The Realization of OFDM System Based on Software Radio

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***Abstract* - In recent years, there has been a lot of interest in applying orthogonal frequency division maltiplexing (OFDM) in wireless systems because of its various advantages in lessening the severe effects of frequency selective fading. This paper firstly introduces the basic principle of OFDM, then analyses OFDM system architecture.Finally, detailed design architeture of the OFDM system in a software radio platform is given.**

Keywords—OFDM system; Software radio; Cyclic prelic; DSP; FPGA

I. INTRODUCTION

UHF/VHF-band digital mobile communication has always been a hot spot in the field of communications. However, there is a serious problem of frequency selective fading, fast fading and slow fading in UHF / VHF band mobile channel, and a variety of noise interference and multipath spread of Intersymbol crosstalk. These problems will seriously affect performance and quality of the digital mobile communication system. In order to overcome these deficiencies to improve system performance ,most of digital mobile communication system has adopted frequency shift keying (FSK) which is not sensitive to the range of jitter and Gaussian filter with frequency shift keying modulation, it also use lower bit-rate and adaptive feedback equalizer and other measures. But the channel utilization of the above-mentioned modulation is not high. As the frequency resources become increasingly strained, there is a wide range of new and highly efficient modulation. Orthogonal frequency division multiplexing (OFDM): Orthogonal Frequency Division Multiplexing) modulation is a better way of it.

Therefore, this paper outlined the structure of OFDM systems ,at the same time,based on the idea of software radio, we design a program of the realization of OFDM sending and receiving with DSP and FPGA as the core.

II. RESEARCH OF OFDM SYSTEM

A. *Overview of the basic principles of OFDM*

OFDM technology is a multi-carrier transmission. The basic principle is that the original high-speed information data flow signals by string / and are converted into N low-speed data streams sub-signals, respectively, and then modulate them on N orthogonal subcarriers with each other with parallel transmission.

Low-speed sub-data streams through parallel transmission to enable the extension of symbolic cycle, this will enable each OFDM symbol to insert a guard interval, if in the interval to add to the protection of "cyclic prefix", OFDM system will overcome ISI and ICI caused by the multi-path channel. OFDM system take full advantage of the time-frequency orthogonality of the signal, allowing N-channel spectrum of 1/2 overlap, so that the utilization of the spectrum compare with the single-carrier serial system nearly doubled. At the same time it can use digital signal processing (DSP) technology - Fast Fourier Transform (FFT) to achieve that without the comb filter group, the realization of user-friendly.

B. *Implementation of OFDM technolog*

1) directly to achieve

Assuming the original base-band modulation signal bandwidth of B, the symbol modulation rate of R, the symbol period of t_s, and the channel maximum delay spread of $\triangle m > t_s$. Due to the principle of OFDM is to divided the original signal into N sub-signals, after that the symbol rate is R/N, the symbol period is $T_s = N t_s$, and the N symbols for transmission in a cycle is(d0, d1, ... dN-1), in which symbols $d_k = a_k + jb_k$; and then use the N sub-signals, respectively, to modulate N orthogonal subcarriers (that is, the first k symbols dk modulate on $\exp(j2\pi f_k t)$of the first k carrier), then Synthesis of OFDM modulated signals can be expressed as:

$$D(t)=\sum_{k=0}^{N=1} d_k \exp(j2\pi f_k t) \quad (1)$$

Here, d_k is the modulation symbol of the first k carrier, and setting it of the set value in a symbol cycle; each sub-carrier frequency as follows:

$$f_k=f_c+k/T_s=f_c+k/Nt_s \quad (2)$$

Where fc is the lowest sub-carrier frequency. When the guard interval is not considered, then the formula (2) into formula (1) make OFDM modulation signal:

$$D(t)=[\sum_{k=0}^{N=1} d_k \exp(j2\pi \frac{k}{Nt_s}t)]\exp(j2\pi f_c t)$$
$$=S(t)\cdot\exp(j2\pi f_c t) \quad (3)$$

Where S (t) is the equivalent complex baseband signal, that is

$$S(t)=\sum_{k=0}^{N=1} d_k \exp(j\frac{2\pi k}{Nt_s}t)$$
$$=\sum_{k=0}^{N=1}(a_k+jb_k)(\cos\frac{2\pi k}{Nt_s}t+j\sin\frac{2\pi k}{Nt_s}t)$$
$$=\sum_{k=0}^{N=1}[(a_k\cos\frac{2\pi k}{Nt_s}t-b_k\sin\frac{2\pi k}{Nt_s}t)$$
$$+j(b_k\cos\frac{2\pi k}{Nt_s}t+a_k\sin\frac{2\pi k}{Nt_s}t)]$$
$$=I(t)+jQ(t) \quad (4)$$

It can be seen that the use of equivalent complex baseband signal to describe the OFDM output signal, in which the real and imaginary parts of OFDM symbols correspond with the phase component I (t) and quadrature component Q (t) respectively (such as QAM or QPSK, because their signal constellation diagram are divided into phase components and orthogonal components Obviously, they can be dealt with separately), in practice they can be multiplied with the cos component and sin component of the corresponding subcarriers, constitute of the final sub-channel signals and the synthesis OFDM symbols. At the receiving end, the input signal is divided into the N road, respectively, with each sub-carrier mixing and integration renewing the sub-signal, and the data can be restored through another string/and transform and conventional QAM demodulation .

Although the principle of this method is very simple, theoretically feasible, but the actual realization is very difficult, especially when the number of subcarriers is very large, sub-carrier spacing is very small, it is very difficult to achieve such a high frequency resolution. The structure of each sub-channel is a quadrature modulator, its structure is very large. The structure use a number of separation modems, the function of which is exactly the same, and the waste of resources is very large. Therefore it is necessary to find a solution that is easy to implement.

2) DSP realization

If sampling to S (t)with $f_s=1/t_s$ for the sampling frequency, that is $t=nt_s$, there are

$$S_n=S(t)\Big|_{t=nt_s}=\sum_{k=0}^{N=1} d_k \exp(j\frac{2\pi k}{N}n)$$
$$=\sum_{k=0}^{N=1}[(a_k\cos\frac{2\pi k}{N}n-b_k\sin\frac{2\pi k}{N}n)$$
$$+j(b_k\cos\frac{2\pi k}{N}n+a_k\sin\frac{2\pi k}{N}n) \quad (5)$$

The real and imaginary part of S_n are the sample values of I (t) and Q (t) at $t=nt_s$ (n=0， 1， …N-1)Department. It can be seen that S_n is precisely Inverse Discrete Fourier Transform(IDFT) of d_k, S (t)will be got when S_n is through the low-pass filter. Thus, OFDM modulation can be achieved by IDFT, DFT can achieve the corresponding demodulation of receiver. This is the basic principles of using digital signal processing (DSP) technology to achieve multi-carrier parallel transmission of.

The advantages of using DFT approach to deal with OFDM is obvious. First of all, it greatly simplifies the design of a modem, making the handling of multi-carrier path through DFT processing can be completed. In addition, DFT has mature and fast calculation method, namely FFT. It can be realized conveniently in the DSP chip and hardware structure making the practicality of OFDM possible. The principle of dealing with OFDM by IFFT/FFT approach is shown as Figure 1.

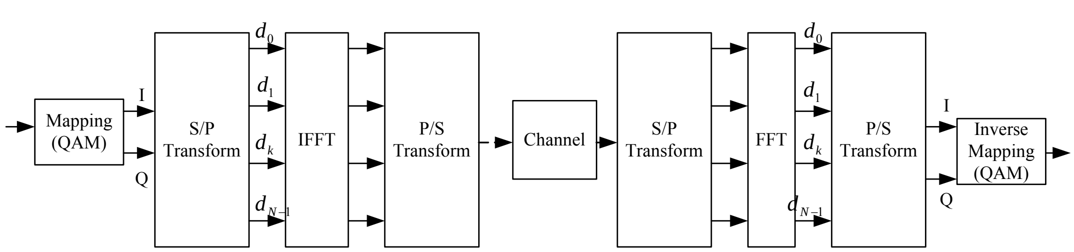

Figure 1. The principle fig of realization of OFDM modulation and demodulation by DSP

III. THE REALIZATION OF OFDM SYSTEM BASED ON SOFTWARE RADIO

A. The measure to improve anti-interference ability of OFDM system

The above result is derived under the condition without taking inter-symbol interference into account and multipath fading, etc. And the multi-path transmission in channel, as well as Rayleigh fading will destroy the orthogonality among subcarriers. The solution is as followed:

1) Insert a guard interval (GI) to overcome inter-symbol interference (ISI)

The symbol cycle is increased as a result of low-speed parallel subcarriers, so that it is possible to insert a guard interval between each OFDM symbol. If the inserted guard interval is greater than the maximum time delay spread, all the multi-path signals whose time delay is less than the guard interval will not be extended to the next symbol period, which can effectively overcome the inter-symbol interference. However, in the protection of time there can be no effective signal.

2) Use the cyclic prefix (CP) to overcome the inter-carrier interference(ICI)

In order to overcome the inter-carrier interference ICI, in the OFDM symbol with guard interval to add to "expand the circle." Specific approach is taken by cyclic prefix, OFDM is about to time-domain waveforms are copied to the end of the previous OFDM symbol as a guard interval, symbol is used to keep a copy of the orthogonality waveform.

Theory shows that with the cyclic prefix guard interval can not completely eliminate the ICI, ISI, check if the guard interval is too long, this will affect the utilization rate; taken too short, will cause more interference, so the choice is between the protection system design One of the major considerations.

B. Framework for software radio OFDM system structure

Usually OFDM system transmitter which is transformed by the DAC will be conducted on the frequency. And the receiver carries on the digitization to the baseband signal. The software radio construction's OFDM system is different with it, therefore, in the article might as well gives a figure 2 the structure. In the chart the above way is the transmitter link, the following way is the receiver link. In among may see that to IFFT/the FFT processing unit, actual IFFT may through take the FFT input parameter the conjugate, will divide FFT in the output parameter the points to obtain, this causes with the identical hardware to receive and transmit will become possible.

At the sending end, serial input data encoding, interleaving (using the two wireless technologies to counter the attenuation of random and burst channel errors), the use of SLM scrambling algorithm in order to reduce the PAPR, Uses the SLM algorithm to harass the code falls the trough compared to, along with it carries on the star map mapping, carries on the pilot frequency insertion according to system's transmission frame form (to restore, carrier frequency difference again for receiving end's mark group synchronization to estimate and channel provides signal balanced), makes up treating processes and so on zero framing, by now obtained the frequency range data. Then through N spot IFFT transformation, completes the multi-carrier modulation, enables the signal in N sub-carrier the parallel transmission, after the transformation signal transforms after and the string, duplicates the front part a serial data rear part's L_{CP} spot, takes the circulation prefix, constitutes a length is the $L_{CP}+N$ complete OFDM data frame. This $L_{CP}+N$ sampling point after D/A and previous frequency conversion sends in the channel. If carries on the baseband transmission, no longer in need frequency conversion.

At the receiving end, through the RF (radio frequency) and A/D conversion, the signal must be sent to sync / timing module, the synchronization algorithm, it is estimated that out of the frame timing and frequency deviation, and by deleting the cyclic prefix; then by N-point FFT transform using the signal for the insertion of pilot channel estimation; FFT output including N months (N for the FFT points) PSK or QAM mapping value, all these values are mapped to the binary inverse, and then decode the binary data to be output.

C. The program of realizing the sampling software radio structure with broadband，intermediate frequency, band-pass in OFDM system

As shown in Figure 2 to realize the sampling software radio structure with broadband, intermediate frequency, band-pass in OFDM system, the program is as followed:

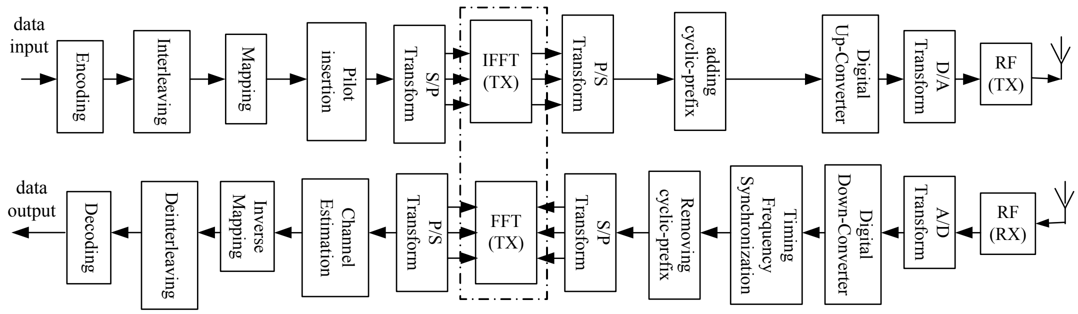

Figure 2. The system fig of OFDM based on software radio

1) The program of realizing the radio frequency section

Use mature Superheterodyne technology, through the links of"analog up/down-conversion", respectively to realize that the D/A output of the broadband analog IF signals are up-conversed to RF signals and RF signals are down-conversed to broadband analog IF signal suitable for A/D sampling.

2) The program of realizing "analog/digital/analog conversion" section

A/D converter can use AD6640 made in AD company; D/A converter can use HI5741 from Harris company.

3) The program of realizing "digital up/down-conversion" section

DUC can use HSP50215 from Harris Corporation; DDC can use HSP50216 from Harris Company. Of course, in addition to the dedicated chips, the FPGA can also be used to achieve, for example FPGA (APEXEP20K200E) produced by Altera Corporation not only complete the digital up/down conversion, digital filtering, but also realize the functions of the modulation / demodulation, spreading / despreading, the synchronization and tracking of the PN code.

4) The program of realizing "base-band digital signal processing" section

a) The DSP program

Considering that there are many high-performance DSP designed specifically for the communications, , such as next-generation high-speed fixed-point DSP TMS320C6x in TI company and fixing / floating-point Tiger SHARC ADSP-TS101S in AD company, etc.. In the program, the DSP can be used to achieve the code and decode, digital QAM modulation and demodulation, IFFT modulation and demodulation, control and so on.

b) The program combined by FPGA and DSP

In the program, the whole complex base-band signal processing can be divided into two parts to process: one is that with the multi-stream parallel processing (compared with DSP, the processing mode in DSP is single-stream) characteristics, the most used resource and speed IFFT/FFT algorithm and synchronization algorithm on the FPGA module to achieve. The other part is that the complicated calculation is processed in the DSP, such as the digital QAM modulation, coding, digital pulse filter and control in the delivery system; digital QAM demodulation, decoding, and control in receiving system.

This division is made to make full use of the FPGA and DSP respective advantages to reduce the amount of work on single-chip DSP and FPGA's workload and reduce system requirements on performance of the DSP and FPGA . In addition, DSP can be used to control the FPGA flexibly, and FPGA can also provide various state information in system.

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