# Performance Analysis Of LEO Satellite(Sky Bridge) For Mobile Terminal With Varying Implementation Margin

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**Abstract- In satellite links the radio frequency signals occupies a much larger bandwidth than the baseband signal. Due to the weak signal the improvement in signal to noise ratio is essential. In the day progress almost all signals are digital as a matter of fact all of the LEO systems are digital taking advantages of voice compression which allows digital signal to be compressed into a bit stream at 4.8kbps.The main focus is to design and calculate the budget for the mobile terminal and then analyze the signal to noise ratio. Implementation margin is varied so that the effective carrier to noise ratio is calculated and on the basis of that the bit error rate is also analyzed.**

**Keywords – LEO, Implementation margin, effective carrier to noise ratio, capacity.**

## I. INTRODUCTION

A satellite with less loss and maximum power utilization is always in demand. To minimize the loss effectively the various budget model and techniques are implemented. Reduction in bit error rate and enhancement of signal strength depends on the implementation margin as nowadays almost all communications are in digital. LEO earth imaging satellites have the potential to provide strong revenue stream. These satellites are hugely in demand for mobile communication and navigation systems. Generally all the Low earth orbit satellites take advantages of voice compression. The capacity of the radio channel also depends upon the modulation techniques employed in the communication process and the signal to noise ratio. The paper investigates the sky bridge type Low earth orbit satellites having being used for mobile terminal. The general uplink frequency for the mobile terminal is 1650 MHz and downlink frequency is 1550 MHz. The digital modulation used for the satellite is either BPSK or QPSK. But the acceptable bit error rate depends on the satellites particular applications. The digital links are designed with ideal filters which have noise bandwidth “Bn”Hz equal to the symbol rate of the digital signal in symbols per second. In the handheld transceivers (BPSK modulation), the maximum permitted BER is $10^{-4}$ leads to a S/N ratio in the speech channel of 34 dB. The performance of a satellite is calculated on what the C/N ratio it gathers so as to meet the standard communication .But for the mobile terminal (multimedia) services a good C/N ratio or S/N ratio is needed. The C/N or S/N ratio for standard communication to produce a very good quality signal needs S/N ratio around 50 dB or so.

| Signal to Noise ratio | Value in dB | Remark on signal | Noise |
|---|---|---|---|
| S/N | <40dB | Low signal quality | Full involvement of noise |
| S/N | 45dB | Good quality signal | Partial involvement of noise |
| S/N | 50dB | Very good signal | Noise is just perceptible in background |
| S/N | 55dB | Outstanding signal quality | No noise/negligible interference |

Table1: SNR values with noise interpretation.

## II. PROPOSED ALGORITHM

**The performance analysis of the system is based by this proposed algorithm:**

Step1: Define system specification/satellite parameters.
Step2: Propose the uplink and downlink frequency with transponder bandwidth.
Step3: Specify the modulation technique involved and compare why it is essential.
Step4: Calculate the power budget by considering various losses into account.
Step5: Calculate the (C/N) ratio for both up and down link.
Step6: Mathematically propose the effective C/N ratio having considering the implementation margin.
Step7: Control the IM to a stable value to standardize the C/N ratio.
Step8: Analyze the BER value compared to C/N ratio.
Step9: Formulate SNR.
Step10: Analyze the performance of the system link by plotting (C/N)eff. with BER.
Step11: Maximize the SNR value to float around 50dB.
Step12: max (SNR1, SNR2, SNR3....) provides the label of signal quality for communication.

**Description:**

A: satellite type: low earth orbit (Sky Bridge)
Maximum range of coverage zone is: 1469km
Uplink frequency for mobile terminal is 1650MHZ
Downlink frequency for mobile terminal is 1550MHZ
Boltzmann's constant=-228.6dBW/K/HZ
Temperature=Ts=500k=27.0dB

B: Modulation technique employed is generally digital in nature. It is the better choice for satellite transmission of a signal that originates in digital form. Most preferable digital modulation technique is PSK may be BPSK or QPSK. The PSK gives lower BER than FSK and others for a given C/N ratio. The capacity of the radio channel also depends upon the modulation techniques employed in the communication process and the signal to noise ratio. The BER of BPSK depends on the C/N effective ratio value. To minimize the bit error rate or to have a nominal value of the bit error rate a standardized value of C/N is required. The analysis of the system performance of a radio link using BPSK is always carried out in terms of C/N ratio not in Eb/No.

The total energy per symbol of QPSK is

$$E_{s,qpsk} = 2 \times E_{b,bpsk}$$

The qpsk system carries twice as much information as by bpsk but needs extra 3dB of C/N ratio to achieve the same BER as bpsk. So BPSK modulation is preferable here.

C: The Implementation Margin of a satellite communication system is defined as the degradation of the signal after travelling through the up and downlink equipment .An Implementation Margin of 1dB means that bit energy, Eb, has to be increased by 1dB in order to achieve the same BER as with the modem on its own. In other words, the noise has increased by a factor of 1dB by travelling via the system's up and downlink. The implementation margin must be added to the C/N ratio to account for the difference between a real system and the ideal system such as SCPC channels in VSAT system and LEO mobile satellite links, implementation margins as low as 0.5dB have been reported.

$$(C/N)_{eff} = (C/N)o - \text{implementation margins in dB}$$

$$(C/N)_{eff\ ratio} = 10^{(C/N)eff/10} \quad \text{as a ratio}$$

$$(BER)_{BPSK} = 1/2\ \mathrm{erfc}[\sqrt{(C/N)_{eff\ ratio}}]$$

$$= Q\ [\sqrt{(2C/N)_{eff\ ratio}}\ ]$$

The implementation margin can be used as a factor to standardize the BER of the system .A good SNR ratio gives better communication and effective result in signal transmission along with reception. The capacity of a system or a link depends upon the BW and SNR value. As we know that the capacity is formulated by

$$C = B\log_2(1+SNR)$$

$$= B\log_2(1+P/N_0B) \text{ bps}$$

Where B is the channel bandwidth in HZ
P is received power in watts
$N_0$ is noise power

## III. EXPERIMENT AND RESULT

**A: Budget calculation:**

The mathematical calculations are done by considering all the required values into account:
Uplink frequency for mobile terminal: 1650MHZ
Downlink frequency for the mobile terminal: 1550MHZ
Transponder bandwidth: 1MHZ
Antenna gain (1650MHZ uplink): 23dB
Antenna gain (1550MHZ downlink):23dB
Maximum range of coverage zone: 1469km
Modulation: BPSK
Transmitter output power: 0.5W
The received power is given by

Received power $(P_r) = EIRP + G_r - L_p - L_m$ dBW

The path loss $= L_p = (4\pi R/\lambda)^2$

$= 20\log_{10}(4\pi R/\lambda)$dB

Uplink frequency is 1650MHZ so $\lambda$=0.1818m.Mximum range is approximated to 1500km.
Thus $L_p=20\log_{10}(4\pi * 1.5*10^6/0.1818)$
=160.31dB
Miscellaneous losses= $L_m$=-3.5dB
So power received=$P_r$= -3dB+ 23dB-160.31-3.5dB
= -142.81dBW
Transponder Noise power budget:
System noise temperature=$T_s$=27.0dB
Noise bandwidth=$BW_n$=36.8dBHZ
Noise power =N= -164.8dBW
$P_n=kT_sB_n=k+T_s+B_n$ dBW
= - 228.6 +27 +36.8
=164.8dBW
Carrier to noise power ratio for uplink:
$(C/N)_{up}=P_r/N$
= - 142.81dBW - (-164.8dBW )
=21.99dB
This is the lowest C/N ratio that should occur in the transponder in clear air conditions.
For the downlink
EIRP= -10.0dB
Gain of the received antenna = $G_r$= 53.3dB
Path loss = $L_p$ = -182.5dB
$L_m$ = -3.5 dB
So $P_r$ = -10.0+ 53.5 -182.5 -3.5 dBW
= - 142.5 dBW
Noise power=-170.3dBW

Station noise power budget = $(C/N)_{dn} = P_r/N$ = -142.5-(-170.3)
=27.8dB
Overall $(C/N)_0$ can be calculated using the below formula
$1/(C/N)_0 = 1/(C/N)_{up} + 1/(C/N)_{dn}$
=0.0454+0.03597
=0.08137
So overall $(C/N)_0$ = 12.2895dB
Effective carrier to noise power is calculated by

$$(C/N)_{eff} = (C/N)_0 - \text{Implementation margin in dB}$$

The implementation margin can be used as a factor to standardize the BER of the system .A good SNR ratio gives better communication and effective result in signal transmission along with reception. Implementation margin for the BPSK system can be varied from 0 to 0.5 dB.

$$(C/N)_{eff} = 10^{(C/N)eff/10} \text{ as a ratio}$$

Implementation margin should be within 0dB to 0.5dB

| SI NO. | $(C/N)_0$ | Implementation margin | $(C/N)_{eff}$ | $(C/N)_{eff}$ as a ratio |
|---|---|---|---|---|
| 1 | 12.2895dB | 0dB | 12.2895dB | 16.94 |
| 2 | 12.2895dB | 0.1dB | 12.1895dB | 16.55 |
| 3 | 12.2895dB | 0.2dB | 12.0895dB | 16.17 |
| 4 | 12.2895dB | 0.3dB | 11.9895dB | 15.81 |
| 5 | 12.2895dB | 0.4dB | 11.8895dB | 15.45 |
| 6 | 12.2895dB | 0.5dB | 11.7895dB | 15.09 |

Table 2 : Effective Carrier to noise ratio with varying implementation margin

As for calculation considering IM =0.1dB

So, $(C/N)_{eff} = 10^{(C/N)eff/10}$ as a ratio

$=10^{1.21895}$

$=16.55$

The table shows the C/N ratio is better for low IM value.

**B: SNR calculation:**

Again according to the relation between SNR with C/N we can write,

$S/N = (C/N)_0$ +Improvement factor

In order to maintain a good S/N ratio so as to match for better communication S/N should be around 50dB

That means the improvement factor has to be more.

For the system we have S/N =12.2895 dB+ Improvement factor as required.

Considering SNR to be around 50 dB

The improvement factor has to be around 20-30dB

As of actual analysis the SNR is here

$$SNR= 12.2895+5.5 = 17.7895dB$$
$$=60.103Watt$$

**C: Capacity calculation:**

The capacity can be calculated as

$$C = B \log_2 (1+SNR)$$
$$=1*10^6*\log_2(1+60.103)$$
$$=1.786*10^6 \text{ bps}$$
$$=1.786\text{Mbps}$$

The capacity of the given link is around 1.786Mbps which is effective for the communication. That's why the encryption and decryption rate is quite admissible.

**D: BER calculation:**

The bit error rate should be around in the order of $10^{-4}$ to $10^{-8}$ for the BPSK modulation having 34dB to 50 dB of SNR value. As SNR is equal to $1/4P_e$ where $P_e$ is the BER.

BER of BPSK = $(1/2)\text{erfc}[\sqrt{C/N_{eff\ ratio}}]$

$=Q[\sqrt{2C/N_{eff\ ratio}}]$

When $(C/N)_{eff\ ratio}$ is 16.94

Then $BER_1 =Q[\sqrt{2*16.94}]$

$=Q[5.83]=3.3*10^{-9}$

When $(C/N)_{eff\ ratio}$ is 16.55

$BER_2 = Q[\sqrt{2*16.55}] =Q[5.75] =4.65*10^{-9}$

When $(C/N)_{eff\ ratio}$ is 16.17

$BER_3$ =Q[√2*16.17] =Q[√32.34] =Q[5.69] =1.073*$10^{-8}$
When $(C/N)_{eff\ ratio}$ is 15.81
$BER_4$=Q[√2*15.81] =Q[√31.62] =Q[5.59] ≈1.902*$10^{-8}$
When $(C/N)_{eff\ ratio}$ is 15.45
$BER_5$=Q[√2*15.45] =Q[√30.90] =Q[5.5] ≈1.902*$10^{-8}$
When $(C/N)_{eff\ ratio}$ is 15.45
$BER_5$=Q[√2*15.09] =Q[√30.18] =Q[5.5] ≈1.902*$10^{-8}$

| SI NO | $(C/N)_{eff\ ratio}$ | BER value |
|---|---|---|
| 1 | 16.94 | 3.3*$10^{-9}$ |
| 2 | 16.55 | 4.65*$10^{-9}$ |
| 3 | 16.17 | 1.073*$10^{-8}$ |
| 4 | 15.81 | 1.902*$10^{-8}$ |
| 5 | 15.45 | ≈1.902*$10^{-8}$ |
| 6 | 15.09 | ≈1.902*$10^{-8}$ |

Table 3 for $(C/N)_{eff\ ratio}$ with BER value.

| SI NO | $(C/N)_{eff}$ in dB | BER |
|---|---|---|
| 1 | 12.2895dB | 3.3*$10^{-9}$ |
| 2 | 12.1895dB | 4.65*$10^{-9}$ |
| 3 | 12.0895dB | 1.073*$10^{-8}$ |
| 4 | 11.9895dB | 1.902*$10^{-8}$ |
| 5 | 11.8895dB | ≈1.902*$10^{-8}$ |
| 6 | 11.7895dB | ≈1.902*$10^{-8}$ |

Table 4 for BER with $(C/N)_{eff}$ in dB

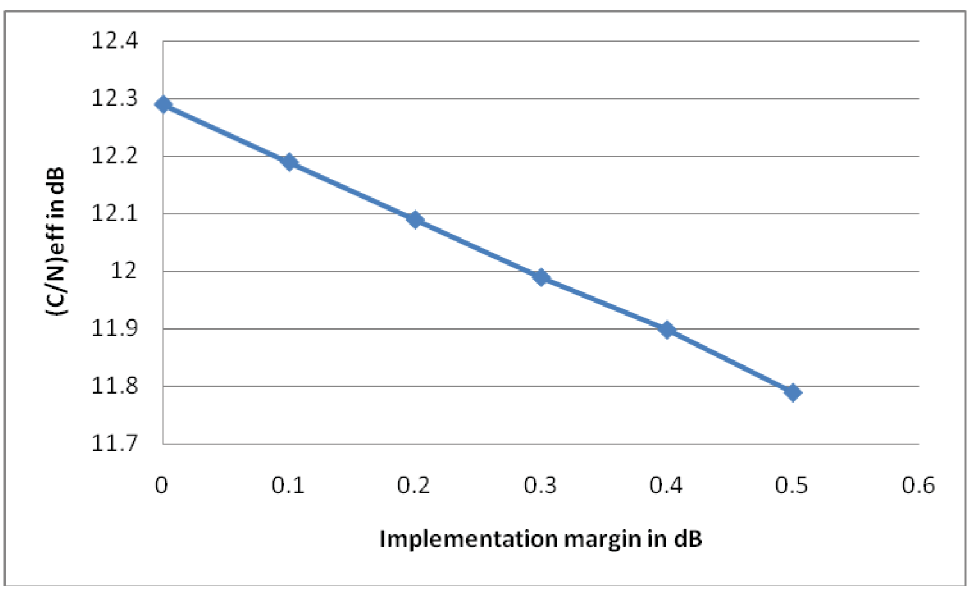


Figure1: Graph for (C/N)eff with implementation margin

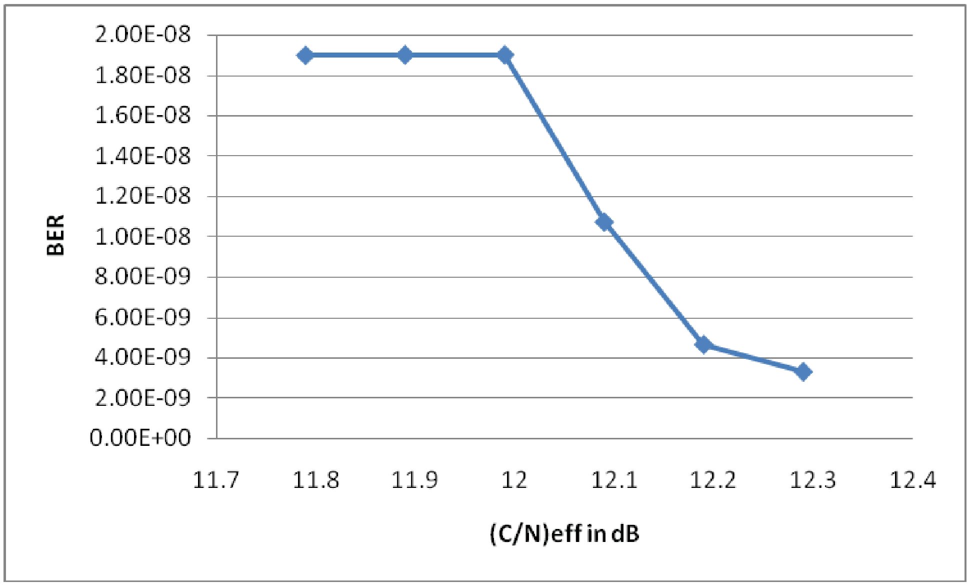

Figure 2: Graph for BER with (C/N)eff

## IV. CONCLUSION

Hence , we have proposed one model for the performance calculation and analysis of LEO satellite by varying implementation margin. The implementation margin is a big factor in getting stable (C/N) ratio. As the implementation margin goes on decreasing the carrier to noise ratio increases. The graph shows how an effective carrier to noise ratio can be achieved by taking into consideration the implementation margin. The graph of BER with carrier to noise ratio is also shown.

## REFERENCES

[1] T. J. Lang. Optimal Low Earth Orbit Constellations for Continuous Global Coverage. In AAS/AIAA Astrodynamics Specialist Conference, Victoria, BC, Aug. 16-19 1993. AAS Paper 93-597.
[2] F. Dosiere, et al. A model for the handover traffic in low earth-orbiting satellite networks for personal communications. In IEEE Globecom, 1993.
[3] A. Ganz, Y. Gong, and B. Li. Performance study of low earth orbit satellite systems. IEEE Trans. Commun., 42(2/3/4), February/March/April 1994.
[4] V. Obradovic and S. Cigoj. Performance evaluation of prioritized handover management for LEO mobile satellite systems with dynamic channel assignment. In Global Telecom. Conf., vol. 1A, 1999.
[5] Lutz E, Werner M, Jahn A. Satellite Systems for Personal and Broadband Communications. Springer-Verlag,2000.