Installation of UiTM’s ground station – Connecting earth and space with amateur band communication

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Abstract This paper portrays the installation of UiTM's Ground Station as being part of BIRDS Ground Station Networks; with its main task being to support BIRDS-2 nanosatellite's monitoring. UiTMSAT-1, UiTM's first nanosatellite, is one of the BIRDS-2 nanosatellites. It is expected to be deployed from International Space Station (ISS) by middle of 2018. The ground station is installed with two (2) Yagi antennas which operates in Amateur bands respectively at Very High Frequency (144 MHz - 148 MHz) ranges and Ultra High Frequency (430 MHz - 438 MHz) ranges. Additionally, an APT antenna for 137 MHz - band polar-orbiting weather satellites is also installed at this ground station for earth weather monitoring. As for security and monitoring matters, lightning/surge protection system and surveillance system (CCTV) also has been installed. Conclusively, several tests had been done as confirmation on the equipment setup. The testing procedure includes receiving HORYU-4 and IO-86 satellite's signal, and evaluating NOAA satellites' processed data of South East Asia's coverage. The uplink communication test, with cooperation with satellite owner, is left for future planning.

1. Introduction

Installation work of UiTM’s ground station started from September 2017. This ground station is built in anticipation of UiTMSAT-1’s deployment by middle of 2018. This first Malaysian University’s nanosatellite comes from Malaysia’s collaboration with Japan, Bhutan and Philippines, in a program called Joint Global Multi-Nations Birds: BIRDS-2 CubeSat Project. BIRDS-2 satellites will be placed at Low Earth Orbit (LEO) area, approximately at altitude of 400 km, similar to the International Space Station (ISS). UiTM’s ground station is a part of BIRDS Ground Station Network which consists of 10 different countries including BIRDS-1 participants [1][2]. It functions as the monitoring and communicating window between ground and BIRDS-2 satellite’s constellation: BHUTAN-1 (Bhutan), MAYA-1 (Philippines) and UiTMSAT-1 (Malaysia). To note, in section 2, this paper will be updating on UiTM’s ground station block diagram which includes the equipment’s installation and safety concerns and in section 3, will present several testing results on ground station’s equipment using chosen satellites.
2. **Ground station’s Setup**

Generally, ground station is an important factor to ascertain the condition of the satellite’s health and its mission’s progress. The design for ground station must be compatible with the satellite communication’s specification to ensure connectivity and must be securely maintained and controlled.

2.1. **Block Diagram of UiTM’s Ground station**

UiTM’s Ground station is built at the rooftop of level 21, Menara 2, Faculty of Electrical Engineering, UiTM Shah Alam. Figure 1 shows the block diagram of UiTM’s ground station. “INDOOR” refers to equipment inside control room which situated directly under the rooftop for ease of maintenance. “OUTDOOR” refers to equipment’s installation includes Antennas such as UHF, VHF and APT; Yaesu Rotator that hold UHF and VHF antennas, and two CCTVs. Inside the control room, two computers were set up for separate tasks. One for VHF/UHF satellite monitoring and the other is for APT satellite receiving data. On the computer for VHF/UHF, GS-232B is connected via USB. This device is a USB-PC interface controller for rotator. It connects with a rotator controller which directly connected to the Yaesu rotator at the rooftop. It receives the satellite’s elevation and azimuth data from SATPC32, a satellite tracking software which installed at control room’s PC.

![Block Diagram of UiTM's Ground Station](image)

Figure 1. Block Diagram of UiTM's Ground Station

Figure 2 shows the two installed Yagi antennas on a tower: one side for VHF band and the other side for UHF band. VHF antenna; model 2MCP22 [3] has frequency range of 144 MHz to 148 MHz.

![Yagi antennas on top of the antenna tower (Left-hand-side); KX-137 APT antenna (Right-hand-side)](image)

Figure 2. Yagi antennas on top of the antenna tower (Left-hand-side); KX-137 APT antenna (Right-hand-side)
On the other side, UHF antenna; model 436CP42UG [4] with frequency range of 430 MHz to 438 MHz. Both VHF and UHF Yagi antennas are circular polarized with gain of 14.39 dBiC and 18.9 dBiC respectively. Boom length of VHF antenna is 5.67 meter and boom length of UHF antenna is 5.75 meter. Current fixed height of the antenna tower is 3.5 meter. Added with height of antenna’s rotator (20 cm), the whole installation conforms for a safe operation during satellite tracking condition.

Antenna rotator is an equipment that controls the antenna movement by azimuth and elevation. The rotator used in this ground station is Yaeus G-5500. This device controls the motor of its rotators. The azimuth rotator unit is securely mounted together with the elevation rotator unit at the top of antenna tower. A fiber glass cross boom (model FGCB60); for connecting both Yagi antennas; is installed at each side of the rotator. Yaeus G-5500 allows azimuth rotation of 360° in approximately 58 seconds and elevation up to 180° in 67 seconds [5]. This rotator helps to accurately point to the location of passing satellite for better connectivity.

For communication activities, ICOM IC-9100 Radio Transceiver is installed. The RF cables from both Yagi antennas installed at the rooftop are connected to the back of this radio transceiver. The radio covers High Frequency (HF) range, VHF and UHF ranges while supporting several modes of operation which includes SSB, CW and FM [6]. It connects to PC (installed with SATPC32) via USB and receives the calculated Doppler-compensated frequency of the tracked satellite. During tracking and communicating process, automatically, the radio will tune to the exact frequency calculated by the SATPC32 software.

For BIRDS-2 nanosatellites command and mission operation from ground station, a specific software is being developed using C# programming language by the BIRDS-2 members at Kyushu Institute of Technology, Japan. This software is a stand-alone application created with Microsoft Visual Studio. In the Main Tab, referring to Figure 3, there is serial port configuration setting which needs the ground station operator to input the correct ports (TNC and Radio) to establish connection with this software. Once the hardware has been confirmed and in compliance with the ground station operation software, satellite tracking can be started. In the event of any BIRDS Ground Station’s operator received the BIRDS-2 nanosatellite’s CW beacon, 20 characters (specific) can be inputted into the Morse Code Beacon Analysis. With that, ground station operator will have the tracked satellite’s status for example battery condition and satellite’s temperature. Additionally, the BIRDS-2 members also have been designing separate tabs for Missions operation and Terminal which act as Serial Monitor for downlink data/packet and acknowledgment from satellite. This design will allow ground operator to read data/packet from satellite in its decoded format.

![Figure 3. BIRDS-2 Ground Station Operation Software - under development](image-url)
Additionally, KX-137, a turnstile VHF antenna (APT) for polar-orbiting weather satellites [7] is also installed at the ground station rooftop. Its best feature includes wide angle reception with its omnidirectional and horizontally mounted cross-dipoles that makes circular polarized signal reception acceptable. At the altitude of approximately 71 meters from ground level, this antenna operates in the 137 MHz band and receives signal from several NOAA (National Oceanic and Atmospheric Administration) satellites such as NOAA 15, NOAA 18, and NOAA 19.

2.2. Safety Concerns
This section will describe the security measures taken which includes installation of lightning/surge protection system and surveillance system (CCTV).

2.2.1 Security camera. Two CCTVs were installed: one pointing outside of ground station’s control room and another installed at the rooftop facing the Yagi antennas. The CCTVs are wired connected to a DVR which recording for whole 24 hours. The system is utilized for securing UiTM’s control room and for monitoring the movement of Yagi antenna while in use and while in dormant state. The CCTV viewing can be remotely accessed via internet connection.

2.2.2 Lightning/Surge Protection. The ground station has the lightning protection system installed at the rooftop - a 7 meter-height of lightning arrester pole at the very end of the rooftop’s perimeter. Attached with copper tape, it is grounded at the building grounding place at ground level. The antenna tower is situated straight 5-meters from this lightning pole. By using trigonometric functions and the 7-meter lightning pole’s cone coverage at 60º angle, it is found that the maximum height covered at the tower’s 5-meter distance is 4.1 meter. Hence, with the installed Yagi antenna’s height of 3.7 meter, it is confirmed that the UiTM’s ground station is covered.

Figure 4. Left-hand-side: Calculation of Lightning pole’s coverage; Middle: SPD box (antenna tower), Right-hand-side: SPD box (outside control room)

In addition to the lightning pole coverage, each equipment also protected by Surge Protection Device (SPD). As shown on Figure 4 Middle and Right-hand-side, SPD is installed at two places inside a weatherproof enclosure box: (1) at the antenna tower and (2) outside of control room. SPD at the antenna tower protects the rotator equipment while the SPD outside of control room protects all the outdoor equipment such as rotator’s cable, Yagi and KX-137 antenna’s RF cable and CCTV’s cable. Both enclosure boxes’ side are secured with copper tape as for grounding purpose. This security measure allows better protection of highly sensitive equipment outside and inside the control room such as antennas, rotator and radio transceiver.

3. Result and Discussion
Every equipment installed must be checked to confirm its function. In this matter, two satellites are chosen (HORYU-4 and IO-86) for UHF Yagi antenna test, and analyzing processed NOAA satellites’ images from KX-137 antenna.

3.1. Receiving satellite’s signal: HORYU-4 and IO-86 (LAPAN-A2)
HORYU-4 is a Japanese built nanosatellite (from Kyushu Institute of Technology) which launched into space at altitude of 575 km on February 17th, 2016. Its communication system includes VHF & UHF frequency ranges in addition to the S-band and L-band patch antenna. To track for HORYU-4’s timing in the ground station’s footprint, SATPC32 software is used. It calculates the expected time for satellite’s arrival and loss of signal. With Continuous Wave (CW) mode transmitted from Horyu-4’s satellite at centered frequency of 437.375 MHz [8], signal is successfully received by UiTM’s ground station. To decode the signal received, a CW decoder is used: HORYU-4 CW Beacon Telemetry Decoder (downloaded from Mike Rupprecht, DK3WN webpage). This decoder will inform the satellite’s health status as an example shown at Left-hand-side Figure 5 which was taken on November 18th, 2017.

IO-86 also known as LAPAN-A2 is an Indonesian microsatellite, developed by LAPAN (Lembaga Penerbangan dan Antariksa Nasional, or the "National Institute of Aeronautics and Space") [9]. The satellite was launched on September 28th, 2015 to circular near equatorial orbit at altitude of 650 km and it passes over Indonesia and other near equatorial region 14 times daily. IO-86 uses UHF frequency for TT&C (Telemetry Tracking and Command) functions. With arrival time estimated by SATPC32 software, the radio I9000 is set to received signal in Frequency Modulation (FM) mode centered at 437.425 MHz for telemetry beacon. The signal is captured as WAV file format and for decoding, FUNCube-1 Telemetry Decoder is used (downloaded from Mike Rupprecht, DK3WN webpage). Figure 5 on the Right-hand-side shows the IO-86’s telemetry decoded data.

Figure 5. Left-hand-side: Decoded data of HORYU-4; Right-hand-side: Decoded data of IO-86

3.2. Receiving satellite’s signal: NOAA Satellites

The KX-137 antenna has been fully operating from late October 2017 and received satellite APT (Automatic Picture Transmission) images in daily basis. The setup is completed with an APT-06 [10], a receiver device which handles the received signal from NOAA satellites and WXtoImg [11], a computer software that can process the satellite’s data into readable images. On November 3rd, 2017, NASA published an article on its website [12], titled “Intensifying Typhoon Damrey Threatens Vietnam”. The article stated that Typhoon Damrey originated in the South China Sea, west of the Philippines on November 1st, 2017, and has moved westward through the South China Sea. This statement matched the satellite images received by KX-137 antenna on UiTM’s ground station. Table 1 shows part of the APT images that KX-137 antenna received dated from November 1st, 2017 until November 4th, 2017. The captured images show the typhoon Damrey’s event time-by-time from accumulation to its dispersion.
Table 1. Typhoon’s movement date-by-date

| Date       | Movement       |
|------------|----------------|
| November 1st, 2017 |                |
| November 2nd, 2017  |                |
| November 3rd, 2017  |                |
| November 4th, 2017  |                |

4. Conclusion
UiTM enhances Malaysia’s development towards space-faring nation by participating the Joint Global Multi-Nation Birds Project (BIRDS-2). In preparation for the deployment of UiTMSAT-1, a ground station is constructed. UiTM’s ground station can monitor and communicate with UiTMSAT-1 and track other satellites that use the VHF/UHF amateur frequency ranges as communication medium. This paper describes the ground station’s block diagram, installation parts, and testing results. Future planning for uplink communication test is to be done with approval from satellites owners. In conclusion, UiTM’s ground station is one move in supporting space research.

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