Design and Implementation of Launching Subsystem of a Radar Parameter Measurement Simulation Training Platform

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Abstract. This paper introduces the design and implementation of the launch subsystem of a radar performance measurement simulation training platform. First, the main functions of the launch subsystem of the platform are determined according to the training requirements of the outline for measuring the radar performance parameters of the troops, including test items and technical indicators; then, comb the launch subsystem analog circuit of work process; finally, the design method of each functional circuit is introduced in detail. The practical application results are given. The launch subsystem of the simulation training platform can realistically simulate the performance parameter measurement training of the radar real launch subsystem. In addition, it can compare the feedback measurement results with the designed indexes, meet the training requirements of radar equipment support personnel, and increase the means of training and integration. Ensuring training time and enhancing support capability can effectively solve the problems of too many personnel and planes and equipment damage in actual training.

1. Introduction

Parameter test is a necessary means to master the technical status of equipment[1], and it is an important skill that radar maintenance personnel must master. For this reason, equipment support training (Air Force military training program) puts forward clear training and assessment requirements for radar equipment support personnel, requiring radar technicians to master the test methods of radar main performance parameters. However, at present, the radar technical support team lacks the real training conditions on the one hand, and the corresponding simulation training platform on the other hand, so it is difficult to carry out test skill training[2-3]. In order to solve the practical problems of the training of parameter testing skills, it is urgent to develop the corresponding performance testing simulation training platform. In order to meet the actual needs of the technical support team of Radar Brigade to carry out the test and training of the performance parameters of the main subsystems of radar, a set of simulation training platform that can provide the test of the main parameters of the subsystems such as antenna feed, launch and reception is proposed to improve the test ability of maintenance technicians.

In this paper, the design and implementation of the simulation training system for the measurement of radar performance parameters are described in terms of its main functions, working process, circuit
2. Main functions
According to the general requirements of the outline, the test items and performance indexes of the platform simulation are designed considering the test items and performance indexes that the army needs to carry out for a certain radar launching subsystem.

2.1. test items
Through the reserved test port on the panel of the platform, using spectrum analyzer, microwave power meter, oscilloscope and other measuring instruments, the simulation training of the main performance parameters of the transmitter, the main performance parameters of the local oscillator module and the main performance parameters of the transmission signal branch is completed. The specific test items are as follows:

- Main performance parameters test of transmitter: radar transmitting power, working frequency, transmitting pulse repetition frequency, transmitting pulse envelope parameter, transmitting pulse spectrum, transmitter improvement factor and other parameters.
- Main performance parameters test of local module: local signal frequency, local signal strength, local signal clutter suppression system, local signal stability and other parameters.
- Main parameters test of transmission signal branch: DDS output signal, pre excitation output power, power amplifier module input power, power amplifier module output power, power synthesis output power and other parameters.

2.2. Performance index
According to the test items, the performance parameters of DDS signal generation, up conversion, power synthesis and other functional modules are required. After the software and hardware joint debugging of the training platform is completed, the function of the platform is tested and trained, and the test and training results can be compared and analyzed with the design indexes.

2.2.1. DDS signal source output frequency and power
- Center frequency \( f_0 \) 30MHz
- Output power \( P_0 \) 0-3dBm

2.2.2. Output signal type and index of DDS signal source

2.2.2.1. Fixed carrier signal
- Output frequency \( f_0 \) 30MHz
- Pulse width 100, 200, 300, 400, 500μs
- Pulse repetition period \( T_r \) 100, 200, 300, 400, 500Hz

2.2.2.2. Linear (nonlinear) FM signal
- Signal bandwidth \( \Delta B \) 1, 2, 5MHz
- Pulse width \( \tau \) 100, 200, 300, 400, 500μs
- PRF \( T_r \) 100, 200, 300, 400, 500Hz

2.2.3. Frequency synthesizer output
- The first coherent local oscillator 250-300MHz (11 frequency points in total, one frequency point 5MHz apart)
- The second coherent local oscillator 70MHz
- Coherent IF 30MHz

2.2.4. Upconverter assembly
- Output frequency 150-200MHz (11 frequency points in total, one
frequency point 5MHz apart)

- Input power \( \geq 10 \text{dBm} \)
- Output power \( \leq 15 \text{dBm} \)
- Attenuation range of attenuator 31dB (step 1dB)

2.2.5. Power synthesizer assembly

- Output power \( \geq 300 \text{mW} \)
- Digital phase shifter 4 bits
- Digital phase shifter step 22.5°

2.2.6. Transmitter load

- Load type matching and mismatching load (open circuit, short circuit, 20Ω, 80Ω resistance load)
- Characteristic impedance 50 Ω

3. Working process

The basic working process of the analog circuit of the transmission subsystem is as follows.

3.1. DDS signal generation and filter amplification

DDS is a kind of if radar signal which transforms a series of digital signals into analog signals through a digital to analog converter. Through the parameter selection function on the platform, the signal type (fixed carrier frequency, linear frequency modulation, nonlinear frequency modulation), local frequency, pulse width, repetition frequency and other parameters can be set. If radar signals are set by "switch filter selection", and "1MHz" (i.e. filter amplifier 1) or "5MHz" (i.e. filter amplifier 2) amplification channels are selected respectively. The bandwidth of filter amplifier 1 is 1MHz and that of filter amplifier 2 is 5MHz.

3.2. Up conversion

If radar signal output by filter amplifier 1 or filter amplifier 2 is sent to the first frequency converter through panel jumper connection. The if radar signal is mixed with the first coherent local frequency to get the difference frequency signal, which is connected to the filter amplifier 3 through the internal circuit of the transmitter, and then sent to the second frequency converter to get the difference frequency of the second coherent local frequency, so as to get the RF radar signal, and then connected to the filter amplifier 4 and sent to the 4-bit digital attenuator through the internal circuit of the transmitter.

3.3. Power amplification synthesis

The RF radar signal output by the 4-bit digital attenuator is sent to the power distributor of the power amplifier module by the way of panel jumper connection. The power distributor divides the input RF radar signal power into three equal parts according to the proportion of 1:3, which are respectively sent to the first, second and third power amplification branches for power amplification through the internal line connection of the transmitter. The RF radar signal output by each power amplification branch is connected to the 3:1 power synthesis input through the internal line of the transmitter, and the power synthesizer synthesizes the output power of the three power amplifier branches into one. The bidirectional directional coupler connected through the internal line is output to the panel. The "forward coupling" output of the bidirectional directional coupler is a part of the incident wave power transmitted from the transmitter to the load direction, and the "reverse coupling" output is a part of the reflected wave power transmitted from the load to the transmitter direction. The bidirectional directional coupler can measure the power and standing wave ratio output from the transmitter to the load.

The RF radar signal is directly connected to the load on the panel through "power synthesis", and
the load impedance is equal to the antenna impedance.

4. design of main circuit
The main functional circuits of radar transmitter simulator include DDS signal source (waveform generation) module, first and second filter amplifier modules, local frequency source module, up conversion module and power amplifier module.

4.1. Design of DDS source (waveform generation) module
Firstly, get the type information of signals input by the trainees on the panel, such as fixed carrier frequency signal, linear (non-linear) frequency modulation signal, pulse width, repetition frequency, etc., send these input information to the MCU for processing after being buffered by 74hct245 input buffer, and the SCM generates DDS amplitude, phase, frequency control words and other register control words according to the input of the trainees According to the register specified by A1-A5 address bus, write the data into the register through d0-d7 data bus, complete the control of DDS working mode, make it output the specified signal according to the input of trainees, and the schematic diagram is shown in Figure 1.

4.2. First and second filter amplifier circuits
Firstly, the input signal work is divided into two channels, i.e. a filter with a center frequency of 30MHz and a bandwidth of 1MHz and 5MHz. A matching circuit is added at the input end and output end of the filter to realize better energy transmission of the signal. After selection by a RF SPDT Switch, the switch is selected by the trainees on the panel as a filter with "1MHz" or "5MHz". After selection, the signal is after over amplification and power division, it is output to the panel as the test signal, in addition, it is output to the rear stage as the baseband signal, and the schematic diagram is shown in Figure 2.

4.3. Local frequency source circuit
In order to achieve coherent signal output, the frequency reference of the same 40MHz is used. After 4-way drive, amplification and isolation, one channel is used as the clock signal, and the other 3 channels are used through the PLL circuit to output one local oscillator and two local oscillators, as shown in Figure 3.
4.4. Up conversion module

The input local oscillator signal and if signal arrive at the mixer after being filtered and amplified for mixing, and then filter Z3 and Z4 are used to select the frequency of the generated RF signal. Since the passive mixer is used, the insertion loss of the signal is large, so N10 and N12 amplifiers are added to improve the amplitude of the output RF signal, as shown in Figure 4.

4.5. Power amplifier module

In this module, the input signal is divided into four channels through two-stage Wilkinson power divider. One channel is used as the input of power amplifier circuit after the digital control phase shift, attenuator P1 phase shift and attenuation. The phase shift and attenuation can be selected by the trainees on the panel. The other three channels are directly input to the power amplifier circuit. The output of four channels of power amplifier circuit is synthesized into one channel through two-stage Wilkinson power divider A small part of the coupler is coupled as the detection branch signal, and the other part is output through the isolator. The circuit diagram is shown in Figure 5.
5. Concluding remarks
The test results show that the radar performance parameters measurement simulation training platform can carry out the simulation measurement training of the main performance parameters of the radar launch subsystem, and meet the training requirements of the training program for radar support personnel. It can effectively solve the practical difficulties of the current radar technical support team, such as the lack of real training conditions and the corresponding simulation training platform. It can also enable the operators to complete the test experiment of the main performance parameters of the launch subsystem in a safe environment, better understand the working principle of the radar launch subsystem, and reduce the damage to the equipment caused by repeated operation in the actual equipment training.

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