An Approach to calculate the Performance and Link Budget of LEO Satellite (Iridium) For Communication Operated at frequency Range (1650-1550) MHz

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Abstract- In our article we are going for Link Budget calculation about one of big LEO's satellite that is Iridium. And 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". Generally this LEO satellite is used for personal communication purposes as it produces effective signal strength with less power consumption and minimum loss. The main focus of link budget in LEO satellite (Iridium) here is to prepare data sheet which enables better communication with effective signal strength.
Keywords – Link budget, LEO (Iridium), Signal strength

I. INTRODUCTION

Satellites are usually semi-independent computer-controlled systems. Satellite subsystems attend many tasks, such as power generation, thermal control, telemetry, attitude control and orbit control. A low Earth orbit (LEO) is an orbit around Earth with an altitude between 160 kilometers (99 mi), with an orbital period of about 88 minutes, and 2,000 kilometers (1,200 mi), with an orbital period of about 127 minutes. The Iridium satellite constellation is a large group of satellites providing voice and data coverage to satellite phones, pagers and integrated transceivers over Earth's entire surface. The constellation consists of 66 active satellites in orbit, and additional spare satellites to serve in case of failure. Satellites are in low Earth orbit at a height of approximately 485 mi (781 km) and inclination of 86.4°. Orbital velocity of the satellites is approximately 17,000 mph (27,000 km/h). Satellites communicate with neighboring satellites via Ku band inter-satellite links.

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

II. PARAMETER SPECIFICATION

PARAMETER	SPECIFICATION
Iridium satellite orbit	: LEO
Orbit altitude	: 780 km
Iridium applications	: Voice and data
Satellites in constellation	: 66
User satellite link band	: 1550 - 1650 MHz
L band	
Gateway -> Satellite up-link	: 29.1 - 29.3 GHz
Satellite -> Gateway downlink	: 19.1 - 19.6 GHz
Inter-satellite link	: 22.55 - 23.55 GHz
Satellite relative velocity	: 26 804 km/hr
Minimum angle of elevation for acceptable operation	: 8.2°
Approximate satellite view time	: 9 - 10 minutes
Access scheme	: FDMA / TDMA
Frequency re-use factor	: 12
Total system capacity	: 172 000 users

III. MATHEMATICAL FORMULATIONS OF 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.

i. *Link budget calculation involves:*

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

Losses:

- The losses experienced by the signal fall into these categories:
- Free Space Loss (FSL)
- Rain
- Oxygen
- Antenna Misalignment

ii. *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

iii. *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 +228.6dB

iv. *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, otherwise 30dB. 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 25dB.

v. *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.

$$\mathbf{(C/N)_{TOTAL} = (C/N)_{UPLINK} + (C/N)_{DOWNLINK}}$$

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

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

Uplink frequency = 1650MHz

Downlink frequency = 1550MHz

As frequency is above 1650MHz it suffers from oxygen and water vapour. For LEO system transmitted gain should not above 3dB.Here we consider that transmitted power for LEO (Iridium) is 10 dBW. Generally for LEO system the transmitted power should not exceed above 10 dBW, so we consider it as reference power.

IV. EXPERIMENT AND RESULT

i. 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 Noise bandwidth should be (10-12) MHz

Let BW =12 MHz

So BW $= 10 \log (12*10^6)$ dBW

=70 dBW (aprox.)

Reference temperature (T) = 290 K

= 10 log (290)

= 24.624 dBK

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

= -228.6 dBW

Received gain (Gr) = 3 dB

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

=20 log ((4*3.141*f*r)/c)

Radius (Iridium) = 780 Km

Free Space Loss = 20 log (4*3.141/c) + 20 log(r) + 20 log (f)

$= -147.558+20 \log (780*10^3) +20 \log (1650*10^6)$

= 154.63 dBW

As frequency above is 1550 MHz 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

= 154.63+1+3+1

= 159.63 dBW

Received power (Pr) = EIRP + Gt + Gr - losses

= 30+3+3-159.63

= -123.63 dBW

G/T = Gr – T(in dBW)

= 3-24.624

= -21.624 dBW

(C/N) up = EIRP+ (G/T)-losses-K-Bn

= 30 + (- 21.624) -159.63 - (-228.6) – 70

= 7.35 dB

Transponder noise power budget,

Noise power (N) = log (K) +log (T) +log (B)

= -228.6+24.624+70 = -133dBW

ii. FOR DOWNLINK DESIGN:

Gain of receiving antenna (Gr) = 3 dB

Transponder output power (Pt) = 10 dBW

EIRP = $P_t * G_t$ = 30 dBW

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

= 20 log ((4*3.141*f*r)/c)

$= 20 \log ((4*3.141*1550*10^6*780*10^3) / 3*10^8)$

= 154.09 dBW

Received Power (P_r) = EIRP + Gr – Losses

= 30 + 3 – 159.09

= - 126.09 dBW

G/T = Gr – T (in dB)

= - 21.624 dB

$(C/N)_{down}$ (in dBW) = EIRP + (G/T) – Losses – K – Bn

= 30 – 21.624 – 159.09 + 228.6-70

= 7.88 dBW

Gateway station- noise power budget,

Boltzmann's constant K = -228.6 dBW/K/Hz

Temperature (Ts) = 250=23.979 Dbk

Noise BW = 70 dBHz

Noise power (N) = -228.6 + 23.979 + 70

= -134.621 dBW

(C/N) total = (C/N) up+ (C/N) down

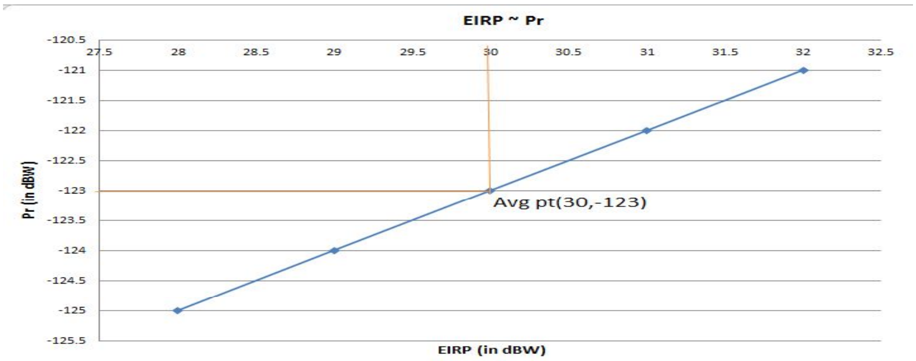
= 7.35 + 7.88

= 15.23 dBW

V. SIMULATION:

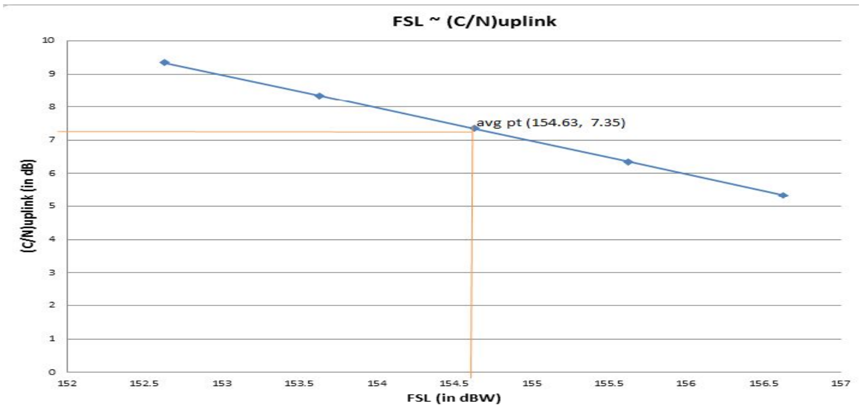
A. Table-1. EIRP ~ Pr

EIRP in dBW	P_r in dBW
28	125
29	124
30	123
31	122
32	121



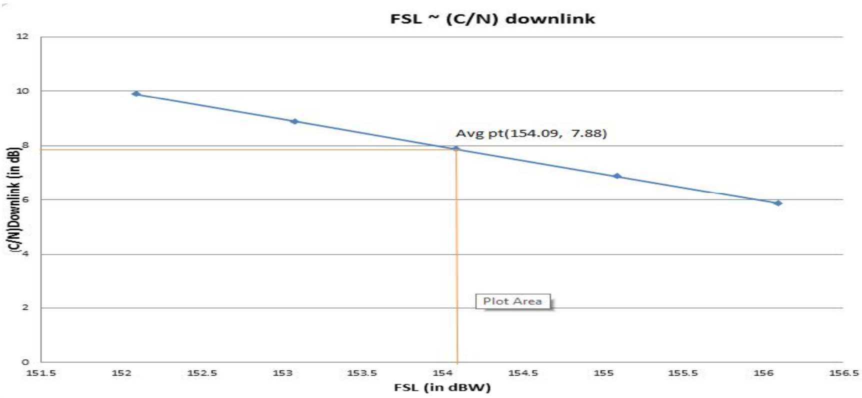
B.Table-2. FSL ~ (C/N) uplink

FSL(in dBW)	(C/N)uplink in dBW
28	9.35
29	8.35
30	7.35
31	6.35
32	5.35



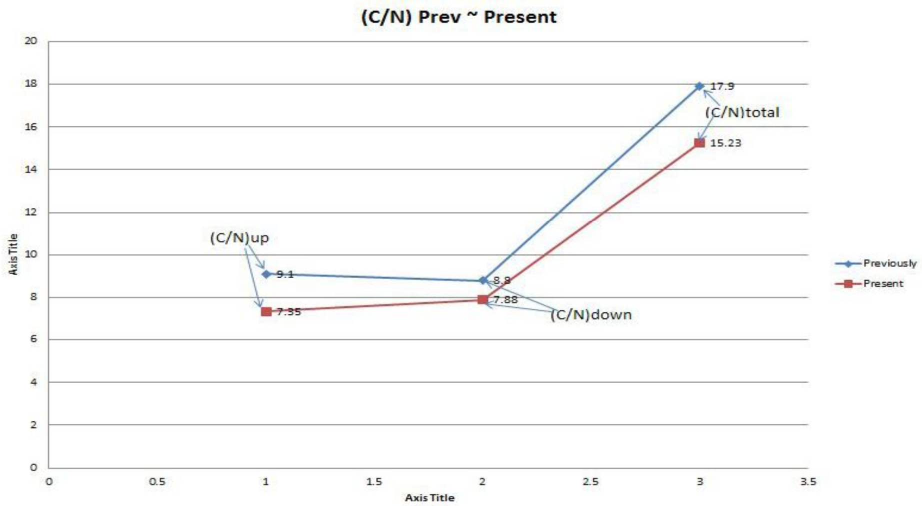
C.Table-3. FSL ~ (C/N) downlink

FSL in dBW	(C/N)downlink in dB
152.09	9.88
153.09	8.88
154.09	7.88
155.09	6.88
156.09	5.88



D.Table (C/N) ratio of previous result Vs Present result:

	Previous Result	Present Result
(C/N)up	9.1	7.35
(C/N)down	8.8	7.88
(C/N)total	17.9	15.23



E. UPLINK POWER BUDGET

SL.NO	**Parameters**	**Symbols**	**Values**	**Result**	**Units (in dB)**
1	Transmitting power	Pt	10		dBW
2	Transmitting gain	Gt	3		dBW
3	Equivalent isotropic radiated power	EIRP		30	dBW
4	Bandwidth	BW	70.79		dBHz
5	Temperature	T	24.624		dBk
6	Boltzmann's constant	K	228.6		dBW/k/hz
7	Received gain	Gr	3		dB
8	Frequency	F	184.34		dB
9	Free space loss	FSL	154.63		dB
10	Atmospheric loss	La	1		dB
11	Polarization loss	Lp	3		dB
12	Antennae misalignment loss	Lant	1		dB
13	Received power	Pr		-123.63	dBW
14	(G/T)ratio	G/T	-21.624		dB
15	(C/N)up	(C/N)		7.35	dB

F. *DOWNLINK POWER BUDGET:*

SL.NO.	Parameters	Symbol	Values	Result	Units(in dB)
1	Transmitting power	Pt	10		dBW
2	Transmitting gain	Gt	3		dB
3	Equivalent isotropic radiated power	EIRP		30	dBW
4	Received gain	Gr	3		dB
5	Frequency	F	183.80		dBHz
6	Free space loss	FSL		154.09	dB
7	Atmospheric loss	La	1		dB
8	Polarization loss	Lp	3		dB
9	Antennae misalignment loss	Lant	1		dBW
10	Received power	Pr		-126.09	dBW
11	(G/T)down	G/T	-21.624		dB
12	(C/N) ratio	(C/N)		7.88	dBW

VI. 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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