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Satellite data receiving antenna system for pleiades neo observation satellite

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Abstract. Pleiades Neo Satellite is a future optical remote sensing satellite designed for launch in 2020 with a very high spatial resolution of up to 30 cm and consists of 4 constellation satellites to continuing Pleiades-1A/1B constellation. Pleiades Neo capable of producing high temporal resolution (revisit time) in one day to collecting imagery at the same location and its performance claimed will increase up to three times when compared to the Pleiades-1A/1B constellation. LAPAN, as the main official provider in high-resolution optical satellite data in Indonesia, has planned to receive the Pleiades Neo data. This paper discusses the antenna system for receiving Pleiades Neo data by LAPAN's remote sensing ground station with analyzing the main antenna parameter requirements if Pleiades Neo will be received on Zodiac or Viasat antenna. By calculating the Carrier to Noise Ratio (C/N) value both of antenna system and compared with Airbus Defense and Space minimum C/N requirement about 13.8 dB at 5-degree elevation. The simulation result is obtained C/N value 14 dB and 6.5 dB on Zodiac and Viasat antenna, respectively. Based on the result analysis, it is found that the Zodiac antenna system is recommended for the Pleiades Neo data reception system.

1. Introduction

The utilization of satellite imagery data is a priority need in various sectors such as development, health, economy, and various other fields [1]. Based on the 2013 Space Law, article 20 states that the National Aeronautics and Space Agency has to provide satellite image data. Satellite image data acquired by the National Aeronautics and Space Agency (LAPAN), especially the Center for Remote Sensing Technology and Data (Pustekdata), is divided into several resolutions, i.e. low resolution, medium resolution, high resolution, very high resolution optical, and very high-resolution SAR [2]. The utilization of satellite data in the development sector, especially in high and very high resolution, is one of the national priority activities, including Detailed Spatial Planning, Mapping of industrial estates, and regional borders [3]. Following Presidential Regulation Number 79 of 2018 regarding national priority programs in the field of regional development directed at development in border areas, village development, agrarian reform, disaster prevention, and management, and acceleration of development, LAPAN has a mandatory and responsibility to provide satellite data for detailed map development with scale of 1: 5000 were it scale can be achieved using very high-resolution satellite data [1].

Until now LAPAN has been providing very high-resolution satellite data including Pleiades-1A/1B (0.5m), Quickbird (0.5m), GeoEye-1 (0.41m), Worldview-2 (0.46m), and Worldview- 3 (0.31 m). In the data provided, LAPAN makes provision through satellite data procurement and conducts direct acquisition systems with satellites and satellite data service providers for each satellite.

2. Satellite Parameters

Pleiades Neo is Airbus' satellite which will be launched in 2020 and 2022 and has 4 satellites. The whole system of Pleiades Neo consists of two parts, namely a constellation of four identical very high-resolution optical satellites and a ground segment used to manage and optimize constellation assignments, receive, reference, and store collected data, processing data into image and information products, and keeping the constellation in operational condition.

What is new to the ultra-high-resolution satellite, Pleiades Neo relates to orbital characteristics and satellite viewing capabilities, state-of-the-art instruments, increased on-board storage, increased assignment capabilities, increased return visits, faster collection of areas of interest, availability faster, and cutting edge ground segment. The detailed specifications are shown in (Table 1).

Table 1. Pléiades Neo technical specifications [4]

Features	Pleiades Neo
Number of satellites	Four (2 pairs) identical satellites in the constellation
Launch time	Mid 2020 for the first 1 pair, April 2022 for the second pair
Altitude	620 km
Orbit	Sun-synchronous, 10:30 AM descending node, phased-in quadrature
Spectral Bands	Pan: 0.45-0.80 um; Deep Blue = 0.40-0.45 um, Blue = 0.43-0.52 um, Green = 0.53-0.59 um, Red = 0.62-0.69 um, Red-Edge = 0.70-0.75 um, Near Infrared = 0.77-0.88 um
Ground Sampling Distance (nadir)	Panchromatic 0.3m Multispectral 1.2m
Revisit capacity	At least twice daily with the angle of incidence extended, increasing with latitude At least once a day with an angle of incidence below 30 degrees, increasing with latitude.
Instrument TM Link Level	1.2Gbps dual polarity
Mission lifetime	Minimum 12 years (10 years for each satellite)

3. Prediction Analysis

3.1 Data

The parameters used in this study is Pleiades Neo satellite technical data shown in table 2. It refers from Airbus Defense and Space. The Pleiades Neo satellite is a new generation satellite from the previous version, namely Pleiades-1A/1B. The Pleiades Neo satellite has 4 satellite constellations, namely Pleiades Neo 1 to 4. The Pleiades Neo satellite has 3 downlink channels on each satellite. With an EIRP of 17 dB, and an altitude of 620 km, each of these satellites has a modulation of type 8PSK. Where the EB/No value of satellite is 10.5dB.

3.2 Algorithm

3.2.1 *Error Control Coding.* Error Control Coding is a control for damage or error reading of information bits received on the demodulator device [6]. The formula based on Equation (1).

$$\text{Data Rate} = \log 2\ (\text{Modulation}) * \text{Bandwidth} \quad (1)$$

Table 2. Pleiades Neo downlink parameters prediction [5]

No	Parameters	Pleiades-1A/B	Pleiades Neo*(based on Airbus Defense and Space)
1	Apoge & Perigee	694 km	620 km
2	Inclination	98.3 Degree	97.9 Degree
3	Carrier Frek Ch 1	8165.5 MHz	8183 MHz
4	Carrier Frek Ch 2	8295.5 MHz	8313 MHz
5	Carrier Frek Ch 3	8353.5 MHz	8371 Mhz
6	Bandwidth Ch1, Ch2, Ch3	105 MHz total 315 MHz	108 MHz total 324 MHz
7	EIRP ch 1,Ch2,Ch3	17 dB	17 dB
9	Modulation	8 PSK	8 PSK
10	BER	Min 10E-11	Min 10E-11
11	EB/No with Coding Gain convolutional code	10.5 dB	10.5 dB
12	Data Rate at 8 PSK	155 Mbps single channel	200 Mbps single channel
13	Data Rate at 8 PSK	465 Mbps Full Channel	600 Mbps Full Channel
14	G/T of Zodiac Antenna at 5 degrees	32.67 dB/K	32.67 dB/K
15	G/T of Viasat Antenna at 5 degrees	27.85 dB/K	27.85 dB/K

However, using error control coding can be reduced by multiplying the bit rate by the error control coding so that the bit/data rate or information bit/data can be obtained by data rate formula (Eq. 2).

$$\text{Data Rate} = \text{Modulation} * \text{Bandwidth} * \text{Coding Rate} \tag{2}$$

For data rate, modulation, bandwidth and coding rate in dB.

3.2.2 Slant Range. Slant Range is the distance of the satellite to the ground station antenna as a data receiver. By using the slant range, distance can obtain and analyze further for the parameters related to the system for receiving data from satellites on the ground station. The slant range formula (Eq. 3) used is the slant range distance at an angle of 5 degrees on the ground station antenna can be obtained by using the earth's radius with the earth's center angle and the satellite radius [6-7].

$$s = \sqrt{\text{Rsat}^2 - \text{RE}^2 - 2\text{RsatREcosB}} \tag{3}$$

For S is slant range distance in km, RE is earth radius in km, Rsat is satellite radius in km and B is central angle in degree.

3.2.3 Free Space Loss. Free Space Loss (FSL) is the effect or resistance of electromagnetic waves in a vacuum and the atmosphere from the satellite to the earth station antenna as a receiver, the power lost due to this effect or obstacle is analyzed as the basis for data transmission from the satellite to the ground station [8]. The value of FSL formula (Eq. 4) depends on 2 parameters, i.e. the frequency of the carrier signal from the satellite and the transmission distance from the satellite to the earth station [9].

$$\text{Free Space Loss(FSL)} = 32.44 + 20\log(\text{h}) + 20\log(\text{f}) \tag{4}$$

For FSL is free space losses in dB, h is altitude in km and f is carrier frequency in MHz.

3.2.4 Gain to Noise Temperature. Gain to noise Temperature (G/T) of the antenna gain at the frequency it receives from the satellite and the temperature of its encoding noise in the environment. Formula carrier to noise ratio and G/T can be obtained by using the relationship [6, 13, 17] with G/T formula (Eq. 5) [10].

$$\frac{G}{T} = \frac{C}{No} - EIRP + FSL + K + B \tag{5}$$

For G/T is gain to noise temperature in dB, EIRP is effective isotropic radiated power in dbW, FSL is free space losses in dB, K is Boltzman constant ($1.38064852(79)\times10^{-23}$ J/K) or ($-2.29\times10^{+2}$ dB), B is bandwidth is dB and L is loss margin in dB.

3.2.5 *Carrier to Noise Ratio.* The ratio is a determinant of whether the receiving earth station antenna can receive the signal emitted from the satellite and also the information encoded in the signal can be retrieved. Where the Carrier to Noise Ratio (C/N) is the ratio of the satellite power to scatter the signal to the noise data density on the receiving antenna. C/N formula (Eq. 6) can be calculated by adding energy per bit to noise power spectral density ratio with the bitrate that has been reduced by bandwidth [6] .

$$\frac{C}{N} = \frac{Eb}{No} + Rb - B \tag{6}$$

In case G/T has been already measured, C/N can be calculated by adding EIRP and G/T and then eliminating FSL, loss margin, Boltzman constant, and bandwidth as formula (Eq. 7).

$$\frac{C}{No} = EIRP + \frac{G}{T} - FSL - L - K - B \tag{7}$$

For C/N is carrier to noise ratio in dB, Eb/No is energy per bit to noise power spectral density ratio in dB, Rb is bit rate in dB, EIRP is effective isotropic radiated power in dbW, G/T is gain to noise temperature in dB, FSL is free space losses in dB, L is loss margin in dB, K is Boltzman constant ($1.38064852(79)\times10^{-23}$ J/K) or ($-2.29\times10^{+2}$ dB), and B is bandwidth in dB.

4. Results and Discussion

4.1 Results of Antenna Requirement Analysis for Pleiades Neo Reception

4.1.1 Slant Range. Slant Range is a distance of satellite to ground station antenna as a data receiver. The following are the results of the slant range analysis for Pleiades Neo, which is shown in (Figure 1). The results of the slant range analysis show that at 5 degrees elevation, the value is 2469 km from the earth station antenna. The 5-degrees elevation condition is the minimum elevation condition at the earth station to carry out the data reception process on the antenna below that value, so data reception on the earth station from the satellite will experience multipath fading and be disturbed by objects around the earth station antenna such as trees, buildings, housing, etc. Derived from (Figure 1) the slant range distance value generated by the Pleiades Neo satellite. The Pleiades Neo slant range distance is lower than the Pleiades-1A/1B, which is 2739.62 km.

As shown in figure 2, the FSL of Pleiades Neo satellite at high elevations has lower than Pleiades-1A/1B which has an FSL of -167.8 dB while at low elevations both Pleiades Neo and Pleiades-1A/1B which is relatively the same or not far apart. So that the Pleiades Neo satellite when viewed from a lower slant range and FSL distance allows a greater opportunity for earth station antenna to receive Pleiades Neo data with the similar gound station antenna as Pleiades-1A/1B.

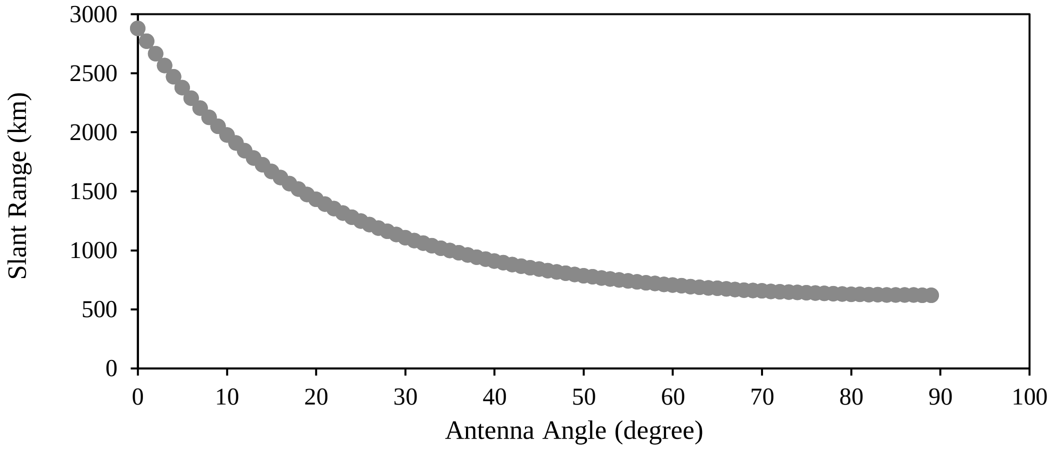

Figure 1. The slant range of Pleiades Neo satellite from parepare ground station antenna

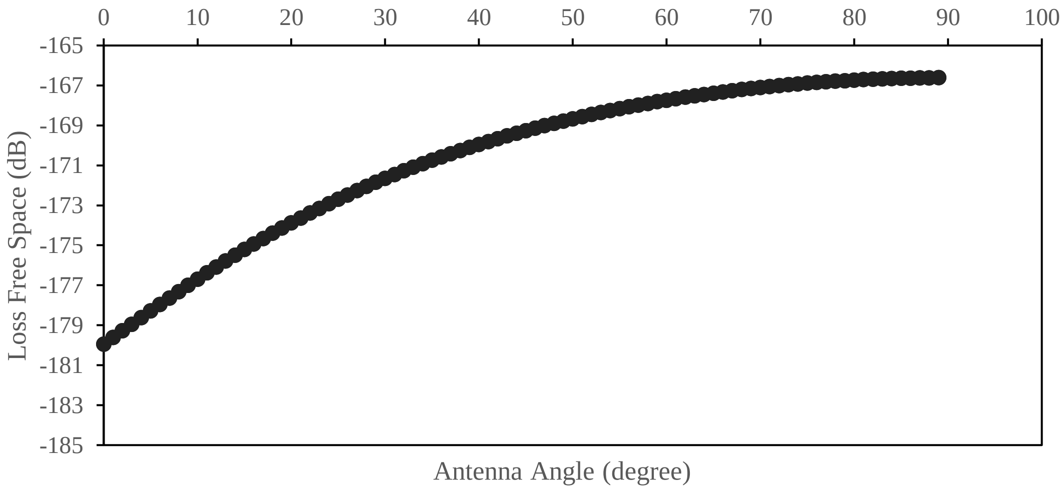

Figure 2. FSL of Pleiades Neo satellite against Parepare earth station antenna

4.1.2 *Gain to Noise Temperature.* Gain to noise temperature of antenna gain (G/T) at the frequency it receives from satellite and temperature of its encoding noise in the environment. Table 3 is shown the G/T antenna value at 5 degrees in each Zodiac and Viasat antenna system after measured. We can see from Table 3 which from two antenna systems, the analysis results show that G/T of the Zodiac antenna system is following recommended criteria for the reception of Pleiades Neo satellite with a G/T value of 32.67 dB/K.

4.1.3 *Carrier to Noise Ratio.* From (Table 3) we can see that the minimum Pleiades Neo satellite G/T is 32.7 dB at 5 degrees elevation of the ground station antenna. Furthermore, based on the Pleiades Neo downlink parameters, we can calculate the C/N. Based on the satellite parameters, i.e. slant range, FSL and G/T from the analysis that has been done, a C/N analysis can be carried out on the type of antenna that will be needed to carry out the process of receiving Pleiades Neo satellite data. C/N is a determinant of whether the receiving earth station antenna can receive the signal emitted from the satellite and also information encoded in the signal can be retrieved. Where the

C/N is the ratio of satellite power to scatter the signal to the noise data density on the receiving antenna. These parameters have been calculated and can be summarized in (Table 4) below.

Table 3. Comparison of G/T in each antenna system

Antenna System	G/T	Unit
G/T Temperature Requirement at 5 degrees	32.7	dB/K
G/T Temperature of Zodiac Antenna System at 5 Degrees	32.67	dB/K
G/T Temperature of Viasat Antenna System at 5 Degrees	27.85	dB/K

Table 4. Pleiades Neo satellite reception parameters at 5 degrees

Downlink parameter (satellite to the station)	Pleiades Neo	Units
EIRP	17	dBW
Loss Margin	-1	dB
Bolzmant Constant	228	dBW
FSL at 5 degrees	178.279	dB
Bandwidth (B)	108	dB
G/T Temperature	32.7	dB/K
C/N at 5 degrees	13.8	dB
C/N Requirement on Demodulator	13.17	dB

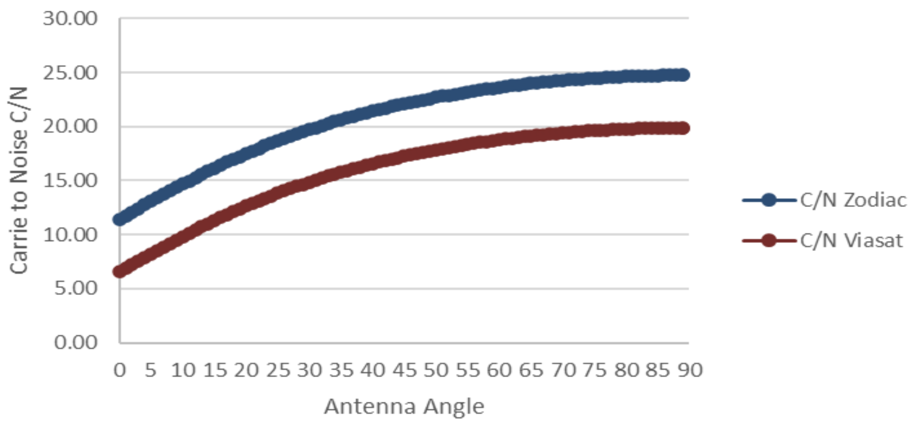

Figure 3. C/N value of Pleiades Neo Satellite on Zodiac and Viasat Antenna

From the results of the carrier to the noise ratio analysis (Figure 3), the C/N value of 13.1 dB was obtained for Pleiades Neo. Where the Pleiades Neo's C/N value is much greater than the Pleiades-1A/1B C/N value, which is only 8.9 dB.

4.2 Results of the Analysis of Pleiades Neo Reception Needs for Zodiac and Viasat Antenna. Based on satellite downlink parameters in (Table 2), it becomes a reference for analyzing precisely the need for G/T on an earth station antenna as a receiver. In this study, an analysis was carried out using two antenna systems, namely the Viasat and Zodiac antenna systems. By using Equation (5), it is produced that at an elevation of 5 degrees the minimum requirement for G/T for Pleiades Neo in the Zodiac antenna system is 32.67 dB/K, while in Viasat antenna system it is 27.85 dB/K. The complete comparison between antenna systems is shown in (Table 3). Moreover, from the results of the C/N analysis, the C/N value of 13.1 dB was obtained for Pleiades Neo. Where the Pleiades Neo's C/N value is much greater than the Pleiades-1A/1B value which is only 8.9 dB as shown in Table 4 It can be seen that from two antenna systems, the analysis results show that G/T and C/N value of the zodiac antenna system is following recommended criteria for the reception of Pleiades Neo satellite with a G/T value and C/N value are 32.67 dB/K and 13.1 dB respectively.

5. Conclusion

From the results of analysis and discussion that has been stated for the overall Pleiades Neo has criteria or characters for reception system that is not much different from Pleiades-1A/1B so that to receive Pleiades Neo, you can use an antenna system that has previously received Pleiades-1A/1B. For the antenna system analyzed in this study using the zodiac and Viasat antenna system. In the results and discussion of C/N for the zodiac antenna system, the value has much different from the C/N requirement on Pleiades Neo compared to the Viasat antenna system. So that from the two antenna systems, it can be concluded that the zodiac antenna system is recommended for the Pleiades Neo reception system. However, this recommendation is still sourced from analysis and analytical simulation of available data, and it is necessary to continue the practical analysis after the Pleiades Neo satellite was launched by related parties.

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