Memo #030
ECHO Project danielcjacobs.com/ECHO
ASU LoCo Lab MHz Astronomy Development

Mitigation of Drone RFI

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Summary

While testing the ECHO calibration procedure at OVLWA, we observed RFI that had lurked undetected when operating at 137MHz. The source of the RFI was narrowed down to a switching power supply which sits right on the main power line; it is tricky to replace safely! We devised a repeatable RFI testing method and then tested several off the shelf replacement power supplies as well as several attenuation methods. Several combinations appear to reach acceptable levels. The best overall combination is the Mauch power module.

Drone RFI

During the site campaign at OVLWA, we saw RFI at ~55MHz with a worst-case amplitude of 10dB above the background. A series of tests in the lab on-site narrowed down the cause to the power module on the drone that steps down the 4S (14.8V) battery voltage to 5V for the flight computer onboard. We further hypothesized that the cause was noisy switching in the power module, however, more testing was needed to confirm and find a solution.

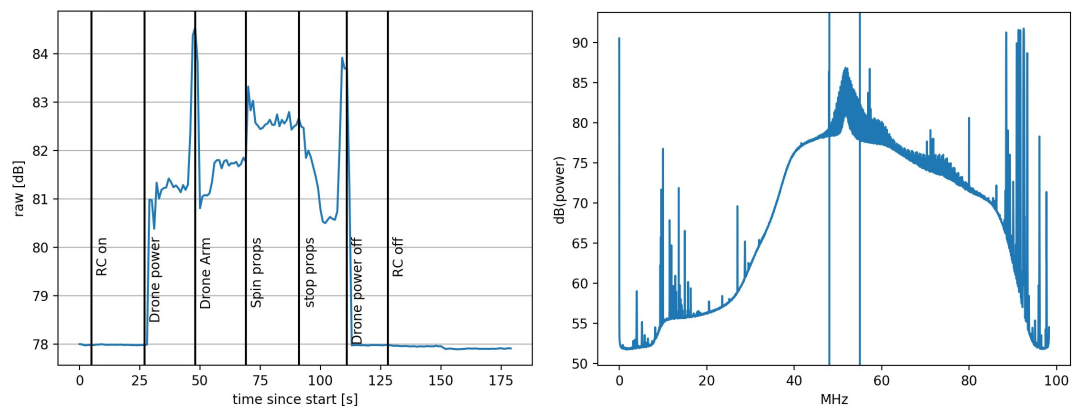


Fig 1: Left: Sequential turn on test with drone on ground 15m from antenna 265, average of log power from 48 to 55MHz. Right: Spectrum at 75s with lines indicating the range used in the time series.

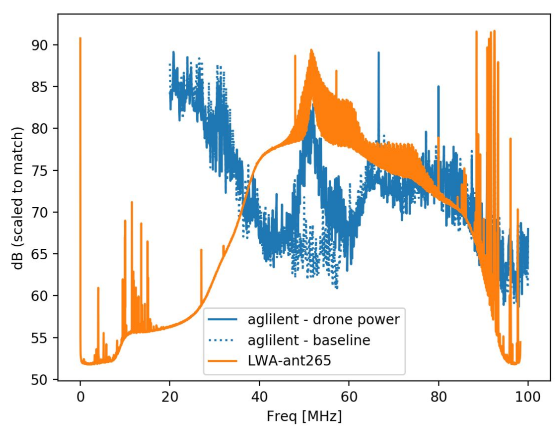


Fig 2: One of several lab measurements using a 4m wire antenna connected to a 6GHz Agilent spectrometer 10kHz RBW. Here the drone is operated on battery power and held within a few inches of the probe antenna. The motors are not running.

Power Modules

The drone system has two power circuits. A high voltage system which runs directly to motors, and a 5V system which powers the flight computer. The payload is powered by an independent battery. The motors are driven by large FETs at speeds of order kHz. The 5V power supply is a buck-mode switching regulator that runs at ~300kHz. These power supplies are typically integrated into the drone high voltage battery distribution harness and provide key current and voltage data required for flight operations. Replacement options range from no action (just mitigate with shielding), replace the power supply with a similar unit having lower EMI, or build a custom unit optimized to produce acceptable noise levels. The simplest solution would be to find an alternative unit on the market.

Lab Tests

RFI testing of the X8 power module using near field probes helped us understand the source of the RFI which happened to be the MOSFET on the board.

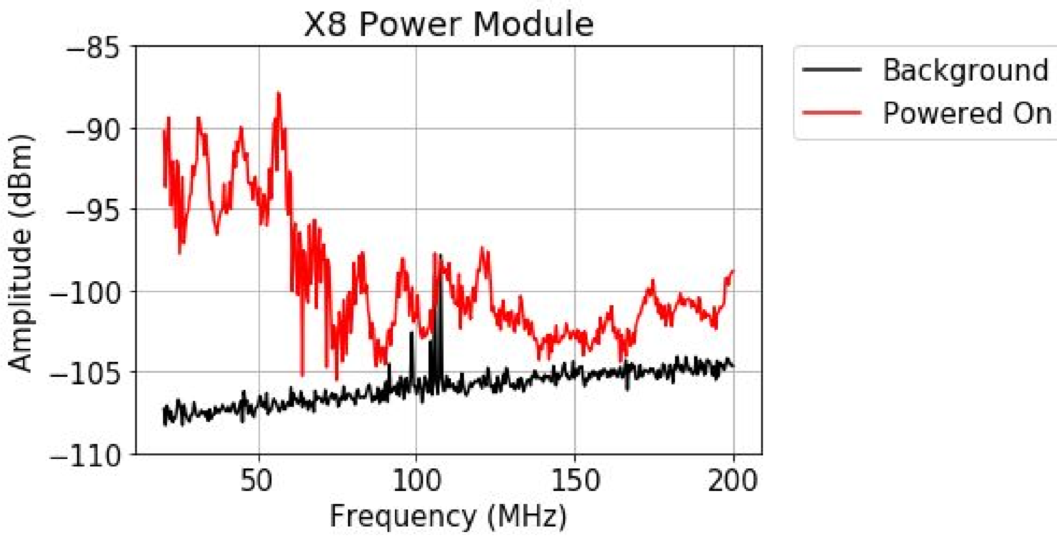


Fig 3: Spectrum of the power module by itself. Measured using an H-field probe held 2cm away from the power module.

Confirming that the power converter is quite noisy we sought alternative equivalent parts as well as RFI mitigation strategies. Measurement of undesirable emission was found to be difficult to reproduce. Factors at play included small changes in probe device geometry, radio background in the lab, and even the geometry of nearby metal surfaces like tabletops. A repeatable test setup shown in Figure 4 was devised using a magnetic field probe, table clamps, a fieldfox spectrum analyzer, and a dedicated tabletop. With probe and device under test clamped securely spectra were seen to be reliably repeatable. These tests were prototyped in the lab and then repeated in an RFI shielded room. A useful summary metric is the mean power above the background shown in Figures 6b and 6c.

Trade Space

The trade space includes the amount of intrinsic emission power, any attenuation or attenuation and operational considerations (mass and data). We tested several alternative power modules: mRo power module, the power brick mini and the Mauch. Shielding methods tested were a "bendable metal" shield that was formed into a cylinder and a tinfoil wrap. Finding that the cylinder was not very effective we also tried adding some Mast absorber. The electrical connections were not filtered in these tests[1]. Spectra for each configuration are shown in Figures 6a and 6c.

[1] The power supply sits in series between the primary battery and the motors, and for this reason power boards are designed to be robust under vibration, shock, and handling. Interruption of power leads to instant loss of thrust. Introduction of filtered feed throughs to these lines would carry substantial risk.

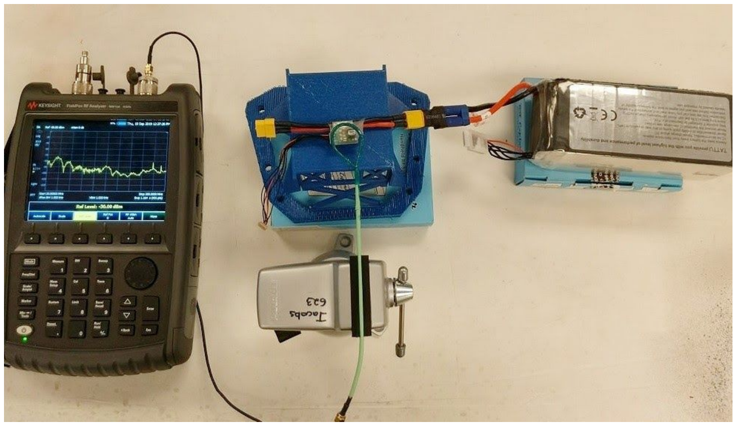


Fig 4: RFI test setup

Fig 5: Different shielding methods. From Left: tinfoil, bendable metal enclosure, bendable enclosure with absorbers

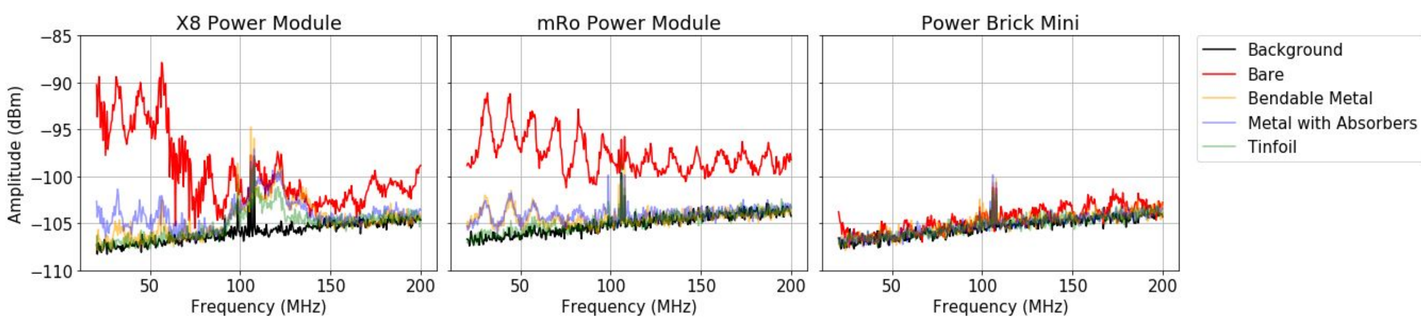
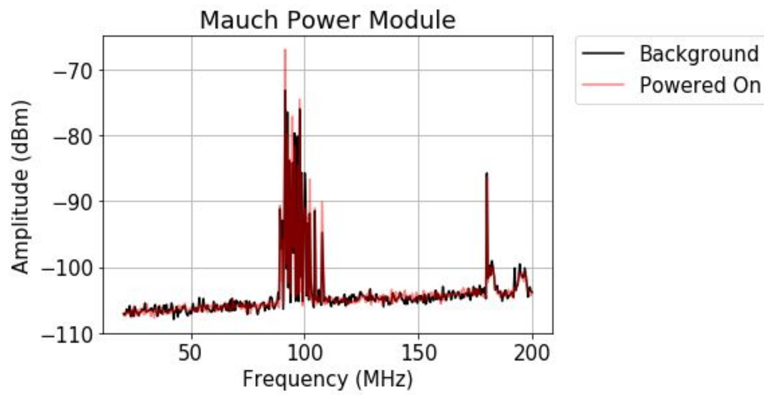


Fig 6a: Results from shielding tests of the three desirable power modules.

	X8 Power Module			mRo Power Module			Power Brick Mini		
Frequency	*50 - 80 MHz*	*120 - 150 MHz*	*20 - 200 MHz*	*50 - 80 MHz*	*120 - 150 MHz*	*20 - 200 MHz*	*50 - 80 MHz*	*120 - 150 MHz*	*20 - 200 MHz*
Powered On	9.49	3.66	6.55	9.22	5.86	7.41	0.57	1.1	0.91
Bendable	0.75	2.76	1.34	1.24	0.23	0.76	0.24	0.39	0.34

Metal									
Metal with Absorbers	1.61	2.35	1.96	1.7	0.61	1.1	0.22	0.19	0.24
Tinfoil	0.36	1.18	0.82	0.33	0.18	0.25	0.11	0.22	0.21

Fig 6b: Table lists mean power above the background in dBm for the three power modules.



	Mauch Power Module		
Frequency	50 - 80 MHz	120 -150 MHz	20 - 200 MHz
Powered On	-0.04	0.07	-0.01
Tinfoil	0.1	0.15	0.16

Fig 6c: Results from shielding tests of the Mauch power module. Table lists mean power above background.

Without any shielding the "mRo", "X8" and "Power Brick Mini" are above background while the "Mauch" is the quietest. With the addition of a simple foil wrapping EMI becomes indistinguishable from the background.

Conclusion

Power Module	**Pros**	**Cons**
X8	Easy to mount, came with X8	Cannot be procured anymore since X8 quadcopter is obsolete.

Power Brick Mini	Standard in DIY drone kits, Easy to mount	Does not give necessary current value for battery monitoring during flight.
mRo	Easy to mount, gives desired battery monitoring data	Noisy, wrapping tin foil is not a very robust solution.
Mauch	Very quiet, gives desired battery monitoring data.	Big and complicated to mount on the drone.

Given the trades above we elected to use the Mauch power module. Parallel to this testing effort we have built a new drone which is optimized for flight time, stability, and field repairability. This new drone (Mark VI in the series) also has more room for mounting bits inside. This retires the only major con for the Mauch power module. The Mark VI (nicknamed the *Chiropter*) flight tests show a 45 minute hover time (vs 14 minutes for previous models), a 200m telemetry range and several other improvements. EMI testing of the as-built system using the quiet power module is currently under way. Preliminary testing suggests that the power module is no longer the dominant concern.