Design of beacon system based on MSP430 micro-controller

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Abstract: In order to solve the onboard recorder search problem, a new beacon system based on radio direction finding technique, which indicates the orientation of the recorder, is designed. The system consists of phase-locked loop (PLL), microprocessor, global position system (GPS) module, power module and so on. The scene simulation verifies the feasibility and reliability of the system. This beacon system can be applied to the recorder search in many fields, and can effectively reduce the search scope and improve work efficiency.

Key words: recorder search; beacon; phase-locked loop (PLL); MSP430

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0 Introduction

Beacon is an electronic device which can transmit radio signals to provide the information concerning where it is located on the ground or in the aircraft. Recorder can record important parameters of the objects measured during operation, such as flight altitude, velocity, trajectory and so on. These parameters are of great significance for studying the performance of the device under test[1], which proves that the recorder search is extremely important. In the missile and other special tests, onboard recorder often falls in the complex natural environment such as the land of desert. Then manual search is relatively difficult for the high costs as well as the long time taken in the search which only relies on human eyes. It directly affects the progress of the project[2]. Currently, the beacon has been applied to recorder search in the field of aviation. Beacon falls with the recorder, and emits radio signals after landing. Then the beacon is searched by a helicopter or vehicle equipment[3]. Making use of beacon to indicate the orientation of the recorder can narrow search scope and reduce search difficulty. At present, the recycling of onboard recorder mostly adopts releasing ribbon, global position system (GPS) location, Beidou satellite location. However, there is no general packet radio service (GPRS) base station in the remote area, besides, real-time monitoring is no longer viable. At the same time, the use of GPS makes Beidou messages function need specialized application by relevant departments. It takes a large amount of time, and its reliability is also a crucial constraint[4-7].

In this paper, a new beacon system based on radio direction finding technique is designed, which can indicate the orientation of the recorder.

1 Overall workflow and system composition

1.1 Design of overall workflow

Onboard recorder radio beacon is the key part of target search work. Taking low power into consideration, the overall workflow is related to the unmanned aerial vehicle carrying the transmitter that sends search signals continuously. Onboard recorder beacon enters receiving state after landing, then it gets into the transmitting mode until receiving wake-up signal from unmanned aerial vehicle. Afterwards, beacon emits radio signals in a continuous way. Unmanned aerial vehicle detects the radio beacon signal in all directions, and sends the strength data to the flight control terminal through the serial port. When the flight control terminal receives the information, it will lock the direction of the beacon roughly. Then the searcher helds search instrument by hand to quickly recover the recorder within a certain range.

Onboard recorder shell is designed as hexahedral

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structure. Six micro-strip antennas are mounted on the surface of the shell. Both the beacon circuit and the recorder circuit are put in the shell. The shell is shown in Fig. 1.

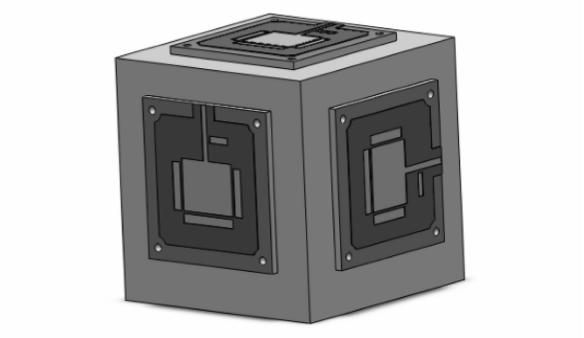

Fig. 1 Outside view of onboard beacon shell

1.2 System composition

This beacon system includes a transmitter and a search instrument. The transmitter adopts MSP430 micro controller unit (MCU) to control phase-locked loop (PLL) chip's frequency division ratio so as to produce a specific frequency. A digital PLL is a loop which extracts bit synchronization signal from the received data directly[8]. The transmitter is composed of PLL chip, reference source, loop low-pass filter (LPF), voltage controlled oscillator (VCO), MSP430 micro-controller, clock circuit and micro-strip antenna.

Reference source adopts temperature compensated crystal oscillator. The frequency is sent to the phase detector to discriminate phase after PLL chip's frequency division. Then the phase detector gets phase error signal and sends it to a loop filter. The phase detector gets DC voltage signal after the loop filter filter out phase discriminator frequency and noise. Afterwards, the phase detector sends DC voltage signal to VCO. The output signal of the VCO returns to the phase detector after frequency division. The set of frequency division is that the micro-controller sends frequency control word to PLL chip to obtain the corresponding frequency. Finally, the transmitter transmits frequency through the antenna.

In order to avoid the damage of the antenna, this system adopts micro-strip antenna structure with the advantages of small size, low profile, low cost, conformality with carrier and so on[9]. The micro-strip antenna adopts copper clad fabrication process. It can withstand great impact acceleration without being damaged.

The function of the clock circuit is to control beacon's working time. It can reduce the power consumption. The block diagram of transmitter is shown in Fig. 2.

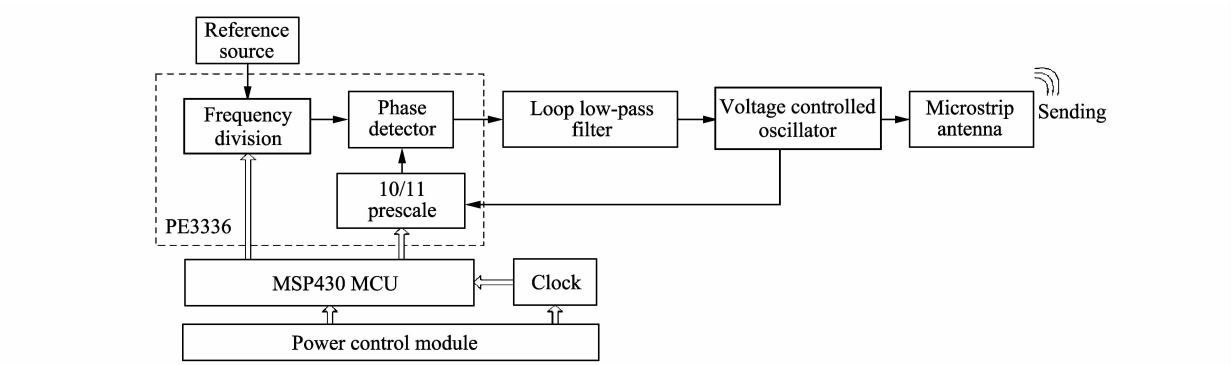

Fig. 2 Block diagram of transmitter

The block diagram of search instrument is shown in Fig. 3.

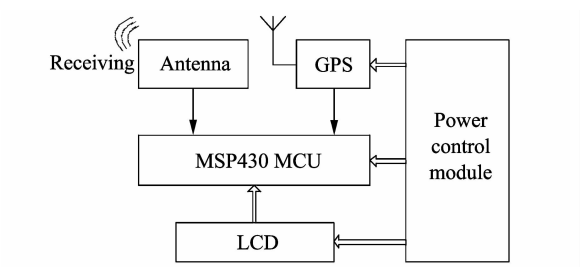

Fig. 3 Block diagram of search instrument

The search instrument includes GPS module, antenna, MSP430 MCU and liquid crystal diode (LCD) screen. GPS module shows the location of the searcher so as to avoid being lost. Antenna receives the signal and sends the signal to the micro-controller. Finally, the strength of the received signal is shown on the LCD screen. Then the searcher can judge the direction of the beacon transmitter.

2 System design

2.1 Hardware design

2.1.1 PLL design

PLL is loop control system that controls the frequency of the oscillation signal according to the phase difference of the input signal and the output

signal[10]. The PLL chip of this design is PE3336. The chip adopts parallel data input mode, and reference source adopts temperature compensated crystal oscillator. The waveform amplitude which is output from the temperature compensated crystal oscillator can not be too high or too low. It should be controlled at about 1 V. The chip uses type II resistance attenuation network to get the required waveform amplitude[11]. The phase detector produces PD _ U and PD _ D dual output signals. Then the phase detector gets a control voltage after the output signal filtered by the loop filter. In the initial phase, the frequency of VCO approximates the frequency of the reference signal. Afterwards, the two frequencies become the same, and the phase is synchronous. At last, the PLL chip achieves frequency locked. The circuit diagram of PLL system is shown in Fig. 4.

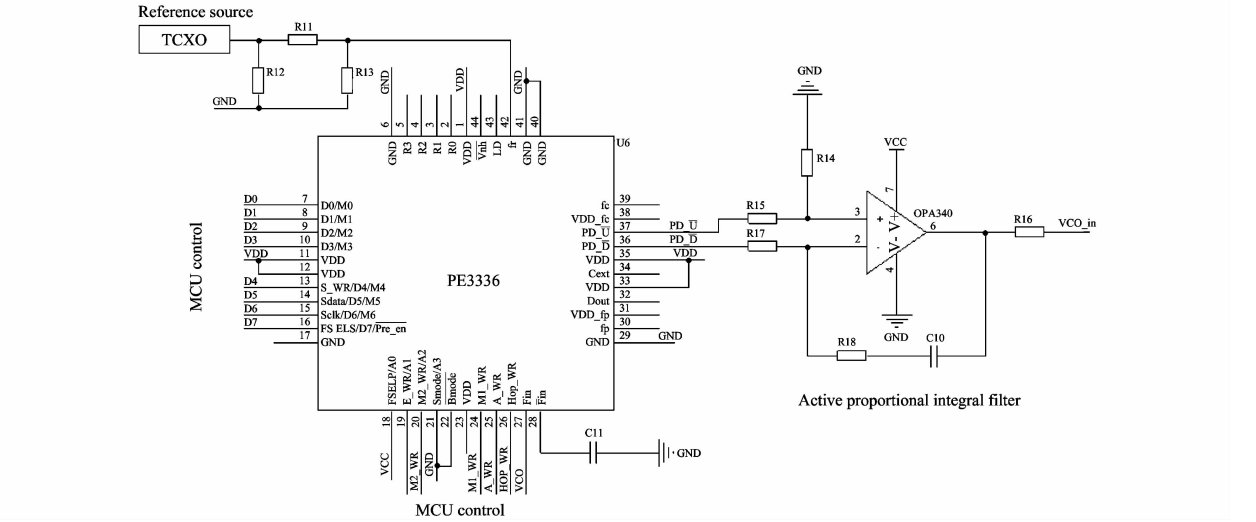

Fig. 4 Circuit diagram of phase-locked loop system

Characterized by low pass, the function of the loop filter is filtering out unwanted high-frequency voltage component. More importantly, it plays a crucial role in adjusting the parameters of the loop. The loop filter is a linear circuit. Commonly, low-pass filter which is used in the loop are RC integrator filter, passive proportional integral filter and active proportional integral filter. This system adopts an active proportional integral filter, which is shown in Fig. 4.

2.1.2 MCU control circuit design

The micro-controllers concerning the transmitter and search instrument use ultra-low-power mixed-signal processing chip MSP430F1611 of TI MSP430 family. With the low voltage and power consumption, its powerful processing capability and rich on-chip peripheral modules could meet the requirements of the system for low power consumption.

2.2 Software design

2.2.1 PE3336 programmable divider data format

MCU controls M2 _ WR, M1 _ WR, A _ WR, HOP _ WR and D0 – D7. So that it can control the 20 bit programmable reference division ratio and prescale ratio. The control word data format of main register is shown in Table 1.

Table 1 Control word data format of main register

Interface mode	R5	R4	M8	M7	Pre _ en	M6	M5	M4	M3	M2	M1	M0	R3	R2	R1	R0	A3	A2	A1	A0
Parallel port	M2 _ WR rising edge load				M1 _ WR rising edge load								A _ WR rising edge load							
	D3	D2	D1	D0	D7	D6	D5	D4	D3	D2	D1	D0	D7	D6	D5	D4	D3	D2	D1	D0

When the loop is locked, the relationship of the locked frequency F_{VCO} and the reference frequency f_r satisfies

$$F_{VCO} = [10(M+1)+A] \times (f_r/(R+1)),$$

where $A \leqslant M+1$, $1 \leqslant M \leqslant 511$, $0 \leqslant R \leqslant 63$, $f_r/(R+1)$ is phase demodulation frequency. The process of writing data divider is as follows: First of all, it keeps the HOP _ WR pin low, then when the M1 _ WR, M2 _ WR, and A _ WR pins become high level, it locks the parallel data D0 – D7 into the main register, respectively. Thereby it completes the settings of programmable frequency divider.

2.2.2 Transmitter software design

Transmitter uses PLL technology to produce a specific frequency signal and then sends out the signal. At the beginning, the main program calls the clock subroutine. When the main program gets the effective time data, it calls control subroutine. The flow charts of the main program and control subrou-

tine program are shown in Fig. 5.

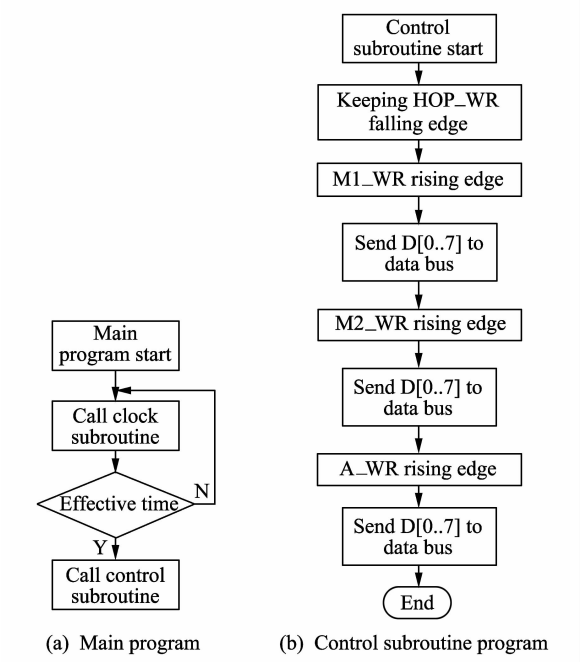

Fig. 5 Software flow chart of transmitter system

2.2.3 Software design of search instrument

On one hand, search instrument receives the specific frequency signal sent by the transmitter. On the other hand, it receives the GPS signal. The system begins to determine whether to open the GPS location request. If GPS location request is switched on, the main program judges the header data. If it is correct, the header data will be saved in the storage array. Finally, the GPS data is shown on the LCD screen. The received specific frequency signal can be shown directly. The flow chart of search instrument is shown in Fig. 6.

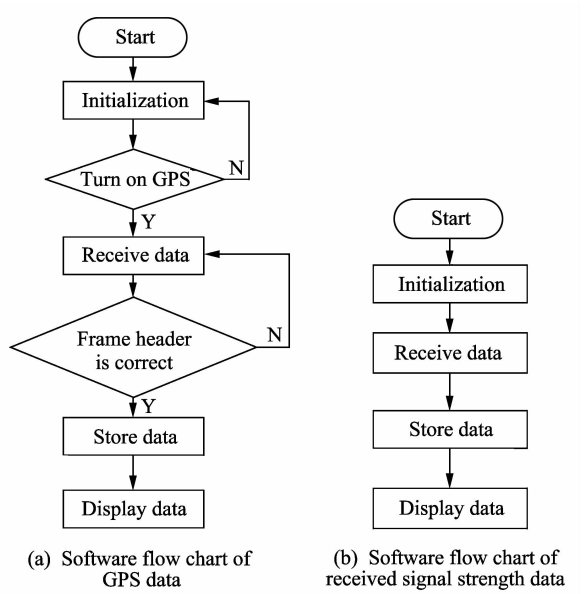

Fig. 6 Software flow chart of search instrument

3 Experiment result

The scene simulation experiment is conducted with a transmitter and a search instrument. Six micro-strip antennas transmit signals cyclically. The frequency of the transmitter signal is 2.645 GHz. Search instrument receives signal in different directions. The strength of the received signal is shown on LCD screen.

The transmitter is placed at distances of 1 200 m, 1 000 m, 800 m, 500 m and 300 m from the search instrument. The searcher holds by hand the search instrument to receive the transmitter signal. Two kinds of experiments are conducted as follows.

1) The transmitter is unobstructed. The searcher sequentially rotates the receiving antenna so as to change the angle from the transmitter. The received signal strength is shown in Fig. 7.

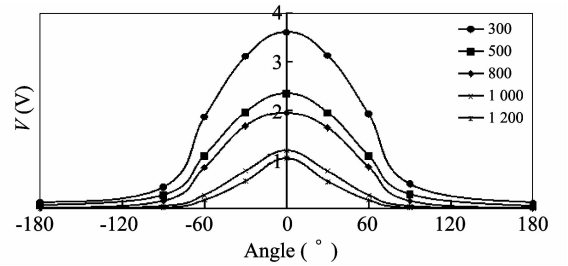

Fig. 7 Received signal strength of transmitter unobstructed

2) The transmitter is partially obstructed. The searcher sequentially rotates the receiving antenna so as to change the angle deom rhw transmitter. The received signal strength is shown in Fig. 8.

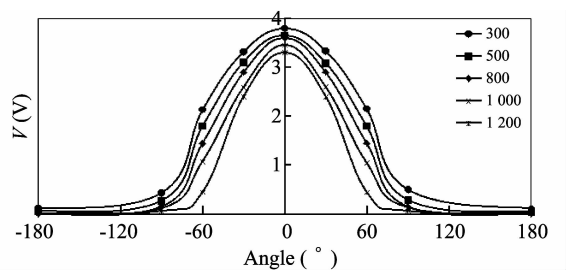

Fig. 8 Received signal strength of transmitter partially obstructed

Fig. 7 shows that the beacon transmitter without any occlusion can complete the process of positioning within the range of 300 – 1 200 m. When the angle is in the range of ±30°, the direction finding effect is good.

Fig. 8 shows that though the beacon transmitter is partially obstructed, it still can complete the process of positioning within the range of 300 – 1 200 m. However, the received signal strength is reduced significantly.

4 Conclusion

In this paper, a new beacon system based on radio direction finding technique, which indicates the orientation of the onboard recorder is designed. PLL and MSP430 MCU are applied to the system, which has low power consumption, small size and other merits. Experiments show that the beacon can complete the process of positioning within the established range. This beacon system based on radio direction finding technique can be effectively used in aerospace field as well as other recorder search fields. It can narrow the search area so as to reduce the difficulty of search.

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基于 MSP430 单片机的信标机系统设计

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摘 要: 针对黑匣子、弹载记录仪搜寻问题, 设计了一种基于无线电测向技术、用于指示记录仪方位的新型信标机系统。该系统由锁相环、微处理器、GPS 模块、电源模块等部分组成。现场模拟实验验证了该系统的可行性和可靠性。该信标机可应用于多领域记录仪的搜寻, 可有效减小搜寻范围、提高工作效率。

关键词: 记录仪搜寻; 信标机; 锁相环; MSP430

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