WI-FLY

Wireless Power for Aerial Robots

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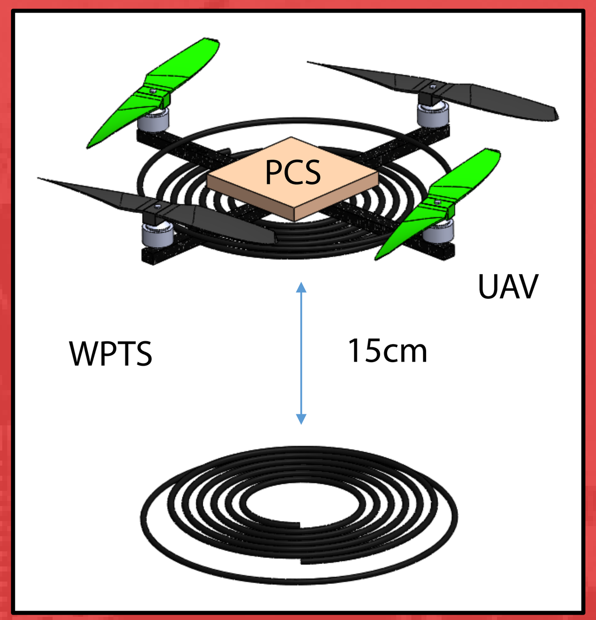
Introduction

The goal of this project is to **design and fabricate a system that provides wireless power to an unmanned aerial vehicle** (UAV). Specifically, we set out to transmit 8W to a Crazyflie 2.0 quadcopter to enable it to hover indefinitely at a distance of 15cm from the transmitter.



We developed three sub-systems:

- wireless power transfer system (WPTS)
- power conditioning system (PCS)
- quadcopter with position control

Wireless power transfer is achieved via magnetically coupled resonators, selected for safety, weight, and power efficiency considerations. The PCS converts wirelessly transferred high-frequency AC power into DC power, useful for the UAV motors and microcontroller. A control system maintains axial and radial alignment of the transmitter and UAV with receiver.

Conclusion

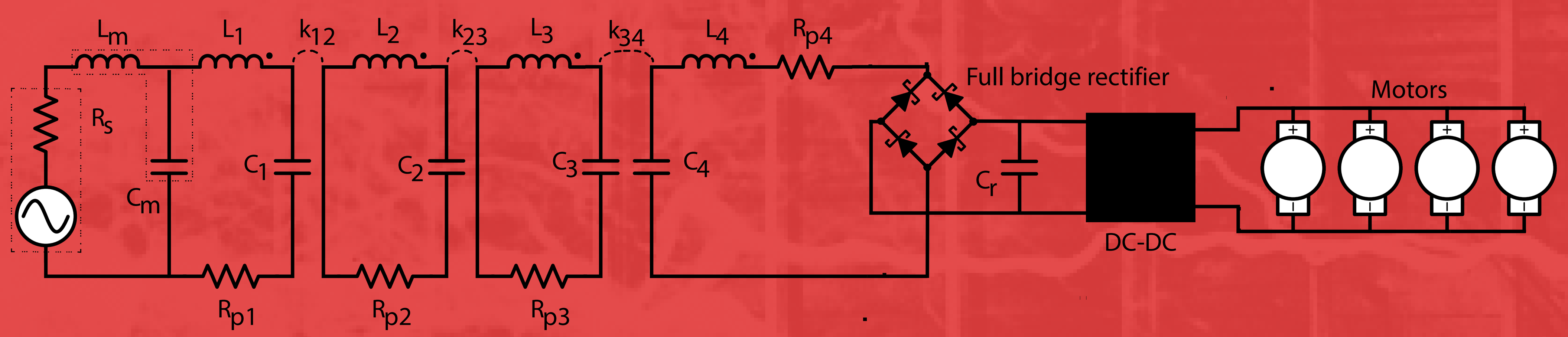
We were able to **wirelessly transfer 8W over 15cm and condition the power to run four quadcopter motors**. However, we failed to regulate the conditioned power to the 3.7V required for quadcopter's microcontroller. Due to time constraints, we were unable to fully integrate the receive module onto the quadcopter.

Future work will be to integrate the receive module onto a UAV and develop a nonlinear control system that senses the generated magnetic field.

Wireless Power

To power the quadcopter, **8W must be transferred through the WPTS and PCS**. Using a 40W RF power amplifier, the overall system **efficiency must be 20% at a separation distance of 15cm**.

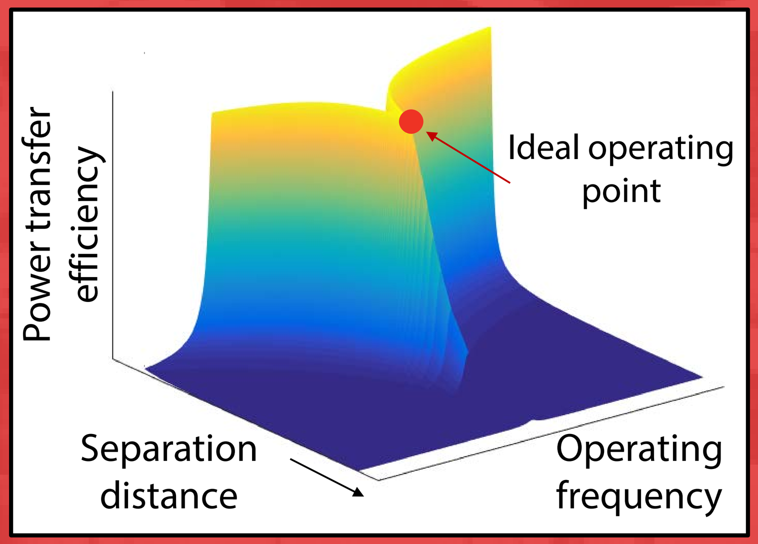
A magnetically coupled resonator system creates a weak magnetic field that is safe for humans compared to laser systems and is lightweight relative to microwave wireless power transfer methods. Power transfer is most efficient at a distance equal to the transmitter diameter.



Circuit diagram of WPTS + PCS + UAV. *The four circuit system with AC power source (including source impedance R_s) and impedance matching L-network (L_m, C_m). The system's load includes the PCS with smoothing capacitor C_r and four quadcopter motors. The interaction between circuits is modeled as a coupling coefficient k.*

Each of the WPTS's four resonators is tuned to an identical resonant frequency, 13.56MHz. At a separation distance of 15cm, the system is driven at this frequency with a 40W RF power amplifier. The AC input generates a magnetic field that induces current in the next circuit; coupling resonators.

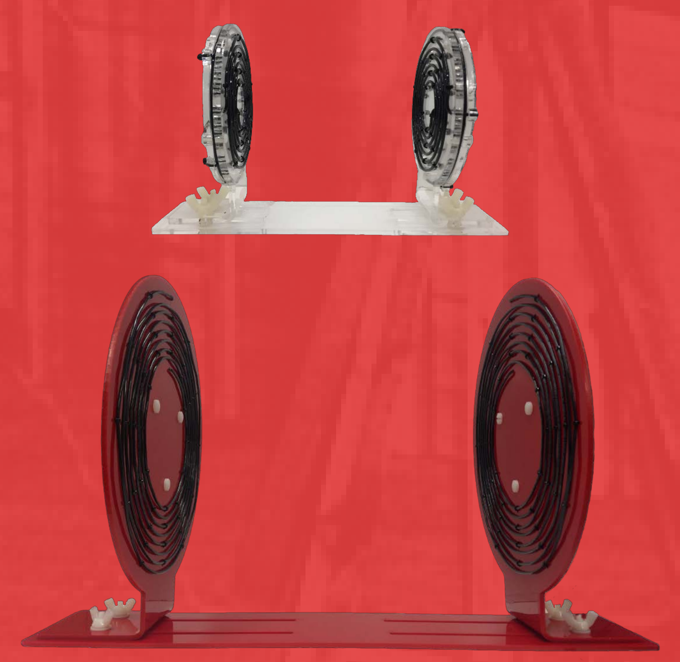
To maximize power amplifier output, the WPTS, PCS, and quadcopter impedance should match R_s. An MFJ-939 antenna tuner is used to match impedances.



Power transfer efficiency. *Maximum efficiency is achieved by operating at the resonant frequency of the system at a distance equal to the diameter of the resonator coils.*

Objective	Target	Achieved
Transfer power through WPTS and PCS at distance	8W, 15cm	8W, 15cm
Condition wirelessly transferred AC power to DC power	13.56MHz AC to 3.7V DC	13.56MHz AC to 3.3V DC

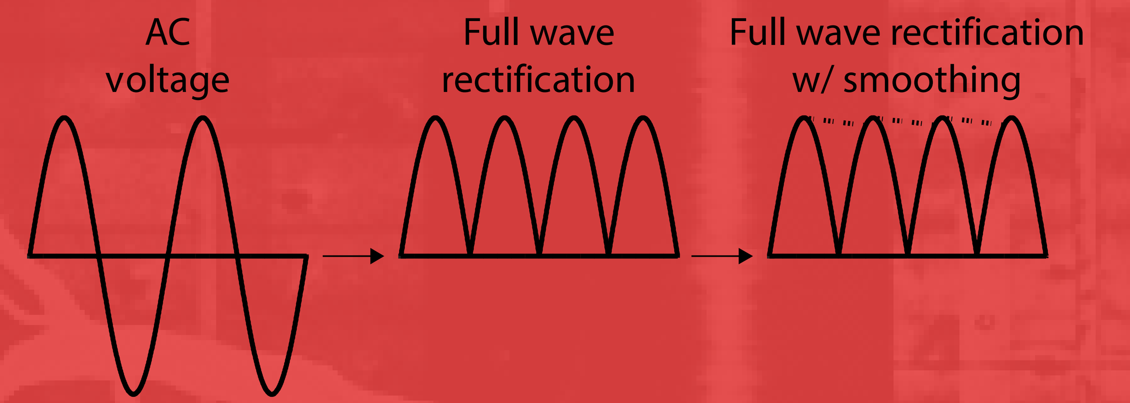
Without power conditioned to specification, an alternative demo was constructed to demonstrate wireless power transfer over 15cm to power a quadcopter with a wired connection. The two different sized systems operate at different distances, but are capable of the same power transfer efficiency.



Wireless power transfer system. *13cm diameter system with 6 turn, 6mm spacing coils (top). 28.5cm diameter system with 8 turn, 7.5mm spacing (bottom).*

Power Conditioning

AC power transferred through the WPTS at 13.56MHz must be conditioned to 3.7V DC for the UAV. This is accomplished using a bridge rectifier, a smoothing capacitor, and a DC-DC converter. The bridge rectifier "flips" the negative part of the AC signal. This is considered "full wave" rectification. The smoothing capacitor reduces the "ripple" of the positive wave in order to output a more constant DC voltage. The DC voltage is further regulated through a DC-DC converter to a desired value.



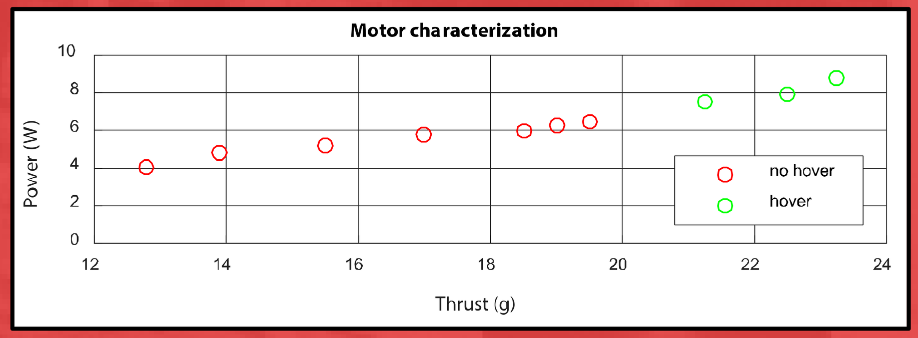
Power conditioning. *Initial signal is 13.56MHz AC voltage (left). An H-bridge rectifier, comprising 3.7ns recovery time Schottky diodes, fully rectifies the signal (center). A 22mF supercapacitor reduces the "ripple" prior to regulation through a DC-DC converter to 3.7V (right).*

UAV

Crazyflie 2.0

Weight	21g
Power to Hover	7W
Vertical Hover Displacement	±1 cm
Radial Hover Displacement	±7cm

A motion-capture control system, using infrared cameras to track markers placed on the quadcopter, employing a PID controller with the Crazyflie in order to maintain vertical and radial position.



Motor characterization. *The Crazyflie brushed motors were analyzed experimentally to determine a thrust-power relationship.*