Shared Access for Family Electrically-Assisted Tricycle – Report on Energy for the UWB System

Badr Diani
Amine Benchekroun
Samia Boukouiss
Baptiste Henriet
Paul Jaulhiac

Tutor: Thierry MONTEIL

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Introduction:

Indeed, UWB technology has emerged as a reliable and efficient solution for high-precision ranging and localisation, particularly in two-way ranging (TWR) systems. However, deploying such a system in a vehicle presents unique challenges as it requires a sustainable and reliable power source capable of meeting the dynamic power requirements of the system while operating in harsh environmental conditions. Overcoming these challenges involves not only analysing the system's power requirements, but also utilising the vehicle's existing power supply and integrating advanced energy harvesting solutions. Furthermore, optimising the energy management and consumption of the UWB system is critical to ensure its efficient operation. Through this report we will try to explore the feasibility of powering a TWR UWB system embedded inside a vehicle, focusing on innovative energy harvesting methods, robust power management strategies and practical solutions tailored to the automotive environment of our application case, such as we have been introduced in our classes on Energy for Connected Objects.

1. Analysis of energy requirements for the TWR UWB system

The UWB two-way ranging system requires a detailed assessment of its energy consumption:

- Typical electric consumption:
  - Transmitting UWB signals: UWB systems transmit short, powerful pulses, which can consume energy intermittently.
  - Reception and processing: Reception requires RF circuits and analogue-to-digital converters (ADCs), which often consume a lot of power.
  - Signal processing: Distance calculation is based on algorithms that require a computing unit, such as a microcontroller or on-board processor.
- Estimating duty cycles: It’s important to identify the system's active and passive periods to assess average consumption. For example, if the TWR is not in continuous operation, it is possible to reduce its consumption in standby mode.
- Voltage and power requirements: We also have to identify voltage requirements (often 3.3 V or 5 V for electronic systems) and average power (in mW or W).

2. Identifying potential energy sources in a vehicle

A vehicle offers several opportunities for powering an on-board system. These options must be exploited according to their availability, reliability and compatibility with the UWB system.

2.1. Using the vehicle's main power supply

In a vehicle, several energy sources can be used to power an embedded system. The main power supply, the 12 V battery (or 24 V for some commercial vehicles), is the most stable and reliable source for a continuous operation of the system. A DC-DC converter can be used to reduce this voltage to suitable levels, such as 3.3 V or 5 V, required by the UWB system. However, this approach involves managing consumption so as not to affect the vehicle's overall battery life.

Figure 1: Car internal battery and DC/DC converter

2.2. Energy Harvesting

To complement or reduce reliance on the main battery, we strongly believe that energy harvesting (EH) should be considered. We think that nowadays, considering all the energy waste issues, it must be a priority to always develop technical solutions by powering them on the most suitable and sustainable energy system. Therefore, here are some of the EH solutions we could think of to power our system.

- Kinetic energy harvesting: It would consist in exploiting the vibrations or movements of the vehicle using piezoelectric sensors to generate energy. This method is particularly suitable for industrial or off-road vehicles.
- Thermal energy harvesting: We could use the thermal gradients generated by the engine or cooling systems to produce electricity through thermoelectric devices (TEG).
- Electromagnetic energy harvesting: Finally, we could install antennas to capture electromagnetic waves from the environment or ambient RF signals. This can provide a small amount of energy, particularly useful in standby mode, if we can properly set-up the system in this mode.

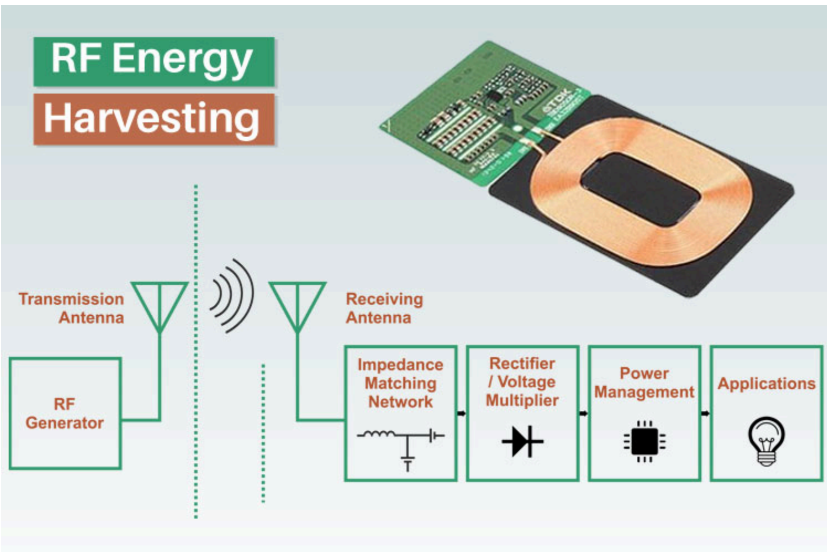


Figure 2: Electromagnetic energy harvesting antenna system

2.3. On-board solar panels

- If the vehicle has surfaces exposed to light, the addition of flexible solar panels can provide a complementary source of energy. Although dependent on available light, they can be used to charge a supercapacitor or secondary battery.

Figure 3: Roof integrated solar panel

3. Energy management

Energy management plays a central role in ensuring that the embedded system is powered efficiently and sustainably. It is essential to store the energy collected to meet peaks in energy demand. Supercapacitors are particularly well suited to providing the rapid and repeated discharges required for the UWB system's energy pulses, while secondary batteries, such as Li-ion batteries, can provide longer-term storage. A power management unit (PMU) is essential for coordinating these different sources. It regulates voltage, protects components against overvoltage and ensures a smooth transition between the available energy sources, guaranteeing a continuous power supply.

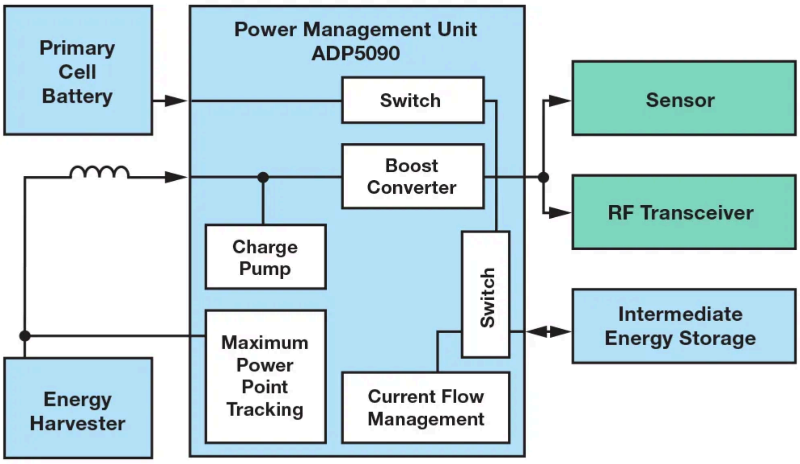


Figure 4: Application example of an Analog Device PMU (ADP5090)

4. Optimising the consumption of the UWB system

To maximise energy efficiency, it is crucial to reduce the power consumption of the UWB system. This is achieved by using low-power modes, such as putting the system on standby when it is not needed. Activation can be conditioned by specific events, optimising the duration of active use. As we currently know the system, the initiator of communications (the user) is the only one who needs to keep sending transmissions at a high rate, towards the vehicle anchors. We could then easily imagine a system where the anchors only wake-up when solicited by the initiator.

In addition, UWB signal processing algorithms need to be optimised to minimise the computational load, which reduces overall power consumption. We have no doubt that NXP's solution is already a greatly optimised algorithm, given how well it initially performed, without much processing time induced errors, compared to our system with the Qorvo DWM1001-DEV boards.

Finally, the transmit power of the UWB pulses can be adjusted according to the range actually required. This is particularly relevant if the system is used in confined spaces, such as inside the vehicle, where maximum range is not required, or even as the user is approaching the vehicle.

5. Reliability and Constraints due to the environment

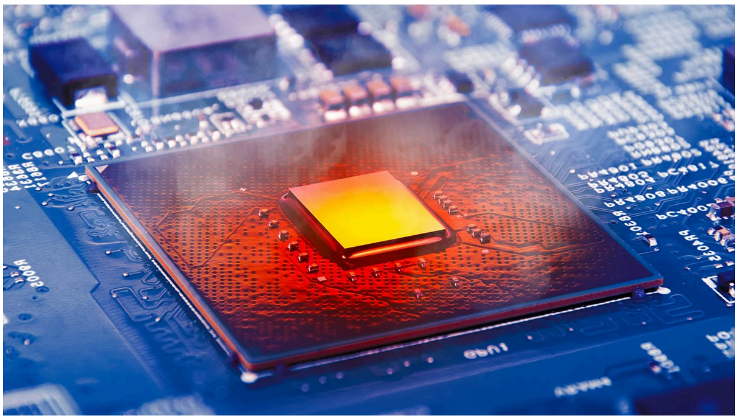
The operation of the UWB system on board a vehicle must take account of a number of environmental constraints. Temperature, which is often extreme in vehicles, can affect the performance of electronic components. It is therefore essential to ensure that the system operates correctly over a wide enough range of temperatures.

Moreover, constant vehicle vibration, particularly in off-road or industrial vehicles, can damage sensitive components. Piezoelectric sensors and storage devices, such as supercapacitors, must be chosen for their robustness in the face of these mechanical constraints.

Also, electromagnetic interference (EMI) generated by the motor or other electronic systems, inside or outside the vehicle, can disrupt the operation of the UWB system. Appropriate protection, such as filters or shielding, must be in place to ensure reliable and stable system performance.

Figure 5: Interferences in a connected environment

Figure 6: Electronic components and heat sensitivity



6. Case study and integrated solutions

As a conclusion to this report, based on all the elements we have gone through, we would like to propose a scenario for a combined solution which, according to us, could meet the energy requirements and constraints of the system. The vehicle's main battery can power the system via a DC-DC converter which adapts the voltage to the device's requirements. In the meantime, integrated piezoelectric sensors exploit car vibrations to generate energy, which is stored in a supercapacitor. The supercapacitor takes care of the instantaneous energy requirements of the UWB system's pulses. A secondary battery, recharged by complementary sources such as flexible solar panels or thermoelectric devices, can provide power for standby periods or interruptions to the main power supply. Finally, a well-optimised power management unit monitors and regulates these different sources to ensure a stable and constant power supply for the embedded system.

Figure 7: Example of a supercapacitor

Conclusion

Integrating a two-way ranging UWB system into a vehicle requires a carefully designed power solution that balances energy efficiency, sustainability and reliability. By combining the vehicle's main battery with energy harvesting technologies such as piezoelectric sensors, thermoelectric devices and solar panels, the system we propose could achieve a hybrid power model. This approach would reduce reliance on the primary power source while accommodating the intermittent but intensive power requirements of the UWB system. In addition, a well-optimised power management unit would ensure seamless coordination of the power sources, ensuring system performance under varying conditions. By considering environmental constraints such as temperature extremes, vibration and electromagnetic interference, the proposed solution would also provide a robust and adaptable framework for efficiently powering the UWB system. With this strategy, we wanted to aim at not only ensuring uninterrupted system operation, but also in line with modern sustainable energy practices, making it an ideal choice for future vehicle-integrated technologies.

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