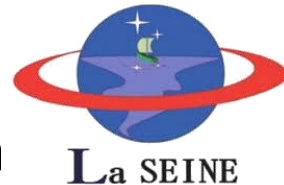


# BIRDS-4 EM Long Range Test Report

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26 August 2019



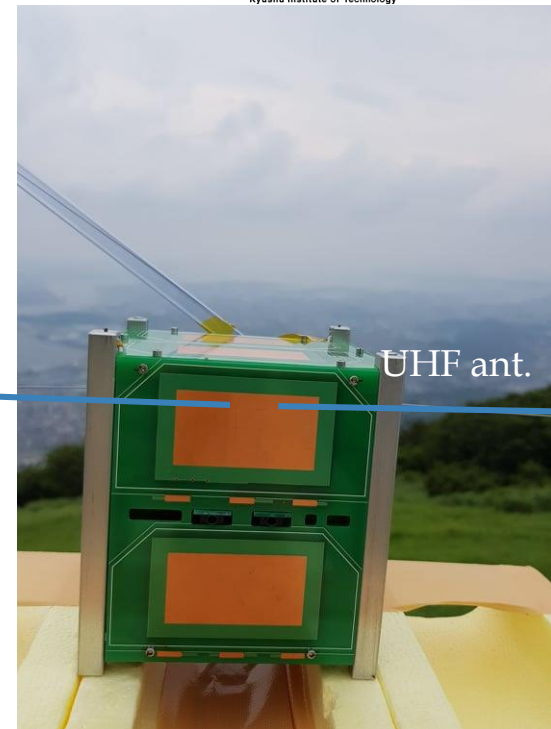
- ☐ Antenna Orientation
- ☐ Effective Downlink Attenuation (EDA)
- ☐ Effective Uplink Attenuation (EUA)
- ☐ Uplink Sensitivity Test
- ☐ Link Budget

# Antenna Orientation

- ❑ Satellite was placed on the platform facing KyuTech GS with azimuth of  $40^{\circ}$ .
- ❑ BIRDS GS antenna was rotated facing Mt. Sarakura. Using spectrum analyzer, received power of satellite's beacon was measured. Maximum received power was achieved at

Azimuth =  $215^{\circ}$

Elevation =  $5^{\circ}$

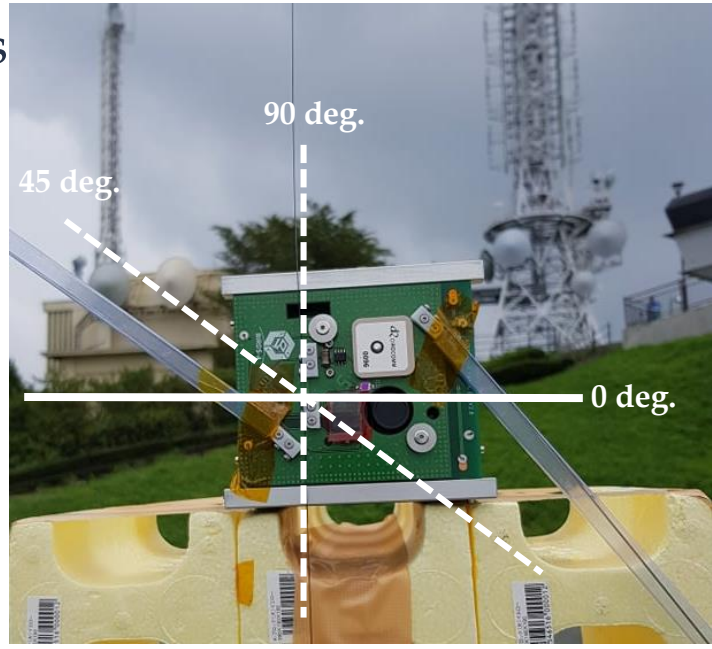


*BIRDS-4 EM at Mt. Sarakura, facing KyuTech GS*

# Effective Downlink Attenuation (EDA)

❑ Satellite transmitted 437.375 MHz continuous beacon (19 dBm), BIRDS GS measured received power using spectrum analyzer.

| Satellite antenna angle | BIRDS GS received power |                    |
|-------------------------|-------------------------|--------------------|
|                         | BIRDS-4 EM              | BIRDS-3 FM Back-up |
| 0°                      | -83.7 dBm               | -67.97 dBm         |
| 45°                     | -69.5 dBm               | -67.35 dBm         |
| 90°                     | <b>-69.5 dBm</b>        | -66.74 dBm         |



*BIRDS-4 EM facing GS antenna*

$$EDA = (19\text{dBm}) - (-69.5\text{ dBm}) = 88.5\text{ dB}$$

# Effective Uplink Attenuation (EUA)

❑ BIRDS GS transmitted 435.313 MHz carrier (46 dBm), received power at Mt. Sarakura was measured using reference dipole.

|                 | Ref. dipole received power |                    |
|-----------------|----------------------------|--------------------|
|                 | BIRDS-4 EM                 | BIRDS-3 FM Back-up |
| $P_{TX}$ (GS)   | 45 dBm                     | 44 dBm             |
| $P_{RX}$ (ref.) | -45 dBm                    | -45 dBm            |

$$EUA = (45 \text{ dBm}) - (-45 \text{ dBm}) = 90 \text{ dB}$$



*Reference dipole was used to measure received power at Mt. Sarakura*

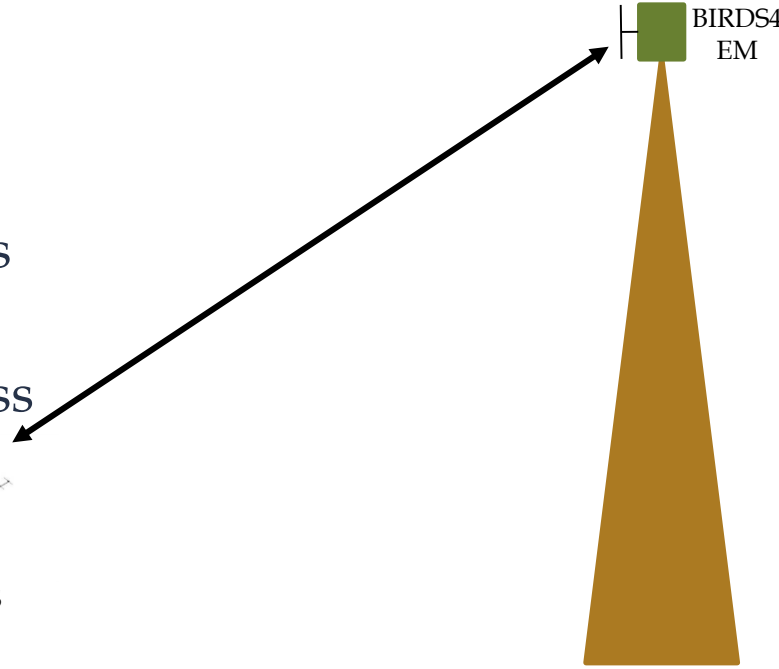
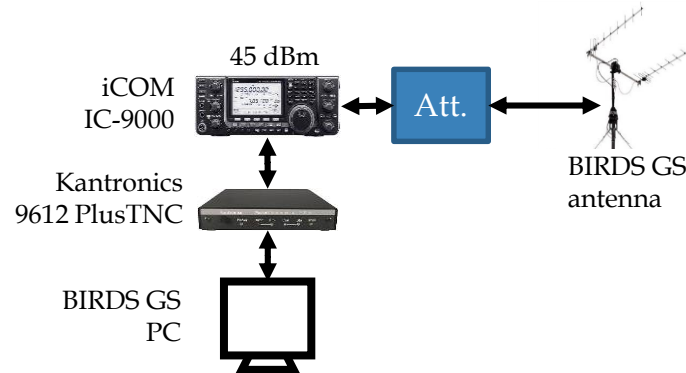
# Effective Attenuation Comparison

| Effective Attenuation | BIRDS-4 EM | BIRDS-3 FM Back-up | BIRDS-2 UPD (Dec 2018 LRT) |
|-----------------------|------------|--------------------|----------------------------|
| Uplink                | 90 dB      | 89 dB              | 97 dB                      |
| Downlink              | 88.5 dB    | 88 dB              | 103 dB                     |

- ❑ BIRDS-4 EM effective attenuation are almost similar to BIRDS-3 FM-B.
- ❑ BIRDS-4 EM effective uplink and downlink attenuation are almost similar.

# Uplink Sensitivity Test Setup

- ❑ BIRDS GS sends uplink command. When ACK from satellite is received, it is considered success. Uplink command is sent 10 times .
- ❑ Additional attenuator is placed and test is again conducted. This is repeated until success rate is zero.
- ❑ Uplink sensitivity is defined at 50% success rate.



# BIRDS-4 Uplink Sensitivity Test Result

| Added Attenuators in GS | Total Attenuation | P <sub>RX</sub> at Mt. Sarakura | Success Rate |
|-------------------------|-------------------|---------------------------------|--------------|
| 40 dB                   | 130 dB            | -85 dBm                         | 9/10         |
| 42 dB                   | 132 dB            | -87 dBm                         | 10/10        |
| 44 dB                   | 134 dB            | -89 dBm                         | 10/10        |
| 46 dB                   | 136 dB            | -91 dBm                         | 9/10         |
| 48 dB                   | 138 dB            | -93 dBm                         | 9/10         |
| 50 dB                   | 140 dB            | -95 dBm                         | 10/10        |

| Added Attenuators in GS | Total Attenuation | P <sub>RX</sub> at Mt. Sarakura | Success Rate |
|-------------------------|-------------------|---------------------------------|--------------|
| 52 dB                   | 142 dB            | -97 dBm                         | 9/10         |
| 54 dB                   | 144 dB            | -99 dBm                         | 8/10         |
| 55 dB                   | 145 dB            | -100 dBm                        | 7/10         |
| 56 dB                   | 146 dB            | -101 dBm                        | 6/10         |
| 57 dB                   | 147 dB            | -102 dBm                        | 3/10         |
| 58 dB                   | 148 dB            | -103 dBm                        | 1/10         |

P<sub>TX</sub> (GS): 45 dBm

EUA: 90dB

Total Attenuation = EUA + Added Attenuators

P<sub>RX</sub> (estimated) = P<sub>T</sub> (GS) – Total Attenuation



# Uplink Sensitivity Comparison

|                       | <b>BIRDS-4 EM</b> | <b>BIRDS-3 FM<br/>Back-up</b> | <b>BIRDS-2 UPD<br/>(Dec 2018 LRT)</b> |
|-----------------------|-------------------|-------------------------------|---------------------------------------|
| Uplink<br>Sensitivity | -101 dBm          | -92 dBm                       | -87 dBm*                              |

- ☐ \*BIRD-2 UPD sensitivity used signal generator setup.
- ☐ BIRDS-4 EM and BIRDS-3 FM-B both used iCOM radio setup.
- ☐ BIRDS-4 EM has 9 dB higher sensitivity than BIRDS-3 FM-B.
- ☐ RF Shielding at OBC, FAB, and COM board may contribute to improve sensitivity.

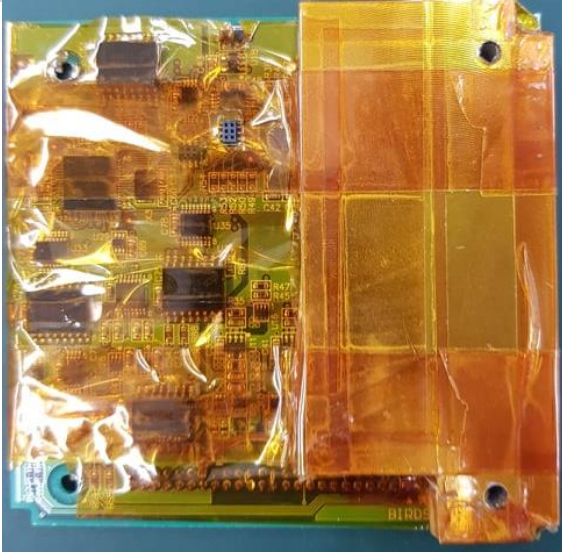
# Uplink Sensitivity Comparison

□ In the last test conducted in anechoic chamber, a comparison between uplink sensitivity during shielded and unshielded conditions was achieved. Result showed that the uplink sensitivity is 9 dB better with RF shielding in OBC, FAB and COM.

## BIRDS-4 Uplink Sensitivity Test in Anechoic Chamber (July 28)

| Shielded OBC +<br>FAB + COM | Unshielded OBC<br>+ FAB + COM |
|-----------------------------|-------------------------------|
| -101 dBm                    | -92 dBm                       |

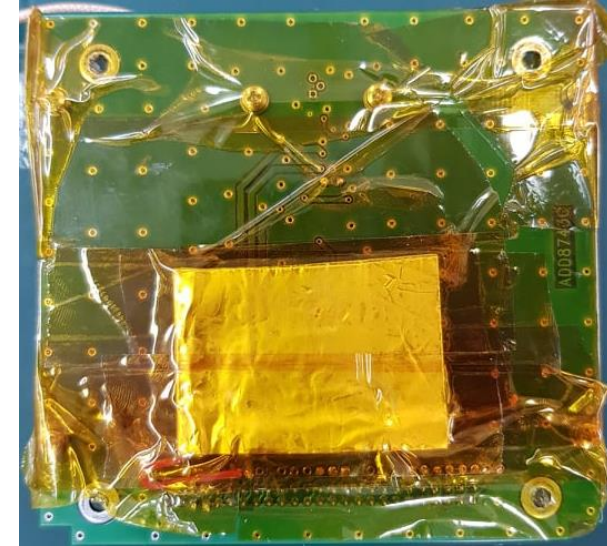
# Uplink Sensitivity Comparison



*Aluminum casing as RF  
shield in FAB*



*Aluminum sheet as RF shield  
in FAB*



*Aluminum sheet as RF shield  
in COM board*

□ In BIRDS-4 EM, RF shield was placed in OBC, FAB and COM board to reduce internal noise and improve SNR.

# BIRDS-4 EM Link Budget

|                                       | 10 <sup>0</sup><br>Elevation | 30 <sup>0</sup><br>Elevation | 50 <sup>0</sup><br>Elevation | 70 <sup>0</sup><br>Elevation | 80 <sup>0</sup><br>Elevation | 90 <sup>0</sup><br>Elevation |
|---------------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
| Transmit Output Power [dBm]           | 47                           | 47                           | 47                           | 47                           | 47                           | 47                           |
| Antenna Gain [dBi]                    | 22                           | 22                           | 22                           | 22                           | 22                           | 22                           |
| Transmission Line Loss [dB]           | 3                            | 3                            | 3                            | 3                            | 3                            | 3                            |
| EIRP [dBm]                            | 66                           | 66                           | 66                           | 66                           | 66                           | 66                           |
| Antenna Pointing Loss [dB]            | 5                            | 5                            | 5                            | 5                            | 5                            | 5                            |
| Polarization Loss [dB]                | 3                            | 3                            | 3                            | 3                            | 3                            | 3                            |
| Atmospheric + Ionospheric Losses [dB] | 1.4                          | 1.4                          | 1.4                          | 1.4                          | 1.4                          | 1.4                          |
| Path Loss [dB]                        | 148.3                        | 142.6                        | 139.4                        | 137.7                        | 137.3                        | 137.2                        |
| Effective Attenuation [dB]            | 138.7                        | 133                          | 129.8                        | 128.1                        | 127.7                        | 127.6                        |
| Power at the satellite [dBm]          | -91.7                        | -86                          | -82.8                        | -81.1                        | -80.7                        | -80.6                        |
| <b>In the satellite</b>               |                              |                              |                              |                              |                              |                              |
| Antenna Pointing Loss [dB]            | 3                            | 3                            | 3                            | 3                            | 3                            | 3                            |
| Antenna Gain + Pointing Loss [dB]     | 0.5                          | 0.5                          | 0.5                          | 0.5                          | 0.5                          | 0.5                          |
| Satellite Received Power [dBm]        | -95.2                        | -89.5                        | -86.3                        | -84.6                        | -84.2                        | -84.1                        |
| Satellite Sensitivity [dBm]           | -101                         | -101                         | -101                         | -101                         | -101                         | -101                         |
| Link Margin [dB]                      | 5.8                          | 11.5                         | 14.7                         | 16.4                         | 16.8                         | 16.9                         |

# BIRDS-3 Link Budget

|  | 10 deg<br>Elevation | 30 deg<br>Elevation | 60 deg<br>Elevation | 80 deg<br>Elevation |
|--|---------------------|---------------------|---------------------|---------------------|
| TX power Out                                     | 50 watt (47 dBm)    | 50 watt (47 dBm)    | 50 watt (47 dBm)    | 50 watt (47 dBm)    |
| Ant gain   | 22 dB               | 22 dB               | 22 dB               | 22 dB               |
| TX line loss                                     | 3 dB                | 3 dB                | 3 dB                | 3 dB                |
| EIRP   | 66 dBm              | 66 dBm              | 66 dBm              | 66 dBm              |
| Ant pointing loss                                | 5dB                 | 5dB                 | 5dB                 | 5dB                 |
| Polarization loss                                | 3dB                 | 3dB                 | 3dB                 | 3dB                 |
| Atmospheric + Ionospheric loss                   | 1.4 dB              | 1.4 dB              | 1.4 dB              | 1.4 dB              |
| Path loss  | 148.54 dB           | 142.7 dB            | 138.6 dB            | 137.5 dB            |
| Effective attenuation                            | -138.94 dB          | -133.1 dB           | -129 dB             | -127.9 dB           |
| Power at the satellite                           | -91.94 dBm          | -86.1 dBm           | -82 dBm             | -80.9 dBm           |
| <b>In the satellite</b>                          |                     |                     |                     |                     |
| Antenna pointing loss                            | 3 dB                | 3 dB                | 3 dB                | 3 dB                |
| Antenna gain + Cable loss                        | 0.5 dB              | 0.5 dB              | 0.5 dB              | 0.5 dB              |
| Received power                                   | -94.44 dBm          | -88.6 dBm           | -84.5 dBm           | -83.4 dBm           |
| Required power                                   | -97 dBm             | -97 dBm             | -97 dBm             | -97 dBm             |
| Link margin<br>(Received power – Required power) | 2.56 dB             | 8.4 dB              | 12.5 dB             | 13.6 dB             |