Mek-2 Roadrunner Solar Team Telemetry

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Abstract - This paper presents the telemetry project for DTU Roadrunner Solar Team (ROAST). In this paper we elaborate on, how we designed a wireless transmission device, capable of reading from a CAN-bus and sending the data to a receiver, for further interpretation. During the project, we also look into the previous project, which didn't work as expected, and successfully found its flaws. Moreover, we look into both the hardware part as well as the software. We designed a PCB, and worked with CAN, RTC, antenna polarization and Matlab. We have performed tests with different antennas, to find the most suitable for our application. This involves tests of the transmission range, sensitivity to noise, and SDR analysis. This paper focuses mainly on these tests of different types of antennas. From the tests it is concluded that using a circular antenna, together with a CEL24-4 linear antenna, gave the most reliable connection.

Introduction

DTU Roadrunner Solar Team (ROAST) is a team at DTU Roadrunners, which purpose is to build a Solar Car, that shall participate in Bridgestone World Solar Challenge 2023 (BWSC). BWSC is a 3000+ km race through Australia, the participants in the race drive electrical cars running on energy from solar panels, mounted to the cars. The car is built by a team of students from DTU Mechanic, Electro, and Compute. The car's three main parts are the motor system, battery system, and solar cell system. Furthermore, the car must have a control unit, lights, horn, telemetry, etc.

Methods

We had last years project to look at for experience and as a stepping stone for how to tackle the assignment. For this project we've focused on some different points, first of all, we examined the old setup to look for flaws and shortcomings. Our aim was to make a setup, which would reach 500 kbps at 1 km. We then analyzed our data collection from the tests and looked for improvements. From this, we started designing our minimum viable product (MVP). After we had designed our MVP, we examined the effect of the new improvements and assessed the setup.
We ended up having enough time after making the MVP, that we could design and order a PCB for the setup. With the use of the PCB and 4 different types of antenna, we could test our setup. We chose to test the setup in a field and an urban area, both with line of sight, to test with and without interference. After this, we worked on some software e.g. RTC, SPI, CAN and Security.

Results

- We've had a lot of testing in our project. In the first test, we tested the setup from last year. We tested the reflection for the antennas and the result can be seen in figure 4.
- In another test, we tried to find the best combination of antennas. We tested the antennas in the case of line of sight, which is the best-case scenario, and we tested the antennas at DTU, which is an urban environment with disturbances, we tested next to a place with road work, thus there were machines and vehicles, which blocked the way. Furthermore, there were trees, cars, buildings and other disturbances. The data from DTU can be seen in figure 9 and the data from Dyrehaven can be seen in figure 10. Our route in Dyrehaven can be seen in figure 5.
- We've used a ADALM-Pluto, which is a software defined radio (SDR), to analyze, how PCB 2 behaves at different frequencies. The result is in figures 7 and 8.
- To improve the signal security, we examined different antennas and tested them to see, which gave the best results. At the test, we analyzed the reflection at different frequencies for our antennas, to get a look into the loss. The data is displayed in figure 6.

Figure 1: Illustration of the telemetry of the solar car.

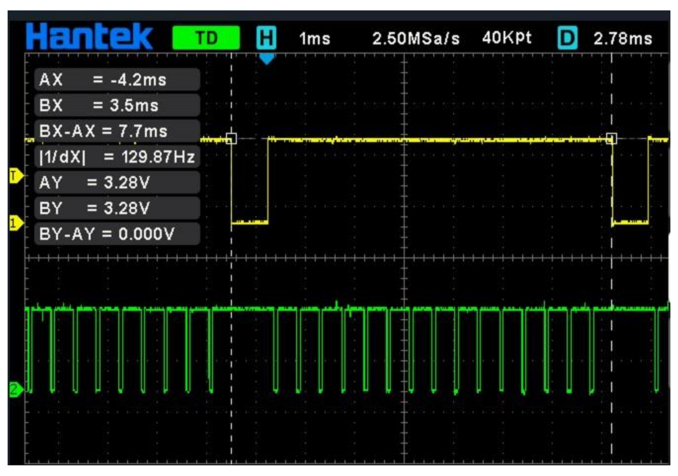

Figure 2: SPI timing

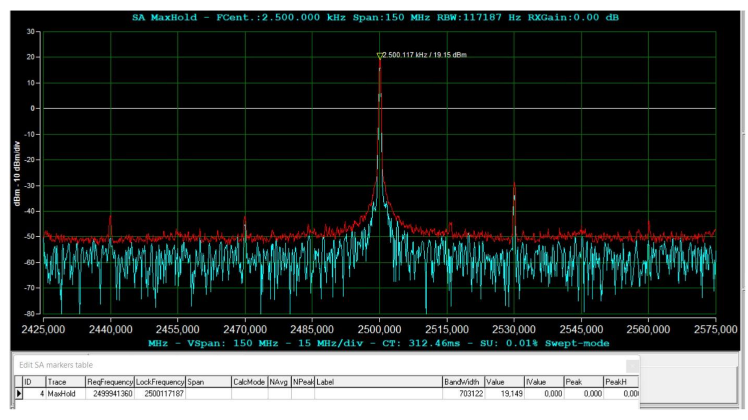

Figure 3: TxPower from 2425 MHz to 2575 MHz for PCB 2 - Test Setup

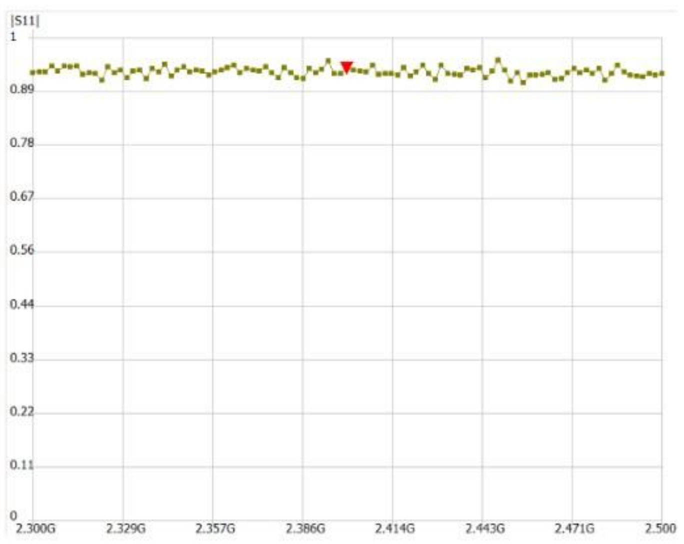

Figure 4: Reflection for the earlier antenna

Figure 5: Test route in Dyrehaven.

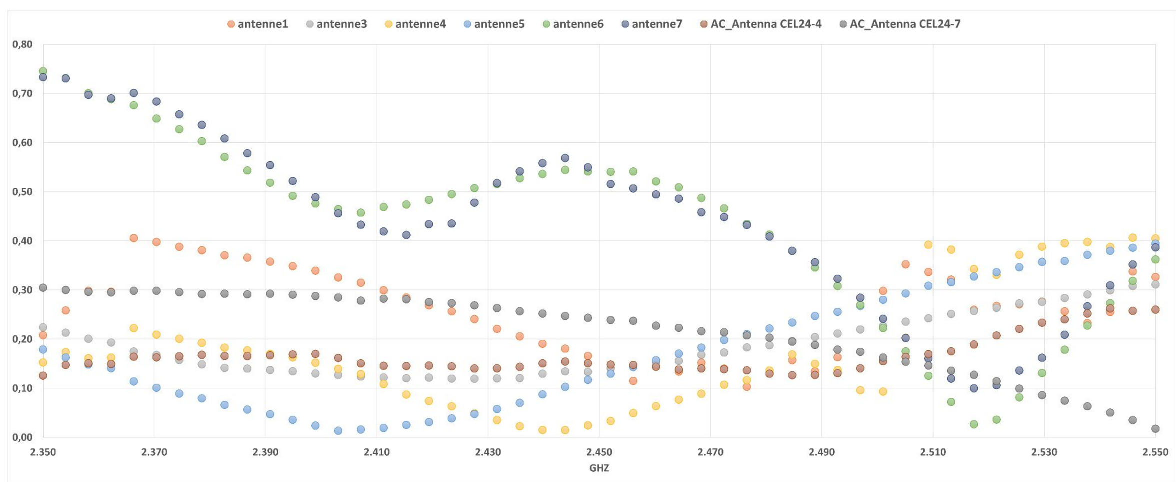

Figure 6: Reflection for different antenna types

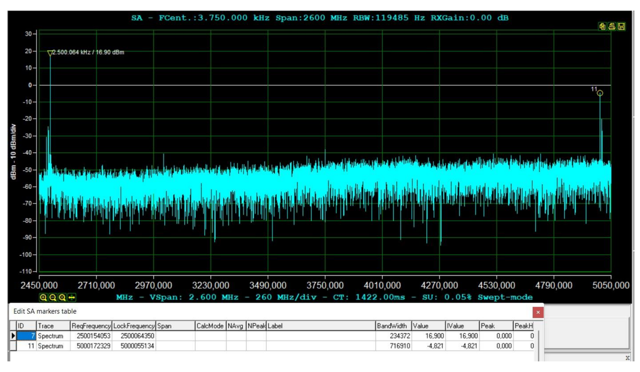

Figure 7: TxPower from 2500 MHz to 5000 MHz for PCB 2

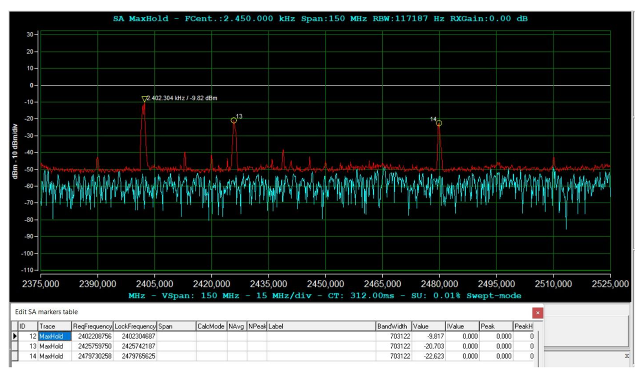

Figure 8: TxPower from 2350 MHz to 2550 MHz for PCB 2

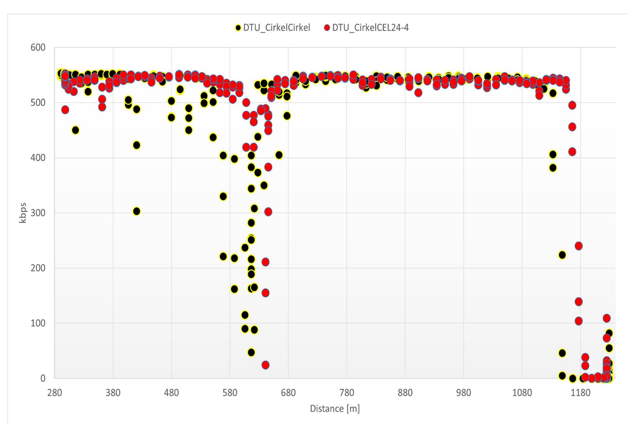

Figure 9: Signal Strength at different distances at DTU

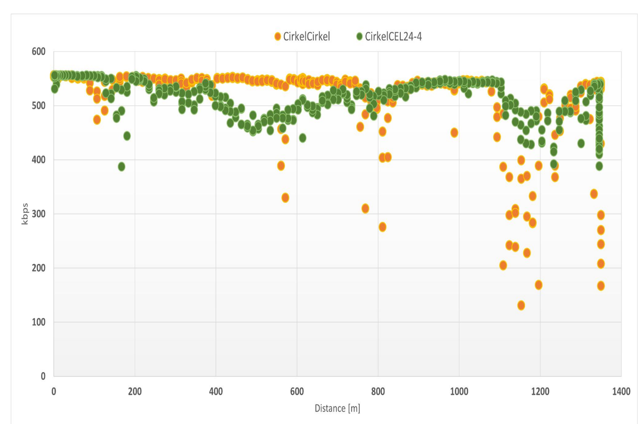

Figure 10: Signal Strength at different distances at Dyrehaven

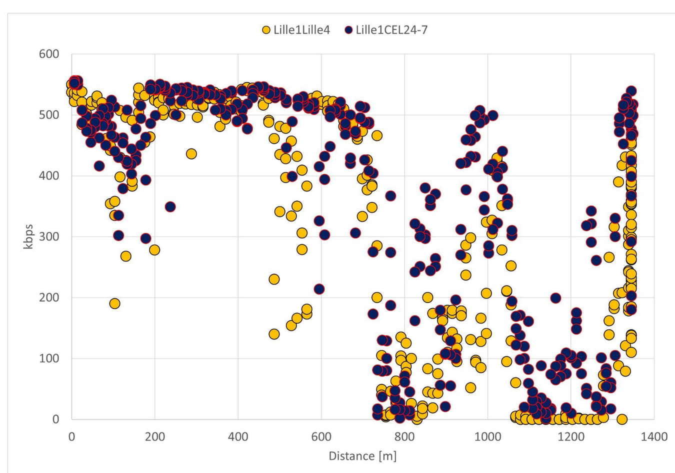

Figure 11: Signal Strength at different distances at Dyrehaven

Discussion

- From figure 6, we can conclude, that it is a good choice to test antennas at the frequency 2.5 GHz, since it is at this frequency, the difference between the antennas' reflections are the smallest.
- Based on figure 4, we can conclude that a lot is reflected, which means the transmitting part is very small. From this observation, we conclude, that this might be a reason, that the range last year only was 150 m.
- It is obvious, from figure 9, that the red data set is more stable than the black data set. Additionally, it is clear, that we enter a valley at 650 m and another valley at 1100 m, since the signal drops rapidly at both valleys.
- From figure 10, we observe, that both the orange data set and the dark green data set have stable signals, but the orange data set drops at valley 3, which is at 1150 m. The drop in the signal strength means, that the orange combination of antennas is more sensitive than the dark green combination. It should be mentioned, that we have three valleys. Valley 1 at 100 m, valley 2 at 800 m and valley 3 at 1150 m.
- It can be seen from figure 8, that there is some noise from some other devices at 2400-2500 MHz, (ISM band), furthermore it is seen from figure 7, that we experience harmonics at 5000 MHz, which means, that a signal also exists at this frequency, since we currently don't have a bandpass filter at this frequency.

Conclusion

Based on how our project has evolved, we can conclude, that we have developed a useful product, which has a full functioning stable 2-way telemetry system with full signal strength, which works up to 1.4 km. The product works both in line of sight and in urban environment, thus it is usable in multiple situations, and last but not least, we have documented the tests thoroughly, so it can easily be argued, why we have taken the choices, that we have. We have tested the reflection for our project and the earlier project, so we could compare them, and look at the improvement. We assess, that our method of solution has been adequate and thorough. We assess, that we have created a product, which lives up to the desired requirements.
Additionally, with our setup we get a throughput of 4000 CAN messages pr. second, which is not only bigger than last year's group's throughput, but also their theoretical. Finally, we have had some reflection along the road, and we have some suggestions to, how the project can be improved in the future.

Acknowledgment

Thanks to the following for help, support and feedback:
Claus Suldrup Nielsen, Laboratory engineer, DTU,
Christian Kampp Kruuse, Student, DTU,
Louise Julie Sternhold-Sørensen, Student, DTU
Sebastian Zeest Rydahl, Student DTU and
Lukas Fredrik Cronje, Student, DTU.

References:
BWSC website: https://www.worldsolarchallenge.org/
Victor Alexander Hansen, Steffan Martin Kunoy, Tjark Petersen: Telemetry Module for DTU Roadrunner Solar Car, 2021.