Slipper2Sat Project



A
EM Long Range Communication Test

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1. Introduction

1.1.General

The long-range communication test shall verify the sufficiency of link budget in all communication channels of satellite operation and RF communication-related SPDM missions. This shall demonstrate proper operation of satellite, ground station and mission-related ground equipment, as well as measure performance of various communication channels. All tests will be conducted in a test setup emulating ground-satellite distance.

1.2.Objectives

The following are the test objectives:

- Verify analyses of various uplink and downlink communication channels in a test setup emulating ground-satellite distance.
- Measure the approximate gain antennas in a long-range test setup.
- Demonstrate the satellite's proper execution of uplink commands and telemetry/mission downlink in a test setup emulating ground-satellite distance.
- Verify the communication performance in a test setup emulating ground-satellite distance.

1.3.Scope

This document is applied to the long-range communication test involving the Slipper2Sat Ground Station, Slipper2Sat EM CubeSat, attenuation (from RF attenuators) to emulate the expected ground-satellite distance. Specifically, the BIRDS ground station antenna is mounted on a mast installed on the top of a Fourth-floor building in NAST technology building and the satellite is installed on a tripod standing in a hilltop located around 6 km away. This setup provides a direct line-of-sight (LOS) between the satellite and the ground station albeit with possibly significant reflections due to the ground, vegetation and infrastructures in between.

2. Reference

Document number	Document description	Revision level or Release date
S2S_RAS	Slipper2Sat Project Requirement Allocation Sheet (COM)	Version 3

Table 1. Requirements from RAS to be satisfied by the test

Requirement Number (from RAS)	Requirement Description
VR1.1.1.1	Ensure received command at UHF band
VR1.1.2.1	Ensuring the data receiving rate is 4800bps
VR2.1.1.1	Ensure transmitted data and ACK at UHF band to GS
VR2.1.3.1	Ensure the signal strength is +32dbm while transmitting

3. Supporting Analysis

Given a transmitter with transmit power P_{TX}, the received power P_{RX} at the receiver is given by

$$P_{RX} = P_{TX} \cdot L_{line,TX} \cdot G_{ANT,TX} \cdot APEL_{TX} \cdot L_{polar} \cdot L_{atmos} \cdot L_{ionos} \cdot L_{path} \cdot APEL_{RX} \bullet G_{ANT,RX} L_{line,RX} \quad (1)$$

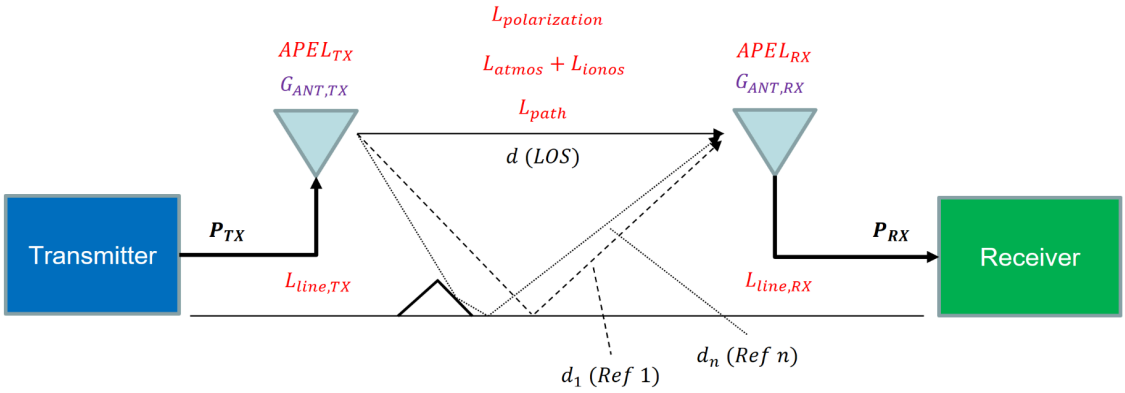


Figure 1. General radio propagation model

where:

$L_{line,TX} = line\ losses\ at\ the\ transmitter\ (e.g.\ due\ to\ RF\ cable) < 1$

$G_{ANT,TX} = transmitting\ antenna\ gain$

$APEL_{TX} = transmitting\ antenna\ pointing\ efficiency\ losses\ (<1)$

$L_{polar} = polarization\ mismatch\ losses\ (< 1)$

$L_{atmos} = atmospheric\ losses\ (< 1)$

$L_{ionospheric} = ionospheric\ losses\ (< 1)$

$L_{path} = path\ loss\ due\ to\ attenuation\ by\ free\ space\ and\ reflections\ (< 1)$

$G_{ANT,RX} = receiving\ antenna\ gain$

$APEL_{RX} = receiving\ antenna\ pointing\ efficiency\ losses\ (< 1)$

$L_{line,RX} = line\ loss\ at\ the\ receiver\ (e.g.\ due\ to\ RF\ cable) < 1$

3.1. Some conversion formulae

SN	Description	Formula
a	**dBm to Watt**	$\mathbf{P_{(Watt)}} = 1W \times \frac{(10^{\frac{P(dBm)}{10}})}{1000}$
b	**Watt to dBW**	$\mathbf{P_{(dBm)}} = 10 \times log(\frac{P(W)}{1W})$
c	**dBm to dBW**	$\mathbf{P_{(dBW)}} = P(dBm) - 30$
d	**Slant Range (d) in km**	$\mathbf{d} = \sqrt{R^2 sin^2\alpha + h^2 + 2hR} - Rsin\alpha$ where, R = Radius of Earth i.e. 6,371 km α = Elevation angle in radian (0 to 90 degree) h = orbital altitude
e	**Path Loss**	$\mathbf{L_{(FS)}}$ = 20log(f) + 20log(r) + 92.44, for d in km and f in GHz $\mathbf{L_{(FS)}}$ = 20log(f) + 20log(r) + 32.44, for d in m and f in GHz

4. Command Uplink (for Ground-Space Communication)

Below is the link budget analysis for command uplink.

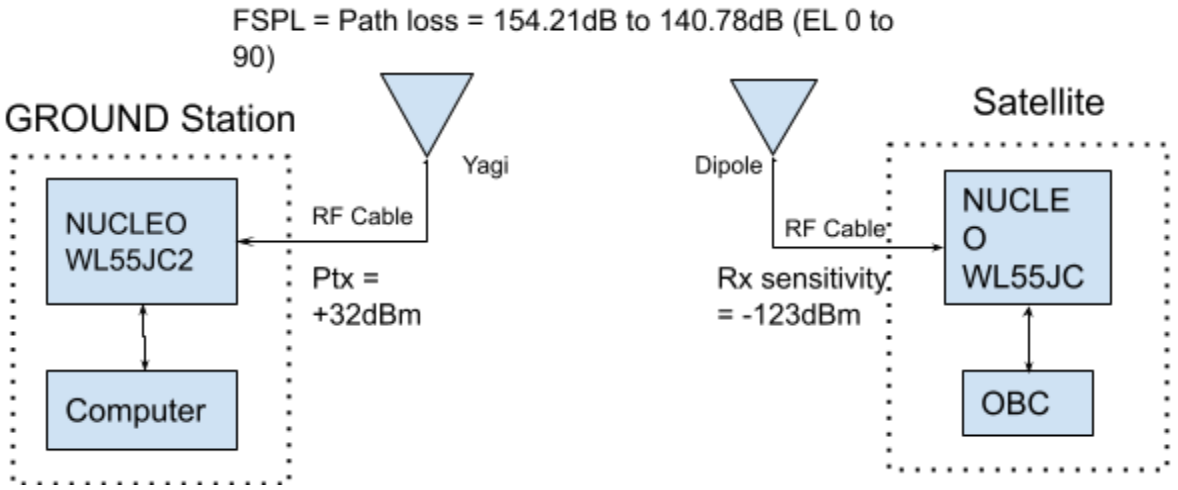


Figure 2. Link budget analysis for command uplink

5. Telemetry/Mission Downlink (for space-ground communication)

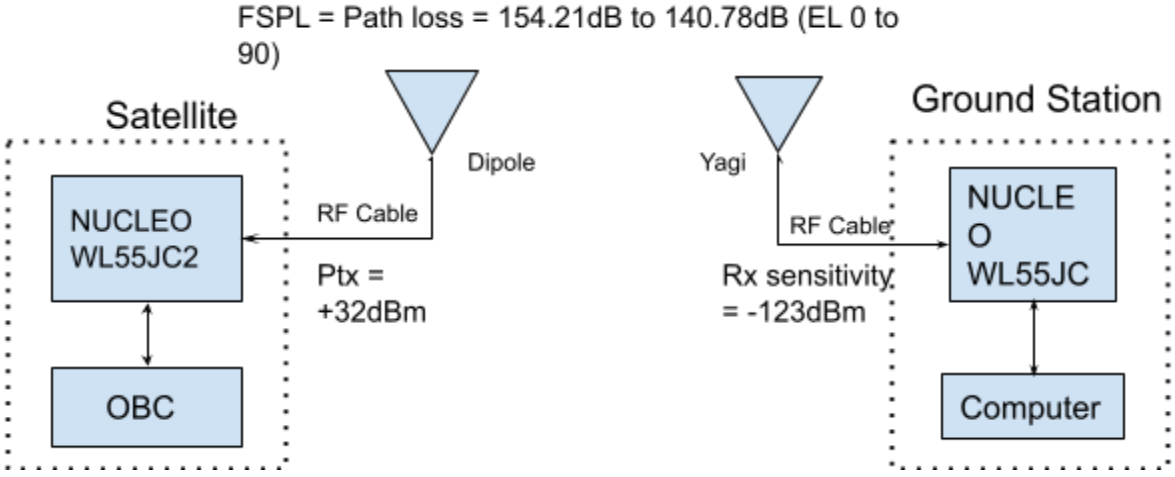


Figure 3. Link budget analysis for telemetry and mission downlink

Command Uplink										
Ground Station										
TX Power [dBm]	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
TX Power [W]	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58
TX POWER [dBW]	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Line Loss [dB]	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60
Antenna Gain [dBi]	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00
GS EIRP [dBW]	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40
Uplink Path										
Orbital Altitude [km]	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00
Elevation Angle [degree]	0	10	15	20	30	50	60	70	80	90
Slant Range [km]	2829.35	1931.64	1625.84	1392.16	1075.09	760.82	683.15	634.91	608.44	600.00
GS Ant. pointing Loss [dB]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Polarization Loss [dB]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Path Loss [dB]	154.25	150.93	149.44	148.09	145.84	142.84	141.91	141.27	140.90	140.78
Atmospheric Loss [dB]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Ionospheric Loss [dB]	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Rain Loss [dB]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Isotropic Signal at Satellite [dbW]	-144.25	-140.93	-139.44	-138.09	-135.84	-132.84	-131.91	-131.27	-130.90	-130.78
Satellite Receiver										
Antenna Pointing Loss[dB]	5	5	5	5	5	5	5	5	5	5
Antenna Gain [dBi]	1	1	1	1	1	1	1	1	1	1
Line Loss [dB]	3	3	3	3	3	3	3	3	3	3
RX power at input [dBw]	-151.25	-147.93	-146.44	-145.09	-142.84	-139.84	-138.91	-138.27	-137.90	-137.78
Expected RX power at input [dBm]	-121.25	-117.93	-116.44	-115.09	-112.84	-109.84	-108.91	-108.27	-107.90	-107.78
Receiver Sensitivity [dB]	-123	-123	-123	-123	-123	-123	-123	-123	-123	-123

Command Uplink

Ground Station										
TX Power [dBm]	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
TX Power [W]	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58
TX POWER [dBW]	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Line Loss [dB]	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60	3.60
Antenna Gain [dBi]	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00
GS EIRP [dBW]	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40
Uplink Path										
Orbital Altitude [km]	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00
Elevation Angle [degree]	0	10	15	20	30	50	60	70	80	90
Slant Range [km]	2829.35	1931.64	1625.84	1392.16	1075.09	760.82	683.15	634.91	608.44	600.00
GS Ant. pointing Loss [dB]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Polarization Loss [dB]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Path Loss [dB]	154.25	150.93	149.44	148.09	145.84	142.84	141.91	141.27	140.90	140.78
Atmospheric Loss [dB]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Ionospheric Loss [dB]	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Rain Loss [dB]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Isotropic Signal at Satellite [dbW]	-144.25	-140.93	-139.44	-138.09	-135.84	-132.84	-131.91	-131.27	-130.90	-130.78
Satellite Receiver										
Link Margin [dB]	1.75	5.07	6.56	7.91	10.16	13.16	14.09	14.73	15.10	15.22

Telemetry Downlink

Satellite										
TX Power [dBm]	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
TX Power [W]	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58
TX POWER [dBW]	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Line Loss [dB]	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Antenna Gain [dBi]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Satellite EIRP [dBW]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Downlink Path										
Orbital Altitude [km]	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00
Elevation Angle [degree]	0	10	15	20	30	50	60	70	80	90
Slant Range [km]	2829.35	1931.64	1625.84	1392.16	1075.09	760.82	683.15	634.91	608.44	600.00
Satellite Ant. pointing Loss [dB]	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Polarization Loss [dB]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Path Loss [dB]	154.25	150.94	149.44	148.09	145.85	142.84	141.91	141.27	140.90	140.78
Atmospheric Loss [dB]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Ionospheric Loss [dB]	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Rain Loss [dB]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Isotropic Signal at GS [dBW]	-165.65	-162.34	-160.84	-159.49	-157.25	-154.24	-153.31	-152.67	-152.30	-152.18
Ground Station Receiver										
Antenna Pointing Loss	1	1	1	1	1	1	1	1	1	1
Antenna Gain [dBi]	22	22	22	22	22	22	22	22	22	22
Line Loss [dB]	3	3	3	3	3	3	3	3	3	3
RX power at LNA input [dBw]	-147.65	-144.34	-142.84	-141.49	-139.25	-136.24	-135.31	-134.67	-134.30	-134.18
Expected RX power at LNA input [dBm]	-117.65	-114.34	-112.84	-111.49	-109.25	-106.24	-105.31	-104.67	-104.30	-104.18
Receiver Sensitivity [dB]	-123	-123	-123	-123	-123	-123	-123	-123	-123	-123
Link Margin [dB]	5.35	8.66	10.16	11.51	13.75	16.76	17.69	18.33	18.70	18.82

6. LRT Setup



Figure 4. Geographical location of the both stations

Venue	Latitude (°)	Longitude (°)	Altitude (m)	Members
Venue 1: Ground Station,NAST Khumatar,Lalitput	27.6563733	85.3273561	1328.76	Prem, Sajan
Venue 2: Slipper2Sat Satellite @ White House Resort, Dakshinkali	27.6518825	85.2679026	1611.80	Anjali, Kriti, Sangam

a. Satellite Setup

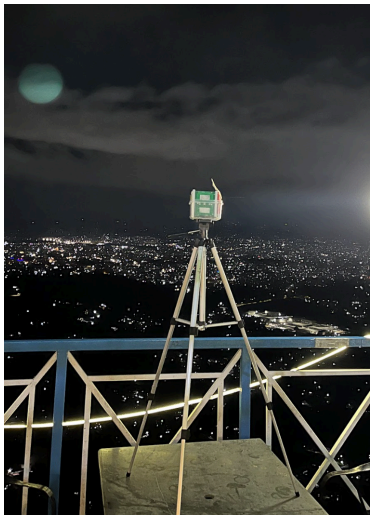


Figure 5. Satellite facing NAST Ground Station

b. Ground Station Setup

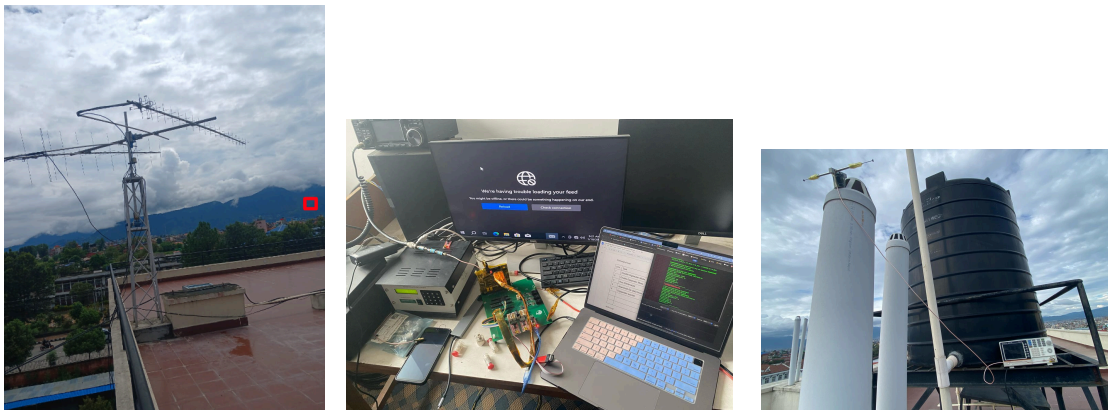


Figure 6. Ground Station Setup

7. Testing Results (Without Solar Panel):

At Elevation 10 degree (Downlink):

Downlink when the GS command is transmitted expect in 50dB attenuator

Attenuator (dB)	Total Attenuation	Effective Distance (Km)	$P_{(Rx)}$ dBm	Success Rate	Error Packet
0	99.88	5.38	-95.5	9/10	0
10	109.88	17.01	-98.5	10/10	0
20	119.88	53.78	-97.7	9/10	1 ack
30	129.88	170.08	-98.2	9/10	1 pack
40	139.88	537.83	-99.7	9/10	0
50	149.88	1700.77	-100.2	10/10	1 pack,1 ack
60	159.88	5378.31	-101.2	0/10	-

At Elevation 0 degree (Downlink):
Downlink when the GS command is transmitted expect in 50dB attenuator

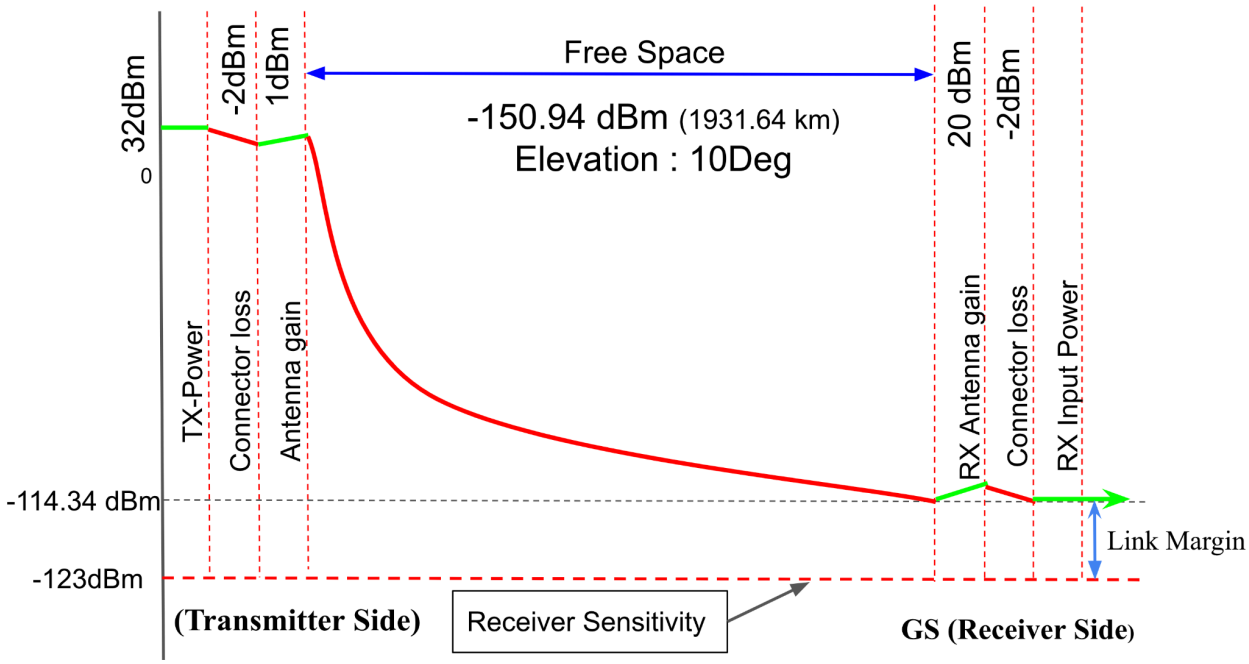
Attenuator (dB)	Total Attenuation	Effective Distance (Km)	$P_{(Rx)}$ dBm	Success Rate	Error Packet
0	99.88	5.38	-95.5	10/10	0
10	109.88	17.01	-98.5	10/10	0
20	119.88	53.78	-97.7	10/10	0
30	129.88	170.08	-98.2	10/10	0
40	139.88	537.83	-99.7	10/10	0
50	149.88	1700.77	-100.2	10/10	1 pack
60	159.88	5378.31	-101.2	0/10	-

8. Testing Results (With Solar Panel):

At Elevation 0 degree (Downlink):
Downlink when the GS command is transmitted expect in 50dB attenuator

Attenuator (dB)	Total Attenuation	Effective Distance (Km)	$P_{(Rx)}$ dBm	Success Rate	Error Packet
30	129.88	170.08	-98.2	10/10	0
40	139.88	537.83	-99.7	10/10	0
50	149.88	1700.77	-100.2	10/10	5 pack
60	159.88	5378.31	-101.2	0/10	-

Downlink Link Margin



9. LRT Test Procedure

Test

1. When the satellite is neither receiving any telemetry command nor digipeater command. The satellite must be able to send a beacon in the interval of 90 seconds.

Beacon Type 1	Telemetry Operation	Beacon Type 2	Digipeater
	90 sec		90 sec

2. When the telemetry command is received, and also digipeater packets are received.

Beacon Type 1	Telemetry Operation	Beacon Type 2	Digipeater	Telemetry Operation
	90 sec		90 sec	

3. When the digipeater mode turned off after BEACON_TYPE_1.

Beacon Type 1	Telemetry Operation	Beacon Type 2	Telemetry Operation
	90 sec		90 sec

4. When the digipeater mode turned off after BEACON_TYPE_2 and turned on after completion of the telemetry operation.

Beacon Type 1	Telemetry Operation	Beacon Type 2	Telemetry Operation	Digipeater
	90 sec		90 sec	

5. When the digipeater mode turned off after BEACON_TYPE_2 and turned on after completion of the telemetry operation and again turned off after completion of digipeater mission.
   Note: After completion of 90 seconds, the BEACON_TYPE_1 is again transmitted.

Beacon Type 1	Telemetry Operation	Beacon Type 2	Telemetry Operation	Digipeater	Telemetry Operation
	90 sec		90 sec		