Hardware-in-the-loop Simulation and Testing System for Millimeter-Wave Seeker

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Abstract– **The implementation of integrated Hardware-in-the-Loop (HWIL) simulation and testing system for Millimeter-Wave (MMW) seeker was presented. The system can implement dynamic real-time testing for MMW seeker. The seeker's ability of detecting, identifying and tracking the target, can be checked and tested in a realistic flight scenario. The system configuration is described, and the implementation of its chief components was proposed which are the MMW scene generator, the high speed data acquisition subsystem, and the central control unit. This system could be applied to the simulation and testing of some types of MMW seeker which are on development.**

I. INTRODUCTION

Hardware-in-the-loop simulation (HWIL) and Testing system provides a comprehensive ground test capability for MMW seeker while providing the realistic modeling of the engagement kinematics of the missile and the target. It is a crucial means of developing MMW seeker. Over the past 30 years, The U.S. Army Aviation and Missile Command (AMCOM) Advanced Simulation Center (ASC) provides many kinds of HWIL systems to support the development of advanced Radio Frequency (RF), Millimeter Wave (MMW), Infrared (IR) and Electro-Optical (EO) guided weapon systems [1][2]. Since 1986, the Ballistic Missile Defense Organization (BMDO) has been developing the Kinetic Kill Vehicle Hardware-in-the-Loop Simulator(KHILS) to provide performance testing of precision guided missile systems and subsystems[3]. At the same time, the Russia has Utilized HWIL simulation facilities as an important tool to support the development of seekers[4]. It uses the HWIL facilities to test and evaluate the performance of dealing with moving targets and the background at all flight height for the seeker. In this paper one integrated HWIL simulation and testing system for MMW seeker was proposed. It can simulate the searching, tracking the target's process of MMW seeker in approaching actual environment, test and evaluate the performance and its parameters of MMW seeker. It provides a means of exercising MMW seeker hardware in real-time simulated flight. Missile flight dynamics are simulated in real-time to determine the missile trajectory and to implement the actual intercept conditions. Its performance parameters are given in Table I. The system can adapted to multiple kinds of pulse signal waveform, such as pulse doppler, stepped frequency, chirp pulse, etc.

Table I. MMW performance characteristics

Performance Parameter	**Value**
Operating Frequency	Ka Band
Field of View	Yawing: ±20° Pitching: ±10°
Polarization	Linear Polarization
Instantaneous Bandwidth	500MHz
Position Accuracy	1mrad

II. SYSTEM OVERVIEW

Figure 1 shows the major components of the simulation and testing system configured. The major components in the system are the anechoic chamber, the target simulator, the flight motion simulator, the high-speed data acquisition subsystem, and the central control unit [5]. The flight motion simulator is composed of two-axis flight table and its control cabinet. It implements the simulation of the airframe dynamics in approaching the actual missile engagement scenario. It represents the azimuth and elevation orientation between the seeker and the target. The ultimate success of the system is primarily dependent on the characteristics of three of these components: the target simulator, the high-speed data acquisition subsystem and the central control unit. The target simulator includes the MMW scene generator and the target motion simulator. The MMW scene generator is used to simulate the target return signal in the missile flight procedure which indicates the range between the target and the seeker, the velocity of the target, the amplitude variety of the echo, and the multiple scatter centers distribution. The target motion simulator is responsible for the simulation of the angular error and the angular velocity between the target and the Line-of-Sight of missile. The target motion simulator is accomplished by two axes crossed-shaped trestle which uses rope-wheel and roll-guide for motion. The high-speed data acquisition subsystem is able to acquire and store the simulation and testing data of the seeker and the state information of all devices. The central control unit includes the central control computer, the interface cards and simulation and testing software. It realizes the simulation and testing control, the airframe dynamic model generation, the data processing and analysis, and the evaluation of the seeker performance.

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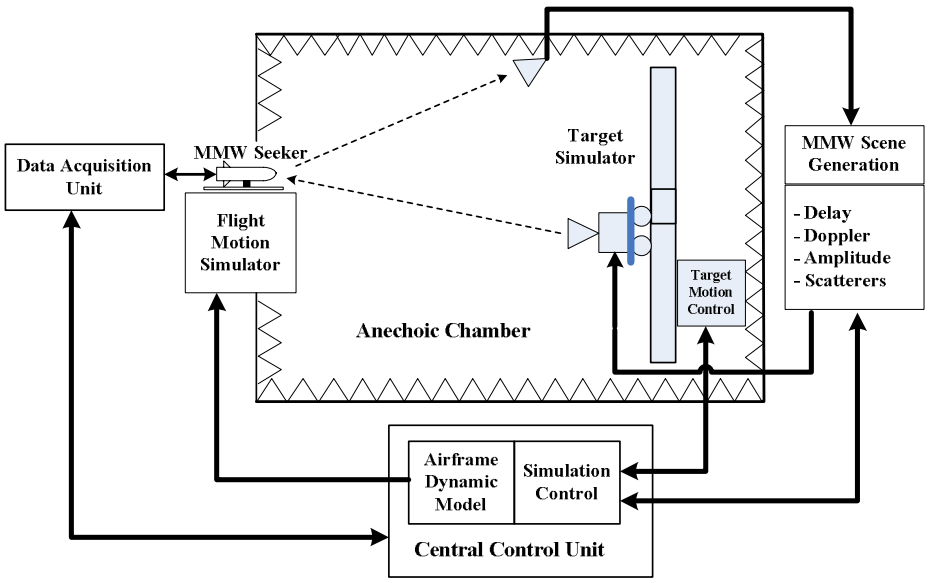

Figure 1. The block diagram of the HWIL simulation and testing system

III. MMW SCENE GENERATOR

The MMW scene generator is the most critical component in the seeker simulation and testing system. Under the condition of ground test, in order to realize the actual performance testing for MMW seeker, the spacial and electromagnetic characteristics of targets must be simulated in accrod with the actual battlefield scenarios. The characteristics of targets mainly represent the following parameters: target range delay, target doppler frequency, the amplitude varying, and the scatterers distribution.

The design diagram of MMW scene generator is shown in Figure 2. The receiving antenna firstly receives the coupled MMW signal from the MMW seeker, and down-converts it to IF signal by mixing with two frequency sources. This IF signal is directly sampled by digital processing unit. The sampling frequency of Analog-to-Digital converts is up to 1GHz. The digital processing unit takes charge of the generation and modulation of MMW scene information. After the DSP in the digital processing unit receives the MMW scene parameters, it calculates the MMW scene data and generates modulation information of data, and then adds the modulation information to the sampled return signal [6]. Afterwards, the Digital-to-analog converter converts the modulated signal to analog signal and output two I and Q signals in quadrature. The signals are single sideband modulated and up-converted to MMW signal. Finally, the generated MMW signal is emitted through the transmitting antenna.

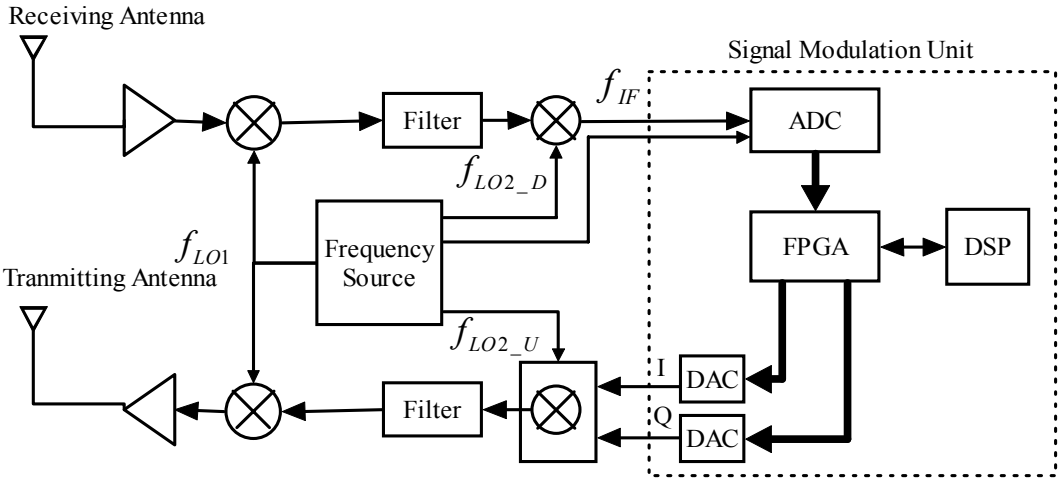

Figure 2. The design diagram of MMW scene generator

IV. HIGH-SPEED DATA ACQUISITION SUBSYSTEM

The block diagram of high-speed data acquisition subsystem is shown in Figure 3. Three major components are the data acquisition card, the data storage card and the host computer. The data acquisition card acquires all testing and state data, and transfers it to the data storage card located in the host computer by LVDS cable. Utilizing LVDS cable can realize high-speed data transfer capability up to 100MB/s.The data storage card accomplishes the data buffer and data transmission which buffers data from the data acquisition card and transfers it to the memory of host computer.

The data acquisition card integrates multichannel high-speed A/D converters and some digital interfaces with other devices. After acquires data, the card packs all digit data. The packed data is stored to local buffer and is forwarded to the host computer. The operation parameter of the card is sent by the host computer. The data storage card is one standard PCI plug-in card that has 20G NAND Flash memory to store all testing data. It communicates with the host computer by PCI interface.

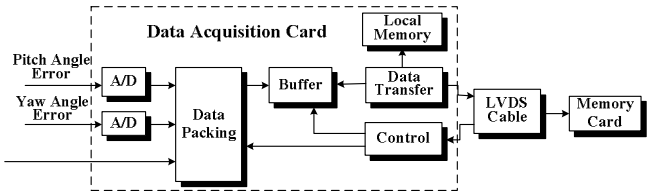

Figure 3. The Block Diagram of High-speed Data Acquisition Subsystem

V. CENTRAL CONTROL UNIT

A. The Central Control Unit Hardware

The Central Control Unit has the central computer and some interfaces with other devices. The central computer controls the operational mode and operating parameters of all subsystem, masters the simulation and testing schedule, monitors the operational state of every subsystem, and gathers the whole testing data. It makes the simulation and testing system operate according to the actual engagement scenario and accomplish the performance test and evaluation for the MMW seeker under test.

The interfaces between the central computer and other devices are shown in Figure 4. The central computer interfaces with the MMW scene generator and the flight motion simulator by RS422 serial ports, and interfaces with the data acquisition subsystem and target motion simulator by network ports. The RS422 interface card and the network card are placed in the central computer to implement the link between it and those devices.

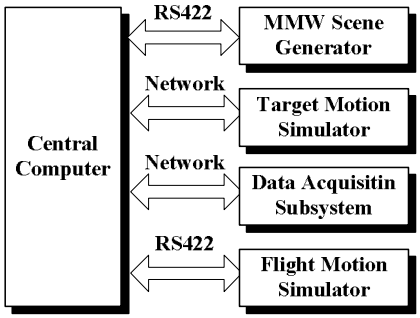

Figure 4 Central computer and its interface with all subsystems

B. The Central Control Software

The Central Control Software monitors and controls the whole HWIL simulation and testing progress for the MMW seeker. Its main functions have: (1) Configuring the simulation and testing parameters, such as the transmitted signal waveform, the characteristics of targets, etc. (2) Communicating with other subsystems, sending command and receiving data. (3)Generating the data of flight trajectory, and modeling the airframe kinematics. (4) Gathering all data and parameters, and storing it. (5) Processing the real-time testing data and displaying it with figures and curves. The flow chart of MMW seeker HWIL simulation and testing process is shown in Figure 5.

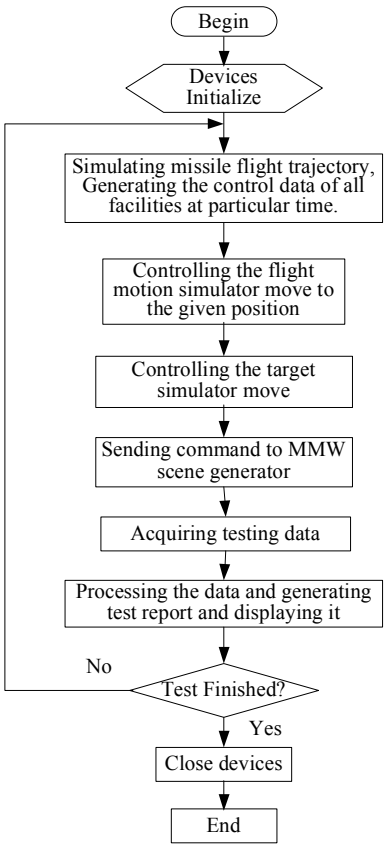

Figure 5. The flow chart of the simulation and testing Process

VI. CONCLUSION

In this paper the design scheme of HWIL simulation and testing system for MMW seeker is described. It integrates HWIL simulation and performance testing of the seeker, and implements dynamic performance testing of MMW seeker in real-time simulated flight. It is able to check the operational performance of searching, capturing and tracking targets of MMW seeker in whole missile flight scenarios. The system can be applied to the development of multiple kypes of MMW seeker, and also applied to the simulation and testing of dual-mode MMW and IR seeker after modifying it.

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