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PERFORMANCE ANALYSIS OF MODIFIED GEOMETRIC CODES

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ABSTRACT

Geometric Codes are a class of three different groups of codes that are easily implemented. This group of codes has greater efficiency over fading channels than regular forward error correcting codes. This paper presents a performance analysis of Modified Geometric Codes and studies the effects of the various parameters such as the number of bits per symbol, the number of parity lines and the code rate as well as compares their performance to the performance of Basic Geometric Codes.

Keywords: geometric codes, modified geometric codes fading channels, code rate, parity symbol.

1. INTRODUCTION

Geometric codes are a class of codes that though are not optimal outperform many codes, particularly over noisy or fading channels (input error rates of 10^{-2} to 10^{-3}). This paper will present the Modified Geometric Code (MGC) present an implementation of both of their encoders and decoders and study their performance over noisy channels. In earlier work, we presented the Basic Geometric Code (BGC), we will show that the MGC has greater distance and outperform the BGC.

We have tested our codes on the systems presented in [2-8] and have gotten significant improvement.

We presented the encoding and decoding algorithms as well as possible hardware implementations. We then presented the simulation results for this code and have shown that the code performance does improve with the increase of the number of bits per symbol and with the coding rate.

2. MODIFIED GEOMETRIC CODES

In the Binary Basic Geometric Code, the location of each code bit is identified with a vertex of a uniformed lattice in the plane. Slopes of the form $1/m_1$, $1/m_2$, $1/m_3$, …, $1/m_r$ are chosen. To determine the jth parity row, a line having the slope $1/m_j$ is drawn through each data bit. The lines wrap cyclically upon reaching the left end of the row as though the block formed a cylinder. These lines are extended into the parity block, and each terminates at a certain parity bit in the jth parity row. This bit is determined so that the sum (mod 2) of the data bits on the line plus the single parity bit is zero. Thus the jth parity row is not affected by the other parity rows.

BGC provides no protection to the parity bits. The MGC partially solves this problem as follows: The first row of parity is determined as in BGC. The second parity row is determined in a similar fashion, but the encoded first row of the parity is included in the parity equation. The third parity row checks both the first and second rows already determined. Continuing in this manner, each parity row checks that data rows as well as the parity rows that lie above it.

This new scheme also provides r orthogonal estimator for each data bit and thus has a minimum distance of at least r+1. This can be significantly improved, by correctly choosing the slopes $1/m_1$, $1/m_2$, …, $1/m_r$, the minimum distance of the MGC may be shown to be $2^r - 1$. This is accomplished by exhibiting $2^r - 2$ orthogonal equations for each bit. The procedure is illustrated in Figure 1 below. The r equations are given by considering the original (primary) parity equations. To obtain a new orthogonal equation, a substitution for each estimating bit is made in one of the primary equations, using an orthogonal estimator having a different slope from the primary line slope [1].

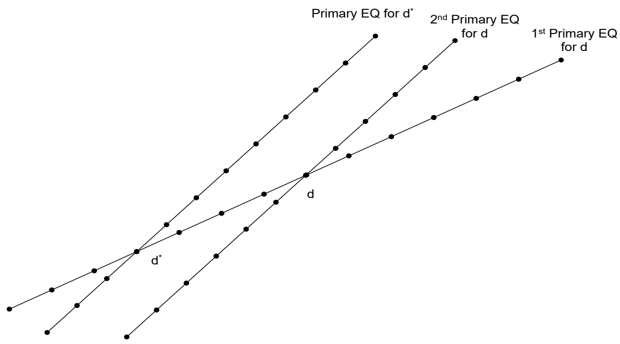

Figure-1. Construction of Secondary Equations (r=2) [1].

This new line will be orthogonal to the primary equation if the substituted line does not intersect any primary line or any previously determined secondary lines. We impose a constraint on the slopes: no triangle with vertices at the bit positions and sides with slopes equal to $1/m_1$, $1/m_2$, $1/m_3$ should be constructible.

It can be shown that the parity condition stated above leads to the equation:

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$$\begin{pmatrix} 1 & x^{m_1} & x^{2m_1} & \cdots & x^{(k-1)m_1} \\ 1 & x^{m_2} & x^{2m_2} & \cdots & x^{(k-1)m_2} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & x^{m_r} & x^{2m_r} & \cdots & x^{(k-1)m_r} \end{pmatrix} \begin{pmatrix} d_1(x) \\ d_2(x) \\ \vdots \\ d_k(x) \end{pmatrix} = \begin{pmatrix} x^{-m_1} & x^{-2m_1} & x^{2m_1} & \cdots & x^{-r\,m_1} \\ x^{-m_2} & x^{-2m_2} & x^{2m_2} & \cdots & x^{-r\,m_2} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x^{-m_r} & x^{-2m_r} & x^{2m_r} & \cdots & x^{-r\,m_r} \end{pmatrix} \begin{pmatrix} c_1(x) \\ c_2(x) \\ \vdots \\ c_r(x) \end{pmatrix}$$

The above equations are in the ring of polynomials modulo x^w+1. Because this is not a field, matrix inversion is not possible; however, the structure of the matrix does permit a solution, which is expressible as:

$$c_i(x) = \sum_{i=1}^{k} d_i(x) q_{ij}(x) \qquad mod\ x^w + 1$$

where the $\{q_{ij}(x)\}$ are polynomial that depend upon the slopes. The above derermination of the parity polynomial shows that the jth parity bit vector is the sum (mod 2) of the outputs of the k tapped cyclic shift registers Imp.lementation is, therefore, straightforward [1].

For simplicity, we will describe the procedure for a specific example, the rate 1/2 MGC with 3-data lines and 3-parity lines.

In the MGC every parity line depends on the parity lines ahead of it as mentioned before. This dependency dictates that we calculate the parity lines in order. As shown in Figure-2, we first calculate the first parity line $p_1$in an exact way as in the BGC. The encoding equation for the i^{th} symbol in the first data line, $d_1(i)$ is as follows:

$$p_1(i-3) = -[d_1(i) + d_2(i-1) + d_3(i-2)]$$

Once we calculate p_1, we can start calculating the second parity line p_2. The second parity line is a function of the data lines and the first parity line. The encoding equation for the ith symbol in the first parity line in $d_1(i)$ is as follows:

$$\mathrm{p_2(i-8) = -[d_1(i) + d_2(i-2) + d_3(i-4) + p_1(i-6)]}$$

Once p_2 is calculated, p_3 is then calculated in a similar manner except that it would be a function of the data lines and the first and second parity lines. In general w,e continue in the same manner until we calculate all r parity lines.

The decoding procedure of the MGC is very similar to that of the BGC, especially the detection part. Except that in the MGC errors occurring on the parity lines will be detected by more that one slope.

The error correcting procedure for the MGC is almost identical to that of the BGC, with two significant differences. First, we attempt to correct errors in the parity lines. This is accomplished by letting j, the row index to attain values up to k+r instead of k for the BGC. Second, the decoding equations would have to be altered to correspond to the encoding equations used in the encoding process. For the MGC the equations used to calculate the error for the i[th] symbol in the first data line are given by:

$$E_1 = -[d_1(i) + d_2(i-1) + d_3(i-2) + p_1(i-3)]$$
$$E_2 = -[d_1(i) + d_2(i-2) + d_3(i-4) + p_1(i-6) + p_2(i-8)]$$
$$E_3 = -[d_1(i) + d_2(i-7) + d_3(i-14) + p_1(i-21) + p_2(i-28) + p_2(i-35)]$$

The remainder of the process is identical to that of the BGC [1].

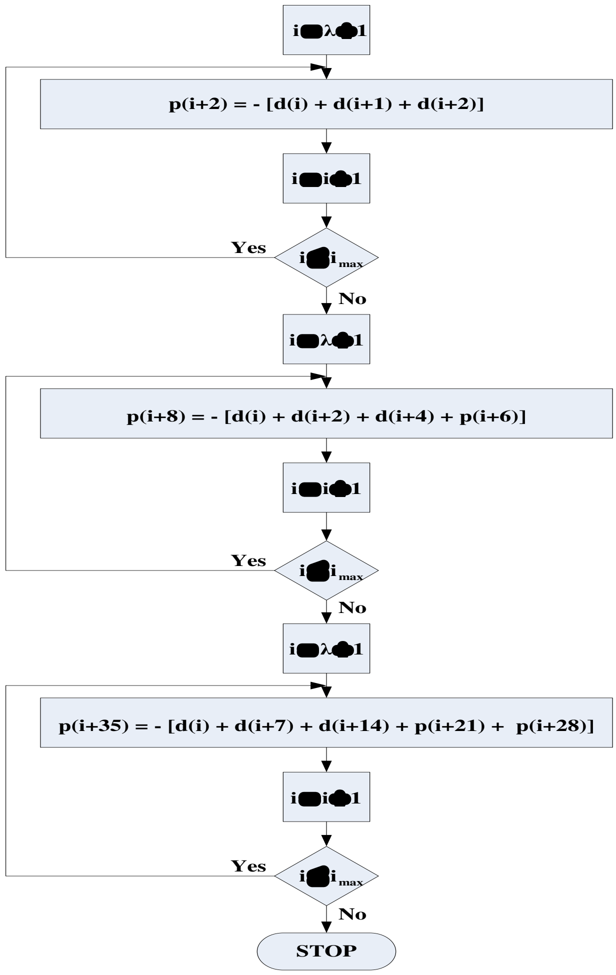

Figure-2. Flow Diagram for the Encoder of Rate 1/2 MGC with 3-Data Lines and 3-Parity Lines.

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3. SIMULATION RESULTS FOR THE MODIFIED GEOMETRIC CODE (MGC)

We simulated many codes using this procedure. In this section, we present some of the simulation results obtained.

Figure-3 shows the results for the binary, 8-ary, and 256-ary MGC rate 1/2 with 3-data lines and 3-parity lines. The figure shows that the 8-ary code represents a significant improvement over the binary code. The 256-ary code introduces even more improvement. As discussed earlier, additional improvements would be introduced by increasing the number of bits per symbol. For by increasing the number of bit per symbol, the chance of two symbols canceling will be less. Therefore, the probability of symbol error out would approach zero as m the number of bits per symbol approaches infinity. Large values of m are undesirable, as discussed in [1]. We did not simulate any codes of $m > 8$ to limit the run time of the simulation programs.

Figure-4 makes the same comparison for the rate of 3/4 codes. Hence, showing the error rate improves with increasing m, no matter the rate of the code used.

Figure-5 compares the results obtained for the 8-ary rate 1/2 code, one using 3-parity lines and other using 4-parity lines. The code using 4-parity lines shows some improvement over the code using 3-parity lines. This improvement is the result of using more estimators per symbol, and therefore, an error will be detected by more slopes. Hence it will be easier to locate. Note that the codes with more than 4-parity lines were not simulated for the reason explained previously.

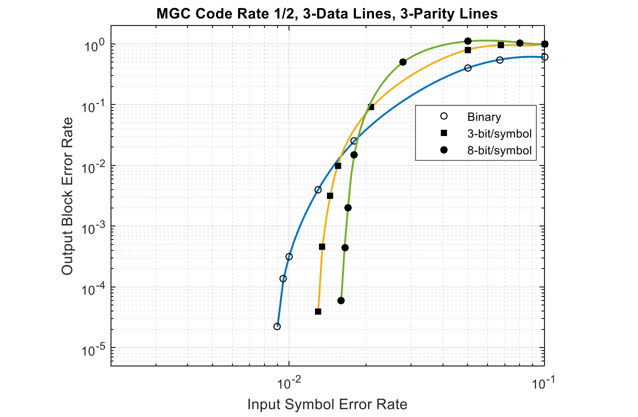

Figure-3.

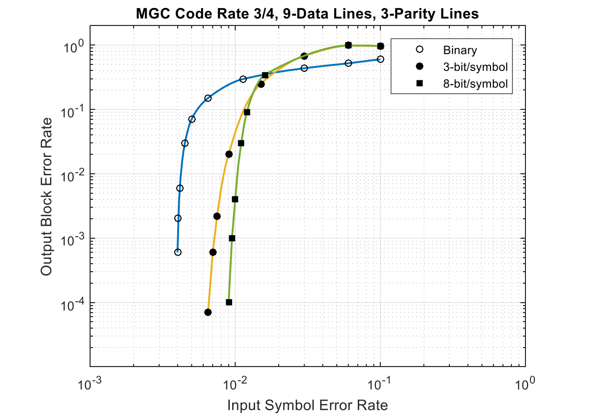

Figure-4.

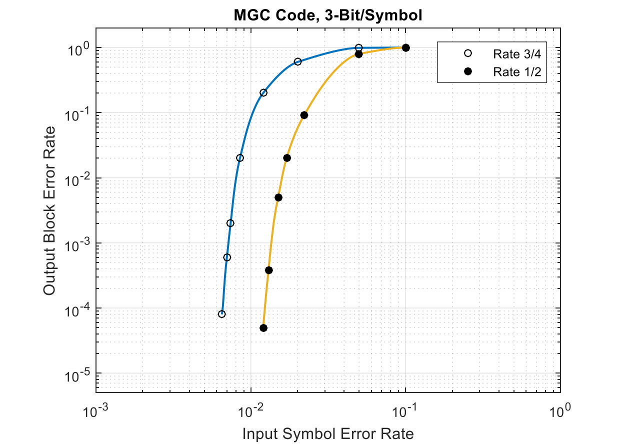

Figure-5.

CONCLUSIONS

In this paper, we presented a group of codes called the Geometric Codes; we presented the encoding and decoding algorithms as well as possible hardware implementations. We studied the performance of the Modified Geometric Code over a noisy channel. We then presented the simulation results for this code and have shown that the code performance does improve with the increase of the number of bits per symbol and with the coding rate.

It was shown that though geometric codes are not optimal, they outperform many codes, particularly over noisy or fading channels (input error rates of 10^{-2} to 10^{-3}).

It was also shown that the Modified Geometric Code offers better results than the Basic Geometric Code because each parity line encodes the lines above it, offering a higher degree of protection.

Furthermore, both codes offer simple coding and decoding implementations. Because of their flexibility, geometric codes can be tailored for use in many communication systems.

ACKNOWLEDGMENT

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