Research on Generalization of Baseband Equipment and Satellite Simulator

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Abstract. The contradiction between the shortage of satellite simulator resources and the diversification of model missions is becoming more and more obvious. The demand for multi-institutional satellite simulators is particularly urgent for each ship, and the satellite simulator and baseband equipment can be fully designed. In this paper, the basic concepts of baseband and satellite simulator are introduced. The key technologies for the generalization of baseband and satellite simulator include hardware platform analysis, functional requirements analysis, generalized modulation and demodulation technology, etc., and the basic baseband and satellite simulator are proposed. Feasibility study.

1. Introduction
At present, there are 6 sets of spacecraft simulators for measuring ship monitoring and control systems, of which 5 sets of satellite simulator hardware platforms adopt universal design. In addition, a set of self-developed shipborne simulation verification equipment is also available, which can be used for multi-target task drills of S-band non-coherent spread spectrum system. In the spacecraft simulator of the ship measurement and control system, the new satellite simulator supports the most measurement and control system, basically meeting the joint test requirements of various types of tasks, but currently only one set, under the situation of high-density space launching marine monitoring and control demand, each The ship is particularly urgent for multi-system satellite simulators. If the hardware simulator of the satellite simulator and the baseband equipment adopts a universal design, the problem of straining the satellite simulator resources can be fundamentally solved by loading different programs to realize different functions.

2. Baseband and Satellite Simulator Overview
Digital baseband based on software radio platform for all digital, integrated digital baseband equipment using a unified hardware platform, by loading different software, on-site reconstruction, to achieve different measurement and control functions. Baseband devices mostly use PC workstations as platforms, with programmable gate array devices (FPGAs), digital signal processors (DSPs), memory devices and standard interface circuits with large redundancy design as hardware motherboards, which are directly digitized at 70MHz IF. Using DSP and FPGA online programmable features, different algorithms or execution software are injected according to requirements, and a large number of digital signal processing and calculation work is completed by software to realize multi-standard measurement and control modulation solutions with different carrier frequencies, modulation modes, transmission rates and patterns. Tune function. Digital baseband equipment has programmable, flexible, reliable, easy to update and upgrade, and can achieve many outstanding advantages such as
generalization, standardization and software. The shipborne spaceborne measurement and control
digital baseband equipment realizes the functions of telemetry remote control, ranging speed
measurement and angular error demodulation under 70MHz in the unified carrier measurement and
control system and spread spectrum measurement and control system on the same software radio
platform.

3. Research on Key Technologies of Generalization of Baseband and Satellite Simulator

3.1. Functional requirements analysis
The satellite simulator platform and the general satellite simulator simulation software together form a
satellite simulation simulation system, combined with the ground measurement and control system to
form a star-ground large loop exercise system, which should specifically include the following
functions:

a). Under the premise of not affecting the data exchange capability with the satellite simulator
platform, the data interface requirements of the satellite simulation software of each survey ship can be
met through simple configuration item changes.

b). It has the function of simulating the existing model satellite telemetry remote control data. By
loading different modes, it is possible to simulate the external measurement function of S-band and C-
band satellites of various platforms, telemetry data, and remote measurement with remote control;
without affecting the existing satellite telemetry and remote control simulation function, it has
expanded the new model satellite. External testing, telemetry data simulation capabilities.

c). It has the function of simulating multi-satellite telemetry remote control data. By configuring
the number of satellites, selecting the model fly file or receiving the simulation data of the model
simulator, it is possible to simulate the multi-satellite telemetry data, and the simulation of each
satellite data does not affect each other. The telemetry data is automatically simulated to the
modulated satellite as required, and the data is automatically identified. Receive remote control
commands from each satellite, and have the function of simulating the execution effect of commonly
used remote command.

d). It has the function of simulating advanced on-orbit system (AOS) telemetry data. According to
the AOS packet telemetry system requirements, it has the ability to simulate packetized telemetry data,
including the simulation source packet data format, packet transmission according to the source packet
data size, and combined transmission with other formats telemetry data.

3.2. Generalized modulation and demodulation technology
Baseband and satellite simulator modulation and demodulation functions correspond to each other
according to different working modes. Although the working modes are different, the modulation and
demodulation methods also have their own characteristics, but in theory, various signals can be
orthogonally modulated and solved. The method of tuning is implemented.

The quadrature modulation method is shown in Figure 1.

![Quadrature modulation implementation block diagram](image-url)
You can write its time domain expression:

\[ S(t) = I(t) \cos(\omega_c t) + Q(t) \sin(\omega_c t) \]

The information of the modulated signal is contained in \( I(t) \) and \( Q(t) \). Since the various modulation signals are implemented in the digital domain, the above equation is digitized when implemented in the digital domain.

\[ S(n) = I(n) \cos(\omega_c / \omega_s) + Q(n) \sin(\omega_c / \omega_s) \]

\( \omega_s \) is the angular frequency of the sampling frequency. When the modulated signal and carrier frequency are digitized, the sampling frequency may be different. Here, the main function of the polyphase filter is to increase the sampling rate of the data source so that the sampling rate of the modulated signal is consistent with the sampling rate of the carrier.

Although the modulation pattern is various, the modulation is essentially a process in which a modulation signal is used to control a certain parameter of the carrier, so that the parameter changes according to the law of the modulation signal. The carrier can be a positive cyclone or a pulse sequence, and modulation with a sinusoidal signal as a carrier is called continuous wave modulation. Only the demodulation of the continuous wave modulated signal will be discussed here. For continuous wave modulation, the digital expression of the modulated signal is:

\[ S(n) = A(n) \cos[\omega(n)n + \theta(n)] \]

The modulated signal can be “parasitic” in the amplitude, frequency and frequency of the modulated signal respectively. The corresponding modulation is the three well-known modulation methods of amplitude modulation, frequency modulation and phase modulation. Since frequency and phase have a certain relationship, in order to facilitate analysis, the above formula can be rewritten as:

\[ S(n) = A(n) \cos[\omega(n)n + \phi(n)] \]

So:

\[ S(n) = A(n) \cos[\phi(n)] \cos(\omega_s n) - A(n) \sin[\phi(n)] \sin(\omega_s n) = X_f(n) \cos(\omega_s n) - X_Q(n) \sin(\omega_s n) \]

Where:

\[ X_f(n) = A(n) \cos[\phi(n)] \]

\[ X_Q(n) = A(n) \sin[\phi(n)] \]

This is the two components of in-phase and quadrature. According to \( X_f(n) \) and \( X_Q(n) \), various modulation patterns can be demodulated, and the instantaneous frequency is calculated by phase difference, that is, when \( f(n) = \phi(n) - \phi(n - 1) \), since the calculation \( \phi(n) \) is to perform division and arctangent operations, this is more complicated for non-dedicated digital processors. The following methods can also be used to calculate the instantaneous frequency when implemented in software:

\[ f(n) = \phi'(n) = \frac{X_f(n)X_Q'(n) - X_f'(n)X_Q(n)}{X_f^2(n) + X_Q^2(n)} \]

For the FM signal, its amplitude is approximately constant, you may wish to set \( X_f^2(n) + X_Q^2(n) = 1 \), then:
\[ f(n) = \phi(n) = X_I(n)X_Q(n) - X_I(n)X_Q(n) = \\
X_I(n)[X_Q(n) - X_Q(n-1)] - [X_I(n) - X_I(n-1)]X_Q(n) = \\
X_I(n-1)X_Q(n) - X_I(n)X_Q(n-1) \]

The above formula is an approximate formula for directly calculating \( f(n) \) using \( X_I \) and \( X_Q \). This method is only a multiplication and subtraction operation, and the calculation is relatively simple. The resulting general model of software radio digital quadrature demodulation is shown in Figure 2.

![Figure 2. General model of digital quadrature demodulation](image)

In Fig. 2, the orthogonal decomposition process is represented by a digital orthogonal down-conversion method. Whether in integrated baseband equipment or in satellite simulators, digital quadrature mixing technology is as general as ever.

4. Baseband and satellite simulator generalization test and test method

4.1. Joint test environment construction method

The integrated baseband, baseband simulator, remote interface inspection software and the modified intermediate frequency switch matrix system are used to construct the joint test environment. Through the telemetry, remote control, ranging and speed measurement functions check and confirmation, the full-range model of the medium-frequency equipment of the shipboard unified carrier measurement and control system is realized, full state measurement and control function check.

Satellite simulator platforms generally have three modes of operation, namely ship center machine simulation, file simulation and dynamic simulation (different satellite simulators may be different). If you need to communicate with the central machine for data communication, choose to work in the ship center machine simulation mode, in this mode you can simulate satellite in and out; if you do not need to communicate with the central machine for data communication, you can choose dynamic simulation mode, by satellite The simulator platform itself generates telemetry data, or selects a file simulation mode to play the source code data from the satellite simulator platform. At the same time, in addition to receiving remote control commands and data from the central unit, the baseband device can also issue commands. In the case of baseband local command, satellite simulator selection file simulation or dynamic simulation mode, joint testing can be performed without a central machine. Joint testing is usually carried out using an IF satellite simulator.

4.2. Function check content

Based on the current baseband equipment for software and hardware upgrades, the baseband network transceiver interface is configured to realize the telemetry simulation function of the central remote mode. The satellite inbound and outbound control commands from the simulation computer are used to start and stop the operation of the encoded telemetry terminal to realize the satellite. Simulation of inbound and outbound. According to the remote control information format, the remote control interface inspection software is developed for the requirements of the model task preparation, which can comprehensively check the baseband remote control command network reception, intermediate frequency modulation and satellite simulator demodulation execution. Based on the above joint test
environment, the following content check is performed:
   (a). Satellite simulator inbound function check
   The central machine satellite simulator simulation machine sends inbound commands and edits the remote data. Click on the satellite simulator platform to start the simulation, automatically turn on the modulator plus switch, modulate the chic, analog data and the satellite simulator simulator. A packet interrupt signal that is consistent with the frame rate of the modulated data is transmitted.
   (b). Telemetry data flow correctness check
   Baseband local telemetry full frame inspection, pointing interface star remote inspection and communication with the central telemetry remote control post to check the telemetry format and data content correctness.
   (c). Remote command correctness check
   The remote control issuing software is used for local remote control, and the small loop comparison, satellite simulator remote control demodulation frame data viewing, pointer comparison, checking the correctness of the remote data content and the consistency with the information exchange format.
   (d). Ranging function check
   Check the baseband ranging function, and compare the ranging, distance forecast data and status code consistency by finger.

5. Conclusion
The carrier frequency of China's existing space measurement and control system is constantly enriched, and the modulation system is becoming more and more abundant. The systems such as FM, PM, PSK, QPSK, UQPSK, coherent direct sequence spread spectrum, and non-coherent direct sequence spread spectrum are all in the system. The space measurement and control system has been applied. On a standardized hardware platform, the application of A/D, D/A and reconfigurable technologies to achieve variable multi-band multi-system modulation and demodulation technology to solve the need for the update of the baseband and satellite simulator measurement and control system has become a basic trend.

References
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