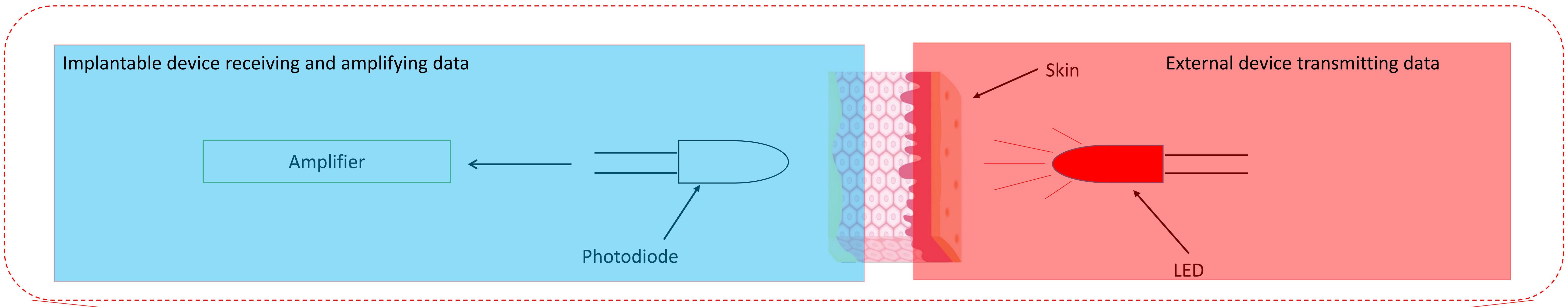
Closed Loop Implantable Sensor System

Mohammed Latif* (16035817), Alexzander Farrall, Patrick Degenaar
Vacation Research Scholarship, 2018
M.Latif@ncl.ac.uk
EEE, Newcastle University, UK, Institute of Neuroscience, Newcastle Upon Tyne, UK

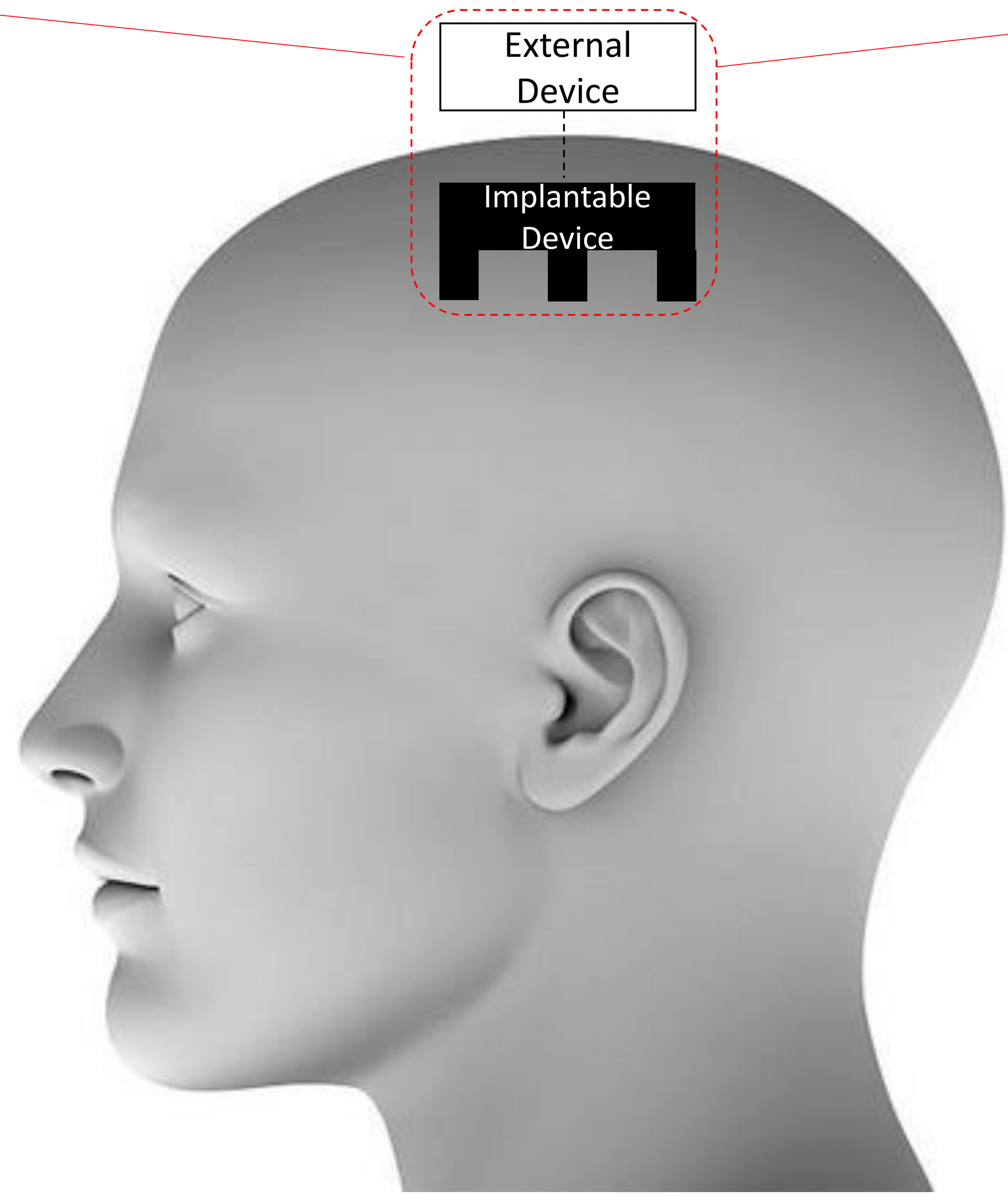
Introduction

To produce an effective implantable system, the device must be able to communicate to the outside world. This project investigated the method of using light as a form of communication between an external device and the implantable device which reduces noise in the brain and prevents epileptic seizures.



For the receiver side of the project, methods of receiving data in the form of light was investigated. In order to successfully receive the data in the form of light, the propagation of light through human skin must be explored. Effects of scattering and absorption must also be strongly considered. The power dissipation through the skin must also be considered as a factor, because the external device has no power constraints the power going into the skin can be assumed to be any value. The internal device however, has a limitation on power and current because an increase in internal temperature by a few degrees can be deadly.

Because this is to be implanted on humans with epilepsy, it cannot be assumed that the skin for each human will be the same, the number of pigments a human has can affect the light transmission through the skin.



The transmission side of the project focusses on the maximum speed of data transmission that can be achieved. The communication of this project will be used to transfer data to and from the implantable device, if a high speed data transmission cannot be achieved it can be time consuming to make changes or charge the implantable device. This, evidently, is not practical as the patient will have to sit still whilst the data transfer takes place.

A microcontroller can be used to blink an LED at high speed, synchronizing the LED to the internal clock of the microcontroller can allow the LED to blink at a frequency in the MHz range. Ideally, the frequency to blink the LED for this project should be around 100MHz allowing it to transfer approximately 100 megabits per second. Transferring data at this speed would mean it will take minutes or maybe seconds to complete the data transfer.

Figure 1 Diagram showing where the implantable device is to be placed and a closer look at the communication that will take place through the skin between both the implantable and external devices.

Methods and Objectives

The methodology and objectives for the receiver side are as follows:

- Investigate the feasibility of receiving a 100MHz data signal with a limited power consumption and current.
- Construct a low power circuit capable of amplifying the received signal.
- Use theoretical calculations to obtain values for the absorption coefficients of the different layers within the skin, and explore the absorption and scattering effect through each layer.
- Investigate the effects of light transmission for different skin tones.

The aims and methodology for the transmission side are:

- Carry out tests to blink an LED at maximum speeds using just a microcontroller.
- Transfer a string of characters from the LED by using ASCII codes to convert characters to binary digits and blinking the LED accordingly.
- Investigate the method of using an FPGA alongside a microcontroller and interfacing them using SPI to increase speed.
- Determine whether a data transmission speed of 100MHz is feasible.

Results and Conclusion

Layers of skin	Thickness	Scattering coefficient	Absorption coefficient
Epidermis	100 µm	11.9 cm^{-1}	11.8 cm^{-1} *
Dermis	3 mm	11.9 cm^{-1}	0.363 cm^{-1} *

** Changes with body types*

Table 1 Calculated scattering and absorption coefficients of different skin layers

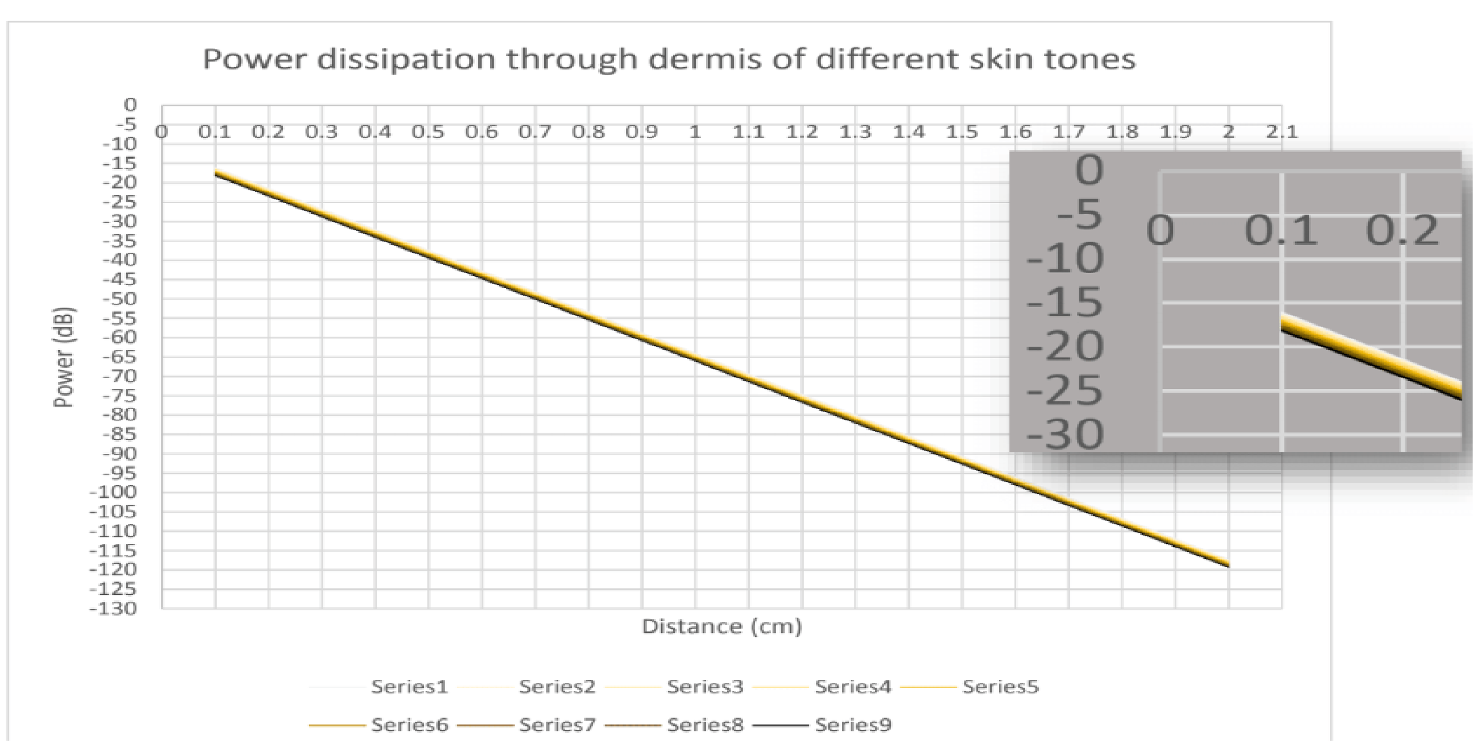


Figure 2 *Power dissipation through skin with different volume fraction of melanosomes.*

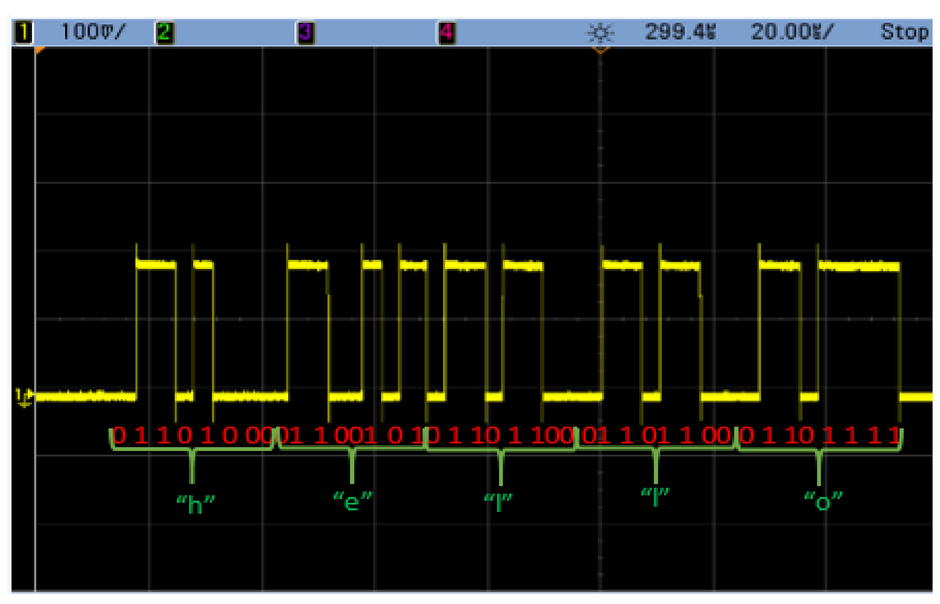


Figure 3 character string of "hello" converted to binary and outputted through the LED as a binary sequence.

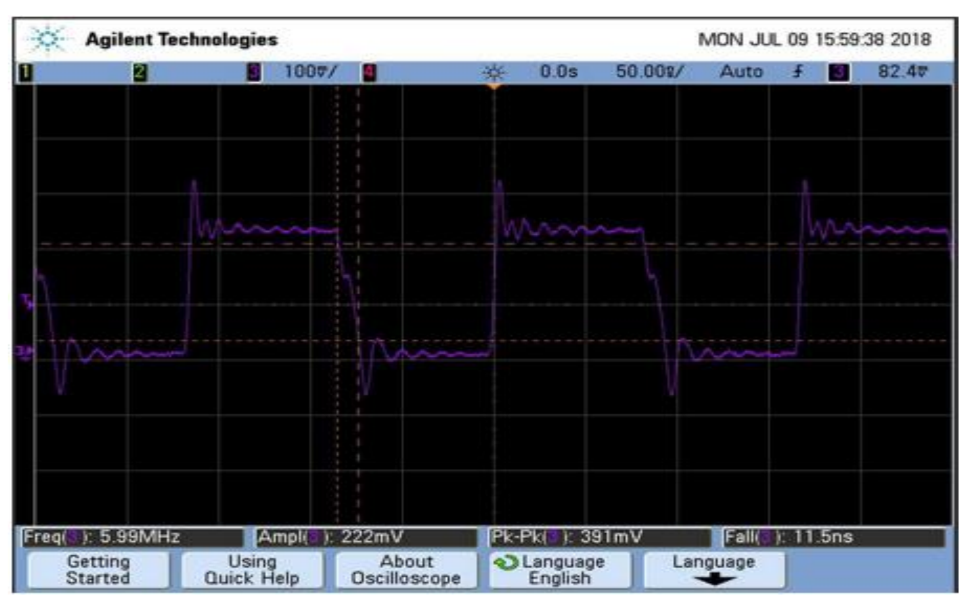


Figure 4 Slightly distorted 6MHz waveform produced from FPGA to toggle LED

Conclusion

It was concluded that for the receiver side, it is not feasible to achieve a data rate of 100MHz with a 10mA constraint, with major issues being a large gain needed to amplify with low currents and processing the signal edges at high frequencies and slew rates.

For the transmission, it is possible to transfer data at high speeds using SPI despite this not being achieved within the time period, using a microcontroller and FPGA with high frequency clocks could make the target of 100MHz achievable.