Design and Implementation of a Simulation Training Platform for Performance Measurement of a Radar Transmitter Sub-system

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Abstract. In order to improve the parameter testing ability of radar equipment support personnel, it is urgent to provide an effective training platform for the army to carry out parameter testing training. In this paper, according to the actual test requirements of radar equipment launching subsystem, the functional requirements of the simulation training platform were analyzed, the parameters of the launching subsystem test training were determined, the overall design scheme of the system was proposed, and the software and hardware design of DDS module, local vibration module and other key functional modules were given. The practical application shows that, on the one hand, the students can be better familiar with the signal flow of the radar transmitting subsystem and understand the working mechanism. On the other hand, it can ensure that students can carry out the measurement practice of transmitter performance parameters in a safe environment and improve their testing skills. The successful development and popularization of the platform can effectively alleviate the contradiction between more people and fewer machines in equipment testing practice, and help to improve the benefits of equipment teaching.

1. Introduction

Parameter measurement runs through every stage of the whole life cycle of radar equipment. It is a basic technical work to evaluate the quality of the equipment and check whether the radar performance meets the design requirements. It is also a technical means to master the technical status of the equipment and isolate equipment fault position. Especially when the radar forces carry out equipment support work, the importance of parameter measurement is more prominent. However, in the current training of test skills, the measurement training of performance parameters is based on radar installation. There are two main problems. First, there are more people and fewer machines in the real test training, and the practice space is narrow. The test operation process is difficult to see, and the teaching effect is difficult to guarantee. Second, repeatedly disassembling and testing the connected parts, which causes serious wear and tear, greatly reduces the reliability of the equipment and affects the service life of the equipment. Here, this paper aims at the design of simulation training platform for performance parameter measurement of radar transmitting subsystem, and discusses from the aspects of demand analysis, system overall design, circuit hardware and software design of key function modules, etc.

2. Demand analysis

According to the requirements of the task, the training and assessment platform developed by the project should be able to simulate the basic functions of the transmitting subsystem of typical radar equipment, and the reserved test port and test signals can meet the requirements of performance parameters test and
training of the radar transmitting subsystem. Through this platform, the testing and training function of the main performance parameters of the transmitter can be realized, including the measurement training of the transmitter's output power, the measurement training of the operating frequency range, and the measurement training of the RF pulse waveform parameters.

2.1 Transmitter output power measurement training

There are two common methods to measure the output power of radar transmitter, which are absorption power measurement method and passing power measurement method. When this training platform carries out test training, both the output signal after power synthesis and the output signal of the directional coupler are small signal power. The absorption power measurement method can be adopted as well as the passing power measurement method.

(1) Absorption power measurement method

When the absorption power measurement method is used for test training, the microwave power meter (AV2436 type power meter) is connected to the coaxial attenuator and connected to the transmitting signal output end on the training platform panel for test.

(2) Passing power measurement method

When the test training is carried out by the passing power measurement method, the directional coupler built in the training platform is used to take a part of the output power from the transmitting branch for measurement, and then the output power of the transmitter is calculated according to the coupling degree of the directional coupler.

Note: in the test, it is necessary to measure the output power of different frequency points. In this case, the working frequency point of the training platform can be changed and the corresponding signal power value can be read out in the power meter respectively.

2.2 Working frequency range measurement training

Radar operating frequency range measurement method usually has two kinds of instrument measurement method, respectively is frequency meter measurement method and spectrum analyzer measurement method.

When using the frequency meter measurement method, the steps are as follows: connect the frequency meter to the coupling port of the directional coupler, open the power source of the frequency meter, and place the "work type" of the frequency meter in the "pulse". Open the transmitter branch output, adjust the tuning button of the frequency meter to the maximum tuning indication, adjust the input attenuation, and make the meter pointer in the middle. Write down the frequency meter scale, check the frequency correction table, you can get the measured frequency value.

Spectrum analyzer measurement method, steps as follows: The transmitting signal from the output coupling port of the directional coupler is transferred to the spectrum analyzer via the high frequency attenuator, open transmitting branch, change radar working frequency, record the working frequency of each frequency point and radar working frequency range being measured as , calculate radar working bandwidth of .

Note: when the spectrum analyzer is used to measure the operating frequency range of the transmitted signal, the signal to noise ratio and signal bandwidth of the transmitted pulse can also be measured.

2.3 RF pulse waveform parameter measurement training

During the measurement of RF pulse waveform parameters, the RF pulse from the transmitter is sent to the envelope detector through the coupling output port of the directional coupler for envelope detection and then sent to the oscilloscope, and the waveform parameters of the RF pulse can be observed on the oscilloscope.

In the actual measurement, the oscilloscope should be designed as an external trigger state, and the radar trigger pulse should be taken as the synchronous trigger signal of the oscilloscope. When using the digital storage oscilloscope to measure the waveform parameters of the transmitted pulse envelope,
the automatic measurement function can be used to complete the measurement of pulse repetition cycle, repetition frequency, pulse width, rising edge time, falling edge time and other related parameters.

3. Overall design of the system

3.1 Hardware composition of the system

Basic design idea: the design of training platform host hardware based primarily on the function of the typical solid-state radar transmitter components, reflects the main steps of transmitting process (that is, "signal waveform generation" → "signal up-conversion" → "excitation signal amplification in advance" → "power allocation" → "multiple components amplification" → "power synthesis"), at the same time consider performance parameter testing and transmitting sensitive branch point reserve test port.

The host hardware composition of the training platform is shown in figure 1.

![System structure diagram of the training platform system](image)

Figure1 System structure diagram of the training platform system

In the figure, modular design is adopted in the host of the platform, which is mainly composed of DDS signal source unit, up-converter unit, power synthesis unit, display control unit, power supply and other five functional modules. Among them, the display control unit adopts an embedded computer and connects with the functional circuit through USB, serial port and other communication buses to realize the control of DDS signal source and local oscillator module. Specifically, the control of DDS signal source is mainly to realize the selection of signal type, local frequency, pulse width, repetition frequency and other parameters. For the control of the local oscillator, the main purpose is to control the frequency of the primary oscillator and the secondary oscillator, in which the operating frequency of the secondary oscillator is 250MHz. There are 5 frequency points in one oscillation, which are 1310, 1330, 1350, 1370 and 1390MHz respectively.

In the figure, the main functional modules are connected with each other by cable, and corresponding test ports are reserved (ports P1 ~ P11 drawn by the dotted line are test ports). By connecting the measuring instrument with these test ports, the performance parameter test training of the launch subsystem can be carried out. Among them, the "power amplifier components" between output port and input port of load absorption concatenated two-way directional coupler, test port P11 for measuring the transmission power, reflected power, working frequency, waveform parameters, launch subsystem main performance parameters, such as signal frequency measurement, measurement results through the transmission power, reflected power, also can calculate the standing wave ratio between directional coupler to load absorption.

3.2 System function indicators

The technical indicators of the training platform mainly reflect the following aspects: (1) DDS signal type, center frequency and output power; (2) pulse width and repetition cycle of various signals; (3) frequency and power of the local oscillator signal; (4) output frequency and power of up-conversion signal; (5) output power after power synthesis. According to the development requirements, the main technical indicators of the training platform are shown in the following table.
Table 1 main technical indicators of the platform

| NO. | Item Content               | Indicator Requirements                                      | NO.   | Item Content                  | Indicator Requirements                                      |
|-----|---------------------------|-------------------------------------------------------------|-------|------------------------------|-------------------------------------------------------------|
| 1   | DDS signal type           | Fixed carrier frequency, linear frequency modulation, nonlinear frequency modulation | 8     | Linear/non-linear frequency modulation signal repetition | 100～500Hz                                                  |
| 2   | DDS center frequency      | 30MHz                                                       | 9     | local oscillator power       | ≥-10dBm                                                     |
| 3   | DDS output power          | ≥-10dBm                                                     | 10    | local oscillator frequency   |                                                            |
| 4   | Fixed carrier frequency   | 5～300μs                                                     | 11    | Up-converter output power    | ≥-3dBm                                                     |
| 5   | signal pulse width        | 100～500Hz                                                   | 12    | Up-converter output frequency| 1030MHz，1050MHz，1070MHz，1090MHz，1110MHz                   |
| 6   | Linear/non-linear FM      | 100μs，200μs，500μs                                          | 13    | Power output after synthesis | ≥25dBm                                                     |

4. Design and implementation of key modules

4.1 Hardware design

4.1.1 DDS signal generating circuit
The core chip used in the DDS signal generation circuit is AD9854, which provides a 48-bit frequency control register to produce very stable frequency, phase and amplitude programmable sine and cosine waveform signals. In the specific implementation of the circuit, the system adopts a two-stage control structure of host computer and slave computer, as shown in figure 2. The host computer connects with the slave computer through USB port, and the slave computer communicates with AD9854 chip through serial port.

![Figure 2. function diagram of DDS signal generation circuit](image)

4.1.2 Local oscillator signal generating circuit
The core chip used in the local oscillator signal generating circuit is the ADF4351 voltage-controlled oscillator, which has the characteristics of low power consumption, small size, and low phase noise of the output frequency. In the specific implementation of the circuit, the system uses a two-stage control structure of the host computer and the slave computer, as shown in Figure 3.
4.2 Software Design

4.2.1 PC control program
The host computer control program mainly completes the setting of parameters such as signal type, repetition frequency, pulse width, signal bandwidth, and transmission frequency. At the same time, the above parameter setting information is compiled into a signal parameter setting instruction, and sent to the slave computer through the serial port for controlling the frequency of the DDS signal waveform and the local oscillator signal. The host computer software interface is shown below.

4.2.2 DDS signal source slave computer control program
The slave computer control program of the DDS signal source mainly performs the following three functions:

(1) Receive the waveform parameter code (signal form, signal repetition frequency, signal pulse width, signal bandwidth, etc.) sent by the host computer through the external serial port on the development board;

(2) Parsing the received waveform parameter code and parsing it into the relevant waveform control word of the AD9854 chip;

(3) Send the relevant waveform control word to the AD9854 chip through the internal serial port of the development board to generate the corresponding signal waveform. In the specific implementation of the control software, the microcontroller on the development board will complete the waveform code reception, the waveform parameter code analysis and the control word transmission through the interrupt processing mode.

The running process of the main function of the slave computer control software is shown in the figure below.
4.2.3 Local oscillator module slave computer control program

The slave computer control program of the local oscillator module mainly completes the following three functions:

1) Receive the register configuration code sent by the host computer through the USB interface on the development board;
2) Store the HEX code received by the USB port into the data buffer area;
3) The code is transmitted to the ADF4351 through the SPI serial interface, and the local oscillator signal corresponding to the frequency is controlled.

The running process of the main function of the slave computer control software is as shown in the following figure:

5. Conclusion

The platform is based on the radar equipment performance parameter test skill training and college teaching and other needs to develop the radar launch subsystem performance parameter test training system. Tested and proved that its various functional indicators and technical indicators meet the design requirements. The successful development of the platform can not only effectively solve the practical difficulties of equipment teaching with fewer machines and less personal training time, reduce the wear of components caused by repeated insertion and removal of equipment during parameter measurement, improve the efficiency of equipment use, and can greatly ensure the safety of equipment teaching, and greatly improve the efficiency of equipment practice teaching.

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