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Comments on "Average LCR and AFD for SC diversity over correlated Weibull fading channels"

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Abstract In a recent paper, two formulae for the average level crossing rate and fade duration at the output of dual-branch selection diversity receivers have been derived. In this short communication, some previously published works including results being in a more general setting are reviewed and compared.

Keywords Average fade duration (AFD) · Level crossing rate (LCR) · Selection combining (SC) · Weibull fading channels

In [1], closed-form expressions for the average level crossing rate (LCR) and the average fade duration (AFD) of dual-branch selection combining (SC) receivers are presented. The analysis includes both correlated[1] as well as independent Weibull fading channels. For the former case, by considering a different bivariate Weibull stochastic model than that in [1], Costa et al. have studied the second order statistics of SC receivers [2]. Moreover for the latter case, more generic formulae for both the average LCR and AFD, than corresponding ones in [1], have been considered in [3,4]. Next, the average LCR and AFD expressions for independent fading are presented and compared to those in [1].

Let R_ℓ be the magnitude of the instantaneous Weibull fading channel envelope in the ℓth diversity input of an L-branch SC receiver ($\ell = 1, 2, \ldots, L$) having probability density function

$$f_{R_\ell}(r) = \frac{\beta_\ell}{\Omega_\ell} r^{\beta_\ell - 1} \exp\left(-\frac{r^{\beta_\ell}}{\Omega_\ell}\right) \qquad (1)$$

with $\Omega_\ell = \mathbb{E}\langle R_\ell^{\beta_\ell}\rangle$ ($\mathbb{E}\langle\cdot\rangle$ denoting expectation) being a scaling parameter related to the average fading power as $\mathbb{E}\langle R_\ell^2\rangle = \Omega_\ell^{2/\beta_\ell}\,\Gamma(1 + 2/\beta_\ell)$ ($\Gamma(\cdot)$ is the well-known Gamma function) and $\beta_\ell > 0$ being the fading parameter expressing the fading severity. Let also R_{sc} be the magnitude of the instantaneous output fading envelope of the SC receiver, i.e., $R_{\mathrm{sc}} = \max\{R_\ell\}$. For statistically independent R_ℓ's, the average LCR and AFD at the output of

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[1] A typo exists in [1, Citation [14]], where the authors are five and not two.

the SC receiver are[2] [3, Eq. 26], [4, Eq. 17]

$$\mathcal{N}_{R_{\mathrm{sc}}}(r) = \sqrt{2\pi}\, f_d \sum_{i=1}^{L} \frac{r^{\beta_i/2}}{\sqrt{\Omega_i}} \exp\left(-\frac{r^{\beta_i}}{\Omega_i}\right) \times \prod_{\substack{k=1\\k\neq i}}^{L} \left[1 - \exp\left(-\frac{r^{\beta_k}}{\Omega_k}\right)\right] \tag{2}$$

and [3, Eq. 27]

$$\mathcal{T}_{R_{\mathrm{sc}}}(r) = \frac{\prod_{k=1}^{L}\left[1-\exp\left(-\frac{r^{\beta_k}}{\Omega_k}\right)\right]}{\sqrt{2\pi}\, f_d \sum\limits_{i=1}^{L} \frac{r^{\beta_i/2}}{\sqrt{\Omega_i}} \exp\left(-\frac{r^{\beta_i}}{\Omega_i}\right) \prod\limits_{\substack{k=1\\k\neq i}}^{L} \left[1-\exp\left(-\frac{r^{\beta_k}}{\Omega_k}\right)\right]} \tag{3}$$

respectively, with f_d being the Doppler frequency shift. The average LCR expression in [1, Eq. 27] seems not to be correct, since for the specific case where $L = 2$, $\beta_\ell = \beta$, $\Omega_\ell = \omega_\ell^\beta$, and $\rho = r/\omega_2 = 2\,r/\omega_1$, Eq. 2 clearly does not agree with [1, Eq. 27]. Moreover, since [1, Eq. 27] is used to derive the AFD, [1, Eq. 29] is also not correct. The incorrect results of [1] stem from the fact that, contrary to [1, Eq. 22], the variance of the time derivative of R_ℓ, $\dot{R}_\ell$, is constant only when conditioned on R_ℓ [4, Eq. 12], [5, Eq. 9]

$$\sigma^2_{\dot{R}_\ell} = \frac{4}{\beta_\ell^2} R_\ell^{2-\beta_\ell}\, \sigma^2_{R_\ell} \tag{4}$$

where $\sigma^2_{R_\ell}$ stands for the variance of R_ℓ, $\sigma^2_{R_\ell} = \Omega_\ell\, \pi^2 f_d^2$.

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Nikos C. Sagias was born in Athens, Greece in 1974. He received the BSc degree from the Department of Physics (DoP) of the University of Athens (UoA), Greece in 1998. The MSc and PhD degrees were received, in 2000 and 2005, respectively, in Telecommunication Engineering from the same university. Since 2001, he has been cooperating with the Laboratory of Electronics of the DoP, while at the same time, he has been involved in various National and European Research and Development projects for the Institute of Space Applications and Remote Sensing of National Observatory of Athens, Greece. In 2006, he joined the National Centre for Scientific Research–"Demokritos," where currently, he is a research associate at the Laboratory of Mobile Communications of the Institute of Informatics and Telecommunications. Dr. Sagias current research interests include topics such as wireless communications, MIMO systems, fading channels, and communication theory. He has authored and/or coauthored over twenty (25) papers in prestigious international journals and more than fifteen (15) in worlds recognized conferences. Since 2006, he has been included in the Editorial Board of the *AEU International Journal of Electronics and Communications*. Additionally, he is a member of the IEEE and the Hellenic Physicists Association, while he acts as a reviewer for several world recognized international journals (*IEEE Transactions*, *Electronics Letters*, *Wireless Personal Communications*, etc) and IEEE conferences.

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[2] A minor typo in [3, Eqs. 26 and 27] and [4, Eq. 17] is that a square root is needed for the first Ω_i just after the summation symbol (just as in Eqs. 2 and 3).

George K. Karagiannidis was born in Pithagorion, Samos Island, Greece. He received his university degree in 1987 and his Ph.D degree in 1999, both in Electrical Engineering, from the University of Patras, Patras, Greece. From 2000 to 2004 he was Researcher at the Institute for Space Applications and Remote Sensing, National Observatory of Athens, Greece. In June 2004, he joined the faculty of Aristotle University of Thessaloniki, Greece where he is currently an Assistant Professor at the Electrical and Computer Engineering Department. His major research interests include wireless communications theory, digital communications over fading channels, cooperative diversity systems, satellite communications and free-space optical communications. He has published and presented more than 70 technical papers in scientific journals and international conferences, he is co-author in two chapters in books and also co-author in a Greek Edition Book on Mobile Communications. Dr. Karagiannidis served as Technical program Committee Member for several IEEE conferences. He is a Senior Member of the IEEE and a member of the editorial boards of *IEEE Transactions on Communications*, *IEEE Communications Letters* and *EURASIP Journal on Wireless Communications and Networking*.