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Measurements of antenna performance ratio using satellite emissions

Arif Hidayat[1]*, Hidayat Gunawan[1],Dedi Irawadi[1], Alfin Hikmaturokhman[2]
[1]Pusat Teknologi dan Data Penginderaan Jauh
[2]Institut Teknologi Telkom Purwokerto

*E-mail arif.hidayat@lapan.go.id

Abstract.Performance of the antenna is parameter in the reception of remote sensing satellite data. Gain to noise ratio becomes one of the variable conditions for satellite data transmitted from transmitters and satellite antennas to be received after power loss in a free space. Remote sensing data reception quality depends on the value of the gain to noise antenna. The Quality gain to noise determines the value of bit energy per noise received in the demodulator. The value of energy bit per noise received by a demodulator corresponds with the required energy bit per noise from modulation systems. Currently gain to noise measurements use the sun, moon, and stars by comparing the power of the transmitter with the received power in the antenna. This measurement takes a time when the antenna is full schedule. The approach in this study uses satellite power distance slant range and carrier to noise received at the receiver. Knowing the elevation angle of the satellite when it passes we can get the slant range. By using satellite transmit power parameters, free space loss, operating bandwidth, and carrier to noise in the receiver, we will find expected gain to noise antenna.The result, measurements using power satellite is success to calculate the gain to noise antenna. This newmethod makes it easier to monitor antenna availability continuously.

1. Introduction

The main role of the antenna in communication radio is to send and receive electromagnetic wave signals [1]. Communication system needs performance test to get the maximum result entire system [2].The communication system requires energy bit per noise (Eb/No) matched with Eb/No in the modulator and receiving signal [3]. To get the required Eb/No, the carrier to noise (C/N) minimum output is required to meet the certain value [4]. The antenna gains to noise (G/T) at the receiver is one of the most important parameters [5]. The gain to noise in the receiver can determine the C/N value[6]. Monitoring of antenna gain to noise is needed periodically so that the entire reception system can run smoothly. By using satellite transmit power parameters, free space loss, operating bandwidth, and carrier to noise in the receiver, we will find expected gain to noise antenna . The correlation between carrier to noise ratio and signal energy bit per noise be seen in equation (1) [6].

$$\frac{C}{N} = \frac{Eb}{No} \cdot \frac{fb}{Bw}, \tag{1}$$

C/N   = Carrier to noise ratio
Eb/No   = Energy bit per noise density ratio
fb/Bw   = Bit rate data per bandwidth

Minor damage to the antenna will affect the gain of the antenna. Gain antenna gain is not maximal in case of damage to LNA systems, RF cables, connectors and other devices. This will affect the total G/T. Remote sensing data reception requires reliable antenna performance. The system failure in receiving remote sensing data is strongly avoided. The antenna condition that needs to be monitored continuously requires periodic measurement of G/T so that the decrease in RF device performances can be known earlier[4].The old method uses measurements based on power emissions from the sun, the moon[7],[8]. The other method is using star power emission[9],[10]. This measurement is done when the antenna is not actively performing satellite tracking. The antenna condition is having a tight tracking schedule; periodic measurements are not possible. To make it easier to get G/T data on a regular basis required new methods of measurement and calculation.

Measurement G/T using solar energy as a reference source has been the standard for a long time. In this research, we will test the new G/T measurement method using Low Earth Orbit Satellite (LEO) power emission.

In general, the measurement process is done by measuring the noise of the antenna when there is no external input power. This noise is called the noise or noise figure system. The antenna measured by obtaining the input of the electromagnetic wave signal from the sun. Using the solar power and wavelength measured antenna we can define the G/T[11].

The LEO satellite also emits electromagnetic waves at a certain frequency. These waves contain information of earth images with low resolution, medium resolution, high resolution or even very high. In this reasearch, we change the input power using the power from LEO satellite."

The system noise temperature consists of the device temperature and the added noise of the surrounding noise. If the antenna system closes with the transmitter the noise of the antenna system will be high[12].
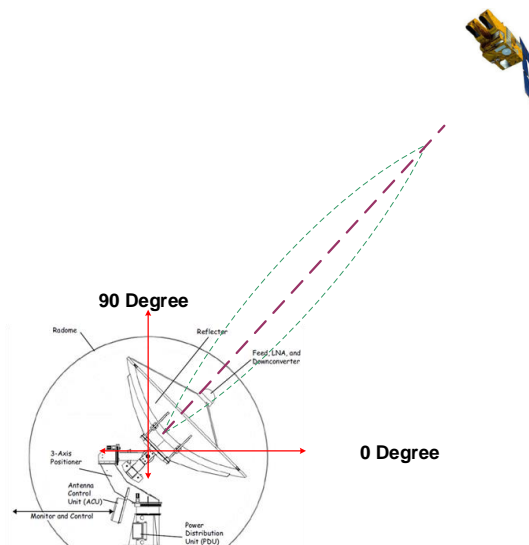

Figure1. LEO Satellite Tracking and Data acquisition

Figure 1 illustrate the antenna measurement method using the power from the satellite, this research use antenna diameter of 3 meters and 5.4 meters. The antenna system track satellite LEO (Low Earth Orbit Satellite). The antenna receives remote sensing satellite data which belongs to the LEO satellite type, this satellite is in orbit of the earth about 400 to 900 km.

Leo satellites have a low distance compared to geostationary satellite. The position of the LEO satellites always moves at a certain angular velocity when observed at the Earth point Ground Station [13]. To get an accurate free space loss is required Slant range calculations can be taken from the antenna elevation angle [14][15].

2. Measurement Method
2.1 Calculating Path (Satellite distance to earth)

To calculate the Loss of free space from the satellite to antenna we need to calculate the distance between satellite to ground station antenna. Since the satellite position of the LEO satellites always moves at a certain angular velocity when observed at the Earth point Ground Station. We will explain with figure
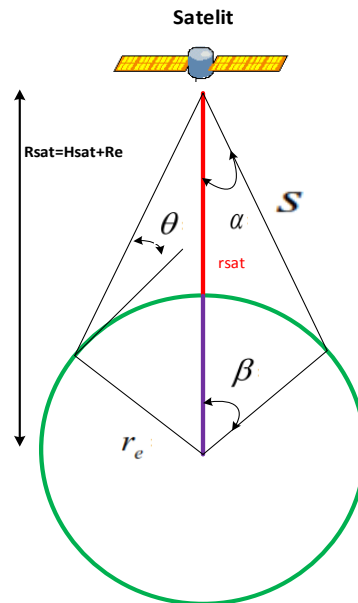

Figure2. Satellite Geometry

Figure 2 show the satellite geometry. We can describe some variable's direction to calculate. The variable are listed below.

α   = nadir angle
β   = central angle
θ   = elevation angle
s   = topocentrict slant range
rsat = geocentric radius of satellite = re + hsat
hsat = altitude of satellite
re   = radius of the Earth

the picture is show the orbit satellite, this system assumptions that all equations assume that the Earth is *spherical*. The basic equations are write below:

$$\theta + \alpha + \beta = 90^o \tag{2}$$

$$s\cos\theta = r_{sat}\sin\beta \tag{3}$$

$$s\sin\alpha = r_e\sin\beta \tag{4}$$

$$s\sin\alpha = r_e\sin\beta \tag{5}$$

$$\alpha = \sin^{-1}\left(\frac{r_e}{r_{sat}}\cos\theta\right) \tag{6}$$

$$\beta = \cos^{-1}\left(\frac{r_e}{r_{sat}}\cos\theta\right) - \theta \tag{7}$$

$$s = \sqrt{r_{sat}^2 - r_e^2\cos^2\theta} - r_e\sin\theta \tag{8}$$

Slant range (s) equation (8) will be used as a free space loss antenna. In sub-chapter will be explained the process of calculating free space loss.

2.2 Loss Free Space

   We need the result of free space loss by calculating the frequency to obtain the equation 10 as in [1], [3], [6], [8]. Loss free space is the loss of waves when it travels in air or vacuum.

$$Lfs = 32.45 + 20\log f + 20 Log D \tag{9}$$

Where

   Lfs   = Loss free space
   f   = Working frequency
   D   = Distance

   We use the distance using the slant range calculation. By put the actual satellite height. Free space loss depends upon frequency and distance. The loss increases with increase in frequency and obviously with increase in distance.

2.3 Carrier to Noise Ratio and Gain over Temperature Noise

   The measurement using a slant range depends on the pointing accuracy of the antenna. At the time of measurement, the antenna is expected to be in 3 dB beam. By pointing the antenna is at 3 dB of loss of power due to a directional error of not less than 3 dB .

      The calculation G/T start with the C/N measurement at the receiver or demodulator. The measurement result put to the analysis calculation and[16] .

$$\frac{C}{N} = EIRP + \frac{G}{T} - Lfs - L - K - B \tag{10}$$

$$G/T = C/N\text{-}EIRP\text{-}G/T\text{+}Lfs\text{+}K\text{+}B \tag{11}$$

Where :

   C/N = Carrier to noise ratio at receiver
   EIRP = Efective Isotropic Radiatic Power
   G/T   = Gain to Noise Temperature
   Lfs   = Loss Free space
   L   = Loss feeder
   K   = Boltzman Constant
   B   = Operational Bandwidth

3. Measurement test using several satellite and antenna

3.1 G./T Prediction Using Satellite Terra And Aqua Signal For 5.4 Meter Antenna

   We analyse G/T antennas using signals from LEO satellites. In this experiment, the antenna used is a 5.4-meter antenna. The satellites used are Terra and Aqua satellites [17], [18].

Table1. G/T Measurement Result Using Leo Satellite at 5.4 Diameter Antenna

Parameters	Terra Satellite	Aqua satellite
EIRP dBW@ 5 degree (dB)	15.81	17.8
Bandwidth (MHz)	60 MHz	15 MHz
Apogee (Km)	704	710
Perigee (Km)	702	708
Elevation Angle Antenna (Degree)	5	5
Azimuth (Degree)	145.443	114.53,
Slant Range Prediction Km (Km)	2665.38	2679.02
C/N Receiver (dB)	14.3	21.04 dB
G/T Prediction (dB/K)	31.60	31.10

Table 1 shows measurement and calculation result for 5.4 diameter antenna. We took measurements using the power meter and spectrum analyser to see the peak power obtained. From the measurement, results obtained C N values are 14.3 for Terra satellites and 21.04 for Aqua satellites. From the results using equations, 10 and 11 we calculated the G / T value. So that the values are 23.30 and 23.90. This value is obtained by using the assumption parameter of cable loss attenuation and 2 dB connector and 1 dB loss pointing. Table 2 shows the satellite in the first row until six row [17], [18].

Table 2. G/T Measurement Result Using Leo Satellite at 3 Meter Diameter Antenna

Parameters	Terra Satellite	Aqua satellite
EIRP dBW@ 5 degree (dB)	15.81	17.8
Bandwidth (MHz)	60 MHz	15 MHz
Apogee (Km)	704	710
Perigee (Km)	702	708
Elevation Angle Antenna (Degree)	5	5
Azimuth (Degree)	253.17	279
Slant Range Prediction Km (Km)	2665.38	2679.02
C/N Receiver (dB)	8.3 dB	15.18 dB
G/T Prediction (dB/K)	23.3	23.90

Table 2 shows the measurement and calculation values using a 3-meter diameter antenna. The satellites used are Terra and Aqua satellites. The results of this measurement show the value of C / N is 8.3 dB for Terrasatellite and 15.18 for Aquasatellite. We use 0.5 dB Error pointing correction factor and 2 dB for loss cable and connector. Here we get G/T prediction at 23.3 dB for Terra and 23.9 for Aqua. From the results of measurements using a source of energy from the sun and compared with the LEO satellite obtained the difference in values as follows.

Table 3. G/T Resultfor 3 Meter and 5.4 Meter

Antenna (meter)	Terra Satellite (dB)	Aqua satellite(dB)
Antenna5.4	31.60	31.10
Antenna 3	23.3	23.90

Table 3 is the calculation and comparison between two antennas 3 meter and 5.4-meter antenna. The 5.4 antenna has the higher gain than 3-meter antenna.

4. Conclusion

From the measurement and calculation, we can conclude that the use of measurement methods using LEO satellites can get the gain to noise parameter of the antenna. The new method can be used as an initial prediction to monitor the antenna's ability to do tracking and acquisition, so this method system can detect anomalies or early damage from the antenna. We can do some measurement periodically using this method during the busy hour antenna.

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