

Small Sat UHF Identification and TT&C radio beacon

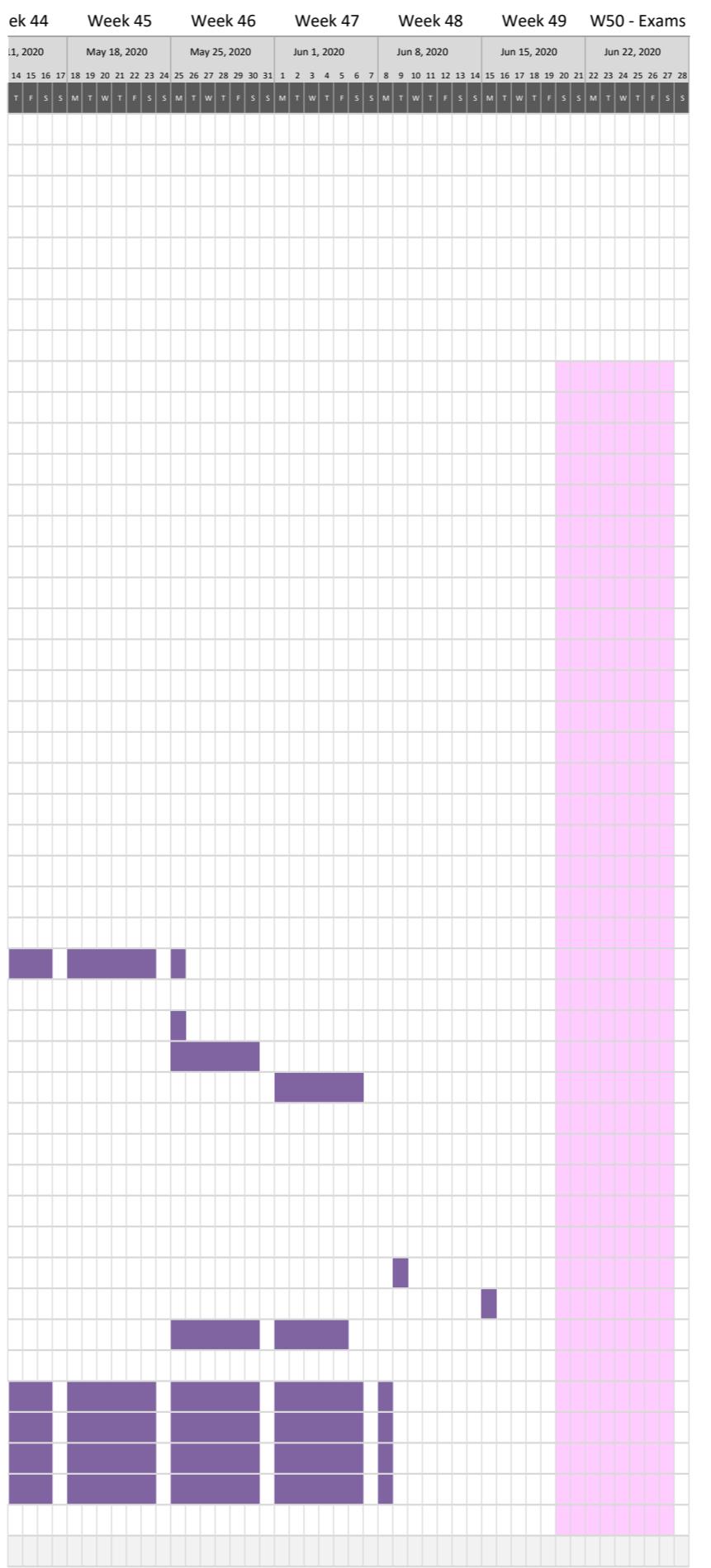
## Appendix A - Project Gantt chart

UNINSW Canberra - Thesis project

<https://www.vertex42.com/ExcelTemplates/simple-qantt-chart.html>

*Insert new rows ABOVE this one*

.0 - Break	Week 21		Week 22		Week 23		Week 24		Week 25		Week 26		Week 27		Week 28		Week 29		Week 30		W31 - Break		Week 32		Week 33		Week 34		Week 35		Week 36		Week 37		Week 38		W39 - Break		W40 - Break		Week 41		Week 42		Week 43																																																																																																																																																																																																																																																																																																																																																																																																																																																															
Nov 25, 2019	Dec 2, 2019	Dec 9, 2019	Dec 16, 2019	Dec 23, 2019	Dec 30, 2019	Jan 6, 2020	Jan 13, 2020	Jan 20, 2020	Jan 27, 2020	Feb 3, 2020	Feb 10, 2020	Feb 17, 2020	Feb 24, 2020	Mar 2, 2020	Mar 9, 2020	Mar 16, 2020	Mar 23, 2020	Mar 30, 2020	Apr 6, 2020	Apr 13, 2020	Apr 20, 2020	Apr 27, 2020	May 4, 2020	May 11, 2020	May 18, 2020	May 25, 2020	May 32, 2020	Jun 8, 2020	Jun 15, 2020	Jun 22, 2020	Jun 29, 2020	Jul 6, 2020	Jul 13, 2020	Jul 20, 2020	Jul 27, 2020	Aug 3, 2020	Aug 10, 2020	Aug 17, 2020	Aug 24, 2020	Aug 31, 2020	Sep 7, 2020	Sep 14, 2020	Sep 21, 2020	Sep 28, 2020	Oct 5, 2020	Oct 12, 2020	Oct 19, 2020	Oct 26, 2020	Nov 2, 2020	Nov 9, 2020	Nov 16, 2020	Nov 23, 2020	Nov 30, 2020	Dec 7, 2020	Dec 14, 2020	Dec 21, 2020	Dec 28, 2020	Jan 4, 2021	Jan 11, 2021	Jan 18, 2021	Jan 25, 2021	Jan 32, 2021	Feb 8, 2021	Feb 15, 2021	Feb 22, 2021	Feb 29, 2021	Mar 6, 2021	Mar 13, 2021	Mar 20, 2021	Mar 27, 2021	Apr 3, 2021	Apr 10, 2021	Apr 17, 2021	Apr 24, 2021	May 1, 2021	May 8, 2021	May 15, 2021	May 22, 2021	May 29, 2021	Jun 5, 2021	Jun 12, 2021	Jun 19, 2021	Jun 26, 2021	Jul 3, 2021	Jul 10, 2021	Jul 17, 2021	Jul 24, 2021	Jul 31, 2021	Aug 7, 2021	Aug 14, 2021	Aug 21, 2021	Aug 28, 2021	Sep 4, 2021	Sep 11, 2021	Sep 18, 2021	Sep 25, 2021	Oct 2, 2021	Oct 9, 2021	Oct 16, 2021	Oct 23, 2021	Oct 30, 2021	Nov 6, 2021	Nov 13, 2021	Nov 20, 2021	Nov 27, 2021	Dec 4, 2021	Dec 11, 2021	Dec 18, 2021	Dec 25, 2021	Jan 1, 2022	Jan 8, 2022	Jan 15, 2022	Jan 22, 2022	Jan 29, 2022	Feb 5, 2022	Feb 12, 2022	Feb 19, 2022	Feb 26, 2022	Mar 5, 2022	Mar 12, 2022	Mar 19, 2022	Mar 26, 2022	Apr 2, 2022	Apr 9, 2022	Apr 16, 2022	Apr 23, 2022	Apr 30, 2022	May 7, 2022	May 14, 2022	May 21, 2022	May 28, 2022	Jun 4, 2022	Jun 11, 2022	Jun 18, 2022	Jun 25, 2022	Jul 2, 2022	Jul 9, 2022	Jul 16, 2022	Jul 23, 2022	Jul 30, 2022	Aug 6, 2022	Aug 13, 2022	Aug 20, 2022	Aug 27, 2022	Sep 3, 2022	Sep 10, 2022	Sep 17, 2022	Sep 24, 2022	Sep 31, 2022	Oct 8, 2022	Oct 15, 2022	Oct 22, 2022	Oct 29, 2022	Nov 5, 2022	Nov 12, 2022	Nov 19, 2022	Nov 26, 2022	Dec 3, 2022	Dec 10, 2022	Dec 17, 2022	Dec 24, 2022	Jan 1, 2023	Jan 8, 2023	Jan 15, 2023	Jan 22, 2023	Jan 29, 2023	Feb 5, 2023	Feb 12, 2023	Feb 19, 2023	Feb 26, 2023	Mar 5, 2023	Mar 12, 2023	Mar 19, 2023	Mar 26, 2023	Apr 2, 2023	Apr 9, 2023	Apr 16, 2023	Apr 23, 2023	Apr 30, 2023	May 7, 2023	May 14, 2023	May 21, 2023	May 28, 2023	Jun 4, 2023	Jun 11, 2023	Jun 18, 2023	Jun 25, 2023	Jul 2, 2023	Jul 9, 2023	Jul 16, 2023	Jul 23, 2023	Jul 30, 2023	Aug 6, 2023	Aug 13, 2023	Aug 20, 2023	Aug 27, 2023	Sep 3, 2023	Sep 10, 2023	Sep 17, 2023	Sep 24, 2023	Sep 31, 2023	Oct 8, 2023	Oct 15, 2023	Oct 22, 2023	Oct 29, 2023	Nov 5, 2023	Nov 12, 2023	Nov 19, 2023	Nov 26, 2023	Dec 3, 2023	Dec 10, 2023	Dec 17, 2023	Dec 24, 2023	Jan 1, 2024	Jan 8, 2024	Jan 15, 2024	Jan 22, 2024	Jan 29, 2024	Feb 5, 2024	Feb 12, 2024	Feb 19, 2024	Feb 26, 2024	Mar 5, 2024	Mar 12, 2024	Mar 19, 2024	Mar 26, 2024	Apr 2, 2024	Apr 9, 2024	Apr 16, 2024	Apr 23, 2024	Apr 30, 2024	May 7, 2024	May 14, 2024	May 21, 2024	May 28, 2024	Jun 4, 2024	Jun 11, 2024	Jun 18, 2024	Jun 25, 2024	Jul 2, 2024	Jul 9, 2024	Jul 16, 2024	Jul 23, 2024	Jul 30, 2024	Aug 6, 2024	Aug 13, 2024	Aug 20, 2024	Aug 27, 2024	Sep 3, 2024	Sep 10, 2024	Sep 17, 2024	Sep 24, 2024	Sep 31, 2024	Oct 8, 2024	Oct 15, 2024	Oct 22, 2024	Oct 29, 2024	Nov 5, 2024	Nov 12, 2024	Nov 19, 2024	Nov 26, 2024	Dec 3, 2024	Dec 10, 2024	Dec 17, 2024	Dec 24, 2024	Jan 1, 2025	Jan 8, 2025	Jan 15, 2025	Jan 22, 2025	Jan 29, 2025	Feb 5, 2025	Feb 12, 2025	Feb 19, 2025	Feb 26, 2025	Mar 5, 2025	Mar 12, 2025	Mar 19, 2025	Mar 26, 2025	Apr 2, 2025	Apr 9, 2025	Apr 16, 2025	Apr 23, 2025	Apr 30, 2025	May 7, 2025	May 14, 2025	May 21, 2025	May 28, 2025	Jun 4, 2025	Jun 11, 2025	Jun 18, 2025	Jun 25, 2025	Jul 2, 2025	Jul 9, 2025	Jul 16, 2025	Jul 23, 2025	Jul 30, 2025	Aug 6, 2025	Aug 13, 2025	Aug 20, 2025	Aug 27, 2025	Sep 3, 2025	Sep 10, 2025	Sep 17, 2025	Sep 24, 2025	Sep 31, 2025	Oct 8, 2025	Oct 15, 2025	Oct 22, 2025	Oct 29, 2025	Nov 5, 2025	Nov 12, 2025	Nov 19, 2025	Nov 26, 2025	Dec 3, 2025	Dec 10, 2025	Dec 17, 2025	Dec 24, 2025	Jan 1, 2026	Jan 8, 2026	Jan 15, 2026	Jan 22, 2026	Jan 29, 2026	Feb 5, 2026	Feb 12, 2026	Feb 19, 2026	Feb 26, 2026	Mar 5, 2026	Mar 12, 2026	Mar 19, 2026	Mar 26, 2026	Apr 2, 2026	Apr 9, 2026	Apr 16, 2026	Apr 23, 2026	Apr 30, 2026	May 7, 2026	May 14, 2026	May 21, 2026	May 28, 2026	Jun 4, 2026	Jun 11, 2026	Jun 18, 2026	Jun 25, 2026	Jul 2, 2026	Jul 9, 2026	Jul 16, 2026	Jul 23, 2026	Jul 30, 2026	Aug 6, 2026	Aug 13, 2026	Aug 20, 2026	Aug 27, 2026	Sep 3, 2026	Sep 10, 2026	Sep 17, 2026	Sep 24, 2026	Sep 31, 2026	Oct 8, 2026	Oct 15, 2026	Oct 22, 2026	Oct 29, 2026	Nov 5, 2026	Nov 12, 2026	Nov 19, 2026	Nov 26, 2026	Dec 3, 2026	Dec 10, 2026	Dec 17, 2026	Dec 24, 2026	Jan 1, 2027	Jan 8, 2027	Jan 15, 2027	Jan 22, 2027	Jan 29, 2027	Feb 5, 2027	Feb 12, 2027	Feb 19, 2027	Feb 26, 2027	Mar 5, 2027	Mar 12, 2027	Mar 19, 2027	Mar 26, 2027	Apr 2, 2027	Apr 9, 2027	Apr 16, 2027	Apr 23, 2027	Apr 30, 2027	May 7, 2027	May 14, 2027	May 21, 2027	May 28, 2027	Jun 4, 2027	Jun 11, 2027	Jun 18, 2027	Jun 25, 2027	Jul 2, 2027	Jul 9, 2027	Jul 16, 2027	Jul 23, 2027	Jul 30, 2027	Aug 6, 2027	Aug 13, 2027	Aug 20, 2027	Aug 27, 2027	Sep 3, 2027	Sep 10, 2027	Sep 17, 2027	Sep 24, 2027	Sep 31, 2027	Oct 8, 2027	Oct 15, 2027	Oct 22, 2027	Oct 29, 2027	Nov 5, 2027	Nov 12, 2027	Nov 19, 2027	Nov 26, 2027	Dec 3, 2027	Dec 10, 2027	Dec 17, 2027	Dec 24, 2027	Jan 1, 2028	Jan 8, 2028	Jan 15, 2028	Jan 22, 2028	Jan 29, 2028	Feb 5, 2028	Feb 12, 2028	Feb 19, 2028	Feb 26, 2028	Mar 5, 2028	Mar 12, 2028	Mar 19, 2028	Mar 26, 2028	Apr 2, 2028	Apr 9, 2028	Apr 16, 2028	Apr 23, 2028	Apr 30, 2028	May 7, 2028	May 14, 2028	May 21, 2028	May 28, 2028	Jun 4, 2028	Jun 11, 2028	Jun 18, 2028	Jun 25, 2028	Jul 2, 2028	Jul 9, 2028	Jul 16, 2028	Jul 23, 2028	Jul 30, 2028	Aug 6, 2028	Aug 13, 2028	Aug 20, 2028	Aug 27, 2028	Sep 3, 2028	Sep 10, 2028	Sep 17, 2028	Sep 24, 2028	Sep 31, 2028	Oct 8, 2028	Oct 15, 2028	Oct 22, 2028	Oct 29, 2028	Nov 5, 2028	Nov 12, 2028	Nov 19, 2028	Nov 26, 2028	Dec 3, 2028	Dec 10, 2028	Dec 17, 2028	Dec 24, 2028	Jan 1, 2029	Jan 8, 2029	Jan 15, 2029	Jan 22, 2029	Jan 29, 2029	Feb 5, 2029	Feb 12, 2029	Feb 19, 2029	Feb 26, 2029	Mar 5, 2029	Mar 12, 2029	Mar 19, 2029	Mar 26, 2029	Apr 2, 2029	Apr 9, 2029	Apr 16, 2029	Apr 23, 2029	Apr 30, 2029	May

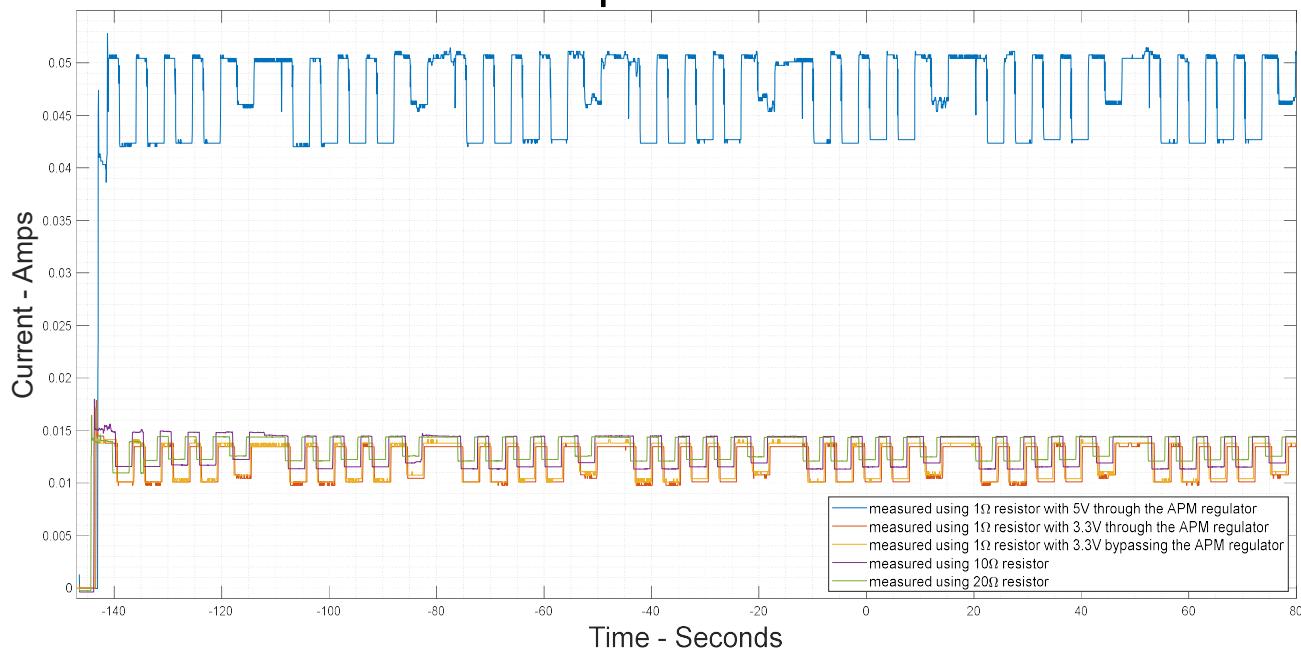


### Arduino Pro Mini power consumption Check

This testing was carried out by in supply the APM module with 5V unregulated and 3.3V regulated power to the RAW pin which supplies the on-board voltage regulator and supplying the 3.3V regulated power to the Vcc pin which bypasses the on-board regulator. When the 3.3V regulated voltage was used on the RAW pin the resistor that is in series with the APM module to measure the voltage to determine the current was changed from  $1\Omega$  to  $10\Omega$  and  $20\Omega$  to increase the accuracy of the measurement.

The testing is started by the software being initialised in Arduino, turning the radio off and then cycling the APM module from a power on mode to a low power mode from the *lowpower.h* library developed by rocketsscream. The testing operates by powering on the Arduino for 2 seconds using the *delay()* command, entering a power saving mode for 3 seconds in the order (*powerDown*, *powerSave*, *powerStandby*, *powerExtStandby* and *idle*) and finally being delayed by 5 seconds before the test is repeated.

### Arduino Pro Mini power mode current checks



*Figure 1 - Arduino Pro Mini power mode current check results*

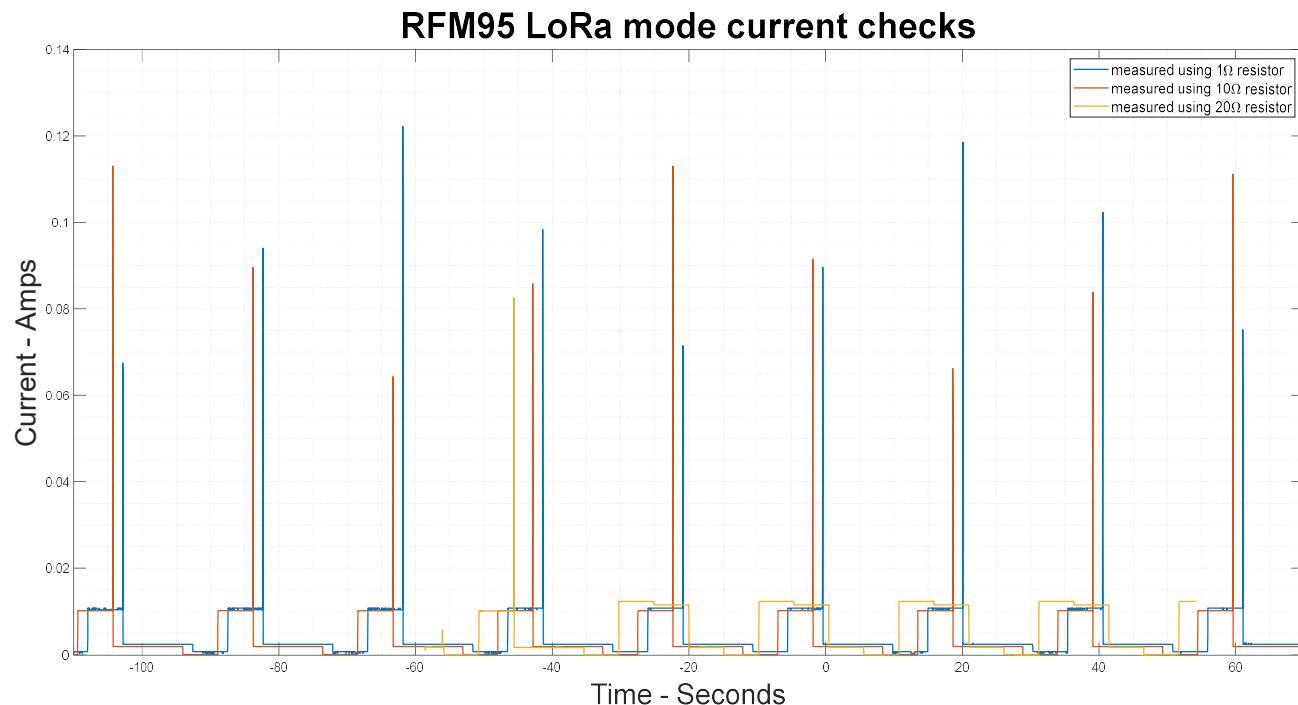
ArduinoPro Mini power mode currents																	
1 Ohm Resistor measurement with Unregulated voltage (5V) on RAW pin								20 Ohm Resistor measurement									
Cycle number	1	2	3	4	5	6	7	Avg	Cycle number	1	2	3	4	5	6	7	8
power on current (mA)	50.76	50.43	51.10	51.10	50.09	50.76	50.43	50.67	power on current (mA)	15.00	14.60	14.60	14.60	14.60	14.60	14.60	14.66
powerDown current (mA)	42.01	42.01	42.35	42.35	42.35	42.35	42.35	42.25	powerDown current (mA)	11.60	11.40	11.40	11.40	11.40	11.40	11.40	11.43
powerSave current (mA)	42.01	42.35	42.35	42.35	42.35	42.35	42.35	42.30	powerSave current (mA)	11.60	11.40	11.40	11.40	11.40	11.40	11.40	11.43
powerStandby current (mA)	42.35	42.35	42.69	42.69	42.69	42.69	42.69	42.59	powerStandby current (mA)	11.70	11.50	11.50	11.50	11.50	11.50	11.50	11.53
powerExtStandby (mA)	42.35	42.35	42.69	42.69	42.69	42.69	42.29	42.54	powerExtStandby (mA)	11.70	11.50	11.50	11.50	11.50	11.50	11.50	11.53
idle (mA)	46.05	45.72	46.05	46.05	46.39	46.39	46.39	46.15	idle (mA)	12.20	11.90	11.90	11.90	11.90	11.90	11.90	11.94
1 Ohm Resistor measurement with Regulated voltage (3.3V) on RAW pin								20 Ohm Resistor measurement									
Cycle number	1	2	3	4	5	6	7	8	Cycle number	1	2	3	4	5	6	7	8
power on current (mA)	13.46	13.46	13.46	13.46	13.46	13.80	13.46	13.51	power on current (mA)	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40
powerDown current (mA)	10.09	10.09	9.76	10.09	9.76	10.09	10.09	10.00	powerDown current (mA)	11.00	12.10	12.10	12.10	12.10	12.10	12.10	11.94
powerSave current (mA)	10.09	10.09	9.76	10.09	9.76	10.09	10.09	10.00	powerSave current (mA)	12.20	12.10	12.10	12.10	12.10	12.10	12.10	12.10
powerStandby current (mA)	10.09	10.09	10.09	10.09	10.09	10.09	10.09	10.09	powerStandby current (mA)	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20
powerExtStandby (mA)	10.09	10.09	10.09	10.09	10.09	10.09	10.09	10.09	powerExtStandby (mA)	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20
idle (mA)	10.43	10.43	10.77	10.77	10.43	10.43	10.77	10.58	idle (mA)	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50
1 Ohm Resistor measurement with Regulated voltage (3.3V) on Vcc pin																	
Cycle number	1	2	3	4	5	6	7	8									
power on current (mA)	13.78	13.78	13.78	13.78	13.78	13.78	13.78	13.78									
powerDown current (mA)	10.09	10.09	9.76	10.09	10.09	9.76	10.09	10.00									
powerSave current (mA)	10.09	10.09	9.76	10.09	10.09	9.76	10.09	10.00									
powerStandby current (mA)	10.41	10.41	10.41	10.41	10.41	10.41	10.41	10.41									
powerExtStandby (mA)	10.41	10.41	10.41	10.41	10.41	10.41	10.41	10.41									
idle (mA)	11.09	11.09	10.77	11.09	11.09	10.43	10.77	10.90									

*Table 1 - APM module power mode current and average current measurements*

### RFM95 LoRa module power consumption Check

The testing for the LoRa module was carried out in three stages to first test the current draw through each radio mode, the second stage checked the current draw for each TX power for a fixed number of Bytes and the final stage measured the time taken for a transmission for a radio packet size at varying power levels. The current was determined by using a variety of resistors ( $1\Omega$ ,  $10\Omega$  and  $20\Omega$ ) in series with the RFM95 module to measure the voltage.

The radio mode current draw checks was carried out by utilising the *RH\_RFM95.h* library where the radio and APM were initialised and the radio was put run through a cycle of modes (*sleep*, *receive*, *transmit* then *idle*) for 5 seconds with the test repeating at the conclusion of the idle cycle. When the radio was put into transmit mode then the APM was ready to transmit but a transmission of data was not carried out.



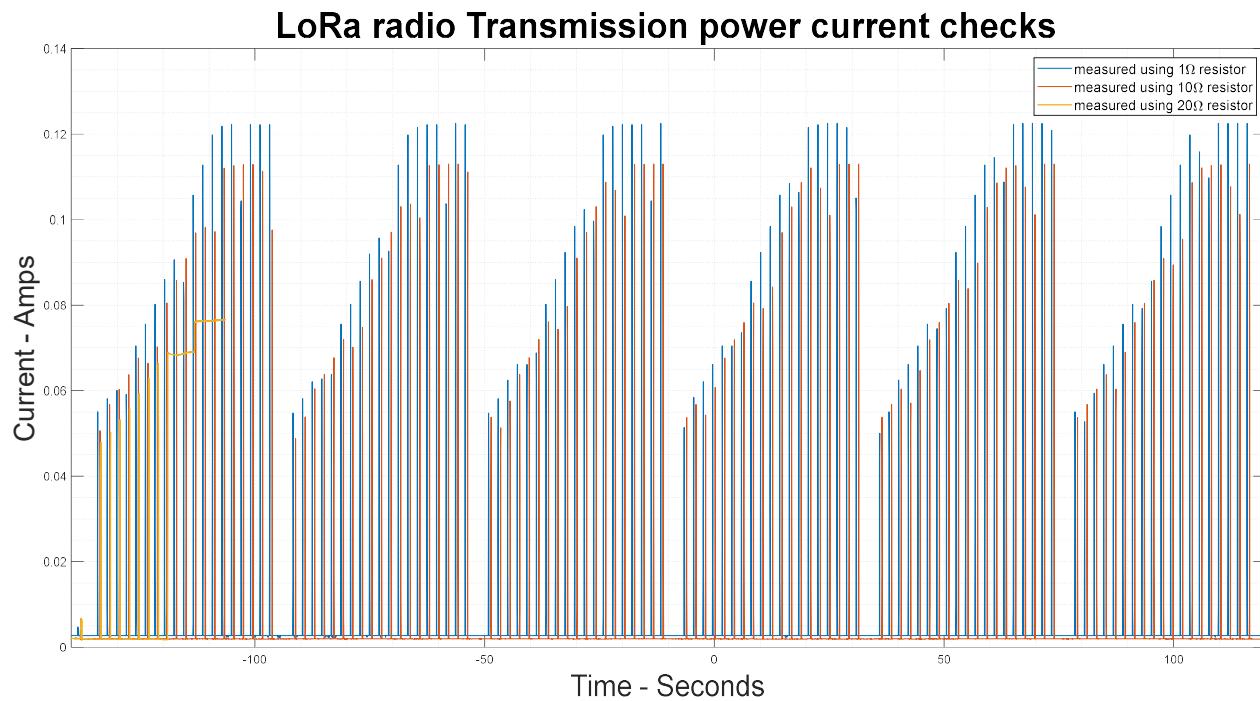
*Figure 2 - RFM95 LoRa radio power mode current check results*

LoRa Radio power mode currents										
Cycle number	1 Ohm Resistor measurement									
	1	2	3	4	5	6	7	8	9	Avg
Sleep current (A)	0.00070	0.00070	0.00070	0.00070	0.00070	0.00070	0.00070	0.00070	0.00070	0.00070
Receive current (A)	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
No data transmit current (A)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Idle current (A)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
10 Ohm Resistor measurement										
Cycle number	1	2	3	4	5	6	7	8	9	Avg
Sleep current (A)	0.00036	0.00070	0.00070	0.00036	0.00070	0.00070	0.00070	0.00070	0.00070	0.00062
Receive current (A)	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
No data transmit current (A)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Idle current (A)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
20 Ohm Resistor measurement										
Cycle number	1	2	3	4	5	6	7	8	9	Avg
Sleep current (A)				-0.00032	-0.00015	-0.00015	-0.00015	0.00012	0.00012	-0.00009
Receive current (A)				0.010	0.012	0.012	0.012	0.012	0.012	0.012
No data transmit current (A)				0.002	0.020	0.001	0.001	0.001	0.001	0.004
Idle current (A)				0.002	0.002	0.002	0.002	0.002	0.002	0.002

*Table 2 - RFM95 module power mode current and average current measurements*

## Appendix B System Power Consumptions Checks

The RFM95 TX power current draw checks were carried out by utilising the *RH\_RFM95.h* library where the radio TX power was increase by 1dBm from 5dBm to 23dBm which are the limits of the module with a transmission carried out every 2 seconds.



*Figure 3 - RFM95 LoRa TX power current check results*

LoRa radio TX power currents														
Cycle number	1 Ohm Resistor measurement - Current (Amps)						10 Ohm Resistor measurement - Current (Amps)							
	1	2	3	4	5	6	Avg	1	2	3	4	5	6	Avg
5dB	0.055	0.055	0.055	0.051	0.050	0.055	<b>0.054</b>	5dB	0.050	0.049	0.054	0.054	0.054	<b>0.053</b>
6dB	0.058	0.058	0.058	0.058	0.055	0.053	<b>0.057</b>	6dB	0.057	0.054	0.051	0.057	0.057	<b>0.056</b>
7dB	0.050	0.062	0.062	0.062	0.062	0.059	<b>0.060</b>	7dB	0.060	0.060	0.057	0.054	0.060	<b>0.059</b>
8dB	0.059	0.063	0.066	0.066	0.066	0.066	<b>0.064</b>	8dB	0.064	0.064	0.064	0.061	0.057	<b>0.064</b>
9dB	0.070	0.064	0.066	0.071	0.071	0.071	<b>0.069</b>	9dB	0.066	0.068	0.068	0.068	0.065	<b>0.060</b>
10dB	0.076	0.076	0.069	0.071	0.076	0.076	<b>0.074</b>	10dB	0.068	0.072	0.071	0.072	0.072	<b>0.069</b>
11dB	0.080	0.080	0.080	0.074	0.075	0.080	<b>0.078</b>	11dB	0.070	0.070	0.076	0.076	0.076	<b>0.074</b>
12dB	0.086	0.086	0.086	0.086	0.079	0.080	<b>0.084</b>	12dB	0.080	0.075	0.074	0.080	0.080	<b>0.078</b>
13dB	0.090	0.092	0.092	0.092	0.092	0.086	<b>0.091</b>	13dB	0.086	0.086	0.080	0.080	0.086	<b>0.084</b>
14dB	0.082	0.096	0.098	0.098	0.098	0.098	<b>0.095</b>	14dB	0.091	0.091	0.084	0.084	0.091	<b>0.089</b>
15dB	0.105	0.093	0.102	0.106	0.106	0.106	<b>0.103</b>	15dB	0.097	0.097	0.097	0.097	0.090	<b>0.095</b>
16dB	0.113	0.113	0.100	0.108	0.113	0.113	<b>0.110</b>	16dB	0.098	0.103	0.103	0.103	0.103	<b>0.101</b>
17dB	0.119	0.120	0.120	0.106	0.114	0.120	<b>0.117</b>	17dB	0.097	0.104	0.109	0.109	0.109	<b>0.106</b>
18dB	0.121	0.122	0.122	0.122	0.108	0.116	<b>0.119</b>	18dB	0.112	0.100	0.107	0.112	0.112	<b>0.109</b>
19dB	0.122	0.122	0.122	0.122	0.122	0.110	<b>0.120</b>	19dB	0.112	0.113	0.101	0.107	0.113	<b>0.110</b>
20dB	0.104	0.122	0.122	0.123	0.123	0.123	<b>0.120</b>	20dB	0.112	0.113	0.113	0.101	0.108	<b>0.113</b>
21dB	0.122	0.104	0.123	0.123	0.123	0.123	<b>0.120</b>	21dB	0.112	0.113	0.113	0.113	0.102	<b>0.110</b>
22dB	0.122	0.123	0.104	0.122	0.123	0.123	<b>0.120</b>	22dB	0.111	0.113	0.113	0.113	0.101	<b>0.111</b>
23dB	0.122	0.122	0.123	0.105	0.121	0.123	<b>0.119</b>	23dB	0.098	0.111	0.113	0.113	0.113	<b>0.110</b>

20 Ohm Resistor measurement - Current (Amps)							
Cycle number	1	2	3	4	5	6	
5dB	0.048	0.048	0.048				<b>0.048</b>
6dB	0.050	0.050	0.051				<b>0.050</b>
7dB	0.053	0.053	0.054				<b>0.053</b>
8dB	0.056	0.056	0.056				<b>0.056</b>
9dB	0.059	0.059	0.059				<b>0.059</b>
10dB	0.063	0.063	0.064				<b>0.063</b>
11dB	0.066	0.066	0.067				<b>0.066</b>
12dB	0.069						<b>0.069</b>
13dB							<b>0.000</b>
14dB							<b>0.000</b>
15dB							<b>0.000</b>
16dB							<b>0.000</b>
17dB							<b>0.000</b>
18dB							<b>0.000</b>
19dB							<b>0.000</b>
20dB							<b>0.000</b>
21dB							<b>0.000</b>
22dB							<b>0.000</b>
23dB							<b>0.000</b>

*Table 3 - RFM95 module TX power current and average current measurements*

## Appendix B System Power Consumptions Checks

The RFM95 transmission packet length current draw checks were carried out by utilising the *RH\_RFM95.h* library where the size of the radio packet transmitted was decreased from 5 Bytes from 250 to 5 Bytes with a second delay between transmissions. The check was repeated for a TX power level of 5dBm, 10dBm, 15dBm and 20dBm.

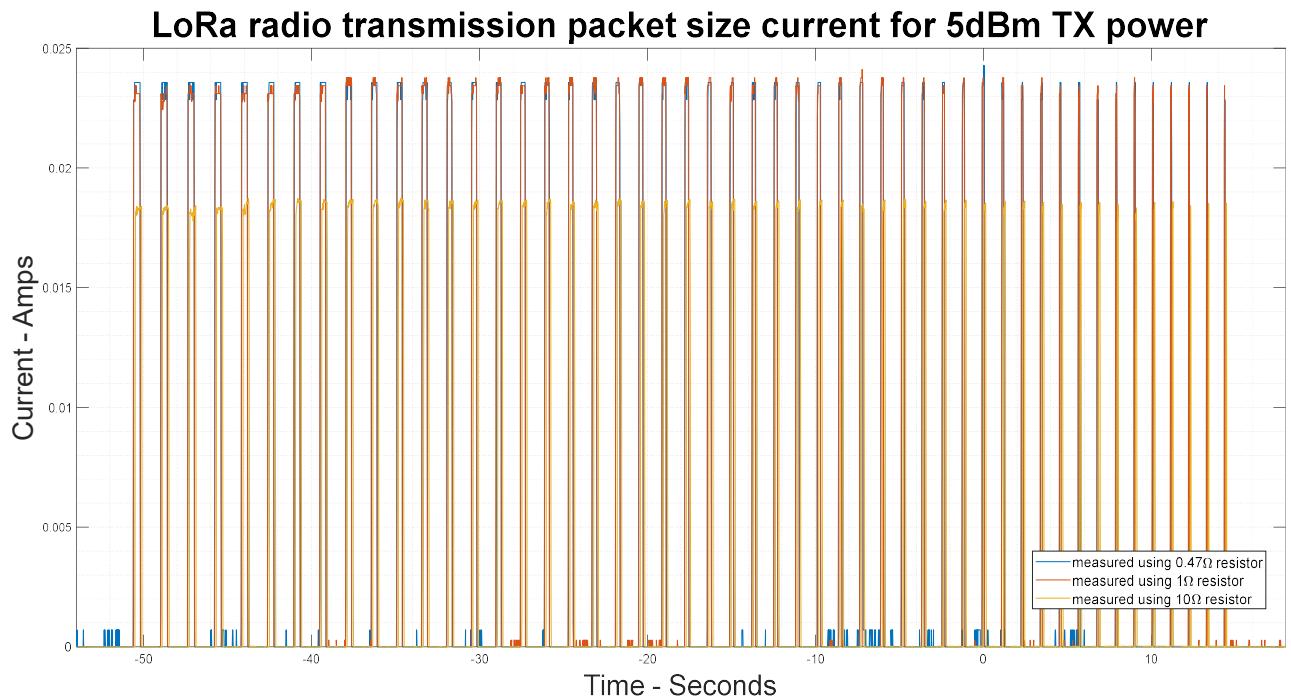


Figure 4 - LoRa TX packet size with 5dBm TX power current draw check results

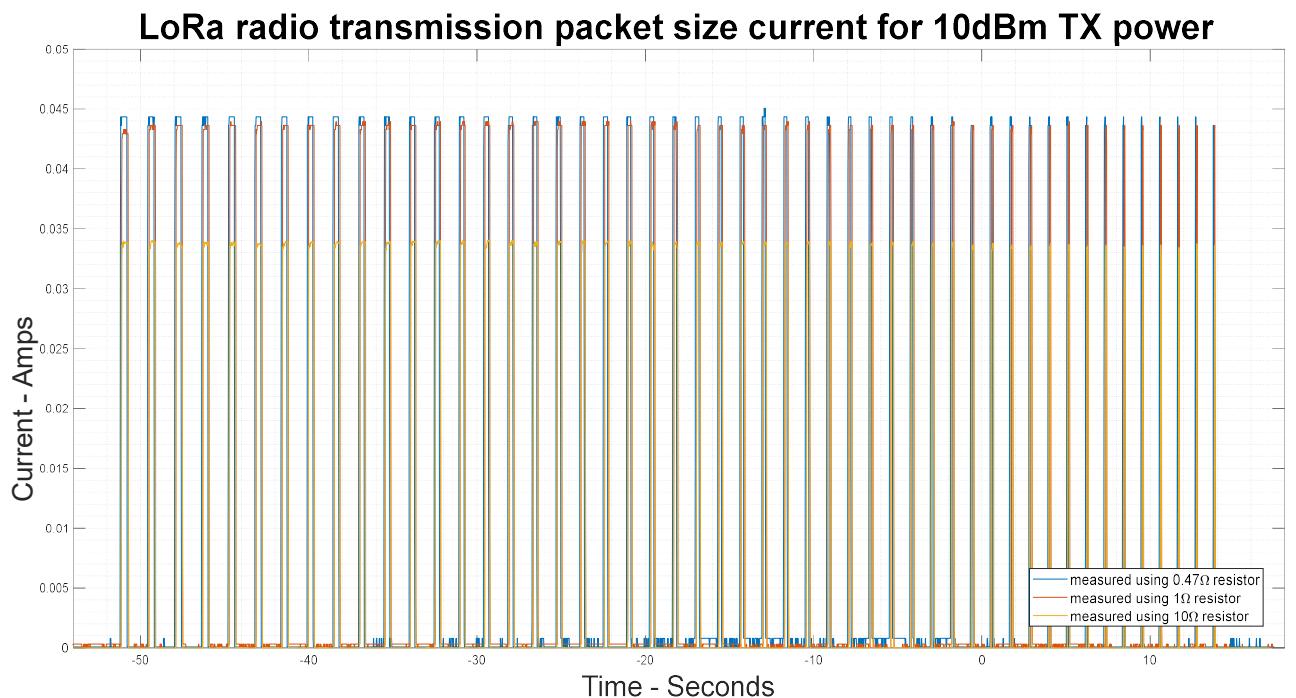


Figure 5 - LoRa TX packet size with 10dBm TX power current draw check results

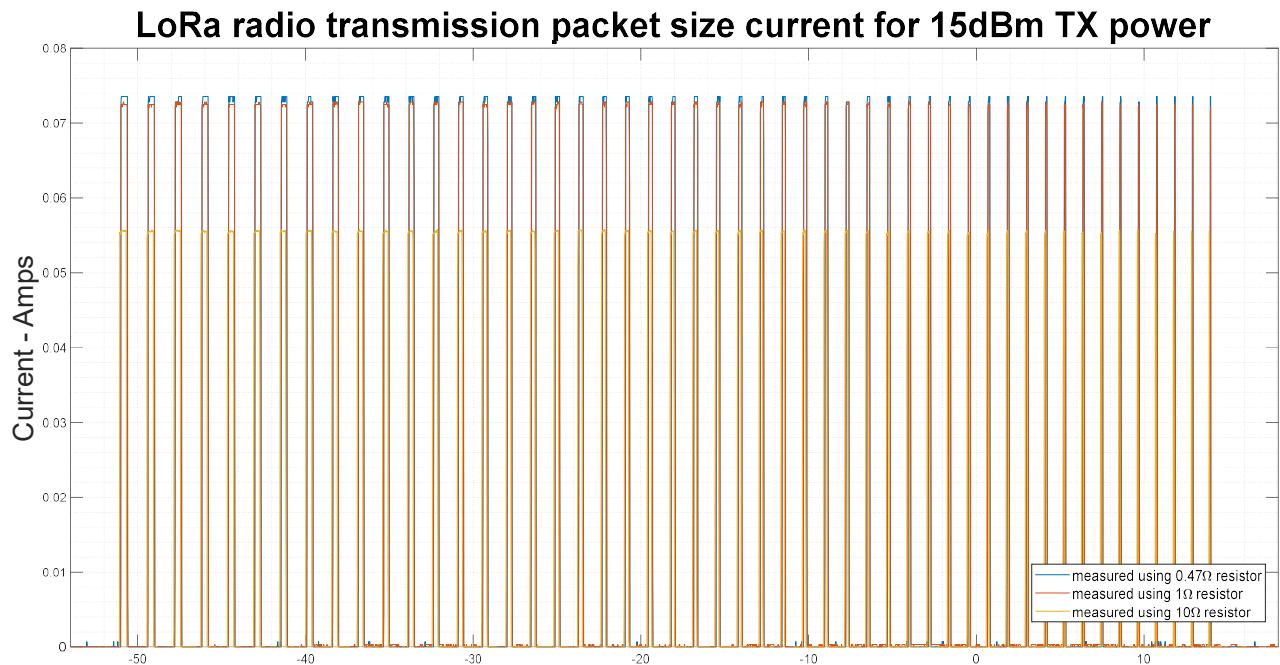


Figure 6 - LoRa TX packet size with 15dBm TX power current draw check results

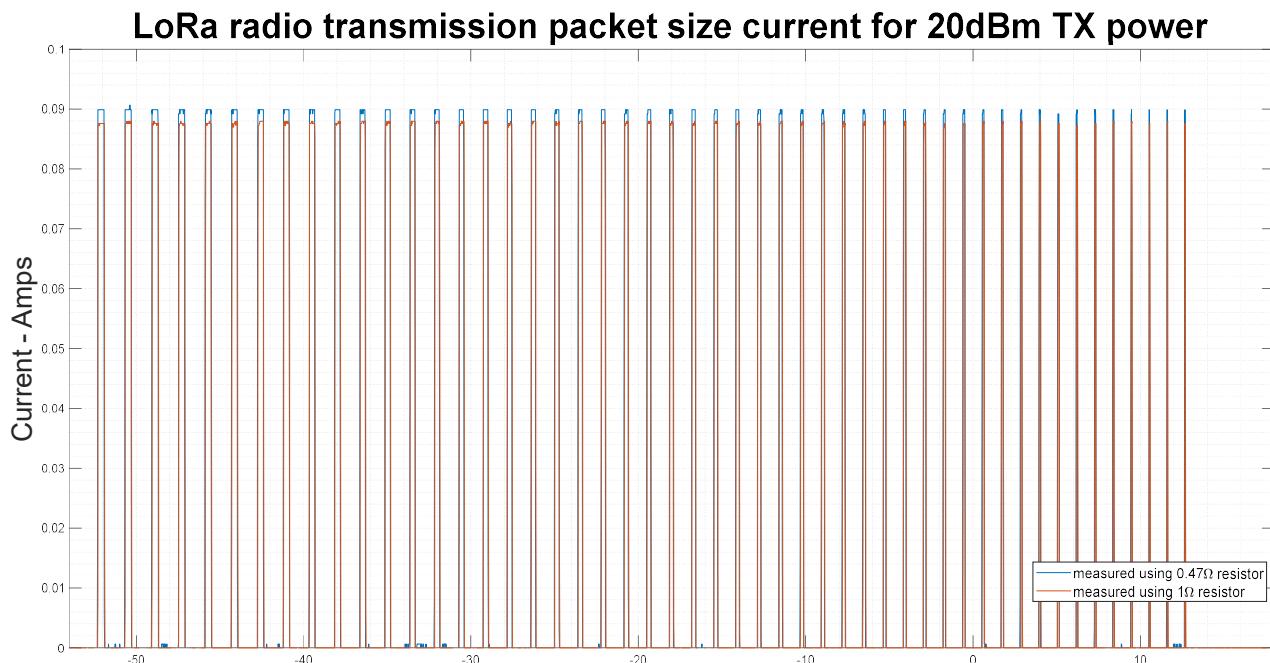


Figure 7 - LoRa TX packet size with 20dBm TX power current draw check results

Appendix B  
System Power Consumptions Checks

LoRa Radio TX packet Size currents					
0.047 Ohm Resistor measurement		Byte Size	TX time (Sec)	Byte Size	TX time (Sec)
Power	Current (Amps)	250	0.38	125	0.20
5dBm	0.024	245	0.38	120	0.18
10dBm	0.044	240	0.37	115	0.18
15dBm	0.074	235	0.35	110	0.18
20dBm	0.089	230	0.36	105	0.17
<b>1 Ohm Resistor measurement</b>		225	0.35	100	0.16
Power	Current (Amps)	220	0.35	95	0.15
5dBm	0.023	215	0.32	90	0.15
10dBm	0.044	210	0.32	85	0.14
15dBm	0.073	205	0.31	80	0.14
20dBm	0.087	200	0.31	75	0.13
<b>10 Ohm Resistor measurement</b>		195	0.30	70	0.13
Power	Current (Amps)	190	0.29	65	0.12
5dBm	0.018	185	0.28	60	0.11
10dBm	0.034	180	0.28	55	0.10
15dBm	0.055	175	0.27	50	0.10
20dBm		170	0.26	45	0.10
		165	0.26	40	0.09
		160	0.25	35	0.08
		155	0.23	30	0.08
		150	0.23	25	0.07
		145	0.22	20	0.07
		140	0.22	15	0.06
		135	0.22	10	0.05
		130	0.22	5	0.05

Table 4 - RFM95 module TX packet size current and TX time measurements

### Solar power generation and regulation check

This testing was carried out to measure the total current generated by the solar panels and measure the power consumed by the voltage regulator (LM1086) and the total current used by the processor and communication sub-system as the system runs through a software testing software. The software cycle will consist of the processor and radio initialising then powering down for 4 seconds to represent the initial launch and then performing a scaled version of an operational cycle. The operational cycle will consist of the processor collecting data for 1 second, transmitting the data with a 1 second delay before and after the transmit, entering a receive mode for 3 seconds, entering a low-power cycle for 5 seconds and then repeat.

### Solar panel generation and regulation power checks

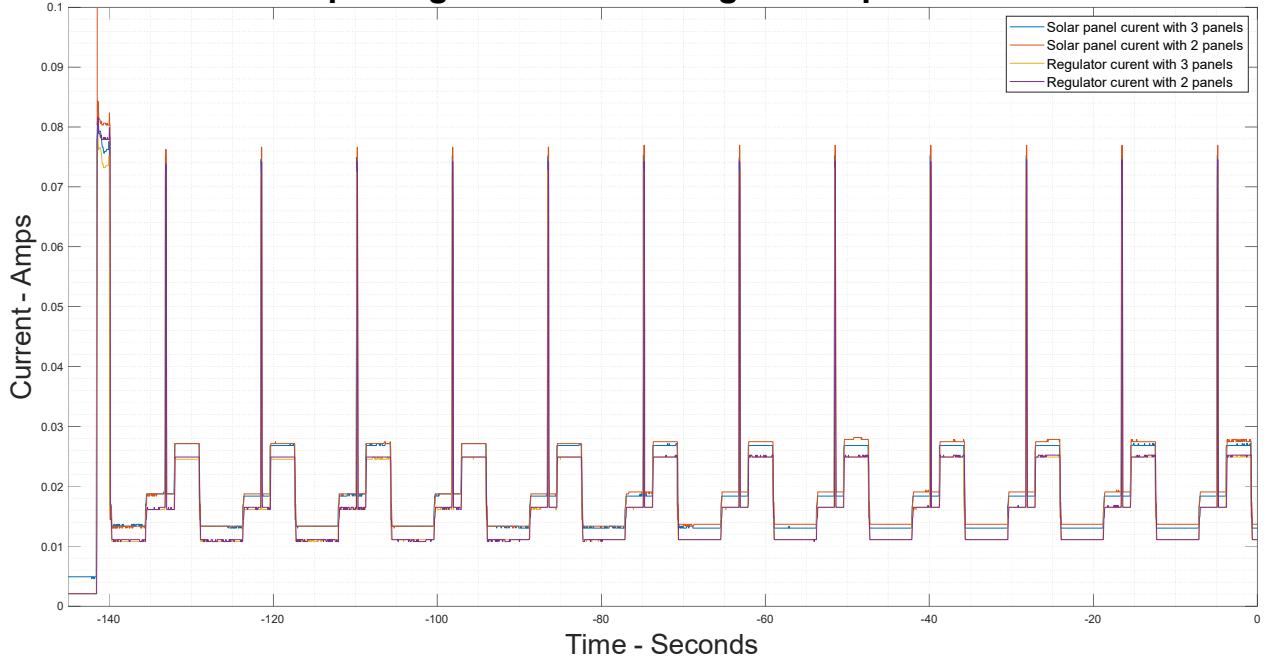


Figure 8 – Solar panel generation and regulation current check results

Solar panel generation and regulator current measurements																	
3 Solar panels connected - Solar panel current								3 Solar panels connected - Regulator current									
Cycle number	1	2	3	4	5	6	7	Avg	Cycle number	1	2	3	4	5	6	7	Avg
Initialisation (mA)	81.65							81.65	Initialisation (mA)	78.56						78.56	
Launch (mA)	13.67							13.67	Launch (mA)	11.10						11.10	
Collect Data (mA)	16.47	16.13	16.13	16.47	16.47	16.13	16.47	16.32	Collect Data (mA)	16.47	16.47	16.13	16.13	16.47	16.13	16.47	16.32
Transmit data (mA)	76.27	76.61	76.61	76.61	76.94	76.94	76.94	76.70	Transmit data (mA)	73.86	74.20	74.20	74.20	74.20	74.20	74.20	74.15
Receive mode (mA)	27.13	27.13	27.13	27.13	27.13	27.13	27.13	27.13	Receive mode (mA)	24.86	24.86	24.86	24.86	24.86	24.86	24.86	24.86
low-power mode (mA)	13.34	13.34	13.34	13.34	13.34	13.34	13.34	13.34	low-power mode (mA)	11.10	11.10	11.10	11.10	11.10	11.10	11.10	11.10
2 Solar panels connected - Solar panel current								2 Solar panels connected - Regulator current									
Cycle number	1	2	3	4	5	6	7	Avg	Cycle number	1	2	3	4	5	6	7	Avg
Initialisation (mA)	84.35							84.35	Initialisation (mA)	81.58							81.58
Launch (mA)	13.67							13.67	Launch (mA)	11.10							11.10
Collect Data (mA)	16.47	16.13	16.13	16.47	16.47	16.13	16.47	16.32	Collect Data (mA)	16.47	16.47	16.13	16.13	16.47	16.13	16.47	16.32
Transmit data (mA)	76.27	76.61	76.61	76.61	76.94	76.94	76.94	76.70	Transmit data (mA)	73.86	74.20	74.20	74.20	74.20	74.20	74.20	74.15
Receive mode (mA)	27.13	27.13	27.13	27.13	27.13	27.13	27.13	27.13	Receive mode (mA)	24.86	24.86	24.86	24.86	24.86	24.86	24.86	24.86
low-power mode (mA)	13.34	13.34	13.34	13.34	13.34	13.34	13.34	13.34	low-power mode (mA)	11.10	11.10	11.10	11.10	11.10	11.10	11.10	11.10

Table 5 - Solar power generation and regulator current measurements