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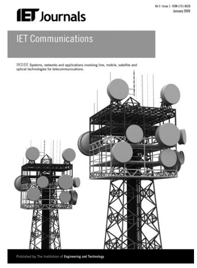

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Spectral efficiency of adaptive transmission and selection diversity on generalised fading channels

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Abstract: The spectral efficiency of L-branch selection diversity (SD) receiver with different adaptive transmission techniques operating over generalised-Gamma (GG) fading channels is studied. Novel expressions for important adaptive transmission techniques are obtained, namely optimal power and rate adaptation, optimal rate adaptation, channel inversion with fixed rate (CIFR) and truncated CIFR. Furthermore, simplified expressions for the capacities are obtained for SD reception in Nakagami-m as well as Weibull fading channels. The derived closed-from expressions extend previously published results to the GG fading model. Numerical results are given to demonstrate the usefulness of the theoretical approach.

1 Introduction

The channel capacity in fading environments depends on the amount of channel state information (CSI) available at the transmitter and/or receiver and it is given by a complex expression of the channel variations in time and/or frequency. Various definitions of the channel capacity have been provided in the past, depending on the different power and rate adaptation policies employed and the existence, or not, of an outage probability [1]. Widely accepted transmission adaptation techniques are the optimal power and rate adaptation (OPRA), constant power with optimal rate adaptation (ORA), channel inversion with fixed rate (CIFR) and truncated CIFR (TIFR). These techniques assume CSI to be available at the transmitter or the receiver or both. For each transmission adaptation policy, it is important to study its performance under different fading channel models.

In the past, the capacity has been studied for several fading distributions and diversity reception techniques, for example, [2–8]. In [2], the general theory for the capacity of fading channels with an average power constraint, under different CSI conditions, was developed. Based on the work in [2], a thorough capacity analysis was presented for Rayleigh fading channels in [3], assuming no diversity, as well as, selection and maximal ratio combining (MRC) diversity receivers. In [4], the results presented in [3] were extended to Nakagami-m fading channels, whereas in [6] expressions for the Shannon capacity of single-branch receivers operating over Nakagami-m, Rice and Weibull fading channels were derived. In [8], bounds for the capacity of Rician and Hoyt fading channels with MRC diversity were obtained. In this paper, we also consider the general framework proposed in [2] for the case of multi-branch (L) selection diversity (SD) receivers operating over generalised-Gamma (GG) fading channels.

The GG distribution includes many well-known multipath fading models, for example, Rayleigh, Nakagami-m and Weibull, as special cases, while it can also describe the lognormal as a limiting case. However, despite the ability of the GG distribution to characterise many different fading channel models, only recently it has been applied to the field of digital communications over fading channels [9–12]. As an example, in [12] the performance analysis of switch and stay combining diversity receivers operating over GG fading channels was studied. In the same work, the spectral efficiency was also obtained for the ORA policy. Furthermore, in a recent work, [13], the capacity of dual-branch, that is, $L = 2$, SD receiver operating over correlated GG fading channels was studied for different adaptation policies. Hence, the capacity of multi-branch SD reception and GG fading channels under the different transmission adaptation techniques has not been yet studied in the open technical literature and thus it is the subject of the current paper.

This paper is organised as follows. In Section 2, the system and channel model are introduced. In Sections 3–6, closed-form expressions for the capacity of GG fading channels are derived for the OPRA, ORA, CIFR and TIFR adaptation policies, respectively. In Section 7, numerically evaluated results are presented and discussed, whereas concluding remarks are provided in Section 8.

2 System and channel model

Let us consider a multi-branch SD receiver operating over slow varying fading channels. The received instantaneous signal-to-noise ratio (SNR) γ at the ℓth input branch, $(1 \le \ell \le L)$, is considered to be a GG distributed random variable with probability density function (PDF) given by [12]

$$f_\gamma(\gamma) = \frac{\beta \gamma^{m\beta/2-1}}{2\Gamma(m)(\tau\overline{\gamma})^{m\beta/2}} \exp\left[-\left(\frac{\gamma}{\tau\overline{\gamma}}\right)^{\beta/2}\right] \tag{1}$$

where $\beta > 0$ and $m \ge 1/2$ are the distribution's shaping parameters related to the fading severity, $\overline{\gamma}$ is the average input SNR per symbol, and $\tau = \Gamma(m)/\Gamma(m + 2/\beta)$, with $\Gamma(\cdot)$ being the Gamma function [14, Equation (8.310/1)]. For different values of m and β, (1) simplifies to several important distributions for fading modelling, that is for $\beta = 2$ it becomes Nakagami-m, for $m = 1$ it becomes Weibull, while as $\beta \to 0$ and $m \to \infty$, (1) approaches the well-known lognormal PDF. The corresponding cumulative distribution function (CDF) is given by

$$F_\gamma(\gamma) = 1 - \frac{\Gamma[m, (\gamma/\tau\overline{\gamma})^{\beta/2}]}{\Gamma(m)} \tag{2}$$

where $\Gamma(\cdot,\cdot)$ represents the upper incomplete Gamma function [14, Equation (8.350/2)].

Furthermore, let γ_{sd} represent the SNR per symbol at the output of a multi-branch SD receiver operating over independent and identically distributed GG fading channels. The SD receiver is one of the simplest diversity reception techniques, as only the branch with the maximum received SNR is processed [15]. The CDF of γ_{sd}, $F_{\gamma_{sd}}(\gamma)$, can be expressed as $F_{\gamma_{sd}}(\gamma) = [F_\gamma(\gamma)]^L$, whereas the PDF of γ_{sd} can be mathematical expressed in closed form as [16, Equation (17)]

$$f^{GG}_{\gamma_{sd}}(\gamma) = \frac{\beta L}{2\Gamma(m)}\left(\frac{1}{\tau\overline{\gamma}}\right)^{\beta m/2} \sum_{p=0}^{L-1} \binom{L-1}{p} (-1)^p \times \sum_{r=0}^{p(m-1)} \lambda_r^p \frac{\gamma^{\beta(m+r)/2-1}}{(\tau\overline{\gamma})^{\beta r/2}} \exp\left[-(p+1)\left(\frac{\gamma}{\tau\overline{\gamma}}\right)^{\beta/2}\right] \tag{3}$$

where

$$\lambda_0^p = 1,\ \lambda_1^p = p,\ \lambda_{p(m-1)}^p = \frac{1}{\Gamma(m)^p}$$

$$\lambda_r^p = \frac{1}{r}\sum_{\ell=1}^{J} \frac{\ell(p+1) - r}{\ell!} \lambda_{r-\ell}^p$$

with $J = \min(r, m-1)$; $2 \le r \le p(m-1) - 1$. Assuming Nakagami-m fading, that is, $\beta = 2$, (3) simplifies to [17, Equation (15)]

$$f^{Nak}_{\gamma_{sd}}(\gamma) = \frac{L}{\Gamma(m)} \sum_{p=0}^{L-1} \binom{L-1}{p} (-1)^p \sum_{r=0}^{p(m-1)} \lambda_r^p \left(\frac{m}{\overline{\gamma}}\right)^{m+r} \gamma^{m+r-1} \times \exp\left[-(p+1)\frac{m\gamma}{\overline{\gamma}}\right] \tag{4}$$

while for Weibull fading conditions, that is, $m = 1$, (3) can be mathematically expressed as [18, Equation (5)]

$$f^{Wei}_{\gamma_{sd}}(\gamma) = \frac{\beta L}{2(\alpha\overline{\gamma})^{\beta/2}} \sum_{k=0}^{L-1} \binom{L-1}{k} (-1)^k \gamma^{\beta/2-1} \times \exp\left[-(k+1)\left(\frac{\gamma}{\alpha\overline{\gamma}}\right)^{\beta/2}\right] \tag{5}$$

with $\alpha = 1/\Gamma(1 + 2/\beta)$.

3 Optimal power and rate adaptation

The channel capacity under an average transmitting power constraint and OPRA is given by [2]

$$C_{opra} = B \int_{\gamma_0}^{\infty} \log_2\left(\frac{\gamma}{\gamma_0}\right) f_{\gamma_{sd}}(\gamma)\, d\gamma \tag{6}$$

where B is the channel bandwidth (in Hertz) and γ_0 is the optimal cutoff SNR. If $\gamma < \gamma_0$ no data are transmitted and hence an outage probability occurs as $P_{out} = F_{\gamma_{sd}}(\gamma_0)$.

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Furthermore, by denoting

$$p_{\mathrm{sd}}(x) = \int_x^{\infty} \left(\frac{1}{x} - \frac{1}{\gamma}\right) f_{\gamma_{\mathrm{sd}}}(\gamma)\,\mathrm{d}\gamma - 1 \tag{7}$$

γ_0 must satisfy $p_{\mathrm{sd}}(\gamma_0) = 0$ [3].

Substituting (3) into (7), making a change of variables and using [14, Equation (8.350/2)], the optimal cutoff function for the SD receiver under GG fading can be obtained as

$$\begin{aligned} p_{\mathrm{sd}}^{\mathrm{GG}}(\gamma_0) = {} & \sum_{p=0}^{L-1} \binom{L-1}{p} (-1)^p \sum_{r=0}^{p(m-1)} \frac{\lambda_r^p}{(p+1)^{m+r}} \\ & \times \left\{ \frac{1}{\gamma_0} \Gamma\left[m+r, (p+1)\left(\frac{\gamma_0}{\tau\bar{\gamma}}\right)^{\beta/2} \right] - \frac{(p+1)^{2/\beta}}{\tau\bar{\gamma}} \right. \\ & \left. \times \Gamma\left[m+r-\frac{2}{\beta}, (p+1)\left(\frac{\gamma_0}{\tau\bar{\gamma}}\right)^{\beta/2} \right] \right\} \frac{L}{\Gamma(m)} - 1 \end{aligned} \tag{8}$$

In the above equation γ_0 cannot be obtained in closed form and hence numerical evaluation will be employed, by using any of the well-known mathematical software packages. Moreover, it can be proved that there is a unique positive value for γ_0, that satisfies $p_{\mathrm{sd}}(\gamma_0) = 0$.

For Nakagami-m fading, (8) becomes

$$\begin{aligned} p_{\mathrm{sd}}^{\mathrm{Nak}}(\gamma_0) = {} & \sum_{p=0}^{L-1} \binom{L-1}{p} (-1)^p \sum_{r=0}^{p(m-1)} \frac{\lambda_r^p}{(p+1)^{m+r}} \\ & \times \left\{ \frac{1}{\gamma_0} \Gamma\left[m+r, \frac{(p+1)m}{\bar{\gamma}} \gamma_0 \right] \right. \\ & \left. - \frac{(p+1)m}{\bar{\gamma}} \Gamma\left[m+r-1, \frac{(p+1)m}{\bar{\gamma}\gamma_0} \right] \right\} \frac{L}{\Gamma(m)} - 1 \end{aligned} \tag{9}$$

Assuming Weibull fading, that is, using (5) in (7), (8) simplifies to

$$\begin{aligned} p_{\mathrm{sd}}^{\mathrm{Wei}}(\gamma_0) = {} & L \sum_{k=0}^{L-1} \binom{L-1}{k} \frac{(-1)^k}{k+1} \left\{ \frac{1}{\gamma_0} \exp\left[-(k+1)\left(\frac{\gamma_0}{\alpha\bar{\gamma}}\right)^{\beta/2} \right] \right. \\ & \left. - \frac{(k+1)^{2/\beta}}{\alpha\bar{\gamma}} \Gamma\left[1-\frac{2}{\beta}, (k+1)\left(\frac{\gamma_0}{\alpha\bar{\gamma}}\right)^{\beta/2} \right] \right\} - 1 \end{aligned} \tag{10}$$

Note that for $\beta = 2$, that is considering Rayleigh fading conditions, and using [19, Equation (06.34.27.0002.01)], (10) simplifies to previous known result, that is, [3, Equation (24)].

For the OPRA capacity, substituting (3) into (6) and using [3, Appendix A], yields

$$\begin{aligned} C_{\mathrm{opra}}^{\mathrm{GG}} = {} & \frac{2LB}{\beta\Gamma(m)} \sum_{p=0}^{L-1} \binom{L-1}{p} (-1)^p \sum_{r=0}^{p(m-1)} \frac{\lambda_r^p}{\ln(2)} \\ & \times \sum_{k=1}^{m+r} \frac{(m+r-1)!}{(m+r-k)!} (p+1)^{-m-r} \\ & \times \Gamma\left[m+r-k, \frac{p+1}{(\tau\bar{\gamma})^{\beta/2}} \gamma_0^{\beta/2} \right] \end{aligned} \tag{11}$$

Assuming Nakagami-m fading, (11) simplifies to

$$\begin{aligned} C_{\mathrm{opra}}^{\mathrm{Nak}} = {} & \frac{LB}{\Gamma(m)} \sum_{p=0}^{L-1} \binom{L-1}{p} (-1)^p \sum_{r=0}^{p(m-1)} \frac{\lambda_r^p}{\ln(2)} \\ & \times \sum_{k=1}^{m+r} \frac{(m+r-1)!}{(m+r-k)!} \frac{\Gamma[m+r-k, (p+1)m\gamma_0/\bar{\gamma}]}{(p+1)^{m+r}} \end{aligned} \tag{12}$$

For the Weibull fading conditions, substituting (5) into (6), making a change of variables, using [14, Equation (3.351/5)] and after some mathematical manipulations, the OPRA capacity under SD reception can be obtained as

$$\begin{aligned} C_{\mathrm{opra}}^{\mathrm{Wei}} = {} & \frac{\beta LB}{2} \sum_{k=0}^{L-1} \binom{L-1}{k} (-1)^{k+1} \left(\frac{2}{\beta}\right)^2 \\ & \times \frac{(k+1)^{-1}}{\ln(2)} E_i\left[-\left(\frac{\gamma_0}{\tau\bar{\gamma}}\right)^{\beta/2} (k+1) \right] \end{aligned} \tag{13}$$

where $E_i(\cdot)$ is the exponential integral function [14, Equation (8.21)].

4 Optimal rate adaptation

The capacity under a constant transmitting power and ORA policy is defined as [2]

$$C_{\mathrm{ora}} \triangleq B \int_0^{\infty} \log_2(1+\gamma) f_{\gamma_{\mathrm{sd}}}(\gamma)\,\mathrm{d}\gamma \tag{14}$$

It can be easily observed that the capacity under the ORA policy, that is (14), is identical with the capacity defined in [20, Equation (1)] so that the transmitter CSI knowledge does not influence the capacity. Substituting (3) into (14) integrals of the following form need to be solved

$$\mathcal{I} = \int_0^{\infty} \gamma^{a-1} \ln(1+\gamma) \exp(-d\gamma^b)\,\mathrm{d}\gamma \tag{15}$$

Expressing $\exp(\cdot)$ and $\ln(\cdot)$ as in [19, Equation (01.03.26.0004.01)] and [19, Equation (01.04.26.0003.01)], respectively, and by using [21], $\mathcal{I}$ can be solved in closed form. Using this solution and after some mathematical manipulations, the capacity of the SD receiver under the ORA policy, $C_{\text{ora}}^{\text{GG}}$, can be expressed as

$$C_{\text{ora}}^{\text{GG}} = \frac{\beta LB}{2\Gamma(m)\ln(2)}\left(\frac{1}{\tau\bar{\gamma}}\right)^{\beta m/2}\sum_{p=0}^{L-1}\binom{L-1}{p}(-1)^p \times \sum_{r=0}^{p(m-1)}\frac{\lambda_r^p}{(\tau\bar{\gamma})^{\beta r/2}}\frac{\sqrt{\kappa}/\lambda}{(2\pi)^{\lambda+(\kappa-3)/2}}G_{2\lambda,\kappa+2\lambda}^{\kappa+2\lambda,\lambda}\left[\left(\frac{p+1}{\kappa(\tau\bar{\gamma})^{\beta/2}}\right)^{\kappa}\left|\begin{matrix}\Delta\left[\lambda,-\frac{\beta}{2}(m+r)\right], & \Delta\left[\lambda,1-\frac{\beta}{2}(m+r)\right]\\ \Delta(\kappa,0),\Delta\left[\lambda,-\frac{\beta}{2}(m+r)\right], & \Delta\left[\lambda,-\frac{\beta}{2}(m+r)\right]\end{matrix}\right.\right] \tag{16}$$

where $G(\cdot)$ is the Meijer's G-function [14, Equation (9.301)], $\Delta(x, y) = y/x,(y+1)/x, \ldots,(y+x-1)/x$, while λ and κ are positive integers with $\lambda/\kappa = \beta/2$ [6].

For Nakagami-m fading conditions, (16) simplifies to

$$C_{\text{ora}}^{\text{Nak}} = \frac{LB}{\Gamma(m)\ln(2)}\sum_{p=0}^{L-1}\binom{L-1}{p}(-1)^p\sum_{r=0}^{p(m-1)}\lambda_r^p\left(\frac{m}{\bar{\gamma}}\right)^{m+r} \times \Gamma(m+r)\exp\left[m\left(\frac{p+1}{\bar{\gamma}}\right)\right] \times \sum_{k=1}^{m+r}\frac{\Gamma[k-m-r,\, m(p+1)/\bar{\gamma}]}{[m(p+1)/\bar{\gamma}]^k} \tag{17}$$

Moreover, for Weibull fading, using (5) in (14) and following a similar procedure as the one used in deriving (16), $C_{\text{ora}}^{\text{Wei}}$ is obtained in closed form as

$$C_{\text{ora}}^{\text{Wei}} = \frac{\beta LB}{2(\alpha\bar{\gamma})^{\beta/2}\ln(2)}\sum_{k=0}^{L-1}\binom{L-1}{k}\frac{(-1)^k\sqrt{\kappa}/\lambda}{(2\pi)^{\lambda+(\kappa-3)/2}} \times G_{2\lambda,\kappa+2\lambda}^{\kappa+2\lambda,\lambda}\left[\left(\frac{k+1}{\kappa(\alpha\bar{\gamma})^{\beta/2}}\right)^{\kappa} \times \left|\begin{matrix}\Delta\left(\lambda,-\frac{\beta}{2}\right), & \Delta\left(\lambda,1-\frac{\beta}{2}\right)\\ \Delta(\kappa,0),\Delta\left(\lambda,-\frac{\beta}{2}\right), & \Delta\left(\lambda,-\frac{\beta}{2}\right)\end{matrix}\right.\right] \tag{18}$$

5 Channel inversion with fixed rate

In CIFR policy the transmitter exploits the CSI in order to maintain constant SNR at the receiver [2]. This method uses a fixed data rate, since the channel after fading appears as an additive white Gaussian noise channel. The channel capacity employing CIFR, C_{cifr}, is given by

$$C_{\text{cifr}} = B\log_2\left(1+\frac{1}{\int_0^\infty f_{\gamma_{\text{sd}}}(\gamma)/\gamma\,\mathrm{d}\gamma}\right) \tag{19}$$

Substituting (3) into (19) and using [14, Equation (3.351/3)], the capacity of an SD receiver under the CIFR policy can be obtained as

$$C_{\text{cifr}}^{\text{GG}} = B\log_2\left[1+\frac{1}{\frac{L/\bar{\gamma}}{\Gamma(m)\tau}\sum_{p=0}^{L-1}\binom{L-1}{p}(-1)^p\sum_{r=0}^{p(m-1)}\lambda_r^p\frac{\Gamma(m+r-2/\beta)}{(p+1)^{m+r-2/\beta}}}\right] \tag{20}$$

Assuming Nakagami-m fading, (20) simplifies to

$$C_{\text{cifr}}^{\text{Nak}} = B\log_2\left[1+\frac{1}{\frac{Lm}{\Gamma(m)\bar{\gamma}}\sum_{p=0}^{L-1}\binom{L-1}{p}(-1)^p\sum_{r=0}^{p(m-1)}\lambda_r^p\frac{\Gamma(m+r-1))}{(p+1)^{m+r-1}}}\right] \tag{21}$$

while for Weibull fading, that is, using (5) in (19), the capacity with CIFR policy is obtained as

$$C_{\text{cifr}}^{\text{Wei}} = B\log_2\left[1+\frac{1}{\frac{L}{\alpha\bar{\gamma}}\sum_{k=0}^{L-1}\binom{L-1}{k}(-1)^k\frac{\Gamma(1-2/\beta)}{(k+1)^{1-2/\beta}}}\right] \tag{22}$$

6 Truncated channel inversion with fixed rate

The CIFR technique is very simple to implement; however, it exhibits a large capacity penalty in extreme fading environments, for example, assuming Rayleigh fading $C_{\text{cifr}} = 0$ [2]. An alternative approach is to consider a truncated CIFR policy, usually referred to as TIFR, where the channel fading is inverted only above a fixed cutoff level γ_0. TIFR policy improves the channel capacity compared to CIFR policy at the expense of outage probability $P_{\text{out}} = F_{\gamma_{\text{sd}}}(\gamma_0)$. In this case the capacity can be obtained as

$$C_{\text{tifr}} = B\log_2\left[1+\frac{1}{\int_{\gamma_0}^\infty f_{\gamma_{\text{sd}}}(\gamma)/\gamma\,\mathrm{d}\gamma}\right](1-P_{\text{out}}) \tag{23}$$

Substituting (3) into (23), making a change of variables and using [14, Equation (8.350/2)], the capacity of an SD receiver

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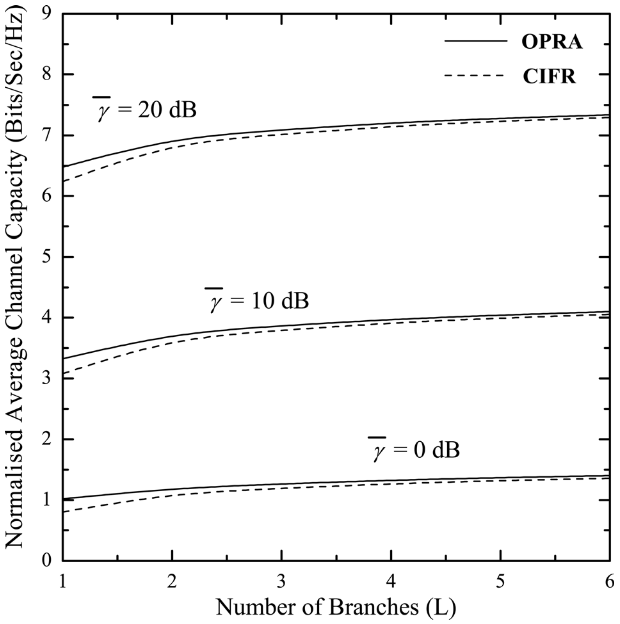

Figure 1 *Normalised average channel capacity with OPRA and CIFR adaptation policies and $\overline{\gamma} = 0, 10, 20$ dB, against the number of branches L*

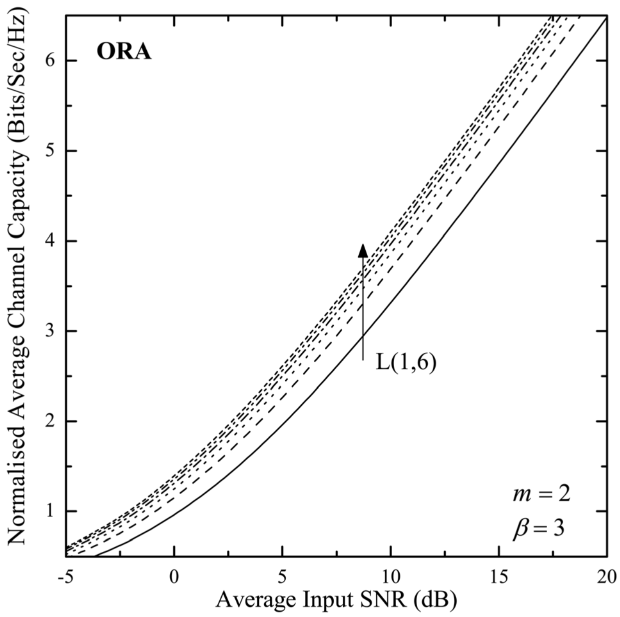

Figure 2 *Normalised average channel capacity with ORA adaptation policy and L = 1, 2, ..., 6, against the average input SNR*

under the TIFR policy can be obtained as (see (24))

where $F_{\gamma_{sd}}(\gamma_0)$ is given by (2). For Nakagami-m fading conditions, (24) simplifies as follows (see (25))

where $F_{\gamma_{sd}}(\gamma_0)$ can be obtained by setting $\beta = 2$ in (2). Assuming Weibull fading, substituting (5) into (23) and using a similar procedure as for deriving (24), the capacity under TIFR policy can be obtained as (see (26))

where $F_{\gamma_{sd}}(\gamma_0)$ can be obtained by setting $m = 1$ in (2).

7 Numerical results and discussion

In this section various numerically evaluated results are obtained using the previously presented results for multi-branch SD receivers. These results include capacity comparisons of different adaptive transmission policies, diversity orders and GG fading channel conditions.

For the conciseness of the presentation, the normalised average channel capacity is denoted as $\widehat{C}$ and can be easily obtained as $\widehat{C} = C/B$, in terms of bits/s/Hz. In Fig. 1, $\widehat{C}$

$$C_{\text{tifr}}^{\text{GG}} = B\log_2\left[1 + \frac{1}{\frac{L/\overline{\gamma}}{\Gamma(m)\tau}\sum_{p=0}^{L-1}\binom{L-1}{p}(-1)^p\sum_{r=0}^{p(m-1)}\lambda_r^p\Gamma\left[m+r-(2/\beta),(p+1)(\gamma_0/(\tau\overline{\gamma}))^{\beta/2}\right]/(p+1)^{m+r-2/\beta}}\right][1-F_{\gamma_{sd}}(\gamma_0)] \tag{24}$$

$$C_{\text{tifr}}^{\text{Nak}} = B\log_2\left[1 + \frac{1}{\frac{mL}{\Gamma(m)\,\overline{\gamma}}\sum_{p=0}^{L-1}\binom{L-1}{p}(-1)^p\sum_{r=0}^{p(m-1)}\lambda_r^p\Gamma[m+r-1,\, m(p+1)\gamma_0/\overline{\gamma}]/(p+1)^{m+r-1}}\right][1-F_{\gamma_{sd}}(\gamma_0)] \tag{25}$$

$$C_{\text{tifr}}^{\text{Wei}} = B\log_2\left[1 + \frac{1}{\frac{L}{\alpha\overline{\gamma}}\sum_{k=0}^{L-1}\binom{L-1}{k}(-1)^k\Gamma\left[1-2/\beta,\,(k+1)(\gamma_0/(\alpha\overline{\gamma}))^{\beta/2}\right]/(k+1)^{1-2/\beta}}\right][1-F_{\gamma_{sd}}(\gamma_0)] \tag{26}$$

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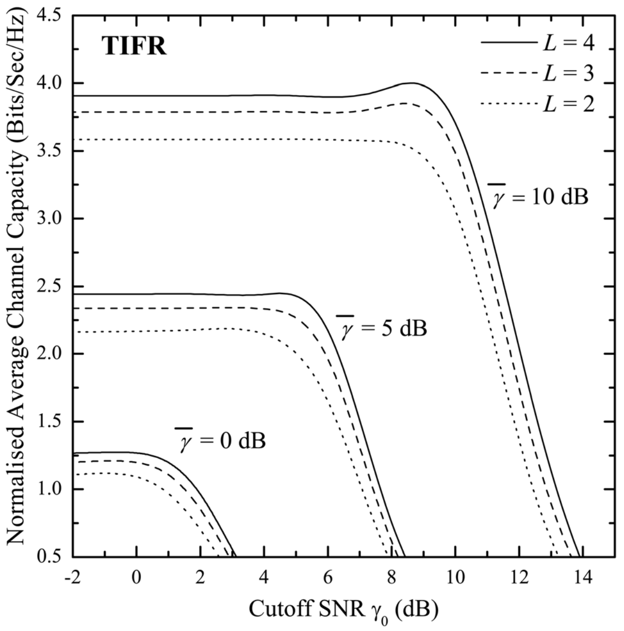

Figure 3 *Normalised average channel capacity with TIFR adaptation policy, $L = 2, 3, 4$ and $\overline{\gamma} = 0, 5, 10$ dB, against the cuttoff SNR*

under the OPRA (using (11)) and CIFR (using (20)) adaptation policies is plotted as a function of the number of branches L for several values of the average input SNR, $\overline{\gamma}$, assuming $m = 2$ and $\beta = 3$. It is depicted that $\widehat{C}$ improves by increasing L and/or $\overline{\gamma}$, while for constant values of $\overline{\gamma}$ and by increasing L, the performance improvement is reduced. Note that OPRA and CIFR capacities become almost equal for increased values of L, that is for $L \geq 4$. In Fig. 2, using (16), the $\widehat{C}$ under the ORA policy is plotted as a function of $\overline{\gamma}$ for several values of L, assuming $m = 2$ and $\beta = 3$. It is depicted that the channel capacity improves by increasing the number of diversity branches employed and/or increasing $\overline{\gamma}$. However, it is evident from the graph that as L increases the amount of capacity improvement diminishes.

Assuming the same fading parameters but TIFR adaptation policy, that is using (24), Fig. 3 plots $\widehat{C}$ as a function of cutoff SNR, γ_0, for several values of $\overline{\gamma}$ and L. It is depicted that $\widehat{C}$ improves by increasing the diversity order and/or increasing $\overline{\gamma}$. Furthermore, in all cases $\widehat{C}$ is maximised for specific values of γ_0, while the difference between the performances of the SD receivers decreases as L increases.

8 Conclusions

In this paper we presented novel closed-form expressions for the spectral efficiency of SD receivers with different transmission adaptation policies operating over GG fading channels. In particular, for this diversity reception technique, the channel capacity was studied for OPRA, ORA, CIFR and TIFR adaptation policies. The derived formulae are quite general as they extend previously obtained results, whereas simplified expressions are provided for the Nakagami-m and Weibull fading conditions. For the adaptation policies under consideration, selected numerically evaluated results were presented, assuming different GG fading/shadowing conditions and various receiver diversity orders.

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