

# Meeting minutes: Design – Adaptive Hearing Aid 1<sup>st</sup> meeting

[17 September 2018], [10:15 am]

Wits Chamber of Mines, School of EIE, Seminar Room

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**Facilitator:** Prof. Rubin

**Note taker:** Arunima Pathania & Fiona Oloo

**Attendees:** Kavilan Nair, Iordan Tchaparov, Joel Oommen, Arunima Pathania, Kyle Govender, William Becerra, Fiona Oloo, Boitumelo Mantji, Verushen Coopoo, Lindokuhle Mbatha,

**Agenda:**  
Overview

**Absent:** Daniel Edwards, Jean Jordaan

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## **Agenda item:** Overview

A brief introduction to project.

- The design must work in simulation
- The design can be completed in pairs thus a clear work distribution and retrospective Gantt chart will be necessary for Appendices in the report (follow up necessary)
- Read over CBO to ensure ELOs are met. A marking rubric will be made available
- The project is a desktop design i.e. it is not necessary to develop it down to the prototype
- The electronics of a hearing aid is more important viz. a full electronic design is necessary
- “Adaptive”: manually be able to change directionality and the sound level depending on sound environment
- It is not imperative that two hearing aids be designed. Designing as one device is sufficient
- Any simulation package can be used (PSpice, Multisim)
- Note: Hearing aids do not amplify across the entire auditory range
- The success in terms of the efficiency in directionality design is at the students’ discretion with sufficient reasoning
- Report page limit is stated in CBO
- Consider amplification limitations
- It is a sufficient assumption that designing for one ear implies the design would hold for both ears.
- Cost is not a strict design constraint
- For the purpose of this project the audiograms for both ears can be treated identical.
- Official meeting times: 10:15 am Mondays, EIE Seminar room

**[11:00 am] Meeting adjourned.**

# Meeting minutes: Design – Adaptive Hearing Aid 2<sup>nd</sup> meeting

[27<sup>th</sup> September 2018], [10:40 am]  
Wits University, Flower Hall Entrance

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**Facilitator:** Prof. Rubin

**Note taker:** Kyle L. Govender

**Attendees:** Kavilan Nair, Jordan Tchaporov, Joel Oommen, Kyle Govender, William Becerra, Fiona Oloo, Boitumelo Mantji, Verushen Coopoo, Lindokuhle Mbatha, Jean Jordaan, Daniel Edwards

**Agenda:**  
Work division  
Project Management  
Directionality  
Filtering  
Miscellaneous

**Also Present:** None

**Apologies:** None

**Absent:** Arunima Pathania

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## **Agenda item:** Work Division

- The course co-ordinator, Dr Masisi, emphasises the importance of the ELO pertaining to individual work for this specific project.
- As previously established, students are allowed to work in pairs. An update in this regard is that each student in the pair solely works on either the Filtering or Directionality component of the project.
- Both students in the pairs need to fully comprehend and understand the aspect of the project that their partner is working on i.e. Filtering or Directionality. The design of the Filtering and Directionality needs to be developed such that these two subsystems ‘can’ be integrated, but actual integration is not required for the final solution.
- The report needs to be centred around the student’s allocated aspect of the project, whilst the other should be referenced where appropriate.
- Each member’s report should adequately convey that they understand their partner’s section of the project.

## **Agenda item:** Project Management

- At this point in the project students should be using the Gantt chart, that should have been already developed in previous weeks, to monitor and track their progress to ensure they are on track.

## **Agenda item:** Directionality

- It can be assumed that the subject has ‘normal hearing’ i.e. a flat response at all frequencies in the audiogram.
- Polar plots considered must be of a 2D projection, not 3D.
- The achieved design must be at the electronic level of abstraction.
- The resolution of achieved directionality is at the student’s justifiable discretion.
- The microphones used in the array need to be omnidirectional.
- Prof. Rubin suggests that a 90° dexterity on either side of the normal to the user’s head orientation is a sufficient dexterity of directionality i.e. spanning a 180° spatial field.
- The behaviour of the achieved design should be validated by means of polar plots.
- Directionality behind the user should not be considered.

## **Agenda item:** Filtering

- The achieved design must be at the electronic level of abstraction.
- The designed filters need to be constructed with narrow enough filter bands to compensate for audiogram limitations.
- The filtering needs to be readily adjustable to different audiograms.

- The auditory system and achieved solution can be considered as one composite system i.e. the hearing deficit for each ear is the same.
- Filtering should realistically/practically stop at 8 kHz, students can go higher if they so wish.
- Prof. Rubin suggests that a standard Desktop PC would not be computationally sufficient for the filtering thus, a dedicated chip should be considered.

#### **Agenda item:** Miscellaneous

- Cost is not a factor to consider in this design however, there is an upper bound on the practicality of the system that needs to be considered at each student's discretion.
- Prof. Rubin will send a link after the meeting to an image of the overall system block diagram of the group who did the hearing aid for the Lab Project.
- The design of a power system required for the design should not be considered for the purposes of this project i.e. off the shelf solutions or mere bench supplies is sufficient.
- The validation of the system should take the form of simulation and level of functionality according to the well-defined objectives stated at the start of the design, comparison to a 'Gold Standard' is not required.
- A digital system is not required, an analogue or hybrid system is perfectly acceptable.
- The hearing aid is to be designed for the purposes of listening to speech and music.
- Lindo brings forward conflicting ELO requirements in two different versions of the Design Project Course Brief and Outline, Prof. Rubin indicates that he will confirm which is the correct version and convey this information to the students.

**[11:30 am] Meeting adjourned.**

# Meeting minutes: Design – Adaptive Hearing Aid 3<sup>rd</sup> meeting

[01 October 2018], [10:30 am]

Wits Chamber of Mines, School of EIE, Seminar Room

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**Facilitator:** Prof. Rubin

**Note taker:** Lindokuhle Mbatha

**Attendees:** Kavilan Nair, Iordan Tchaporov, Joel Oommen, Arunima Pathania, Kyle Govender, William Becerra, Fiona Oloo, Boitumelo Mantji, Verushen Coopoo, Lindokuhle Mbatha, Jean Jordaan, Daniel Edwards

**Agenda:**  
Recap  
Project Management  
Directionality  
Filtering  
Next meeting

**Also Present:** Dr. Nitch

**Apologies:** None

**Absent:** None

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## Agenda item: Recap

- Students need to work individually as this is one of the requirements for the course.
- However, students are allowed to work in pairs to a certain extent, then diverge in which case one student works on directionality and the other works on filtering.
- For directionality, assume a flat audiogram within the frequency range of 20Hz – 20kHz.
- Regarding polar plots, only consider the plot in the horizontal plain at ear level.

## Agenda item: Project Management

- You should have a Gantt chart to help keep track of your progress.
- Apply the project management skills learnt in previous courses.

## Agenda item: Directionality

- Jean (Suggestion):
  - Having an array of 4 microphones arranged in square formation.
  - Directionality can be achieved using either DSP or analogue (electronics).
- Prof. Rubin (Response)
  - 4 elements (microphones) seems to be the bare minimum.
  - Doing directionality using DSP may not be viable.
- Jean (Question): What are the upper limits of the design and to what extent should the directionality be?
- Prof. Rubin (Response):
  - We have to design for real world application, i.e. we have to specify the degree/resolution of directionality with good justification. This will require some background research.
  - Consider dB tolerance from lateral direction while someone is listening in one specific direction.
  - (Side note) Do research on Lombard effect, it may be something to consider in your design ('may' being the operative word).
- Jean (Question): In electromagnetic (EM) systems and array theory, the length of conductors introduce a phase shift, should we correct for this? Also, in reconstructing the source when considering the signals received from multiple microphones, one has to consider relative phase shifts and the correction thereof, isn't this noise cancellation in itself?
- Prof. Rubin and Dr. Nitch (Response):
  - In auditory systems, as opposed to EM systems, electronic delays are negligible.
  - Directionality deals with differential amplification based on direction.
  - The technique of correcting the signal based on multiple inputs from multiple microphones (receivers) is called maximum-ratio combining (MRC) and it is not a noise cancellation technique.
  - Noise cancellation is adding the negative or inverted form of a noise signal to the input signal that may contain noise.

### Agenda item: Filtering

- Fiona (Question): Is it acceptable to assume that the signal coming from the directionality subsystem has maintained its integrity (i.e. is no different from the source signal), or should we consider any alteration that might have been introduced by the directionality subsystem and will the process of band separation affect directionality?
- Prof. Rubin (Response):
  - Have to consider the fact that both the directionality and filtering subsystems should be able to work as a unit that forms one device.
  - Number of channels may affect directionality.
- Prof. Rubin: For directionality, it is not the source of the sound that is being corrected, rather it is the response/detection of the auditory system to that sound that is being corrected. The purpose of the device is to amplify specific bands more than others on an audiogram.
- Note that the sound level is specified in dB with respect to some reference, in this case it is dB SPL (dB of sound pressure level).
- Joel (Question): Why should the students working on filtering worry about the design aspects of the directionality?
- Prof. Rubin (Response): The two subsystems should be compatible in terms of electronics. Note that we should not design a hybrid system, but we should consider the interaction of the two subsystems.
- Fiona (Question):
  - How do we go about designing for signal to noise ratio and should we incorporate feedback cancellation of internal noise?
  - Is it necessary to design a compression circuit?
- Prof. Rubin (Response):
  - For filtering the main requirement is to amplify frequency regions where it is required based on the audiogram. Ignore microphone noise, thus we don't have to design feedback compensation (this is an assumption).
  - Can design a feedback cancellation for microphone noise if time permits, **but make sure you have met all the required specifications of the project.**
  - It is necessary to have a compression circuit.
- Lindo (Question): Should we consider any delays in frequency components of the signal that are introduced by the filtering process?
- Prof. Rubin (Response): Have to do the relevant research to determine if it's necessary.
- Consider looking at the World Health Organization (WHO) Minimal Performance Requirements of hearing aids for more project specs.

### Agenda item: Next meeting

- From henceforth all upcoming meetings will be held on Mondays 10:15 am at Chamber of Mines (School of EIE's seminar room) till further notice.

**[11:10 am] Meeting adjourned.**

# Meeting minutes: Design – Adaptive Hearing Aid 4<sup>th</sup> meeting

[08 October 2018], [10:40 am]

Wits Chamber of Mines, School of EIE, Seminar Room

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**Facilitator:** Prof. Rubin

**Note taker:** Amprayil Joel Oommen

**Attendees:** Kavilan Nair, Iordan Tchaporov, Amprayil Joel Oommen, Arunima Pathania, Kyle Govender, William Becerra, Fiona Oloo, Boitumelo Mantji, Verushen Coopoo, Lindokuhle Mbatha, Jean Jordaan, Daniel Edwards

**Agenda:**  
Apology for Delay in Meeting Start  
Filtering  
Directionality  
Report-related matters  
Miscellaneous

**Apologies:** None

**Absent:** None

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## **Agenda item:** Apology for Delay in Meeting Start

- Prof. Rubin had several matters that he had to attend to and was hence, delayed in getting to the meeting on time. Prof had emailed students and notified Jeannine at the reception, to inform students about the delay.

## **Agenda item:** Filtering

- Fiona (Question):
  - Many dedicated Hearing Aid Digital Signal Processors (DSPs), have predefined filter designs (e.g. centre frequencies, bandwidths); however, this prevents designing our own system with our own considerations.
  - Hence, once decided on a design for the filter (e.g. orders, gains), are we required to design a DSP which is able to implement the filters?
- Prof. Rubin (Response)
  - Rather make use of readily available DSPs, capable of handling the filter design you would like to implement.
  - Can design your own DSP if you want, however, given the current time constraints and even looking at potential commercial South African start-ups, Prof believes it will be easier using readily-available DSPs, components, etc.
- Fiona (Question): Are we able use design considerations from literature, such as attenuation in the cut-off bands, when designing our own filters (e.g. attenuation of 40 dB outside of the passbands, resulting in sounds in those frequency ranges being softer)?
- Prof. Rubin (Response): It is a fair assumption to make.
- Joel (Question): Is the audiogram stored in the DSP? Is it sufficient to provide audiologists with the capability to adjust the gain levels between certain frequency ranges?
- Prof. Rubin (Response):
  - DSPs are required to be able to store the audiogram of an individual, so that the hearing aid is adjustable for them (e.g. if the individual's hearing deteriorates as they age, then the hearing aid must be able to be adjusted to cater for that).
  - An acceptable means of achieving this, is by designing the hearing aid with a discrete number of filters which operate on different frequency ranges and where its gains can be adjusted as required – this is a means of “storing and normalizing” one's audiogram.
- Lindo(Question): Last week, you had specified that we require a compression design, for our Dynamic Range Compression. Are we also required an Expansion Section, within the Compression design, which is a suggested solution for a specific psychoacoustic problem?
- Prof. Rubin (Response): You can include expansion in the design, but you do not need to go into detail about the psychoacoustic analysis behind the implementation.

### Agenda item: Directionality

- Fiona (Question): With regards to focusing on sounds at a particular angle (i.e. having a main lobe focusing on a specific region), how big should the successive “next” lobes be? What must the dB difference between the main lobe and the successive lobes be? Is there some sort of threshold value that we should use for that dB value?
- Prof. Rubin (Response): Use your discretion and design in accordance to what you need / require for your directionality.
- Jean (Question): Depending on the array size, the way we approximate a near-field and far-field sound will be different (i.e. characteristics such as wavelengths of the sound, speed of sound and the distance of the source from the listener). Is it ok for the rest of the design, that we make an assumption that both the near-field and far-field are treated the same?
- Prof. Rubin (Response): Absolutely, show that you understand the problem at hand, but then move on with the design, by stating the compromises and design decisions. Such a consideration can only be tested and verified using practical experimentation, hence show that you have considered it, but move on with the design.

### Agenda item: Simulations and Results

- William (Question): Is it fine to perform simulations of the system on Simulink, using predefined simulation blocks (e.g. Octave bandwidth filters)?
- Prof. Rubin (Response):
  - If elect to go this route, will have high-level system simulations.
  - Will be required to make justifications for design considerations and will need to make certain assumptions of the performance of the device, etc.
- William and Joel (Question): How do we evaluate the errors and performance of the system, seeing that this is a paper design?
- Prof. Rubin (Response):
  - First, you must decide upon design specifications for the Hearing Aid.
  - Then, go about designing and simulating the system.
  - When evaluating and critiquing the design, compare the original design specifications with the simulated design and see if the design meets requirements.
- William (Question): What results are we required to include in the report?
- Prof. Rubin (Response):
  - *Filtering*: Outputs from the filters and perhaps also the compression algorithms / techniques.
  - Not practical to test the designed filters using the entire frequency range for speech. Therefore, try get a few input speech samples (of different frequencies) and obtain the outputs of the filters for those input.
  - *Directionality*: Show outputs of the directionality system (i.e. on a polar plot), when different point sources of sound are used.

### Agenda item: Report-related matters

- Verushen (Question): Please could more clarification be given, pertaining to how the two partner’s systems are to be integrated. Is it for example necessary to simulate a signal being inputted into one of the systems, and its subsequent output being used as the input of the second system?
- Prof. Rubin (Response):
  - The report **MUST NOT** be a presentation of the hybridization of the two partner’s systems – time constraints are too limiting, and this would only be required to be done in a commercial project.
  - Rather, the two systems must be able to be joined in “*principle*” – ensure that communication and thought has taken place in collaboration with your partner, taking reasonable precautions, etc. (e.g. knowing how many outputs will come out of the one system, and using those as inputs of the secondary system).
- Prof. Rubin (Comment): This is a paper design, and we do not have the capability of physically testing and making subsequent changes; therefore, be reasonable and make decent design consideration and assumptions.

- Jean (Question): In the rubric, in order to achieve a “Good” or “Excellent” rating, we are required to show evidences of outstanding features in the design, etc. Please could you clarify what that means in this context?
- Prof Rubin (Response):
  - The markers of the report, understand the time constraints and the difficulty of the problem presented to students.
  - Therefore, to evidence outstanding features, show that you have thought clearly through matters (even if they present themselves as problems that are difficult to address), justifying the design, showing the compromises that have had to be made, etc. If you can evidence this clear thinking and can motivate decisions, it is likely that the markers would consider this favourably.
  - What we are more concerned is the design cycle and how you approached solving the problem, as opposed to the actual design.
- Jean and Verushen (Question): Please could you give details about the content and structure of the Appendices?
- Prof Rubin (Question):
  - *Appendix A*: The CBO mentions this must be a non-technical report of the impacts of the engineering solution, and about the improvements that can be applied in reducing the negative impacts.
  - This can detail the social and economic impacts of the hearing aid on the community (both locally in South Africa and even internationally) and vice versa.
  - Format of Appendix A must follow IEEE standards, as well as anything further dictated in the CBO. Can write it like an essay, can insert headings if you desire, etc. (provided the proper standards and dictated guidelines are conformed to).
  - *Appendix B and C*: Previously, had mentioned that a Gantt Chart could be included as an Appendix. Furthermore, it would be valuable including a rough cost breakdown of the entire hearing aid device (you will not be marked down if you do not have one, nonetheless, it can be insightful in giving an idea of how sustainable an idea this is, thus aiding in evaluating the appropriateness of the design etc).
- Joel (Question): Please can more clarification be given on the format of the report.
- Prof Rubin (Response): Use the guidelines given in the CBO to dictate the details of the style requirements of the report (e.g. 15 pages, single column), and use the Blue Book to ensure that these details conform to the IEEE styling standard.

### **Agenda item: Miscellaneous**

- Lindo (Question): Are we allowed to use a FPGA, instead of a DSP, if necessary?
- Prof Rubin (Response): Yes. The FPGA allows you to digitally code the device and dedicate the device for processes / operations / functionality. In addition, it allows for parallelism of operations. Can be a good alternative to the DSP if need be.

**[11:35 am] Meeting adjourned.**



# Meeting minutes: Design – Adaptive Hearing Aid 5<sup>th</sup> meeting

[15 October 2018], [10:15 am]

Wits Chamber of Mines, School of EIE, Seminar Room

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**Facilitator:** Prof. Rubin

**Note taker:** Kavilan Nair

**Attendees:** Kavilan Nair, Iordan Tchaparov, Joel Oommen, Arunima Pathania, Kyle Govender, William Becerra, Fiona Oloo, Boitumelo Mantji, Verushen Coopoo, Lindokuhle Mbatha, Daniel Edwards, Jean Jordaan

## **Agenda:**

Revised Project Brief

Directionality

Filtering

Next meeting

**Apologies:** None

**Absent:** None

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## **Agenda item:** Revised Project Brief

- Revised brief was sent out in the morning which mentioned that a **low cost** should be a requirement. **PLEASE IGNORE THIS STATEMENT AS THE DESIGN DOES NOT HAVE COST AS A CONSTRAINT.**

## **Agenda item:** Directionality

- Verushen (Question): There are a lot of polar plots that we can show in the report, should we include all?
- Prof. Rubin (Response):
  - Only some key plots should be necessary
  - Jean (Suggestion): Can plot a 3D graph to combine and make the graphs concise.
- Kyle (Question): Is it advantageous to increase the range beyond 180 degrees?
- Prof. Rubin (Response):
  - Not really, you can if you want but make sure it doesn't sacrifice the performance
- Verushen (Question): Can we use digital mics?
- Prof. Rubin (Response):
  - You can use it but it must be compatible with what your partner needs to work with
- Iordan (Question): Is there a limit to the number of DSPs that the design uses?
- Prof. Rubin (Response):
  - No hard cap, but it should be within reason and practical.
- Kyle (Question): Is 100 microphones too many?
- Prof. Rubin (Response):
  - It needs to be reasonable

## **Agenda item:** Filtering

- Fiona (Question): I have picked my DSP device, do I need to explain the concepts of it or have a detailed pinout?
- Prof. Rubin (Response):
  - Yes, you need a pinout so you can embed it in the circuit diagram
- Joel (Question): What level of detail is required for the electronic circuit diagram and algorithms?
- Prof. Rubin (Response):
  - Given the allocated time for this project, it doesn't have to be low level
  - Can provide the pseudocode in the form of flowchart for the algorithms implemented on the DSP

- Fiona (Question): If the DSP already contains a built in DAC, do I need to design my own?
- Prof. Rubin (Response):
  - Can treat the DSP as a black box
  - Don't worry about the internals of the device, using an example, you don't need to worry about the transistor level if you are using an operational amplifier
- Boitumelo (Question):
  - Is the DAC and speaker design components only for the adaptive filtering students?
- Prof. Rubin (Response):
  - This is where the teamwork comes into play and it depends on the design and how the two systems integrate.
- William (Question): Do we need to simulate the DAC and ADC?
- Prof. Rubin (Response): It isn't necessary.
- Fiona (Question): Is it better to have full simulation or modular simulations
- Prof. Rubin (Response):
  - Makes sense to modularize and it makes things a bit easier
- Joel (Question): Is Dynamic Range Compression (DRC) essential?
- Prof. Rubin (Response):
  - Yes, you have to have compression
- Lindo (Question): Can we use libraries?
- Prof. Rubin (Response):
  - Yes you can, but make sure you show the design thought that you put into setting some of those parameters
- Lindo (Question): In terms of building up the design and justifying, can I use a filter bank with variable bandwidths?
- Prof. Rubin (Response):
  - Sure, as long as you can justify it.
- Fiona (Question): What is meant by adaptive?
- Prof. Rubin (Response):
  - The directionality must be adaptive in terms of being able to focus the microphones within a specific range
  - The filter must be adaptive in terms of the gains adjusting to match the audiogram
- William (Question): Do we need to show the power supply circuitry?
- Prof. Rubin (Response):
  - Yes you should, show the power to the components with a voltage regulator for example.
- Fiona (Question): Can we map the -1 → 1 of a signal as the dynamic range?
- Prof. Rubin (Response):
  - Not too sure, maybe test it yourself or message Kirsten at Optinum?

### Agenda item: Report and group aspects

- Joel (Question): How much does the individual report relate to the other group member
- Prof. Rubin (Response): Don't talk about the detail implementation of partners system. Talk in terms of input/output and how the two subsystems will interface with each other.
- William (Question): In terms of the integration of the two systems, will there be a penalty if that parts doesn't make sense.
- Prof. Rubin (Response): There will be a penalty, as group work does make up a component of the project.
- Jean (Question): When we are discussing the other person's design in the report, how do we reference it?
- Prof. Rubin (Response): You should have a section where you discuss the partners design in terms of input/output and you should reference their report like you would reference any other paper.
- Prof. Rubin (Statement): Write the partners name on the front of the report, but it should be small and at first glance the reader should know whose paper this is.
- Verushen (Question): Should the abstract go on the cover page?
- Prof. Rubin (Response): It should not be on the cover page.
- Jordan (Question): Can we have an acknowledgements section?

- Prof. Rubin (Question): It is essential, especially for directionality, with the help from Dr. Nitch.
- Dan (Question): Can I use a design approach where I build up and prove some of the design decisions, such as how many filters to use.
- Prof. Rubin (Response): Sounds good, as long as you link it back to the original spec. One thing to note is that Design is not always objective, it can be subjective.

**Agenda item:** Next meeting

- There will be a meeting next week on the 22nd of October, this meeting will however, not be compulsory and no minutes will be taken.

**[11:15 am] Meeting adjourned.**