Reducing the wear costs of Ericsson’s test equipment: 2 cases

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Abstract

This thesis has attempted to reduce costs associated with wear parts in test equipment at Ericsson’s master and industrialization center (MIC) in Kista. Two different cases have been pursued, and each has been designed to follow a, for the purpose, adapted version of the design research methodology (DRM). The adapted model was presented and its use in both cases was additionally evaluated.

Both cases were based on products that already have been launched and are used in production. In order to avoid expensive changes to surrounding equipment, incremental product development was chosen in both cases.

The first case focused on test equipment used in the production of digital units for radio base stations. After the wear parts of this test equipment were examined, it was found that a plastic detail was manufactured through milling and as a result was quite expensive. The plastic detail was redesigned so that it could be manufactured using the injection molding process instead. This resulted in an estimated cost reduction of 48%.

The second case focused on wear parts of test fixtures used in the production of radio filters, also used in Ericsson’s radio base stations. A more process-oriented view was adopted in this case and parameters believed to be causing added wear such as positional and angular misalignment were examined further. Tolerance chains for each wear part in the assembled test fixture were calculated to determine the degrees of possible misalignment. The resulting data did however not correlate with each wear part’s individual wear interval, and no concrete cost reductive improvements could be delivered. Instead suggestions which can lead to further cost reductions in the long term were presented.

The model used to develop improvements for these two cases was found to have helped the process in both cases, however further research of this model is recommended in order to determine if it is suitable for these types of projects in general.

Key-words: Ericsson, cost reduction, test equipment, tolerance chains, injection molding
Preface

This master thesis was carried out in the spring of 2012 and concludes our education in mechanical engineering at Kungliga Tekniska Högskolan (the Royal Institute of Technology). The thesis has comprised of 30 högskolepoäng (ECTS-credits) and been performed at Ericsson AB.

For giving us the opportunity to write our thesis at Ericsson and supporting us throughout this project we would like to thank our supervisors at Ericsson: Jonas Jangdin and Erik Simonsson.

The rest of MIC Kista has also been very helpful. Certain individuals have devoted a large part of their time to help us and thus deserve a special mention:

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- Elinor Anderson – For assisting in CAD-related matters and being our link into the parallel running wear board project.
- Björn Falk – For answering all questions related to digital units.
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## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. INTRODUCTION</strong></td>
<td>9</td>
</tr>
<tr>
<td>1.1 BACKGROUND</td>
<td>9</td>
</tr>
<tr>
<td>1.2 PRESENTATION OF MIC Kista</td>
<td>9</td>
</tr>
<tr>
<td>1.3 PRODUCT DESCRIPTION</td>
<td>10</td>
</tr>
<tr>
<td>1.4 PROBLEM DESCRIPTION</td>
<td>11</td>
</tr>
<tr>
<td>1.4.1 PURPOSE AND GOALS</td>
<td>12</td>
</tr>
<tr>
<td>1.5 DELIMITATIONS</td>
<td>12</td>
</tr>
<tr>
<td>1.6 COMMENTS TO THE READER</td>
<td>12</td>
</tr>
<tr>
<td><strong>2. LITERATURE STUDY</strong></td>
<td>13</td>
</tr>
<tr>
<td>2.1 INNOVATIONS AND COST REDUCTION</td>
<td>13</td>
</tr>
<tr>
<td>2.2 PRODUCT DEVELOPMENT</td>
<td>14</td>
</tr>
<tr>
<td>2.3 COST REDUCTION</td>
<td>16</td>
</tr>
<tr>
<td>2.3.1 INFLUENCE OF MATERIAL</td>
<td>16</td>
</tr>
<tr>
<td>2.3.2 INFLUENCE OF THE PRODUCTION PROCESS</td>
<td>17</td>
</tr>
<tr>
<td>2.3.3 INFLUENCE OF ASSEMBLY</td>
<td>18</td>
</tr>
<tr>
<td>2.4 SUMMARY</td>
<td>19</td>
</tr>
<tr>
<td><strong>3. METHODOLOGY</strong></td>
<td>21</td>
</tr>
<tr>
<td>3.1 DESIGN RESEARCH METHODOLOGY</td>
<td>21</td>
</tr>
<tr>
<td>3.2 INTERNAL SOURCES</td>
<td>22</td>
</tr>
<tr>
<td><strong>4. FIRST CASE: DIGITAL UNITS</strong></td>
<td>25</td>
</tr>
<tr>
<td>4.1 DESCRIPTION OF THE DIGITAL UNITS CASE</td>
<td>25</td>
</tr>
<tr>
<td>4.2 SITUATION ANALYSIS</td>
<td>26</td>
</tr>
<tr>
<td>4.2.1 WEAR PARTS</td>
<td>26</td>
</tr>
<tr>
<td>4.2.2 WEAR INTERVALS</td>
<td>27</td>
</tr>
<tr>
<td>4.2.3 WEAR PARTS ECONOMICS</td>
<td>28</td>
</tr>
<tr>
<td>4.2.4 PROBLEMS</td>
<td>29</td>
</tr>
<tr>
<td>4.2.5 CONNECTOR GUIDE</td>
<td>30</td>
</tr>
<tr>
<td>4.3 IMPROVEMENTS</td>
<td>31</td>
</tr>
<tr>
<td>4.3.1 CHOICE OF MANUFACTURING PROCESS</td>
<td>31</td>
</tr>
<tr>
<td>4.3.2 INJECTION MOLDING</td>
<td>33</td>
</tr>
<tr>
<td>4.3.3 REDISEIGN WORK</td>
<td>33</td>
</tr>
<tr>
<td>4.4 RESULTS OF THE DIGITAL UNITS CASE</td>
<td>34</td>
</tr>
<tr>
<td>4.5 DISCUSSION OF THE DIGITAL UNITS CASE</td>
<td>35</td>
</tr>
<tr>
<td>4.5.1 RESULT RELATED DISCUSSION</td>
<td>35</td>
</tr>
<tr>
<td>4.5.2 PROCESS RELATED DISCUSSION</td>
<td>36</td>
</tr>
<tr>
<td><strong>5. SECOND CASE: RADIO FILTERS</strong></td>
<td>37</td>
</tr>
<tr>
<td>5.1 DESCRIPTION OF THE RADIO FILTER TEST FIXTURES</td>
<td>37</td>
</tr>
</tbody>
</table>
1. Introduction

1.1 Background

With increasing global competition, it becomes more important for companies involved in product development to deliver attractive products with higher levels of quality, shorter lead times and lower costs (Colosimo & Senin, 2011, p.V). This type of pressure has resulted in the creation of this thesis which aims to reduce the wear costs of two specific product categories for the Swedish telecom giant Ericsson.

From the customer’s perspective, cost reductions are rarely exciting as they do not offer any improved performance other than perhaps a lower price. For a company however, they have the ability to reduce production costs while maintaining the same performance which can generate enormous added-value. Often new products belonging to the category of cost reductions can even be the most economically advantageous for a company (Trott, 2008, p.400). A study conducted by Griffin (1997) showed that 9% of all new product introductions belonged to the cost reduction category.

The development of the cost reductions in this thesis will follow the outline of the design research methodology (DRM) framework, but will be adapted for the purpose of cost-oriented product development. This adapted methodology will be developed and presented, as well as evaluated after the project’s completion. The goal is to create a model which can encourage standardized and continuous cost reduction developments. Having a standardized procedure for this is important in order to ensure quality and consistency (Liker, 2004, p.143).

1.2 Presentation of MIC Kista

The thesis work has been carried out in the department of Hardware Design & Supply Services (HWDSS) at Ericsson’s master and industrialization center (MIC) in Kista. MIC Kista is a sub-division of the telecom company Ericsson which was founded in 1876 by Lars Magnus Ericsson. As of December 31st, 2011 the company has 104,525 employees, with 17,500 based in Sweden. They are market leaders within mobile networks but is also a leading player within core networks, microwave transport, Internet Protocol networks and fixed-access solutions for copper and fiber. Ericsson also provides service for these networks. The organizational chart can be seen below in Figure 1. (Internal source 1)

![Figure 1. Organizational chart of Ericsson (Source: Internal source 1).](image-url)
MIC Kista has about 450 employees and is part of BUSINESS UNIT NETWORKS seen in Figure 1. They are responsible for industrializing new products and to a smaller degree supply radio filters for radio networks as well as high technology prototypes and reference models. In addition MIC is responsible for designing and manufacturing test hardware and customized products used in Ericsson’s different supply sites; Hardware Design & Supply Services is the department responsible for this.

Ericsson outsources its high-volume production to electronic manufacturing services (EMS) in low-cost countries such as Estonia and China. A large part of its R&D is however still located in Sweden (Berggren & Bengtsson, 2004). MIC’s purpose is to act as a link between R&D and high volume production abroad. Ericsson-specific production equipment is produced by MIC and when new products are launched the production methods required to build these products are designed in MIC’s production lines. When the production methods are stable, the concept is exported abroad where Ericsson’s supply sites initiate high volume production (Internal source 2).

1.3 Product description

The products examined in this thesis are used as test equipment in Ericsson’s production of radio base stations (RBS). Within Ericsson’s supply chain, they are used in the Produce & Test activity highlighted in Figure 2 below.

![Figure 2. The role of testing within a supply chain (Source: Persson, 2011).](image)

The different components of an RBS require different types of test equipment; the test equipment this thesis will focus on is used to produce radio filters and digital units. An RBS-cabinet can be seen below in Figure 3, with a radio filter (blue, above) and a digital unit (green, below) highlighted and magnified. As can be seen, each RBS can include several radio filters and digital units.
The radio filter’s purpose is to prevent outside signals from interfering with the radio base stations’ designated frequencies (Internal source 3). MIC Kista has a small scale production of radio filters, which meant that information and data regarding radio filter products were easily available during this thesis project.

The digital unit receives IP telephony and converts this into digital data which is transmitted through the base station’s radio unit (Internal source 3). Within the test equipment for digital units, MIC produces the wear parts that are used in digital test fixtures.

1.4 Problem description

In the present situation the replacement of wear parts in the quality testing stations make up a significant part of the total production costs. As internal pressure to cut costs is being placed on Ericsson’s entire supply organization, the costs related to wear parts need to be placed under scrutiny. Costs associated with testing in production are generally considered a part of the total quality costs (TQC). TQC can be broken down into four categories (Cheah, Shahbudin & Taib, 2010) as can be seen in Figure 4 below.

![Figure 4. The components of total quality costs.](image)

Testing is one of the major components of the appraisal costs category. This includes testing of incoming material or parts, material in stock and finished products. The other components making up appraisal costs are the cost of maintaining accurate measuring instruments and test stations, as well as the costs of materials and supplies used during testing (Krishnamoorthi, 2006, p.16). Because this thesis focuses on test equipment, costs discussed will from this point belong to the category of appraisal costs.
1.4.1 Purpose and goals

The thesis project’s purpose and goals have been decided in agreement with the stakeholders at Ericsson. The purpose is to suggest activities to minimize the production costs associated with quality test equipment. The goals for the thesis and their corresponding success criteria are:

- To determine the life times of the wear parts used in current production lines, how their actual wear intervals correlate with those stated by suppliers, and to estimate the costs they incur. To consider this goal achieved, the costs and life times of all wear parts within the delimitations should be presented.
- To give suggestions on how to decrease the effect of wear parts on the end price of products. To achieve this goal, at least one concrete improvement should be presented for each case which can be shown to lead to a cost reduction of at least 15% compared to the cost level at the thesis project’s initiation.

1.5 Delimitations

In order to be able to describe the issues at a detailed level, certain delimitations have been made.

- Non-technical ways of reducing the cost of wear parts are excluded from the thesis’s scope. This means that the purchasing and logistics routines surrounding the wear parts have not been considered.
- The scope has also been limited to certain wear parts. The wear parts that this thesis will try and optimize are wear boards used in digital test fixtures and the connector wear parts included in radio filter fixtures.
- The radio filters are currently undergoing a modular shift from platform 4 to platform 5. Platform 4 still has a higher volume than its designated replacement but is slowly but surely being phased out. For this reason the wear parts associated with platform 4 will be excluded from the scope of this thesis project.
- In addition, the report will focus on delivering suggestions for improvements for the strategically important wear parts, meaning those that can offer the best economic return. The reasons for this are the time limitation as well as a desire to deliver as qualitative and detailed suggestions as possible.

1.6 Comments to the reader

Ericsson’s internal product names will be used throughout in this report. An Ericsson internal product name will look something like this: ABC 123 456/1. The name to some extent signifies the function of the product, so similar products will share the ABC and 123 part of the name. To an external reader these names are not meant to give any added meaning, they are simply used to distinguish products from one another.

In some parts of the report, prices are listed and economic comparisons are made. For these sections it may be necessary to point out that the varying value of currencies has not been taken into account as the differences over the limited period of time this thesis was performed were assumed to be negligible.
2. Literature study

A general review of literature related to cost reductions will be presented in the literature study.

2.1 Innovations and cost reduction

It becomes increasingly important for companies to cut costs within operations and supply chains to remain competitive. Globalization has had a large impact on increasing this pressure (Jackson et al., 2008, p.8) and the recent financial crisis has further increased this cost reduction pressure on companies (Warren, 2009). Cost reductions are commonly strived for in the specific phase of the innovation cycle that was introduced by Utterback and Abernathy in 1978 and is visualized in Figure 5 below.

![Figure 5. The innovation cycle. (Source: Abernathy & Utterback, 1978).](image)

They (Abernathy & Utterback, 1978) divide the innovation cycle into three different phases that can be seen in Figure 5 above. In the first stage, the fluid phase, a new technology has emerged and with it high uncertainty regarding how the technology will be configured and who will want it. Due to this uncertainty there is widespread experimentation to find the “right” technological configuration. Eventually the experiments tend to converge around certain concepts, and the earliest signs of a dominant design can be detected. Experimentation outside this dominant design becomes increasingly difficult because both entrepreneurial interest and resources are focused on the dominant design concept. The experimentation instead moves to refining the dominant design. This stage of transition to a dominant design is called the transitional stage by Abernathy and Utterback (1978). As the dominant concept continues to mature, focus tends to increasingly shift to lowering costs through the pursuit of for example scale economies and process innovations. This is the specific phase.

Tidd and Bessant (2009, p.42) write that innovations in this phase tend to be incremental and to a large extent are stimulated by a pressure to reduce costs as this is where the primary competitive emphasis is placed during this phase. When all competitors begin pursuing the same dominant design, price is one of few remaining differentiation possibilities.
There are certain elements that point to the radio base stations being in their specific phase. Ericsson’s operating margin has for instance gone down significantly in the last five years, from 16.3% in 2007, to 7.9% in 2011 (Ericsson, 2011), which suggests added cost pressure. In addition, innovations within these products are to a large extent incremental, related to increased capacity or higher speeds for data traffic.

As such this thesis will be a rather typical improvement project for a technology in its specific phase. Focus will be placed on reducing costs through incremental innovations. This will be done with a focus on wear parts, or in other words on the component level as demonstrated by Figure 6 below.

![Figure 6. The dimensions of innovation (Source: Tidd & Bessant, 2009, p.38).](image)

Utterback and Abernathy (1978) differentiate between product and process innovations in their cycle. Because the approach of this thesis has been to reduce costs of test equipment, the area of product development will be explored further.

### 2.2 Product development

Product developments are critical for a company to become or stay competitive (Johne & Snelson, 1989), and many studies have examined the topic. New product development (NPD) is described as inherently risky but can often result in an opportunity for differentiation and competitive advantage for companies (Song & Montoya-Weiss, 1998). New product development can result in one of the following new product categories, according to the widely accepted new product classification introduced by Booz, Allen & Hamilton in 1982 (Trott, 2008, p.399).

- New to the world products
- New product lines
- Additions to existing lines
- Improvements and revisions to existing products
- Cost reductions
- Repositioning
Johne and Snelson (1989) use a different terminology in the classification of product development. The development of modifications, upgrades or extensions for existing products belongs to the category they call old product development (OPD). Only relying on rejuvenating old technology increases the risk of being overtaken by competitors, which is why they write that only pursuing OPD is not enough. OPD is inherently different to the development of completely new products and requires different management styles, staff and structures. (Johne & Snelson, 1989).

They (Johne & Snelson, 1989) conducted an empirical study of forty large American and British companies in various product markets. The study showed that companies with clear, detailed OPD strategies enjoyed two major advantages:

- First, it raised the internal valuation of the process, necessary for generating the drive to overcome operational hurdles.
- Secondly, it allowed top managers to take a step back from the development process and not get involved on a daily basis. This meant energy otherwise used for briefing managers could be placed elsewhere.

Further, the companies that were considered successful in their OPD tasks also integrated cross-functional elements into the OPD-process. In all cases, technical and marketing functions were involved. Often design, manufacturing and engineering departments also had representatives involved from the very start of the project. Cross-functional involvement is important because of the problem solving nature of OPD. If all relevant opinions can be accessed and are considered in the project’s early stages, misguided decisions can be avoided before significant funds have been tied up. (Johne & Snelson, 1989)

Regardless of the type of product development, it is essential that it is executed correctly. This is because 90 % of a product’s cost is determined in product development and production planning. Managing successful product development involves (Ehrlenspiel, Kiewert & Lindemann, 2007, pp.13-24):

- Managing personnel to ensure that motivated and suitable employees fill each position,
- Configuring the organization to maximize chances for success such as creating physically co-located and integrated teams, and
- Planning a suitable employee capacity. With employees constantly under deadline constraints they will not have time to search for alternative, more cost efficient solutions but instead will only work to finish the documents that currently have the highest priority.

Cost management is one approach used to ensure cost-efficient product development. Cost management is the targeting and systematic steering of costs with the aim to reduce costs of products, processes and resources. The goal is to create a competitive product with the minimum use of resources. To achieve this it needs to be ensured that the right people can and are communicating with each other. Development engineers that are unsure about costs need to be able to turn to an appropriate person within other departments for advice. In addition, systems which can present cost information need to be in place so that projects constantly can reassess decisions against their projected cost-target. (Ehrlenspiel, Kiewert & Lindemann, 2007, pp.25-26)
Cost management can be divided into three different forms (Groth & Kinney, 1994):

- Cost containment
- Cost avoidance
- Cost reduction

Because the scope of this thesis is limited to cost reduction this area will be the coming focus.

2.3 Cost reduction

The key contributing factors in cost reduction are to improve or change manufacturing processes, change the materials used, and to decrease the number of moving parts (Trott, 2008, p.400, (Ehrlenspiel, Kiewert & Lindemann, 2007, p.144), as illustrated below in Figure 7.

![Cost reduction diagram](image)

Figure 7. Cost reduction’s key contributing factors (Source: Ehrlenspiel, Kiewert & Lindemann, 2007, p.144).

The primary cost decider for the costs of a product is its concept or the principle function, the definition of its necessary properties. Other main design factors that influence costs are (Ehrlenspiel, Kiewert & Lindemann, 2007, p.144):

- The task statement, or in other words the requirements placed on the product
- Size, the dimensions of the product as well as the amount of material that is required to produce it
- Quantities produced
- And finally production and assembly technology

If changes cannot be made within these areas, other factors become more prominent such as tolerances, surface finishing and shape details.

When modifying products already in use, many of the above mentioned factors are difficult and costly to alter. This includes the concept and the task statement. The ability to change size-related aspects can also be severely limited. This leaves production and assembly as the only key contributing factor where some flexibility exists.

2.3.1 Influence of material

In material costs, the cost of purchased parts and semi-finished products are included. These costs make up a large part of entire costs, how large this part is differs greatly between different industries. Material costs for single-unit production of large machines can for example surpass 50 % of total costs. Material costs are particularly significant in the way that they in certain circumstances
completely can be eliminated, for example through a redesign which decreases the amount of parts in an assembly. Except for these rare cases, there are two main ways to cut material costs (Ehrlenspiel, Kiewert & Lindemann, 2007, pp.176-177):

- To use less material
- To change to lower-cost materials

2.3.2 Influence of the production process

Production costs represent a large part of a product’s total costs. In the machine industry for instance, production costs (28 % of total costs) are second only to material costs (38 %). With this in mind, it is clear that the choice of production processes is an important one. Often however, this decision is too much based on know-how and existent resources within the organization instead of what in fact would be the least expensive. (Ehrlenspiel, Kiewert & Lindemann, 2007, p.195)

Jarfors et al. (2010, p.8) write that it is the functional demands of the product that should decide which manufacturing process to use, not previous experiences. They list the following factors that need to be considered when deciding manufacturing method:

- Material choice
- Desired function
- Geometric complexity
- Production quantity
- Production costs
- Tolerances and surface finish

These features are inter-linked. The material choice will lead to exclusion of several methods, as will the size of the products, the complexity, how exact the product needs to be and how fine surface it needs to have. (Ehrlenspiel, Kiewert & Lindemann, 2007, pp.198-200)

Dimensional tolerances are important for both the production cost and production process. Salustri and Ye (2003) highlight the importance of tolerances and describe them as “a bridge between design, manufacturing and quality engineers”. The tolerances are the allowed variations in a product characteristic (for example dimension). They are necessary because variability in a process is unavoidable, but has to be to a known and acceptable degree (Krishnamoorthi, 2006, p.156).

Ehrlenspiel, Kiewert and Lindemann (2007, pp.249-250) write that the golden rule of tolerancing is “only as precise as necessary”. The flaw of this rule is that the designers must be aware of what is necessary to be able to use it. Often this is not the case (Salustri & Ye, 2003). Lack of communication between design and process engineers or too little knowledge of the manufacturing process with design engineers are common underlying reasons (Salustri & Ye, 2003). Tight tolerances are more expensive for manufacturers to achieve but can also affect other factors such as making the product easier to assemble in a coming assembly process or improve the length of life or reliability of the final product (Krishnamoorthi, 2006, p.156). The conflict between manufacturing costs and ensured product performance makes it very difficult to reach optimal tolerance specifications (Salustri & Ye, 2003). Every manufacturing method has a limit of how tight tolerances it can achieve, therefore certain processes need to be rejected if the demands are too high.
2.3.3 Influence of assembly

Assembly alone can make up as much as 50% of production costs. Assembly makes up the largest part of costs when there are a large number of parts or the product is of high complexity. Figure 8 shows the activities that make up the total assembly time along with the estimated time each step takes. As can be seen, the actual assembly process only represents 27% of the time required in this particular case. (Ehrlenspiel, Kiewert & Lindemann, 2007, pp.252-254)

![Figure 8. The activities included in the typical machine industry assembly process (Source: Ehrlenspiel, Kiewert & Lindemann, 2007, p.253).](image)

A large part of the assembly process is decided in the concept and embodiment stage of the design process. Often designers have limited experience within assembly and as such an employee from the assembly department can be good to include in the design work that affects the assembling. Generally though, there are two principles that should be kept in mind during design. The first is to try and avoid the assembly processes altogether. This can be done through integral design and manufacturing methods such as casting, injection molding or sintering. If several parts that used to be produced separately can be combined into one there is nothing to assemble. The second principle is to simplify the assembly process if it cannot be eliminated. This can be done in three ways (Ehrlenspiel, Kiewert & Lindemann, 2007, p.253):

- Including features which make assembly easier, for example suitable connection methods and rougher tolerances.
- Designing shapes which are more ergonomic, will lead to making the assemblies easier for assemblers.
- Design the products so that technical resources such as motor driven tools and fixtures can be used. This is especially important in production with a high repetition frequency.

These three ideas are similar to the foundations of design for assembly (DFA). The goal of DFA is to make design engineers aware of the limitations of manufacturing processes and design a product with maximum manufacturability without compromising the products' performance. There are several guidelines which have been suggested to ensure design in alignment with DFA. Some of the most common ones are (Krishnamoorthi, 2006, pp.165-166):

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18
1. Minimize the number of parts
2. Create a modular system
3. Design parts with several uses in mind
4. Design parts to be easy to manufacture
5. Design for top-down assembly
6. Design for symmetry
7. Keep designs simple and complexities to a minimum
8. Provide connecting surfaces with lead-in chamfers
9. Design to simplify transportation and handling
10. Avoid using or designing parts that can tangle

Properly executed DFA based on standardized components and practices will shorten the product development cycle, lower development costs and make the transition from prototype to production stage less problematic according to a study by Khan conducted in 2008. The study conducted on the compact medical electronics products industry showed that implementation of DFA could cut up to 30% of testing and debugging time at the specific company studied.

Another example of successful DFA is described by Boothroyd, Dewhurst and Knight (2001, p.270). A two-speed reciprocating power saw, was analyzed and redesigned with the DFA principles in mind. The redesign of the power saw decreased the number of parts from 41 to 29 and time required for assembly from 6,37 to 2,58 minutes.

2.4 Summary

The technology of radio base stations has arguably been shown to be in its specific phase. The specific phase is characterized by incremental innovations, often focused on cost reductions. While cost reductions are classified as one of the new product categories, research has shown that development projects belonging to this category require a different approach than those pursuing less incremental innovation.

The development of a cost reduction has the goal of reducing the price of the product without changing its level of performance. To do this, the manufacturing costs are most suitable to address. These costs are made up of three categories; material costs, part production costs, and assembly costs. Within each of these areas there are several ways to reduce costs. The possibilities of introducing change within these areas are however limited after the development stage. This is because it is during this stage that 90% of a product’s cost is determined. It is this type of limitation which results in incremental innovations.

In the following chapters, incremental cost reductions will be pursued for two products which have passed their development stage. The literature study has, as mentioned, resulted in certain areas which are suitable to address in these situations. These options will be considered and analyzed in these cases. Additionally, the process of cost reduction development will be described and evaluated. The methodology used is described in the next chapter, chapter 3.
3. Methodology

The development process for each product’s cost reduction will be described separately in two cases. Each case will have its own chapter (chapters 4 and 5) and will follow the same template; the process of investigating and suggesting cost reductive efforts for the case-specific product will be described. The case-methodology was chosen partly to contribute to the literature on the area with concrete examples from an industrial setting. The products chosen are purposely very different to ensure different focuses for the two cases and thus result in a broader report. After the two case chapters a cross-case analysis (chapter 6) will attempt to analyze the similarities and differences between two cases.

3.1 Design research methodology

The methodology for each case will be based on the framework of the design research methodology (DRM) developed by Blessing and Chakrabarti (2009). The framework aims to support the design research and make it more effective and consistent. Design research has two objectives according to Blessing and Chakrabarti (2009, p.13):

- To formulate and validate models and theories concerning the design phenomenon
- To develop and validate theories to improve design practice and its outcomes

It was deemed important to use an accepted methodology so that the results and the choices made during the process easily could be compared and understood. This particular methodology was chosen because of its link to the design process. It was however adapted to be more suitable for the specific task of cost-oriented product development. This adapted model will be presented and its use evaluated in chapter 6.

The methodology itself as developed by Blessing and Chakrabarti (2009) consists of four stages, as Figure 9 below shows. The basic means and main outcomes of each stage are also included in the picture. Each stage will be described in more detail in the following text.

![Figure 9. The DRM-framework. (Source: Chakrabati & Blessing, 2009, p.15)](image-url)
Research clarification (RC)
During the research clarification stage researchers are intended to formulate a clear and realistic overall research plan. Within this stage the following aspects are identified: the research’s goals, measurable success criteria for these goals, the research project’s focus, its main research problems, the areas to be reviewed and contributed to and an initial picture of the existing situation (Chakrabati & Blessing, 2009, pp.29-31). The research clarification stage has been included in the first two chapters of this thesis, the introduction and the literature study.

Descriptive study 1 (DS1)
The first descriptive study aims to improve the understanding of the current state, highlight the problems found, relate this to the chosen research topic and to identify the factors which should be addressed in order to improve the situation (Chakrabati & Blessing, 2009, pp.31-33). The elements of the first descriptive study will be included in the situation analysis of each of the case-specific chapters (sections 4.2 and 5.2).

Prescriptive study (PS)
In this stage, the expected improvement of the situation that can be achieved is described. The effects are evaluated and measured against the success criteria decided in the research clarification stage (Chakrabati & Blessing, 2009, pp.33-35). The purpose of this stage will be filled by the last three sections of each case-specific chapter (sections 4.3-4.5 and 5.3-5.5). The final evaluation of the results against the success criteria will be included in the “Conclusions” chapter, chapter 7.

Descriptive study 2 (DS2)
In the second descriptive study, the ability of the designed solution to result in the expected effects on key factors is evaluated and further improvements are identified (Chakrabati & Blessing, 2009, pp.36-38). The second descriptive study will be included in the thesis’s last two chapters, the “Conclusion” (chapter 7) and “Further research” (chapter 8).

3.2 Internal sources
Many of this thesis’s major sources of information have been found internally at MIC Kista. Countless interviews have been made, mostly with employees at MIC, and where information obtained in this way has been used this will be referenced in the reference chapter (chapter 9) using the name of the interviewee, his or her title and company, as well as when the interview was performed. The interviews were to a large extent conducted in an unstructured or semi-structured manner. These types of interviews allow for the interviewer to add questions during the interview to pursue more detail or new issues that arise (Collis & Hussey, 2009, pp.145-146). The interviews were conducted in this manner with the purpose of gathering a broad range of personal opinions concerning problem areas.

For more technical information, several of Ericsson’s internal systems have been used. For natural reasons these sources will only be available to Ericsson-employed readers. These references will for this category of readers be included. In Table 1 below, the internal systems used are listed as well as the type of data retrieved from each source.
Table 1. The internal systems used for this thesis.

<table>
<thead>
<tr>
<th>Internal system</th>
<th>Type of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIwin</td>
<td>Product documentation, including drawings, specifications, verification documents, etc.</td>
</tr>
<tr>
<td>SAP One</td>
<td>Supplier and purchasing information</td>
</tr>
<tr>
<td>Eliza</td>
<td>Supplier and purchasing information</td>
</tr>
<tr>
<td>PRO Engineer</td>
<td>CAD-models</td>
</tr>
<tr>
<td>NX</td>
<td>CAD-models</td>
</tr>
<tr>
<td>Internal web</td>
<td>Organizational information</td>
</tr>
</tbody>
</table>

Additionally, several internal documents have also been accessed, as can be seen below in Table 2.

Table 2. The internal documents used for this thesis.

<table>
<thead>
<tr>
<th>Document</th>
<th>Type of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRP, Material requirements planning</td>
<td>Forecasted demand for products</td>
</tr>
<tr>
<td>Wear board quotes</td>
<td>Manufacturing costs of wear boards</td>
</tr>
<tr>
<td>Design Guidelines fixtures</td>
<td>Internal guidelines for designers</td>
</tr>
</tbody>
</table>
4. First case: Digital units

In this chapter, the first case is presented. The products examined in this case are the wear parts of the test fixtures used in the production of digital units, the case will thus be referred to as the digital units case. The entire case from product description to results will be included in this chapter.

4.1 Description of the digital units case

The digital units of the radio base stations are tested in test fixtures such as the DUx-fixture which can be seen in Figure 10 below. The DUx fixture is a modular design which can be adapted for testing the different types of connections and connection combinations required. The suitable adapting kit (seen to the right in Figure 10) is placed inside the cabinet (left) to prepare it for the necessary connections. Attached to the adapting kit are the wear boards which simulate the connections the digital unit is designed to handle. The wear boards are the wear parts of the digital fixtures and as such will be the coming focus.

![Figure 10. The DUx-fixture (left) and an adapting kit of the DUw application (Source: Internal source 4).](image)

A digital unit is placed in the test fixture (to the left in Figure 10) where wear boards, attached to the adapting kit, test its function. The wear board is designed to replicate an existing type of connection available on the digital units. One of these connections is for example the Ethernet connection which is commonly used to connect computers to networks. The reason for using wear boards instead of regular connecting plugs is the large volume of products that is tested in test fixtures. The wear boards used today can be connected thousands of times before being replaced while standard connecting plugs only are designed for about 70 connections (Internal source 5). Regular connecting plugs are as such not a viable option despite their low price; the down-time and labor associated with replacing them results in extra costs. A CAD-model of a wear board can be seen in Figure 11 below.
The different wear boards are used to simulate three different connections, RJ45, SFP and IDL/ESB. Within these connections the wear boards are based on the same concept and it can therefore be said that there are only three variations of wear boards. The wear board shown in Figure 11 above belongs to the RJ45 category (the one which simulates an Ethernet connection). The other two can be seen in Figure 12 below, the SFP board is to the left, and the IDL/ESB board is to the right.

**4.2 Situation analysis**

In the situation analysis, the wear boards will be investigated further. Their manufacturing costs, volumes and wear intervals will be examined with the aim of determining how the wear boards affect costs and which boards have the greatest economic footprint. The current problems will also be highlighted and described.

**4.2.1 Wear parts**

The entire wear board is a wear part and has a wear interval which is specified by Ericsson. After this number of connections is reached the entire wear board is replaced. The wear boards have been designed by the Hardware Design & Supply Services-department of MIC and are also manufactured in MIC Kista. The wear boards are only used by Ericsson and its contracted suppliers.
The first step in analyzing the current situation of the wear boards was to map out the wear boards that are currently in use. This was done by first determining which test fixtures currently are in use and going through the list of components that are assembled to create each test fixture. This information can be found in the internal product database, PIwin (Internal source 4). By accessing all active fixtures in PIwin and examining the included components of each fixture, an entire product map could be compiled.

Besides resulting in a list of wear boards used in each test fixture, this process also gave the quantity of each wear board present in the test fixture as well as a list of the digital units that are tested in that specific test fixture. Part of the compilation can be seen below in Figure 13. From the top the picture shows the test fixtures (LTN number), the adapting kits included in each fixture (only for DUx fixture) and in the next level the wear boards (LTY number followed by quantity). Finally, at the bottom are the product numbers for the radio filters tested in each fixture. The entire compilation can be found in Appendix 1.

![Digital fixtures](image)

**Figure 13.** Part of the compilation of the digital wear boards. The black boxes hide confidential information.

### 4.2.2 Wear intervals

As the wear boards are manufactured by Ericsson instead of an external supplier, manufacturing costs were compiled instead of purchasing prices. The manufacturing quotes for the wear boards were requested (Internal source 7). The total costs of each wear board and their wear interval can be seen below in Table 3.
4.2.3 Wear parts economics

With access to the forecasted number of digital units being produced from March 2012 to January 2013 (Internal source 8) it was possible to calculate the total amount of connections for each of the wear boards. Combining this with the determined wear interval for each wear board resulted in the number of wear boards that this year’s production of digital units would require. To finally calculate the annual cost for each wear board, the manufacturing costs for each wear board from Table 3 were used. The forecasted need for each wear board under the period of March 2012 – January 2013 as well as the total cost of each wear board for this period is displayed in Table 4 below.

Table 3. The wear interval and price for each wear board.

<table>
<thead>
<tr>
<th>Wear board</th>
<th>Wear interval</th>
<th>Price (SEK), when purchasing 25 % of annual needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTY 151 0739/1</td>
<td>4 000</td>
<td>1 367 kr</td>
</tr>
<tr>
<td>LTY 151 0740/1</td>
<td>1 500</td>
<td>538 kr</td>
</tr>
<tr>
<td>LTY 151 0741/1</td>
<td>1 500</td>
<td>535 kr</td>
</tr>
<tr>
<td>LTY 151 0748/1</td>
<td>500</td>
<td>836 kr</td>
</tr>
<tr>
<td>LTY 151 0750/1</td>
<td>3 000</td>
<td>921 kr</td>
</tr>
<tr>
<td>LTY 151 0751/1</td>
<td>3 000</td>
<td>1 190 kr</td>
</tr>
<tr>
<td>LTY 151 0870/1</td>
<td>500</td>
<td>3 143 kr</td>
</tr>
<tr>
<td>LTY 151 0947/1</td>
<td>1 500</td>
<td>1 110 kr</td>
</tr>
<tr>
<td>LTY 151 0948/1</td>
<td>1 500</td>
<td>3 482 kr</td>
</tr>
<tr>
<td>LTY 151 0961/1</td>
<td>3 000</td>
<td>2 028 kr</td>
</tr>
<tr>
<td>LTY 151 0996/1</td>
<td>500</td>
<td>761 kr</td>
</tr>
</tbody>
</table>

Bearing in mind that wear boards of the same connection are very similar, the total costs of each connection type can be grouped up as in Table 4 above, where the red fields distinguish RJ45, the green SFP, and the yellow IDL/ESB. The reasoning behind this is that the similarities between interconnection wear boards should allow for certain types of changes to be implemented across the entire field, affecting all of the wear boards of the same connection type. As such they should be compared as a group.

Table 4. The forecasted volume and total price of each wear board. Red marks RJ45 boards, green marks SFP and yellow marks IDL/ESB.
The relative cost and need of each wear board group is visualized in Figure 14 below, the color used for each wear board in this figure is the same as in Table 4 above. As can be seen, the differences between the three connection types are quite large, with the RJ45 group being the most expensive. A contributing factor for this is that RJ45 has a volume of 3095 while SFP and IDL/ESB have volumes of 862 and 997 respectively.

![Relative need of each wear board](image1)

![Relative cost of each wear board](image2)

**Figure 14. The relative need and cost of each wear board.**

Considering that the RJ45 wear board makes up such a big part of the total wear board costs, the decision was made to focus improvement efforts on this particular type of wear board. The reasoning behind this is that a cost reduction of a certain percentage would lead to the biggest cost saving for the company if implemented on the RJ45 board.

### 4.2.4 Problems

The problems associated with the wear boards in general are mainly cost related. The cost of the RJ45 wear boards range from about 500 to 3500 SEK each. This is very expensive considering how simple the wear boards’ construction is, the underlying factors for this price level are:

- **Low purchasing volumes.** The current purchasing system is that each production site purchases wear boards separately, this causes purchasing volumes to be so low that administrative costs have a high impact on end price. Small purchasing volumes also mean that set-up and changeover times in machines have a bigger impact on the end price as well.

- **Expensive production methods.** The wear boards have not been designed for inexpensive production. Several production steps require manual labor, the connector guides are for example assembled manually using a screw and two dowel pins as can be seen in Figure 12. These connector guides are plastic details which currently are produced through milling.

Each RJ45 wear board is mechanically very similar, as mentioned earlier. Each wear board is made up of a circuit board, the connector guide and the screw and dowel pins used to fasten the guide to the circuit board. Table 5 below shows the internal product numbers of the main components included in each wear board.
Table 5. The main components included in each RJ45 wear board.

<table>
<thead>
<tr>
<th>Wear board</th>
<th>Circuit board</th>
<th>Connector guide</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTY 151 0740/1</td>
<td>ROA 128 3091/2</td>
<td>SXA 129 1743/1</td>
</tr>
<tr>
<td>LTY 151 0741/1</td>
<td>ROA 128 3091/2</td>
<td>SXA 129 1743/1</td>
</tr>
<tr>
<td>LTY 151 0750/1</td>
<td>ROA 128 3080/1</td>
<td>SXA 129 1743/1</td>
</tr>
<tr>
<td>LTY 151 0751/1</td>
<td>ROA 128 3091/1</td>
<td>SXA 129 1743/1</td>
</tr>
<tr>
<td>LTY 151 0870/1</td>
<td>ROA 128 4593/1</td>
<td>SXA 129 1743/1</td>
</tr>
<tr>
<td>LTY 151 0947/1</td>
<td>ROA 128 5019/1</td>
<td>SXA 129 1743/1</td>
</tr>
<tr>
<td>LTY 151 0948/1</td>
<td>ROA 128 5022/1</td>
<td>SXA 129 1743/1</td>
</tr>
<tr>
<td>LTY 151 0961/1</td>
<td>ROA 128 3303/1</td>
<td>SXA 129 1743/1</td>
</tr>
</tbody>
</table>

As can be seen the circuit boards vary to a large extent between the different RJ45 wear boards; eight wear boards use seven different circuit boards. On the other hand, the same connector guide is used in all wear boards. Improvements to the connector guide would thus benefit the whole RJ45-range while circuit board improvements would affect a maximum of two wear boards. The two wear boards that share a common circuit board are LTY 151 0740/1 and LTY 151 0741/1.

Parallel to this thesis, a project to improve the circuit board in LTY 151 0740/1 and LTY 151 0741/1 has been started at the Hardware Design & Supply Services department at MIC. The goal of this project has been to improve the wear interval of these two wear boards. These wear boards were chosen because they currently have a high volume (as was seen in Table 4), but if the changes implemented by this project are successful, they will in all likelihood also be implemented in the rest of the RJ45-range.

The decision was made to further focus improvement efforts on the connector guide used in RJ45 wear boards. The main reasons for this were described in the two previous paragraphs. In order to ensure that the improvement can be used for as long a time period as possible, the connector guide will be adapted to the changes suggested by the parallel-running project.

4.2.5 Connector guide

The plastic details at the front of the wear boards (the connector guides) are designed to guide the wear boards into the connections of the digital units. This does not require an elaborate design which can be seen in the current detail, in Figure 15.

Figure 15. The connector guide of the RJ45 wear board (product number SXA 129 1743/1).
The plastic details are currently not the cause for the limited wear intervals, the main wear of wear boards is instead on the front of the gold-plated part of the circuit board. An example of this type of wear can be seen in Figure 16 below.

![Figure 16. Visible wear of an RJ45 circuit board (Source: Internal source 3).](image)

The connector guides are thus considered to be performing at an acceptable level, but are far too costly. The price is driven up by the requirement for the detail to be ESD- (electro static discharge)-proof which means only specialized, expensive materials are viable. Further increasing the price; the detail is manufactured through milling. Currently the plastic component costs 49 SEK for Ericsson to purchase.

In addition to costing 49 SEK to purchase, the component also has an unnecessarily complicated process required to attach it to the wear board. Two dowel pins and one screw are used in the assembly process, and the dowel pins especially are causing trouble in the assembly. The assembly process today is internally calculated to cost 10 SEK in labor costs (Internal source 7 & 9).

4.3 Improvements

Considering the key contributing cost factors described in section 2.3, many were not realistic to change for the connector guide:

- A change in task statement of the connector guide would require major changes in the rest of the wear board, and perhaps the test fixture as well.
- Changing the quantities produced was not realistic either, the wear boards are built to order and the amount ordered depends entirely on the number of radio base stations ordered, a factor this thesis could not affect.
- Because the connector guide in its current concept enters the connection, the possibility to alter its size was also severely limited.

This leaves possibilities changing the production and assembly process, as well as the amount of material used.

4.3.1 Choice of manufacturing process

The manufacturing processes associated with plastics differ depending on if the plastic is a thermoplastic or a thermoset. Thermoplastics are the most commonly used plastics today, with advantages such as recyclability and being easy to process. Thermosets can be used at higher
temperatures than thermoplastics, but are difficult to recycle and brittle unless reinforced with fillers. (Kar Heng, 2011, pp.109-119)

The material currently used for the connector guide is a thermoplastic in the acetal group, called POM C-SD. Acetals are known to be very strong and can in many cases replace metals as load bearers, they do however have a poor resistance for higher temperatures (Kar Heng, 2011, p.109). The material has proved capable and is approved by Ericsson and is described as a very good option for snap fit applications (Berggren, Jansson, Nilsson & Strömvall, 1997, p.176). For these reasons, as well as the strict ESD-related requirements, material change will not be pursued.

In order to fully benefit from a change in manufacturing process, the process chosen should also preferably allow for the integration of what today are separate parts (two guiding pins, one fastening screw, the connector guide itself) in accordance with the design for assembly principles. In this way assembly costs can also be lowered. Processes where this is possible belong to the primary shaping category (Ehrlenspiel, Kiewert & Lindemann, 2007, p.199). The material itself further limits the possible manufacturing methods; in this case a thermoplastic is desired. Kar Heng (2011, pp.119-120) lists eleven plastic manufacturing processes that are suitable for thermoplastics, these can be seen below in Table 6.

Table 6. The plastic manufacturing processes for thermoplastics and their respective properties.

<table>
<thead>
<tr>
<th>Production method</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection molding</td>
<td>Extremely convenient for large scale production, can handle complicated shapes.</td>
</tr>
<tr>
<td>Extrusion</td>
<td>Used to produce rods, pipes and sheets.</td>
</tr>
<tr>
<td>Blow molding</td>
<td>Primarily used for bottles and other thin-walled, hollow parts that have an opening.</td>
</tr>
<tr>
<td>Rotational molding</td>
<td>Not suitable for large scale production.</td>
</tr>
<tr>
<td>Calendering</td>
<td>Used to produce shower curtains, raincoats and ground sheets.</td>
</tr>
<tr>
<td>Thermoforming</td>
<td>Used in for example polystyrene trays.</td>
</tr>
<tr>
<td>Platisol molding</td>
<td>Used to coat wires with plastic.</td>
</tr>
<tr>
<td>Casting</td>
<td>Not suitable for large scale production.</td>
</tr>
<tr>
<td>Laminating</td>
<td>Used to produce furniture, walls and ceiling panels.</td>
</tr>
<tr>
<td>Reinforced molding</td>
<td>Used to mold composite materials.</td>
</tr>
<tr>
<td>Foam molding</td>
<td>Used to form sponge-like materials.</td>
</tr>
</tbody>
</table>
Excluding methods that are unsuitable for this type of product and for large scale production leaves injection molding as the only option. The possibilities of manufacturing the connector guide with this production method will as a result be looked into in the rest of this case.

4.3.2 Injection molding

Injection molding is one of the most important manufacturing processes for plastics. The process offers the ability to cheaply mass-produce complicated products of varying sizes. It is however limited by a large initial cost which makes the process unsuitable for smaller volumes. (Rosato, Rosato & Rosato, 2004, p.192)

A mold cavity of the desired product is created and injected with melted plastic under pressure. When this plastic cools it solidifies and the desired product is created. Designing the mold is the most expensive part of the process. Because the quality of the mold ultimately determines the quality of the products the process can result in, this is a very important step. The mold’s quality is also however dependent on the product it is meant to recreate.

It is important for the injected plastic to cool evenly in order to avoid problems such as sink marks. For this reason the product needs to be designed with an even thickness. It is also necessary to consider how to extract the molded parts from the cavity wall; this is done through tapering. In order to create more complicated products, the tool needs to be divided into more sections. The addition of more sections will however increase the cost of the process. (Rosato, Rosato & Rosato, 2004, pp.195-197, Berggren, Jansson, Nilsson & Strömwall, 1997, p.200)

4.3.3 Redesign work

The connector guide was redesigned with three goals in mind, the last two to keep costs down:

1. To fit the new RJ45 design created by the parallel project
2. To be manufactured using injection molding with only two mold halves
3. To follow the principles of design for assembly, as described in the literature study (section 2.3.3)

Adapting the product’s design for injection molding involved changing the previously solid structure to a thin-walled, hollow structure. Besides being a requirement for injection molding this also means the use of less material, which is beneficial both economically and environmentally. Further, injection molded components require a draft angle of at least 1°, a rib height that is ten times less than the component’s wall thickness, and a rib thickness that is 50-70 % of the wall thickness (Strömwall, 2001, pp.176-177). All of this was accounted for and included in the new connector guide design.

To replace the screw and guiding pins, guiding pins and a snap fit were integrated into the component’s design. This made the new component more complicated than the old one, but as long as the number of tool sections did not increase, this would not make the component any more expensive. The necessary dimensions for the snap fit were calculated using Berggren, Jansson, Nilsson and Strömwall’s Konstruera i Plast (1997, p.178), as can be seen in Appendix 2.
The resulting design of the plastic connector guide can be seen below in Figure 17 and a drawing including the component’s dimensions can be accessed in Appendix 3. The slots that can be seen at the front of the connector guide were added solely so that the guide would fit the new wear board design introduced by the parallel project.

![Figure 17. The new design of the plastic component.](image)

The finished design was approved by an injection molding company and a manufacturing quote was requested, this quote can be accessed in Appendix 4. A cost analysis can be found in the next section.

### 4.4 Results of the digital units case

The improvement of the first case has attempted to cut costs within all three areas of manufacturing costs, as described in section 2.3; material costs, part production, and assembly costs. The change from milling to injection molding allowed for the integration of assembly parts, a thin-walled construction, as well as a much less expensive process. An injection molding company has approved the new design and considers it suitable for this production method. They also left a quote for the manufacture of this part; this quote has been used to estimate the costs of the new connector guide. The costs for the connector guide are as previously based on the forecasted volume for the period March 2012 to January 2013. A comparison of the costs can be seen in Table 7 below. The setup cost of 1500 SEK is triggered when the order value is lower than 7000 SEK, and under the assumption that all 3095 pieces are ordered at the same time this setup cost will not be incurred.

Table 7. The costs to produce the plastic component before and after reconstruction.

<table>
<thead>
<tr>
<th>Costs</th>
<th>Before reconstruction</th>
<th>After reconstruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per component</td>
<td>49</td>
<td>5,25</td>
</tr>
<tr>
<td>Setup cost</td>
<td>-</td>
<td>(1500)</td>
</tr>
<tr>
<td>Tool cost (3095 pieces)</td>
<td>-</td>
<td>75000</td>
</tr>
<tr>
<td>Guiding pins, Screw</td>
<td>0,50</td>
<td>-</td>
</tr>
<tr>
<td>Assembly</td>
<td>10</td>
<td>1,70</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>59,50 SEK</strong></td>
<td><strong>31 SEK</strong></td>
</tr>
</tbody>
</table>
If this solution works as intended it should lower the cost of the connector guide by 48%, as shown in Table 7 above. If function and cost reduction are achieved, this component’s redesign should be considered as a model for the other two wear board concepts, SFP and IDL/ESB. With the economic data from this project, accurate economic calculations should be possible to make for the other two. The primary question is naturally if their volume is significant enough to balance the tool cost. Using the economic data from the RJ45 component, the break-even point where injection molding and the current milling method have the same costs is at a volume of 1427 components.

Before these cost reductions can be realized however, it has to be determined if the new design functions in the intended manner. Possible problem areas are the snap fit fastening system, as well as if the new manufacturing process can achieve the necessary tolerance width.

4.5 Discussion of the digital units case

A discussion of the digital units case is presented in this section. The first part of the discussion relates to the results from the previous section and the next part is a discussion about the process.

4.5.1 Result related discussion

The economic calculations of the result section are based on the assumption that the new design of the connector guide works as intended. Before they can be considered as realized, rigorous testing and evaluation needs to take place. We consider the snap fit to be the most critical part of the new design. Should this type of application be difficult to use, we recommend the use of a self-tapping screw instead. The screw would need to be self-tapping to avoid an extra process in manufacturing. This would however lead to a more complicated assembly process than the one in the current suggestion, though it would still be simpler than the one currently used.

Both SFP (annual volume 862) and IDL/ESB (997) currently have annual volumes under the break-even point calculated in the previous section, but if a low-cost supplier could be found this break-even point would naturally change. During this thesis, a Chinese supplier was encountered which could offer injection molding with a tool cost of only 20 000 SEK as well as with a lower price per component (Internal source 10). If these prices can be realized, a business case for changing manufacturing process for both SFP and IDL/ESB can be made. This track was not pursued in this thesis due to the limited time frame, but this option should be looked into.

Due to difficulties associated with outsourcing to China regarding communication and uncertain quality we feel that it may be wise to first use a Swedish supplier where closer communication is possible. This is especially important as the department lacks previous experience of injection molding and the connector guide has undergone a complete design overhaul. We feel that the department can look to foreign suppliers when enough knowledge about the process and its implications for design and quality has been gathered, it should continuously be evaluated if this maturity has been reached.

For the economic calculations of the connector guide, the tied-up capital associated with ordering all 3095 connector guides has not been included, and needs to be considered. Remuneration for the two authors receive from Ericsson has also been left out. There are a number of reasons for this:
First, the thesis has not only delivered this digital units case but has also included the radio filters case and suggestions for future research.

Second, the remuneration can be considered as a sunk cost as it is agreed upon in the project’s initiation (even if it to some extent is performance-based). Some remuneration will be paid regardless of the project’s result.

Third, the level of remuneration is performance related. As such the remuneration level cannot be decided until after this report’s completion and an accurate number could not be used.

4.5.2 Process related discussion

The decisions made in this case have been explained, but it can naturally be argued that other choices should have been made. While RJ45 wear boards have been shown to have the highest total cost (see section 4.2.3), they do in fact not have the highest cost in proportion to their volume. The SFP wear boards have the highest cost in proportion to their volume which is made clear by Figure 14 at the end of section 4.2.3. As such it could be argued that these wear boards have a higher cost reduction-potential. Because this thesis had the stated goal to reduce costs as much as possible however, the area of cost reduction potential was given a lower priority than addressing the total costs.

Another argument that can be made is that the connector guide represents a rather small part of the entire wear board’s cost. The most effective way to reduce the total costs for these wear parts is to increase the wear intervals of the wear boards. This is because of the direct correlation between wear interval and the number of wear boards consumed. The reason for why this type of improvement was not attempted was that a parallel project at the department already was working with ways of improving the wear intervals. If the thesis would have had the same focus, very close collaboration with the other project would have been necessary to avoid doing the same work twice. This type of collaboration was not deemed possible due to the thesis having a more limited time frame.
5. Second case: Radio filters

This chapter describes the second case, the radio filters case. The chapter will largely follow the structure established in the previous chapter.

5.1 Description of the radio filter test fixtures

The production of radio filters requires the use of test fixtures. Their purpose is primarily to allow for repetitive and fast connections of radio filters in the production line test stations. The fixtures hold the radio filter steady while connecting to the radio filter’s different outputs. The test fixtures are connected to computers which display the radio filters’ test results on a monitor for production personnel to assess.

The radio filters are divided by platform, the most modern products belong to platform 5 which was launched in late 2011, but products from platform 4 and 3 are still produced due to customer demand and warranty obligations (Internal source 11). Each platform uses its own set of test fixtures due to the fundamental differences of the platforms. Because the test equipment for platform 5 is the most modern it will in all likelihood have a longer future service time than the test equipment for platform 4 and 3. For this reason, the test fixtures for platform 5 were chosen as the thesis’s focus within this case.

Platform 5 radio filters use two different chassis, internally called RUS and RRUS, each requiring its own set of test fixtures. These different sets of fixtures do however to some extent use the same wear parts.

5.1.1 RUS-fixtures

The RUS-chassis uses the test fixtures LTN 214 2014/1 and LTN 214 2014/2. Pictures of the fixtures’ CAD-models can be seen in Figure 18 below, LTN 214 2014/1 to the left and LTN 214 2014/2 to the right. The reason for having two test fixtures is that different test stations test different properties and connections.

![Figure 18. The test fixtures for RUS radio filters (Source: Internal source 4).](image)

These test fixtures are used simultaneously in production lines in three different test stations, the tune and test station, the IM test station, and the final test station. The purpose of each of these test stations is not considered important for this thesis and will therefore not be described. Figure 19 is a schematic illustration of the test station setup in a RUS production line. As can be seen, LTN 214
2014/1 is part of the tune and test station while LTN 214 2014/2 is part of both the IM test and the final test stations, meaning that one LTN 214 2014/1 and two LTN 214 2014/2 test fixtures are present in each production line. A visualization of the entire produce and test process is included in Appendix 5, and can be accessed if a more detailed overview is desired.

![Tune and test LTN 214 2014/1](image1.png) ![IM test LTN 214 2014/2](image2.png) ![Final testing LTN 214 2014/2](image3.png)

**Figure 19. The test stations of the RUS fixtures.**

### 5.1.2 RRUS-fixtures

The RRUS, like the RUS radio filters, also use two different fixtures, LTN 214 2072/1 and LTN 214 2072/2. As is the case with the RUS radio filters, the LTN 214 2072/1 and LTN 214 2072/2 versions look very similar, but have different purposes. The LTN 214 2072/1 fixture is used in the tune and test station, while the LTN 214 2072/2 version is used in IM test and in the final test station. In Figure 20 below a picture of the LTN 214 2072/2 test fixture can be seen.

![Figure 20. A CAD-model of the LTN 214 2072/2 test fixture (Source: Internal source 4).](image4.png)

The big difference in appearance between the RRUS and the RUS fixtures is in part due to a different radio filter design, but also due to a different concept. While the RUS fixture uses a manual fastening system, the RRUS is pneumatic. The radio filter is fastened and lowered onto connectors at the press of two buttons.

### 5.2 Situation analysis

In the situation analysis, the wear parts of the test fixtures will be examined including their costs, volumes and wear intervals. The aim is, as in the digital units case, to determine how the different wear parts affect costs.
5.2.1 Wear parts

The male connectors which connect to the radio filters' female connectors are the main wear parts here. Due to the nature of the tests it is important that the connectors remain undamaged, for this reason they are changed after given intervals, called wear intervals. After a connector is replaced the fixture needs to be calibrated. This process (including the physical connector change itself) takes about 45 minutes (Internal source 11). During this period of time the fixture cannot be used in a testing station. This means that the costs for wear parts in fact are more than just the purchasing price; associated labor and downtime (even if the production lines often replace test fixtures that need part replacement and calibration) also need to be considered.

The wear parts in the radio filter fixtures are standard solution probes, adapters, etc. which are bought from suppliers. The biggest suppliers of these wear parts are Huber Suhner, Rosenberger, Columbia and Spinner. Each wear part has a product specification from the supplier stating the minimum amount of connections it should be able to handle. Ericsson's fault rate analysis group (FRAG) uses this as a base for deciding the interval which Ericsson’s supply sites will use. The wear parts’ endurance is tested at MIC Kista where FRAG is stationed.

Table 8. The wear parts present in each radio filter fixture, as well as their quantity.

<table>
<thead>
<tr>
<th>Fixture</th>
<th>Chassis</th>
<th>IND 102 0970</th>
<th>RNT 408 9003/02</th>
<th>RNT 408 9003/33</th>
<th>RPT 501 33/1</th>
<th>RPT 501 39/1</th>
<th>RPT 899 281/1</th>
<th>RPT 899 281/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTN 214 2014/1</td>
<td>RUS</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>LTN 214 2014/2.1</td>
<td>RUS</td>
<td>18</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>LTN 214 2014/2.2</td>
<td>RUS</td>
<td>18</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>36</strong></td>
<td><strong>6</strong></td>
<td><strong>4</strong></td>
<td><strong>0</strong></td>
<td><strong>2</strong></td>
<td><strong>3</strong></td>
<td><strong>0</strong></td>
</tr>
<tr>
<td>LTN 214 2072/1</td>
<td>RRUS</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>LTN 214 2072/2.1</td>
<td>RRUS</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>LTN 214 2072/2.2</td>
<td>RRUS</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>36</strong></td>
<td><strong>0</strong></td>
<td><strong>0</strong></td>
<td><strong>14</strong></td>
<td><strong>4</strong></td>
<td><strong>0</strong></td>
<td><strong>6</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>72</strong></td>
<td><strong>6</strong></td>
<td><strong>4</strong></td>
<td><strong>14</strong></td>
<td><strong>6</strong></td>
<td><strong>3</strong></td>
<td><strong>6</strong></td>
</tr>
</tbody>
</table>

The wear parts present in each fixture and in which quantity can be seen in Table 8 above, with the internal Ericsson product names of the wear parts. The reason for including LTN 214 2014/2.2 and LTN 214 2072/2.2 is simply to account for that these two fixtures in their /2 versions are used both in IM test and final testing, which means two LTN 214 2014/2 and two LTN 214 2072/2 fixtures are present in each production line. Pictures of the wear parts can be seen in Appendix 6.
5.2.2 Wear Intervals

Each wear part comes with a set wear interval specified by the supplier. The fixture designer initially decides which parts of the fixtures should be considered wear parts and state a wear interval for these (usually in accordance with suppliers’ specification). FRAG are then responsible for changing this interval if they notice that the interval is set either too low or too high. This process is largely experimental: a wear part is connected a set amount of times and later taken out and analyzed. The electrical performance is measured and a visual inspection of the mechanical wear takes place in this analysis. Depending on the results from this analysis, FRAG can choose to adjust the wear interval. The wear interval set by FRAG is the interval that all Ericsson supply sites will use. Table 9 below shows both FRAG’s and the suppliers’ wear intervals for each wear part, as well as their purchasing price.

Table 9. The wear intervals for each wear part.

<table>
<thead>
<tr>
<th>Wear part</th>
<th>Wear interval (FRAG)</th>
<th>Wear interval (Supplier)</th>
<th>Price (EUR)/piece</th>
</tr>
</thead>
<tbody>
<tr>
<td>IND 102 0970</td>
<td>10 000</td>
<td>1 000 000</td>
<td>€1,48</td>
</tr>
<tr>
<td>RNT 408 9003/02</td>
<td>2 500</td>
<td>min 1000</td>
<td>€6,36</td>
</tr>
<tr>
<td>RNT 408 9003/33</td>
<td>2 500</td>
<td>min 1000</td>
<td>€29,86</td>
</tr>
<tr>
<td>RPT 501 33/1</td>
<td>2 500</td>
<td>500</td>
<td>€36,70</td>
</tr>
<tr>
<td>RPT 501 39/1</td>
<td>2 500</td>
<td>1 000</td>
<td>€71,80</td>
</tr>
<tr>
<td>RPT 899 281/1</td>
<td>100</td>
<td>100</td>
<td>€5,19</td>
</tr>
<tr>
<td>RPT 899 281/2</td>
<td>100</td>
<td>100</td>
<td>€14,90</td>
</tr>
</tbody>
</table>

5.2.3 Wear parts economics

The calculations of the cost for each wear part were conducted in the same way as previously in the digital units case, using Ericsson’s internal product database, PIwin, and Ericsson’s internal forecasts.

By collecting wear intervals on each wear part from FRAG, the number of wear parts required to meet the expected demand could be calculated. Adding the purchasing price of the individual wear parts showed what the total cost for each wear part would be in the period of the forecast (May 2012-March 2013), at the forecasted demand. This can be seen in Table 10 below.

Table 10. The number of wear parts required for the forecasting period as well as their total costs.

<table>
<thead>
<tr>
<th>Wear part</th>
<th>The need of connectors between May 2012 - Mar 2013</th>
<th>Total price for each product number (connectors) between May 2012 - Mar 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>IND 102 0970</td>
<td>997</td>
<td>€1 476</td>
</tr>
<tr>
<td>RNT 408 9003/02</td>
<td>314</td>
<td>€1 997</td>
</tr>
<tr>
<td>RNT 408 9003/33</td>
<td>209</td>
<td>€6 250</td>
</tr>
<tr>
<td>RPT 501 33/1</td>
<td>818</td>
<td>€30 039</td>
</tr>
<tr>
<td>RPT 501 39/1</td>
<td>339</td>
<td>€24 306</td>
</tr>
<tr>
<td>RPT 899 281/1</td>
<td>3 925</td>
<td>€20 370</td>
</tr>
<tr>
<td>RPT 899 281/2</td>
<td>8 770</td>
<td>€130 666</td>
</tr>
</tbody>
</table>
5.2.4 Problems

Many problems with the radio filter fixtures’ wear parts are seemingly to a large extent a reflection of shortcomings within the processes involved in the development of fixtures. Developers of test equipment feel that the radio filters often are designed without thought given for the production tests (Internal source 12). This leads to the test fixture designers having few options and being forced to settle for less-than optimal solutions.

Another problem that has surfaced has to do with the manual fastening mechanism in the RUS fixtures. This leads to an increase in demand on production personnel to:

- Place the radio filter in the right position
- Be careful not to place the radio filter with too much force
- To engage the fasteners in the right order

Besides meaning several added potential sources of human error compared to the pneumatic RRUS fixtures, the manual fastening also is less ergonomic and operators can if not careful get fingers caught in fasteners and under the radio filter.

Another encountered issue is that hardware developers lack clear routines on how to set tolerances. While there are internal guidelines (Internal source 13) these are relatively new and there is doubt if they are followed or not. The guidelines are also very general and recommend the use of ISO 2678-1 tolerancing. While the ISO tolerancing system is wide-spread, it is not always suitable for use. As can be seen in Table 11 below, the tolerance width will increase with increasing dimensions. Setting a general ISO 2678-1 tolerance on a drawing will thus give different tolerances to different dimensions if they vary enough in size despite perhaps a need for similar precision in both applications. For critical dimensions, the practice has been for designers to set tighter tolerances separate from the ISO-system. The problem lies in the individual interpretation of which dimensions are critical, and how tight tolerances for such dimensions should be.

Table 11. The permissible deviations for linear dimensions in ISO 2768-1 (Source: Internal source 13).

<table>
<thead>
<tr>
<th>Tolerance class</th>
<th>Permissible deviations for basic size range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designation</td>
<td>from 0,5* up to 3</td>
</tr>
<tr>
<td>f</td>
<td>fine</td>
</tr>
<tr>
<td>m</td>
<td>medium</td>
</tr>
<tr>
<td>c</td>
<td>coarse</td>
</tr>
<tr>
<td>v</td>
<td>very coarse</td>
</tr>
</tbody>
</table>

* For nominal size below 0,5 mm, the deviation shall be indicated adjacent to the relevant nominal size(s).

The fixtures themselves accumulate long tolerance chains, especially when including the connecting test object in the chain. With too wide individual tolerances set, these tolerances will add up and can result in faulty positioning within the fixtures.
The importance of tolerances for the wear parts lie in the misalignment that they can lead to. Misalignment for the male connector in relation to the female connector on the radio filter can lead to situations like the one in Figure 21 below where a connector gets caught on the radio filter in the connection sequence. Besides disrupting the test this can also damage both connectors.

![Figure 21. A misaligned connector getting caught on the edge of its female connector (Source: Internal source 4).](image)

### 5.3 Improvements

This section will describe the efforts made to solve some of the problems mentioned in the current situation analysis. Because the wear parts in the radio filter fixtures are standard parts, purchased from external suppliers, the possibilities of altering the key contributing cost factors of the wear parts were severely limited. While the concept and task statements of these wear parts have been set by Ericsson and not external suppliers, these aspects cannot realistically be changed at this stage in the product’s life.

Instead, the way the wear parts were used was examined. As mentioned in section 2.3.2, tolerancing is one of the areas which can be focused on when the key contributing cost factors are already set. Probing into the area of tolerancing in interviews with hardware developers showed signs that the area could be worth focusing on.

Of the described problems, the tolerance related uncertainties was chosen as the main focus for further improvements. This issue is one that affects both pneumatic and manual test fixtures; it also to a high degree affects both current test fixtures as well as future designs. Clarifying the effects of tolerances and misalignment is necessary to in the future be able to influence radio filter design projects; if problematic designs cannot be identified they cannot be avoided either.

#### 5.3.1 Choice of fixture

To investigate the problem further, it was decided that a tolerance chain of a radio filter test fixture would be calculated. The purpose was to see how the positioning of connectors on the fixture could differ while still being within the specified tolerance width. The choice fell on the RUS fixtures partly because it has been considered to have more problems internally (Internal source 12) and partly because of the pneumatic insertion system in the RRUS fixtures. The pneumatic insertion system means that those fixtures have more exact insertions with regard to positioning than the manual RUS fixtures (Internal source 12). This should mean that the RUS fixtures will have a bigger spread in
insertion positioning, which would lead to a greater demand placed on the positioning within the fixtures.

Within the two RUS fixtures, LTN 214 2014/2 was chosen because:

- It has more complicated connections than the LTN 214 2014/1 version.
- It is used twice in each production line instead of once like the LTN 214 2014/1.
- Eight LTN 214 2014/2 fixtures have gone through recently implemented factory acceptance tests which allows for a comparison between theoretical tolerance widths and the real variation of dimensions on products. None of the LTN 214 2014/1 fixtures had undergone this type of test when this report was written.

5.3.2 Tolerance chain of LTN 214 2014/2

The tolerance chains were calculated from the guiding holes on the fixtures, using the tolerances specified on the component drawings. Each connector position was given a number which would be used to identify it, as can be seen in Figure 22 below. Number 6 and 7 mark two different points of the same connector bracket and so are related to the same connector. Close-up pictures of each wear part can be accessed in Appendix 7.

![Figure 22. The LTN 214 2014/2 fixture with its wear parts numbered (Source: Internal source 4).](image)

Of the six connectors, 2 and 3 are identical, as well as 4 and 5. This means that the fixture includes four different types of connectors. The identical connectors also have identical sub-assemblies, and as such also identical tolerance chains. The tolerance chain for each of these four different connectors was calculated and can be seen in Appendix 8. The calculations have been conducted according to two models; the worst case (WC) and the root sum square model (RSS). WC is the maximum positional difference with all parts of the chain still being within its specified tolerances. That all of the components that make up the chain would simultaneously have their maximum allowed variance is naturally highly unlikely and for this reason the RSS model is often used instead. In the RSS model a normal distribution is assumed for the variations (Chase & Parkinson, 1991). Internally, the root sum square model should be used when calculating chains longer than three tolerances (Internal source 13). The RSS model works like this: \( L_1, L_2, \) and \( L_n \) are lengths of individual
components in an assembly. Their total length is \( L \), Equation 1. If \( T_1 \), \( T_2 \), and \( T_n \) are the tolerances for each individual length, then \( T \) will be the tolerance on the total length, Equation 2 (Krishnamoorthi, 2006, pp.158-159).

\[
L = \pm L_1 \pm L_2 \pm \cdots \pm L_n \quad (1)
\]

\[
T = \sqrt{T_1^2 + T_2^2 + \cdots + T_n^2} \quad (2)
\]

Table 12 below shows the results from the tolerance chain calculations for each position according to both the WC and RSS models. The column labeled variation (test records) shows the biggest measured positional difference (from the nominal position) of the eight LTN 214 2014/2 that were measured in factory acceptance tests. The complete results from the eight measurements can be found in Appendix 9. The results from these measured fixtures are included because they give an indication of what tolerances the components included in the assembly actually have. As can be seen the variation is never larger than the worst case-scenario, but occasionally falls outside of the RSS-calculated interval.

Table 12. The measured positional variance for each connector position compared to the accumulated tolerance chains for each position. D is the variance of the circular connector bracket’s diameter.
The other two columns, labeled drawing, show the tolerances that accumulate from all the dimensions according to the tolerances specified in their technical drawings. The tolerance chains themselves are of little use without comparing them to the misalignment which each connector can tolerate before connection becomes impossible. With correctly specified tolerances, the maximum misalignment should be greater than the deviation calculated from the tolerance chain using the RSS model.

Designers use chamfers so that certain degrees of misalignment can be tolerated. The concept is explained by Figure 23 below. The maximum allowed misalignment for each connector was calculated and then compared to the actual tolerance widths which are allowed according to specification (those seen earlier in Table 12). This comparison will be presented in the next section, section 5.4.

**Figure 23.** An illustration of the conditions required for a male connector to enter its female connector (Source: Internal source 4).
5.4 Results of the radio filters case

Table 13 below shows the tolerance requirements placed on the fixture for each connector position. This was calculated using the method described in Figure 23 of the previous section. The last column “Allow. Fix.” is thus the sum of \( G_{\text{DUT}} - G_{\text{FIX}} - T_{\text{DUT}} \) as shown in Figure 23.

**Table 13. The tolerances that are required in the fixture for each connector position.**

| Connector position | Connector surface radius | Tolerances | |
|--------------------|--------------------------|------------|
|                    | \( G_{\text{FIX}} \) & \( G_{\text{DUT}} \) & \( T_{\text{DUT}} \) | Allow. Fix. |
| 1                  | WC                       | 5,125 & 6,500 & 0,200 | 1,175 |
|                    | RSS                      | 5,125 & 6,500 & 0,141 | 1,234 |
| 2                  | WC                       | 1,510 & 1,800 & 0,350 | -0,060 |
|                    | RSS                      | 1,510 & 1,800 & 0,229 | 0,061 |
| 3                  | WC                       | 1,510 & 1,800 & 0,350 | -0,060 |
|                    | RSS                      | 1,510 & 1,800 & 0,229 | 0,061 |
| 4                  | WC                       | 1,420 & 2,450 & 0,150 | 0,880 |
|                    | RSS                      | 1,420 & 2,450 & 0,150 | 0,880 |
| 5                  | WC                       | 1,420 & 2,450 & 0,150 | 0,880 |
|                    | RSS                      | 1,420 & 2,450 & 0,150 | 0,880 |
| 6                  | WC                       | 0,265 & 0,525 & 0,350 | -0,090 |
|                    | RSS                      | 0,265 & 0,525 & 0,229 | 0,031 |
| 7                  | WC                       | 0,265 & 0,525 & 0,350 | -0,090 |
|                    | RSS                      | 0,265 & 0,525 & 0,229 | 0,031 |

The significance of the “Allow. Fix.” column is that it shows the total positional variance that the fixture can allow for the connector to still be able to insert into its designated connector in the radio filter. This means that the tolerances of the fixture, \( T_{\text{FIX}} \) in Figure 23, needs to be lower or equal to the value stated in the “Allow. Fix.” column.

As can be seen, certain values are negative, meaning that the connector may not be able to insert into its connector even when all parts of the assembly are within their specified tolerance width. All of these cases are however worst case-scenarios which means that they are unlikely to occur.

The results for connector positions 2 and 3 indicate that the fixture requires very tight tolerances for these two particular connectors. The reason for this is that these two connections have a very wide tolerance width, 0,2 mm, in one step of their tolerance chains (the connectors’ positioning on the circuit board). This has had a large effect on the calculation. Measuring a sample of these circuit boards however showed that the tolerance width achieved was tighter, about 0,1 mm. With these tolerances used instead the results for these connector positions instead changed to those below, in
Table 14. Similar circumstances are possible regarding connector positions 6 and 7, but these two have not been possible to control due to limited access to the measurement lab.

Table 14. Adjusted tolerances required for connector position 2 and 3.

<table>
<thead>
<tr>
<th>Connector position</th>
<th>Connector surface radius</th>
<th>Variation</th>
<th>Tolerances</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>WC</td>
<td>1,510</td>
<td>1,800</td>
</tr>
<tr>
<td></td>
<td>RSS</td>
<td>1,510</td>
<td>1,800</td>
</tr>
<tr>
<td>3</td>
<td>WC</td>
<td>1,510</td>
<td>1,800</td>
</tr>
<tr>
<td></td>
<td>RSS</td>
<td>1,510</td>
<td>1,800</td>
</tr>
</tbody>
</table>

It was believed by the authors that the allowed tolerances of each connector position in the fixture should have a certain correlation with the wear intervals each wear part is able to achieve. The reasoning was that the connectors that are most sensitive to misalignment most often should be those with the greatest demand on tolerances in the fixture. When comparing these results to the wear intervals of each connector, however, there are no signs of correlation. If misalignment had critical negative effects on wear interval these connectors (2, 3, 6, and 7) should also have the lowest wear intervals which, as can be seen in Table 15 below, is not the case.

Table 15. The wear interval and product name for each connector.

<table>
<thead>
<tr>
<th>Connector position</th>
<th>Connector component</th>
<th>Wear interval (FRAG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RPT 899 281/2</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>RNT 408 9003/02</td>
<td>2 500</td>
</tr>
<tr>
<td>3</td>
<td>RNT 408 9003/02</td>
<td>2 500</td>
</tr>
<tr>
<td>4</td>
<td>RNT 408 9003/33</td>
<td>2 500</td>
</tr>
<tr>
<td>5</td>
<td>RNT 408 9003/33</td>
<td>2 500</td>
</tr>
<tr>
<td>6</td>
<td>IND 102 0970</td>
<td>10 000</td>
</tr>
<tr>
<td>7</td>
<td>IND 102 0970</td>
<td>10 000</td>
</tr>
</tbody>
</table>

5.5 Discussion of the radio filters case

In this section the results and the process of the radio filters case are discussed.

5.5.1 Results related discussion

Even if these results have not led to reduce the costs of the wear parts in the radio filter fixtures, we believe that these results can lead to long term improvements. A designer with access to these results can easily tell which areas are more critical than others and focus efforts on improving the most critical positions. Ways for a designer to improve the situation for the connectors can for example be to specify tighter tolerances on certain dimensions, to increase existing chamfers or add new ones, or make use of floating connectors which more easily can be guided into female connectors. Efforts like this can reduce costs by preventing connectors from getting caught on connector edges and in the process damaging both the radio filter and the wear part itself.
While these results only are based on calculations from the LTN 214 2014/2 test fixture, the calculations behind these results can and, according to the authors, should be made for all test fixtures. The calculation methods used (root sum square, chamfer vs. tolerance) are set as standard by the department, but as mentioned it is unclear as to how widely these methods are used. We feel that these methods are sufficient for the calculations that need to be done and so the only area in need of change is in ensuring that they in fact are used. How to do this is outside the scope of this thesis, but its importance is recognized.

To evaluate the effects of positional and angular misalignment on the wear parts, further research needs to be done. During this thesis, the main wear part suppliers were contacted and inquired about such information without result. It is not certain if such data is classified or simply unavailable. In either case it seems necessary for MIC to develop and perform tests of its own regarding the effect of these parameters on wear. The benefits of performing such tests lie in the resulting data. Information such as at what degrees of maximum positional and angular alignment result in acceptable connection and to what extent varying degrees of misalignment causes added wear would be valuable for fixture designers. We believe that more detailed knowledge of the testing processes can give long term competitive advantages such as higher wear intervals for the wear parts. This would in turn lead to lower costs and also a smaller environmental impact.

5.5.2 Process related discussion

A major difference between this and the previous case was the differences in focus. The previous case resulted in concrete technical changes with associated cost reductions. While this initially was the goal for this case as well, we felt it was not possible to achieve after having performed the situation analysis. The problems that were exposed in the situation analysis were less concrete in their nature. Of these problems the focus was placed on tolerance chains. This issue was considered to be more fundamental than the other two and had the possibility to have positive effects on the other two as well.

While input in the design process for future radio filters is important, thorough knowledge about allowable misalignment and tolerancing was deemed necessary in order to truly be able to come with valid input in the design-stage. Our hope is that the implementation of more careful tolerance routines can lead to the department having clear input ready when development of the next radio filter platform begins.

The problems associated with the manual fastening system of the RUS fixtures are also largely related to misalignment and tolerances in the way that manual insertion of the radio filter increases the possibilities of misalignment. With better knowledge about the effects of misalignment the magnitude of these problems can be evaluated. If they are serious, a solution to these problems has already been developed in the form of the pneumatic test fixture. We believe that this type of insertion system is superior and that utilization of this system should be expanded to cover all radio filter test fixtures in the future.
6. Cross-case analysis and discussion

The two cases included in this thesis have until this stage been described separately. In this chapter they will be compared and analyzed in order to determine differences and similarities between the two.

6.1 Case comparison

An overview of the similarities and differences between the digital units and the radio filters case can be seen below in Table 16.

Table 16. A comparison of the two cases.

<table>
<thead>
<tr>
<th></th>
<th>Digital units case</th>
<th>Radio filters case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal</td>
<td>Cost reduction</td>
<td>Cost reduction</td>
</tr>
<tr>
<td>Methodology</td>
<td>Cost-oriented DRM</td>
<td>Cost-oriented DRM</td>
</tr>
<tr>
<td>Product-stage</td>
<td>Currently used in production</td>
<td>Currently used in production</td>
</tr>
<tr>
<td>Perspective</td>
<td>Manufacture</td>
<td>Use</td>
</tr>
<tr>
<td>Improvement</td>
<td>Manufacturing method</td>
<td>Product application</td>
</tr>
<tr>
<td>Result</td>
<td>New manufacturing method</td>
<td>Suggestions for improved process control</td>
</tr>
</tbody>
</table>

As can be seen, both cases had similar starting points. Each case was initiated with the same goal, and the same methodology was used in the execution of both. Both cases also examined products currently used in production. This proved to have a limiting effect on the improvement possibilities. Improvements that would require changes to surrounding equipment would thus incur large implementation costs and were therefore ruled out. Instead only changes compatible with the current set-up were considered. This type of thought-process can only lead to incremental innovations (“doing what we do better”); which as mentioned in the literature study is the type of innovation that is most common for the specific phase of a product. The two cases thus gave examples of the reasons behind incremental innovations being so common in the specific-phase; radical innovations are simply too expensive at this stage. While incremental innovations are less expensive to develop, they also have a limited ability to cut costs. It was found in the literature study that 90% of a product’s cost is determined in the design-stage (Ehrlenspiel, Kiewert & Lindemann, 2007, p.13), and without a major change in design it is naturally difficult to reduce those 90% of costs.

The main difference between the two cases was the perspective. For the digital units case, the perspective was limited to manufacturing in order to focus on a reduction of manufacturing costs. This was both possible and appropriate due to the Ericsson-specific nature of the wear board and the in-house production of these in MIC Kista. In the radio filters case this type of perspective was not suitable, mainly because the wear connectors are standard products purchased from external
suppliers. With these circumstances, not only is there lack of insight into production, but design changes are difficult to implement without losing the price advantage associated with standard products. For these reasons the perspective was limited to the stage that follows manufacture; the use of the product.

The two different perspectives affected the entire cases. In the digital units case, different manufacturing methods were investigated and suggested while in the radio filters case, the use of the wear parts and their circumstances in the test fixtures was examined. The two cases thus resulted in cost reduction efforts focusing on both manufacturing (digital units case) and application (radio filters case). This fundamental difference between the two cases has in our opinion been positive for the report as a broader picture of the issue of cost reduction can be described. In addition this has allowed for the methodology we have used to undergo a more thorough evaluation, as it was evaluated for two different types of cost reduction projects. We believe this will lead to added benefit and future implications for the model itself.

6.2 Model for cost reduction development

DRM (described in detail in chapter 3) is as the name states, a methodology designed for design research. In the cases described in this thesis, focus was not placed on design research itself, but on the development of cost reductions. The framework of DRM was not found to be adapted to the specific task of cost reduction and the need for a new model was thus recognized. Using DRM and the experiences from executing the two cases as a base, a new model was created: the model for cost reduction development, MCRD.

MCRD has four stages as can be seen in Figure 24 below. The figure summarizes the means and outcomes of each stage. Each stage is described in more detail in the coming text.

Figure 24. Model for Cost Reduction Development, MCRD.
• **Product mapping.** In this stage the product for development is chosen, goals are set up for the development project and success criteria are defined.

• **Situation analysis.** In this stage a general understanding of the product is built and its cost contributing factors are analyzed. Areas where there is potential to reach the goals specified in the research clarification stage are identified and the most promising is chosen for further pursuit.

• **Improvement development.** In this stage improvements within the chosen area are developed.

• **Improvement verification.** When this stage is reached the improvements developed in the previous stage are verified with regards to the success criteria. Additionally, further research is suggested.

The *product mapping* stage is meant to lead to the selection of a limited amount of products to focus on. Doing this early will result in the next stage, the *situation analysis*, being more focused and detailed. Added detail to the situation analysis will lead to more accurate cost estimations as well as a clearer picture of the product itself. These advantages are important in order to determine the right area to focus future work. From a cost perspective this area is crucial to identify in order to ensure that the time spent on *developing improvements* achieves the most leverage. Can no area which realistically will lead to the fulfillment of the success criteria be identified; a premature end to the project should be considered. In the case of cost-reduction projects reasonable success criteria for the improvement could be that the cost reduction should be greater than the sum of the development and implementation costs associated with the cost reduction. After a cost reduction has been developed the *verification* stage begins, where the suggested cost reduction is evaluated before the decision to implement is made.

### 6.3 Model evaluation

As shown in the literature study, having a clear strategy for product development can lead to two major advantages (Johne & Snelson, 1989); First, the internal valuation of the process is increased which generates drive to overcome hurdles in the process. Second, it allows managers to take a step back from the development process, which means less time is spent in briefing sessions. Using a model such as MCRD is, in our opinion, part of having a clear product development strategy and can thus lead to these mentioned advantages.

We believe that the MCRD can be beneficial to use in cost reduction projects. Having a clear model to use will in many cases improve the process, which affects the final result as well. The model has however only been based on the experience of these two cases, and further research is required before the model can be recommended in the use of other projects.
7. Conclusions

Large parts of the literature available on both innovation and product development do not distinguish between the development of incremental or innovative products. In the cases where such differentiation is made, innovative product development is the most common focus. It is clear that cost reductions are very different from revolutionary new technology and these differences are reflected in the development processes too. In order to truly gain insight into cost reduction, more research is required and more specifically research that focuses on this area of product development alone.

Two cases demonstrating the development of cost reductions have been described and these can contribute to the practical knowledge of the area. The conclusions drawn from the two cases will now be described.

7.1 Conclusions of the digital units case

The manufacturing process of the connector guide in the RJ45 wear board should, from an economical point of view, be changed from milling to injection molding. The amount of material, the time required for assembly, the number of parts included and the purchasing price of each component will all decrease with the change of manufacturing process. This change in manufacturing process should be thoroughly evaluated to ensure that it can deliver components of sufficient quality. If this solution is successful, further implementation for the connector guides on SFP and IDL/ESB wear boards should be considered, as well as other plastic details which currently are milled.

7.2 Conclusions of the radio filters case

The wear parts in the radio filter fixtures were difficult to improve as they are purchased from external suppliers. Instead this thesis has aimed to examine reasons for added wear to these connectors. Given the size and weight of the radio filters tested in the test fixtures, it was determined that misalignment between male connectors in the test fixtures and female connectors in the radio filter was likely to damage the male connector. The tolerated misalignment and the tolerance chains for each connector position were calculated and compared in order to find reasons for misalignment. This showed that certain connectors have a higher demand for exact positioning than others.

These results however did not correlate with the wear intervals set by FRAG for the connector positioning; the wear parts with the highest need for positional exactness were not those with the lowest wear interval. This means that the connectors themselves are very individual and the only way to ensure correct tolerancing is to test the connectors with different degrees of positional and angular misalignment to see how this affects both mechanical wear and electrical performance.

Adding and increasing chamfers is one way that designers use today to try and ensure connectability. This could perhaps be done to a greater extent, but it is possible that the chamfers contribute to added wear on the male connectors and decreased electrical performance. If thorough tests of the connectors were performed the effect of chamfers could be clarified.
7.3 Improvement verification

As is concurrent with the design research methodology used in this thesis, the goals for each case and their corresponding success criteria will be compared to the actual results. The success criteria were initially described in section 1.4.1 but are repeated here to make the criteria comparison easier to make.

- To study the life times of the wear parts used in current production lines, how their actual wear intervals correlate with those stated by suppliers, and to examine the costs they incur. To consider this goal achieved, the costs and life times of all wear parts within the delimitations should be presented.

The situation analysis of each case has presented all the data mentioned above. As such the goal has been achieved.

- To give suggestions on how to decrease the effect of wear parts on the end price of products. To achieve this goal, at least one concrete improvement should be presented for each case which can be shown to lead to a cost reduction of at least 15 % compared to the cost level at the thesis project’s initiation.

Each case has resulted in suggestions which can reduce costs. Only the digital units case has however presented an improvement of which the cost reduction can be quantified. As can be recalled, the digital units case resulted in a cost reduction of 48 % on the connector guide. If the perspective is limited to the connector guide, the goal has thus been achieved. If however the perspective is a whole wear board, the connector guide itself stands for such a small part of the total cost that a 15 % cost reduction is not achieved. Because a cost reduction has not been introduced for the radio filters case, this goal has not been achieved regardless of the perspective chosen for the digital units case’s cost reduction.

While not able to achieve this goal we believe some of the suggestions presented in this thesis can lead to further cost reductions in the long term if the department chooses to continue the work that was started in these areas.

7.4 MCRD conclusions

The cases that were described in the thesis were both performed using the DRM framework. During the execution of the cases, the need for a model specifically designed for the development of cost reductions was recognized. A new model was created specifically for the purpose of developing cost reductions: the model for cost reduction development (MCRD). A clear product development strategy has been shown to be advantageous for organizations and as such a model specifically designed for cost reductions is valuable. Elements included the model were found to be effective and helpful during the execution of this thesis, but further evaluation is necessary. It will need to be used in more projects and preferably by other individuals in different companies in order to determine its general suitability in these types of projects.
8. Further research

In this chapter we will describe how the department could continue working with the improvements we have presented. We will also point out other areas where we have seen potential for improvement within the organization.

8.1 Further research within the cases

Within the digital units case there are two main areas that should be researched further:

- Verifying that the design proposed by the case works as intended. This verification process should be done with prototypes to keep costs down. Areas that need to be verified are if the new connector guide still can fill its old function and if the snap fit can fasten the guide tightly to the circuit board and keep doing this over time.
- Looking for low-cost suppliers so that the connector guides can be purchased at a still lower price than described in the results section. Finding low-cost suppliers could mean that SFP and IDL/ESB connector guides also can be injection molded to a reduced cost.

Within the radio filters case there is one area which in particular should be looked into:

- Gaining a more detailed understanding of how different parameters affect the wear parts. The importance of this was discussed in section 5.5.1. We believe the best way to do this is to perform rigorous tests in-house of different parameters deemed to be interesting. This type of capability is not available today but we believe the potential benefits can justify the cost.

8.2 Further research within other areas

Two other areas with improvement potential were noticed and are described below.

The fault rate analysis group (FRAG) at MIC Kista currently is responsible for setting the wear intervals for all the supply sites. Considering the volume of products these sites produce, the wear intervals can have significant economic effects. The method used by FRAG today to determine wear intervals is based on trial and error for new wear parts and historical data for previously used wear parts. Our impression is that these wear intervals could be optimized through a better testing process. If this testing could be combined with the tests described in the previous section this would make this additionally beneficial.

Better communication between test and product designers. During this thesis a common complaint heard from designers at the department of Hardware Design & Supply Services at MIC is that their opinions rarely are considered by product designers designing digital units or radio filters. Seemingly small and unimportant changes for a product designer can make a big difference for test equipment designers. For this reason test equipment designers need to be involved in the start of design projects; to avoid solutions that unnecessarily complicate testing. This is an organizational issue which could lead to important improvements with regards to testing.
9. References

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Internal source 9: Isaksson, O., production engineer, Ericsson, interview, April ’12.


Internal source 11: Anastasiou, P., senior test master, Ericsson, interview, March ’12.

Internal source 12: Aït-Hamou, I., mechanical design engineer, Ericsson, interview, March ’12.

Internal source 13: Design guidelines, internal document.
Appendix

Appendix 1: A product map of the wear boards

The product map of the wear boards shows the different test fixtures used in digital unit production and their included wear boards. The black boxes hide the digital units that each fixture tests, this is confidential information.
Appendix 2: Snap fit calculations

This appendix includes the calculations used to decide the dimensions of the snap fit of the new connector guide design. The first calculation is used to determine the snap fit’s flexibility. The second calculation determines its maximum displacement.

Calculation of the snap fit’s flexibility (to ensure the ability to enter the circuit board’s hole)

![Diagram of snap fit calculations]

\[ R = \text{Radius} \quad R = 1,825 \text{ mm} \]
\[ r = \text{Radius} \quad r = 0,9125 \text{ mm} \]
\[ f = \text{Grip} \quad \alpha = 60^\circ \]
\[ \alpha = \text{Security angle} \]
\[ l_c = \text{Length (clearance)} \quad l_{cl} = 0,3 \text{ mm} \]
\[ l_c = \text{Length (circuit)} \quad l_{cl} = 0,85 \text{ mm} \]
\[ l_r = \text{Length (recess)} \]
\[ a = \text{Geometry factor} \]

\[ f = l_{cl} \cdot \tan \alpha = 0,3 \cdot \tan 60^\circ \approx 0,52 \text{ mm} \]

\[ \frac{r}{R} = 0,5 \text{ and } 75^\circ \rightarrow a = 1,25 \text{ (Berggren et. el. 1997 p.178)} \]
\( \varepsilon_{\text{perm}} = \text{Permitted elongation} \quad \varepsilon_{\text{perm}} = 8\% \text{ POM (Berggren et. el. 1997 p.176)} \)

\( C = \text{Geometry factor} \quad C = 1 \text{ (Berggren et. el. 1997 p.178)} \)

\( l_t = \text{Length (total)} \)

\[
f = \varepsilon_{\text{perm}} \cdot a \cdot c \cdot l_t^2 / R \rightarrow l_t = \sqrt{R \cdot f / \varepsilon_{\text{perm}} \cdot a \cdot c} = \sqrt{1,825 \cdot 0,52 / 0,08 \cdot 1,25 \cdot 1} \approx 3,08 \text{ mm}
\]

\( l_r = l_t - (l_{c1} + l_{c1}) = 3,08 - (0.3 + 0.85) = 1,93 \text{ mm} \)

**Calculation of maximum displacement (to prevent snap fits from colliding)**

\( f = \text{Grip} \)

\( l_h = \text{Length (height snap fit)} \)

\( l_t = \text{Length (total)} \)

\( D = \text{Deflection} \)

\( f = 0,52 \text{ mm} \)

\( l_h = 5,3 \text{ mm} \)

\( l_t = 1,93 \text{ mm} \)

\( D < r \) (For possible bending)

\[
\frac{f}{l_t} = \frac{D}{l_h} \rightarrow D = f \cdot \frac{l_h}{l_t} = 0,52 \cdot \frac{5,3}{3,08} \approx 0,89 \text{ mm}
\]

\( r = 1,825 \cdot 0,5 \approx 0,91 \rightarrow D < r \)
NOTE:
Solid 3D model is made nominal with theoretical exact form and position, if not otherwise stated.
Sharp edges broken.
Radii on all edges is 0.2 mm if not otherwise stated.
Angles are 1° if not otherwise stated.
Material for prototype: ABS.
INDIKATIONS-OFFERT!
Vi tackar för Er förfrågan angående ”Connector Guide SXA1293010/4 Rev.1”, och har härmed nöjet att offerera:

**Prov-verktyg 1-fack:**
- Pris: 28 000 Kr
- Lev.tid: Enl. ök
- Bet.villkor: 30 dagar netto

Pris provdetalj beroende på antal och materialval.

**Produktions-verktyg, 2-fack:**
- Pris: 75 000 Kr
- Lev.tid: 6 arb.v från order, dock ej leverans tidigast v32
- Bet.villkor: 30 dagar netto

OBS! Lös stålkärna i centrum pga känsliga tätningar

**Detalj:**
- Material: POM-C SD
- Pris: 5:25 Kr/st
- Material: EC 140XF
- Pris: 2:15 Kr/st
- Lev.tid: Enl. ök
- Lev.villkor: Fritt Fabrik
- Bet.villkor: 30 dagar netto

Vid ordervärde understigande 7 000 kr per produkt, tillkommer en ställkostnad om 1 500 Kr. Emballage tillkommer.

Offertens giltighetstid 30 dagar.

Med Vänlig Hälsning

*Emil Granstrand*

LILJAS PLAST AB
Appendix 5: The processes involved in radio filter production
Appendix 6: Pictures of the different connector wear parts in RUS fixtures

IND 102 0970

RNT 408 9003/02

RNT 408 9003/33

RPT 501 33/1

RPT 501 39/1

RPT 899 281/1
RPT 899 281/2
(difference in length)
Appendix 7: The numbered wear parts of LTN 214 2014/2

This appendix includes pictures of the wear parts present in the LTN 214 2014/2 test fixture, as well as their supporting connector brackets. The numbers are used to identify different positions of the test fixture to improve understanding in measurements and calculations.
Appendix 8: Tolerance chains calculations

MBX Connection
Fixture: LTN 214 2014/2
Base plate: SXA 129 2980/1
Connector position: 1
Connector bracket: SXA 129 3355/1
MBX wear part: RPT 408 9024/01

The tolerances are tolerated according to two models; the worst case model (WC) and the root sum square model (RSS) as described by Krishnamoorthi (2006, pp.158-159).

\[
T_{WC} = 0,025 + 0,02 + 0,10 + 0,05 = 0,195 \text{mm}
\]

\[
T_{RSS} = \sqrt{0,025^2 + 0,02^2 + 0,10^2 + 0,05^2} \approx 0,116 \text{mm}
\]
SMP Connection
Fixture: LTN 214 2014/2
Base plate: SXA 129 2980/1
Connector bracket: SXA 129 3121/1
Connector position: 2, 3
Wear part: RNT 408 9003/02

\[ T_{WC} = 0.025 + 0.02 + 0.10 + 0.05 = 0.195 \text{mm} \]
\[ T_{RSS} = \sqrt{0.025^2 + 0.02^2 + 0.10^2 + 0.05^2} \approx 0.116 \text{mm} \]
SMP Connection
Fixture: LTN 214 2014/2
Base plate: SXA 129 2980/1
Connector bracket: SXA 129 3121/1
Connector position: 4, 5
Wear part: RNT 408 9003/33

\[
T_{WC} = 0,025 + 0,02 + 0,10 + 0,05 = 0,195 \text{mm}
\]
\[
T_{RSS} = \sqrt{0,025^2 + 0,02^2 + 0,10^2 + 0,05^2} \approx 0,116 \text{mm}
\]
IND Connection
Fixture: LTN 214 2014/2
Base plate: SXA 129 2980/1
Connector bracket: SXA 129 3124/1
Connector position: 6, 7
Wear part product number: IND 102 0970

\[ T_{WC} = 0.025 + 0.02 + 0.10 = 0.145 \text{mm} \]
\[ T_{RSS} = \sqrt{0.025^2 + 0.02^2 + 0.10^2} = 0.105 \text{mm} \]
Appendix 9: Measurements of the connector positions in eight LTN 214 2014/2 fixtures [mm]

The measurements are conducted in both the X and Y-axis, with the guiding pin’s position being used as origin. In the cases when a male connector is attached to a circular connector bracket, the diameter of this connector bracket has also been measured. The measurements were conducted by a coordinate measuring machine at MIC Kista.

<table>
<thead>
<tr>
<th>Connector position</th>
<th>Nominal value</th>
<th>Test record 1</th>
<th>Test record 2</th>
<th>Test record 3</th>
<th>Test record 4</th>
<th>Test record 5</th>
<th>Test record 6</th>
<th>Test record 7</th>
<th>Test record 8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Y 15,504</td>
<td>15,505</td>
<td>15,367</td>
<td>15,489</td>
<td>15,651</td>
<td>15,575</td>
<td>15,485</td>
<td>15,419</td>
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<tr>
<td></td>
<td>D 15,100</td>
<td>15,066</td>
<td>15,069</td>
<td>15,066</td>
<td>15,068</td>
<td>15,079</td>
<td>15,090</td>
<td>15,071</td>
<td>15,079</td>
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<tr>
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<tr>
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<td>10,669</td>
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