TURBO CODES FOR NONGEO SATELLITE COMMUNICATIONS

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ABSTRACT

Turbo codes have a performance that approaches the Shannon limit on the capacity of a band limited communication channel. The transmission performance of NONGEO services is mainly impaired by rapid amplitude and phase fluctuations of the received signal (fading). In this paper, the performance of turbo codes with different code parameteres in slow and fast fading is presented for this channel.

Because of the interleavers these codes offer some immunity to the correlated signal disruptions effects. So, as will be shown the effect of code length increment is greater than other parameters.

1. INTRODUCTION

Turbo codes are one of the most active areas of research in coding theory. These codes initially described by Berrou, Gavieux, and Thitmajshima in 1993[1]. These codes have a performance that approaches the Shannon limit on the capacity of a band limited communication channel. Non-geostationary orbits greatly diminish the propagation delay and allow increasing the complexity of coding schemes to achieve the quality requirements for data.

In this paper, Turbo codes with different parameteres (number of iteration, K factor, rate of coding, . . .) are simulated and compared.

2. TURBO CODES

Turbo codes consist of concatenation of two or more component codes separated by interleaves. These codes, initially introduced turbo codes, are parallel-concatenated convolutional codes, whose encoder is formed by parallel concatenation of two recursive systematic convolutional codes jointed by an interleaver. A 1/3-rate turbo code is obtained by parallel concatenation of two ½-rate Recursive Systematic Convolutional (RSC) codes separated by a pseudo random interleaver.

Purpose of the interleaver is to randomize bursty error patterns so it correctly decoded. In order to increase the transmission efficiency, puncturing can be used. Puncturing is basically removing certain bits from the output stream according to a fixed pattern given by a puncturing matrix. It uses of iterative decoding algorithm. Two component of decoders are linked by interleavers in a structure similar to that of the encoder. There are different algorithms for decoding consists of MAP, SOVA, Log-MAP, and MAX-Log-MAP. The MAP algorithm is the optimal component decoder for turbo codes. The Log-MAP algorithm is theoretically identical to the MAP algorithm, but its complexity is dramatically reduced. The MAX-Log-MAP algorithm further reduces the complexity of Log-MAP algorithm. MAX-Log-MAP and SOVA is both less complex, but give a slightly degraded performance.

In this paper a Log-MAP algorithm has been choose for decoding because of its simplicity and efficiency. For application of turbo codes in NONGEO satellite systems the channel model is explained.

3. CHANNEL MODEL FOR NONGEO SATELLITE SYSTEMS

The model, which is used in this work, is the Hwang's model [3]. This model is suitable for NONGEO stationary satellite systems and is a combination of Rice and Lognormal statistics model with independent shadowing effecting both direct and diffuse components of receiving signals, respectively. In the received signal the shadowing occurs in both the direct and diffuse component of signals due to gross changes in the topology of the physical channel and each propagation path. Therefore, it is appropriate modeling of the shadowing effects on each direct and diffuse component as the independent shadowing with the same statistics.

The channel model is combination of Rice and Lognormal statistics, with independent shadowing effecting each direct and diffuse component, respectively, that given by

$$ae^{j\varphi} = A_c S_1 e^{j\varphi} + RS_2 e^{j(\theta+\varphi)} \quad (1)$$

Where S_1 and S_2 are independent Lognormal distributions, respectively and R has a Rayleigh distribution.

If S_1 and S_2 are temporally kept constant, then the conditional probability density function of R is simply that of a Rician vector:

$$P(a|S_1,S_2) = \frac{r}{b_o S_2^2}\exp\left[-\frac{(r^2/S_2^2)+(A_c S_1/S_2)^2}{2b_o}\right] I_o\left(\frac{r A_c S_1}{b_o S_2^2}\right) \quad (2)$$

Where b_o represents the average scattered power due to multi path, A_c is LOS component, and $I_o(\bullet)$ is the modified Bessel function of zero order.

It has been assumed that both of $P(S_1)$ and $P(S_2)$ is independent Lognormal given by:

$$P(S_1) = \left(\frac{1}{\sqrt{2\pi d_{o1}} S_1}\right)\exp[-(\ln S_1 - \mu_1)^2 / 2d_{o1}] \quad (3)$$

$$P(S_2) = \left(\frac{1}{\sqrt{2\pi d_{o2}} S_2}\right)\exp[-(\ln S_2 - \mu_2)^2 / 2d_{o2}] \quad (4)$$

Where $\sqrt{d_{o1}}$, $\sqrt{d_{o2}}$ and μ_1, μ_2 are the standard deviation and mean, respectively. The parameters of this channel are given in Table 1.

Table 1: The parameters of channel Model (Hwang Model)

	$\sqrt{d_{o1}}$, $\sqrt{d_{o2}}$	$\mu_1 \cdot \mu_2$	K
Light	0.12	0.145	4.0
Heavy	0.34	-1.15	0.6

The overall model of the system is shown in Figure 1. In this model n(t) is white Gaussian noise process with two-sided power spectral density N/2 and a(t) is given by (1).

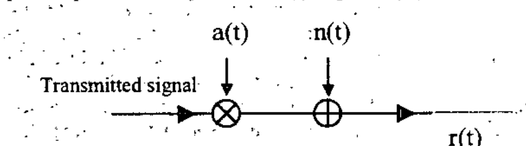

Figure1: Channel model schematic

We have used this model and simulated the performance of the channel using turbo codes.

4. SIMULATION RESULTS

In this section, performance of Turbo Codes in NONGEO satellites is simulated. The simulation has been done for slow and fast fading under light and heavy shadowing conditions. In this work, simulation done basically for heavy shadowing but the performance of light shadowing studied briefly, too. All computer models for the fading channels are based on the manipulation of a white Gaussian random process.

4.1- Slow fading case

The Rayleigh random variable is generated from combination of two-independent normal distribution and is give by:

$$X_r = \sqrt{X_1^2 + X_2^2} \quad (5)$$

And for the slow fading, Lognormal random variable is generated from a nonlinear transformation of a normal distribution, given by:

$$X_e = \exp[\mu + \sqrt{d_o} X_1] \quad (6)$$

Where μ and d_o are the mean and variance respectively.

4.2- Fast Fading

For the fast fading case, white Gaussian random process is approximated by a sum of sinusoid with random phase angle [2] and is given by:

$$X(t) = X_1(t) + jX_2(t) = \sum_{n=-N/2}^{N/2} a_k \exp[j2\pi f_o t + \phi] \quad (7)$$

Where a_k is amplitude and ϕ is a random phase angle uniformly distributed between 0 and 2π, N is the Number of sinusid.

The envelope "X_r" of two narrow-band Gaussian random processes is Rayleigh and its phase is uniform. Therefore

$$X_r(t) = \sqrt{X_1^2(t) + X_2^2(t)} \quad (8)$$

$$\theta(t) = \tan^{-1}\left(\frac{X_2(t)}{X_1(t)}\right) \quad (9)$$

The fast fading Lognormal model is given by:

$$X_l(t) = \exp[\mu + \sqrt{d_o} X_1(t) + j\sqrt{d_o} X_2(t)] \quad (10)$$

$X_l(t)$ and $X_r(t)$ are simulated by "equal area method" [4]. In this method, the Rice factor, which is defined as the ratio of the power of LOS Component to the total power of diffuse component is equal to 7.44 dB for light shadowing and –2.23 dB for heavy shadowing.

4.3- Turbo Codes performance

Turbo codes performance in a channel with light shadowing has been shown in Fig. 2 and 10 for slow fading and fast fading, respectively. As shown, the code performance for slow fading is obviously appropriate.

Fig. 3 shows the performance of turbo codes for heavy shadowing with K=3, r=1/2 and code length of F_s=1000. Increasing the iteration number cause improvement in code performance, but for iteration higher than 5 the performance will not been significantly improved. Simulation results show that, in heavy shadowing and slow fading conditions, the performance is improved for E_b/N_0 values higher than 8 dB and for fast fading this occurred only for E_b/N_0 values higher than 13 dB. Fig. 4 shows the code performance versus the constraint length. As shown in this figure, the code performance in $E_b/N_0 = 10$ dB and for K=5 is 10 times better than K=3, but this increases the complexity of the system.

Fig. 5 shows the performance of code versus the code length and in Fig. 6 the effect of code rate is shown for rates of ½ and 1/3. In this case, performance of 1/3 rate is better than ½ rate, but the effective rate of data transmission decreases. Fig. 7 shows the turbo code performance for rate 1/3, k=5 and frame length of 5000. It is seen that in $E_b/N_0 = 10$ dB, a turbo code with 3 iterations introduces a BER in 10^{-7} order that is very appropriate but it is very complex. In figures 8 to 10, the turbo code performance with fast fading is investigated. Fig. 8 show the performance for 10500 bit rate and maximum doppler frequency shift of 5900 Hz versus the different lengths and for a appropriate elevation angle (80^0). From this figure we will find that in fast fading environment and $E_b/N_0 = 15$dB, if the iteration number increase from 1 to 3, the code performance (BER) improve by order of 1000. In Fig. 9 the codes with different parameters are compared. Finally, we have compared the performance of turbo codes with the same parameters, in fast fading and slow fading enviroments (Fig. 10). As it is obviuos, if we want a similar performance, E_b/N_0 should be increased by a 3.5 dB factor in fast fading case.

5. CONCLUSION

Turbo codes are the nearest codes to shanon limit and show a very appropriate performance in data transmission. In satellite channels, because of the very high fading levels we should use error correctting codes. One of the condidate is turbo codes. In this paper, the performance of turbo codes is simulated in light and heavy shadowing with fast and slow fadeng environment. It is concluded that the performance is very appropriate in light shadowing for low E_b/N_0. In heavy shadowing and slow fading conditions, the performance is improved for E_b/N_0 values higher than 8 dB and for fast fading this occurred only for E_b/N_0 values higher than 13 dB. The most improvement is due to increase of the code length and code rate of 1/3.

6. REFERENCES

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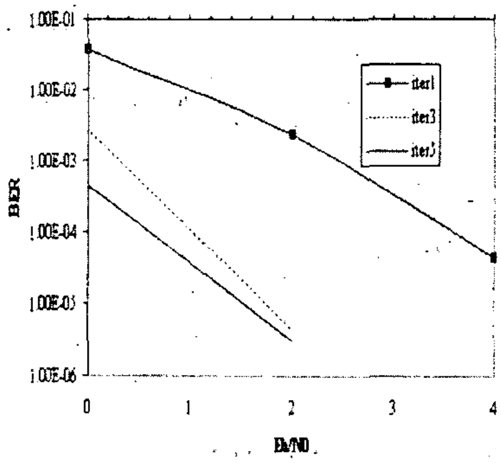

Figure2: turbo code performance with Fs= 1000, r=1/2, K=3, and different iteration in slow fading and light shadowing

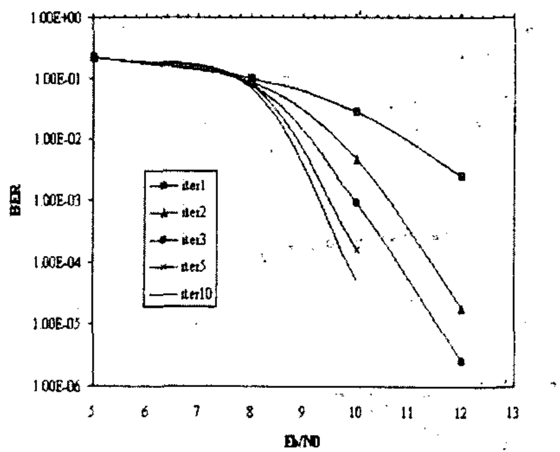

Figure3: turbo code performance with Fs = 1000, rate 1/2, K=3, and different iteration in slow fading and heavy shadowing

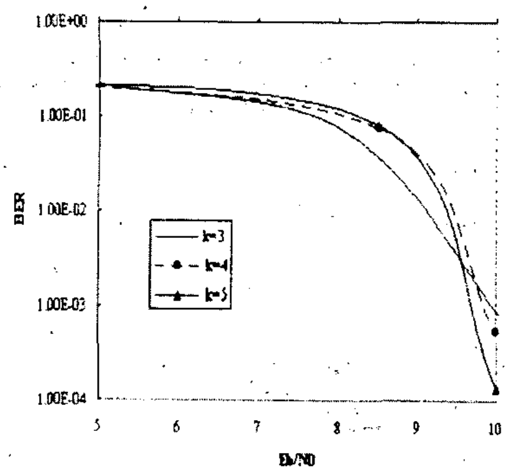

Figure4: turbo code performance with iter=3, r=1/2, fs=1000 and different K_S in slow fading and heavy shadowing

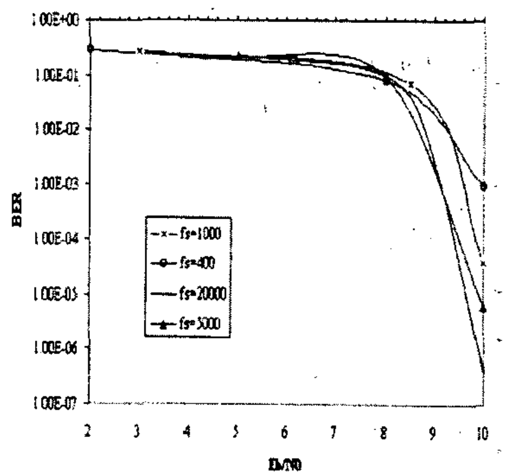

Figure5: turbo code performance with iter=5, r=1/2, k=3 and different lengths in slow fading and heavy shadowing

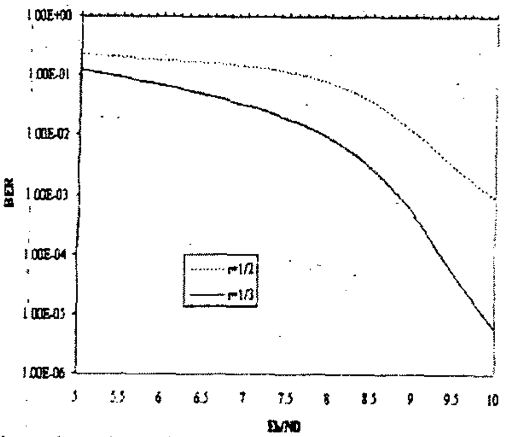

Figure6: turbo code performance with Fs=1000, iter=3, k=3 and different length in slow fading and heavy shadowing

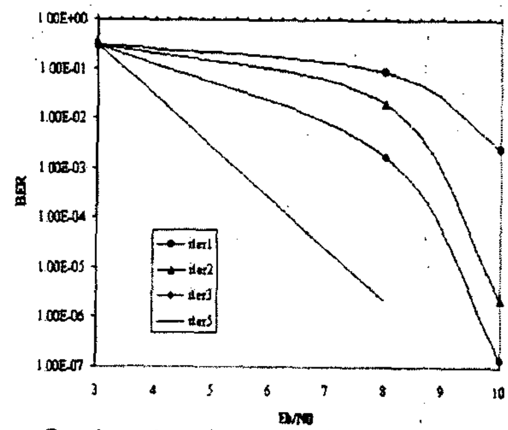

Figure7: turbo code performance with Fs = 5000, rate 1/3, K=5 in slow fading and heavy shadowing

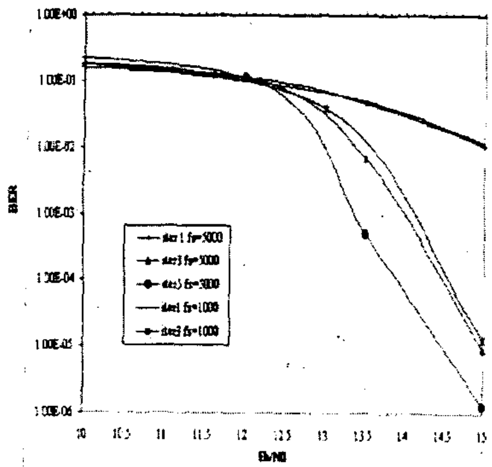

Figure8: turbo code performance with r=1/2 k=3 f_{max}=5900, bit rate=10500 in fast fading and heavy shadowing

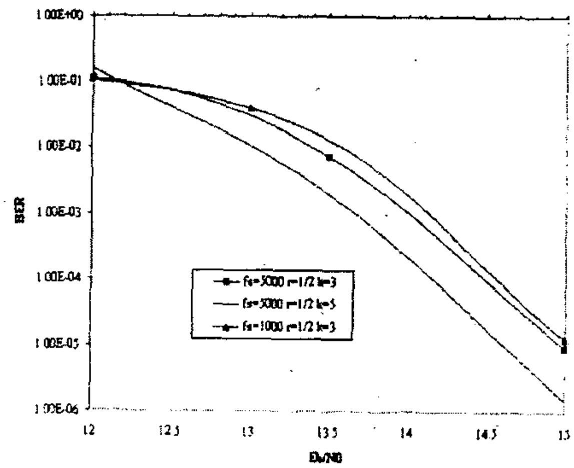

Figure9: turbo code performance with iter=3, f_{max} =5900, bit rate=10500 in fast fading and heavy shadowing

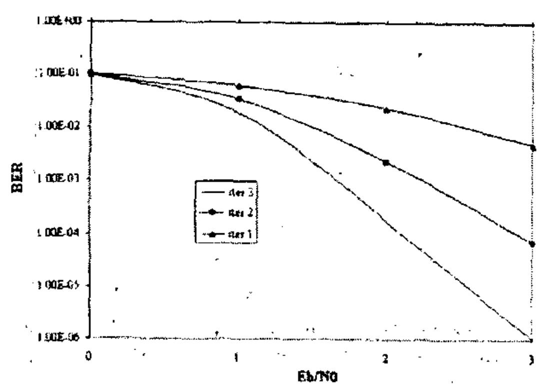

Figure10: turbo code performance with Fs= 1000, r=1/2, K=3, and different iteration in slow fading and light shadowing

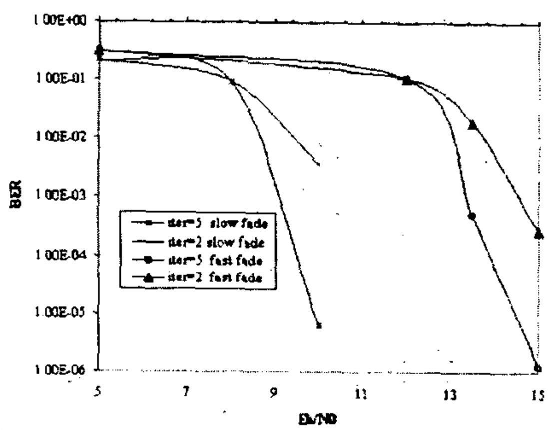

Figure11: Performance of turbo code in slow and fast fading With Fs=5000, K=3, r=1/2 and heavy shadowing