A New 8B10B Block Code for High Speed Data Transmission Over Unshielded Twisted Pair Channels

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Abstract: A new 8B10B code is reported which has similar spectral properties to the pseudoternary MLT3 code, but has the advantages of requiring binary rather than ternary signalling and providing a set of non-data codewords.

Introduction: In recent years several schemes have been proposed for data transmission at speeds of approximately 100 Mb/s over unshielded twisted pair (UTP) cables. In each case, a major constraint on the coding and modulation schemes chosen has been the need to avoid excessive radiated emission from the cable plant at frequencies above 30MHz. One approach is to code data such that the energy of a rectangular pulse amplitude modulated signal is concentrated below 30MHz, a technique we shall refer to as "spectral shaping". For example, the IEEE 802.3 100BASE-TX [1] standard has specified a spectral shaping pseudoternary code known as MLT3. Other spectral shaping ternary codes have also been reported which improve upon MLT3 [2]-[4] by guaranteeing that a transmitted signal is d.c. balanced.

We report here a new *binary* block code (8B10B) which exhibits a power spectral density (psd) with similar advantages to MLT3 and is also d.c. balanced. Binary transmission has significant benefits for low complexity data transmission schemes. These benefits include: reduced transmitter voltage for constant symbol separation, fixed receiver threshold level and reduced sensitivity to intersymbol interference. The block code reported here also provides a set of non-data codewords that may be used for control signalling purposes. Although 8B10B coding requires a symbol rate 25% greater than the data rate, a similar overhead is incurred in schemes such as [1] where a block code precedes the MLT3 code.

Code Design and Description: From the 1024 possible codewords, 256 were chosen based on their low spectral content at high frequencies. This set of 256 codewords, consisting of 10 bits d_0 to d_9, is listed in Table 1. 123 codewords are identical to the reverse of another codeword, as indicated in the table. The 256 codewords have weights equal to or greater than zero (weight is defined as the difference between the number of 1's and 0's in a codeword) and are assigned according to a one to one mapping between input bytes and output codewords. This mapping does not affect the spectral properties of the code and is not shown here. The 8B10B encoder maintains a record of the running digital sum (rds) at its output and selectively inverts codewords according to the value of this rds. If the rds is > 0 and the weight of the next codeword is >0, this codeword is inverted before being transmitted. Otherwise codewords are always transmitted without inversion. The rds of coded data is bounded between +13 and -11, and the maximum runlength is 17.

The psd of this new 8B10B block code is shown in figure 1 along with the psd of the MLT3 code and random uncoded data. The psd's have been calculated assuming equal symbol amplitude spacing and equal symbol rates for the binary and ternary codes. The spectral shaping of the 8B10B code is clearly visible. The small increase in psd over MLT3 at some frequencies is compensated by the benefits of binary transmission and the further advantages of the 8B10B code described below.

In many applications there is a requirement for non-data codewords to be transmitted when data is not being transmitted (e.g. an idle signal), without the spectral properties of the signal deteriorating. In addition, it is often desirable for these non-data codewords to remain unique from data codewords even when errored. The 8B10B code reported here provides eight zero weight 10-bit codewords which all have Hamming distance 2 from any data codeword, and when chosen randomly have advantageous spectral properties similar to the data code. These non-data codewords are listed in Table 2, and their psd is also shown in Figure 1.

In addition to these non-data codewords there are a further 2 zero weight codewords, (0101010101) and (1010101010), which do not share the advantageous spectral properties of the data codewords, but do have other favorable properties. Specifically, they are Hamming distance 4 from any data codeword or non-data codeword listed in Tables 1 and 2, and cannot appear in a concatenation of any number of codewords from Tables 1 and 2. These codewords might be used to occasionally signal control information, provided their use is so infrequent as to not deteriorate the spectrum of the transmitted signal.

Conclusions: A new 8B10B block code has been reported which exhibits spectral shaping similar to the pseudoternary MLT3 code, but benefits from the added advantages of binary signalling. A set of codewords with Hamming distance 2 from any data codeword but with similar spectral properties to the data codeword set has also been described. This code is suitable for data transmission on UTP cables.

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References

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Table 1: Data Codewords

$d_0 \ldots\ldots d_9$ or $d_9 \ldots\ldots d_0$	$d_0 \ldots\ldots d_9$ or $d_9 \ldots\ldots d_0$	$d_0 \ldots\ldots d_9$ or $d_9 \ldots\ldots d_0$	$d_0 \ldots\ldots d_9$ or $d_9 \ldots\ldots d_0$
0011111111	0011100110	1100110111	1011000011
1111100111	1100011001	0111111011	1011100111
1111110011	1000111111	0111000110	0110100011
0001100111	1110111111	1000111001	1001011100
1111111110	1110011110	0011011110	1101001111
1111111000	0000111011	0111011000	0011001011
0000011111	1111000100	1000100111	1100110100
0001110011	0001111110	1001110111	0010011101
0011000111	1001110011	1001101111	1101100010
1111100001	0011101111	0111100110	0111100100
1111100011	0110001111	1011001111	1000011011
0001111100	1110011001	1110010111	0110111011
1110000011	1101111000	1011000111	1101111001
0011001110	0001110110	0100001111	1101101111
1100110001	1110001001	1011110000	0100110011
1111101111	0110111111	1011111001	1011001100
0011100011	0111111001	0000101111	0110111110
0011100111	0111110011	0111001001	0011110110
0111110000	1111111101	1000110110	0110110111
1000001111	0100111111	0001011011	0111011110
1111000111	0011011111	1001011111	1001110110
0111111100	1101100011	1110100100	0001101101
1111111001	1101100111	1111101101	1110010010
1101111111	1100111101	0100111110	1011011100
0011110111	1111100110	1111100101	0110001011
1111001110	1101111100	0111100001	1001110100
0001111001	0011111101	0010111100	0011010011
1110000110	0010011111	1101000011	0101100110
1101110011	1111010011	1111011110	1010011001
0011011100	1100100111	1101101110	0111101000
1100100011	0010111111	0100111100	

$d_0 \ldots\ldots d_9$	$d_0 \ldots\ldots d_9$	$d_0 \ldots\ldots d_9$	$d_0 \ldots\ldots d_9$
0011111100	0111111110	0111001110	1000010111
1110000111	1100110011	1001111001	
1111001111	1110110111	1101111011	

Table 2: Non-data Codewords

$d_0 \ldots\ldots d_9$	$d_0 \ldots\ldots d_9$	$d_0 \ldots\ldots d_9$	$d_0 \ldots\ldots d_9$
0000110111	0001001111	0011110001	0111000011
1111001000	1110110000	1100001110	1000111100

Figure 1 Power spectral density of random data (solid line), MLT3 (heavy solid line), new 8B10B code (heavy dashed line) and non-data codewords (dashed line).