DUAL DIVERSITY RECEPTION OF FH/BFSK SIGNAL

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I INTRODUCTION

The performance of noncoherent FH/BFSK system in the presence of multiple tone interference, when both signal and interference are affected by Rician fading, has been investigated in papers [1] and [2]. In paper [3], bit error rate (BER) expression for BFSK system with correlated dual diversity reception, was derived. In this paper we will examine the influence of Rayleigh fading and multitone interference on the performance of FH/BFSK system, when dual divesity reception is applied.

II SYSTEM MODEL

We assume that there are N nonoverlapping FH bands. Over each FH band a BFSK signal is transmitted. At the reception, double-diversity noncoherent BFSK receiver is used.

The n interfering tones are assumed to be distinct and spread uniformly over the entire FH bandpass. They correspond exactly to any n of the possible $2N$ signaling tones and share equally a total power of P_{JT} . Hence, the power of a single interfering tone is P_{JT}/n. Due to the assumption of uniform spreading and distinct interfering tones, at one moment a FH band may contain zero, one, or two interference tones. Therefore, $1\leq n\leq 2N$.

III ERROR PROBABILITY

In this paper we will consider two different cases in the system's performance analysis. In the first case, only the influence of Rayleigh fading on the system performance will be observed . Without loss of generality, we can assume that zero is transmitted. In that case, the signal in the signal branch can be expressed as:

$$X_0(k)=s_0(k)+n_0(k) \tag{1}$$

and in the nonsignal branch as:

$$X_1(k)=n_1(k) \tag{2}$$

where and k refers to the receiver and $k=1,2$. $n_0(k)$ and $n_1(k)$ are the noise terms due to additive white Gaussian noise (AWGN) in the signal and nonsignal branch of the receiver, with the same variance, σ^2. $s_0(k)$, $k=1,2$, are correlated, Gaussian random variables, zero mean, with variance σ_s^2 and correlation coefficient defined as:

$$\rho=\frac{1}{\sigma_s^2}E\left[s_0(1)\cdot s_0(2)\right]$$

Error probability, in this case, is equal to:

$$P_e=P(Y_1<Y_2) \tag{3}$$

where

$$Y_1=\sum_{k=1}^{2}\left[(s_{I0}(k)+n_{I0}(k))^2+(s_{Q0}(k)+n_{Q0}(k))^2\right] \tag{4}$$

$$Y_2=\sum_{k=1}^{2}\left[n_{I1}(k)^2+n_{Q1}(k)^2\right] \tag{5}$$

are decision variables. Gaussian random processes denote as $s_{I0}(k)$, $s_{Q0}(k)$, $n_{I0}(k)$, $n_{Q0}(k)$ and $n_{I1}(k)$, $n_{Q1}(k)$, $k=1,2$, represent quadrature components of the user signal, and AWGN in the signal and nonsignal branch of the receiver, respectively. Error probability can be expressed from [3] as:

$$P_e=f_0(SNR,\rho)\cdot f_1(SNR,\rho) \tag{6}$$

where

$$f_0(SNR,\rho)=\frac{1}{(2+(1+\rho)\cdot SNR)\cdot(2+(1-\rho)\cdot SNR)}$$

$$f_1(SNR,\rho)=1+\frac{1+(1+\rho)\cdot SNR}{2+(1+\rho)\cdot SNR}+\frac{1+(1-\rho)\cdot SNR}{2+(1-\rho)\cdot SNR}$$

In the second case, we will examine only the influence of the multitone interference on the probability of error. Hence, signals in the signal and the nonsignal branch, can be expressed as:

$$\begin{aligned}X_0(k)=&A\cos(\omega_0 t+\varphi_k)+\\&+A_i\cos(\omega_0 t+\theta_0+\varphi_k)+n_0(k)\end{aligned} \tag{7}$$

and

$$X_1(k)=A_i\cos(\omega_1 t+\theta_1+\varphi_k)+n_1(k) \tag{8}$$

for $k=1,2$. A and A_i are the amplitudes of the user signal and interference, respectively, and φ_k is the phase of the signals for $k=1,2$. Without loss of generality we can set $\varphi_1=0$, and $\varphi_2=\varphi$, where φ denotes the random phase difference between the user signals at the output of the receiver for $k=1,2$, uniformly distributed over $[0,2\pi]$. θ_0 and θ_1 are uniformly distributed phases of single tone interference in the signal and nonsignal branch, respectively.

In this case one FH band can contain zero, one or two tones interference. In order to evaluate the average error probability, we have to consider four different cases. If logical zeros and ones in information sequence are equiprobable, then the probability of error can be written as:

$$P_e = P_2 P_{e2} + \frac{P_1}{2}\left(P'_{e1} + P''_{e1}\right) + P_0 P_{e0} \quad (9)$$

where P_0, P_1 and P_2 are, respectively, probabilities that a FH band contains none, one or two equal-power interference tones. P_{e2}, P'_{e1}, P''_{e1} and P_{e0} denote conditional probabilities of error when FH band contains two interfering tones, one interfering tone in a signal branch, one interfering tone in a nonsignal branch and zero interfering tones, respectively.

Conditional error probabilities for dual diversity reception of noncoherent BFSK signal, P_{e2}, P'_{e1}, P''_{e1} and P_{e0}, can be calculated with equation (3), while decision variables Y_1 and Y_2, from (4) and (5), are given as follows:

$$Y_1 = \sum_{k=1}^{2}\left[\left(A + A_i \cos\theta_0 + n_{I0}(k)\right)^2 + \left(A_i \sin\theta_0 + n_{Q0}(k)\right)^2\right] \quad (10)$$

$$Y_2 = \sum_{k=1}^{2}\left[\left(A_i \cos\theta_1 + n_{I1}(k)\right)^2 + \left(A_i \sin\theta_1 + n_{Q1}(k)\right)^2\right] \quad (11)$$

These conditional error probabilities can be expressed as:

$$P_{el} = \int_0^\infty p_{2l}(x)\int_0^x p_{1l}(y)\,dy\,dx = \int_0^\infty p_{2l}(x)\cdot F_{1l}(x)\,dx \quad (12)$$

where $p_{1l}(x)$, $p_{2l}(x)$ and $F_{1l}(x)$, for $l = 0,1,2$, represent the PDF functions of random variables Y_1 and Y_2, and the CDF of random variable Y_1, respectively, for each conditional probability mentioned above. In the sequel, the PDF function of random variable Y_2, and the CDF function of random variable Y_1, will be given for each conditional error probability.

In the first case FH band contains two interfering tones. The PDF function of random variable Y_2 can be represented as [4]:

$$p_2(x) = \frac{1}{2\sigma^2}\cdot\sqrt{\frac{x}{a^2}}\cdot\exp\left(-\frac{a^2 + x}{2\sigma^2}\right)\cdot I_1\left(\sqrt{x}\,\frac{a}{\sigma^2}\right) \quad (13)$$

where

$$a^2 = 2A_i^2 \quad (14)$$

and the CDF function of the random variable Y_1 as:

$$F_1(x) = 1 - Q_2\left(\frac{b}{\sigma}, \frac{\sqrt{x}}{\sigma}\right) \quad (15)$$

where

$$b^2 = 2\left(A^2 + A_i^2 + 2AA_i\cos\theta_0\right) \quad (16)$$

and $Q_2(u,v)$ is a Marcum function, defined as:

$$Q_2(u,v) = \int_v^\infty \frac{x^2}{u}\cdot\exp\left(-\frac{x^2 + u^2}{2}\right)\cdot I_1(ux)\,dx$$

Error probability P_{e2} can be calculated by substituting (13)-(16) into (12) and averaging over θ_0. In the second case, there is single tone interference in signal branch. Therefore, the CDF function of the random variable Y_1 can be expressed with equation (15), while the PDF function of random variable Y_2 can be written as:

$$p_2(x) = \frac{x}{\left(2\sigma^2\right)^2}\exp\left(-\frac{x}{2\sigma^2}\right) \quad (17)$$

Again, after substituting (15) and (17) into (12), using parameter b defined in (16), and after averaging over θ_0, the probability P'_{e1} is obtained.

When an FH band contains one interfering tone that corresponds to the nonsignal branch, functions $p_2(x)$ and $F_1(x)$ are defined with (13) and (15), parameter a is defined with (14) and b is defined as:

$$b^2 = 2A^2 \quad (18)$$

Substituting b from (18) into (15), probability of error P''_{e1} can be calculated using (12).

In the last case, when FH band contains no interfering tones, conditional error probability can be calculated by substituting (17) and (15) into (12), and using parameter b defined in (18).

Substituting these conditional probabilities in (9), we can calculate average error probability in the presence of multitone interference.

IV NUMERICAL RESULTS

The performance of the FH/BFSK system with dual diversity noncoherent receiver was investigated for $N = 100$.

The error probability versus signal to noise ratio for different values of correlation coefficient, in case of dual diversity noncoherent reception of FH/BFSK signal transmitted over Rayleigh channel, is shown in Fig.1. Results were calculated according to (6).

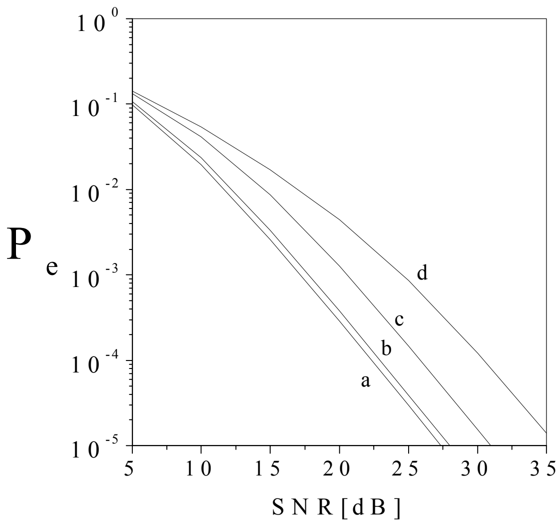

Fig. 1. Error probability for: a) $\rho = 0$, b) $\rho = 0.5$, c) $\rho = 0.9$, d) $\rho = 0.99$

As we can see from Fig.1, performance of the system degrades with the increase of the correlation coefficient values.

Fig. 2. presents the error probability versus signal to noise ratio (*SNR*), for a signal to interference ratio of 5 dB (*SIR=5dB*) and the number of interfering tones of 10 (n=10). The numerical results were obtained by using an analytic expression (9).

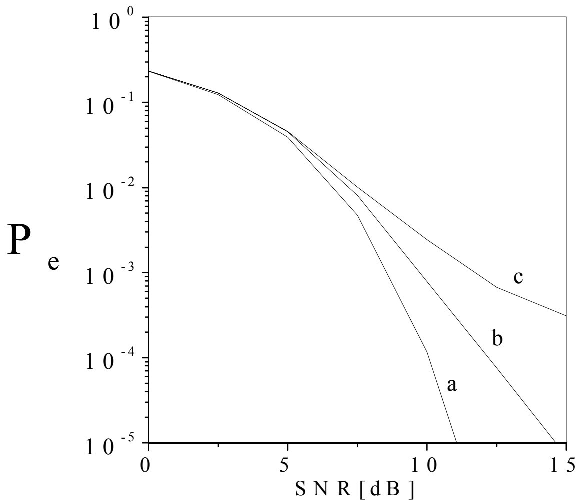

Fig. 2. Error probability for: a) n = 10, SIR = 5 dB, b) n = 30, SIR = -5 dB, c) n = 10, SIR = -5 dB

With the increase of *SIR* or the number of interfering tones, the value of the error probability decreases. As it has been mentioned above, the total power of interference P_{JT} is constant and distributed over *n* equal-power interfering tones. Hence, if the number of interfering tones is higher, the power of a single interfering tone is lower, and so are the values of the error probability.

V CONCLUSION

The influence of Rayleigh fading and multitone interference on the performance of noncoherent FH/BFSK system with dual diversity reception was investigated in this paper. Two different influences on the performances of the system were considered i.e.the influence of Rayleigh fading and the multitone interference. It has been shown that results are much better in the case when a multitone interference is present in the channel ,then when the signal is transmitted over a Rayleigh fading channel. The approach presented in this paper enables us to improve the system performance by using a dual diversity receiver.

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Abstract - In this paper, the influence of Rayleigh fading and multitone interference on the performance of FH/BFSK system when dual divesity reception is applied, was investigated. Two different influences on the system's performance were considered i.e. the influence of Rayleigh fading and the multitone interference. It is assumed that interference tones have the equal energy.

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