Small Sat UHF Identification and TT&C radio beacon

Appendix A - Project Gantt chart

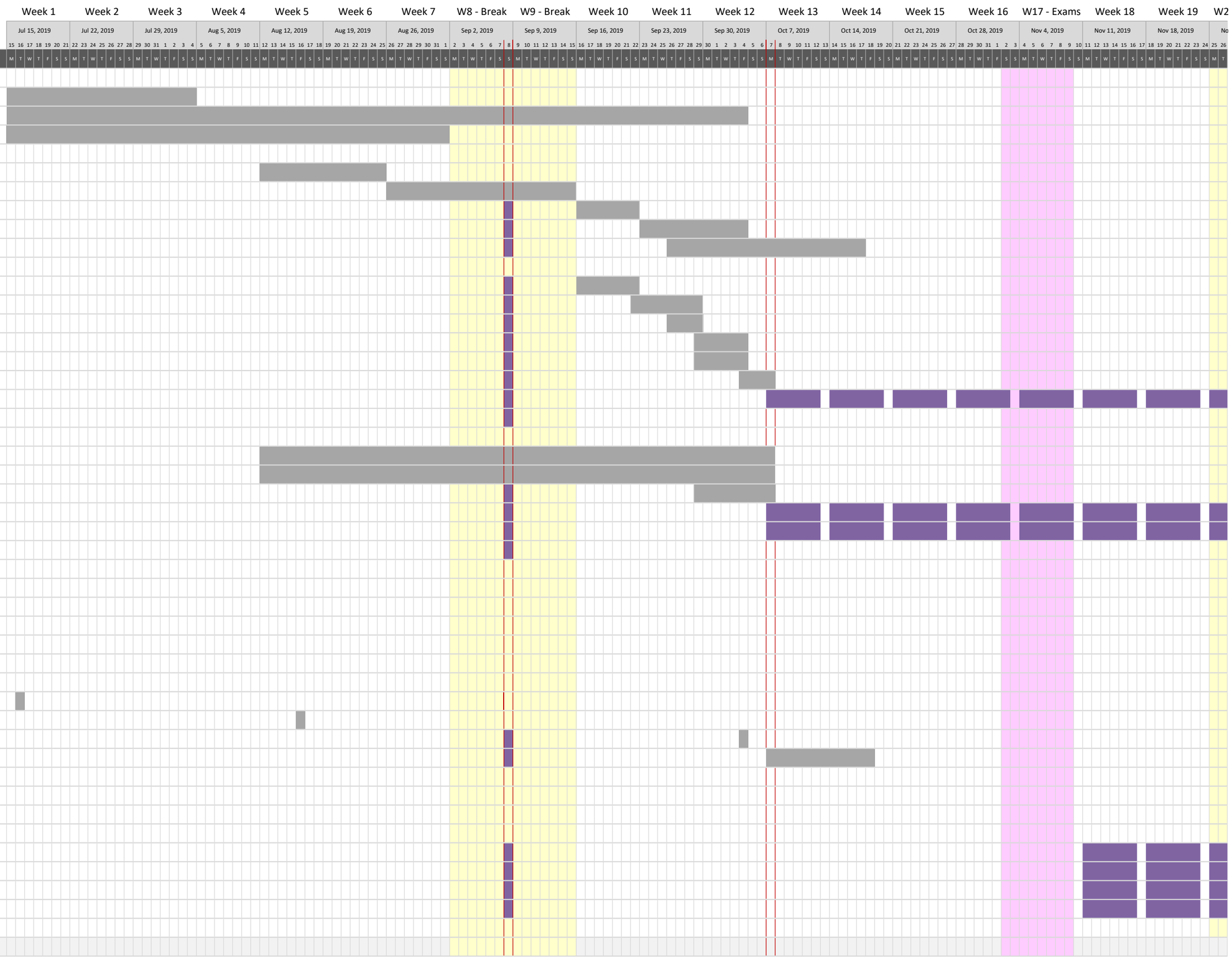
UNINSW Canberra - Thesis project
Travis MCKee

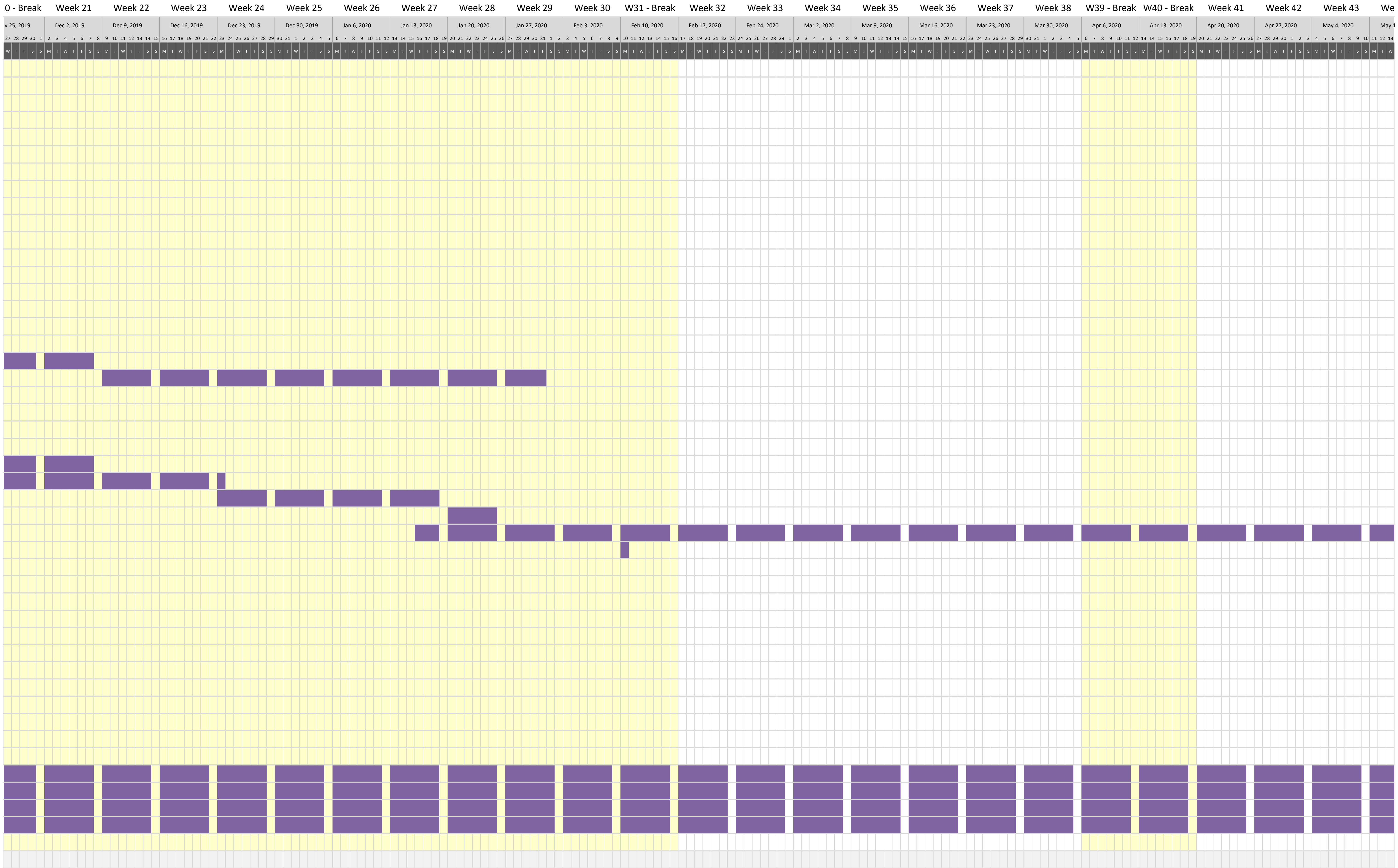
https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html

Project Start: Wed, 7/17/2019
Display Week: 1

TASK	ASSIGNED TO	PROGRESS	START	END
Planning				
Scope Determination		100%	15-Jul-19	04-Aug-19
Literture Review		100%	15-Jun-19	04-Oct-19
General Research		100%	15-Jul-19	01-Sep-19
Breadboard design and build				
Initial system design		100%	12-Aug-19	25-Aug-19
Processor and comms build		100%	26-Aug-19	15-Sep-19
Ground Solar generation and regulation build		100%	16-Sep-19	22-Sep-19
Full breadboard intergration		100%	23-Sep-19	04-Oct-19
breadboard extra peripherals design and build		100%	26-Sep-19	17-Oct-19
Testing and Evaluation				
Initial testing		100%	16-Sep-19	22-Sep-19
Power cycle testing		100%	22-Sep-19	29-Sep-19
Solar Power Testing		100%	26-Sep-19	29-Sep-19
Short and full beacon cycle testing		100%	29-Sep-19	04-Oct-19
Extra peripherals testing		100%	29-Sep-19	04-Oct-19
VIVA presentation testing		100%	04-Oct-19	07-Oct-19
Initial testing plan		0%	07-Oct-19	08-Dec-19
Final testing plan		0%	09-Dec-19	31-Jan-20
Incremental development milestones				
breadboard Model for VIVA presentation		100%	12-Aug-19	07-Oct-19
Initial software development		100%	12-Aug-19	07-Oct-19
Initial breadboard testing		100%	29-Sep-19	07-Oct-19
Finial breadboard testing		0%	07-Oct-19	08-Dec-19
Intial PCB Design		0%	07-Oct-19	23-Dec-19
Initial PCB prototype		0%	23-Dec-19	19-Jan-20
Initial PCB testing		0%	19-Jan-20	26-Jan-20
Build, Test, Evaluate and Redesign cycle		0%	16-Jan-20	25-May-20
1st deliverable working PCB model		0%	10-Feb-20	10-Feb-20
Final PCB model		0%	25-May-20	25-May-20
Final model tested and complete		0%	25-May-20	31-May-20
Final software design for PCB model (seminar presentat		0%	01-Jun-20	06-Jun-20
Documentation				
Access approval forms		100%	16-Jul-19	16-Jul-19
TSG/WHS/Ethics plan		100%	16-Aug-19	16-Aug-19
Interim Report		100%	04-Oct-19	04-Oct-19
VIVA		100%	07-Oct-19	18-Oct-19
Final Report		0%	09-Jun-20	09-Jun-20
Deliverables		0%	15-Jun-20	15-Jun-20
Project Seminar		0%	25-May-20	05-Jun-20
Extension				
Full SSA system concept, design and protype		0%	11-Nov-19	08-Jun-20
Full Control intergration		0%	11-Nov-19	08-Jun-20
LEO tracking system concept and design		0%	11-Nov-19	08-Jun-20
Amatuer tracking system		0%	11-Nov-19	08-Jun-20

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
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
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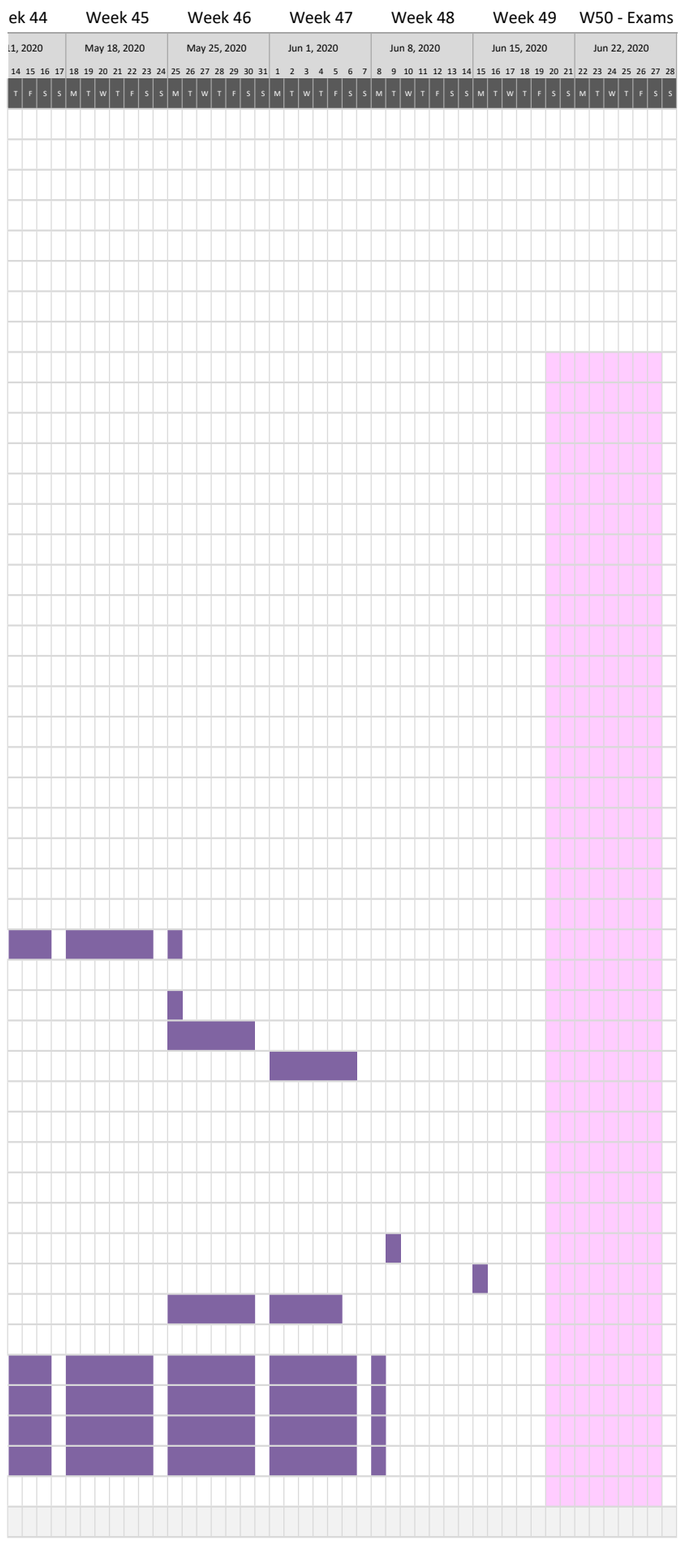
Apr 27, 2020
May 4, 2020


ek 44
Week 45
Week 46
Week 47
Week 48
Week 49
W50 - Exams
1, 2020
May 18, 2020
May 25, 2020
Jun 1, 2020
Jun 8, 2020
Jun 15, 2020
Jun 22, 2020
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
T F S S M T W T F S S M T W T F S S M T W T F S S M T W T F S S M T W T F S S M T W T F S S M T W T F S S

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 rocketscream. 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.

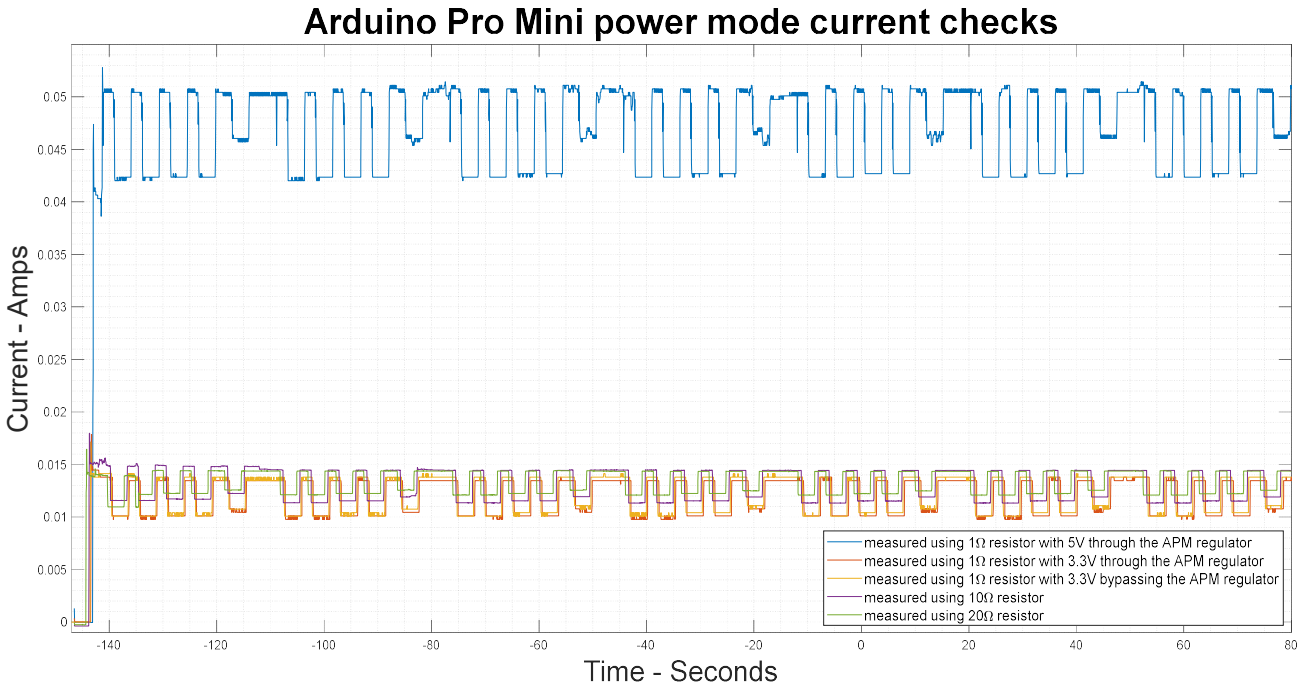


Figure 1 - Arduino Pro Mini power mode current check results

ArduinoPro Mini power mode currents																	
1 Ohm Resistor measurement with Unregulated voltage (5V) on RAW pin									**10 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	10.09	9.76	10.09	9.76	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	10.09	9.76	10.09	9.76	10.09	**10.00**	powerSave current (mA)	12.10	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.

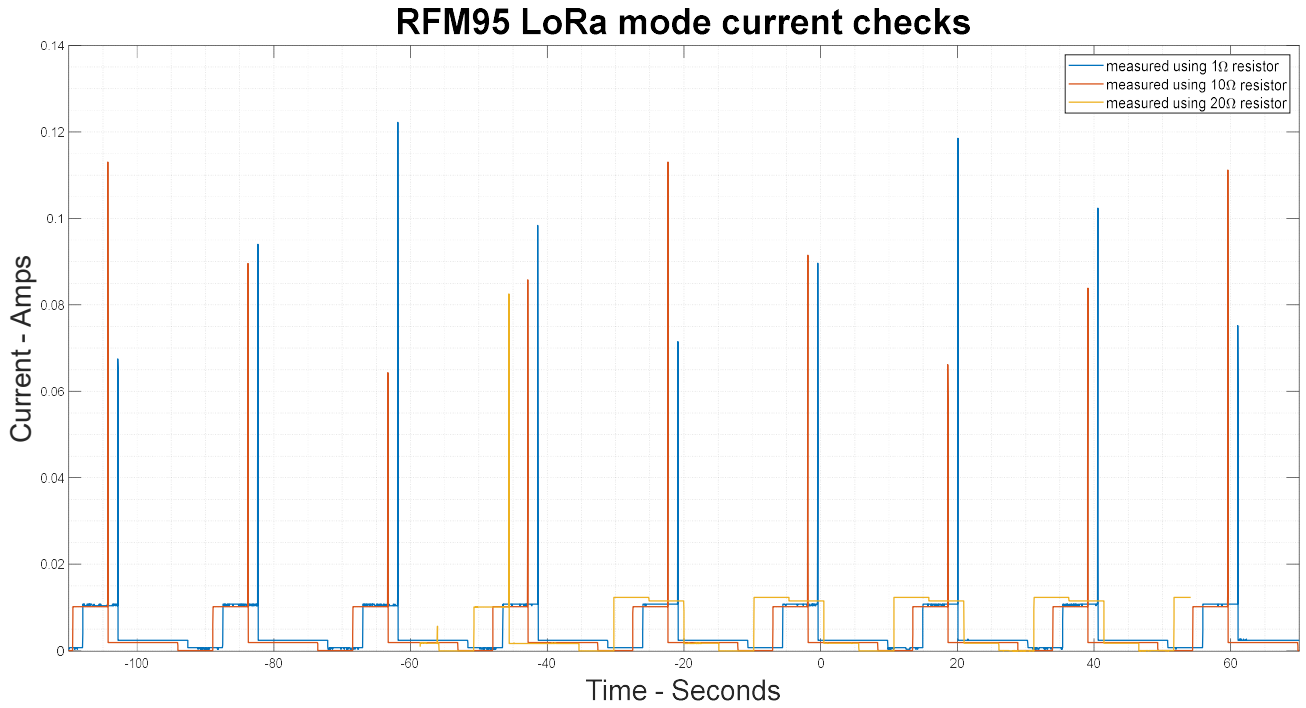


Figure 2 - RFM95 LoRa radio power mode current check results

LoRa Radio power mode currents										
1 Ohm Resistor measurement										
Cycle number	**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**
Recieve 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**
Recieve 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**
Recieve 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

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.

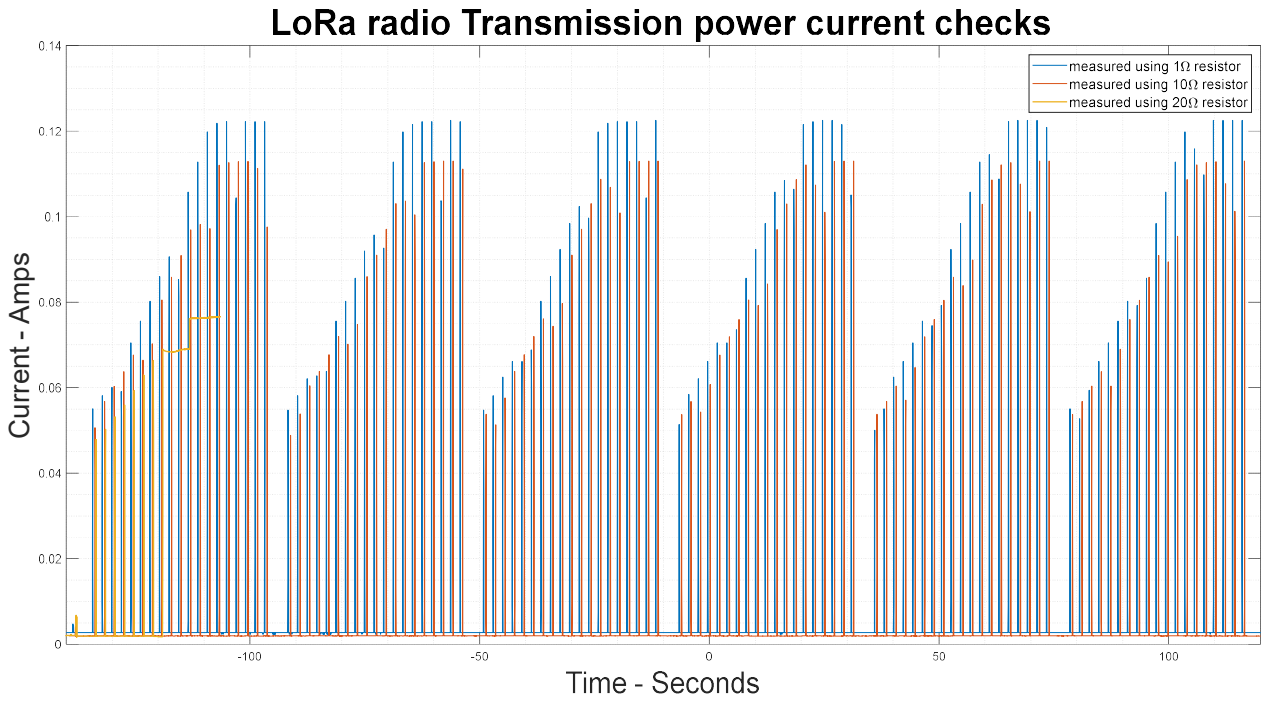


Figure 3 - RFM95 LoRa TX power current draw check results

LoRa radio TX power currents

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

20 Ohm Resistor measurement - Current (Amps)							
Cycle number	1	2	3	4	5	6	Avg
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

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.

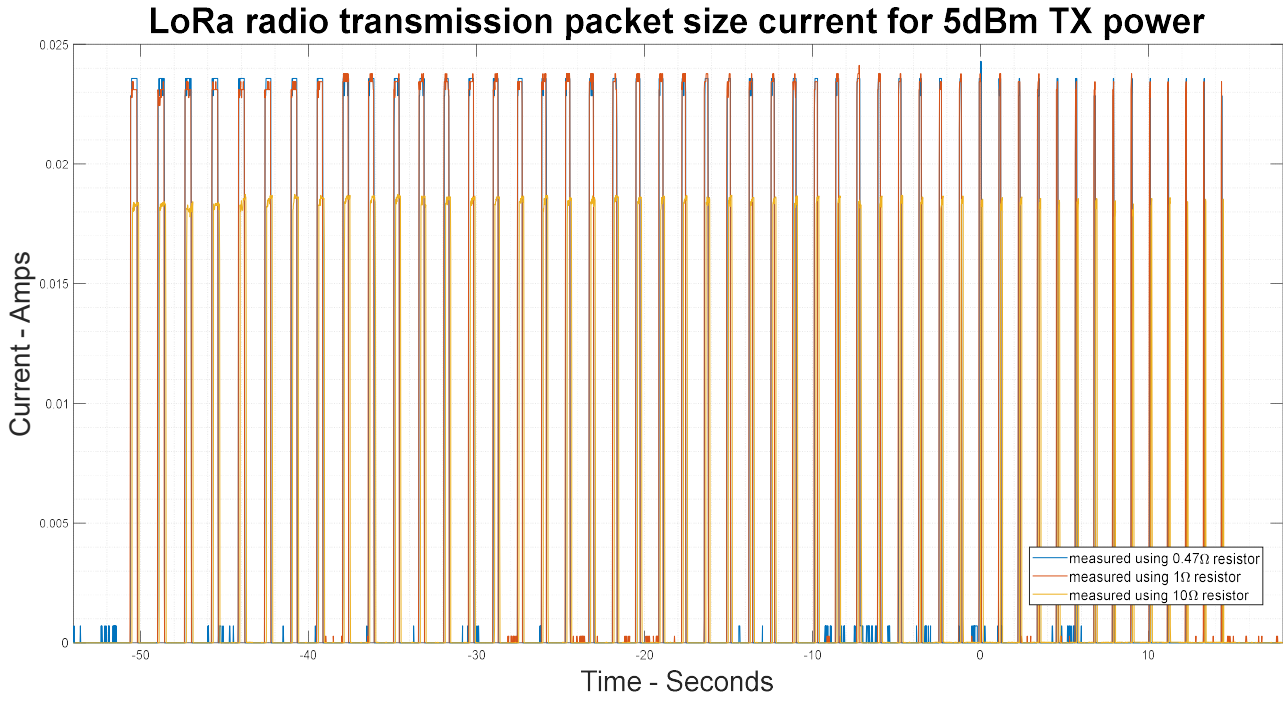


Figure 4 - LoRa TX packet size with 5dBm TX power current draw check results

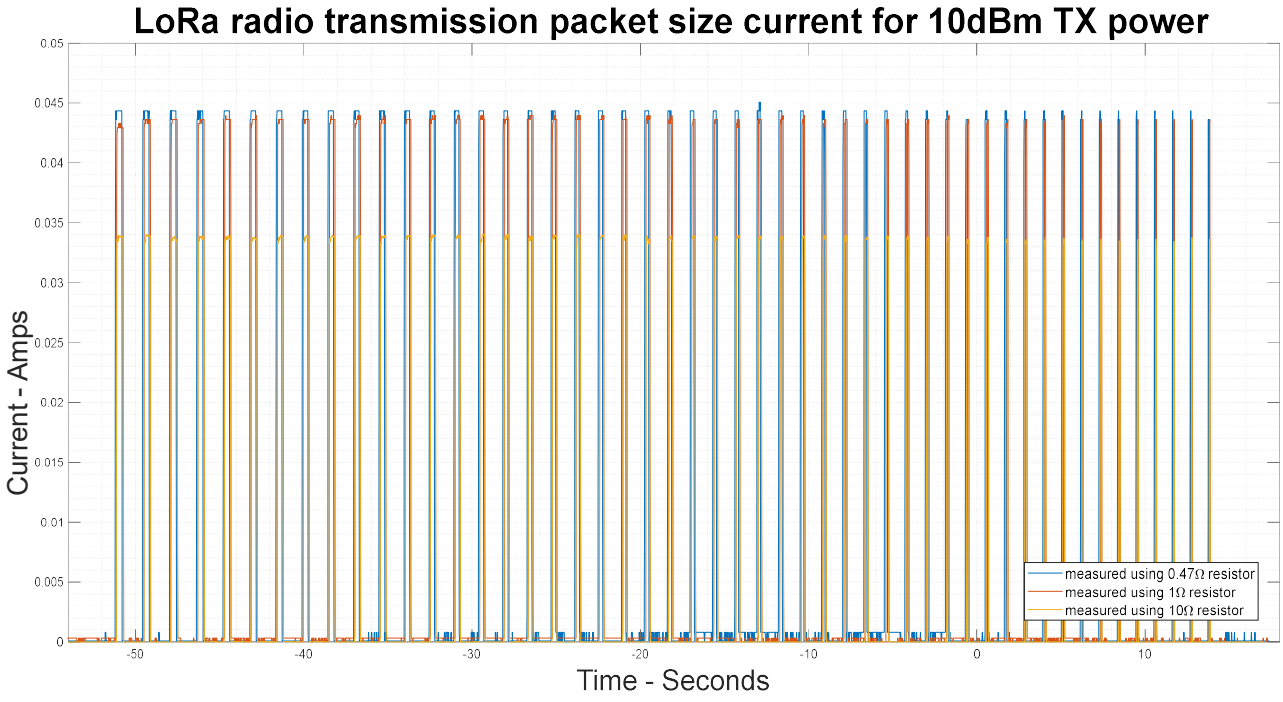


Figure 5 - LoRa TX packet size with 10dBm TX power current draw check results

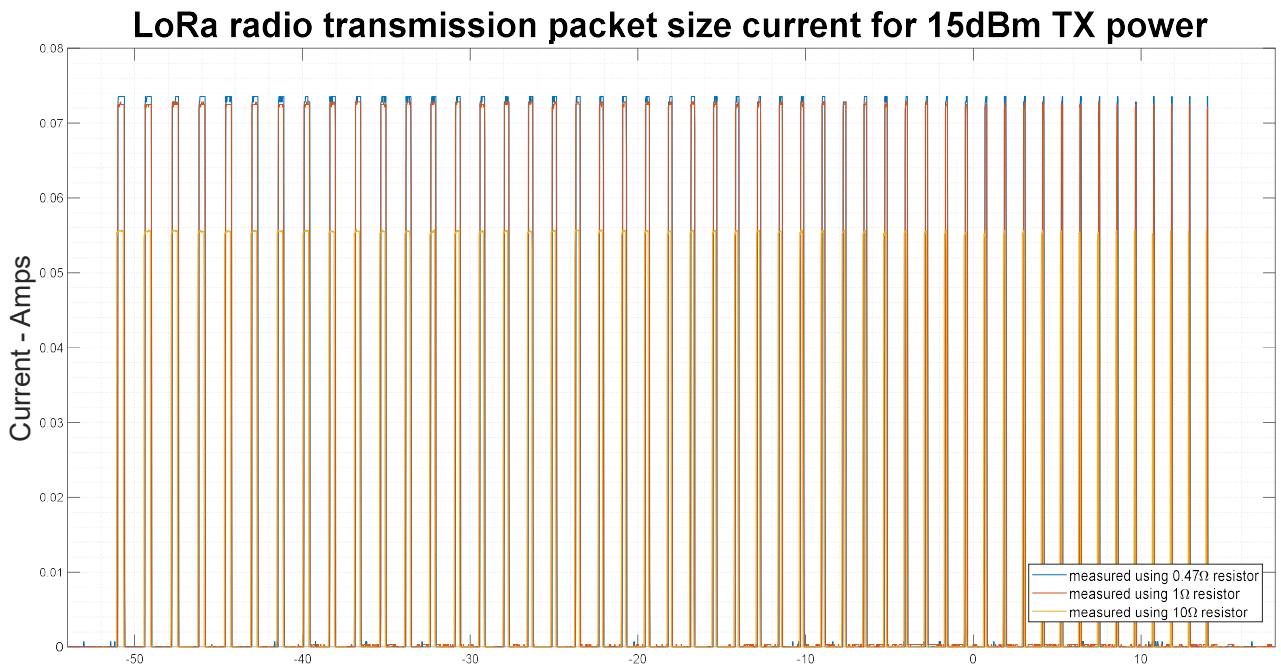


Figure 6 - LoRa TX packet size with 15dBm TX power current draw check results

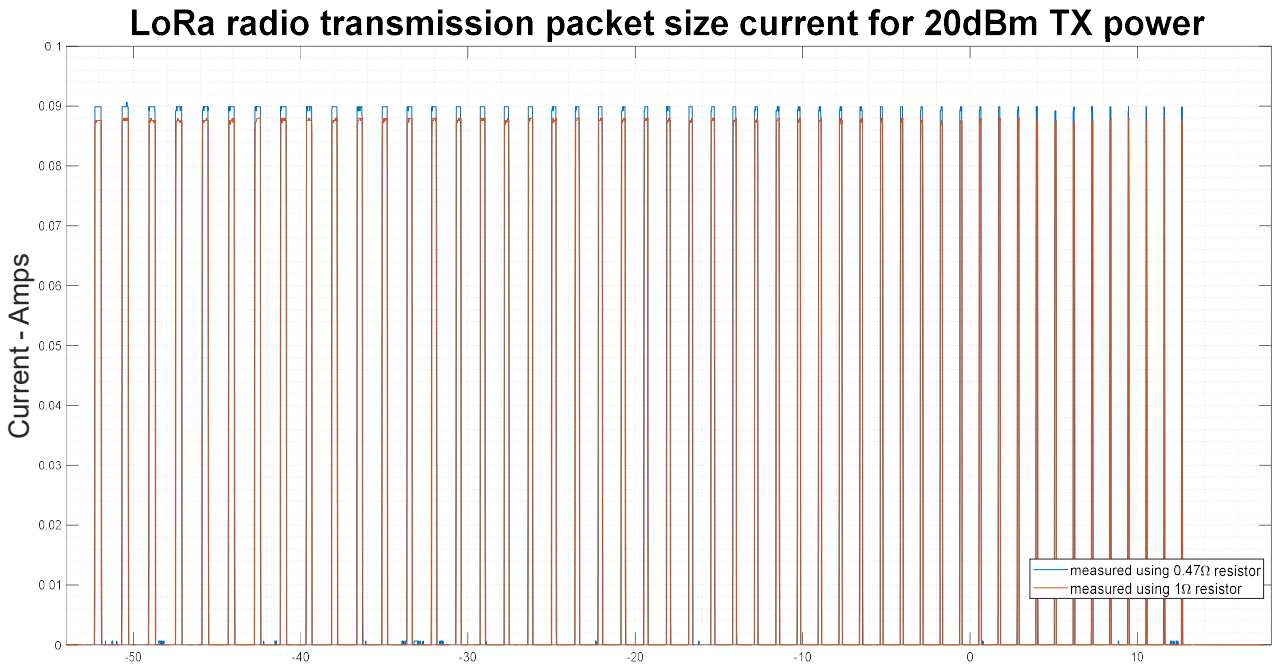


Figure 7 - LoRa TX packet size with 20dBm TX power current draw check results

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 will 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.

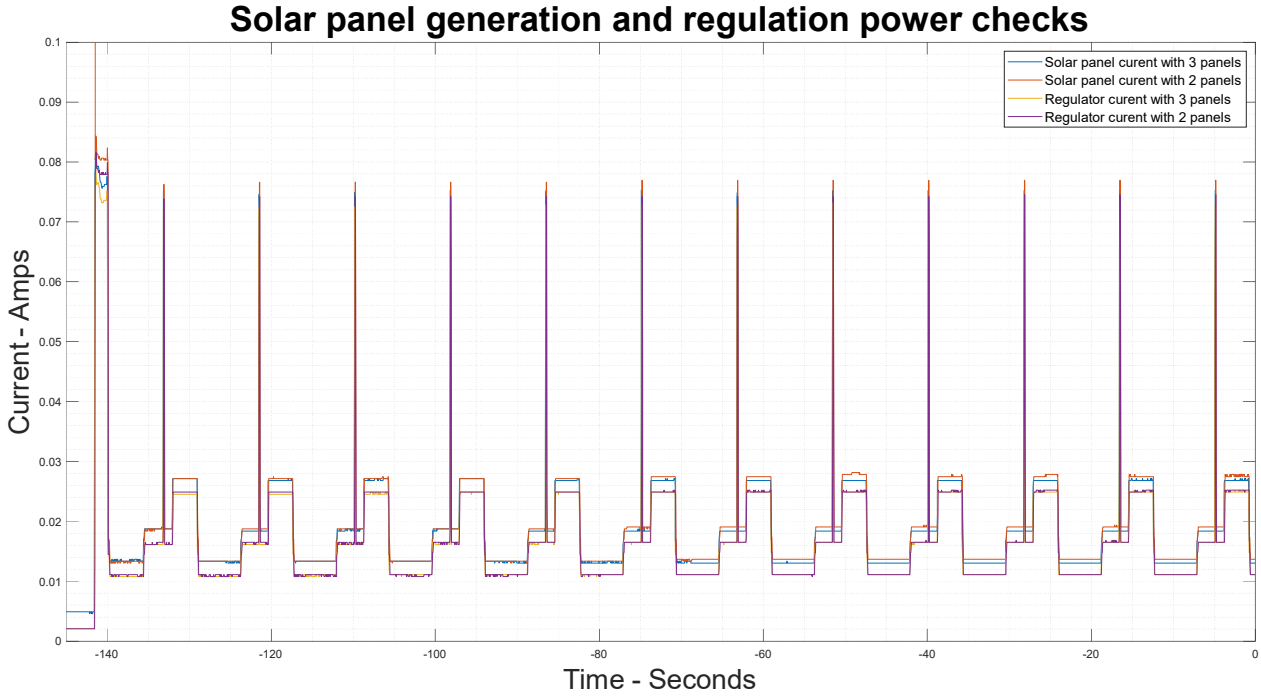


Figure 8 – Solar panel generation and regulation current check results

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