Hindawi Publishing Corporation
EURASIP Journal on Wireless Communications and Networking
Volume 2007, Article ID 60408, 6 pages
doi:10.1155/2007/60408

Research Article

Performance of Selection Combining Diversity in Weibull Fading with Cochannel Interference

Mahmoud H. Ismail and Mustafa M. Matalgah

Center for Wireless Communications, Department of Electrical Engineering, University of Mississippi, Oxford, MS 38677-1848, USA

Received 11 April 2006; Revised 24 November 2006; Accepted 17 January 2007

Recommended by Visa Koivunen

We evaluate the performance of selection combining (SC) diversity in cellular systems where binary phase-shift keying (BPSK) is employed and the desired signal as well as the cochannel interferers (CCIs) is subject to Weibull fading. A characteristic function-(CF-) based approach is followed to evaluate the performance in terms of the outage probability. Two selection criteria are adopted at the diversity receiver: maximum desired signal power and maximum output signal-to-interference ratio (SIR). We study the effect of the fading parameters of the desired and interfering signals, the number of diversity branches, as well as the number of interferers on the performance. Numerical results are presented and the validity of our expressions is verified via Monte Carlo simulations.

1. INTRODUCTION

Selection combining (SC) diversity is one of the simplest available schemes used to combat the detrimental effect of fading. It has been very well studied in the literature over different models of fading channels (see [1, Section 9.8] and the references therein). Also, the performance of such diversity scheme in presence of cochannel interference (CCI) has been investigated under a variety of assumptions in the literature. For example, in [2], the performance of such scheme over the Nakagami/Rayleigh (by Nakagami/Rayleigh, we mean that the desired signal is subject to Nakagami fading while the cochannel interferers are subject to Rayleigh fading. This shorthand will be used throughout the paper) and the Rice/Rayleigh fading environments with quadrature phase-shift keying (QPSK) modulation has been investigated. Also, the performance of the dual-branch version of this receiver in presence of a dominant Rayleigh-faded interferer with a minimum signal power constraint was analyzed in [3]. Very recently, its performance under different selection criteria has been investigated in the Nakagami/Rayleigh fading environment in [4].

The Weibull distribution has been proposed decades ago as a possible fading model for radio environments [5–7]. It provides flexibility in describing the fading severity of the channel and subsumes special cases such as the Rayleigh fading. The appropriateness of the Weibull distribution to describe the fading phenomenon on wireless channels has been recently asserted by experimental data collected in the cellular band by two independent groups in [8, 9]. As a result, in the past few years, a renewed interest has been expressed in studying the characteristics of the Weibull fading channel and the performance of different wireless receivers operating on such channel. This is evident by numerous publications covering different aspects of this fading model. In particular, in [10], the second-order statistics and the capacity of the Weibull channel have been derived. The performance of various receive diversity systems has been extensively studied in [11–19] but with no CCI present. Also, we have analyzed the performance of cellular networks with composite Weibull-lognormal faded links in the presence of CCI in terms of outage probability in [20].

In this paper, we analytically evaluate the performance of SC diversity in the presence of CCI in terms of outage probability under the Weibull/Weibull fading scenario, in which both the desired as well as the interfering signals are Weibull faded. Due to the interference-limited nature of cellular systems, the background noise can be neglected and thus, the outage probability is defined as the probability that the signal-to-interference ratio (SIR) drops below a specific threshold γ_{th}. This threshold is usually chosen to satisfy a specific quality-of-service (QoS) metric. In this work, we use two selection criteria at the diversity receiver: maximum desired signal power and maximum SIR and we investigate the effect of the fading parameters of the desired and interfering signals, the number of interferers and the number of diversity branches on the system performance. Our Analytical results are verified via Monte Carlo simulations.

The rest of the paper is organized as follows. In the following section, we briefly outline our system and channel models and state our assumptions. In Section 3, we analyze the performance of SC in the Weibull/Weibull fading environment in terms of the outage probability. Our numerical results are then presented in Section 4 and compared to results obtained via Monte Carlo simulations. Finally, the paper is concluded in Section 5.

2. SYSTEM AND CHANNEL MODEL

As in [2, 4, 21], we consider a cellular network where K equal-power interfering signals share the same bandwidth with the desired user (assumed to be the 0th). Binary phase-shift keying (BPSK) with raised cosine pulse shaping is assumed for all the signals and all the receivers are equipped with an L-branch SC diversity scheme. The received signal at the jth branch of the desired user is thus given in [4] as follows:

$$\begin{aligned} r_j(t) &= \sqrt{2P_0T}R_{0,j}s_d(t)\cos(\omega_c t) \\ &\quad + \sum_{i=1}^{K}\sqrt{2PT}R_{i,j}s_i(t-\tau_j)\cos(\omega_c(t-\tau_i)+\theta_{i,j}), \\ &\qquad j = 1,2,\dots,L, \end{aligned} \tag{1}$$

where

$$\begin{aligned} s_d(t) &= \sum_{k=-\infty}^{\infty} a[k]g_T(t-kT), \\ s_i(t) &= \sum_{k=-\infty}^{\infty} b_i[k]g_T(t-kT), \end{aligned} \tag{2}$$

P is the transmitted power of any interferer, ω_c is the carrier angular frequency, T is the symbol duration. $g_T(t)$ denotes the transmitter signal baseband pulse whose energy is normalized to unity, $a[k], b_i[k] \in \{+1,-1\}$ with equal probabilities and τ_i represents the symbol timing offset between the ith user and the desired one, which is assumed to be uniformly distributed over $[0,T)$. In (1), $R_{0,j}$ and $R_{i,j}$ are the fading amplitudes of the desired and the ith interfering signal, respectively, both on the jth branch. We assume that the two sets $\{R_{0,j},\ j = 1,\dots,L\}$ and $\{R_{i,j},\ i = 0,\dots,K,\ j = 1,\dots,L\}$ are mutually statistically independent for all i, j and each set of them is a set of independent and identically distributed (i.i.d.) random variables (RVs). The random phases $\{\theta_{i,j},\ i = 0,\dots,K,\ j = 1,\dots,L\}$ are also i.i.d., all uniformly distributed over $[0,2\pi)$.

In this work, both the desired as well as the interfering signals are subject to Weibull fading, that is, $\{R_{0,j},\ j = 1,\dots,L\} \sim$ Weibull (m_s,γ_s) and $\{R_{i,j},\ i = 0,\dots,K,\ j = 1,\dots,L\} \sim$ Weibull (m_I,γ_I), in contrast with the typical Rayleigh or Nakagami fading. The shorthand $X \sim$ Weibull (m,γ) means that the RV X is Weibull distributed with parameters m and γ, for which the probability density function (PDF), $f_X(x)$, is given by

$$f_X(x) = \frac{m}{\gamma}x^{m-1}\exp\left(-\frac{x^m}{\gamma}\right) \tag{3}$$

and the cumulative distribution function (CDF), $F_X(x)$, is

$$F_X(x) = 1-\exp\left(-\frac{x^m}{\gamma}\right). \tag{4}$$

Assuming that coherent detection is employed, the decision statistic for the desired user data symbol $a[0]$ on the jth branch is given by [4] as follows:

$$D_j[0] = \sqrt{\frac{P_0T}{2}}a[0]R_{0,j} + \sum_{i=1}^{K}\sqrt{\frac{PT}{2}}R_{i,j}\cos\phi_{i,j}\rho_i, \tag{5}$$

where $\phi_{i,j} = \theta_{i,j} - \omega_c\tau_i$ is a uniformly distributed RV over $[0,2\pi)$, $\rho_i = \sum_{k=-\infty}^{\infty} b_i[k]g(-kT-\tau_i)$ and $g(\cdot)$ is the pulse shape at the receiver. The instantaneous SIR of the jth branch is thus straightforwardly found in [4] as follows:

$$\text{SIR}_j = \frac{P_0Z_{0,j}}{\alpha PB} = \frac{P_0Z_{0,j}}{\alpha P\sum_{i=1}^{K}Y_{i,j}}, \tag{6}$$

where $\alpha = 1-\beta/4$, with β being the excess bandwidth of the pulse shapes, $Z_{0,j} = R_{0,j}^2$, and $Y_{i,j} = R_{i,j}^2\cos^2(\phi_{i,j}) = Z_{i,j}\cos^2(\phi_{i,j})$. We define the desired user average SIR as

$$\text{SIR}_{\text{av}} = \frac{P_0\mathbb{E}(R_{0,j}^2)}{\mathbb{E}(R_{i,j}^2)KP} = \frac{P_0\gamma_s^{2/m_s}\Gamma(1+2/m_s)}{\gamma_I^{2/m_I}\Gamma(1+2/m_I)KP}, \tag{7}$$

where $\mathbb{E}(\cdot)$ is the expectation operator and $\Gamma(\cdot)$ is the Gamma function.

3. OUTAGE PROBABILITY ANALYSIS

3.1. Maximum desired signal power criterion

We first consider the case in which the receiver selects the branch with the maximum desired signal power. The SIR at the output of the diversity combiner is thus given by

$$\text{SIR} = \frac{P_0A}{\alpha PB}, \tag{8}$$

where $A = \max(Z_{0,1}, Z_{0,2},\dots,Z_{0,L})$. It is straightforward to show that $\{Z_{0,j},\ j = 1,\dots,L\} \sim$ Weibull $(m_s/2,\gamma_s)$ and, assuming independent and identically distributed (i.i.d.) diversity branches, that the PDF of A is given by

$$\begin{aligned} f_A(a) &= \frac{d}{da}\left[F_Z(a)\right]^L = \frac{m_sL}{2\gamma_s}\left(1-e^{-a^{(m_s/2)}/\gamma_s}\right)^{L-1} \\ &\quad \times a^{m_s/2-1}e^{-a^{(m_s/2)}/\gamma_s} \\ &= \sum_{p=0}^{L-1}(-1)^{L-1-p}\binom{L}{p}f_X(a)\mid_{m\to m_s/2,\gamma\to\gamma_s/(L-p)}, \end{aligned} \tag{9}$$

where $F_Z(a)$ is the CDF of any $Z_{0,j}$ and $\binom{L}{p}$ is the binomial coefficient. In (9), the equation on the second line results from the use of the binomial theorem and $f_X(a)|_{m\to m_s/2,\gamma\to\gamma_s/(L-p)}$ is the standard Weibull PDF in (3) after replacing m by $m_s/2$ and γ by $\gamma_s/(L-p)$. The outage probability can now be calculated as

$$\begin{aligned} P_{\text{out}} = \Pr(\text{SIR} < \gamma_{\text{th}}) &= \int_0^\infty f_A(a)\left[1 - F_B\left(\frac{P_0 a}{\gamma_{\text{th}} P\alpha}\right)\right]da \\ &= \frac{1}{2} + \frac{1}{\pi}\int_0^\infty \frac{\Im(\Phi_B(\omega))\Re(\Phi_A(\omega P_0/\gamma_{\text{th}} P\alpha))}{\omega}d\omega \\ &\quad - \frac{1}{\pi}\int_0^\infty \frac{\Re(\Phi_B(\omega))\Im(\Phi_A(\omega P_0/\gamma_{\text{th}} P\alpha))}{\omega}d\omega, \end{aligned} \tag{10}$$

where $F_B(\cdot)$ is the CDF of B, $\Phi_X(\omega) \triangleq \mathbb{E}(e^{j\omega X})$ is the characteristic function (CF) of the RV X, and $\Re(\cdot)$ and $\Im(\cdot)$ denote the real and imaginary parts, respectively. The second line in the equation above results from the use of the Gil-Pelaez inversion lemma [22] and the fact that the CF is effectively the Fourier transform of the PDF, which is a real function, and hence, its Fourier transform must have an even real part and an odd imaginary one. Now, in order to evaluate (10), $\Phi_A(\omega)$ and $\Phi_B(\omega)$ need to be evaluated. As for $\Phi_A(\omega)$, using (9), it is straightforward to arrive at

$$\Phi_A(\omega) = \sum_{p=0}^{L-1}(-1)^{L-1-p}\binom{L}{p}\mathcal{M}_X\left(\frac{m_s}{2}, \frac{\gamma_s}{L-p}, -j\omega\right), \tag{11}$$

where $\mathcal{M}_X(m,\gamma,s) = \mathbb{E}(e^{-sX})$ is the moment-generating function (MGF) of the RV $X \sim$ Weibull (m,γ), which has been found in closed form in [10, equation (28)] in terms of Meijer's G function, $G_{p,q}^{m,n}(\cdot)$ [23, equation (9.301)] as

$$\begin{aligned} \mathcal{M}_X(m,\gamma,s) &= \frac{m}{\gamma}\frac{(k/\ell)^{1/2}(\ell/s)^m}{(2\pi)^{(\ell+k)/2-1}} \\ &\quad \times G_{\ell,k}^{k,\ell}\left(\frac{1}{\gamma^k s^\ell}\frac{\ell^\ell}{k^k}\,\middle|\, \begin{matrix}\Delta(\ell, 1-m) \\ \Delta(k,0)\end{matrix}\right), \end{aligned} \tag{12}$$

where ℓ and k are the minimum integers chosen such that $m = \ell/k$ and $\Delta(n,\zeta) = \zeta/n, (\zeta+1)/n, \ldots, (\zeta+n-1)/n$. Now, making use of the independence assumptions stated earlier, one can obtain $\Phi_B(\omega)$ as $\Phi_B(\omega) = \prod_{i=1}^K \Phi_{Y_{i,j}}(\omega)$, where $\Phi_{Y_{i,j}}(\omega)$ can be obtained as follows:

$$\begin{aligned} \Phi_{Y_{i,j}}(\omega) &= \mathbb{E}\left(e^{j\omega Z_{i,j}\cos^2(\phi_{i,j})}\right) \\ &= \frac{1}{2\pi}\int_0^{2\pi}\int_0^\infty f_{Z_{i,j}}(z_{i,j})e^{j\omega z_{i,j}\cos^2(\phi_{i,j})}dz_{i,j}\,d\phi_{i,j} \\ &= \frac{1}{2\pi}\int_0^{2\pi}\mathcal{M}_{Z_{i,j}}(-j\omega\cos^2(\phi_{i,j}))d\phi_{i,j}, \end{aligned} \tag{13}$$

where $\mathcal{M}_{Z_{i,j}}(s) = \mathcal{M}_X(m_s/2, \gamma_s, s)$ is the MGF of $Z_{i,j}$. Now, making use of the symmetry of the integral and using the substitution $x = \cos^2(\phi_{i,j})$, one gets

$$\begin{aligned} \Phi_{Y_{i,j}}(\omega) &= \frac{2}{\pi}\int_0^{\pi/2}\mathcal{M}_{Z_{i,j}}(-j\omega\cos^2(\phi_{i,j}))d\phi_{i,j} \\ &= \frac{1}{\pi}\int_0^1 \frac{\mathcal{M}_{Z_{i,j}}(-j\omega x)}{\sqrt{x(1-x)}}dx. \end{aligned} \tag{14}$$

The last integral in the previous equation has finite limits and can be easily evaluated numerically. Furthermore, assuming that $|\arg(-j)^\ell| < ((\ell+k)/2)\pi$, where ℓ and k are the smallest integers such that $m_I = \ell/k$, $\Phi_{Y_{i,j}}(\omega)$ can also be obtained in closed form, using [23, equation (9.31.2)] followed by [24, equation (2.24.2.2)], as

$$\begin{aligned} &\Phi_{Y_{i,j}}(\omega) \\ &= \frac{m_I^{1/2}\ell^{(m_I-1)/2}}{2^{(\ell+k)/2}\pi^{(\ell+k-1)/2}\gamma_I(-j\omega)^{m_I/2}} \\ &\times G_{\ell+k,2\ell}^{\ell,\ell+k}\left(\frac{(\gamma_I k)^k}{(-j\omega/\ell)^{-\ell}}\,\middle|\, \begin{matrix}\Delta\left(\ell, \frac{m_I+1}{2}\right), \Delta(1, 1-\Delta(k,0)) \\ \Delta\left(1, 1-\Delta\left(\ell, 1-\frac{m_I}{2}\right)\right), \Delta\left(\ell, \frac{m_I}{2}\right)\end{matrix}\right). \end{aligned} \tag{15}$$

Now, the outage probability can be calculated using (10) in conjunction with (11) and either (13) or (15).

3.2. Maximum SIR criterion

We now consider the scenario in which the receiver selects the branch with the maximum SIR. Again, assuming i.i.d. diversity branches, the outage probability is given by

$$\begin{aligned} P_{\text{out}} &= \Pr(\max\{\text{SIR}_1, \ldots, \text{SIR}_L\} < \gamma_{\text{th}}) \\ &= [\Pr(\text{SIR}_j < \gamma_{\text{th}})]^L. \end{aligned} \tag{16}$$

The probability $\Pr(\text{SIR}_j < \gamma_{\text{th}})$ is exactly given by (10) after replacing the RV A with the RV $Z_{0,j}$ and noting that $\Phi_{Z_{0,j}}(\omega) = \mathcal{M}_X(m_s/2, \gamma_s, -j\omega)$.

It is worth mentioning that the integrals in this paper, which involve Meijer's G function, can be calculated using any software package having Meijer's G function as a built-in routine. It is also possible to approximately compute these integrals in a very efficient manner by approximating the MGF of the Weibull RV by a rational function using Padé approximation [25–27].

4. NUMERICAL AND SIMULATION RESULTS

The results of the numerical evaluation of the outage probability expressions in this paper are presented in this section. For all our results, we assume that $\beta = 1$ and $\text{SIR}_{\text{av}} = 15$ dB. Results obtained via Monte Carlo simulations are also shown for comparison purposes.

In Figure 1, $m_s = m_I = 2$ and the outage probability obtained from our analysis is plotted for different number of diversity branches versus the threshold γ_{th}. We note that there is an excellent agreement between the numerical results

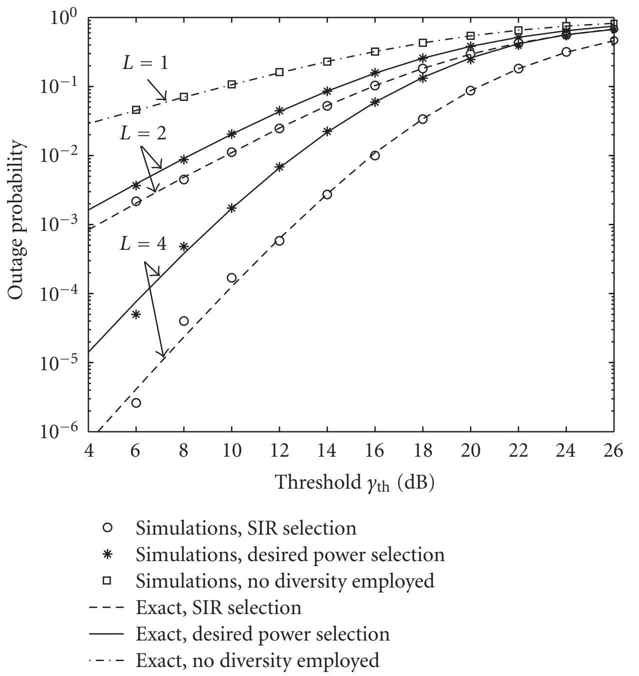

Figure 1: The effect of the number of diversity branches of the SC receiver on the outage probability for $m_s = m_I = 2$, $K = 2$, $\beta = 1$, and $\text{SIR}_{\text{av}} = 15$ dB.

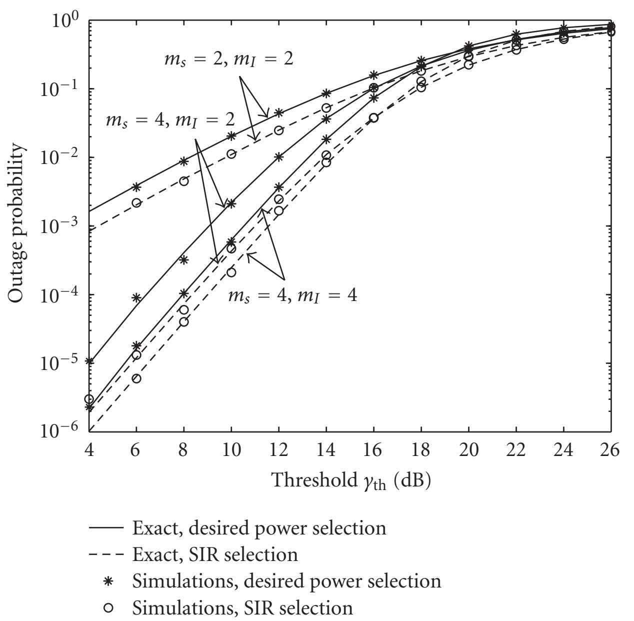

Figure 2: The effect of changing the values of m_s and m_I on the performance of the SC receiver with $L = 2$, $K = 2$, $\beta = 1$, and $\text{SIR}_{\text{av}} = 15$ dB.

and Monte Carlo simulations thus proving the validity of our expressions. It is also clear that the maximum SIR selection criterion outperforms the maximum desired power selection criterion. For $L = 2$, the improvement is about 2 dB and then it increases to about 4 dB as L is increased to 4. Also, the no diversity case is depicted for reference and the enhancement compared to the no diversity case is evident from the figure.

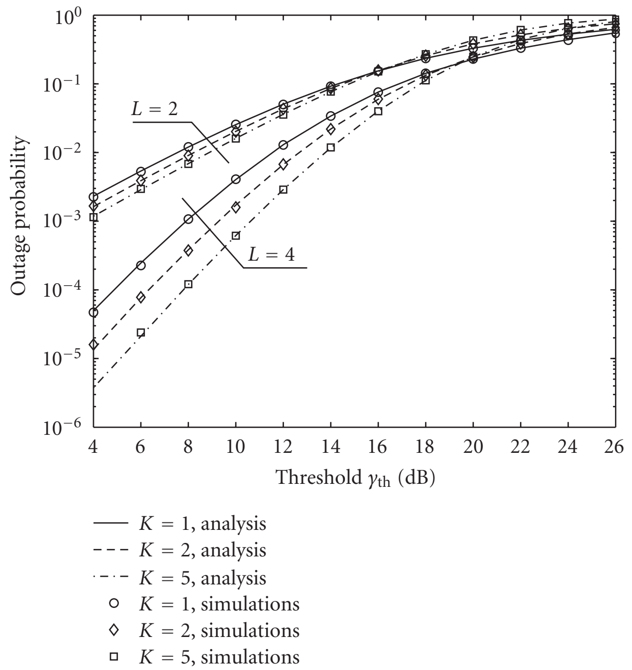

Figure 3: The effect of changing the number of interferers on the performance of the SC receiver employing the maximum desired signal power criterion with $m_s = m_I = 2$, $\beta = 1$, and $\text{SIR}_{\text{av}} = 15$ dB.

In Figure 2, the effect of changing m_s and m_I is investigated and simulation results are again presented. We note that increasing m_s from 2 to 4 while keeping m_I fixed at 2 results in an improvement in the performance. This is quite expected since increasing the value of the fading parameter is interpreted as a decrease in the degree of severity of the desired signal fading channel. Also, we note that increasing m_I from 2 to 4 while keeping m_s fixed at 4 leads to an improvement in the performance as well. A similar observation has been reported earlier for the Nakagami fading channel in [21] in which a physical explanation related to the upconcavity of the Q-function has been also given. This explanation still holds for the Weibull fading channel and will not be repeated here.

Figure 3 depicts the outage probability evaluated for the case of $m_s = m_I = 2$ with $L = 2$ and 4 and for different number of interferers. The SC receiver is assumed to employ the maximum desired signal power criterion. We note an interesting behavior; for threshold values less than $\simeq$ 16 dB for $L = 2$ and less than $\simeq$ 19 dB for $L = 4$, as the number of interferers increases, the outage probability starts to decrease. However, as γ_{th} starts to increase beyond the aforementioned values, the outage probability starts to increase with the increase in the number of interferers. We again investigate the effect of the number of interferers in Figure 4, but when the SC receiver is employing the maximum SIR selection criterion. It is clear that, over the usual practical range of interest for γ_{th}, the outage probability increases as the number of interferers increases.

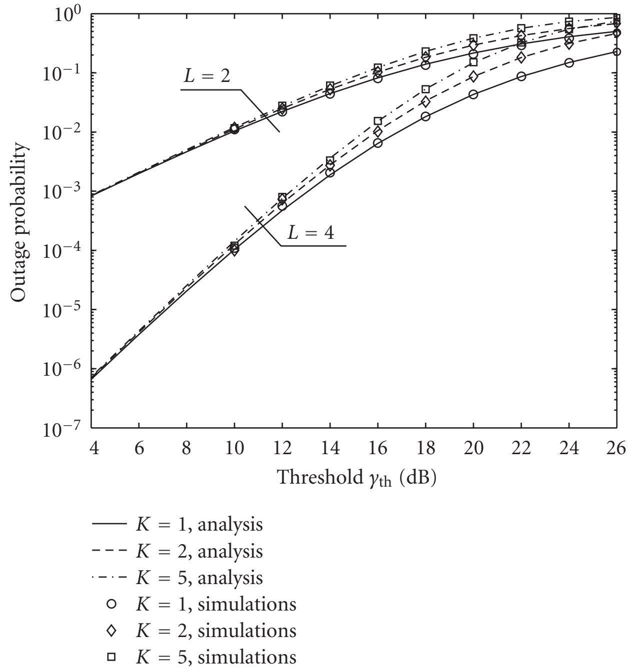

Figure 4: The effect of changing the number of interferers on the performance of the SC receiver employing the maximum SIR criterion with $m_s = m_I = 2$, $\beta = 1$ and $\text{SIR}_{\text{av}} = 15$ dB.

5. CONCLUSIONS

In this paper, we derived analytical expressions for the outage probability of the SC diversity scheme operating in a cellular network over a Weibull/Weibull fading environment. We adopted a CF-based approach to reach our goal. Numerical results were presented and the validity of our expressions has been verified using results from Monte Carlo simulations. We compared two different selection criteria that can be employed at the diversity receiver: the maximum desired signal power and the maximum output SIR. Based on our presented results, the maximum SIR criterion provides a significant gain in performance when compared to the maximum desired signal power criterion, with the improvement more pronounced as the number of diversity branches increases. We also investigated the effect of changing the values of the fading parameters of the desired as well as interfering signals, the number of interferers, and the number of diversity branches on the performance.

REFERENCES

[1] M. K. Simon and M. S. Alouini, *Digital Communication over Fading Channels*, John Wiley & Sons, Hoboken, NJ, USA, 2005.

[2] A. A. Abu-Dayya and N. C. Beaulieu, “Diversity MPSK receivers in cochannel interference,” *IEEE Transactions on Vehicular Technology*, vol. 48, no. 6, pp. 1959–1965, 1999.

[3] H. Yang and M.-S. Alouini, “Outage probability of dual-branch diversity systems in presence of co-channel interference,” *IEEE Transactions on Wireless Communications*, vol. 2, no. 2, pp. 310–319, 2003.

[4] K. Sivanesan and N. C. Beaulieu, “Precise outage analysis of selection diversity in bandlimited micro-cellular systems with cochannel interference,” in *Proceedings of 62nd IEEE Vehicular Technology Conference (VTC ’05)*, pp. 1494–1498, Dallas, Tex, USA, September 2005.

[5] N. H. Shepherd, “Radio wave loss deviation and shadow loss at 900 MHz,” *IEEE Transactions on Vehicular Technology*, vol. 26, no. 4, pp. 309–313, 1977.

[6] H. Hashemi, “Indoor radio propagation channel,” *Proceedings of the IEEE*, vol. 81, no. 7, pp. 943–968, 1993.

[7] “Coverage prediction for mobile radio systems operating in the 800/900 MHz frequency range,” *IEEE Transactions on Vehicular Technology*, vol. 37, no. 1, pp. 3–72, 1988.

[8] G. Tzeremes and C. G. Christodoulou, “Use of Weibull distribution for describing outdoor multipath fading,” in *Proceedings of IEEE Antennas and Propagation Society International Symposium (APS ’02)*, vol. 1, pp. 232–235, San Antonio, Tex, USA, June 2002.

[9] G. L. Siqueira and E. J. A. Vásquez, “Local and global signal variability statistics in a mobile urban environment,” *Wireless Personal Communications*, vol. 15, no. 1, pp. 61–78, 2000.

[10] N. C. Sagias, D. A. Zogas, G. K. Karagiannidis, and G. S. Tombras, “Channel capacity and second-order statistics in Weibull fading,” *IEEE Communications Letters*, vol. 8, no. 6, pp. 377–379, 2004.

[11] M.-S. Alouini and M. K. Simon, “Performance of generalized selection combining over Weibull fading channels,” in *Proceedings of 54th IEEE Vehicular Technology Conference (VTC ’01)*, vol. 3, pp. 1735–1739, Atlantic City, NJ, USA, October 2001.

[12] N. C. Sagias, D. A. Zogas, G. K. Karagiannidis, and G. S. Tombras, “Performance analysis of switched diversity receivers in Weibull fading,” *Electronics Letters*, vol. 39, no. 20, pp. 1472–1474, 2003.

[13] N. C. Sagias, P. T. Mathiopoulos, and G. S. Tombras, “Selection diversity receivers in Weibull fading: outage probability and average signal-to-noise ratio,” *Electronics Letters*, vol. 39, no. 25, pp. 1859–1860, 2003.

[14] N. C. Sagias, G. K. Karagiannidis, D. A. Zogas, P. T. Mathiopoulos, and G. S. Tombras, “Performance analysis of dual selection diversity in correlated Weibull fading channels,” *IEEE Transactions on Communications*, vol. 52, no. 7, pp. 1063–1067, 2004.

[15] G. K. Karagiannidis, D. A. Zogas, N. C. Sagias, S. A. Kotsopoulos, and G. S. Tombras, “Equal-gain and maximal-ratio combining over nonidentical Weibull fading channels,” *IEEE Transactions on Wireless Communications*, vol. 4, no. 3, pp. 841–846, 2005.

[16] M. H. Ismail and M. M. Matalgah, “Performance of dual maximal ratio combining diversity in nonidentical correlated Weibull fading channels using Padé approximation,” *IEEE Transactions on Communications*, vol. 54, no. 3, pp. 397–402, 2006.

[17] M. H. Ismail and M. M. Matalgah, “On the use of Padé approximation for performance evaluation of maximal ratio combining diversity over Weibull fading channels,” *EURASIP Journal on Wireless Communications and Networking*, vol. 2006, Article ID 58501, 7 pages, 2006.

[18] M. H. Ismail and M. M. Matalgah, “BER analysis of diversity M-PSK receivers over the Weibull fading channel with cochannel interference,” in *Proceedings of IEEE International Conference on Communications (ICC ’06)*, vol. 11, pp. 5134–5139, Istanbul, Turkey, June 2006.

[19] N. C. Sagias, D. A. Zogas, and G. K. Karagiannidis, "Selection diversity receivers over nonidentical Weibull fading channels," *IEEE Transactions on Vehicular Technology*, vol. 54, no. 6, pp. 2146–2151, 2005.

[20] M. H. Ismail and M. M. Matalgah, "Downlink outage probability analysis in cellular systems with Weibull faded lognormal-shadowed links," *IEE Proceedings: Communications*, vol. 153, no. 6, pp. 949–954, 2006.

[21] N. C. Beaulieu and J. Cheng, "Precise error-rate analysis of bandwidth-efficient BPSK in Nakagami fading and cochannel interference," *IEEE Transactions on Communications*, vol. 52, no. 1, pp. 149–158, 2004.

[22] J. Gil-Pelaez, "Note on the inversion theorem," *Biometrika*, vol. 38, no. 3-4, pp. 481–482, 1951.

[23] I. S. Gradshteyn and I. M. Ryzhik, *Table of Integrals, Series and Products*, Academic Press, San Diego, Calif, USA, 2000.

[24] A. P. Prudinikov, Yu. A. Brychkov, and O. I. Marichev, *Integrals and Series, Volume 3: More Special Functions*, Gordon and Breach Science, Amsterdam, The Netherlands, 1990.

[25] S. P. Suetin, "Padé approximants and efficient analytic continuation of a power series," *Russian Mathematical Surveys*, vol. 57, no. 1, pp. 43–141, 2002.

[26] H. Amindavar and J. A. Ritcey, "Padé approximations of probability density functions," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 30, no. 2, pp. 416–424, 1994.

[27] G. K. Karagiannidis, "Moments-based approach to the performance analysis of equal gain diversity in Nakagami-*m* fading," *IEEE Transactions on Communications*, vol. 52, no. 5, pp. 685–690, 2004.