Simulation of OFDM

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1. Abstract

I have learned about OFDM through the course, but have not fully understood the OFDM simulation process. I spent time learning the entire OFDM process, and completed the simulation of the entire OFDM process using Gaussian channels in Matlab.

2. Introduction

OFDM(Orthogonal Frequency Division Multiplexing) is a special multi-carrier transmission scheme. It can be regarded as a modulation technique or a multiplexing technique.

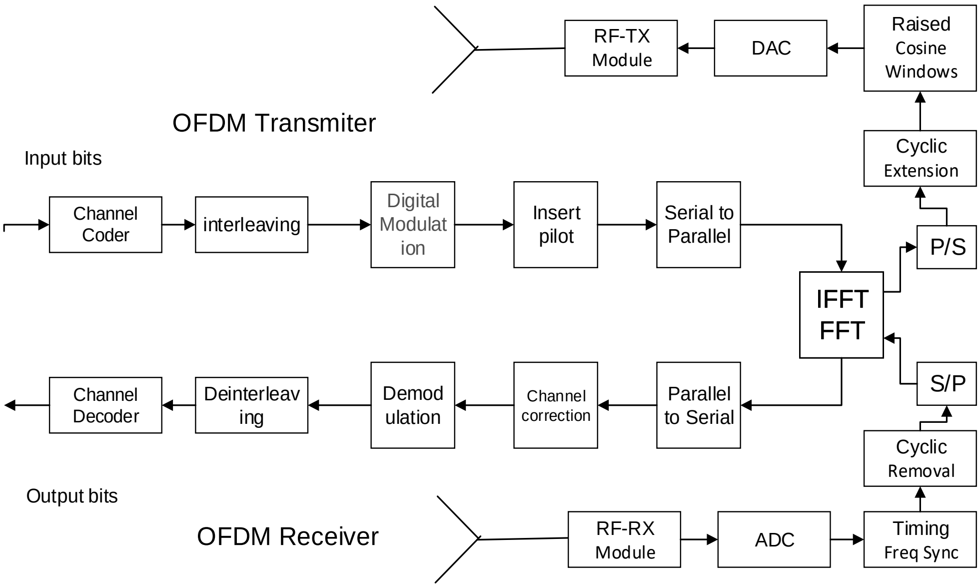
For a simple version, OFDM is a multi-carrier transmission method. It divides the frequency band into multiple sub-channels to transmit data in parallel, divides the high-speed data stream into multiple parallel low-speed data streams, and modulates them to the sub-carriers of each channel. Transfer on. Because it converts the non-flat fading wireless channel into multiple orthogonal flat fading sub-channels, it can eliminate the interference between channel waveforms and achieve the purpose of combating multipath fading.

Orthogonal frequency division multiplexing (OFDM) is an improvement to multi-carrier modulation (MCM). Its characteristic is: the sub-carriers are orthogonal to each other, so the spectrum after spread spectrum modulation can overlap each other, which not only reduces the mutual interference between the sub-carriers, but also greatly improves the spectrum utilization.

A big reason for choosing OFDM is that the system can well resist frequency selective fading and narrowband interference. In a single-carrier system, a fading or interference will cause the entire link to fail, but in a multi-carrier system, only a small part of the sub-channels will be affected by deep fading at a certain time.

3. Basic principles

3.1The typical block diagram of the OFDM system transceiver



Among them, the upper half corresponds to the transmitter link, and the lower half corresponds to the receiver link.

The transmitting end converts the transmitted digital signal into sub-carrier amplitude and phase mapping, and performs Discrete Fourier Transform (IDFT) to change the spectral expression of the data to the time domain. IFFT and IDFT transform have the same function, but have higher calculation efficiency, so it is suitable for all application systems. The receiving end performs the opposite operation to the sending end, and uses FFT transform to decompose, and the amplitude and phase of the sub-carrier are finally converted back to a digital signal.

3.2 OFDM modulation and demodulation

An OFDM symbol includes a composite signal of multiple modulated sub-carriers, each of which can be modulated by PSK (phase shift keying) and QAM (quadrature amplitude modulation).

The OFDM transmitter maps the information bit stream into a PSK or QAM symbol sequence, and then converts the serial symbol sequence into a parallel symbol stream. Every N symbols that undergo serial-to-parallel conversion are modulated by different subcarriers.

An OFDM symbol is a composite signal of N parallel symbols. If the transmission time (period) of a single serial symbol is Ts, the duration (period) of an OFDM symbol is T_{sym}=N*Ts.

The frequency of the frequency domain modulation signal X[k] is: $f_k=k/T_{sym}$, and the number of sub-carriers is N, then k=0,1,2...N-1. (Deduced by DFT principle)

4. Methods and procedures

4.1 Guard interval

The multipath channel will affect the ISI of the OFDM symbol and destroy the orthogonality between subcarriers. Therefore, some methods are needed to eliminate the inter-symbol interference (ISI) effect caused by the multipath channel, that is, insert a guard interval.

There are two ways to insert the guard interval: one is zero padding (ZP), that is, 0 is filled in the guard interval; the other is to insert cyclic prefix (CP) or cyclic suffix (CS) to implement cyclic extension of OFDM (for a certain Continuity).

ZP does not insert any signal in the guard interval, but in this case, due to the influence of multipath propagation, inter-carrier interference (ICI) will occur, that is, interference will occur between different sub-carriers.

Generally, CP is used. CP copies the samples from the back of the OFDM to the front, and the length is T_{cp}, so the length of each symbol is $T_{sym}=T_{sub}+T_{cp}$, and T_{sub} is the number of subcarriers in the data part. T_{cp} is greater than or equal to the multipath delay, the ISI influence between symbols will be limited to the guard interval, so it will not affect the FFT transformation of the next OFDM.

4.2 Interweaving

The function of interleaving is to convert burst errors into random errors, which is conducive to the decoding of forward error correction codes and improves the reliability of the entire communication system. Interleaving consists of two transformation processes. The first transformation ensures that adjacent coded bits are mapped to non-adjacent subcarriers. The second transformation ensures that adjacent coded bits are respectively mapped to the important and non-important bits of the constellation diagram, avoiding long-term low-bit mapping.

The length of the interleaving block, Ncbps, is 2, 4, and 6 for QPSK, 16qam, and 64qam, respectively, s=Ncbps/2, and d=16.

4.3 Channel coding

Due to interference and fading in mobile communication, errors will occur during signal transmission. Therefore, error detection and error detection technology must be used for digital signals, that is, error detection and error detection coding technology, to enhance the data transmission in the channel against various interferences. Ability to improve the reliability of the system.

The channel coding here generally adopts convolutional coding and Viterbi decoding.

Convolutional coding is a common forward error correction code in modern digital communication systems. It is different from conventional linear block codes. The codeword output of convolutional coding is not only related to the information symbol input at the current moment, but also related to the previous input information. Symbol related.

4.4 Spread Spectrum

"Spread-spectrum communication technology is an information transmission method. The frequency bandwidth occupied by the signal is much larger than the minimum bandwidth necessary for the transmitted information; the expansion of the frequency band is completed by an independent code sequence, which is achieved by encoding and modulation. Yes, it has nothing to do with the transmitted information data; at the receiving end, the same code is used for relevant synchronous reception, dispreading and recovery of the transmitted information data"

According to Shannon's theorem, bandwidth and signal-to-noise ratio can be interchanged, and spread spectrum expands the bandwidth, so the requirement for signal-to-noise ratio can be reduced.

4.5 Pilot

The pilot frequency does not carry information. The pilot frequency is the known data of both parties and is used for channel estimation.

In the receiver, although the received training sequence and long training sequence can be used for channel equalization and frequency deviation correction, there will still be a certain residual deviation in the symbol, and the deviation will accumulate over time, which will cause all the subcarrier produces a certain phase offset. Therefore, it is also necessary to keep track of the reference phase. To achieve this function, pilot symbols need to be inserted in 52 non-zero subcarriers.

4.6 RF (Radio Frequency) Modulation

The output of the OFDM modulator produces a baseband signal. This baseband signal is mixed with the frequency to be transmitted, which can be completed by using analog technology or digital up-conversion. As the digital modulation technology improves the matching between the processing I and Q channels and the accuracy of the phase of the digital IQ modulator, it will be more accurate.

5. Selection of OFDM basic parameters

5.1 bandwidth, bit rate, and guard interval

By convention, the length of the guard interval should be 2 to 4 times the root mean square value of the delay spread of the mobile environment channel.

After the guard interval is determined, the OFDM symbol period length is determined. In order to minimize the loss of signal-to-noise ratio caused by inserting guard bits, the OFDM symbol period length is much longer than the guard interval length. However, the symbol period cannot be arbitrarily large. Otherwise, more sub-carriers will be needed. The bandwidth will remain unchanged, and the sub-carrier spacing will become smaller. The complexity of the system implementation will increase, and the peak-to-average power ratio of the system will be increased. The system is more sensitive to frequency deviation. Therefore, the symbol period length is generally selected to be 5 times the guard interval, so that the loss of signal-to-noise ratio caused by inserting guard bits is only about 1dB.

After determining the guard interval and symbol period length, the number of subcarriers can be obtained by dividing the -3dB bandwidth by the subcarrier interval (that is, the reciprocal of the symbol period after removing the guard interval). Or the number of subcarriers can be determined by dividing the required bit rate by the bit rate of each subchannel. The bit rate transmitted in each channel can be determined by the modulation type, coding rate, and symbol rate.

5.2 Useful symbol duration T

T has an impact on the interval between subcarriers and the waiting period for decoding. In order to maintain data throughput, the number of subcarriers and the length of the FFT must have a relatively large number, which results in a longer symbol duration. In short, the choice of symbol period length is based on ensuring the stability of the channel.

5.3 Number of subcarriers

N=1/T Its value corresponds to the number of complex points processed by FFT, which needs to be adapted to the requirements of data rate and guard interval.

5.4 Modulation mode

The modulation mode of the OFDM system is selected based on power and spectrum utilization, and QAM and PSK can be used.

In order to make all points have the same average power, the complex numbers after binary sequence mapping must be normalized. (BPSK\QPSK\16QAM\64QAM is correspondingly multiplied by 1, $\frac{1}{\sqrt{2}}$,$\frac{1}{\sqrt{10}}$, $\frac{1}{\sqrt{42}}$), and then change back when demodulating.

5.5 Illustrate with specific examples

If I have these requirements: (1) The bit rate is 25Mbit/s (2) The tolerable delay extension is 200ns (3) The bandwidth is less than 18MHz.

1) The guard interval is 800ns extended by 200ns delay;

2) The symbol period length is 6*800ns=4.8us from the guard interval of 800ns;

3) The interval of subcarriers is selected as the reciprocal of 4.8-0.8=4us, which is 250KHz;

4) From the ratio of the required bit rate to the OFDM symbol rate, the bits that need to be transmitted for each symbol: (25Mbit/s)/(1/4.8us)=120bit.

5) In order to complete the above 120bit/symbol, there are two options: 16QAM and a coding method with a code rate of 1/2, so that each subcarrier carries 2bit useful

information, so 60 subcarriers are needed; the other is to use QPSK and A coding method with a code rate of 3/4, and each sub-carrier carries 1.5 bits of information. Therefore, 80 sub-carriers are needed, but 80 sub-carriers have unexpected bandwidth: 80*250KHz=20MHz, which is greater than the given bandwidth requirement, so the first type is 60 sub-carriers. It can be realized by 64-point IFFT, and the remaining 4 sub-carriers are filled with 0.