Feasibility study of LDS antennas for hearing aid applications

Master Thesis

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Abstract

By the use of Laser Direct Structuring and plating techniques (LDS), it is possible to trace electrical circuits directly on the supportive plastics, thereby creating Moulded Interconnected Devices (MID). The use of LDS for antenna applications, is a well established technology in the electronic integration of consumer electronics. LDS antennas have though not yet been implemented in hearing aid applications, which therefore calls for innovative designs and reliability testing, paving the way for this project. The aim is to study the feasibility of LDS antennas in hearing aid applications.

This project has focused on a robust implementation of the LDS antenna and especially its connectivity to the advanced carrier PCBA. Furthermore, hearing aids are exposed to aggressive environments, and therefore the reliability of the solution has been evaluated in regards to these critical factors.

The results of the project are presented through a systematic product development process, a physical prototype and tests. A final concept design is recommended, and interesting areas for future work are suggested.

Resumé

Ved brug af Direkte Laser Strukturering og plettering (LDS), er det muligt at placere ledende baner direkte på plastikken, og forbundne støbte enheder skabes. Brugen af LDS til antenne formål er en veletableret teknologi når elektronikken skal integreres i forbruger elektronik. LDS antenner har dog ikke været implementeret i høreapparater, til hvilket der er brug for innovative designs og pålideligheds undersøgelser, hvilket er grundlaget for dette projekt. Formålet er at studere gennemførligheden af LDS antenner til høreapparats formål.

Der er i projektet fokuseret på en robust implementering af LDS antennen og særligt dennes forbindelse til det avancerede PCBA. Derudover, er høreapparater eksponeret overfor et aggressivt miljø, så løsningens pålidelighed er blevet undersøgt i forhold til disse kritiske faktorer.

Projektets resultater er præsenteret igennem en systematisk produktudviklingsproces, en fysisk prototype og tests. Et endeligt koncept design er blevet anbefalet, og interessante områder til videre arbejde er foreslået.

Preface

During the summer of 2017, I contacted GN Hearing A/S due to my interest in their development projects in the connected hearing aid industry. After a mutual agreement on the project definition, a thorough literature study was carried about hearing instruments, moulded interconnected devices and antenna theory.
Due to the wide extent of the project, focus is on the design of the interface connecting the PCBA to the antenna, and secondarily, on the actual use of LDS antennas in hearing instrument applications.

The thesis is supposed to be acknowledged as a 30 ECTS weighted workload project, and as part of the contentment of the Master of Science degree in Engineering Design and Applied Mechanics at the Technical University of Denmark (DTU).
The work for this project has been realized from the 14th. of September 2017 until the 4th of April 2018, excluding previous contact about the project definition with GN Resound and DTU.
The project was carried out at the Section of Manufacturing Engineering which is part of the Department of Mechanical Engineering (MEK) at DTU in cooperation with GN Hearing. The study has been supervised by Aminul Islam (MEK) and Anders Michaelsen Hjermø (GN Hearing).

Greater Copenhagen, April 17, 2018

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I would also like to acknowledge Ismo Tolonen, Markku Sartanen, Ray Chen and the rest of the team from Shanghai Amphenol Airwave and Dirk Baecker from LPKF for their support and knowledge sharing, and Ronna You and co. from DSM for their assistance in providing material for the prototype, which has been really appreciated. Also I would like to thank for the collaboration with Derek Han, Mogens Marquard, Rene Bergqvist and Kenneth Pilgaard for interesting discussions about the production and for their sharing of useful information.

Finally, I would like thank my family for their support and encouragement through this project and during my entire life.

Nomenclature

Abbreviations:

ABS	Acrylonitrile butadiene styrene
BTE	Behind The Ear
CAMM	Centre for Acoustic-Mechanical Micro Systems
DECT	Digital Enhanced Cordless Telecommunications
DFA	Design for Assembly
DFM	Design for Manufacturing
DTU	Technical University of Denmark
ESD	ElectroStatic Discharge
FPC	Flexible Printed Circuit
HI	Hearing Instrument
ITE	In The Ear
LCP	Liquid Crystal Polymers
LDS	Laser Direct Structuring
MEK	Department of Mechanical Engineering at DTU
MID	Moulded Interconnected Device
MIPTEC	Microscopic Integrated Processing Technology
OTA	Over The Air
PA	Polyamid
PC	Polycarbonates
PCB	Printed Circuit Board
PCBA	Printed Circuit Board Assembly
PCT	Polycyclohexylenedimethylene Terephtalate
PEEK	Polyetheretherketone
PPA	Polyphtalamide
RF	Radio Frequency
RH	Relative Humidity
RIE	Receiver in the ear
SMD	Surface Mounted Design
SMT	Surface Mount Technology
TRP	Total Radiated Power

Roman symbols:

h	Bridge height	[m]
c	Speed of light	[m/s]
f	Frequency	[Hz]

Greek symbols:

λ	Wave length	[m]

Terminology:

Behind-The-Ear hearing aid: A hearing aid positioned behind the ear.
Laser direct structuring: Production Method for tracing electrical circuits on plastics.

Contents

CHAPTER 1

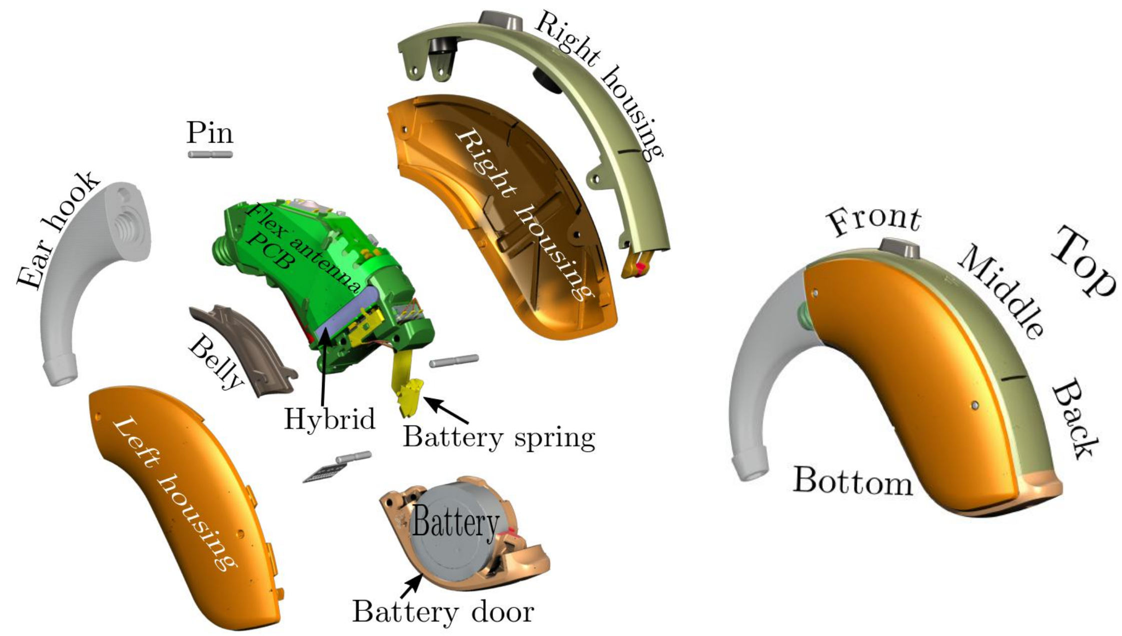
Introduction & background

The increasing amount of electronic features and functions in medical devices, calls for innovative manufacturing methods and robust designs to conserve simplicity, increase performance but still reduce the size and weight of the devices. Such market demands are very relevant for hearing instruments (HI).

Regarding the antenna in a GN Hearing Behind The Ear (BTE) hearing aid, an FPC (Flexible Printed Circuit) antenna is used as the 2.4 GHz antenna which takes place in the wide part of the hearing aid. It is a free component, which is mounted manually, with its placement tolerances, which influence on the performance of the antenna. The Laser Direct Structuring (LDS) technology allows the creation of conductive circuits, like an antenna pattern, directly structured on the plastic. The process takes place on an injection-moulded part, and the laser beam transfers the circuit layout directly on the part. A simpler design is obtained and the number of components during assembly is reduced. Conducting channels can furthermore be placed on curved surfaces and be directed through walls. The LDS technology is thereby increasing the design freedom, which in theory, should be able to decrease the size of the hearing aid. Weight, dimensions and tolerance stack ups are reduced, improving manufacturability, but also the ergonomics and aesthetics for the user.

One of the big challenges with the implementation of an LDS antenna is that a robust interface between the antenna and the advanced carrier Printed Circuit Board Assembly (PCBA)is needed, and especially this design, will be the focus of the thesis, where Design for Manufacturing (DFM) and Design for Assembly (DFA) will also be considered. HI are furthermore exposed to an aggressive environment, where sweat and ear wax can degrade rust proof steel types and gold alloys if the design is not well considered. High reliability is important when the interface to the carrier PCB is designed.

A 3D model of a HI is shown in Figure 1.1. The definitions shown graphically here will be used throughout the project.



(a) Exploded view. (b) 3D model.

Figure 1.1: Berlin 60.

Project Objectives. The aim of this thesis is to conduct a feasibility study on the robust implementation of an LDS antenna in a BTE HI, in collaboration with GN Resound and DTU.

The objectives and activities have been divided into the following sections:

- A thorough literature study was conducted regarding Moulded Interconnected Devices (MID), the LDS technology, suitable materials, and state-of-the-art LDS implementations.

- An identification of the optimal and possible placements of the antenna, being on the frame or on the interior / exterior of the housing. In collaboration with Radio Frequency (RF)engineers and antenna designers, a suitable antenna pattern should be found for the chosen placement and available surface space.

- An analysis of LDS-suitable materials and a material selection will be carried out for the part where the antenna will be placed. Especially biocompatibility, colour compatibility, corrosion resistance, and other functional requirements will be considered.

- Development of the interface between antenna and carrier PCBA, through a systematic design process. Further applications and design recommendations were made too.

– For a verification of the robustness and the reliability of the design, a prototype was made for testing the interface, regarding robustness and environmental conditions. Furthermore, the quality of the LDS lines and their behaviour in HI applications was evaluated as well.

The project plan and its activities are summarized in the diagram of Figure 1.2.

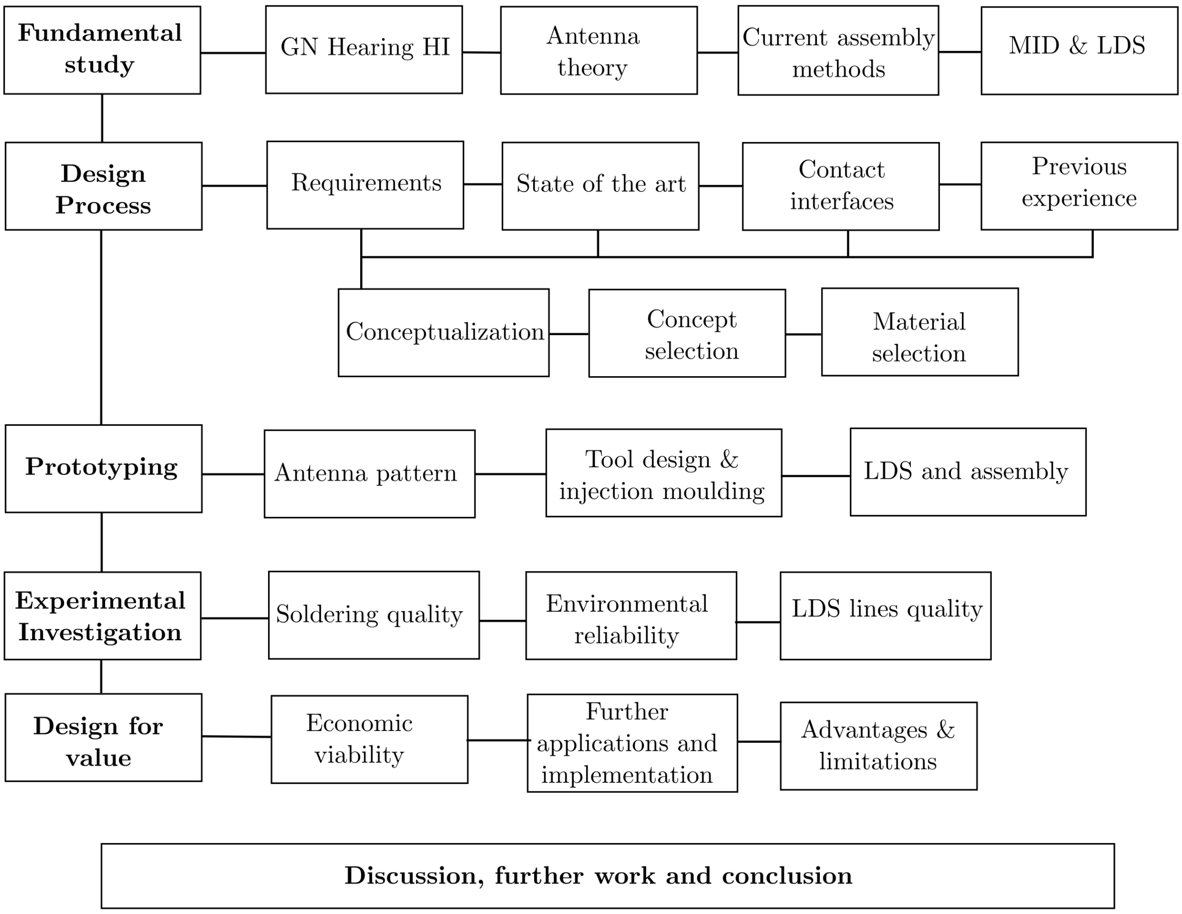


Figure 1.2: Project plan.

CHAPTER 2

Theory & Methods

2.1 HI at GN Hearing

Different types of hearing instruments exist, and GN ReSound - a GN Hearing brand - designs and produces the following in their latest product family:

Figure 2.1: GN ReSound Linx 3D product family.

The initial implementation of the LDS antenna will be based on GN ReSound's Berlin 70, since it is a good fit for an LDS implementation due to its size and its current assembly model which will be further described in Section 2.3. The same design concepts can later be applied for to other HI types, and also to the next generation HIs.

A 3D model and picture of the Berlin 70 HI is shown in Figure 2.2 and 2.3a.

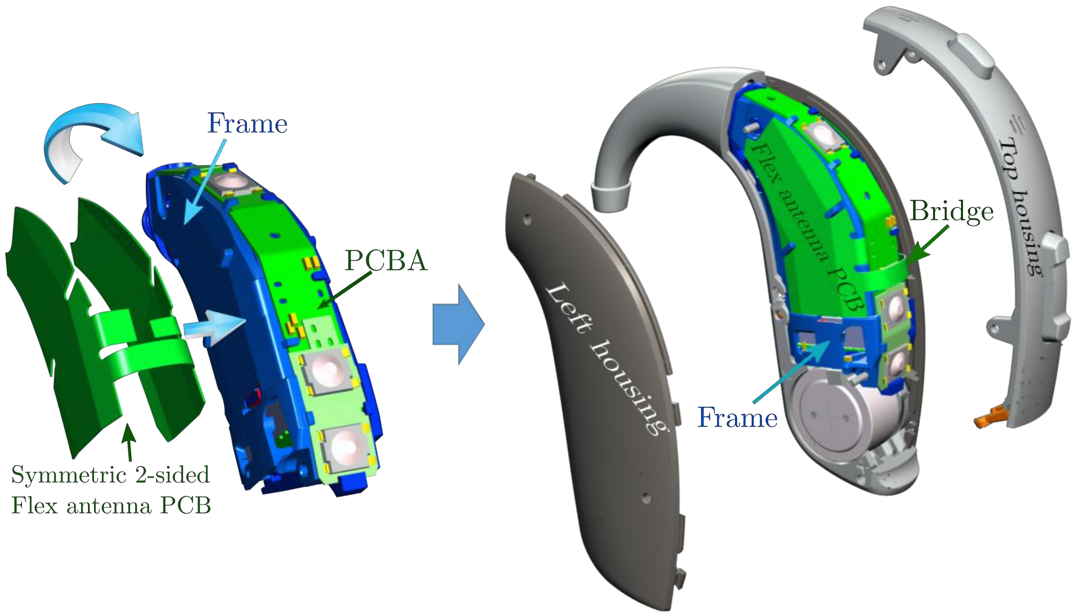
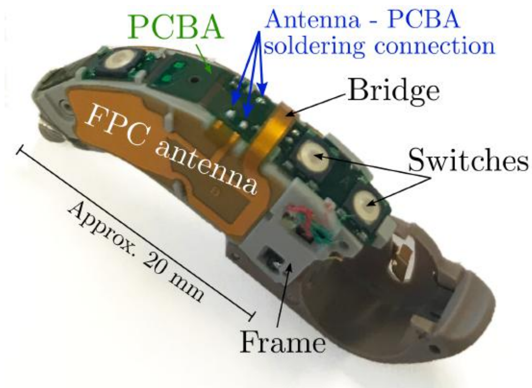
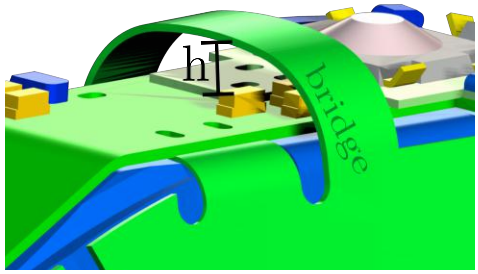


Figure 2.2: Exploded view 3D model of Berlin 70.

An important part of the GN ReSound antenna designs is the bridge of Figure 2.3b which connects both sides of the antenna through a continuous FPC. Its RF function will be described in Section 2.2.



(a) Photo of Berlin 70 without housing.



(b) Bridge 3D model.

Figure 2.3: Berlin 70.

2.3 Current assembly methods

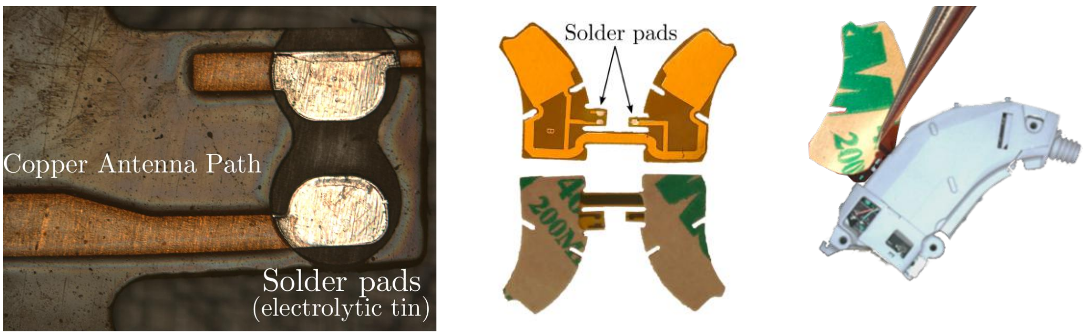
For the existing HIs, the antenna is in most cases an FPC as shown in Figure 2.5b. At the soldering spots, the antenna has 2 soldering pads made of electrolytic tin shown in Figure 2.5a for easing the soldering with lead free solder paste. The PCBAs used have the composition described in Table 2.1, where the Electroless Nickel Immersion Gold (ENIG) plating is used on the soldering oval holes in order to facilitate adhesion of the soldering paste, and the gold layer protects from corrosion. That means that the current assembly connects the electrolytic tin plating of the FPC antenna with the gold plating of the PCBA, through lead-free soldering.

Stack-up	Layer thickness
Solder mask	10-30 µm, ≤ 20 µm over tracks
ENIG	IPC-4552
Copper (TOP)	15-25 µm
Polyimide	25 µm*
Copper (INNER1)	10-20 µm
Adhesive	25 µm**
Polyimide	25 µm*
Copper (BOTTOM)	15-25 µm
ENIG	IPC-4552
Solder mask	10-30 µm, ≤ 20 µm over tracks
Solder mask dam	55 µm -10µm/+5µm

*tolerance according to IPC-4204. **tolerance according to IPC-4203

Table 2.1: PCBA composition.

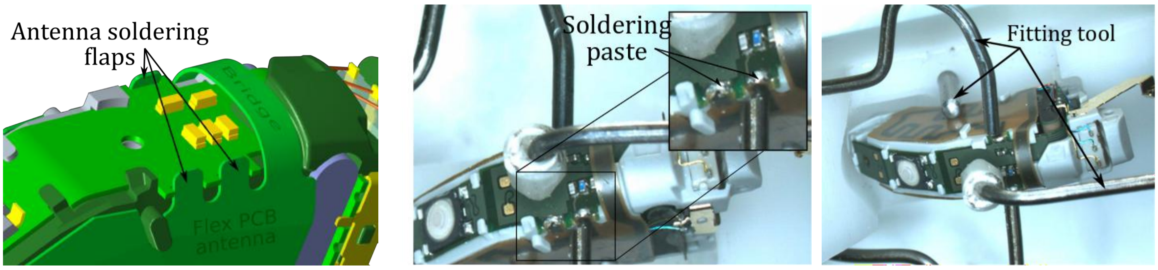
After soldering the 3 pads to the PCBA, the antenna is glued as a sticker wrapped around the frame as shown in Figure 2.5c. As it is a sheet, the frame must then have a "diamond" shape, to take into account that the flex antenna can be curved in one dimension only. Therefore no double curved surfaces can be used on the frame. This is the standard procedure for assembling a flexible antenna.



(a) Microscope image. (b) Flex antenna. (c) Fixing antenna on frame.

Figure 2.5

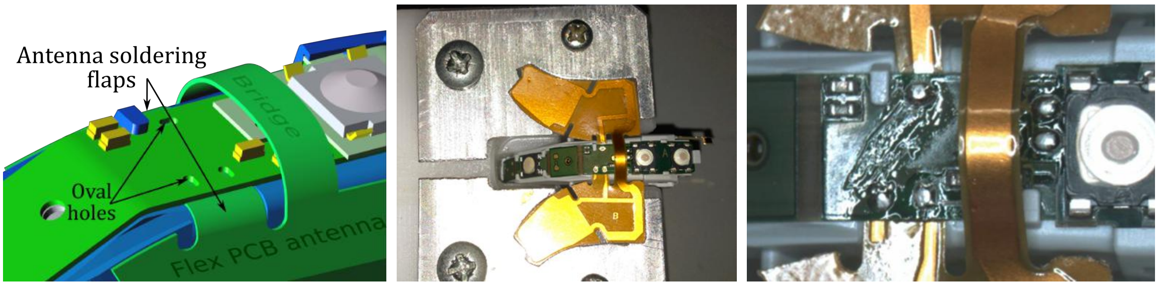
The antenna assembly on the Berlin 60, is shown in Figure 2.6. As it can be seen, the fixing tool formed by 2 metal wires is needed to fix the connection pads in order to solder the FPC antenna flaps on the side of the PCBA. This interface design was made in order to occupy minimal space on the PCBA. Also less material is to be warmed up around the soldering spots, facilitating the soldering process. By this design, it is also easier to inspect the quality of the soldering. Though, the precision requirements are increased and the assembly - especially the soldering - is rather complex.



(a) 3D model. (b) Fixing tool and flaps. (c) Fixing tool.

Figure 2.6: Antenna soldering for Berlin 60.

The antenna soldering is made differently on the Berlin 70, as shown in Figure 2.7. The flex antenna is fixed under the PCBA, and oval holes are made on the PCBA, through which it is soldered to the flex antenna's soldering pads. The oval holes have metallized contours for soldering and connecting. So it is through the hole that it is soldered. Compared to Berlin 60, a bigger area has to be warmed up making it a less desirable option for soldering, but this setup is easier to solder because it avoids vertical flaps.

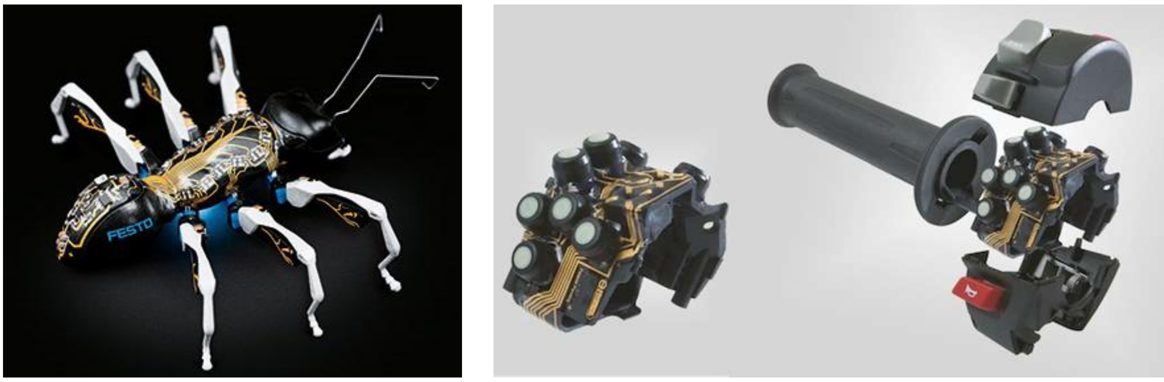


(a) 3D model. (b) Fixing tool. (c) Soldering spots.

Figure 2.7: Antenna soldering for Berlin 70.

2.4 Moulded Interconnected Devices (MID)

An MID is a 3D thermoplastic device which takes advantage of its mechanical design to include conductive traces directly on the supportive material. It is an unique way of combining electrical and mechanical properties in a device. MIDs permit an improved volumetric design freedom, an important step towards miniaturization of electronic devices. Cables and other components can be saved away, easing the assembly process.



(a) BionicANT (13.5 cm length) [8]. (b) MID in automotive handle [9].

Figure 2.8

2 examples are shown in Figure 2.8 where many electronic features are connected through MID parts, both for a small bionic robot like the BionicANT and for automotive applications. The thermoplastic part is called substrate, on which the metallization is made. A wide variety of manufacturing techniques for MID exist which will be briefly presented in Table 2.2 with their simplified steps.

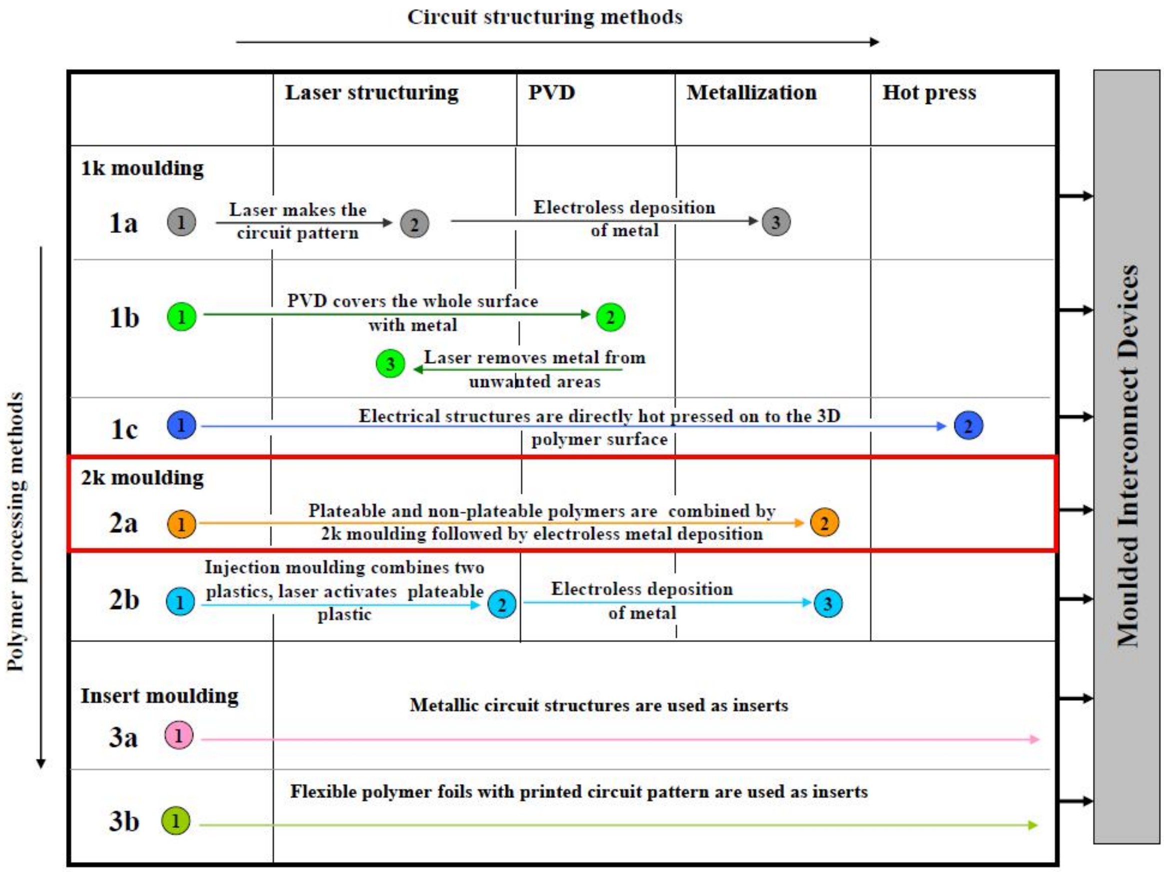


Table 2.2: Different MID processes [10].

1K moulding. The process is characterized by a cost efficient high-volume production and short cycle times. The plastic substrate can be made with one-shot injection moulding, where the melted thermoplastic is pushed by a screw feeder into the injection moulding tool. Here it cools and remains as its final shape. Thereafter, one of these main 3 MID process types begins: In 1a, the laser activates the immersed metallic particles in the thermoplastic in the desired pattern. This path is then plated through electroless deposition of the metal to be used. The process is commonly known as LDS. 1b takes the opposite approach. Physical Vapor Deposition (PVD) is used to coat the substrate surface with metal, and then the laser eliminates the metal from the unwanted areas, leaving the desired electrical path. In 1c, electrical structures are directly hot pressed into the surface of the 3D substrate.

2K moulding. 2 component injection moulding, as the name implies, involves 2 materials in the moulding process. In 2a, plateable and a non-plateable thermoplastics are injection moulded together, and the plateable one is thereafter metallized forming the electrical circuit. In 2b, a laser-activable thermoplastic substitutes the plateable material of 2a. This material is 2K injection moulded in the desired path, then laser activated and finally electroless plated. The method is similar to LDS, but at a reduced cost, since the expensive LDS grade material is only used in the predefined path, and the rest is the standard thermoplastic.

Insert moulding. The electrical circuits are directly inserted in the injection moulding process. A metallic structure is the insert in 3a and a flexible polymer with the printed metallic circuit pattern is used as the insert in 3b.

Laser Direct Structuring and 2K-moulding (process 2a) are the two processes most suitable for mass production 2.2, and they have also shown high reliability at microdimensional scale. The main advantage of LDS is that the pattern design is much more convenient, and not limited by the mold, as in 2K-moulding. For an antenna application, this is a valuable property, because the pattern can be modified easier and at a very low cost. GN Hearing has earlier experimented with 2K-moulding for antenna applications with the material Schulatec TinCo 50 [11] and the main results showed considerably lower RF efficiency for a higher electrical resistivity. Established MID processes exist at the moment, both within 1k, 2k and insert moulding, all differing in terms of process chain, quality, time factor and cost. The scope of this thesis was predefined to concern LDS due to its predominant position within antenna manufacturing for MID.

2.5 Laser Direct Structuring (LDS)

The use of laser techonology for MID has gained traction due to the modern development and accuracy of lasers, and because of the versatility in 3D space. Within laser structuring, 3 main types exist and which are summarized in Table 2.3:

Additive	Semiadditive	Subtractive
Mold plastic body	Mold plastic body	Mold plastic body
Laser-structure plastic	Surface activation	Surface activation
Chemical copper	Chemical copper	Chemical copper
Surface finishing	Apply photoresist	Electrolytic copper
	Laser structuring of photoresist	Galvanically build etch resist
	Galvanic copper and surface finishing	Laser structuring of etch resist
	Etch away photoresist and base metallization	Etch away copper
		Surface finishing

Table 2.3: Types of Laser Structuring [12].

- Additive: Metal layers are only deposited on the desired pattern, which is laser structured.
- Semiadditive: A laser-sensitive photoresist covers a metallic base layer. The laser structuring allows another copper layer on the structured pattern. Finally the photoresist and the base metal layer is removed by etching.
- Subtractive: The laser is used to be able to etch areas of copper away, leaving only the desired copper pattern.

The most popular techniques within the additive processes, are LPKF-LDS® and ADDIMID. Within the semiadditive, Microscopic Integrated Processing Technology (MIPTEC) from Panasonic is the most used while the subtractive processes are mostly used in ceramic materials [13].

LPKF-LDS® is the simplest of the three types and actually accounts for 50% of the MID market [13]. It includes a high versatility, mass production, prototyping, and a wide range of thermoplastics are becoming available. It is a fast and economic process for MID and therefore a preferred LDS supplier for many applications.

ADDIMID is very similar to LPKF-LDS®, and involves a similar process chain, but the technology is still under development. Early results have shown potential indications for the future of MID.

MIPTEC can achieve very fine conductor lines down to 50 µm and high surface qualities. But only PPA and two types of ceramics can be used, limiting the material options significantly. Furthermore, it has a decreased 3D design freedom due to positioning constraints in its process chain, which also requires more steps than additive techniques, like the PVD step. There is also more waste in this process compared to a total additive method.

Due to the mentioned above, within the LDS technologies, the focus will be on LPKF-LDS®. It has already been used in a GN ReSound accessory device, called MultiMic, which will be described in Section 4.2.1.

LPKF-LDS®. Based on the above, LPKF-LDS is a clear choice for a HI antenna application. It consists of 4 main steps: injection moulding, laser activation, metallization and surface finish. The injection moulded materials, which can be used for LPKF-LDS®, must be a socalled LDS grade, meaning it contains an organo-metallic additive which is laser-sensitive and gets activated with laser irradiation. The organometallic complexes are based on palladium (Pd^{2+}) and/or copper (Cu^{2+}) and when these get activated, they will act as catalysts for the electroless plating deposition [13].

All LDS grades are compatible with injection moulding, but some may need elevated moulding temperatures to ensure a homogeneous mix of the additives in the material. When the injection moulding of the part is done, the substrate can be laser structured.

Laser structuring

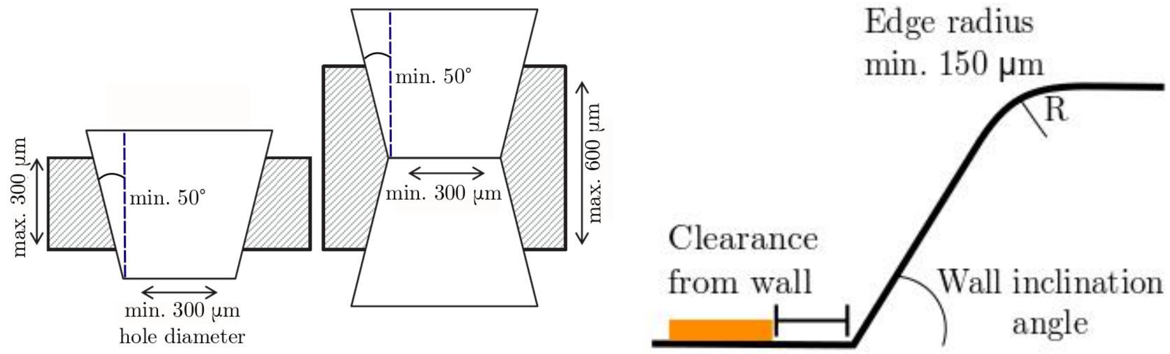
The concept is to maintain the non-conducting matrix of the polymer and to release free organometallic seeds to the surface of the substrate [14]. This happens when the laser ablates 1-2 µm on the surface, creating a rough surface as seen in Figure 2.11. Simultaneously, the additive gets activated making the metallization possible. Process rates of up to 4000 mm/s are achievable depending on the 3D complexity. LDS track widths down to 150 µm are common, while minimum a 200 µm track separation is recommended by LPKF-LDS®, although even smaller designs are possible.

For the Berlin 70 application, the track width and spacing is not an issue since the separation at the soldering points is more than 400 µm and no track widths smaller than 300 µm are desired.

For the 3D parts there are some design rules which must be obeyed in order to lower the LDS cost. The laser can not access all corners of a 3D part, but most angles are achievable if the part is moved and/or rotated, though it is not desired. To minimize the complexity of the setup, following rules must be taken into consideration:

Plated vias. As seen in Figure 2.9a, vertical connections can be achieved through plated via holes. This is very useful for saving surface area since the LDS line can go through the material instead of having to cross an edge. The represented guidelines are valid for via holes. In order to make the laser reach all surfaces in the hole, the diameter must be increased for increasing wall thickness.

Edge radius and wall spacing. If structuring is to be made on an edge, 150 µm radius is recommended, and a 150 µm spacing is recommended to a 45° wall and 250 µm to a 70° wall, as seen in Figure 2.9b. This is due to the risk of laser debris depositing close to the corners, which can provoke depositing of unwanted metallisation near walls.

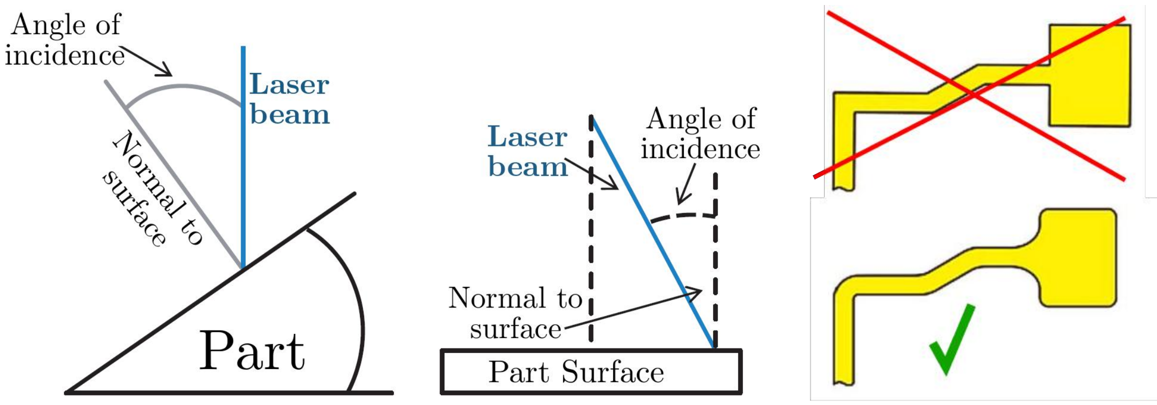


(a) Via holes. (b) Edge radius and wall spacing.

Figure 2.9: Design guide [15].

Angle of incidence. The angle of incidence is important since the energy transfer to the surface will decrease for increasing angles. Therefore, a maximum 70° between the orthogonal to the substrate surface is recommended. This is shown in Figure 2.10a. This is a design recommendation, that will reduce cost in production. 3D LDS tracks requiring an angle bigger than 70° are possible but will just need either the laser or the part to be fitted by moving / rotating accordingly, which increases production time and cost.

Smooth and rounded paths. As in Figure 2.10b the corners should be rounded in order to avoid peeling, especially due to the thermal stresses when soldering. The conductive tracks should have smooth width transitions and sharp-edged turns should be avoided.



(a) Laser angle of incidence.

(b) Corner roundings.

Figure 2.10: Design guide [15].

Metallization

After the structuring, the surface is cleaned from laser debris, e.g. with water jet, CO^2 snow-jet or wet-chemical / ultrasonic cleaning, but carefully avoiding the structured surface is not deactivated again. The reason to a careful cleaning, is that otherwise there will be a risk of metallizing unwanted areas, which can create issues as short circuits and similar. Wet-chemical / ultrasonic is the most efficient method for small devices and mass production, while water-jet is not suitable for 3D geometries and miniaturized components. CO^2 snow-jet is more efficient for large surfaces [16]. Then the activated substrates are immersed in an electroless bath, which consists of an aqueous metal salt solution, a reductant (providing the electrons) and some additives for stabilization. This bath must be optimized so the metal deposition only occurs on the active areas and so the adhesion is strong enough. First, a copper bath starts the metallization, normally followed by a nickel and gold overplating. Nickel binds the Cu and the Au layer, while Au increases conductivity, improves galvanic contacts and protects from corrosion.

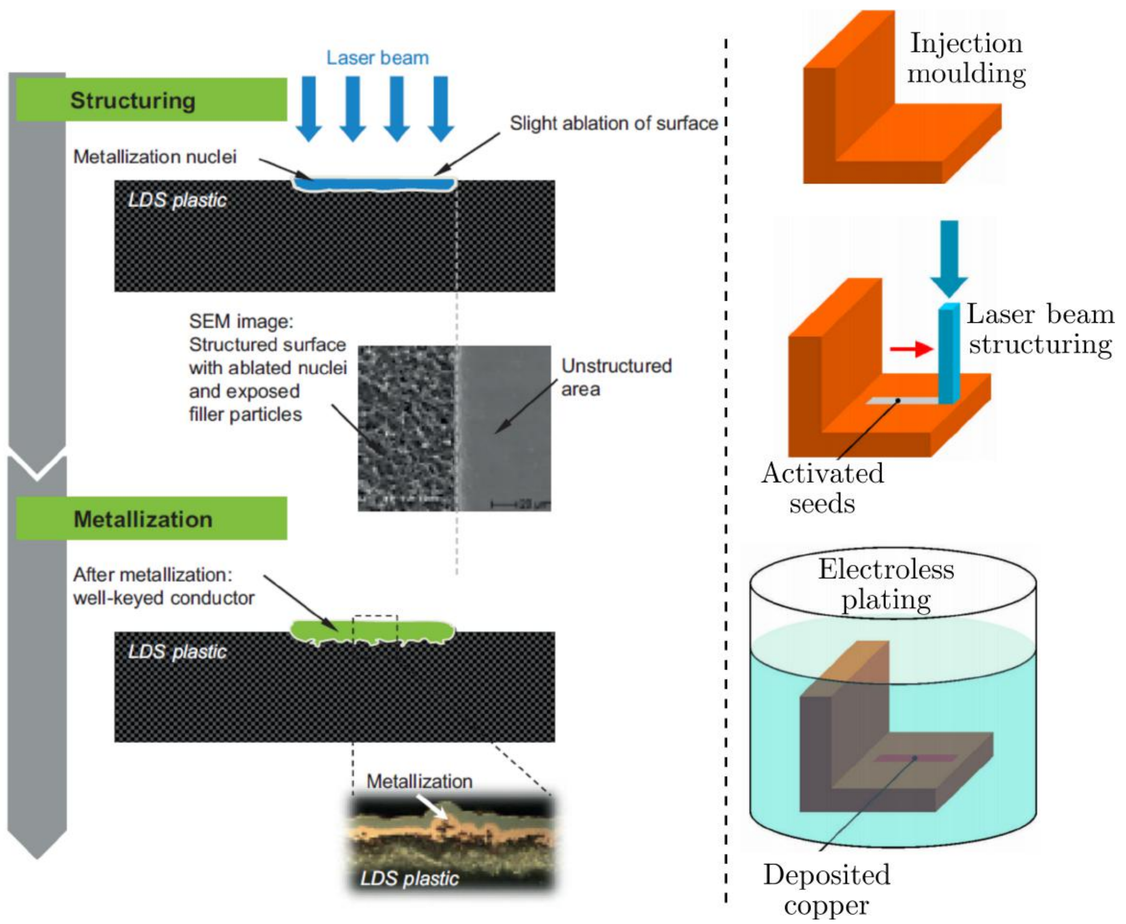


Figure 2.11: LPKF-LDS® process.

Electroless plating involves a set of reactions carried out in an aqueous solution without the need of external electrical power, opposite to the also common electroplating. The method achieves uniform thickness on the plated surface, which is important for antenna applications where a consistent and homogeneous conductivity is needed. After the copper electroless plating, some of the most common finish surfaces are[15]:

1. Electroless Ni + immersion Au (EN-IG)
2. Electroless Ni + electroless Pd / immersion Au (EN-EP-IG)
3. Electroless Ni + immersion Au / electroless Au (EN-IG-EG)
4. Electroless Ni + immersion Pd / immersion Au (EN-IP-IG)

Nickel-free options are also available (auto-catalytic Ag / immersion Au (ASIG)), which may be relevant depending on the user-case, in regards to issues with nickel allergies.
Different layer thickness are used for different applications. A standard 12-18 µm Cu, 2-4 µm Ni and min. 0.1 µm Au is widely used. These processes can be automatized and designed for high-volume production, e.g. by drum metallization, where the parts

uniformly get plated in a rotating drum. The following cleaning should be a continuous process, for increased homogeneity of the MIDs.

In the plating process, there are also some recommendations to take into account in the 3D design [17] and in the process itself:

- Avoid metallization on sharp edges.
- If drum metallization is used, snagging of the parts on each other should be avoided by 3D designs of softer shapes.
- Ejector pins should be positioned away from the LDS lines.
- Avoid cavities where chemicals can be trapped during bathing.
- Control the surface cleanliness throughout the whole process.

CHAPTER 3

Requirements

3.1 Mission statement

The device should implement an LDS antenna, potentially reducing the size of the HI, increasing its design freedom and facilitate an easier assembly of the device. The existing problem is fairly open, but the following assumption is made:

LDS antennas have been proved successful in a wide range of applications, including cell phone applications, laptops, medical devices etc. Therefore, the project will not focus on optimizing antenna performance based on its pattern. Focus is on identifying the new opportunities which arise with MID, both in regards to RF design, mechanical design and manufacturing. All of this depends on the possibility of making a robust interface between the PCBA and the LDS antenna.

3.2 Identifying the needs

The implementation of the LDS antenna should satisfy the following needs:

- Incorporate a proven interface for connecting the PCBA to the LDS antenna.
- Be able to withstand the typical tough environments for HIs.
- Maintain or increase current antenna quality, and materials involved for the HI application.
- Based on design for value, the LDS antenna should increase design freedom, ease manufacturability and respond to an economically viable solution.

Furthermore, there are many different stakeholders involved in developing such an antenna solution: Antenna / RF designers, mechanical design / material engineers, manufacturing, material suppliers, LPKF-LDS® and their licenses. Email correspondences, meetings, investigating state of the art and LDS applications theory, led to the following basic specification table.

3.3 Basic Specification Table

In Table 3.1 the basic specifications of the desired design are described based on theory and the above research. These will be prioritized in the decisions made throughout the design process. The design requirements regarding the connection interface will be highly prioritized though, since this project focuses on the antenna-PCBA connection.

Topic	Subtopic	Requirement	Criteria	Remarks
Dimensions	Antenna		Maximize possible antenna area	2.4 GHz ≃ 90 mm antenna pattern length
	LDS part		Minimize part volumen	
	Bridge			1 mm width has shown feasible for flex antenna
Orientation	Antenna	Parallel to head surface	Two sided and symmetrical	
	Bridge	Perpendicular to head surface		
Concept Design	Part Surface		LDS manufacturability	Obey LPKF-LDS® design rules.
	Part Material	Minimum same physical and mechanical properties as the material of which the existing part is made of	- Cost efficient - Lightweight - High durability	
	Antenna placement		Away from other conductive components	It is suggested that it is placed on the frame.
	Bridge placement		Away from other conductive compnents	
Connections	Bridge Connection	Biocompatible	- High durability - Ease of assembly	Lead-free if soldered
	PCBA connection	Biocompatible	- High durability - Ease of assembly	Lead-free if soldered

Table 3.1: Basic specification table.

Biocompatibility. The use of lead in medical devices has been prohibited since July 2016 [18], therefore no option including lead will be considered. The chosen LDS grade material should as well be biocompatible for HI applications.

CHAPTER 4
Design Process & Concept Generation

In this project, focus is placed on creating an innovative and robust design by the use of LDS manufacturing technology. Design for manufacturing is a driving force of the implementation. In the following, several concepts have been presented and rated against each other, in order to find the most feasible solution. The methodology used is the one described by Eppinger et al. [19] in *Product Design and Development*.

This chapter is supported by the design path of the diagram in Figure 4.1, where the subproblems are identified, the external exploration and the internal idea generation are conducted, for a final concept combination, rating and concept selection.

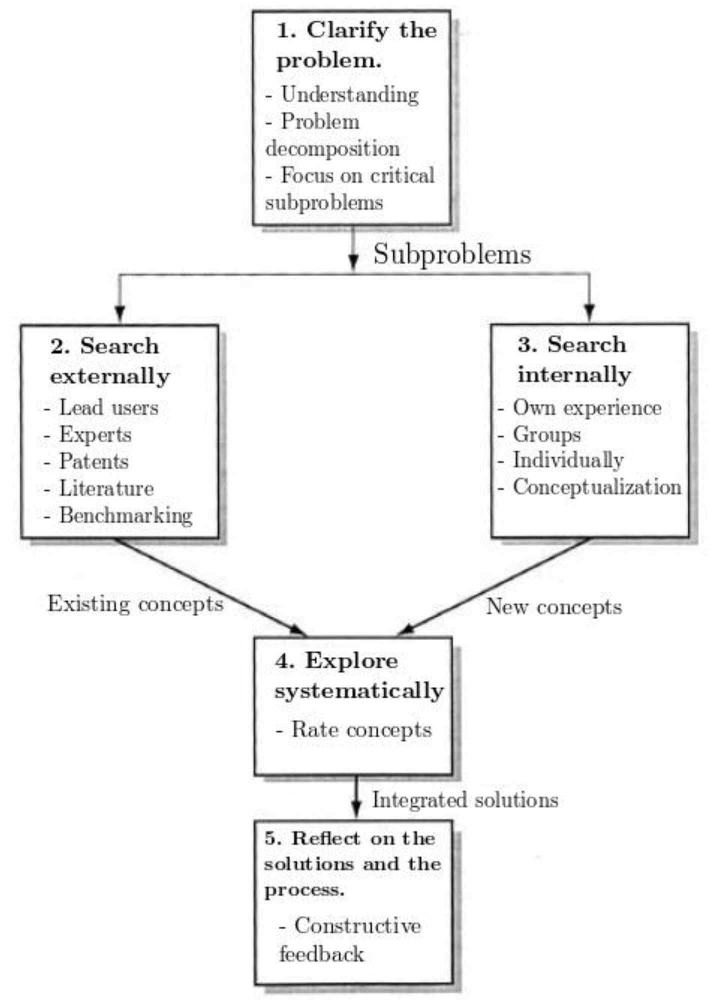


Figure 4.1: Design Path.

First of all the subproblems have been identified:

- A) LDS antenna contact interface to PCBA.
- B) Antenna position in the HI. Which part should it be mounted on.
- C) Bridge type and position.
- D) Bridge connection: If the bridge is not continuous, it needs a connection interface.
- E) Design modifications: Based on the above mentioned subproblems, design modifications of the chosen LDS part will be necessary. Related concerns about DFM and DFA will be analysed.

The preliminary brainstorm of possibilities was structured in the following diagram in Figure 4.2 and the following research and conceptualization was then narrowed down to the most relevant solutions.

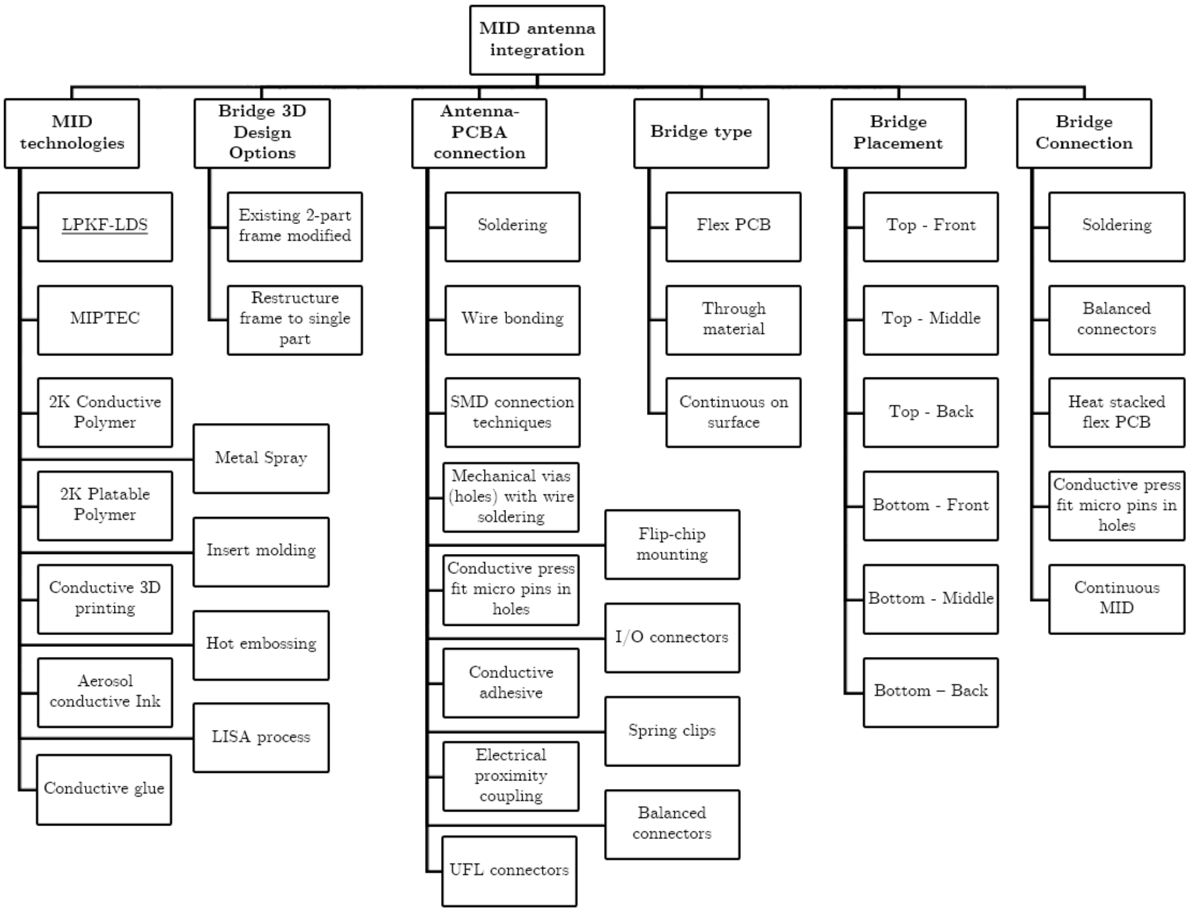


Figure 4.2: Idea diagram.

4.1 State of the art and external exploration

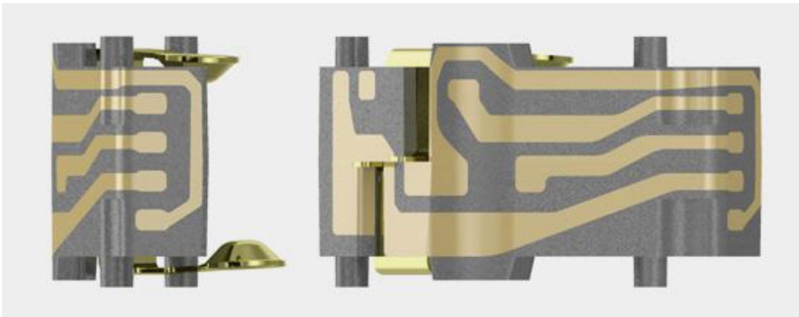
LDS has been used in numerous applications within the automotive, medical and smartphone industries, though it has not gained traction in hearing aids yet, due to the high reliability and precision requirements in these. So firstly, a research study was conducted about state of the art MID implementations through LDS, focusing on the HI industry.

MID frontrunners in the hearing industry.

- Siemens Audiologische Technik GmbH launched their first and only BTE with LDS in 2005, shown in Figure 4.3a.
- GN ReSound MultiMic SM2 Pro: HI accessory with LDS antenna.
- Phonak is part of the 3D-HiPMAS project, funded by EU, with a 5,3 million euro budget. A pilot factory for 3D High precision MID assemblies was the focus, and the project ended in 2015.

- Sivantos should be working on an LDS antenna placed on their HI frames, and Molex should be the LDS supplier.
- Microson is exploring LDS in an early phase, as shown in Figure 4.3b.

(a) Siemens Acuris P.



(b) Microson [20].

Figure 4.3

The design by Siemens Audiologische Technik GmbH is the only example of LDS in BTE HIs on the market. The purpose is to integrate three microphones onto the MID as shown in Figure 4.3a.

The same HI was disassembled as shown in Figure 4.4 and the LDS microphone carrier was found to have a coating for protecting the LDS lines from the environment. It is suspected that it is a SL1367 coating from Peters, also used by GN Hearing. At GN Hearing, different coatings are already used, so it would be a natural treatment for the LDS plating in future products.

(a) Disassembled HI.

(b) LDS Mic. carrier soldered to the PCBA.

Figure 4.4: Siemens Acuris P

The microphone carrier was made of LCP Vectra E 820i LDS, and the connection to the PCBA has been manually soldered with the wires seen in Figure 4.4b, a possible solution for the subproblem A in this project.

4.1.1 Types of LDS contact interfaces to PCBA

Up until now, the antenna-PCBA connection has been done by soldering as it was shown in Figure 2.7. Now, with the implementation of an LDS antenna, alternative ways of connecting the antenna have been explored. First of all, limited types of materials are available for LDS, and concerns arise about the temperature resistance of these materials, if soldering is to be considered. Secondarily, an easier and more cost-effective assembly of the hearing aid may be possible by integrating other types of connections or other ways of soldering. In the following, a selection of relevant contact interfaces will be described:

Non-detachable interfaces

These are the connections that require soldering or gluing, and the most relevant solutions, are the ones below:

Surface Mounting Technology (SMT) with reflow soldering. Different types of soldering exist, but it is first of all important that the method complies with the basic specifications of Table 3.1, where a lead free connection is emphasized. SMT and reflow soldering is an efficient and high-volume process, which can be automatized in production. The components are mounted directly on the conductive surface, normally being a printed circuit board (PCB). In this case, the surface would be the one of the LDS part where the tracks are to be connected. The process is shown in the diagram of Figure 4.5.

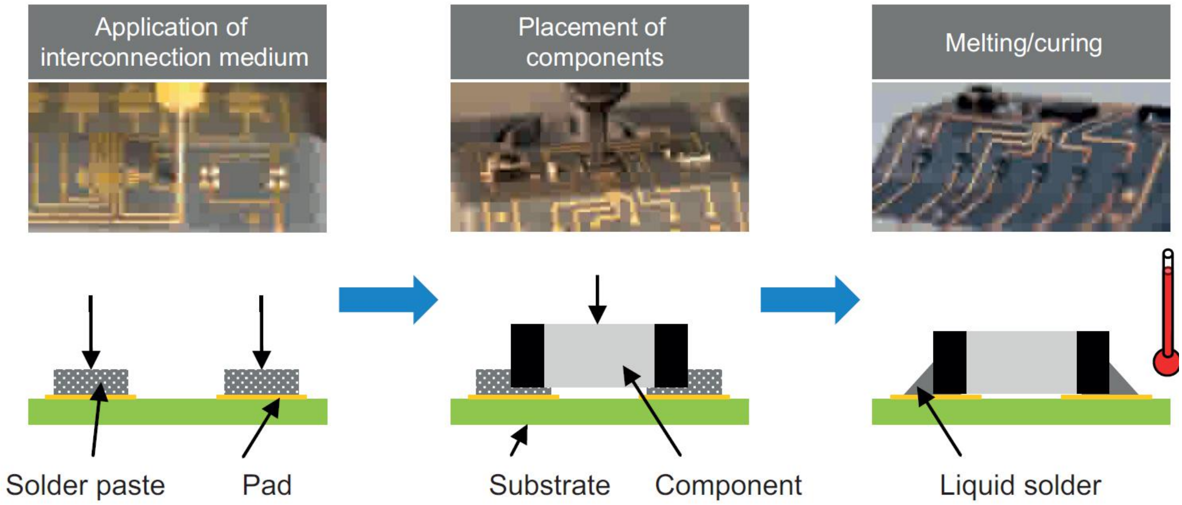
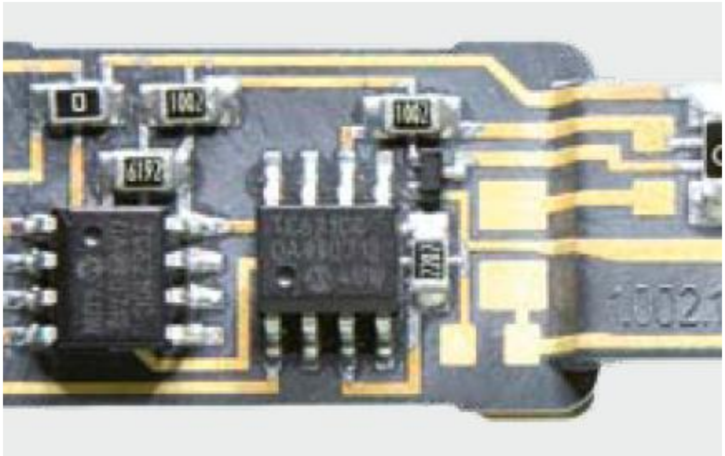


Figure 4.5: SMT [13].

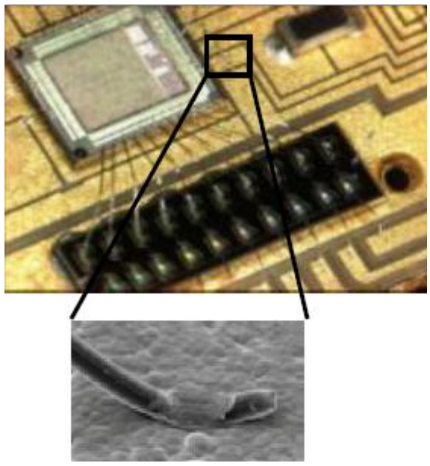
First, the solder paste is placed on the connection spot which in this case would be on the LDS trace or on the PCBA. Then, the components are placed on the solder paste spots and it is all heated in an oven, where the solder melts and fixes the components. This is a highly effective and automated process, reducing labour costs related to e.g. manual soldering.

One of the most used types of reflow soldering is the **vapor phase**. The main advantage of the vapor phase soldering is the low temperatures of the process, e.g. being 230°C for lead-free SnAgCu solder paste [21]. Since this method is based on heat transfer to the components, the geometry of the circuit to be soldered is not a limitation [22]. There are no blind angles, as there is when handling a soldering iron, but only when depositing the solder paste. This is an advantage for the curved and rather complex geometries of the plastic components in HIs.

An example of a Surface Mounted Device (SMD) with reflowed components on LDS, can be seen in Figure 4.6a.



(a) SMD on LDS traces, KaVo Dental GmbH[23].

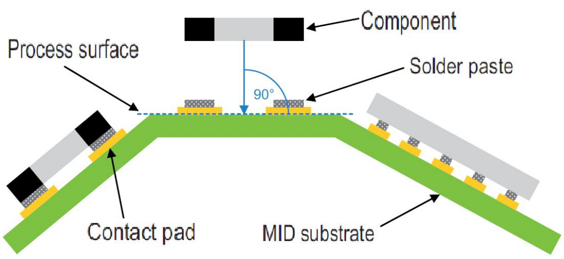


(b) Wire bonding, HSG-IMAT [24].

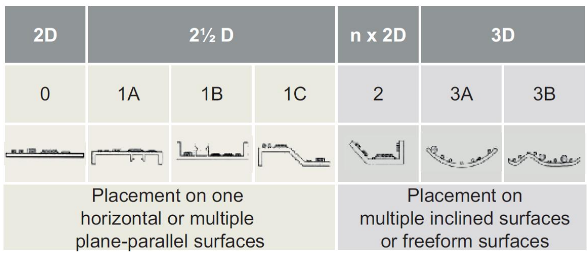
Figure 4.6

The most important factor to consider is the automated assembly requirements and the complexity of the 3D MID. The component of Figure 4.7a has to be picked up by a gripping tool and placed on the correct solder spot. At the positioning moment, the surface must be perpendicular to the component, otherwise there is a risk of misplacement or tilting of the component. In this case, the PCBA would be the component and the LDS antenna is the surface, or viceversa. Conventional pick & place methods are therefore not well developed yet for 3D applications, and 3D MID would need a multi-axis assembly machine for non-planar applications.

As seen in Table 4.7b, different categories exist depending on the complexity of the 3D arrangement of components, where 0 is the desired constellation and 3B is the most complex. When designing the MID and the LDS antenna connection, this should be taken into account. The scale also applies to most other connection techniques like manual soldering, or detachable connections that may have to be soldered on the part nevertheless.



(a) Component placement.

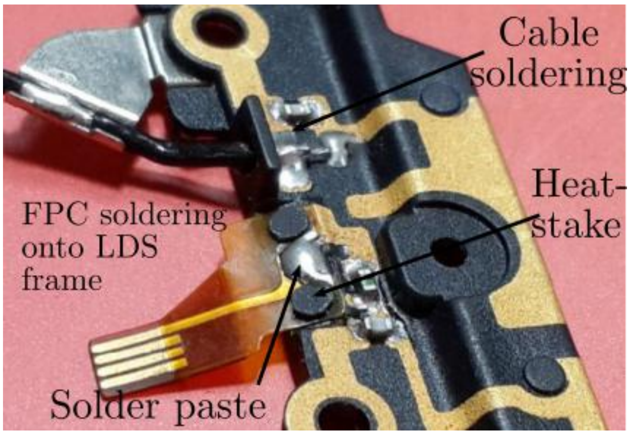


(b) 3D capabilities.

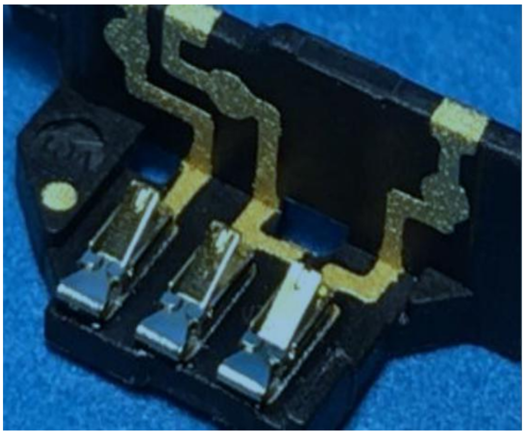
Figure 4.7: [13].

When the component is placed on the solder paste it is prone to fall off if the surface is tilted. There is though some adhesive strength in the solder paste, but bigger components will not be secured. If a whole PCBA is to be soldered to the LDS antenna, sizes are too big to rely on the solderpaste alone. Therefore there is a method (*in situ fixation*) where glue is used to secure the component while it is still hold by the grabbing tool [13]. An alternative is to use conductive adhesive, which also establishes the electrical connection at the same time.

Manual soldering. It is the current method used for soldering the flex antenna to the PCBA. One of the reasons is the complexity related to handling the flex PCB antenna and the jig required in order to fix it precisely to the frame and PCBA. Higher temperatures than vapor phase soldering are necessary. Usually a solder tip temperature of 340°C is used. The solder paste consists of an alloyed metal powder and the flux, which removes oxide layers and wets the solder pads when soldering.



(a) Flex PCB soldered to LDS.



(b) Connector clips soldered to LDS.

Figure 4.8: [24]

Conductive and non-conductive adhesives. Due to the relatively high temperatures needed for soldering, adhesives can be an alternative capable of connecting at much lower temperatures (80 to 150°C) [13]. Compared to soldering, the glue connection is better at impact absorption due to its non rigid structure. Similar SMT methods can be used to deposit the glue and the components. Three different types exist, and these are represented in Figure 4.9

Isotropic Conductive Paste (ICP) bonding fixes the components with electrical conductivity in all directions. The mechanical strength of the adhesive keeps the connexion together, while the immersed metallic fillers in the polymer establish the electrical connection. It is widely used in miniaturized devices.

Anisotropic Conductive Paste (ACP) bonding fixes the components with electrical conductivity, only in the vertical directions, i.e. the direction of the bonding force. The metal particles of the polymer establish the connection only when they are compressed together. Therefore it is normally applied as films adjusted to the position and size of the application, and the fillers will act as insulators in the horizontal directions.

Non-conductive Paste (NCP) bonding does mostly rely on a simple electrical connectivity by direct contact of the conducting surfaces. The adhesive is normally heated and put on the edges of the connection. In some situations, an additional connection step like wire bonding is used, especially for chip mounting applications.

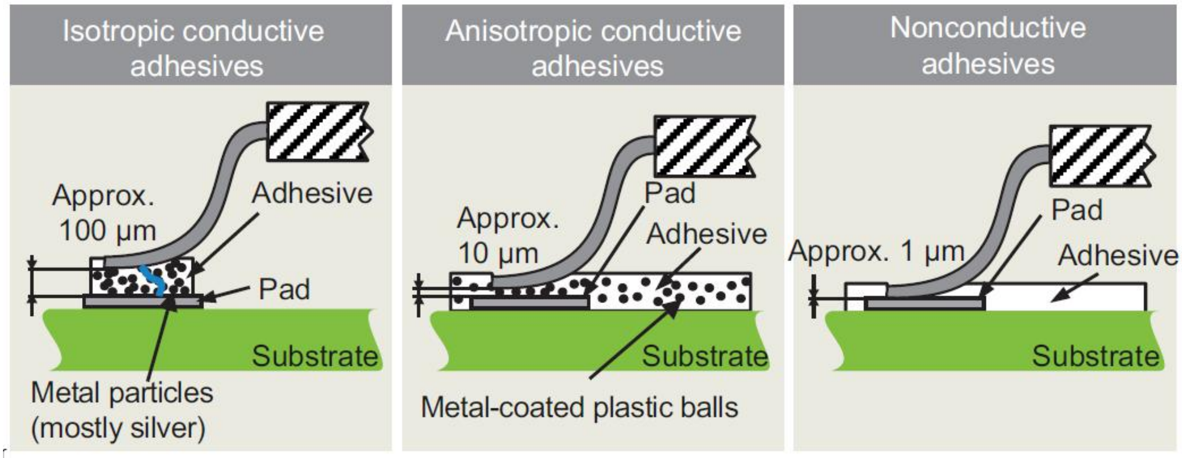


Figure 4.9: Connection adhesives [25].

Wire bonding. An example of wire bonding on LDS tracks is shown in Figure 4.6b. The ultrasonic vibration bonding is the technique recommended for MID [13] due to the relatively rough surfaces on MIDs after laser structuring. The connection is made by welding the wire to the point of contact, and the energy is delivered by ultrasonics. As stated earlier, it is normally used in complex and microscopic silicon chip connections.

Heat staking. Figure 4.10 shows the principle of heat staking, where a plastic stud is heated and thereby fixing the part which is under it, by compression. It is especially relevant for flex PCBs as the solution shown in Figure 4.8a. The method could fix an eventual flex PCB if it was to be combined with the LDS traces. The method is normally combined with soldering for establishing the electrical connection.

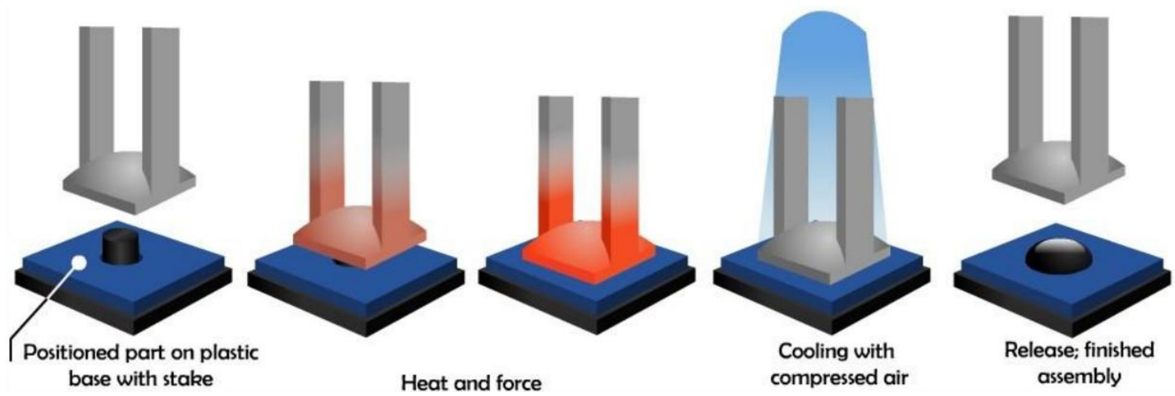


Figure 4.10: Heat staking [26].

Detachable interfaces

Amongst the detachable interconnective interfaces, these could be relevant solutions:

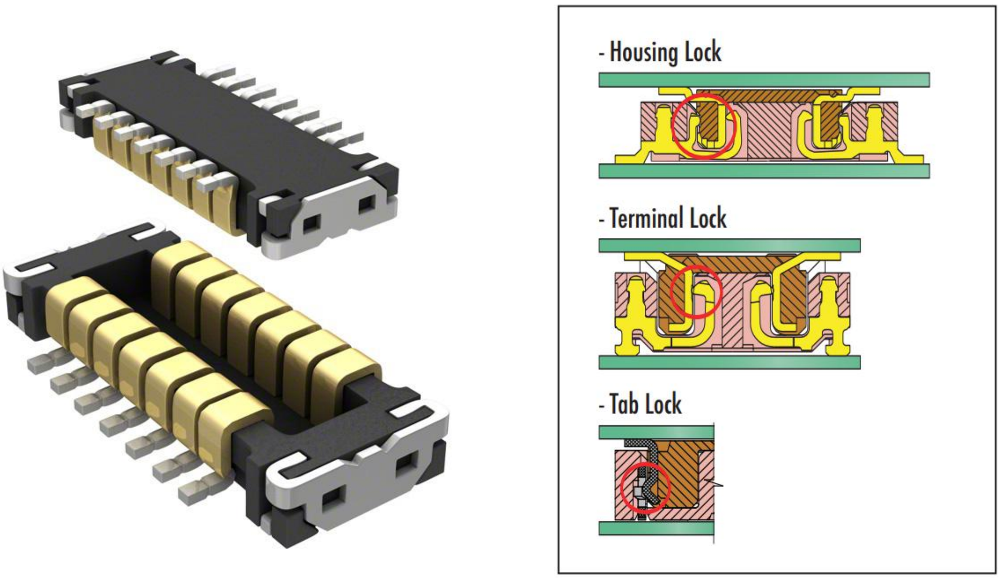
Press-in connection. These connections do not require thermal loading and the contact is simply established by pressing a pin into a plated hole. The contact must be tight in order to have a reliable connection, which will then have an increased shock and vibration resistance. An example can be seen in Figure 4.11a, where it is designed orthogonally for a top push when entering the hole, and thereby fitting in the cavity. It is important to have enough copper layer thickness in the hole, and optimize the design for the expected number of insertion / pull-out cycles and the contact forces involved.

Pogo-pins provide reliable connections for applications with risk of vibrations and impacts, which is the case in HIs. These include a spring, acting as a damper for vibrations as well as applying a continuous pressure towards the connection pad, as it can be seen in Figure 4.11b. The smallest found pogo pins have a height of 2.2 mm, which are big dimensions for a HI connection, but worth considering. The main challenge is though to design the pogo-pin for a reliable matched-impedance circuit, which is very relevant for antenna applications.

(a) Press in pin [27].
(b) Pogo pin diagram [28].
(c) Spiral spring connector.
(d) Spring clip.

Figure 4.11

Spiral spring connectors are similar to the pogo-pins, but can be found in heights down to 2.0 mm, so they take up less space in the vertical direction, but their width is normally minimum 4 mm. An example from Yokowo Co. Ltd. is shown in Figure 4.11c. The challenge with spring connectors and pogo pins, is the need of having a pushing force in order to keep the contact. So the mechanical design must take this into account, and put the LDS and PCBA connection in constant compression.



(a) Slim Stack ballanced spring connector [29]. (b) Different locking mechanisms.

Figure 4.12

Spring clips. As the one in Figure 4.11d, this connection offers high reliability. It would be soldered to the PCBA or the LDS line and izes down to 2 mm exist, though taking up a lot of space in HI applications.

Balanced spring connectors. A 14-pin SlimStack from Molex is shown in Figure 4.12a which allows minimal forces to lock the connection and is reliable against shock and vibration as shown in Figure 4.12b. Connector heights down to 0.6 mm can be found which will save space. These are ideal for tight packaging applications, but normally used for multiple connections in a row.

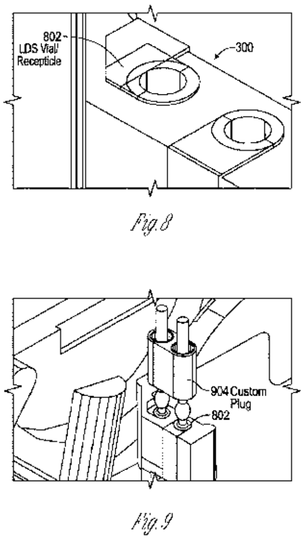
The drawback of using a spring connection to LDS is that a nonconductive protective coating can not be used on the connection pads, and therefore corrosion may occur in this zone, especially if a constant high pressure force is not maintained.

Proximity electrical coupling. No physical contacts are present between the feed line and the antenna, which makes it a simple and space saving connection. Earlier studies by Færch et al. [30] have shown prototypes of using proximity electrical coupling to connect a copper antenna to the RF chip of the HI PCBA, and has shown successful results. The technology is though not matured yet but could be considered for future implementations.

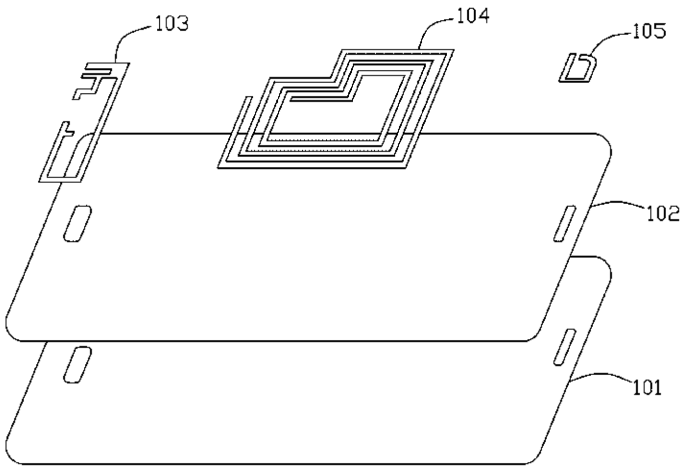
4.1.2 Existing patents

Solderless module connector for a hearing assistance device assembly (EP 2016 0166704 - Starkey Laboratories Inc) describes a connection to LDS traces by direct compression of an Universal Circuit Module (UCM) into the LDS structure without the use of wires or solder. A representation can be seen in Figure 4.13a where the custom plug is the UCM for the shown application, which connects to LDS via holes through a press fit connection.

Mobile device with LDS antenna module and method for making LDS antenna module (0005392 - AAC Technologies) describes the method for making an LDS antenna module on the back cover of a mobile device. Figure 4.13b shows the diagram.



(a) Universal Circuit Module.



(b) LDS antenna for mobile devices.

Figure 4.13

These were taken into consideration in the design phase.

4.2 Conceptualization and Internal Exploration

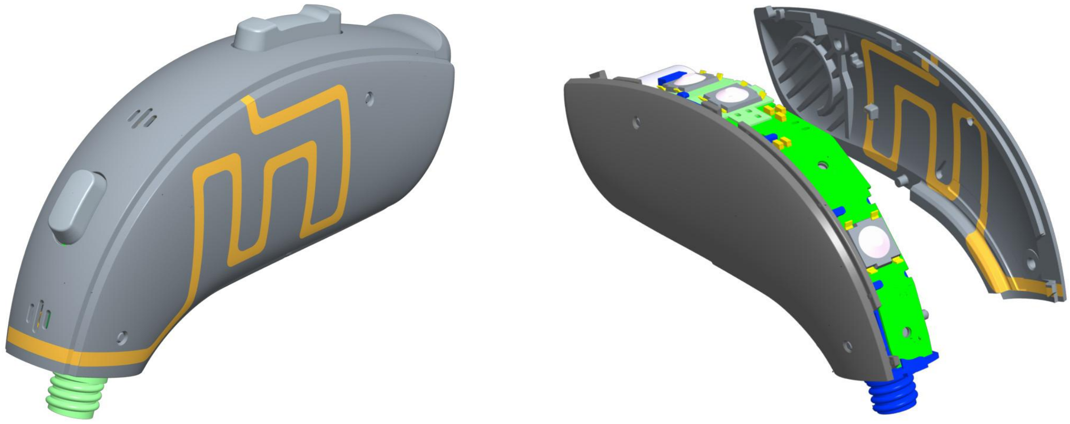
Based on the external exploration, the following conceptualization of solutions will be carried out in regards to the basic specifications of Table 3.1. First, the previous experience of GN Hearing will be analysed in order to design new concepts for the LDS antenna implementation.

4.2.2 Antenna position

The antenna pattern needs as large as possible an area to be put on, since the length of the pattern determines the performance of the antenna [7]. The biggest plastic areas are found on the following 3 positions, where the antenna also is isolated from the rest of the electronics:

On housing exterior. By placing the antenna on the exterior of the housing as in Figure 4.23a, the biggest achievable area could be exploited for antenna pattern optimization. Also, the antenna is moved as far away as possible from the rest of the components and potential interferences.

Though, the pattern will be in direct visual and skin contact with the user, so a covering insulating paint would be needed. Since the housing parts are detachable components, a detachable connection is needed for connecting the pattern on the top housing with the 2 side shells, and from here, to the PCBA, increasing the complexity and variation risks. The LDS design rules presented earlier, are also a potential issue. Marked in red in Figure 4.24 some of these are shown, where the laser would have difficulties in following the path and connecting the lines. If selected for the LDS antenna placement, workarounds could be found, were the housing is redesigned for the purpose, e.g. as in Figure 4.25a, where a two-shell housing is shown, instead of a 4 shell solution as it is in Berlin 70. In the two-shell, the LDS lines could travel on the orange coloured area all the way from the left to the right side of the HI.

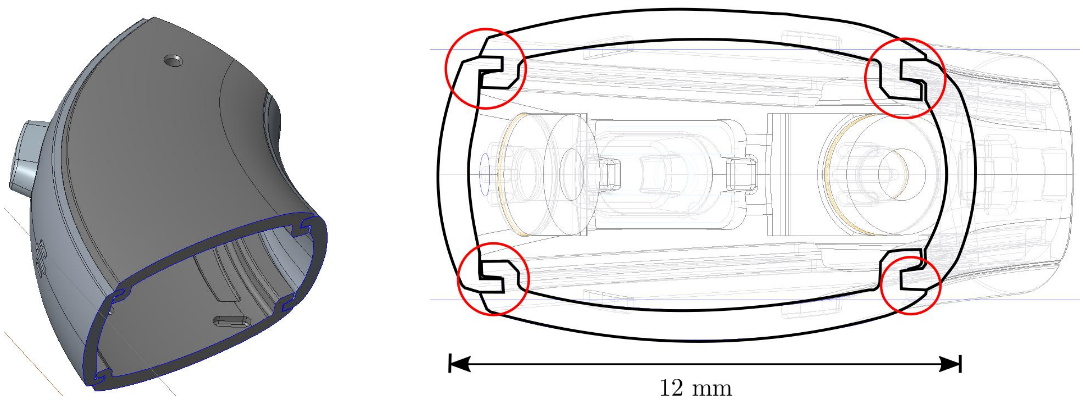


(a) LDS on housing exterior.

(b) LDS on housing interior.

Figure 4.23

On housing interior. By situating the pattern on the housing interior as in Figure 4.23b, the plating will not be in direct visual or skin contact with the user and the painting is not necessary. Though, same detachable connection issues arise as in the exterior plating, an important disadvantage. Similar LDS design constraints arise too.



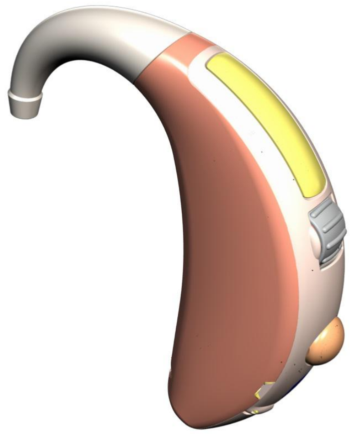
(a) Shell cross section.

(b) Identified geometry issues.

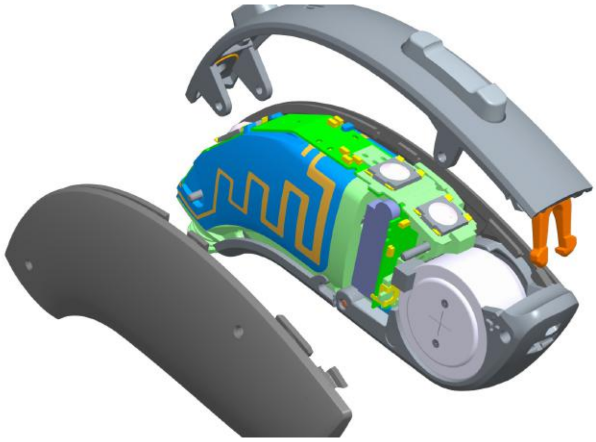
Figure 4.24

In correspondence to the basic specification of being able to paint the housing exterior, the most efficient method is using a tumble spraying system where the small plastic parts are tumbled in an elliptical-shaped barrel while a spray nozzle adds the paint. For the housing parts, both sides would be sprayed, leaving no way for the LDS plating to be interconnected. So if the LDS was to be done on the housing parts, a conventional spraying method should be used, which is less efficient.

On frame exterior. In the current designs, the flex PCB antenna is placed and glued to the frame. By placing the LDS antenna on the frame, the amount of interconnections is reduced, due to the immediate contact of the frame to the PCBA as shown in Figure 4.25b, and there is also no direct user contact to that part, which is desirable.



(a) Two-shell design.



(b) LDS on frame.

Figure 4.25

The on body performance of the antenna is highly affected by the position of the antenna, and if placed on the housing shell, the antenna will be closer to the human head, reducing the reach of the antenna by early meeting of these obstacles which have low transmission coefficients. This is due to the high water content of human tissues which promote high losses at 2.4 GHz [35]. This is especially an issue for the ear to ear connectivity.

An identified potential issue with LDS is the use of nickel (in standard platings) which can cause allergy by direct and prolonged contact with the human skin [36]. No cases of nickel migration by sweat have been identified, if nickel is not in direct skin contact. Having LDS on the frame is biocompatible and therefore preferred.

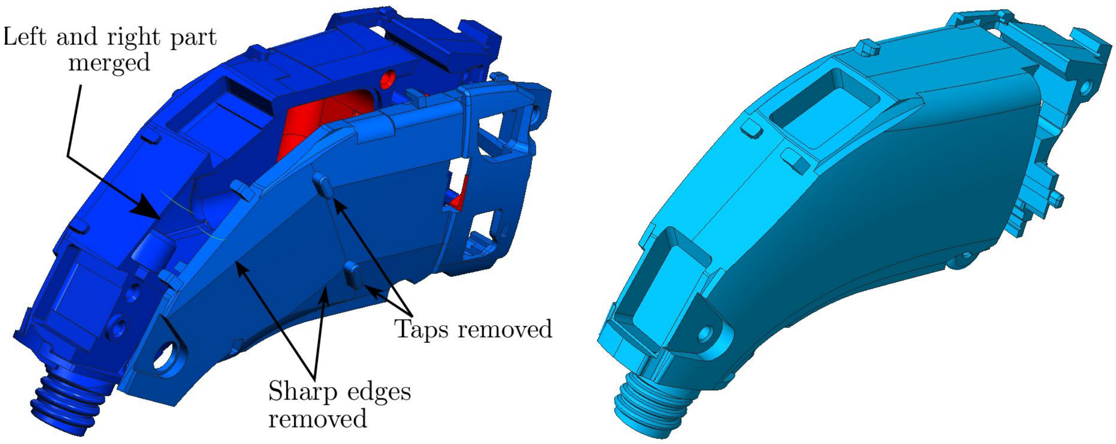
Conclusions

A screening of the above concepts is summarized in Table 4.1. Based on a weighted concept screening of the properties named and described above, it was decided to place the LDS antenna on the frame exterior.

		Antenna placement					
		On housing exterior		On housing interior		On frame exterior	
Selection criteria:	**Weight**	Rating	Weighted score	Rating	Weighted score	Rating	Weighted score
Antenna design freedom (area)	10%	5	0.5	3	0.3	1	0.1
Distance from other electronic components	5%	5	0.25	3	0.15	2	0.1
E-2-E RF performance based on theory	15%	1	0.15	3	0.45	5	0.75
Biocompatibility complexity	10%	1	0.1	4	0.4	5	0.5
LDS design rules compliance	20%	2	0.4	1	0.2	4	0.8
Connectivity complexity	25%	1	0.25	1	0.25	4	1
Assembly complexity	15%	1	0.15	2	0.3	5	0.75
Total Score		1.8		2.05		4	
Rank		3		2		1	
Continue?		No		No		Yes	

Table 4.1: Concept screening.

Now that the frame was chosen to be the antenna carrying part, following preliminary design reconstruction shown in Figure 4.26 was made:



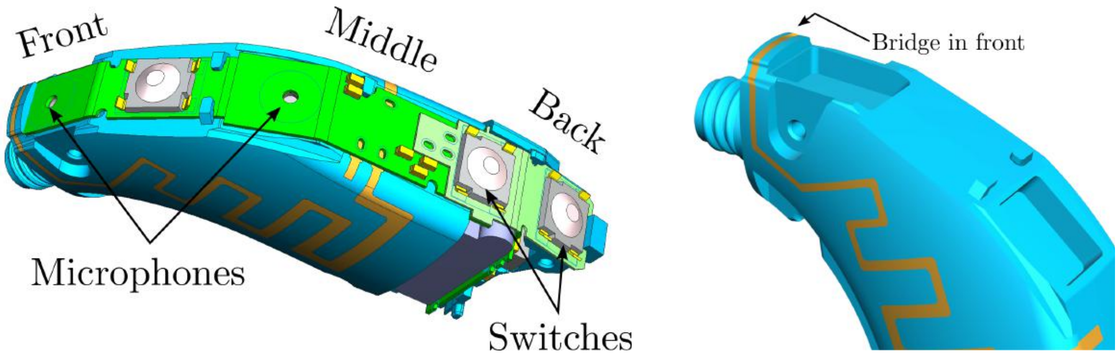
(a) Original frame. (b) LDS optimized frame.

Figure 4.26

The taps have been removed since their main function was to guide the FPC antenna. The antenna surface has been curved following the original shell skeleton, because with LDS there is no need of having the ”diamond” shaped surfaces of the original frame.

4.2.3 Bridge

As stated earlier, the bridge must be perpendicular to the surface of the head [4, 5] and on the top of the HI. Now that the LDS antenna is chosen to be placed on the frame, it must be possible to redesign the frame so the bridge is not needed to be an external part as a flex PCB, which would increase complexity. In that way the bridge will be an integrated part of the frame. For implementing this, the two lids of Figure 4.26a were merged together. The bridge was now chosen to be positioned at the top and front part of the frame as shown in Figure in 4.27 because most electrical components are positioned in the middle and in the back. So the front zone was identified to be the one where it would be easiest to pass the bridge avoiding potential interferences. Other solutions could include passing the bridge over the PCBA by extending the LDS substrate forming a bridge from side to side, which would though increase complexity.



(a) (b)

Figure 4.27: Bridge demonstration.

4.2.4 LDS-PCBA Connection Interface

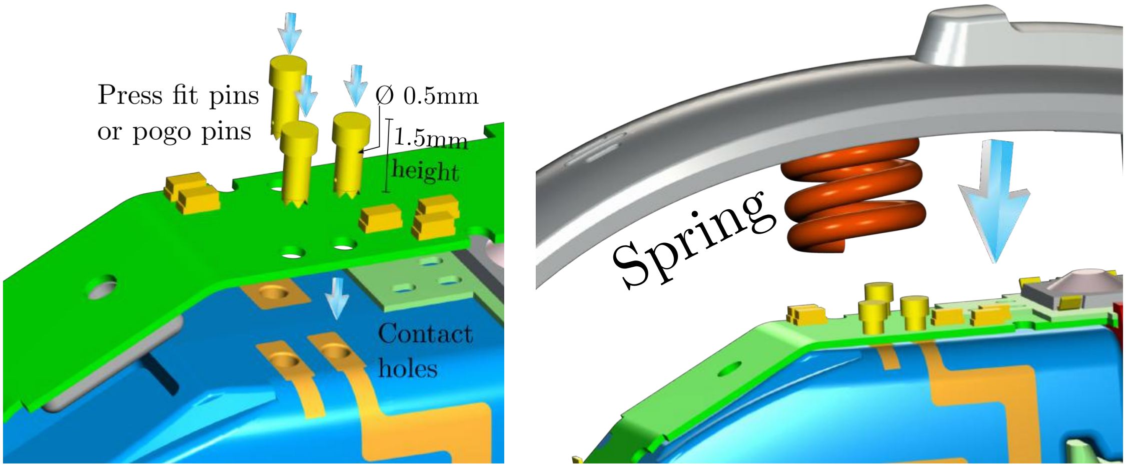
Based on the connection exploration of Section 4.1.1 a few methods were considered for further development.

4.2.4.1 Detachable connections

As presented on page 33, detachable connection solutions are available for LDS. Examples are pogo-pins, press-fit pins and c-springs. The advantages are that these can be disassembled, facilitating repairs and replacements of parts and similar. Furthermore, these are normally more tolerant with impacts since the flexibility of the connections are increased, especially for spring based solutions. The downside of the detachable connections is their general big sizes, which is an issue in the limited space of HI applications.

Pin connection

A concept was developed for a pin connection as seen in Figure 4.28. It is based on 3 connective pins, which could be pogo-pins or press-fit pins. The pins are inserted and soldered to the PCBA, and the connection is made through the contact holes in the LDS. Concerns can arise of wearing of the plating in the contact holes. For this, these could be coated with electrolytic tin or other material which would protect against mechanical wear. As seen in the dimensions of Figure 4.28a it is hard to find commercially available pins of these sizes, but these could possibly be manufactured if adopted as a solution.



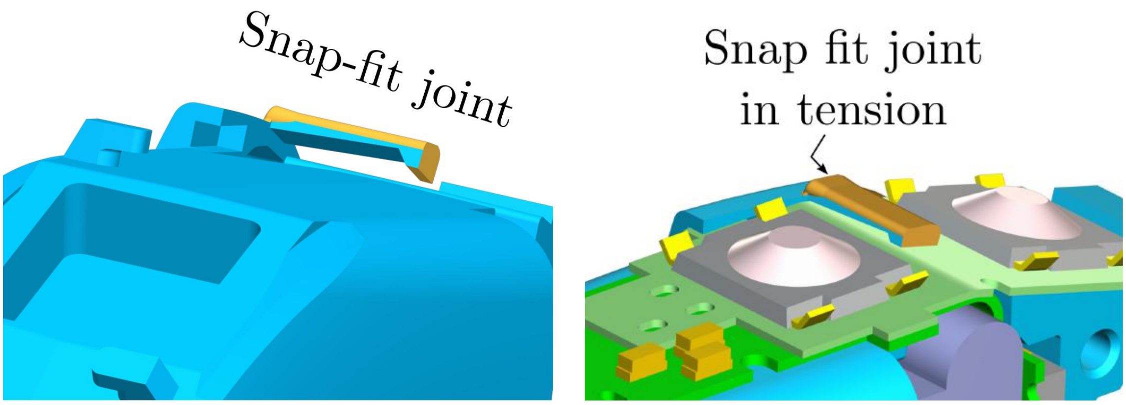
(a) (b)

Figure 4.28: Detachable connection concept.

The PCBA will naturally be bended around the frame, creating stress at the connection interface. Therefore, a compression force is needed in order to maintain the contact between the pin and the LDS lines. A conceptual illustration is shown in Figure 4.28b, where the red spring represents a way to maintain a constant force towards the plating. The durability and fatigue of springs, is the issue which should be evaluated for the application, because cyclic loading and constant compression will make the spring loose force and shorten over time.

Snap fit

Other concepts including elongation of the substrate material for LDS were considered as well. Designs including snap-fit joints as the concept of Figure 4.29 could be designed to maintain the constant pressure on the connection spot, and a solder-free solution could perhaps be achieved. The viability of such a connection would require a proper snap-fit design able to withstand the forces involved, in order to have a continuous PCBA contact without early fatigue. The connection could be assisted by soldering, similar to the LDS tap-PCBA concept which will be presented on page 49.



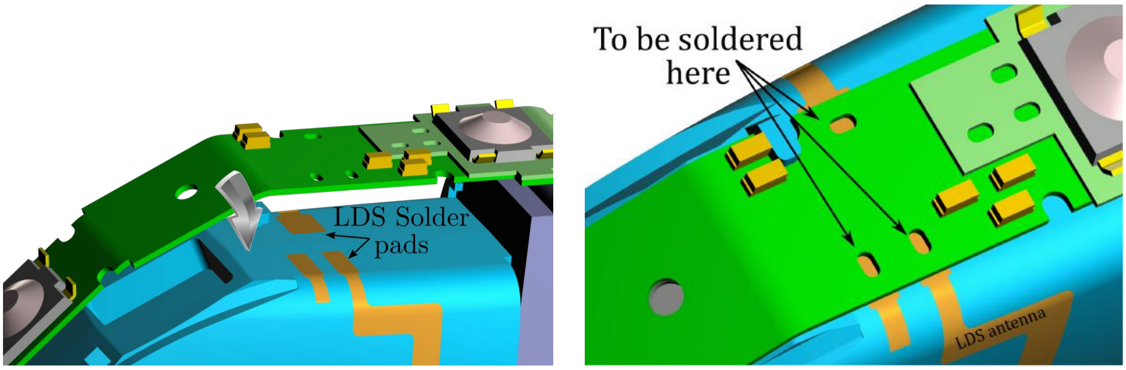
(a) (b)

Figure 4.29: Snap fit joint concept.

4.2.4.2 Non-detachable connections

Soldering connection through oval holes

Transferring the principle of soldering the Berlin 70 of Figure 2.7 to an LDS antenna, the soldering connection has been designed as shown in Figure 4.30.



(a) (b)

Figure 4.30: LDS soldering through holes.

The method is directly comparable to the Berlin 70 design. It would be necessary to evaluate the external forces and environmental factors which could influence the soldering. The LDS-PCBA soldering should be more influenced by external forces and environmental factors compared to the FPC antenna where the flexible soldering flaps can slightly move vertically and horizontally. The LDS soldering pads would be fixed to the frame allowing very minimum translations of the PCBA on top. This would be something to be simulated and tested if implemented. The challenge is to design the fixation of the PCBA so translations are not allowed. Extra taps could be positioned around the solderings for keeping the PCBA in place.

Connection through PCBA fixing tap

Another design solution satisfying the desire of being able to connect the LDS antenna to the PCBA on its side, would be taking advantage of the taps shown in Figure 4.31. The design would let the LDS track follow until the top of the tap, plating the whole tap as shown in Figure 4.32. Thereby, the maximum downwards force is also applied right at the connection, keeping the PCBA down to the frame. Then, the tap would be soldered to the PCBA allowing the antenna connection from here, saving space on the PCBA. If the tap was designed to maintain a constant pressure on the PCBA, the connection could be made solder-free.

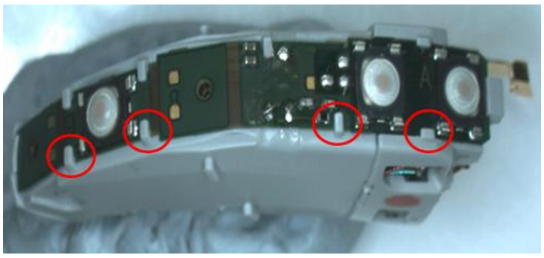
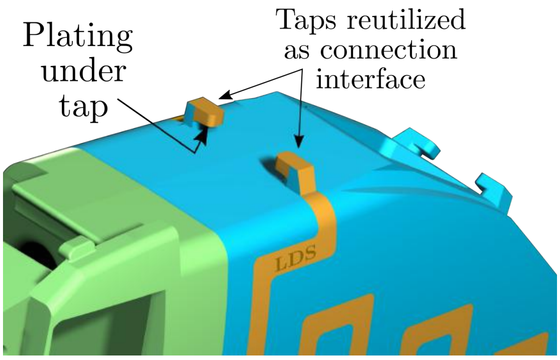
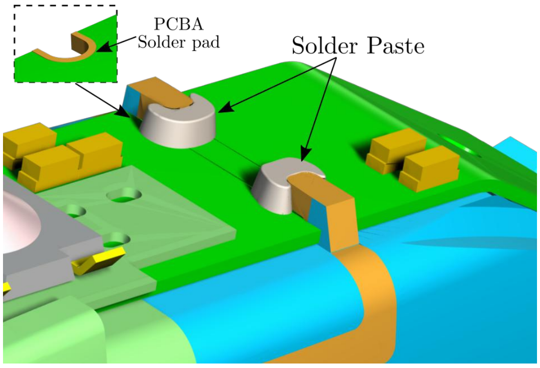


Figure 4.31: Berlin 70 frame taps.



(a) Plated taps

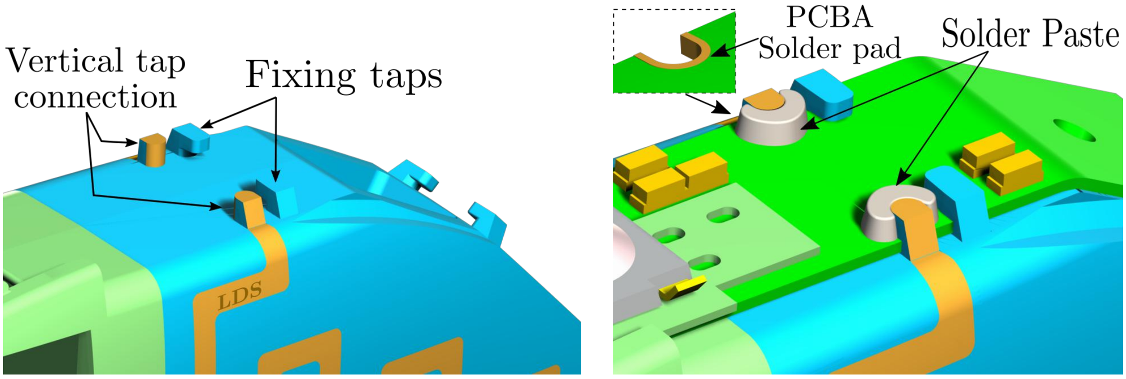


(b) 3D model concept

Figure 4.32

Vertical connection on the PCBA side

Implementing a vertical soldered connection, as the one of Berlin 60 in Figure 2.7, would be a concept saving even more space on the PCBA than the one above. For assuring that the PCBA is held down, additional fixing taps would be needed, as the ones of Figure 4.33.



(a) (b)

Figure 4.33: Vertical connection concept.

The tap design must though be considered to allow the insertion of the PCBA on the top of the frame.

4.2.5 Conclusion

Due to the limited space in HI applications, soldering has been chosen as the connective interface to test in this project. By testing the soldering connection of the LDS antenna to the PCBA as in Figure 4.30 it will be verified if the concept is robust. If time would have allowed, more concepts, especially the snap fit and press fit pin connections would have been tested, identified as other interesting opportunities for detachable connectivity.

For testing the solderability of the LDS and plated lines on the material, manual solderings will be tested. Manual soldering is a more aggressive connection process, with high temperatures, and less controllable compared to SMT techniques and reflow soldering.

If the test results are satisfactory it could therefore be concluded that a later on automation of the soldering process could be implemented through reflow soldering.

4.3 Frame modifications

For implementing the LDS antenna with a continuous bridge, the frame needs a redesign so it can accommodate the PCBA and insert the receiver and the telecoil, and their interconnections. The main issue is to create the closed receiver compartment, which has to be accessible for connecting the receiver to the hybrid. Figure 4.34 shows the current frame assembly. The receiver is connected to the hybrid by wires, and so is the telecoil.

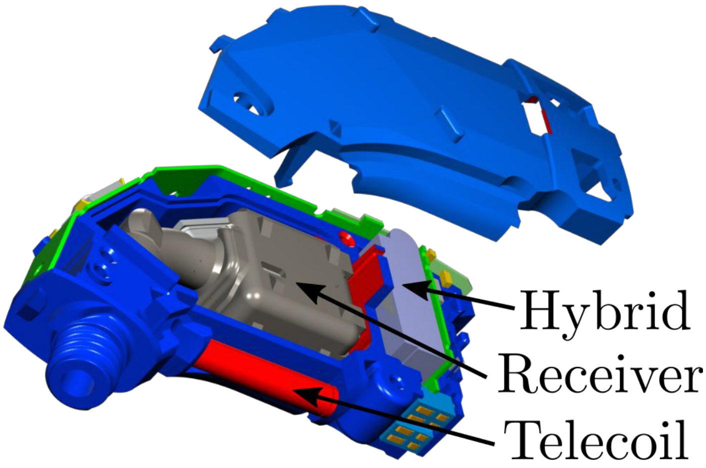


Figure 4.34: Current frame assembly.

For inserting the receiver, the frame has to be split in two parts for this to be possible. The receiver compartment is desired to be closed, due to acoustic requirements. The four most realistic concepts are represented in Figure 4.35, showing the relation between the overpart (A) and the underpart (B).

As stated, the current assembly is split in two lids as represented by illustration ① of Figure 4.35. Concept ② suggests to insert the receiver through the top front having a small overpart (A). Difficulties will though arise on how to connect the receiver to the hybrid. The telecoil will be inserted from the bottom as in the current design.

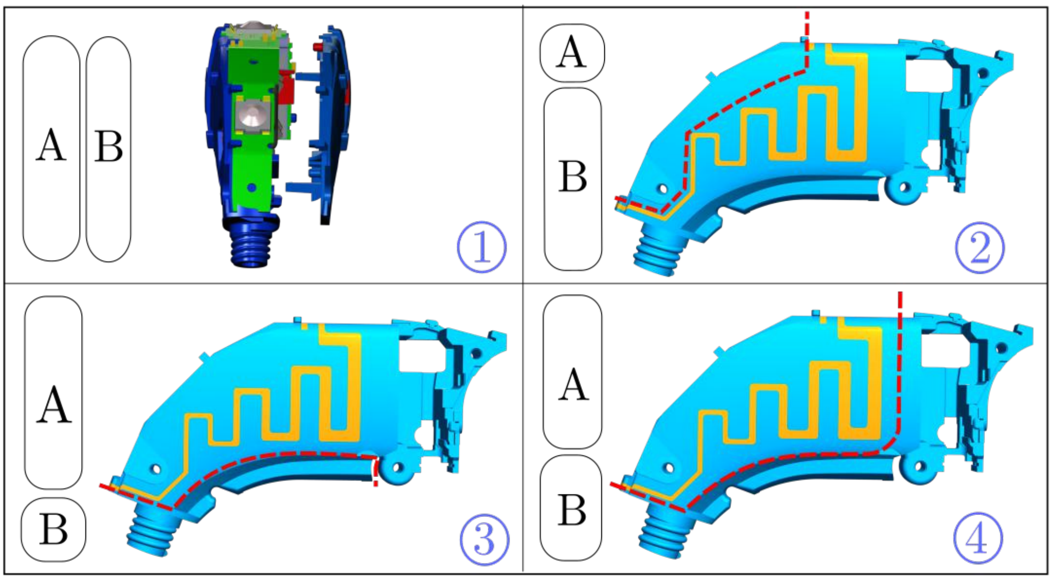
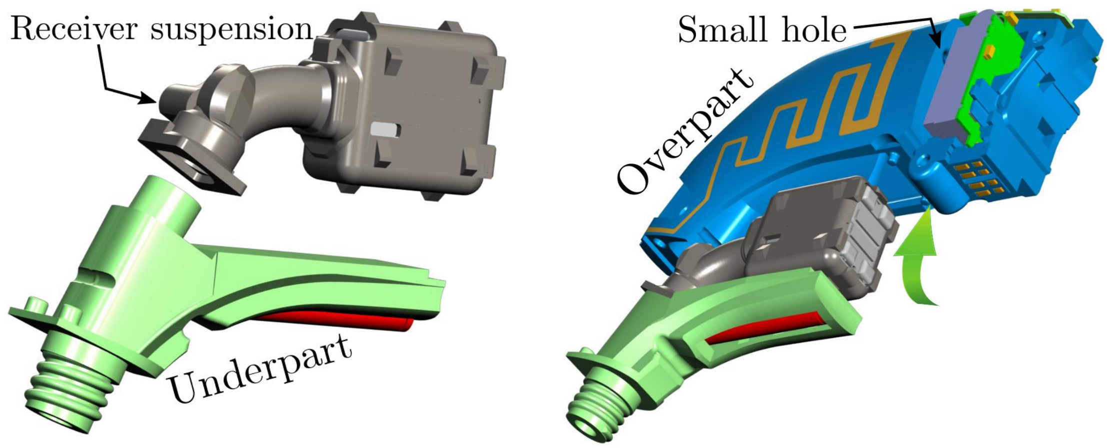


Figure 4.35: Frame design concept diagrams.

Concept ③ divides the frame from below making the underpart (B) of minimal size.

It leaves an opening in the bottom, as shown in Figure 4.36. This allows the insertion of the receiver which then can be soldered to the hybrid passing its cables through a small hole in the overpart, it will though be a high precision task due to blind angles when assembling.

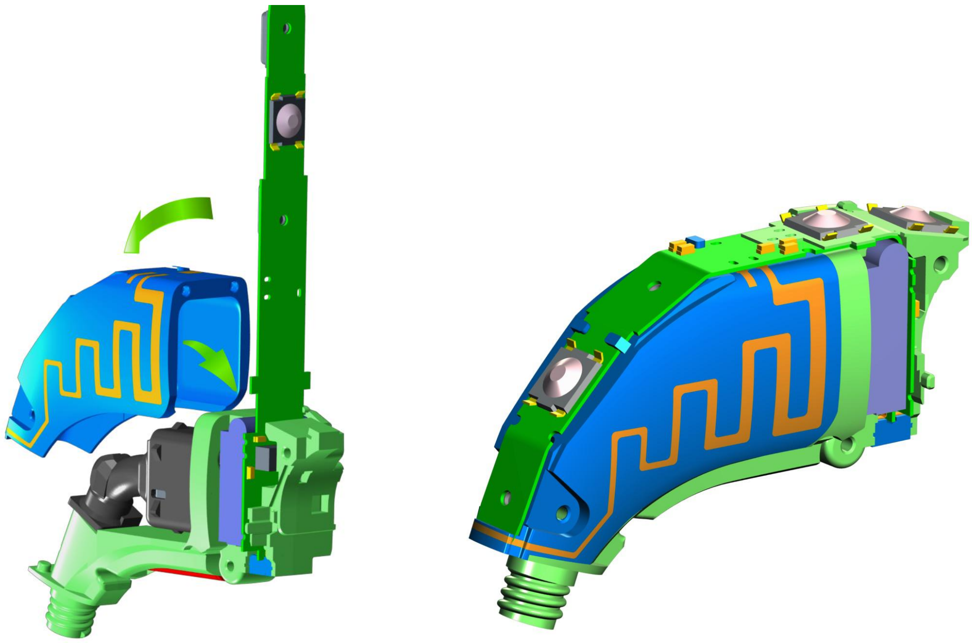


(a) Receiver suspension insert into underpart.

(b) Insertion of receiver and underpart with telecoil.

Figure 4.36: Concept ③.

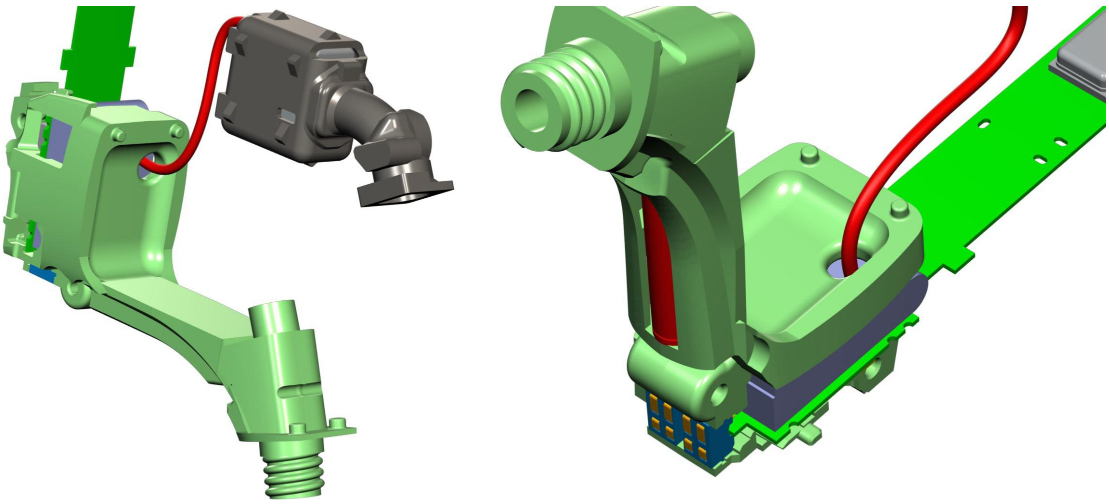
Concept ④ suggests a more even split. The idea behind is to minimize the amount of material to be used as the substrate for LDS. LDS-grade material is more expensive than regular polymer resin, therefore the design should divide the part such that minimum part volume is taken up by the LDS substrate. The underpart does also include the PCBA insertion part, which has the most complex geometry and small tolerances because battery springs and other components must fit in the cavities. Since limited types of LDS-grade materials exist, it is advantageous that complex parts, as this one, can be injection moulded with regular polymers. The assembly of the concept is shown in Figure 4.37, and inserting the receiver into the frame is also allowed by the design. The overpart will be fitted on top of the overpart and thereafter, the PCBA should be buckled over the overpart, making the soldering of the antenna possible.



(a) (b)

Figure 4.37: Concept ④ assembly.

In Figure 4.38 the intended way to connect the receiver to the hybrid is shown. A soldered red wire connects the hybrid to the receiver through a hole in the underpart. The same would be done for the telecoil. Making these connections before mounting the overpart, will ease the assembly.



(a) (b)

Figure 4.38: Receiver connected to hybrid wire through hole in underpart.

Due to above mentioned advantages of concept ④, it was selected for the LDS antenna application, and will be the design recommended for implementing an LDS antenna in a BTE HI. The final concept is seen in Figure 4.39.

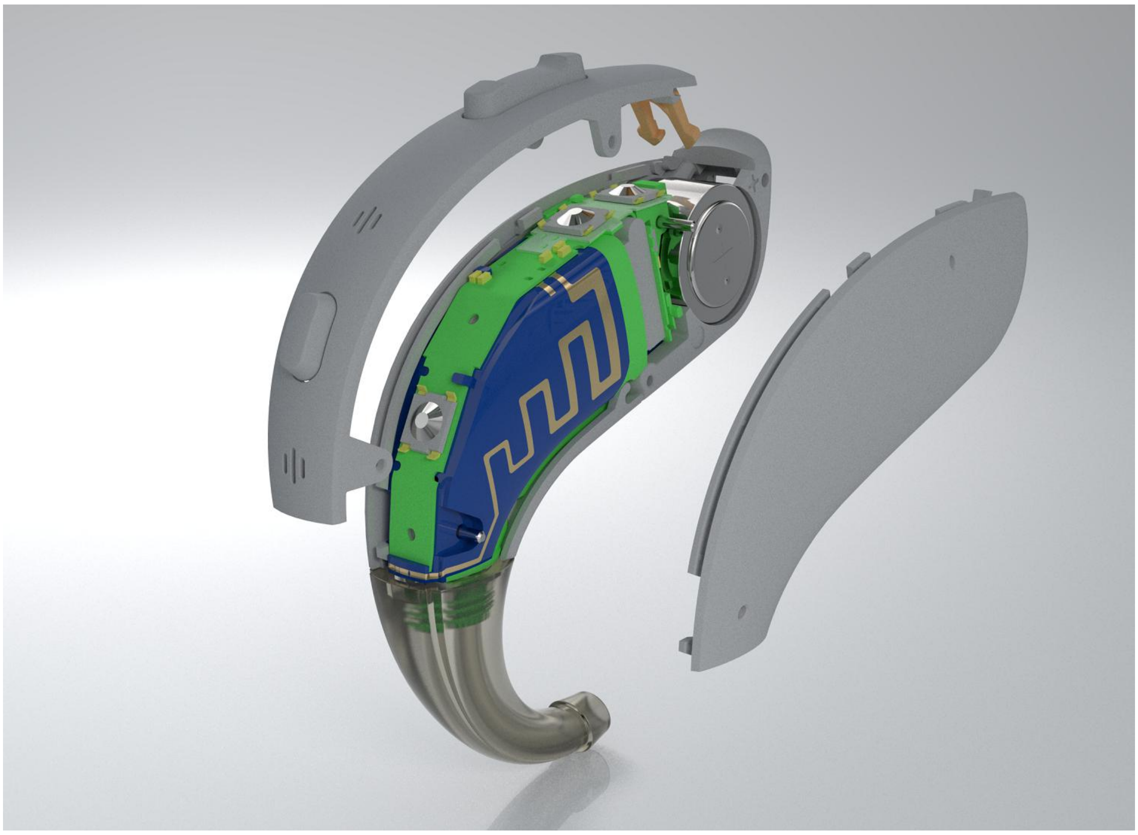


Figure 4.39: Final concept model in exploded view.

Figure 4.40 shows a 3D-print of this concept, which was made for testing the assembly possibilities.

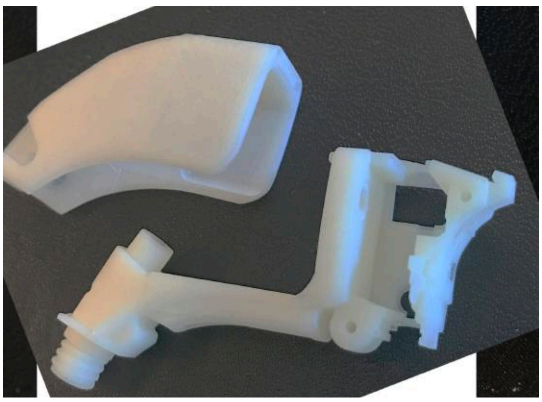


Figure 4.40: 3D prototype.

CHAPTER 5
Material Selection

Hearing aids are exposed to an aggressive environment, where sweat and ear wax can degrade rust proof metal types and gold alloys if the design is not well considered. Therefore, the choice of materials must withstand these environmental conditions, previously described in the basic specification table of Section 3.3.

Due to the increased use of LDS in consumer electronics, a big variety of LDS grade materials are available as shown in Figure 5.1. Based on the functional requirements described in the basic specification table, and regarding the mechanical and thermal properties relevant for a soldered LDS antenna on the frame, a material selection was carried out.

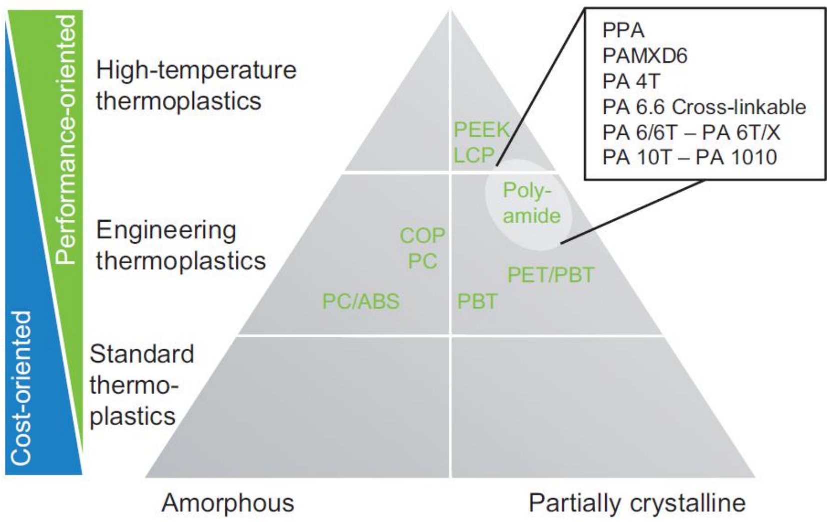


Figure 5.1: LPKF-LDS® compatible materials [13].

The identified relevant main properties are:

- **Thermal properties** as melting and deflection temperatures: The material must be able to at least withstand the melting temperature of lead-free solder paste, e.g. Sn96.5 Ag3.0 Cu0.5 compound which has a 217-218°C melting temperature.
- **Water absorption:** Due to the HI exposure to humid environments, this property must be kept low, since humidity could potentially infiltrate under the LDS lines, provoking corrosion despite of eventual coatings.
- **Mechanical properties** (tensile modulus): Potential fitting hooks and similar, must be able to withstand the contact forces applied during assembly.

Furthermore, the chosen LDS grade material should have superior properties to the material it is replacing. For the frame, the used material is Zytel® HTN54G35HSLR BK031 PA-IGF35, which properties are shown in the first column of Table 5.2 and its datasheet in Appendix A. Furthermore, processing capability (micro injection moulding), low dielectric constant, availability and cost are important factors as well.

Through Cambridge Engineering Selector EduPack (CSE), the generic polymer types were narrowed down to the ones of Figure 5.2 which are possibilities complying with minimum requirements described above.

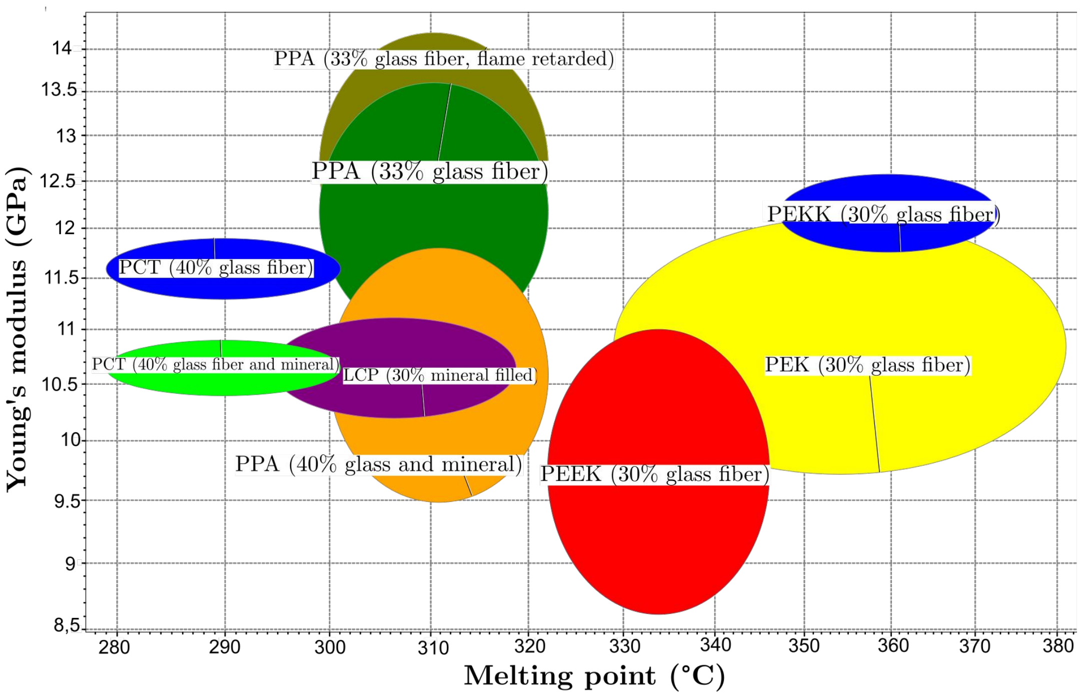


Figure 5.2: CES chart.

The Polyphtalamides (PPAs) with a 30-40% glass reinforcement are polyamids (PA) positioned in an acceptable melting point interval. These do also have good processing capabilities and their tensile strengths do fit for the application. Their prices are significantly lower than Polyetheretherketone (PEEK). Polycyclohexylenedimethylene Terephtalate (PCT) has lower melting temperatures and similar price ranges compared to polyamids. The earlier mentioned polycarbonate (PC) Sabic DX11355 used in the ReSound Multi Mic was also considered due to earlier LDS experience, but due to its low melting temperature (280°C - 300°C) it was discarded for this application. Liquid Crystal Polymers (LCP) do also have acceptable properties, Siemens uses Vectra LCP E820i LDS for their Acuris P HI, and its thermal properties are also satisfying for soldering temperatures. LCP is also widely used for connector applications, it is good for thin wall thickness and it can withstand high temperatures (suitable for reflow soldering). Though, its mechanical properties were rather complex for injection moulding, so polyamids were investigated further. Comparing the materials through Table 5.1, shows that PA holds a good position in regards to solderability, cost and peel strength. Peel strength is important since it evaluates the anchoring and adhesion capacity of the metallic lines to the substrate, and for a soldered solution, forces may apply in all directions. PA is marked ”0” for normal reflow solderability, but engineered PA grades with excellent reflow properties can easily be found, since there is a constant development of new materials for MID applications.

	Material	Abbreviation	Peel Strength		Solderability			Relative cost
			Chemical	Hot Embossing	Reflow normal	Reflow Low melting point solders	Selective	
A	Polypropylene	PP	+	+	-	0	+	
A	Acrylonitrile Butadien Styrene	ABS	+	+	-	-	+	
A	Polycarbonate	PC	+	+	-	+	+	
B	Polyethylene Terephtalate	PET	-	+	-	0	+	
B	Polybutylene Terephtalate	PBT	+	+	0	+	+	
B	Polyamide	PA	+	+	0	+	+	
B	Polyphenyle Sulfide	PPS	+	-	+	+	+	
C	Polysulfone	PSU	+		0	+	+	
C	Polyethersulfone	PES	+	+	+	+	+	
C	Polyetheremide	PEI	+	+	+	+	+	
C	Liquid Crystal Polymer	LCP	+	0	+	+	+	

Material	Peel Strength	Solderability
A: Commodity Thermoplastics	+ > 0.8 N/mm	+ Standard process
B: Technical Thermoplastics	0 0.5-0.8 N/mm	0 Parameter adjustment
C: HT-Thermoplastics	- Usually not plateble	- Special processes

Table 5.1: Typical substrate materials for MID [37].

In collaboration with Shanghai Amphenol Airwave (SAA) and DSM, the material Fortii® LDS85 was found to include the desired properties. Its datasheet can be found in Appendix B. As seen in Table 5.2, Fortii® LDS85 outperforms BK031 in most parameters, so 10 kg were ordered to be used for the prototype.

	Zytel BK031	**ForTii LDS85**
Generic polymer type	Polyphtalamide	PA 4T
Glass reinforcement [%]	35	30
Melting T [^{0}C]	300	325
Deflection T at 1.8 MPa load [^{0}C]	255	285
Deflection T at 0.45 MPa load [^{0}C]	283	305
Water absorption ISO62 - 24h [%]	0.64	0.3
Density [kg/m^3]	1420	1470
Tensile modulus [MPa]	10500	10500

Table 5.2: Material comparison.

Soldering on the plating of LPKF-LDS® on a polyamid substrate, did also show acceptable results in the experiment of page 40, justifying the choice.

CHAPTER 6

Prototyping

In order to evaluate the LDS antenna and especially the PCBA - LDS antenna soldering connection, a prototype has been designed, produced and assembled.

The requirements for the prototype were based on the tests to be made:

- **Demonstration of the PCBA - LDS antenna soldering:**
  - Temperature shock test: The prototype should have similar geometries and components as a real HI. Especially big metallic components as the battery and the receiver, are important thermal masses which can attract humidity and alter the thermal distribution in the HI.
- **Demonstration of a functional LDS antenna:**
  - Other than visual inspections, the prototype includes a functional antenna pattern approximated to 2.4 GHz performance, making it possible to measure RF variations after tests.
- **Demonstration of environmental influence on the LDS antenna:**
  - Salt-mist, synthetic earwax and sweat tests were conducted: the antenna pattern is spread out on the available frame area to inspect the reaction in different areas of the LDS pattern.
  - The LDS pattern varies in width, to inspect the quality and accuracy of thin LDS lines.

The frame and assembly were designed as shown in Figure 6.1, in order to fit into a full HI with all of its components except the telecoil due to its irrelevant function for the prepared tests.

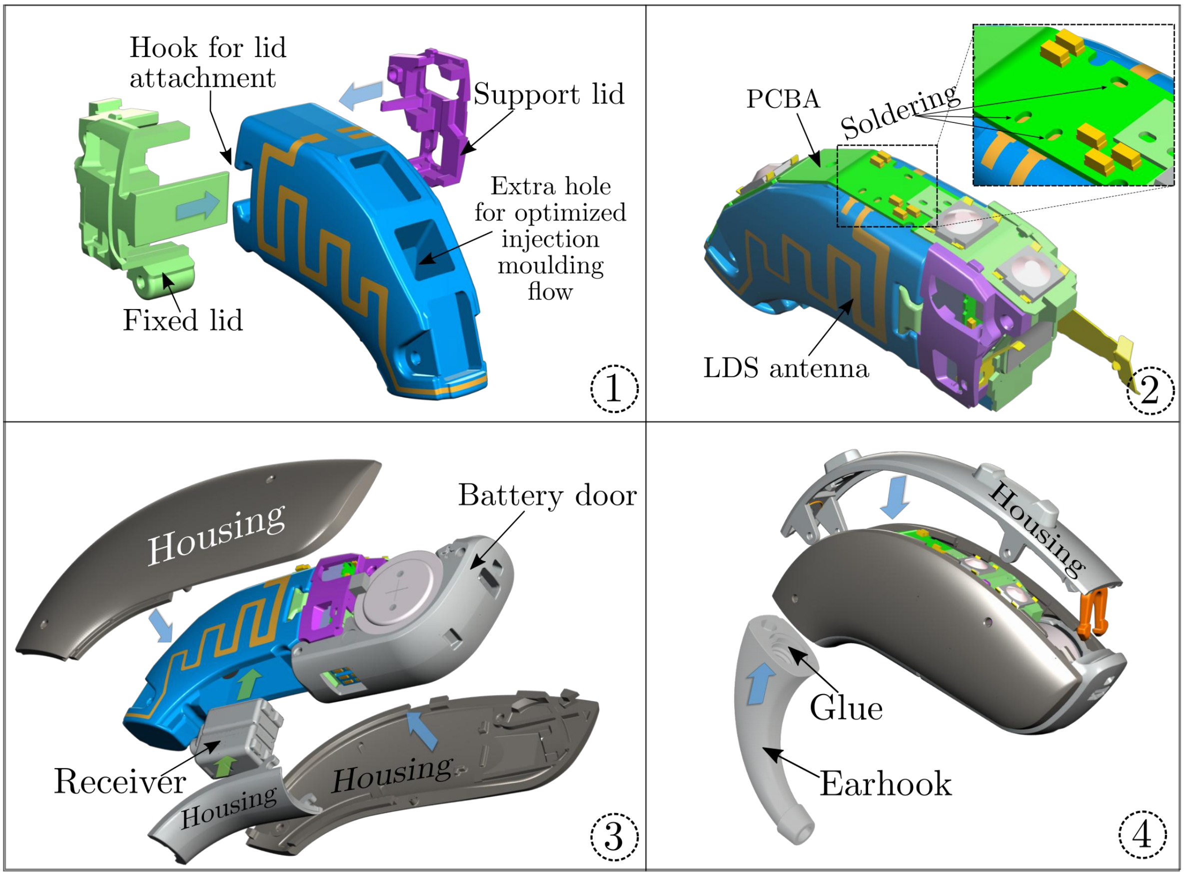


Figure 6.1: 3D diagram of prototype.

The support lid and the fixed lid in Step ①, are made by additive manufacturing in the material Visijet M3 Crystal and the frame (in blue) is injection moulded in the material Fortii® Stanyl LDS85. Thereafter, the LDS and plating takes place, carried out by SAA. In Step ②, the PCBA is mounted and soldered to the LDS antenna soldering pads through the oval holes. In Step ③, the receiver is glued to the inside of the frame and the battery is inserted as thermal masses, as also shown in the cross section view in Figure 6.2. In Step ④, the earhook is glued and the HI is closed, simulating a real HI geometry for being able to evaluate the thermal distribution at the shock test and to conduct RF measurements on the ear. The final prototype HI 3D models can be seen in Figure 6.3.

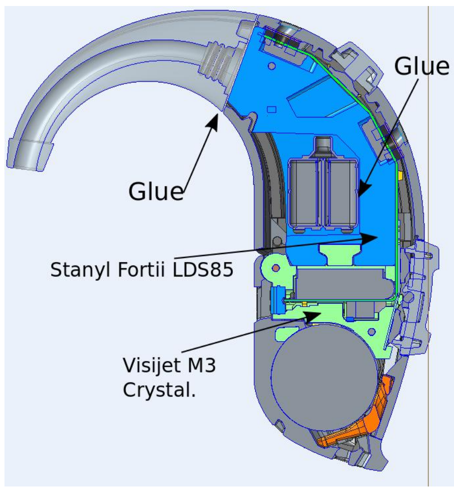
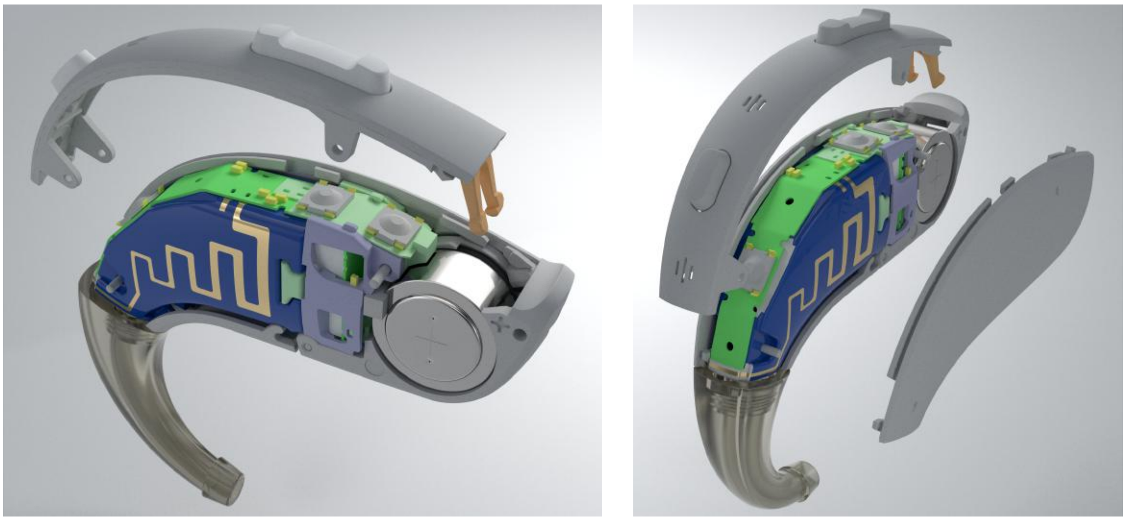


Figure 6.2: Prototype cross section.



(a) (b)

Figure 6.3: 3D renders of the prototype.

A full description of the prototype assembly can be seen in Appendix C.

6.1 Antenna pattern

For being able to test the LDS antenna, before and after exposure, the pattern was designed with dimensions as seen in Figure 6.4, where the 90 mm path length is used as proposed in Section 2.2.

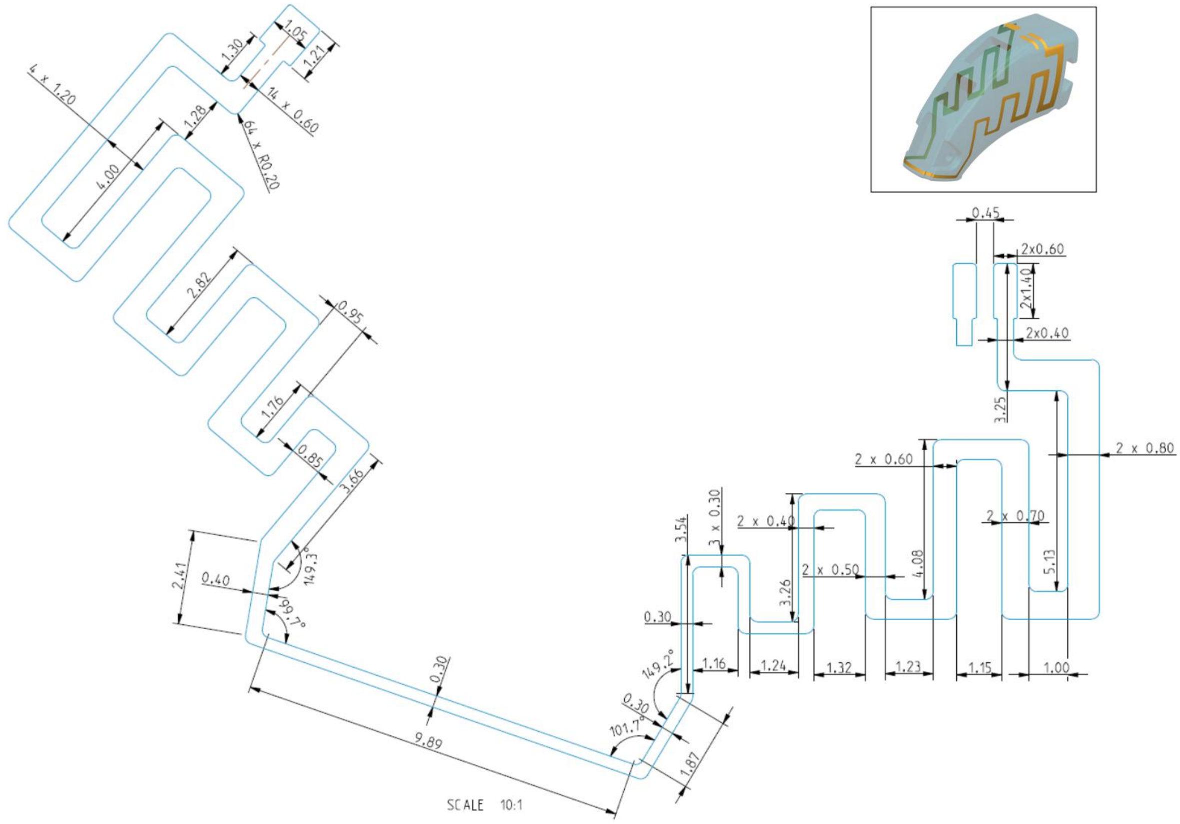


Figure 6.4: 2D drawing of pattern.

The pattern was chosen to be two sided and symmetrical since this has shown best RF performances, as explained in the theory. As seen in Figure 6.5, there are 3 soldering spots, one for ground, another for feed, and the third is a coupling element acting as a tuning component for the antenna. The left side of the pattern conserves a constant width and the right side has varying line widths (from 0.80 mm to 0.30 mm), simply for inspecting the quality of thin LDS lines. The pattern is also spread as much as possible on the frame surface for detecting if certain areas are more or less prone to degradation and corrosion.

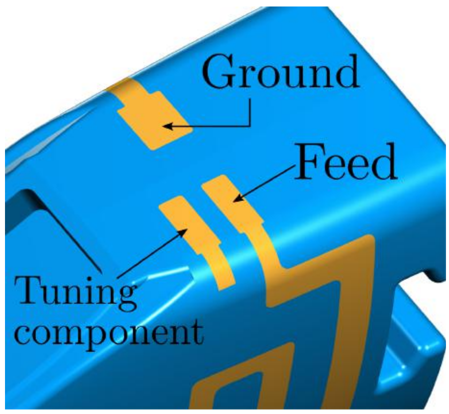


Figure 6.5: Soldering connections.

6.2 Tool design and injection moulding

First, SAA assisted with a preliminary simulation for identifying potential issues with injection moulding in such a geometry, which can be seen in Figure 6.6. Therefore, the part was modified to avoid risks of considerable shrinking issues, especially in zones with large wall thickness. The upper wall above the receiver was made thinner and an extra hole was made where the red rectangle marks an issue in Figure 6.6.

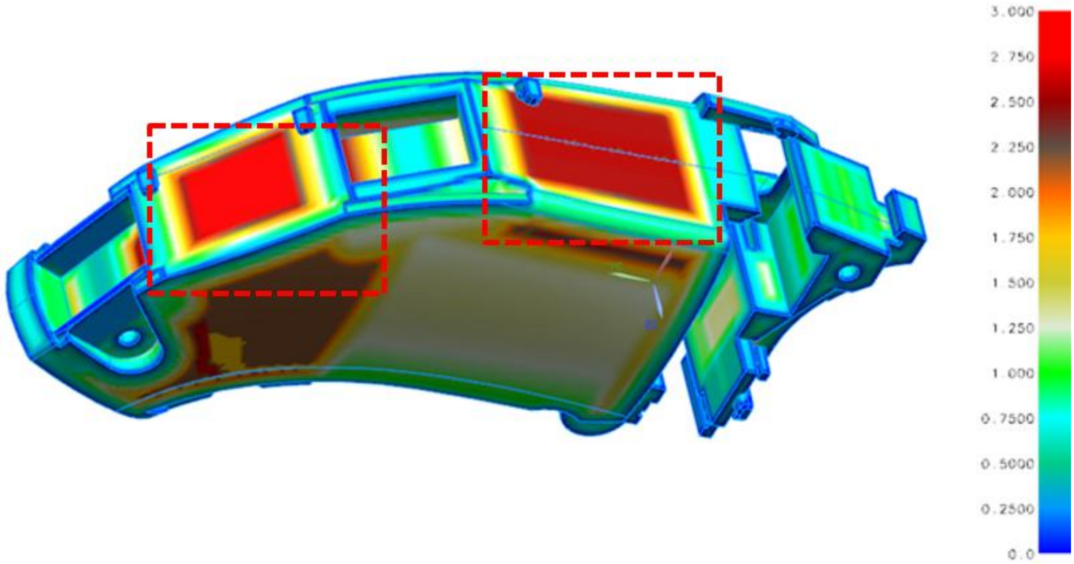
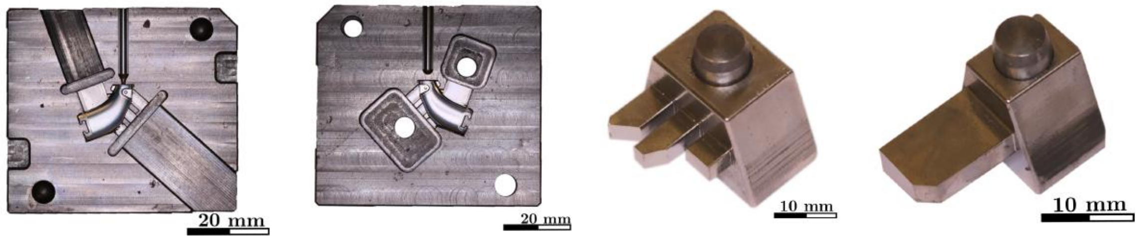


Figure 6.6: Moulding simulation.

The designed injection moulding tool can be seen in Figure 6.7 and Figure 6.8. The runners were designed and produced to fit the prototype cavities, with knobs for manual extraction. All parts were milled out of aluminium. LDS design guides recommends a standard surface finish of Rz 5 µm and polishing the surface is not necessary. For this prototype, a milled aluminium mould was suitable, because the part was simplified and aluminium is easier to mill which produced acceptable surface finishes for the prototype. When using an aluminium tool, there is a potential issue of having extraneous plating, because aluminium particles can infiltrate in the substrate surface, but it was not the case in this prototype.

For mass production, it is recommended to use through-hardened steel types, as 1.2343 or 1.2767 [15] and copper electrodes instead of milling, should be used for complex geometries in the parts.



(a) Lower mold part. (b) Upper mold part. (c) Runner 1. (d) Runner 2.

Figure 6.7

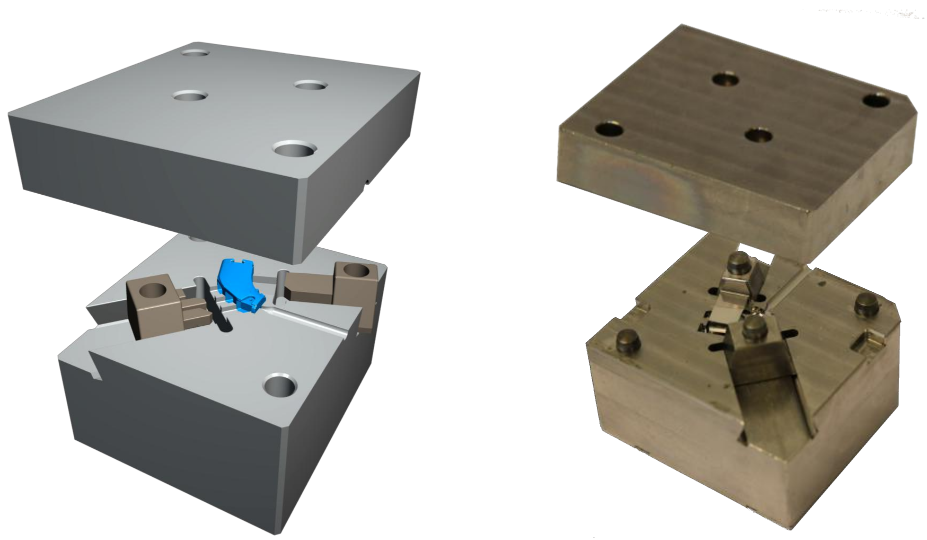
A shrinkage percentage of 0.8% was used for the part, and the vertical injection moulding machine Boy 22A VV with an 18 mm screw performed the injections. The recommended parameters by the supplier (DSM), can be seen in Appendix B, and the ones used, can be seen in Table 6.1:

Mould temperature	**Nozzle temperature**	**Melt temperature**
95°C	330°C	330°C
Injection speed	**Injection pressure**	**Holding pressure**
0.25 s	950 bar	500 bar for 1 s

Table 6.1: Moulding parameters.

The recommended mould temperatures of 100°C - 150°C are hard to achieve in conventional setups without dedicated heater bands, therefore 95°C was used instead based on recommendations by Amphenol from Appendix B where 85°for the same material has shown satisfactory results.

It is though recommended for the future, to keep the tool temperature at the recommended temperatures over time and on all surfaces. For LDS grades, an additive rich surface is needed for the laser structuring and the plating process. A low tool temperature can lead to rough surface, and a less homogeneous spread of the additive on the surface. These defects can attract copper in the plating bath, and lead to plating on unintended areas.



(a) 3D model of mold. (b) Picture of mold.

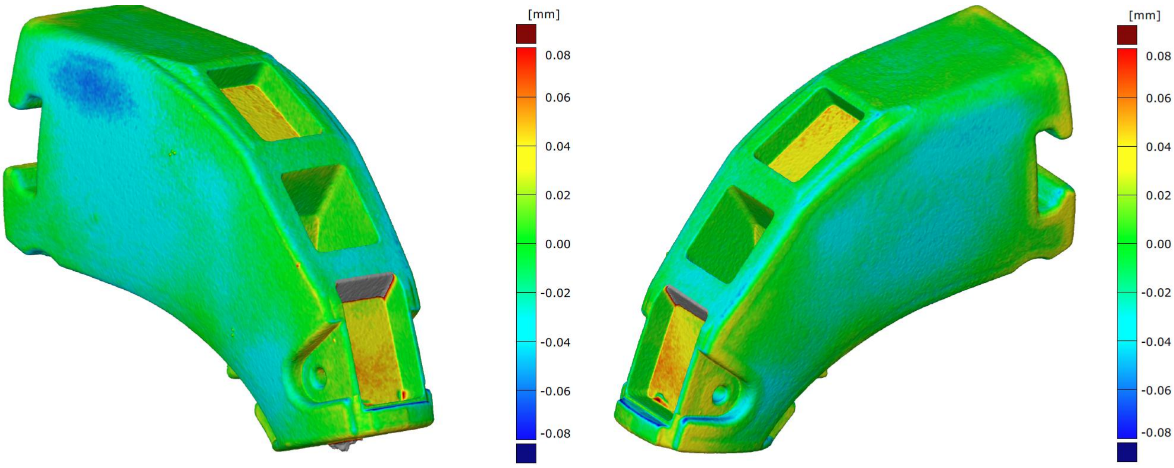
Figure 6.8: Injection moulding tool.

Specifically for Fortii LDS85, it is recommended to achieve a tool temperature above its glass transition temperature ($T_g = 125°C$) for the best mechanical properties and stability. For thin walled parts, which is often the case in hearing aid plastic components, a tool temperature close to T_g should be avoided, so either around 100°C or above 140°C is ideal.

Figure 6.9 shows a badge of the produced parts:

Figure 6.9: Injection moulded parts.

Before having the parts laser structured, these were inspected by a 3D scan of the geometry. Figure 6.10 shows a superposition of the scanned 3D part geometry on top of the 3D CAD model, to see the differences in the produced part. The analysis was conducted in the software GOM Inspect 2017. The injection moulding parameters have not been optimized for this prototype, therefore there is discrepancies in the geometry, especially zones on the side of the frame which had thick walls which have shrunk. For further applications it is important to maintain low tolerances across the part geometries since the LDS fixture will be designed based on the geometry of the part. For this part, the anchoring point to make the fixture, was the front pin hole, which needed to have a positioning tolerance of ± 0.01 mm, which was achieved in the prototype mouldings.



(a) (b)

Figure 6.10: 3D scan comparison.

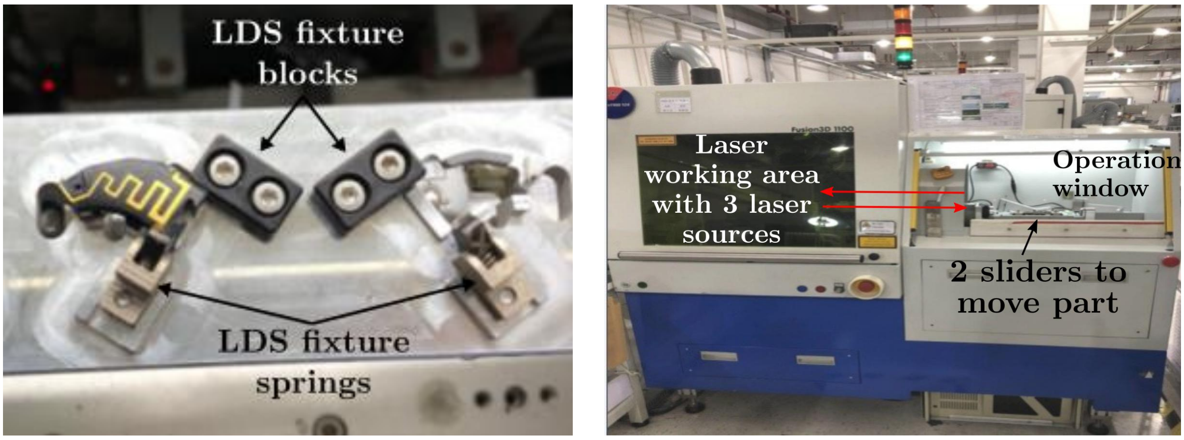
Finally, the additive manufactured lids were produced in the Projet 3500 HDMax 3D printer, in the material Visijet M3 Crystal. After taken out of the 3D printer as seen in Figure 6.11, they were warmed up at 50°C, and the support wax was removed in an ultrasonic bath at 70°C. Lastly, they were cleaned with bioethanol.

(a) (b)

Figure 6.11: 3D prints.

6.3 LDS and assembly

The LDS process and electroless plating was carried out at SAA. First, the LDS fixture is designed and prepared, as it can be seen in Figure 6.12a. Then the fixture is mounted in the LPKF Fusion3D 1100 laser structurer as shown in Figure 6.15a and 6.12b. Here, the laser activation takes place following the specified 3D antenna pattern.



(a) LDS Fixture. (b) Fusion3D 1100.

Figure 6.12

Afterwards, the plating of the LDS tracks will commence. First, a layer combination of Cu (4-6µm), Ni (3-4µm) and Au (0.2µm) was proposed, but it showed that it was hard to control the layer thickness, and the thick Au layer would not be economically viable. As explained earlier, it is also not common to provide an Au layer thicker than 0.1µm.

The following plating layers were then specified for this prototype: 12-18 µm Cu, 2-4 µm Ni and min. 0.1 µm Au, represented in Figure 6.14b. The process chain follows the one of Figure 6.13 and a graphical representation of the process is shown in Figure 6.14a.

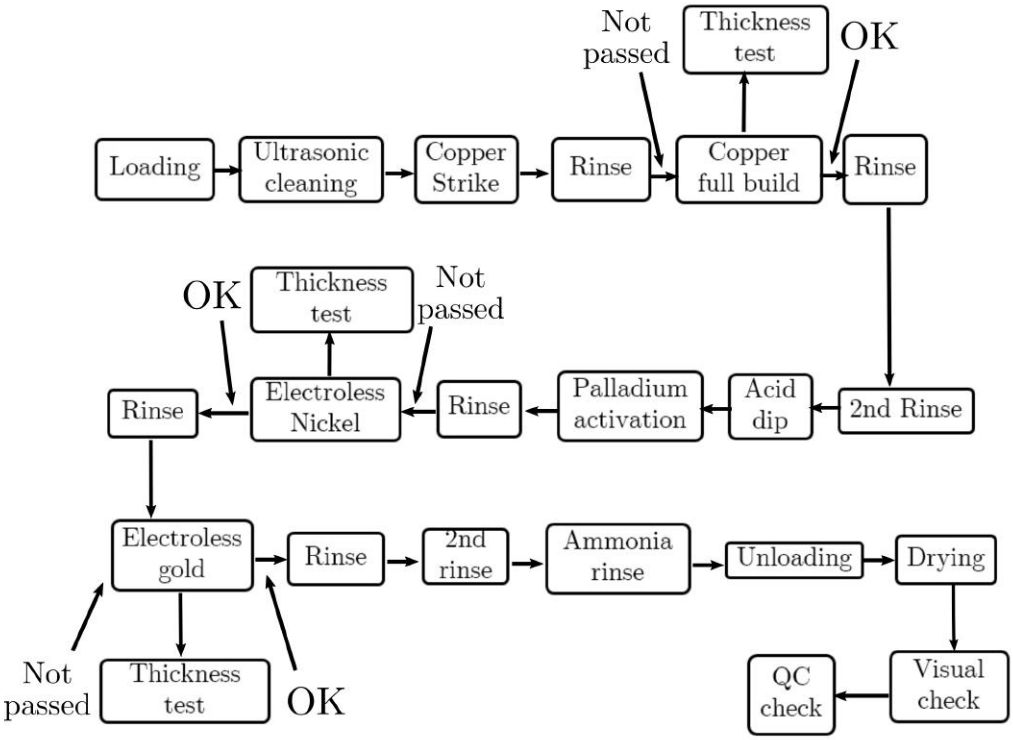
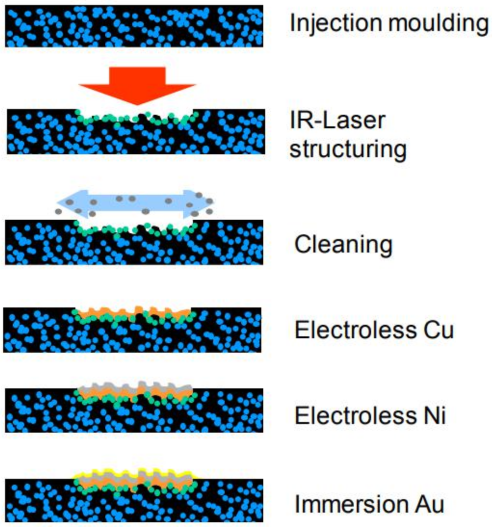
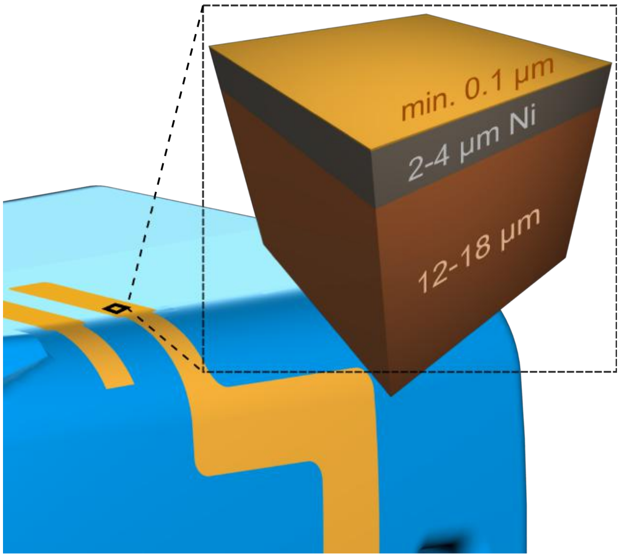


Figure 6.13: Plating process chain.

To ensure clean parts, these are introduced in an aqueous ultrasonic bath at 40 kHz, transferring the ultrasonic vibrations selectively to the surface. Between all steps, the parts have been thoroughly cleaned and the layer thickness is tested after each plating process. The electroless copper plating starts hereafter, first by an initial copper strike, and then the full copper build. The parts are then dipped in acid for a better Palladium activation. The electroless nickel is then started, followed by the gold plating. Ammonia was used for the final rinse and the parts were dried in circulating air for a spotless drying.



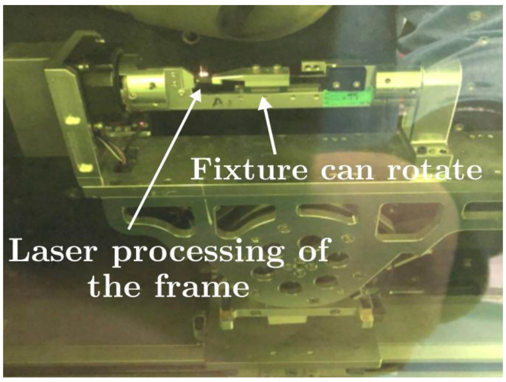
(a) LDS process.



(b) LDS Layer thickness.

Figure 6.14

All these processes were carried out in the plating line setup of Figure 6.15b, which is specifically prepared for MID.



(a) Mounted fixture.

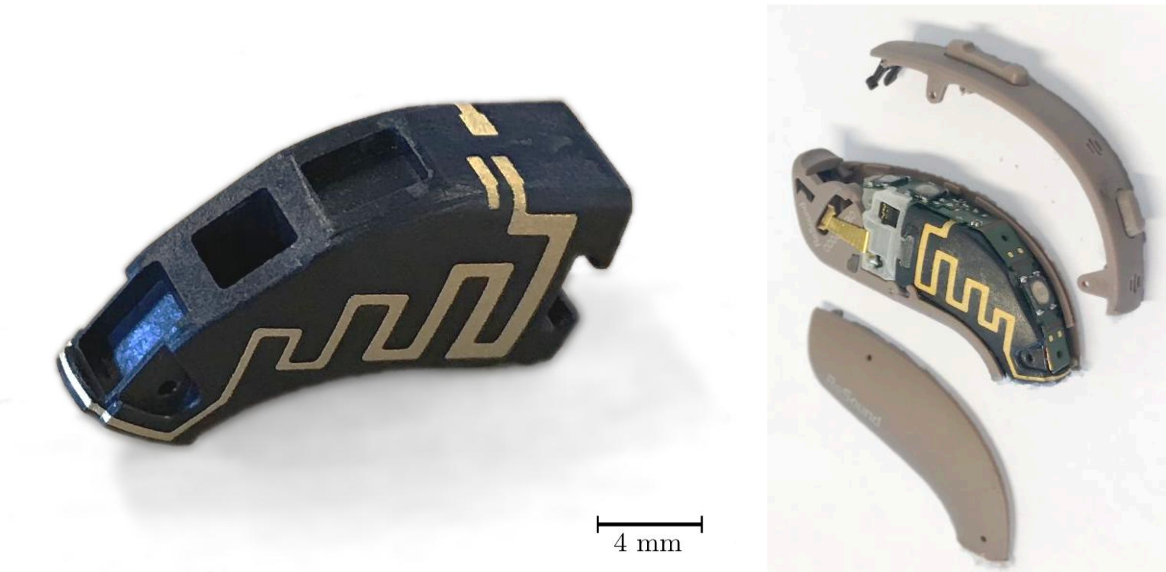
(b) Plating line.

Figure 6.15

The LDS parts are then packaged, and in this step it is important to avoid electrostatic charging by the packaging material, as done by the tray produced in Figure 6.16. Some applications may require ElectroStatic Discharge (ESD) specific packaging, but it depends on the circuit technology [15].

Figure 6.16: Prototype ESD tray.

The final prototype was assembled manually with all its components for a functional RF system in the HI. The prototype can be seen in Figure 6.17.



(a) Prototype frame. (b) Prototype assembly.

Figure 6.17: Prototype.

CHAPTER 8

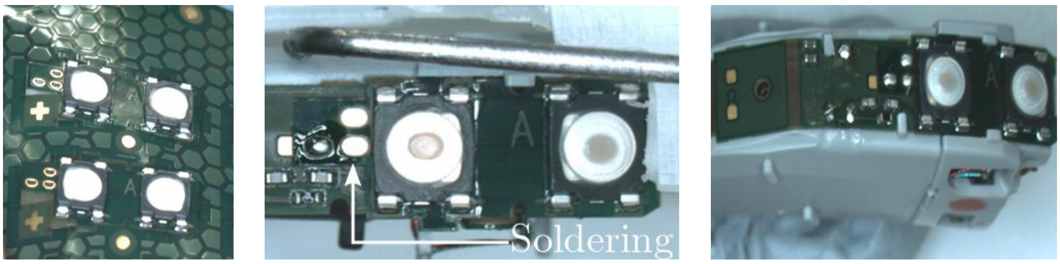
Design for value

8.1 Further applications

When the LDS is done on a part, a laser fixture is specifically designed and manufactured for the specific geometry. It is therefore desirable to implement as many LDS connections as relevant and as possible, primarily, for economic viability but also for a less complex manufacturing and assembly chain. Other than the antenna, the connection between peripheral components and shielding components could be connected through LDS tracks too. Some of these have been identified:

Peripheral components

One case would be the switch PCB of the Berlin 70 and similar models. In the current assembly, the toggle switch PCB shown in Figure 8.1, is first SMD mounted and reflowed on a PCB, and then manually soldered to the PCBA as in Figure 8.1b.



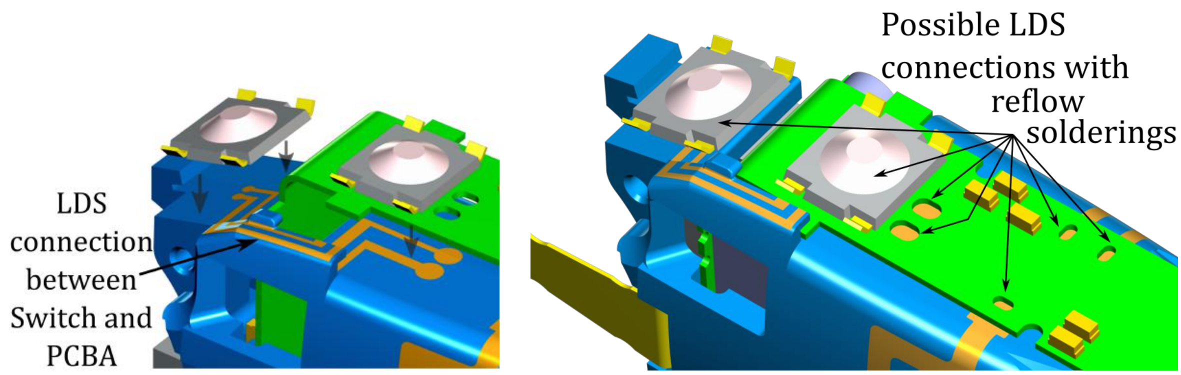
(a) Switch PCB after reflow soldering.

(b) Soldering switch PCB to the PCBA.

(c) Assembled PCBA with switches.

Figure 8.1: Switch PCB.

The concept of Figure 8.2 shows how the switch can be SMD mounted on the LDS connecting lines of the frame. There would be no need of having a PCB under the switch. This is also speculated to increase stability of the switch and furthermore eliminate at least one manual soldering if implemented by reflow. The switches are connected to the PCBA by a signal connection each, and they share a ground connection. So the signal soldering from the left switch, could be done by reflow while the rest could potentially also be reflowed with a few modifications.



(a) (b)

Figure 8.2: Switch on LDS.

The connection to the telecoil could also be done by an LDS trace, as well as the connection to the docking module, already presented on page 41.

Shielding

Another case of LDS use is the shielding of electric components. Shielding is widely used for reducing the electromagnetic field by blocking it with conductive components. These do normally require large areas acting as shelters, where LDS could be directly applied to these surfaces.

8.2 Surface Mounted Technology

A potential manufacturing benefit of using LDS for the antenna and other connections, is its firm adhesion to the substrate material, remaining in accurate positions at all moments, which is ideal for Surface Mounted Technology (SMT) and reflow soldering setups as the one shown in the example of Figure 8.3.

Figure 8.3: SMD assembly example [41].

For the specific case of the Berlin 70, Figure 8.4 gives an idea of how the solder paste dispensing and the surface mounting of the switches would happen. First, solder paste is dispensed on the soldering pads. Thereafter, the PCBA and switches can be mounted on top. It is preferred to have a planar surface for the SMT process, so 3D design of the part should be considered for the application. The marked 14° inclination of the Berlin 70 is a small inclination on which components would normally still be fixed, due to the adhesive properties of the solder paste before reflow.

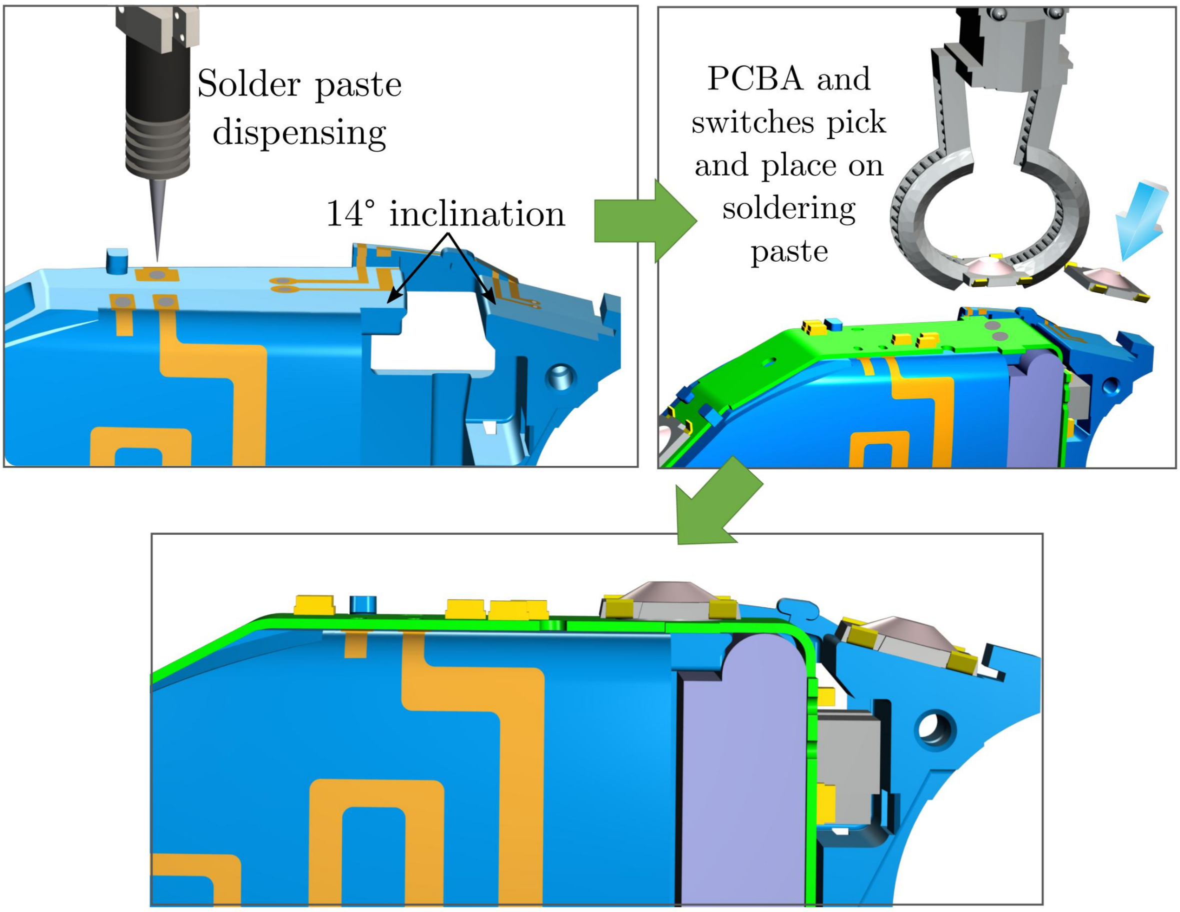
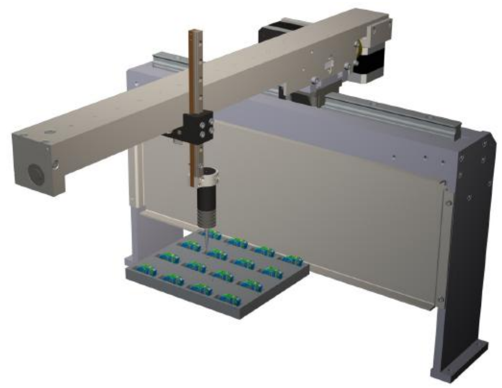
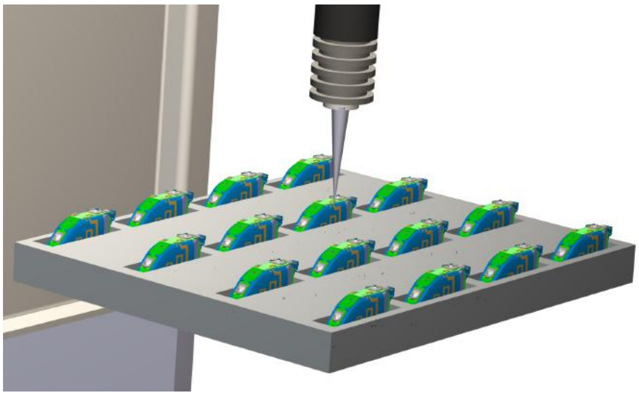


Figure 8.4: Solder paste dispensing and surface mounting process chain.

As shown in Figure 8.5b, the LDS frame with PCBA would be positioned in the jig and the remaining components (e.g. switches) would be surface mounted on the LDS lines of the frame, being sticked to the LDS lines by the solder paste, due to its viscosity. By introducing a badge of frames into the solder oven, the solderings would be fixed effectively, precisely, and in high volume.



(a) Dispenser / pick and place tool.



(b) Reflow ready jig.

Figure 8.5: Surface Mount Technology.

The material selected for the prototypes, Fortii® LDS85, is reflow ready and can withstand such temperatures of 230°C for the commonly used vapor phase reflow soldering.

8.4 Advantages

In the following, the main advantages of implementing LDS for the antenna are identified and presented:

Labour processes are reduced. As seen in Figure 8.6, the time consuming preparation and wrapping of the flex antenna will not be needed. By the lucrative combination of LDS and SMT techniques, the manufacturing of HIs will go one step further in the automation of the process chain.

Mechanical design freedom is increased, since there is no need to take account for the "diamond" shape of the frame, required for the flex antenna bends. This has been demonstrated in Figure 4.26.

Antenna design freedom. The antenna design can be transferred from CAD data directly onto the moulded frame. New antenna patterns can easily be changed and tested, since the laser structuring pattern can immediately be changed for the same part, which is inexpensive and less complex compared to producing new FPCs for testing.

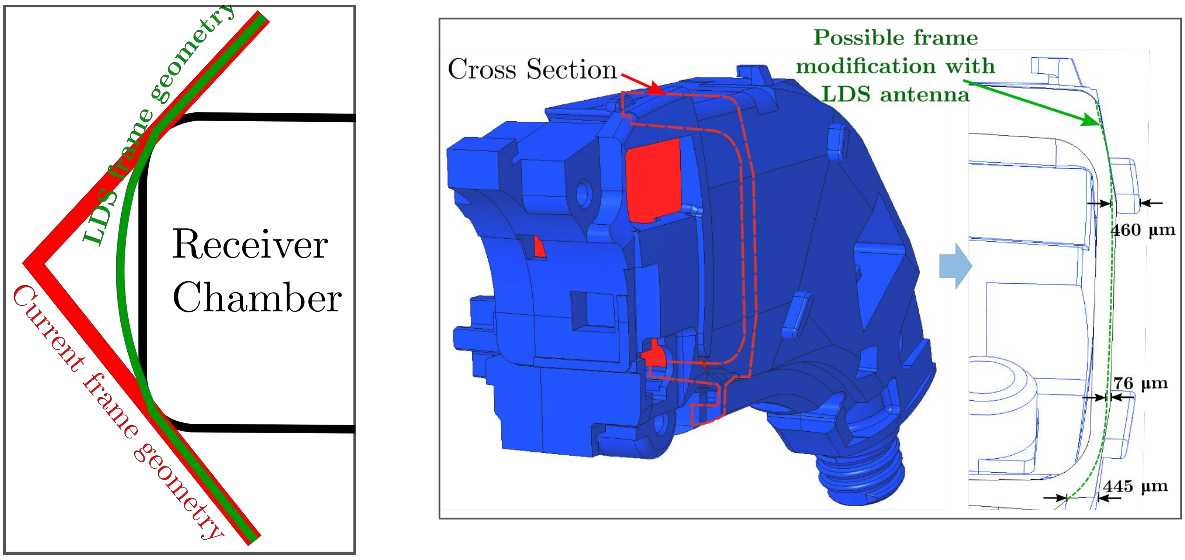
Firm connections. When having connections directly on the supportive material, these are expected to act robust and with high precision. It is suspected that if implemented for the switch connection too, the switch press sensation will be improved since no underlying PCB will be there.

HI size reduction. LDS can potentially make the HI smaller in size. The current flex antennas, earlier shown in Figure 2.5b are formed by the layers of Table 8.8 having a total height of 130.5 μm. The ≃ 18 μm LDS height is almost negligible since the LDS lines do also slightly sink into the plastic material making its height minimal. So potentially, 261.0 μm (accounting for both sides) would be gained on the width using LDS, theoretically reducing the frame width.

Stack-up	**Layer thickness**
Base Polyimide	25 μm
Copper (Bottom)	18 um
Adhesive	15 μm
Cover layer	12.5 μm
Electrolytic tin	3-10 μm
3M 467MP adhesive	50 μm
3M 467MP liner	100 μm

Figure 8.8: Flex antenna composition.

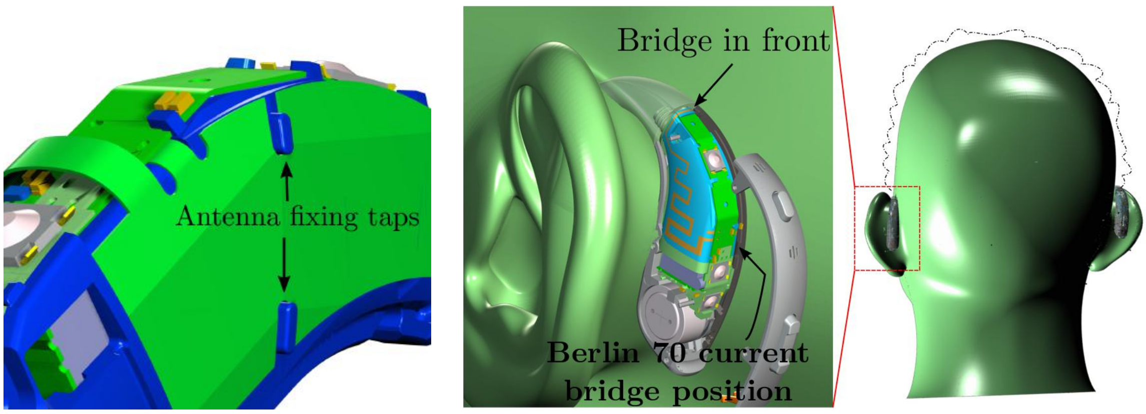
Furthermore, in Figure 8.9a an illustrative diagram is shown, which represents the design freedom achieved with LDS, where it will be possible to have curvilinear surfaces in more than 1 dimension since there is no need to include bending edges for the flex antenna, in relation to the mechanical design freedom described above. Dimensions from Berlin 70 are shown in Figure 8.9b.



(a) Illustration. (b) Berlin 70 width comparison.

Figure 8.9

As seen in Figure 8.10a, the function of the taps is to guide and fix the flex antenna when assembling it and therefore these could be deleted if an LDS antenna was introduced. Though they carry a second function guiding the side housing into the frame, but a new solution could be used for this, e.g. making the taps inwards instead. The taps account for a relatively big distance on the width of the HI, being 460 µm.



(a) Berlin 70 taps. (b) Bridge in front.

Figure 8.10

Accounting for both sides of the HI, a total HI width reduction of $\simeq$ 920 µm is possible, specifically for Berlin 70. In positions where the tap width is not taken into account, the HI could be reduced $\simeq$ 413µm including only the antenna width and the 76 µm due to the design freedom presented in Figure 8.9b. As a consequence, the assembly weight will be reduced too.

Potential better ear-to-ear RF performance. It can be speculated that a better ear-to-ear RF performance can be achieved when the bridge is moved to the front on the top of the HI as shown in Figure 8.10b, so it will be on a shorter path around the head to its pairing HI.

Recycling properties. Metal and electronic components must be separated from plastic substrates if the components are to be recycled. A method for separating the metal from the substrate in MIDs is already developed, and consists of a mechanical separation process. The parts are subjected to a high degree of turbulence and the high shear forces applied will separate the metal from the plastic. The separated plastic and metal particles can then be recycled by standard processes [42].

8.5 Limitations

One concern about implementing the LDS antenna is the corrosion properties, but these should be evaluated in further investigation, and are expected to be solved with coating.

Another concern is still the connection between the PCBA and the LDS antenna, which has shown satisfactory results in the experiments made, but impact tests still need to be done in a final design, as it will be described in Section 9.1.

For further applications, the use of LDS has a relatively low circuit density. MIDs normally only have 2 layers of connections, one for each side of the substrate part, while traditional PCBs can have more than 32 layers of interconnections in a very small space.

CHAPTER 9

Discussion & Conclusion

This final chapter presents the recommendations for future testing and future development based on the subconclusions found throughout this project. Furthermore, the results are summarized creating an overview of the findings during the development of the LDS antenna for HIs.

9.1 Further work

With MID & LDS technology, it is possible to innovate and create modern robust designs in the electro-mechanical fields, but it does also involve important developments in reliable production methods, for a full integration of MIDs. Some of the identified uncertainties which should be investigated in future work, will be presented below:

Chemical resistance - coatings. The tests conducted showed corrosion on the LDS lines. The following options can be tested to improve the chemical resistance of the LDS tracks:

- Test thinner nickel and copper lines, since the roughness will decrease and improve corrosion resistance [34].
- Test which of the following coatings give best results on an HI application:

  - Non-conductive isolating paint (15-30µm): Many applications take advantage of structuring the LDS antenna on the outside of the device casing, e.g. on mobile phones, and then covered by non-conductive paint. This treatment primarily has an aesthetic purpose but does also protect the lines from the environment. Therefore non-conductive paint is a widely used protection method, and the only experience SSA could provide.

  - SL1367 Peters® acrylic conformal coating which is widely used at GN Hearing for most protection applications.

  - Metasu® HS-15P sealing, presented on page 40, conserves the appearance of the surface, electrical property, and soldering capabilities, so only the corrosion resistance is increased. The long term behaviour of Metasu still needs to be tested. Its datasheet can be seen in Appendix E.

  Organic solderability preservative (OSP) is a very thin organic surface finish typically used for copper pads, since it can bond to copper which is protected until soldering. It allows soldering and provides flat surfaces, so the soldering does not become an issue but is very sensitive to handling [43]. Testing could be done on evaluating its protection abilities, while the solderability remains unchanged.

Depending on the solution chosen, it should also be tested whether the antenna performance gets affected by the use of these protective layers.

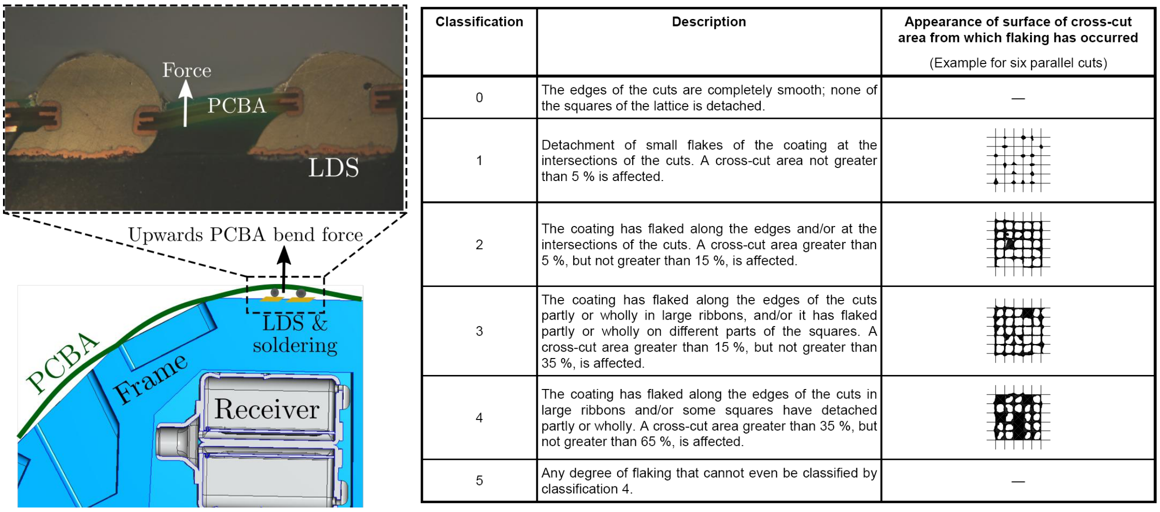
Nickel allergy. Regarding the nickel allergy concern presented earlier, which relied on the recommendations of the EU nickel directive [36] which stated that if no direct skin contact was present, then the nickel would not be an issue. In subtropical (Mediterranean) countries, the EU nickel directive has not been fully tested, so the effect of climate should be investigated through experimental testing for HI applications. If the nickel allergy concern is wanted to be totally avoided, these plating solutions can be used:

- 1) 12-18µm Cu + 0.5µm Ag + 15-30µm non-conductive isolating paint, Metasu HS-15P or SL1367 Peters® coating.
- 2) 12-18µm Cu + 4-8µm Ni + min 0.1µm Au + non-conductive isolating paint 15-30µm, Metasu HS-15P coating or SL1367 Peters® coating.

  - The isolating properties of these 3 presented coatings should be evaluated, since no nickel should dissipate out of the HI at all.

Interface - Solder joints. If the solder joint is kept as a solution, random free fall (tumble test) should be made. When a final design is made it will be important to analyse the failure modes, e.g. delamination or cracking of the LDS and solder joint cracks.

Adhesion tests. For assuring the adhesion of the LDS lines to the frame, ASTM D 3359 Standard Test Methods or the ISO 2409 cross-cut test could be used, which is shown in Figure 9.1b. Methods normally used for paints and varnishes, but these could also be used to determine the LDS resistance to scratches and to the upwards force applied to the soldering spot. The PCBA will be in stress when bended as shown in Figure 9.1a and only held down by taps. The size of these vertical forces should be evaluated either by simulations or experimentation.



Classification	Description	Appearance of surface of cross-cut area from which flaking has occurred (Example for six parallel cuts)
0	The edges of the cuts are completely smooth; none of the squares of the lattice is detached.	—
1	Detachment of small flakes of the coating at the intersections of the cuts. A cross-cut area not greater than 5 % is affected.	
2	The coating has flaked along the edges and/or at the intersections of the cuts. A cross-cut area greater than 5 %, but not greater than 15 %, is affected.	
3	The coating has flaked along the edges of the cuts partly or wholly in large ribbons, and/or it has flaked partly or wholly on different parts of the squares. A cross-cut area greater than 15 %, but not greater than 35 %, is affected.	
4	The coating has flaked along the edges of the cuts in large ribbons and/or some squares have detached partly or wholly. A cross-cut area greater than 35 %, but not greater than 65 %, is affected.	
5	Any degree of flaking that cannot even be classified by classification 4.	—

(a) Cross section demonstrating vertical PCBA force.

(b) ISO 2409 cross-cut test.

Figure 9.1: Adhesion test.

Another mature method for evaluating the adhesion would be using a dolly for a pull off test, as shown in Figure 9.2. The method is usually used for testing the adhesion properties of coatings, but it could also be used for the LDS adhesion, designing a dolly in a smaller size than conventional ones. The dolly is placed and glued on the LDS line and an uniform constant upwards hydraulic pressure is applied, which is measured until the lines are lifted away from the surface. This will give a measure of the strength of adhesion of the LDS lines.

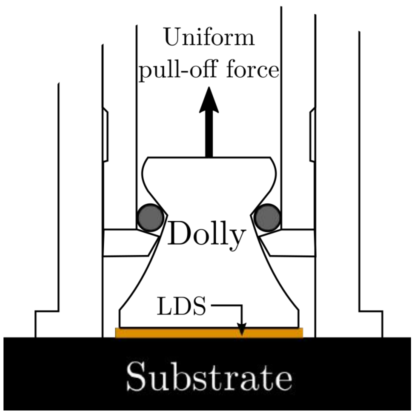


Figure 9.2: Dolly diagram.

Electron microscopy. The prototypes made can also be inspected with an electron microscope for getting closer to the layer interconnections and for inspecting the thin gold layer which has not really been measured in the microsectioning experiments. Furthermore, small marks in the soldering sections could be closely analysed to study whether any of the spots found can be microplanar voids or cracks, which could potentially be an issue for the solder joint reliability.

9.2 Conclusion

Manufacturing by LPKF-LDS® and assembly of the 2.4 GHz antenna for HI applications has shown feasible based on the design and tests presented in this project. Therefore it has been identified to be a promising approach, which includes numerous benefits for modern electronic integration of HIs.

First, the requirements for the implementation were determined based on stakeholder specifications, practical experience, state of the art literature and theory. The contact interface between the LDS antenna and the PCBA has been prioritized and decomposed into relevant subproblems creating an overview of the whole process and the critical factors involved. The following findings have been made:

- Soldering the LDS antenna to the PCBA was determined to be the most feasible solution up to date. Pb-free soldering tests at different temperatures showed satisfactory results at 300°C and up. It has though been recommended that a 340°C is maintained for manual soldering. The HIs with soldered LDS antenna were subjected to thermal cycling, and the results after the testing were also found to be acceptable. The soldering connection and the LDS antenna were evaluated based on visual inspections and RF measurements. Several other detachable connection methods are also presented, which may be an option for future implementations. The prototype developed for these tests had PA4T Fortii® LDS85 as the substrate material and a plating of 12-18µm Cu + 4-8µm Ni + min 0.1µm Au.

- The antenna was decided to be two sided, symmetrical and placed on the frame exterior. These decisions were based on optimizing connection possibilities, biocompatibility and RF performance.

- The bridge, necessary for enhancing ear-to-ear communication, was chosen to be continuous and placed on the top front of the HI based on simplicity and for avoiding interferences with nearby electrical components.

- Mechanical design freedom has been identified as a true benefit of MID, amongst other properties. The frame has been redesigned, to show the 3-dimensional possibilities present with LDS manufacturing. As a consequence, it will be possible to reduce the size of the HI while increasing manufacturing accuracy. The final concept can be seen in Figure 9.3.

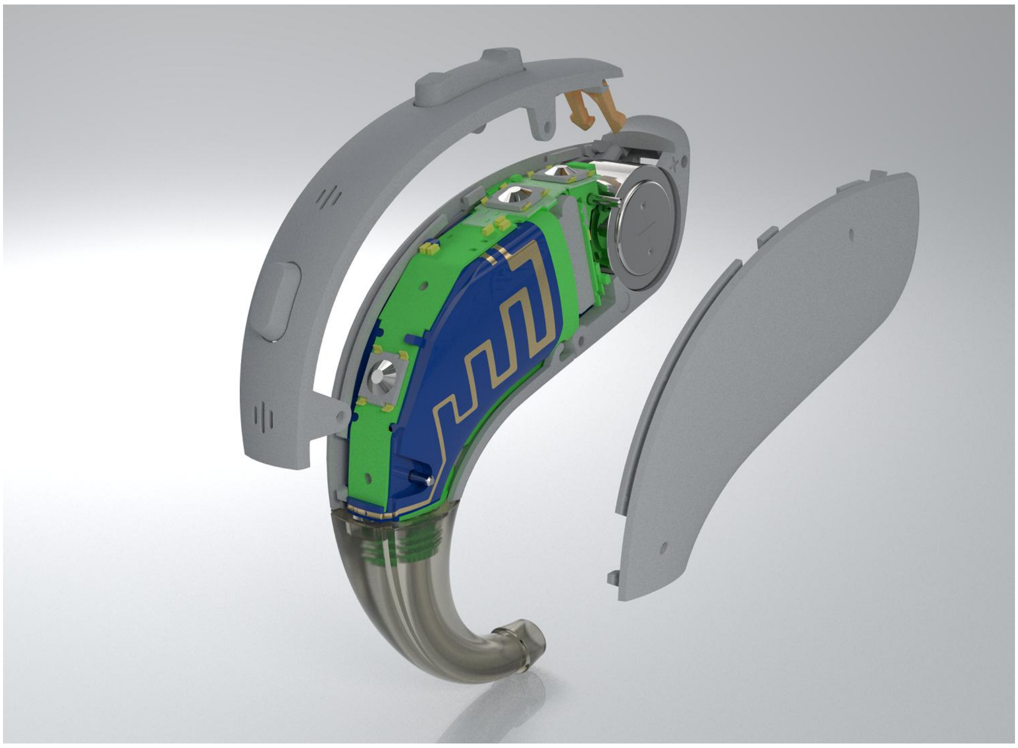


Figure 9.3: Final concept.

- Environmental tests based on artificial sweat, ear-wax, and salt-mist have been conducted on the prototypes, which showed signs of corrosion during all three exposures. These findings were confirmed by measurements showing increased electrical resistance in the LDS tracks. Possible solutions for chemical resistance have therefore been recommended.

- The quality of the LDS lines were evaluated in terms of layer heights, dimensional fidelity, positioning accuracy and edge sharpness. These findings showed an acceptable precision compared to the tolerances of the original flex antenna. Only the positioning accuracy showed important discrepancies of up to 200µm, but is expected to be improved for optimized injection moulding.

- The automation of the manufacturing can be implemented by SMT and reflow soldering techniques which have been explained, and the concept was demonstrated specifically for the BTE HI application through illustrations.

- Finally, a cost analysis for the specific case of the Berlin 70 was conducted, showing a prosperous economic viability for the LDS antenna.

The findings made, have been used to give design recommendations and proposals for future work, based on the critical factors identified. The core success of this M.Sc. thesis is the documentation, development and testing of an LDS antenna, focusing on the connection interface between antenna and PCBA, and the reliability of LDS in HI applications.

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Product Information

DuPont™ Zytel® HTN

high performance polyamide resin

Zytel® HTN54G35HSLR BK031

Zytel® HTN54G35HSLR BK031 is a 35% glass reinforced, toughened, heat stabilized, hydrolysis resistant high performance polyamide resin. It is also a PPA resin.

Property	Test Method	Units	Value	
			DAM	50%RH
Identification				
Part Marking Code	ISO 11469		>PA-IGF35<	
Part Marking Code	SAE J1344		>PPA-IGF35<	
Mechanical				
Stress at Break	ISO 527	MPa (kpsi)	180 (26)	166 (24)
Strain at Break	ISO 527	%	3.0	2.7
Tensile Modulus	ISO 527	MPa (kpsi)	10500 (1520)	10800 (1560)
Poissons Ratio	ISO 527		0.38	
Flexural Modulus	ISO 178	MPa (kpsi)	9300 (1350)	9500 (1380)
Flexural Strength	ISO 178	MPa (kpsi)	280 (40.6)	
Unnotched Izod Impact Strength	ISO 180/1U	kJ/m^2	80	
Notched Charpy Impact Strength	ISO 179/1eA	kJ/m^2		
-30°C (-22°F)			10	9
23°C (73°F)			12	11
Unnotched Charpy Impact Strength	ISO 179/1eU	kJ/m^2		
-40°C (-40°F)			75	
23°C (73°F)			85	70

Contact DuPont for Material Safety Data Sheet, general guides and/or additional information about ventilation, handling, purging, drying, etc
ISO Mechanical properties measured at 4.0mm, ISO Electrical properties measured at 2.0mm, and all ASTM properties measured at 3.2mm.
Test temperatures are 23°C unless otherwise stated.

During molding, use proper protective equipment and adequate ventilation. Avoid exposure to fumes and limit the hold up time and temperature of the resin in the machine. Purge degraded resin carefully with HDPE.

090804/090804

Zytel® HTN54G35HSLR BK031

Property	Test Method	Units	Value	
			DAM	50%RH
Thermal				
Deflection Temperature	ISO 75-1/-2	°C (°F)		
0.45MPa			283 (541)	
1.80MPa			255 (491)	
Melting Temperature	ISO 11357-1/-3	°C (°F)		
10°C/min, First Heat			300 (572)	
CLTE, Parallel	ISO 11359-1/-2	E-4/C (E-4/F)		
-40 - 23°C (-40 - 73°F)			0.20 (0.11)	
23 - 55°C (73 - 130°F)			0.20 (0.11)	
55 - 80°C (131 - 176°F)			0.20 (0.11)	
CLTE, Normal	ISO 11359-1/-2	E-4/C (E-4/F)		
-40 - 23°C (-40 - 73°F)			0.65 (0.36)	
23 - 55°C (73 - 130°F)			0.68 (0.37)	
55 - 80°C (131 - 176°F)			0.72 (0.40)	
Electrical				
Surface Resistivity	IEC 60093	ohm	>1E15	
Volume Resistivity	IEC 60093	ohm m	>1E13	
CTI	UL 746A	V	600	
Flammability				
Flammability Classification	UL94			
0.75mm			HB	

Contact DuPont for Material Safety Data Sheet, general guides and/or additional information about ventilation, handling, purging, drying, etc
ISO Mechanical properties measured at 4.0mm, ISO Electrical properties measured at 2.0mm, and all ASTM properties measured at 3.2mm.
Test temperatures are 23°C unless otherwise stated.

090804/090804

Zytel® HTN54G35HSLR BK031

Property	Test Method	Units	Value	
			DAM	50%RH
Temperature Index				
RTI, Electrical	UL 746B	°C		
0.75mm			150	
1.5mm			150	
3.0mm			150	
RTI, Impact	UL 746B	°C		
0.75mm			105	
1.5mm			120	
3.0mm			130	
RTI, Strength	UL 746B	°C		
0.75mm			115	
1.5mm			130	
3.0mm			140	
Other				
Density	ISO 1183	kg/m^3 (g/cm^3)	1420 (1.42)	
Water Absorption	ISO 62, Similar to	%		
Immersion 24h			0.64	
Molding Shrinkage	ISO 294-4	%		
Normal, 2.0mm			0.5	
Parallel, 2.0mm			0.2	
Processing				
Melt Temperature Range		°C (°F)	320-330 (610-625)	
Melt Temperature Optimum		°C (°F)	325 (620)	
Mold Temperature Range		°C (°F)	85-135 (185-275)	
Drying Time, Dehumidified Dryer		h	6-8	
Drying Temperature		°C (°F)	100 (210)	
Processing Moisture Content		%	<0.10	

Contact DuPont for Material Safety Data Sheet, general guides and/or additional information about ventilation, handling, purging, drying, etc
ISO Mechanical properties measured at 4.0mm, ISO Electrical properties measured at 2.0mm, and all ASTM properties measured at 3.2mm.
Test temperatures are 23°C unless otherwise stated.

090804/090804

Property Data (Provisional)

DSM

ForTii®

ForTii® LDS85

PA4T-GF30

30% Glass Reinforced, Laser Direct Structuring (LDS)

Print Date: 2018-01-19

Properties	Typical Data	Unit	Test Method
Rheological properties	dry / cond		
Molding shrinkage (parallel)	0.5 / *	%	ISO 294-4
Molding shrinkage (normal)	1.25 / *	%	ISO 294-4
Mechanical properties	dry / cond		
Tensile modulus	10500 / 10500	MPa	ISO 527-1/-2
Stress at break	150 / 150	MPa	ISO 527-1/-2
Strain at break	2 / 2	%	ISO 527-1/-2
Charpy impact strength (+23°C)	30 / -	kJ/m²	ISO 179/1eU
Charpy notched impact strength (+23°C)	4 / -	kJ/m²	ISO 179/1eA
Thermal properties	dry / cond		
Melting temperature (10°C/min)	325 / *	°C	ISO 11357-1/-3
Temp. of deflection under load (1.80 MPa)	285 / *	°C	ISO 75-1/-2
Temp. of deflection under load (0.45 MPa)	305 / *	°C	ISO 75-1/-2
Coeff. of linear therm. expansion (parallel)	0.25	E-4/°C	ASTM D696
Coeff. of linear therm. expansion (normal)	0.45	E-4/°C	ASTM D696
Burning Behav. at thickness h	HB / *	class	IEC 60695-11-10
Thickness tested	0.8 / *	mm	IEC 60695-11-10
Electrical properties	dry / cond		
Relative permittivity (1GHz)	3.7 / -	-	IEC 60250
Dissipation factor (1GHz)	200 / -	E-4	IEC 60250
Volume resistivity	>1E13 / >1E13	Ohm*m	IEC 60093

Property Data (Provisional)

DSM

ForTii® LDS85

Print Date: 2018-01-19

Properties	Typical Data	Unit	Test Method
Surface resistivity	* / >1E15	Ohm	IEC 60093
Comparative tracking index	550 / -	V	IEC 60112

Other properties

Other properties	dry / cond		
Water absorption in water at 23°C after 24h	0.3 / *	%	ISO 62
Thickness tested WA	2	mm	ISO 62
Humidity absorption	1.6 / *	%	Sim. to ISO 62
Density	1470 / -	kg/m³	ISO 1183

Recommendations for injection molding

ForTii®

ForTii® LDS85

PA4T-GF30

30% Glass Reinforced, Laser Direct Structuring (LDS)

Print Date: 2017-10-25

GRADE CODING

ForTii® laser direct structuring grades.

MATERIAL HANDLING

Storage

In order to prevent moisture pick up and contamination, supplied packaging should be kept closed and undamaged. For the same reason, partial bags should be sealed before re-storage.
Advisable is storage at room temperature.

Packaging

ForTii® grades are supplied in airtight, moisture-proof packaging.

Moisture content as delivered

ForTii® grades are packaged at a moisture level ≤ 0.1 w%.

Conditioning before molding

To prevent moisture condensing on granules, bring cold granules up to ambient temperature in the molding shop while keeping the packaging closed.

Moisture content before molding

Since ForTii® is delivered at molding moisture specification (≤ 0.1 w%), the resin can be molded without pre-drying. However, to overcome the fluctuation from package to package we advise to pre-dry (see drying section below). Furthermore, pre-drying is required in case the material is exposed to moisture before molding (package damage or open for longer period of time).
Moisture content can be checked by water evaporation methods or manometric methods (ISO 15512).

Recommendations for injection molding

ForTii® LDS85

Print Date: 2017-10-25

Drying

ForTii® grades are hygroscopic and absorb moisture from the air relatively quickly. Preferred driers are de-humidified driers with dew points maintained between -30 and -40°C / -22 and -40°F. Vacuum driers with N_2 purge can also be used. Hot air ovens or hopper driers are not suitable for pre-drying ForTii® grades; the use of such driers may result in non-optimum performance.

Moisture content	Time	Temperature	
[%]	[h]	[°C]	[°F]
0.1 - 0.2 and as delivered	2	100	212
0.2 - 0.5	4 - 8	100	212
>0.5	<100 or 24 or 4	100 110 120	212 230 248

Regrind

Regrind can be used taking into account that this regrind must be clean/low dust content/not thermally degraded/dry, of same composition and similar particle size as the original material. The acceptable level of regrind depends on the application requirements (e.g. UL Yellow Card). Be aware that regrind can cause some small color deviations.

Recommendations for injection molding

ForTii® LDS85

Print Date: 2017-10-25

MACHINERY

ForTii® grades can be processed on general injection molding machines.

Screw geometry
Typically 3-zone screw designs with volumetric compression ratios of approximately 2.5 work fine.

Steel type
Abrasive resistant tool steels which are normally used for glass and/or mineral reinforced materials are also to be used for ForTii® polymers in tools, nozzles and screws.

Nozzle temperature control
Due to the combination of the typical high melting temperature of ForTii® and consequently its high processing temperature, it is necessary to have a good temperature control for the nozzle. The use of an open nozzle or, even better, a reversed tapered nozzle with good temperature control and an independently-controlled thermocouple nearby the tip and heater bands with sufficient output is recommended.
The nozzle temperature should be set as high as possible to prevent a cold slug, yet low enough to prevent excessive drool.

Venting design
A good venting design is crucial for good molding behavior (easy filling) and low outgassing/mold deposit. Blocked vents can lead to incomplete parts and/or burning at the end of the flow path (diesel effect).
It is recommended to use venting on all inserts (explosive venting) and also on the runner system. Use decreased injection speeds during filling in order to make the venting as effective as possible.

Hot runner layout
The fast crystallization of ForTii® asks for specific hot runner design rules. For more details, there is also a special hot runner flyer available for all ForTii® grades. Please contact your DSM sales or check our websites.

Try to achieve a close contact with your hot runner supplier and DSM as the material supplier, to ensure that the right hot runner system is chosen.
When processing ForTii® with hot runners, keep in mind these basic rules:

- Central bushing heated separately
- Only use external heated system
- Manifold heated from both sides
- Tip with thermocouple in front (near gate)
- Very accurate temperature control in the gate area

Recommendations for injection molding

ForTii® LDS85

TEMPERATURE SETTINGS

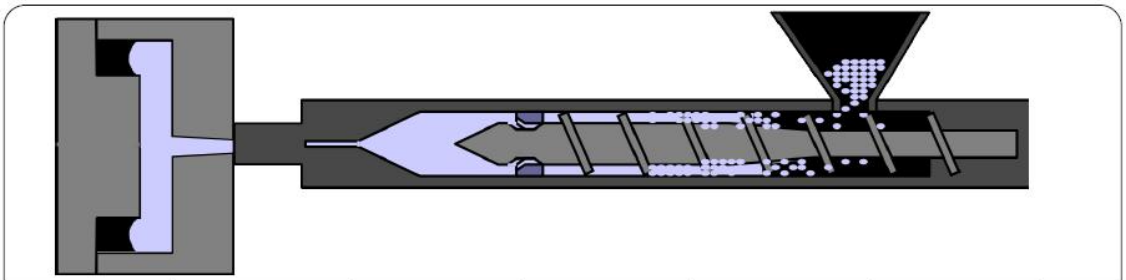
Print Date: 2017-10-25

Mold temperature

ForTii® can be used with a wide range of tool temperatures (100 - 150°C / 212 - 302°F). However, to achieve optimal mechanical properties and stable dimensional parts, it is recommended to apply a tooling temperature above the glass transition temperature (Tg) of ForTii® (125°C / 257°F), preferably 140°C/284°F.
For obtaining the best surface quality in thin wall applications, tooling temperatures close to Tg should be avoided; either tooling temperatures sufficiently below Tg (e.g. 100°C / 212°F) or above Tg (e.g. 140°C / 284°F) can be used in this case.

Barrel temperature

Due to the high melting point of ForTii® this temperature should be set high enough to provide a homogeneous melt without getting too near to the degradation temperature of 350°C / 662°F. A flat or rising temperature profile is recommended. Optimal settings are governed by barrel size and residence time. Furthermore, the temperature settings for small parts/machines can typically be 5-10ºC lower to avoid excessive outgassing/mold deposit.



Mold	Melt	Nozzle	Front	Center	Rear	
100 - 150°C *212 - 302°F*	330-340°C *626-644°F*	330-335°C *626-635°F*	330-335°C *626-635°F*	325-335°C *617-635°F*	320-330°C *608-626°F*	

Given barrel temperature settings are for shot weights > 2 grams.
For smaller shot weights (< 2 grams) barrel temperature settings are typically 5-10°C lower.

Melt temperature

To generate a good and homogeneous melt, the melt temperature should always be above 330°C / 626°F. Optimal mechanical properties will be achieved at melt temperatures between 330-340°C / 626-644°F. Melt temperatures on the low side of this window are recommended to minimize the risk of mold deposit and corrosion.
We advise to frequently measure the melt temperature by pouring the melt in a Teflon cup and inserting a thermo probe into the melt.

Residence time

Melt residence time for ForTii® in general should not exceed 4 minutes; preferably, melt residence time for ForTii® is <2 minutes. See also the separate section on residence time below.

Hot runner temperature

A hot runner temperature set to the same level as the nozzle temperature should work fine and not lead to excessive overheat of the ForTii® grade. When starting up, an increased tip temperature may be necessary to overcome a frozen nozzle.

试模&试换料记录表(Trail run record table)

品名系列(Product Serires)：XXXX	模号(Molding number): 700-00041A	产品料号(P/N)：060-0001-277

空模运行测试 Trial running	低压下合模是否有异响、阻滞；合模是否不顺畅、有干涉。 □是 □否 异常叙述： Checking noise, blocking or interferance as closing molding □ Yes □ No Abnormal Description
	顶出系统是否有异响、松动、不回位现象；顶块螺丝是否松动或脱落。 □是 □否 异常叙述： Checking noise, loosing, not returning for ejection system; Screw loosing or missing for ejector block □ Yes □ No Abnormal Description：
	滑块运行是否有阻滞、不牢固、不顺畅现象；是否与顶针有干涉。 □是 □否 异常叙述： Checking blocking, no good fixing, not smooth for silder, interferance or not with ejection pin □ Yes □ No Abnormal Description：
试换料之材料外观确认 Material Comestic	

成型五大要素收集区(5 key molding parameters collection)

成形條件/Molding Condition			第（ 1 ）次收集 1st	第（ ）次收集 2nd	第（ ）次收集 3rd
试制原因 Trial purpose			Setting test die		
试制日期 Trial date			2017.6.23		
模座编号 mold base NO.			700-00041		
设计穴数 Design Cavity			1		
实际穴数 Actual Cavity			1		
CT			20		
模具温度 Tooling temp	設定温度Setting Temp	(可)/Mov	85 ℃		
		(固)/Fix	85 ℃		
	实际温度 Actual Temp	(可)/Mov	/ ℃		
		(固)/Fix	/ ℃		
Cylinder Heater	料口/Under Hopper		50 ℃		
	區段/Cylinder 4		310 ℃		
	區段/Cylinder 3		310 ℃		
	區段/Cylinder 2		315 ℃		
	區段/Cylinder 1		330 ℃		
	區段/Nozzle		350 ℃		
射出·保压設定Shoot .Hold setting	射出速度 V1 Shot speed		135mm/s		
	射出速度 V2 Shot speed		110 mm/s		
	射出速度 V3 Shot speed		/mm/s		
	充填压力P1 Filling pressure		170 KG/CM^2		
	充填压力P2 Filling pressure		/KG/CM^2		
	充填压力P3 Filling pressure		/KG/CM^2		
	保压压力P1 Dwell pressure		80KG/CM^2		
	保压压力P2 Dwell pressure		/ KG/CM^2		
	保压時間t1 Dwell time		0.5Sec		

参考区域（Reference data)

	名称项目(Item）	位置mm Position	速度% Speed	压力% Pressure
顶出 Ejection	初顶(Initial ejection）	20	3	25
	顶出(Ejection)	40	3	25
	回位（Back)	0	/	30
	顶出次数(Ejection times)	1	顶出模式 Ejection type	3
	顶针保持开/关 Ejection pin open/close	□开 □关 □ Open □ Close	延迟sec Delay	/
型开闭设定	名称项目 Item	位置mm Position	速度% Speed	压力% Pressure
	开模1st 1st phase/Open	15	20	/
	开模2段 2nd phase /Open	170	40	/
	开模3段	250	35	/
	开模止 Stop/Open	/	/	/
	合模1st 1st phase/Close	100	35	/
	合模2段 2nd phase/Close	50	25	/
	低压闭模 Close mold @ low pressure	2.1	/	23
	合模止 Stop/Close	1.18	20	/
单重(weight)	产品单重 Product weight	0.3385		
	Molding material weight	1.2476		

第一次试模&试换料问题描述 1st trial runing issues
1:产品拐角处有毛刺 There is burr at the corner of the product
2:产品顶肿发白 The product is swollen and whitish
3:产品应力痕明显 The product stress mark is obvious
4:设变取样20模 Set change sampling 20 Modulus

	保压時間t2 Dwell time	0.6 Sec			
	保压速度v1 Hold speed	20 mm/s			第二次试模&试换料问题描述 2nd trial runing issues
计量&充填位置 Measure&Filling Position	計量位置 S Measure Position	12 mm			
	充填位置 S1 Filling Position	8mm			
	充填位置 S2 Filling Position	6.3mm			
	充填位置 S3 Filling Position	/mm			
螺旋设定 Screw setting	背压/ Bace press	2.0 KG/CM2			
	回轉数/Screw rev	150RPM			
	前松退 (loose/Forward)	/ mm			
	后松退 Loose/Backforward	6mm			
冷却(Cold)	冷却時間 Cold time	10Sec			
设备参数 Machine Parameter	成型机规格/机号 Machine	住友50T/M07			第三次试模&试换料问题描述 3rd trial runing issues
	型缔力 Ton	300KN			
	螺杆直径mm Screw D	Φ22			
	喷咀口径mm Nozzle D	Φ1.8			
干燥 Drying	材料品名 Material Name	LDS85			
	干燥设备编号/干燥时间	M09/5H			
产品 Product	外观是否OK Comestic	■ 是 □ 否 ■ Yes □No			
	Feature	■ 是 □ 否 ■ Yes □No			
check	收集者 Collector	Haizhao.song			
	审 核 Approval	Huangdefei			

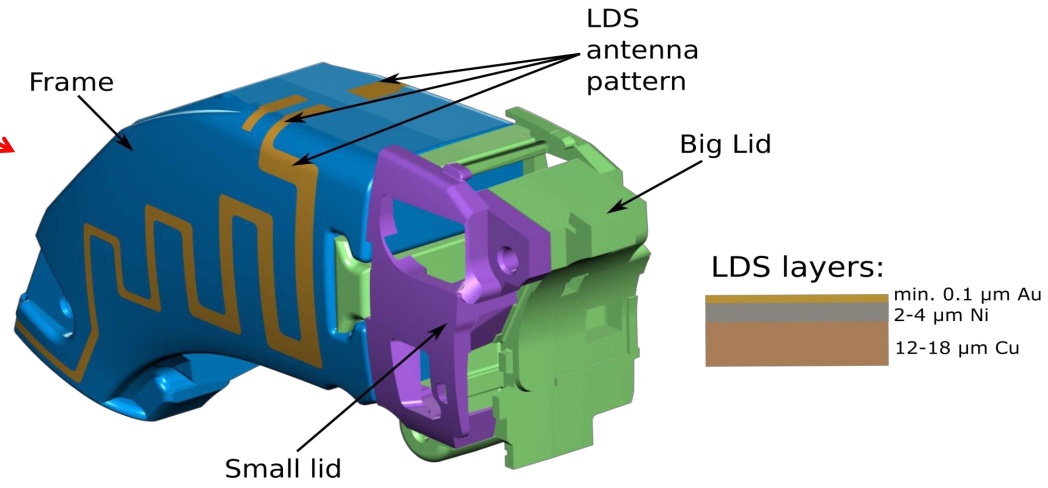
表单编号：FMC0191

Document Title: Berlin 70 prototype work instruction	Doc. #:0001	Rev #: I
GN		Lautrupbjerg 9 P.O. Box 130 DK-2750 Ballerup Denmark
Prepared by: Nicolai D. Nielsen		GNResound
Date: 2017/12/28		

This work instruction is fit for below models

Berlin 70 LDS prototype

Terms explanation



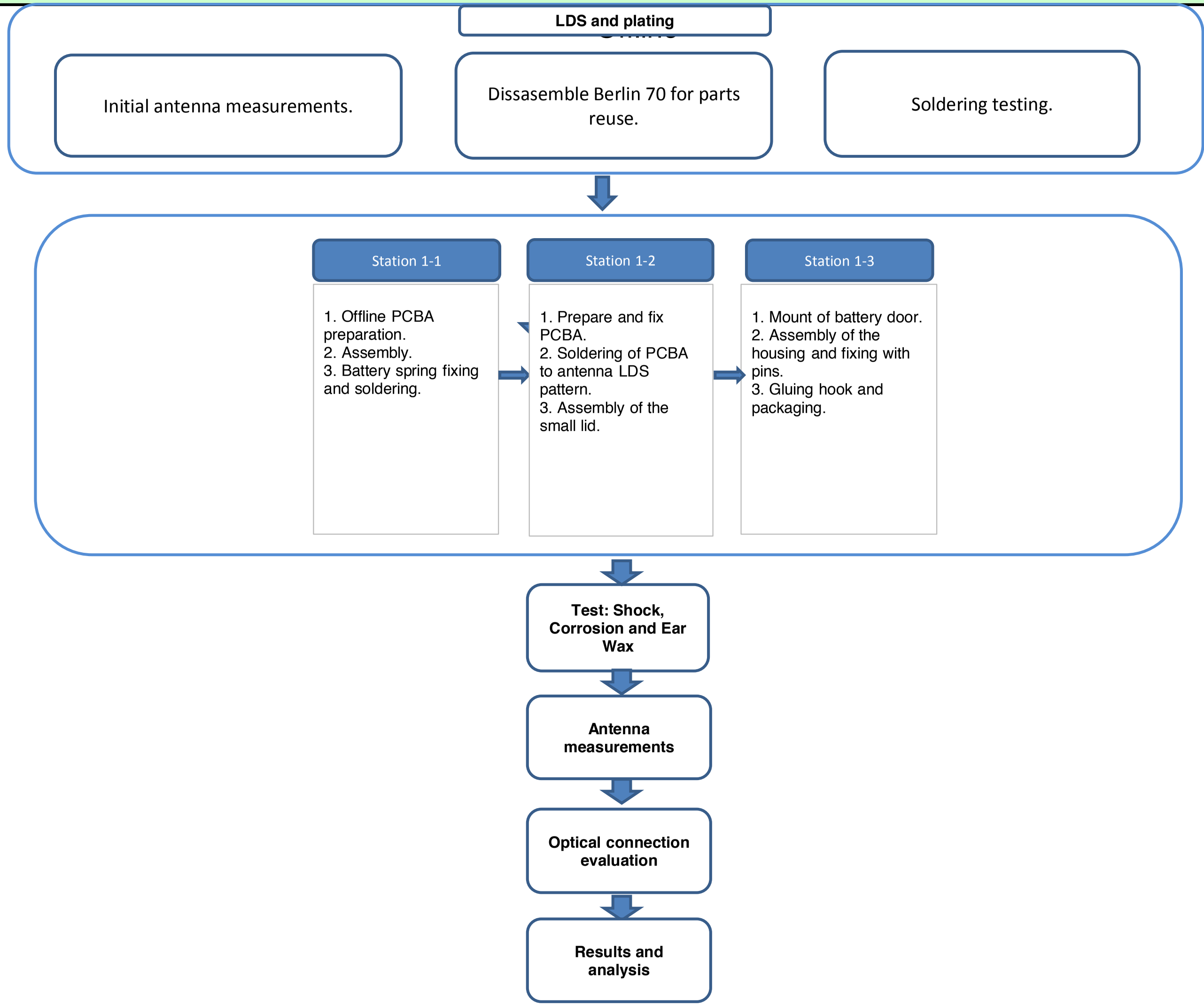
Document Title: Berlin 70 LDS prototype work instruction		Document #: 0001		Rev #:I	
Step :	SITE	CPH	P.E		SAFETY PROTECTION
Description:	MODULE		Prod.		
WI change record	Berlin 70 LDS prototype		M.E		
			Q.A.		
			Engineering Manager	Anders Michaelsen	
			CREATED BY	Nicolai D. Nielsen	HSE QUALITY
			DATE	28-12-2017	

ENGINEERING CHANGE RECORD

DATE	VERSION	CHANGE DESCRIPTION	CHANGE REASON	CHANGE OWNER
2017.12.21	A	First time release Berlin70 LDS prototype work instruction	First release	Nicolai D. Nielsen
2017.12.28	B	1. Update term explanation picture. 2. Add: Lint-free cotton gloves / similar gloves.	1. Add explanation. 2. Add instruction.	Nicolai D. Nielsen

Document Title: **Berlin 70 work instruction**		**Document #: 0001**		**Rev #:I**	
Description: Work flow	***SITE***	***CPH***	***P.E***	*0*	***SAFETY PROTECTION***
	MODULE		***Prod.***	*0*	
	Berlin 70 LDS prototype		***M.E***	*0*	
			Q.A.	*0*	
			Engineering Manager	*Anders Michaelsen*	
			CREATED BY	*Nicolai D. Nielsen*	***HSE*** ***QUALITY***
			DATE	***28-12-2017***	

Standard Operation Flow

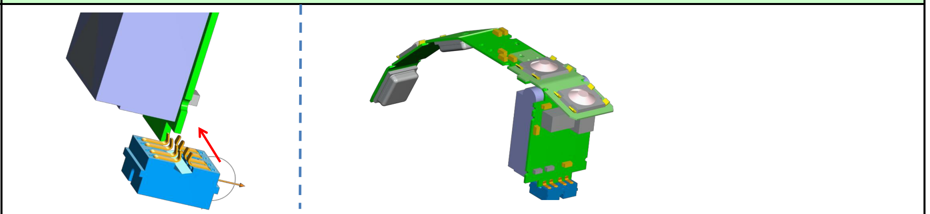
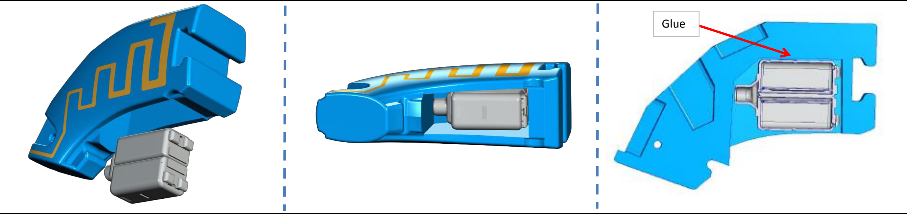
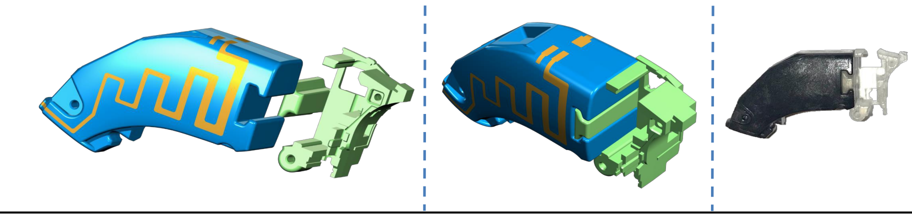
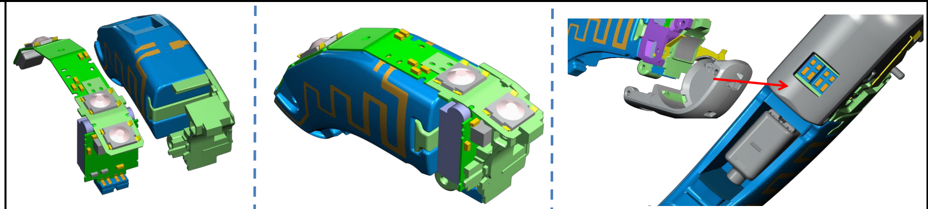


Document Title:
Berlin 70 LDS prototype work instruction

Document #: 0001

Rev #:I

Step : 1	*SITE*	CPH	
Description: Assembly	*MODULE*		
	Berlin 70 LDS prototype		
P.E	0	*SAFETY PROTECTION*	
Prod.	0		
M.E	0		
Q.A.	0		
Engineering Manag	Anders Michaelsen		
CREATED BY	Nicolai D. Nielsen	HSE	QUALITY
DATE	28-12-2017		

Material/Part Number 物料/工号	NO 序号	MAIN PROCEDURE 主要步骤	DETAIL PROCEDURE (ANALYSIS) 详细流程（分析）	KEY POINTS 关键点	FIGURE/EXPLANATION 图例、说明
PCBA：19250100 Docking module：16021200	1	Assembly and soldering.	1. Insert and solder docking module into PCBA.		
Frame: A_FRAME_0004 420 glue：LOC02MF1	2	Assembly.	1. Insert receiver into frame, fix it, and glue it to the top.	1. Avoid damage and contamination (e.g. metal or skin contact, scratches) especially on the activated LDS areas. 2. Use lint-free cotton gloves or similar when handling the frame. 3. Glue: Loctite 420 (Cyanoacrylate)	
Big Lid: B_FRAME_OG_0001	3	Assembly.	1. Insert big lid into frame.		
	4	Assembly.	1. Insert PCBA into frame.	1. Fix PCBA into snap joint on big lid compeltely. 2. Insert docking module completely and test with battery door allignment as seen on 3rd picture. 3. Docking module must touch the limit part of the frame.	
Positive spring：15967601	5	Assemble / soldering battery spring	1. Insert positive battery spring into the lid. 2. Solder it to the PCBA.	1. Soldering ball must be smooth, can not be cold soldering.	

Document Title:
Berlin 70 LDS prototype work instruction

Document #: 0001

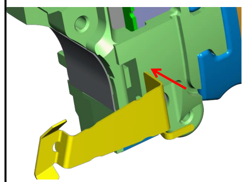
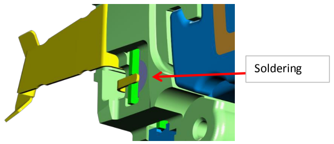
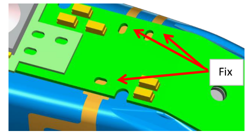
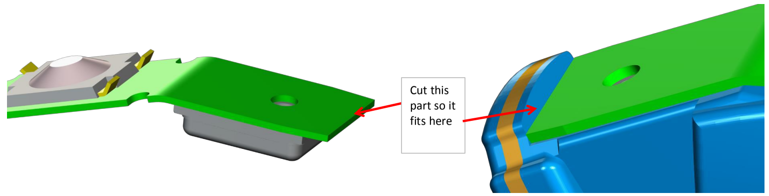
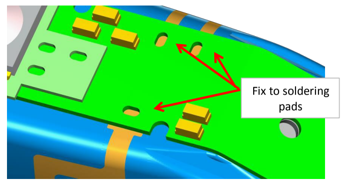
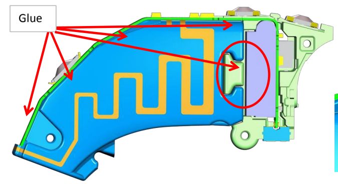
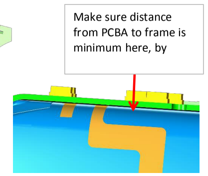
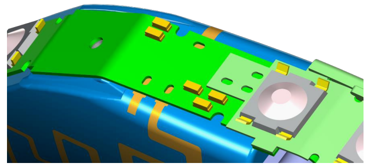
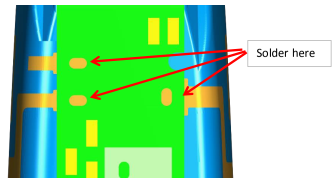
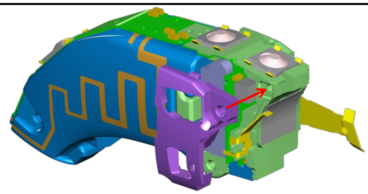
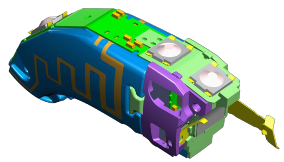
Rev #:I

Step : 1-2
Description:
Assembly

SITE	CPH
MODULE	Berlin 70 LDS prototype

P.E	0
Prod.	0
M.E	0
Q.A.	0
Engineering Manag	Anders Michaelsen
CREATED BY	Nicolai D. Nielsen
DATE	28-12-2017

SAFETY PROTECTION
HSE
QUALITY

Material/Part Number 物料/工号	NO 序号	MAIN PROCEDURE 主要步骤	DETAIL PROCEDURE (ANALYSIS) 详细流程（分析）	KEY POINTS 关键点	FIGURE/EXPLANATION 图例、说明
Negative spring: 15967501	6	Assemble / soldering battery spring	1. Insert negative battery spring into the big lid. 2. Solder it to the PCBA.	1. Soldering ball must be smooth, can not be cold soldering.	  
	7	Cutting.	1. Cut PCBA end in order to make it fit in the frame.		
	8	Assembly.	1. Fix antenna soldering semiholes of PCBA on top of LDS antenna soldering pads. 2. Align the rest of the PCBA and glue it to the frame and big lid. 3. Glue frame to the big lid at the hook as shown in picture 2.	1. Glue: Loctite 420. 2. Avoid glue on LDS soldering pads. 3. Adjust soldering pad so there is no gap between antenna soldering pad and soldering hole of PCBA	  
	9	Soldering.	1. Solder PCBA semiholes to the three LDS soldering pads below.	This is the connection to be tested. 1. Use as low solder tip temperature as possible. Preferably below 285°C since the frame material (Stanyl Fortii LDS85) has a melting point at 325°C and a 285°C deflection T under a load of 1.8MPa. The LDS soldering pads are though made of Au 0.10µm, Ni 2-4µm, Cu 12-18µm.	 
Small lid: LID_OG_0001	10	Assembly.	1. Small lid is pressed into the big lid and fixed with glue, to the big lid and the frame.	1. Glue: Loctite 420.	 

Document Title:
Berlin 70 LDS prototype work instruction

Document #: 0001

Rev #:I

Step : 3	SITE	CPH	
Description: Assembly	MODULE		
	Berlin 70 LDS prototype		

P.E	0
Prod.	0
M.E	0
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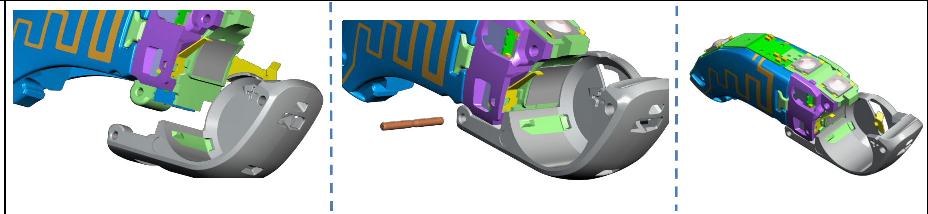
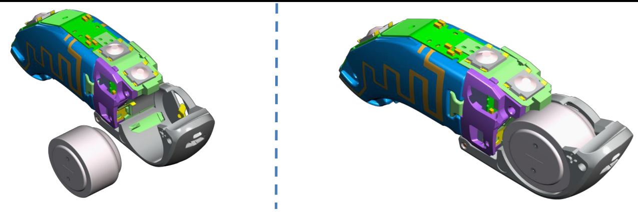
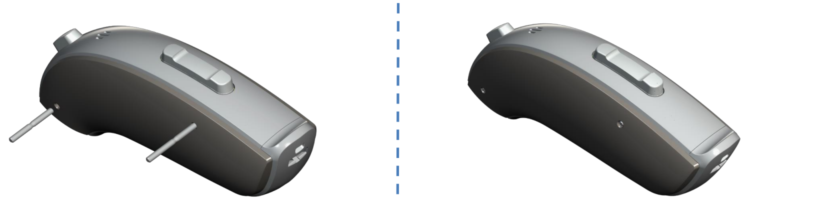
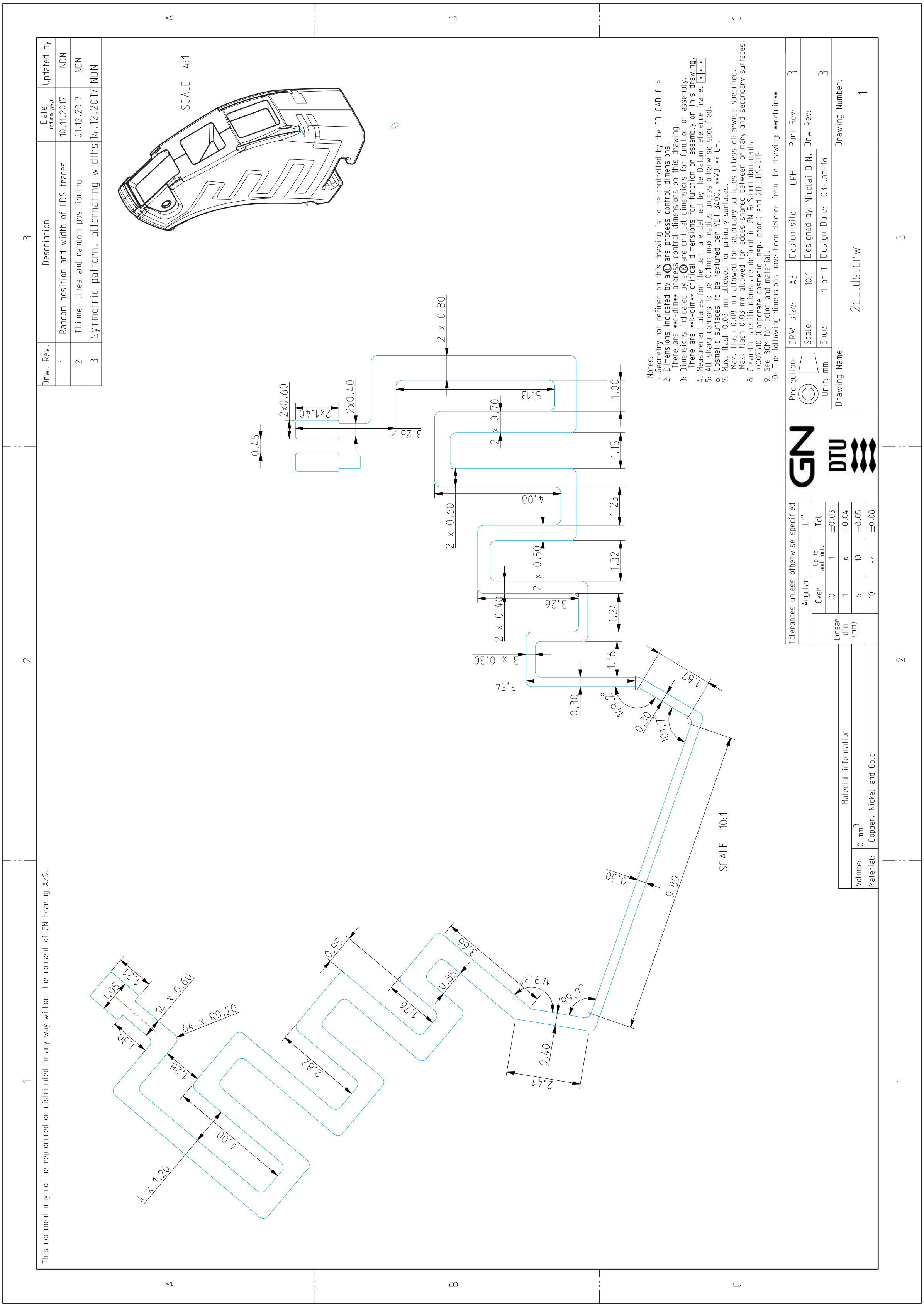
Battery door：RS:189240 Battery pin：19069900	11	Assembly.	1. Assemble battery door and fix with pin.		
	12	Assembly.	1. The battery can now be inserted.		
Battery door：RS:189240 Battery pin：19069900	13	Assembly.	1. Assemble housing and belly.	Check gap for below palce: 1.Gap between battery door and left/right housing 2.Gap between belly band and left/right hosuing 3.Gap between Top hosuing and left/right hosuing 4.Gap between frame and housing 5.Gap between belly band and battery door	
Front pin:16059600 Back pin:18926700	14	Assembly.	1. Fix with pins.		
	15	Assembly.	1. Glue hook to hearing aid end. 2. Packaging in same boxes.		 Glue

2D LDS antenna pattern drawing



PRODUCT NEWS

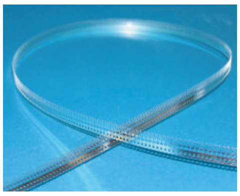
Products from Yuken
No.3 2011

YUKEN INDUSTRY CO., LTD.

Surface Treatment Chemical for Electronic Parts

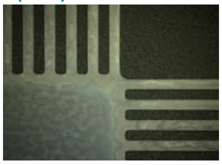
メタス METASU

Low carbon type bright Sn plating process (METASU SNV-300)

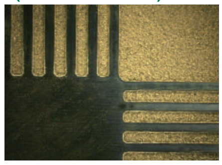


1) Does not cause change in surface film after reflow (No drawing).
2) Decrease change in color after reflow and no degradation for solder-wettability.
3) It has good resistance against scratching.

●Appearance after reflow (As is)

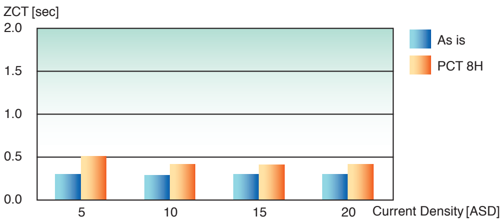


●Appearance after reflow (METASU SNV-300)



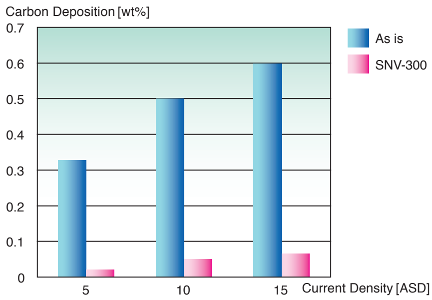
■It gas great appearance after reflow.

●The Solder-Wettability of METASU SNV-300



■No big degradation for solder-wettability after PCT.

●Comparison of Carbon Deposition

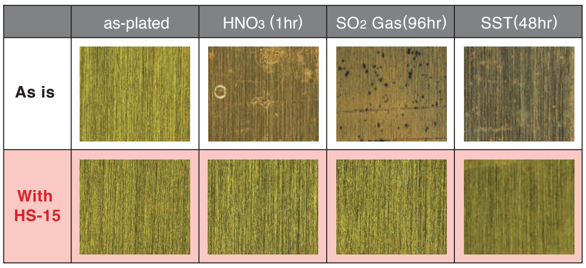


■When compared, METASU SNV-300 has much lower carbon deposition.

Sealer for Au plating (METASU HS-15)

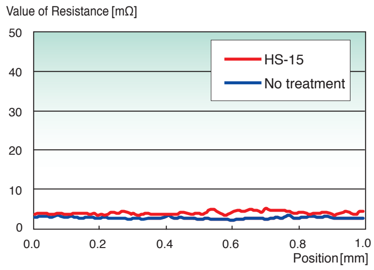
1) Excellent anti-corrosion performance against corrosion environments such as HNO_3.
2) No degradation for contact resistance and solder-wettability after treatment of METASU HS-15.
3) No stains regardless of rinsing or no rinsing because of no-emulsion type.

●Corrosion Resistance (Evaluation after 60sec. under 260°C)



■It is proven that there is a significant improvement on resistance performance.

●Contact Resistance (5gf・1mm move)



■No change in contact resistance after METASU HS-15.

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