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Design Of Baseband Ofdm Transmitter

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Abstract

Orthogonal Frequency Division Multiplexing is a technique where the main signal to be transmitted is divided into a set of independent signals called subcarriers in the frequency domain. Thus, the original data stream is divided into many parallel streams (or channel). Each subcarrier is then modulated with a conventional modulation scheme, and then they are combined together to create the FDM signal at the receiver. Orthogonal frequency division multiplexing (OFDM) is a modulation technique which is now used in most new and emerging broadband wired and wireless communication systems, because it is an effective solution to inter-symbol interference caused by a dispersive channel. Main advantage of this scheme is robustness against channel fading. In this paper OFDM transmitter is designed. This includes modules like mapper, serial to parallel converter, parallel to serial converter and IFFT. The tool used to achieve the set of objectives is Xilinx. Code is written in VHDL language to generate desired environments and response can be generated in the form of waveforms.

1. Introduction

Orthogonal frequency division multiplexing (OFDM) is a parallel transmission scheme, where a high rate serial data stream is split up into a set of low-rate sub-streams, each of which is modulated on a separate sub-carrier (frequency division multiplexing). Thereby, the bandwidth of the sub-carriers becomes small compared with the coherence bandwidth of the channel i.e. the individual sub-carriers experience flat fading, which allows for simple equalization. This implies that the symbol period of the sub-streams is made long compared to the delay spread of the time-dispersive radio channel. By selecting a special set of orthogonal carrier frequencies, high spectral efficiency is obtained, because the signal spectra corresponding to the different sub-carriers overlap in frequency domain, while mutual influence among the sub-carriers can be avoided.

Using interactive software, such as **XILINIX** it is now possible to place more emphasis on learning new and difficult concepts than on programming algorithms. Interesting practical examples can be discussed, and useful problems can be explored. VHDL is a high performance language for technical computing. It integrates Computation, Visualization and programming in an easy way.

2. Wireless Ofdm

The concept of using parallel-data transmission and Frequency-division multiplexing (FDM) was developed in the mid-1960s, the total signal frequency band is divided into N non overlapping frequency sub channels. Each sub channel is modulated with a separate symbol, and then the N sub channels are frequency multiplexed. To eliminate inter-channel interference avoid spectral overlap. However, this leads to inefficient use of the available spectrum. To overcome with the inefficiency, the idea is to use parallel data and FDM with overlapping sub-channels, in which each, carrying a signalling rate b, is spaced b apart in frequency to avoid the use of high-speed equalization and to combat impulsive noise and multipath distortion, as well as to use the available bandwidth. OFDM is one of the applications of a parallel-data-transmission scheme, which reduces the influence of multipath fading and makes complex equalizers unnecessary. In OFDM, a single data stream is transmitted over a number of lower-rate subcarriers. OFDM can be seen as either a modulation technique or a multiplexing technique. One of the main reasons to use OFDM is to increase robustness against narrowband interference. In a single-carrier system, a single fade or interferer can cause the entire link to fail, but in a multicarrier system, only some SCs will be affected. Error-correction coding can then be used to correct for the few erroneous SCs.

3. Orthogonality

Since the original OFDM model was proposed in the 1960s, the core structure of OFDM has hardly changed. The key idea of OFDM is that a single user would make use of all orthogonal subcarrier in divided frequency bands. Therefore, the data rate can be increased significantly. Since the bandwidth is divided into several narrower Sub-channels, each sub-channel requires a longer symbol period. Therefore OFDM systems can overcome the inter symbol interference (ISI) problem. As a consequence, the OFDM system can result in lower bit error rates but higher data rates than conventional Communication Systems. So Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier transmission technique, where single data stream is transmitted over a no. of lower rate subcarrier. In order to guarantee the high spectral efficiency subchannel of the waveforms must have overlapping transmit spectra. [7]

To satisfy the orthogonality there are some rules to be satisfied. The receiver and transmitter have to be entirely synchronized. In order to satisfy this requirement is it necessary to guess the same modulation frequency and the same time scale for transmission which is not really possible. It is also necessary to have the best quality of the analogue transmitter and receiver part.Orthogonality is defined for both real and complex valued functions.

4. OFDM Transmission System

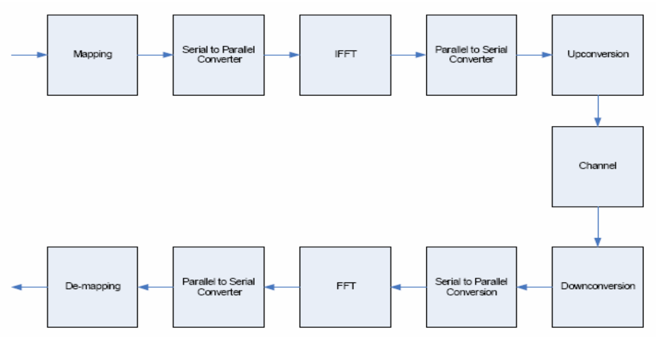

Figure 1 OFDM Transmission System

The serial data stream is mapped to symbols with a symbol rate of 1/Ts using modulation scheme like M-PSK, QAM. The resulting symbol stream is de-multiplexed into N data symbols So to SN-1 (in this example). The parallel data symbol rate is 1/NTs. This means the parallel symbol duration is N times longer than the serial symbol duration Ts. The inverse FFT (IFFT) of the data symbol is computed and the output s0 to sN-1 constitute an OFDM symbol. This symbol period is transmitted serially over the channel with symbol rate of 1/Ts. [2]

At the receiver, the received time domain symbols are decomposed by employing FFT operation, the recovered data symbols are restored in serial order. Assume the OFDM spectrum is finite, the corresponding time domain signal has an infinite duration. Recall, the DFT operation assume the signal is periodic for infinite duration. However, in practice, it is sufficient to repeat the time domain signal periodically for the duration of channel delay spread. Hence, for transmission over dispersive channels, each time domain OFDM symbol is extended by cyclic extension or guard interval of Ng samples duration in order to overcome ISI due to channel delay spread. The disadvantage of cyclic extension is it's reducing the OFDM transmission rate by N/(N+Ng) assuming the transmission rate is N.

5. Design of OFDM Transmitter

The generation of OFDM signal starts from amplitude modulation mapping bank. The serial input data is mapped to appropriate symbol to represent the data bits. These symbols are in serial and need to be converted into parallel format since IFFT module requires parallel input to process data. The serial to parallel module does the conversion. These parallel symbols are transformed from frequency domain into time domain using IFFT module. These signals are converted into serial format and being added a cyclic prefix to data frame before being transmitted.

Fig. 2 shows the mapping module for transmitter. The mapping module used is BPSK type of modulation. BPSK is used because this type of module is much easier to design as compared to QPSK or other modulation method. If the input is '1' then the value is mapped with '1' while if the input is '0' the value is mapped with '0'. This type of modulation is monopodal type. The input passed through this module actually does not get any changes to the value, but it can be assumed that the input is modulated after passing through it.

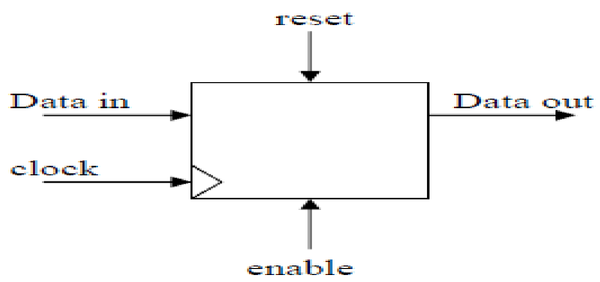

Figure 2 Mapping Module

A serial to parallel converter is somewhat the reverse of the operation of parallel to serial converter. The data comes serially from the input port SERIN. The parallel data is output from DOUT port. Output port DRDY is asserted '1' when the start bit, 8 bit data and the parity bit is received. Output port PERRn is asserted '0' when the parity bit received is different from the parity generated inside the serial to parallel circuit. When parity error is detected, the serial to parallel circuit would be reset before its normal operation can be performed. This is the operation for serial to parallel module.

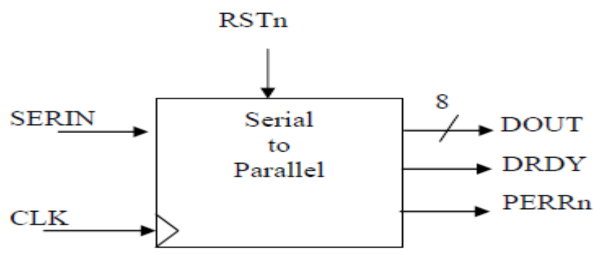

Figure 3 Serial to Parallel Module

A parallel to serial converter is a special function of shift register. The data is parallel loaded to the shift register and then shift out bit by bit also is bounded by a start bit and stop bit. In OFDM transmitter module, a parallel to serial converter is used to convert computation result which is in parallel to serial before being sent to other module for processing. This parallel to serial module is design such that the data to be transmit is first parallel loaded then transmitted bit by bit by a start bit of value '1'. This is followed by the 8-bit data with

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the left bit most bit first. The converter holds the output low when the transmission is completed.

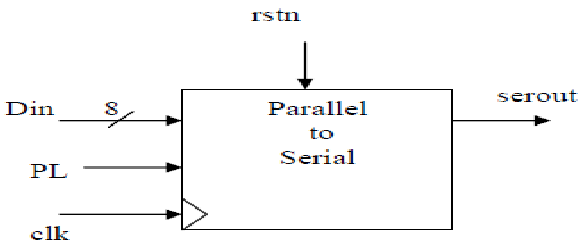

Figure 4 Parallel to Serial Module

Inverse Fast Fourier Transform (IFFT) is used to generate OFDM symbols. The data bits is represent as the frequency domain and since IFFT convert signal from frequency domain to time domain, it is used in transmitter to handle the process. IFFT is defined as the equation below:

$$x(n) = \frac{1}{N} \sum_{k=0}^{N-1} X(k) W^{-nk}, \; k = 0,1 \,..$$

6. Results

Results are driven for the transmitter block using XILINIX. Codes have been written in VHDL language. Results can be compared with theoretical concepts.

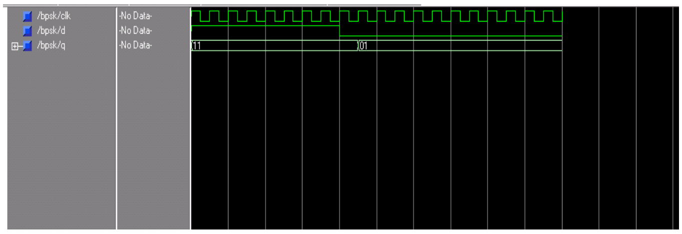

Figure 5 Mapping Module Response

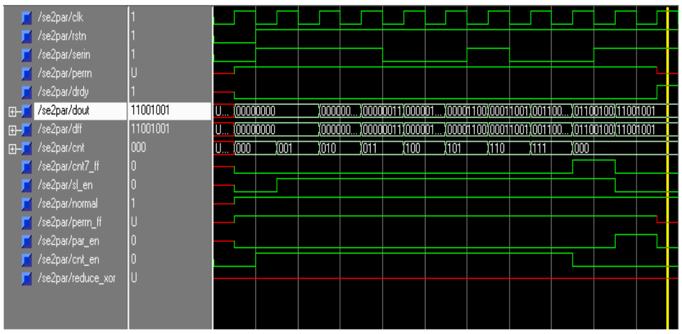

Figure 6 Serial to parallel Module Response

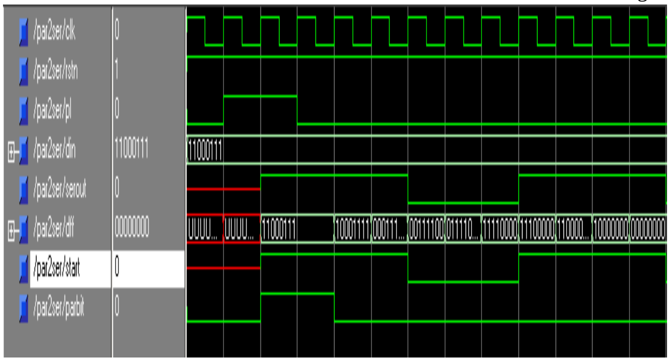

Figure 7 Parallel to Serial Module Response

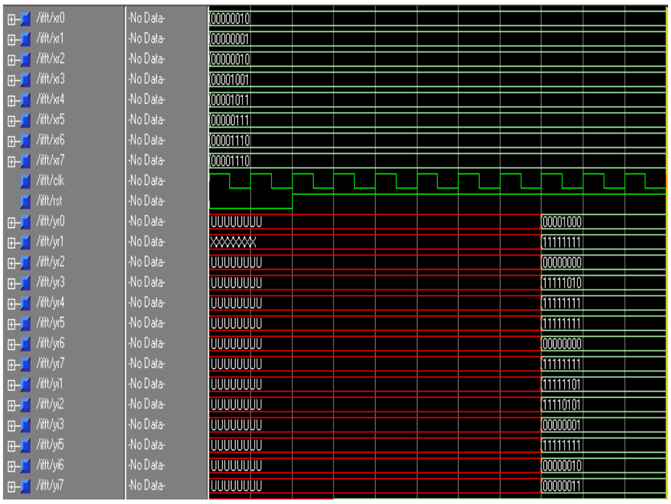

Figure 8 Inverse FFT Response

7. Conclusion

A base band OFDM transmitter was successfully designed. On the transmitter part there are four blocks which consists of mapper, serial to parallel converter, Inverse Fast Fourier Transform (IFFT) block and parallel to serial block. Each of these blocks was tested using Xilinx Project navigator software during design process. During the implementation stage, the operation for IFFT was tested using Xilinx Project navigator software. IFFT module is working correctly as the Xilinx Project navigator computation. Thus, base on the test result, it was concluded that IFFT module was viably used in transmitter part as processing module.

8. References

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