FACTA UNIVERSITATIS
Series: **Automatic Control and Robotics** Vol. 11, N° 1, 2012, pp. 37 - 43

AVERAGE OUTPUT SIGNAL-TO-INTERFERENCE RATIO OF SYSTEM WITH TRIPLE-BRANCH SELECTION COMBINING BASED ON DESIRED SIGNAL ALGORITHM OVER CORRELATED WEIBULL FADING CHANNELS [*]

UDC 621.396.94 621.395.38 621.391.8

Nikola Sekulović[1], Aleksandra Golubović[2],
Časlav Stefanović[2], Mihajlo Stefanović[2]

[1]School of Higher Technical Professional Education, Niš, Serbia
[2]University of Niš, Faculty of Electronic Engineering, Serbia

Abstract. *This paper analyzes system performance of triple-branch selection combining (SC) diversity operating over correlated Weibull fading channels based on desired signal algorithm. Average output signal-to-interference ratio (SIR) is used as system performance measure. Numerical results are graphically presented to show the influence of fading severity, correlation coefficient and average input SIR on the diversity receiver performance. The results are also compared to the results obtained using SIR based algorithm.*

Key words: *average output SIR, co-channel interference, correlated Weibull fading channels, desired signal algorithm, selection diversity*

1. INTRODUCTION

Fading and co-channel interference (CCI) pose limitation to wireless communication system performance. Fading is the result of multipath propagation and CCI is the result of frequency reuse. Depending on the propagation environment, many fading models can be used to describe the fading envelope. The most frequently used are Rayleigh, Rician, Nakagami-*m* and Weibull model. Although less used comparing to other models, Weibull distribution is simple and flexible and it shows good results in urban area when Rayleigh distribution is not adequate [1].

Received June 3, 2012

Corresponding author: Nikola Sekulović
School of Higher Technical Professional Education, Aleksandra Medvedeva 20, 18000 Niš, Serbia
E-mail: sekulani@gmail.com

[*] **Acknowledgement**. This work was supported in part by the Ministry of Science of Serbia within the projects TR-32051, TR-32052 and III-44006.

Diversity techniques are a powerful tool for mitigating the destructive impact of fading and CCI. They are based on simultaneous reception of the same radio signal over two or more paths to increase the overall signal-to-noise ratio (SNR) [2]. The diversity paths can be based on space, frequency and/or time diversity and diversity techniques require some redundancy in time, frequency or spatial domain. Space diversity combines input signals from multiple receive antennas [3] and it is power and bandwidth efficient compared to other diversity techniques. It also represents the most common form of diversity [4]. There are several principal types of space diversity combining techniques which essentially depend on the complexity restrictions put on the communication system and the amount of channel state information (CSI) available at the receiver [5].

The most popular are maximal-ratio combining (MRC), equal-gain combining (EGC) and selection combining (SC). SC diversity is the least complicated for practical realization. In interference-limited environment, SC receiver can employ one of the combining algorithms: the desired signal algorithm, the total signal algorithm and the signal-to-interference ratio (SIR) algorithm. In the desired signal algorithm, the SC combiner selects the branch with the largest desired signal power. This requires the desired signal and interfering signals to be identified and separated, and may be difficult to implement in practice [6]. The total signal algorithm selects the diversity branch with highest total power (desired signal and interference), which is easiest to realise in practise. The SIR algorithm selects the branch with highest SIR. This algorithm usually provides the best performance of interference-limited systems [7].

In papers [8]-[11], the SC diversity system exposed to CCI and Weibull fading was considered. The case of SC diversity system when diversity branches are placed sufficiently apart, thus having no correlation, was considered in [8]. However, in practice, due to insufficient spacing between antennas when diversity is applied on small terminals, correlation between diversity branches exists. Studies investigating performance of dual-branch, triple-branch and *L*-branch SC diversity operating over correlated Weibull fading channels applying SIR based algorithm were reported in [9], [10] and [11], respectively. Average bit error probability (ABEP) of triple-branch SC diversity system applying desired signal algorithm was calculated in [12]. This paper is an extension of our efforts presented in paper [12]. Numerically evaluated results for the average SIR at the output of considered system are presented to show the effect of the average input SIR, fading severity and correlation coefficient on the systems performance. In addition, the desired signal algorithm and SIR algorithm are compared using previously published results in [10].

2. SYSTEM AND CHANNEL MODEL

We consider triple-branch SC diversity operating in Weibull fading environment. Both desired signal and CCI envelopes follow correlated Weibull distribution with joint probability density functions (PDFs) [1, eq. (23) for L=3]:

$$
\begin{aligned}
p_{x_1x_2x_3}(x_1,x_2,x_3) &= \frac{\beta^3}{\Omega_{d_1}\Omega_{d_2}\Omega_{d_3}(1-\rho)^2}\exp\left\{-\frac{1}{1-\rho}\left[\frac{x_1^{\beta}}{\Omega_{d_1}}+\frac{x_3^{\beta}}{\Omega_{d_3}}+\frac{(1+\rho)x_2^{\beta}}{\Omega_{d_2}}\right]\right\} \\
&\times \sum_{k_1,k_2=0}^{\infty}\left[\frac{\sqrt{\rho}}{\sqrt[3]{\Omega_{d_1}\Omega_{d_2}\Omega_{d_3}}(1-\rho)}\right]^{2(k_1+k_2)}\frac{x_1^{(k_1+1)\beta-1}x_3^{(k_2+1)\beta-1}x_2^{(k_1+k_2+1)\beta-1}}{\left(k_1!k_2!\right)^2}
\end{aligned}
\tag{1}
$$

$$
\begin{aligned}
p_{y_1y_2y_3}(y_1,y_2,y_3) &= \frac{\beta^3}{\Omega_{c_1}\Omega_{c_2}\Omega_{c_3}(1-\rho)^2}\exp\left\{-\frac{1}{1-\rho}\left[\frac{y_1^{\beta}}{\Omega_{c_1}}+\frac{y_3^{\beta}}{\Omega_{c_3}}+\frac{(1+\rho)y_2^{\beta}}{\Omega_{c_2}}\right]\right\} \\
&\times \sum_{l_1,l_2=0}^{\infty}\left[\frac{\sqrt{\rho}}{\sqrt[3]{\Omega_{c_1}\Omega_{c_2}\Omega_{c_3}}(1-\rho)}\right]^{2(l_1+l_2)}\frac{y_1^{(l_1+1)\beta-1}y_3^{(l_2+1)\beta-1}y_2^{(l_1+l_2+1)\beta-1}}{\left(l_1!l_2!\right)^2}.
\end{aligned}
\tag{2}
$$

In these equations, ρ represents correlation coefficient and β represents Weibull fading parameter (β>0) which indicates fading severity (for the special case of $\beta = 2$, Weibull distribution becomes Rayleigh). $\Omega_{di} = \overline{x_i^{\beta}}$ and $\Omega_{ci} = \overline{y_i^{\beta}}$ represent the average powers of desired and interference signal at i-th branch $(i = \overline{1,3})$, respectively.

Joint PDF of envelopes of desired signal and CCI at the output of triple-branch SC receiver based on desired signal algorithm can be calculated using the following equation:

$$
\begin{aligned}
p_{xy}(x,y) &= \int_0^x\int_0^\infty\int_0^x\int_0^\infty p_{x_1x_2x_3}(x,x_2,x_3)p_{y_1y_2y_3}(y,y_2,y_3)dx_2dy_2dx_3dy_3 \\
&+\int_0^x\int_0^\infty\int_0^x\int_0^\infty p_{x_1x_2x_3}(x_1,x,x_3)p_{y_1y_2y_3}(y_1,y,y_3)dx_1dy_1dx_3dy_3 \\
&+\int_0^x\int_0^\infty\int_0^x\int_0^\infty p_{x_1x_2x_3}(x_1,x_2,x)p_{y_1y_2y_3}(y_1,y_2,y)dx_1dy_1dx_2dy_2.
\end{aligned}
\tag{3}
$$

The PDF of instantaneous SIR at the output of triple-branch SC diversity system, $z=x/y$, can be calculated as:

$$
p_{z_{SC}}(z) = \int_0^\infty y p_{xy}(zy,y)dy. \tag{4}
$$

After some mathematical transformations, using [13] the PDF of instantaneous SIR at the output of triple-branch SC diversity system can be written as [12, eq. (6)]:

$$
\begin{aligned}
p_{z_{SC}}(z) = & \sum_{k_1,k_2=0}^{\infty} M_{1,2} \frac{z^{(k_1+1)\beta-1}}{\Omega_{c_1}} \left(\frac{\Omega_{d2}}{B}\right)^{k_1+k_2+1} \left(\frac{\Omega_{d3}}{A}\right)^{k_2+1} (k_1+k_2)!k_2! \\
& \times \Bigg[\frac{\Gamma(k_1+2)}{\beta\left(\frac{1}{\Omega_{c_1}}+\frac{A}{\Omega_{d1}}z^{\beta}\right)^{k_1+2}} - \sum_{m=0}^{k_1+k_2} \frac{1}{m!}\left(\frac{B}{\Omega_{d2}}z^{\beta}\right)^{m} \frac{\Gamma(k_1+m+2)}{\beta\left(\left(\frac{1}{\Omega_{c_1}}+\frac{A}{\Omega_{d1}}z^{\beta}+\frac{Bz^{\beta}}{\Omega_{d2}}z^{\beta}\right)\right)^{k_1+m+2}} \\
& - \sum_{n=0}^{k_2} \frac{1}{n!}\left(\frac{A}{\Omega_{d3}}z^{\beta}\right)^{n} \frac{\Gamma(k_1+n+2)}{\beta\left(\frac{1}{\Omega_{c_1}}+Az^{\beta}\left(\frac{1}{\Omega_{d1}}+\frac{1}{\Omega_{d3}}\right)\right)^{k_1+n+2}} \\
& + \sum_{m=0}^{k_1+k_2} \frac{1}{m!}\left(\frac{B}{\Omega_{d2}}z^{\beta}\right)^{m} \sum_{n=0}^{k_2} \frac{1}{n!}\left(\frac{A}{\Omega_{d3}}z^{\beta}\right)^{n} \frac{\Gamma(k_1+m+n+2)}{\beta\left(\frac{1}{\Omega_{c_1}}+\frac{A}{\Omega_{d1}}z^{\beta}+Az^{\beta}\left(\frac{(1+\rho)}{\Omega_{d2}}+\frac{1}{\Omega_{d3}}\right)\right)^{k_1+m+n+2}} \Bigg] \\
& + \sum_{k_3,k_4=0}^{\infty} \frac{z^{(k_3+k_4+1)\beta-1}}{\Omega_{c_2}} \left(\frac{\Omega_{d1}}{A}\right)^{k_3+1} \left(\frac{\Omega_{d3}}{A}\right)^{k_4+1} k_3!k_4! \\
& \times \Bigg[\frac{\Gamma(k_3+k_4+2)}{\beta\left(\frac{1}{\Omega_{c_2}}+\frac{B}{\Omega_{d2}}z^{\beta}\right)^{k_3+k_4+2}} - \sum_{i=0}^{k_3} \frac{1}{i!}\left(\frac{A}{\Omega_{d1}}z^{\beta}\right)^{i} \frac{\Gamma(k_3+k_4+i+2)}{\beta\left(\frac{1}{\Omega_{c_2}}+\frac{B}{\Omega_{d2}}z^{\beta}+\frac{A}{\Omega_{d1}}z^{\beta}\right)^{k_3+k_4+i+2}} \\
& - \sum_{j=0}^{k_4} \frac{1}{j!}\left(\frac{A}{\Omega_{d3}}z^{\beta}\right)^{j} \frac{\Gamma(k_3+k_4+j+2)}{\beta\left(\frac{1}{\Omega_{c_2}}+\frac{B}{\Omega_{d2}}z^{\beta}+\frac{A}{\Omega_{d3}}z^{\beta}\right)^{k_3+k_4+j+2}} \\
& + \sum_{i=0}^{k_3} \frac{1}{i!}\left(\frac{A}{\Omega_{d1}}z^{\beta}\right)^{i} \sum_{j=0}^{k_4} \frac{1}{j!}\left(\frac{A}{\Omega_{d3}}z^{\beta}\right)^{j} \frac{\Gamma(k_3+k_4+i+j+2)}{\beta\left(\frac{1}{\Omega_{c_2}}+\frac{B}{\Omega_{d2}}z^{\beta}+z^{\beta}A\left(\frac{1}{\Omega_{d1}}+\frac{1}{\Omega_{d3}}\right)\right)^{k_3+k_4+i+j+2}} \Bigg] \\
& + \sum_{k_5,k_6=0}^{\infty} M_{5,6} \frac{z^{(k_6+1)\beta-1}}{\Omega_{c_3}} \left(\frac{\Omega_{d1}}{A}\right)^{k_5+1} \left(\frac{\Omega_{d2}}{B}\right)^{k_5+k_6+1} k_5!(k_5+k_6)!
\end{aligned}
$$

$$\begin{aligned}&\times\left[\frac{\Gamma\left(k_6+2\right)}{\beta\left(\frac{1}{\Omega_{c_3}}+\frac{A}{\Omega_{d3}}z^{\beta}\right)^{k_6+2}}-\sum_{p=0}^{k_5}\frac{1}{p!}\left(\frac{A}{\Omega_{d1}}z^{\beta}\right)^{p}\frac{\Gamma(k_6+p+2)}{\beta\left(\frac{1}{\Omega_{c_3}}+\frac{A}{\Omega_{d3}}z^{\beta}+\frac{A}{\Omega_{d1}}z^{\beta}\right)^{k_6+p+2}}\right.\\&-\sum_{q=0}^{k_5+k_6}\frac{1}{q!}\left(\frac{B}{\Omega_{d2}}z^{\beta}\right)^{q}\frac{\Gamma(k_6+q+2)}{\beta\left(\frac{1}{\Omega_{c_3}}+\frac{A}{\Omega_{d3}}z^{\beta}+\frac{B}{\Omega_{d2}}z^{\beta}\right)^{k_6+q+2}}\\&\left.+\sum_{p=0}^{k_5}\frac{1}{p!}\left(\frac{A}{\Omega_{d1}}z^{\beta}\right)^{p}\sum_{q=0}^{k_5+k_6}\frac{1}{q!}\left(\frac{B}{\Omega_{d2}}z^{\beta}\right)^{q}\frac{\Gamma(k_6+p+q+2)}{\beta\left(\frac{1}{\Omega_{c_3}}+\frac{A}{\Omega_{d3}}z^{\beta}+z^{\beta}\left(\frac{A}{\Omega_{d1}}+\frac{B}{\Omega_{d2}}\right)\right)^{k_6+p+q+2}}\right]\end{aligned}\tag{5}$$

where $M_{i,j}=\sum_{k_i,k_j=0}^{\infty}\frac{\beta}{(1-\rho)^2}\left[\frac{\sqrt{\rho}}{1-\rho}\right]^{2(k_i+k_j)}\frac{1}{(k_i!k_j!)^2}$, $A=\frac{1}{1-\rho}$ and $B=\left(1+\rho\right)A$.

3. AVERAGE OUTPUT SIR

Without loss of generality, this section analyzes the behaviour of balanced triple-branch SC diversity system ($S=\Omega_{d1}/\Omega_{c1}=\Omega_{d2}/\Omega_{c2}=\Omega_{d3}/\Omega_{c3}$) operating over correlated Weibull fading channels in the presence of CCI for two different decision algorithms: desired signal algorithm and SIR algorithm. The average output SIR is one of the accepted and most important performance measures for diversity systems operating in fading environment. It can be evaluated as:

$$\overline{z_{sc}}=\int_0^{\infty}z\cdot p_{z_{SC}}(z)dz.\tag{6}$$

Fig. 1 shows the numerically obtained results for the average output SIR as a function of ρ for different fading severity when the system applies desired signal algorithm as well as SIR based algorithm. The figure shows that the average output SIR decreases as Weibull fading parameter increases. Average output SIR degrades rapidly for higher values of ρ i.e. for smaller spatial separation between receiving antennas in terminals when deep fades in branches occur simultaneously resulting in low improvement degree of considered space diversity. The degradation is more significant for lower values of fading parameter. Fig. 2 demonstrates average output SIR for different values of *S*. It is clear that for higher values of *S* the system performance becomes better. Comparing two algorithms, it is evident from both figures that SIR based algorithm shows better performance.

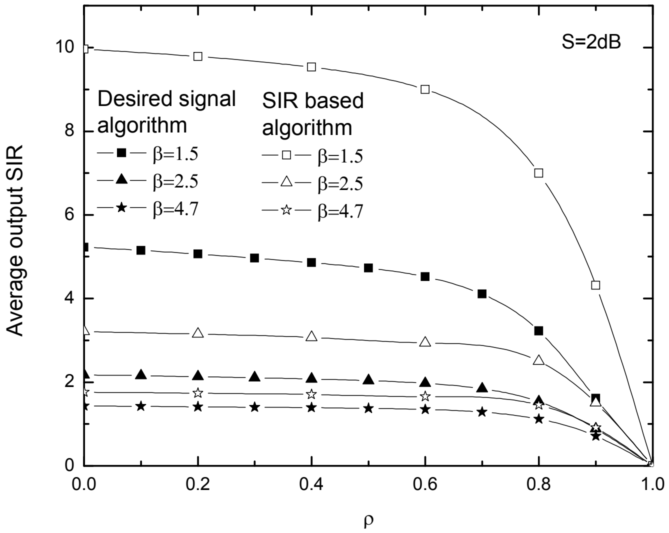

Fig. 1. The influence of Weibull fading parameter on average output SIR

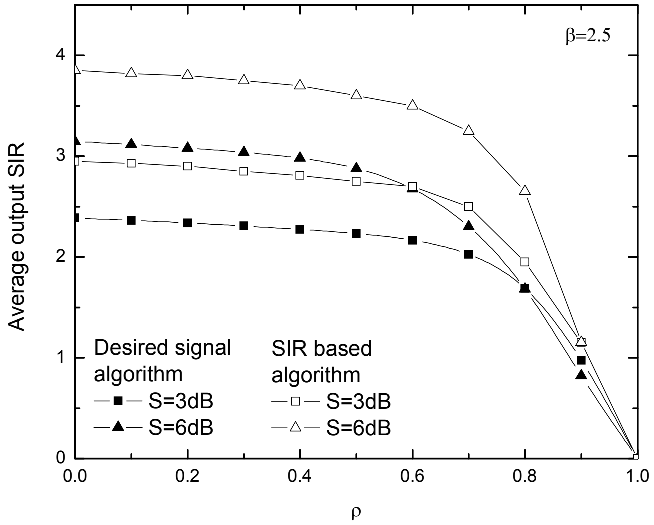

Fig. 2. The influence of average input SIR on average output SIR

5. CONCLUSIONS

In this paper, the performance of triple-branch SC receiver operating over correlated Weibull fading channels in the presence of Weibull distributed CCI for the case when desired signal decision algorithm is applied was studied. Using the expression for the PDF of the instantaneous SIR at the SC combiner output, average output SIR was evaluated. The results were compared to the results obtained using SIR based algorithm showing that the overall system performance is better in the case of SIR based algorithm.

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SREDNJA VREDNOST ODNOSA SIGNAL-INTERFERENCIJA NA IZLAZU SISTEMA SA TRI GRANE I SELEKTIVNIM KOMBINOVANJEM KOJE JE ZASNOVANO NA KORISNOM SIGNAL U KORELISANOM VEJBULOVOM FEDING OKRUŽENJU

Nikola Sekulović, Aleksandra Golubović,
Časlav Stefanović, Mihajlo Stefanović

U ovom radu analizirane su performanse diverziti sistema sa tri korelisane grane i selektivnim kombinovanjem (SC) koristeći odlučivanje zasnovano na korisnom signalu u Vejbulovom feding okruženju. Srednja vrednost odnosa signal-interferencija (SIR) na izlazu sistema je korišćena kao pokazatelj performansi sistema. Numerički rezultati su prikazani grafički kako bi se pokazao uticaj oštrine fedinga, korelacije i odnosa srednjih snaga signala i interferencije na ulazu sistema. Rezultati su takođe upoređeni sa rezultatima koji su dobijenu za slučaj SIR algoritma.

Ključne reči: *srednja vrednost SIR-a na izlazu, međukanalna interferencija, korelisani Vejbulovi feding kanali, algoritam zasnovan na korisnom signalu, selektivni diverziti*