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CONTROLLING THE PERFORMANCE OF MDPSK IN BAD SCATTERING CHANNELS

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ABSTRACT

This paper describes a modification of the conventional M-ary Differential Phase Shift Keying MDPSK scheme. This method reduces the number of phases which improves the performance of the system by applying a mathematical method from the combinatorial theory called Balanced Incomplete Block Design BIB-design. It is a coding modulation technique in which the signal is represented by a set of phases selected and controlled by the encoder. Each block is transmitted serially or in parallel with equal energy.

Key Words: MDBSK, Nakagami-m, Bad scattering channels, BIB-design.

INTRODUCTION

Physical limitations on wireless channels present a fundamental technical challenge to reliable communications. Bandwidth limitations, propagation loss, noise, interference, and multi-path fading make the wireless channel a narrow pipe that does not readily accommodate rapid flow of data. Transmit diversity schemes use processing at the transmitter to spread information across the antennas.

BIB design is a collection of b blocks, formed by the arrangement of v distinct elements, satisfying the following conditions (Bose and Manvel, 1986): each block contains w elements, each element occurs in r blocks and each pair of elements occurs together in λ blocks. This arrangement of element is called a BIB design with parameters (v, b, r, w, λ). There are two basic relations among these parameters,

$$bw = vr \qquad (1)$$

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$$\lambda(v-1)=r(w-1) \quad (2)$$

The number of blocks and the number of repetitions of a particular element are given by

$$b=\lambda\frac{v(v-1)}{w(w-1)} \quad (3)$$

$$r=\lambda\frac{v-1}{w-1} \quad (4)$$

A special case of BIB design when λ = 1, it is called Steiner systems, $S_w(v,k)$, where *k* is the number of bits per symbol. Only some values of *v* and *w* are possible to insure integer numbers of *b* and *r* where *v* must be

$$v\equiv w \bmod w(w-1) \quad (5)$$

The BIB-MDPSK is an arrangement of *v* phases into *b* waveforms, each waveform contains *w* distinct phases. Every single phase in a waveform can be used in the transmission of *r* different waveforms, and every pair of phases occurs in λ waveforms. (Bose and Manvel, 1984), Table 1 shows the admissible values of *v* for different *w*, required to represent $M= 2^k$ waveforms for BIB-MDPSK. A comparison between these values to these required by conventional MDPSK modulation is illustrated. (Mobbaiden, 2000)

From this table, it is clear that BIB-MDPSK have some advantages rather than MDPSK such as the lower number of phases *v* than *M* which will improve the BER. Also, increasing the distance between the elements will also make good improvements.

Table - 1. The values of *v* for *w* =3, 4, 5 to represent $M = 2^k$.

	$S_3(v,k)$		$S_4(v,k)$		$S5(v,k)$		MDPSK
k	***v***	***b***	***v***	***b***	***v***	***b***	***M***
1	7	7	13	13	21	21	2
2	7	7	13	13	21	21	4
3	9	12	13	13	21	21	8
4	13	26	16	20	21	21	16
5	15	35	25	50	41	82	32
6	21	70	37	111	41	82	64
7	31	155	40	130	61	183	128
8	43	301	61	305	81	324	256
9	57	532	85	595	105	546	512
10	79	1027	112	1036	145	1044	1024

This paper studies the performance and determine the advantages and limitations of diversity applied to a modulation/coding scheme using MDPSK signals. This modulation/coding scheme is referred to as BIB-MDPSK, and is implemented based on balanced incomplete block design (BIB-design) from combinatorial theory. It is expected to gain power efficiency when comparing the BIB-MDPSK to the conventional MDPSK without increasing the complexity of the system. The paper is organized as follows: in Section 2, we present the system model. The probability of error is introduced in Section 3, and the channel model is presented in Section 4, then the numerical results are compared with conventional MDPSK and presented in Section 5. Finally, Section 6 presents the conclusions of our study.

SYSTEM MODEL

Figure- 1. Block diagram of BIB-MDPSK transmitter

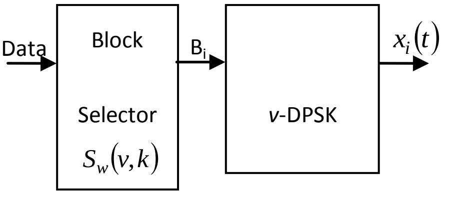


Figure 1 shows the transmitter block diagram. The transmitter selects, according to the input data, a block of w elements from the $S_w(v,k)$. Then, the v-DPSK modulator divides equally its energy into the signal corresponding to the elements forming the selected block, transmitting a signal consists of w phases, each of them corresponds to a certain element of the input block. (Atkin and Corrals, 1989) The transmitted output signal $x_i(t)$ is

$$x_i(t) = \Re\left\{ \sum_{k=1}^{w} u_{i_k}(t - kT_w) e^{j2\pi f_c t} \right\} \quad (6)$$

where:

- $T_w = \dfrac{T_s}{w}$ (7)
- w is the number of phases to represent the i^th signal.
- f_c is the carrier frequency
- u_{i_k} is the k^th phase transmitted in the i^th signal

The signal $x_i(t)$ is to be send over multi-path frequency non-selective Nakagami-*m* fading channels with impulse response.

$$c = \alpha e^{-j\theta} \quad (8)$$

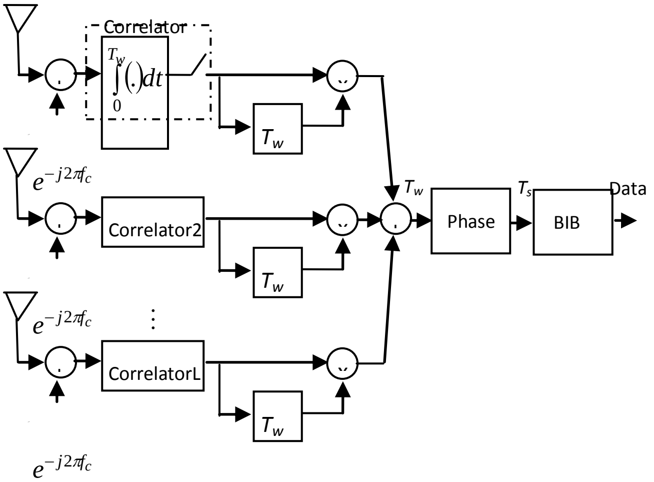
The received signal for the L channel is

$$r^{(l)}(t) = \Re\left\{ \sum_{k=1}^{w} u_{i_k}(t - kT_w) \alpha_l e^{-j\theta_l} e^{j2\pi f_c t} + z_{i_k,l} \right\} \quad (9)$$

where $z_{i_k,l}$ is the AWGN associated with the k^th phase on the i^th signal over the l^{th} channel.

The receiver will consist of L branches, each of them consists of a matched filter (matched to f_c) and a differential detector. After that, all the branches are summed, before inserted to a phase detector to get the estimated transmitted block $\hat{B}_i$ then, the block design decoder recovers the data stream back. The block diagram of the transmitted MDPSK based on BIB design receiver is shown in Fig. 2

Figure -2. Block diagram of BIB-MDPSK receiver



PROBABILITY OF EROR

Probability of error calculations To insure that the signal is correct, all the w phases in the block must be correct, so, (Papoulis, 2002)

$$P_c = P\{\psi_{i1} \text{ is correct} \cap \psi_{i2} \text{ is correct} \cap \cdots \cap \psi_{iw} \text{ is correct}\} \qquad (10)$$

The probability that ψ_{ij} is correct is:

$$P\{\psi_{ij} \text{ is correct}\} = P\{\psi_{ij} = \Delta\phi_{ij} | \Delta\phi_{ij} \text{ is transmitted}\} \qquad (11)$$

substituting equation (11) in equation (10), we have

$$P_c = P\{\psi_{i1} = \Delta\phi_{i1}|\Delta\phi_{i1} \cap \psi_{i2} = \Delta\phi_{i2}|\Delta\phi_{i2} \cap \cdots \cap \psi_{iw} = \Delta\phi_{iw}|\Delta\phi_{iw}\} \qquad (12)$$

because all the decisions are independent, we can write equation (12) as:

$$P_c = \left[P\{\psi_{i1} = \Delta\phi_{i1}|\Delta\phi_{i1}\}\right]^w \qquad (13)$$

The probability of error is The probability that one chip of the block is in error can be treated as the ordinary probability of error calculation for the conventional MDPSK given in equation (14)

$$P_{e,b} = \frac{W}{K}\sum_{i=1}^{v} P_r\{r_i \in R_i|\Delta\theta_o\} \qquad (14)$$

FADING CHANNEL MODEL

When we transmit a signal over a radio channel, it travels over multi-path channels. Each path is a time varying random process. The large number of paths make it possible to represent the channel impulse response as a complex valued Gaussian random process according to the central limit theorem. If the impulse response has zero mean, the envelope of the channel response at any time has a Rayleigh probability density function (PDF) and a uniformly distributed phase over the interval $[0,2\pi]$ (Proakis, 1995). But if the impulse response in no longer with zero mean, Nakagami-*m* distribution is presented as a statistical model for the envelope of the channel response. The PDF of Nakagami-*m* is (Proakis, 1995).

$$f_\alpha(\alpha)=\frac{2}{\Gamma(m)}\alpha^{2m-1}e^{-m\alpha^2/\Omega}, \quad \alpha \geq 0 \qquad (15)$$

where: α is the absolute value of the impulse response.

Ω is the mean square of α

$\Gamma(.)$ is the gamma function

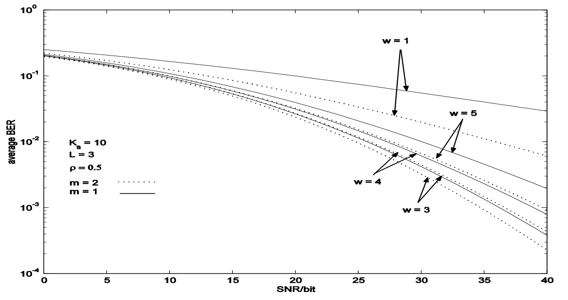
$m \geq 0.5$ is the fading parameter

Nakagami-*m* distribution is the most general case that fits the practical measurements of the envelope of the channel impulse response. Special cases of Nakagami-*m* distribution is when m = 0.5 and m = 1 which represent a one-sided Gaussian distribution and Rayleigh distribution respectively. Also, under certain conditions, Rician and log-normal distributions may be obtained from Nakagami-*m* distribution.

RESULT AND DISCUSSION

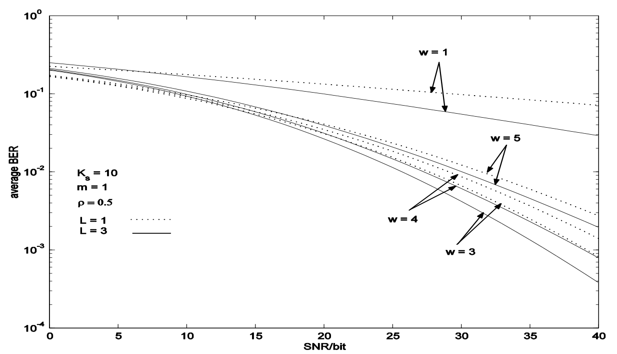
Figure 2 shows the microstructure of SS440C steel in (a) as-received and (b) as-quenched steel. The as-received sample had been treated through the annealing process at 1040^{o}C. This treatment results in the formation of ferrite matrix and carbide particles. In this section, We'll show that BIB-*v*DPSK has some improvements compared with the conventional MDPSK. When using K_s = 10, we have 1024 phases per symbol in conventional MDPSK and 79, 112 and 145 phases in BIB-MDPSK for w = 3, 4 and 5 respectively. So, we expect improvement because there are reduction in phase numbers. There are many factors that affect the performance of the system when transmitting in a wireless channel. In case of Nakagami-*m* channel, the fading factor *m* is one of the most effective factors. In Fig. 3, a comparison between MDPSk and BIB-*v*DPSK has been shown for different values of fading parameter. It is clear that all of the BIB design cases are much better than MDPSK specially when w = 3. This is because the system will treat the BIB design model as a 79-DPSK instead of 1024-DPSK.

Figure- 3. BIB-*v*DPSK vs. MDPSK for different fadings.



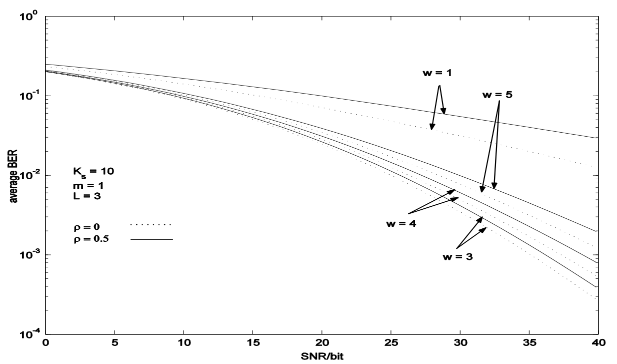
In Fig. 4, we did the same plotting but for different diversity levels of the multi-path channel. We tested the system for a single bath and 3 paths. It has been shown the diversity gave enhancement in the behavior, and BIB-*v*DPSK still better that MDPSK.

Figure -4. BIB-*v*DPSK vs. MDPSK for different diversities



The same thing is done in Fig. 5, but for different correlation values. Correlation factor gives an idea about the multi-path channels to know how much the different paths are correlated to each other. Correlation values are the element for the covariance matrix of the channel.

Figure- 5. BIB-*v*DPSK vs. MDPSK for different correlations.



CONCLUSION

Balanced incomplete block design is studied and applied to the MDPSK modulation to form an important modulation/coding technique, which improve the performance of the MDPSK modulation by reducing the bit error rate by reducing the number of transmitted phases. This modulation/coding technique have been studied over Nakagami-m fading channels, and its performance is better than the conventional MDPSK with less complexity.

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