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2.22 GHz S-Band Helical Antenna Design for Earth Surveillance Lapan-Tubsat Data Acquisition in Indonesia Regional Security

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Abstract

It is necessary to have a LAPAN-TUBSAT (Institute of Aeronautics and Space - the Technische University of Berlin Satellite) satellite data-receiving system that is low-cost and can be placed in various parts of Indonesia. This system will later spearhead the data receiver and this meets all areas detected by the earth surveillance method in real-time and can be recorded at the Earth Station. By using a helical antenna that is engineered independently with the rules of the S-Band at 2.22 GHz, it will be able to control the Indonesian region. The Design will be acquisition of the data from a satellite, and with the helical antenna. The Helical that by the requirement of the 2,22 GHz design. With the LHCP (Left Hand Circular Polarization) and with a bandwidth of 27 MHz. for the antenna parabola as a catcher of signal from the satellite we use the type of Prime focus which is the point focal in the central face of the parabola and we will put feed Horn that includes inside is the Helical feed antenna. The antenna has a specification movement is 0,25 degrees per second with the successful engineering of the development of the Helical antenna, it can also later apply it to various other satellites with adjustments to the dimensions of the antenna only and the receiving system.

Keywords: *Helical Antenna; S-Band; Earth Station*

1. Introduction

Indonesia is an archipelagic country that stretches from 95 degrees East Longitude to 141 degrees East Longitude and 6 degrees North Latitude to 11 degrees South Latitude, with around 17,000 islands and is flanked by 2 continents and 2 oceans (Lasabuda, 2013). Indonesia is at an important crossroads in terms of geography and astronomy. With so many ALKI and Choke Points, making Indonesia an important shipping route between countries. Based on the Djuanda declaration, states that the Indonesian sea is the surrounding sea, between and within the Indonesian archipelago into a unified territory of the

Republic of Indonesia (Nurhidayati, 2016). With abundant resources, the great potential contained in the territory of Indonesia is very important to defend, where defense and security are the main things to form a force that must be able to deter, fend off, and defeat these threats. Under the mandate of the 1945 Constitution, namely protecting the entire Indonesian nation and all of Indonesia's bloodshed, promoting public welfare, educating the nation's life, and participating in carrying out world order based on freedom, eternal peace, and social justice, which is always realized in the life of society, nation and state (Preamble to the 1945 Constitution of the Republic of Indonesia). Furthermore, our Defense Industry promotion program is capable of formulating defense policies and being able to apply the Defense Industry concept with a national and international perspective that can also keep up with the times and innovate, as well as carry out modernization (Law No. 16 of 2012). Mastery from upstream to downstream directly or indirectly makes us an independent country in science and technology by the mastering of steel technology, electronics, information and communication, automation, and big data (Ministry of Defense, 2015).

The development of land and sea surveillance technology in Indonesia continues to develop, including the use of earth surveillance technology, satellite development technology which began in the SKSD era, and Communication satellites in 1976 we continue to grow until Micro satellites such as the LAPAN TUBSAT satellite. LAPAN TUBSAT is a micro-satellite resulting from a collaboration between LAPAN and Technische University Berlin (TU Berlin). The satellite was launched into orbit on January 10, 2007, using the Polar Satellite Launch Vehicle (PSLV) along with the Cartosat-2 satellite payload and the Indian Space Space & Research Organization's (ISRO)'s Spacecraft Recovery Experiment (SRE) and Argentina's Pneumsat from the Satish Dawan Space Center (SDSC), Sriharikota, India. This satellite has a payload of 2 cameras that will be used to take pictures of the earth's surface and the resulting video data is transmitted to the ground station in real-time. The results of both analog video format cameras at the S-Band frequency of 2220 MHz with FM video modulation. The RF signal transmitted from the satellite is then received at an earth station that has an S-Band receiving system (Jagdish, 2008).

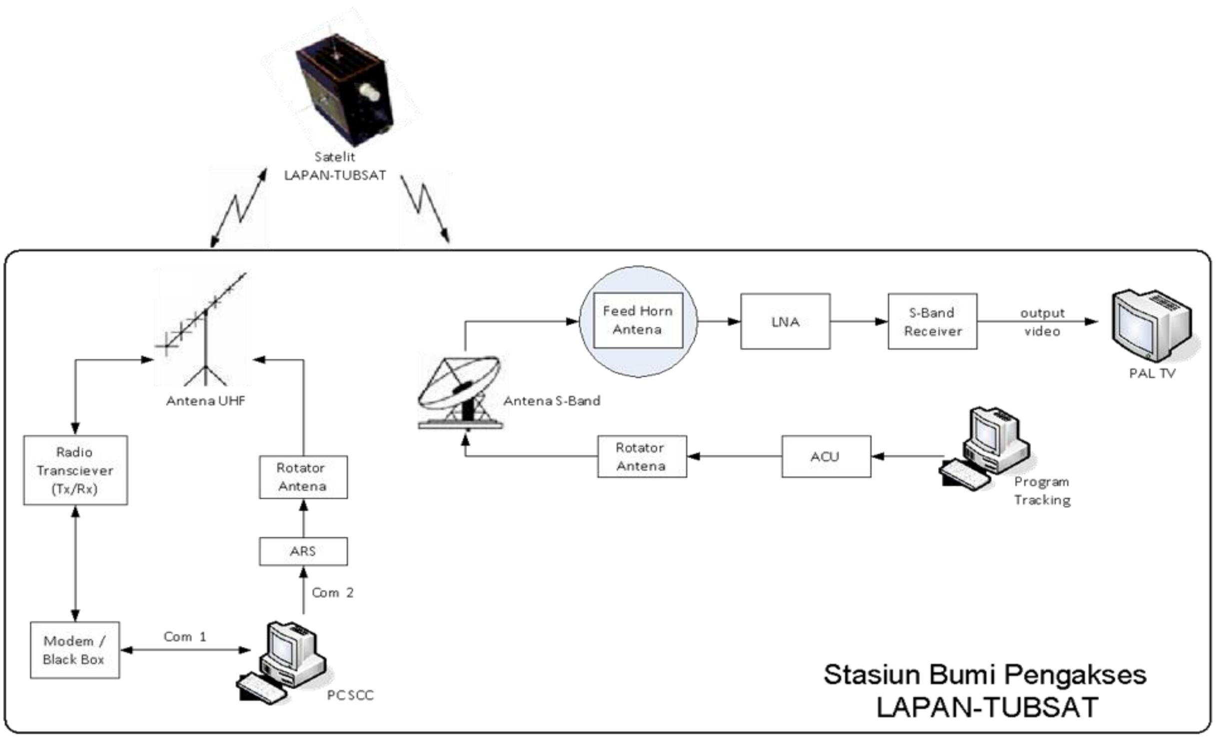

Figure 1. Block Diagram of Lapan-Tubsat Accessing Ground Station.

Due to the limited coverage of the LAPAN-TUBSAT satellite antenna, in the process of controlling and receiving video images, several earth stations with different geographical locations are needed so that the entire territory of the Republic of Indonesia is within the coverage area of LAPAN-TUBSAT operations. The need for these results supports the supervision of Indonesia's state security. The LAPAN-TUBSAT accessing ground station must have UHF and S-Band communication systems (Figure 1). UHF communication systems are used in the process of controlling and receiving LAPAN-TUBSAT telemetry data. These systems include UHF sender (Tx) systems and UHF receivers (Rx). LAPAN-TUBSAT operates at 437.325 MHz for uplink and downlink. The S-Band communication system is used in the process of receiving analog video data from the results of the LAPAN-TUBSAT shooting. The system includes an S-Band receiver system that operates at a center frequency of 2,22 Mhz with a bandwidth of 27 MHz (Miranti Siahaan, 2013).

2. Research Method

Engineering activities are carried out in the field of Earth Section, LAPAN Satellite Technology Center. Engineering begins with the design of a helix antenna operating at a center frequency of 2,22 MHz. Then the procurement of materials and supporting components continued with assembly. This prototype will be tested for performance using a parabolic antenna with a certain diameter and an analog video signal transmitted by the LAPAN-TUBSAT satellite (Paul, 2022). To achieve a coherent engineering process, this engineering will be carried out in several stages, namely:

a) Literature studies and helix antenna studies. In this engineering, it uses the base helix antenna as a feed horn in the LAPAN-TUBSAT video receiver system, so it is necessary to study and study what parameters affect the performance of the helix antenna;
b) Helix antenna design. Helix antenna as feed horn is designed to be able to work at 2,220 MHz middle frequency, 27 MHz bandwidth, and LHCP circular polarization;
c) Designing an antenna system with a helix as a feed horn and a parabolic antenna. The receiving antenna system that combines helix as a feed horn on a parabolic antenna is designed to be able to work at a center frequency of 2,220 MHz, a bandwidth of 27 MHz, polarization of LHCP, and a gain of at least 10 dB;
d) Helix antenna assembly. The components of making helix antennas are assembled according to the design that has been made according to the material and design of the literature and structure of the helix antenna;
e) Assembly of the LAPAN-TUBSAT video receiving antenna system. Pre-assembled helix antenna, combined with a parabolic antenna as well as other supporting components (cable, LNA, S-Band video receiver);
f) Testing of LAPAN-TUBSAT video receiving antenna system. The LAPAN-TUBSAT S-Band video receiving antenna system consisting of a combination of the helix as a feed horn and a parabolic antenna coupled with supporting components is tested for performance using direct signals from DFS and LAPAN-TUBSAT satellites; and
g) Study of the influence of the parameters of helix antennas and parabolic antennas. The helix parameters to be engineered are diameter (D), number of winding (N), and space between windings (S). While the parameters of the parabola are diameter (d) and focal distance (f). The combination of these parameters is expected to produce the best-performance LAPAN-TUBSAT video receiver system (highest linking).

3. Result and Discussion

From the results of this engineering, it is expected that the condition of the helix antenna parameter as a feed horn on the most optimal parabolic antenna is obtained. So that this prototype can be used by LAPAN to receive LAPAN-TUBSAT S-Band video data. From this engineering, it is also hoped that LAPAN will have independence in mastering the technology of earth sections, especially antenna subsystems. The results that have been achieved from this engineering activity have only reached the stage of literature study, helix antenna design, and antenna system design with helix as a feed horn of a parabolic antenna. For the procurement stage of raw and supporting materials to date is in progress. Meanwhile, the assembly and testing phase has not been carried out until now, and it is planned to be carried out in the second phase. The following is a description of the results that have been achieved.

Helix Antenna

Antennas are an important part of an earth station. The antenna is a component that functions to receive electrical vibrations from the sender (Tx) and emit it as radio waves. It also functions the other way around, accommodating radio waves and passing the electric boom to the receiver (Rx). Antennas were first used by Heinrich Heirtz in 1889 to prove the existence of electromagnetic waves.and Electromagnetic signals are emitted through the air in 2 polarizations, namely linear polarization (vertical or horizontal) and circular polarization (RHCP-Right Hand Circular Polarization or LHCP-Left Hand Circular Polarization).

Helix antennas have several advantages, including having wider bandwidth, easy manufacturing, and can generate and receive elektromagnetic waves with circular polarization. This can be utilized in satellite communication systems. This helix antenna (Figure 2) can also be used as a feed horn for a parabolic antenna so as to produce a higher gain. The combination of the helix horn feed and the parabolic antenna results in a receiver system with high gain and can capture electromagnetic waves by circular polarization. The disadvantage of this combination is the limitation of the type of circular polarization that can be captured, only for one type of circular polarization, RHCP only or LHCP (Krauss, 2022).

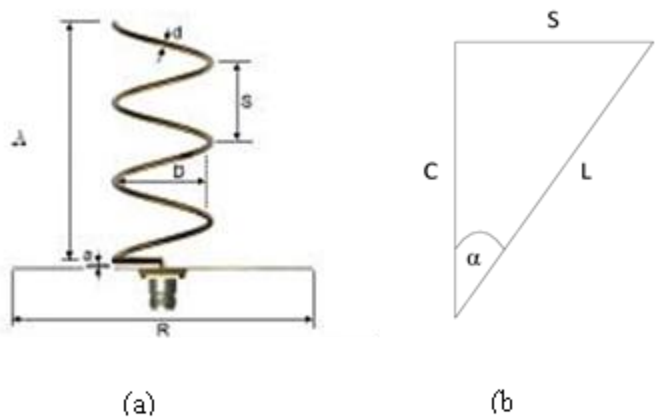

Figure 2. (a) Dimensions of helix antenna (b) Relationship between C, S, L, and α.

Helix antennas have several important parameters, namely: antenna diameter (D), helix circumference (C), space between windings (S), number of windings (N) and antenna height (A).

$$\lambda = \frac{c}{f} \quad (1)$$

$$D = \frac{\lambda}{\pi} \quad (2)$$

$$C = \pi D \quad (3)$$

$$A = nS \quad (4)$$

$$S = 0{,}225C \quad (5)$$

$$d = \frac{\lambda}{100} \quad (6)$$

$$R_{min} = \frac{3}{4}\lambda \quad (7)$$

$$a = \frac{R_{min}}{2} \quad (8)$$

With:

c	= speed of electromagnetic waves (c = 3 x 10^8 m/s)
λ	= wavelength (m)
f	= center frequency (Hz)
D	= helix diameter (m)
C	= circumference of helix (m)
π	= circle parameter ($\pi = 3{,}14$)
S	= *pitch angle* ($arctan \frac{S}{\pi D}$)
L	= length 1 winding
n	= number of windings
A	= antenna length (m)
d	= diameter of conductor (m)
R_{min}	= minimum diameter of *ground plane* (m)
a	= distance between *ground plane* and conductor (m)

There are several important parameters that affect the performance of axial mode helix antennas, namely beamwidth, gain, impedance, and axial ratio. Beamwidth and gain are interdependent parameters ($G \propto \frac{1}{HPBW^2}$), while the other parameters (impedance and axial ratio) are a function of the number of windings (n), pitch angle (α), and frequency (f) (Kraus, 2021). The relationship between these parameters can be seen in the following equations.

$$\begin{cases} E = \left(sin\frac{90^o}{n}\right)\frac{\sin\left(\frac{n\psi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)}cos\emptyset \\ where\ \psi = 360^o\left[S_\lambda(1-cos\emptyset)+\frac{1}{2n}\right] \end{cases} \quad (9)$$

Beamwitdth, $HPBW = \frac{52^{o}}{C_{\lambda}\sqrt{nS_{\lambda}}}$

(10)

Directivity, $D = 12C_{\lambda}^{2}nS_{\lambda}$, on condition: $0{,}8 < C_{\lambda} < 1{,}15;\ 12^{o} < \alpha < 14^{o}, n > 3$

(11)

Resistance (axial feed), $R_s = 140C_{\lambda}$, on condition: $0{,}8 < C_{\lambda} < 1{,}12;\ 12^{o} < \alpha < 14^{o}, n \geq 4$

(12)

Axial Ratio (increased directivity), $AR = \frac{2n+1}{2n}$

(13)

Helix Antena Design

Using the reference equation (1) to (9), a helix antenna design was made that could operate at a middle frequency of 2,22 MHz with a bandwidth of 27 MHz. There are conditions that limit the design process, namely $0{,}8 < C_{\lambda} < 1{,}15;\ 12^{o} < \alpha < 14^{o}, n > 3$ and $0{,}8 < C_{\lambda} < 1{,}12;\ 12^{o} < \alpha < 14^{o}, n \geq 4$ for parameters and is specifically restricted to this designing process. The calculation results of the helix antenna design process are:

From equation (1) obtained $\lambda = \frac{c}{f} = \frac{3 \times 10^{8}}{2{,}22 \times 10^{9}} = 135\ mm$

From equation (2) obtained $D = \frac{\lambda}{\pi} = \frac{13{,}5}{3{,}14} = 43\ mm$

With $C = \lambda = 135\ mm, n =$ 4, equation (5) is obtained $S = 0.225C = 0.225 \times 135 = 30.375\ mm$

From equation (6) obtained $d = \frac{\lambda}{100} = \frac{135}{100} = 1.35\ mm$

The results of the calculation of the diameter of this conductor material must be adjusted to the availability of raw material specifications on the market.

From equation (7) obtained $R_{min} = \frac{3}{4}\lambda = 101.25\ mm$

The calculation results for the diameter of *the ground plane*, obtained a minimum value of 101.25 mm. So that in the process of designing a helix antenna, a circular raw material with a diameter greater than 10.125 cm will be used.

From equation (8) obtained $a = \frac{R_{min}}{2} = 50.625\ mm$

The distance between the ground plane and the first conductor winding is 5.0625 cm. While the electronic design, covering beamwidth, gain, and resistance using equation (10), equation (11), and equation (12) will get the following results.

$$HPBW = \frac{52^o}{C_\lambda\sqrt{nS_\lambda}} = \frac{52^o}{1\sqrt{4 \times 0.225}} = 54^o$$

$$D = 12C_\lambda^2 nS_\lambda = 12 \times 1^2 \times 4 \times 0.225 = 10.8\ dBic$$

$$R_s = 140C_\lambda = 140 \times `1 = 140\ \Omega$$

This *D value (directivity*) can be used as a reference for the gain value of the helix antenna as a result of the design, assuming there are no losses. From this statement, it can be interpreted that the gain (*gain*) of this helix antenna is in the range of 10 dB.

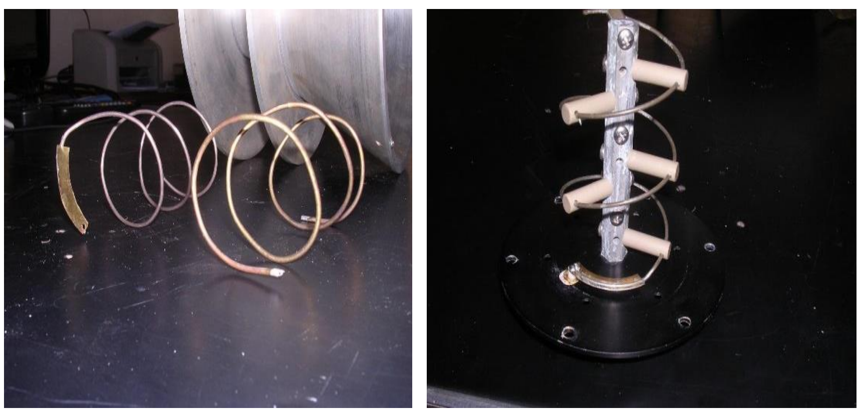

Figure 3. Design Helix Antenna Model

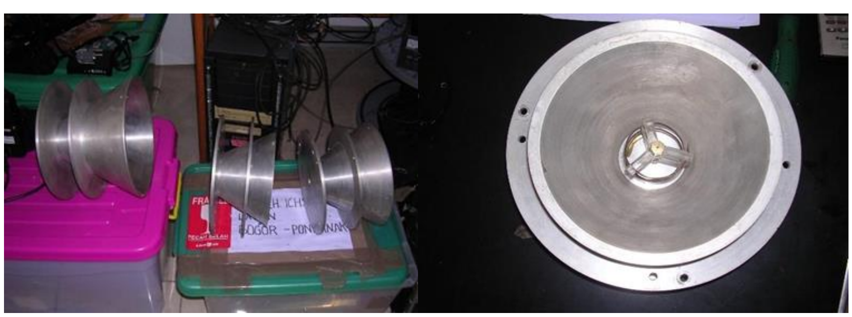

Figure 4. Model Desain Antenna Helix and Feedhorn

Designing an antenna system with helix as a feed horn and parabolic antenna

The basic characteristic of a perfect parabolic reflector is that it converts a spherical wave shining from a point source placed in focus into a planar wave. Instead, all the energy received by the parabolic disk from a distant source is reflected all the way to a point in the focus of the parabola. The dimensions of the satellite dish are the most important factor because they determine the maximum gain that the antenna can obtain at a frequency and beamwidth used. The dimensions of the parabolic antenna can be seen as shown in figure 5 below.

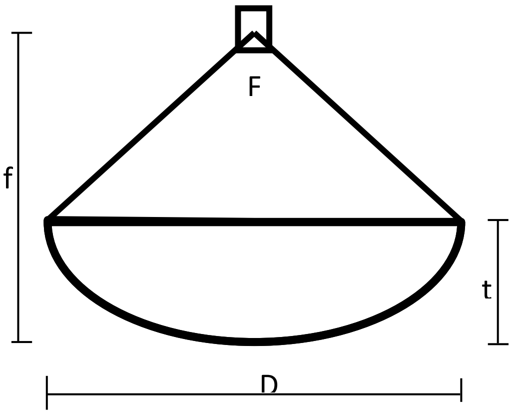

Figure 5. Parabolic antenna parameters

The design process of the LAPAN-TUBSAT S-Band video receiving antenna system is carried out by placing the helix antenna as *a feed horn* mounted right at its focal point (f), resulting in the best signal gain. The parabolic antenna used is a modification of the C band antenna which was originally designed to be static, then modified to be able to move using a rotator, with a diameter of 1.8 m and 2.4 m.

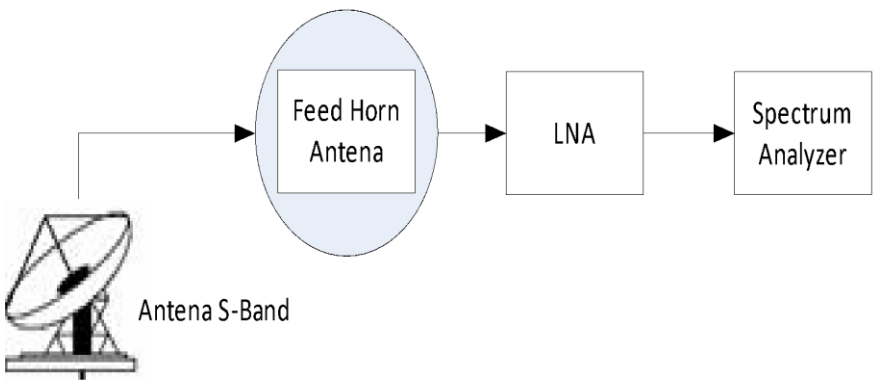

Figure 6. Test configuration of the receiving antenna system

With the configuration as in Figure 6 above, it is expected that the signal detected on the spectrum analyzer has a minimum value of -60 dBm, so that the video data received has good image quality.

Figure 7. Install Feed Horn on Parabola

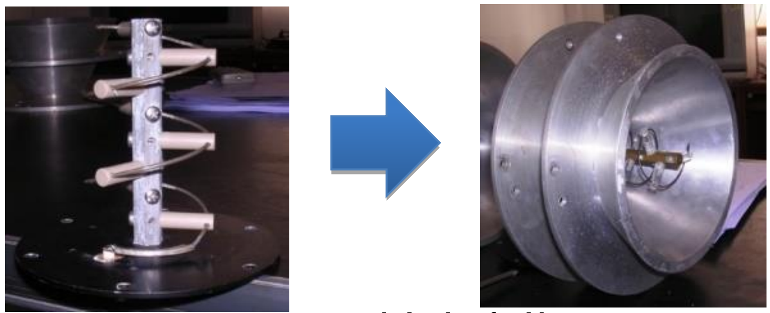

Figure 8. Integration helical to feed horn.

As the signal catcher helical will be integration to the feed horn that can more increase the aqusition sensitivity. And it as the final work after we test the performance.

Conclusion

The conclusion that can be drawn from this first phase of engineering activities is that the design of using helix antennas as feed horns for the LAPAN-TUBSAT video receiving antenna system can be implemented to participate in supervising the territorial sovereignty of the Republic of Indonesia. With this combination, it is expected to produce a large reinforcement. This design is only limited to be used to receive S-Band signals from LAPAN-TUBSAT. The long-term targets are: Build the ability for the LAPAN-TUBSAT satellite receiver system with independence; Fostering human resource capabilities in the engineering of antenna systems; Documenting the technical results of the LAPAN-TUBSAT Satellite receiver system; and build a state defense system that can monitor the territory of the Republic of Indonesia. Based on the experience felt by the ground station team, PUSTEKSAT is expected to have an antenna laboratory and mechanical equipment to make modifications if needed such as lathes. In addition, LAPAN requires a minimum of 5 earth stations that operate regularly and are geographically distributed, so that all areas of the Republic of Indonesia can be included in the coverage area of LAPAN-TUBSAT shooting.

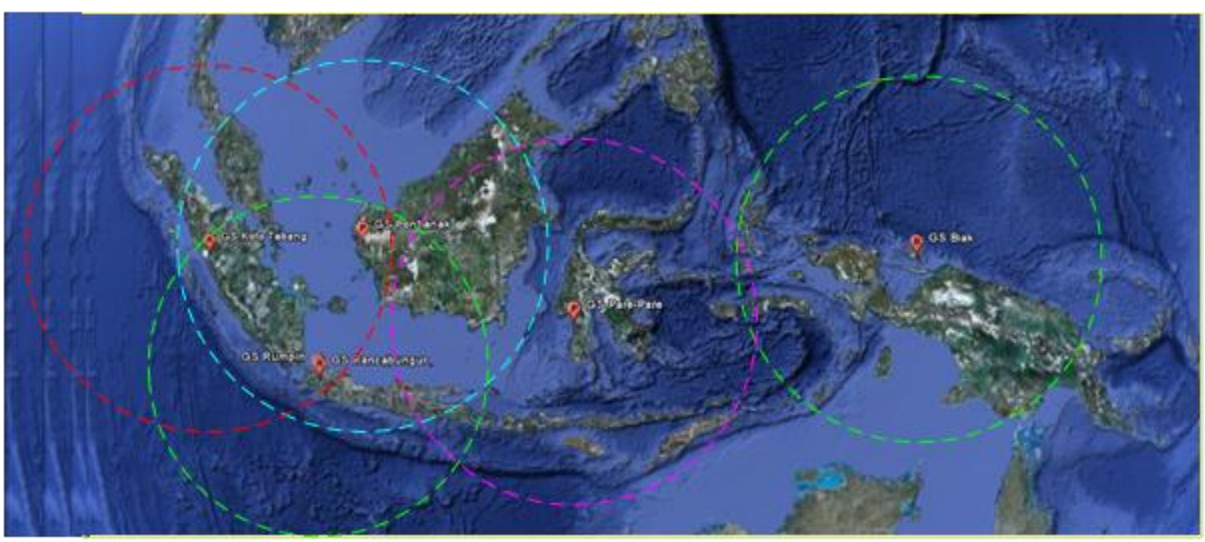

Figure 9. Proposed Earth Station.

Examples of data acquisition area development that can be monitored by LAPAN-TUBSAT satellite and with data acquisition by Helical antenna:

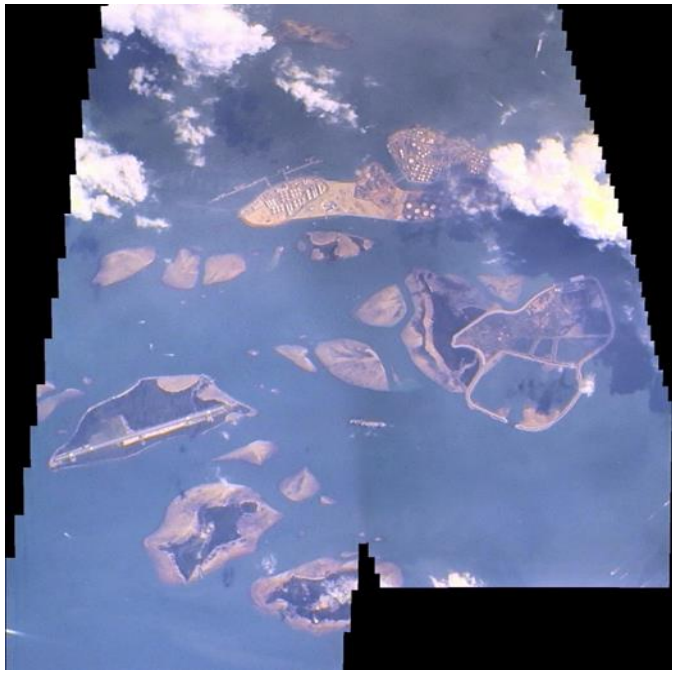

Figure 10. Earth Surveillance data acquisition results.

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