

**RF**

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**Conceptual Design of Telemetry, Command and Ranging Subsystem RF  
Link Budget for Communication Satellite**

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**Abstract**

A conceptual design on the link budget of TC&R RF subsystem which transfers command and telemetry data as RF signal between the ground system and the 2005SAT spacecraft is presented in this paper. In order to perform the analysis of the link budget, we divided the analysis process into two processes, i.e., uplink and downlink process. For the uplink the power flux density at the spacecraft and the margin of the command receiver are calculated. In the case of the downlink the downlink EIRP and the margin of  $C/N_0$  and  $E_b/N_0$  at the ground station are calculated. Through the uplink performance analysis, the power at the command receiver has well efficient margin, and the margin of  $C/N_0$  and  $E_b/N_0$  is also fully proper for the downlink case.

2005SAT RF  
RF

EIRP  $C/N_0$   $E_b/N_0$

가 C/N<sub>0</sub> E<sub>b</sub>/N<sub>0</sub>

가

:(telemetry, command and ranging subsystem), radio frequency,  
(link budget)

1. 가

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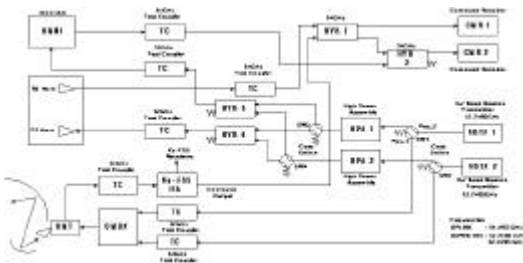
가  
가

(Signal to Noise Ratio, S/N)  
(Bit Error Rate, BER)

(RF Link )  
( , )

2005SAT  
RF

1 2005SAT  
RF



1. 2005SAT

RF

2.

2.1

- 1) (Circuit Losses) :
- 2) (Receive Multipath Loss)
- 3) (Slant Range) :
- 4) : EIRP,  
(Ground Station Pointing  
(Atmosphere Loss),  
(Free Space Spreading Loss),  
(Rain Attenuation)
- 5) (Margin) : 4)  
(Isotropic Aperture),  
, 1)  
(Threshold)

- 1) :
- 2) (Transmit Multipath Loss)
- 3) EIRP : SSPA/ BTX  
, 1) , 2)
- EIRP
- EIRP
- 4) C/ No. : 3)  
EIRP, (Free Space

Path Loss),  
 $(10\log(k))$

5)  $E_b/N_o$   
 $S/N_o$   
 $E_b/N_o$  : 4)  
 $C/N_o$ ,  
 (Modulation Loss),  $1/$ ,  
 (Implementation Loss)  
 $E_b/N_o$  BER(Bit Error  
 Rate)  $E_b/N_o$   
 $E_b/N_o$   
 : 4)  
 $C/N_o$ ,  
 (Ranging Bandwidth)

, 10.0m

## 2.2

1) :  
 $= APL \times \text{cosec}(\theta)$  dB  
 $\theta$  (Elevation Angle), APL  
 (Atmosphere Loss) 12.7475GHz  
 (Total Zenith Attenuation)  
 $0.075$ ,  $\text{cosec}(\theta) = 1/\sin(\theta)$   
 $0.075/\sin(\theta)$

2) (d):  
 a.

$$d = R^2 + r^2 - 2Rr \cos \gamma$$

$$= R^2 + (R+h)^2 - 2R(R+h)$$

$$\times (\sin \phi \sin \gamma + \cos \phi \cos \gamma \cos \Delta \lambda)$$

,  $R=$ ,  $h=$ ,  $\Psi=$   
 ,  $v=$ ,  $\Delta \lambda=$

b.  
 $d = \cos \phi \cos \Delta \lambda$

3) :  
 $= 10 \log(1/(4\pi d^2))$

4) (Isotropic Aperture):  
 $= 10\log \lambda^2 / 4\pi$   
 $\lambda = c/f$ ,  $c = 3 \times 10^8$  m/s,  $f$   
 14.491GHz

5) (Polarization Loss):  
 $= 20 \log \cos(\theta_f)$   
 $\theta_f = 12/14\text{GHz}$   $4^\circ$   
 (Faraday Rotation)

6) (Free Space Path Loss):  
 $= -10 \log (4\pi d)^2 / \lambda$

7) (Crane)

a. : D

b. (Rain Rate)  $R_p$ ,  
 (Outage Percentage)

c.  $0^\circ$  (Isotherm)

d.  $0^\circ$  H:  
 $H=0^\circ$

e.  $0^\circ$  L :  
 $L = H / \sin \theta$   
 $\theta$

f. D:  
 $D = L \cos \theta$

g. Raindrop ( $\alpha, \beta$ )

h. (dB)

$$A_p = \alpha R_p^\beta L / D(X - Y + Z)$$

$$X = (e^{u\beta d} - 1) / u\beta,$$

$$Y = (x^\beta e^{v\beta d}) / v\beta,$$

$$Z = (x^\beta e^{v\beta d}) / v\beta,$$

$$u = (\ln x e^{vd}) / d,$$

1 2

$$x = 2.3R_p^{-0.7},$$

$$d = 3.8 - 0.6 \ln R_p,$$

$$v = 0.026 - 0.03 \ln R_p$$

- 3 (HPA)  
EIRP  
EIRP  
4 C/N<sub>0</sub>  
5 E<sub>b</sub>/N<sub>0</sub>  
6 S/N
- 8) (Pointing Loss): -0.2dB  
가.
- 9) (Modulation Loss): J<sub>0</sub>  
(Bessel) 가
- 10) 1/ Bit Rate = -10 Log(Bit Rate), RF
- 11) (Implement Loss):  
-2.0dB 가. RF
- 12)  $E_b/N_0 = C/N + (1/\text{Bit Rate} + )$  4.
- 13) E<sub>b</sub>/N<sub>0</sub>: 1x10<sup>6</sup> 2005SAT
- 14) : 5Hz Fine Tone Loop RF RF
- 15) 10 1σ S/N  
:  $S/N = 1/(2R_e^2), R_e$

### 3.

- EIRP C/N<sub>0</sub> E<sub>b</sub>/N<sub>0</sub>
2. 가  
C/N<sub>0</sub> E<sub>b</sub>/N<sub>0</sub>
- 3 가
- 가
- 99.9% TC&R RF
- 1 EIRP
- 2 EIRP

## 1.

| Flux Density at Spacecraft |                          |                    |               |               |           |   |
|----------------------------|--------------------------|--------------------|---------------|---------------|-----------|---|
| Parameters                 | Unit                     | Transfer orbit     |               | Mission       |           | Comments  |
|                            |                          | Geosynch. Altitude | Operations    | Emergency     | Emergency |   |
| G/S ERP                    | dBW                      | 89                 | 87            | 87            |           |   |
| G/S Pointing Loss          | dB                       | -0.4               | -0.4          | -0.4          |           | Estimate  |
| Atmosphere Loss            | dB                       | -0.11              | -0.11         | -0.11         |           | Calculated  |
| Free Space Spreading Loss  | dB/m <sup>2</sup>        | -163.32            | -162.45       | -162.45       |           | Calculated : $10 \cdot \log(1/(4 \cdot \pi \cdot d^2))$ |
| Rain Attenuation           | dB                       | -5.2               | -5.05         | -5.05         |           | Guam at 20, Daejeon at 45, 99.9%                        |
| <b>Flux Density at S/C</b> | <b>dBW/m<sup>2</sup></b> | <b>-80.03</b>      | <b>-81.01</b> | <b>-81.01</b> |           |   |
| Specified PFD              |                          | -80.00             | -95.00        | -80           |           |   |

## 2.

| UpLink Budget on Calculated Flux Density From Ground EIRP |                    |                |                    |              |                    |               |                    |                      |                    |               |                    |
|---|--------------------|----------------|--------------------|--------------|--------------------|---------------|--------------------|----------------------|--------------------|---------------|--------------------|
| Parameter   | Unit               | Transfer Orbit |                    |              |                    |               |                    | Geosynchronous Orbit |                    |               |                    |
|   |                    | Cruise Att.    |                    | Earth Att.   |                    | LAE Burn Att. |                    | Mission Ops.         |                    | L.O.P.L       |                    |
|   |                    | Omni Antenna   | Wide Angle Antenna | Omni Antenna | Wide Angle Antenna | Omni Antenna  | Wide Angle Antenna | Comm. Antenna        | Wide Angle Antenna | Comm. Antenna | Wide Angle Antenna |
| Flux Density at S/C                                       | dBW/m <sup>2</sup> | -80.03         | -80.03             | -80.03       | -80.03             | -80.03        | -80.03             | -81.01               | -81.01             | -81.01        | -81.01             |
| Isotropic Aperture  | dB                 | -44.67         | -44.67             | -44.67       | -44.67             | -44.67        | -44.67             | -44.67               | -44.67             | -44.67        | No                 |
| Polarization Loss   | dB                 | -0.02          | -0.02              | -0.02        | -0.02              | -0.02         | -0.02              | -0.02                | -0.02              | -0.02         | Ranging            |
| S/C Antenna Gain  | dB                 | 2.00           | 2.00               | 7.00         | 7.00               | -0.50         | -0.50              | 41.20                | 41.20              | 7.00          | during             |
| Multipath and Scattering Loss                             | dB                 | 0.00           | 0.00               | -2.16        | -2.16              | 0.00          | 0.00               | -0.06                | -0.06              | -2.16         | Loss-of-           |
| Circuit Losses  | dB                 | -8.55          | -8.55              | -17.11       | -17.11             | -8.55         | -8.55              | -34.52               | -34.52             | -17.11        | Pitch              |
| S/C Received Power  | dBW                | -131.27        | -131.27            | -136.99      | -136.99            | -133.77       | -133.77            | -119.08              | -119.08            | -137.97       | Lock or            |
| Command Receiver Threshold                                | dBW                | -138.00        | -135.00            | -138.00      | -135.00            | -138.00       | -135.00            | -138.00              | -135.00            | -138.00       | Emergen-           |
| Margin[Cmr2]  | dB                 | 6.73           | 3.73               | 1.01         | -1.99              | 4.23          | 1.23               | 19.92                | 15.92              | 0.03          | cy                 |
| Margin[Cmrl]  | dB                 |                |                    | 4.81         | 1.81               |               |                    | 22.72                | 19.72              | 3.83          |                    |

## 3. EIRP

| Downlink EIRP Budget Summary |      |                |                 |               |                      |                 |              |
|------------------------------|------|----------------|-----------------|---------------|----------------------|-----------------|--------------|
| Parameter                    | Unit | Transfer Orbit |                 |               | Geosynchronous Orbit |                 |              |
|                              |      | Cruise Att.    | Earth Att.      | LAE Burn Att. | Mission Ops.         | L.O.P.L         |              |
|                              |      | Omni Antenna   | Wide Angle Horn | Omni Antenna  | Comm. Antenna        | Wide Angle Horn | Omni Antenna |
| HPA/KBTX Output              | dBW  | 7.99           | 7.99            | 7.99          | -10.00               | 7.99            | 7.99         |
| Transmit Circuit Losses      | dB   | -5.83          | -12.68          | -5.83         | -5.06                | -12.68          | -5.83        |
| Multipath Loss               | dB   | 0              | -18.17          | 0             | N/A                  | -18.17          | -3.83        |
| Transmit Antenna Gain        | dB   | 2.20           | 7.00            | -0.50         | 40.20                | 7.00            | -0.50        |
| Downlink EIRP                | dBW  | 4.36           | -15.86          | 1.66          | 25.14                | -15.86          | -2.17        |
| Required EIRP                | dBW  | 0              | 0               | 0             | 10.00                | 0               | 0            |
| Margin                       | dB   | 4.36           | -15.86          | 1.66          | 15.14                | -15.86          | -2.17        |

## 4. CN

| On Station Link Budget for Downlink Telemetry/Ranging(99.9%) |          |                 |               |              |                      |
|--|----------|-----------------|---------------|--------------|----------------------|
| Parameter  | Unit     | Wide Angle Horn | Comm. Antenna | Omni Antenna | Remarks              |
| S/C EIRP   | dBW      | -15.86          | 15.14         | -2.16        | Analysis             |
| Free path loss   | dB       | -205.98         | -205.98       | -205.98      | at 12.7 GHz, 37400km |
| Rain Attenuation   | dB       | -2.96           | -2.96         | -2.96        | Crane's Rain 99.9%   |
| Atmospheric Loss   | dB       | -0.106          | -0.106        | -0.106       | Calculated 45E       |
| Pol. & Point. Loss   | dB       | -0.21           | -0.21         | -0.21        | Calculated           |
| G/S G/T  | dB/K     | 38.63           | 38.63         | 38.63        | Daejeon              |
| $10 \cdot \log(k)$   | dBW/K-Hz | 228.6           | 228.6         | 228.6        | Boltzman's Constant  |
| Ground Receive C/No  | dB-Hz    | 42.12           | 73.12         | 55.82        | Worst Case           |

5. E/N

| Telemetry Link(99.90%)                  |        |                    |        |        |                    |        |        |               |        |        |                         |
|---|--------|--------------------|--------|--------|--------------------|--------|--------|---------------|--------|--------|-------------------------|
| Parameter                               | Unit   | Omni Antenna       |        |        | Wide Angle Antenna |        |        | Comm. Antenna |        |        | Remarks                 |
| Received C/No                           | dB-Hz  | 55.82              |        |        | 42.12              |        |        | 73.12         |        |        | Calculated              |
| S/C Attitude                            |        | Loss of Earth Lock |        |        | Loss of Earth Lock |        |        | Earth Lock    |        |        |                         |
| Num. of Subcarriers                     |        | 1                  | 2      | 3      | 1                  | 2      | 3      | 1             | 2      | 3      | TLM/AUX, TLM/RNG        |
| Modulation Loss                         | dB     | -4.81              | -8.56  | -10.05 | -4.81              | -8.56  | -10.05 | -4.81         | -8.56  | -10.05 | 1.0/0.7/0.6 radian each |
| 1/Bit Rate                              | dB-bps | -33.11             | -33.11 | -33.11 | -33.11             | -33.11 | -33.11 | -33.11        | -33.11 | -33.11 | Data Rate=2048Kbps      |
| Implementation Loss                     | dB     | -2.00              | -2.00  | -2.00  | -2.00              | -2.00  | -2.00  | -2.00         | -2.00  | -2.00  | Typical(Estimate)       |
| Received Eb/No                          | dB     | 15.9               | 12.15  | 10.66  | 2.2                | -1.55  | -3.04  | 33.2          | 29.45  | 27.96  |                         |
| Min. Band. for RFB=1x10 <sup>-6</sup> F | dB     | 10.50              | 10.50  | 10.50  | 10.50              | 10.50  | 10.50  | 10.50         | 10.50  | 10.50  |                         |
| Eb/No Margin                            | dB     | 5.4                | 1.65   | 0.16   | -8.3               | -12.05 | -13.54 | 22.7          | 18.95  | 17.46  |                         |

6. S/N

| Ranging Link(99.90%)   |       |              |       |        |                    |       |        |               |       |        |                          |
|------------------------|-------|--------------|-------|--------|--------------------|-------|--------|---------------|-------|--------|--------------------------|
| Parameter              | Unit  | Omni Antenna |       |        | Wide Angle Antenna |       |        | Comm. Antenna |       |        | Remarks                  |
| Received C/No          | dB-Hz | 55.82        |       |        | 41.12              |       |        | 73.12         |       |        | Calculated               |
| S/C Attitude           |       | Globe        |       |        | Earth              |       |        | LAE Burn      |       |        |                          |
| Num. of Subcarriers    |       | 1            | 2     | 3      | 1                  | 2     | 3      | 1             | 2     | 3      | TLM/AUX, TLM/RNG         |
| Modulation Loss        | dB    | -4.81        | -8.56 | -10.05 | -4.81              | -8.56 | -10.05 | -4.81         | -8.56 | -10.05 | 1.0/0.7/0.6 radian each  |
| Ranging Bandwidth      | dB    | 6.99         | 6.99  | 6.99   | 6.99               | 6.99  | 6.99   | 6.99          | 6.99  | 6.99   | Fine Tone Loop BW=5 Hz   |
| Range Tone S/N         | dB    | 58           | 54.25 | 52.76  | 43.3               | 39.55 | 38.06  | 75.3          | 71.55 | 70.06  |                          |
| S/N Reqd. for 10m Acc. | dB    | 35.67        | 35.67 | 35.67  | 35.67              | 35.67 | 35.67  | 35.67         | 35.67 | 35.67  | For 10m, 1sigma accuracy |
| Ranging Margin         | dB    | 22.33        | 18.58 | 17.09  | 7.63               | 3.88  | 2.39   | 39.63         | 35.88 | 34.39  |                          |

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