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An Efficient OFDMA receiver using MIMO IFET Structure

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ABSTRACT: ***This letter extends our previous work on layered inverse Fast Fourier Transform (IFFT) structure to a multistage layered IFFT structure where data symbols can input at different stages of the IFFT. We first show that part of the IFFT in the transmitter of an OFDM system can be shifted to the receiver, while a conventional one-tap frequency-domain equalizer is still applicable. We then propose two IFFT split schemes based on decimation-in-time and decimation-in-frequency IFFT algorithms to enable interference-free symbol recovery with simple linear equalizers. Applications of the proposed schemes in multiple access communications are investigated. Simulation results demonstrate the effectiveness of the proposed schemes in improving bit-error-rate performance.***

Index Terms—IFFT, multicarrier systems.

INTRODUCTION:

We extended the convolution theory of Discrete Fourier Transform (DFT) and introduced a layered inverse Fast Fourier Transform (IFFT) structure which includes three layers, the frequency and time domains and a new intermediate domain between them. Based on the framework we proposed the asymmetric OFDM system which bridges conventional OFDM and single carrier with frequency domain equalization (SC-FDE) [2] systems. Its multiple access version, Quadrature OFDMA, is developed in [3]. The asymmetric OFDM and quadrature OFDMA systems illustrate one typical application of the layered IFFT structure from the decimation-in-time IFFT algorithm. At the presented form, the asymmetric OFDM is mathematically similar to the vector OFDM [4] and interleaved OFDM systems [5]. In this letter, we extend the layered IFFT structure to a multistage layered IFFT structure, and investigate its applications in multicarrier communications. In the layered IFFT structure, data symbols are input at the same layer; while in the multistage structure, the intermediate domain is further divided into multiple stages and symbols can be input at different stages simultaneously. Such a multistage inputting approach provides many options and flexibility in designing multicarrier systems.

Notations:

Symbols belonging to different layers are represented with different accents: and without accent are used for frequency-domain, intermediate-domain and time-domain symbols, respectively.

Existing System:

We introduced a layered IFFT structure where an intermediate domain corresponding to signals at S3 is added between conventional frequency and time domains. We show that by inputting information symbols at the intermediate domain, the receiver can recover the symbols using the same one-tap frequency-domain equalizer as that in conventional OFDM systems. Actually, as we highlighted in [1], it is equivalent to shifting part of the IFFT, which corresponds to S1 and S2, from the transmitter to the receiver. The advantages of allowing inputs in the intermediate domain include lower PAPR, more robust to frequency offset, and improved BER at higher SNR thanks to better frequency diversity [1], [3]. When we repeatedly apply the D&C algorithm in either S2 or S4, or both, we obtain an extended multistage layered IFFT structure. This concept is illustrated in Fig. 1, referring to a 8-point decimation-in-frequency radix-2 IFFT algorithm. Expanding the intermediate domain,

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every 2-point IFFT generates a new stage in the intermediate domain. Indexing the stages from the frequency domain as Stage 0 to the time domain as Stage , we get a total of stages, denoted as Stages . When data symbols are input at any of the same stage, systems similar to those present

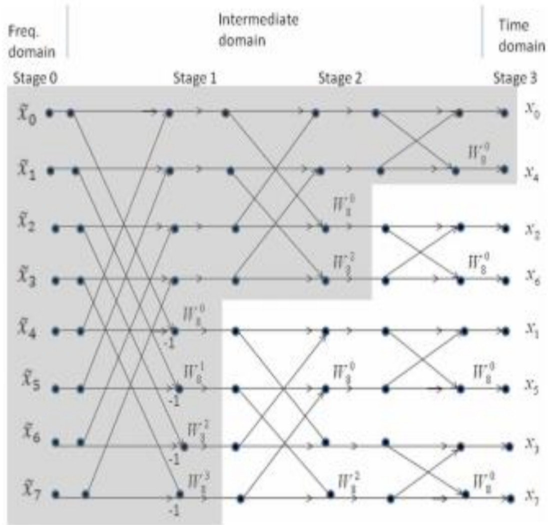

Fig. 1. An example of the multistage layered IFFT structure for an 8-point decimation-in-time IFFT. The IFFT is split to two parts, the shadowing part as T_1, and the rest as T_2. T_2 is implemented in the transmitter, and T_1 is equivalently shifted to the receiver. Data symbols are input to T_2, and the time-domain signals are appended with cyclic prefix and transmitted.

Proposed System:

We use to denote a symbol input at a spot with location and stage , where is aligned with respect to the frequency-domain indexes. Let and denote the set of available and assigned input locations at stage , respectively. One stage may have multiple sets. The key idea for the splitting is to make sure that symbols input at different stages will not be mixed at the places where they are input. For example, referring to Fig. 1, data symbols should not be input from (0,1) and (4,0) once is used. In this way, the signal to be estimated will see no interference. Such a split is called "clear-split" hereafter. The decimation-in-time and decimation-in-frequency IFFT structures enable different clear-splitting schemes, which can have different physical interpretation, implementation structures and applications. Next, we propose two clear-split schemes based on the two IFFT structures, respectively. These two schemes are not exhaustive solutions for splitting; however, they have some unique properties: the symbols input at different stages are not mixed in either time or frequency domains. Such property can be very useful in applications.

Input: $k = \log_2 N$, $n \in [0, N-1]$,
$\mathcal{V}_{\log_2 N} = \{0, 1, \cdots, N-1\}$;
while $k \geq 0$ *or allocation is incomplete* **do**
  If inputs at stage k are needed, $\mathcal{U}_k = \{\ell + pN/2^k\}$
  for $p = 0, 1, \cdots, 2^k - 1$, $\ell \in [0, N/2^k - 1]$ and
  $\ell + pN/2^k \in \mathcal{V}_k$;
  $k = k - 1$, $\mathcal{V}_k = \mathcal{V}_{k-1} - \mathcal{U}_{k-1}$;
end

Algorithm 2. Clear-split scheme based on Decimation-in-frequency IFFT.

Once input spots are determined, the -point IFFT is split into and parts and is applied to the input signal . The final outputs in the time-domain are re-ordered in the bit-reversed order of the binary form of . For example, for in a system with subcarriers, its corresponding output is at . Remark 1: The signals from different sets are independent in the time domain, and mixed in the frequency domain. All the subcarriers are needed if any inputs need to be in the frequency

APPLICATIONS IN MULTIPLE ACCESS COMMUNICATIONS

There can be various applications by enabling symbols to input at different stages. One promising application is to exploit the many combinations of input spots at different stages and locations for secure communications. Different combinations can be pre-defined and information inputs are hopped on these combinations. Without knowing the hopping pattern, intruders are hard to retrieve the correct data. The hopping pattern can be similarly defined to the pseudo-random frequency hopping and direct spreading sequences. Another important application is in multiple access communications. Generally, a user can have inputs at any locations and stages in a given split scheme. Here, we propose special allocations where each user only has inputs at the same stage, and the allocated stage depends on the user's SNR.

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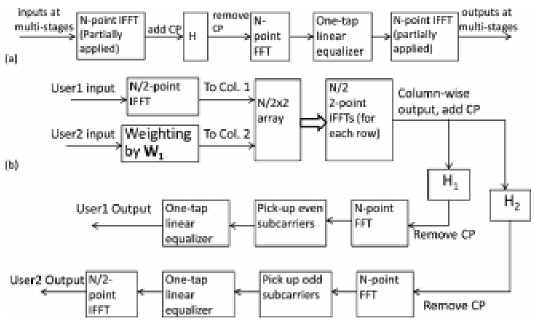

Fig. 2. (a) General transceiver structure and (2) equivalent transceiver structure for Setup 1. The $N/2 \times N/2$ weighting matrix $\mathbf{W}_1$ is diagonal with element $W_{m,m} = \exp(-j2\pi m/64)$.

SIMULATION RESULTS

We consider an OFDM system of , with a guard interval of 16. For , we can have 7 stages. Complex Gaussian channels with 16 independent multipath taps are simulated, and we assume perfect channel estimation. We consider the downlink of a two-user system. In the first setup, using split scheme 2, the input sets of the two users are given by and . In the second setup, both users are at stage 0, using even and odd subcarriers, corresponding to a conventional OFDMA system. Both setups can be implemented in a fixed transceiver architecture as shown in Fig. 2(a), while a simplified equivalent structure for Setup 1 is shown in Fig. 2(b). In the simulation, user 1's mean SNR is fixed as 20 dB, and user 2's SNR varies. Both users use 64QAM and 2/3-rate convolutional coding. For user 2 in the first setup, MMSE receiver is applied, and in other cases.

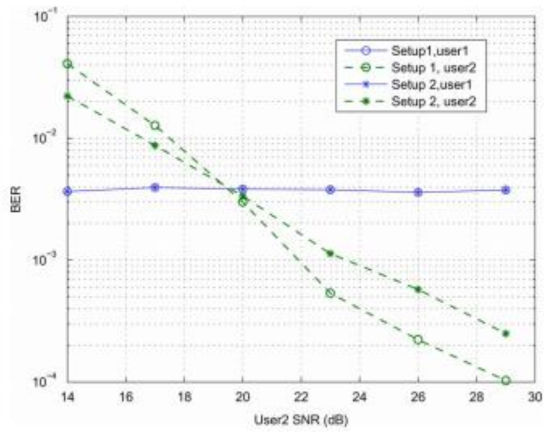

Fig. 3. BER performance for setup 1 and 2. Solid curves denote the BER of user 1 at a fixed SNR of 20 dB, dashed curves show how BER varies with SNR for user 2.

Fig. 3 shows the BER results. User 1 has almost identical BER in the two setups, which indicates that its signal is not affected by the signal at a different stage. User 2's BER curves cross at 20 dB, and the first setup outperforms the second at higher SNR values. This shows that to achieve better performance, we can allocate user 2 to stage 5 if SNR is higher than 20 dB, and stage 0 otherwise.

CONCLUSION

This letter proposes a multistage layered IFFT structure where data symbols can be input at different stages simultaneously and simple linear equalizers can be applied to estimate the symbols at the receiver. This novel multistage structure provides various options and flexibility in system design, and it is very promising for future broadband communications. Efficient implementation of the proposed system demands new IFFT architecture which allows symbols to be input in the intermediate domain without compromising the performance of pipelined IFFT.

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