Telemetry Project Design overview

Solar Car Telemetry Module

- Interface with Solar vehicle CAN Bus and retrieve any relevant data required by the support vehicle
- Receive wireless tyre pressure sensor data from a standard 315 - 433 MHz TPMS[1].
- Transmit tyre pressure data to CANBUS and Support vehicle.
- Ensure reliable data transmission to a support vehicle up to a maximum distance of ∼500 meters.
- Transmission between solar car is to be a two-way communication up to 1 Mbps.
- Majority of data bandwidth is to be CANbus data from solar car to support vehicle.
- Solar car can receive CAN bus commands from support vehicle. (Function might not be used, but still implemented)

Support Vehicle module

- Standalone battery powered transceiver capable of transmissions according to the specification above.
- USB Interface & firmware to connect to both Linux (primary & easy?) and Windows (secondary & harder to guarantee) computers.

To reduce design complexity and costs, a single hardware design will be created incorporating both designs. Thus we only have to solder required components on to the module in question. A visualization of the proposed design is shown in Figure 1, using a Si4468 RF Transceiver. The IC chosen is a low cost (3 euro), low current integrated circuit which should suffice for the distance of 500 meters. Rudimentary range calculations can be found in the following sections.
The frequency chosen is to coincide with the ISM[2] bands at ∼400 MHz and ∼900 MHz. This specific IC supports all sub 1 GHz bands, an important feature as we can switch band if one is too occupied (Often the 433 Mhz band), and as European (880 MHz) and Australian (915 MHz) bands do not coincide.

Range calculations

Assuming ideal free space conditions, these calculations will be significantly lower in the real world. The Si4468 RF Transciever has a default output power of 20 dBm (100 mw), with support up to 30 dBm. We ignore Antenna gain, however these typically add an additional 3-6 dBi each

$$G_{out} = 20\text{dBm} \tag{1}$$

When transmitting a radio wave, there is a significant loss as the wave propagates. The free space path loss according to Friis' formula (Lecture notes 31405 eq 3.188) is given by:

$$L_{0,db} = 20\log 10(\frac{4\pi * R * f}{c}) = 20\log 10(\frac{4\pi * 500 * 915\text{MHz}}{c}) \approx 85.65\text{dB} \tag{2}$$

[1] Tyre Pressure Monitoring System

[2] Industry, Science and Medical Radio bands which can be used with no license, trade off is a higher noise floor.

Where R is the distance in meters, f is the frequency, and c is the speed of light in meters per second. We use worst case scenario of the 915 MHz ISM band in Australia. A lower frequency results in a lower path loss. The total received power is the sum of these two values.

$$P_{rec} = G_{out} - L_{0,dB} = 20 - 85.65 = -65.65\text{dBm} \tag{3}$$

The received power has significantly diminished, but the IC has a sensitivity of -133 dBm! In the ideal case we have a significant gain margin at 500 meters distance.

$$G_{margin} = -53.65\text{dB} - (-133\text{dB}) = 67.35\text{dB} \tag{4}$$

When we account for losses due to fresnel zone, multi path, and attenuation from penetrating vehicle interiors, the wireless communication system should be more than capable of a reliable transmission. This calculation also did not account for the increased gain possible by the IC power amplifier, and possible gains by good Antennas.

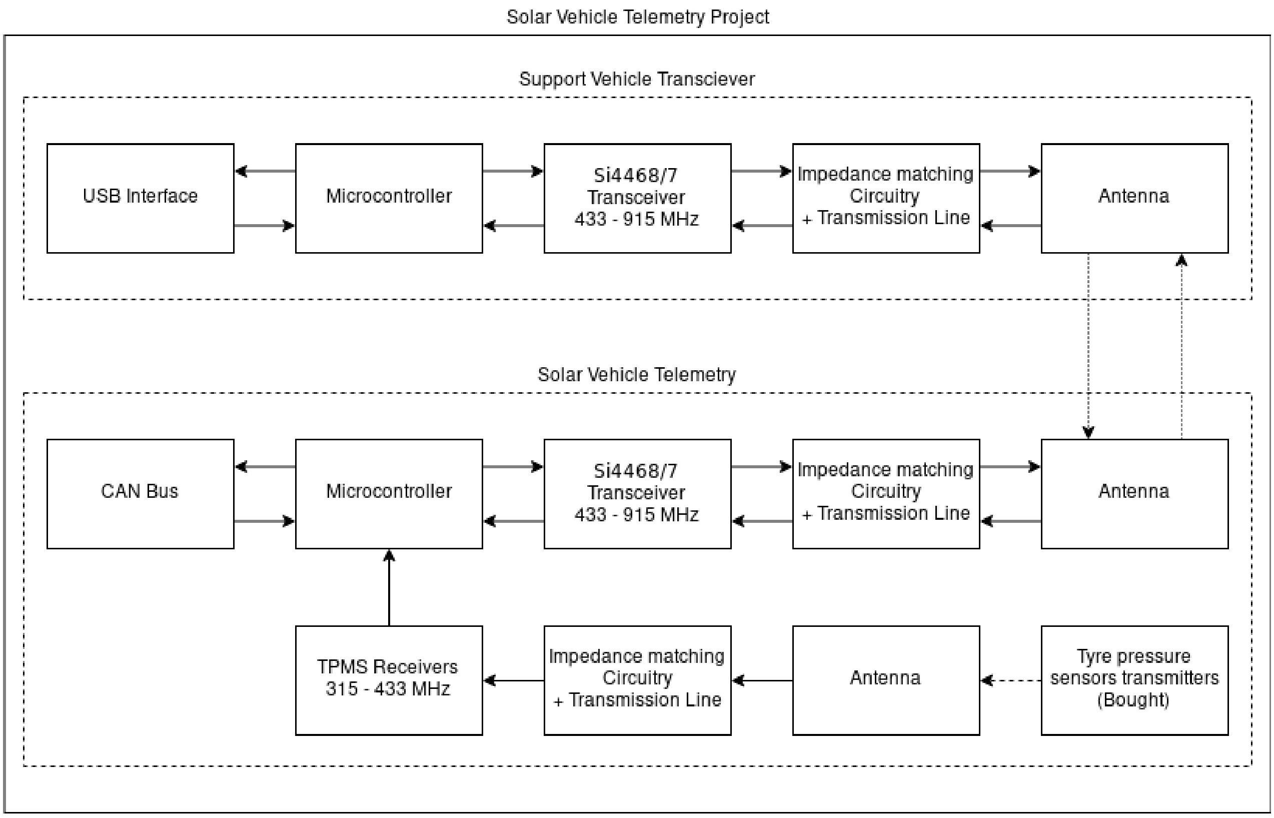

Figure 1: Proposal for detailed telemetry project design

Design philosophy, Components and costs

Large parts of this project provide brand new challenges for us, as such we strive to choose IC's that reduce the workload required as most functions are built in.

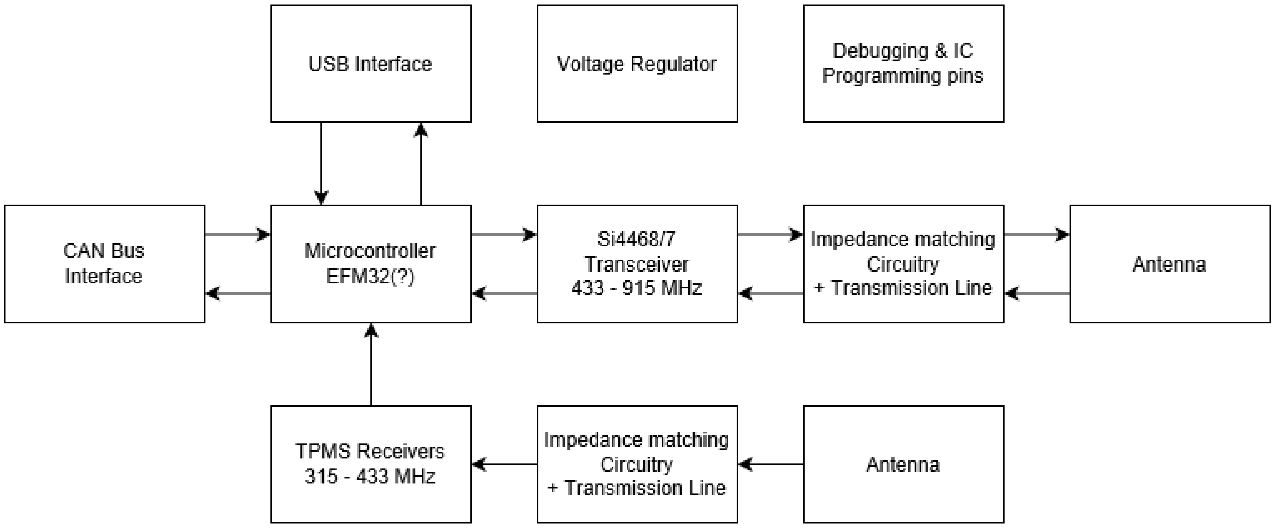

Figure 2: Single board hardware implementation with all modules required.

Transceiver

We looked up on Mouser.com and found a Sub GHz RF Transceiver that supported up to 1 MBps and ensured range with the calculations above. An added bonus is suggested projects is telemetry and long range battery powered operations. There were several other IC's, but this was the first one that fit all specifications. It costs 2.98 euros.

Microcontroller

Again looked up on Mouser.com, searching for a microcontroller that supports both CAN bus, SPI and USB communication. The EFM32 is very similar to the STM32 ARM Cortex 7 which we programmed in the programming project on 2nd semester. It is again used for low power applications, and should (?) support the desired bandwidth. Personally I think the specifications are overkill, but it is also very cheap! (1.8 euros)

TPMS Receiver

We have no clue! It is entirely dependant on the prepurchased TPMS, and that can only be purchased once the wheels are settled on. We'll have to contact mechanical for this, and arrange something. We've looked at the ATA5745C, which automatically handles everything. But it is sold out, and you can only buy them in reels of 6000.

Antennas

We can not determine an Antenna until the design is reviewed by Vitaliy. Given the range calculations, I believe we can exclude any large directional antennas, although we may require to embed a wire antenna into the chassis. I discussed the possibility with mechanical, and as long as it can simply be taped on to the car they have no quarrels.

Fabrication

According to Vitaliy, there is a technician on DTU that can fabricate simple PCB's. Gabriel states there is no facilities on DTU to fabricate PCB's. Both recommended to use JLCPCB, which we plan to do for the final design. Currently I am unsure regarding SMD components as we will require reflow to mount them (?).

Current uncertainties & Questions

- This estimate of range in the ideal case proves to more than enough for our use case. Will this also prove true in the real world scenario?
- What is the effect of Doppler shift on the system? As I understood it is only function of the relative velocity between transmitter and receiver, given both cars are traveling at approx. the same velocity this should be minimal.
- Material electromagnetic transparency: The chassis is made of glass fiber, this module and another module may require to transmit through the material. Is there an index of the "Transparency" of the material (Specifically from 300 MHz to 3000 MHz) ?.
- Gabriel has stated that we can use the Elektro MICE(?) components through Christian. Could we have a list of any relevant microprocessors and RF Transcievers that Elektro may have on hand, as we may avoid buying unnecessary components.
- We need to know the chosen tyres ASAP. We need to pick an IC for TPMS receiver, and the the TPMS system is heavily dependant on the chosen wheels. Additionally we would prefer a simple insecure TPMS module as it'll be easier to integrate into our system.
- Where can we assemble our PCBs using reflow for SMD components? The Transceiver has no visible legs and would probably fry if we tried to solder it on ourselves.

1 What is planned next

Given that the current design course is approved;

- We'll contact Vitaliy and discuss if the technical aspects of the design are feasible.
- Then we will create an indepth electrical diagram using KiCad, Eagle or similar software.
- Peer review of electrical schematics.
- Upon approval, create PCB design.
- Peer review of PCB design.
- Upon approval, gather all required components and PCB from JLCPCB?