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## ASTROPI CALLIOPEO EMC FACILITY TEST REPORT

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## **1. INTRODUCTION**

The equipment CalliopEO is operated together with the AstroPi computer to transfer files and read sensor data as part of an educational program on the ISS.

This document reports the EMC tests performed on the CalliopEO standalone and operated by the AstroPi, based on the test procedure in [AD1].

## 2. DOCUMENTS

#### 2.1. Applicable Documents

- [AD1] ESA-TECEPE-LAB-TP-022082 Astro Pi PAO item EMC Test Procedure v1.1 (The AstroPi PAO test procedure has been used due to similarity)
- [AD2] COL-ESA-RQ-014, COLUMBUS EMC & Power Quality Requirements, Issue 2/E, 10/12/2001

#### 2.2. Reference Documents

[RD1]	MIL-STD-461, Rev. C, 04/08/1986
[RD2]	SSP 30237, Space Station Electromagnetic Emission and Susceptibility
	Requirements, Rev. F, 17/05/2001
[RD2]	Implementation Plan ESA PR with Col-Ka, ESA-ISS-COL-OPS-PL-0001
	Issue 1.0, 04/092020

## **3. ACRONYMS AND ABBREVIATIONS**

- CE Conducted Emissions
- CS Conducted Susceptibility
- CUT Cable Under Test
- EGSE Electrical Ground Support Equipment
- EM Engineering Model
- EMC Electromagnetic Compatibility
- ESA European Space Agency
- ESTEC European Space Research and Technology Center



EUT	Equipment Under Test
LISN	Line Impedance Stabilization Network
NCR	Non-Conformance Reports
P/N	Part Number
RE	Radiated Emissions
RS	Radiated Susceptibility
S/N	Serial Number
ISS	International Space Station



# 4. TEST SUMMARY

Below is a listing of the tests performed on the AstroPi CalliopEO.

All test plots and photos can be found in the applicable annexes.

Table 1 – Test Summary of the RE/RS test on 19.08.2021

Test	Annex	Plot	Result
RE AC Magnetic Field	Annex A	Plot 1 - Plot 3	Passed
RS Electric Field	Annex B	Plot 4 - Plot 10	Passed
RE Electric Field	Annex C	Plot 11 - Plot 15	Passed

## **4.1. Test Procedure Deviations**

N/A. There is no deviations from Test Procedure.

## **4.2. Test Non Conformances**

N/A. All tests have successfully passed.

## 4.3. Test Sequence Logbook

#### Table 2 – Test Summary of the RE/RS test on 19.08.2021

Time	Description	Mode	Position	Status		
Setup prepa	Setup preparation for RE H-Field					
14:21	RE 30Hz-250KHz H Field	Mode A	Right Side (looking from cable side)	OK		
14:25	RE 30Hz-250KHz H Field	Mode A	Back side (opposite side to usb cable)	OK		
14:27	RE 30Hz-250KHz H Field	Mode A	Top side (above EUT)	OK		
Setup preparation for RS E-Field						
15:03	RS 14 kHz - 5 MHz	Mode A	-	OK		
15:16	RS 5 MHz - 30 MHz	Mode A	-	OK		
15:29	RS 30 MHz - 1 GHz (Hor)	Mode A	-	OK		
15:43	RS 30 MHz - 1 GHz (Ver)	Mode A	-	OK		



16:09	RS 1GHz - 4.2 GHz (Ver)	Mode A -	OK
16:18	RS 1GHz - 4.2 GHz (Hor)	Mode A -	OK
16:38	RS 4.2 GHz - 18 GHz (Hor)	Mode A -	OK
16:55	RS 4.2 GHz - 18 GHz (Ver)	Mode A -	OK
Setup prepa	aration for RE E-Field (with AstroP	i)	
-	RE 10kHz - 30MHz	Mode A -	OK
-	RE 30MHz - 1 GHz (Hor)	Mode A -	OK
17:52	RE 30MHz - 1 GHz (Ver)	Mode A -	OK
17:56	RE 1GHz - 18 GHz (Ver)	Mode A -	OK
18:06	RE 1GHz - 18 GHz (Hor)	Mode A -	OK



# **5. EQUIPMENT UNDER TEST**

## 5.1. EUT Description

Customer:	Calliope
Project:	AstroPi CalliopEO
Equipment under test:	AstroPi (P/N: AP2-VIS-01 – S/N: 01)
	CalliopEO (Ground Model 03)

The RE E-field test was performed with the AstroPi and the CalliopEO as EUT. The AstroPi was powered by a power plug and commanded via Ethernet by the EGSE laptop located outside of the anechoic chamber. The CalliopEO was operated via USB by the AstroPi (see Figure 1 left).

The RE H-field and RS E-field tests were performed with the CalliopEO as the only EUT. The CalliopEO was powered and controlled directly by the EGSE laptop outside of the anechoic chamber via USB. (see Figure 1 right).



Figure 1 – Left picture shows the CalliopEO operated by the AstroPi, which is controlled by the EGSE laptop via Ethernet. Right picture shows the CalliopEO operated and commanded by the EGSE laptop via USB.

## 5.2. EUT Modes

CalliopEO was operated in one mode through-out the test campaign. In that mode, the sensor data of the CalliopEO was read out, either by the AstroPi or by a laptop. Throughout the document this mode is named Mode A.



## 5.3. EUT Monitoring

The EUT was monitored by the customer. The CalliopEO sensor read-out data was saved in a log file and then checked for false data entries during susceptibility tests.



# 6. GENERAL TEST SETUP

#### **6.1. Environmental Conditions**

During the tests, the environmental parameters of the EMC Test Facility were controlled: Temperature: 20.4 °C Relative humidity: 67.3% Cleanliness: visible clean

### 6.2. Test Setup



Figure 2 – photo of the general EUT setup in the EMC chamber

#### 6.3. Test Equipment and Software List

The following two tables gives an overview over the equipment and software that has been used during the test campaign.



#### Table 3 – Test equipment list used during the test

Equipment	Type No	ESA Inv	Calibration	
			Last	Next
Generic	-		I	
EMI receiver (R&S)	ESW 44	101642	05/09/2019	05/09/2021
Biconical log antenna (ETS-Lindgren)	ETS 3142C	60444	-	-
Horn antenna wo PA (ETS-Lindgren)	ETS 3117	75822	-	-
Radiated Emissions E-Field				
Active rod antenna (ARA)	SAS-2/A	21257	-	-
Radiated Susceptibility E-Field				
Field probe (LumiLoop)	LSProbe	129	03/12/2020	03/12/2022
Field probe (Holaday)	HI-4450	74817	13/11/2019	13/11/2021
Antenna (ETS-Lindgren 3107B)	ETS 3107B	2031	-	-
Signal generator (R&S)	SMA 100A	100247	19/09/2019	19/09/2021
Signal generator (R&S)	SMB 100A	179608	14/11/2018	14/11/2021
Amplifier (AR)	AR50WD1000	327969	-	-
Amplifier (AR)	AR20ST1G18A	335669	-	-
Radiated Emissions H-Field	•		1	
Shielded coil antenna (ETS-Lindgren)	ETS 7604	2040	25/04/2019	23/03/2022

#### Table 4 – Test software used during the test

Software	Identification	Revision
R&S EMC32	100069	V10.35.02
RadiMation Pro	SIH00133	V2020.2.10



# 7. TEST RESULTS

## 7.1. RE AC H-Field Test Results

#### 7.1.1. Test Parameters

Pictures of the test set-up and all measurement data can be found in Annex A. The measurements have been performed using the following parameters and settings.

30 Hz – 250 kHz
Coil antenna positioned at approximately 7 cm from the EUT enclosure,
at different positions. EUT operated in Full Mode.
Table 3 of [AD1].
Position 1: antenna on the right side of AstroPi CalliopEO
Position 2: antenna on the back side of AstroPi CalliopEO
Position 3: antenna on the top side of AstroPi CalliopEO

#### 7.1.2. Test Sequence

The following table shows the performed tests. The plots of the measurements and the photos of the setup can be found in the Annex A. The test was executed the 19th august 2021.

Time	Test	Plot	Picture	Comment	Result
	RE H-Field				
14:21	30 Hz to 250 kHz, AstroPi CalliopEO right side (Position 1)\ Mode A	Plot 1	Figure 3	Position 1: right side (looking from cable side)	PASS
14:25	30 Hz to 250 kHz, AstroPi CalliopEO back side (Position 2) Mode A	Plot 2	Figure 4	Position 2: back side (opposite side to USB cable)	PASS

#### Table 5 – Test sequence of the RE and RS tests including results



14:27	30 Hz to 250 kHz, AstroPi CalliopEO top side (Position 3)	Plot 3	Figure 5	Position 3: top side (above EUT)	PASS
	Mode A				



### 7.2. RS E-Field Test Parameters

#### 7.2.1. Test Parameters

Pictures of the test set-up and all measurement data can be found in Annex B. The measurements have been performed using the following parameters and settings.

Frequency range:	14 kHz – 18 GHz
Step width:	custom
Dwell time	1 s
Test limit:	Figure 8 from [AD1]
	14 kHz – 700 MHz 2 V/m
	700 MHz – 18 GHz 10 V/m
Modulation:	Continuous Waveform (14 kHz – 5 MHz)
	1 kHz AM 50% (5 MHz – 18 GHz)
RS method:	Field levelling method
Test mode:	Full Mode
Polarisation:	Vertical and horizontal (only vertical up to 30 MHz)
Antenna distance:	1 m
Antenna height:	1.3 m
Pass/fail:	as defined and evaluated by the customer

#### 7.2.2. Test Sequence

The following table shows the performed tests. The plots of the measurements and the photos of the setup can be found in the Annex B. The test was executed the 19th august 2021.

Time	Test	Plot	Picture	Comment	Result
	RS E-Field				
15:03	14 kHz to 5 MHz at 2 V/m	Plot 4	Figure 6	-	PASS
	Mode A				

#### Table 6 – Test sequence of the RS E-Field



15:16	5 MHz to 30 MHz at 2 V/m Mode A	Plot 4	Figure 6	-	PASS
15:29	30 MHz to 700 MHz at 2 V/m 700 MHz to 1 GHz at 10 V/m Mode A – Horizontal Pol.	Plot 5	Figure 7	-	PASS
15:43	30 MHz to 700 MHz at 2 V/m 700 MHz to 1 GHz at 10 V/m Mode A – Vertical Pol.	Plot 6	Figure 8	-	PASS
16:09	1 GHz to 4.2 GHz at 10V/m Mode A – Vertical Pol.	Plot 7	Figure 9	-	PASS
16:18	1 GHz to 4.2 GHz at 10V/m Mode A - Horizontal Pol.	Plot 8	Figure 10	-	PASS
16:38	4.2 GHz to 18 GHz at 10V/m Mode A – Horizontal Pol.	Plot 9	Figure 11	-	PASS
16:55	4.2 GHz to 18 GHz at 10V/m Mode A – Vertical Pol.	Plot 10	Figure 12	-	PASS



## 7.3. RE E-Field Test Results

#### 7.3.1. Test Parameters

Pictures of the test set-up and all measurement data can be found in Annex C. The measurements have been performed using the following parameters and settings.

Freq. range (MHz)	Measurement time (s)	Bandwidth (kHz)	Pre-amplifier (dB)
0.01 – 0.15	10	1	20
0.15 – 30	10	10	20
30 – 1000	0.15	10	20
1000 – 18000	0.15	1000	30

#### Table 7 – RE Electric Field, test parameters

Peak
Vertical
Horizontal (except 10 kHz – 30 MHz)
1 m
1.3 m
Table 1 from [AD1]

#### 7.3.2. Test Sequence

The following table shows the performed tests. The plots of the measurements and the photos of the setup can be found in the Annex C. The test was executed the 19th august 2021.

Table 8 – Test sequer	ce of the RE and RS	tests including results
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Time	Test	Plot	Picture	Comment	Result
	RE E-Field				
17:40	10 kHz to 30 MHz	Plot 11	Figure 13	-	PASS
	Mode A				



17:45	30 MHz to 1 GHz	Plot 13	Figure 15	-	PASS
17.40	Mode A, Horizontal Pol.				
17.50	30 MHz to 1 GHz	Plot 12	Figure 14	-	PASS
17.52	Mode A, Vertical Pol.				
17.56	1 GHz to 18 GHz	Plot 14	Figure 16	-	PASS
17.50	Mode A, Vertical Pol.				
18.06	1 GHz to 18 GHz	Plot 15	Figure 17	-	PASS
10.00	Mode A, Horizontal Pol.				

## ANNEX

# Annex A. RE H-field (CalliopEO only)



Figure 3 – RE H-field, 30 Hz to 250 kHz, right side (CalliopEO only)





Plot 1 - RE H-field, 30 Hz to 250 kHz, right side (CalliopEO only)



Figure 4 – RE H-field, 30 Hz to 250 kHz, back side (CalliopEO only)





Plot 2 – RE H-field, 30 Hz to 250 kHz, back side (CalliopEO only)



Figure 5 – RE H-field, 30 Hz to 250 kHz, top side (CalliopEO only)





Plot 3 – RE H-field, 30 Hz to 250 kHz, Mode A, top side (CalliopEO only)



## Annex B. RS E-field (CalliopEO only)



Figure 6 – RS E-field, 14 kHz to 30 MHz (CalliopEO only)



Plot 4 – RS E-field, 14 kHz to 5 MHz (top) and 5 MHz to 30 MHz (bottom) (CalliopEO only)





Figure 7 – RS E-field, 30 MHz to 1 GHz, horizontal polarization (CalliopEO only)



Plot 5 – RS E-field, 30 MHz to 1 GHz, horizontal polarization (CalliopEO only)





Figure 8 – RS E-field, 30 MHz to 1 GHz, vertical polarization (CalliopEO only)



Plot 6 – RS E-field, 30 MHz to 1 GHz, vertical polarization (CalliopEO only)





Figure 9 – RS E-field, 1 GHz to 4.2 GHz, vertical polarization (CalliopEO only)









Figure 10 – RS E-field, 1 GHz to 4.2 GHz, horizontal polarization (CalliopEO only)









Figure 11 – RS E-field, 4.2 GHz to 18 GHz, horizontal polarization (CalliopEO only)



Plot 9 – RS E-field, 4.2 GHz to 18 GHz, horizontal polarization (CalliopEO only)





Figure 12 – RS E-field, 4.2 GHz to 18 GHz, vertical polarization (CalliopEO only)







## Annex C. RE E-field (AstroPi and CalliopEO)



Figure 13 – RE E-field, 10 kHz to 30 MHz (AstroPi and CalliopEO)



Plot 11 – RE E-field, 10 kHz to 30 MHz (AstroPi and CalliopEO)





Figure 14 – RE E-field, 30 MHz to 1 GHz, vertical polarization (AstroPi and CalliopEO)



Plot 12 – RE E-field, 30 MHz to 1 GHz, vertical polarization (AstroPi and CalliopEO)





Figure 15 – RE E-field, 30 MHz to 1 GHz, horizontal polarization (AstroPi and CalliopEO)



Plot 13 - RE E-field, 30 MHz to 1 GHz, horizontal polarization (AstroPi and CalliopEO)





Figure 16 – RE E-field, 1 GHz to 18 GHz, vertical polarization (AstroPi and CalliopEO)



Plot 14 – RE E-field, 1 GHz to 18 GHz, vertical polarization (AstroPi and CalliopEO)





Figure 17 – RE E-field, 1 GHz to 18 GHz, horizontal polarization (AstroPi and CalliopEO)



Plot 15 – RE E-field, 1 GHz to 18 GHz, horizontal polarization (AstroPi and CalliopEO)