DESIGN AND ANALYSIS OF SATELLITE'S GROUND STATION

by

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Thesis submitted in fulfilment of the requirements for the
Bachelor Degree of Engineering (Honours) (Aerospace Engineering)

June 2018

ENDORSEMENT

I, YIAP JOO ZHENG hereby declare that all corrections and comments made by the supervisor and examiner have been taken consideration and rectified accordingly.

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DECLARATION

This thesis is the result of my own investigation, except where otherwise stated and has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any other degree.

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Date:

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to USM and School of Aerospace Engineering where I had my 4 years degree and during the final year, I was provided an opportunity to pursue Final Year Project as part of the requirements for the degree of Bachelor of Engineering (Honours) in Aerospace Engineering.

I offer my sincere thankfulness to Dr. Norilmi Amilia Ismail as my supervisor for supporting and me through the hardship in the project. I appreciate her sustained enthusiasm and efforts in helping me to understand fundamental and leading me to muster knowledge about Space Engineering. I feel grateful to Dr. Norilmi for her willingness to sacrifice her time in explaining the problems that I had voiced out and giving constructive advices.

I would also like to thank Encik Azwan and Encik Ismail from School of Aerospace Engineering, USM. Encik Azwan willingness to help and advise in solving the problems and uncertainties related to electronics part. Encik Ismail, as the person in charge in USSL, gave me the access into the lab and always worked alongside with me throughout the project.

A special thanks to Agensi Angkasa Malaysia for lending us a plenty of electrical devices. Without their aid, I might not be able to complete this project smoothly.

Finally, yet importantly, I would like to express my gratitude to those stand aside with me throughout my life, my beloved family and friends for their unconditional love and encouragement, lecturers I had met and learnt from throughout my 4 years of degree.

DESIGN AND ANALYSIS OF SATELLITE'S GROUND STATION

ABSTRACT

Design and Analysis of Satellite's Ground Station is a thesis project based on the development of the ground station for LEO satellite, MYSat, which is going to be launched by USM Space System Lab (USSL) in near future. The ground station consists of azimuth & elevation controller, terminal nodes controller (TNC), amplifier and pre-amplifier, rotator, a fabricated rotator-computer interface and VHF & UHF antennas that operated at dual frequencies which are 145.8 MHz and 437.45 MHz. This study investigated on the design and fabricated of rotator-computer interface, design of antennas with its supporting holder and design of ground station that includes visually integration between software and hardware. Rotator-computer interface is origin from Yaesu and is an open source device. An interface operated by Arduino Mega was designed and fabricated in this study, which allows the connection to computer simply through USB port. Coding is uploaded to the interface/Arduino that is compatible with GS232 command and allow the satellite tracking software to control both the azimuth and elevation rotators. The antenna was designed, and its performance was optimized and simulated using numerical electromagnetic code (NEC). At the end of the study, a complete ground station was designed to give vision on the integration between software and hardware, including the transmission lines used.

REKA BENTUK DAN ANALISIS STESEN BUMI SATELIT

ABSTRAK

Reka bentuk dan analisis stesen bumi satelit merupakan satu tesis project yang menumpu pada pembinaan stesen bumi untuk satelit LEO, MYSat, yang dipersedia oleh USM Makmal Sistem Angkasa (USSL). Stesen bumi terdiri daripada pengawal azimut dan aras tinggi, pengawal stesen nod (TNC), penguatkuasa dan pra-penguatkuasa, mesin pemutar, reka bentuk, antara muka mesin pemutar-komputer serta sepasang antena VHF dan UHF yang beroperasi dengan dwi-frequensi setinggi 145.8 MHz dan 437.45 MHz. Projek ini mengkaji tentang reka bentuk dan penghasilan antara muka mesin pemutar-komputer, reka bentuk antena-antena dengan pemegang, serta reka bentuk stesen bumi yang memberikan pembayangan tentang penggabungan antara perisian dan perkakasan. Antara muka pemutar-komputer merupakan sistem yang terbuka dimiliki oleh syarikat Yaesu. Satu antara muka yang beroperasi dengan kegunaan Arduino Mega telah direka bentuk serta dihasilkan dalam projek ini. Kaedah ini memudahkan penyambungan antara komputer dan antara muka tersebut melalui bas bersiri semesta (USB). Kod akan dimuat naik dalam antara muka/Arduino merupakan kod yang bersesuian dengan GS232 dan membenarkan perisian menjejak dan mengesan satelit untuk mengawal pemutar azimut dan aras tinggi. Antena telah direka bentuk dan prestasinya telah ditiruan dengan penggunaan kod elektromagnet berangka (NEC). Akhir sekali, stesen bumi yang lengkap telah direka bentuk untuk memberikan bayangan atas penggabungan antara perisian dan perkakasan, termasuk talian penghantaran antena.

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LIST OF ABBREVIATIONS

APT	Automatic Picture Transmission
AOS	Acquisition of Signal
BVCOE	Bharati Vidyapeeth College of Engineering
CCS	Code Composer Studio
CubeSat	Cube Satellite
EIRP	Effective Isotropic Radiated Power
GUI	Graphical User Interface
HPBW	Half Power Beamwidth
IDE	Integrated Development Environment
IIT-B	Indian Institute of Technology Bombay
JPSS	Joint Polar Satellite System
LEO	Low Earth Orbit
LHCP	Left-Hand Circular Polarization
LNA	Low Noise Amplifier
LOS	Loss of Signal
MYSat	Malaysia Youth Satellite
NOAA	National Oceanic and Atmospheric Administration
NPP	(Suomi) National Polar-orbiting Partnership
NTNU	Norwegian University of Science and Technology
NUTS	NTNU Test Satellite
PA	Power Amplifier
PC	Personal Computer

PLF	Polarization Loss Factor
POES	Polar Orbiting Environmental Satellites
RF	Radio Frequency
RHCP	Right-Hand Circular Polarization
SDR	Software Defined Radio
SEEDS-2	Space Engineering Education Satellite-2
SNR	Signal to Noise Ratio
SWR	Standing Wave Ratio
TEC	Total Electron Content
TNC	Terminal Node Controller
UHF	Ultra-High Frequency
UNOOSA	United Nations Office for Outer Space Affairs
USB	Universal Serial Bus
USM	Universiti Sains Malaysia
USSL	USM Space System Lab
UTC	Coordinated Universal Time
VHF	Very High Frequency
VSWR	Voltage Standing Wave Ratio

LIST OF SYMBOLS

$\mathbf{E}_i$	:	electric field of incoming wave
$\mathbf{E}_a$	:	electric field of receiving antenna
f	:	frequency
G_R	:	receiving antenna gain
G_t	:	transmitting antenna gain
K_G	:	gain factor
K_B	:	half power beamwidth factor
L_a	:	atmospheric losses
L_i	:	ionospheric losses
L_l	:	total transmission line losses
L_P	:	antenna polarization losses
L_R	:	rain losses
L_S	:	free space loss
L_θ	:	antenna pointing loss
$\hat{\rho}_w$	:	unit vector of the wave
$\hat{\rho}_a$	:	unit vector of polarization (polarization vector)
T_S	:	effective noise temperature
φ_P	:	angle between the two unit vectors
λ	:	wavelength of the electromagnetic wave

CHAPTER 1

INTRODUCTION

This chapter gives an overview of the project and introduces the importance and validity of the problem. The research objectives have been derived as a guide to be attained throughout the project.

1.1 Background

Quoted as the "Inventor of the Communication Satellite", British science writer and futurist, Arthur C. Clarke had proposed the very first concept of putting the artificial satellites in geostationary orbits for the purpose of relaying radio signals (Clarke, 1945). Although the first artificial Earth satellite, Sputnik 1 launched in 1957, was not put in the orbit for the purpose of global communications, it was followed by Echo 1, the first artificial communication satellite launched in 1960. Echo 1 featured with the ability to relay signals to other points on Earth, yet relied on human's oldest flight technology, ballooning, to soar above 1,600 km above. Since then, the spacecraft industry is growing rapidly, especially after the launching of Sputnik 1, it triggered the Space Race during the Cold War between two major nations at that time, United States and Soviet Union. The development of spacecraft was prior to the usage of more advance technology to carry out harder missions, and also the reduction is size and mass, to reduce the cost of sending the spacecraft or satellites to the orbit. This encourages the continuous invention and development of small satellites.

Table 1.1: Different Types of Small Satellite with Respective Mass

Type of Satellite	Mass (kg)
Mini Satellite	100 to 500
Micro Satellite	10 to 100
Nano Satellite	1 to 10
Pico Satellite	0.1 to 1
Femto Satellite	< 0.1

Cube Satellite (CubeSat) is one of the result from the growing development of spacecraft technology. In 2000, professors Jordi Pruig-Suari of California Polytechnic State University and Bob Twiggs of Stanford University proposed the design of CubeSat (Hank Heidt, 2000). This proposal allowed university students and those interested in radio amateur to learn to design and build their own satellites to be operated in space. The 10×10×10 cm cubic satellite with no more than 1.33 kg, featured to be much lower in costings is the reason why it is largely used in commercial and amateur projects. According to the statistics done by United Nations Office for Outer Space Affairs (UNOOSA), there are around 4600 satellites orbiting the Earth in 2017, an increase of 8.91% compared to the previous year (Pixalytics, 2017).

Malaysia Youth Satellite (MYSat) is the first nanosatellite designed and built by USM Space System Lab (USSL), Universiti Sains Malaysia (USM). MYSat is a 1-U CubeSat to be used for electron-density measurement or ionospheric data measurement. The data is expected to be collected before the earthquake, as the acoustic gravity wave moves vertically and disturb the profile of electron density in e-layer of ionosphere. MYSat will detect the disturbance and transmit the data to be used in the research of earthquake precursor.

In communication system of MYSat, the satellite is proposed to work on dual frequencies, very high frequency (VHF) and ultra-high frequency (UHF). The amateur radio band for both frequencies are 144 to 146 MHz (VHF) and 435 to 438 MHz (UHF). Meanwhile, the satellite system is not complete without a ground station that allows the communication between the operator on Earth and the satellite. The communication system of MYSat works in the way that transferring the command from ground station to satellite (uplink) using VHF and transferring the data from satellite to the ground station (downlink) using UHF. To facilitate the communication system, USSL is going to build a ground station in USM Engineering Campus, in co-operation with Agensi Angkasa Malaysia. The ground station first will be used to retrieve open data from National Oceanic and Atmospheric Administration (NOAA) series environmental satellites and will focus on the communication with MYSat after the satellite is launched.

1.2 Problem Statement

This project is to design and fabricate a ground station for USSL to facilitate the communication system of MYSat and future satellite, in co-operation of Agensi Angkasa Malaysia. Agensi Angkasa Malaysia had provided help in lending some of the hardware components of ground station to USSL. However, USSL is still lacking rotator-computer interface, which acts as an interface to connect between the rotator controller with personal computer (PC), and the dual frequencies (UHF-VHF) antennas with the holder to complete the fabrication of USSL ground station.

1.3 Research Objectives

Total of three objectives derived from the problem stated in section 1.2, are to be attained in this study as below:

- To design and fabricate rotator-computer interface for USSL ground station.
- To design UHF – VHF antennas with the antenna holder for USSL.
- To design the ground station with visually integration between software and hardware.

1.4 Thesis Organization

The main body of this thesis is divided into five chapters. Each chapter explains the details on respective part of the overall project. The first chapter is the Introduction that gives readers an overview of the study done in this thesis, includes the problem statement and the research objectives to be attained.

Next, second chapter is the Literature Review that presents the mission heritage in the previous studies and works on ground station for different kind of satellites. This chapter includes researches and findings on different antennas being used over the world with their expected performances. This chapter also explains how other radio amateurs designed and fabricated the rotator-computer interface.

Moving on to the third chapter, is the Methodology. This chapter will explain step by step procedure in designing and building the ground station for USSL. This includes all the software and hardware used, and how to integrate both. Every subject will be explained in detail.

The forth chapter is the Results and Discussion. This chapter will present a complete account of results to be analysed and discussed in the form of figures, tables and texts. This will include the verification of the rotator system and the functionality of the antenna.

At the end of the main body is the fifth chapter, which is Conclusion and Recommendation. This chapter concludes the findings and products of the project in line with the objectives set, acknowledges the limitations and possible further research is suggested.

CHAPTER 2

LITERATURE REVIEW

This chapter presents a critical review of literature related to the project. The review includes others' researches and studies (university students, professors or amateur radio hobbyist) on design and analysis of ground station. Every section in designing ground station (includes design and fabrication of dual frequencies antenna with its holder and the design and integration of the rotator-computer interface) had been reviewed in detail to ensure the base for the experiment or analytical section is clear and understandable.

2.1 Background

Ground station, also understood as a complete antenna system, is a vital part for the communication system of the satellite. As explained by Dylan Ichikawa, ground station is the first and final piece of the communication link (Ichikawa, 2007). Without ground station, the whole communication system will be functionless and can be metaphor as "human brain". The satellite can simply work fine on its own, but it doesn't matter if no one is using it on Earth by commanding and transmitting data collected for the mission.

There are a lot of different software and hardware components that build up a complete ground station. Components used may differ for different designs of the ground station. A good design of ground station is to achieve the main goal, that is simply able to communicate with targeted satellite successfully. Referring to Figure 2.1, the sketch of antenna system is used in communication system by Norwegian University of Science and Technology (NTNU) in 2011. Both VHF (2×9 element crossed Yagi) and UHF (2×19 element crossed Yagi) antennas are connected in mechanical and electrical way. In electrical way, each antenna is connected to one set of Low Noise Amplifier (LNA) and Power Amplifier (PA), which they had added later in their ground station as expected to achieve better signal to noise ratio (SNR). Then, the system is connected to the radio (Icom IC9100) followed by the PC. In mechanical way, both antennas are connected to rotator (Yaesu 5500), followed by PC through the controller interface (Idom Press Interface)

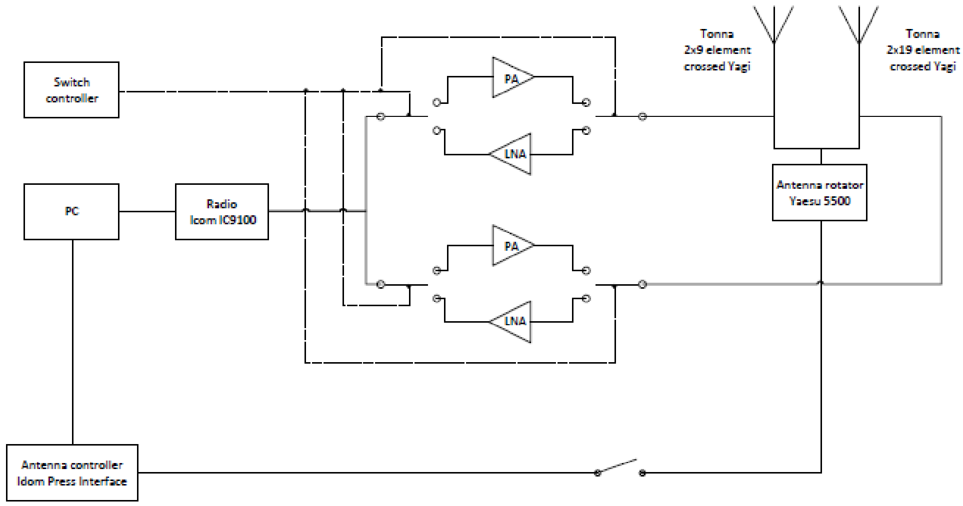

Figure 2.1: Sketch of Antenna System Used by NTNU (Stenhaug, 2011)

From Figure 2.2, is the system diagram of ground station used in Space Engineering Education Satellite-2 (SEEDS-2), developed by Nihon University in 2008. SEEDS-2 works on frequencies band, 144 MHz for uplink and 430 MHz for downlink. For polarization control system, which is respective to electrical way, antennas are connected to relay and preamplifier, then followed by the receiver/transmitter and terminal node controller (TNC). Data from the PC is modulated in TNC for transmission and receiving signals are demodulated into data to be received by the PC. In tracking control system, which is respective to mechanical way, the antennas are connected to rotator with the controller, and then the rotation is controlled by the satellite tracking software in PC.

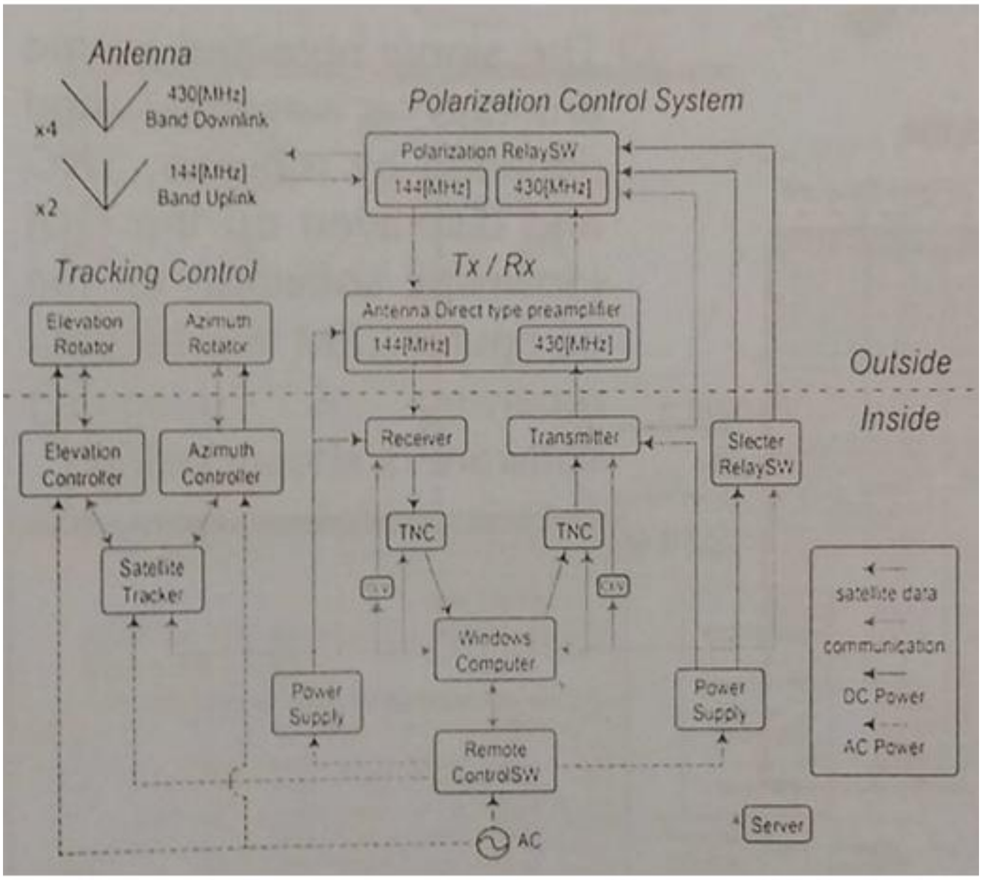

Figure 2.2: System Diagram of Ground Station of SEEDS-2 by Nihon University (2017)

2.2 Link Budget

Before the design of the communication system, the link budget calculation should come first. Link budget is a planning on the radio frequency telemetry link, which accounts all the various gains and losses between the transmitter and receiver (Campbell-Scientific.Inc., 2016). The link budget for MYSat had been done by previous master student, Ahmad Shaqeer in 2017. The link budget is revised, and Table 2.1 and 2.2 show the separated link budget for uplink and downlink.

Table 2.1: Uplink Budget (Thaheer, 2017)

Parameter	Value	Unit
Ground Station (Hank Heidt)		
Frequency, f	145	MHz
Transmitter Power Output, P	20.00	W
Transmitter Power Output, P	13.01	dBW
Total Transmission Line Losses, L_l	0.00	dB
Antenna Gain, G_t	15.7	dBi
EIRP	28.75	dBW
Uplink		
GS Antenna Pointing Loss, L_θ	0.26	dB
GS-to-SAT Antenna Polarization Losses, L_P	0.06	dB
Free Space Loss, L_S	139.20	dB
Atmospheric Losses, L_a	2.10	dB
Ionospheric Losses, L_i	0.70	dB
Rain Losses, L_R	0.00	dB
Isotropic Signal Level at SAT	-113.57	dBW
Satellite (SAT)		
Antenna Pointing Loss, L_θ	0.27	dB
Antenna Gain, G_R	2.15	dBi
Total Transmission Line Losses, L_l	0.00	dB
Effective Noise Temperature, T_S	283.22	K
Figure of Merit, *G/T*	-22.37	dB/K
Signal-to-Noise Power Density, C/N_0	92.39	dB-Hz
System Desired Data Rate, R	8888	bps
System Desired Data Rate, R	39.49	dB-Hz
Command System, E_b/N_0	52.91	dB
Demodulation Method Selected	GMSK	
Specified Bit-Error-Rate	1.00×10^{-5}	
Demodulator Implementation Loss	1.00	dB

Telemetry System Required E_b/N_0	9.60	dB
E_b/N_0 Threshold	10.60	dB
System Link Margin	**42.31**	**dB**

Table 2.2: Downlink Budget (Thaheer, 2017)

Parameter	**Value**	**Unit**
Satellite (SAT)		
Frequency, f	453	MHz
Transmitter Power Output, P	1.50	W
Transmitter Power Output, P	1.76	dBW
Total Transmission Line Losses, L_l	0.00	dB
Antenna Gain, G_t	2.15	dBi
EIRP	3.91	dBW
Downlink		
Satellite Antenna Pointing Loss, L_θ	0.10	dB
SAT-to-GS Antenna Polarization Losses, L_P	0.06	dB
Free Space Loss, L_S	148.74	dB
Atmospheric Losses, L_a	2.10	dB
Ionospheric Losses, L_i	0.40	dB
Rain Losses, L_R	0.00	dB
Isotropic Signal Level at SAT	-147.49	dBW
Ground Station (Hank Heidt)		
Antenna Pointing Loss, L_θ	0.05	dB
Antenna Gain, G_R	15.74	dBi
Total Transmission Line Losses, L_l	0.00	dB
Effective Noise Temperature, T_S	205.71	K
Figure of Merit, *G/T*	-7.39	dB/K
Signal-to-Noise Power Density, C/N_0	73.67	dB-Hz
System Desired Data Rate, R	8888	bps

System Desired Data Rate, R	39.49	dB-Hz
Command System, E_b/N_0	34.18	dB
Demodulation Method Selected	GMSK	
Specified Bit-Error-Rate	1.00×10^{-5}	
Demodulator Implementation Loss	1.0	dB
Telemetry System Required E_b/N_0	9.60	dB
E_b/N_0 Threshold	10.60	dB
System Link Margin	**23.58**	**dB**

Furthermore, the revised block diagram for uplink and downlink systems are showed in Figure 2.3 and Figure 2.4 on the next page.

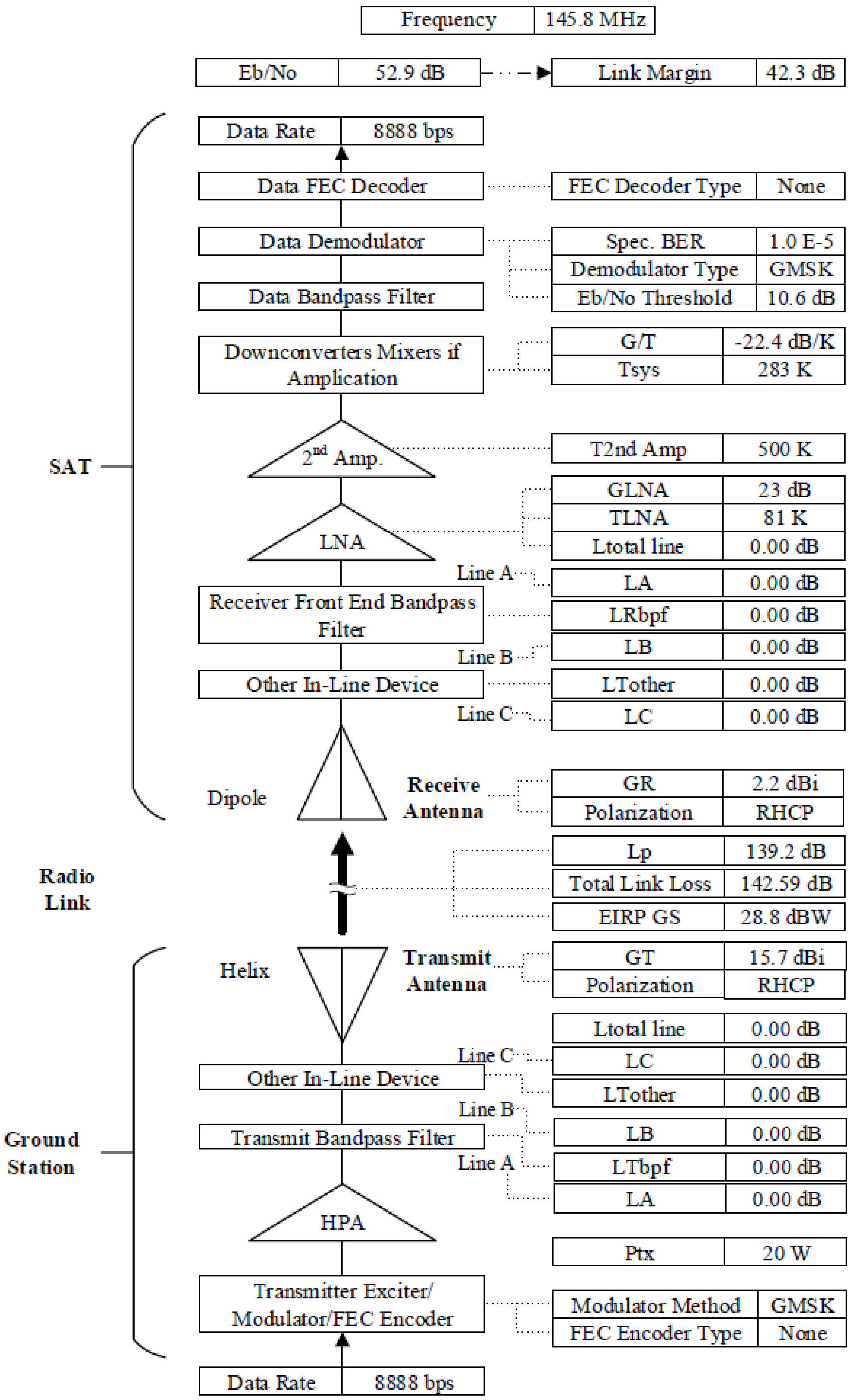

Figure 2.3: Revised Block Diagram for Uplink System (Thaheer, 2017)

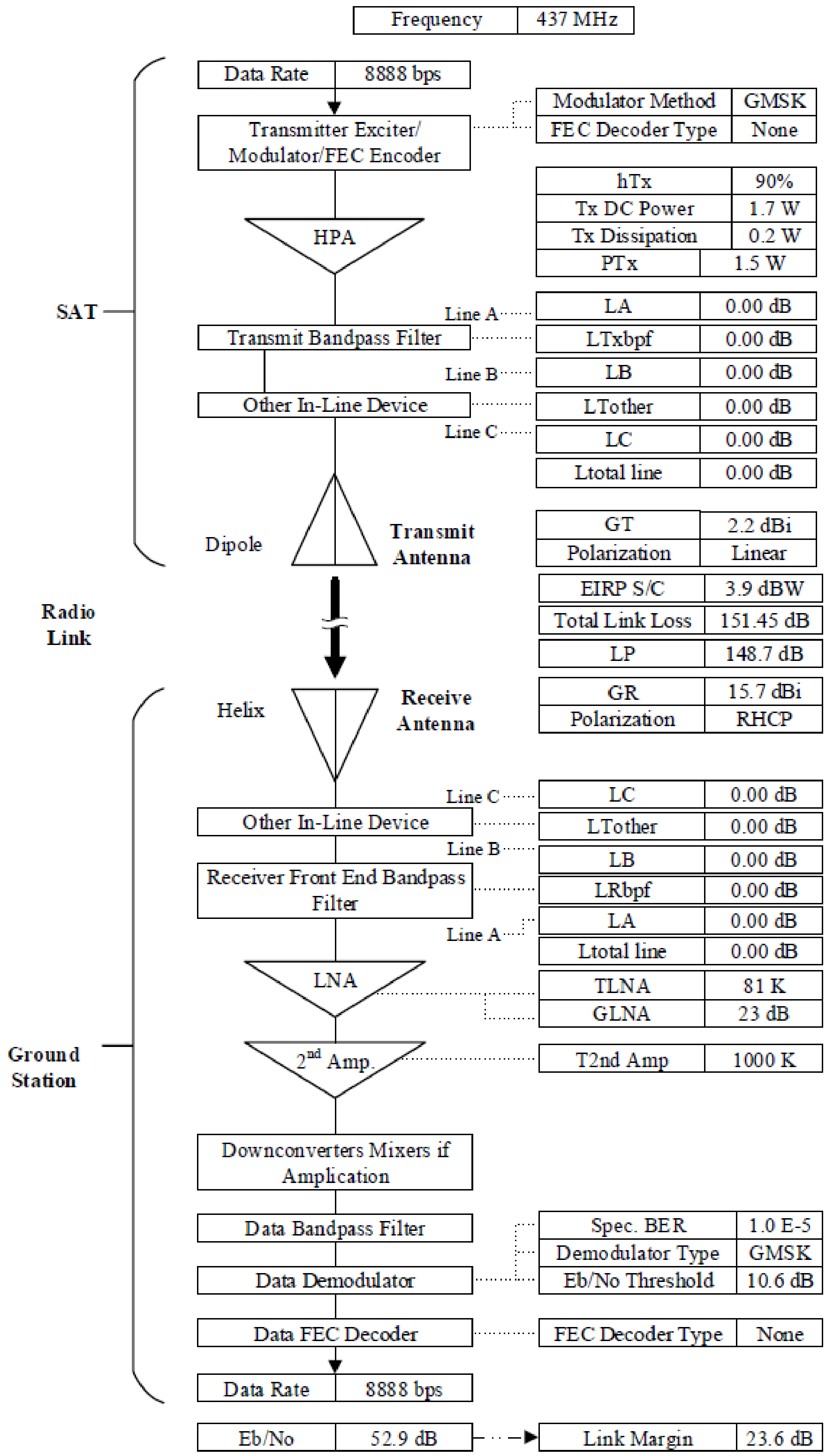

Figure 2.4: Revised Block Diagram for Downlink System (Thaheer, 2017)

2.3 Rotator-Computer Interface

Yaesu GS-232A/B is used as the interface to connect the Yaesu G-5500 rotation controller with the PC. However, a new original Yaesu GS-232A/B costs over USD 550 (which is around RM 2365), is very high in cost and unaffordable. Fortunately, a replacement for the interface can be manufactured as United State company, Yaesu has provided a detailed circuit diagram for his GS-232B interface in online manual, as shown in Figure 2.5. It uses Programmable Intelligent Computer (PIC) as microcontroller to control the electronic devices. This can be replaced by using Arduino as microcontroller.

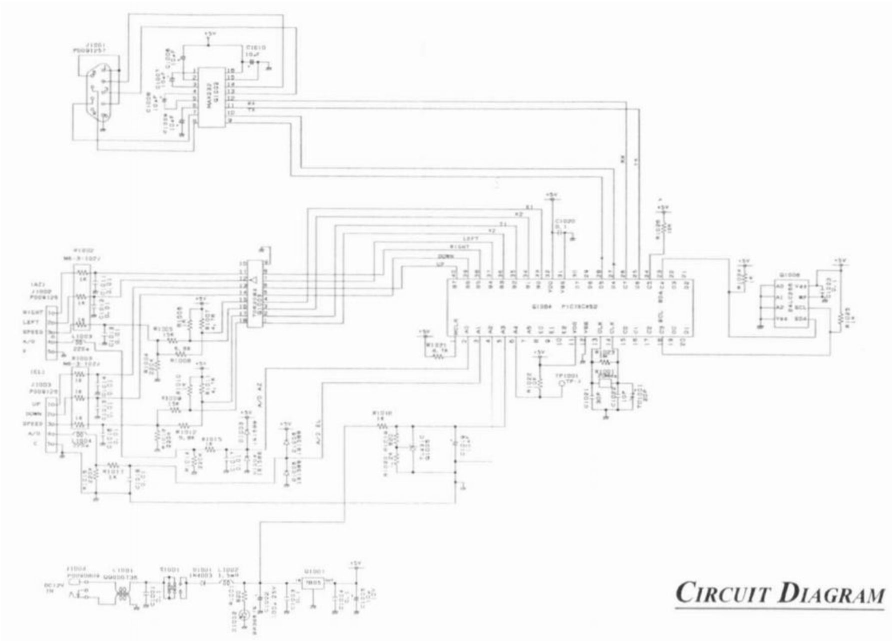

Figure 2.5: Circuit Diagram of Yaesu GS-232B (YAESU, 2004a)

It is hard to compare both PIC and Arduino as both have different architectures. However, Arduino has advantageous over PIC and very much easier to start with as explained below:

- PIC is a microcontroller while Arduino is actually a development board uses Atmega328 microcontroller. Arduino is an open source electronics platform, together with the software, too, is open source which allow students, hobbyists or professionals to adapt into their studies and researches.
- Precisely due to Arduino’s popularity and simplicity when compared to PIC, one can easily find supports and valuable information on the net.
- The programming language used for PIC is C/C++, which is high in complexity when one approaches it from scratches. Meanwhile, Arduino provides Integrated Development Environment (IDE) that minimizes the complexity for the user to program with the help of automatically installed header files or libraries.
- Arduino uses universal serial bus (USB) to connect with computer and ready to be programmed, while PIC requires separate PIC programmer to upload the codes. Due to this feature, Arduino allows user to perform quick alteration in coding when there is occurrence of error.
- USB connection also allow Arduino to gain power supply directly from the PC. As compared to original GS-232B uses serial port (DB9/RS2320) to connect with computer, USB is better than this as replacement can be found much easier and cheaper when the connection is malfunction.

As mentioned, Arduino is highly popular and suitable to be used in replacement of GS-232 interface, many radio amateur hobbyist had made their own Arduino based rotator-computer interface that uses GS-232 command. Anthony Good, a radio amateur hobbyist that also known as K3NG, started his project on designing and fabrication of Arduino based rotator-computer interface by referring to Yaesu GS-232B in 2011. He profiled his work and shared it on the net, includes the hardware and software he used, the way he fabricated and the programming he used. He welcomes other radio amateur hobbyists or professionals, either to learn and to use his work, or to share, to test and to improve his work in terms of programming and hardware used. This made his work profile or so-called documentation keeps updating until now, with latest knowledge in hardware of the interface and programming that can suit every type of command. Table 2.3 give a list of descriptions of some radio amateur hobbyists' works on fabricating the rotator-computer interface, includes Anthony Good, Steve and Tom Doyle. Among the radio amateur hobbyist, their works were proved to be success and highly referred by the others.

Table 2.3: Description on Past Experiments / Fabrication of Rotator-Computer Interface

Name	Description	Remarks

Anthony Good "ID: K3NG" (2018 – latest update)	• Arduino-based
	• Azimuth only and azimuth / elevation rotator support
	• Serial interface using the standard Arduino USB port
	• Control Port Protocol Support:
	  ○ Yaesu GS-232A & GS-232B
	  ○ Easycom
	• Support for position sensors:
	  ○ Potentiometers / Analog Voltage
	  ○ Rotary Encoders
	  ○ Incremental Encoders
		• Provided a clear-view of schematic diagram
		• Provided a full documentation of the fabrication
		• Provided a source code
		• The code is flexible
		• With addition of a proper capacity power supply and several interface components such as relays, this unit could also serve as a total replacement for a rotator control unit or serve as the basis for a 100%

	○ Pulse Output ○ HMC5883L digital compass ○ ADXL345 accelerometer ○ LSM303 digital compass and accelerometer ○ HH-12 / AS5045 ○ A2 Absolute Encoder (under development)	homebrew rotation system

Steve
“ID: G4HSK”
(2016)
	• Arduino-based
	• Comprises of 4 modules
	  • Arduino Uno board
	  • Switching board
	  • LCD interface plus a 2x20 LCD module
	  • Emulates Yaesu GS-232 interface
		• Method based on Anthony good
		• Included PstRotator
		• Does not include documentation and source code

Tom Doyle “ID: W9KE” (2012)	• Arduino-based • Used only 4 resistors and 4 transistors in terms of hardware • Works with SatPC32 and may work with other tracking programs that use Yaesu GS-232 commands	• Included source code but not documentation • Included introduction of Code Composer Studio (CCS)

2.4 Satellite Tracking Software

The communication between ground station and the satellite work best (best signal acquisition) when the ground station is directly pointing to the satellite. To facilitate this, tracking system must be employed, either in automatic tracking using satellite tracking software, or manually tracking by using manual command. Satellite tracking software means a kind of software that can be used to take control of rotator controller and give command automatically so that the antenna will be rotated and directed towards the track of targeted satellite. Most of the software has its input of most of the well-known satellites' positions. As compared to manual tracking where operator is required to be clear with the expected position of the satellite and give manual commands to the rotator controller, automatic tracking software does not need operator standing by for 24 hours.

There are numbers of satellite tracking software available, either it does charge or conditionally free of charge or totally free for usage. The most important consideration in choosing the suitable software is to know whether the software coordinates with the rotator-computer interface. When the software is not using the same command with Yaesu GS-232B, the software will fail to control the rotator controller and rotate the antenna to the direction directing to the position of targeted satellite. Table 2.4 shows a list of satellite tracking software with respective description.

Table 2.4: Different Satellite Tracking Software Available in Microsoft Windows

Satellite Tracking Software	Description
SatPC32 By Erich Eichmann (ID: DK1TB), Germany (Eichmann, 1967)	• Erich Eichmann used his program to support the work of AMSAT, worldwide amateur radio satellite organizations, particularly in AMSAT-DL (Europe), AMSAT-NA (North American) and AMSAK-UK (Great Britain). This is at least proved the capability and reliability of the program to be used in satellite tracking. • Full version of the program costs £ 34.00 or can be obtained through registration at AMSAT. However, the demo version of the program is free of charge. It is fully functioning with only one restriction, that is the user's location / coordinate will not be stored and required to key in manually every restart of the program. • The program allows users to configure newly launched satellite, which is useful when MYSat is launched, we can configure the data / orbit parameter of MYSat into the program and the program will automatically tracking the position of MYSat • The creator of the program does provide a detailed manual /FAQs, explain and provide solutions for known problems.

	• Following interfaces and controllers are supported: ➢ Yaesu GS-232 and compatible interfaces ➢ Egis-Rotoren ➢ WinRotor Interface ➢ SAEBRTrack Satellite Tracker ➢ AMSAT's LVB Tracker ➢ EA4TX's ARSWIN • The frequency and mode control work with following radios: ➢ Yaesu transceivers (FT-736R, FT-847, FT-817, FT-857 and FT-897) ➢ Kenwood transceiver (TS-790E/A and TS-2000) ➢ ICOM transceivers (IC-820, IC-821, IC-910H and IC-9100)
SimpleSat Look Down By Tom Doyle (ID: W9KE) (Doyle, 2012a)	• Tom Doyle used his program to support work for AMSAT, furthermore, AMSAT introduced his program in its official site. This proves the credibility and capability of the program. • This program is completely free of charge and is much easier to operate (user-friendly) • This program also allow user to install the data of newly launched satellite to be tracked by the program.

	• The creator of the program had provided videos to explain how to use the program. The videos are clear and understandable. • The program only support GS-232 and compatible interfaces. • The biggest advantage of the program is it works best with the coding Tom Doyle created for the rotator-computer interface, as mentioned in Section 2.2, Table 2.3.
WXtrack By David Taylor (1999)	• Following interfaces and controllers are supported: ➢ Yaesu GS-232 and compatible interfaces ➢ AMSAT's LVB tracker ➢ WiSPDDE ➢ EA4TX's ARSWIN • The program is free of charge with some restrictions. The registered version of the program cost $45.99, that provides service to ensure the satellite data is up-to-date in autonomous way and the user can easily ask for technical supports and some extra facilities. • The student satellite project of NTNU used this program in their ground station to track their satellite, NTNU Test Satellite (NUTS) (Stenhaug, 2011).

2.5 NOAA

National Oceanic and Atmospheric Administration (NOAA) is a scientific agency under Department of Commerce, United State. Officially formed in 1970 (with tracing back its history, the oldest precursor which is named as United States Coast and Geodetic Survey established in 1807), NOAA functions to understand and predict changes in climate, weather, oceans and coasts, to share that knowledge and information with others, and to conserve and manage coastal and marine ecosystems and resources (NOAA, 1970). NOAA has plenty of satellites either currently flying or has ended its mission. The currently orbiting satellites include NOAA-20, DSCOVR, GOES-S, GOES-16/GOES East, Jason-3 and Suomi NPP. NOAA-20, also known as JPSS-1, is one of the satellite in NOAA's Joint Polar Satellite System (JPSS) which is the latest generation of United State polar-orbiting environmental satellite system that provide short- and long-term forecast, to help us to predict and prepare for severe weather events. Before NOAA-20, Suomi National Polar-orbiting Partnership (Suomi NPP) is the first satellite within JPSS launched in 2011 and basically serve as the bridge between old series of satellite – Earth Observing System (EOS) and JPSS. Both NOAA-20 and Suomi NPP joined in the same orbit in which NOAA-20 is orbiting 50 minutes ahead of Suomi NPP by circling the Earth for nearly 14 times daily, providing full global coverage twice per day. The orbital parameters for NOAA-20 are 98.7° inclination, 824.3 km perigee, 827.8 km apogee and 101.3 mins period, while for Suomi NPP's, 98.7° inclination, 833.7 km perigee, 834.3 km apogee and 101.4 mins period.

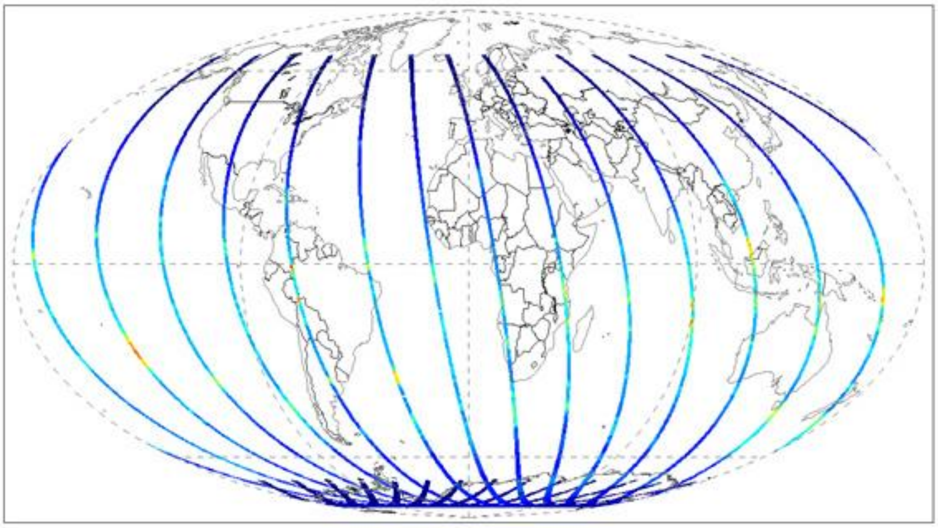

Figure 2.6: Path of NOAA-20 (NOAA, 1970)

Table 2.5: Predicted Date and Time for NOAA-20 to pass by Malaysia [Source from N2YO.com, retrieve: April 17th, 2018]

Start		**Max Altitude**			**End**	
Date, Local Time	**Az**	**Local Time**	**Az**	**El**	**Local Time**	**Az**
18-Apr 02:31am	NNE 15°	02:39 am	ESE 120°	75°	02:46 am	S 189°
18-Apr 01:36pm	SE 136°	01:42 pm	E 77°	19°	01:48 pm	NNE 16°
18-Apr 03:15am	S 190°	03:22 pm	W 258°	28°	03:29 pm	NW 326°
19-Apr 02:12am	NNE 24°	02:20 am	E 99°	45°	02:27 am	S 179°
19-Apr 03:54am	NNW 334°	04:00 am	W 284°	12°	04:05 am	SW 237°
19-Apr 01:18pm	SE 125°	01:23 pm	E 76°	11°	01:29 pm	NNE 28°
19-Apr 02:56pm	S 180°	03:03 pm	W 261°	47°	03:10 pm	NNW 336°
20-Apr 01:54am	NE 34°	02:01 am	E 102°	27°	02:08 am	S 169°
20-Apr 03:34am	N 346°	03:41 am	W 283°	20°	03:47 am	SW 223°

20-Apr 02:37pm	S 170°	02:44 pm	SW 235°	78°	02:52 pm	N 345°
21-Apr 01:36am	NE 45°	01:42 am	E 103°	16°	01:48 am	SSE 158°
21-Apr 03:15am	N 355°	03:22 am	W 281°	33°	03:29 am	SW 213°
21-Apr 02:18pm	SSE 161°	02:26 pm	E 82°	63°	02:33 pm	N 354°
22-Apr 02:56am	N 4°	03:03 am	WNW 290°	55°	03:11 am	SSW 202°
22-Apr 02:00pm	SSE 151°	02:07 pm	E 77°	37°	02:14 pm	N 3°
22-Apr 03:41pm	SSW 205°	03:47 pm	W 259°	14°	03:53 pm	NW 311°

Table 2.5 and 2.6 shows a list of time that NOAA-2 and Suomi NPP respectively are expected to pass by any part of Malaysia (not necessary pass through the location of USSL's ground station, which is in USM Engineering Campus).

Table 2.6: Predicted Date and Time for Suomi NPP to pass by Malaysia [Source from N2YO.com, retrieve: April 17th, 2018]

Start		**Max Altitude**			**End**	
Date, Local Time	**Az**	**Local Time**	**Az**	**El**	**Local Time**	**Az**
18-Apr 01:42 am	NE 41°	01:49 am	E 100°	19°	01:55 am	SSE 161°
18-Apr 03:22 am	N 352°	03:29 am	W 285°	28°	03:35 pm	SW 216°
18-Apr 02:25 pm	SSE 164°	02:32 pm	ENE 68°	75°	02:39 pm	N 351°
19-Apr 01:24 am	NE 52°	01:30 am	E 102°	11°	01:35 am	SE 149°
19-Apr 03:03 am	N 1°	03:10 am	W 283°	47°	03:17 am	SSW 206°

19-Apr 02:06 pm	SSE 154°	02:14 pm	ENE 72°	44°	02:21 pm	N 0°
19-Apr 03:48 pm	SSW 208°	03:53 pm	W 256°	12°	03:59 pm	NW 307°
20-Apr 02:44 am	N 10°	02:51 am	W 272°	78°	02:58 am	SSW 196°
20-Apr 01:48 pm	SE 143°	01:55 pm	E 79°	27°	02:01 am	N 10°
20-Apr 03:28 pm	SSW 196°	03:35 pm	W 257°	20°	03:41 pm	NW 319°
21-Apr 02:25 am	NNE 18°	02:33 am	ESE 111°	63°	02:40 am	S 186°
21-Apr 01:30 pm	SE 133°	01:36 pm	E 77°	16°	01:42 am	NNE 20°
21-Apr 03:09 pm	S 187°	03:16 pm	W 258°	33°	03:23 pm	NW 330°
22-Apr 02:07 am	NNE 28°	02:14 am	E 99°	37°	02:21 am	S 175°
22-Apr 03:48 am	NNW 338°	03:54 pm	W 285°	14°	03:59 pm	SW 232°
22-Apr 02:50 pm	S 176°	02:57 pm	W 261°	56°	03:04 pm	NNW 339°

Jason-3 satellite belongs to a series of spacecraft that measure the surface height of global ocean, monitor the rate of sea-level rise and helps in the forecast of the strength of tropical cyclones (NOAA, 1970). Jason-3 will fly over the same ocean point in an interval of 9.9 days with the orbital parameters are: 66.05° inclination, 1328 km perigee, 1380 km apogee and 112 mins period.