# BIRDS-2, BIRDS-3
# Long Range Test Results

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# Performed Tests

Test – 1 : Calibration

- Measuring downlink effective attenuation
- Measuring uplink attenuation

Test – 2 : Measuring UHF TRX receiving sensitivity of BIRDS-2 , BIRDS-3 satellites using signal generator setup

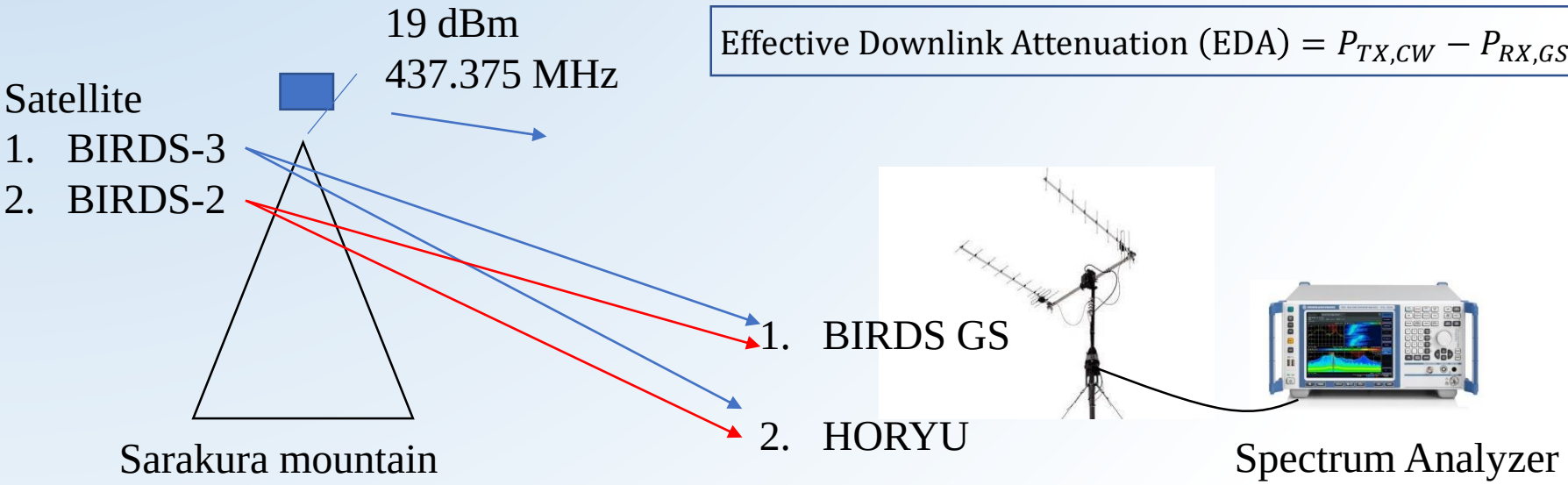
Test – 3 : Measuring UHF TRX receiving sensitivity of BIRDS-3 satellite using ICOM radio setup

# Test-1:Measuring effective downlink attenuation (EDA)

Procedure

- First BIRDS-3 satellite transmitted continuous beacon signal (437.375 MHz, 19dBm)
- BIRDS GS antenna and HORYU GS antenna were pointed towards sarakura mountain until maximum power received.
- Finally received power from BIRDS-3 was measured and antenna direction was fixed and then BIRDS-2 satellite was started to transmit beacon from same location.

Effective Downlink Attenuation (EDA) $= P_{TX,CW} - P_{RX,GS}$



# Satellite Orientation and Kyutech Ground Station

BIRDS-2

BIRDS-3

GS view from sarakura mountain

# Effective Downlink Attenuation (EDA) Results

BIRDS GS Antenna

| Transmitted from | Power received using BIRDS GS antenna | Effective downlink Path loss (19- RX Pwr) | Comparison |
|---|---|---|---|
| BIRDS-3 FM | -69 dBm | 88 dB | BIRDS-3, reception is 15 dB better |
| BIRDS-2 UPD | -84 dBm | 103 dB | |

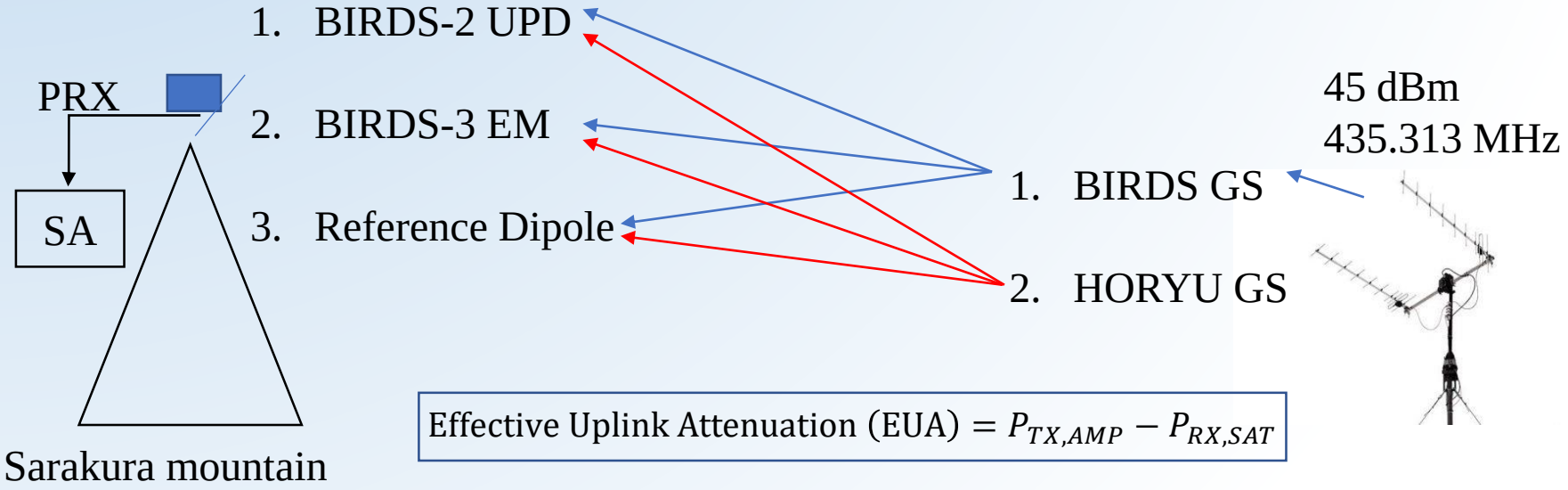
HORYU GS Antenna

| Transmitted from | Power received using HORYU GS antenna | Effective downlink Path loss (19- RX Pwr) | Comparison |
|---|---|---|---|
| BIRDS-3 FM | -73 dBm | 92 dB | BIRDS-3, reception is 13 dB better |
| BIRDS-2 UPD | -86 dBm | 105 dB | |

# Test-1:Measuring the effective uplink attenuation (EUA)

Procedure

- BIRDS GS and HORYU GS transmitted 435.313MHz 45dBm signal
- At sarakura side below antennas received transmitted signal from GS
  i. BIRDS-3 EM antenna (To represent BIRDS-3 FM)
  ii. BIRDS-2 UPD antenna
  iii. Reference dipole antenna
- For every antenna received power is recorded was recorded at sarakura side

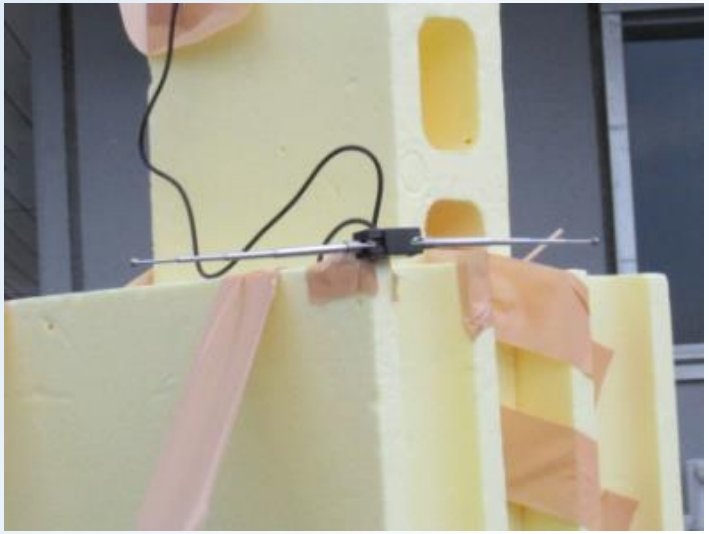



Effective Uplink Attenuation (EUA) $= P_{TX,AMP} - P_{RX,SAT}$

# Satellite Orientation and Kyutech Ground Station

BIRDS-2 UPD

BIRDS-3 EM



Reference Dipole Antenna

This was not the correct position of the dipole antenna. It was place exactly like satellite (Forgot take a photo)

# Effective Uplink Attenuation (EUA) Results

Transmitted from BIRDS GS Antenna

| Received using | Received power | Effective uplink Path loss (45- RX Pwr) | Comparison |
|---|---|---|---|
| BIRDS-2 UPD | -52 dBm | 97 dB | BIRDS-3, reception is 3dB better |
| BIRDS-3 EM | -49 dBm | 94 dB | |
| Reference Dipole | -49.5 dBm | 94.5 dB | |

Transmitted from HORYU GS Antenna

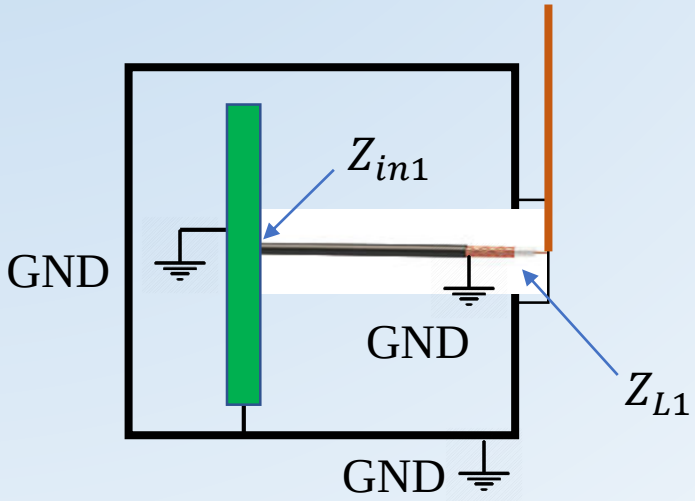
| Received using | Received power | Effective uplink Path loss (45- RX Pwr) | Comparison |
|---|---|---|---|
| BIRDS-2 UPD | -56 dBm | 101 dB | BIRDS-3, reception is 5dB better |
| BIRDS-3 EM | -51 dBm | 96 dB | |
| Reference Dipole | -51.5 dBm | 96.5 dB | |

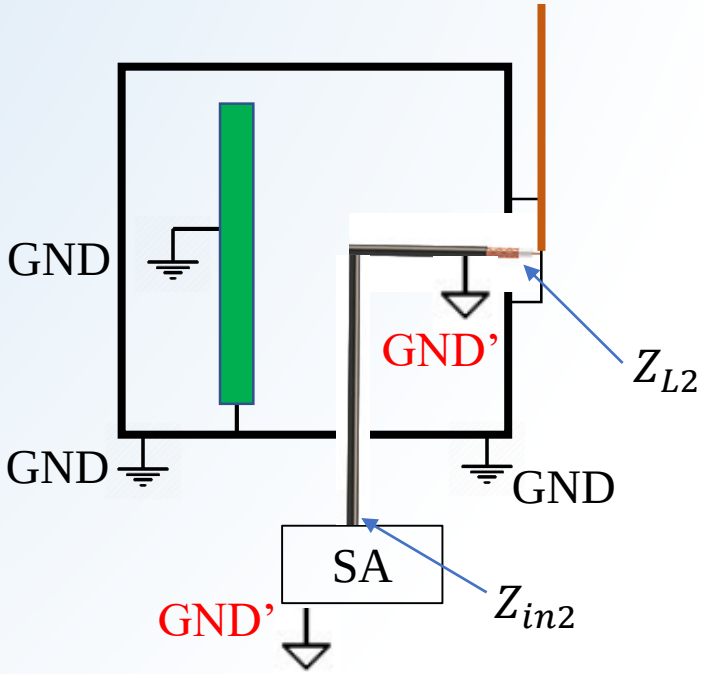
Received power levels using BIRDS-3 EM antenna and Reference dipole antenna were similar. Since uplink path loss for BIRDS-3 FM satellite was taken as 94dB.

# BIRDS-2 Antenna

| When 19 dBm transmitted from Sat (Downlink) | | |
|---|---|---|
| Sat name | Received power at GS | |
| BIRDS-3 | -69 dBm | 15 dB |
| BIRDS-2 | -84 dBm | |

| When 45 dBm transmitted from GS (Uplink) | | |
|---|---|---|
| Sat name | Received power at Sat | |
| BIRDS-3 | -49 dBm | 3 dB |
| BIRDS-2 | -52 dBm | |




$$Z_{in} = Z_0 \frac{Z_L + iZ_0 \tan(\beta L)}{Z_0 + iZ_L \tan(\beta L)}$$

$Z_0 = 50\Omega$

# EUA and EDA Comparisons

## EDA

| Transmitted from CW TX | BIRDS GS Antenna | HORYU GS Antenna | Comparisons |
|---|---|---|---|
| BIRDS2 UPD | **103 dB** | **105 dB** | -In flight configuration, BIRDS3 FM antenna performs 13-15 dB better than BIRDS2 UPD antenna. |
| BIRDS3 FM | **88 dB** | **92 dB** | |

*Note: Both are nearly flight configuration: UHF antenna connected to UHF TRX port, no external connectors*

## EUA

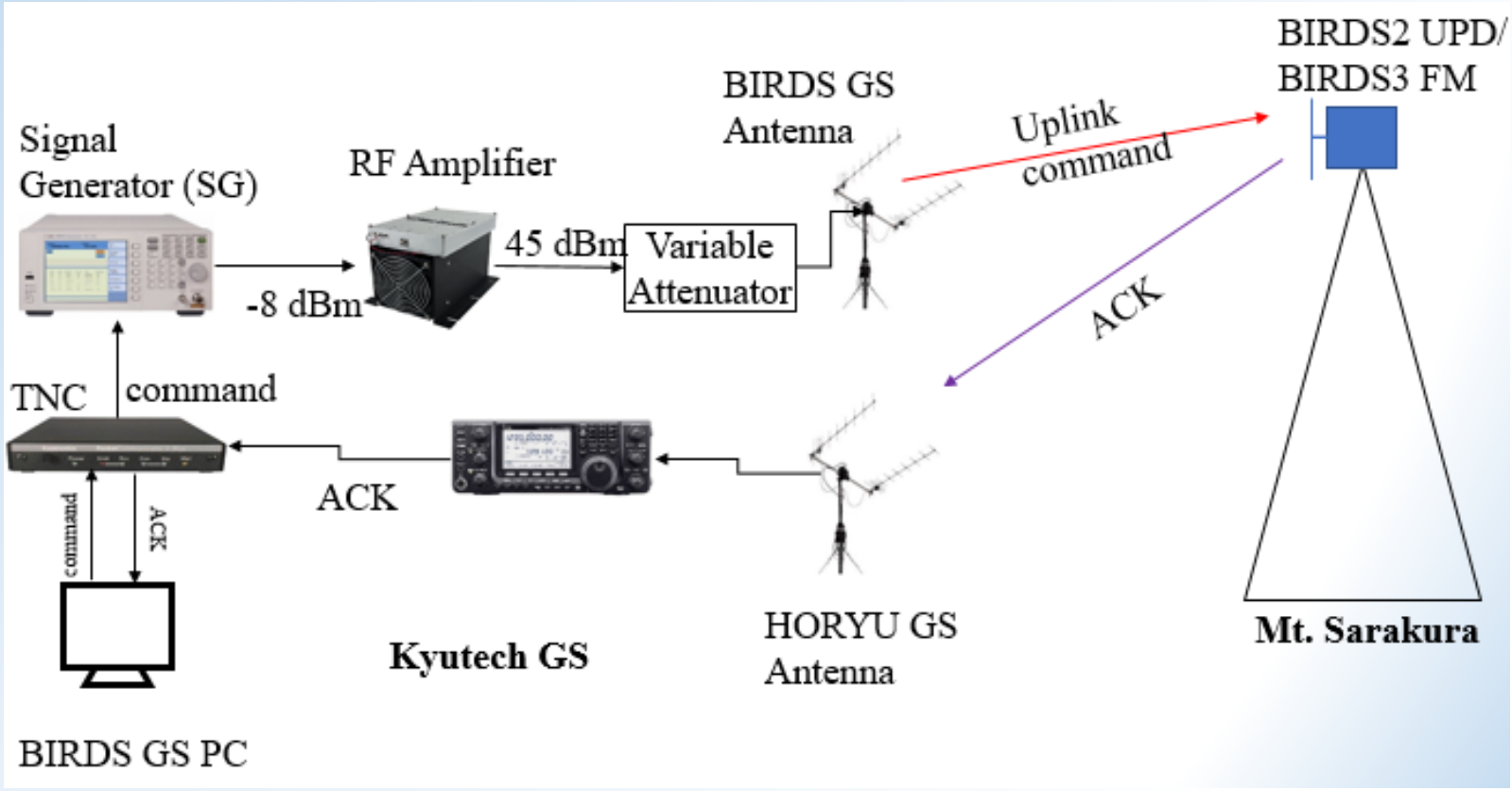
| Receiving by | BIRDS GS Antenna | HORYU GS Antenna | Comparisons |
|---|---|---|---|
| BIRDS2 UPD | **97 dB** | **101 dB** | -When both connected to SA, BIRDS3 EM antenna performs 3-5 dB better than BIRDS2 UPD antenna.<br>-BIRDS3 EM and dipole REF antennas perform similarly. |
| BIRDS3 EM | **94 dB** | **96 dB** | |
| Dipole REF | **94.5 dB** | **96.5 dB** | |

*Note: All antennas are connected to spectrum analyzer (SA) so not fully in flight configuration*

# Test-2: Measuring UHF TRX Sensitivity of BIRDS-2 and BIRDS-3

Procedure

1. For the uplink commands BIRDS ground station was used.
2. First Signal Generator setup was used to send uplink to BIRDS-2 and BIRDS-3 satellites

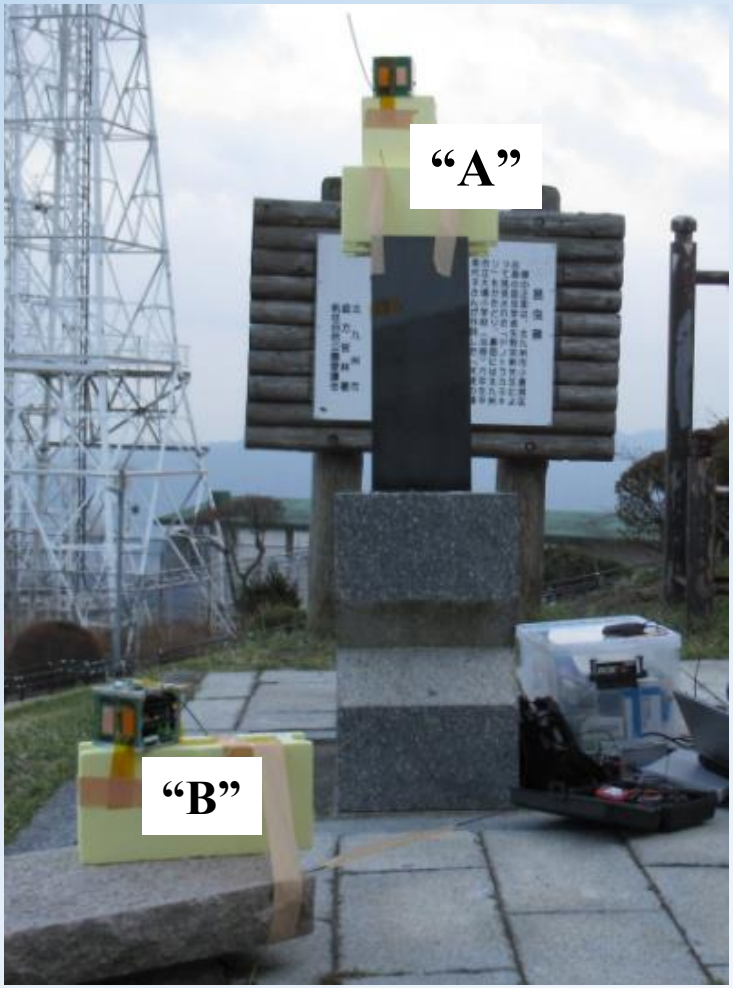


# Procedure continues..

3. For given variable value ground station sent commands to the satellite and at sarakura side, If satellites receive the correct command it sent acknowledgment to ground station. Then it is taken as success.

4. First BIRDS-2 sensitivity was measured and then BIRDS-3 sensitivity was measured.

# Receiving power measurement at sarakura side using BIRDS3 EM




- First BIRDS-3 EM satellite was placed at “A”. And received power from GS was measured.
- Then it was placed at “B” and receiving power was measured.
- Finally power level difference for “A” and “B” was calculated.
- “B” point power reception level was 5dB higher than “A”.
- 5dB was subtracted from every BIRDS-3 EM power reading to get position “A” power level.

# Indirect Method of Estimating Received Power for BIRDS2 UPD

Total Uplink Attenuation

= EDA of BIRDS2 UPD + (EUA-EDA for BIRDS3) + Var. ATT

Accounts for actual antenna gain (symmetric)

Accounts for the fact that uplink channel would provide 6 dB higher loss than downlink channel

Total Uplink Attenuation **= 103 dB + 6 dB + Var. ATT**

RX Power Estimate **= 45 dBm – (109 dB + Var. ATT)**

# Uplink Success Rate for BIRDS2 UPD Using its Own Antenna

SG Frequency Deviation = 12.5 kHz

| Variable Attenuator Value (dB) | Uplink Success Rate | Total Uplink Attenuation* (dB) | BIRDS2 Command RX Power (dBm), estimated | RX Power Measured by BIRDS3 EM (dBm) |
|---|---|---|---|---|
| 0 | 6/6 | 109 | -64 | -50 |
| 10 | 4/6 | 119 | -74 | -60 |
| 13 | 6/6 | 122 | -77 | -63 |
| 19 | 6/6 | 128 | -83 | -71 |
| 23 | 6/6 | 132 | -87 | -75 |
| 26 | 0/6 | 135 | -90 | -78 |
| 29 | 0/6 | 138 | -93 | -80 |
| 30 | 0/6 | 139 | -94 | -80 |

SG Frequency Deviation = 16 kHz

| Variable Attenuator Value (dB) | Uplink Success Rate | Total Uplink Attenuation* (dB) | BIRDS2 Command RX Power (dBm), estimated | RX Power Measured by BIRDS3 EM (dBm) |
|---|---|---|---|---|
| 26 | 0/6 | 135 | -90 | -78 |
| 30 | 0/3 | 139 | -94 | -80 |

# Uplink Success Rate for BIRDS2 UPD Using Dipole REF Antenna

# Uplink Success Rate for BIRDS2 UPD Using Dipole REF Antenna

SG Frequency Deviation = 12.5 kHz

| Variable Attenuator Value (dB) | USR | Total Uplink Attenuation** (dB) | BIRDS2 Command RX Power (dBm), estimated | RX Power Measured by BIRDS3 EM (dBm) |
|---|---|---|---|---|
| 30 | 4/4 | 124.5 | -80 | -79.5 |
| 40 | 4/4 | 134.5 | -89 | -89.5 |
| 43 | 3/3 | 137.5 | -92 | -92.5 |
| 50 | 3/3 | 144.5 | -99 | -99.5 |
| 55 | 3/3 | 149.5 | -104 | -104.5 |
| 57 | - | 151.5 | - | -106.5 |
| 60 | 0/1 | 154.5 | -109 | -109.5 |

*Total Uplink Attenuation = EUA for dipole REF antenna = 94.5 dB

=> When using dipole reference antenna, there was 32 dB improvement over using own satellite antenna. This may be explained by better antenna and lower captured noise level (antenna a little far from satellite body).

# Receiving sensitivity results for BIRDS-3

- Frequency deviation of signal generator = 12.5 kHz
- Transmitted power = 28 Watt (45dBm)
- Average noise level in the receiver = -109dBm

| Extra attenuators added in ground station | Total attenuation (= Added Att + Uplink path loss) | Received power at sarakura side (Measured) | Success rate |
|---|---|---|---|
| 40 dB | 134 dB | -89 dBm | 8/10 |
| 43 dB | 137 dB | -92 dBm | 3/10 |
| 45 dB | 139 dB | -94 dBm | 3/10 |
| 47 dB | 141 dB | -96 dBm | 0/10 |

Using wired test. Maximum receiving sensitivity of the transceiver was given when 15KHz frequency deviation was used. Then by changing from 12.5KHz to 15KHz again same test was performed.

# Receiving sensitivity results for BIRDS-3

- Frequency deviation of signal generator = 15 kHz
- Transmitted power = 28 Watt (45dBm)
- Average noise level in the receiver = -109dBm

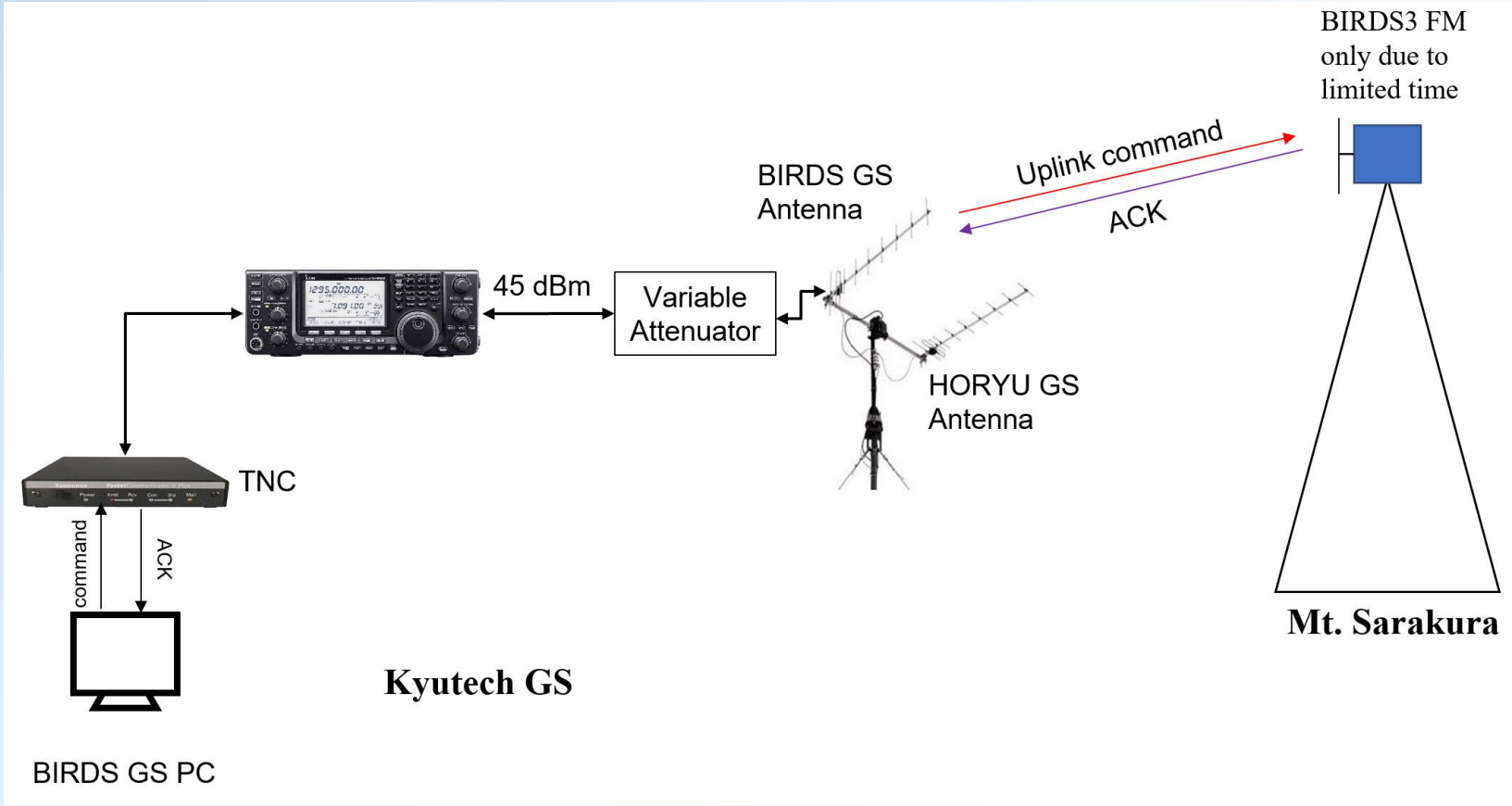
| Extra attenuators added in ground station | Total attenuation (= Added Att + Uplink path loss) | Received power at sarakura side (Measured) | Success rate |
|---|---|---|---|
| 40 dB | 134 dB | -89 dBm | 6/10 |
| 43 dB | 137 dB | -92 dBm | 8/10 |
| 45 dB | 139 dB | -94 dBm | 6/10 |
| 47 dB | 141 dB | -96 dBm | 7/10 |
| 48 dB | 142 dB | -97 dBm | 3/10 |
| 50 dB | 144 dB | -99 dBm | 1/10 |

- 1st Long range test we could use only 40 dB attenuator (Success rate was 3/5). With 41dB was attenuator value zero success.
- Improvement from 1st Long rang test is about 8dB
- This time we transmitted 3dB more, because of data rate reduction uplink gained 3dB and because of other things (RF shielding) uplink has gains about 2dB more

# Test-3: Measuring UHF TRX Sensitivity of BIRDS-3 using ICOM radio setup

Procedure

1. For the uplink commands BIRDS ground station was used.
2. ICOM radio setup was used to send uplink to BIRDS-3



# Receiving sensitivity results for BIRDS-3 using ICOM radio setup

- Transmitted power = 28 Watt (45dBm)
- Average noise level in the receiver = -109dBm

| Extra attenuators added in ground station | Total attenuation (= Extra Att + Uplink path loss) | Received power at sarakura side (Calculated) | Success rate |
|---|---|---|---|
| 30 dB | 124 dB | -79 dBm | 5/6 |
| 34 dB | 128 dB | -83 dBm | 5/10 |
| 36 dB | 130 dB | -85 dBm | 5/10 |
| 38 dB | 132 dB | -87 dBm | 4/10 |
| 40 dB | 134 dB | -89 dBm | 0/10 |

- In 1st BIRDS-3 Long range test, this test was not performed.
- Because of not enough time this test could not be performed for BIRDS-2

# Link Budget for BIRDS-3

| | 10 deg Elevation | 30 deg Elevation | 60 deg Elevation | 80 deg 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 |
| **In the satellite** | | | | |
| 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 (Received power – Required power) | 2.56 dB | 8.4 dB | 12.5 dB | 13.6 dB |

# Summary and Conclusions for BIRDS-3

- Uplink success rate is 5dB better than previous long range test (Without considering power increment by 3dB).
- Measured noise level in the receiver is about -109dBm. this make the receiver sensitivity deviate from it's performance. (According to wired test, to decode a command correctly SNR should be more than 12dB)
- According to link margin calculation for new ground station setup BIRDS-3 has a positive link margin without considering doppler effect.

# Summary and Conclusions for BIRDS-2

- Uplink success rate in this LRT is worse than in previous LRT.
  - Despite the fact that we used the new GS configuration and transmitted 3 dB higher power, successful uplink could be achieved up to only 23 dB maximum attenuator (34 dB in previous LRT).
- Exact reason for degraded performance is still unknown and large difference difficult to explain.
  - The combined effects of different noise levels and satellite antenna pointing may have caused this difference but this is unlikely.
- Using dipole antenna provided 32 dB better uplink performance over using satellite's own antenna. *Due to better antenna gain and lower noise?*
- Different received power sensitivity vs previous wireless sensitivity test likely due to more noise from satellite captured in this LRT.

# Thank You

# Extra Slides for BIRDS-2 UPD Results and Discussion (if necessary)

# Comparison with Previous Long Range Test

| Parameters | Previous LRT (2018/03/22) | This LRT (2018/12/19) |
|---|---|---|
| GS Transmitter | IC9100 | SG+RF Amplifier |
| TX Power (dBm) | 42 | 45 |
| Tuning of BIRDS GS antenna position | None, by default fixed to AZ=220˚ , EL=5˚ /6˚ | Yes, tuned to AZ=238˚ , EL=5˚ |
| Satellite UHF antenna direction | Horizontal, element oriented such that maximum reception at GS (max gain direction, θ=315˚ )* | Horizontal, element simply parallel to GS antenna element (θ=0˚ )* |
| Noise level | Not measured | Not measured (could not be) |
| Maximum attenuator (dB) with received ACK | 34 | 23 dB |

* In previous LRT, during downlink calibration, gain at θ=315˚ was 3 dB higher than at θ=0˚ .

- Exact reason unknown. Large difference difficult to explain. The combined effects of different noise levels and satellite antenna pointing may have caused this difference but this is unlikely.

# Comparison with Previous RX Power Sensitivity Results

| Parameters | This LRT Using Satellite Antenna | This LRT Using Dipole Reference Antenna | Previous Wireless RX Sensitivity Test |
|---|---|---|---|
| GS Transmitter | SG+RF Amplifier | SG+RF Amplifier | SG+RF Amplifier |
| Satellite Location | Mt. Sarakura | Mt. Sarakura | Seikyo |
| Satellite and Antenna Configuration | Flight configuration, own antenna | Dipole antenna connected by cable, about 0.3 m away from satellite body | Satellite inside shield box, monopole antenna connected by cable but outside shield box |
| RX Power Sensitivity | **-87 dBm** (uncertain, estimated only) | **-104 dBm** (measured) | **-96 dBm** (measured) |
| Noise contribution from satellite internal noise | High | Low/Medium | Low |
| Noise floor measurement with antenna connected to SA | No proper measurement data (-97 dBm but relative offset of SA was set to -20 dB) | No measurement data with satellite nearby (-120 dBm w/o satellite) | <-110 dBm (-110 dBm is the measurement when monopole antenna was connected and not connected to SA, measured on 2018/12/24 w/o satellite and RX box) |

| Parameters | Link Budget (at EL=45°) | Previous LRT | This LRT |
|---|---|---|---|
| GS TX Power | 45 dBm (IC9100/SG + RF Amp) | 42 dBm (IC9100) | 45 dBm (SG + RF Amp) |
| Path Loss due to propagation environment | 144.5 dB | 114.6 dB (may be overestimated) | 109.1 dB (likely correct) |
| Cable losses | 3.9 dB | 3.9 dB | 3.9 dB |
| GS antenna gain | 18 | 18 | 18 |
| Satellite antenna gain | ~ -10 dB (new estimate) | ~ -10 dB (new estimate)<br>1 dB (old estimate) | ~ -13 dB (new estimate) |
| Polarization loss | 3 dB | 0 dB | 0 dB |
| GS antenna pointing loss | 3 dB (new) | ~ 3 dB | 0 dB |
| Satellite antenna pointing loss | 3 dB | 0 dB (lumped into gain) | 0 dB (lumped into gain) |
| Ionospheric loss | 0.4 dB | 0 dB | 0 dB |
| Atmospheric loss | 1.1 dB | 1.1 dB | 1.1 dB |
| Attenuator Used | 0 dB | **34 dB** | **23 dB** |
| Effective Attenuation | 150.9 | 148.6 | 132.1 |
| Performance loss due to Doppler error | Not considered | Not considered | Not considered |
| Actual RX Noise Floor | **Lower in space than on ground?** | Not measured | No proper measurement data |
| RX Power | -105.9 dBm | -106.6 dBm (new estimate)<br>-95.6 dBm (old estimate, I thought we had 5 dB margin at EL=20° , assumed -101 dBm RX sensitivity from cable test) | -87 dBm (estimated only) |
| Result | Uplink not successful | Uplink successful at this attenuator | Uplink successful at this attenuator |