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A N-Radon Slantlet Transforms Based OFDM System Design with PCC Algorithm to improve the Performance

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ABSTRACT: A N-Radon Slantlet Transforms Based mapper has the ability to increase orthogonality of subcarriers, it is non sensitive to channel parameters variations, and has a small constellation energy compared with conventional FFT, N-RADON, DMWT based orthogonal frequency division multiplexing. SLT is used in OFDM systems to reduce inter-symbol interference (ISI) and inter-carrier interference (ICI). This eliminates the need for cyclic prefix (CP) and increases the spectral efficiency of the design. It works as a good interleaver, which significantly reduces the bit error rate (BER). In this paper both NRAT mapping technique and SLT modulator with PCC algorithm are implemented in a new design of an OFDM system. The new structure was tested and compared with conventional FFT based OFDM, N Radon transform-based OFDM, and SLT-based OFDM for additive white Gaussian noise (AWGN) channel, flat fading channel (FFC), and multipath selective fading channel (SFC). The proposed system has increased orthogonality, the spectral efficiency, reduced ISI and ICI, and improved BER performance compared with other systems.

KEYWORDS: SLT, FRNT, N-FRNT, N-FRNT-SLT.

I. INTRODUCTION

Orthogonal frequency division multiplexing system is one of the most promising technologies for current and future wireless communications. It is a form of multicarrier modulation technologies where data bits are encoded to multiple subcarriers, while being sent simultaneously [1]. Each subcarrier in an OFDM system is modulated in amplitude and phase by the data bits. Modulation techniques typically used are binary phase shift keying, quadrature phase shift keying (QPSK), quadrature amplitude modulation (QAM),16-QAM, 64-QAM, and so forth. The process of combining different subcarriers to forma composite time-domain signal is achieved using FFT and inverse FFT (IFFT) operations [2].The main problem in the design of a communications system over a wireless link is to deal with multipath fading, which causes a significant degradation in terms of both the reliability of the link and the data rate [3]. Multipath fading channels have a severe effect on the performance of wireless communication systems even those systems that exhibit efficient bandwidth, like OFDM. There is always a need for developments in the realization of these systems as well as efficient channel estimation and equalization methods to enable these systems to reach their maximum performance.

The OFDM receiver structure allows relatively straightforward signal processing to combat channel delay spreads, which was a prime motivation to use OFDM modulation methods in several standards [5–8]. In transmissions over a radio channel, the orthogonality of the signals is maintained only if the channel is flat and time-invariant and channels with a Doppler spread and the corresponding time variations corrupt the orthogonality

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of the OFDM subcarrier waveforms [9]. In a dispersive channel, self-interference occurs among successive symbols at the same subcarrier casing ISI, as well as among signals at different subcarriers casing ICI. For a time-invariant but frequency-selective channel, ICI, as well as ISI, can effectively be avoided by inserting a cyclic prefix before each block of parallel data symbols at the cost of power loss and bandwidth expansion [2]. Conventional OFDM/QAM systems are robust for multipath channels due to the cyclically prefixed guard interval that is inserted between consequent symbols to cancel ISI.

II. SLANTLET TRANSFORM-BASED OFDM SYSTEM

The slantlet transform was first proposed by Selesnick [17].It is an orthogonal discrete wavelet transform (DWT) with two zero moments and with improved time localization. It uses a special case of a class of bases described by Alpertet al. in [27], the construction of which relies on Gram Schmidt orthogonalization. SLT is based on the principle of designing different filters for different scales unlike iterated filter-bank approaches for the DWT. Selesnick described the basis from a filter-bank viewpoint, gave explicit solutions for the filter coefficients, and described an efficient algorithm for the transform. The usual iterated DWT filter-bank and its equivalent formare shown in Figure 1. The "slantlet" filter-bank is based on the equivalent structure that is occupied by different filters that are not products. With this extra degree of freedom obtained by giving up the product form, filters of shorter length are designed satisfying orthogonality and zero moment conditions.

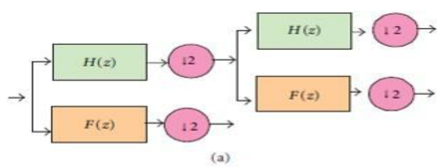

Figure:1 Slantlet Transform

Some characteristic features of the SLT filter-bank are being orthogonal and having two zero moments, and it also has octave-band characteristic. Each filter-bank has a scale dilation factor of two and provides a multiresolution decomposition. The slantlet filters are piecewise linear. Even though there is no tree structure for SLT, it can be efficiently implemented like an iterated DWT filter-bank [17].Therefore, a computational complexity of the SLT is of the same order as that of the DWT. For the two-channel case the Daubechies filter [28] is the shortest filter, which makes the filter-bank orthogonal and has K zero moments. The filters coefficients used in the SLT filter-bank as derived in [17].

III. THE RADON MAPPING TECHNIQUE

Radon transform-based OFDM was recently proposed [24,25]; it was found that, as a result of applying FRAT, the bit error rate (BER) performance was improved significantly, especially in the existence ofmultipath fading channels Also, it was found that Radon transform-based OFDM structure is less sensitive to channel parameters variation, like maximum delay, path gain, and maximum Doppler shift in selective fading channels, as compared with the standard OFDM structure.In Radon transform-based OFDM system, FRAT mapping is used instead of QAM mapping [25, 26].

The other processing parts of the system remain the same as in the conventional QAM OFDM system. It is known that FFT based OFDM obtain the required orthogonality between subcarriers from the suitability of IFFT algorithm [2]. Using FRAT mapping with the OFDM structure increases the orthogonality between subcarriers since FRAT computation uses one-dimensional (1D) IFFT algorithm. Also, FRAT is designed to

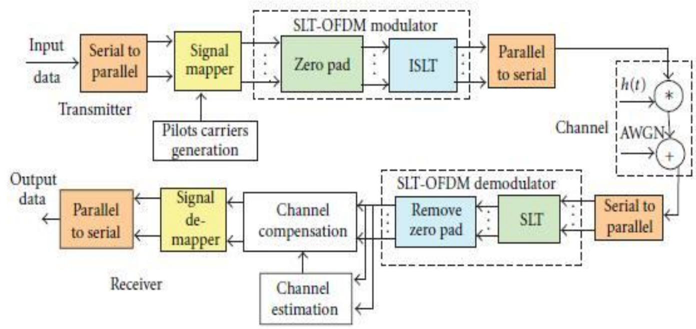

Figure:2 SLT-OFDM Block Diagram

increase the spectral efficiency of the OFDM system through increasing the bit per Hertz of the mapping. Subcarriers are generated using N points discrete Fourier transform (DFT), and guard interval (GI) inserted at the start of each symbol is used to reduce ISI. The procedure steps of using the serial Radon transform based OFDM mapping are as follows [25].

IV. PCC BASED OFDM

In PCC-OFDM you have choosen only one linear combination out of n carriers. We want to choose several linear combinations forming a orthonormal basis. For modulation we modulate each new basis vector distinct from each other. So we can reduce the loss of degrees of freedom and remain the spectral eciency. This was the intermediate result from above: The combined frequency domain function of n OFDM single carriers you can write as The denominator is a x polynomial of degree n. Thus the term is well dened. In the numerator can be dependent on the coefficients ck a polynomial of degree n - 1.This weighting is given by the Sinus and the polynomial in the denominator. The Singularity of the Sinus is lifting the root of the polynomial in the denominator. Perhaps you can write a numerical search algorithm which nds this basis. A good criterion would be the sum (or max value) of variances of the basis vectors in the frequency domain. If you don't want to use the variance, you could also look at the max-values of the basis vectors with norm 1 in frequency domain. After we selected m polynomials, we can generate a real matrix, which transforms n complex values of the OFDM single carriers into complex values in the m dimensional basis.

V. PROPOSED SYSTEM FOR N-RADON-SLT-BASED OFDM TRANSCEIVER

Due to good orthogonality of both SLT and RAT, which reduce ISI and ICI, in the proposed system there is no need of using cyclic prefix (CP). The block diagram of the proposed N-Radon-SLT-based OFDM system is depicted in Figure 4 and the ISLT modulator and SLT demodulator are also shown in the same figure.The processes of serial to parallel conversion, signal demapping, and insertion of training sequence are the same as in

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the system of FFT-OFDM. Also, the zeros are added as in the FFT-based case and for the same reasons. After that the ISLT is applied to the signal. The main and important difference between FFT-based OFDM and SLT-based OFDM is that in SLT-based OFDM the cyclic prefix is not added to OFDM symbols. Therefore, the data rates in SLT-based OFDM are higher than those of the FFT-based OFDM. At the receiver, the zeros padded at the block diagram transmitter are removed, and the other operations of channel estimation, channel compensation, signal demapping, and parallel to serial (P/S) conversion are performed in the same manner as in FFT based OFDM.

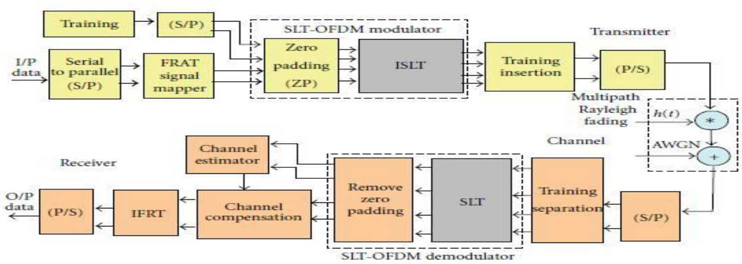

Figure :4 N-Radon-Slt-Based Ofdm Transceiver

In the conventional OFDM system, the length of input data frame is 60 symbols, and after S/P conversion and QAM mapping the length becomes 30 symbols. Zero padding operation makes the length 64 symbols, which are the input to IFFT (sub-carrier modulation). After adding CP (usually 40% of the length of the frame), the frame length becomes 90 symbols. Since OFDM operations applied to the training symbols are the same as those applied to the transmitted data (except the mapping operation), the length of the training symbols is also 90 symbols.

VI. SIMULATION RESULTS OF PROPOSED SYSTEM

Four types of OFDM systems were simulated: FFT-OFDM, Radon-OFDM, SLT-OFDM, and proposed Radon-SLT based OFDM systems using MATLAB version 12. The BER performances of the four systems were found for different channel models: AWGN channel, flat fading channel, and selective fading channel. System parameters used through the simulations are TS = 0.1 μsec, R AT window: 7 by 7, and DWT bins N = 64

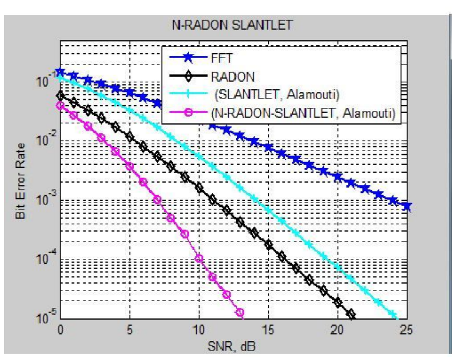

Figure 5: BER performance of NRAT-SLT-based OFDM in AWGN channel.

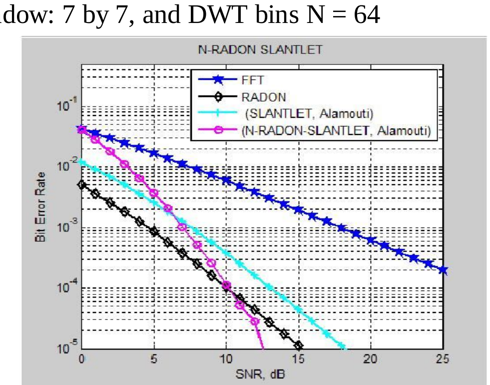

Figure 6: BER performance of RAT-SLT-OFDM in FFC at Doppler frequency 4Hz

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6.1. Performance of Proposed OFDM System in AWGN Channel

Figure 5 shows the results of simulation of the proposed system compared with other systems in AWGN channel. It is clearly seen that RAT-SLT-based OFDM has better vperformance than the other three systems: FFTOFDM, SLT-OFDM, and RAT-OFDM.

This is due to the high orthogonality of the proposed system. To have BER =10−4, FFT-OFDM requires 28 dB, RAT-OFDM requires 25.5 dB, SLT-OFDM requires 21.5 dB, and RAT-SLT-based OFDM requires 17 dB. And to have BER = 10−5, FFT-OFDM requires 31.5 dB, RAT-OFDM requires 28 dB, SLT-OFDM requires 23 dB, and RAT-SLT-based OFDM requires 19 Db. From the results it can be noted that the proposed system has 12 dB advantage over FFT-OFDM, 9.5 dB over RAT-OFDM, and 5 dB over SLT-OFDM.

6.2. Performance of Proposed OFDM System in Flat Fading Channel with AWGN.

In this channel, all signal frequency components are affected by a constant attenuation and linear phase distortion, in addition to an AWGN. The channel was selected to be multipath and Rayleigh distributed. Doppler frequency used in simulation is calculated as follows: c =300 × 106 m/sec, in GSM system fc = 900MHz so, The Doppler frequency used is that corresponding to a walking speed (4.8 km/hour), and it has a value fd = (3/1m) × (4.8 × 1000m/3600 sec) = 4 Hz. The results of simulations for 4Hz Doppler frequency are shown in Figure 6. From Figure 6 it can be seen that to have BER = 10−5, FFT-OFDM requires 33 dB, RAT-OFDM requires 31 dB, SLT-OFDM requires 25 dB, and RAT-SLT based OFDM requires 20.5 dB. So the proposed system offers 12.5 dB SNR improvement compared with FFTOFDM, 10.5 dB compared with RAT-OFDM, and 4.5 dB compared with SLT-OFDM for this channel model. Other Doppler-Shift frequencies were used for proposed system simulation over the flat fading Rayleigh channel; the values used are 80Hz corresponding to car speed (96 km/hour), 300 Hz corresponding to helicopter speed (360 km/hour), and 500 Hz corresponding to airplane speed (600 km/hour), and the same results were obtained for these frequencies. The reason for best performance results of N-RAT-SLT-based OFDM is the good orthogonality of Radon transform and the excellent orthogonality of SLT.

VII. CONCLUSIONS

In this paper a novel OFDM generation method is proposed, simulated, and tested. The proposed system uses n-Radon-SLT mapping instead of QAM/BPSK mapping, which increases the orthogonality. The optimal ordering (best direction) in the Radon mapper can be considered as a good interleaver, which serves in error spreading. In the proposed system there is no need for using CP because of excellent orthogonality offered by NRAT and SLT, which in its order reduces the system complexity, increases the transmission rate, and increases spectral efficiency. Simulation results of the proposed N-Radon-SLT-based OFDM show a very good SNR gain improvement and a BER performance as compared with SLT-OFDM, RAT-OFDM, and FFT-OFDM in an AWGN, a flat fading, and a selective fading channels. It offers more than 15 Db SNR improvement compared with FFT-OFDM for selective fading channel at Doppler frequency 4 Hz. From the simulation results, it can be seen that the proposed N-Radon-SLTbased OFDM has the smallest sensitivity to variations of the channel parameters.

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