Optimization Design of Communication-radar Integrated Waveform Generation System

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***Abstract*—With the increasingly complex electromagnetic and transmission environment, in order to reduce the volume of the platform and the mutual interference of the communication radar signals, the demand of the integrated platform is more and more strong. Based on the integrated method of radar communication, three kinds of ways of integration are summarized, and the existing design scheme is introduced in the paper. And then analysis of the program found output frequency instability problems by using direct digital frequency synthesis technology. Therefore, we propose the integration system optimization design based on FPGA and DSP to control DDS. The stability of output frequency is improved by the feedback of the system, and the stability of the output frequency is increased. The simulation results show that the proposed scheme has a better stabilizing effect on the output frequency.**

Keywords—radar communication synthesis, DDS technology, stable transmitter, DSP feedback

I. INTRODUCTION

In order to adapt to the increasingly complex environment of war, the army need equipped more and more electronic devices, but in limited load range and resources, how to achieve functional integration is the major problems of the future development to solve. One of the effective ways is to realize the integrated design of the communication radar system. For a long time, radar and communication systems have been strictly distinguished because of the different research objects, which are divided into two different fields: radar countermeasure and communication countermeasure. But in fact, radar and communication systems are the way of information transfer, acquisition and signal processing. They are different in the hardware and software architecture, but they are same in the working principle, system architecture and working frequency. Therefore, the integration of radar communication system is not only the urgent need of modern war, but also the direction of future technology development. It had entered the implementation stage from the hardware resource sharing to software architecture, radar and communication integrated, can greatly improve the system security, and operational capabilities, also it can overcome the defects such as slow speed, huge size of the traditional system.

The idea of radar communication integrated in 1960s has appeared. There were three kinds of integrated system. The first is the sub-time system, radar and communication function used hardware resources in different time, communication can not be achieved when the radar system work, so there is a blind spot, but the project is simple. Second is the sub beam system, the different functions are implemented by different beams, the functions included radar detection and data communications. The third is the simultaneous transmission, which is the mainstream of the current study of the integrated waveform system, radar and communication waveform synthesis together. The transmission waveform not only carries the function of the communication data, but also can realize the function of the radar detection. The two is carried out at the same time, there is no detection blind area. Although this way is not easy to achieve, it is the future direction of the development of radar communications. The key technology of this mode is the waveform synthesis. According to the comprehensive way, the waveform design can be divided into three categories: the first is based on the radar carrier waveform, the waveform carrier the communication data. Second way is based on the communication waveform, the communication waveform is transformed into the waveform suitable for radar detection. Third waveform of the radar waveform is generated independently, and the output waveform is obtained. The following is the introduction of the previous classification, and finally put forward the optimization program.

II. INTEGRATED WAVEFORM

A. Integrated waveform design based on radar waveform

Radar and communication integrated used radar waveform to achieve communication function, the radar waveform is the carrier, using a communication signal modulated carrier to achieve integration. This is the most basic, most conventional way.

2007 literature [1] has proposed using amplitude modulation methods to obtain integrated waveform frequency modulated continuous wave (FMCW), this way used radar waveform to do detection, and the waveform carry communication information. The program can only be used on continuous wave, pulsed radar can not be applied. More importantly, the AM signal to go through the radar power amplifier, after the nonlinear region will have a serious distortion, thus affecting the last communication information demodulation, corrupt communications performance.

Document [2] proposed the concept of a communication based on Chirp signal to achieve the integration of radar. Integration of radar and communication based on fractional

Fourier transform used the same modulation frequency and different initial frequency chirp signal, to achieve the transfer of binary data without affecting the performance of the radar premise. This design makes communication signals hidden in the radar signal, to enhance the transmission of confidentiality and anti-interference ability.

At the receiving end, integrated waveform received by the antenna and sent to the sampler discrete to sampling, then handled by fractional Fourier transform. In radar processing, the data were converted into FRET, then pass through the band-pass filter to filter out noise sidebands used fractional Fourier transform can restore the Chirp signal, and then sent to the matched filter with the original signal. Finally the output makes the threshold determination, then starts the radar signal processing. In communication data processing, data converted into peak position judgment system, the system based on the signal peak at the specific location found the coordinates of the peak point, according to peak value sampling pointed the initial frequency chirp signal, according to the initial frequency it can map the initial signal, the final output is the binary data.

B. Integrated waveform design based on communication waveform

This way is mainly concentrated in the OFDM signal waveform transformed, the idea want to reform the OFDM signal into radar signal with communication data. OFDM has been a relatively mature technology in the communications field, but in the radar field it is the new research topics.

Dmitriy Garmatyuk and Jonathan Schuerger studied the OFDM signal as an application, radar modulation waveform is PSK. Experimental results show the feasibility of OFDM waveform radar detection. Then Christian Sturm studied the OFDM application in radar communications. By using the frequency domain characteristic of OFDM signal, the radar ranging signal is processed by Fourier transform, and the integrated waveform is not only fast, but also independent of the modulation data.

Although the OFDM signal has better anti-jamming and security performance than the LFM signal in the radar application, the OFDM signal envelope fluctuation is bigger, the peak is higher, it can only be used for short distance communication or detection. If you do long-range detection waveform in the military field, since the radar transmitter power amplifier operates in a nonlinear region. It will cause serious distortion of the transmitted signal, this distortion can not channel estimation and equalization to mitigate the demodulated at a disadvantage. Furthermore, OFDM is sensitive to the Doppler shift, not suitable for communication between the relative velocity larger platform.

C. Waveform overlay synthesis design

Integrated waveform design method of synthesis is substantially superimposed using two mutually orthogonal waveforms to perform detection and communication functions, respectively. Two waveforms are generated independently and then superimposed waveform synthesis is integrated. At present, the research of this method is more common, it reformed the radar system as small as possible, and can meet the requirements of the system.

In 2003, Roberson and Brown proposed a radar communication integrated system based on chirp spread spectrum, as shown in Figure 5. In this system, the Up-chirp signal is used as the communication waveform, and the Down-chirp signal is used as the radar detecting waveform. The time width of each waveform is 2us, the radar repeat period is 6us, and the communication signal waveform is modulated. Obviously, the communication signal is a continuous wave, then the transmitter and receiver can not share the antenna. This is not suitable for pulse radar.

In 2006, Shaojian Xu et al. proposed that used two orthogonal direct sequence (DS) to detect the radar pulse and the communication data separately The two waveforms are modulated by the synthesis of a wave after the launch. The receiver uses the method of solving the expansion, separating the radar echo and the communication signal, and then carries on the corresponding processing. The scheme is relatively easy to implement, does not need to make big changes to the radar, but the disadvantage is that communication waveform damages the detection performance, and the scheme doesn't apply to high speed mobile platforms.

In 2008, the Jamil Monin and others proposed using the complex Oppermann multi column code to distinguish the radar detection function and communication function. In the literature, they compared the performance of Oppermann sequence with P1, P2, P3 and other sequences, which showed that the Oppermann sequence is rich and has a large correlation domain to meet the needs of communication. At the same time, it analyzes the performance of the sequence in radar detection, and it shows that the fuzzy function has better performance. But the Oppermann sequence also has the problem of split transmission power and damage detection performance.

III. TRANSMITTER OPTIMIZATION SCHEME

A. Programme summary

Through the introduction and analysis of the above three types of programs, it can be seen that the demand for hardware conditions of radar communication integration is more stringent. In the implementation process, it is necessary to ensure the stability of the communication performance, but also take into account the stability of the radar, the final purpose of the three schemes is to achieve the integration of the transmitter, but the process faced a main problem is the interference between multiple frequency bands, the transmitter hardware in the long-term work in the process, will inevitably produce a frequency offset and frequency instability. This is a fatal problem for signals of radar communication integration. Due to the integrated, frequency resolution is especially accurate, frequency fluctuation will cause a huge difference. In order to increase the stability of transmitter, and provide a stable integrated environment for the integrated platform, put forward the design scheme, the program used FPGA and DSP to control the DDS to optimize the transmitter. The stability of output frequency is improved by the feedback of the system.

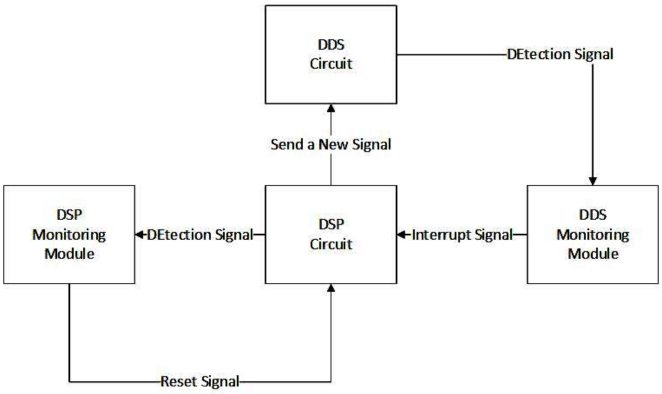

Fig.1 Block design block diagram

DSP is the core control part of the system, its working state directly affects the whole system work. In order to ensure the stability of the DSP, we joined the DSP monitoring module, the design is shown in Figure 1. When the monitoring module detects the abnormal signal of the DSP, the detection module sends the reset signal to the DSP to reset it to the normal working state. When the DDS chip output signal deviate from the normal operating frequency range, the DDS detection module will issue a command to enable the DSP to run the interrupt program, and then reset the DDS and re configuration. In this way, the working reliability of the radar transmitter can be improved, and the output waveform can be more stable.

B. *Performance testing*

First, we use the host computer to send different frequency values, from the spectrum analyzer (E4402B Agilent) we can observe the waveform and record the frequency of continuous wave at different time points, the specific values is shown in Table 1.

Table.1 Measurement comparison

Theoretical value / Hz	***Actual numerical value/Hz***	***Theoretical value /MHz***	***Actual numerical value /MHz***
1	1.006	10	10.005
100	99.997	50	49.992
10000	1.004×104	70	69.989
1×106	1.005×106	100	100.003

It can be calculated by $M=\frac{|f_1-f_0|}{f_0}$ that the relative error between the measured value f_1 and the theoretical value f_0 is less than 1%, which meets the requirement of the actual transmitter.

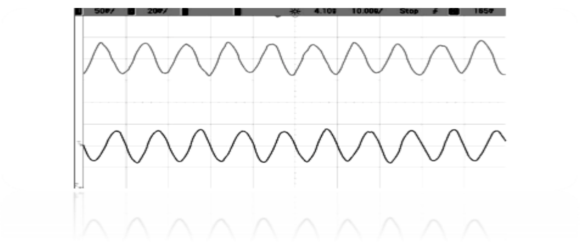

Fig.2 Frequency 100 MHz continuous wave signal

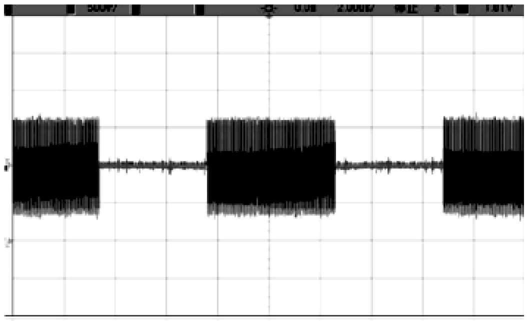

Fig.3 Single pulse signal

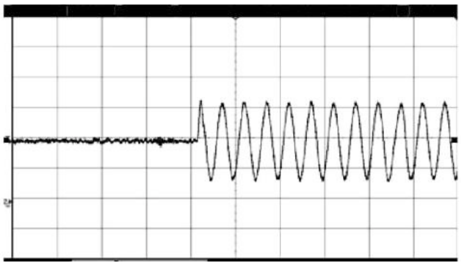

Fig.4 Local magnification

From the experimental results it can be seen that the radar transmitter outputs a continuous wave through an oscilloscope. FSK signals and single-frequency pulse signal waveform are curve, spectrogram main spectrum is good. There is no attenuation when the frequency becomes 100 MHz, it has high frequency stability to meet the demand. This system can produce a stable signal by feedback system.

IV. CONCLUSION

In this paper, the excellent performance of the radar transmitter with high speed and stability is developed, which is based on DSP/FPGA control DDS technology. Compared with the former design transmitter scheme, the performance of the whole machine has 3 advantages.

1) High speed. Compared with the previous MCU control DDS chip, TMS320C6416 DSP, maximum clock speed can be up to 1 GHz to solve the shortcomings of not enough speed control chip, and the DSP chip has powerful computing processing ability, it can control the DDS chip to generate the waveform.

2) Stability. As in the past generated radar signal with a crystal oscillator program compared by DDS technology to solve the radar transmitter output signal frequency instability, the problem of high spectral purity and disadvantages cannot be changed. The DSP work monitoring circuit is added to ensure the stability of the transmitter. Compared with the signal generator without adding the monitoring module, the output signal is more stable in the strong interference environment, the system is also more normal working hours.

3) Real-time. The program used C language to achieve a simple human-computer interaction interface. We can change the parameters at the interface, the software writes parameters

from DDS to DSP to control output different signals. The DDS chip has large power consumption and its heat dissipation performance is poor, all of these shortcomings affect the stability of the radar.

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