

POSTDETECTION MACRO SC DIVERSITY SYSTEM WITH TWO MICRO DIVERSITY SYSTEMS FOR FSK DEMODULATION

Borivoje Milosevic

Technical College - VTS, Nis, Serbia

Slobodan Obradovic

Technical College - VISER, Belgrade, Serbia

Mihajlo Stefanovic

Faculty of Electronic Engineering, Nis, Serbia

Radoslav Bogdanovic

ZTP, Nis, Serbia

Abstract

In this paper the dual SC (Selection Combining) diversity system is considered. The correlated Rayleigh fading is presented. Macrodiversity system consists of the two Microdiversity systems with SC combining and three branches receivers for FSK signal demodulation. The probability density function of the dual SC output signals and the joint probability density function of output signal and its first time derivative is determined.

Keywords: FSK, PDF, CDF, MGF, Rayleigh channels, SC, Postdetection.

INTRODUCTION

Diversity combining is one of the most practical, effective and widely employed techniques in digital communication receivers for mitigating the effect of multipath fading and improving the overall wireless systems performance.

In this paper we considered characteristic of signals at the output of macro SC diversity system in the presence of Rayleigh fading. Macrodiversity combiner takes out signal which has larger input power. In this chapter, a diversity system of FSK modulated signal with two branches is observed. Each receiver has three branches. Each branch contains a narrow-band filter and an envelope detector. Signal demodulation is noncoherent. Each receiver's branch contains a narrow filter and a linear envelope detector. A square - law envelope detector can be used as well, since it is much easier to handle. On the basis of the results for signal probability density at the system output, when a linear envelope detector is used, it is possible, by simple transformation, to obtain the signal probability density at the output of the system when a square-law envelope detector is used.

The probability density function is calculated at the output of Macrodiversity system and by help with that probability density, error probability, system probability, cumulative probability density, moment generating function

and average symbol error rate, can be calculated.

EXPOSITION

In this paper we considered macro diversity system, figure 1, made from two micro diversity systems. Each micro diversity system is made from two receivers. Each receiver has three branches for FSK signal demodulation. Each branch contains a narrow-band filter and an envelope detector.

Output signals from the first receiver envelope detector and the first micro diversity system are:

$$x_{111}, x_{112}, x_{113}.$$

Output signals from the second receiver envelope detector and the first micro diversity system are:

$$x_{121}, x_{122}, x_{123}.$$

Output signals from the first receiver envelope detector and the second micro diversity system are:

$$x_{211}, x_{212}, x_{213}.$$

Output signals from the second receiver envelope detector and the second micro diversity system are:

$$x_{221}, x_{222}, x_{223}.$$

Output signal from the first micro diversity system is: x_1 .

Signal x_1 is equal to x_{111} if

$$\begin{aligned} x_{111} &> x_{112}, \\ x_{111} &> x_{113}, \\ x_{111} &> x_{121}, \\ x_{111} &> x_{122}, \\ x_{111} &> x_{123} \end{aligned}$$

Signal $x_1 = x_{112}$ if

$$\begin{aligned} x_{112} &> x_{111}, \\ x_{112} &> x_{113}, \\ x_{112} &> x_{121}, \\ x_{112} &> x_{122}, \end{aligned}$$

Signal $x_1 = x_{113}$ if

$$\begin{aligned} x_{113} &> x_{111}, \\ x_{113} &> x_{112}, \\ x_{113} &> x_{121}, \\ x_{113} &> x_{122}, \\ x_{113} &> x_{123}. \end{aligned}$$

Signal $x_1 = x_{121}$ if

$$\begin{aligned} x_{121} &> x_{111}, \\ x_{121} &> x_{112}, \\ x_{121} &> x_{113}, \\ x_{121} &> x_{122}, \\ x_{121} &> x_{123}. \end{aligned}$$

Signal $x_1 = x_{122}$ if

$$\begin{aligned} x_{122} &> x_{111}, \\ x_{122} &> x_{112}, \\ x_{122} &> x_{113}, \\ x_{122} &> x_{121}, \\ x_{122} &> x_{123} \end{aligned}$$

Signal $x_1 = x_{123}$ if

$$\begin{aligned} x_{123} &> x_{111}, \\ x_{123} &> x_{112}, \\ x_{123} &> x_{113}, \\ x_{123} &> x_{121}, \\ x_{123} &> x_{122} \end{aligned}$$

Based on the expression above we can say:

$$x_1 = \max(x_{111}, x_{112}, x_{113}, x_{121}, x_{122}, x_{123}).$$

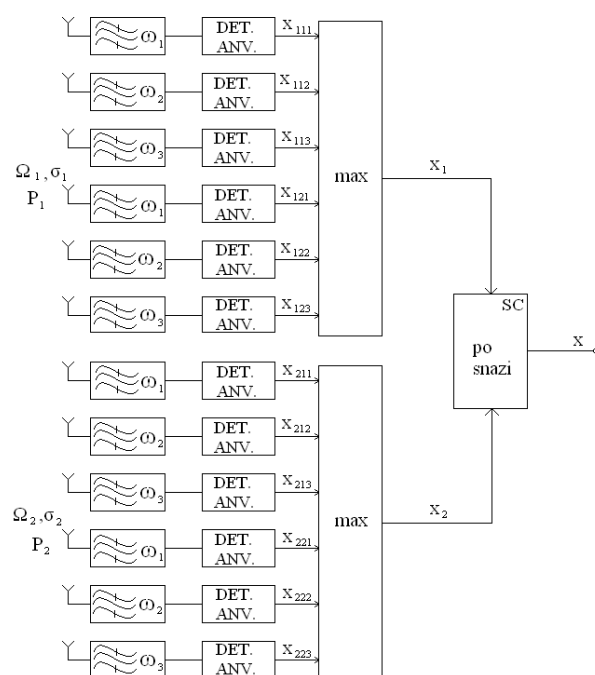


Fig. 1. System model

Output signal from the second micro diversity system is: x_2 .

Signal x_2 is equal to x_{211} if:

$$\begin{aligned} x_{211} &> x_{212}, \\ x_{211} &> x_{213}, \\ x_{211} &> x_{221}, \\ x_{211} &> x_{222}, \\ x_{211} &> x_{223}. \end{aligned}$$

Signal $x_2 = x_{212}$ if

$$\begin{aligned} x_{212} &> x_{211}, \\ x_{212} &> x_{213}, \\ x_{212} &> x_{221}, \\ x_{212} &> x_{222}, \\ x_{212} &> x_{223}. \end{aligned}$$

Signal $x_2 = x_{213}$ if

$$\begin{aligned} x_{213} &> x_{211}, \\ x_{213} &> x_{212}, \\ x_{213} &> x_{221}, \\ x_{213} &> x_{222}, \\ x_{213} &> x_{223}. \end{aligned}$$

Signal $x_2 = x_{221}$ if

$$\begin{aligned} x_{221} &> x_{211}, \\ x_{221} &> x_{212}, \\ x_{221} &> x_{213}, \\ x_{221} &> x_{222} \end{aligned}$$

$x_{221} > x_{223}$.
Signal $x_2 = x_{222}$ if

$$\begin{aligned} x_{222} &> x_{211}, \\ x_{222} &> x_{212}, \\ x_{222} &> x_{213}, \\ x_{222} &> x_{221}, \\ x_{222} &> x_{223} \end{aligned}$$

Signal $x_2 = x_{223}$ if

$$\begin{aligned} x_{223} &> x_{211}, \\ x_{223} &> x_{212}, \\ x_{223} &> x_{213}, \\ x_{223} &> x_{221}, \\ x_{223} &> x_{222} \end{aligned}$$

Based on the expression above we can say:

$$x_2 = \max(x_{211}, x_{212}, x_{213}, x_{221}, x_{222}, x_{223}).$$

Signals x_1 and x_2 are connected to the inputs of the macro diversity combiner. Signal at the output of the macro diversity combiner is x . Macro diversity combiner is selective [1,4,5,6,19,28,51,124,125]. Signal at the output x is equal to the signal x_1 if $P_1 > P_2$. Otherwise, if $P_1 < P_2$ then the signal at the output of the macro diversity combiner x is equal to x_2 . P_1 and P_2 are total power of the first and second micro diversity systems.

Conditional density probability x_{111} is:

$$p_{x_{111}}(x_{111}/A, n) = \frac{x_{111}}{\sigma_1^2} e^{-\frac{x_{111}^2 + A^2(1+Cn)^2}{\sigma_1^2}} I_0\left(\frac{x_{111}A(1+Cn)}{\sigma_1^2}\right) \quad (1)$$

Impulse number probability of the impulse noise is:

$$P(n) = \frac{\lambda^n}{n!} e^{-\lambda} \quad (2)$$

Density probability of amplitude A is:

$$p_A(A) = \int_0^\infty d\Omega \frac{A}{\Omega} e^{-\frac{A^2}{2\Omega_1}} \frac{1}{\sqrt{2\pi\sigma_1^2\Omega}} e^{-\frac{(\ln\Omega - \mu)^2}{2\sigma^2}} \quad (3)$$

By averaging, signal probability density is obtained x_{111} :

$$\begin{aligned} p_{x_{111}}(x_{111}) &= \\ &= \sum_n \int_0^\infty \frac{x_{111}}{\sigma_1^2} e^{-\frac{x_{111}^2 + A^2(1+Cn)^2}{2\sigma_1^2}} I_0\left(\frac{x_{111}A(1+Cn)}{\sigma_1^2}\right) \\ &\int_0^\infty d\Omega_1 \frac{A}{\Omega_1} e^{-\frac{A^2}{2\Omega_1}} \frac{1}{\sqrt{2\pi\sigma^2\Omega_1}} e^{-\frac{(\ln\Omega_1 - \mu_1)^2}{2\sigma^2}} dA \end{aligned} \quad (4)$$

Signal probability density of x_{112} and x_{113} are Rayleigh:

$$\begin{aligned} p_{x_{112}}(x_{112}) &= \frac{x_{112}}{\sigma_1^2} e^{-\frac{x_{112}^2}{2\sigma_1^2}} \\ p_{x_{113}}(x_{113}) &= \frac{x_{113}}{\sigma_1^2} e^{-\frac{x_{113}^2}{2\sigma_1^2}} \end{aligned} \quad (5)$$

Signal probability density of x_{121} is:

$$\begin{aligned} p_{x_{121}}(x_{121}) &= \\ &= \sum_n \int_0^\infty \frac{x_{121}}{\sigma_1^2} e^{-\frac{x_{121}^2 + A^2(1+Cn)^2}{2\sigma_1^2}} I_0\left(\frac{x_{121}A(1+Cn)}{\sigma_1^2}\right) \\ &\int_0^\infty d\Omega_1 \frac{A}{\Omega_1} e^{-\frac{A^2}{2\Omega_1}} \frac{1}{\sqrt{2\pi\sigma^2\Omega_1}} e^{-\frac{(\ln\Omega_1 - \mu_1)^2}{2\sigma^2}} dA \end{aligned} \quad (6)$$

Signal probability density of x_{122} and x_{123} are Rayleigh:

$$\begin{aligned} p_{x_{122}}(x_{122}) &= \frac{x_{122}}{\sigma_1^2} e^{-\frac{x_{122}^2}{2\sigma_1^2}} \\ p_{x_{123}}(x_{123}) &= \frac{x_{123}}{\sigma_1^2} e^{-\frac{x_{123}^2}{2\sigma_1^2}} \end{aligned} \quad (7)$$

Signal probability density of x_{211} is:

$$\begin{aligned} p_{x_{211}}(x_{211}) &= \\ &= \sum_n \int_0^\infty \frac{x_{211}}{\sigma_2^2} e^{-\frac{x_{211}^2 + A^2(1+Cn)^2}{2\sigma_2^2}} I_0\left(\frac{x_{211}A(1+Cn)}{\sigma_2^2}\right) \\ &\int_0^\infty d\Omega_2 \frac{A}{\Omega_2} e^{-\frac{A^2}{2\Omega_2}} \frac{1}{\sqrt{2\pi\sigma^2\Omega_2}} e^{-\frac{(\ln\Omega_2 - \mu_2)^2}{2\sigma_2^2}} dA \end{aligned} \quad (8)$$

Signal probability density of x_{212} and x_{213} are Rayleigh:

$$p_{x_{212}}(x_{212}) = \frac{x_{212}}{\sigma_2^2} e^{-\frac{x_{212}^2}{2\sigma_2^2}}$$

$$p_{x_{213}}(x_{213}) = \frac{x_{213}}{\sigma_2^2} e^{-\frac{x_{213}^2}{2\sigma_2^2}} \quad (9)$$

Signal probability density of x_{221} is:

$$p_{x_{221}}(x_{221}) = \sum_n \int_0^\infty \frac{x_{221}}{\sigma_2^2} e^{-\frac{x_{221}^2 + A^2(1+Cn)^2}{2\sigma_2^2}} I_0\left(\frac{x_{221}A(1+Cn)}{\sigma_2^2}\right) \cdot \int_0^\infty d\Omega_2 \frac{A}{\Omega_2} e^{-\frac{A^2}{2\Omega_2}} \frac{1}{\sqrt{2\pi\sigma^2\Omega_2}} e^{-\frac{(\ln\Omega_2 - \mu_2)^2}{2\sigma_2^2}} dA \quad (10)$$

Signal probability density of x_{222} and x_{223} are Rayleigh:

$$p_{x_{222}}(x_{222}) = \frac{x_{222}}{\sigma_2^2} e^{-\frac{x_{222}^2}{2\sigma_2^2}}$$

$$p_{x_{223}}(x_{223}) = \frac{x_{223}}{\sigma_2^2} e^{-\frac{x_{223}^2}{2\sigma_2^2}} \quad (11)$$

Signal probability density at the output from the first micro diversity system x_1 is:

$$p_{x_1}(x_1) = p_{x_{111}}(x_1)F_{x_{112}}(x_1)F_{x_{113}}(x_1)F_{x_{121}}(x_1)F_{x_{122}}(x_1)F_{x_{123}}(x_1) +$$

$$+ p_{x_{112}}(x_1)F_{x_{111}}(x_1)F_{x_{113}}(x_1)F_{x_{121}}(x_1)F_{x_{122}}(x_1)F_{x_{123}}(x_1) +$$

$$+ p_{x_{113}}(x_1)F_{x_{111}}(x_1)F_{x_{112}}(x_1)F_{x_{121}}(x_1)F_{x_{122}}(x_1)F_{x_{123}}(x_1) +$$

$$+ p_{x_{121}}(x_1)F_{x_{111}}(x_1)F_{x_{112}}(x_1)F_{x_{113}}(x_1)F_{x_{122}}(x_1)F_{x_{123}}(x_1) +$$

$$+ p_{x_{122}}(x_1)F_{x_{111}}(x_1)F_{x_{112}}(x_1)F_{x_{113}}(x_1)F_{x_{121}}(x_1)F_{x_{123}}(x_1) +$$

$$+ p_{x_{123}}(x_1)F_{x_{111}}(x_1)F_{x_{112}}(x_1)F_{x_{113}}(x_1)F_{x_{121}}(x_1)F_{x_{122}}(x_1)F_{x_{123}}(x_1) \quad (12)$$

Signal probability density at the output from the second micro diversity system x_2 is:

$$p_{x_2}(x_2) = p_{x_{211}}(x_2)F_{x_{212}}(x_2)F_{x_{213}}(x_2)F_{x_{221}}(x_2)F_{x_{222}}(x_2)F_{x_{223}}(x_2) +$$

$$+ p_{x_{212}}(x_2)F_{x_{211}}(x_2)F_{x_{213}}(x_2)F_{x_{221}}(x_2)F_{x_{222}}(x_2)F_{x_{223}}(x_2) +$$

$$+ p_{x_{213}}(x_2)F_{x_{211}}(x_2)F_{x_{212}}(x_2)F_{x_{221}}(x_2)F_{x_{222}}(x_2)F_{x_{223}}(x_2) +$$

$$+ p_{x_{221}}(x_2)F_{x_{211}}(x_2)F_{x_{212}}(x_2)F_{x_{213}}(x_2)F_{x_{222}}(x_2)F_{x_{223}}(x_2) +$$

$$+ p_{x_{222}}(x_2)F_{x_{211}}(x_2)F_{x_{212}}(x_2)F_{x_{213}}(x_2)F_{x_{221}}(x_2)F_{x_{223}}(x_2) +$$

$$+ p_{x_{223}}(x_2)F_{x_{211}}(x_2)F_{x_{212}}(x_2)F_{x_{213}}(x_2)F_{x_{221}}(x_2)F_{x_{222}}(x_2) \quad (13)$$

If macro diversity combiner selects according to the extent of signal amplitude at the outputs of the micro diversity combiner and if there is no slow fading, then the signal probability density of x is:

$$p_x(x) = p_{x_1}(x)F_{x_2}(x) + p_{x_2}(x)F_{x_1}(x) \quad (14)$$

Cummulative power probability density of P_1 and P_2 is:

$$p_{P_1P_2}(P_1P_2) = \frac{1}{2\pi\sigma_3^2(1-r^2)P_1P_2} \cdot e^{-\frac{(\ln P_1 - \mu_1)^2 - 2r(\ln P_1 - \mu_1)(\ln P_2 - \mu_2) + (\ln P_2 - \mu_2)^2}{2\sigma_3^2(1-r^2)}} \quad (15)$$

If macro diversity combiner selects according to the signal power at the inputs of the micro diversity combiners, then the signal probability density at its output is equal:

$$p_x(x) = \int_0^\infty dP_1 \int_0^{P_1} dP_2 \cdot p_{P_1P_2}(P_1P_2) \cdot p_{x_1}(x/P_1) +$$

$$+ \int_0^\infty dP_1 \int_{P_1}^\infty dP_2 \cdot p_{P_1P_2}(P_1P_2) p_{x_2}(x/P_2) =$$

$$= \int_0^\infty dP_1 \int_0^{P_1} dP_2 \cdot p_{x_1}(x/P_1) \cdot \frac{1}{2\pi\sigma_3^2(1-r^2)P_1P_2} \cdot e^{-\frac{(\ln P_1 - \mu_1)^2 - 2r(\ln P_1 - \mu_1)(\ln P_2 - \mu_2) + (\ln P_2 - \mu_2)^2}{2\sigma_3^2(1-r^2)}} +$$

$$+ \int_0^\infty dP_1 \int_{P_1}^\infty dP_2 \cdot p_{x_2}(x/P_2) \cdot \frac{1}{2\pi\sigma_3^2(1-r^2)P_1P_2} \cdot e^{-\frac{(\ln P_1 - \mu_1)^2 - 2r(\ln P_1 - \mu_1)(\ln P_2 - \mu_2) + (\ln P_2 - \mu_2)^2}{2\sigma_3^2(1-r^2)}} \quad (16)$$

Average signal value at the output x is:

$$\bar{x} = \int_0^\infty x p_x(x) dx \quad (17)$$

Mean square value of the signal at the output x :

$$\overline{x^2} = \int_0^\infty x^2 p_x(x) dx \quad (18)$$

The mean value of the cubic signal at the output x is:

$$\overline{x^3} = \int_0^\infty x^3 p_x(x) dx \quad (19)$$

Moment of the n -th signal order at the output x is:

$$\overline{x^n} = \int_0^\infty x^n p_x(x) dx \quad (20)$$

Central moment of the second order is:

$$\overline{(x - \bar{x})^2} = \int_0^\infty (x - \bar{x})^2 p_x(x) dx \quad (21)$$

Central moment of the third order is:

$$\overline{(x - \bar{x})^3} = \int_0^\infty (x - \bar{x})^3 p_x(x) dx \quad (22)$$

Central moment of the n -th order is:

$$\overline{(x - \bar{x})^n} = \int_0^\infty (x - \bar{x})^n p_x(x) dx \quad (23)$$

Based on the calculated moments could be determined signal characteristic function and can determine the optimal receivers parameters set. Of all of these moments in practice is most commonly used the second central moment or variance of the signal. Starting with the moment generating function (MGF) of the SC output, signal-to-noise ratio (SNR), we can derive closed-form expressions for the average combined SNR, outage probability, and average error probability of a wide variety of modulation schemes operating over diversity paths.

CONCLUSION

Using some reasonable approximations we have analyzed the performance of the dual SC (Selection Combining) diversity system, while the performer is noncoherent FSK demodulation of binary frequency modulated signal. Hopefully, this work will be a basis for further research on this very promising diversity noncoherent technique.

REFERENCE

- [1] W. Tsao, S.C. Yang: Performance Analysis of Optical FSK Phase Diversity Receivers in the

Presence of Thermal Noise. *Journal of Optical Communications* 10 (1989) 3, pp. 97-100.

- [2] H.W. Tsao, Y.H. Lee: Performance Analysis of Optical Phase Diversity FSK Receiver Using Delay-and-Multiplying Diskriminator. *Journal of Optical Communications* 13 (1992) 1, pp. 8-16.
- [3] Mihajlo Stefanović, Stefan Panić, Aleksandar Mosić, Marko Petković, Dušan Stefanović, *Selektivno kombinovanje kanala sa korelisanim α - μ fadingom*, TELFOR 2008, Bg, Serbia.
- [4] A. Annamalai, C. Tellambura, and V. K. Bhargava, "Equal-gain diversity receiver performance in wireless channels," *IEEE Trans. Commun.*, vol. 48, pp. 1732-1745, Oct. 2000.
- [5] M. K. Simon and M.-S. Alouini, *Digital Communication over Fading Channels*. 1st ed., New York: John Wiley, 2000.
- [6] J. Luo, J. R. Zeidler, and S. McLaughlin, "Performance analysis of compact antenna arrays with MRC in correlated Nakagami fading channels," *IEEE Trans. Veh. Technol.*, vol. 50, pp. 267-277, Jan. 2001.
- [7] Borivoje Milosevic, Vasko Todosijevic, Radoslav Bodganovic, *The statistics characteristics on output signals of MRC or EGC diversity systems in the presence of the fading*, UNITECH 2008, Bulgaria.
- [8] Mihajlo Stefanović, Daniela Milović, Dragana Krstić-Indjić and Petar Spalević, "Influence of Interchannel Interference on Optical Phase Diversity FSK Systems", *Facta Univ. Ser.: Elec. Energ.*, vol. 11, No. 3, 1998, pp. 285-290.
- [9] Dragana Krstić, Mihajlo Stefanović, Petar Spalević "Diversity System with L Branches for the Demodulation of n-FSK Signals", *XLI International Scientific Conference on Information, Communication and Energy Systems and Technologies- ICEST 2006*, jun 2006, Sofia, Bulgaria
- [10] M. Alouini and M. Simon, "Performance of Coherent Receivers with Hybrid SC/MRC over Nakagami-m Fading Channels," *IEEE Transactions on Vehicular Technology*, Vol. 48, pp. 1155-1164, July 1999.
- [11] Annamalai and Tellambura, "Error Rates of Hybrid SC/MRC Diversity Systems on Nakagami-m Channels," *Proc. IEEE Wireless Communications and Networking Conference*, pp. 227-231, Sept. 2000.
- [12] A. Annamalai and C. Tellambura, "Performance Evaluation of Generalized Selection Diversity Systems over Nakagami-m Fading Channels," to appear in the *International Journal on Wireless Communications and Mobile Computing*, Wiley, 2002.