Link Budget Analysis For 3u Nanosatellite (Tigrisat) Operating At S-Band

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ABSTRACT. Assessment of link budget estimation for TIGRISAT Low Earth Orbit satellite and its communication with ground station located in Baghdad/Iraq is introduced in this article. Communication link between the satellite and the ground station depends on various propagation parameters and losses which are either constant or variable. Uplink and downlink design parameters were considered. Simulation results show a linear behaviour between isotropically radiated power and received power in uplink and downlink respectively. Simulation outcomes illustrate how the precise amount of dust attenuation over Iraq dwindles the carrier to noise ratios as concerned with uplink and downlink in turn. In order to present high data rates telecommunication between a satellite at LEO and the earth station, this article reviews link budget requirements, besides for futuristic signal impairments consideration for enhancing transceiving performance for Tigrisat [11].

Keywords: link budget, dust attenuation, LEO satellites, TIGRISAT, 3U nanosatellite.

1. INTRODUCTION

TIGRISAT is the first Iraqi 3U nanosatellite for monitoring dust storm using RGB camera. It was launched into sun synchronous orbit since 19 June 2014 with altitude 620 km, inclination angle of 97.976 degree above the equator, orbiting the earth 14.8 revolution through 24 hours, bisecting the earth every one and half hour passing above Iraq for 4 to 6 times per day (speed 7.54 km/s). The main problem facing communication in Iraq is the dust storms posing a looming threat to microwave radio system reliability [1, 2]. [1] introduced 3-dimensional model of dust storms to be included by considering the attenuation of dust to the link margin of LEO satellites which in turn is as identical as the dust amount of attenuation in Iraq as Saudi Arabia. The previous studies considered no striking portion of dust attenuation, in which dire effects occur on accurate link budget estimation. Link budget of LEO satellite (SKY Bridge and Iridium) was presented by [2] and [3]. In the current study, the link budget of TIGRISAT under different attenuation parameters has been evaluated for a ground station situated in Baghdad Iraq.

The rest of this paper is organized as follows: Link budget parameters are tabulated in section 2. Power link design parameters and their calculations are presented in section 3. Simulation results are introduced in section 4. concluding remarks are presented in the fifth section.
1.1 SATELLITE ORBIT
Figures (1,2) clarify both orbital views of satellite ground trajectory from General Mission Analysis Tool (GMAT) [12].

![Figure 1. Current Tigrisat-one rotation around the globe](image1)

![Figure 2. Tigrisat ground track for two revolutions](image2)

| Field                        | Value           |
|------------------------------|-----------------|
| Semi-Major Axis (SMA)        | 6945.068657722795 km |
| Eccentricity (ECC)           | 0.0827060000000004 |
| Inclination (INC)            | 97.971 deg      |
| Argument of Perigee (AOP)    | 350.459000000001 deg |
| Right Ascension of the       | 131.017000000001 deg |
| Ascending node (RAAN)        |                 |
| True Anomaly (TA)            | 8.9999999999999961 deg |

General Mission Analysis (GMAT) is utilized to mimic the orbital movement of Tigrisat. The epoch and six Keplerian orbital elements are in need to put to GMAT [12].

2. LINK BUDGET PARAMETERS OF TIGRISAT
Subjective design of radio link is to guarantee a reliable telecommunication between a transmitter and receiver [9]. By utilizing equation 1, it is accessible to calculate the SNR (or written as C/N) at the receiver under specific system parameters, both in the downlink and uplink transmission, summarized in Table 2. Moreover, we leave on purpose undefined the satellite parameters (EIRP in downlink and G/T in uplink) because these are the ones that should be precisely designed to meet the power budget requirements. Changing these satellite parameters would patently affect the received SNR.
Table 2. Link Budget Parameters

| Satellite Orbit          | Sun synchronous (LEO) |
|--------------------------|-----------------------|
| Orbit altitude           | 620 km                |
| Satellite working band   | S-band, UHF           |
| Downlink frequency       | 435 MHz               |
| Uplink frequency         | 2450 MHZ              |
| Satellite view           | 4-6 times per day     |
| Orbital velocity         | 7.5 km/s              |
| No. of full rounds over Earth | 14.8/24 hour |

| Losses       |                |
|--------------|----------------|
| FSL          | 0.5 dB         |
| Rain         | 0.4 dB         |
| Antenna misalignment | 1 dB      |
| Fog attenuation | 0.03 dB     |
| Dust attenuation | 0.6254 dB   |
| Polarization loss | 0.3 dB      |
| Atmospheric loss | 1 dB         |

Regarding Table 2, Tigrisat parameters are precisely presented. Equation 1 calculates the overall link budget for Tigrisat. It is obtainable to gain the spectral efficiency as a function of satellite EIRP for uplink case and G/T for downlink one, as highlighted in figure 3. It’s been taken into account merely Low Earth Orbit (LEO) satellite, with the corresponding altitude given in Table 2.

3. POWER LINK DESIGN PARAMETERS

Link budget analysis is predominantly utilized for satellite systems. In such situations, the levels of specified signal are sustained to ensure that the received signal levels are adequately upper than the level of noise, to guarantee admissible bit error rates limits. Moreover, link budget assessment is essential for various telecommunication systems such as cellular systems and for scrutinising the base station coverage [7]. In order to obtain results performance, an aggregation of all gains and losses are required [4]. The general mathematical formulation of link budget as for propagation medium from transmitter to receiver, neglecting several marginal interferences, is clarified as follows [9].

\[
\frac{C}{N}(dB) = EIRP(dBW) + \frac{G_t}{T_r}(dB/K) - FSL(dB) - A_{tota}(dB) - A_{dota}(dB) - K(dBW/K) - 10 \cdot \log_{10}(BW) \tag{1}
\]
4. SIMULATION
The link budget regards signal and noise levels on either ends of the telecommunication systems. Having stated obviously all the system components in previous studies, it can currently make an estimation for the aggregate SNR on the link.

A. Table 3. EIRP related to power received

| EIRP in dBW | $P_r$ in dBW |
|------------|-------------|
| 28         | - 119.45    |
| 29         | - 118.45    |
| 30         | - 117.45    |
| 31         | - 116.45    |
| 32         | - 115.45    |
Due to the harsh and volatile circumstances of weather over Iraq, power received should be estimated and considered differently according to lateral impairments.

B. **Table 4: Free-Space loss against Carrier-to-Noise uplink**

| FSL in dBW | \((\frac{C}{N})_{\text{Uplink in dBW}}\) |
|------------|----------------------------------------|
| 150.1      | 13.526                                 |
| 151.1      | 12.526                                 |
| 152.1      | 11.526                                 |
| 153.1      | 10.526                                 |
| 154.1      | 9.526                                  |

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**Figure 3.** EIRP against power received

**Figure 4.** Impact of FSL on \((\frac{C}{N})_{\text{Uplink}}\) Uplink
C. Table 5: Free-Space loss against Carrier-to-Noise downlink

| FSL in dBW | \( \frac{C}{N} \) downlink in dBW |
|------------|---------------------------------|
| 141.1      | 23.876                          |
| 142.1      | 22.876                          |
| 143.1      | 21.876                          |
| 144.1      | 20.876                          |
| 145.1      | 19.876                          |

Table 5 highlights the substantial relevant comparison and the pivotal influence of Free Space Losses on downlink design.

![Figure 5. FSL to \( \frac{C}{N} \) Downlink impact](image)

D. Table 6. Previous-Current Tigrisat outcomes Comparison

| Carrier-to-Noise Ratio | Past Results (without dust attenuation) in dBW | Current Results in dBW |
|------------------------|-----------------------------------------------|------------------------|
| \( \frac{C}{N} \)\text{up} | 14.1514                                       | 13.526                 |
| \( \frac{C}{N} \)\text{down} | 24.0964                                       | 23.876                 |
| \( \frac{C}{N} \)\text{total} | 38.2478                                       | 37.402                 |

It can vividly be noticed that the dust attenuation remarkably influences on link budget, via degrading the overall calculation, in which as compared to past dust-free link budget assessment, as clarified in table 6.
Figure 6. Results comparison

E. Table 7. Uplink power budget

| No. | Parameter                        | Symbols | Values   | Result  |
|-----|----------------------------------|---------|----------|---------|
| 1   | Transmitting power               | $P_t$   | 10       |         |
| 2   | Transmitting Gain                | $G_t$   | 3        |         |
| 3   | Equivalent Isotropic Radiated Power | EIRP   | 30       |         |
| 4   | Bandwidth                        | $B_W$   | 70       |         |
| 5   | Temperature                      | $T$     | 228.6    |         |
| 6   | Boltzmann’s Constant             | $K$     | 228.6    |         |
| 7   | Received Gain                    | $G_r$   | 3        |         |
| 8   | Frequency                        | $F$     | 2450 MHz |         |
| 9   | Free Space Loss                  | $FSL$   | 150.1 dB |         |
| 10  | Atmospheric Loss                 | $L_a$   | 1        |         |
| 11  | Polarization Loss                | $L_P$   | 0.3      |         |
| 12  | Antenna Misalignment Loss        | $L_{ant}$ | 1        | -117.45 |
| 13  | Received Power                   | $P_r$   | 21.624   | 13.526  |
| 14  | (G/T) ratio                      | $G/T$   | 21.624   |         |
| 15  | (C/N)up                          | (C/N)   | 13.526   |         |
5. RESULTS AND DISCUSSION
In accordance to the outcomes obtained, dust effect remarkably degradates link budget. Dust portion 0.6254 dB [1] is regarded into calculation to accurately gain link budget for TIGRISAT for further consideration. The aforementioned amount increases the losses which in turn the carrier to noise ratios are inversely proportional as highlighted in Figure 4.

6. CONCLUSIONS
To conclude, link budget of TIGRISAT LEO satellite has been estimated with respect to ground station located in Baghdad-Iraq. simulation results show dramatic agreement with the calculations. As for link impairments regarded, the measurements are calculated accordingly for further enhancement for the link dedicated. It can patently be noticed that the previous calculations concerned with no dust attenuation, but in this paper the precise dust attenuation portion over Iraq is taken into account.
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