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Abstract

This paper presents a new spreading matrix for block spread OFDM (BSOFDM) to improve the performance of the system by increasing the correlation between the symbols. This is achieved by rotating the modulation scheme used at the transmission, say QPSK, into a higher order modulation scheme, for example 16QAM. By this the correlation between the transmitted symbols is increased. The advantage of this new spreading matrix over more traditional spreading matrices is its flexibility in achieving different higher order modulation schemes during transmission depending on the angle α . This is compared to other spreading matrices in frequency selective channel environment.

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A NEW SPREADING MATRIX FOR BLOCK SPREAD OFDM

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ABSTRACT

This paper presents a new spreading matrix for Block Spread OFDM (BSOFDM) to improve the performance of the system by increasing the correlation between the symbols. This is achieved by rotating the modulation scheme used at the transmission, say QPSK, into a higher order modulation scheme, for example 16QAM. By this the correlation between the transmitted symbols is increased. The advantage of this new spreading matrix over more traditional spreading matrices is its flexibility in achieving different higher order modulation schemes during transmission depending on the angle α . This is compared to other spreading matrices in frequency selective channel environment.

Key Words-Spreading matrix, BSOFDM, Frequency selective channel

1. INTRODUCTION

Many solutions have been presented to allow a communications system to improve its spectral efficiency of the modulation schemes by applying different schemes such as adaptive modulation based on the Bit Error Rate or the signal to noise ratio. But these systems suffer from complexity issues and the fact many still, after various algorithms to improve the spectral efficiency, end up using BPSK or QPSK. This paper proposes a new method to increase the correlation between the symbols through the use of a rotation of the modulated symbols, and depending on the rotation angle, α , a new and higher order modulation is used in the transmission of the system to increase the correlation between the transmitted symbols to improve the BER performance. At the receiver the inverse of this rotation is carried out to return to the same modulation scheme used at transmission. This is not the same as adaptive modulation as this does not retransmit the data when the new modulation scheme is created but rather has the same modulation scheme at the transmission. This paper has the following sections. Section 2 provides a description of the system used to test the new matrix and discusses the advantages of this new spread matrix over other existing spreading matrix. In Section 3 gives

the results achieved with the new spreading matrix and the comparisons between it and the existing spreading matrices over selective frequency channels. And finally in Section 4 provides a conclusion and future work on this spreading matrix.

2. SYSTEM DESCRIPTION

Primarily this new spreading matrix is used in what has been described as Block Spread OFDM (BSOFDM), which is when the full set of subcarriers are divided into smaller blocks and using spreading matrices to spread the data across these blocks so to achieve multipath diversity across each block at the receiver [1] [2]. The BSOFDM channel model is shown in Figure 1.

The output of the receiver's FFT processor is

$$y = Cq + n \quad (1)$$

where y is the FFT output, $q \in A^N$ is the vector of transmitted symbols, each drawn from an alphabet A , C is a diagonal matrix of complex normal fading coefficients, and n is a zero mean complex normal random vector. Equalization of the received data is done through multiplication by C^{-1} and then "quantized independently on each subcarrier to form the soft or hard decision $\hat{q}$ which may be further processed if the data bits are coded" [3]. There is no loss in performance when the detection is performed independently on each carrier due to the noise being independent and identically distributed with fading been diagonal [3].

The block spreading matrices are used to introduce dependence among the subcarriers. N subcarriers are split into $\frac{N}{M}$ of blocks of size M , where $M = 2$ for this example. Then each of the blocks are multiplied by a 2×2 unitary matrix U_2 . The length two output vectors are interleaved using general block interleaving to ensure the symbols are statistically independent so as to encounter independent fading channels. This will ensure in a dispersive frequency selective channel the data is statistically less likely to become

Fig. 1. Block diagram representation of the BSOFDM channel for a block length of two [3].

corrupted and studies and simulations have shown this to be correct.

The transmitter's IFFT has the interleaved data passed through it and this data is sent across the frequency selective channel. The data is passed through an FFT processor at the receiver and deinterleaved before using block by block processing.

The spreading matrices are generally used to increase the correlation between the transmitted symbols after the transmission has occurred. Unlike adaptive modulation schemes where depending on the system, a higher order modulation scheme is used to retransmit the data depending on the conditions presented, this scheme utilizes spreading matrices to increase the correlation between the symbols, rather than retransmitting. This is depicted in Figure 2. So say at the transmission the system modulates the data using QPSK modulation, with spreading matrices a higher order modulation is used to increase correlation and therefore overall system performance. There are a number of matrices available and well studied, this paper will introduced another matrix using angles to increase the order of modulation. Depicted in Figure 3 is the scatter plot of QPSK modulation which will be used to test the new spread matrix.

2.1. Hadamard codes

By selecting as codewords the rows of a Hadamard matrix, it is possible to produce Hadamard codes. An $N \times N$ matrix of 1's and 0's is a Hadamard matrix "such that each row differs from any other row in exactly $\frac{N}{2}$ locations. One row contains all zeros with the remainder containing $\frac{N}{2}$ zeros and $\frac{N}{2}$ ones" [4].

$\frac{N}{2}$ is the minimum distance for these codes and as an

Fig. 2. The process through which the transmitted modulation is converted into a higher order modulation and then returned at the receiver.

Fig. 3. The well known QPSK modulation scatter plot.

Fig. 4. After the Hadamard Matrix, the scatter plot of the data shows that it went from QPSK modulation to a higher modulation scheme.

example for $N = 2$, the Hadamard matrix A is

$$A = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

After the modulated data is multiplied by the Hadamard matrix, a higher order modulation scheme is created which increases the correlation between the transmitted symbols, therefore achieving a better system performance. This can be seen in Figure 4, where the modulation at the transmission was carried using QPSK shown in Figure 3, the new modulation scheme scatter plot is shown in Figure 4. The new scheme shows it has increased from the four QPSK constellation points to nine.

2.2. Rotated Hadamard

The rotated Hadamard codes are the same as that described above with the exception it is rotated using the rotation equation given below,

$$U = \frac{1}{\sqrt{2}} H_{M \times M} \text{diag} \left(\exp \left(\frac{j \times \pi \times m}{C} \right) \right) \quad (2)$$

Where C is the rotation value which the modulation rotated back on to it self, for QPSK it is four. H is the Hadamard matrix described above and M is the size of the

Fig. 5. after the Rotated Hadamard Matrix, the scatter plot of the data shows that it went from QPSK modulation to 16QAM.

matrix, in this example set at two. The modulation data is multiplied by the value U and the rotation takes place producing a higher modulation scheme. This can be seen in Figure 5 depicting the modulated data after the rotated Hadamard matrix. The rotated Hadamard is capable of achieving 16QAM with the rotation setup in the way it is described above. So as can be seen this rotated Hadamard produces a higher order scheme than the traditional Hadamard. This is directly translated into a better BER performance in BSOFD system of rotated Hadamard over Hadamard. This can be seen in the Results section of this paper.

2.3. New Spreading Matrix

The following is a description of the new spread matrix for BSOFD, where for example to make QPSK into 16QAM the choice of $\tan(\alpha) = 0.5$. This achieves different modulation schemes to that of Hadamard and Rotated Hadamard.

$$A = \begin{bmatrix} 1 & \tan(\alpha) \\ \tan(\alpha) & -1 \end{bmatrix}$$

Depending on the choice of α , different modulation schemes are possible. Naturally, not all angles can be chosen since this would not yield a better result than the Hadamard matrix. For example an angle of $\alpha = \frac{\pi}{4}$ would result in one, which would mean that the matrix is a Hadamard matrix. Other angles which cannot be used when using QPSK are

Fig. 6. The new matrix for block spread OFDM showing higher modulation is achievable.

$\alpha = \pi$ and $\frac{\pi}{2}$ since the rotation of QPSK would rotate back onto it self and the new rotation would be the same as the rotated, that is QPSK. Other angles then can be used and in future work would be discussed in detail.

This matrix allows a system of Block Spread OFDM, which relies on spreading matrices to increase the correlation between the symbols to increase the correlation between the symbols by increasing the modulation scheme, say from QPSK to 64QAM, during transmission. This is done depending on the angle chosen. Figure 6 depicts the new modulation scheme after the M sized blocks are multiplied by the new spread matrix U .

$$P = U \times q \quad (3)$$

where U is the spreading matrix and q is a vector of M sized blocks. Figure 7 depicts the new spread matrix multiplied by the same rotation used with the Rotated Hadamard. It can be seen to have a higher modulation scheme than that of the Hadamard and Rotated Hadamard.

3. RESULTS

Figure 8 depicts the result of the BER of the new spreading matrix compared to the Rotated Hadamard and the Hadamard matrix and as can be seen there is performance improvement. The advantage of the new spread matrix is that de-

Fig. 7. The new matrix for block spread OFDM with rotation showing more higher order matrices are possible.

pending on the requirement of the system, varies types of spreading matrices can be made depending on the α angle. This gives the designer more flexibility than more traditional spreading matrices which are set.

Figure 9 depicts the new spreading matrix using the $\alpha = \frac{\pi}{6}$ and compares the BER with the Rotated Hadamard and Hadamard spreading matrices within the BSOFDM system. Again it can be seen to show a better performance over the traditional spreading matrices.

4. CONCLUSION

This paper has proposed a new solution for Block Spread OFDM to increase the correlation between transmitted symbols through a new spreading matrix which depends on the angle α . This is done by rotating the coordinates of the modulation symbols at the transmitter and then taking the inverse at the receiver. By increasing the correlation between the transmitted symbols a better performance is achieved in terms of BER. Another advantage of the new spreading matrix is its flexibility, depending on the system requirements, the angle α can be changed to suit. Not all angles will yield a better performance than other spreading matrices, for example $\alpha = \frac{\pi}{4}$ will have the same result as that of Hadamard matrix.

5. REFERENCES

- [1] Ibrahim S. Raad, Xiaojing Huang, "Exploiting Time diversity to improve Block Spread OFDM", First IEEE International Conference on Wireless Broadband and Ultra Wideband Communications, Aus Wireless 2006, Sydney, March.
- [2] Ibrahim S. Raad, Xiaojing Huang and Darryn Lowe "Study of Spread Codes with Block Spread OFDM", First IEEE International Conference on Wireless Broadband and Ultra Wideband Communications, Aus Wireless 2006, Sydney, March.
- [3] Michael L. McCloud, "Optimal Binary Spreading for Block OFDM on Multipath Fading Channels", WCNC / IEEE Communications Society, volume 2, 2004, 965-970, March.
- [4] T.S. Rappaport, Wireless Communications - principles and practice 2002, edition second, Prentice Hall.

Fig. 8. $\frac{5\pi}{6}$ New spread versus rotated Hadamard and Hadamard matrices in BSOFD.

Fig. 9. $\frac{\pi}{6}$ New spread versus rotated Hadamard and Hadamard matrices in BSOFD.