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EFFICIENT DIGITAL MODULATION AND ENCODING APPROACH USING TAPSK AND MULTILEVEL NON-COHERENT BLOCK CODES

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ABSTRACT

Non-coherent detection provides simple receiver architecturethen coherent detectors becauseit does not require carrier phase tracking. Also since non-coherent detectors works differently than coherent it facilitates the application of multilevel non-coherent blockcoding which provides an effective error correcting capacity at higher coding efficiency. The further insight on Non-coherent system shows that the coding efficiency can be further improved by increasing the minimum non-coherent distance between the modulations symbols. This results the development of new modulation technique derived from MPSK and named as TAPSK (Twisted Amplitude Phase Shift Keying). The TAPSK may provide higher coding efficiency then traditional techniques for similar error correcting capacity when configured properly for specific block size and multilevel block codes. This paper presents the simulation and analysis of TAPSK with multilevel non-coherent blockcodes (NBC) for development of efficient digital communication technique. Finally the simulation result shows that properly designed TAPSK configured with multilevel non-coherent blockcodes (NBC) can achieve much better coding efficiency.

Keywords: *TAPSK, Non-coherent detection, block coded modulation, multilevel coding.*

1. INTRODUCTION

The non-coherent detection provides simple receiver architecture because it does not require carrier phase trackinghence it is preferred for the systems where the simpler receiver architecture are required. To improve the reliability non-coherent detection Non-coherentblock codes techniques for theadditive white Gaussian noise (AWGN) channel were also proposed in [2],[5], including non-coherent block-coded MPSK(NBC-MPSK) [4],[5], differentially encoded QAM(quadrature-amplitude modulation) without channel codingwas proposed [1]. The authors of [1] derived a minimum energy constraint for enlarging the minimumnon-coherent distance between the symbols.

The signal constellation considered for TAPSK (twisted amplitude and phase shift keying) is considered with two different amplitudes for successive symbols. In this paper only a limited numbers of MTAPSK (M = 8 and 16) is considered for convenienceof presentation. However, the proposed non-coherent schemescan be easily extended to any possible value of M.

This paper deals with analysis and impact of different configuration parameters ofTAPSK with multilevel non-coherent blockcodes (NBC) for development of efficient digital communication technique. In rest of paper the second section presents the briefliteraturereviewaboutthe TAPSK and multilevel non-coherent blockcodes (NBC). The thirdsectionpresentsthemodelofthesimulatedsystemfollowedbythesimulationresultsandconclusionin fourth and fifth sections respectively.

2. LITERATURE REVIEW

A new non-coherent sequence detectionalgorithms for combined demodulation and decoding of codedlinear modulations transmitted over additive white Gaussiannoise channels, possibly affected by inter-symbol interference, are presented in [6]. The literature also proposed optimal sequence detection in the presence ofa random rotation of the signal phase based on proper approximations. These results a simple suboptimal detectionschemes based on the Viterbi algorithm, whose performance approaches that of coherent detection. In the proposed schemes [6], the tradeoff between complexityand performances is simply controlled by a parameter, referredto as implicit phase memory, and the number of states of atrellis diagram. Besides being realizable, these schemes havethe convenient feature which facilitates to remove the constantphase assumption and encompass time-varying phase models. Ruey-Yi Wei et al [3] propose three non-coherent block-coded twisted amplitude and phase shift keying (NBC-TAPSK) schemes which are derived from non-coherent block-codedMPSK. The authors also proposed a new non-coherent detector and a corresponding non-coherent distance for non-constant-energy signalsover the additive white Gaussian noise (AWGN) channel. At highdata rates, NBC-8TAPSK has the best bit error performanceamong all non-coherent schemes.Further Results onNon-coherent Block-Coded MPSK is presented in [5]. The paper first focus on the rotational invariance (RI) of NBC-MPSK. Based on the RI property of NBC-MPSKwith multistage decoding, a non-coherent near-optimal linear-complexity multistage decoder for NBC-MPSK is proposed; they also investigated a tree-search ML decoding algorithm for NBC-MPSK shown to have low complexityand excellent error performance. The authors also utilizedthe idea of the NBC-MPSK to design non-coherent space-timeblock codes, called non-coherent space-time block-coded MPSK (NSTBC-MPSK). Multiple-Phase Codes for Detectionwithout Carrier Phase Reference in proposed by Feng-Wen Sun et al [4] in the paper authors consider the construction and analysis of linear block codes for M-array Phase-Shift Keying that can bedecoded without carrier phase synchronization. Under these circumstances, the function that has a significant impact

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on performance is the non-coherent distance, analogously to the Euclideandistance for the coherent case.The major difficulty in constructing and analyzing such codes lies in the fact that the non-coherentdistance is not a true metric. For this reason, prior work mainlyrelies on numerical approaches to search for good codes and todetermine the corresponding minimum non-coherent distance. However in this literature the author's first present a theorem that links the non-coherentdistance with the Euclidean and Lee distances. This theoremallows to construct good codes and determine their minimumnon-coherent distances analytically.

3. TWISTED AMPLITUDE PHASE SHIFT KEYING (TAPSK)

According to the definition and explanation given by [3] the constellation diagram of 8PSK and 8TAPSK is shown in Fig. 1 (a) (b), where the bit in level a decides the symbol energy. The radiuses of the inner and outer circles are denoted by $r0$ and $r1$, respectively.

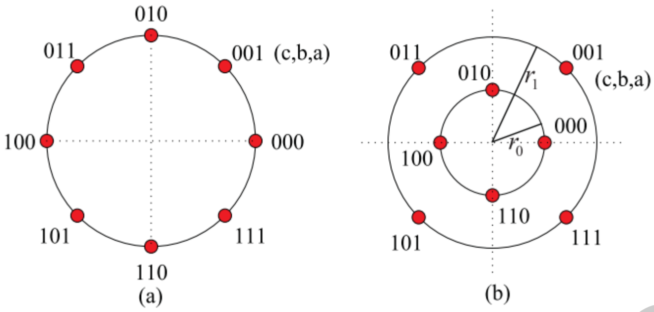

Figure 1: Constellation with bit labeling for (a) 8PSK (b) 8TAPSK.

4. NON-COHERENT DISTANCE

For MPSK signals, the squared non-coherent distance between x_1 and x_2 is defined by$d_{nc}^2(x_1, x_2) = N - |(x_1, x_2)|$[2]. The minimum squared non-coherent distance of a code$C$, denoted by d_{nc}^2, is defined as the minimum value of$d_{nc}^2(x_1, x_2)$ between any two codewords x_1 and x_2 of Cwhich correspond to different information bits.

Non-coherentblock-coded MPSK is defined as block-coded MPSK whosecomponent codes for coding level a, b and $c(2^0, 2^1 \text{ and } 2^2)$are $C_a, C_b$and C_c, respectively. The minimum squared non-coherentdistance of NBC-8PSK is

$$d_{nc}^2 = min\{d_{nc,a}^2, d_{nc,b}^2, d_{nc,c}^2\},$$

Where

$$d_{nc,a}^2 = \sqrt{N - \left(N - \frac{2-\sqrt{2}}{2} d_{a,min}\right)^2 + \frac{d_{a,min}^2}{2}},$$

$$d_{nc,b}^2 = \sqrt{N - (N - d_{b,min})^2 + d_{b,min}^2}$$

$$\text{and } d_{nc,c}^2 = 2d_{c,min}.$$

5. NON-COHERENT BLOCK-CODED TAPSK SCHEMES

To increase $d_{nc,a}$ of NBC-8PSK, we propose to enlarge theenergy of the symbols with $a = 1$ and reduce the energy ofthe symbols with $a = 0$, which becomes 8TAPSK. Hence, thebit in level a decides the power which the considered symbolshould spend. Define$r = r_1 / r_0$. When$r = 1$, 8TAPSK is thesame as 8PSK. For the energy normalization, the values of r_0 and r_1 $(r_0 \leq 1 \leq r_1)$ should satisfy $p_0 r_0^2 + (1 - p_0) r_1^2 = 1$where p_0 denotes the probability of transmitting the symbolswith $a = 0$ which depends on the component code C_a.

6. MULTILEVEL BLOCK CODES (MLBC)

For M > 2-ary digital transmission schemes like ASK, PSK, QAM or CPM (incl. FSK) an efficient combining of channel coding and modulation is possible using multilevel-coding (MLC). Transmission schemes with high power and bandwidth efficiency can be designed by this method in various ways. MLC method is based on an iterative partitioning of the set of signal elements of the modulation scheme.The distance structure of MLC-schemes is in principle known as methods of generalized concatenated codes can be applied.Often, design of MLC-schemes is done according to the minimum Euclidean distance criterion.

A multilevel block code of L levels uses L block codes each of the same length n, called component codes, over finite alphabets of possibly different sizes. A signal set S, called thebasic signal set, of dimension N, has$\prod_{i=1}^{L} m_i$ points, where $m_i, i = 1, 2, 3, \ldots, L$ are the size of the alphabets, with each point labeledby an ordered $L - tuple$ with one entry from each alphabet. With this labeling, a set of L codewords, one from each code, corresponds to a point in Nn dimensions, with each coordinate of Lcode words choosing a point in S. Multilevel coded signal sets with linear codes over GF (2) as component codes have been studied in [1]–[5] andin various general settings in [6]–[10]. Kschischang et al. [11] uselinear codes over non-binary fields to construct multilevel signal sets and give algebraic structural properties of these codes. Multilevel codes for the purpose of unequal error protection have been discussed in [12] and [13]. Sub optimal multi stage decoding and performance analysis of multi level codes have been studied in [14]–[16].This correspondence deals with two-level ($L = 2$) group codes with the basic signal set consisting of points on a circle. The blockdiagram of a two-level block-coded modulation is shown in Fig. 2(a).When C_s and C_r are length n

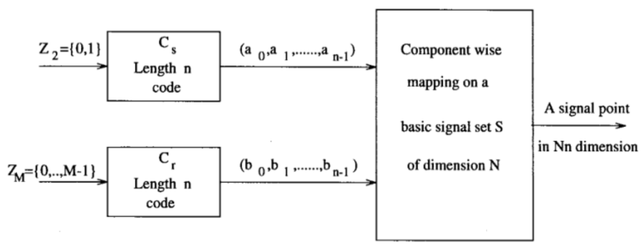

Figure 2(a): Block diagram of a two-level block-codes modulation

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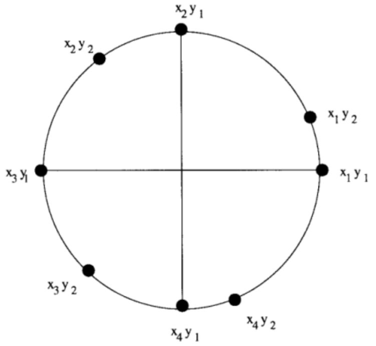

Figure 2(b): Labeling of an 8-PSK signal set with X and Y

Codes over alphabets $Y = \{y_1, y_2\}(m_1 = 2) and\ X = \{x_1, x_2, x_3, x_4\}\{m_2 = 4\}$, Fig. 2(b)shows a labeling of S consisting of eight points on the circle with$X$ and Y. For code words

$$a = (a_0, a_1, \dots, a_{n-1}) \in C_s\ and\ b = (b_0, b_1, ,, , b_{n-1}) \in C_r$$

Each pair (a_i, b_i); $i = 0, 1, ,, , n-1$;selects a point in S, and the pair $(a; b)$ specifies a point in $2n$dimensions. The collection of all such points in $2n$ dimensions corresponding to all possible pairs of code words constitute the two-level block-coded modulation code (signal set) or signal space code. This correspondence concerns Y and X being $Z_2$and Z_M residue class integers modulo 2 and M, respectively, and the basic signalset being a collection of $2M$ points on a unit circle matched to the dihedral group with $2M$ elements.

7. SIMULATION RESULTS

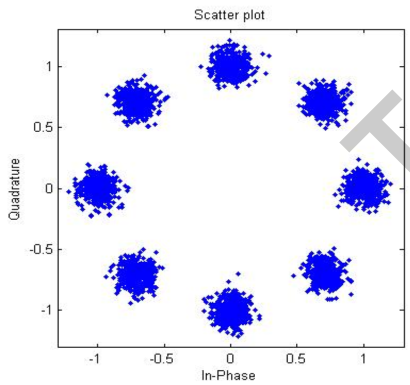

Figure 3: Constellation Diagram of 8PSK at 20dB SNR

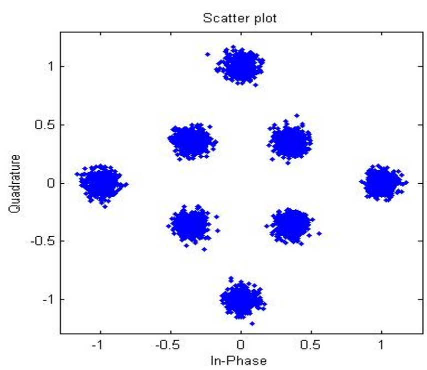

Figure 4: Constellation Diagram of 8TAPSK at 20dB SNR

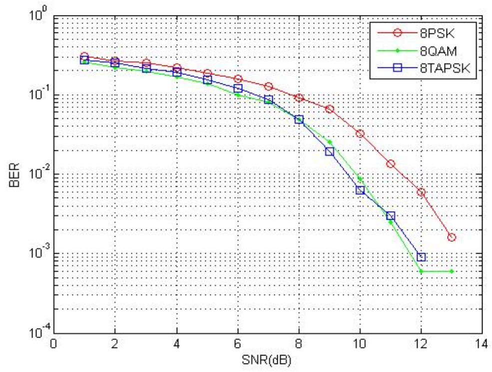

Figure 5: SNR vs. BER Comparison plot for minimum distance (d) = 3, r = 0.5, Block Length = 31.

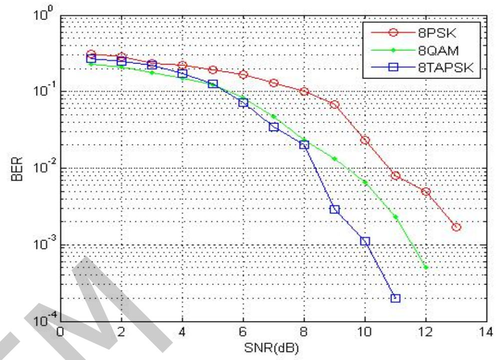

Figure 6: SNR vs. BER Comparison plot for minimum distance (d) = 4, r = 0.5, Block Length = 31.

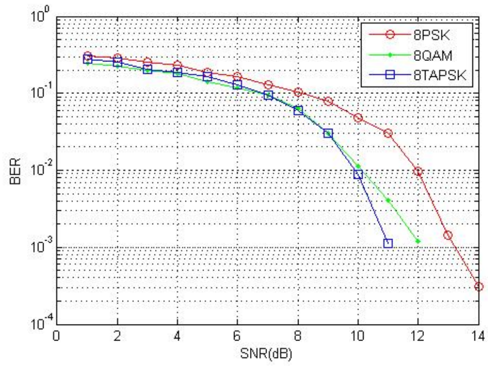

Figure 7: SNR vs. BER Comparison plot for minimum distance (d) = 4, r = 0.5, Block Length = 63.

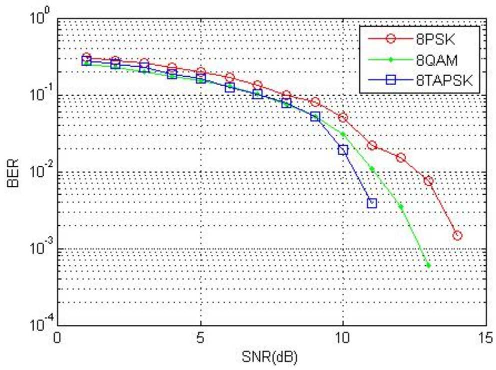

Figure 8: SNR vs. BER Comparison plot for minimum distance (d) = 4, r = 0.5, Block Length = 127.

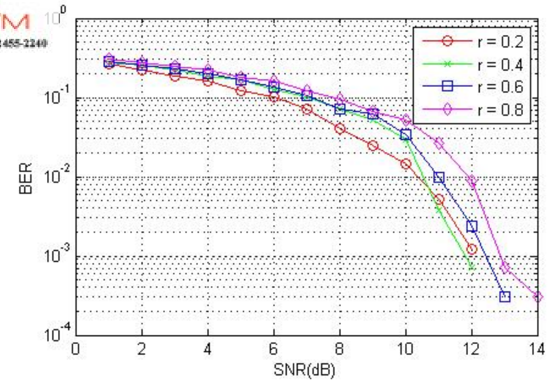

Figure 8: SNR vs. BER Comparison plot for minimum distance (d) = 4, r = 0.2, 0.4, 0.6, 0.8, Block Length = 127.

Table 1: Spectral Efficiency (bits/sym) Comparison

Block Length	8PSK	8QAM	8TAPSK
31	2.1935	1.5484	1.3871
63	2.5238	2.0952	2.0476
127	2.7244	2.4488	2.4488

Table 2: 8TAPSK Spectral Efficiency Comparison for Different Values of r.

r	Spectral Efficiency
0.2	1.3465
0.4	2.3386
0.6	2.5591
0.8	2.6142

8. CONCLUSION

The simulation performed for the 8PSK and 8TAPSK modulation techniques with multilevel NBC and AWGN channel conditions for non-coherent detection, shows that the 8TAPSK provides a Lower BER at small spectral cost. The result also shows that 8TAPSK greatly outperformsthe 8PSK and 8QAM for AWGN Channels while the increased Block Length can also be used to increase the spectral efficiency. Furthermore the ratio "r" can be optimally set to get tradeoff between spectral efficiency and BER.

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