Power Electronics for Wireless Power Delivery in Synthetic Sensor Networks

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Abstract. Energy harvesting is a very popular means of augmenting batteries or displacing their use for powering the wireless sensor networks; however, an alternative approach is to use wireless power delivery to energise the nodes. For a network occupying a well-known and confined physical geometry, it may be possible to achieve this via one or multiple sources in fixed locations; however, when the nodes cover a wide area, or are themselves mobile, fixed sources may not be practical. A possible solution is to use drones which can fly close to the sensor nodes, which then transfer power inductively from drone to node. In such systems the drone could also be used to gather data from the sensors nodes, reducing their power requirement for long distance data transmission. However, here we investigate the power electronics and energy storage solutions for this so-called synthetic sensor network (synthsense) setup. Here we describe the preliminary hardware subsystems which will allow the demonstration of synthsense.

1. Introduction

Inductive power transfer is becoming well known in short range, low power applications such as mobile phone charging, where the Qi standard has been adopted [1]. This technology offers an alternative solution to the problem addressed by energy harvesting: that of maintaining a remote power supply, typically of a sensor node, without the need for physical battery replacement or tethering through wires. One main advantage of harvesting is that it relies on ambient energy and so no additional physical infrastructure is required outside of the sensor node. Wireless power delivery on the other hand, requires an energy transmission source. In the case of wireless mobile phone charging, the use of a dedicated transmitter is straightforward: a charging pad on one’s desk will suffice. However, for a large, distributed network of sensor nodes, perhaps fitted on a piece of civil infrastructure for health monitoring, or across a farm or vineyard to monitor crop or plant growth, installation of a fixed transmitter infrastructure may not be desirable or possible.

A possible way forward is to use a mobile vehicle as a power delivery source. Here we investigate the use of a drone, complete with a lightweight wireless power transmitter, capable of rapidly charging a storage element on the sensor node inductively, as the drone flies past.

2. Requirements

From an operational perspective, there are two main requirements for power delivery using this technique: the system must be capable of fast recharging thereby minimizing drone hovering time close to a sensor node; and the system must have the ability to efficiently transfer power over an air gap with variable geometry and over around 10 cm preventing the need for contact or docking between the drone...
and the sensor node. From a technical perspective, the power source, mounted on the drone, must be light weight due to limited payload and must be efficient to transfer the maximum energy from the drone to the sensor node. We have previously demonstrated a drone charged above a charging pad and [2] and the solution for synthsense builds on this technology.

3. Solution and Results
The system uses high frequency inductive power delivery at 6.78 MHz. This contrasts with the Qi standard (which is based around 100 kHz). The reason to choose high frequency is two-fold: the efficiency of an inductive link is dependent on the product of the magnetic coupling between transmitter and receiver, $k$, and the $Q$-factors of the coils. High frequency allows high $Q$-factors and thus reduces dependence on $k$, increasing the effective range of the link. To achieve efficient power electronics in the MHz region, soft switching is mandatory, but it is hard to achieve the soft switching conditions when the magnetic link geometry is changing and the load is variable. A solution to this is to use the load independent class EF topology [3] which keeps soft switching as load conditions alter, using an aluminium PCB substrate for thermal management, Figure 2.

![Figure 1 Load invariant class EF inverter](image1)
![Figure 2 Inverter for mounting on drone using insulated metal substrate for thermal management (60 mm x 70 mm)](image2)
![Figure 3 Receive side hardware for stepping up and down the capacitor voltage](image3)

On the receive side, the main challenge is to charge the sensor node as quickly as possible. This requires use of a supercapacitor, in this case an AVX 6 V, 5F device, which has shown a charge rate of 30 J/s, minimizing the hovering time of the drone when it is recharging a receiver.

4. Conclusions
We have discussed the requirements and presented preliminary hardware of the power electronics for the new paradigm for powering of sensor networks whereby a drone flies close to a sensor node to recharge it. The obstacles to overcome are achieving a light weight transmitter, achieved using MHz transmission and an IMS PCB, variable air gap geometry, achieved using a load independent inverter, rapid charging of the receiver, which is possible with a supercapacitor, and compact receiver dc-dc converter necessary to process the highly variable voltage output from the supercapacitor. We will show a working system in the poster presentation.

References

[1] Wireless Power consortium, "The Qi Wireless Power Transfer System Power Class 0 Specification," Wireless Power Consortium, 2016.

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[3] S. Aldhaher, P. D. Mitcheson and D. Yates, "Load-Independent Class EF Inverters for Inductive Wireless Power Transfer," in IEEE Wireless Power Transfer Conference, Portugal, 2016.