

Design and Development of a High-and-Low-Altitude Air Observation System for Rainmaking Process in Thailand

P. Chodkaveekityada and P. Wardkein

Abstract—Thailand has been known as a top agricultural exporter in the world. But in every year, we miss a lot of opportunities to export some agricultural products due to drought condition. In the years 2017 and 2018, the areas in risk of a drought crisis were 47 areas throughout the whole country amounting to around 1.5 million acres. There was not enough water to grow plants in these areas. As a matter of fact, Thailand is located near the equator which has more cumulative rainfall volume than any other areas in the world. Still, drought crisis happens every year. One of the reasons behind this may be lack of valid predictive information. Weather information is very important for an agricultural country. Thailand has not invested sufficiently in building an effective weather sensor network. A compromise has been made by employing high technology to produce rain in specific areas instead to alleviate drought crisis. This work was a design and development of a high-and-low-altitude air observation system suitable for rainmaking process in Thailand that aimed to reduce the import of advanced and expensive technology.

Index Terms—Rainmaking, high-and-low altitude air observation, ground station.

I. INTRODUCTION

Currently, technology has changed very rapidly. In the past, the gap of transitional change was about 10 years, but nowadays, 2 years is considered quite long for a new technology. Thailand is one country that imports most technologies from developed countries and cannot produce many technological products on its own. It is one of the reasons why Thailand cannot step forward to be a developed country. Most import technologies have been designed for general global usage, but for some of our purposes, a specific kind of technology is required. If we do not develop a know-how on how to produce a specifically needed technology, it is equivalent to the country stepping backward. We will continually need to a lot more money to buy the technology from other countries. Now is the right time to develop, adapt and apply current technologies for use within our country. At the very least, if we can acquire some know-how, we will be a smarter buyer and we can apply the know-how to conduct some immediate missions to protect the lives and assets of the people such as the recent case of Tam-Luang cave rescue.

Nowadays, sensor network system has made our life easier

such as its uses in smart city, health monitoring and IoT. Agriculture is another area that follows this trend called smart farming. For smart farming, many sensors will be used for monitoring the growth of plants, for providing weather information and for automating agricultural machine operation. Sensor network will help increase the quality of agricultural products and help to manage the overall agricultural system. At present, a sensor network for farming process, for predicting the rain and for managing water for farming is very much in need. Thailand produces a lot of agricultural products to serve the world such as rice, fruits and vegetables, but we also face a lot of problem of drought and water resource management to efficiently provide water to farmers. To deal with this issue, the department of royal rainmaking and agricultural aviation was established so that farmers can grow plants throughout the year.

The weather observation system technology in Thailand was imported several decades ago. The technology that supports rainmaking is known as a radiosonde [1]-[7] system for observing the weather of the upper-air. A radiosonde system includes many subsystems such as a communication subsystem, an electrical power subsystem, and a sensor subsystem. Every subsystem was designed as a general-purpose module that is easily applied to any commercial applications. However, sometimes we need more kinds of information from a radiosonde other than temperature, pressure, and humidity that a general radiosonde provides. For example, the information on its location and its remaining battery life during an operation is very important for many of our expected operations. This research aimed to improve a radiosonde so that it can support suitable replaceable subsystems for a specific mission, not only for a conventional observation by balloon flight. For example, it was desirable to be able to attach a radiosonde to a drone, a UAV, or an airplane. Moreover, it was also desirable to be able to get personalized weather information for an individual's home from a radiosonde.

The conventional ground system for radiosonde uses a very big antenna hence needs a lot of space. This is a waste of resource and budget. This conventional system is very old. New technology is released every day and it can be used to gain more precise weather information for efficient rainmaking operation. Therefore, the ground station needs to be improved to support an advanced sensor network in the future.

Ground station design [8]-[12] is quite dependent of the specific purpose of the application. Several factors need to be considered such as operating frequency, antenna gain, operating distance and type of antenna. For our purpose, we would like to develop a ground station not only for using with

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a weather sensor network for rainmaking process but also for general weather observation. Our design was up-to-date and would be able to support any advanced sensor network. Specifically, our ground station was designed to reduce the weight of the tracking system and antenna to make it portable and easy to installed. Moreover, this paper also proposes to develop a radiosonde, a portable sensor and radio transmitter system, to be more effective than the existing system in order to better serve a variety of weather observation missions.

II. SYSTEM DESIGN

A. Radiosonde

A radiosonde is an instrument for weather observation [13], [14] which includes sensors and a radio transmitter. In order to develop an equipment like radiosonde, its main subsystems should be considered: the sensor subsystem and the electrical subsystem which is described below.

1) Sensor subsystem

Normally, weather observation sensors include plain temperature, pressure and humidity sensors, but our design aimed to improve the system to be more intelligent than the existing one. Fig. 1 shows our sensor subsystem that included a GPS sensor, an accelerometer sensor and a power monitor device. A microcontroller was used to create packages of formatted data that are uniquely identifiable in order to avoid interfering with other packages. Moreover, we installed a data logger to record and store all sensor data in case data loss happens while the system is in operation. The transmitter we used was a LoRa module [15]-[18] due to its long operational range of over 20 km.

2) Electrical subsystem

This system is quite important because the its power supply has to generate sufficient power to cover all operations at all time. There were several sensors that needed a lot of power and current in order to work adequately. We selected to use a rechargeable 9V 800 mAh battery that could supply continuous power for more than 2 hours. Fig. 2 shows the electric flow of the electrical subsystem from the source to every device. Since each device needed a maximum supply voltage of 5V, we had to convert the voltage down from 9V to 5V efficiently. Moreover, some device could use the power supplied from microcontroller ports that produced about 3.3V.

Fig. 3 shows the designed weather observation instrument including all of the sensors mentioned that could transmit data back to a base station with a LoRa module operating at 433 MHz. We attached a strip of sticker to the instrument with detailed information for anyone who happened to collect it to understand its purpose and not feel panic. Moreover, we employed a parachute to reduce the descent rate as the instrument was falling down to the ground.

B. Ground Station

Ground station is design based on the mission of the operation. This project aimed to design and develop a ground station for receiving the weather information from a transmitter high up in the air that is going to be used in

rainmaking operation. The altitude of the transmitter operation is between 1 km to 15 km high because the transmitter has to be at about the same height from the ground as the airplane that carries out the rainmaking operation does, not exceeding 10 km in height. Thus, this system must be able to operate at a height that is higher than the standard equipment typically does.

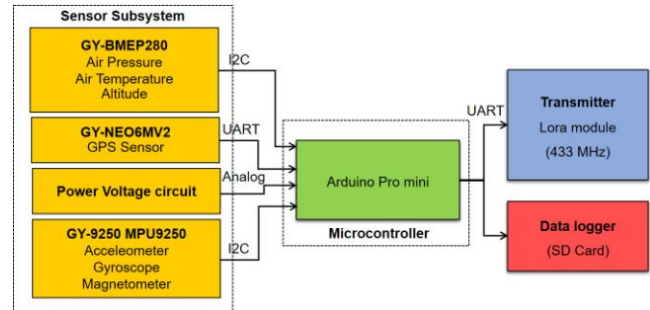


Fig. 1. Sensor subsystem diagram.

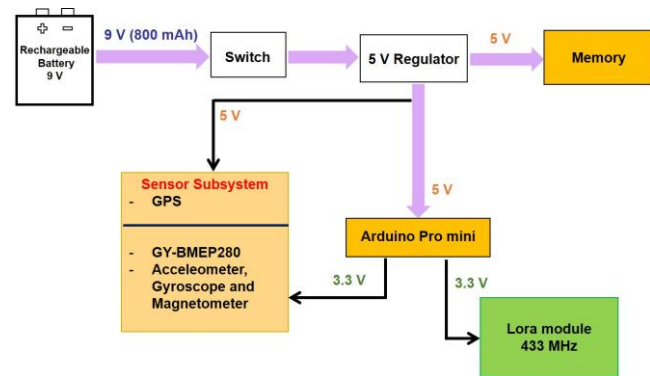


Fig. 2. Electrical subsystem diagram.



Fig. 3. The designed radiosonde configuration before a test.

Presently, the type of existing ground station used in Thailand is not suitable for receiving today's huge amount and diverse type of data from an advanced transmitter. For example, the existing ground station uses a very big antenna and is only able to receive data from only a single transmitter at one time, but the present technology dictates a need for a ground station to receive data from multiple sensors to get more precise data that will increase the effectiveness of the rainmaking operation. The cost of the existing system is also very high due to its having been imported from another country. This project also aimed to develop and manufacture new equipment within the country to reduce the average cost of investment and operate more effective than the existing system in order to better serve a variety of weather observation missions.

This proposed ground station is shown in Fig. 4. It consists of an antenna, a tracking system, a receiver and a GUI interface. Two operational frequencies are utilized in this project: 2.4 GHz by an Xbee module, aiming to operate at a

low altitude of no more than 2 km and for drone operation; and 433 MHz by LoRa module for high altitude use up to 15 km carried by a helium balloon. Both Xbee and LoRa receiver modules were supplied with power from a laptop.

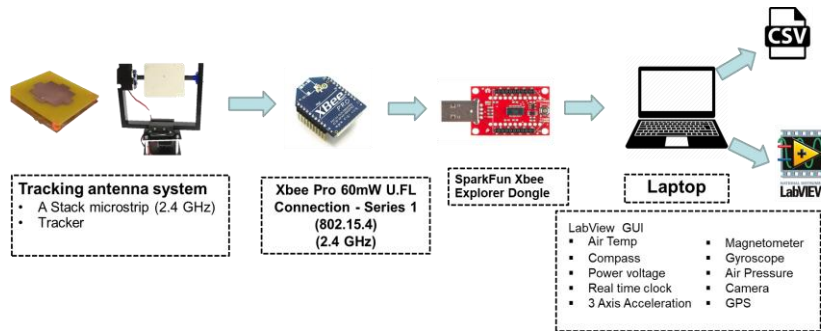


Fig. 4. Ground station diagram.

1) Antenna

Antenna is a significant part of a base station that can increase the efficiency of the system. Gain and pattern of antenna design are the priority consideration. This paper chose to design only a 2.4 GHz antenna because of its merit of lightweight, compactness, portability and inexpensiveness. The stack microstrip antenna shown in Fig. 5 was made of FR4 dielectric substrate with a relative permittivity and loss tangent of 4.40 and 0.02, respectively.

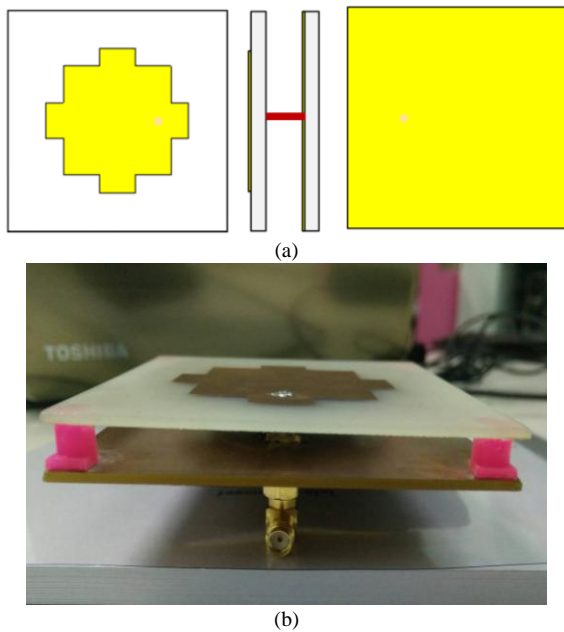


Fig. 5. A stack microstrip antenna (a) simulation (b) actual.

The simulated S11 of the antenna was lower than -10 dB covering a frequency range from 2.38 GHz to 2.56 GHz. The peak S11 was at 2.45 GHz. And the simulated radiation pattern was unidirectional with a gain of 8.31 dBi.

The measured results of the antenna are shown in Fig. 6. The S11 was better than the acceptable standard of -10 dB meaning that this antenna was usable. The determined pattern was wider than the simulated pattern. The half power beamwidth was about 60 degrees. The measurement gain was 6.5 dBi.

2) Tracking system

Tracking system is a very important part to the operation of

rainmaking because the receiver needs to receive weather information data from every desired altitude accurately. If we could get more and accurate weather data, it would be useful for successful rainmaking in the desired area. Due to rapid lifting up of helium balloon, the tracking system had to be able to automatically follow the helium balloon accurately. The structure of the tracking system was designed to be portable and lighter than the old system by using aluminium frame as shown in Fig. 7. This tracking system was designed to carry a load of antenna of about 1 kg. The antenna might be a 2.4 GHz stack microstrip antenna or a 433 MHz yagi antenna.

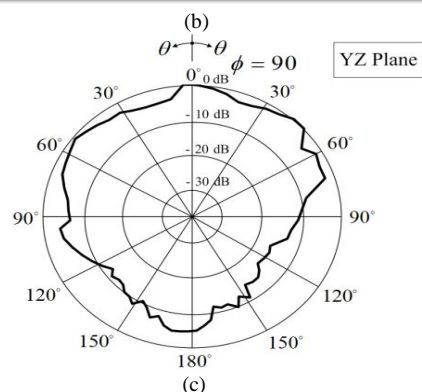
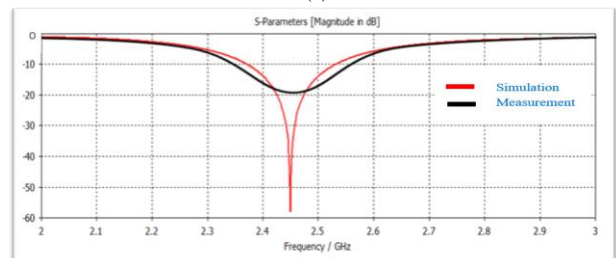
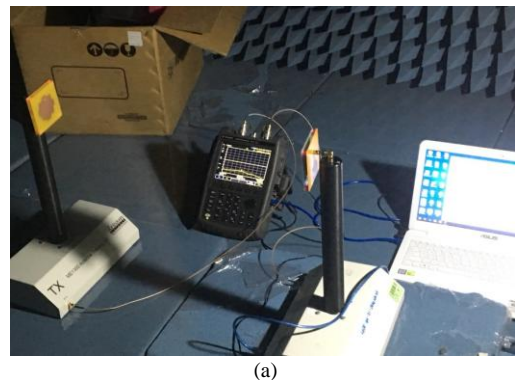


Fig. 6. Measurement results (a) chamber room test (b) S11 (c) pattern.

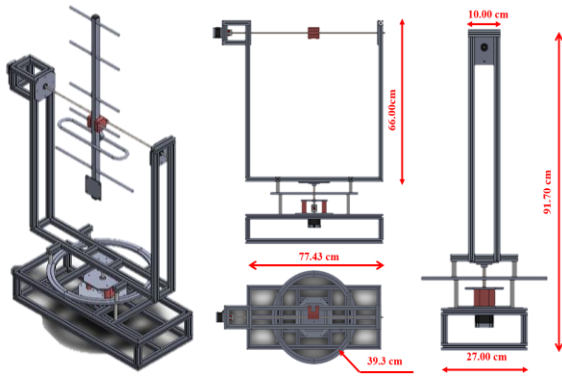


Fig. 7. Structure of tracking antenna.

This tracking system can be rotated 180 degrees around the vertical axis and 360 degrees around the horizontal axis by a step motor. To control the step motor, the tracking antenna system would be installed with Arduino, a GPS module, a compass sensor and an accelerometer sensor for calculating bearing angle and elevation angle between the location of the tracking antenna and the weather sensor equipment installed in the helium balloon. The motor of tracking system was supplied with power from a 24V 7.2 Ah battery for an

operation time of about 2 hours.

3) Display screen

The display design used LabVIEW software program as the basic engineering tool that showed the data from each significant sensor in the transmitter equipment attached to the balloon. The purpose of the design was for the easiest use by technicians and other non-engineers. The needed weather observation data were mainly surrounding weather parameters such as temperature, pressure and humidity, but in this project, the entire system was aimed to be a smart system hence a variety of sensors would be installed. Increasing the number of sensors means increasing weight, bandwidth and power requirement and complexity of the system, but it would be worthy to do so. Fig. 8 shows the designed screen with many data blocks consisting of date, time, GPS location from Google map, voltage level, compass direction, 3-axes acceleration and elevation speed. Each data block can be zoomed in and out freely. All sensor data would be displayed in real time when the system is operating and also after the operation was finished. The data would be stored in a format such as excel file format so that they were easy to access.

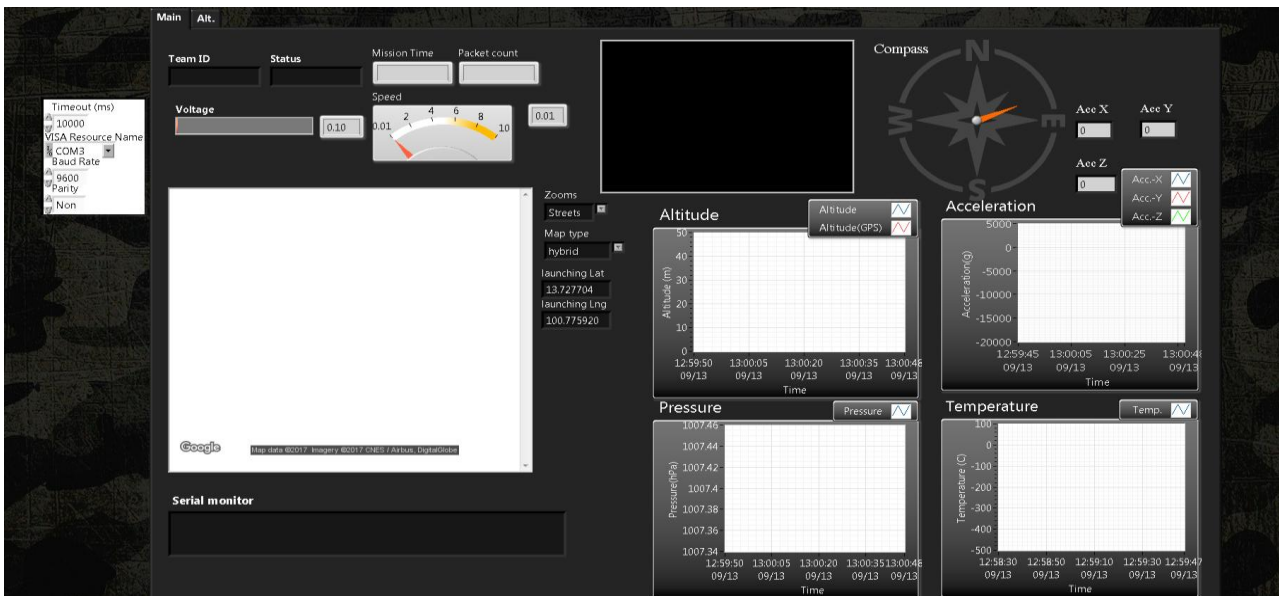


Fig. 8. Display screen.

III. EXPERIMENTAL RESULTS

To test the operation of this designed system, a balloon flight was suitable for testing from the ground up to a high altitude. However, a permission to release a balloon in an area was very difficult and complicated to get due to high plane traffic. Hence, we launched a balloon at two sites that have already been permitted to do so which belonged to the department of royal rainmaking and agricultural aviation. We also launched it at the same time that this department launched its balloon once a day.

The first balloon flight test was at Takli station. This site was at an uphill location about 400m above sea level. Fig. 9 shows the received weather data from about 400m to almost 1200m altitude to the base station. The comparative results between a current commercial radiosonde (the red straight

line) and our designed radiosonde (the blue connected dots) shown in Fig. 9 are results of pressure and temperature data. It can be observed that the trends of the pressure data in Fig. 9(a) sensed by both radiosondes were almost exactly the same, while the temperature data obtained from the commercial radiosonde varied more than the data from our designed radiosonde because the sensor that we used was cheap and less sensitive (Fig. 9(b)).

The second balloon flight test was at Phimai station. This station was located at a usual drought area in Thailand. The environment of this area was an open space at sea level. It was really suitable as a test site. The operation altitude of this second test was up to 6 km because the sky was very clear on the test day. Our designed radiosonde was improved by an added humidity sensor. This sensor and several other sensors were arranged to be exposed directly to the open air. The results are shown in Fig. 10 (a-c): pressure, temperature and

humidity. It was found that the measurements from our designed radiosonde were still not comparable to those from a commercial radiosonde, but it was operating well. Successful measurements were made from the ground level to the highest altitude tested. In the future, we will try to replace the inexpensive sensors with more capable and more expensive sensors and fully expect the new radiosonde to produce improved measurements.

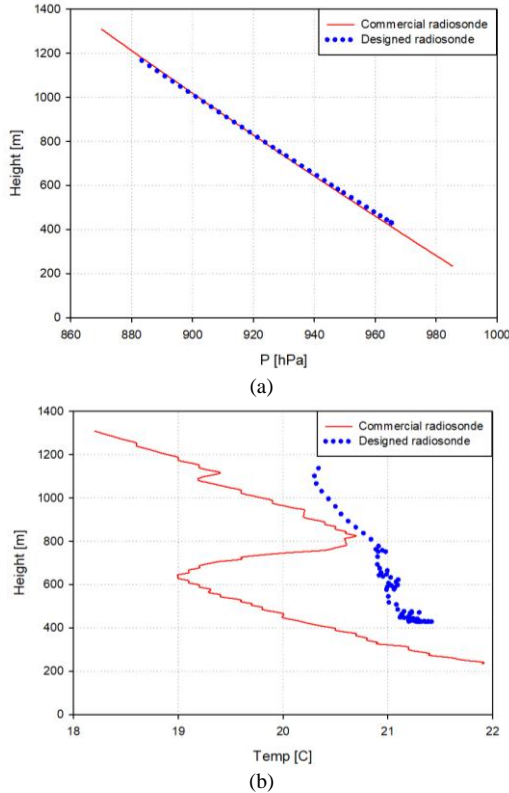


Fig. 9. Comparative weather sensor data between the two radiosondes at an altitude up to 1200m (a) pressure (b) temperature.

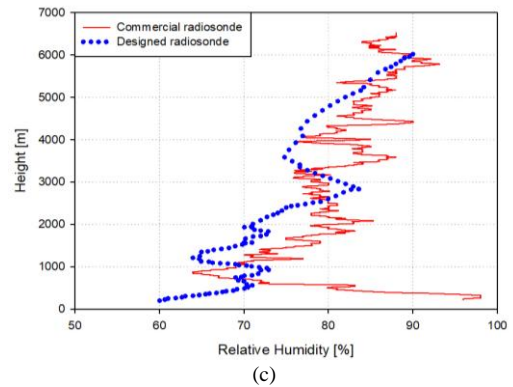
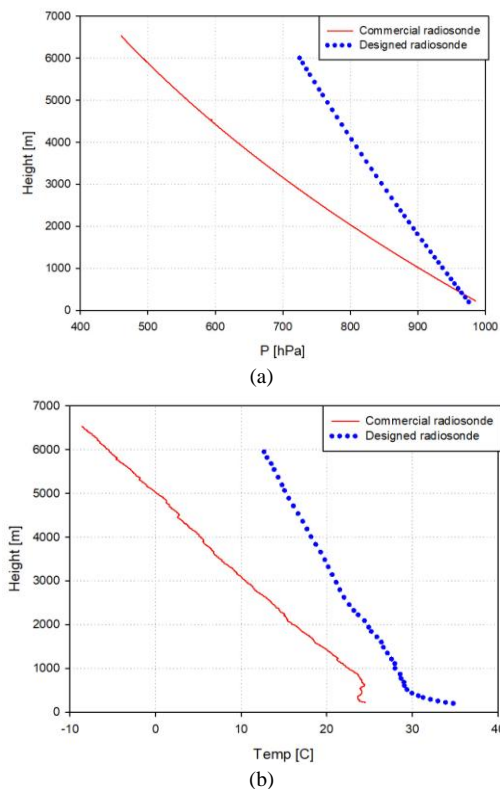


Fig. 10. Improved measurements from the designed radiosonde at a high altitude up to 6000m (a) pressure (b) temperature (c) humidity.

We plan to test the designed radiosonde to acquire data at varying altitudes to cover rainmaking operation at 6-10 km above the ground several more times. Our next test will not only be limited to balloon flight but it may be attached to a drone for low altitude weather observation. In order for our designed radiosonde to be able to replace the current commercial one, we need to design into it a friendlier container and make it easy to operate by non-engineers.

IV. CONCLUSION

This paper describes how to design a high and low altitude air observation system for a future advanced sensor network for rainmaking and weather observation. The radiosonde was improved by installing many weather, voltage, and GPS sensors to make the system more capable. The flow diagram of this ground station is almost the same with a station for other purposes. However, the specific purpose of a mission makes each system unique. Finally, this designed system is very valuable in reducing imports of foreign technologies and in enhancing the technology developed in the country.

In a future work, we aim to improve the design and implement it to a rainmaking system for use within the country. We plan to test our system several times and compare its performance with a commercial system in order to make sure that our developed system work effectively. The operation time was completely tested, but the altitude test was still not complete. We need to test whether the station can successfully receive data at 6-10 km range because a balloon mission for rainmaking operation will cover this kind of range.

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