

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 1Ω to 10Ω and 20Ω 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

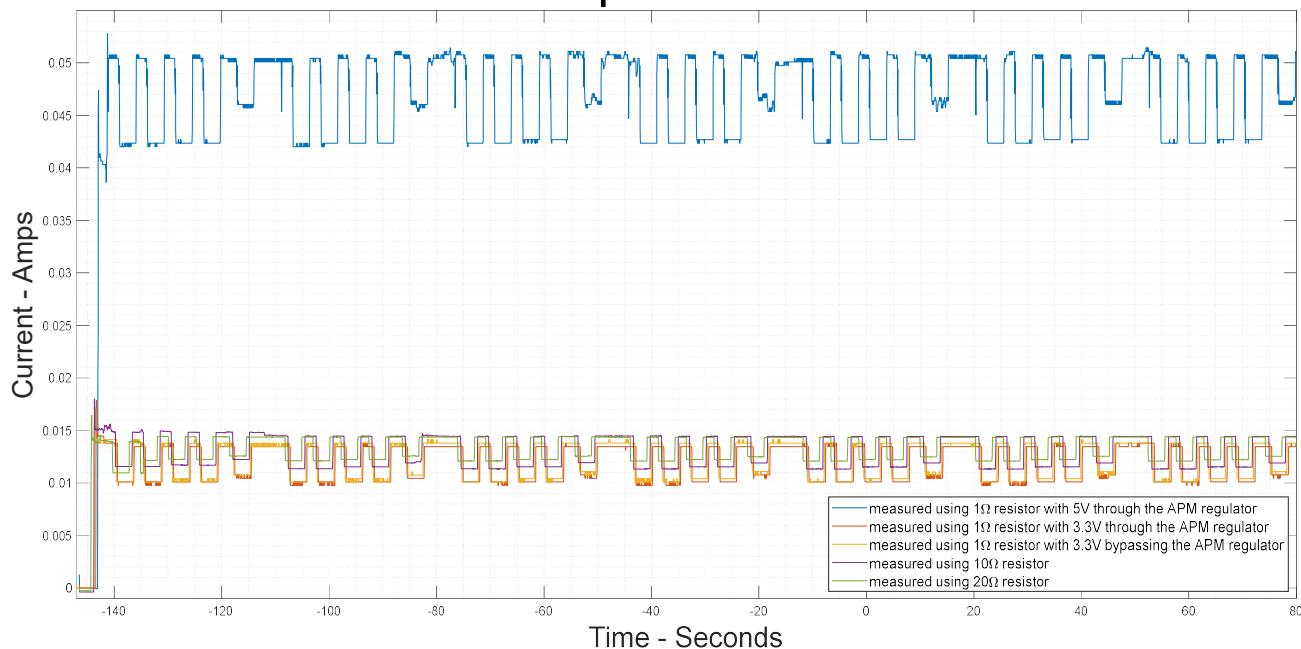


Figure 1 - Arduino Pro Mini power mode current check results

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 (1Ω , 10Ω and 20Ω) 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.

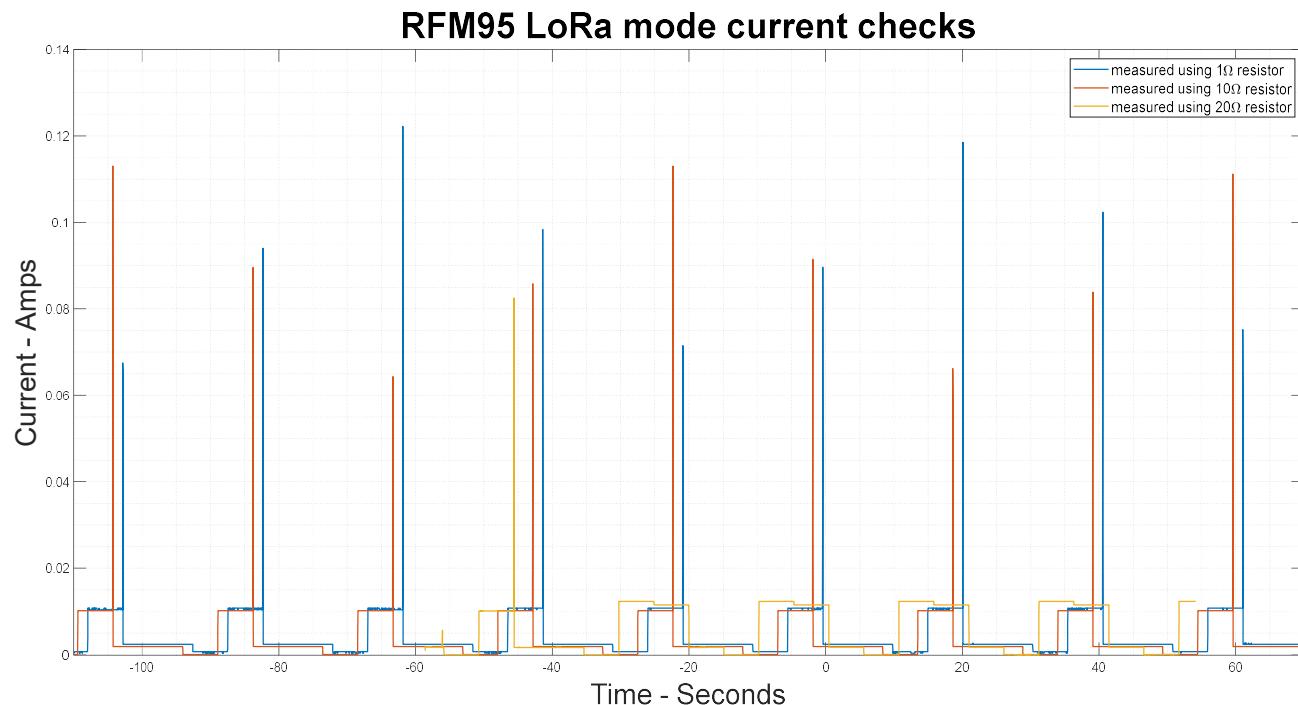


Figure 2 - RFM95 LoRa radio power mode current check results

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
	0.00036	0.00070	0.00070	0.00036	0.00070	0.00070	0.00070	0.00070	0.00070	0.00062
Sleep current (A)	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Receive 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
				-0.00032	-0.00015	-0.00015	-0.00015	0.00012	0.00012	-0.00009
Sleep current (A)				0.010	0.012	0.012	0.012	0.012	0.012	0.012
Receive current (A)				0.002	0.020	0.001	0.001	0.001	0.001	0.012
No data transmit current (A)				0.002	0.002	0.002	0.002	0.002	0.002	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.

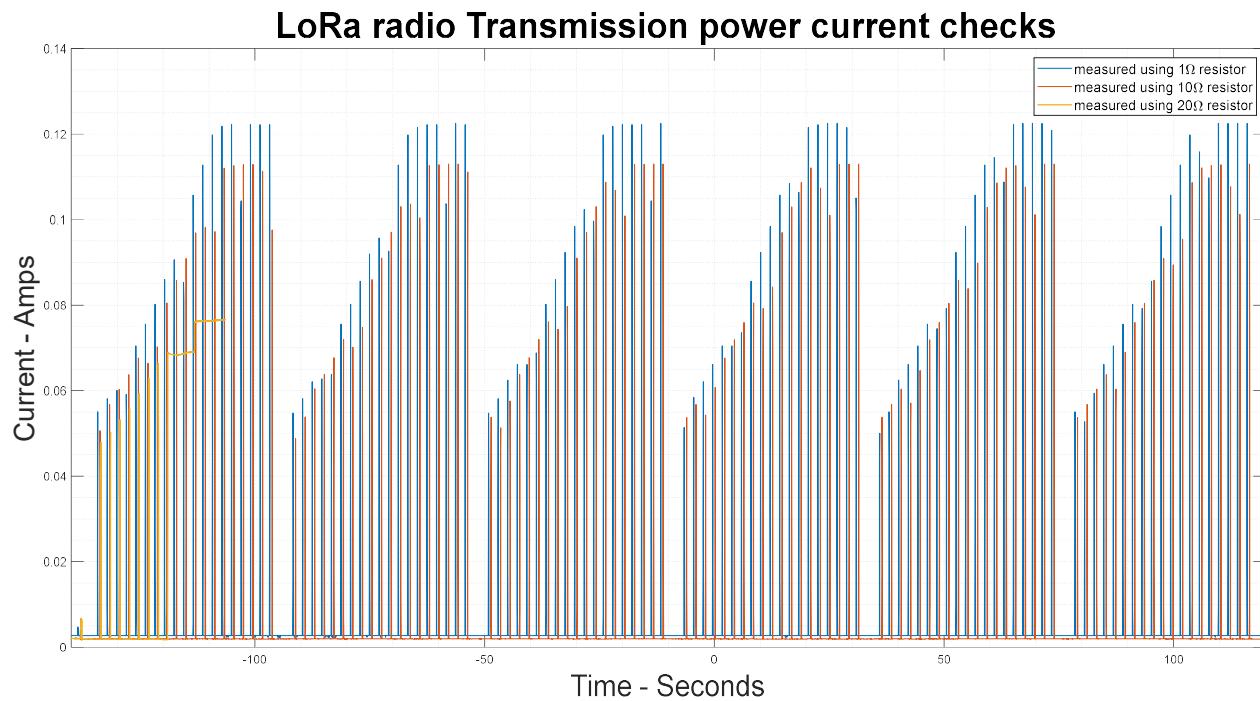


Figure 3 - RFM95 LoRa TX power current check results

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
5dB	0.055	0.055	0.055	0.051	0.050	0.055	0.054	0.050	0.049	0.054	0.054	0.054	0.053
6dB	0.058	0.058	0.058	0.058	0.055	0.053	0.057	0.057	0.054	0.051	0.057	0.057	0.056
7dB	0.050	0.062	0.062	0.062	0.062	0.059	0.060	0.060	0.060	0.057	0.054	0.060	0.059
8dB	0.059	0.063	0.066	0.066	0.066	0.066	0.064	0.064	0.064	0.064	0.061	0.057	0.064
9dB	0.070	0.064	0.066	0.071	0.071	0.071	0.069	0.066	0.068	0.068	0.068	0.065	0.060
10dB	0.076	0.076	0.069	0.071	0.076	0.076	0.074	0.068	0.072	0.071	0.072	0.069	0.071
11dB	0.080	0.080	0.080	0.074	0.075	0.080	0.078	0.070	0.070	0.076	0.076	0.076	0.074
12dB	0.086	0.086	0.086	0.086	0.079	0.080	0.084	0.080	0.075	0.074	0.080	0.080	0.078
13dB	0.090	0.092	0.092	0.092	0.092	0.086	0.091	0.086	0.086	0.080	0.080	0.086	0.084
14dB	0.082	0.096	0.098	0.098	0.098	0.098	0.095	0.091	0.091	0.084	0.084	0.091	0.089
15dB	0.105	0.093	0.102	0.106	0.106	0.106	0.103	0.097	0.097	0.097	0.090	0.089	0.095
16dB	0.113	0.113	0.100	0.108	0.113	0.113	0.110	0.108	0.103	0.103	0.103	0.095	0.101
17dB	0.119	0.120	0.120	0.106	0.114	0.120	0.117	0.097	0.104	0.109	0.109	0.109	0.106
18dB	0.121	0.122	0.122	0.122	0.108	0.116	0.119	0.112	0.100	0.107	0.112	0.112	0.109
19dB	0.122	0.122	0.122	0.122	0.122	0.110	0.120	0.112	0.113	0.101	0.107	0.113	0.110
20dB	0.104	0.122	0.122	0.123	0.123	0.123	0.120	0.112	0.113	0.113	0.101	0.108	0.113
21dB	0.122	0.104	0.123	0.123	0.123	0.123	0.120	0.112	0.113	0.113	0.113	0.102	0.110
22dB	0.122	0.123	0.104	0.122	0.123	0.123	0.120	0.111	0.113	0.113	0.113	0.101	0.111
23dB	0.122	0.122	0.123	0.105	0.121	0.123	0.119	0.098	0.111	0.113	0.113	0.113	0.110

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

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.

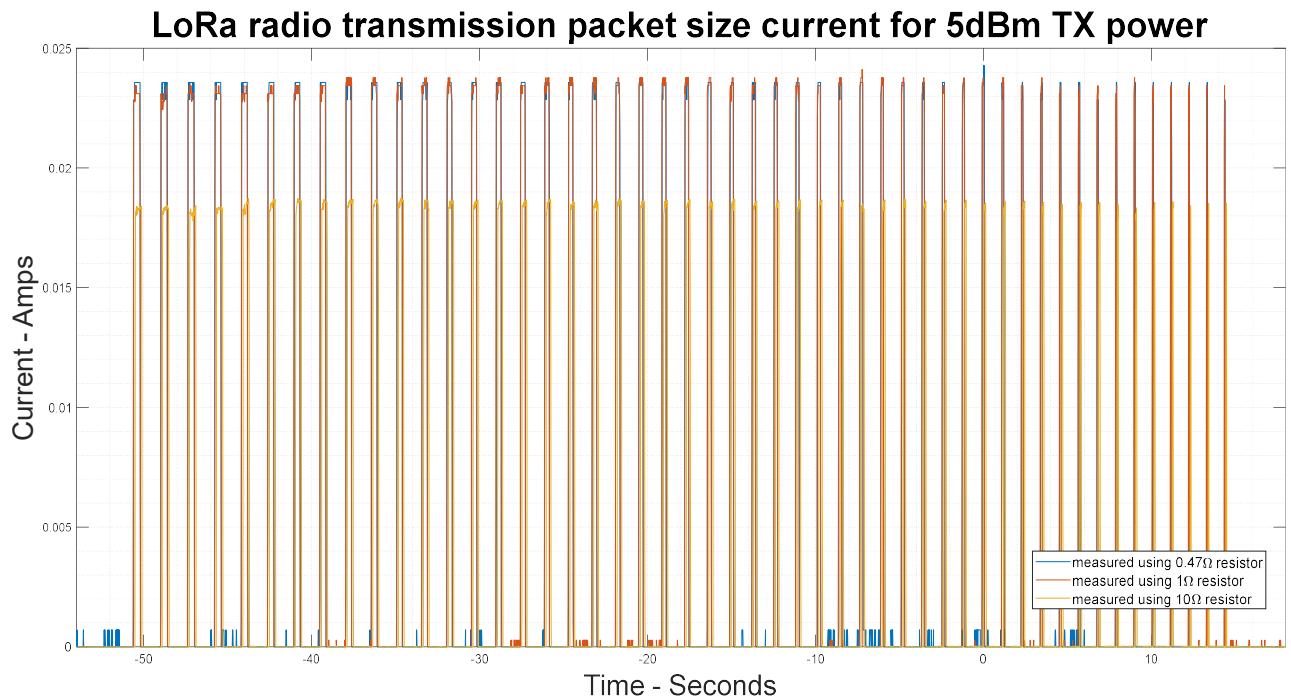


Figure 4 - LoRa TX packet size with 5dBm TX power current draw check results

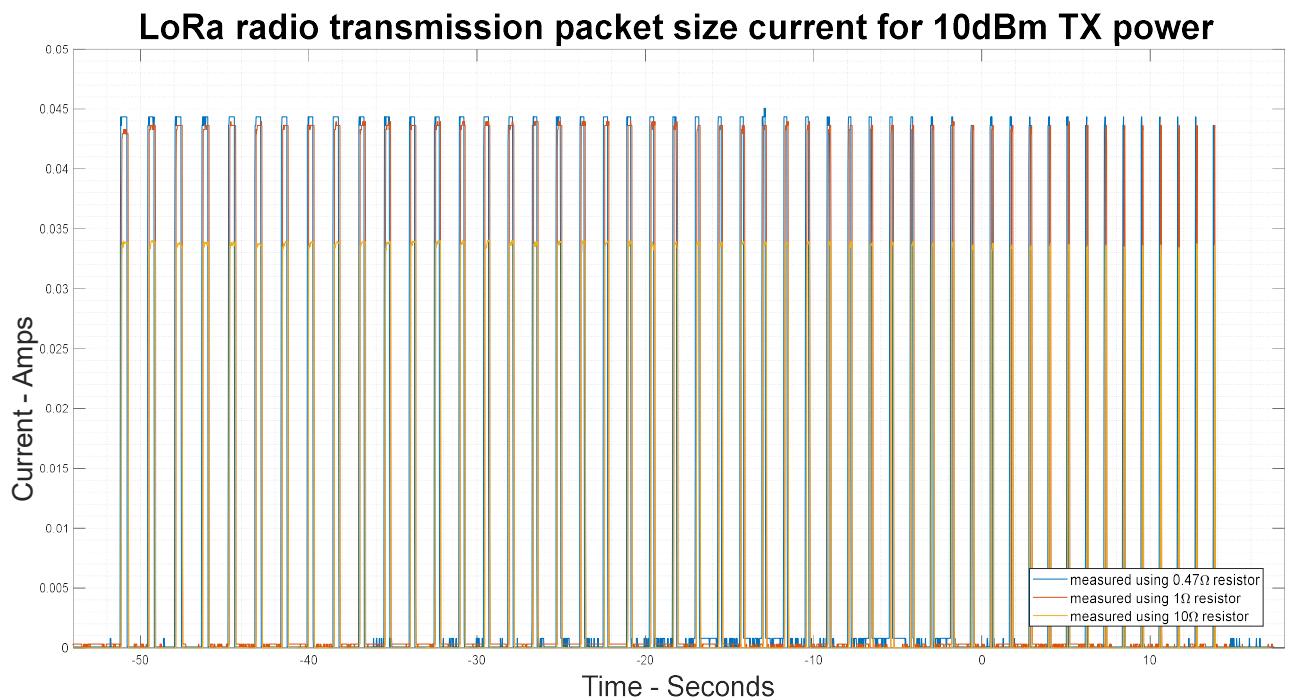


Figure 5 - LoRa TX packet size with 10dBm TX power current draw check results

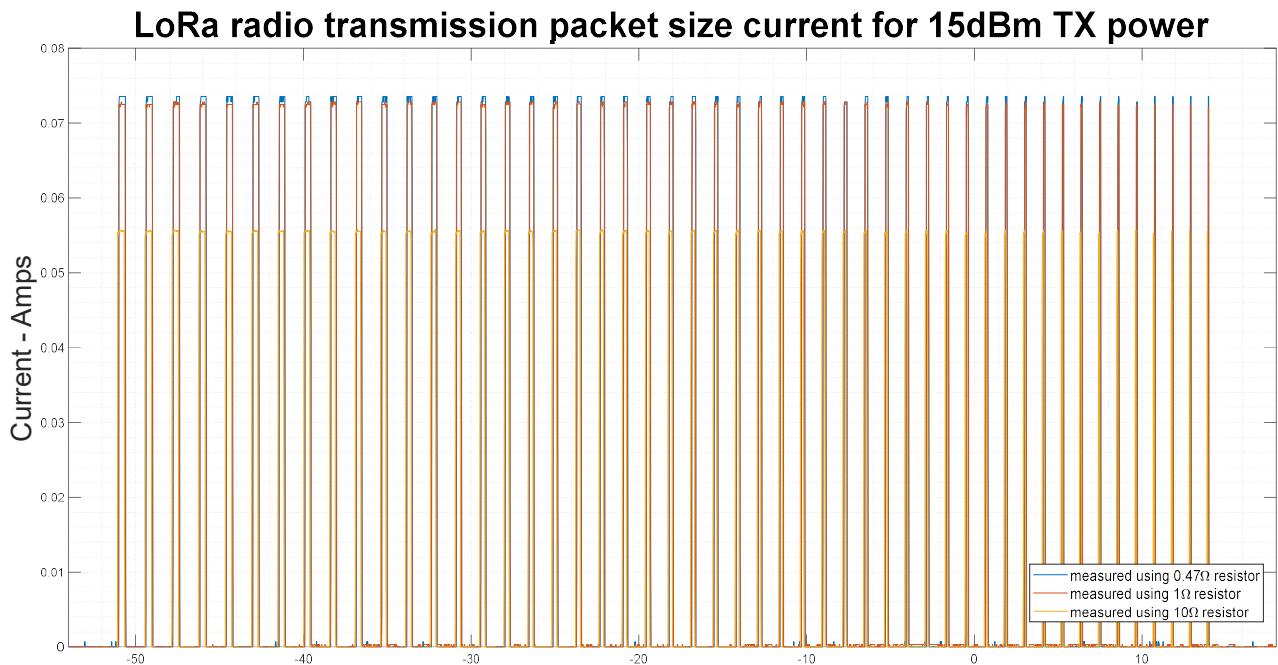


Figure 6 - LoRa TX packet size with 15dBm TX power current draw check results

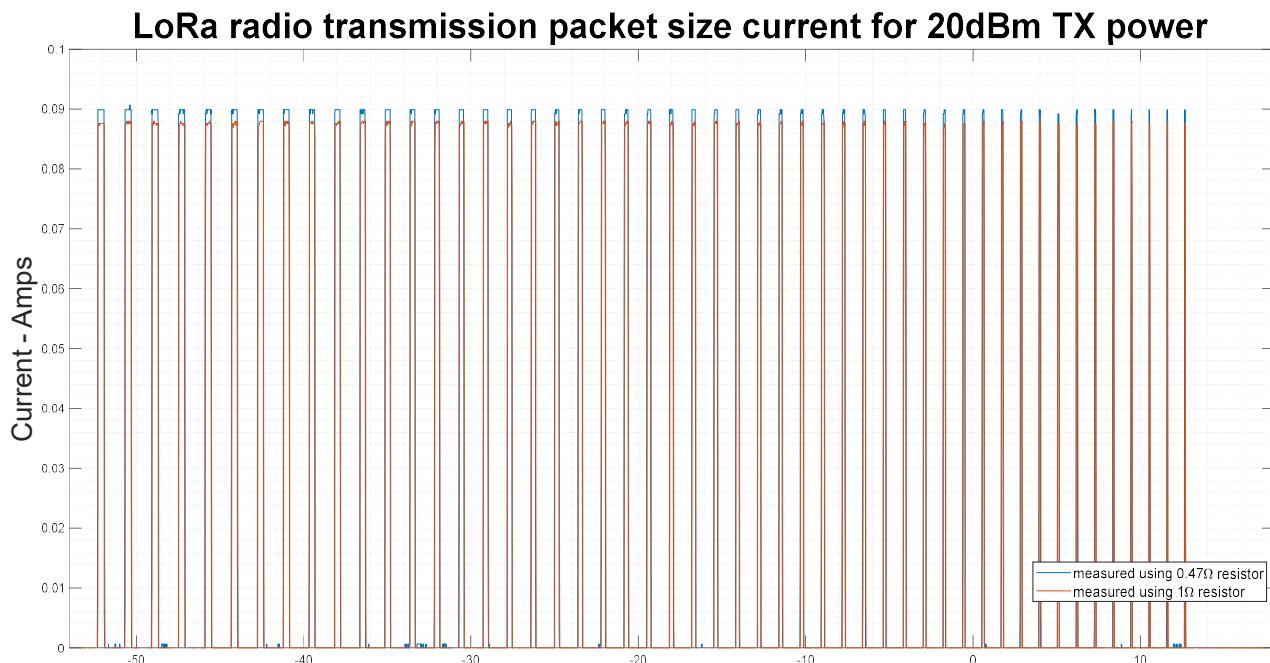


Figure 7 - LoRa TX packet size with 20dBm TX power current draw check results

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
1 Ohm Resistor measurement		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
10 Ohm Resistor measurement		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

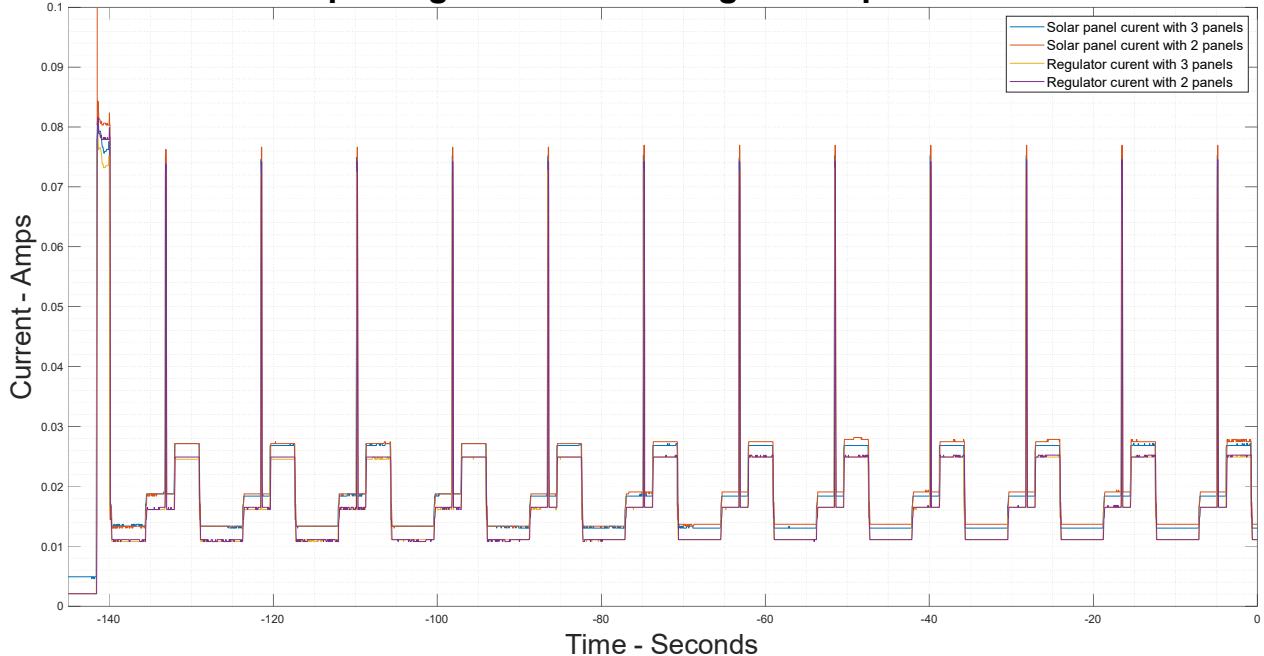


Figure 8 – Solar panel generation and regulation current check results

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