Electrotechnische Vereeniging
Issue 20.2 | February 2017 | Delft

Maxwell

Biomedical Engineering

Lab on a Chip
For Biomedical Applications

Single Photon Detection
With Picosecond Time Resolution

From the board

Commissioner of Education

Lucas Enthoven

Hello again! A lot has happened during the past quarter. First off, an update on the accreditation process: this went very well and the visitation committee has given a positive report. That is good news as it means that the study program will stay valid for another 6 years! To celebrate this, pie (an accreditasty pie) was given away in the main hall of EEMCS on the 1st of December.

Currently, the master kick-off is being evaluated. A group of students consisting of FSC members, the Commissioner of Education of Christiaan Huygens, the ETV and DelftSEA are currently discussing how to improve it with Education & Students Affairs. There were some problems this past year since the study programs at the EEMCS faculty have grown a lot over the last years and currently there is quite a bit in the works on how to improve it.

Another upcoming change is the switch from Blackboard to Brightspace. I currently hold a seat in the central advisory group, consisting of representatives from all TU Delft faculties, which gives regular feedback on the new system. As it appears now, Brightspace will be used from the beginning of the 2017-2018 academic year.

Rob Remis was elected teacher of the year EEMCS in May. On Wednesday the 14th of December, education day was held for teachers and this included the university wide selection of the teacher of the year. Unfortunately, Rob did not win, but the day was nevertheless a success!

There have also been a lot of excursions in the past quarter. A group of students went on excursion to Tennet. In addition, all first year students also went on excursions to companies like Huisman, Mapper, LUMC and YES!Delft.

In other news, another LaTeX workshop has been organized. This time the target group was the first year students. Again, more than 90 students showed up! Do you have any recommendations on another type of workshop? Send an email to *education-etv@tudelft.nl*!

Do you have any other questions, complaints or suggestions about education? Feel free to shoot me an email at *education-etv@tudelft.nl*.

Kind regards,
Lucas Enthoven

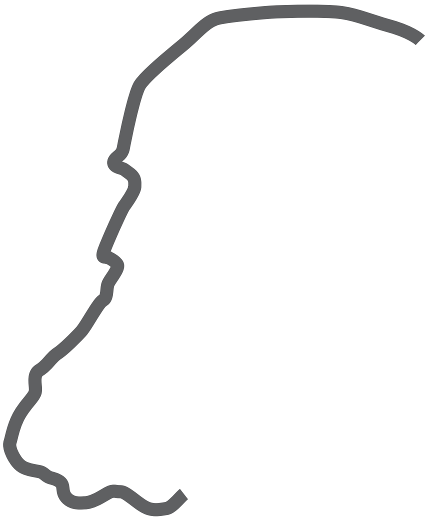
Secretary

Roel de Rijk

This edition it is my turn to tell you about the wonderful things our association is doing. In contrary to most animals the Electrotechnische Vereeniging does not go into hibernation during the winter, even while the first snow has been spotted.

The ETV has organised a number of activities the past few months. The second quarter of the year started with two big events: a symposium and an EESTEC event. The symposium was a great success with around 500 people in attendance making it one of the biggest events of 2016. As for the EESTEC event, lots of students from all over Europe got to spend a week visiting Delft (our university of course!), Amsterdam and Rotterdam.

Since it is still more or less the beginning of 2017, I will elaborate a bit one of this year's events. This year we will have a study tour during which some students will visit China, Japan and Australia. Furthermore, the ETV committees are very busy organising activities and trips for our members. We look forward to a connecting 2017!



Editorial

When you're in university, you learn about all kinds of theoretical matter every single day. Depending on your field of study this can get quite abstract. Although most of us don't have too much trouble dealing with this abstract world, we as engineers do like to see those theories in action.

When it comes to abstract subjects, the one that is probably in the top 3 would be quantum physics. A subject every Electrical Engineering student is taught in his first year, but probably only a handful of people on the planet can really wrap their head around.
So, how do we see this in action? Well, there's this object that we all use on a daily basis and it really obeys the quantum principle. It is a pen. These things just seem to appear out of nowhere, but also disappear into thin air. We can never really tell if a pen is in our bag. Best we could do is a define a sort of field of potential pen. This then tells us the likeliness of a pen being at a certain place (like your purse).

What does all this have to do with the editing of Maxwell 20.2? Well, nothing really. Other than the fact that we're just a bunch of students with crazy ideas like this one. I hope you enjoy reading this issue and think of some crazy applications of theories yourself!

Daniël Kappelle

Colofon

Year 20, edition 2, February 2017
5100 copies

Editors
Martijn Hoogelander
Daniël Kappelle
Jelimo Maswan
Elke Salzmann
Tristan Wieffering

Contributors
Floris van den Brink, Edoardo Charbon, Karel Devriendt, Ibrahim Diab, Lucas Enthoven, Moritz Fieback, Jeroen van Gemert, Marinke van der Helm, Harald Homulle, Daniël Kappelle, Niels van Lith, Mathieu Odijk, Michiel Pertijs, Rob Remis, Roel de Rijk, Elke Salzmann, Ralph van Schelven, Ide Swager, Ids van der Werf, Eric Winkel

Advertisements
Inside cover front - Navingo
Page 13 - AME
Back cover - DNV GL

Printing
Quantes, Rijswijk

Electrotechnische Vereeniging

The 145th board of the ETV
President: Philip van den Heuvel
Secretary: Roel de Rijk
Treasurer: Francesc Varkevisser
External Affairs: Declan Buist
Education: Lucas Enthoven

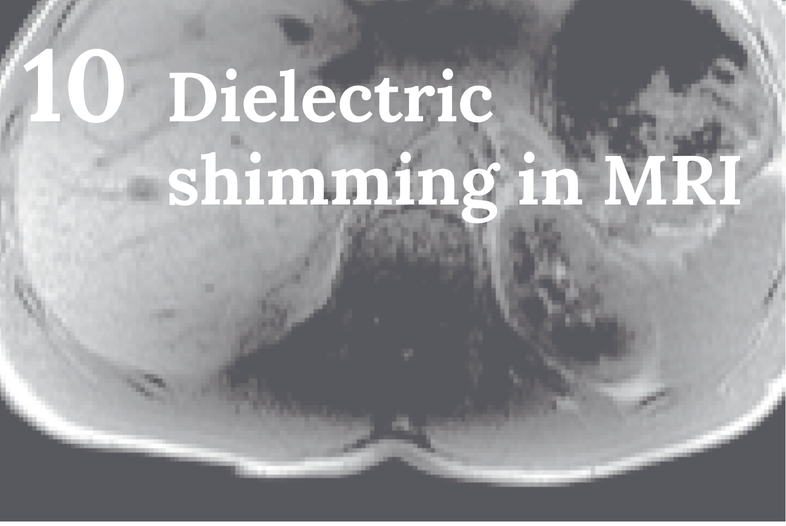
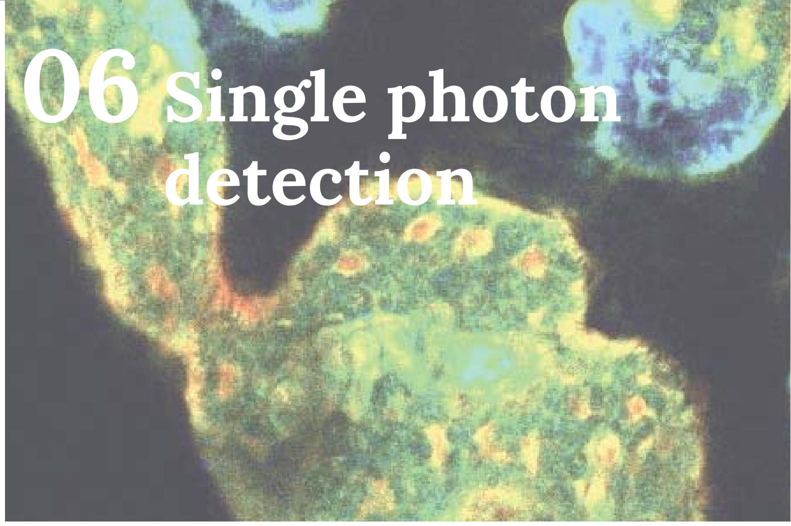
Contact
Electrotechnische Vereeniging
Mekelweg 4
2628 CD Delft
The Netherlands

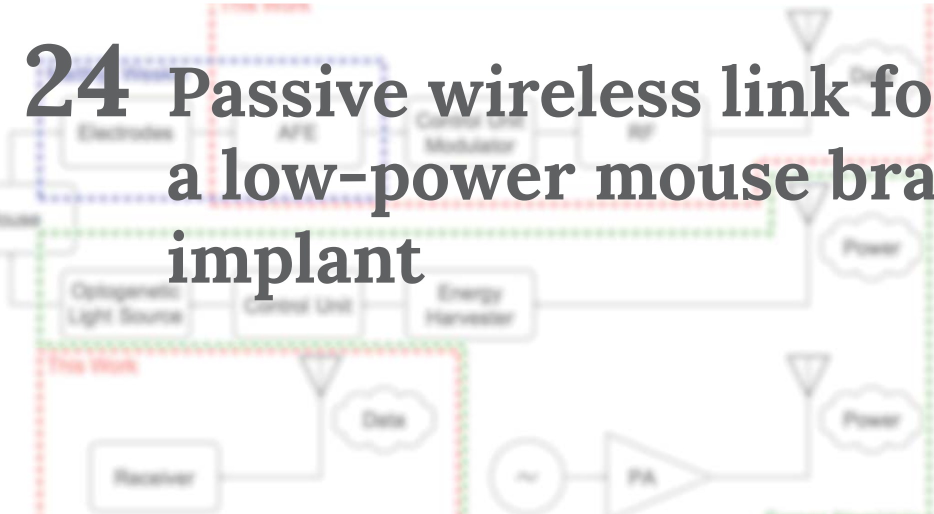
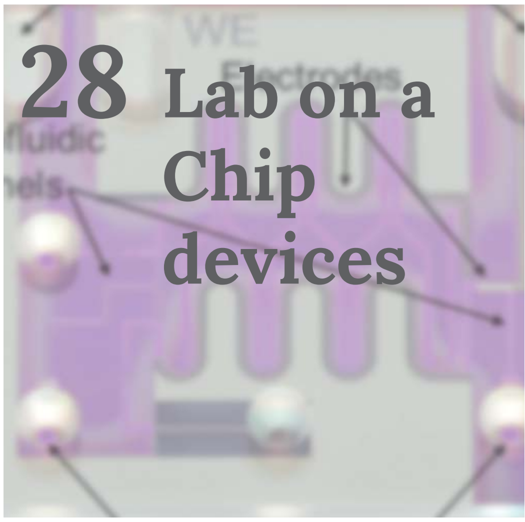
Phone number: +31 (0) 15 278 6189
E-mail: Board-ETV@tudelft.nl
Website: www.etv.tudelft.nl

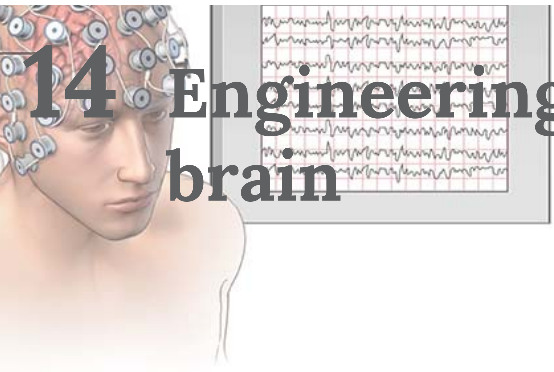
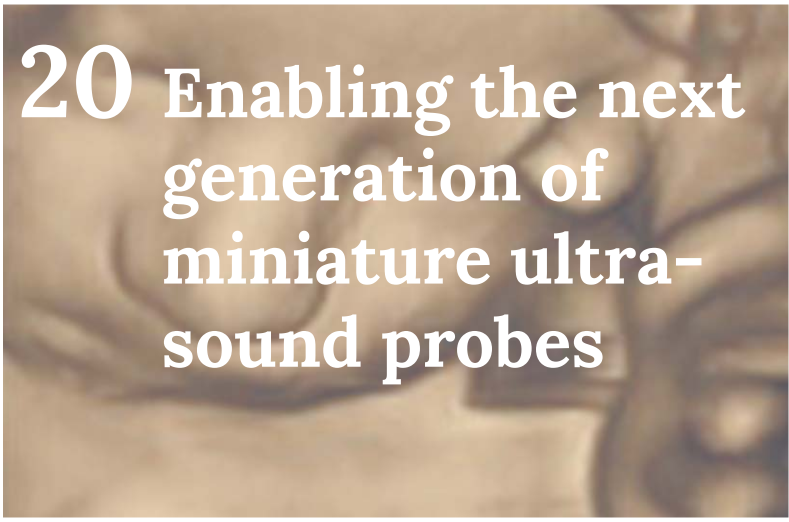
Subscriptions
Non-members can receive the Maxwell four times a year, against a contribution of €10,- per year.

You receive this edition because you are an alumnus of the TU Delft or a member of the ETV.

Change of address
Please send your changes to the address above, or use the website.

Single photon detection
with picosecond time resolution

Harald Homulle & Edoardo Charbon

Light, is it a wave or a particle? The answer to the question is dual. Light has properties of both electro- magnetic waves and light particles. Every day we sense and record light information with our cameras and eyes. However, we cannot sense or detect single light particles, or photons. Conventional cameras based on CCD (charge-coupled device) or CMOS (complementary metal-oxide-semiconductor) technologies do not in general have the capability of sensing elementary particles, especially with high timing resolution. For this reason a new type of sensor was developed capable of detecting single-photons with very high accuracy. Welcome to the age of single-photon imagers.

Applications of single-photon imaging

Every device needs an application in order to make it worthwhile. There are several useful applications that require the detection of single-photon events. One of the most common uses of single-photon imagers is 3D imaging using time-of-flight (ToF) measurements of single-photons. Since time and distance are directly related, measuring the flight time of photons gives very accurate information on the distance of objects on which the photons will reflect back into the sensor. The result of such an acquired image is shown in figure 1(a). The depth of the face can be measured with up to millimeter depth precision [1].

Also in biomedical applications, the measurement of single-photon events is beneficial. Two examples are positron emission tomography (PET) and fluorescence lifetime imaging microscopy (FLIM). For PET, a patient is injected with a radioactive tracer that emits gamma rays at180 degrees in opposite directions. While the tracer spreads through the body, it accumulates in areas with large cell activity, such as cancer cells. When the gamma rays are detected on a circular detector around the patient, the point of origin is tracked back by exploiting the correlation between the opposite gamma rays. This technique makes it possible to accurately determine areas in the body with large cell activity and thus possible sources of cancer cells. Figure 1(b) shows the example of a tumor in a human body measured with a PET system [2].

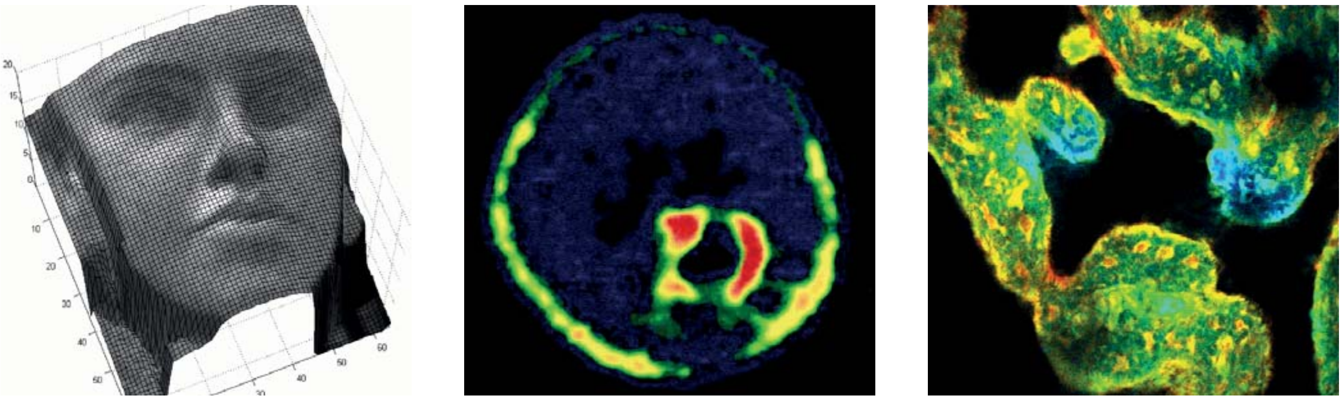


Figure 1: *Example applications: 3D ToF image from a face (a) [1], tumor in a human body measured with a PET system (b) [2] and fluorescence lifetime image of a pig skin injected with ICG (c) [3].*

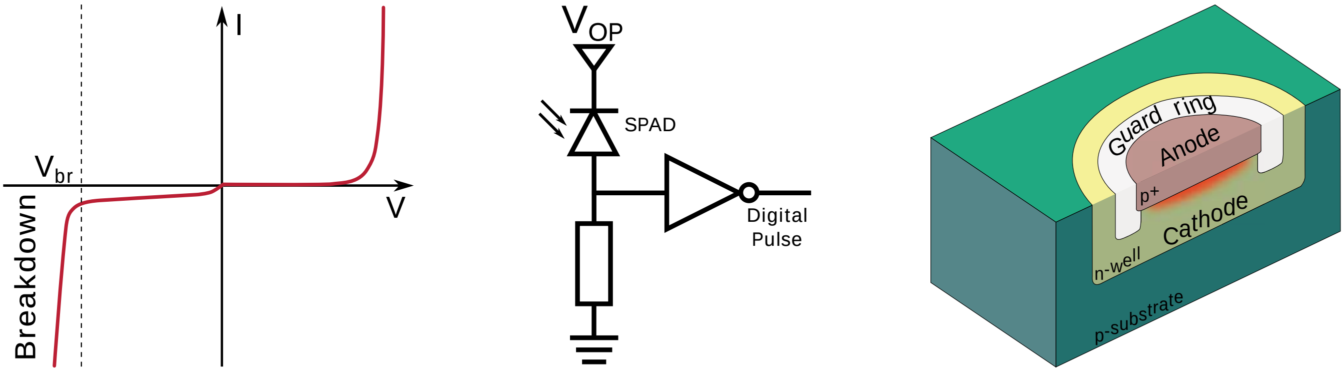


Figure 2: *Single-photon avalanche diode IV-characteristics (a), implemented circuit (b) and device cross section (c).*

In FLIM the patient is also injected with a tracer. However, in this case the cells emit fluorescence light once excited by an external source, such as a laser. This tracer can be targeted at specific types of cells, allowing it to trace cancerous cells as well. This technique will be discussed in more detail in the following sections. In figure 1(c) an example of a FLIM image is shown of a pig skin injected with ICG [3].

Single-photon detection

Several methods exist to detect or measure single photons. The photomultiplier tube (PMT) is the oldest method of detecting single photons. The impact of a photon on the PMT cathode generates one or more electrons that are attracted by the PMT anode on the other side of the tube. The electron current is multiplied several orders of magnitude generating a very large current on the arrival of each single photon. Although the performance of these detectors is unmatched in terms of noise, accuracy and speed, their size and price is limiting their use in single-photon imagers.

For an imaging sensor, an integrated solution compatible with standard (Bi)CMOS technologies is preferred. Therefore, a single-photon detector was developed in standard CMOS technologies [4], capable of doing exactly the same as a PMT: creating a large current upon arrival of a single photon. An avalanche photodiode, biased with a voltage exceeding the junctions breakdown voltage, known as single-photon avalanche diode or SPAD, is triggered upon the arrival of a single photon and creates an avalanche of electrons.

“A real-time FLIM system (...) is just waiting around the corner.”

The SPAD circuit in its most basic form is implemented as the circuit shown in figure 2(b). The SPAD is biased on the IV-curve above its breakdown voltage Vbr, figure 2(a). With only a slight disturbance, the current in the junction will grow exponentially. In order to prevent permanent damage to the SPAD, the junction voltage has to be rapidly decreased. The resistor is implemented for this purpose. When the SPAD generates a growing current, the voltage drop across the resistor increases. In turn, the voltage across the junction will decrease to a value below breakdown, stopping the avalanche. The junction is finally recharged to its initial voltage, allowing a new photon to trigger a new avalanche.

This simple yet effective technique allows us to accurately measure the arrival of photons on the detector in the digital domain. However there are several challenges in creating and optimizing these detectors. Limitations are found in the noise generated by spurious avalanches generated without an actual photon being sensed (dark counts), breakdown of the junction on its edges due to a higher electric field, the quantum efficiency of converting photons into avalanches and the fill factor of the sensor limiting the area in which photons can be detected. The physical cross section of a simple SPAD structure is shown in ??(c). For example, to prevent edge breakdown, a guard ring is implemented around the p-n junction for protection against high electric fields on the edges.

Single-photon timing

Upon the arrival of photons on the SPAD, digital pulses are generated that need to be accurately timestamped. Different techniques exist, largely dependent on the required specifications and application.. d

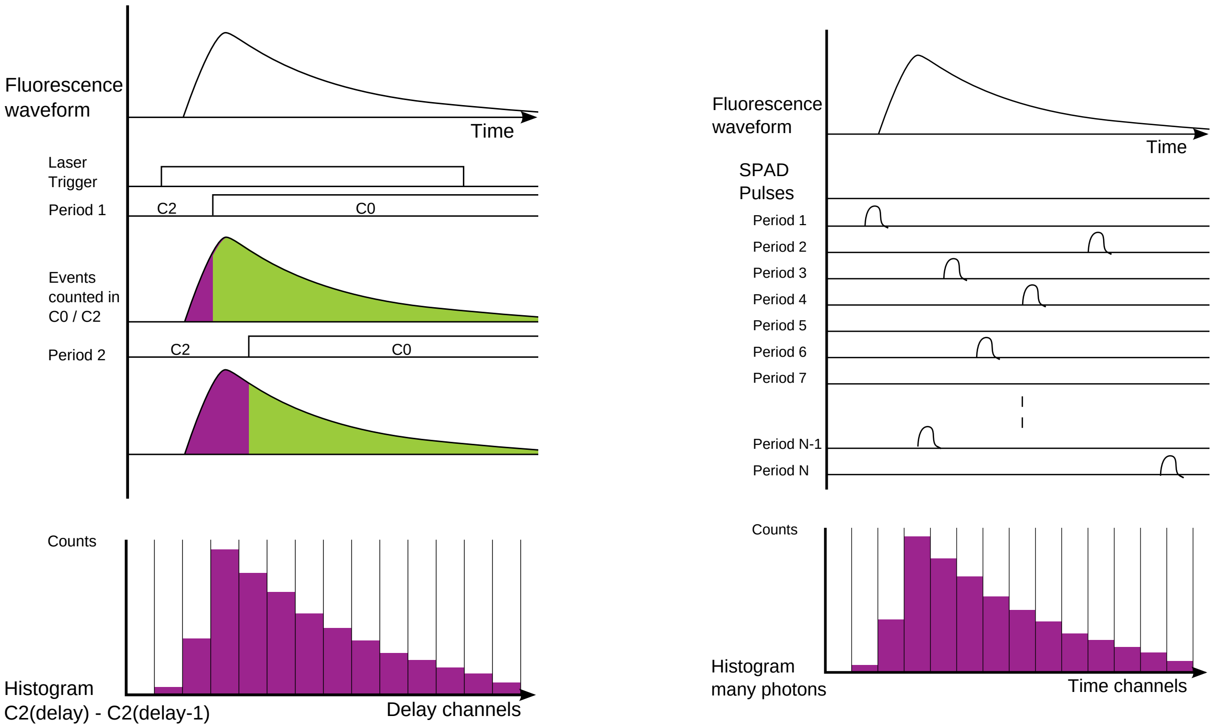


Figure 3: *Comparison of the gating and TCSPC technique in the case of a FLIM camera system acquiring the fluorescence response from a target. In (a), a gate is shifted over the fluorescence response, acquiring its integral. Differentiating reveals the original binned waveform. (b) acquires the same binned histogram, but by acquiring different photons timestamps directly in the histogram.*

The most used techniques are gating and time-correlated single-photon counting (TCSPC). In gating, a gate of certain time width is shifted in small steps (usually on the order of tens of picoseconds) over the optical signal of interest, and counts all impinging photons in the gate window. The optical response is thus sliced with very high time accuracy, allowing the reconstruction of the original signal. TCSPC on the other hand measures the arrival time of each individual photon. Once a photon hits the detector, the generated pulse is timestamped with a time-to-digital converter. Acquiring multiple timestamps allows again to reconstruct the original signal shape. Both techniques are summarized in figure 3 for a system measuring the fluorescence response in FLIM camera systems.

FLIM

Fluorescence lifetime imaging microscopy holds the promise of differentiating healthy from cancerous tissue, allowing precise control of tissue to be removed during operations and thus potentially reducing excessive tissue ablation and improving treatment of cancer in many patients. The concept works as follows: the patient is injected with an indocyanine green (ICG) tracer, which can be combined with an RGD peptide for higher directivity toward cancerous cells. Once the tracer is sufficiently absorbed by the body, it has to be exited by a (pulsed) near-infrared laser. Each laser pulse generates a fluorescence response as the ones shown before in figure 3. The exponential decay or lifetime of the fluorescence response is extracted and is correlated to the tissue type.

We developed a compact camera system employing the gating technique for the purpose of FLIM. The camera system is shown in figure 4 and consists of three

Figure 4: *The FluoCAM camera system consists of three PCB, containing the camera module, FPGA, delaylines and voltage regulators [5].*

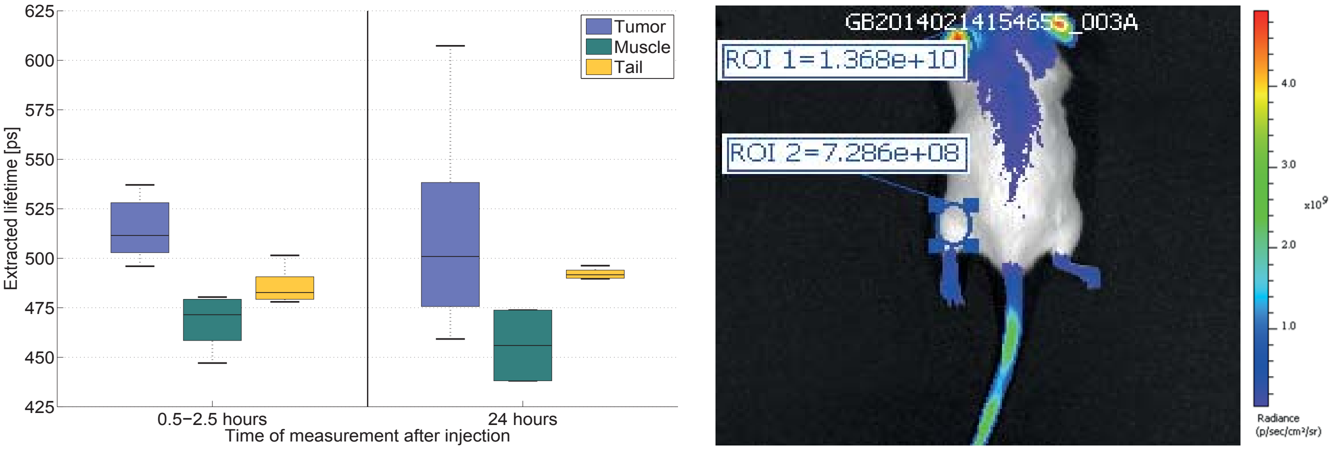


Figure 5: *(a) Demonstration of the capability of discriminating healthy tissue and tumor tissue. Data was acquired from a mouse with a glioblastoma mouse model, an aggressive type of brain cancer. (b) Mouse measured with a fluorescence intensity camera to demonstrate the directivity of the RGD peptide towards the tumors [5].*

PCBs with camera, FPGA, delaylines and voltage regulators [5]. The camera-module contains an array of 64×48 SPADs, with two 8-bit counters, selectable by the moving gate, in each pixel. Single-photon events are stored in the counters and read out through a USB link to calculate the original fluorescence response.

This system is used to demonstrate the feasibility of discriminating healthy and cancerous tissue, demon- strated with figure 5(a). For the study, a mouse was grown with a glioblastoma mouse model, an aggressive form of brain cancer and injected with ICG-RGD. Measurements were taken shortly and 24 hours after injection and the fluorescence lifetime was recorded using the FluoCAM system. There is a clear distinction between healthy tissue, tail and muscle, and the tumor lifetimes. Measurements were also taken with a fluorescence intensity camera to demonstrate the directivity of the RGD peptide towards the tumors. Figure 5(b) indeed shows indeed excellent directivity of ICG-RGD.

Summary

SPADs are used in many applications ranging from 3D to biomedical imaging. There is a clear advantage in measuring single photons and timestamping their arrival to accurately reconstruct optical responses. FluoCAM demonstrates the possibility of reconstructing the fluorescence response and accurately extracting the lifetime. While lifetimes are to a great extent dependent on the target, a clear distinction can be made between healthy and cancerous tissue, thus allowing a physician to see clearly during an operation what tissue has to be removed.

In the near future, we plan on further system miniaturisation and overall performance improvements, not only by optimizing SPAD performance, but also by using TCSPC techniques to faster and more accurately find fluorescence lifetimes. A real-time fluorescence lifetime imaging system, capable of discriminating healthy from cancerous tissue during surgical procedures, is just waiting around the corner. c

[1] C. Niclass and E. Charbon, “A single photon detector array with 64×64 resolution and millimetric depth accuracy for 3D imaging,” in ISSCC. 2005, 2005, pp. 364–604.

[2] Y. Takahashi, Y. Imahori, and K. Mineura, “Prognostic and therapeutic indicator of fluoroboronopheny-lalanine positron emission tomography in patients with gliomas,” Clinical Cancer Research, vol. 9, no. 16, pp. 5888–5895, 2003.

[3] W. Becker, The bh TCSPC handbook. Becker & Hickl, 2014.

[4] A. Rochas, M. Gosch, A. Serov, P. Besse, R. Popovic, T. Lasser, and R. Rigler, “First fully integrated 2-D array of single-photon detectors in standard CMOS technology,” IEEE Photonics Technology Letters,vol. 15, no. 7, pp. 963–965, 2003.

[5] H. Homulle, F. Powolny, P. Stegehuis, J. Dijkstra, D.-U. Li, K. Homicsko, D. Rimoldi, K. Muehlethaler,J. Prior, R. Sinisi et al., “Compact solid-state CMOS single-photon detector array for in vivo NIR fluorescence lifetime oncology measurements,” Biomedical optics express, vol. 7, no. 5, pp. 1797–1814, 2016.

Dielectric shimming in MRI
Addressing RF interference problems

Ir. Jeroen van Gemert & Dr. Ir. Rob Remis

Strong magnetic background fields are of great interest in Magnetic Resonance Imaging (MRI), since images with high spatial resolution can be obtained at reduced scanning times. Strong background fields may cause RF interference effects, however, and these effects can severely degrade the quality of an MR image. This problem can be partly resolved using various advanced and mostly expensive techniques, but there is also a cheap and practical solution, namely, dielectric pads. The main goal of our project is to develop a tool that allows us to efficiently design effective dielectric pads for High Field MRI.

For about 2 years we have been working on a project in Magnetic Resonance Imaging or MRI. This project is in joint collaboration with the C.J. Gorter Center for High-Field MRI at the Leiden University Medical Center and addresses interference effects that may be encountered in High-Field MRI. Such interference effects severely degrade the quality of an MR scan, but fortunately can be avoided through the use of dielectric pads. Specifically, by placing high-permittivity pads in a neighborhood of a body part that needs to be imaged, interference effects may disappear and high-quality MR images are obtained. Dielectric pads are a practical and cheap solution and work really well provided these pads are properly designed. In this article, we discuss the approach that we have developed in our project to systematically design effective dielectric pads in MRI.

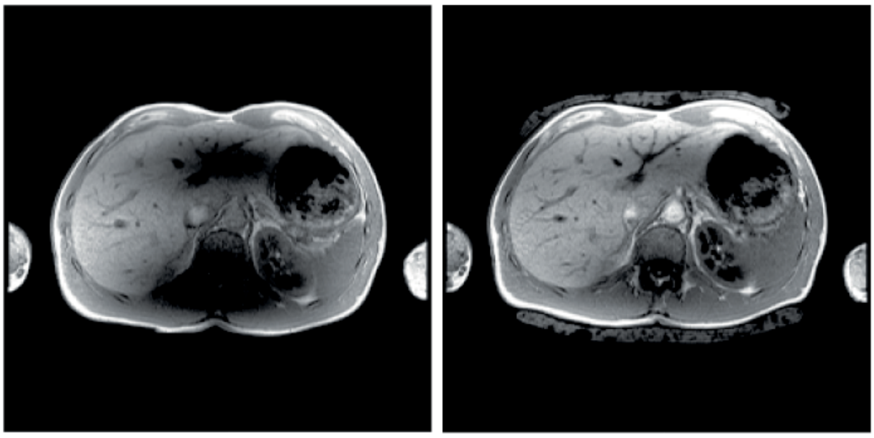


Figure 1: *Left: MR image of a slice through the abdomen obtained without any dielectric pads. Signal voids in the anterior and posterior of the abdomen are clearly visible. Right: MR image of the same slice through the abdomen, but this time obtained with dielectric pads. The signal voids have disappeared due to the presence of high-permittivity pads.*

Introduction

Magnetic Resonance Imaging is a well-known technique that is used to create detailed images of the anatomy of the body. The first MR scanner dates from the early 70's and although significant improvements have been achieved, the fundamentals remain the same. Below, we briefly discuss these fundamentals.

Basically, the key component of the scanner is the main magnet. This superconducting solenoid produces a static uniform magnetic field on the order of 1.5 - 7T, which is up to 200,000 times the Earth's magnetic field. When a person is positioned in the bore it causes the hydrogen nuclei in our body (protons) to spin around this static magnetic field, which is known as precession. The angular frequency of this precession is referred to as the Larmor frequency and it is linearly related to the static magnetic background field. For typical field strengths of 1.5T, 3T, and 7T the corresponding Larmor frequencies are 64 MHz, 128MHz, and 298 MHz, respectively.

By transmitting a circular polarized magnetic field – the so-called B_1^+ field – with an RF coil operating at the Larmor frequency, we are able to exert some torque on the magnetic moments of the nuclei such that they absorb energy. This works since the circular polarized field rotates with the same angular velocity as the hydrogen nuclei, i.e. they are at resonance. When the RF field is switched off, the nuclei return to their equilibrium position, emitting energy while they do. This energy is emitted in the form of RF radiation and is picked up by a receiver coil. Finally, an image of the interior of the body is obtained by applying some basic Fourier transformation techniques on the received signal [1].

There is great interest in High-Field MRI, since it leads to an increased Signal-to-Noise Ratio (SNR) and consequently a higher spatial resolution or shorter scanning times or both. There are some downsides too, however, one of which is that the Larmor frequency increases as well and therefore the RF wavelength decreases. For 3T (128 MHz) the wavelength in free space is about 2.3 meter, and inside the body it decreases to about 0.25 meter. Since the wavelength now becomes comparable with the dimensions of the body, we have to deal with destructive (and constructive) interference effects. The destructive interference effects cause signal voids inside the body, since the B_1^+ field distribution is simply too weak at these particular locations. As a result the MR image contains dark spots and the anatomy is not visible anymore at some locations, see Figure 1 (left) for the scan and Figure 3 (right) for the corresponding simulated B_1^+ field. In the scan there are clearly some signal voids in the anterior and posterior of the abdomen. We would like to remove these voids from the image by having a homogeneous B_1^+ field throughout the complete Region of Interest (ROI). To this end, we tailor or shape the B_1^+ field through a process called shimming. There are basically two shimming techniques available, namely, active and passive shimming. Active shimming uses multiple transmit antennas or local transmit antennas to bring the source closer to the ROI. Most of the active shimming techniques require additional hardware and are often quite expensive. Passive shimming techniques, on the other hand, do not use active current driven coils and use dielectric materials instead. These materials induce a secondary magnetic field that allows us to reshape the total RF field inside the human body.

Dielectric pads

Our project focuses on the use of passive dielectric shimming using dielectric pads [2]. These pads (see Figure 2) have a high relative permittivity in the order of 80 - 300. Fabricating these pads is relatively cheap, and they can be used in existing MRI systems, i.e. no additional hardware

Figure 2: *High permittivity pad with a relative permittivity of 200 and dimensions 13x16x1 cm^3. The material of the pad is a mixture of calcium titanate, barium titanate, and deuterated water.*

is required. The dielectric pads affect the B_1^+ field in a ROI and may significantly improve the quality of an MR image. An example of the effect of a well-designed dielectric pad is shown in Figure 1 (right). Here, one pad is placed on the anterior and another on the posterior of the abdomen. The quality of the MR image is drastically improved, as the anatomy is visible

"Fabricating these pads is relatively cheap, and they can be used in existing MRI systems."

again. The design of the dielectrics is not trivial, however, and patient dependent as well. For example, scanning the inner ear of a male requires a dielectric pad different from a pad needed to scan the inner ear of a female. Furthermore, the d

***Figure 3:** On the left side a typical simulation configuration, created with Remcom XFdtd software. The birdcage antenna around the human voxel model emits the RF field. The right figure depicts the B_1^+ field for a transverse slice around the liver. The signal voids (blue) are clearly visible in the anterior and posterior.*

volume of the subject and the ROI have a significant influence on the design as well, since wavelength effects are typically more severe for larger volumes.

Normally, standard commercial electromagnetic fields solvers are used to design effective dielectric pads. These solvers can easily be used to model common MR configurations, i.e. the RF coil combined with a virtual voxel model of the human body, as shown in Figure 3. Simulations are commonly carried out for a wide variety of dielectric pads with different parameters (i.e. location, geometry, and constitution). Such simulations are computationally intensive with very long associated simulation times. Designing a proper dielectric pad for a single ROI and for a single virtual voxel model often takes hours and sometimes even days to complete. This approach is obviously very cumbersome and the main objective of our project is to significantly speed up the design process.

Approach towards solution

The dielectric pad is in most cases small compared with the dimensions of the body and introduces a small perturbative term in Maxwell's equations. By exploiting this feature, we are able to speed up the process of evaluating dielectric pads. However, to find a pad that meets certain design criteria, many different pads still need to be evaluated. To formalize the search for an optimal pad, we therefore pose our design problem as an optimization problem and computation times can be reduced even further by incorporating reduced-order modeling techniques in the optimization procedure. This approach allows us to systematically design dielectric pads within a couple of minutes instead of hours or days. Our tool is presently used in several clinical applications to produce high quality MR images of the cerebellum and the inner ear. The combination of electromagnetics, modeling, optimization, and the collaboration with the C.J. Gorter Center for High-Field MRI makes it a really enjoyable and exciting project. c

[1] McRobbie, Donald W., et al. MRI from Picture to Proton. Cambridge University Press, 2007.

[2] De Heer, P., et al. "Increasing signal homogeneity and image quality in abdominal imaging at 3 T with very high permittivity materials." Magnetic resonance in medicine 68.4 (2012): 1317-1324.

Engineering the Brain

A Doctor, a Physicist and an Engineer Walk Into a Room

Karel Devriendt

Monday morning, 9 am. A doctor, a physicist and an engineer walk into a room... It might sound like the beginning of a typical joke, but in the Neurophysiological department of the VUMC hospital in Amsterdam this is a scene that happens every week. And what they are doing is definitely not the beginning of a joke. In the KNF (clinical neurophysiology) research group, they are working on something amazing: trying to understand how our brain works and maybe more importantly, why sometimes it doesn't work...

In the context of my master's program in Electrical Engineering at the TUDelft, I had the opportunity to be involved with the KNF research group in a four-month internship. I learned about their work during a guest lecture by professor Stam from the KNF group, and I immediately decided I would like to get involved. So, a few e-mails and meetings later, they agreed that I could work with them for my internship. With a background in signal processing, network theory and some statistics I was all set to join them in their work of better understanding the brain.

You can't manage what you can't measure

At first sight, it might seem strange that there is room for an Electrical Engineer in the world of neuroscience. Probably things like medicine and biology are the first that come to mind, and of course they play a major role. But, how are you going to study the functioning of the brain if it is nicely packed away under the skull? Since we are interested in studying the brain in its normal conditions, we need a way to look at what is going on inside the brain. And that is where technology and engineering enter the scene.

The hard work of preceding generations has created a whole range of medical equipment that does exactly what we are talking about: enable us to look inside the body. X-ray imaging is a well-known example of how advances in physics and engineering allowed scientists to study the human body in a non-invasive way. In the same way, the development of medical ultrasound enabled doctors to look at soft tissues in the body for example to examine the foetus during pregnancy. If you think about how enabling these technologies have been in the study of the human body, and how they are used in everyday medical practice, it becomes easy to appreciate the importance of imaging technologies in medicine.

In the same way as X-ray allowed doctors to study the skeleton and ultrasound led to new insights in the development of the foetus, imaging and measurement

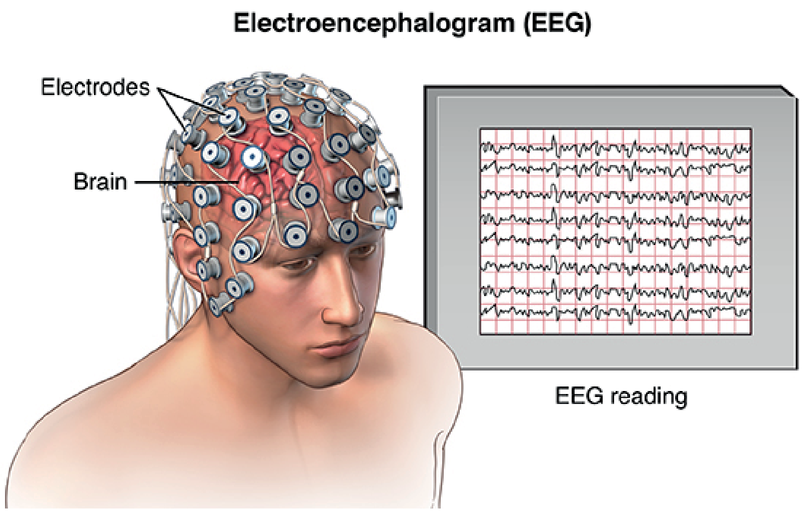


Figure 1: *In EEG, voltage measurements are taken on the scalp resulting in the spiky signals we see on the EEG reading screen. The voltage fluctuations come from collective excitations of neurons. [1]*

technologies are playing a key role in the study of the brain. From simple and widespread techniques like EEG (electroencephalography) to more niche/experimental techniques like MEG (Magnetoencephalography), there is a whole range of possibilities enabling us to 'look' at the brain. Both MEG and EEG are techniques that measure the electrical activity related to brain activity. Figure 1 shows an example of a typical EEG measurement.

From the perspective of imaging and measurement, the role of engineering in the development of new and better medical practices is very tangible. But in other domains, again the need for other types of engineering comes up. For example, an X-ray image of the leg can be easily understood by the physician since it is an actual image of the bone, but what about the electrical signals measured by EEG or MEG? For all you know these spiky signals might as well be fluctuating prices in the stock market, or even Delft's daily rain forecast. Without the right interpretation and signal processing tools, the technologies that exist lose a lot of their power. This is the perspective from which the KNF group works and from which I did my research internship: trying to model and understand the brain to make sense of the measurements.

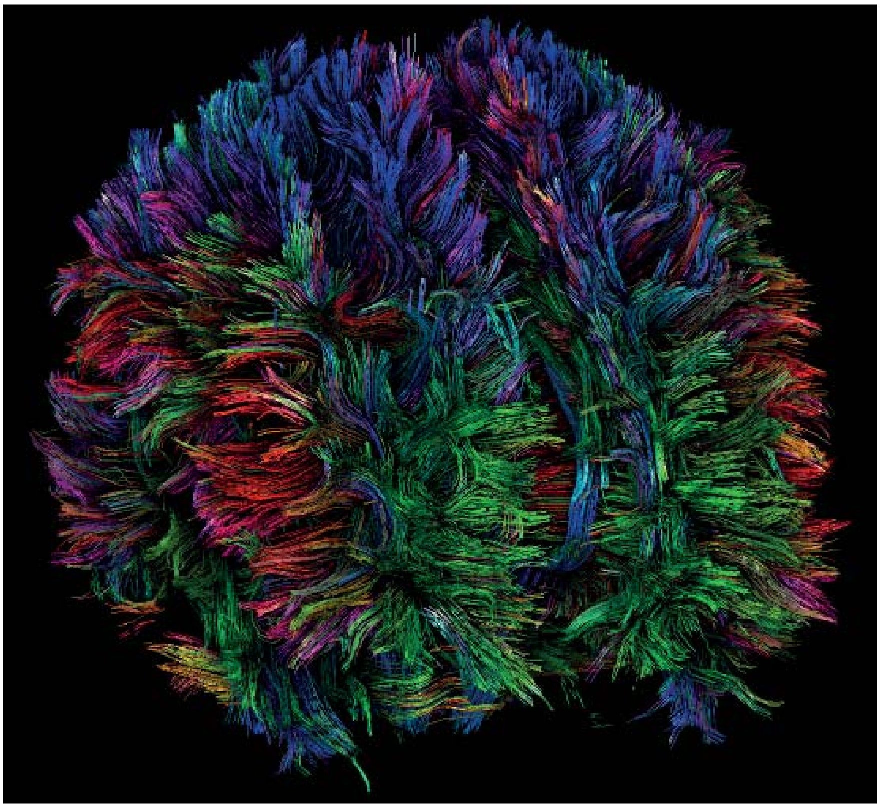


Figure 2: *Diffusion tensor imaging (DTI) is a technique that is used to image the axons in the brain. [2]*

The brain as a network

Based on the electromagnetic signals that are constantly produced in the brain, the KNF group is investigating how groups of neurons and brain regions work together as a network. For this purpose, they use the mathematical models from a field known as network science. To model a wide variety of problems, actually all you need are nodes and links. Examples of such nodes can be people in a social network or websites on the WWW. In these cases, links are representations of friendships and hyperlinks referring to other websites. In the case of brain networks, nodes correspond to brain regions and links represent connections between them (either physical or statistical).

This approach of abstraction from a complex, real-world system to a simple model based on just two fundamental building blocks is one of major benefits of network science. Another strength is the ability to uncover strong similarities between seemingly unrelated problems. Just by describing one problem in terms of simple network properties, you are suddenly able to use intuitions acquired from completely different fields. A straightforward example is that the spread of a disease in a country and the spread of a virus on a computer network are studied using the same network models. But maybe more surprising is the fact that engineers who study the robustness of the aviation network are probably using the same models as neuroscientists who are looking at failing connections correlated with Alzheimer's disease...

The KNF group in Amsterdam is certainly not alone in this approach of studying the brain in the context of networks. All over the world research groups d involved in neuroscience and networks are joining forces in a similar pursuit. In analogy with the other famous "-omics" like genomics or proteomics, the term connectomics has been used to refer to this effort to study the brain by looking at its connections.

Hubs: from Schiphol to Alzheimer's disease

When I first started in the hospital I hardly knew anything about the brain, let alone about connectomics. But through weekly meetings and discussions, I got the wonderful opportunity to learn about these subjects from experts in the field. Since some people in the group are also active as doctors in the hospital, the research focus is closely related to medical practice. They are really trying to solve the problems they come across in the treatment and understanding of diseases like epilepsy, dementia, Alzheimer's or multiple sclerosis.

For my project, I was asked to look at how the brain network behaves at the beginning of epileptic seizures, and more specifically at the role of "hub nodes" in the network. Hub nodes or simply hubs are those nodes in a network that play a "more important role" than others. In a social network for example, that guy with 1.471 Facebook friends and 500+ followers on Twitter is probably a hub. Or in aviation networks the airports with many intercontinental flights like Schiphol can be seen as hubs. Interestingly, there also seems to be a special role for hub nodes in the brain's network. Many studies are showing, for instance, that in neurological disorders like Alzheimer's disease or epilepsy there are hub nodes that are functioning abnormally. The question is then of course, why do these hubs exist in the brain and why are they causing problems...

In my project, I worked with dEEG recordings from ten epileptic patients and tried to relate the location of hubs to the occurence of seizures. Depth EEG (dEEG) is a measurement technique where electrodes are implanted in the brain to locally measure the electrical activity in the brain. It is a highly invasive measurement technique as you can see in Figure 2, but it offers high resolution in measuring brain activity. This resolution is critical for finding the starting point of the seizure, also called the seizure onset zone (SOZ). Localization of the SOZ is an important diagnostic tool in the treatment of epilepsy. If it can be found and a number of additional criteria are met, partial resection of this area of the brain can "cure" the epilepsy. In other words, finding the right piece of brain to cut out can stop the epileptic seizures. Currently, the neurologists are looking at the dEEG recordings with the naked eye to locate the channels in which the seizures start, and thus locate the SOZ. Therefore, the ability to obtain the same localization based on network parameters (if possible) would certainly be of great use. Additionally, any result that relates network properties to manifestations of the disease might lead

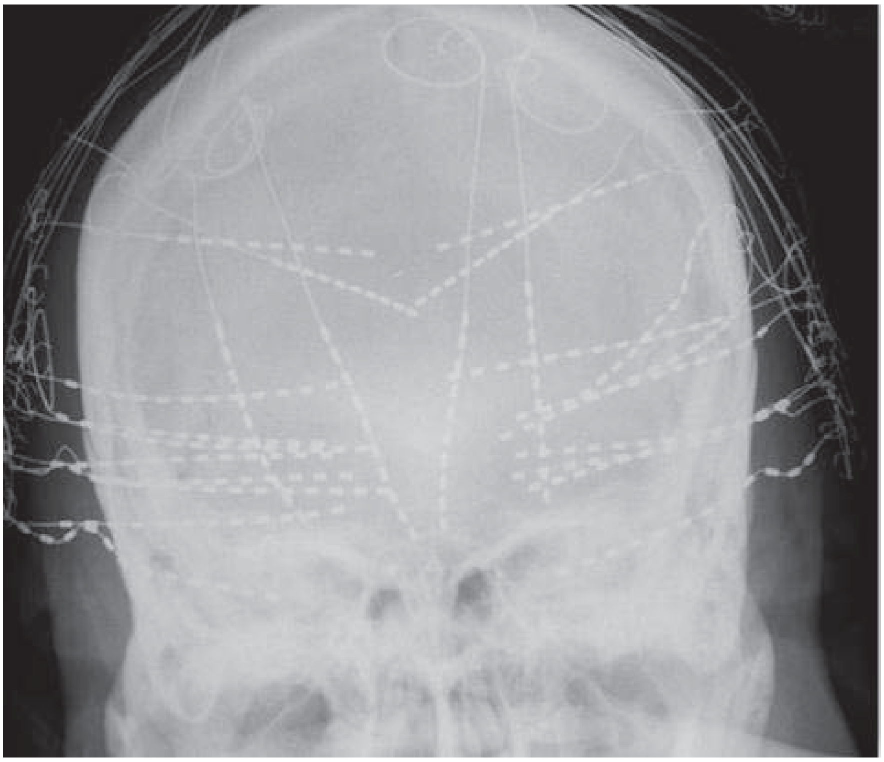


Figure 3: *In depth EEG measurement electrodes are implanted in the brain to provide very precise activity readings. This image shows an X-ray image of implanted electrodes.*

to a deeper understanding of the exact nature of epilepsy.

Four months later...

During the four months I was working at the VUMC, not only did summer change to autumn, but also my project evolved from a one-page proposition into some really nice results. A first outcome I had was the development of a Matlab tool that calculated the 3D coordinates of the dEEG electrodes from images of the head. In Figure 4 you can see how this allows for an insightful representation of the measurement setup. Secondly, we came up with a method that uses hubs in the functional brain network to find a prior hypothesis of the seizure starting location. The method might be used in further research on a larger group of patients to investigate whether it consistently performs well.

So, in practical terms, the project attained good results. But for me, the most important outcomes of the internship have been the personal and professional experiences. I learned a lot, got to cooperate with people from completely different professional backgrounds and had a great time because of the nice work atmosphere and the great colleagues. And, while initially I didn't know anything about the brain, the commute time to Amsterdam, or the possible role of an engineer in medical research, I now feel like I've caught a glimpse of what my future career might look like. All things considered, I can only conclude that it was a great experience, and I'm happy to be able to share it!

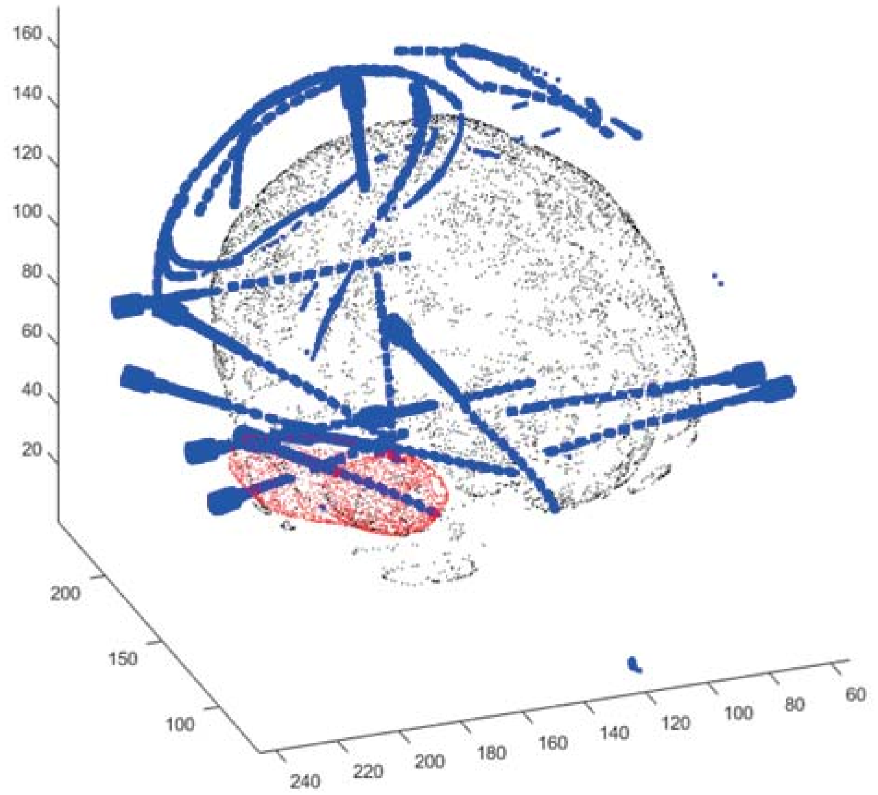


Figure 4: *Based on CT scans, similar to figure 3, the locations of the implanted electrodes can be reconstructed. The coordinates allow a 3D representation of the measurement setup. [3]*

Interested?

If you are interested in learning more about the fascinating world of neuroscience, the website of the KNF group is a great place to start: http://home.kpn.nl/stam7883/index.html. If you want to find out more about network science and which network-related projects the TU Delft is involved in, the website of the Network Architecture and Services group https://www.nas.ewi.tudelft.nl is the place to go.

[1] Olav Krigolson: that neuroscience guy blog, *http://www.olavkrigolson.com/that-neuroscience-guy/archives/04-2016*

[2] Tobias Isenberg (2015) A Survey of Illustrative Visualization Techniques for Diffusion-Weighted MRI Tractography. In Visualization and Processing of Higher Order Descriptors for Multi-Valued Data, pages 235–256. Springer, 2015. ISBN 978-3-319-15089-5 (hardcopy) and 978-3-319-15090-1 (e-book).

[3] The epilepsy foundation, *http://www.epilepsy.com/information/professionals/diagnosis-treatment/surgery/presurgical-evaluation/pre-surgery*

Advertorial

Bulk is beautiful

Rene Smeets
Innovation Manager & service area leader DNV GL KEMA Laboratories

There is no doubt about the rapid increase in non-fossil energy generation in the world. It is mostly generated in remote areas (wind power in US and China), offshore (wind power in Germany), in desert-like environments (solar power in Africa) or in mountainous regions (hydro power in China and India).

Large-scale renewable sources are being developed at a very high rate, requiring bulk energy transmission to the load centers of the world. The one-liner "Bulk is Beautiful" is already gaining traction in renewable energy circles.
Indeed, many companies and authorities are studying plans for "overlay" grids, new power systems, or "supergrids" having very large transmission capacity.

In the framework of the EU Horizons 2020 program, DNV GL is managing the PROMOTioN project on meshed offshore DC transmission networks. In this project, KEMA Laboratories will demonstrate the testing of HVDC circuit breakers which are needed for such networks. At present, almost all DC systems are point-to-point interconnectors, where a fault means loss of the system. In multi-terminal DC grids, this is unacceptable and DC circuit breakers are being developed to isolate faulted network sections without compromising the stability of the entire system.
ENTSO-E, the European Network of Transmission System Operators, envisages a North Sea network, partially DC, to harvest many tens of GW of wind power by 2030. China State Grid is already starting the construction of the first meshed DC grid in the world, at 500 kV, in order to handle the wind and solar power in the north of the country. Also in China, several 1100 kV AC (and soon DC) backbones are in commercial operation, while in India a 1200 kV AC grid is under construction. Japan has plans to revive its – now dormant – 1000 kV system.
In the US, transmission planning is changing in response to the need, mandate and opportunity to integrate large amounts of renewables into the energy mix.
The increase in scale has an impact on testing. Stresses on equipment will increase, because of maximum exploitation of capacity. Nature does not scale, so extrapolation of designs successful at lower-than-super dimensions does not work. Short-circuit currents will increase along with greater transmission capacity, interconnectedness and density of generation. Nowadays, short-circuit currents are increasing up to 80 kA, and test laboratories have to cope with this. New devices, such as current limiters (often based on superconductors) claiming to limit fault current to the withstanding capability of the installation are rapidly coming onto the market – and they need to be tested

with a lot of power.

In AC systems, typical “long distance” components such as series and shunt capacitor/reactor banks, cables, gas-insulated lines provide new challenges for components. Unlike fault current breaking, switchgear dealing with these stabilizing components has to operate on a daily basis. Especially at the highest voltages, new switching duties cause tremendous transients which are potentially dangerous for components.

Standards have to be adapted to include the new ultra-high voltage equipment. They need to take into account new environments, such as long submarine cables and equipment like converter transformers, offshore high-voltage GIS and a host of DC equipment for which there are no standards.

KEMA Laboratories has demonstrated high-power testing of 1100 kV class circuit breakers by applying a double stage synthetic circuit to reach a recovery voltage of over 2000 kV, right after interruption of current up to 50 kA. This was the first time in the world such breaking power was applied.

“Nature does not scale, so extrapolation of designs successful at lower-than-super dimensions does not work.”

Due to the remoteness of their application and the huge capacity at stake, the requirements for equipment reliability are higher than ever.

One way to increase reliability is monitoring and/or diagnostics, but questions have been raised on the reliability of the supervising electronic equipment, its economic lifetime, the interpretation of data and the threshold above which to intervene.

Another approach is reliability testing. In order to accommodate for this, IEC has introduced various endurance classes in its standards, e.g. in the switchgear standard different classes for mechanical and electrical endurance are now defined. In case of higher than usual stresses, the standard provides test programs simulating lifetime ageing of equipment in an affordable test program.

Users of equipment should be aware of the do’s and don’ts of such an approach: it makes no sense to test for electrical endurance in cable systems (with far fewer faults than in overhead line systems) or test a standard circuit breaker for 10.000 mechanical operations. Care must be taken not to inflate requirements beyond reality, which would lead to unnecessary costs.

Standards are like a menu to choose from and not every course should be consumed. Indeed, sometimes problems arise simply from having too many choices. c

Enabling the Next Generation of Miniature Ultrasound Probes

Dr. ir. Michiel Pertijs
Electronic Instrumentation Laboratory, EEMCS, TU Delft

Medical ultrasound uses acoustical waves to visualize internal structures of the human body. A well-known example is the visualization of a baby in the womb. It is a very powerful imaging technique, capable, for instance, of making real-time images of blood flow in the beating heart. The term "ultrasound" refers to the fact that the frequencies used are typically in the MHz range, well above the audible part of the acoustic frequency spectrum. Compared to other imaging techniques, such as magnetic resonance imaging (MRI) and computed tomography (CT), ultrasonic imaging has many advantages: it is safe, portable, fast and relatively cheap.

At the Electronic Instrumentation Laboratory, the Ultrasound ASICs group develops integrated electronics for the next generation of miniature ultrasound probes. "Miniature", because they will be small enough to fit at the tip of an endoscope or catheter, orders of magnitude smaller than conventional handheld probes. Moreover, our probes will be capable of performing real-time three-dimensional (3D) imaging, which leads to extreme challenges in integration density and power efficiency. This calls for innovation in the design of the critical electronic building blocks, such as low-noise amplifiers, analog-to-digital converters and high-voltage pulsers.

We do this multidisciplinary research in close collaboration with the Acoustic Wavefield Imaging group of the Faculty of Applied Sciences and the Thoraxcenter of Erasmus MC in Rotterdam. In several joint research projects, we are developing advanced ultrasound probes, for instance for endoscope- and catheter-based real-time 3D cardiac imaging.

Medical ultrasound

In medical ultrasound, an ultrasonic transducer, a device that can both transmit and receive acoustic signals, is used to generate short acoustic pulses that travel into the body at a speed of about 1540 m/s. Whenever they meet the interface between different types of tissue, they partially reflect back. The arrival time of these echoes at the transducer provides information about the depth of the structure from which the echo originated. Thus, structures that are located along a line extending from the transducer into the body can be visualized, a so-called "a-mode" scan.

Much more information can be obtained if a two-dimensional (2D) image can be made. To do so, the transducer is divided into a number of transducer elements, each of which can independently transmit and receive acoustic pulses. In a so-called phased-array transducer, the individual transducer elements are pulsed with small relative time delays, so that the waves they generate together form a beam in a particular direction. Thus, only structures along the path of this beam will generate echoes. When these echoes return to the transducer, they will arrive at slightly different times at different transducer elements, as shown in Fig. 1. By ap-

"Extreme challenges in integration density and power efficiency"

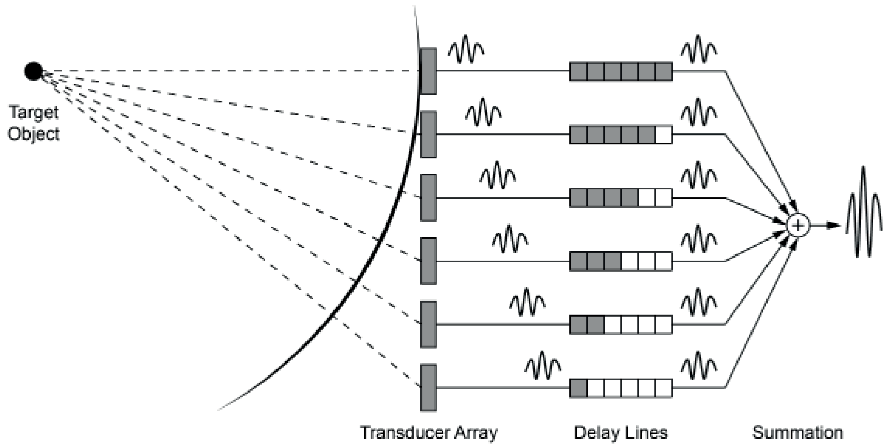


Figure 1: *Phased-array ultrasonic transducer in which received echoes are combined by means of a delay-and-sum beamformer.*

propriately delaying the signals received by the elements, only echoes arriving from the direction of the beam will constructively add up. Thus, a phased-array transducer is capable of selectively imaging structures within a beam through the tissue. By electronically changing the delays in successive pulse-echo measurements, the direction of the beam can be changed and a volume of tissue can be scanned.

From 2D to 3D

Conventional phased-array transducers consist of a one-dimensional (1D) array of 64 up to 256 transducer elements, each of which is wired up to an imaging system on the bedside of the patient, with electronics for generating pulses and recording echoes. Using such a 1D array, beam steering can only be performed in one dimension, resulting in a 2D cross-sectional image of the body, also known as a "b-mode scan". Such phased-array transducers are used, for instance, to make images of the heart using a handheld probe on the chest of the patient.

To make 3D images, which are easier to interpret and provide more useful visualization during complex medical interventions, beam steering in two dimensions is needed. This calls for 2D transducer arrays, also known as matrix transducers, which consist of thousands of elements. Connecting these individually to an imaging system is not feasible. Therefore, electronics are integrated close to the transducer array in the probe tip, to perform multiplexing or local beamforming. Matrix transducers can produce impressive 3D images of a baby in the womb (Fig. 2), or can provide valuable guidance during complex catheter-based interventions in the heart, such as valve replacement.

Advanced electronics

Due to the large number of elements, realizing 3D imaging in a handheld probe is technically challenging. Doing the same in an endoscope, or at the tip of a catheter, is even more so. Endoscope-based probes are used, for instance, to obtain high-quality images of the heart from the esophagus of the patient. Catheter-based probes can do the same from within the heart. The mm-scale dimensions of such probes require extreme miniaturization. Fig. 3 shows, as an example, a prototype matrix transducer that we have developed for endoscope-based cardiac imaging. It consists of 32 x 32 elements. This number far exceeds the number of cables that can be realistically accommodated by an endoscope or catheter. Therefore, channel reduction should be performed locally, using an Application-Specific Integrated Circuit (ASIC) closely integrated with the transducer array.

The design of such an ASIC is challenging for several reasons. First of all, per element, a chip area of only about 150 × 150 μm^2 is available. Moreover, there is a strict limit on the power d

Figure 2: *Example of a 3D rendering of a baby in the womb, generated using a matrix ultrasound transducer (source: www.philips.com).*

“A maximum power dissipation below a mW per element”

consumption, since the associated temperature rise should be kept within regulatory limits (no more than 4 °C). This translates into a maximum power dissipation below a mW per element, while signals with a bandwidth of several MHz and a dynamic range on the order of 80 dB have to be processed. Finally, the number of cables with which the ASIC is connected to an imaging system, should be comparable to that of conventional 2D probes, i.e. an order-of-magnitude less than the number of elements.

In the ASIC, shown in Fig. 4, we solve these challenges by dividing the array into sub-arrays of 3 × 3 elements, and locally applying the time delays required for beamforming. Thus, a 9 × channel reduction is achieved. We have developed a power-efficient analog implementation of this concept, requiring only 0.27 mW per element. In a next generation of the chip, which is currently being evaluated in our lab, we have managed to also integrated analog-to-digital converters in the same chip area, providing a further 4 × reduction in the number of channels.

Outlook

The ability to integrate matrix transducers with many elements with low-power integrated electronics is not only useful for cardiac imaging. We are also working on high-speed imaging of the carotid arteries (the major blood vessels in the neck that supply blood to the brain), for early diagnosis of cardiovascular diseases and risk of stroke, and on intra-vascular imaging, for diagnosis and treatment of conditions of the coronary arteries of the heart. Recently, a new research project has been granted in which we will expand our activities towards neonatal brain imaging. In this project, we will develop a battery-powered, wearable ultrasound device that will monitor the blood perfusion in the brain of preterm babies, enabling doctors in the neonatal intensive care to detect early on whether perfusion problems occur in the brains of these underdeveloped, fragile children. A common feature of these projects is that they require electronics with integration density and power efficiency beyond the state-of-the-art, thus providing a challenging and interesting context for research in integrated circuit design. c

Figure 3: *Miniature ultrasound probe for cardiac imaging from the esophagus: (left) an artist’s impression of the probe; (right) a realized prototype chip with a 1024-element matrix transducer built on top.*

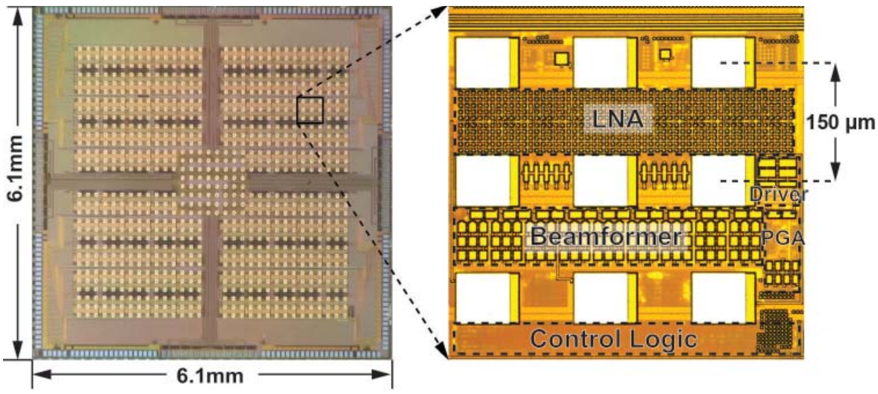


Figure 4: *Chip photo of our ASIC for endoscope-based cardiac imaging.*

Passive wireless link
for a low-power mouse brain implant

Ir. Ide Swager

From August 2015 to September 2016 I worked on my graduation project in the Bioelectronics section headed by Prof. Wouter Serdijn. One of the Bioelectronics section focus areas is the development of electroceuticals. They are the electronic equivalent to pharmaceuticals. Typical examples of these devices are pacemakers and cochlear implants, but many more applications are emerging, leading to the development of a wide variety of diagnostic and treatment tools. Electroceuticals measure and/or manipulate the electrical signals present in the body, e.g. a pacemaker activates the heart muscle. In this article, I will try to explain the part of my thesis work that focused on a wireless communication system for such a device. I start with background information on the application and the requirements, after which I describe the design of the system and the practical realisation. Only one result will be highlighted.

Epilepsy

The brain is essentially a big electrochemical processor; hence it can theoretically be monitored and influenced by electronics. Many brain-related diseases cannot be treated well by conventional medicine, or with considerable side effects. Epilepsy is one such disease.

Patients suffering from epilepsy experience seizures that exhibit symptoms like body wide spasms or complete apathy. They generally do not remember the seizures and suffer brain damage with every seizure. This limits the patients in their freedom, because seizures can be life threatening in many situations (e.g. while driving a car). In the mouse brain signal depicted in Figure 1, red boxes indicate seizures.

About 70% of patients can be treated adequately with drugs, with moderate to significant side effects. For the remaining 30%, neurosurgery might be an option. However, invasive brain surgery is a high-risk operation that can cause loss of brain functionality.

The neuroscience department of the Erasmus Medical Centre (EMC) works on the analysis and treatment of epilepsy. In cooperation with the Bioelectronics section, an electroceutical for epilepsy is being developed. My thesis project was part of a larger whole, and builds further on the work of previous MSc and PhD students. During my project, collaboration was needed to work towards an integrated system. A schematic overview of the system is given in Figure 2. On the one hand, the brain signal is measured. This data is transmitted via a wireless link. Another wireless link provides power to the device, and a means of influencing the brain using optogenetic stimulation. This form of stimulation is based on modifying certain cells of the brain to become light sensitive. With light at specific wavelengths, these cells can be stimulated. My

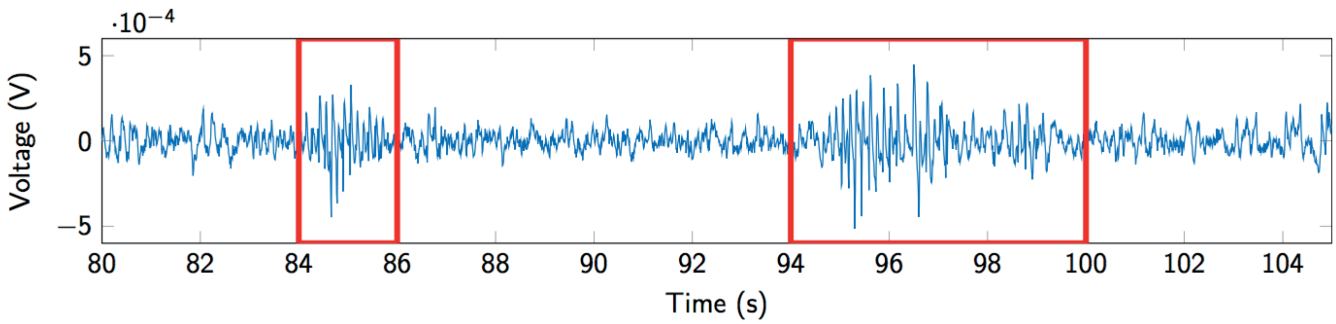


***Figure 1:** Recorded mouse brain signal (Electrocorticogram), with seizures indicated by red boxes; the recording was performed using the Analog Front-end developed for my work, in collaboration with ir. Matthijs Weskin.*

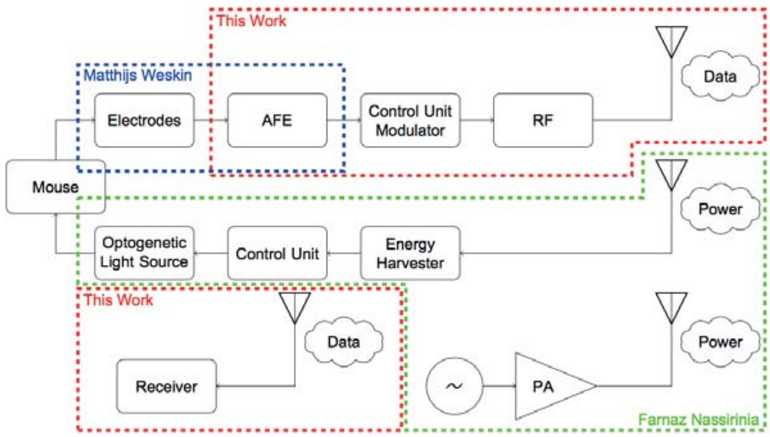


Figure 2: *System overview*

colleague ir. Farnaz Nassirinia worked on this part. For more information on optogenetic stimulation, please refer to her article in the Maxwell 18.4.

Algorithmic brain data analysis is then used to detect seizures. When a seizure has been detected, the brain can be stimulated to stop the seizure. This means the system is a closed-loop system.

Requirements

My task in the project was to build a wireless link to get the brain signals from the head of the mouse to a receiver. Why wireless? Because it is important that the mouse moves freely with minimal influences on the mouse's normal behaviour. To make the system more versatile, I decided to design it such that multiple mice could move around and interact in the same confined space. Neuroscience experiments involving social aspects would then become possible.

One of the big challenges of this project was the practical environment. A mouse weighs on average a little less than 20g. It can maximally carry 10% of its weight on its head (imagine yourself carrying 6-8kg on your head). This puts a hard limit of 2g on the weight of the device. The size was limited to a cubic centimetre.

As with all portable wireless devices, the available energy storage is limited. For this reason, I decided to make use of a passive wireless communication link or backscatter link. Backscatter links are used in many applications today: your public transport card (OV-chipkaart) is a well-known example. The basic principle is that the link becomes highly asymmetrical. At one side, there is a transmitter that transmits a carrier wave, 915 MHz in my case. The tag antenna picks up this carrier wave. Meanwhile, the load that is attached to the tag antenna is changed between two predefined states. This changing of antenna load changes the reflective properties of the antenna, reflecting the carrier wave. A receiver can detect this difference in the reflected signal, thus establishing the communication.

A fun analogy

To make this more understandable for readers that are less familiar with electromagnetic wave theory, I have thought of an analogy. Imagine you are stranded on an uninhabited island, and you would like to survive and get off the island. In the distance, you see a ship. However, it is too far away to spot you. You do not know how to make a signalling fire. Luckily, you appear to have a reflecting piece of metal with you. The sun is shining brightly. Using the mirror (tag antenna load), you can reflect the sun's light (carrier wave) onto the ship, on the eyes of the captain (receiver). By alternating between shining in the captain's eyes, and shining somewhere else (On-Off Keying), you can communicate in binary or Morse code (the encoding) that you are on this island.
Similar to the actual experimental setup, there is a large difference in signal strength between the sun's light and the light that is reflected by your mirror. In practical backscatter systems, this difference can be up to 100 dB. This is about the same as trying to hear a mosquito when a jet fighter is doing a low altitude flyby.

In the realisation of the backscattering system, I decided to make it as flexible as possible. Flexibility (in the design) is important, because experiments may change, and the device should be adaptable to new experiments. That is why I decided to use off-the-shelf components and software implementations as much as possible. In Figure 3, a rough overview of the system is displayed. The brain d

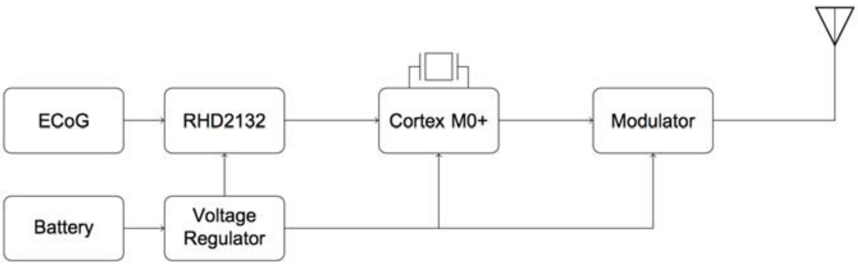


Figure 3: *System at the side of the mouse*

of the device is formed by the Cortex M0+ microcontroller (MCU). This MCU communicates with the AFE IC (RHD2132) to acquire the neural data. By controlling the modulator (essentially a switch) in a certain way, the data can be backscattered to the receiver.

Multi-animal compatibility

The multi-animal aspect of my design, in combination with the required datarates for the neural signals (320 kbit/s) formed the core of the innovative part of my thesis. To achieve this, I had to apply an additional technique to the backscatter modulator. If more tags (mice) would be in the range of the receiver, they would likely interfere. I needed a so-called Multiple Access technique, where multiple tags could communicate with the same receiver simultaneously. There are 4 main multiple access techniques: FDMA, TDMA, CDMA and SDMA. Each first letter corresponds to the aspect of the signal that is used to create the multiple access: frequency, time, coding and space respectively. CDMA is used extensively in cellular communications, whereas a variant of FDMA (OFDMA) is used in Wi-Fi.

To keep the electronics at the tag as simple and low-power as possible, I decided to implement FDMA on the backscatter link. In FDMA, the different tags use different subcarrier frequencies. This subcarrier is created by multiplying the main carrier with a lower frequency. In the receiver, filtering can be used to filter out the different subcarriers. By digitally generating the subcarrier signal in the MCU, I was able to generate a flexible solution with as few external components as possible.

Figure 4 depicts a schematic overview of the frequency spectrum that can be present at the receiver in such a system. The red arrows indicate subcarriers, the blue lines are the sidebands (data). Guard bands, which assist with the filtering of the different signals, are indicated between the subcarriers. Figure 5 illustrates how this system works at the tag side. The switch is not controlled by the data signal directly, but in an OOK manner with different subcarriers for mouse A and B.

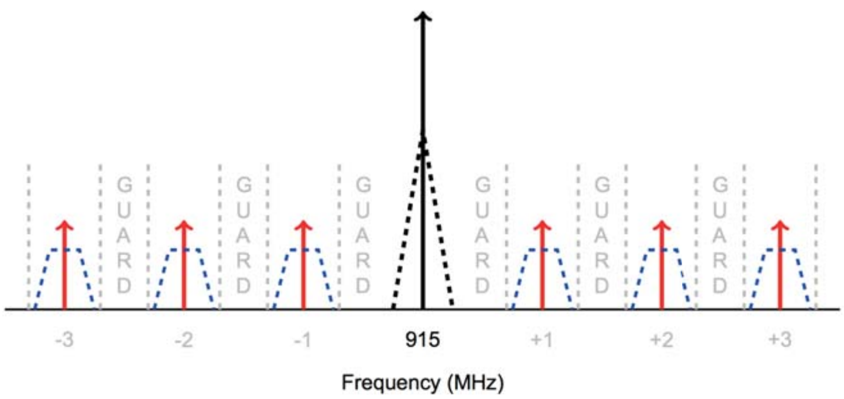


Figure 4: *Illustration of FDMA applied to backscattering*

The engineering

To make the prototype, I had to develop a custom printed circuit board (PCB). As it contained a chip scale antenna, I had to consider high frequency PCB design guidelines, as well as correct matching impedances. These are interesting skills that are not part of the standard curriculum in an MSc or BSc education. Luckily, this is where fellow academic staff and students can be of great help.

For the base station, I bought patch antennas and I used prefab RF amplifiers, filters, mixers and a signal generator. In this proof of principle design, I used a high-speed digital oscilloscope as ADC (R&S RTO1044) and data storage device. Using MATLAB, I performed the demodulation to decode the data (not real-time). Using this set-up, I wanted to investigate the effectiveness of my communication system for this application.

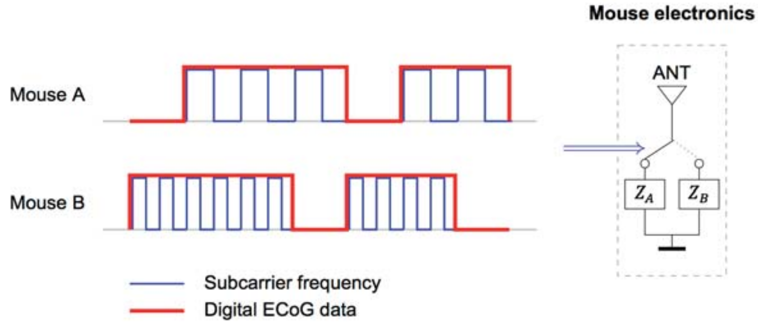


Figure 5: *Practical realisation of FDMA*

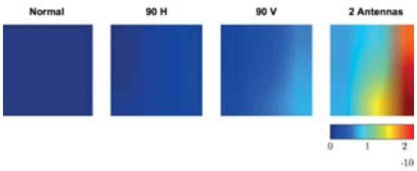


Figure 6: *Subcarrier signal power across the measurement grid*

Results

For this article, I choose to highlight a small part of my results. When I had developed the system, I started evaluating it in different ways. One of these evaluations was very practical in nature: I wanted to know how the communication link would perform when the mouse is moving around the cage. I created a setup made from wood and drew a measurement grid on it. Then I started measuring the subcarrier signal power in all different positions (on a 3x3 grid) and different alignments (90 degrees horizontal and vertical). Furthermore, I also made a system where 1 tag has 2 antennas that are orthogonally oriented with respect to each other. The idea behind this was to compensate for the misalignment caused by the head of the mouse. In Figure 6, the results are plotted in heat maps with all scales normalized. As can clearly be concluded, using two antennas can improve the subcarrier signal power by an order of magnitude. Higher signal power means a lower Bit Error Rate (BER) and thus a more reliable communication link. There is a slight dependence on location, which I concluded to be caused by the laboratory environment. To avoid this, measurements can be performed in an anechoic chamber (which I did not do).

In Figure 7, the received signal is plotted in the frequency domain. The reflected main carrier and 3 subcarriers (red crosses) can be seen by visual inspection. At 920 MHz and upwards, T-Mobile cellular network interference is visible. This is one of the disadvantages of working with the 902-928 MHz ISM band: devices must allow interference by other band users.

Potential future work

Work on this project is still being continued. Additional steps in system integration are needed, as well as further miniaturization. I experienced some limitations in using an MCU, so an FPGA (or CPLD) implementation might be a better option. Depending on the implementation of downlink communication, other multiple access techniques can be considered. If you are interested and looking for internship or graduation opportunities, do not hesitate to contact Professor Wouter Serdijn. Should you have any questions about the article or my work, I will be happy to answer them via email (*ideswager@gmail.com*). c

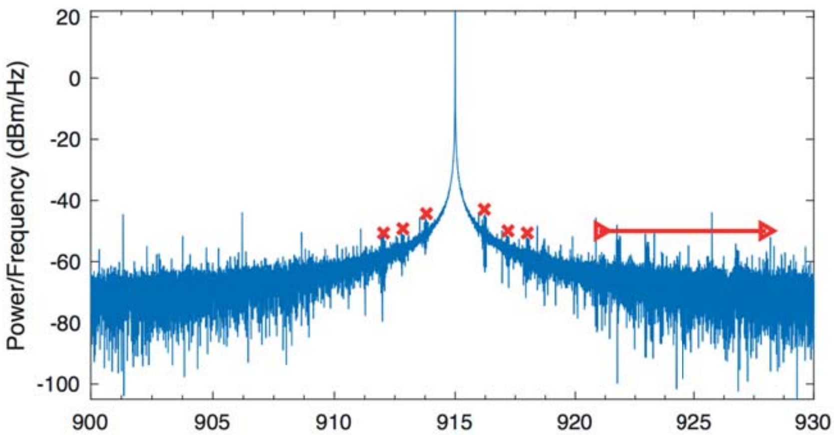


Figure 7: *Received backscattered signal of three subcarriers (indicated in red crosses); interference from T-Mobile band visible at 920 MHz and upwards.*

Lab on a Chip devices
for medical applications

Marinke van der Helm, Mathieu Odijk & Floris van den Brink

Miniaturization of fluidic structures to micrometer-size dimensions offers scaling benefits that enable one to achieve high mass and heat transfer rates, reduced reaction volumes and ultimately the establishment of uniform reaction conditions that can be accurately controlled. This concept has been pioneered by Manz et al. [1], who explored and exploited these scaling benefits to introduce the world to miniaturized total chemical analysis systems (μ-TAS) for chemical separations. Integration of multiple miniaturized functionalities in a single 'Lab on a Chip' device enabled (bio)chemical reactions or measurements to be carried out in small volumes, reducing the amounts of reagents consumed and waste produced, ultimately lowering costs and increasing safety [2]. An example of such a Lab on a Chip is shown in Figure 1. Typically, these devices are equipped with fluidic channels of sizes comparable to a human hair or smaller (50 micrometer or less).

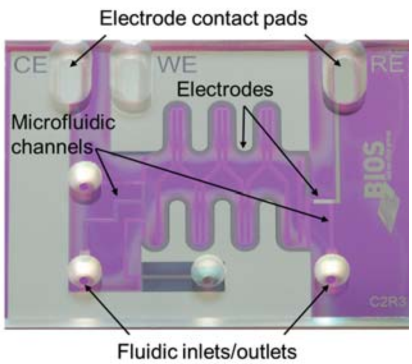


Figure 1: *Example of a microfluidic chip for electrochemical conversion. (Photo: Henk van Wolferen)*

As explained previously in the Vonk magazine [3], research efforts in Labs on Chips have expanded rapidly since the early '90s. One of the main driving forces was the challenge to map the human genome. In 2001, the costs of mapping the genome of a person was $100 million, while in 2015 this had dropped below $2 thousand (see Figure 2). Moreover, the amount of kilobases per day that could be analyzed by one apparatus went from 10 for manual operation in the 1980s to 100 million in 2009 [4]. These are decreases in sequencing time and cost per base pair that were made possible by developments in Lab on a Chip technology.

The BIOS – Lab on a Chip group, embedded in the MESA+ Institute for Nanotechnology and the MIRA Institute for Biomedical Technology and Technical Medicine at the University of Twente, is a research group that develops Lab on a Chip technology for a wide variety of applications, including medical. Many of these developments taking place in this relatively new and exciting field would not be possible without Electrical Engineers. In the following two sections, we show how electrical engineering expertise combined with chemistry and biomedical technology can result in highly relevant medical solutions.

Mimicking xenobiotic metabolism

Many foreign substances are oxidized by enzymes from the cytochrome P450 family, which are abundantly present in the liver [5]. Therefore, oxidative metabolism reactions are of interest for toxicity screening of environmental pollutants, in particular polycyclic aromatic hydrocarbons, which are released, e.g., upon the use of fossil fuels. Several analytical techniques are developed with the goal of mimicking cytochrome P450 activity, among which is direct electrochemical oxidation at an electrode surface. This approach enables rapid evaluation of possible covalent adducts that are formed with endogenous macromolecules, such as proteins or DNA, using a micromixer integrated on-chip with an electrochemical cell (Figure 1 and 3) [6]. Rapid and sensitive detection of reaction products is accomplished by on-line mass spectrometric analysis.

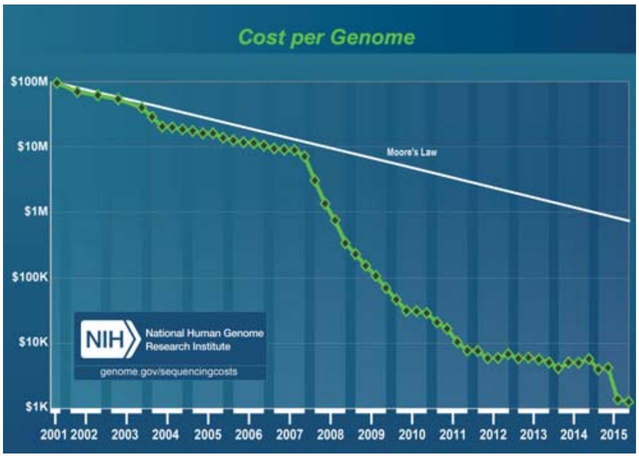


Figure 2: *Cost per genome. (Source: http://www.genome.gov/sequencingcosts/)*

Some design aspects of electrochemical microreactors

Electrochemical cells used in these kinds of analyses consist of a three-electrode system, involving a working electrode (WE) that drives the reaction of interest, which is maintained at a defined potential versus a reference electrode (RE). A counter electrode (CE) closes the electrical circuit. To integrate such a system in a microfluidic chip (Figure 1), both the fluidic and the electrical properties of the microchannels must be considered. Small channel dimensions provide the advantage of high surface-to-volume ratios, enabling rapid electrochemical conversion due to short diffusion distances (x), which is for a 1-dimensional gradient related to the diffusion time (t) per $x = \sqrt{2Dt}$, with D the diffusion coefficient. Therefore, efficient diffusive transport of molecules can be established by locating the electrode at the bottom of a shallow channel. However, the electrical resistance in microchannels with height h increases proportional to $1/h$, whereas the hydraulic resistance increases proportionally to $1/h^3$, so problems associated with Ohmic drop and high pressures should be considered.

Electrical measurements in Organs-on-Chips

Organs-on-Chips are emerging as a new class of tissue models that can be used for biomedical research. These chips combine (human) cells with microfluidics and micro-engineering to mimic the natural environment and function of tissues and organs [7,8]. In addition, (electrochemical) sensors can be integrated into these devices to directly monitor the function of the tissues grown in these chips. Examples are monitoring pH, glucose consumption and production of all kinds of analytes by the cells.

The BIOS – Lab on a Chip group develops a blood-brain barrier on chip (BBB-on-chip). The BBB protects the brain from potentially harmful agents in the blood, such as the xenobiotics and metabolites described previously. Its function is illustrated in Figure 4. However, it also hinders drug delivery into the brain, for example for Alzheimer's disease. Before starting to test drug transport in these BBBs-on-chips, we want to make sure that a proper barrier has formed. Therefore, electrodes were integrated into the chip to measure the barrier function electrically.

Impedance spectroscopy on the blood-brain barrier

The BBB chip (Figure 5) comprises a top channel (representing blood) d

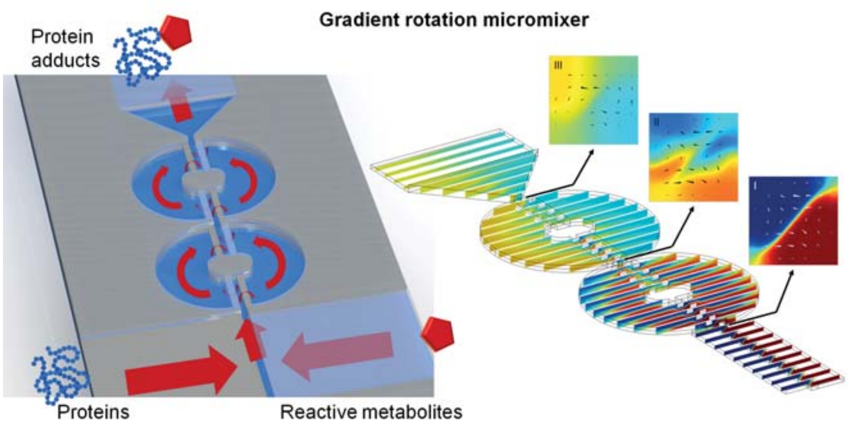


Figure 3: Gradient rotation micromixer to study adduct formation with reactive metabolites generated electrochemically on-chip. (Reproduced from ref. [6] with permission from The Royal Society of Chemistry)

Figure 4: *Schematic illustration of the blood-brain barrier's function. Left: A dye injected into a mouse stains every organ except for the brain. Right: a dye directly injected into the brain is confined there and is prevented from entering the bloodstream. (Adapted from [9])*

and a bottom channel (brain), which are separated by a membrane on which the BBB forms [10]. Four electrodes are inserted into these channels to perform impedance spectroscopy on the formed barrier. By measuring the impedance at different frequencies, information can be obtained about the resistive and capacitive behavior of the cell barrier (arising from the conducting aqueous contents and surroundings of the cells, and their isolating lipid bilayer membranes respectively). Especially the resistance of the cell barrier is of interest, as the "transendothelial electrical resistance (TEER)" is a good predictor of barrier functionality. As these electrical measurements are non-invasive, fast and relatively easy to carry out, they form a powerful tool to assess the quality of cellular barriers.

Summary

These two examples show the tip of the iceberg regarding electrical engineering expertise used in the field of Lab on a Chip for medical applications. Network analysis is used to manage flows and pressure drops in microfluidic systems, impedance spectroscopy is employed to characterize the quality of biological cell barriers, and integrated electrode systems can drive electrochemical reactions to support toxicity studies. Many other exciting examples could be given, and in (almost) every case the collaboration with experts from the fields of chemistry, biology, physics or medicine is essential to obtain optimal results. This makes the BIOS – Lab on a Chip group a fascinating multidisciplinary research environment for students from a variety of backgrounds, including electrical and biomedical engineering, applied physics or nanotechnology. See our website for more information: *https://www.utwente.nl/ewi/bios/*.

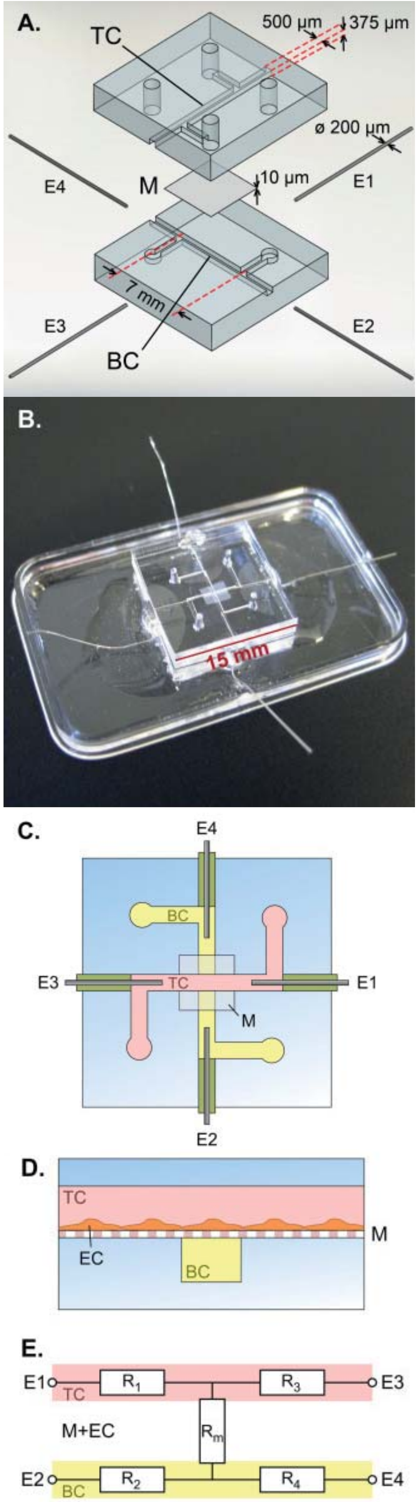


Figure 5: *Blood-brain barrier chip. A. Exploded view with top channel (TC), bottom channel (BC), membrane (M) and integrated platinum electrodes (E1-4). B. Picture of actual chip. C. Schematic top view. D. Schematic cross-section at the center, showing endothelial cells (EC) forming the BBB between the channels. E. Simplified equivalent electrical circuit. (Reprinted from [10] with permission from Elsevier)*

[1] A. Manz, N. Graber and H.M. Widmer, Sensors and Actuators B, 1990, 1, 244-248.
[2] G.M. Whitesides, Nature, 2006, 442, 368-373.
[3] F.T.G. van den Brink, S. Dekker, S.H. Roelofs and M. Odijk, De Vonk (periodical of the E.T.S.V. Scintilla), 33, 10-15.
[4] M.R. Stratton, P.J. Campbell and A. Futreal, Nature, 2009, 458, 719-724.
[5] L.C. Wienkers and T.G. Heath, Nature Reviews Drug Discovery, 2005, 4, 825-833.
[6] F.T.G. van den Brink, T. Wigger, L. Ma, M. Odijk, W. Olthuis, U. Karst and A. van den Berg, Lab on a Chip, 2016, 16, 3990-4001.
[7] A.D. van der Meer and A. van den Berg, Integrative Biology, 2012 4, 461-470.
[8] S.N. Bhatia and D.E. Ingber, Nature Biotechnology, 2014, 32, 760-772.
[9] http://carmichaellab.neurology.ucla.edu/subject/molecular-memory-systems-neural-repair, retrieved on 19-12-2016.
[10] M.W. van der Helm, M. Odijk, J.-P Frimat, A.D. van der Meer, J.C.T. Eijkel, A. van den Berg and L.I. Segerink, Biosensors and Bioelectronics, 2016, 85, 924–929.

Train detection for shunting yards

Ralph van Schelven & Moritz Fieback
MSc students Electrical Engineering, TU Delft

A durable, low power and cheap detection system for trains on a remote shunting yard with a low usage density.

This article describes the implementation of a detection system designed for a rarely used remote shunting yard. The system needs to be durable, low power and cheap. This project is done in cooperation with Prorail, the company responsible for the maintenance and extension of the Dutch railroad system. The problem definition of the project is:

The system needs to detect and identify the trains entering and leaving the shunting yard. The system must be able to output the locations of the trains and the carts on request. The system should be as cheap and low maintenance as possible and run on batteries. The system has to be non-intrusive to the process of the shunting yard.

Three levels of precision were defined:

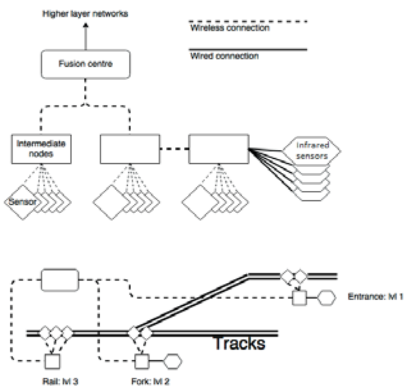
1. Is there a train in the shunting yard?
2. Is there a train on a specific track in the shunting yard?
3. Is there a train at a certain location on a specific track in the shunting yard?

In order to achieve this goal, several concepts for detecting trains were explored following the methodology described by Sage and Armstrong [1]. The measuring methods investigated included: weight sensors, induction sensors, RFID, radar, acoustic sensors, infrared, thermal imaging and vision based detection. After a brief review of the different methods of detection, a score card (table 1) was made from which the best system could be determined.

Table 1: Conceptual design overview

Options	Level 1	Level 2	Level 3	Cost	Overall
Acoustics	+	+	-	+ +	+
Weighing	+ -	+ -	- -	-	-
Induction	+ +	+ +	+ -	+	+
Radar	-	+ -	+ +	+	+
Thermal	-	-	+	-	-
RFID	+	+	+	+ +	+ -
Infrared	+ +	+ +	+ -	+ +	+ +
Vision	+	+ -	-	+ -	-

Based on the score card (table 1) the methods of detection to achieve all three levels of precision were chosen to be infrared (level 1), induction sensors (level 2) and an overview radar (level 3). The infrared sensors will function as a trigger for the induction sensors, which consume more power, to be activated. The infrared sensors will be placed at the entrances of the shunting yard, the induction sensors at the entrances and exits of the individual tracks in the shunting yard, and the radar will be placed in the center of the shunting yard to maximize the overview. Each sensor will be connected to a dedicated battery system, which is recharged by a small solar panel. The sensors are connected through a wireless low power network based on the ZigBee protocol. One central processing node, the fusion center, will combine the results of all sensors and process the data before sending it to Prorail. The following figure shows the installation of the system schematically:



As the targeted shunting yard is not used very frequently, testing the system on such a shunting yard would take a lot of time. Therefore the test system will be deployed in a very frequently used train station, like Utrecht Central Station in the Netherlands. This will allow fast and cheap verification of the system without the need for expensive testing trains on site. If the system proves to work well, it can be deployed at the infrequently used, remote shunting yards.

[1] Sage, A.P. and Armstrong (Jr.), J.E., Introduction to Systems Engineering, John Wiley & Sons, Inc. 2010

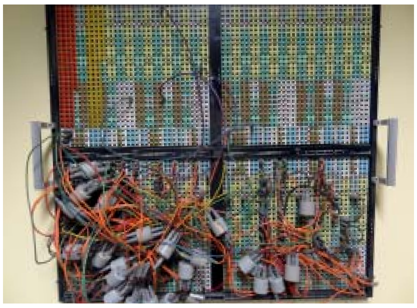
Analoge computer

Het uitvoeren van simulatieberekeningen

Eric Winkel

Een analoge computer bestaat uit een aantal versterkers, schakeleenheden.
De versterkers zijn geschakeld als lineaire versterkers, maar ook als integratoren en differentiatoren. Bij gebruik als integrator wordt een terugkoppeling over de versterker aangebracht met een condensator.
Met behulp van een integrator kan bijvoorbeeld een (gemeten) versnelling worden geïntegreerd tot een snelheid. Met nog een integrator kan de snelheid worden omgezet in een afgelegde weg.
De te gebruiken versterkers zijn zgn. gelijkspanningsversterkers.
De nauwkeurigheid van een versterker was in de jaren 1960 – 1970 nog beperkt. De drift- en ruiseigenschappen van de analoge versterker leidden tot problemen.
Het bereik van de uitgangsspanning van deze getransistoriseerde versterkers was -10 Volt tot + 10 Volt. Vroegere buizenversterkers hadden een bereik van -100 Volt tot +100 Volt.
Omdat zeer stabiele gelijkspanningsversterkers erg moeilijk waren te construeren, nam men zijn toevlucht tot zgn. chopperversterkers: De gelijkspanning werd in mootjes gehakt waardoor de spanning een wisselspanning werd; de wisselspanning werd versterkt en dan weer synchroon gelijkgericht.

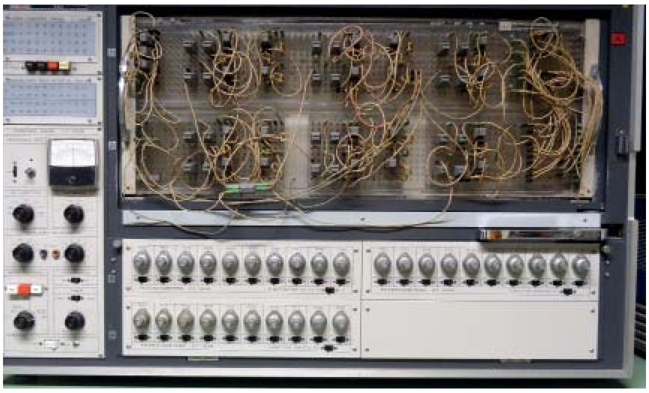
Analoge computers zijn vooral geschikt om oplossingen van differentiaalvergelijking te benaderen. Zeker tot in de jaren 70 van de twintigste eeuw was deze methode in gebruik. Het voordeel ten opzichte van de toenmalige digitale computers was dat de resultaten direct na een initiële stabilisatietijd, beschikbaar waren en het variëren van parameters slechts het draaien aan een knop vereiste. Bij digitale computers was het in die tijd nog gebruikelijk om een programma eerst in te ponsen de ponskaarten bij de balie af te leveren en dan later de uitvoer op te halen. De uitvoer (vaak als functie van de tijd) werd met behulp van een X-Y-plotter op papier gezet of met een oscilloscoop afgelezen. Ook werd een storage-oscilloscoop gebruikt waaraan een speciale printer was gekoppeld. Met de opkomst van snelle, digitale computers met grafische interfaces nam toepassing van analoge computers af; de met de analoge computer mogelijke berekeningen en simulaties zijn op dergelijke systemen in software veel eenvoudiger te realiseren en te visualiseren.
De programmering bestaat uit het met elkaar verbinden van de diverse onderdelen en het instellen van parameters door het instellen van potentiometers. Als je een ander systeem wilde doorrekenen dan moest de schakeling weer worden afgebroken en op een andere manier weer worden opgezet. Door het gebruik van patchborden was dit niet meer nodig en kon je eenvoudig van schakeling wisselen. Zie figuur 1.



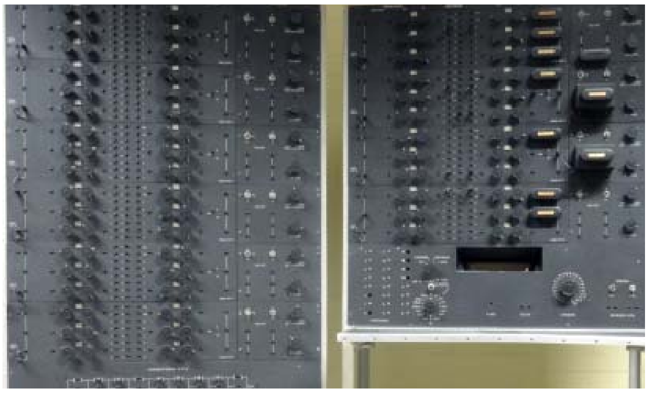
Figuur 1: Patchboard analoge computer Applied Dynamic 4 (AD4). In de Jaren 1960-1970 stonden er twee van deze systemen bij het Rekencentrum van de TU.

Een van de oudste analoge computers in de studieverzameling is gebouwd door de Technisch Physchische Dienst van TNO en tot 1965 gebruikt bij de faculteit Luchtvaart- en Ruimtevaarttechniek. Met behulp van schakelaars kan de uitgang van een van de 16 versterkers worden gekozen. De uitlezing gebeurt met een spiegelgalvanometer. Voor iedere nieuw op te lossen probleem moet er gepatcht worden en de oude schakeling worden afgebroken.

Referenties
Workshop – Analoog Computing, Bern Ulmann
Vitrine museum, TU Delft, Kees Pronk

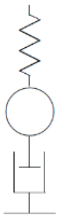


Voorbeeld hoe een analoge computer te programmeren.



Een voorbeeld van een analoge computer met een patchbord is de Hitachi 240. Deze heeft 40 chopper gestabiliseerde versterkers, 30 potentiometers, variabele diode functie generator, vermenigvuldigers, logische blokken, etc. in gebruik rond 1970.

Simulatie van het gedrag van een mechanisch systeem bestaande uit een massa, veer en demping. De basiselementen met de mathematische representatie van de krachten zijn:



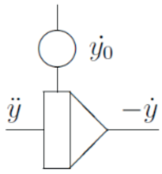
$F_s = sy$

$F_m = ma = m\ddot{y}$

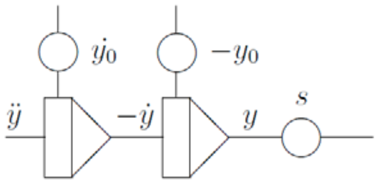
$F_d = d\dot{y}$

Met behulp van Newton geeft dit de volgende vergelijking, $F_m + F_s + F_d = 0$ of $m\ddot{y} + d\dot{y} + sy = 0$.

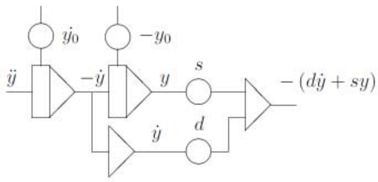
Om dit op te lossen op een anologe computer moet dit herschreven worden zo dat de hoogte afgeleide van y aan de linkerzijde staat: $\ddot{y} = -1/m\ (d\dot{y} + sy)$. We nemen nu aan dat $\ddot{y}$ bekend is en dat we de andere termen kunnen generen door integratie, vermenigvuldiging en sommeren. Let op: Sommeren en integreren veranderen het teken. We verkrijgen $-\dot{y}$ door het integreren van $\ddot{y}$ door gebruik te maken van een integrator. We moeten nog wel een initiële waarde toe kennen $\dot{y}_0$ zie volgende figuur:



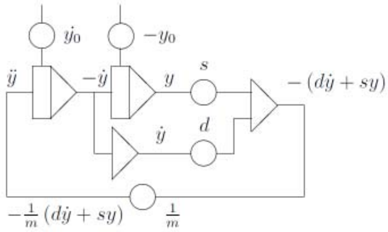
Met de volgende stap maken we de kracht $F_s = sy$



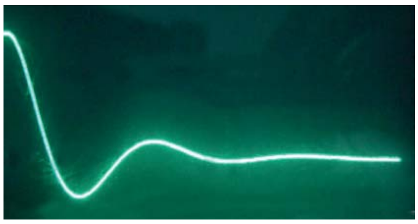
De krachten van de demper, F_d, maken we aan de hand van $-\dot{y}$



De som van $-(F_s + F_d)$ kunnen we nu maken door deze te vermenigvuldigen met 1/m wat dan $\ddot{y}$ oplevert. De hele schakeling ziet er dan als volgt uit:



Dit implementeren we op de analoge computer door het maken van de verbindingen tussen de juiste componenten. We kunnen dan een oscilloscoop aansluiten om het verloop ven y te zien in de tijd. Dit geeft voor de waarde s = 0.6 en d = 0.8 het onderstaande figuur:



Voordeel van analoog rekenen, aan de knoppen draaien levert direct resultaat. Iets wat in die jaren nog niet mogelijk was op een digitale machine.

Advertorial

Here's your contact with the future

Be part of progress

Electrical Engineering student Kevin on being a campus promoter for ASML

Kevin will be finishing his bachelors this year, and then it's on to the next step: a Masters in Telecommunication, specializing in wireless information transfer. He is an old hand at putting students in touch with potential employers; that's what he did during his Board Year in the Electrotechnical Study Association (ETV). Electricity is all about making the right connections. And if you want to make the right connections at ASML, Kevin is your man.

He first got to know ASML while on the Board of ETV and immediately realized that this could be a great place to work. How else? For a guy who is so into cutting edge technology, there was an instant attraction to this super-high-tech company. ASML develops and manufactures the highly advanced machines used in the fabrication of microchips. Therefore, when Menno, the previous ASML campus promoter, suggested to Kevin that he should take over his role, he needed no further encouragement. "Menno and I had worked together before, and have quite a lot in common, so I thought I would also be a good fit for the company, like he was." It was Kevin's enthusiasm – and possibly also the fact that he is a communicator at heart – that landed him the job.

How Kevin can help you

Kevin: "Basically, together with two of my colleagues, I represent ASML in Delft. We help organize events, arrange field trips and Excursion Days to ASML, assist with the recruitment of students, interview them and give them a hand with the application process, and generally act as the go-between, connecting students and the company.

As an ambassador and promoter of ASML, Kevin and his colleagues have "direct hotlines" to the company's Human Resources staff. "If we recommend a promising student to ASML, they take it as an endorsement by us, and will treat the application as a priority. So, being introduced to ASML through a promoter will definitely speed up the process, and you are more likely to get an interview soon."

Kevin went on a two-day training course at ASML in Veldhoven to learn precisely what it is that the company is looking for in potential employees. "It's not just about getting good grades (but it helps of course). It's also about being socially active, doing something extracurricular like a Board Year, and basically being a well-adjusted, balanced human being!"

Kevin raves about ASML

Kevin says the people at ASML are very supportive and helpful, and this applies not only to the HR staff. “In fact, I noticed something that I thought was quite cool about the Customer Support Department at Veldhoven: they’re not just sitting in a call center fielding calls, but when there’s an issue, they will sometimes literally assemble a team of experts from R&D to sort out the problem. They even have an aerospace engineer on board at Customer Support.”

Besides the training he underwent at ASML, Kevin has a good feel of what’s required. “The more students we put in touch with ASML, the more feedback we receive about the suitability of applicants. So we’re forming a pretty good idea of what ASML wants.”

He says the company is looking for employees with talent, qualifications and commitment. “The Extreme Ultra-Violet lithography machine that ASML is developing brings a whole new set of challenges. They’re working at a much smaller wavelength of light, at incredibly tight tolerances, so everything has to be done with extreme precision.”

A cool place to work

About ASML as an employer: “My first impression at Veldhoven was that the company seemed a lot smaller than it really is. That’s because it’s so informal. The big corporate mindset is non-existent. Sure, there’s a hierarchy, but everyone is treated as equals and each person’s opinion is appreciated. I also see a lot of interaction between departments.”

> *“If we recommend a promising student to ASML, they take it as an endorsement by us, and will treat the application as a priority.”*

About campus life

“Delft is really good on a national level. In my faculty there is a lot of contact between students and lecturers. The professors are very cool, and always willing to help. They even join us sometimes in our pub in the basement of the faculty building.”

Kevin is a master organizer. Together with three other students, he is organizing a study tour for August 2017 during which 23 students and a professor will visit companies in China, Japan and Australia. In 2014, he was the chairperson of the congress of the Electrical Engineering Students’ European Association (EESTEC), which was held in Madrid and attended by over 160 delegates. Kevin said he learned a great deal at that event about bringing people together and how to approach differences in cultural and other viewpoints.

About being a campus promoter

“I’d like students to see me as a very approachable person. For many students, there is a huge perceived obstacle between them and a potential employer, especially when the company is situated far away. My colleagues and I understand how these aspiring employees feel and we know how to deal with this level of communication. We strive to make the process painless.”

Connect with Kevin

To chat with Kevin about the opportunities offered at ASML, give him a call at 06 – 448 610 84 or mail *asml.delft@gmail.com* with Kevin in the subject line. c

Faculty Student Council

Daniël Kappelle

Ever run into problems in the faculty? Ever wonder why things are going the way they're going? Fear not, the Faculty Student Council (FSC) has got your back. Continue reading to find out what we are all about!

What is the FSC?

Some may know what we do, but for those who do not yet know: the FSC or Faculty Student Council is a student representative council within our faculty EEMCS (or EWI). The council consists of 4 Electrical Engineering students, 4 Computer Science students, 3 Mathematics students and 1 SET student of both master and bachelor programmes. In practice the FSC will try to improve the faculty on behalf of the students by giving advice and participating in important meetings and discussions within the faculty. An important method of achieving this, is the FSC-faculty meeting, which is an official meeting between the FSC and the dean, although the Directors of Studies and possibly other relevant guests are usually present as well. Furthermore, the FSC has to approve several official documents. These documents are the Teaching and Exam Regulations of both the bachelor and the master, the education programmes from the Student Charter, the faculty budget and the faculty regulations. Additionally, the FSC has the right to advise and the right of initiative regarding anything relevant to the students of EEMCS. The right to advise entails that the faculty has to ask the FSC for input on certain matters. The right of initiative implies that the FSC is free to discuss and advise on any subject. Last but not least, the FSC of EEMCS also discusses university-wide issues through meetings with all of the FSC's and the Student Council (SC) of the university.

Your input counts!

As the FSC our job is to represent all the students of our faculty. This means we can not operate on our own. We need your input!

One way we get your input is by organizing our 'coffee moments'. We have already had one of these this year, which was a great success. The general idea is simple: we serve free coffee in the main hall of EEMCS and in turn you tell us what you think of certain topics. During our last moment, we had tons of post-it notes on the boards and many lively discussions with students about issues concerning our faculty.

So, does this help? Well, yes! We gathered all the notes afterwards, categorized them and drew some conclusions. Probably the most common problem was a lack of places to study in the building. We thought about this problem and discussed it with the faculty. This resulted in opening unused lecture halls during exam periods, so they can be used as study space!

Want to know more?

There is a ton more to tell about the FSC and what we do, so make sure to have a look at our Facebook page: *facebook.com/eemcs.fsc*. Also if you have any questions or remarks, you can leave them on our facebook, send an email to *fsr-etv@tudelft.nl* or find somebody in one of those fashionable FSC sweaters!

Symposium

The Future of Driving

Elke Salzmann

Ever since the car was invented people have tried to improve them. However, it took almost a century for the first automated vehicle started to hit the road. Cars now have cruise control, lane keeping assist technology and a bunch of other cool 'automatic' stuff. We even already have a few driverless cars on the roads, although we still have a long way to go before most if not all cars are autonomous.

The human factor in safe driving is probably the greatest cause of fatal road accidents. If we can somehow remove human beings altogether from the equation, then is it possible to prevent road accidents using better technology? This was the main topic of discussion during the 'Future of Driving' symposium. The presentations covered pretty much everything that concerns car automation; from car safety to radar in a more technological vein and several social and ethical concerns that pertain to driverless cars.

The chairman for the day was Dariu Gavrila, who is a professor at the TU Delft in charge of the newly created research group 'Intelligent Vehicles'. He opened the day with a presentation of currently running projects on car automation at TU Delft and introduced the other speakers. He also moderated the discussions between the speakers and the audience when the presentations had been concluded.

A lot of interesting questions particularly on the challenges of automated driving were asked such as "Should the driver be protected at all cost, even if an accident is not preventable?" and "How could the automated vehicle be integrated in the existing infrastructure?" bringing to light the fact that a lot is yet to be done before automated cars can legally drive on our roads.

All in all, the event was a great success. Pictures and links to the presentations can be found at *symposiumetv.nl*.

Activities

EESTEC

It has been a year since a group of EESTEC members came to Delft. The participants in our workshop came all the way to Delft to explore the university and experience the Dutch student life with a bit of sightseeing. We had the pleasure of hosting students from all over Europe (Turkey, Germany, Greece, Serbia, Macedonia, Romania and Slovenia).

The participants had a busy week ahead of them from the moment they arrived. From typical Dutch games, a trip to Amsterdam to a practical session on solar energy in the Solar lab. All in all it was an exhausting but fun week! Something to highlight is the international night. During the International night we were able to try local foods and drinks that the participants brought with them. It most certainly was a week to remember!

Do you want to know more about EESTEC? Then visit EESTEC.net, ask one of the committee members or someone in the ETV Board!

Niels van Lith

The SET Pubcrawl

On Friday November 18, Delft SEA had its first pubcrawl. About 50 students split into three teams and rotated around some pubs in Delft (Willie Wort, De Kurk, and De Joffer) before meeting at Area 015 at the end for a closing party. The event was a great opportunity to mix first and second year students in a fun environment. It served also as a fundraiser for other future events of the association, and the great discounts from the pubs allowed the purchase of affordable tickets while still offering a lot to the participants. The event went from around 19:30 to well after midnight, and was such a success that another will be organized after the exam period of Quarter 2, this time including more pubs as well.

Ibrahim Diab

Party in Leiden

On Wednesday 26 October 2016 the annual joint party of the ETV and Emile, the study association of the program Educational Sciences from Leiden, was held. It was at the nightclub NEXT in Leiden where the famous Armin van Buuren started his DJ-career! Of course Armin was not present, but the amazing party DJ “aangeschoten Bob” (tipsy Bob) was the DJ of the night. Since it was a Halloween-themed party, a lot of people came wearing exceptional or surprising costumes. I thought the board of the ETV had made the best ones, combining the sophistication of a vest and tie with the Halloween vibe of being covered in blood and having a knife through your head! The party was very successful and I hope it will be even better next year.

Ids van der Werf

TRACKx

Students from the MSc Sustainable Energy Technology need to choose in their first year a track to follow so as to specialize in a form of renewable energy. The track leaders present their tracks to the new students, and give them insights into the research and courses of each profile.
To help students with their choices, DelftSEA organized TRACKx on October 13, a week after the presentations from profile leaders.
The TRACKx event, pulling its inspiration from the TEDx talks, is an “independently organized Track event.”

“The track leaders present their tracks to the new students"

The event brought student representatives from each track to speak of their personal experiences and internships/projects. Later, everyone moved to the /Pub where students had the opportunity to socialize with the second year students and ask more about the tracks to help narrow down their choices. In a survey filled after the event, almost half of the students had made a track choice.

Ibrahim Diab