Experimental test for receiving X-Band data LAPAN-A3 Satellite with 5.4m antenna diameter

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Abstract. LAPAN-A3 / LAPAN-IPB Satellite launched on June 22, 2016 (03:56 UTC) as an experimental micro-satellite for remote sensing and monitoring of maritime traffic. The Satellite was launched as a secondary payload on ISRO Cartosat-2C as its main payload, the launch carried out at SDSC (Satish Dhawan Space Centre) in India using PSLV-C34 rocket launcher. The Satellite was in orbit polar sun-synchronous with a height of 505 km above sea level. It has an inclination angle of 97 degrees and heavy satellite 115 kg, with this orbit, the satellite will pass through Ground station 4 times (2 times during the day and two times at night) with a duration of the track at the time of the pass about 10-15 minutes. The Satellite payload carried 4 bands Line Scan Cameras and Digital Imager (SpaceCam). For main mission is the earth observation for food vegetables And as additional mission is carrying AIS (Automatic Identification System) receiver to monitor maritime traffic in the region of the poles, then Star Sensor made by LAPAN for qualifying room, then for scientific contained magnetometer sensor for monitoring the Earth's Magnetic field. The purpose of this scientific paper is to test the reception of data payloads of the LAPAN-A3 satellite on X-Band frequency of 8.2 GHz using a 5.4 M solid antenna Ground Stations LAPAN in Pare-Pare. The purpose of this experiment will tell us with 5.4 meter of diameter solid antenna is capable or not enough for HDRM receiver to lock a signal and produce the data output, and how this result if compare with 11 meter of diameter antenna in Splitzberg Groundstation in Norway.

1. Introduction

The first phase of LAPAN micro satellite program was started by developing LAPAN-TUBSAT. This satellite is still operational in orbit since January 2007. Gaining experience in developing, launching, and operating micro-satellite as well as in developing and operating satellite's ground station, LAPAN continue in developing its second satellite, named LAPAN-A2 also known as LAPAN-ORARI. The mission for LAPAN-A2/ORARI is Earth observation using RGB digital camera, maritime traffic monitoring, and amateur radio communication in near equatorial orbit. And these day LAPAN have LAPAN-A3/IPB satellite which become the first Indonesian Remote Sensing Experimental Satellite. In figure 1, it shows the orbital characteristic of LAPAN-A2/ORARI and LAPAN-A3/IPB satellite [1]. LAPAN-A3 / LAPAN-IPB Satellite also known as LISAT (LAPAN IPB Satellite), is a program of cooperation in terms of microsatellite remote sensing between Space agency (National Institute of Aeronautics and Space of Indonesia) in Jakarta and Bogor Agriculture University (Institut Pertanian Bogor) located in Bogor, Indonesia. The purpose of this mission is to monitor the food sources in Indonesia and to provide environmental monitoring. The real purpose of the satellite LAPAN-A3/ LAPAN-IPB is to provide actual data, frequent and accurate to observe and predict the condition of the Indonesian archipelago. Republic of Indonesia with an estimated population of 258 million is the largest archipelago (island countries) in the world with more than 17,500 islands. Two third of country territory is covered by the sea and 1/3 of the country most of the land is covered by forests and agriculture. In this cooperation project, LAPAN responsible for the design and development of microsatellites, while IPB is responsible for algorithm development and application datasets. This satellite one of main program of PUSTEKSAT (Pusat Teknologi Satelit) programs from National Institute of Aeronautics and Space (LAPAN) Indonesia, this satellite designed for specific experimental mission such as remote sensing, marine and fisheries research, land cover and ship monitoring using Automatic Identification System (AIS), that were needed to observe of Indonesian territory. In order to simulate LAPAN-A3/IPB satellite for line imager data acquisition is required high data rate modulator and demodulator (HDRM) [2]. This satellite will have the main mission as an imager satellite with 4 bands multi spectral imager using optical line scan camera to monitor the land cover, cultivated area and sea, and also ship monitoring for additional mission. Because of this satellite have a polar orbit path in 24 hour is only 4 times passed across the groundstation with 2 in the morning and 2 in the night. LAPAN-A3 Satellite used 8.2GHz X-Band frequency for main payload whereas early LAPAN Satellites use S-Band frequency, one facilities for X-Band that LAPAN have is 5.4m antenna in Pare-Pare which as usually used for receive Modis data.

This research will show an experimental result for receiving X-Band data from LAPAN-A3 Satellite by using 5.4 meter diameter antenna and also compared to 11 meter diameter antenna that has used so far in Splitzberg Norway.

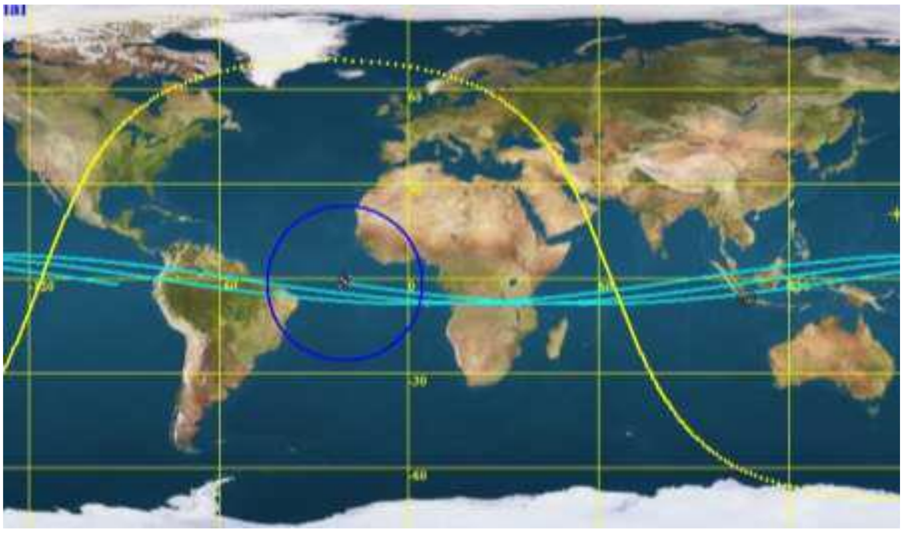

Figure 1. LAPAN-A2 and LAPAN-A3 Orbit (A2 Blue, A3 Yellow)[1].

2. Methodology

Figure 2 describes how to receive a data from LAPAN-A3 Satellite, from X-Band antenna with diameter of 5.4 meter and LHCP polarization Feed go through Low Noise Amplifier (LNA). This frequency is converted from 8.2 GHz to 720 MHz using X-Band Down Converter. This is due to the Demodulator HDRM is only support 720 MHz or 1200 MHz (Mix) as its input, and the data will be stored in RAW Data model in a Hard Drive HDRM itself.

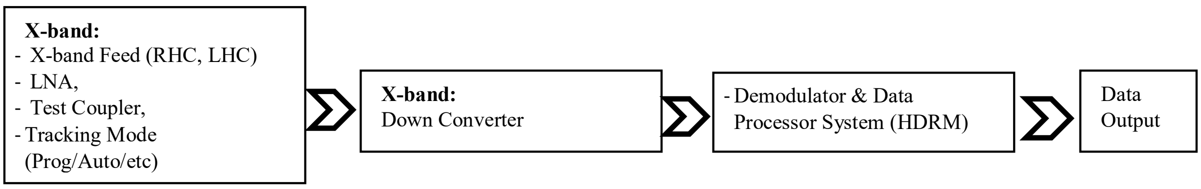

Figure 2. Flowchart System Test Receive X-Band LAPAN-A3 Satellite [10].

Modulation is a technique to carry digital data over analog waveform core of signal modulation is to put the message and place it on a carrier signal for transmission. While Demodulation is the reverse process, i.e. to get the message signal by splitting the carrier signals. To facilitate the operation of the transmission signal frequency used is generally a high frequency for reasons easy to be separated. LAPAN-A3 / LAPAN-IPB Satellite is very similar to a satellite in particular LDCM satellite LANDSAT-8, so it is identical to the modulation scheme. The modulation scheme of Landsat Satellite can be seen in figure 3.

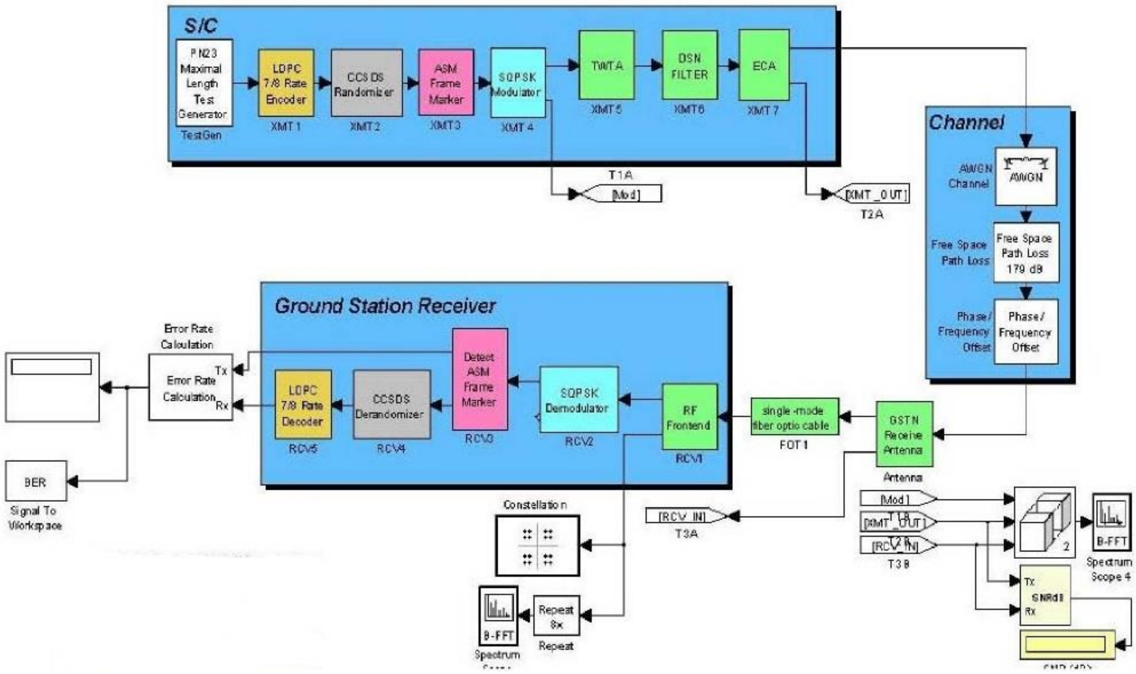

Figure 3. System flow data reception LDCM [2].

High Data Rate Modem is a multi-receiver satellite data, data processing, and system simulation system that supports CCSDS (Consultative Committee for Space Data Systems) with CDL standards, DVB - S2, and the spectrum of a direct connection. This HDRM demod perform data reception, entering, processing, distribution, and archiving functions at speeds up to 1.7 Gbps. It is most commonly used in ground stations, but is also ideal for applications including integration and test a satellite or aircraft data acquisition.

HDRM demod (figure 4) is implemented as a digital, software radio. can be configured to accommodate multiple modulation schemes, data rates, coding algorithms, and data formats. It provides demodulation filters that can be tuned to match the characteristics of the satellite transmitters, and can improve communication performance. Linear wideband system allows adaptive filtering of the received signal based on the symbol rate and Doppler. These characteristics also ensures compatibility with complex modulation and coding which is suitable to be developed for future missions.

Figure 4. Demodulator HDRM LAPAN-A3/LAPAN-IPB [2].

HDRM used is highly modular system that can be configured. HDRM It has a high level of full modulation and demodulation, the ability to use multiple commands modulation and Forward Error Correction algorithms to support a diverse set of waveforms. There are lots of applications and scenarios that allow configuration to meet the requirements of a variety of different missions. Different applications can be achieved through configuration software and a wide selection of modular hardware. Figure 5 illustrates the modular architecture.

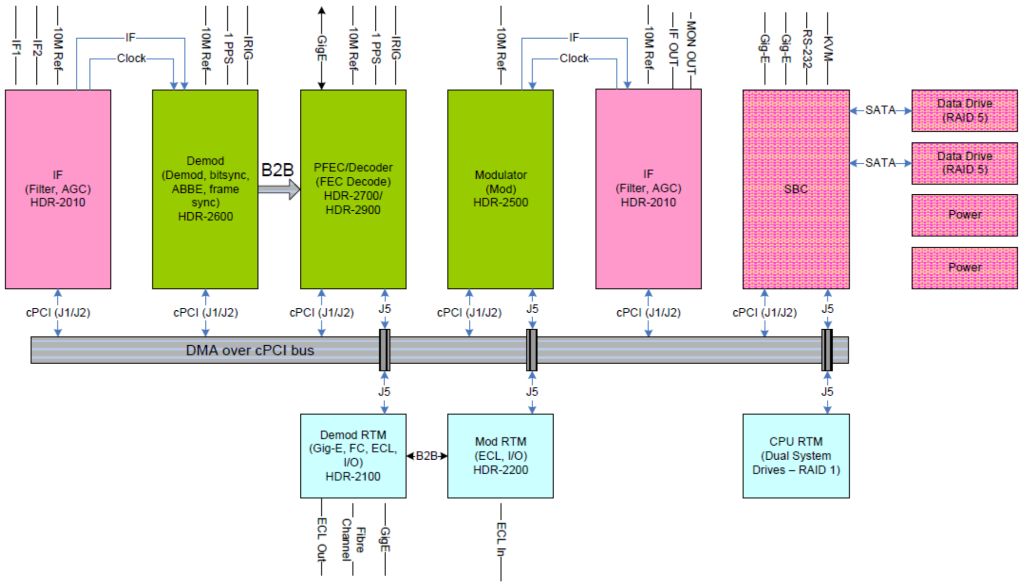

Figure 5. Architecture scheme HDRM [8].

The purpose of this test was to try receiving X-Band signal and data from LAPAN-A3 / LAPAN-IPB Satellite, the data received in real time from satellite to 5.4-m antenna diameter in Pare-Pare Ground station.

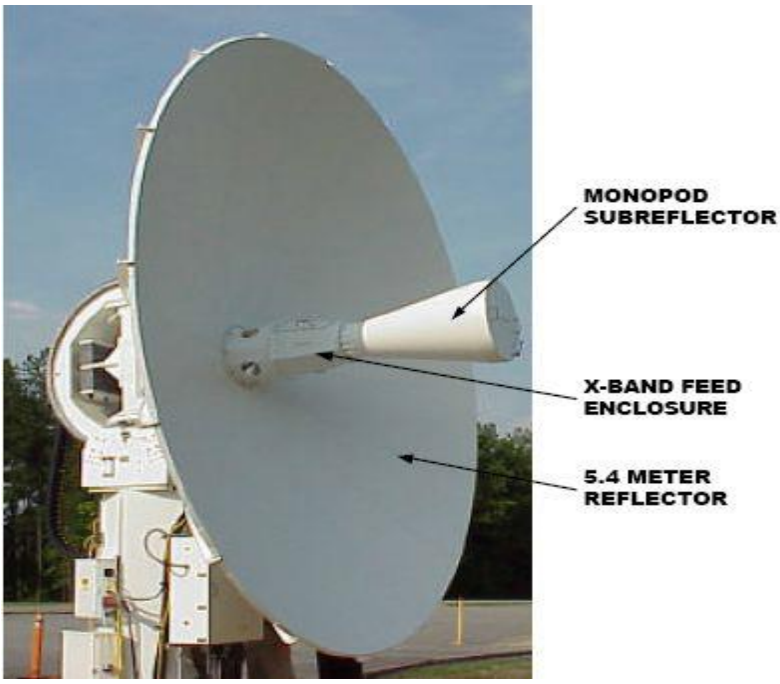

Figure 6. Antenna Subsystem ViaSat 5.4-m [3].

The antenna consists of a 5.4-meter dual shaped reflector and Cassegrain feed. Both the high efficiency X-band feed and the sub reflector are enclosed in one monopod type structure which maintains the accuracy of the alignment. This monopod structure is heated and pressured to prevent ice formation and any negative performance effect due to weather (figure 6).

This system features a high performance autotracking X-band feed. The Y- over X-axis pedestal configuration is mounted on a rigid base extension suitable for ground or rooftop installation. The dual shaped optics use a monopod feed/subreflector to optimize efficiency. The result is superior G/T performance.

In telecommunication, free-space path loss (FSPL) is the loss in signal strength of an electromagnetic wave that would result from a line-of-sight path through free space (usually air), with no obstacles nearby to cause reflection or diffraction. It is defined in "Standard Definitions of Terms for Antennas", as "The loss between two isotropic radiators in free space, expressed as a power ratio". Usually it is expressed in dB, The FSPL is rarely used standalone, but rather as a part of the Friis transmission equation, which includes the gain of antennas.

Free-space path loss is proportional to the square of the distance between the transmitter and receiver, and proportional to the square of the frequency of the radio signal.

The equation for FSPL is

$$FSPL = (4\pi d/\lambda)^2 = (4\pi df/c)^2 \quad (1)$$

where:

λ = is the signal wavelength (in meters),
f = is the signal frequency (in hertz),
d = is the distance from the transmitter (in meters),
c = is the speed of light in a vacuum, 2.99792458 × 108 meters per second.

This equation is only accurate in the far field where spherical spreading can be assumed; it does not hold close to the transmitter.

A convenient way to express FSPL is in terms of dB

$$\begin{aligned} \mathrm{FSPL(dB)} &= 10\log_{10}\left(\left(\frac{4\pi df}{c}\right)^2\right) \\ &= 20\log_{10}\left(\frac{4\pi df}{c}\right) \\ &= 20\log_{10}(d) + 20\log_{10}(f) + 20\log_{10}\left(\frac{4\pi}{c}\right) \\ &= 20\log_{10}(d) + 20\log_{10}(f) - 147.55 \end{aligned} \quad (2)$$

The size of antenna is determines by link budget calculations, the estimation calculation is used for antenna development, link availability, power requirements, bit error rate, as well as the overall customer satisfaction with the satellite service. This link budget is a method for assessing the power received and the noise ratio in link radio wave. The calculations must be calculated for an individual transponder, and must be recalculated for each of the individual links. Link budgets are usually calculated for a worst-case scenario, the one in which the link will have the lowest C/N ratio or lowest tolerable availability [4]. Image of LAPAN-A3/LAPAN-IPB Satellite, its specification, its satellite link, satellite link parameter, and system scheme module grooves on Demod HDRM can be seen in figure 7, table 1, figure 8, table 2, and figure 9 respectively.

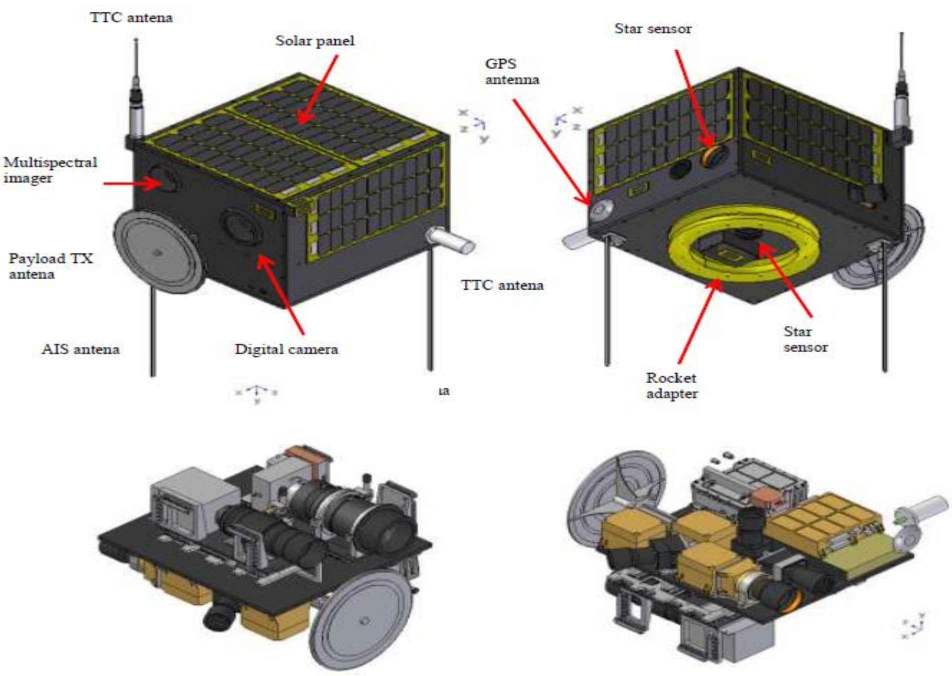

Figure 7. LAPAN-A3/LAPAN-IPB Satellite [5].

Table 1. LAPAN-A3 Satellite specification.

Mission	Payload	Spectral Resolution	Spacial Resolution	Orbit	Communication	Total Weight
Design, Integration, Test and Operation is down in Indonesia	Push broom 4 band multispectral imager Experiment with 18m resolution and 100 Km swath.	0.45 - 0.52 Blue	18 m resolution and 100 Km swath	Polar sun synchronousat 97° inclination	Payload : Tx X-Band (8200 MHz, BW 168 MHz)	80 - 100 Kg
Earth observation with 4 band multispectral imager for land use classification and environment observations	Digital space camera with 4 m resolution and 8 Km swath.	0.52 - 0.60 Green	4 m resolution and 8 Km swath		TTC : UHF	
Supporting global maritime awareness by the reception of AIS signal from ship	Automatic Indentification System (AIS) receiver ex. AIS Sat (Norwegian Satellite)	0.63 - 0.69 Red 0.76 - .090 NIR				

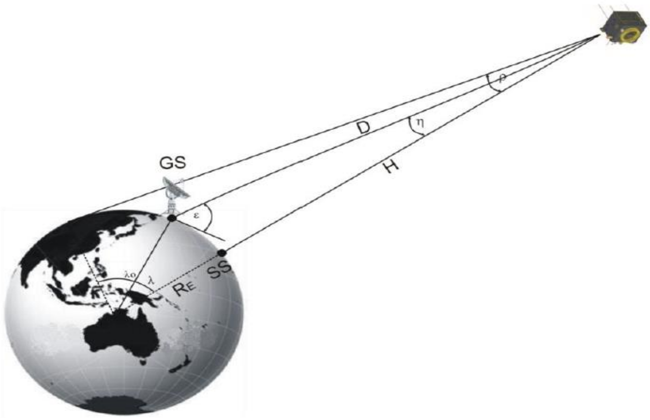

Figure 8. LAPAN-A3/LAPAN-IPB Satellite Link [6].

Table 2. LAPAN-A3 Satellite link parameters

No.	Link Parameters	Value	Unit
1	Altitude	505	Km
2	Slant Range (5 deg elev)	2448	Km
3	Transmission Power TX (5 Watt)	7	dBW
4	Frequency Operation	8200	MHz
5	Waveguide / cable loss (satellite)	1	dB
6	Antenna gain (satellite)	5	dBi
7	EIRP (satellite)	11	dBW
8	Free space loss	178.5	dB
9	Atmosphere Absorption Loss	0.1	dB
10	Antenna Gain (Groundstation)	52.1	dBi
11	Received waveguide / Cable Loss (Groundstation)	1	dB
12	Received Carrier Power (Groundstation)	-35.4	dBm
13	G/T (Groundstation)	29.5	dB/K
14	Boltzmann's constant	-228.6	dBW/Hz/K
15	Data Bandwidth (168 MHz)	82.3	dB Hz
16	Data Rate (105 Mbps)	81.8	dB
17	Carrier to Noise ratio (C/N)	8.3	dB
18	Eb/No	10.3	dB

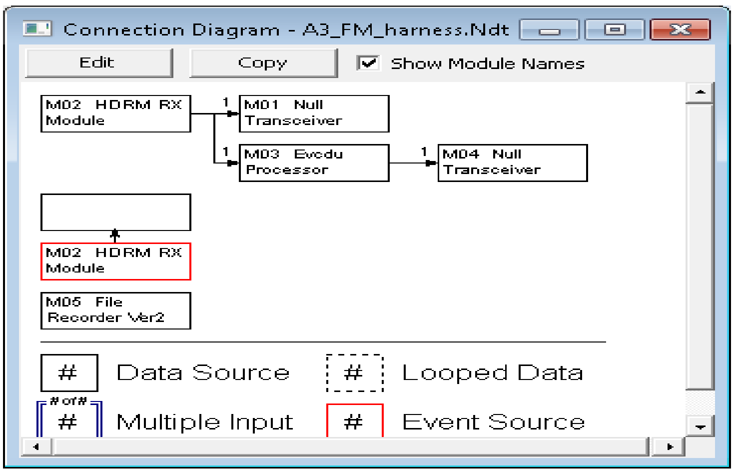

Figure 9. LAPAN-A3 system scheme module grooves on Demod HDRM [9].

3. Results and analysis

For the configuration at 5.4m antenna the first things should do is to add LAPAN-A3 Satellite schedule for tracking activity, because the satellite in polar orbit which is moving from the North Pole to South Pole of the Earth depending the day-night time when the satellite is passing above Groundstation. For configuration editor program for input of RF setting for LAPAN-A3 Satellite which as center frequency is 8200 MHz (8.2GHz) and polarization is Left Hand Circular Polarization (LHCP).

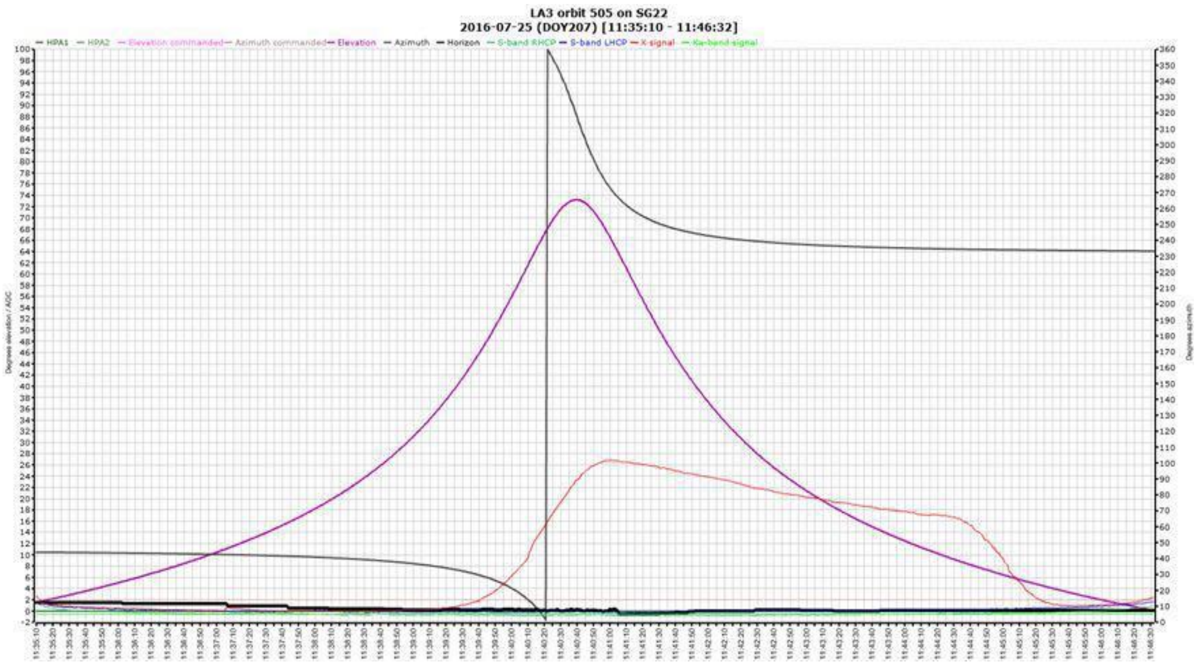

Figure 10. X-Band signal LAPAN-A3 Satellite acceptable received.

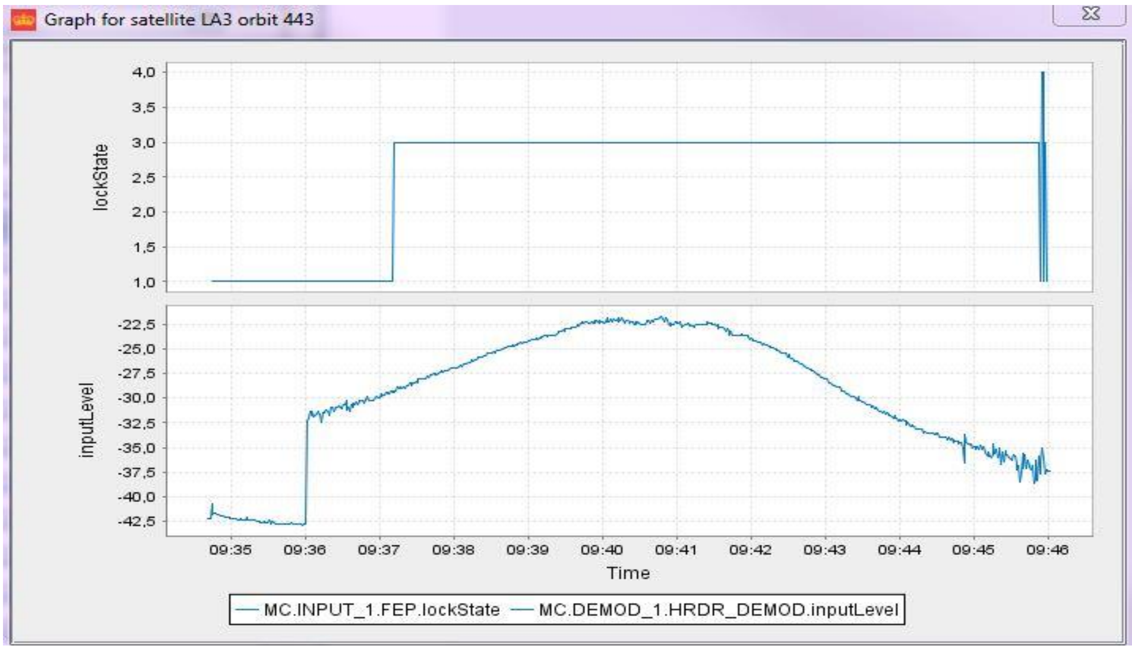

Figure 11. Locked signal X-Band LAPAN-A3 Satellite.

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The result of receiving X-Band Signal of LAPAN-A3 Satellite for acceptable condition is shown in figure 10 and figure 11. Which as in figure 10 is a data for a movement of antenna azimuth and elevation when tracking a satellite and also a data when a signal X-Band is receive in receiver or spectrum analyzer. Figure 11 describes for signal lock on receiver, from the data we can see for locking signal condition is start from around -30 dBm and lost at -35 dBm, this data is get when using a 11 meter of diameter in Splitzberg Groundstation in Norway.

For this experiment we used a 5.4 meter of diameter for receive a signal X-Band from LAPAN-A3 Satellite, for controlling an antenna movement is using a program at Antenna Control Unit. This program can track a satellite position and directed an antenna pointing to that position, this means that a azimuth and elevation of antenna is a same position with LAPAN-A3 Satellite.

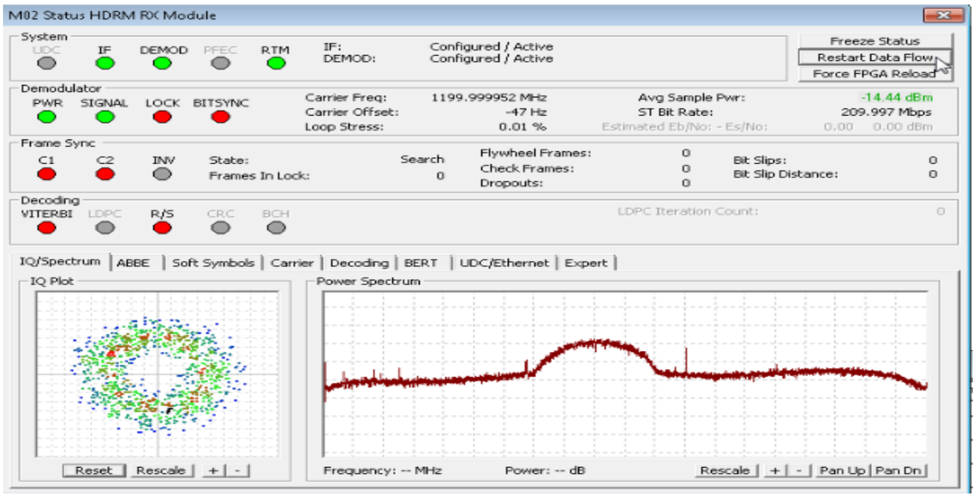

Figure 12. Received signal X-Band LAPAN-A3 Satellite in HDRM.

The result for this experiment with using 5.4-meter diameter is shown on figure 12 and figure 13. Which as in figure 12 is signal receive in HDRM receiver, the status for receiving signal is the HDRM can detect a signal from a satellite (this show on indicator signal in demodulator turn on) this result is not enough for HDRM to demodulate a signal and to decode. The same result is also shown when used a spectrum analyzer for see a signal strength, the signal receive is below from -35 dBm this meaning a signal receive with 5.4 meter diameter is not enough for HDRM receiver to lock a signal.

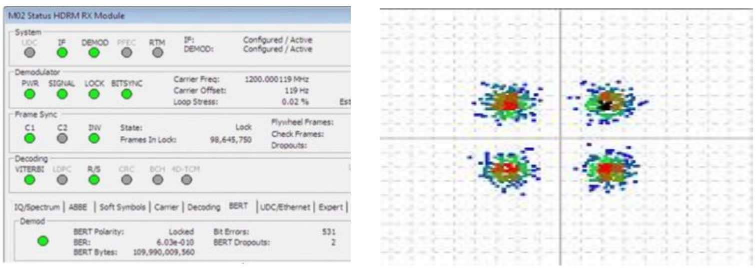

Figure 13. HDRM Status Signal Condition For Demodulate X-Band Signal.

For condition how to HDRM receiver can modulate and to decode a signal is shown in figure 13, When indicator is on (turn green) this mean a HDRM can demodulate and decoding a signal and its shown a QPSK signal condition is how to be. The QPSK signal is in locking condition is located to 4 position in diagram whereas in not locking condition a QPSK signal is in circular shape in diagram.

4. Conclusion

Quadrature-phase shift keying (QPSK) is a form of phase-shift keying in which four different phase angles are used [7]. In QPSK, the four corners are usually separated by 90° spacing [8]. LAPAN-A3 Satellite is using QPSK for modulate a signal, and for receive this a Groundstation used a HDRM receiver. At the end, we compare a receiving signal X-Band of Satellite LAPAN-A3 with 11 meter diameter antenna in Splitzberg Norway and antenna 5.4 meter of diameter in LAPAN Pare-Pare Groundstation. The best result is get from antenna 11 meter, the signal more than enough to reached minimum signal for demodulate data, but for 5.4 meter antenna a signal can be receive but not enough for HDRM receiver to demodulate it, that's why in this experiment with using 5.4 meter antenna the result is cannot be used.

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References

[1] Hasbi W and Suhermanto 2013 Development of LAPAN-A3/IPB satellite an experimental remote sensing microsatellite **34** 1508-1515
[2] Harsono SD and Suhata 2015 Analysis of Transmission System and Receiver Satellite Data LDCM based High Data Rate Modulator *Aeronautics and Space Technology, Research and Engineering of UAV, Rocket, and Satellite* 140–149
[3] Dankberg MD 2017 5.4 Meter Fixed X-Band Tracking System: Operation and Maintenance. Carlsbad (California: ViaSat)
[4] Atayero AA, Luka MK, and Alatishe AA 2011 Satellite Link Design: A Tutorial *Inter. Jour. of Elect. and Comp. Sci.* **11**(4)
[5] Judianto CT and Nasser EN 2015 The Analysis of LAPAN-A3/IPB Satellite Image Data Simulation Using High Data Rate Modem. *Procedia Environ. Sci.* **24** 285–296
[6] Judianto CT and Wurianto E 2014 Analisis Potensi Gangguan Interferensi Microwave Link Terhadap Operasi Satelit Lapan-A3 *Jurnal Teknologi Dirgantara* **12**(1) 59-72
[7] Asif R and Haithem M 2017 10 Gbit/s mode-multiplexed QPSK transmission using MDM-to-MFDM based single coherent receiver for intra- and inter data center networking *Opt. Commun.* **391** 106–110
[8] Branning T 2010 High Data Rate Modem: Operations and Maintenance Manual. Chantilly (Virginia: Avtec Systems, Inc.,)
[9] Branning T 2011 Kratos Company September 2011 Programmable Telemetry Processor : User Guide. Chantilly (Virginia: Avtec Systems, Inc.,)
[10] Branning T 2013 HDR-8SE-64R10: Configuration & Installation Document. Chantilly (Virginia: Avtec Systems, Inc.,)