AI based Digital Companding Scheme for OFDM system using custom constellation Mapping and selection

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Abstract - Data rate is important in telecommunication because it is directly proportional to the cost of transmitting the signal. Saving bits is the same as saving money . In this paper we propose new digital companding scheme for OFDM system based on using different constellation orderings (QAM modulator) , depending on the data to be transmitted . Depending on the data to be transmitted AI (Artificial Intelligent) block compresses and expands the signal, 8 to 3 bit compression is proposed(32:1 compression). The proposed scheme was simulated in Matlab7.4 and it was shown that the proposed companding scheme effective with low compression error.

Key words – Companding , OFDM system

Introduction

Recently, OFDM (Orthogonal Frequency Division Multiplexing)has drawn explosive attention as a new type of high data rate transmission schemes for digital broadcasting systems as well as wireless multimedia networks[1,2]. In the OFDM systems, whole system bandwidth is divided into many orthogonal sub-channels with narrow bandwidth, and data symbols are independently transmitted through the sub channels. The OFDM system significantly increases bandwidth efficiency by allowing overlapping of the sub channels, while maintaining orthogonality between them. Moreover, robustness against frequency selective fading channels can be easily achieved since frequency selective fading becomes approximately flat for each sub-channel, which can be compensated by employing simple single-tap equalizers.

In addition, the OFDM transceiver can be efficiently implemented by using FFT (Fast Fourier Transform) algorithm, and serious inter-symbol interference is readily circumvented by introducing the cyclic prefix[1].

OFDM (Orthogonal Frequency Division Multiplexing) system has been used for the high-speed digital communications such as DAB (Digital Audio Broadcasting), DVB (Digital Video Broadcasting) and WLAN (802.11 a) due to robustness to the narrowband interference and severe multi-path fading[3] [4].

Recently, there has been an interest [5, 6,7,8] in the effect of the pulse code modulation (PCM) companding [5] mechanism (introduced to improve voice transmission), inherent in communication networks, on the detectability performance of digital Quadrature Amplitude Modulation (QAM) signals transmitted through these networks. As has been previously shown [5, 6, 7,8], the effect of the companding process is to introduce quantization noise which is multiplicative in nature. This noise is amplitude dependent, i.e., large amplitude signal points in the QAM constellation will be surrounded by more noise than signals closer to the origin. The effect of this noise is such that the outermost points in a simple rectangular constellation suffer more performance degradation than the smaller internal signals. Saltzberg and Wang in [8] made the observation that not only is the noise around each point dependent on its amplitude, but that this noise is elliptical and not circular . The noise components in the two dimensional QAM space are not equal . In [8], it was also shown that the two dimensional noise components are not only unequal, but also correlated for most choices of vector bases. These properties make the detection problem and the signal constellation design problem very interesting, and represent a new challenge in signal design.

Quadrature Amplitude Modulation is best suited for high data rate transmission since it uses quadrature and in phase components to modulate the signal. Different combinations of quadrature and in phase components can be used to modulate the signal , which result in binary coded mapping , Gray coded mapping and custom mapping schemes .The performance of QAM will not change much with coding scheme adopted[5]

In this paper we propose a compression scheme which uses Thirty two types of constellation orderings to compress the signal depending on the data to be transmitted .This paper is organized as follows. In section 2 the proposed scheme is explained, Section 2.1 explains about Compressor , Section2.2 explains about Expander , in section 3 results are given and in section 4 paper is concluded.

2 .Proposed Scheme

Digital Companding scheme proposed by K.Seshadri Sastry and Dr .M.S.Prasad Babu in [11] is modified in proposed scheme. Proposed Companding algorithm is as follows. Incoming data bits are compressed (32:1) and transmitted to convolutional Encoder , modulated, inverse fast Fourier transform (IFFT), injection of guard interval (GI) and transmitted and the received signal demodulated , decoded and expanded using AI based expander. Proposed system is simulated in Matlab 7.4 . The parameters of OFDM system used are as follows, IFFT Size is 512 , Number of sub carriers are 512 , Number of sub bands are 32 , Number of sub carriers per sub band are 16 , Guard Time Duration is 128 , Frame size is 6 , SNR 1-35 dB , Modulation schemes used are MPSK, MQAM , convolutional coder with code rate 2/3 , Bandwidth 5MHz , Carrier Frequency 2 GHz , Sampling Frequency 5.4MHz

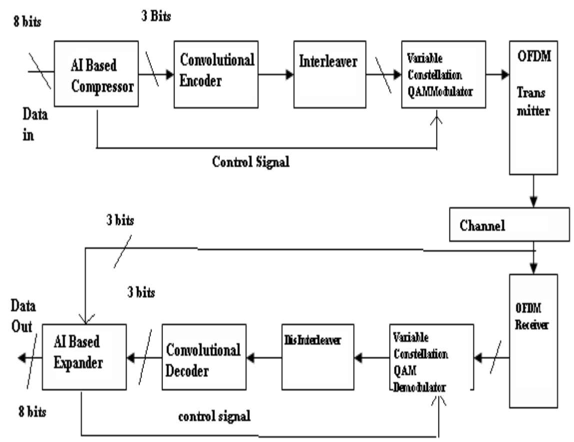

Fig 1 Block Diagram of Proposed Scheme

2.1 AI Based Compressor

AI based compressor divides the incoming bit sequence to MSB and LSB parts (.For example if bit sequence is “11001000” it is divided to MSB (“110”) and LSB (“01000”) parts) . Depending on the LSB part one custom constellation ordering out of 32 constellation orderings is selected. Details of LSB bits and corresponding constellation ordering s to be selected is placed in Table 1

SNO	LSB Bits	Selected Constellation Ordering
1	00000	Const 1
2	00001	Const 2
3	00010	Const 3
4	00011	Const 4
5	00100	Const 5
6	00101	Const 6
7	00110	Const 7
8	00111	Const 8
9	01000	Const 9
10	01001	Const 10
11	01010	Const 11
12	01011	Const 12
13	01100	Const 13
14	01101	Const 14
15	01110	Const 15
16	01111	Const 16
17	10000	Const 17
18	10001	Const 18
19	10010	Const 19
20	10011	Const 20
21	10100	Const 21
22	10101	Const 22
23	10110	Const 23

24	10111	Const 24
25	11000	Const 25
26	11001	Const 26
27	11010	Const 27
28	11011	Const 28
29	11100	Const 29
30	11101	Const 30
31	11110	Const 31
32	11111	Const 32

After selecting the constellation ordering depending on LSB bits , 3 bits of MSB are transmitted to QAM modulator . So out of eight bits five bits are used to select constellation ordering and three(MSB) bits are transmitted (i.e. five bits are compressed , which results to 32:1 compression) .

The proposed scheme uses thirty two types of custom constellation orderings of QAM. Each constellation ordering differs from other in using phase and quadrature components. For example custom ordering 1 uses 2 , 2 ,-2 , -2 as quadrature component and -4 , -2 ,2 ,4 as phase components , whereas custom ordering 2 uses 3 , 3 ,-3 , -3 as quadrature component and -4 , -2 , 2 , 4 as phase components (i.e. each constellation ordering varies from other in arrangement of quadrature and phase components).

The block diagram of AI based compressor is shown in Fig 2.

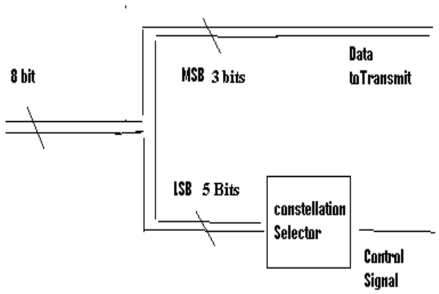

Fig 2 AI Based Compressor

After selecting the constellation depending on LSB bits the AI based compressor sends control signal to Variable QAM modulator . Depending on the control signal the modulator uses pre defined constellation ordering (i.e. const 1 , const 2…..etc.).

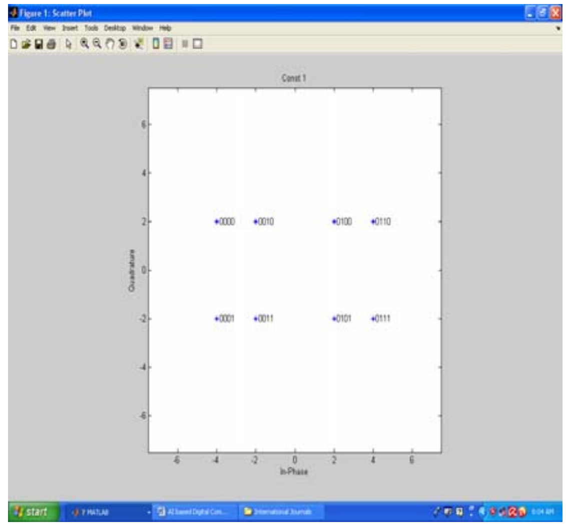

Fig 3 Const 1

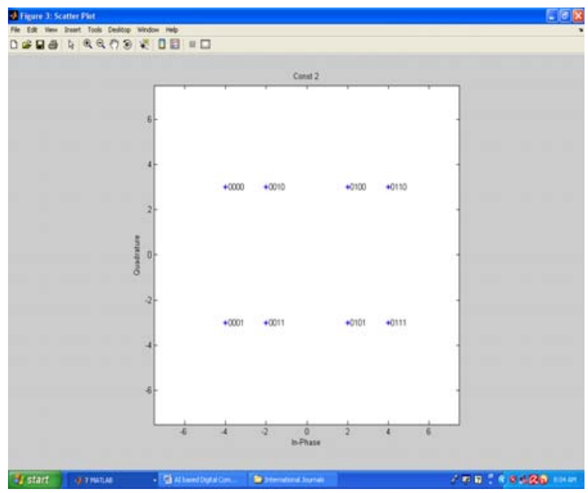

Fig 4 Const 2

Fig 1,2,3 and 4 shows four custom constellation orderings (out of 32 constellation orderings used) as an example . Actually 32 custom constellation orderings used , but we cannot show 32 custom constellation orderings in this paper , since they occupy more space.

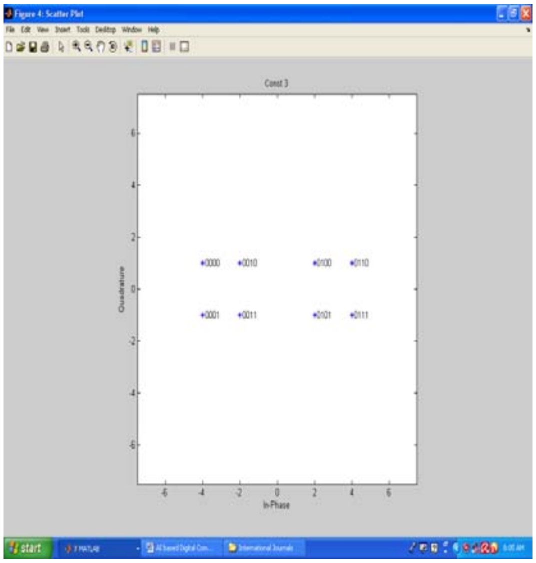

Fig 5 Const 3

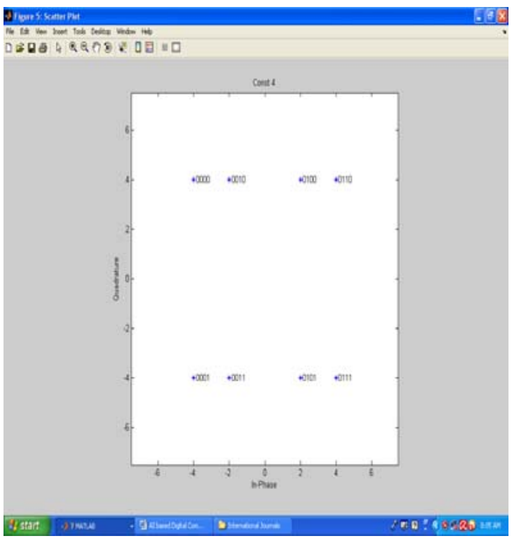

Fig 6 Const 4

2.2 AI based Expander

AI based expander lies in receiver part. In AI based expander incoming bit sequence is divided to real part and imaginary part (Imaginary part consists of Quadrature components and real part consists of phase components) . Real part and imaginary part are compared to preloaded data in memory. Constellation ordering followed in transmitter can be detected by comparing real and imaginary part (since arrangement of quadrature and phase components are different from constellation ordering to constellation ordering , for example if incoming signal consists of quadrature component 2 and phase component 4 , it will be ordering 1(const 1) , otherwise if quadrature component is 3 and phase component is 4 , it is ordering 2, which is predetermined).

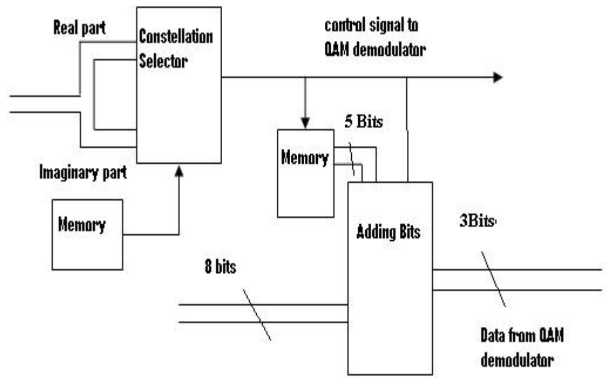

Fig 7 AI based Expander

After sensing the constellation ordering, one control signal is sent to variable QAM demodulator, so that constellation ordering followed in QAM modulator is followed in QAM demodulator. Another control signal is sent to adding bits block so that it adds bits in LSB to data coming from QAM demodulator (depending on constellation ordering followed) as shown in Table 2

SNO	Constellation ordering Detected	LSB bits Added
1	Const 1	00000
2	Const 2	00001
3	Const 3	00010
4	Const 4	00011
5	Const 5	00100
6	Const 6	00101
7	Const 7	00110
8	Const 8	00111
9	Const 9	01000
10	Const 10	01001
11	Const 11	01010
12	Const 12	01011
13	Const 13	01100
14	Const 14	01101
15	Const 15	01110
16	Const 16	01111
17	Const 17	10000
18	Const 18	10001
19	Const 19	10010
20	Const 20	10011

21	Const 21	10100
22	Const 22	10101
23	Const 23	10110
24	Const 24	10111
25	Const 25	11000
26	Const 26	11001
27	Const 27	11010
28	Const 28	11011
29	Const 29	11100
30	Const 30	11101
31	Const 31	11110
32	Const 32	11111

So incoming 3 bits are expanded to 8 bits . Assumption of bits to be expanded depends on AI based expander block to assume (calculate) constellation ordering followed in transmitter.

4.Results

The proposed scheme was simulated in Matlab7.4. The compression error is uniform and negligible for all values of data , since estimating the expanded signal is based on constellation mapping . The Bit Error Rate (BER) of companded signal is shown in Fig 8. The comparison of companded and un companded signal is shown in Fig 8. In the proposed scheme eight bits are compressed to three bits for example , if incoming data is “11111111” , then it is divided to “111” and “11111” . Since LSB is “11111” , “111” is modulated and transmitted through channel using constellation ordering ‘const 32’ . At receiver after comparing received real and imaginary components constellation ordering used at transmitter can be found . Since Constellation ordering ‘const 32’ is used for demodulated signal “11111” can be added at LSB part which will give expanded signal “11111111” . In the proposed scheme 8 bits data is compressed to 3 bits and
8 QAM is used to modulate . In uncompressed scheme 8 bits are modulated with 256 QAM and transmitted. The Bit Error Rate using proposed scheme is much less compared to uncompressed scheme and the compression error is negligible .

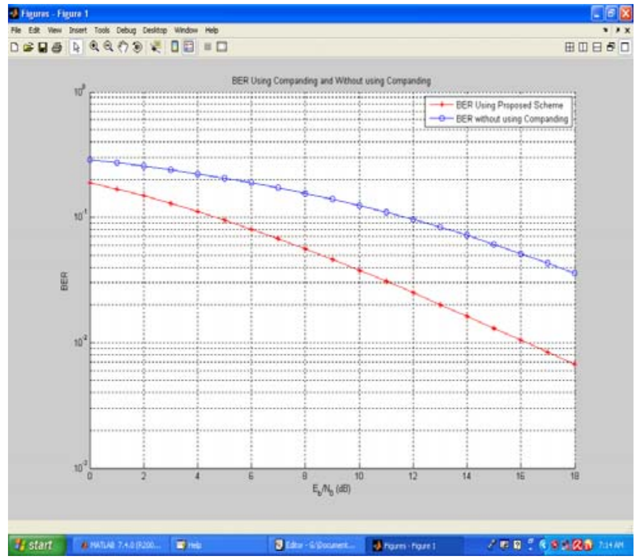

Fig 8 Bit Error Rate Comparison of Proposed Companding and un companded schemes

5.Conclusion

Digital companding of the signal using constellation ordering of QAM signal improves the performance of transmission. Companding error obtained in this process is negligible since accurate estimation of expanded signal is possible.

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