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Analysis the impact of sun outage and satellite orbit at performance of the telkom 3S satellite communication system

Vi Bauty Riska Utami[1], Imam MPB[2], Shinta Romadhona[3*]
[1,2,3] Institut Teknologi Telkom Purwokerto
DI. Panjaitan Street No. 128 Purwokerto, Jawa Tengah, Indonesia
*Corresponding email: shinta@ittelkom-pwt.ac.id

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Abstract — Satellites of communication are located at an altitude of thousands of kilometers above the earth's surface, so the signal is transmitted by satellite to earth station is very susceptible to interference. Every March and September equinox or when the sun crosses the earth's equator for several days, an earth station occurs a natural interference called by sun outage. At this time, satellite and the sun reach the closest distance because satellite's position is in same direction as the sun. This interference makes the signal received by the earth station weaken and even disappear due to temperature noise which increases drastically. Loss of signal on the downlink side caused by noise greatly affects the performance of satellite communication system. This study aims to analyze the impact of sun outage to determine performance of Telkom 3S satellite communication system, and satellite orbit to determine sun outage period. The results obtained that indicate the signal quality is represented by degradation in the Carrier to Noise Ratio (C/N) from 14.777 dB to 6.0 dB, Energy bits per Noise Ratio (Eb/No) from 11.515 dB to 2.738 dB, and increase the Bit Error Rate (BER) from 8.29×10^{-7} to 11.08×10^{-3}. In addition, sun outage makes loss of satellite communication traffic and affecting link availability to 99.855324%. And the last analysis is to calculate the satellite orbit when sun outage occurs. The results of calculation of the satellite orbit for sun outage period based on the ITU-R S.1525 standard are closer to measurement data than based on satellite handbook.

Keywords – Telkom 3S satellite, sun outage, link availability, sun outage period.

I. INTRODUCTION

Satellite communication systems are needed for modern society, because it is a high speed and farther transmission than using fiber optic cables[1].With this main advantage, satellite communication system is very superior to satisfy communication needs, especially in Indonesia. Many companies that utilize this communication technology include banking, insurance, mining, broadcasting, and the backbone network in cellular communications[2]. The application of a satellite communication system as a means of sending and receiving signals is inseparable from serving service needs, for example the application of television, internet, and telephone services such as those of Telkom 3S satellite. Communication satellites are located at an altitude of thousands of kilometers above the earth's surface, so the satellite signals to earth stations are very vulnerable to interference. Sunlight is radiated throughout the spectrum, including to the microwave frequency spectrum (such as C-Band, Ku-Band, and Ka-band) which are used to communicate with satellites and to send electromagnetic radiation to the satellites[3].

Every twice a year and for several days, the receiving of earth station occur an orbital interference called by sun outage or sun transit for several minutes at that time[4]. This interference is caused by excessive solar radiation. In the Northern Hemisphere, sun outage occurs before March equinox (February and March) and after September equinox (September and October), and in the Southern

Hemisphere, sun outage begins after March equinox and before September equinox[3]. During this period, the sun passing through the satellite antenna rays causes the temperature of C-band antenna to increase by 27000°. This is equivalent to increased system noise temperature up to 20 dB and the loss of Carrier to Noise Ratio (C/N) with same number of it[4].

As a result, in addition to partial degradation (increased transmission error) and interference in the form of total signal destruction at earth stations[3]. Sun outage also causes a drastic increase in satellite system noise temperature in the downlink transmission direction which greatly affects to the quality of transmission and limits the availability systems[5]. This study aims to analyze the effect of sun outage by comparing the results calculations during normal conditions and during sun outage. To know the performance of Telkom 3S satellite communication system, the author needs calculation parameters from Carrier to Noise Ratio (C/N), Energy Bit per Noise Ratio (Eb/No), Bit Error Rate (BER), and link availability. Then, to analyze the satellite orbit for determine sun outage period is using two calculation models with manual calculations based on handbook and calculations based on ITU-R S.1525 standard, so can be determine the precision based on the data. This calculations covers affected days, affected minutes, and maximum duration in every equinox.

Sun outage causes the signal received by earth station to weaken and even disappear according to the duration of sun outage. The loss of signal on downlink side greatly affects the performance of satellites and earth stations that are affected by sun outage, such as happened on Telkom 3S satellite. This paper consists of a sixth sections. Section I discuss the background and purposes of research. Then the basic theory about satellite communication system in general, sun outage, and Telkom 3S satellite is contained in Section II. The research method that author use in this paper is discusses in Section III. Section IV discusses the result based on calculations of research. Section V discusses analysis or discussion based on the result, and section VI discusses the conclusion of research.

II. RESEARCH METHODS

This study uses the Jakarta link as the transmitting earth station and Natuna Besar as the receiving earth station. The antenna diameter used in downlink communication is 2.4 meters. This research was conducted by analyzing the quality of communication using link budget calculations during normal conditions, analyzing the impact of sun outage on the performance of Telkom 3S satellite communication system, and analyzing the calculation of satellite orbits when sun outage occurs. The calculations in this study were carried out by comparing manual calculations, using the Satmaster, and based on ITU standards.

A. Sun Outage

The phenomena that occur during equinox are sun outage that occurs between earth and sun, so the sun enters the beamwidth of earth station antenna as Fig.1. Sun outage is interference or distortion of satellite communication signals caused by solar radiation interference. Sun outage causes interference especially to the signal received on the downlink side, which makes satellite services especially on communication satellites disrupted. Sun outage only lasts a short time, sun outage usually occurs daily for about 6 days, and the maximum time for normal sun outage is about 10 minutes[5].

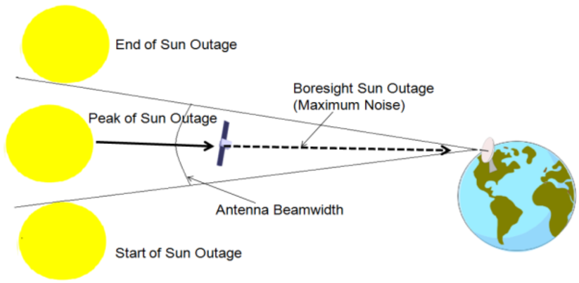

Fig. 1. Sun outage phenomena

B. Satellite Orbit of Sun Outage Period Calculation

The sun and satellite conjunction occurs when the antenna beamwidth from earth station is pointing towards the satellite passing through the sun. This discribes that the sun's declination is equal to the angle of antenna's radiation with equatorial plane. To calculate the sun outage period, the author used two model calculations, there are manual calculations based on handbook[6] and based on ITU-R S.1525[7].

a) Manual Calculation Using Handbook

- Antenna Beamwidth

In antenna beamwidth, gain at an angle according to the direction where the gain will be half the maximum value. The wider the antenna diameter, the smaller the $\theta\, 3_{dB}$ value, meaning that the signal beam transmitted will be more coherent. The equation for calculating the antenna beamwidth is as follows (1) [8].

$$\theta_{3dB} = 70\left(\frac{c}{fD}\right) \quad (1)$$

Information:
θ_{3dB} = Antenna beamwidth (°)
c = Speed of light (3×10^{8} m/s)
f = Frequency (GHz)
D = Antenna diameter (m)

- Number Uninterrupted Days of Sun Outage

Conjunctions are determined by the alignment of the earth, satellite, and solar stations. If the antenna beamwidth is assumed to be very narrow, the conjunction relates to situation with the length of time earth station has been disturbed. If these rays have an equivalent aperture (θi), interference will occur on several consecutive days around the start date determined by the angle value θ. Therefore, the number of days (Ni) of solar-satellite interference for several consecutive days has the following values[6].

$$N_i = 2.5\theta_i \; days \quad (2)$$

Information:
Ni = The number of affected days by sun outage (days)
θi = Antenna beamwidth (°)

- Duration of Sun Outage

The duration of interference is determined by observing daily apparent movement of sun around the earth, which is 360°/24×60 = 0.25° per minute [6].

$$\Delta t_i = 4\theta_i \; min \quad (3)$$

Information:
Δti=The duration of sun outage (minutes)
θi = Antenna beamwidth (°)

- Maximum Duration of Sun Outage Interruption

The duration of interference for geostationary satellites in sun outage conditions based on the apparent movement of the sun is 0.25° per minute, then the duration of the solar interference is as follows (4) [6].

$$T_i = \left(\frac{2\theta_{3dB}+0.5°}{0.25}\right) min \quad (4)$$

Information:
Ti = Maximum duration of sun outage (minutes)
θ_{3dB}= Antenna beamwidth (°)

b) Recommendation ITU-R S.1525 Calculation

- Number of days affected

Because the sun's declination angle changes about 0.4° per day at equinox, and 0.48° is the optical diameter of the sun. Thus, the number of days affected in each equinox can be estimated by the following (5) [7].

$$Affected\ days = \frac{\theta_{3dB}+0.48°}{0.4°} \quad (5)$$

Information:
θ_{3dB} = Antenna beamwidth (°)

- Maximum Duration

Because the hour angle from the sun changes by about 0.25º per minute. The maximum duration of sun transit can be estimated using (6) [7].

$$Affected\ minutes = \frac{\theta_{3dB}+0.48°}{0.25°} \quad (6)$$

- Total Duration at Each Equinox

At equinox, the sun's declination angle changes by about 0.4º per day and the hour angle changes by about 0.25º per minute. So the total duration of sun outage can be calculated as follows (7) [7].

$$Total\ Duration = \frac{\pi\times(\theta_{3dB}+0.48°)^2}{4\times0.4°\times0.25°} \quad (7)$$

C. Link Budget of Sun Outage Calculation

Link budget calculations when there is a sun outage using the equation of the normal link budget, including G/T (Figure of Merit) downlink, C/N (Carrier to Noise Ratio) uplink, C/N downlink, Eb/No (Energy bits per Noise Ratio), and BER (Bit Error Rate).

a) Figure of Merit (G/T)

Figure of merit or G/T is between gain of the antenna reception and noise temperature of the reception system which shows the quality of a signal reception system[9]. G/T can be calculated using (8) [10].

$$\frac{G}{T} = G - 10\log T \quad (8)$$

Information:
G/T = Figure of merit (dB/°K)
G = Antenna gain (dBi)
T = System temperature (°K)

b) Carrier to Noise Ratio Uplink (C/N_{up})

C/N is ratio of carrier to noise (C/N) desired by a link, which is a measure of the link's performance. C/N uplink can be calculated using (9) [11].

$$\left(\frac{C}{N}\right)_U = EIRP_U + \left(\frac{G}{T}\right)_U - Losses_U - k - B \quad (9)$$

Information:
C/N_u = Uplink carrier to noise ratio (dB)
$EIRP_U$ =Effective Isotropic Radiated Power Uplink (dBW)
G/T_U = Satellite figure of merit (dB/°K)
$Losses_u$ = Uplink total attenuation (dB)
k = Boltzman's constant (-228.6)
B = Noise bandwidth (dB/Hz)

c) Carrier to Noise Ratio Downlink (C/N_{down})

It is a ratio calculation of the carrier power to noise power from the satellite transmitter antenna on the space segment, with user on the ground segment. The C/N_{down} formula is as follows (10) [11].

$$\left(\frac{C}{N}\right)_D = EIRP_D + \left(\frac{G}{T}\right)_D - Losses_D - k - \quad (10)$$

Information:

C/N_d = Downlink carrier to noise ratio (dB)
$EIRP_D$ =Effective Isotropic Radiated Power Downlink (dBW)
G/T_D = Figure of satellite merit (dB/°K)
$Losses_D$ = Downlink total attenuation (dB)
k = Boltzman's constant (-228.6)
B = Noise bandwidth (dB/Hz)

d) Carrier to Noise Ratio Total (C/N_C)

After knowing the uplink and downlink C/N values, to find out the overall signal, and then calculate the total C/N. To find the total C/N, is using (11) [12].

$$\left(\frac{C}{N}\right)_C = \left(\frac{1}{(C/N)_U^{-1} + (C/N)_D^{-1}}\right) \quad (11)$$

Information:
C/N_c is Carrier to Noise Ratio combined (dB), C/N_{Up} is Carrier to Noise Ratio uplink (dB), and C/N_{Down} is downlink Carrier to Noise Ratio (dB).

e) Energy bits per Noise Ratio (Eb/No)

Eb/No (Energy Per Bit to Noise Density Ratio) is a ratio of energy per bit noise density from the demodulator output in a digital modulation system. This value also shows the quality of the RF (Radio Frequency) signal received by the modem[13]. To calculate the amount of Eb/No, calculation components such as total C/N and the amount of bandwidth allocated to a BW_{All} link are needed. To find out the amount of Eb/No using the following (12) [12].

$$\frac{E_b}{N_0} = \frac{C}{N}\left(\frac{B}{r_b}\right) \quad (12)$$

Information:
Eb/No = Energy Per Bit to Noise Ratio (dB)
C/N = Carrier to Noise Ratio total (dB)
B = Required bandwidth (Hz)
r_b = Data bit rate (bps)

f) Bit Error Rate (BER)

BER is ratio between the number of bits on information received incorrectly or incorrectly with the number of bits from information transmitted. The lower of BER produced by digital transmission, better performance of the digital transmission. To find out Bit Error Rate is using the following (13) [14].

$$BER = \frac{e^{\frac{-Eb}{No}}}{\sqrt{4\pi\frac{Eb}{No}}} \quad (13)$$

Information:
BER = Bit Error Rate
Eb/No = Energy Per Bit to Noise Ratio (dB)

g) Link Availability

Link availability or system availability is defined as the availability of a link from transmitting earth station (transmitter) to satellite and down to receiving earth station. To find out the probability of availability on a satellite link, use the following (14) [15].

$$P_{AL} = 1 - \left(\frac{Down\ Time}{Total\ Time}\right) \times \% \quad (14)$$

D. Link Budget of Normal Condition Calculation

The link budget calculation is a calculation of power level carried out to ensure that the receiving power level is greater or equal to the power level transmitted. The aim is to maintain the balance of gain and loss from the transmitting antenna (Tx) to the receiving antenna (Rx)[9].

a) Azimuth

Azimuth angle is the angle measured in a clockwise direction from the north. Azimuth and elevation angles are needed to help direct the position of the earth station antenna towards the satellite antenna, so that there is no pointing loss. To calculate the azimuth angle (A'), first perform the calculation of A'. To calculate A' use the following (15) [8].

$$A' = tan^{-1}\left(\frac{\tan|\theta s - \theta L|}{sin\theta\ l}\right) \quad (15)$$

Information:
A' = Azimuth angle (°)
θs = Longitude of satellite (°)
θL = Longitude of earth satellite (°)
θl = Latitude of earth station (°)

b) Elevation Angle

Elevation angle is the angle generated by north direction, from the point of antenna is mounted on to the vertical direction of satellite and antenna. The elevation angle is obtained using the following (16) [8].

$$E = tan^{-1}\left[\frac{cosl \cdot cosL - 0{,}151}{\sqrt{1-(cosl \cdot cosL)^2}}\right] \quad (16)$$

Information:
E = Elevation angle (°)
L = The difference between the longitude of the earth station and the satellite (°)
l = Latitude of earth station (°)

c) Slant Range

Slant range between earth station and satellite is actual distance measured from earth station drawn straight to the position of satellite above[8]. The value of slant range is calculated using the following (17) [10].

$$R = \sqrt{R_E{}^2 + (R_E + h)^2 - 2R_E(R_E + h)cos\varphi} \quad (17)$$

Information:
R = Slant range between earth station and satellite (km)
h = Altitude of geostationary satellite orbit (35786 km)
Re = Earth's radius (6378 km)
$Cos\varphi$ = The difference between the longitude of earth station and satellite (°)

d) Propagation Delay

Propagation delay is the time required to send information from transmitter to receiver[6].

$$t_{SL} = \frac{R}{c} \quad (18)$$

Information:
t_{SL} = Propagation delay (ms)
R = Slant range (km)
c = Speed of light ($3x10^8$ m/s)

e) Antenna Gain

Antenna gain is gain of power on antenna both transmitter (Tx) and receiver (Rx)[9]. The equation for antenna gain is calculated using the following (19) [6].

$$G_{max} = 10log\,\eta\left(\frac{\pi Df}{c}\right)^2 \quad (19)$$

Information:

G_{max} = Gain of transmitter or receiver antenna (dBi)
D = Diameter of the transmitting or receiving antenna (m)
H = Efficiency of the transmitting or receiving antenna (%)
f = Frequency (GHz)
c = Speed of light (3×10^8 m/s)
π = The value of phi (3.14)

f) Effective Isotropic Radiated Power (EIRP)

Effective Isotropic Radiated Power (EIRP) is the number of power a carrier emitted by an antenna. The unit of EIRP is expressed in watt decibels (dBW)[11]. The EIRP calculation equation is as follows (20) [6].

$$EIRP_{ES} = (P_{TX}G_{Tmax} - L_T - L_{FTX}) \quad (20)$$

Information:

$EIRP_{ES}$ = Effective Isotropic Radiated Power of earth station (dBW)
P_{TX} = Antenna power (Watt)
G_{Tmax} = Transmitter antenna gain (dBi)
L_T = Loss transmitting antenna (dB)
L_{FTX} = Loss feeder (dB)

g) Free Space Loss (FSL)

Free space loss occurs due to signal propagation from transmitter to receiver use free space in satellite communications[9]. Free space loss (FSL) can be calculated using this equation (21) [16].

$$L_{FS}(dB) = 32.4 + 20\,log\,r + 20\,log\,f \quad (21)$$

Information:

L_{FS} = Free space loss (dB)
f = Uplink or downlink frequency (GHz)
r = Distance between earth station to satellite (km)

h) Rain Attenuation

Rain attenuation is influenced by the frequency used, rainfall and the distance of propagation path through the rain[10].

$$L_{rain(dB)}{}^{(r=0.01\%)} = \alpha L_s r_{0.01} \quad (22)$$

Information:

L_{rain} = Total rain attenuation (dB km)
Ls = Length of slant path affected by rain (km)

E. Application of Sun Outage Methodology Using Different Antenna Sizes

The impact on performance of satellite link depends on the size of antenna and the noise temperature at that link. For large antennas with high gain, C/N degradation can be as high as 15 dB, but less if a small antenna with a beamwidth is used. The results show that the depth of degradation or reduction in C/N depends on the size of antenna and the duration of sun outage. The following is a diagram showing the increase in noise temperature and received degradation of C/N based on differences in antenna diameter [7].

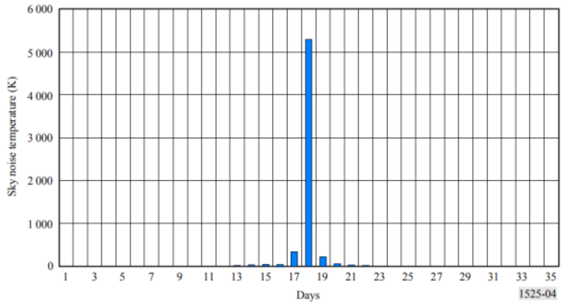

Fig. 2. Daily maximum noise temperature increase for antenna 10 meters

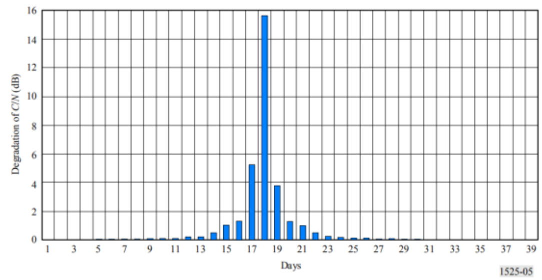

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Fig. 3. Daily maximum degradation of C/N received from the antenna 10 meters

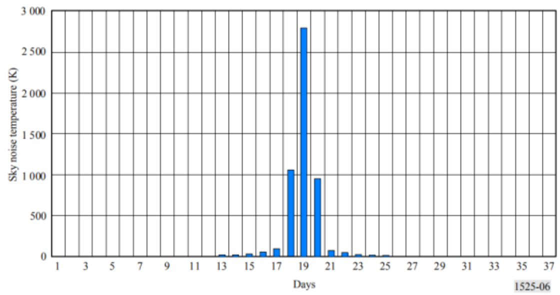

Fig. 4. Daily maximum noise temperature increase for antenna 3 meters

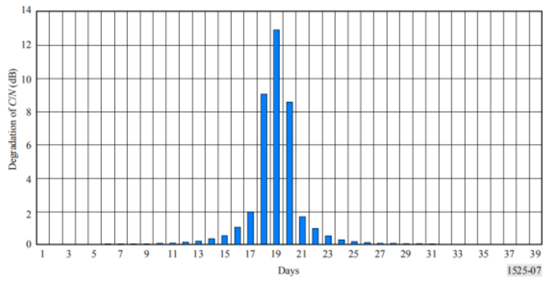

Fig. 5. Daily maximum degradation of C/N received from the antenna 3 meters

F. Satmaster Setting of Telkom 3S

The calculation of link budget using the Satmaster application is used as comparison between manually calculations result with software calculations result. Calculations using Satmaster can minimize errors because the results obtained when using this software are not much different with manually.

G. Telkom 3S Satellite

Telkom 3S satellite is a satellite owned by PT Telekomunikasi Indonesia, Tbk and is a geostationary satellite that was launched on February 14, 2017 with a mass of 3550 kg. The satellite located at 118° E, has a capacity of 24 C-Band transponders, 8 extended C-Band transponders, and 10 Ku-band transponders. The Telkom 3S satellite is a replacement satellite for Telkom 3, which was launched using Ariane 5 ECA Rocket in Kourou, French Guiana, and has active period of ±15 years. The coverage area of Telkom 3S Satellite covers all regions of Indonesia, Southeast Asia, and parts of East Asia[17].

III. RESULTS

The results obtained based on calculation of link budget in normal condition, link budget of sun outage, and satellite orbit for sun outage periods have been attached to the following table. Table 1 is the result of link budget calculations during normal conditions based on manual calculations and Satmaster calculations.

Table 1. Satmaster result calculation of Telkom 3S satellite

No	Parameters	Calculation Result	Satmaster Result	Derivation
1	Azimuth uplink	61.861°	61.86°	0.001
2	Elevation uplink	74.724°	74.71°	0.014
3	Slant range uplink	35935.244 km	35978.83 km	43.586
4	Propagation delay uplink	0.119 s	0.120 s	0.001
5	Free space loss uplink	199.195 dB	199.25 dB	0.055
6	Free space loss downlink	195.231 dB	195.28 dB	0.049
7	Antenna gain uplink	52.874 dBi	52.89 dBi	0.016
8	Antenna gain downlink	37.861 dBi	37.87 dBi	0.009
9	G/T downlink	22.238 dB/°K	18.61 dB/°K	3.628
10	EIRP uplink	42.554 dBW	41.59 dBW	0.964
11	Rain attenuation uplink	4.524 dB	4.4 dB	0.124
12	Rain attenuation downlink	4.275 dB	4.2 dB	0.075

The calculations result of C/N, Eb/No, and BER for March 2020 and September 2020 in sun outage condition are represented in the following table.

Table 2. Comparison result calculation of sun outage's link budget in March and September 2020

No	Parameters	March 2020	September 2020
1	C/N uplink	53.005 dB	53.080 dB
2	G/T downlink	5.027 dB/°K	4.994 dB/°K
3	C/N downlink	4.196 dB	4.417 dB
4	C/N Total	5.897 dB	6.103 dB
5	Eb/No	2.635 dB	2.841 dB
6	BER	12.4×10^{-3}	9.76×10^{-3}

The results of the calculation of the parameters C/N, Eb/No, and BER in normal condition and sun outage are represented in Table 3.

Table 3. Comparison result calculation of normal and sun outage link budget average per year

No	Parameters	Normal Condition Result	Sun Outage Result
1	C/N uplink	54.314 dB	53.042 dB
2	G/T downlink	22.238 dB/°K	5.010 dB/°K
3	C/N downlink	67.229 dB	4.306 dB
4	C/N Total	14.777 dB	6.0 dB
5	Eb/No	11.515 dB	2.738 dB
6	BER	8.29×10^{-7}	11.08×10^{-3}
7	Link Availability	-	99.855324%

In addition, to know time of interference, the author also calculates the satellite orbit to predict sun outage period. The calculations are carried out based on the formula in satellite handbook and ITU-R S.1525 standard. Then the results are shown in the following table.

Table 4. Comparison result calculation of sun outage period and data of period

No	Parameters	Handbook Result	ITU Result	Data of Period[18]
1	Affected Days	5.6 days	6.8 days	7 days
2	Affected Minutes	9.0 minutes	10.9 minutes	8.9 minutes
3	Total Duration	20 minutes each equinox	59 minutes each equinox	62.5 minutes each equinox

IV. DISCUSSION

Analysis the impact of sun outage on system performance is by comparing the results calculation of C/N, Eb/No, and BER in normal and sun outage conditions. Because in 2020 sun outage occurs in March and September, so the authors calculate C/N, Eb/No, and BER in two equinoxes. In the March 2020 sun outage calculation, the author calculates the total C/N based on equation (11). Then because the calculations result of C/N uplink is 53.005 dB, G/T downlink 5.027 dB/°K, and C/N downlink 4.196 dB. So, the total C/N is 5.897 dB. The calculation of Eb/No March 2020 uses equation (12) which is obtained from total C/N of 5.897 dB with the required bandwidth is 3020090 Hz, and a data rate of 6400000 bps, so the result of Eb/No in March 2020 is 2.635 dB. Meanwhile, the calculation of BER is obtained based on equation (13) with Eb/No 2.635 dB, then the result of BER is 12.4×10^{-3}.

For sun outage calculation in September 2020, the author calculates the total C/N uses equation (11) based on the calculations result of C/N uplink is 53.080 dB, G/T downlink 4.994 dB/°K, and C/N downlink 4.417 dB (based on Table 2). So, the total C/N is 6.103 dB. Then, the calculation of Eb/No in September 2020 uses equation (12) which is obtained from total C/N is 6.103 dB, required bandwidth is 3020090 Hz, and the data rate is 6400000 bps. So the Eb/No in September 2020 results is 2.841 dB.

Meanwhile, the calculation of BER has obtained uses equation (13) with Eb/No is 2.841 dB, then the BER is 9.76×10^{-3}. And the comparison of the decrease and increase in signal quality parameters such as C/N, Eb/No, and BER for sun outage in March 2020 and September 2020 is shown in Fig.6.

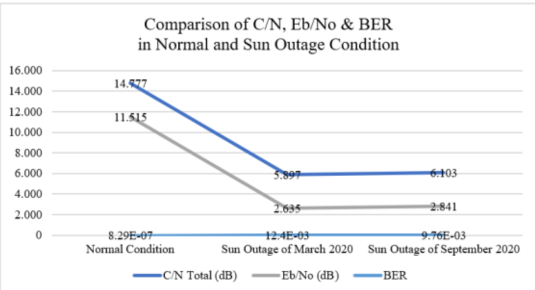

Fig. 6. Comparison of C/N, Eb/No, BER in normal condition and sun outage of March and September 2020

Because the calculation results of normal link budget represent the annual average, so the calculation results from sun outage's link budget in March 2020 and September 2020 need to be calculated so that the magnitude of the decrease in Carrier to Noise Ratio (C/N) parameter is known. The figure below represents the decrease of C/N.

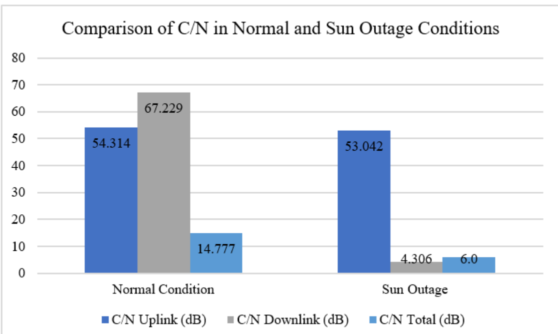

Fig. 7. Comparison C/N result in normal condition and sun outage average per year

The graph in Fig.7 shows that if uplink C/N and downlink C/N decreased, the resulting total C/N also decreased due to interference from sun outage. If the total C/N decreases, the resulting signal quality will get worse. And the Eb/No parameter will be lower, and the resulting Bit Error Rate will be higher.

After calculating C/N, Eb/No, and BER based on the March 2020 and September 2020 equinoxes, the authors add up the two results to obtain C/N, Eb/No, and BER for the annual average. The following is a graph shows the comparison of C/N, Eb/No, and BER in normal and sun outage conditions for average per year.

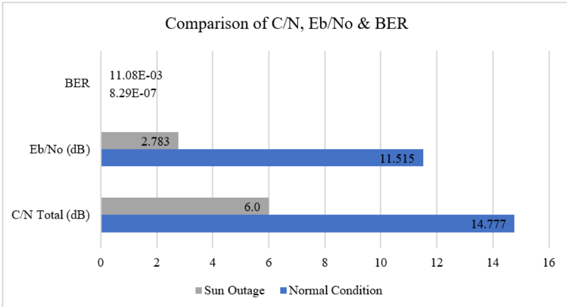

Fig. 8. Comparison of C/N, Eb/No & BER in normal condition and sun outage average per year

G/T downlink calculation of sun outage is calculated because temperature of the receiving earth station antenna is increase. The antenna temperature increased to 1920°K at the sun outage in March 2020 period, resulting in downlink G/T of 5.027 dB/°K. As for the sun outage in September 2020 period, the antenna temperature increased to 1935°K, and the resulting G/T calculation was 4.994 dB/°K. While the average downlink G/T per year is 5.010 dB/°K which is obtained from the results of March G/T downlink and September downlink G/T. It can be analyzed that the increasing temperature of the downlink earth station antenna makes a figure of merit have significant decrease.

In the uplink communication, only G/T as changes parameter when sun outage occurs. Based on Table 3, the normal downlink C/N results and sun outage have decreased very drastically. This is due to decrease in the EIRP (Effective Isotropic Radiated Power) of satellite, an increase in loss due to thermal noise during sun outage, and decrease in the downlink G/T value due to high noise temperature on the antenna. This causes the quality of information received in the downlink direction to become weak. It can be analyzed that the decrease in the total C/N value during sun outage occurs due to a decrease in the uplink C/N and downlink C/N, and the presence of thermal noise so that the loss increases and makes the quality and performance of the satellite communication system link worse when compared to normal.

If the total Carrier to Noise Ratio calculation result is small or has decreased, then the resulting Eb/No is also small, because the C/N value is directly proportional to the Eb/No value. Sun outage makes sending data from earth station to satellite as well as from satellite to earth station have problematic, so that the BER value will be even greater. When the resulting BER is greater, the error or wrong data bits will be more and there will be fewer bits of data to be submitted successfully.

The availability of links obtained when sun outage occurs is 99.855324% meaning that the availability of links from the transmitting earth station to the satellite and down to the receiving earth station is only 99.855324%. It can be analyzed that in March 2020 and September 2020 or at the 2020 equinox there is link unavailability by 0.144676%. It meaning that there loss of satellite communication traffic by 0.144676% during the sun outage period. In the satellite communication system, the percentage of link unavailability of 0.144676% shows which is very detrimental to users and customers because the traffic of the satellite communication system is very large or extensive.

In the calculation of the satellite orbit, the author calculates the sun outage period which can be used to predict the time of sun outage. The calculation uses the equation in the ITU-R S.1525 standard and satellite handbook, so the two calculation methods produce different values. However, these two calculations both discuss the calculation of the number of affected days by sun outage, the duration of sun outage in one day, and the total duration of sun outage at each equinox. Based on the calculation of sun outage predictions in the satellite handbook, namely equation (2), (3), and equation (4) in Table 4, sun outage in 2020 occurs for 5 to 7 days, in one day occurs for 9 minutes, and the total duration of sun outage in each equinox is 20 minutes on antenna 2,4 meters. Meanwhile, based on the calculation of sun outage predictions according to ITU standards in Table 4, namely equation (5), (6), and equation (7), sun outage in 2020 occurs for 6 to 7 days, one day occurs for 10 until 11 minutes. And the total duration sun outage at each equinox for 50 minutes on antenna 2.4 meters.

Based on Table 4, the data for sun outage period in 2020 of March and September shows that the sun outage occurs for 7 consecutive days, for 8.9 minutes in one day, and the total sun outage duration at the equinox is 62.5 minutes. So the calculation based on ITU-R S.1525 is closer to data of sun outage period and closer to precision than the calculation based on the handbook.

V. CONCLUSION

Based on normal condition or before sun outage interference occurs, the link budget calculations in Table 2 show that the total Carrier to Noise Ratio obtained is 14.777 dB, resulting from 54.314 dB uplink C/N and 67.229 dB downlink C/N. The parameters needed in the calculation of C/N include: antenna gain, EIRP, G/T (figure of merit), free space loss, rain attenuation whose calculation results are by Satmaster. It also shows that the quality of satellite communication system is in good condition before sun outage occurs even though there are losses during the transmission process. Because the C/N obtained is good, the Eb/No of 11.515 dB shows the ratio of carrier signal energy to noise which is received well. Meanwhile, BER 8.29×10^{-7} shows that the bits of data that have been successfully sent are more than the bits with error.

The sun outage interference causes signal quality parameters such as C/N to decreased from normal condition is 14.777 dB to 6.0 dB, Eb/No from 11.515 dB to 2.738 dB, as well as increase the BER parameters from a normal state of 8.29×10^{-7} to 11.08×10^{-3}. Sun outage makes the information signal transmitted to be suppressed by noise so the data bit received is an error. Meanwhile, the availability of links obtained during sun outage is 99.855324%, which means that sun outage also affects the disconnection of satellite communication traffic by 0.144676% each year.

The calculation of the satellite orbit for sun outage period gives almost a different result, so the manual calculation based on ITU-R S.1525 is closer to the data of sun outage period and closer to precision than the calculation based on the handbook. But, the conclusion based on two method calculations is the same. If the diameter of receiving earth station antenna is getting smaller or the antenna beamwidth is greater, then the sun outage interference time in both days and minutes is getting longer.

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