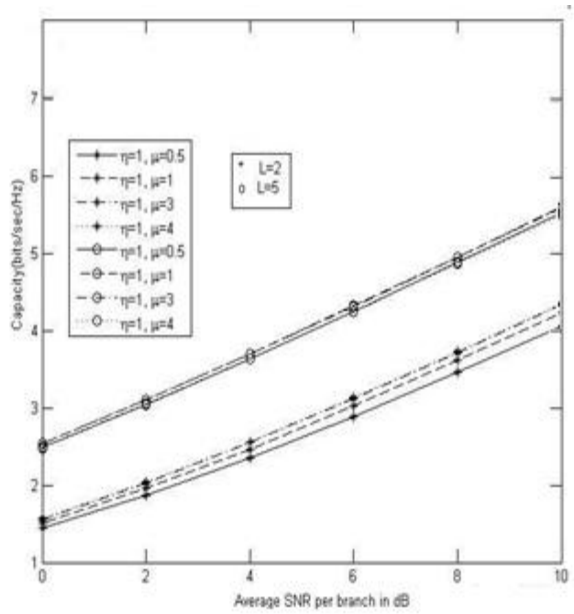
Thus the final expression for the capacity of this scheme can be obtained by putting (18) into (15).

$$R_{cifr} = \left[\frac{(1-\rho)}{(1+(L-1)\rho)}\right]^{2\mu} \times \left[\frac{\mu(1+\eta)}{\overline{\gamma}(1-\rho)\sqrt{\eta}}\right]^{2L\mu}$$
$$\times \sum_{t_1,t_2=0}^{\infty} \frac{(\mu)_{t_1}}{t_1!}\left[\frac{L\rho\mu(1+\eta)}{\overline{\gamma}(1-\rho)(1+(L-1)\rho)}\right]^{\lambda} \times \frac{(\mu)_{t_2}\,\Gamma(2L\mu+\lambda-1)}{t_2!\,\eta^{t_1}\Gamma(2L\mu+\lambda)}\left(\frac{\overline{\gamma}(1-\rho)}{\mu(1+\eta)}\right)^{2L\mu+\lambda-1}$$
$$\times{}_2F_1\left(L\mu+t_1, 2L\mu+\lambda-1; 2L\mu+\lambda; \frac{\mu(\eta^2-1)}{\eta(1-\rho)\overline{\gamma}}\,\frac{\overline{\gamma}(1-\rho)}{\mu(1+\eta)}\right) \qquad (17)$$

NUMERICAL RESULT AND DISCUSSION

4.The expressions for capacity with different power and rate adaptation techniques are obtained. These expressions are numerically evaluated for different values of fading parameter and diversity order and plotted for illustration. Capacity (per unit bandwidth) of ORA scheme has been plotted in Fig. 1. It can be observed from the figure that for a given fading parameter the capacity increases with increase in *L*. As the parameters η and μ increase the capacity increases in a linear fashion for low correlation co-efficient i.e. ρ=.1. For higher value of ρ the case for increase in capacity with the increase in the number of branch is not satisfied which in turn is not satisfied which is shown in fig. 2. The capacity vs average SNR for TIFR and CIFR schemes has been plotted in Figs. 2 and 3, respectively. In both schemes it can be observed that capacity increases with the increase in L. The same case that capacity increases with the increase in parameters η and μ can be observed again for certain interested value of ρ. A good channel capacity in obtained when the parameter ρ=.1 in both the cases. In the plot of TIFR scheme γ_0 is assumed to be 2*dB*. Therefore, plots are given for 2 *dB* onwards. Capacity plots for OPRA scheme have not been included here, but it is possible to plot the capacity from the given analytical expression. The numerical results obtained are verified against the special case published result and found to be matching. The convergence of the infinite series involved in the





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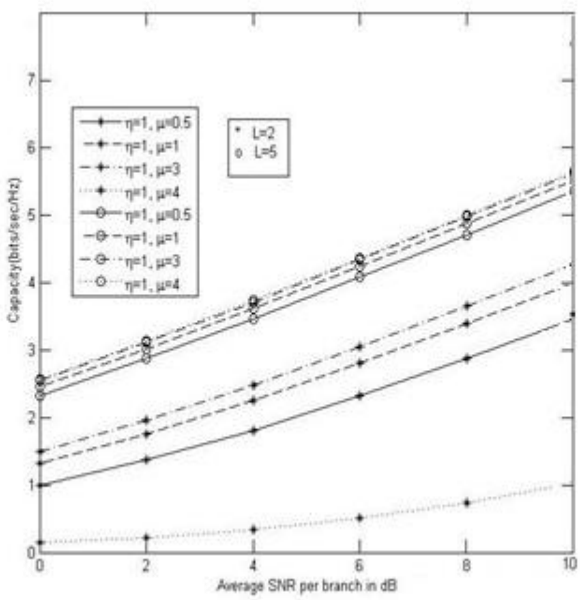

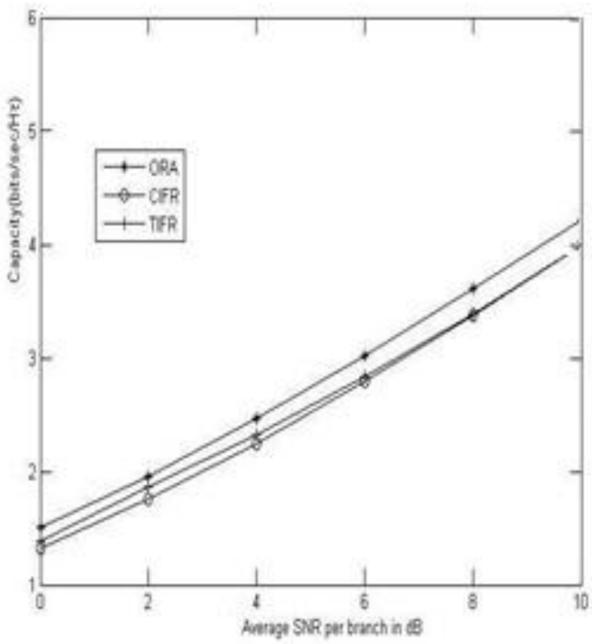

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CONCLUSION

5. In this paper, the capacity of L-MRC diversity system over *η-μ* Fading Channel is analyzed, for different known power and rate adaptation transmission techniques. The various expressions for respective adaptive transmission techniques are obtained. Numerical evaluations are carried out for respective schemes for the different parameters L, η, μ and ρ. The results are plotted for different parameter of interest and compared with the available special case results. It is observed that Diversity technique increases the channel capacity for all transmission schemes. Out of the adaptive transmission schemes, the maximum diversity gain is observed in Optimum Rate Adaptation method.

APPENDIX A EVALUATION OF INTEGRAL $I_n(\mu)$

6.We evaluate the integral $I_n(\mu)$ defined using partial integration, namely

$$\int_0^{+\infty} u\,dv = \lim_{t\to+\infty}(uv) - \lim_{t\to 0}(uv) - \int_0^{+\infty} v\,du \qquad (A.1)$$

First, let

$$u = \ln(1+t),\, du = \frac{dt}{1+t} \qquad (A.2)$$

$$dv = t^{n-1}e^{-\mu t}dt \qquad (A.3)$$

Performing *n-1* successive integration by parts yields [31.eq. (2.321.2), p. 112]

$$v = -e^{-\mu t}\sum_{k=1}^{n}\frac{(n-1)!t^{n-k}}{(n-1)!\mu^k} \qquad (A.4)$$

Substituting (*A*.2) and (*A*.4) in (A.1), we see that the first two terms go to zero. Hence

$$I_n(\mu) = \sum_{k=1}^{n}\frac{(n-1)!t^{n-k}}{(n-1)!\mu^k}\int_0^{+\infty}\frac{t^{n-k}e^{-\mu t}}{1+t}\,dt \qquad (A.5)$$

The integral in (*A*.5) can be written in a closed form giving

$$I_n(\mu) = (n-1)!e^{\mu}\sum_{k=1}^{n}\frac{\Gamma(-n+k,\mu)}{\mu^k} \qquad (A.6)$$

Where $\Gamma(.,.)$ is the complementary incomplete gamma function.

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