Advances in Engineering Research, volume 127
3rd International Conference on Electrical, Automation and Mechanical Engineering (EAME 2018)

Design on Dropsonde Meteorological Detection System Based on UAV

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***Abstract*—Aims to the defect of using pilot balloon theodolite to track and detect the rising balloon and get meteorological data, the project is put forward that using intermediate, long-range, long-endurance unmanned aerial vehicle (UAV) as a platform, mounting dropsonde to implement meteorological detection on unfamiliar terrain. The obtained real-time meteorological data is sent back to the ground control center by UAV's data link and being processed and analyzed by the computer software system, and the remote obtaining of meteorological information in harsh environment and unfamiliar territory is realized.**

Keywords—UAV; meteorological; sonde

I. INTRODUCTION

The obtaining of meteorological elements plays an important role in many fields. People now mainly adopts the conventional meteorological observation method, using pilot balloon theodolite to track and detect the moving trajectory of the rising balloon in the air, to determine elevation angle, azimuth angle and height of the balloon per minute, and then calculate different level average wind direction, wind speed, etc., which is the most widely used means of air wind observation. In addition, the obtaining of meteorological information can be realized by means of wind profiler radar and portable wind lidar. But the above methods are unable to implement obtaining meteorological information in remote stranger territory and harsh environment, can only to be used for routine endurance.

In recent years, the application of unmanned aerial vehicle (UAV) in military and civilian fields is being paid more attention in countries all over the world[1]. Technology is increasingly matured and high-middle-low altitude, dual-use, long-endurance and multi-purpose is realized, which has been formally applied to military and civilian fields. As far as the weather detection equipment is concerned, some countries began to use dropsonde at the end of last century[2]. Although China started late, it has now reached the worlds advanced level and has realized the launch of small unmanned aerial vehicles.

If we use middle-low altitude, long-endurance UAV as a platform to mount dropsonde, the accurate weather information of remote target area can be obtained, which has a very broad application prospects in the atmospheric environment detection, typhoons and other fields, etc..

II. OVERALL DESIGN

In view of the difficulty and high risk of remote meteorological information acquisition and typhoon detection, on the basis of extensive research and discussion, the paper put forward project of dropsode meteorological detection technology based on UAV. When detection is conducting, the drone is flown to the target area by means of pre-path planning or manual control. After reaching the target area, the ground control station sends instructions to release and start the dropsonde, and the UAV flies away from the target area. The sonde collects the meteorological information of each altitude layer during the descent, and sends it real time back to the ground control center by UAV's data link. The computer software system completes the processing, analyzing and judge.

The overall system is composed of air detection system, ground control system and satellite communications system, as showed in Figure I. The air detection system including UAV and the mounting meteorological detection system; the ground control system is composed of ground control station (GCS) and information processing terminal.

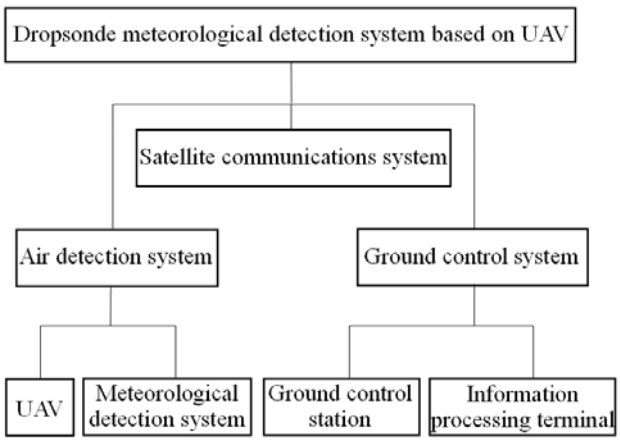


FIGURE I. SYSTEM ARCHITECTURE

UAV is the carrier of meteorological detection systems on the basis of data link technology, under the remote control of the ground control station, it is responsible for delivery of detection system to the intended target region to detect, and the communications relay of control instructions and data returning between the ground control station and the meteorological detection system.

The meteorological detection system is composed of dropsonde and airborne receiving equipment, used in detecting relating meteorological information of predetermined altitude, and using the data link of UAV to realize its work control and data returning with ground control station.

The ground control station is composed of antenna feed

equipment, transceiver equipment tracking and positioning equipment, mainly uses data link communication technology to realize flight control of UAV, remote control of meteorological detection system and receiving and calculating of information data, etc..

The information processing terminal is composed of computer and software system to realize real-time display and real-time processing, analyzing and judge on the basis of meteorological information received from the ground control center.

The satellite communications system is composed of three parts, the airborne on-and-move, the master ground station and the satellite. It is a double-way communication link of information of ground- air upward flight and control, air-ground downward detection and feedback, to meet the need of UAV link control and big data real-time transmission over the horizon.

III. AIRBORNE DETECTION SYSTEM

A. UAV

UAV is the carrier and air platform of the mission load of the system and an important part of the system. At present, the research in the field of UAV has achieved fruitful results, the size of UAV has grown from small to large, and the take-off weight from light to heavy with characteristics such as high-middle-low altitude, dual-use, long-endurance and multi-purpose, and so on[3]. The existing research results provide a strong support for the UAV selection of this system.

According to the actual functional need of the system, UAV “Rainbow-3” (CH-3) is proposed to adopt as the system airborne platform (as showed in Figure II).

FIGURE II. UAV “RAINBOW-3” (CH-3)

Because of its excellent comprehensive performance and high reliability, it has been tested in practical application with the lag time exceeds 10h, Cruise speed reaches 200km/h, which can meet the need of remote meteorological detection. It uses wheeled take-off and landing mode to meet the need of the system reusing. It has the ability of full autonomous take-off and landing and flight control. The workload of flight operators has been greatly reduced. The need for manual intervention is small. It is easy to use and operate, and the security of flight and take-off and landing is greatly improved. CH-3 belongs to medium size UAV with only 8 meter wingspan, small volume and light weight, relatively low cost, and may get the best cost-benefit ratio on the premise of satisfying the system function. It also has a sound security system which can meet the need of system function well.

B. Meteorological Detection System

In recent years, the study of sonde is being paid more attention and the technology is increasingly maturing [6-7]. At present, there are at least 10 kinds of sonde in use in the world. Although China began the study and application in this aspect not earlier, it develops very fast and the technology is among the best in the world. After research and analysis, this system proposes to use Big Dipper dropsonde, it is also now one of the most advanced sonde systems at home, which is mainly composed of parachute, Big Dipper dropsonde (Hereinafter referred to as sonde), airborne receiving equipment and sonde installation and delivery equipment.

1) Sonde

Sonde includes two parts, the parachute and the Big Dipper dropsonde, as showed in Figure III.

FIGURE III. REAL FIGURE OF SONDE

The parachute is mainly used in controlling the sonde drop speed. The shape, size and quality of sonde match to severe convection weather, which ensures the parachute to open normally in extreme weather conditions, and to control its drop speed in 10~15m/s[4-5]. The drop sonde is mainly composed of Big Dipper receiving module, sensor, acquisition and control module, transmitter and battery, etc..

In the dropping process, the sonde finished real-time acquisition of temperature, humidity, air pressure and wind from the dropping altitude to the ground, sent the acquisition information and data to the airborne receiving equipment for further processing.

2) Airborne receiving equipment

Airborne receiving equipment is installed on UAV, composed of sonde signal receiver, satellite navigation reception module and sonde signal receiving antenna. It can finish automatically receiving transmitted signal, demodulate it and send the demodulated one back to the ground control system by UAV data link.

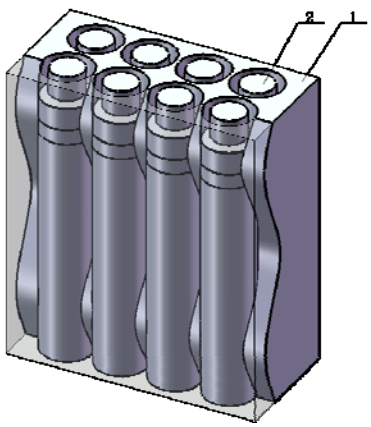
Airborne receiving equipment uses frequency division multiple access method, designed for four channels, can simultaneously receive four signals from the drop sonde and go on relevant processing.

Because the airborne receiving equipment is an UAV load, design of light and small size is adopted as much as possible in the case of ensuring system reliability with compact design of Circuit board and simple structure design. Some machining parts in the inner structure are aluminum or other lightweight materials. The receiver box may be adjusted properly according to the installation condition on UAV. The power supply system of the receiving system is 12V, which can directly use the power supply of UAV.

Sonde signal reception antenna uses portable small size one for the convenience of installing on UAV. It can be installed on the tail, using light and small size knife-shape antenna. The tail of flight as a reflective surface to concentrate the lobe of the antenna under the UAV, and to adjust antenna's fixed position properly by testing, which makes the maximum gain direction of antenna concentrated on the sonde dropping direction to ensure reliable reception of the sonde signal.

3) Installation of sonde and delivery equipment

The installation of sonde and delivery equipment is composed of installation unit and delivery unit, as showed in Figure IV.



1. Installation unit 2. Delivery unit

FIGURE IV. OVERALL STRUCTURE OF INSTALLATION OF SONDE AND DELIVERY EQUIPMENT

The installation unit is a combination of mechanical and electrical connections with the loader; the internal part is for installing delivery unit with a locking structure to fix and remove the installation unit.

The delivery unit is composed of delivery control unit, energy releasing unit, sonde locking releasing unit, delivery volume cavity, sonde, etc.. It is used to install, remove, release and control the sonde, to ensure it with a departure speed above 5m/s, to open smoothly the parachute of the sonde, to release the sonde under the control of airborne computer and finish release smoothly the traction rope of parachute to secure dropping safety of the carrier aerial vehicle and the sonde.

When the carrier aerial vehicle reaches the predetermined location, selects a sonde and sends a drop signal to the sonde drop system, the drop control unit works and controls to release energy in the release energy unit. The sonde locking release unit is unlocked; the sonde accelerates motion through the delivery volume cavity. When the sonde moves on 1.5m, the traction rope of parachute rapidly pulls the parachute out and the parachute opens, the traction rope separaes from the sonde delivery system and the sonde delivery is done.

IV. GROUND CONTROL SYSTEM

The ground control system includes ground control station and information processing terminal.

A. Ground Control Station

The ground control station with strong mobility, easy to use and flexible, strong expansibility and high versatility, is mainly composed of antenna feed equipment, transceiver equipment tracking and positioning equipment and terminal seat, etc. It is to finish the produce, coding, modulation, launch of upward data and demodulation receiving of downward data and data processing. The ground station is mounted on a cross-country chassis Volvo FMX 6×6, which may be mobile deployed.

The ground control station is mainly used to be responsible for the remote control of UA, flight data processing, display and storage, including the sliding control of take-off and landing, cruising, direction, speed, climbing, diving, tracking and positioning, etc.. What's more, it is responsible for load operation and release management, and that's the sonde delivery and control. When comes to the target area, sends instruction to the airborne sonde mounting device at a proper time to deliver and start the sonde, receives the real-time meteorological data from the sonde and transmitting it to the information processing terminal to do the processing and delivery calculation.

B. Information Processing Terminal

The information processing terminal is composed of computer and software system. According to the detected meteorological information coming from the ground control station and processes by the computer software system. It is mainly to finish data checking, calculating, displaying, processing, storage and meteorological report, etc.. To complete specific tasks as the following:

To display and output the tempreture, pressure, humidity, speed and direction of wind and corresponding height in specified flight level;

To display and output winds at any height and the maximum of winds;

Relative to each sonde data from the sonde, to display a two dimensional coordinate diagram with the zoom function and constructed by time and corresponding speed and direction of wind, tempreture, pressure, humidity;

Relative to each sonde data from the sonde, to display a two dimensional coordinate diagram with the zoom function and constructed by altitude and corresponding speed and direction of wind, tempreture, pressure, humidity;

Can generate secondary data such as air density, and so on;

To display all detected data of sonde and its flight orbit, support Google Earth;

To display the state data of sonde, such as voltage of battery, inner tempreture, and so on, for the convinience of fault diagnosis;

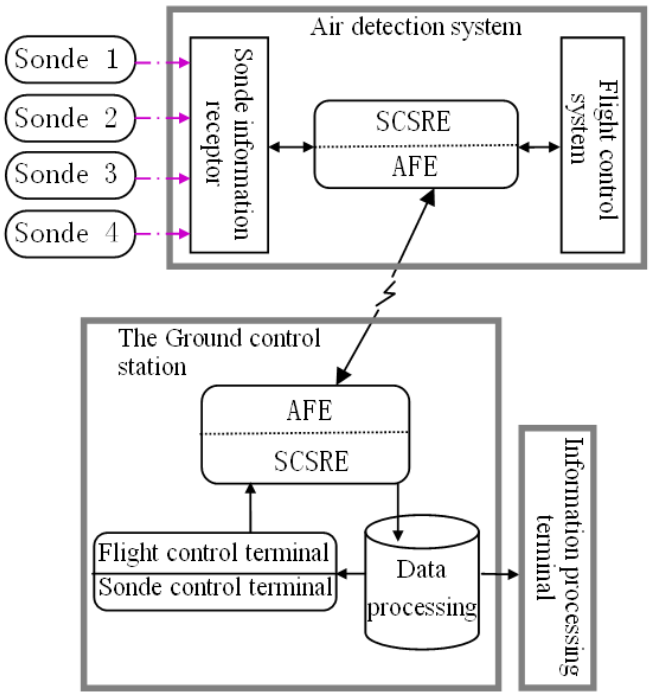
To save the original data and the processing data, which can be called and output, with print function.

V. SATELLITE COMMUNICATIONS SYSTEM

The satellite communications system is composed of three parts, the airborne on-and-move, the master ground station and the satellite. By using high quality satellite resources, reliable satellite communication network, flexible transmitting link structure and advanced satellite carrier coding debugging technology to provide a safe and reliable double-way communication link to meet the need of UAV link control and big data real-time transmission over the horizon.

The airborne UAV part is composed of satellite communication antenna surface and feedback source, antenna controller, BUC, LNB, Modem, image compression encoder, GPS, inential navigator, servo controller, mechanical drive mechanism, the power supply, airborne task and working condition sensor, etc..

The ground control part is composed of computer and its network system, image display, flight state display and operating platform, satellite communication control platform, etc., which is to constitue the other end of the communication system. The delivery and control of sonde and the sending back of acquisition of sonde information are all completed by the communication system. Figure V is the system information and controlling flow chart.



AFE–Antenna feed equipment
SCSRE–Satellite communication sending and receiving equipment

FIGURE V. FLOW CHART OF SYSTEM INFORMATION AND CONTROL

VI. CONCLUSION

At present, there is no good way to obtain remote meteorological information and detect typhoons in unfamiliar regions. This system is exactly an exploration in this aspect, and the application project of UAV and drop sonde in meteorological detection is proposed. After previous studies and experiments, it is proved that the existing technology can completely meet the functional requirements of system, which realizes the dropsonde on aircraft and UAV, the meteorological information has reached the expected requirement. Therefore, the technology of UAV is completely feasible. Believe that it will play an important role in many fields in the future, and enhance the ability of meteorological support greatly.

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