Link Budget of LEO Satellite (Sky Bridge) For Communication Operated At Ku Band Frequency Range (12-14) GHz

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Abstract- A communication's "link" refers to the transmission of the signal from a transmitter and its reception by a receiver. An accounting of signal strength and noise is an important part of system design and is known as a "link budget". The ability to communicate depends on the strength of the signal and the amount of thermal noise that make its way into the system. The main focus of link budget in LEO satellite here is to prepare data sheet which enables better communication with effective signal strength. Experimental results show that iterative techniques must be used to find a set of parameters for the earth stations and the satellite that provides the performance that required from the satellite communication system.

Keywords – Link, budget, LEO, Signal strength.

I. INTRODUCTION

Satellite communication systems have become an essential part of the world's largest telecommunication infrastructure , serving billions of people with telephone ,data and video service .LEO earth imaging satellites have the potential to provide strong revenue stream .A communication's "link" refers to the transmission of the signal from a transmitter and its reception by a receiver. The ability to communicate depends on the strength of the signal and the amount of thermal noise that make its way into the system. An accounting of signal strength and noise is an important part of system design and is known as a "link budget". Low-earth-orbit satellite communication link margins vary greatly as the satellite moves in its orbit around the earth. A major design consideration that needs to be addressed for any satellite system is the choice of forward-error-correction code (FEC).This type of FEC and the optimal packet length are chosen so as to optimize the system for all expected link margins. This paper presents a link quality prediction scheme, which would enable both the satellite and ground station to adjust the coding rates used in the real time. The error performance of the code as the function predicted link quality will be optimized by this scheme. This project has set out the procedures for calculation of received power from a satellite and noise power in a receiver .Satellite systems operate in the microwave frequency band using frequencies between 1 to 50 GHz. Above 10 GHz, rain causes significant attenuation of the signal . Above 20GHz attenuation in heavy rain causes the link will fail .In today's generation the mobile communication system has expanded its field of application in many sectors because of which it is facing some major problems like limited bandwidth and large number of users. So to reduce these problems and to ensure maximum utilization of power and bandwidth a link budget is generally prepared which involves a very complex procedure. The main aim of this project is to prepare a link budget (with minimum limitations and maximum advantages) for LEO (Sky Bridge) satellite at (12-14) GHz frequency in a much simpler way which will find its application in the present mobile communication system.

Sky-Bridge is a very attractive solution to provide access in a cost effective manner on a global basis to a very wide range of high-quality broadband and narrow-band services, thus contributing to the objective of universal access to communication services .In Iridium type of satellite it uses up to 3GHz with orbital height of 780 km , orbital velocity of 7.4624 km/s and orbital period of 1 hours 40 minutes 27sec .If we compare between two type of LEO satellite system.

Types of satellite	Orbital height(in km)	Orbital velocity(in km/sec)	Orbital period H M S
SKY-BRIDGE	1,469	7.1272	1 55 17.8
IRIDIUM	780	7.4624	1 40 27

Link budget:

A link budget is actually simple addition and subtraction of gains and losses within an RF link. When these gains and losses of various components are determined and summed, the result is an estimation of end-to-end system performance in the real world. To arrive at an accurate answer, factors such as the uplink power amplifier gain and noise factors , transmit antenna gain, slant angles and corresponding atmospheric loss over distance, satellite transponder noise levels and power gains, receiver antenna and amplifier gains and noise factors, and climatic attenuation factors must considered.

Link budget needs the following information's:

- Latitude and longitude of the uplink and downlink earth stations.
- Planned data or information rate.
- Modulation type (BPSK or QPSK)
- Forward error correction rate (1/2 or 3/4)
- Spread Factor - if any (use only for spread spectrum systems)
- Uplink and Downlink frequencies.
- Uplink and Downlink antenna sizes.
- Uplink and Downlink antenna efficiency.
- Uplink and Downlink transmit and receive gains at frequency.
- Minimum digital signal strength (EB/No) for desired Bit Error Rate (BER) performance.

II. PROPOSED WORK

A: Link budget calculation involves–

1. To minimize the cost of spacing one satellite in proper channel in space for better communication.
2. To respond to the real world problem by proposing effective power calculation.
3. To control the satellite orbiting in the range of our requirements
4. Losses control.
5. EIRP Calculation.
6. FSL calculation.
7. Carrier to noise ratio calculation.
8. BER (Bit Error Ratio) performance.

Losses:

The losses experienced by the signal fall into these categories:

- Free Space Loss (FSL)
- Rain
- Oxygen
- Antenna Misalignment

B: Satellite links: The Upwards satellite link

The satellite receive beam will have a G/T value for the direction from your earth station. Reviews the uplink beam coverage map and determine the satellite receive G/T in the direction from your site. Values like -8 to +10 dBK are typical .Broad, earth coverage global beams have the lowest G/T; their beam width is approx 17.5 deg, which is what the earth looks like from a geostationary orbit position. Spot beams (say 1 deg diameter) have the highest uplink G/T.

C/N_{up} = earth station EIRP - path loss + satellite G/T - bandwidth +228.6Db

C: Satellite links: The Downward satellite link

The downlink EIRP from the satellite is either: For single carrier, whole transponder operation, Satellite downlink carrier EIRP For multi-carrier operation, Satellite downlink carrier EIRP = EIRP (as per beam contour) - transponder output back off - 10 x log (your carrier bandwidth / transponder bandwidth)

Consider the downlink receive earth station. This will have a diameter size; receive frequency and system noise temperature. Put these together and you will get the receive earth station G/T. The equation for G/T is: Earth station G/T =Gain - 10 log (system noise temperature)

Now use the link budget equation for satellite links:

C/N_{down} = satellite downlink EIRP - path loss + earth station G/T - bandwidth +228.6 Db

D: Satellite links: Miscellaneous noise entry factors in satellite links

Earth station intermodulation noise: If you are operating a multi-carrier BUC put in say 30 dB interference. Uplink interference from other earth stations pointed to nearby satellite: If you are a low power spectral density uplink put 25dB, otherwise30dB. Uplink interference from multiple beams on same satellite: In any, put 30 dB. Uplink cross polar interference: Put in 30 dB, if you can't trust the installers and NOC staff, put in 25 dB. Transponder intermodulation: If multi-carrier the put in 21 dB
Down-link interference from other nearby satellite: If you are a low power spectral density uplink put 25 dB, otherwise30dB.Down-link interference from multiple beams on same satellite: In any, put 30 dB. Down-link cross polar interference: Put in 30 dB, if you can't trust the installers, put in 25 dB.

Finally add them all together to obtain the total link budget C/N

$$C/N_{TOTAL} = C/N_{UPLINK} + C/N_{DOWNLINK}$$

Received power=transmitted power + transmitted gain + received gain - sum of all losses (in dB)

Here we are using LEO (Sky Bridge) satellite with Ku-band frequency band whose

Uplink frequency = 14GHz

Downlink frequency = 12GHz

As frequency is above 12GHz it suffers from oxygen and water vapour.

For LEO system transmitted gain should not above 3dB

Here we consider that transmitted power for LEO (Sky Bridge) is 10 dBW. Generally for LEO system the transmitted power should not exceed above 10 dBW, so we consider it as reference power.

III. EXPERIMENT AND RESULT

A: FOR UPLINK DESIGN:

Transmitted Power = 10 dBW

Transmitted Gain = 3 dBW

EIRP of Transmitted Antenna (UPLINK)

EIRP = P_t*G_t

EIRP =30 dbW

As this satellite is used for mobile terminal the bandwidth should be (0.5-1.5) GHz

Let BW = 1.5 GHz

= 10 log ($1.5*10^9$)

= 91.76 dBHz

Reference temperature (T) = 290 K

= 10 log (290)

= 24.624 dBK

Boltzmann's constant (K) = $1.23*10^{-23}$

= -228.6 dBW/K/Hz

Received gain (G_r) = 3 dB (for downlink 12 GHz)

Free space loss (FSL) = $10 \log (4*3.141*r/f)^2$
=

$20 \log ((4*3.141*f*r)/c)$

Radius (sky bridge) = 1469 km

FSL = $20 \log (4*3.141/c)+20 \log(r)+20 \log (f)$
= $-147.558+20 \log (1469) +20 \log (14*10^9)$
= -147.558+63.34+202.922
= 118.704 Db

As frequency above is 12 GHz so it suffers from oxygen and water vapour
So the losses are

1. FSL
2. Rain (0.1-0.12) dB
3. Atmospheric losses (1 dB)
4. Polarization loss (3 dB)
5. Antenna misalignment loss (1 dB)

Sum of all losses = FSL+ atm.loss+ polarization loss+ antenna misalignment loss
= 118.704+1+3+1
= 123.704 dB

Received power (P_r) = $P_t+G_t+G_r$-losses
= 10+3+3-123.704
= -107.704 dB

G/T = G_r-T (in dB)
= 3-24.624
= -21.624 dB

$(C/N)_{up}$ = EIRP+ (G/T)-losses-K-Bn

= 30+ (-21.624)-123.704-(-228.6)-91.76

= 30-21.624-123.704+228.6-91.76
= 21.512 dB

Transponder noise power budget,

Noise power (N) = log (K) +log (T) +log (B)
= -228.6+24.624+91.76=-112.216 dB

B: FOR DOWNLINK DESIGN

Gain of receiving antenna (G_r) = 3 dB
Transponder output power (P_t) = 7 dBW
EIRP = P_t*G_t
= 21 dBW

FSL = 20log (4*3.14*1469*12*10^9/3*10^8)
= -147.558+63.34+201.583
= 117.365 dBW

Propagation loss (Lprop) = 117.365+1+3+1
= 122.365

P_r = 21+3-122.365=-98.365 dBW

(G/T) = G_r-T

= 3-24.624=-21.624 dB

(C/N)dBW = 21-21.624-122.365+228.6-91.76

= 13.851 dB

Gateway station- noise power budget,

K = -228.6 dBW/K/Hz

Ts = 250=23.979 Dbk

BW = 91.76 dBHz

N = -228.6+23.979+91.76=-112.861

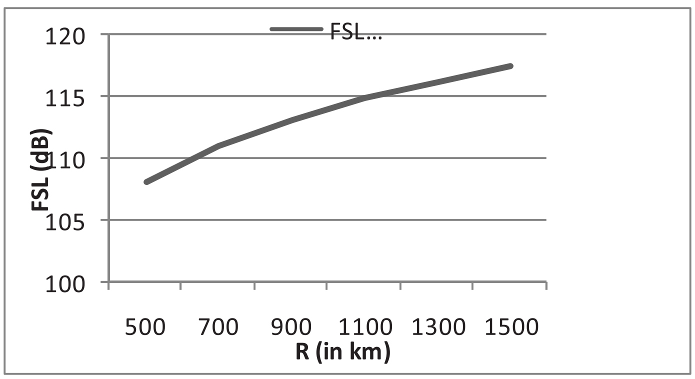
$(C/N)_{total}$ = $(C/N)_{up} + (C/N)_{down}$

= 21.512+13.851

= 35.363 dB

TABLE-1(For LEO)

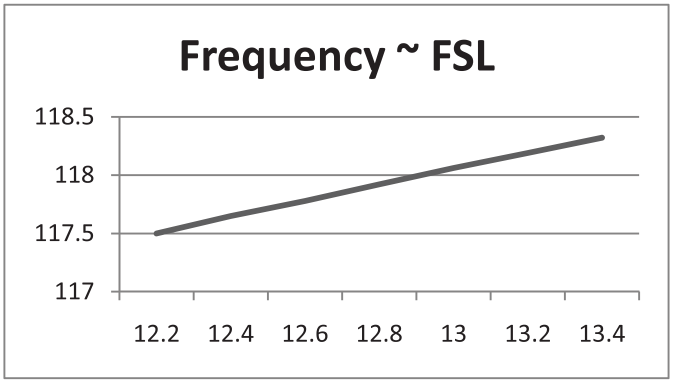
RADIUS(in km)	FSL(in dB)
500	108.003
700	110.925
900	113.108
1100	114.851
1300	116.303
1500	117.546



Graphs between FSL with radius

TABLE-2(For LEO)

FREQUENCY (in Hz)	FSL (in dB)
12.2	117.50
12.4	117.65
12.6	117.78
12.8	117.92
13.0	118.06
13.2	118.19
13.4	118.32
13.6	118.45



Graph between FSL with frequencies

DOWNLINK POWER BUDGET

Sl. No.	Parameters	Symbols	Values	Result	Units
1.	Transmitting Power	P_t	7		dBW
2.	Transmitting Gain	G_t	3		dB
3.	Equivalent Isotropic Radiated Power	EIRP		21	dBW
4.	Received Gain	G_r	3		dB
5.	Frequency	F	201.583		dBHz
6.	Free Space Loss	FSL		117.365	dB
7.	Atmospheric Losses	L_a	1		dB
8.	Polarization Losses	L_p	3		dB
9.	Antenna Misalignment Loss	L_{ant}	1		dB
10.	Received Power	P_r		-98.365	dBW
11.	(G/T)ratio	G/T	-21.624		dB
12.	$(C/N)_{DOWN}$	$(C/N)_{DOWN}$		13.851	dB

UPLINK POWER BUDGET

Sl. No.	Parameters	Symbols	Values	Result	Units (in dB)

1.	Transmitted Power	P_t	10		dBW
2.	Transmitted Gain	G_t	3		dB
3.	Equivalent Isotropic Radiated Power	EIRP		30	dBW
4.	Bandwidth	BW	91.761		dBHz
5.	Temperature	T	24.624		dBK
6.	Boltzmann's Constant	K	-228.6		dBW/K/Hz
7.	Received Gain	G_r	3		dB
8.	Free Space Loss	FSL	118.704		dB
9.	Atmospheric Losses	L_a	1		dB
10.	Polarization Losses	L_p	3		dB
11.	Antenna Misalignment Losses	L_{ant}	1		dB
12.	Received Power	P_r		-107.704	dB
13.	(G/T)ratio	(G/T)	-21.624		dB
14.	$(C/N)_{UP}$	$(C/N)_{UP}$		21.512	dB

IV.CONCLUSION

Hence , we have proposed one model for the link bud-get calculation as per the assumptions we have taken effectively .The calculations involved in formulating various graphs ,simulation results ,mathematical evaluations successfully .The result of whose has been attached previously

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