Research and Design of proximity fuze Scheme Based on 24GHz Radar Sensor

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Abstract. Modern warfare requires more and more adaptability to the environment. The proximity fuze based on microwave radar sensor has high anti-interference performance, which can achieve accurate hit and high efficiency damage in the complex environment. The microwave radar sensor has the characteristics of strong anti-interference ability, high precision of ranging and high speed measurement, and can accurately extract target information. This paper mainly introduces a design and implementation scheme of proximity fuze based on 24GHz microwave radar. With a small spatial structure and high integration, combined with the Doppler principle, antenna scanning technology and FFT system software design, the detonation range of the lowest 0.5m and 30m is determined effectively and reliably with a low false alarm probability.

1. Introduction

From the 1930s, proximity fuze began to appear. Early fuze systems were mainly divided into mechanically triggered fuze, electronic time fuze, optical and magnetically fuze. During the Second World War, proximity fuze entered a stage of rapid development, and Doppler radio fuze, electrostatic fuze, pressure fuze and infrared fuze were successfully developed[1]. With the development of radar technology, integrated circuit and power amplification technology, the proximity fuze based on radar sensor has been successfully developed, which makes the fuze become an intelligent fuze system that can adapt to multi-environment, multi-task, self-adapting, identify enemy and foe targets, and select the best operational point[2]. In recent years, as the key technology of missile guidance, microwave proximity fuze has been paid more and more attention. Due to the limitation of ammunition system and detonation system in modern warfare, there are higher requirements for the structure, quality, cost, performance and volume of proximity fuze. In order to meet the needs of modern information warfare, it is urgent to break through the existing technology and realize the scheme and technological innovation. This paper introduces a realization scheme of proximity fuze system based on 24GHz microwave radar. In order to achieve the best point of detonation control, it is necessary to use highly integrated radar sensors to sense the surrounding environment, and to extract the relative velocity, relative direction of motion and distance information of the target[3].

2. Solution design

The action process of microwave proximity fuze refers to the action process from launching to detonating warhead by fuze. Fire control system detects and extracts target information through proximity fuze sensors. The main function of fire control system is to eliminate unnecessary interference from complex environment to find target and determine the optimal initiation point. The
exploding foil initiator system receives the control signal from the fire control system to start the initiation sequence[4].

The sensor scheme of microwave proximity fuze proposed in this paper is based on 24GHz microwave radar. Its basic block diagram is shown in Figure 1. It consists of receiving and transmitting antenna, radio frequency transceiver module, IF signal filtering module, video signal amplification module, frequency synthesis module, processor module and power module.

![Figure 1. Microwave proximity fuze sensor system block diagram.](image1)

2.1. **TR component**

T/R component uses Infineon’s 24 GHz radar transceiver MMIC-BGT24MTR11 which highly integrates low phase noise VCO. The chip also has the following functions: 1.5GHz and 23KHz frequency dividing output can be turned off for easy interconnection with frequency synthesis module and current frequency measurement. The transmitting channel integrated power amplifier (PA) can be programmed by SPI with a maximum power of 15 dBm to meet the requirements of the transmitting power of proximity fuze. The receiving channel integrates low noise amplifier (LNA) and mixer (MIXER). On-chip power and temperature sensors can support more intelligent design. In addition, the BGT24MTR11 transmission channel adopts differential output mode, and the RF power can be synthesized by using a 180 degree hybrid loop circuit to improve the transmission signal power[5]. Figure 2 shows the TR component of the 24G radar sensor.

![Figure 2. TR component of the 24G radar sensor](image2)

Compared with the conventional 24 GHz radar implementation scheme, the TR component is usually composed of discrete components and transmits and receives control signals through antenna transceiver switch, which greatly increases the system design complexity and circuit board area[6].

2.2. **Frequency synthesis**

In the scheme, PLL technology is used for frequency synthesis, and ADF4159 of ADI company is selected. It has a 13GHz decimal N-frequency dividing frequency synthesizer with modulation, fast and slow waveform generation capability. Its 25-bit fixed modulus provides sub-hertz resolution for frequency synthesis, which makes up for the shortcoming of low resolution of frequency synthesis using PLL technology[5]. ADF4159 also has a cycle reduction circuit, which can maximize the
sub-characteristic without modifying the loop filter. Figure 3 shows the phase-locked loop of ADF4159 and BGT24MTR11 used in FMCW radar system. In this system, ADF4159 is used to generate triangular modulation ramp of radar system. Based on this mechanism, the method of generating the required type of ramp driven by direct digital frequency synthesizer (DDS) is no longer used, which greatly saves the cost and makes the scheme simpler. In addition, the PLL solution is superior to another method to generate FMCW slopes (using DAC to drive VCO directly), which needs to compensate for the nonlinearity of VCO tuning characteristics, while the PLL solution can provide high linearity slopes without calibration.

Figure 3. Frequency synthesis.

In the figure 3, C16, U3 and C17 are the loops of 1.5GHz signal to ADF4159 RF input pin generated by VCO in BGT24MTR11 after 16 frequency division. C14, R1, C13, R3 and C15 constitute third-order passive loop filters. Capacitor C14 converts pulses from ADF4159 charge pump (CP) pins into DC voltage. Resistor R1 and capacitor C13 are used to stabilize the loop. Resistor R3 and capacitor C15 are used to filter out the corresponding ripple interference of the loop and spurious components brought by phase discriminator[7].

2.3. IF signal processing

In radar system, the modulated wave based on 24GHz radiates from antenna to target and returns to the local oscillator signal after mixing with MIXER. There are a lot of clutter information in this signal, which is not suitable for direct AD sampling analysis. It needs to filter out useful clutter information and amplify it. Because there are two signals (I and Q) output by BGT24MTR11 mixer, and the processing of the two signals needs a high degree of matching, the filter chosen in this scheme is LTC6602 of LINEAR TECHNOLOGY, and the integrated operational amplifier is MAX4451 of MAXIM. LTC6602 is a dual-channel, phase matching, controllable gain and programmable low-pass/band-pass filter. The characteristics of fully differential input, output and support three-wire SPI programming greatly simplify the system design and control. MAX4451 is a single power supply with low power consumption and 210 MHz-3 dB bandwidth. It has two channels full differential input and rail-to-rail output. It is used to amplify and process useful signal signals for signal processor sampling and recognition.

2.4. Signal processor

Considering the low-cost application of microwave proximity fuze and the simplicity of system structure, the processor used in the system is STM32F405 of ST Company. The core of the chip is 32bit-Cortex-M4 with embedded FPU. Its adaptive real-time accelerator (ART Accelerator) allows execution from Flash memory 0 in a waiting state. The clock frequency is as high as 168MHz, and it has memory protection unit and DSP instructions. Based on the above points, there is no need to use the DSP processor in the system[9]. In addition, 3-channel 12 bit-ADC (up to 16 external channels) allows the system to no longer configure external ADC sampling circuit, it supports SPI communication and can be easily programmed with other modules.
2.5. Software framework
The software development environment of the system is IAR7.10. According to the support of compiler and processor for library files, a large amount of code can be reduced.

![System program flow chart](image)

Figure 4. System program flow chart.

The software system is a typical modular design, which is convenient for debugging. The flow chart of the system software is shown in Figure 4. After launching the projectile, the system begins to sample the IF signal filtered and amplified by ADC in the processor chip after the rapid initialization. The sampled data is stored in two buffers to ensure that the current ADC sampled data can be stored in buffer 2 while the data of buffer 1 is processed subsequently. This ensures that the current ADC sampled data can be stored in buffer 2. The fuze system works normally with high performance.

3. Conclusion
Through describing the characteristics of modern warfare and the development of microwave proximity fuze, this paper puts forward a realization scheme of proximity fuze based on 24GHz microwave radar sensor. On this basis, compared with the traditional realization scheme of proximity fuze, the optimized hardware system design of this realization scheme can control the space volume, realization cost and work power consumption in a lower range. On the basis of Doppler radar principle, antenna scanning technology and FFT software algorithm, the range of explosion height from 0.5m to 30m can be judged with lower false alarm probability, which meets the requirements of proximity fuze and is realizable. Based on the processing performance of the system scheme, the processing speed of intermediate frequency signal is limited. The working performance of proximity fuze can be further improved by using DSP or FPGA.

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