University of Applied Sciences of Fribourg

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New Probe for Depth Estimation of Records: PROBE AND SOUND EVALUATION

Documentation

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ABSTRACT

ENGLISH

Today there exist a lot of old records that you cannot play with a normal stylus system, because the discs are too old or they are broken. This system reads the discs without touching them. The system is a 3D system that reads the light reflection of 180 points at the same time with a probe. All these points read the depth of the groove. With this depth measurement we calculate the groove and after that the lateral movement of the groove, so that at the end the sound can be recalculated.

My part of this project was to analyze the quality of the new probe. The analysis of the quality was made with different methods. The second part of the project was to optimize the acquisition of the measurement with a rotation of the probe. For the rotation of the probe a recalculation of the time difference in the measurement had to be done. The last part of my project was to analyze the different methods to recalculate the groove center and also to analyze the project with the 2D system IRENE. The results of my work are, that we can read more discs and that the measurement has an improved quality, what results in a better sound quality.

DEUTSCH

Es gibt viele Schallplatten, die heutzutage mit einem herkömmlichen Schallplattenleser nicht mehr abgespielt werden können, da diese zu alt oder schon beschädigt sind. Das System liest die Schallplatten, ohne diese zu berühren. Das System an dem ich arbeite, ist ein 3D System, welches mit einem Sensor die Licht Reflexion in 180 Punkten zur gleichen Zeit misst. Alle diese Punkte lesen die Tiefe der Rillen auf der Schallplatte. Diese Tiefenmessungen werden danach zurückgerechnet und man erhält den ursprünglichen Ton auf der Schallplatte.

In meiner Arbeit ging es darum, den neuen Sensor zu testen und die Qualität des berechneten Sounds zu ermitteln. Die Qualität wurde mit verschiedenen Aspekten angeschaut. Der zweite Teil umfasst die Verbesserung der Qualität durch das Drehen des Sensors, sowie die Zurückrechnung der Zeitdifferenz, welche durch die Drehung entsteht. Im letzten Teil ging es darum, die verschiedenen möglichen Arten von Algorithmen zu testen, welche den Sound berechnen und das beste Resultat mit dem 2D System IRENE zu vergleichen. Das Ergebnis meiner Arbeit ist, dass mehr Schallplatten gelesen werden können und dies mit einer besseren Qualität. Am gleichen Projekt arbeitet auch Adrien Nicolet, welcher vor allem den Softwareteil des Projekts verbesserte.

FRANÇAIS

Ca existe beaucoup de records, quelque on ne peut pas jouer avec une lecteur normal parce que les record sont trop vieux ou déjà endommagés. Le system sur le quelle je veux travaille lire les records sont le toucher. Et c'est une system 3D avec un capteur que mesure la réflexion de la lumière dans 180 points en même temps. Tout le point mesure la profondeur des rainures. Avec ces mesures en recalculé le son de le record.
Dans mon travaille, il était le but de teste le nouvelle capteur et détermine la qualité de le Sound qui est recalculait. La qualité est détermine avec plumier aspect. La deuxième partie de mon travaille était de améliore la qualité avec une rotation de la sonde et recalcule te différence de temps qui était masure. Le dernière partie était de teste le différents types d'algorithmes qui calculent les sont et de compare le meilleur résultat de la système 3D avec le system IRENE 2D. Le résulte d mon travaille est, on peut lire plus de record avec le rotation et le nouvelle sonde. Et on a une meilleur qualité de son. Sur le même projet travaille également Adrien Nicolet, qui a amélioré en particulier la partie logicielle du projet.

TABLE OF CONTENT

1 INTRODUCTION

The purpose of this paper is the documentation of the project. That means that all the work that is done for the project is documented. It explains what the goal of this project is and in which context the project has began. Further it shows how the goals are reached.

At the end you find a short conclusion of the whole project.

1.1 INTRODUCTION OF THE PROJECT

The goal of this project is to achieve the sound from record discs without touching them with a stylus. That means that we want to read some record probes with a laser in order to get the information of these records. We want to get the information because there exist a lot of records that we cannot read with a stylus. It is either too old or the disc is cracked.

1.2 HISTORY

Leon Scott recorded the first sound on cylinders in 1957, but the mechanical cylinder phonograph that played the sound from this disc was invented by Thomas Edison in 1877. The first method was to store the sound on wax cylinders in order to get the sound from these cylinders.

In 1887 Berliner succeeded to store the data on a disc and not on a cylinder. He stored the data in the form of a spiral on the disc and the movement was lateral and not as in the cylinder up and down.

In 1900 the disc records became more and more important. From 1900 to 1920, before the introduction of magnetic tapes, phonographic records were the most common way to store music. The standard music format at this time was the 78rpm discs. Therefore most of the sound was stored on these kind of discs. [1]

1.3 78 RPM DISCS

At the beginning, there existed different kind of discs, from 60 to 100 rpm. But in 1950 the disc that was used the most, was the 78rmp, because that was the best compromise between the electrician frequency of Europe and America. [1]

The sound recorded on this disc was stored on a groove spiral form the outside to the center of the disc. The principal for playing the sound was that a stylus followed the groove and the sound was reproduced by the lateral velocity of the needle.

The depth of the groove is usual 70µm but it changes some microns more or less. It is only the lateral movement of the needle that makes the sound.

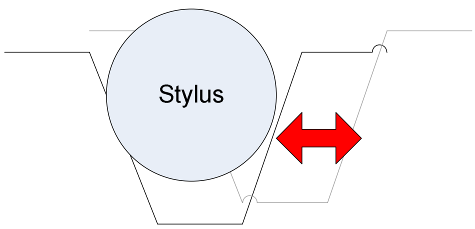


Figure 1 Movement of the stylus

1.4 Optical reading method

To extract the sound from a disc without physical contact, there are different optical reading methods. The first one is to make a 2D image and the other is to make a 3D image of the groove and to read this groove. By digital process it is possible to reconstruct the sound from the discs that are not playable with a stylus, because they are cracked or worn. Different optical reading systems are developed at Lawrence Berkeley National Laboratory (LBNL) and also at the University of Applied Sciences in Fribourg (EIA FR).

1.4.1 2D imaging

In the 2D method the main goal is to make a high-resolution monochromatic picture of the medium and to recognize the groove after that by image processing. In the picture the dark pixels represent the steep section and the flat section is represented by bright pixels.

This method is used in the project called IRENE at the LBNL. It is able to extract sound from phonographic records, which in some cases is comparable to the quality of analogue playback systems.

A similar project was developed at the University of Applied Sciences in Fribourg in Switzerland. There they retrieve the audio data from damaged phonographic records. That means that they are cracked or the lacquer has layer shrunk over the years. They take a high-resolution photograph on a film and then they scan these films. With this technique they are able to save unplayable records in a digital form.[2]

1.4.2 3D imaging

In the 3D method the scanning process is different. We have a probe that measures the depth of the surface of the disc in different points of the disc. So it detects the different depths of the groove and saves them in a file. By digital processing the stylus movement is simulated virtually to extract the sound.

This method was applied at LBNL to extract the sound. First it measured the depth with a single-point color-coded confocal microscope. This single-point microscope was then replaced by a multiple-point line sensor (MPLS 180).

With this method it is possible to extract the sound from discs and cylinders in just 20 minutes what is a big advantage compared to the 2D method. [2]

1.4.3 Status before this project

At the moment the LBL can read some records with the 3D method. The problem that exists is that not all record discs can be read by this 3D method. If the 3D method can read the disc the result is not so bad. But if the discs are too old or the disc is too shiny the LBL cannot read the discs really well according to the project from last year. In December 2009 the LBL has bought a new probe the MPLS v2. This that new probe can read more discs, but it has not been tested until now.

1.5 PREVIOUS PROJECTS

1.5.1 PROJECT FROM 2008

In 2008 Sven Hezel and Severin Nowak worked on the project 3DSEVEN. In this project they read some matte discs. The probe stayed vertical to the disc. The problem was that the probes only read matte discs, the other discs had too much reflection. For the disc they could read they implemented some different algorithm to get the groove and thereof they extracted the sound. And finally they checked the quality of the sound file that they had extracted. [2]

1.5.2 PROJECT FROM 2009

In 2009, Philippe Ballestraz and Raynald Seydoux worked on the project PRISM, this is the program that they made in the LBL to read the cylinders. The first thing that they did was to tilt the probe for 20°, so that they did not have so much reflection in the probe. The problem was that they had to read the disc two times, one time from both directions. The data had to be taken from the same place in order to reconstruct the groove with different methods in the program PRISM. [3]

1.6 GOAL OF THE NEW PROBE

The old probe had some problems with reading data on discs that are too shiny. A lot of reflection was measured with the old probe, the reflection are explain in the chapter 5. With the new probe we hope to be able to read more data than before. The difference between the old and the new probe will be explained later in this documentation. The goal is to read the data more precisely with the new probe and to read more discs.

The disc will be measured with a better quality and will give a better audio file with the program PRISM, so that we do not need so much filter to get a good audio file.

1.7 STRUCTURE OF THIS DOCUMENTATION

The documentation is structured in 14 chapters and the main part of the project is between chapter 3 and 11. It begins with an introduction about the records and the hardware system. In the following four chapters I compare how good the quality of the new probe is and also what the quality is if we rotate or tilt the probe. In chapter 8 and 9 I talk about the shift of the measurement files because of the rotation. Furthermore I compare the new measurements with the old ones. In chapter 10 I talk about the different parameters in the program PRISM and in the last chapter of this project I compare all the changes in the system 3D and PRISM, including the changes of Adrien Nicolet with the 2D system IRENE and a normal system that reads the data with a stylus. At the end of the documentation you find a conclusion over the whole project.

1.8 SUSTAINABLE DEVELOPMENT

It exist a lot of 78 records and some of they are older than 60 years, a lot of records are only available on 78'2 and represent an important part of music or audio history.

It is important to archive some old records for future generation. In some cases on the records are not only sound it can also have some person they send a message to a other person. It exist a lot of disc in some archives and if they cannot be read with a normal stylus system we need another system without touching that do not touch the records It can be important that the information on the records you can archived now to a normal audio file so that in the future someone can analyze this old documentation.

For example, wax cylinders of the 19th century, with American Indians music could be saved.

This process can be considered as sustainable development. Indeed, restoring and preserving the historical archives for the future generations constitutes an important heritage.

2 Objectives of the project

2.1 Analysis of the new probe MPLS 180 v2

The first objective is to analyze the result ot the new probe MPLS 180 v2. In this case I will see how the program works and why is the new probe is better than the old one. The result of the new measurement will be compared with the old one. We measure the groove and the result of the energies in both cases. To compare I will use the histogram of the measurement and also the Signal to Noise and Distortion ration (SINAD) to compare which one is better.

2.2 Rotation of the probe

At the moment we have the problem that a mirror disc can reflect some points of the disc from one slope to the other and so we get the problem that at one point of the groove we have a deep measurement that does not exist. I can now turn the probe so that the reflected signal does not go into the probe. Further I test if the signal that we can get now is better or not. If the result of the histogram is better, then the result of the WAV file also is better.

2.3 Shifting the file

If we rotate the probe, we do not read every point in one measurement from the same point of time on the disc. That means that we must recalculate the groove from more than one measurement before we create the WAV file. I want to shift the *.pri file so that the file has in one line only one time section of the disc. I want to calculate how much the data must be shift. And I have to shift the data in the right direction. So at the end the *.pri file is modified so that we can read it normally in PRISM. If the shift is made, the new file must be tested to see if the result is better and how it depends on the disc.

2.4 Make a self adaptive analysis with different algorithms

The third objective is to adapt those tests which are the best to get the optimal case automatically. That means that I test the different WAV signals that I receive from PRISM 2010 to determine which file has the best result. That program tests and compares different WAV files automatically and plots some statistics to see what the results are. It also tries to find the best parameter and the best fit method for this disc.

2.5 Changes in the Specification

After studying the reflection of the disc another solution with a tilted probe should also be possible. First measurements have indicated that the tilt of the probe also eliminates the reflection.

The chapter 2.4 has changed his sentence, it would be new an analysis form different algorithms. It is very difficult to test the quality of a sound file automatically, because the quality is not the same over the whole measurement. Accordingly it is not really possible to find the quality of a sound file automatically.

2.5.1 Tilt of the probe

For the same problem as before, the reflection of mirror discs, I can also tilt the probe for some degrees, so that the reflection does not go into the probe. I will test if the new measurements now are better and if we can read more discs than before. This will be compared with the rotation of the probe and then I choose the better solution. To test is, if the histogram is better and if the WAV files are better in this case.

2.5.2 Analysis of different algorithms

The new objective is to make it possible to test the different algorithms in the program PRISM very easily, to be able to test the disc very fast and to find out which algorithms and which parameters are the best for this disc. And is one parameter the best for all discs.

3 DISC ACQUISITION

3.1 GROOVE DIMENSION

The dimension of the groove is not very big. We have a depth of 70µm and an opening of 50µm. The slopes at the sides have an angle of about 45°.

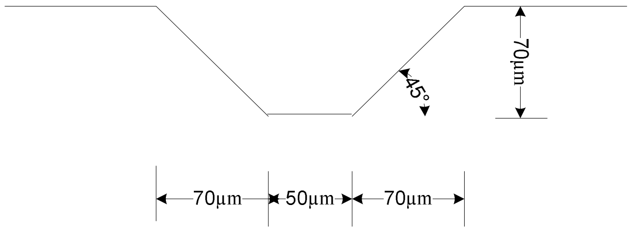


Figure 2 dimension of the groove

One of the disadvantages of these records is that if you use them a lot with the stylus, the groove will be deformed.

3.2 HARDWARE

3.2.1 *HARDWARE EXPLICATION*

The system that the LBL uses is a system with three axis, one for the rotation, one for the high position of the probe and one for the distance to the center of the disc. With these three axis we can read the whole disc. The main part of this system is the MPLS 180 (multiple point line sensor). The motion controller controls all the movement of the system. To get the best result it is necessary to get the high detector for the auto focusing of the probe. Further it is important to get the same focus on the disc every time. [4]

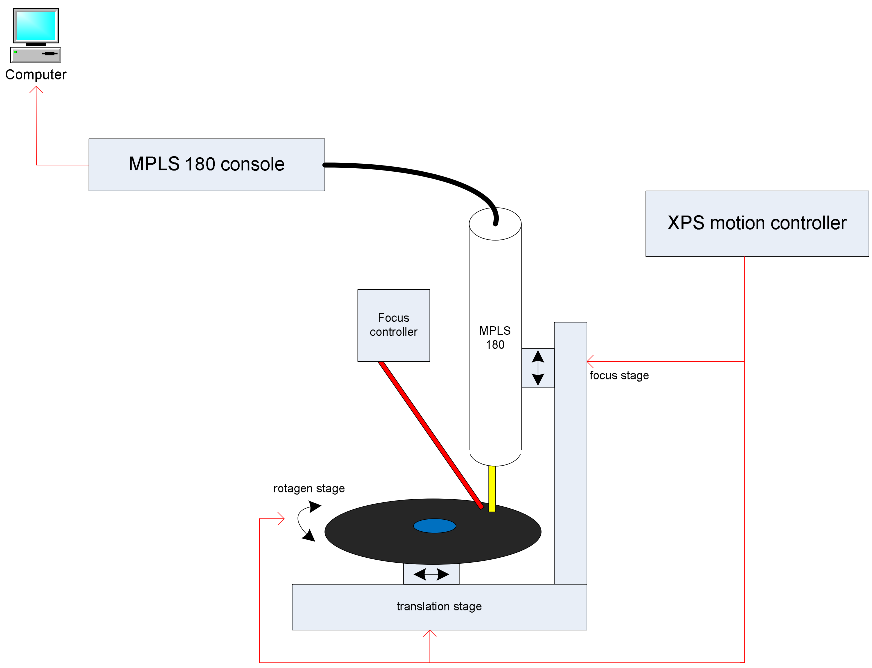


Figure 3 Hardware components

With this system we can measure the disc in one time and do not have to change anything or measure twice.

3.2.2 MEASUREMENT EXPLICATION

If we measure the disc, we read one turn of the disc and then change the place in the translation stage and measure the second turn. Another method is to overlaps the scans, so that we measure the disc at the same place more than once. Then we take the average of the measurements what gives us a result that is more precise than the data that we get by reading the disc only once.

In one measurement we take 180 points. Then we rotate the disc and take the second measurement. The change from one measurement to the other can be chosen, but we often use a rotation of 0.02°. That corresponds to a sampling of 18000. A better solution is 0.01° what means 36000 samplings.

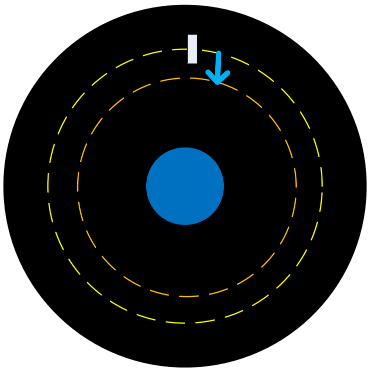


Figure 4 measurement turns of the disc

The frequency of the measurement is between 200 Hz and 1.8 kHz, that means that we can make new measurements every 0.55-5ms.

In one measurement we take 180 points in a distance of 1.8mm. So we have a measurement point with a diameter of 2.5µm every 10µm.

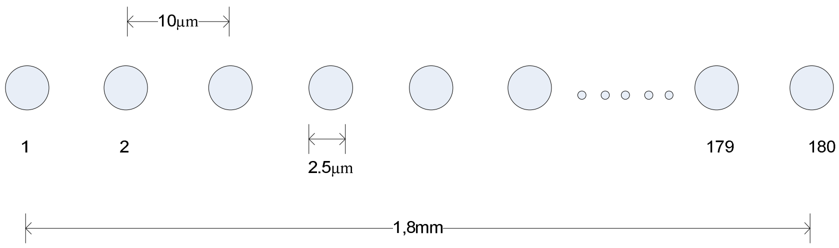


Figure 5 points of measurement

Each point of this measurement has its own fiber cable that goes to the MPLS 180 consol and sends all the 180 points to the computer by USB cable.

3.3 ACQUISITION PROCESS

To make an acquisition you must prepare the system before. That means that the focus of the probe must be in the depth of the field and also the autofocus must be set for the start position of the acquisition. The acquisition is made with the program LabVIEW. This program commands the MPLS controller and also the XPS motion control. The speed for the MPLS controller and the rotation axes is triggered by the program LabVIEW and it by the exposure time. The y ax is also commanded during the acquisition. With the focus control the height of the disc is always regulated so that all the groove is in the depth of the field. The measurement begins in the start position and makes one ring. After one ring of acquisition the platter palace for the distance of one ring. And take the second measurement ring. It goes on, until the end position for the acquisition is reached. The acquisition can be made with an exposure time of 400 Hz to 1800 Hz. The standard exposure time is 600 and the standard distance between two measurements is a rotation of 0.2°. That makes 18'000 measurements of 180 points in one ring. This gives us a sampling rate of 23.4 kHz in the normal case.

In one acquisition the program generates a table with all depth measurements. This table is saved in a file .pri. This file is explained later. Also the intensity of every point is measured and saved in a file .pri.bri.

3.3.1 CONVOCAL MICROSCOPE MPLS180

The MPLS is a multiply points line sensor. It contains 180 light spots and receptors. The probe is connected with two strings of 180 fibers. In one string the depth measurements are sent to the MPLS and in the second the intensity. In every fiber the system sends a white light over a chromatic convocal lens to the platter. This light is reflected, normally only in the direction of the sending light. This reflection goes back to the sending spot. The chromatic convocal lens has the advantage that not all colors have the same depth and only one color is reflected to the spot. This color is recalculated to a depth measurement.[4]

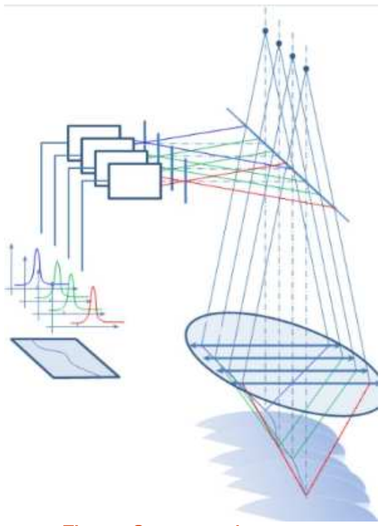


Figure 6 convocal system

3.3.2 RECALCULATION IN PROGRAM PRISM

The program PRISM is the program that is written in c# by the LBL. This program recalculates the sound file from the file .pri and the file pri.bri. It does not only contain the recalculation from the disc, it also contains the program for the cylinders. The program also contains a lot of different algorithms to recalculate the groove center and there are also some methods included that are improving the sound quality. For more details of the program PRISM please refer to the report of Adrien Nicolet.

3.3.3 The whole process

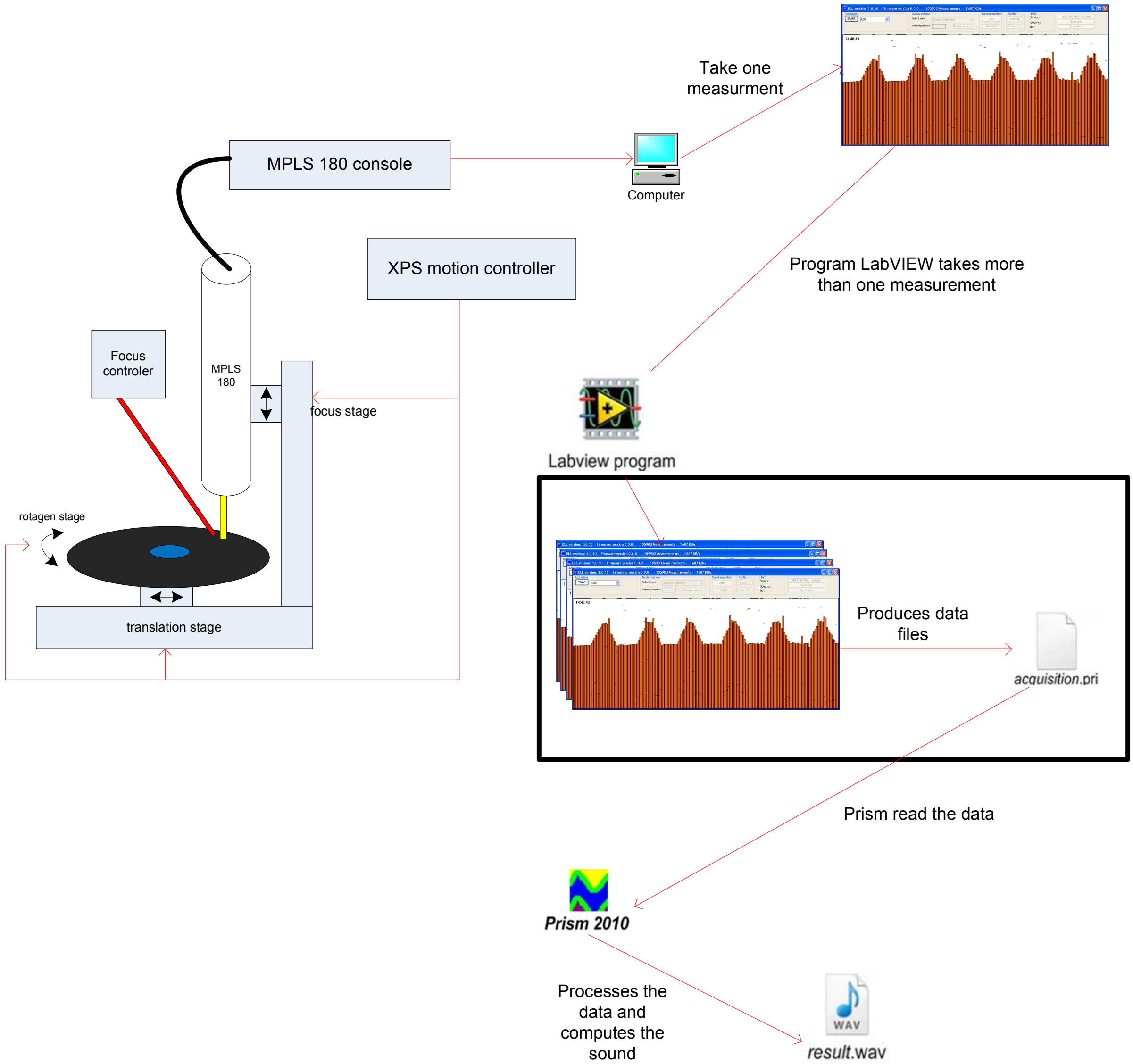


Figure 7 whole process from the acquisition to the sound file

The MPLS 180 measure 180 points at the time this is send to the PC and the program can show this one measurement as a image. The program LabVIEW takes a lot of this images and saved all this data in one file. The data are one after the other so that you get the data for a 3D image in the acquisition file. This file is read by the program PRISM which have different algorithm implemented, how calculate the groove bottom at all the times if and following after all this groove bottom this following the groove bottom make a movement in the time and is the movement of the stylus or in other words this is the sound on the disc.

3.4 MPLS180 probe

The new probe has a lot of changes. It has a new lens and two different fiber cables that go to the analyzer and not only one as it had before. Further all the mechanism in the probe has changed. The new probe has a depth of field of 350 µm, with 500 **µm** the old probe was bigger. This is not really better but it has the advantage that we have now a depth resolution of 90 nm, before we had one of 120 nm. The spots are now smaller, they measure a circular surface with a diameter of 2.5 µm, before it was 3.5 µm. New is also that the numerical aperture is 0.55. For the MPLS v1 it is not exactly defined, but it is smaller than 0.55. The rest is nearly the same or has not changed at all.[4]

3.5 USED PLATTER

For the calculation of the angle, explication follows later, I had also used the platter of the acquisition system. This platter is a normal aluminum disc which is produced to put the disc on it like on a normal stylus system. So this platter is the underground for the disc which is connected to the rotation axis of the system. It is not really clean and flat, but for the normal use it is okay. Another thing is that the platter is shiny. For the calculation of the angle the platter has a radial groove on it, that means that the platter contains a groove from the center to the border of the disc. During the project this groove was made with a normal machine, it is not a special groove. The dimensions of this groove is not the same in every place. Not both of the slopes are the same, one slope is steeper than the other. This groove is not to compare with the groove on a normal disc, it has different characteristics.

Figure 8 platter of the system with the groove

3.6 DIFFERENT ANALYZE

In this documentation I will make some different analyzes about the measurement for this I will always compare two method. Until the chapter 9 I use the program PRISM as it was at the beginning from this project I do not include the improvement from Adrien Nicloet. In chapter 9 and 10 I work with the new version from PRISM that also include the improvement from Adrien Nicolet.

For my test I will use every time the same metrics. This are first compare the spectrum of the generated sound file with PRISM, in the program Sony Sound forge, then analyze the SINAD and THD form the test disc and the SNR from normal sound disc, this analyze are explain in chapter 4. The last part would be comparing the audio resolution of the files.

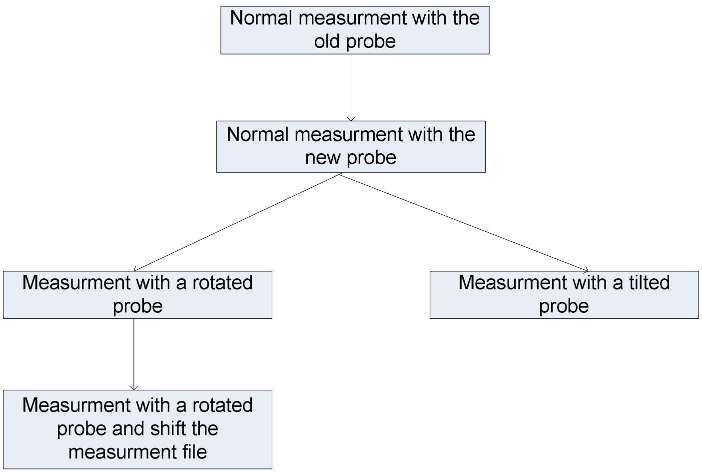


Figure 9 steps of the different improvement and analyzes

All steps are explaining it later in this documentation. I will always compare the new step with the step before. And at the end in chapter 8 I will give an overview overall improvement of this steps.

3.7 RECORDS USED IN THIS PROJECT

It is useful to compare different measurements with different records of different quality. So that we can compare the disc, I take some records that were also used in the project 2008. Then I compare the MPLS v2 with the MPLS v1. For the MPLS it is difficult to read the data if the disc is shiny. That means the disc reflects a lot. If the record reflects a lot, the light cannot go back to the right measurement point and gives a wrong data of the groove. If we have an old disc that has a lot of cuts or was used a lot, it is difficult to read the data.

Figure 10 Different types of records

The different discs are:

Label	Title	Disc type	Disc quality	Content	Named
Columbia	Constant tone frequency record	Mostly matte	Medium quality, fairly used	Single tones	Constant
Columbia	In the evening by the Moonlight	Mostly matte	Very bad quality, holes, cracks	Song by Stellar quartette 1908	Moonlight
Victor	Aloha Oe	Mostly matte, Acoustic recording	Old, very used, lots of holes	Song by the Hawaiian Quintette,1908	Aloha
Columbia	Wabash cannon ball	Shinny	Bad quality, widely used	American folk song	Wabash
Columbia	Old black Joe	Half shiny	Bad quality, hard to scan	Song by Taylor Trio	Old black Joe
Universal	Frequency record	Shiny	Good quality very shiny	Single tones	Frequency

4 ANALYSIS OF THE NEW PROBE MPLS 180 V2

In this part I compare the old probe MPLS v1 with the new probe MPLS 180 v2. I compare the picture of the probe and the quality. Further I explain how I calculate the SINAD and the THD, so that I can compare the probes.

4.1 DIFFERENCES OF THE PROBES

The new probe has differences, if we compare it with the old one. The main thing that is new is that the new probe measures a with a depth resolution of 90 nanometers, compared to 120 nanometers of the old MPLS v1. The depth resolution indicates that the value can change in every measurement some kind, it has a Gaussian distribution in which is σ is 90 nm. [4] The new MPLS can read the date in a much smaller range and read more steps in the groove.

4.2 COMPARISON OF THE IMAGE

All measurements here are with 2 milliseconds (ms) exposure time. We can measure with different exposure times from 59μs to 5ms. But, to read discs we often use 1.66ms (600Hz). In most of the cases, this exposure time gives a good result, but for very shiny discs it would be better to choose a smaller exposure time as that gives a better result.

If we take a longer exposure time the measurement is longer and we need more time, but the result of the measurement is more accurate.

The images that we can take show the depth of the measurement and the intensity of the measurement. The result of the measurement is inverted the upper side of the image is the disc and the lower side the orange part is the air. So the end of the orange part gives us the surface of the disc and the groove is the white area between the orange hills. The groove profile is upside down.

The intensity of the measurement says us how much light was returned in this point of measurement. The intensity depends on the reflection of the disc and can give us a value. It shows us how good or how bad a point of measurement is.

4.2.1 *IMAGES OF THE NEW AND THE OLD PROBE*

For all these images I use the same exposure time of 2.5ns, so that the results can be compared.

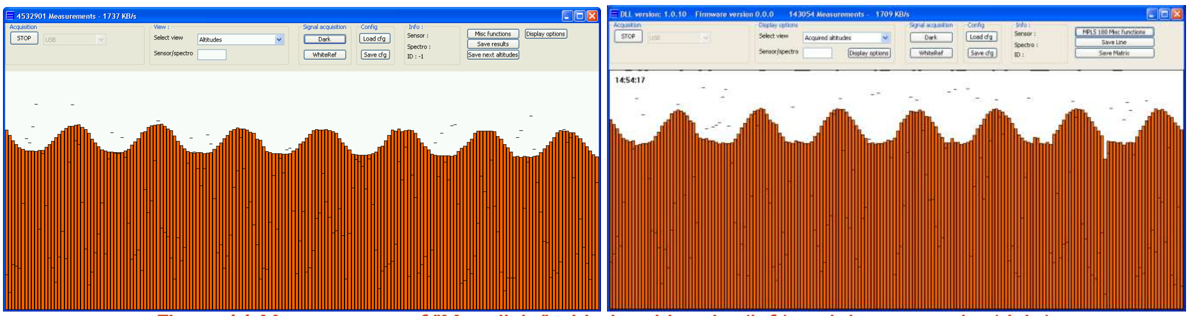


Figure 11 Measurement of "Moonlight" with the old probe (left) and the new probe (right)

A record that has a good quality to read with the MPSL v1 is the disc Moonlight. As we can also see, the MPLS v1 and the MPLS v2 can read this disc very well. The ranges of measured values are greater for the MPLS v2 which suggest greater sensitive. But both of them give a result, which we can reconstruct the groove with.

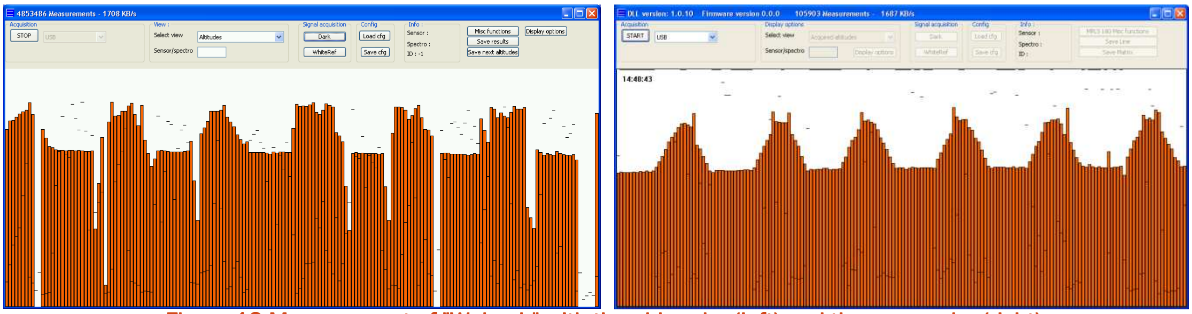


Figure 12 Measurement of "Wabash" with the old probe (left) and the new probe (right)

The Wabash is a disc that the MPLS v1 cannot read very well, but the MPLS v2 can read it quite well. For the MPLS v2 there exists some measurement points that are too deep. At these points, we do not have a big intensity. It is possible that the light reflects from one to the other groove.

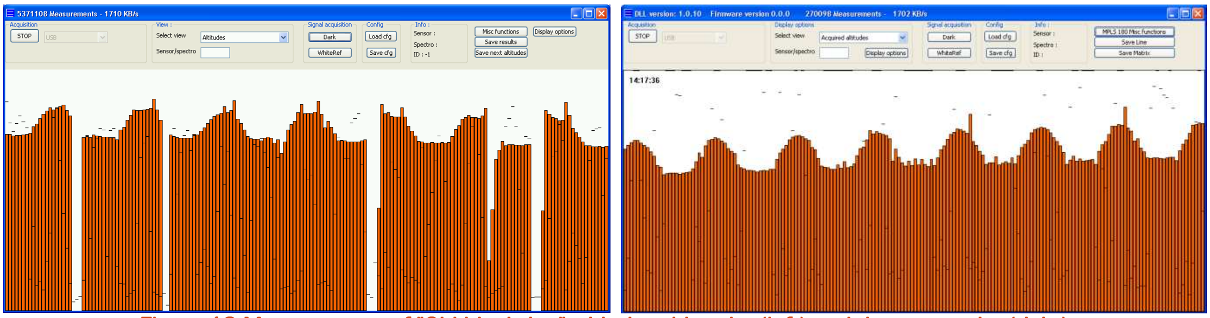


Figure 13 Measurement of "Old black Joe" with the old probe (left) and the new probe (right)

The same thing as for the Wabash disc applies also for the Old black Joe record. We have a much better result for both of these discs than we had from the old probe.

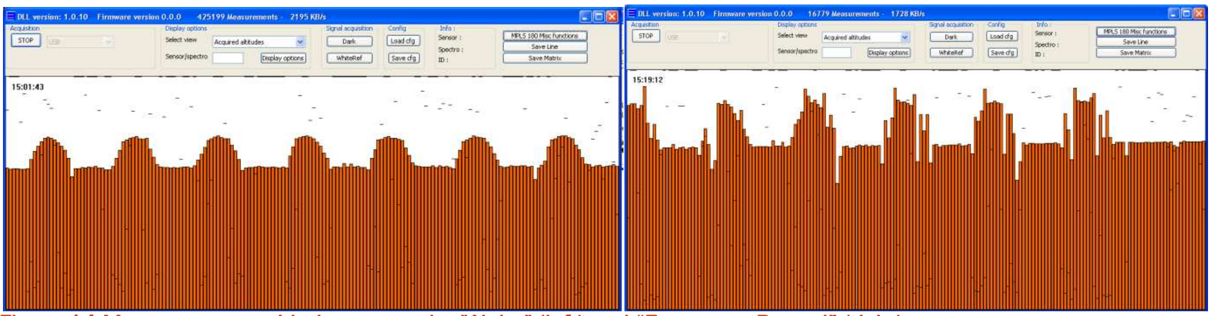


Figure 14 Measurements with the new probe "Aloha" (left) and “Frequency Record” (right)

These two discs are bad discs to read them optically. They are very shiny and reflect a lot. The old probe MPLS v1 does not read these discs. So we only have images from the new probe. The new probe MPLS v2 can read it. But not every measurement point gives a right depth. So some points are missing or wrong.

4.2.2 Conclusion to the image of the new probe

The images that we can get with the MPLS v2 are better than the results with MPLS v1. We can get images from records that were impossible to get with the old one. Not only the groove depth measurement is better in these pictures but also the intensity for the good points that we measure is higher than for the good points of the old probe. That means that we have a bigger difference in the intensity between the good and the bad points. So it is easier to keep apart the good and bad measurements.

4.3 COMPARISON OF THE SPECTRUM

To compare the spectrum and after also the SNR and the SINAD, the calculation are all made with the same parameters in the program PRISM. In the program PRISM exist different method to find the bottom of the groove, this different methods are explained in the documentation of Adrien Nicolet. I use the algorithm Fit-Line with the parameters Fit Num: 5 Width: 11 and Width Cut: 12. So all measurements are made under the same conditions.

4.3.1 COMPARISON WITH MEASUREMENTS OF THE MPLS V1

To compare the quality of a sound file it is necessary to check how the frequency spectrum looks. In this case I compare the spectrum of the old measurement with the new measurement from the same disc and the same place. So the two different measurements are both taken with an exposure time of 2.5ms and the measurement wave files are all made without some improvement. It is the file that we create only with the method Fit-Line.

If we check the quality of the new probe with the test tone disc we cannot find a big difference, because the old probe also has read this disc well. The spectrum for the fundamental frequency is nearly the same. The new measurement is a bit larger but not so much. For lower frequency the new probe is a little bit better, the high frequency we do not can compare because we do not sampling with the same frequency. With a faster measurement that means less sampling we get the same result as before. The high frequency could be filtered with a low pass filter. We can also see that the spectrum of the new probe does not have any harmonic peak. That means the sound quality is better.

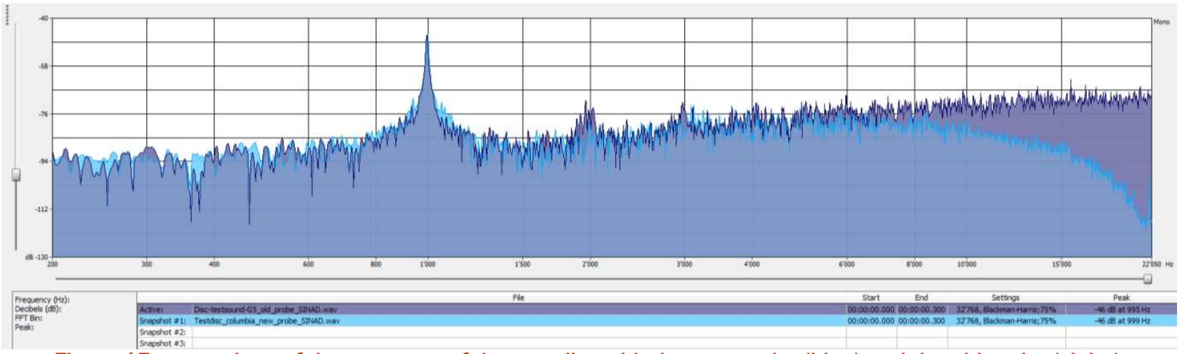


Figure 15 comparison of the spectrum of the test disc with the new probe (blue) and the old probe (violet)

If we test the new probe with the disc “In the evening by the moonlight”, also a disc with a good quality, we see that the spectrum of the new probe is the same. We also recognize that the new measurement with the MPLS v2 has a smaller spectrum for the high frequency. We do not know if the improvement in the high frequency comes from the new probe or only from a smaller sampling rate. The sampling rate for the old probe is not defined in this file. For high frequency in the MPLS 180 v1, there is not a sound that we want to hear, there is only noise. So we can also say for this good disc that the new probe gives a better result.

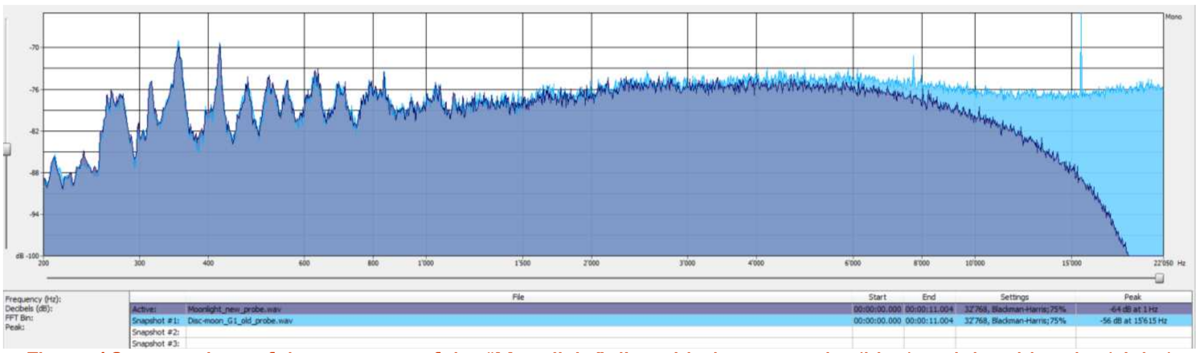


Figure 16 comparison of the spectrum of the “Moonlight” disc with the new probe (blue) and the old probe (violet)

4.3.2 SPECTRUM WITH MEASUREMENTS ONLY FROM THE MPLS V2

With the new probe MPLS v2 we can read more discs than we can read with the old probe. And we can get more examples of wave files, so we can also measure the spectrum of these wave files.

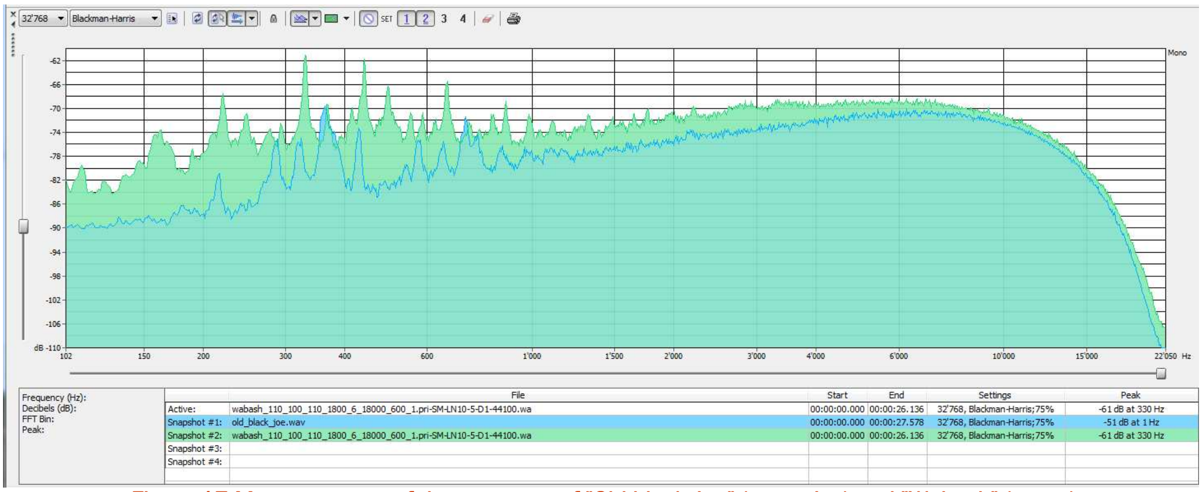


Figure 17 Measurements of the spectrum of "Old black Joe" (turquoise) and "Wabash" (green)

We can see that we now also can get the spectrum of the “Old black Joe” and the “Wabash”, which were indicated as unreadable in the two projects before.

4.3.3 CONCLUSION OF THE SPECTRUM

The Spectrum that we can get with the new probe is not extremely better for discs that can be read with both probes, but the spectrum is a bit more precise for the test disc and for the Moonlight. We can see that with the new probe we can get more discs than before. So the new probe is better and we get data that are not so bad. We are also sampling with a lower frequency and get the same result that means we measurement faster than before.

4.4 Comparison of the SINAD and the THD of both MPLS 180

If we want to compare some sound files it is good to make this in a way that we can use fast and that is not depending on the ear of a person. We aim to compare the files with only different numbers in order to say this file is better than the other one. We can make this in the way that we measure the SINAD (Signal to Noise and Distortion ratio) value and the THD (Total Harmonic Distortion) of a signal. In our case the signal to analyze is an audio signal.

4.4.1 Explication to the SINAD

We need the SINAD (Signal to Noise and Distortion ration) to define the quality of a signal. We want a SINAD that is high. A really good SINAD is about 55 to 60 dB. So the SINAD gives us a good value to compare some different audio files.

The SINAD is a value that compares the total input signal with the total input noise signal. It is a measure of the quality of a signal. It is calculated as follows: we take the average power of the signal and the average power of the noise added to the average power of the distortion. The sum is divided by the average power of the noise and the average power of distortion. [6]

$$SINAD = 10 * \log\left(\frac{P_{signal} + P_{nois} + P_{distrotion}}{P_{nois} + P_{distrotion}}\right)\ [dB]$$

We can only measure the SINAD on the test tone disc because only there we can find some single sinus. In a normal sound file we have always more than one frequency at one time and so we have at any time some diffusion from different frequencies.

4.4.1.1 The SINAD with LabVIEW

The analyzeing of the SINAD I make in LabVIEW because the program LabVIEW is also used to make the acquisition and is already used in this project. The program LabVIEW contains the advantage that it contains a lot of function for signal processing and analyzing. The programming for the analyzing does not need any extra libraries or anything else. Programming with LabVIEW is a language which programs on the interface. You have two fronts, one is the interface front which contains all the controllers and indicators and the second panel is the block panel. On this panel you make the connection from the controllers to the methods and back to the indicator with lines that you draw.
In LabVIEW, we have a function that calculates automatically the SINAD from a signal. So we can use the LabVIEW program to read audio files and to calculate the SINAD.

The SINAD Analyzer in LabVIEW calculates the fundamental frequency of the entering signal. It proposes to make an overlap of the fundamental frequency and the entering signal to calculate the SINAD.

$$SINAD = 10 * log\left(\frac{P_{rms\,in}}{P_{rms\,in} - P_{fundamental}}\right) = 20 * log\left(\frac{U_{rms\,in}}{U_{rms\,in} - U_{fundamental}}\right)\ [dB]\ [7]$$

A problem that we have with the calculation of the SINAD is that the discs are not really round and the center is not in the middle of the disc. That means that the frequency of the test disc can change a bit every time. The SINAD is calculated by the effect that it takes the signal and searches the fundamental and subtracts the founding fundamental from the signal. To compare the SINAD it is important to have a look at the noise signal. This signal does not contain a sinus, it should only contains white noise. And the spectrum of the noise must be random. If this is the case the SINAD is right.

The second thing to control is to calculate the SNR itself. In this case the program searches the fundamental frequency and calculates at which point the fundament is. You can choose which window you want to use for the FFT. Then the program calculates the sum of all points in the fundament and for all points around the fundament. With these two pieces of information the program calculates the SNR.

The program LabVIEW which I have written contains some different measurements. The first measurement is the SINAD with the method in LabVIEW. This is a block that subtracts the founded fundamental sinus from the entry signal. The second thing is a plot of the sound without the fundamental sinus. This short sound file looks only like white noise. And the third part is a calculation of the sum of all points in the fundament and the sum of all points around the fundament. With this information the SNR is calculated.

To check if the SINAD is correct, it is important that you only have white noise in the graphic and not any different frequencies in the noise that you can detect.

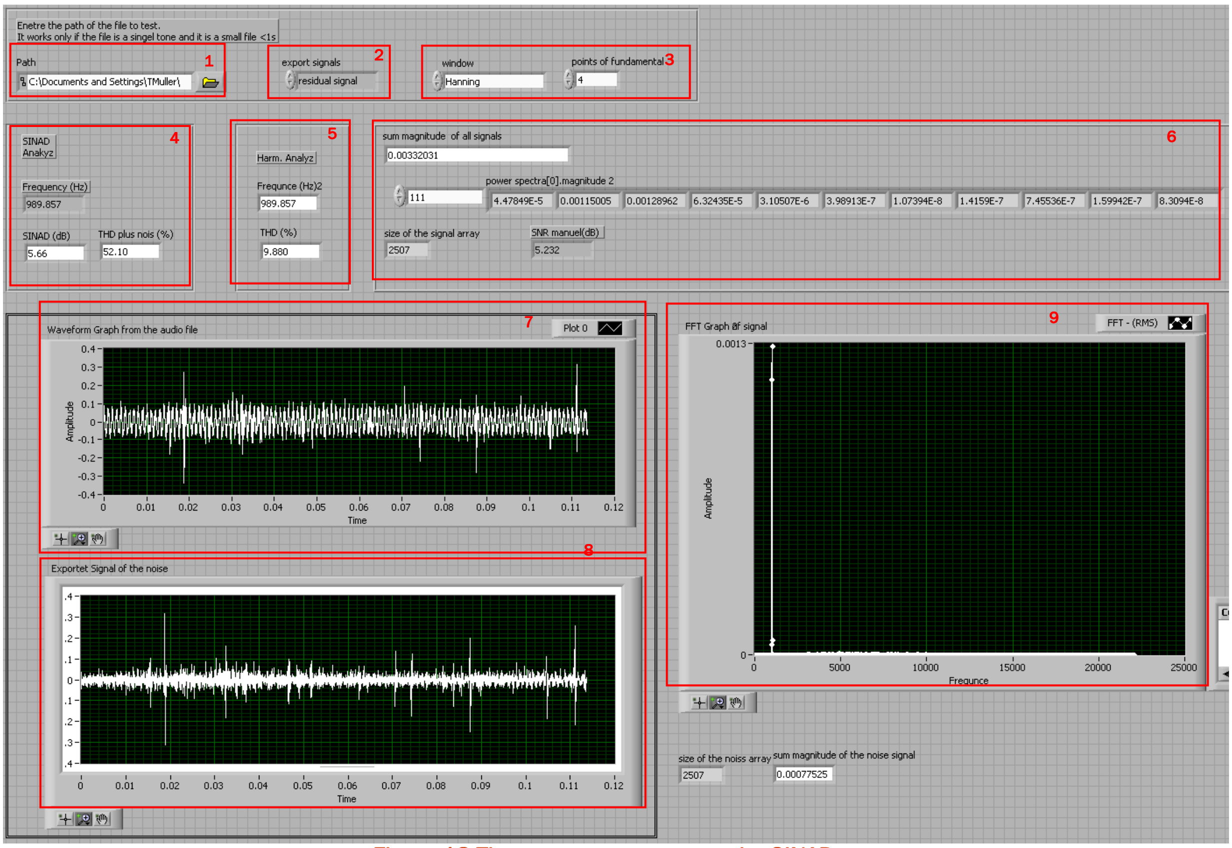


Figure 18 The program to compare the SINAD

1) Choose the file to test. It must be short because of the different frequencies on the disc
2) Choose the residual signal to get only the noise back in the graphic
3) Choose the window for the FFT transformation and the points that must be calculated in the fundament of the SNR
4) The result of the SINAD calculation from the program LabVIEW with the fundament
5) The result of the THD calculation of the program LabVIEW
6) The result of the calculation SNR with the FFT function
7) The wave signal from the input file
8) The wave signal from the expected signal of the SINAD function in LabVIEW
9) The FFT function with the amplitude

4.4.2 EXPLICATION TO THE THD

The THD (Total Harmonic Distortion) is a measurement of the harmonic distortion that is present. The THD is defined as a ration of the sum of the powers of all harmonic components to the power of the fundamental frequency. So with this value you can compare how much energy is in the harmonics and how much is in the fundament. [1]

$$THD = \frac{P_2 + P_3 + P_4 + \cdots + P_\infty}{P_1} = \frac{\sum_{n=2}^{\infty} P_n}{P_1} \quad [\%]$$

4.4.2.1 The THD with LabVIEW

In LabVIEW there exists a method to calculate the THD automatically, the Harmonic Distortion Analyzer. But only if we use the test disc, because also here we need only one frequency that exists and some harmonicas to calculate. [7]

The Harmonic Distortion Analyzer calculates the fundamental frequency and all harmonic amplitude levels, so that he can calculate the total harmonic distortion. As you need the THD in percentage you must multiply the result of the analyzer by 100. We want to have a small value for the THD, which means that we do not have a lot of power in the harmonicas, all the power is in the fundamental frequency.

For the calculation of the total harmonic power, the LabVIEW program calculates the sum of the voltage square and takes the radical of the sum.

$$THD = 100 * \frac{\sqrt{{U_2}^2 + {U_3}^2 + {U_4}^2 + \cdots + {U_\infty}^2}}{U_1} \quad [\%]$$

4.4.3 EXPLICATION TO THE SNR

The SNR is only the Signal to Noise Ratio. It seems similar to the SINAD, but it calculates only the signal that you can use to the noise of a signal. It is defined as the ratio of signal power to the noise power corrupting the signal.

The signal to noise ratio is better when it is big. A file with a good quality of sound has a SNR of 55 to 50dB.

$$SNR = 10 * log\left(\frac{P_{signal}}{P_{noise}}\right) \quad [dB]$$

If we want to calculate the SNR that exists from a sound file, there exist several methods. One method is to take a measurement with sound and one without sound. And then we compare the power of the part with sound to the part without sound. In this method we have the problem that we are not sure to have the same noises in the part with as in the part without sound. The other method is to take a file and have a look at a part of the spectrum where sound is not possible and take this power intensity as the noise. The noise power is at all frequencies the same and we take this noise as the general noise in the high frequency. The problem for this method is that we are not sure that the noise is constant on all frequencies. And if you use an algorithm that only improves the frequency that you take as a noise, you also get a wrong measurement.

To test the quality of audio records it is better to take the first method, as in the records we have the noise from the stylus that makes the groove. And this noise is often the same in the part of the sound file with sound and without sound.

4.4.3.1 Calculation of the SNR with LabVIEW

We can calculate the SNR with all sound files. If we want to calculate the SNR, we use a signal that we can compare with a signal that contains only the noise. For this case, the best thing is to take the normal audio signal, which contains real song information, as the power of signal input. And for the noise input we take a part of a file from the same disc but without song information. That means that we take a part from the beginning of the disc or between the songs. This part contains only noise, but no information.

If we compare the signal of the sound with the beginning of the disc, we do not get the accurate SNR because we do not know how the noise is in the part we have sound information. But this calculation allows us to compare the different measurements.

In LabVIEW we take the RMS voltage from the signal and the RMS voltage before the sound and then we take the logarithm of this.

$$SNR = 20 * \log\left(\frac{U_{sound}}{U_{befor\ the\ sound}}\right)\ [dB]$$

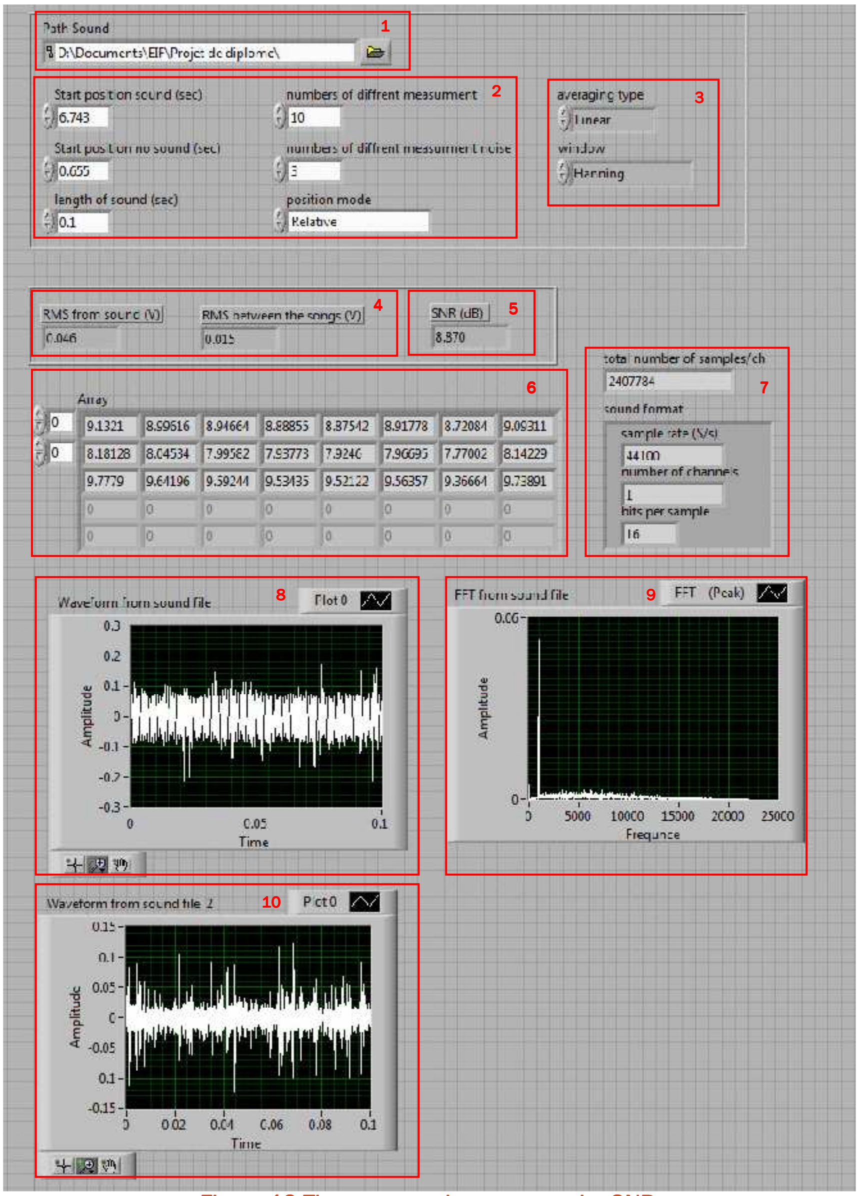


Figure 19 The program the compare the SNR

1) The path for the sound file is necessary.
2) -Two points of the sound are necessary, the first point is the start position for the sound file and the second point is the start position for the noise part of the disc.
   -The length of both sound parts are requested. It should be over a longer distance, so that the sound is less delicate to some particular noise (1-2sec)
   -Number of different sound measurements. That means it takes one or more times the sound part and compares this one with the noise part. For the first measurement it takes the start position, for the other it takes as start position the point of start plus the length of the sound.
   -Number of different noise parts as the sound part takes more than one noise part . Compare all the different noise parts with all the different sound parts.
   -position mode: with absolute it takes the start position from the beginning of the file, with the mode relative it takes the start position at the current location of the file mark plus position offset. (Normal is Absolute)
3) Is used for the calculation of the RMS
   -averaging type is the type of averaging used during the measurement:
   - -Linear –Integration time is equal to the record length
   - -Exponential- Time constant is half the record length

   -Window applied to the time record before RMS computation
   - -Rectangular (no window)
   - -Hanning
   - -Low side lobe
4) Result of the last measurement of the calculation of the RMS. The first value is the RMS value of the sound file and the second value is the RMS of the noise file.
5) The mean value of all different SNR calculations (dB)
6) The output array of all different calculations of the SNR. The rows are the different parts of the noise and the colons are the different parts of the sound.
7) Information about the sound file.
8) The graph of the wave from from the file with sound.
9) The FFT transformation from the last sound part.
10) The FFT transformation from the last noise part.

The result of the measurement is good if all different measurements of the sound part and the noise part are nearly the same and not that at one place the SNR is small and at the other place the SNR is big. We want to have a SNR that is nearly constant. For this it is better to compare the noise with a longer part of sound and noise.

In this documentation the program that is used is in the basic the same, but it works with two different files at the place of one with start and position. The calculation in the file is the same and gives the same result, but with this program it was too difficult to compare a lot of different files. So this new program is easier to use and gives more comfort. One other thing that has changed at the end of the project is that it is better to compare the SNR with longer parts of sound and noise. The reason is that the SNR is more stable and does not change so fast. With short parts of sound and noise the SNR can change very fast. So the next tests are all done with small files. In chapter 10 the measurements are done with longer files and you can see that the SNR is more stable and does not change so much.

4.5 Comparison of the sound from both probes

4.5.1 Comparision of the Test disc

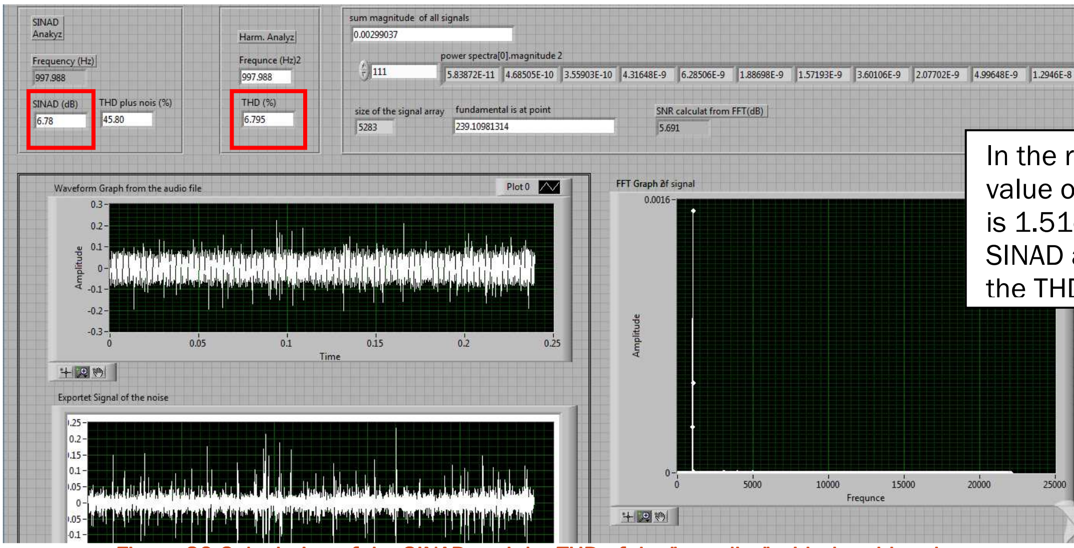
4.5.1.1 Calculation of the SINAD and THD with LabVIEW

With the SINAD method in LabVIEW we can only calculate the quality of the single tone disc (Test tone disc). If we have a normal disc, which contains real songs they always have some overlaps of more than one frequency.

This test with LabVIEW only works with short sound files, because the SINAD analyzer makes an overlap of the fundamental frequency that it found and the entering signal. The fundamental frequency is not so exact that we can take an input file that is long. We can only test files that are small. That means only 0.4 seconds or less in the case of a frequency around 1kHz

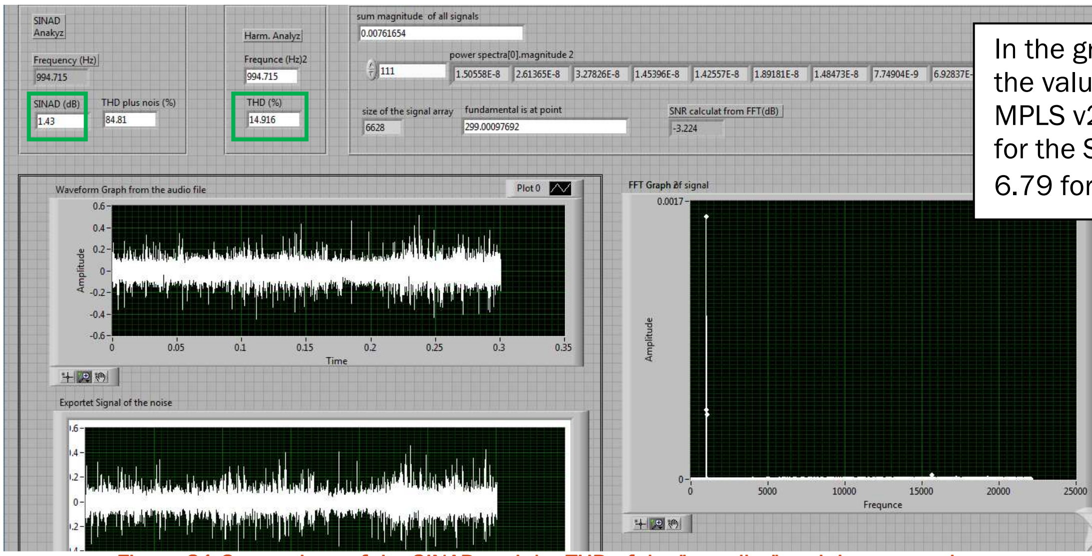
4.5.1.2 Comparison of the SINAD and the THD

We compare some files from the MPLS v1 and v2. For this comparison we take a file that is only 0.1 seconds and we take for both files the same frequency. Both files are made with the same disc but not in the same year so that the new probe measurement is two years later. That means that the disc cannot be better, because the disc is not stored cleanly and carefully in the laboratory.



In the red quad the value of the MPLS v1 is 1.51dB for the SINAD and 14.9 for the THD.

Figure 20 Calculation of the SINAD and the THD of the "test disc" with the old probe



In the green quad the value of the MPLS v2 is 6.78dB for the SINAD and 6.79 for the THD.

Figure 21 Comparison of the SINAD and the THD of the "test disc" and the new probe

If we compare some small files from the test disc, we arrive at a SINAD of 1.5dB for the old probe and 6.8dB for the new probe. These values are not very exact and depend on the part of the disc we take. But with these values we can compare the new probe with the old probe. And we see that the SINAD of the new probe is better than the one of the old one. It is not the best quality, but the new probe is better than the old one. We get a difference of 5.3 dB that the new probe is better than the old one.

If we compare the THD we see as we have already seen in the spectrum, that the new probe had less power in the harmonicas, which means that we have a sinus that is better for the test disc. We read a sinus that is more precise than before. We have now a value for the THD that is 6.8% and we want a THD that is as small as possible.

To control the SINAD calculation I made the calculation in the program SINAD itself with the FFT transformation. He takes the fundamental at 997Hz and takes with the window rectangular 3 points of the FFT.

The calculation gives the result:

$$10 * \log\left(\frac{0.00299}{0.00299 - (0.00026 + 0.00153 + 0.00052)}\right) = 6.6dB$$

The result of the SINAD looks good if we take a part of the disc in which we have only one frequency. You can find it if you look at the extracted noise and this noise is only white noise.

4.5.1.1 Compare the SNR

We can compare also the SNR from the test disc. Therefore we test the frequency at 1000Hz and we compare it with a part of the disc that does not contain some tone information.

In the red quad the value of the MPLS v1 is 1.37dB SNR. In the green quad the value of the MPLS v2 is 7.3dB SNR.

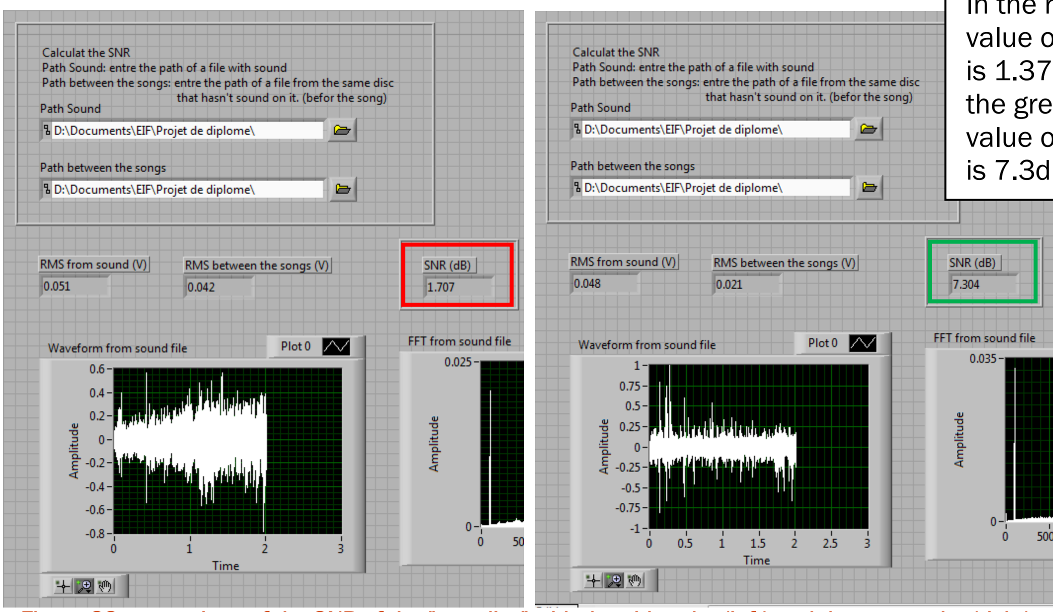


Figure 22 comparison of the SNR of the "test disc" with the old probe (left) and the new probe (right)

The SND for the old probe is 1.3dB and for the new probe we arrive at a value about of 7.3dB. So these values are similar to the SINAD that we have calculated before. We can say the calculation of the SNR is not so bad. It is possible that the SNR is higher than the SINAD, because we do not take the noise from the same place of the disc and we do not calculate the distortion value of the sound file.

4.5.2 COMPARISON OF SOUND DISCS

WE we can also calculate the SNR from a normal sound disc. Therefore it is important that there exists a file with sound and one without.

4.5.2.1 Comparison of the SNR

The disc with the file that we can read with the old probe and the new probe is the disc “Moonlight”. If we compare the SNR from both discs. The problem to compare is that we do not have a file with only noise on this disc. But we can find some part that does not have sound on it.

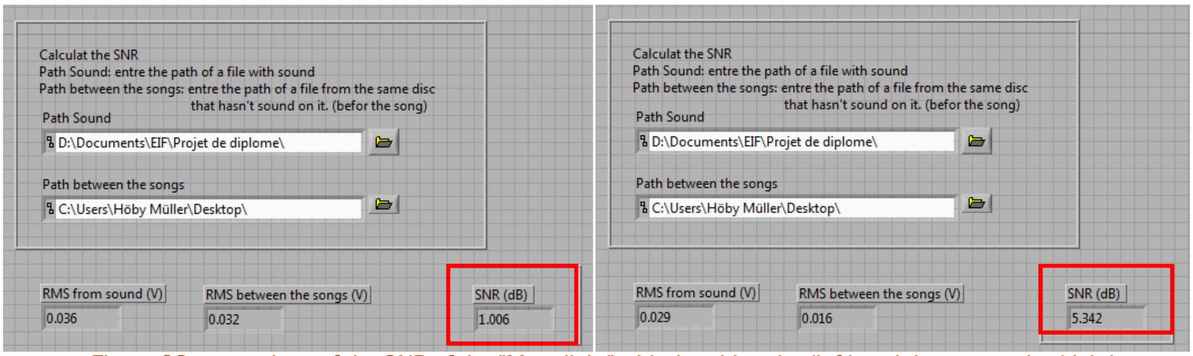


Figure 23 comparison of the SNR of the "Moonlight" with the old probe (left) and the new probe (right)

We find a SNR of 1.1dB for the old probe and a SNR of 5.3dB for the new probe. The new probe is 4dB better, if we compare with this record.

So two other measurements that we can make with the new probe is the disc “Wabash” and the disc “Aloha”. And we can get the SINAD from it. To make the Comair is not possible because the old probe has not read this disc.

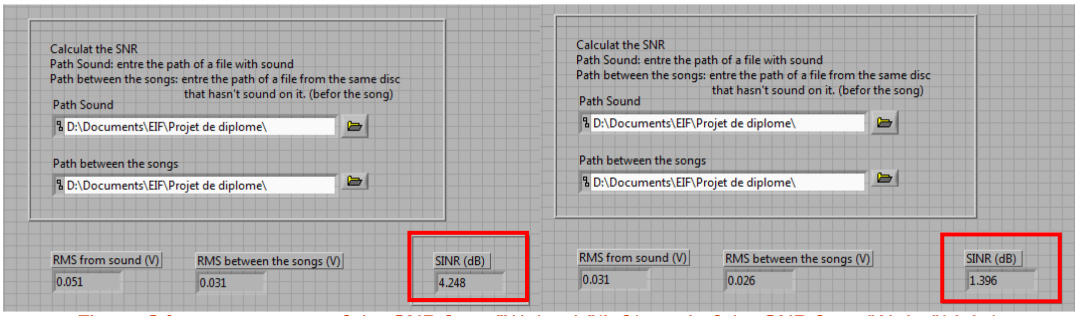


Figure 24 measurement of the SNR from "Wabash"(left), and of the SNR from "Aloha"(right)

We get a SNR for the Wabash of 4.2 dB and for the Aloha a SNR of 1.4 dB. These results are very low and we can say that these files are not good. These files are made with the algorithm Fit-Line and without some improvement. So the disc has a lot of potential to improve them.

4.5.2.2 Discs that we cannot read

With the new probe we cannot read all the discs. If we measure with the normal position of the probe. We have some problem with the disc “Old black Joe” a disc that is not so shiny, but that is not plain. It is a bit bended and that has the consequence that we cannot read all of the 180 points from the probe with the right groove depth. The program PRISM cannot find the groove at this point.

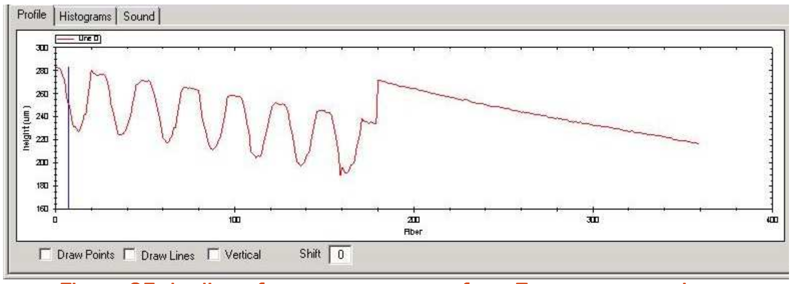


Figure 25 the line of one measurement from 7 grooves goes down

The other test disc with different frequencies on it is too shiny. So if we measure this disc, we get the problem that we have a lot of reflections with a normal measurement.

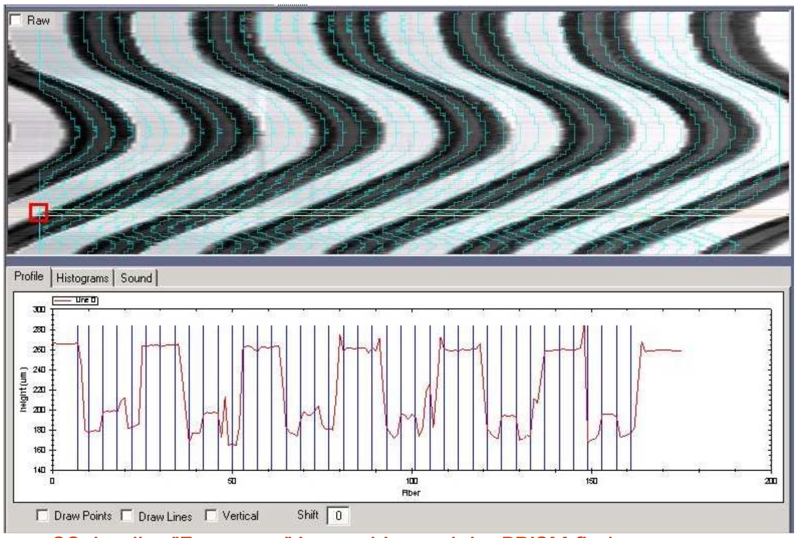


Figure 26 the disc "Frequency" is too shiny and the PRISM finds too many grooves

We can see that the program PRISM finds too many grooves because it has some reflection at the slopes and that makes the measurement much lower than it really is.

4.5.3 Comparison of the audio sound

One of the most important thing to compare in this project is what we hear and how that the wave files look. It is not always easy to say which file is better. Sometimes it occurs that the file is better in some frequency than the other and inverse. And it can depend on the part of the file that you hear that not every measurement has the same quality.

4.5.3.1 Comparison of the sound from the test disc

You can hear that the new probe is a bit better. It contains not so many frequencies as the old one. But the difference is not so big. One problem with the new probe is that it contains smaller clicks in it. It is difficult to say where these new clicks are from. The reason could be in the new probe or because the disc was not stored well.

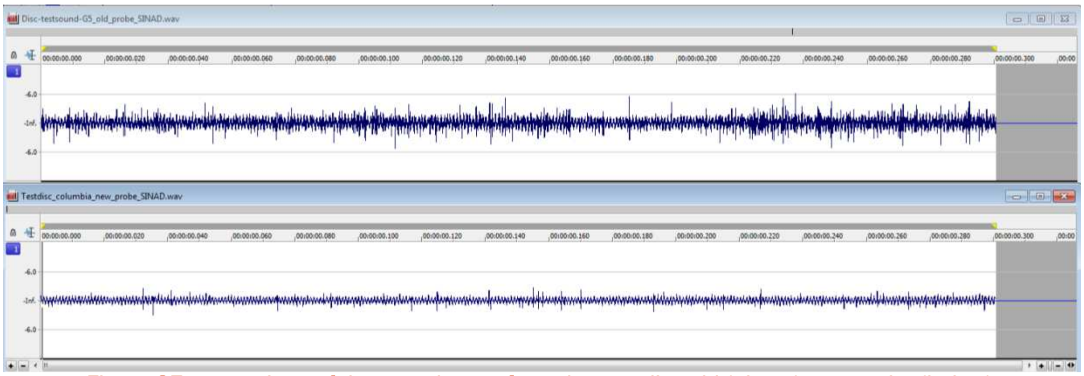


Figure 27 comparison of the sound wave from the test disc old (above) new probe (below)

If you have a look at the wave form of these 2 files the wave from above is from the old probe and the other from the new probe. It is the same frequency and has the same axis. The spectrum is this one in Figure 15 comparison of the spectrum of the test disc with the new probe (blue) and the old probe (violet). It has the same fundamental intensity. So you see that the new measurement gives us a sinus that is better and does not have so much different frequencies.

4.5.3.2 Comparison of the sound from the disc “Moonlight”

Also for this comparison we take two files that have the same sound part and give the sound to the same intensity. The sound is not really different. We have the same problem with the new probe, we also have a lot of clicks. But in general there is not so much noise. For the new probe it is easier to understand the words in the song. But the clicks are disturbing a lot.

4.6 Conclusion MPLS 180 v2

If we make a short summary of the new MPLS 180 v2 we can say that the new probe is better than the old one. The reason is that we can read more discs than before. If we look more precisely, we can see that for the disc that the old probe also had read, the new probe is not much better. We see that the new probe has a much better solution in the high frequency and it is more precise in case of harmonics. So at this part we can say that the new probe is a better solution than the old one.

5 REFLECTION ON THE DISC

5.1 EXPLICATION TO THE REFLECTION

One problem with the shiny disc that exists is, that we have too many reflections that go into the probe and are measured. We can see that the reflections are on different points of the slope, but they are always at the same place.

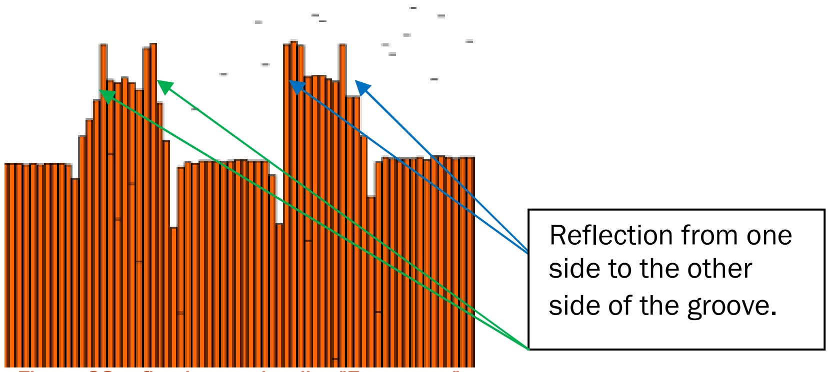


Figure 28 reflection on the disc "Frequency"

Remember, this image is taken the record upside down. So you can see that the high peaks in the image are depth measurements.

It is not for all discs the same point of the slope that has a too deep measurement but on one disc it is the same position at the most groove. The second thing that we can recognize is that we often have a reflection at both sides of the groove.

A possible problem is, that the signal, that the probe sends is reflected at the slope and for some angles it occurs that the sending signal from one measurement point goes to the opposite slope and is there also reflected in an outer measurement point of the probe. As the groove is the same on both sides, we also have the other way of the reflection, so that both sides of the groove have a measurement that is too depth. We can also see, that the light, that we measure often is the same at both slopes. Therefore the way for the light must be the same in both directions.

So we have a wrong measurement with a large depth. Now we have more than one possibility to change some measures.

5.2 Solutions for the reflection

The first solution is to change the firmware because the new firmware has a first measurement solution included. That means that we make a threshold and if we measure enough energy, we save the depth of this point.

The second solution is to rotate the probe. That means we turn the probe on its axes. If we rotate the probe it is possible that the reflected light does not go into the other measurement point and we get only the light back that we want.

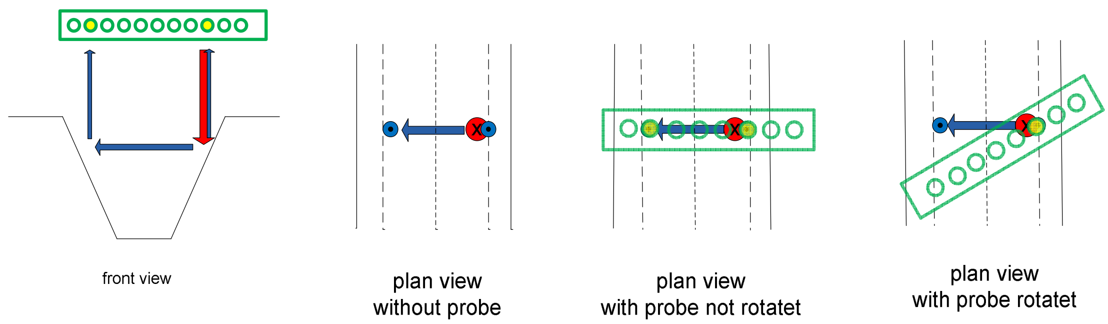


Figure 29 the problem from the reflection in the probe and the rotation

We want to find out, if there is no reflection that goes into the probe, when we turn the probe. As we work with light and as the reflection does not only go in one direction, it is possible that the light that goes in another direction does not have enough energy to measure in the fiber.

The third solution is to test if we can tilt the probe for some degree in order to get a better solution. We only want to test if we can tilt the probe for some degree, so that we do not have to read the disc two times, as they did it last year. If it is possible to read both slopes of the groove and calculate then with this data, the groove bottom.

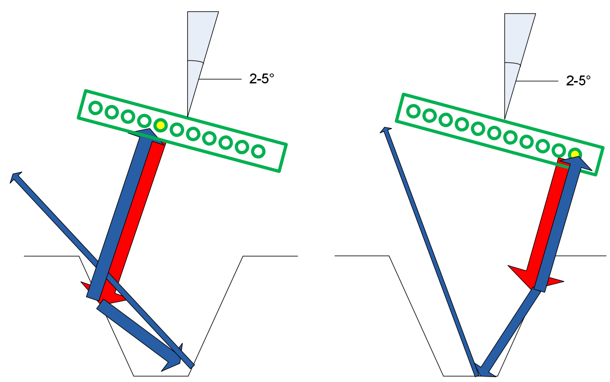


Figure 30 Different measurements if the probe is tilt for some degree

It is important that we can read both sides of the groove without any reflection and that we can measure many of the 180 points. So the challenge is to measure both sides of the groove without having the reflection in the probe.

5.3 CHOICE OF THE SOLUTION

The first measurement result is not as expected. The new firmware does not have a better solution as we cannot only read the first measurement. It is too difficult to find the right threshold, in order to get only the depth that we are looking for. If we take a threshold that is too high we do not get all the slope points. If we take one that is too small, we measure a reflection as normally. The threshold is not the same for every disc. That means that you cannot find the right threshold once and always have good measurements with all groove points.

The best threshold for one disc does neither give a result that is acceptable. Until a threshold of 200 the measurement has some missing parts. If we take a threshold that is only a little bit bigger the measurement has some other parts that are missing. In every case of the measurement it has some missing parts.

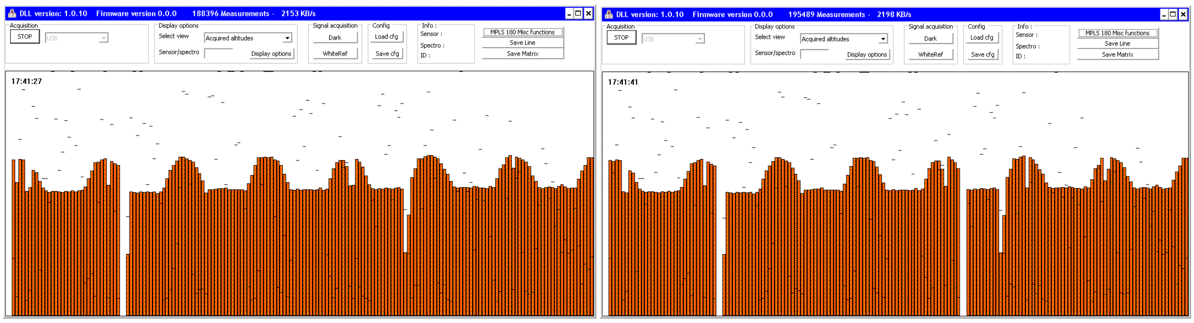


Figure 31 first measurement solution with threshold 200 (left) and threshold 220 (right)

The threshold solution is not the right solution. That means that the other two possibilities to get less reflection look better after the first measurement. Further measurements for these two solutions are necessary.

The results for the probe with rotation and the tilted probe are better. To check how well the solutions are, it is important to see which one is better. So these two results are explained and checked precisely in the next two chapters.

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6 ROTATION OF THE PROBE

We talk about rotation of the probe, if the probe keeps the horizontal position, but makes a turn in its axis. With this rotation we want to test, if it is possible not to have so much reflection as we had before.

6.1 ANGLE OF THE ROTATION

The angle of the rotation is important. If the angle is too small, the light reflection goes into the probe. It is better if the angle is not too large, because we read a smaller part of the disc if we rotate the probe more.

For the rotation is important that we rotate more than, the maximal movement of the groove in the lateral is. The maximum change in this direction has an angle of 10°. We must have an angle that is bigger than this 10°.

The first test proved that this is correct. If we take an angle that is smaller than 10° we have the same reflection as we have without rotation. With more than 10° we have less reflection that goes into the probe.

The distance of that we can measure with an angle of 10° is:

$$d = \cos(10°) * 1.8 * 10^{-3} = 1.77\text{mm}$$

The distance with 20° is 1.69mm and for 30°it is 1.56mm. We did not loose so much of distance that we can measure, if we rotate the probe.

6.2 REFLECTION OF THE MEASUREMENT

If we measure some discs, that the probe has also read before we rotated the probe, we do not find any differences. We get the same image as before.

If we measure some discs that we could not read very well with the normal position of the probe, we get some points of the measurements that are better.

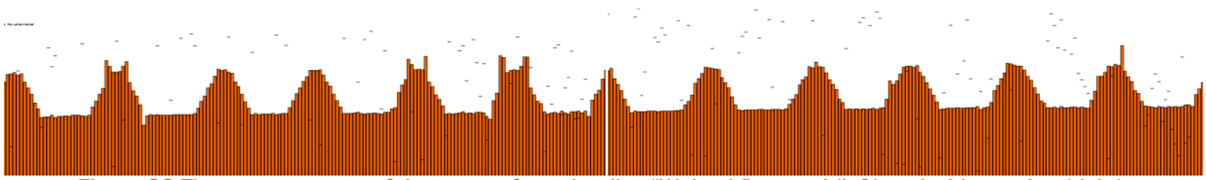

Figure 32 The measurement of the groove from the disc “Wabash” normal (left) and with rotation (right)

If we measure the disc "Wabash", we see that we get some better measurements. A lot of reflections disappeared and we get an image with the measurement that is much better than the normal measurement.

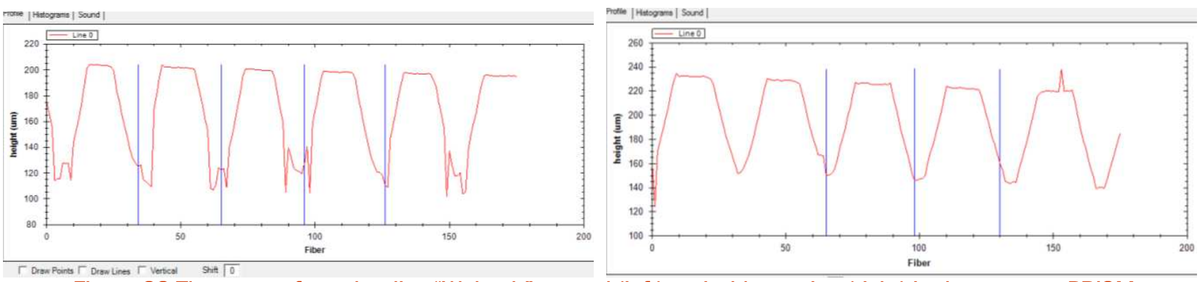

Figure 33 The groove from the disc “Wabash” normal (left) and with rotation (right) in the program PRISM

Also the image from PRISM is much better than before. We see the groove (red line) is really nice, and it did not have a lot of points that are reflected and have a false depths. So the groove bottom can be detected precisely.

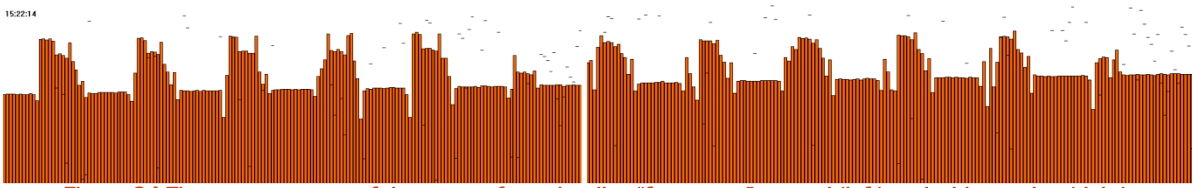

Figure 34 The measurement of the groove from the disc “frequency” normal (left) and with rotation (right)

For discs that reflect a lot, like the disc constant tone frequency record, we get a measurement that does not have a lot of reflection. The measurements of the points are not so deep, they are much better than before. The problem is that we measure some points wrong when they measurements points are too high. Not all of the points are in the right place.

6.2.1 COMPARISON OF HOW MANY POINTS ARE IN THE GROOVE TOLERANCE

One thing to test is how many points are in the tolerance of the groove. That means how many points are in the 70µm of the groove. So I take all points from 100 measurements, what makes 18'000 points and then I calculate how many points are not in this 70µm from the groove. For this I calculate the mean value of all points and take 35µm more or less and add some tolerance for the disc difference (15µm). At the end I count all the points that are bigger or smaller than the mean value plus or minus 50µm.

For the disc Wabash, I calculate that in 100 measurements I had for the normal measurement 239 points were wrong. In the rotation measurement I calculate only 11 points that are wrong.

Method	**Incorrect points too depth**	**Incorrect points too high**	Total points out of the groove	Percentage
Normal	232	7	239	1.3%
Rotation	5	6	11	0.06%

Figure 35 Calculation of points that are not in the groove tolerance for the disc “Wabash”

So we can say that in 18'000 points we have with the rotation of the probe, only 0.06% of the points are wrong. Before we had 1.3% points that were wrong.

I did the same test as before for the disc frequency, which is shinier. We did not get a good result for the normal disc.

Method	**Incorrect points too deep**	**Incorrect points too high**	Total points out of the groove	Percentage
Normal	783	546	1329	7.4%
Rotation	240	48	288	1.6%

Figure 36 Calculation of points they are not in the groove tolerance for the disc “Frequency”

I get a result that has fewer points out of the possibility of the groove. I reduce this point to 5.6%, but that does not mean that all other points are right. They are in the groove tolerance and not too high or too low.

6.3 SPECTRUM IF WE ROTATE THE PROBE

If we compare the spectrum of the measurements of some discs that had a good quality when reading with the optical method, we get a spectrum that is very similar. We did not have a big difference between these two methods.

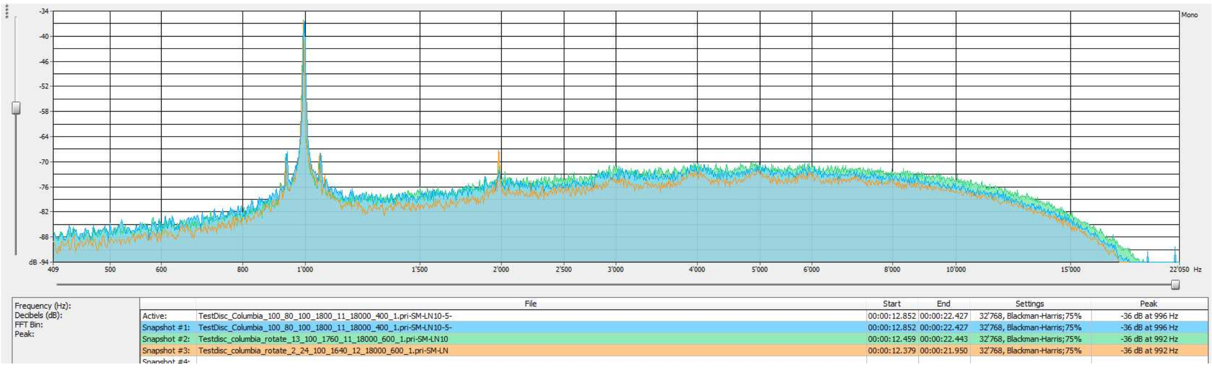

Figure 37 Spectrum from the Test disc with normal position (blue), 13° rotated (green) and 24° rotated (orange)

The spectrum is for all three variant nearly the same, the best solution looks in the figure with a rotation of 24° because the noise is lower than in the other measurements. With a rotation for 13° we get more noise but the intensity of the first harmonic is lower. But for the test disc, the rotation does not make a difference. It is only the echo that we got in the sound.

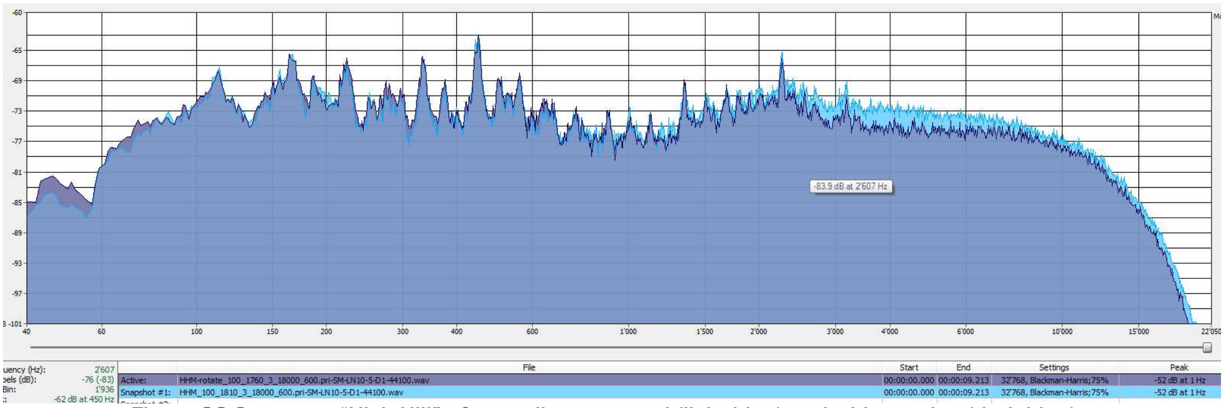

Figure 38 Spectrum “High Hill” of a small part normal (light blue) and with rotation (dark blue)

For the disc High Hill we get nearly the same spectrum. Only in the high frequency of more than 200Hz the spectrum of the rotated probe is a bit smaller than before. It is about 2dB smaller, the quality of the sound is nearly the same.

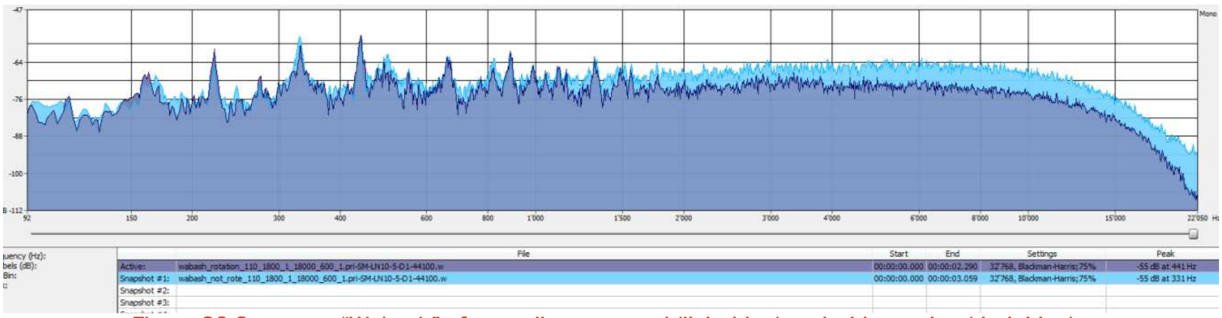

Figure 39 Spectrum “Wabash” of a small part normal (light blue) and with rotation (dark blue)

For the spectrum of Wabash (Figure 39) we have to remember that it is a disc with some reflection on it. With the normal method we get a spectrum that is the same in the low frequency and in the high frequency it is different. The new spectrum is smaller in these frequencies. With the spectrums we cannot say which of these two spectra is better.

6.4 COMPARISON OF THE SOUND

6.4.1 COMPARISON OF THE TEST DISC MEASUREMENTS

The comparison of the test discs checks if we can get a better measurement, if we rotate the probe or if the result is in minimum of the same quality. The test disc can be read well with the normal position of the probe. So we do not want that the rotated probe gives us a worse result.

6.4.1.1 Comparison of the SINAD and the THD

The rotation angle of the probe is also something that is not clear. Which is the best angle to get the best result? It is difficult to get an angle that is very precise with the probe. So the angle can change a bit. The first two measurements are with an angle of 13° and 24°.

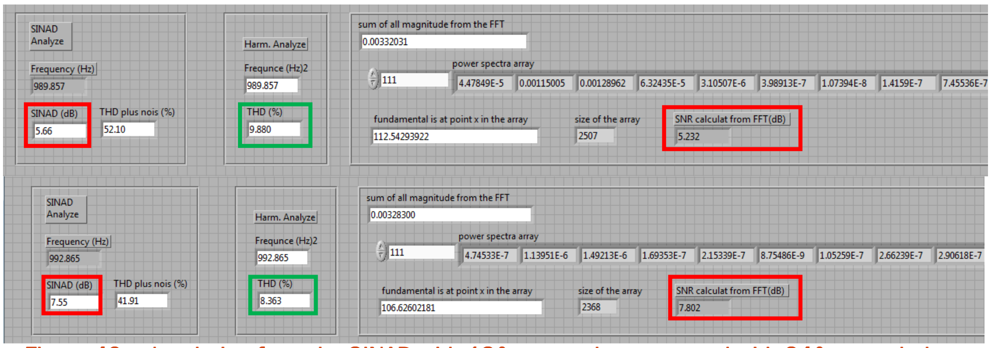

Figure 40 calcualation from the SINAD with 13° rotate above and with 24° rotate below

If we compare the SINAD with 13° and 24°, we can see that the measurement with 13° rotation gives us a SINAD of 5.7dB and the measurement with 24° gives us a SINAD of 7.6dB. The measurement of 24° rotation is a bit better than the measurement with 13° rotation. To compare is, how much the SINAD for the measurement without a rotation was. This SINAD was 6.8dB and the THD was 6.8%. The measurement with only 13° is worse than without rotation. The rotation with 24° is a bit better but not so much, it seems like the same.

If we calculate the SNR with the FFT transformation we arrived at a SNR of 7.8dB, what is a bit better than before. The wrong result that we get comes from the wrong frequency in the noise part. You can find some small sinus structure from another frequency. It is very important that we compare with a point of the sound, in which the frequency does not change.

6.4.1.2 Comparison of the SNR

The comparison of the SNR in this part is only to control the measurement of the SINAD and the program SNR. The SNR is not really the SNR that we calculated. It is a comparison of a part of the sound file without sound in it and a part with sound. The result for the test disc must be nearly the same as the SINAD.

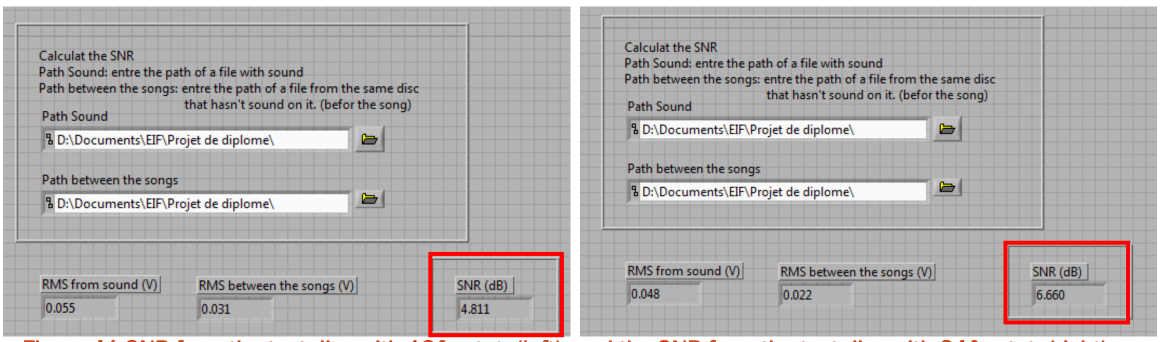

Figure 41 SNR from the test disc with 13° rotate(left), and the SNR from the test disc with 24° rotate(right)

For the SNR we nearly get the same values as the SINAD, for a 13° rotation 4.8dB and for a 24°rotation 6.7dB. The quality changes nothing compared to the probe in the normal position.

6.4.2 Comparison of sound discs

To compare sound discs, we need the SNR method. We can compare the same part of the sound with the rotated SNR and with the SNR not rotated.

6.4.2.1 Comparison of the SNR

For the first test, we also compare the value of rotated measurement with 13° and 22° to get some points that we can say how the rotation angle must be.

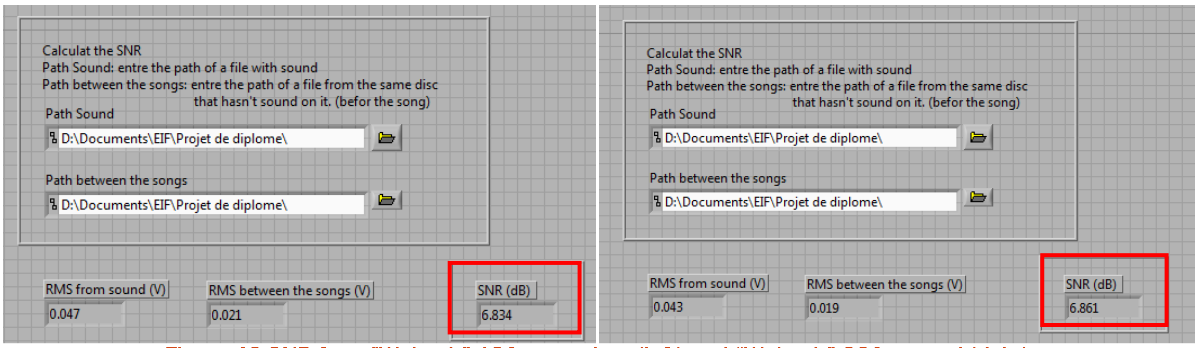

Figure 42 SNR from "Wabash" 13° rotated (left) and "Wabash" 22° rotated (right)

The values of these two measurements are nearly the same. That means it does not depend from the angle of the rotation for the disc "Wabash", important is only that we rotate more than 10°, then the lateral movement can be in maximum 10°, and so we do not get the reflection at some points of groove. If the angle is over 10°, the result of the measurement is better.

The result of the measurement with "Wabash" is now 6.8dB, without rotation the result was 4.2dB. The result of this disc is not really better, but the result is 2.6dB better than before.

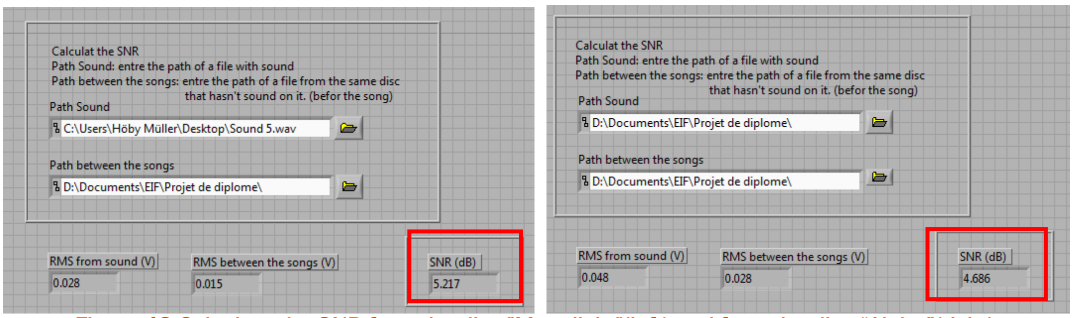

Figure 43 Calculate the SNR from the disc "Moonlight"(left) and from the disc "Aloha"(right)

For the disc "Moonlight", we get now a SNR of 5.2dB what is the same than before. So the measurement gives us the same result for the disc "Moonlight" which is a disc with a good quality. The disc Aloha in contrast is better than before, without a rotation the SNR was 1.3dB with rotation the SNR is 4.6dB in an optimal case. Not every point of the disc is like this.

6.4.2.2 Disc that we cannot read

The disc "Frequency" and the disc "Old black Joe", cannot be read with the rotated probe. The frequency is always too shiny, we get to much of groove and cannot find the right position for the groove. We got a lot of points in the groove interval but the problem is that we got too many chains in the groove depth. The points are not well measured. For the "Old black Joe" it still is the problem of the disc, which is bended.

6.4.3 COMPARISON OF THE AUDIO SOUND

It is not easy to hear a difference between the files. They are similar to our tests. All measurements say that for good quality the sound must be the same. And for discs that do not have too much reflection, the sound must be better.

6.4.3.1 Compare the sound from the test disc

To compare the sound of the test disc is really difficult. You do not hear any changes and you cannot hear that the rotation probe has an echo or a frequency that is a bit lower. It is nearly the same sound. So it is not a problem, if the measurement is taken with a probe that is rotated for a disc with a good quality.

6.4.3.2 Compare the sound from the disc Wabash

We can compare the sound from the disc Wabash and can hear that the sound is cleaner. It does not contain so much white noise, it is cleaner.

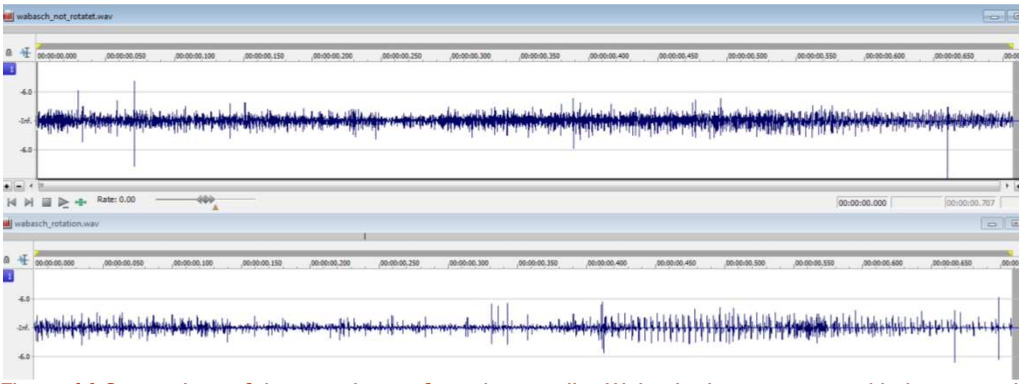

Figure 44 Comparison of the sound wave from the test disc Wabash above not rotated below rotated

We can also see that the rotated probe result is cleaner. In the Wabash with the probe not rotated, the sound is not so clear, it has a lot of frequency in this file. In the file below, the sound is cleaner, it does not have so much frequency in the file.

Also for the other discs like "Aloha" or "Old black Joe", the part that we can read has a better sound quality. It reduces the noise, but the noise is still there you also have a lot of clicks in the sound if you make the measurement not with the right displacement for one tour.

6.5 SUMMARY FOR THE ROTATION OF THE PROBE

The rotation of the probe gives us as better measurement and with this measurements we can calculate the probe more precisely than without a rotation of the probe. If we rotate we can read more discs. The rotation of the probe is a well change to take the measurement. The problem that we have is that we have some echo in the measurement and this echo is also calculated in the program PRISM.

The sound files that I get with the rotated probe are better and they do not have so much noise in it. The SNR is also better as I get the same results for the good discs and for discs with a worse status we can win 2dB with the rotation. The most efficient result we get with the rotation probe is if we rotate the probe for 20-25° In this case we do not have so much reflection in the probe and can measure over a long distance.

7 Tilt of the probe for some degree

In this trial we do not make a rotation in the axis; we change the position of the vertical. That is another method to check if the light reflection goes into the probe or not. In the last year they tilt the probe for 45°, what gave resulted in a good quality of measurements for the slopes, but there were a lot of problems. It could not measure both slopes in one measurement and the recalculation of the bottom of the slope was difficult. It was also difficult to get two measurements with the same beginning of the slope.

In the new case we only to want test, if it possible that we tilt the probe for only some degree that we do not have any reflection in the measurement, but that we can measurebooth slopes at the same time. So we only make one measurement and thereof we calculate the groove position.

7.1 Tilt angle of the probe

I only want to tilt the probe for some degree. The main thing is to have an angle we do not measure any light reflection with. The second important thing is that we want to get a good measurement in all the measurement points.

7.1.1 *Calculation of a possible angle*

To calculate the angle we need to know some information about the probe. The measurement is over a distance of 1.8mm and the depth of field is 350µm. The groove depth is 70µm. The maximum angle that is possible to get for all the 180 points a good measurement is:

$$\sin^{-1}\left(\frac{350 * 10^{-6} - 70 * 10^{-6}}{1.8 * 10^{-3}}\right) = 8.9°$$

This is really the maximum, that you can tilt the probe to get a result for all measurements. The problem is that the disc is not really smooth at every point. And the second thing is that the measurements are not so good at the extreme value of the depth of field. If we want to measure all the points, the maximum angle is 5.5°. For this angle we need a space of 242µm.

To get different measurements we also calculate the space for an angle of 2°, what is 133µm and 164µm for an angle of 3°.

7.2 Reflection of the measurement

If we tilt the probe we get some images in which we do not have all the points of the groove bottom at the same depth. But the groove depth is always the same. It is only the measurement that makes some changes in this point. It is difficult to find a place in which all 180 points are in the range of a good measurement. If we compare the new measurements with the probe that was not tilted, we get the same result.

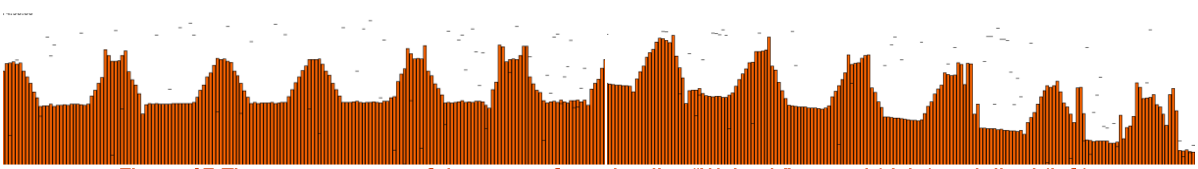

Figure 45 The measurement of the groove from the disc “Wabash” normal (right) and tilted (left)

The groove that the program PRISM uses has much less reflection for the first 120 points and it can calculate the groove at this position better than before. The only problem we got is that the grove from one measurement to the other makes a big step.

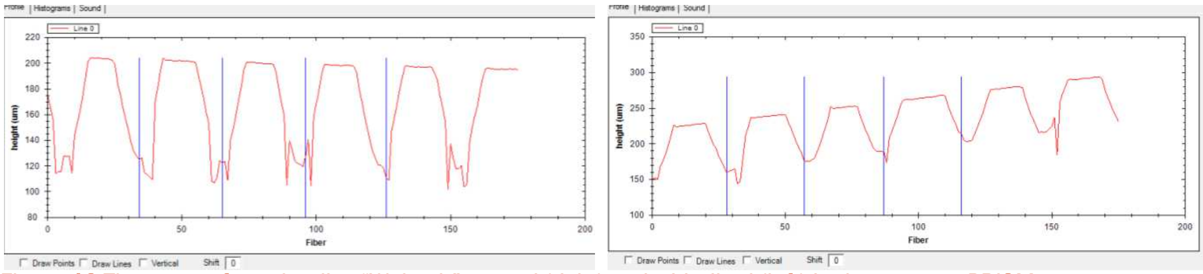

Figure 46 The groove from the disc "Wabash" normal (right) and with tilted (left) in the program PRISM

For discs like the "Frequency" disc that we could not read well before, we now get a measurement that is much better. We see that more points of a shiny disc are read exactly with the tilted one. The problem that exists is that for the shiny discs only a short distance can be read very well. In this case we read half of the points well and three quarters are usable. It is really an extreme case that only half of the points are well. For the "Wabash" disc there are more points that are well.

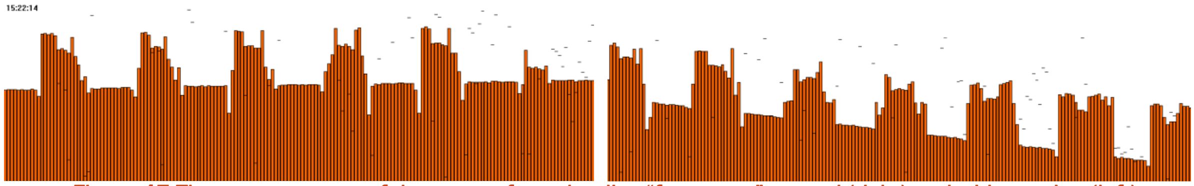

Figure 47 The measurement of the groove from the disc "frequency" normal (right) and with rotation (left)

7.2.1 COMPARE HOW MANY POINTS ARE IN THE GROOVE TOLERANCE

If the tilted probe had less points out of the groove, the same test would give us a value to say if this method is useful or not. I made the same calculation as before. The only thing that changed is that the received file is first recalculated by a line, so that all the grooves have the same height.

I also get 100 lines with 180 points and calculate which measurements points are out of the groove tolerance. The test with all the 180 points was not good because at the end of a measurement we got too much points they were wrong. And the result was that I had more points out of the groove tolerance than without tilting the probe (normal).

One solution is not to take all of the 180 points possible. If we take only 120 points of the probe we get a better result than with all the 180 points.

Method	Incorrect points too deep	Incorrect points too high	Total points out of the groove	Percentage
Normal	176	6	182	1.5%
Tilt 2.4°	118	1	119	1.0%
Tilt 3.5°	233	1	234	1.9%

Figure 48 Calculation of points that are not in the groove tolerance for the disc "Wabash"

For the disc Wabash you can see that the tilt of only 2.4° gives us more points in the grove tolerance if we only take 120 points. If we tilt for 3.4° we get fewer points in the groove tolerance. That means if we want to tilt the probe for more than 2.4° we can only use less than 120 points.

The same test as before for the disc frequency, which is very shiny. We do not get a good result. With 120 points we always have a lot of reflection. If we take fewer points, we can have a much better result, but we can only use 90 points to get a lot of points in the grove tolerance.

Method	Incorrect points too deep	Incorrect points too high	Total point out of the groove	Percentage
Normal	457	330	787	6.6%
Tilt 2.4°	317	291	608	5.1%
Tilt 3.4°	513	216	729	6.1%

Figure 49 Calculation of points that are not in the groove tolerance for the disc "Frequency"

We have fewer points that are out of the groove tolerance but we can use less points than we have in the probe. And we have a longer time to scan, because the distance that we can measurement is much less, for one disc we must measure for a longer time.

7.3 Spectrum if we tilt the probe

The sound files that we create are made with all of the 180 points, because the program is not adapted for fewer points. But this is not the problem as we can create some .WAV files with all the points and compare this file.

If we compare the spectrum from the measurement with the tilted probe and the normal probe we see, that for a good disc we nearly have the same spectrum for the tilted version of only 2.4° . For the tilted version with a higher degree the result is worse.

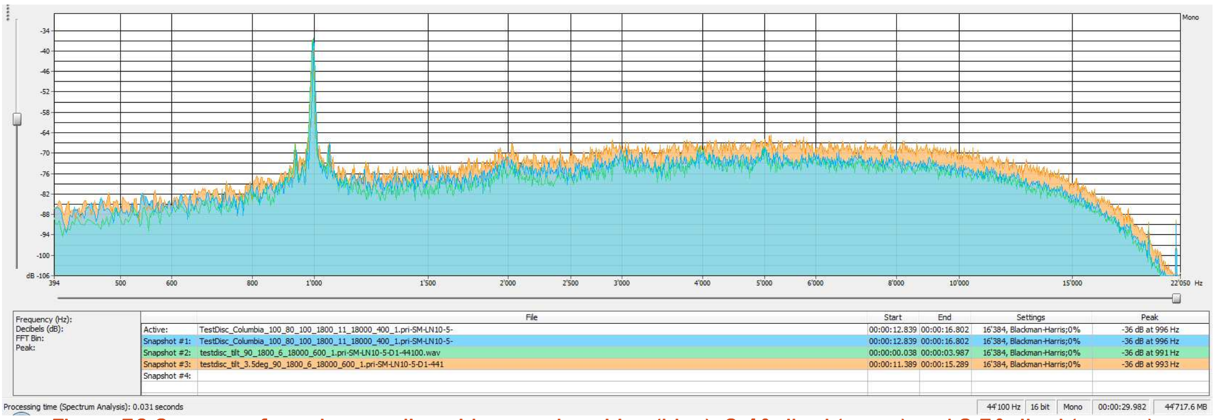

Figure 50 Spectrum from the test disc with normal position (blue), 2.4° tilted (green) and 3.5° tilted (orange)

For the disc Wabash we have the best spectrum with the normal probe. With the tilted version the result is worse. And if the tilt is bigger the result is not better. For the tilted version of 3.5° you cannot find any differences between the sound frequency and only the noise frequency. The spectrum is really flat.

Figure 51 Spectrum from the disc “Wabash” normal position (blue), 2.4° tilted (green) and 3.5° tilted (orange)

This spectrum is made with all of the 180 points and it is possible that the noise that we have now in this files comes from the measurement points that do not have a good quality. Furthermore there is a lot of reflection.

7.4 COMPARISON OF THE SOUND

Although the spectrum does not look really well, we compare the sound file with the SINAD and SNR to get more information about the sound quality. To compare the sound files I use the same method as before for the rotation of the probe.

7.4.1 COMPARISON OF THE TEST DISC MEASUREMENTS

To compare the SINAD I get some files from the test disc with 1kHz. These files are small and the residual signal has only noise in the file and does not contain any sinus forms.

7.4.1.1 Compare the SINAD and THD

I assume that the result for the SINAD and the THD is not better than before without tilt, because the spectrum was not better before.

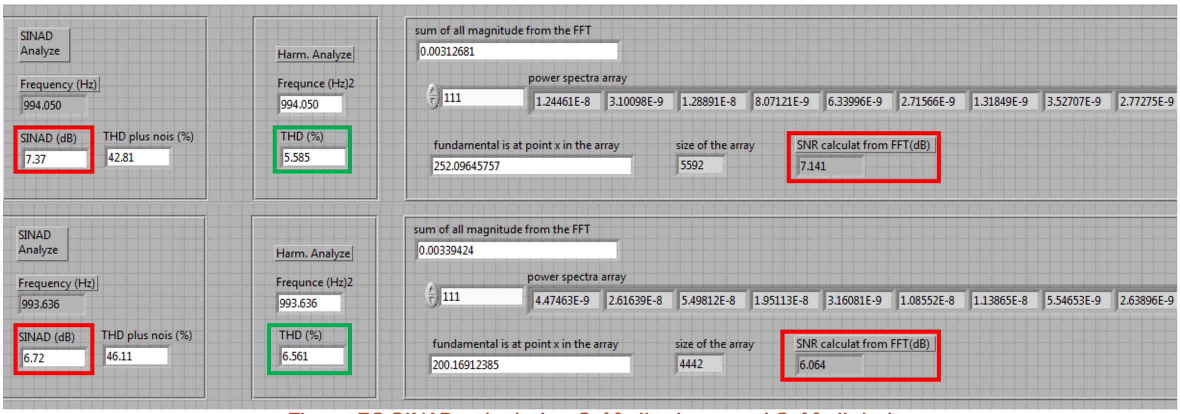

Figure 52 SINAD calculation 2.4° tilt above and 3.4° tilt below

For the tilted version of 2.4° we find a part of the test disc that has a SINAD of 7.4dB and a THD of 5.6%. The calculation of the SNR with the method FFT gives a result of 7.1dB. For the tilted probe of 3.4° we get a SINAD that is less, it is only 6.7dB and the THD is 6.6%. The calculation with FFT gives a SNR of 6.1dB. This SINAD is worse than the normal measurement. So the tilt is too big or we use too much points of the measurement for the sound file. The tilted version of 2.4° is 0.6dB better, before the SINAD was 6.8dB and the THD was 6.6%. The amelioration of 0.6dB is not so much, but it helps to get a better result.

7.4.1.2 Comparison of the SNR

Comparing the SNR is a control if the SINAD is correct or inverse if the calculation for other discs with the method SNR is also correct to compare. Do we get the same result for the tilted version for other discs, if we take a part with sound and a part without to compare.

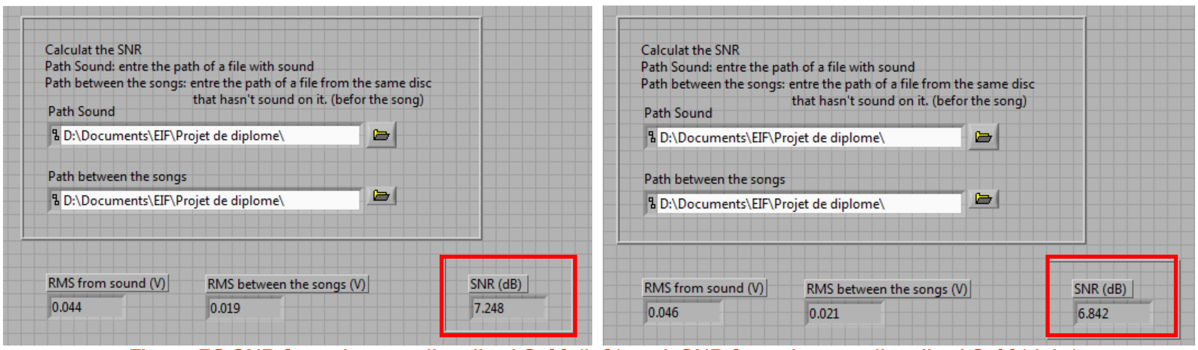

Figure 53 SNR from the test disc tilted 2.4° (left) and SNR from the test disc tilted 3.4°(right)

For the test disc I get a SNR of 7.2dB for the probe tilted 2.4° and a SNR of 6.8dB for 3.4°. These are nearly the same values as before and the result for the test disc looks good. Once more the 2.4° tilted probe is better than before.

7.4.2 COMPARISON OF SOUND DISCS

The tilted version of 2.4° is much better than the 3.4°, so I compare the sound disc only for the 2.4°, because a tilt for more degrees is not useful.

7.4.2.1 Comparison of the SNR

The disc “Wabash” did not have a bad quality before without tilt or rotation. Before I got a SNR of 4.8 dB. For the disc “Moonlight” I measured a SNR of 5.3dB.

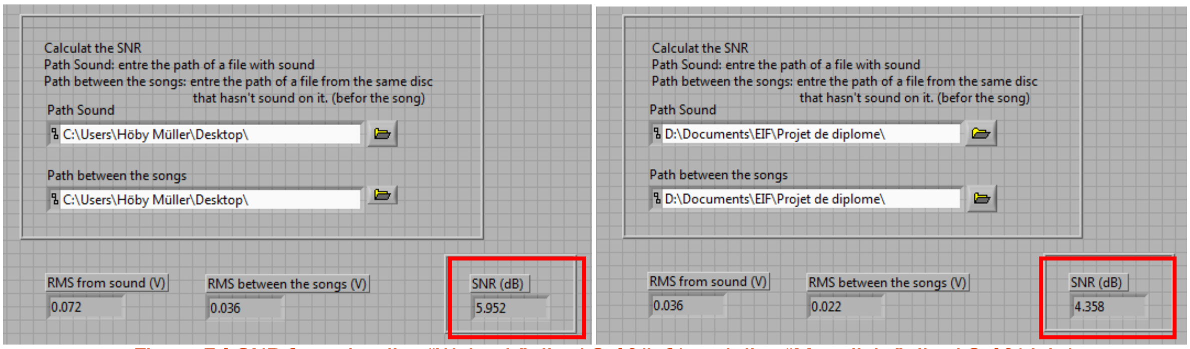

Figure 54 SNR from the disc “Wabash” tilted 2.4°(left) and disc “Moonlight” tilted 2.4°(right)

The SNR for the tilted probe is 6.0dB, which means that the SNR is 1.2dB better than without tilt. For the disc Moonlight I get a SNR of 4.4dB, what is 0.9dB less than version without tilt. The SNR can be better or worse with the tilted version. This depends a lot of the place of the measurement. With a probe that is tilted it is difficult to make very good measurements, because the deep field of the probe is not so big and with the tilt more places is needed in the deep field. Not every measurement point of the groove gives us a good quality and it is more difficult to compute the groove center of all these measurements.
If the measurement is well done, the result of the SNR can be better as the disc “Wabash” shows. If you have measurements as you have with the disc "Moonlight", the result is not better.

7.4.3 COMPARISON OF THE AUDIO SOUND

It is not easy to hear which file is better, because at some places the tilted file is better and at some places the normal file is better. It depends a lot of the measurement, but it is difficult to make good measurements with the tilted probe. For some measurement you can hear that at some tours of the groove the sound is better, because this one was in the deep field, but in some rings they are really wrong.

7.4.3.1 Comparison of the sound from the test disc

You can hear that the measurement with the tilted probe has less clicks and the result is really good. You do not have a lot of noise in this file and the quality is really good for the probe that is tilted for 2.4°. For the probe that is tilted for 3.4°, the result is nearly the same as the probe without tilt. The problem with the tilted probe is that you have different measurements of depths and it can happen that the focus does not stay in the whole measurement distance of the 180 points, because the discs are not flat in all the parts. So the second measured ring or more have some missing parts and you do not have sound at every place of the measurement.

7.4.3.2 Comparison of the sound from the disc Wabash

For the measurement of the disc “Wabash” it was not so easy to get a really good file. You can see that in the comparison of the wave from. In some places the noise is really good and in others you have more noise. The out coming of this effect is that the disc is not really in the center and so every tour some points of the groove are at the border of the deep field of the probe. The measurement at these places has more light reflection.

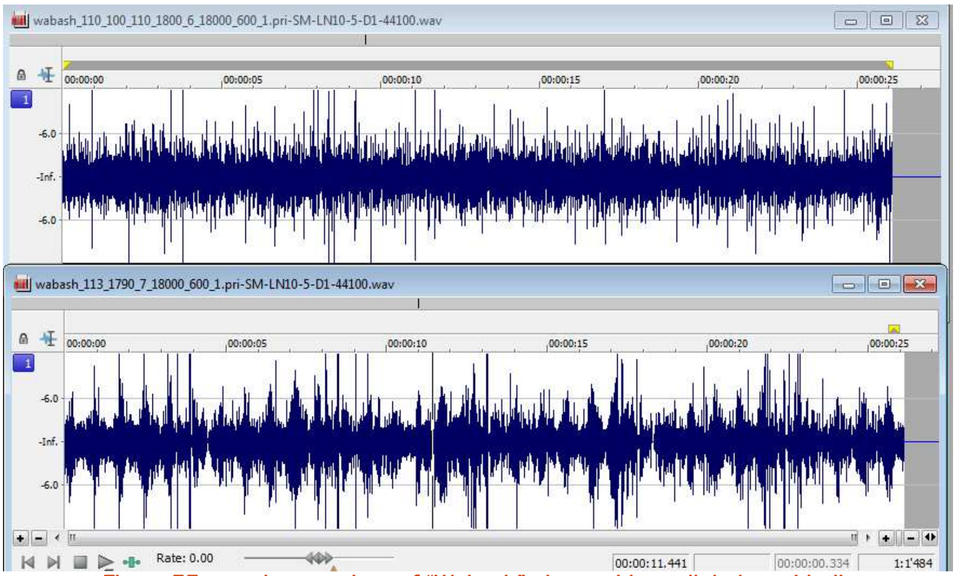

Figure 55 sound comparison of “Wabash” above without tilt below with tilt

The sound of the measurement is a bit better with the tilted version. It does not have so much of noise in it. In some parts of the measurement you can hear that the quality is good. But the program calculates with all of the 180 points and this gives us the effect that not all of the points are in a good measurement deep field. And in these places the sound has more noise that in the file before. The noise is not really constant in this file and it is not comfortable to hear.

7.5 CONCLUSION FOR THE TILTED PROBE

The tilted probe can give us as better measurement and with some good measurements the result of the calculation can be better. If the probe is only tilted for 2-3° most of the points of the probe are in the measurement deep field, but not all of them. For some good discs you can use more points than for shiny discs. And the measurement start point must be good arranged to get a measurement that is better than without the tilt. The program PRISM must be changed and once more we have to compare if the result is better if we only take 120 points of the 180 points. Also the distance to replace the probe from one ring to the next must be changed. So that every place of the disc is included in the measurement.

We only get good and efficient measurements if we tilt the probe for less than 3.5°. Otherwise it is too much and you cannot read both sides of the groove. The tilt must be between 1.5-2-5° for a really good quality of the measurement.

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8 CHANGES FOR THE ROTATION

We analyze both methods before we show that the rotation of the probe is the better solution than the tilted probe. For this reason I implemented some changes to get a good quality of the sound every time. With the rotation of the probe we got the problem that we have a time difference from the first to the last measurement points. This time difference depends on the angle of the rotation and the distance to the center of the disc.

8.1 SHIFT THE TIME DIFFERENCE

8.1.1 EXPLICATION OF THE SHIFT

The calculation of how many turns we have to shift the file depends on the distance from one measurement to the other and on the rotation angle. The rotation angle of the probe must be calculated before we can get the measurements. We need this information in the program PRISM to recalculate the file. Also the distance from one measurement to the other depends on the rotation angle. The distance from the center of the disc to the position of the probe is also important.

We do not get the same change for the points at the same place of the platter. The problem is that the disc is round and we measure the points near the center of the disc with a smaller distance to the next measurement.

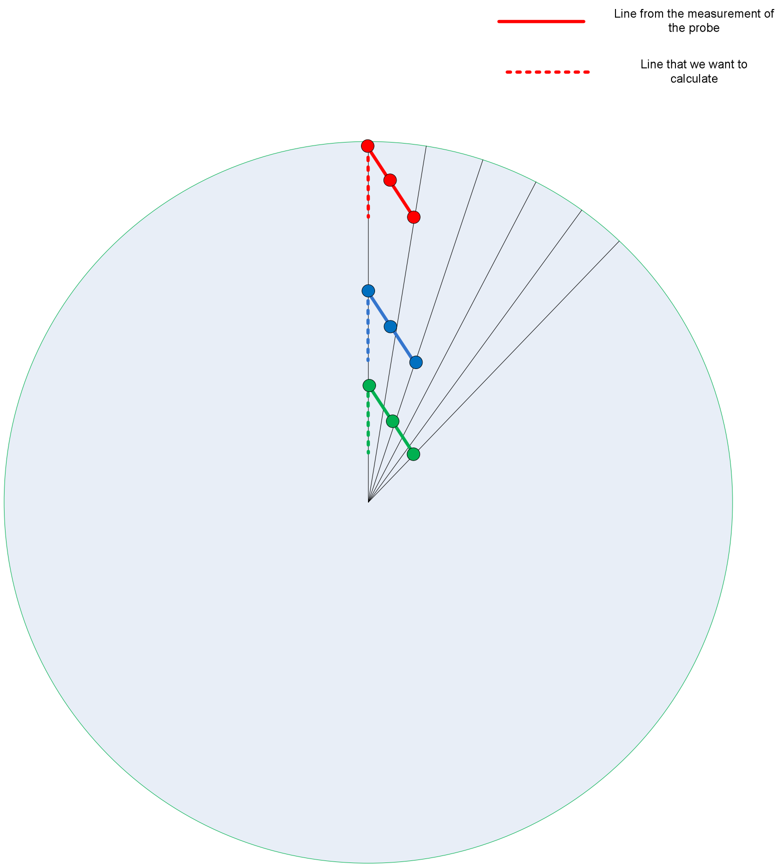


Figure 56 Problem of the rotated probe

The black lines are the lines in which the probe normally takes the measurements. Also the dashed lines are the normal measurement positions of the probe. In the rotated part we now measure the point of different measurements in the normal case. The big problem is that the shift difference is not always the same. If we go near the center, we must shift more measurement than if we are at the border. In the example we see that at the end of the red probe we must shift for one measurement. For the blue one we must shift two and for the green one near the center we must shift 5 times. At every point we have to calculate how many times we have to shift.

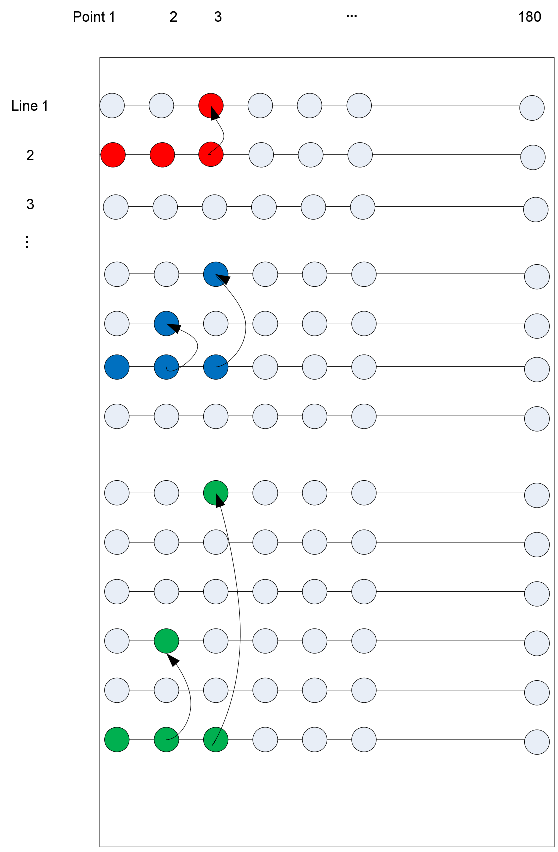


Figure 57 File after measurement with rotation and how much the point must change

The colors of this image correspond to the image before. The first measurement does not have to change so much, because the distance of the rotation for one measurement is bigger than in the middle. And you can also see that the changes are not linear near the center of a disc.

8.1.2 CALCULATION OF THE SHIFT

The calculation of how many lines we have to shift a file is the simplest way to calculate the shift for every 180 points in one ring and then make this shift in a new file. After that we make a new calculation of the second ring and make this shift for the second ring

For the shift it is important to have an array with the shift for all the 180 points we recalculate this table for every run. Also the distance for the changes in one pass is included in the calculation. If we take more than one measurement from the one ring the distance between these two measurements is also included.

8.1.2.1 Table to calculate

$$Shift_x = \frac{Point_{\ x\ from\ the\ probe} * 10 * 10^{-9} * \sin\left(\alpha_{rotation\ probe}\right)}{\frac{2 * \pi * r}{360} * \alpha_{rotation\ between\ measurments}} \quad [points]$$

$$r = d - r_x \quad [m]$$

$$d = distance\ from\ the\ center\ measured =$$
$$R_{Start} - n * co\,s\left(\alpha_{rotaion\ probe}\right) * 1.8 * 10^{-3} - n_{passes} * distance_{passes} \quad [m]$$
$$r_x = Point_{\ x\ from\ the\ probe} * 10\mu m * co\,s\left(\alpha_{rotation\ probe}\right) \quad [m]$$

The distance from the center measured is the value that is saved in the header of the file pri. For all rings it can be recalculated with the length of one measurement and the length for one pass.

8.2 Explication to get the angle of the rotation

To find the angle of the rotation we get a new platter for the disc. This platter has one line on it. This line is the radius of the disc. To get the angle of the rotation we measure at which rotation place of the platter the first measurement point measured the groove. Then we measure at which rotation of the platter the probe measured the depth. If we know the radius and the distance between these two measurement points, the program can calculate the angle of the probe.

This calculation is done more than once, in a different distance from the center and also with different measurement points, not only with the first and the last measurement point, but also with some points in between.

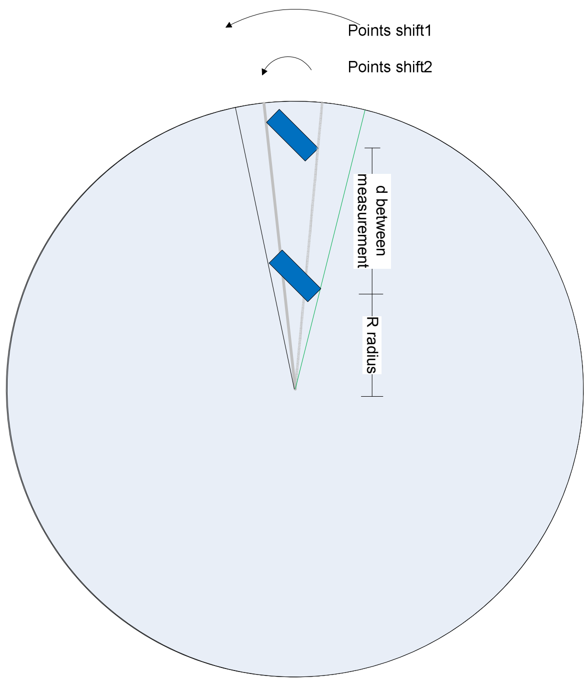


Figure 58 Angle test disc with the grove in the radius

The green grove in the figure goes from the right side of the probe to the left side of the probe and we always measure the surface of the disc.

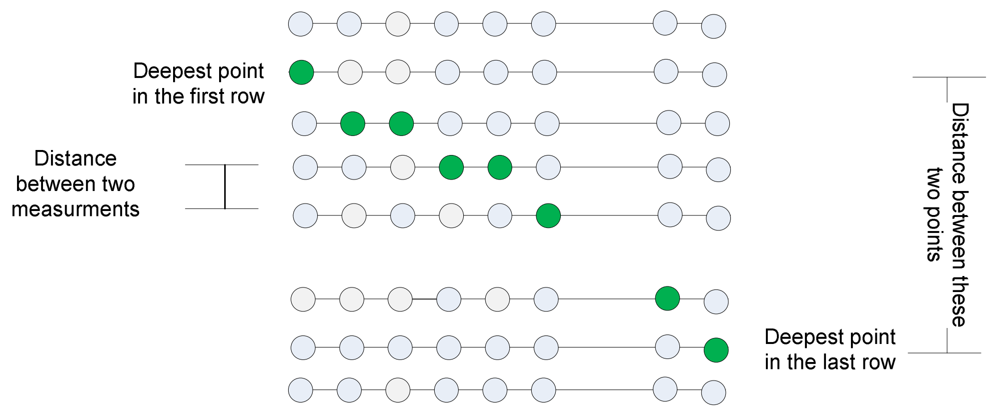


Figure 59 Measured the radius grove in the program with the distance between

The groove is measured like the green points and we can recalculate the angle of the groove with this information.

8.2.1 CALCULATION OF THE RADIUS TO THE FIRST MEASUREMENT

$$\frac{\frac{2\pi * Points\ rotation1}{360} * \alpha_{per\_measurement}}{1.8 * 10^{-3}} * r_{centerprobe} = \frac{\frac{2\pi * Points\ rotation2}{360} * \alpha_{per\_measurement}}{1.8 * 10^{-3}} * (r_{centerprobe} + d_{between\ measurement})$$

$$Points\ rotation1 * r_{centerprobe} = Points\ rotation2 * (r_{centerprobe} + d_{between\ measurment})$$

$$r = \frac{Points\ rotation2 * d_{between\ measurement}}{Points\ rotation1 - Points\ rotation2}$$

8.2.2 CALCULATION OF THE ANGLE

$$\alpha_{rotationProbe} = \cos^{-1}\left(\frac{d_{FirstLst}}{1.80 * 10^{-3}}\right)\ [deg]$$

$$d_{FirstLst} = \frac{2 * r_{centerprobe} * 10^{-3}}{360} * (\alpha_{first} - \alpha_{last})\ [m]$$

8.3 Realization

8.3.1 Changes in the program LabVIEW

In the program LabVIEW I made some changes to get a measurement with a rotated probe. First it is important that you can choose that you want to work with a rotated probe so I added a button to choose this mode.

In the background this button has the effect that the program does not make a file .pri, it makes a file .pri.rot. In the header it makes a new value: the element number 9 is now the angle of the rotation, if the button is active and at 0 if the rotation is not active. The rotation angle must be calculated before with a separate program that is explained later.

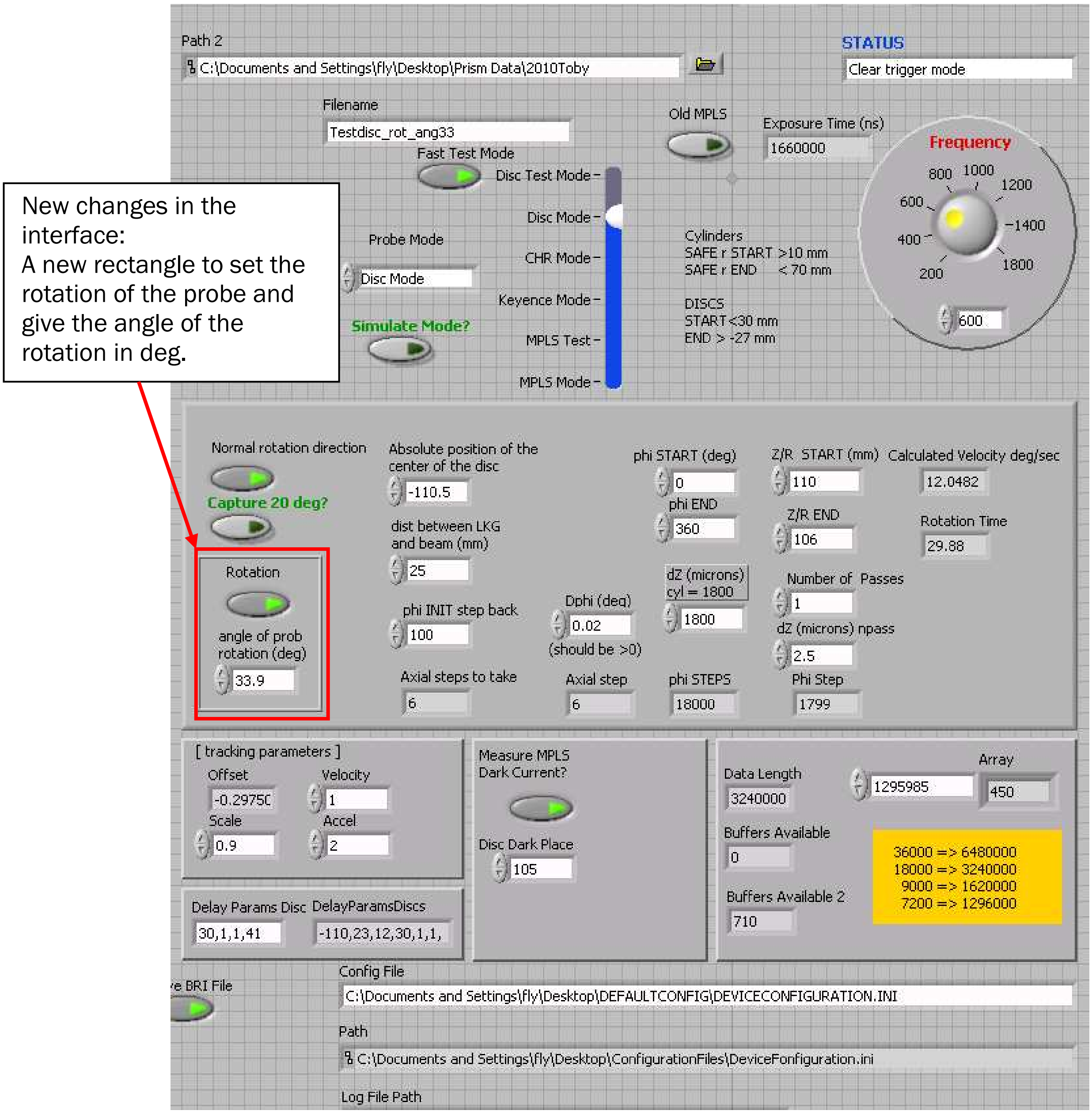


Figure 60 changes in the program LabVIEW

8.3.1.1 New data file

With the new LabVIEW code we create a file .pri.rot. This is the case if we make a file with the rotation at on. This file is the same like the .pri file, with the only differences that the points are not in the right place and that in the header of this file there is now a new entry. The header has the same length, it is only the element 9 what is the angle of the rotation. Also the file .pri.bri is now a file with the rotation and therefore also this file has the new entry in the header.

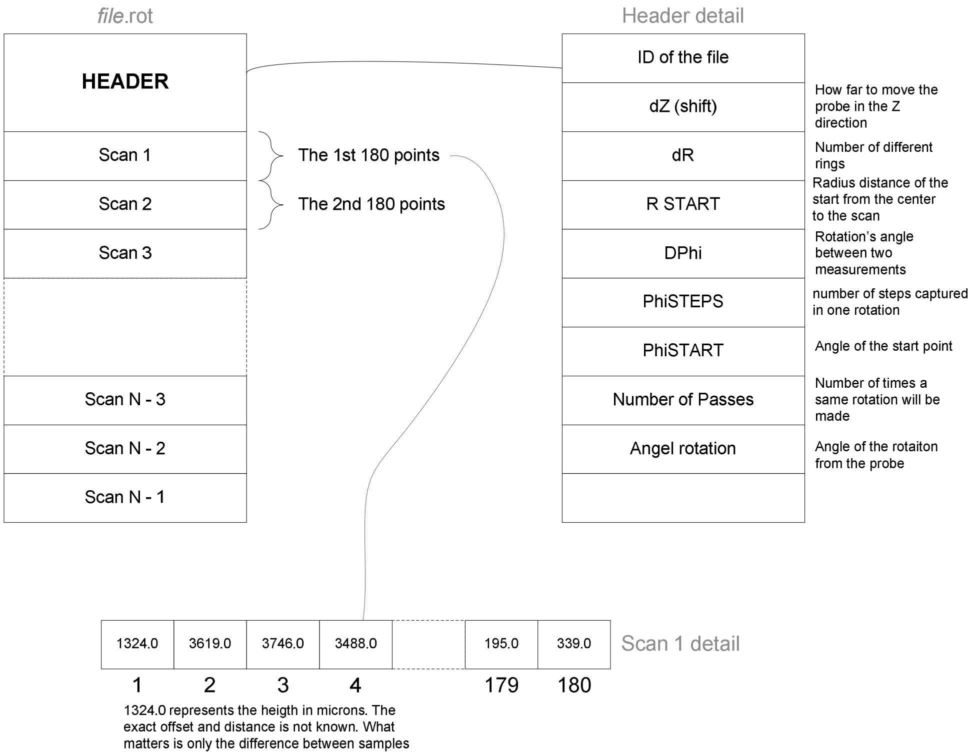


Figure 61 structure from one file .rot

All the other parameters are the same and do not change if you measure with or without rotation. You can find all the parameters in the Diploma project 2008 in Chapter 4. The angle in the header file is set to 0 if the rotation button is not activated. Also the different modes to make a measurement are documented in the project 2008

8.3.2 Program to get the angle of the rotation

This program is to calculate the angle of the probe if I rotate the probe. For this program we use the platter of the system. This platter has a groove in the radial direction so that I can measure at which angle the probe measures the groove for the first time and at which angle the for the last time. In this program it is really important that the system is fixed in the center of the disc, so that we know the exact radius. It is also important, that we read the groove at a place where the groove has a nice form.

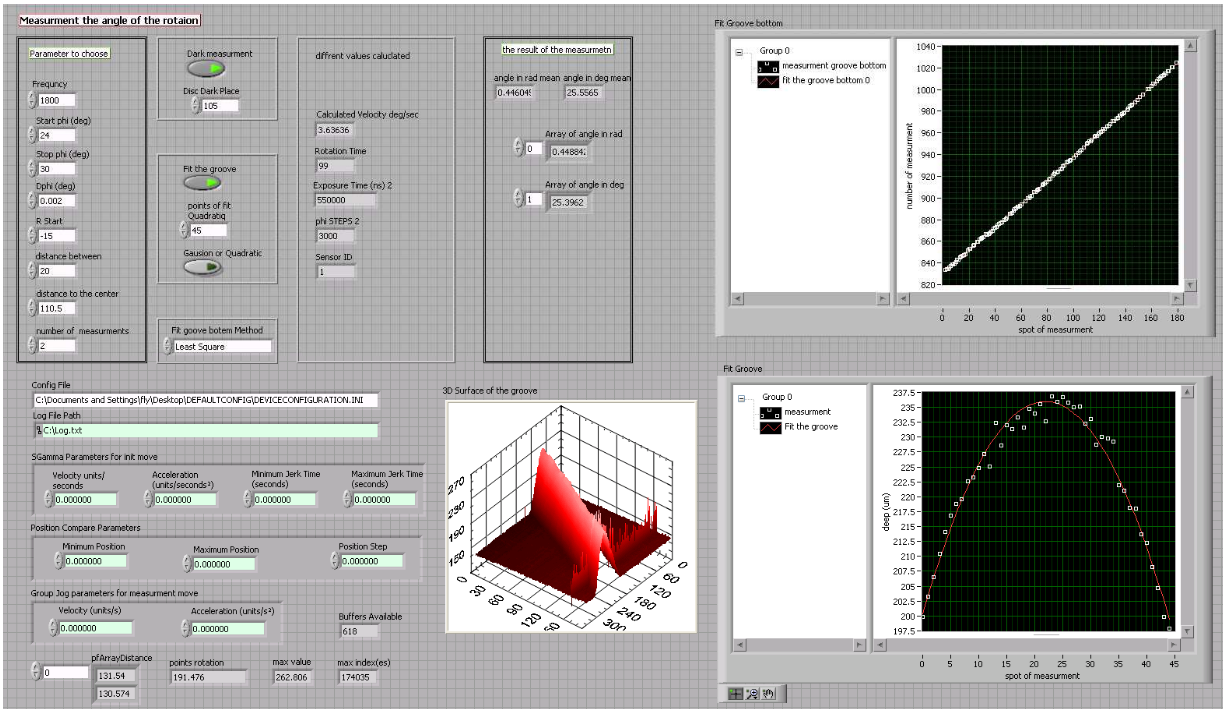


Figure 62 Program to calculate the angle of the probe

1) Parameters to choose
    a. Frequency: That is the frequency of the exposure time for the platter. Because the platter is shiny this parameter should be small (default 1800Hz)
    b. Start phi (deg): is the place at which the probe begins to measure. This must be before the groove begins (default 24°)
    c. Stop phi (deg): is the place at which the probe stops to measure. This must be after the groove ends (default 30°)
    d. Dphi(deg): is the distance between two measurements. The distance should be small, so that we have a lot of measurements that measure the groove (default 0.002°)
    e. R Start (mm): is the distance from the center to the first measurement (default 95)
    f. Distance between: is the distance between two different measurements (default 20)
    g. Distance to the center: is the calculated distance to the zero-point of the system to the center. This value should be exact (default 110.5)
    h. Number of measurements: gives the value of how many different measurements the program should take
2) Dark measurement: If this is active, the program first makes a dark measurement at the given place. This should be outside the disc
3) Fit the groove: If this is active, the program fits all groove measurements with the method Gaussian (second button not active) or Quadratic (active).

   a. How many points the fit uses is given with the points of fit. If you make the fit with too many points the fit groove graph would be too flat and with too little points the fit is too steep. The number of points for a well quality of the calculated angle depends on the angle.
4) Fit groove bottom fit the all deepest points of the groove or the deepest point of the fit the grove function with the given method.
   a. Least Square is more for Gaussian distributed
   b. Least Absolute Residual is robust fitting method (default)
   c. Bisquare is like Least Absolute Residual more robust than Least Square
5) The different values calculated are some values that are needed in the program. They are calculated for every new run.
6) The result of the measurement:
   a. The mean angle in rad and the mean angle in deg are the mean value of all different measurements.
   b. The array of the angle in rad and the array of all angles in deg are the result of the different measurements to control if all the values are about the same
7) Graphic of fit all groove bottom from the last measurement
8) Graphic of the last fit of the groove
9) Graphic 3D of the measured groove shows only a part of the measurement. The x direction shows the different measurements, the y direction shows all of the 180 points of one measurement and the z direction shows the depth of the measurement.
10) Configure file for the probe must be at the given path and the log files are saved at the log file path.

All the other parameters are only needed for the measurement or the calculation and are not that important.

For a measurement it is important that you measure the angle with a low frequency. Further the energy of the measurement sound has to be low so that you do not have any points that have a saturated energy, because the measurement of the groove is not nice with a saturated point. Further it is difficult to find the deepest point very exactly. In the image of the groove bottom most of the points have to be on the fitting line and also the fit groove should be near a perfect fit.

8.3.2.1 Problem with the calculated radius

As I already explained before, the idea was to calculate the distance from the center to the measurement point. The problem that I had was to find the distance between the first and the last groove bottom that is exactly enough to get the right angle.

One reason why I cannot calculate the angle is that the measurement of the same place on the disc does not always give the same result. It always has some small changes. The other problem is the groove on the platter. The groove on the platter is not really well.

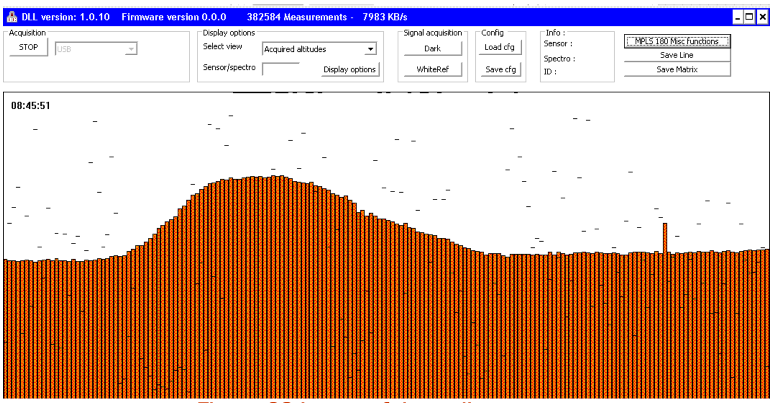


Figure 63 Image of the radius groove

On the figure above you can see an image of the radial groove. This groove (the image is upside down) has not one point that is the deepest. The bottom is really flat. That it why it is difficult to find the deepest point. This is not the problem if we can fit all points of the groove or if we can measure booth slopes, but here we have the problem that the slopes are not steep and additionally both slopes have another angle. So to fit the groove with Quadratic or Gaussian does not give us the deepest point.

We do not find the deepest point in every measurement and we cannot calculate the exact angle of rotation from the first to the last deepest point. With two measurements that are not exact I cannot calculate the distance to the center very exactly.

With small changes in the radius the angle of the measurement cannot be calculated correctly. So the problem is that with some accumulated failures I calculate a wrong radius and with the wrong radius a wrong angle.

8.3.3 Changes in the program PRISM

The changes for the time difference in the measurement I decide to recalculate in the program PRISM which is already used to recalculate the sound file. So it is easy to handling the shift also in this program that you use in any cases. The program PRISM is written in c# and contains the whole process for recalculation the sound for disc and cylinders.

The rotated measurement does not take all of the points in the same time place on the disc and the program LabVIEW makes now with the rotation a file pri.rot and a file .rot.bri. For these two reasons I had to change the program PRISM. The changes on the interface for the rotation in PRISM are on the top on the right. You can choose the rotation. The effect of this check box is that if you open a file you can directly see all the file .pri.rot and you do not have to change the kind of files that you want to open. And the second decision that you can make is which method you want to use. Either you take only the nearest point for the shift or you make an interpolation of the two nearest points.

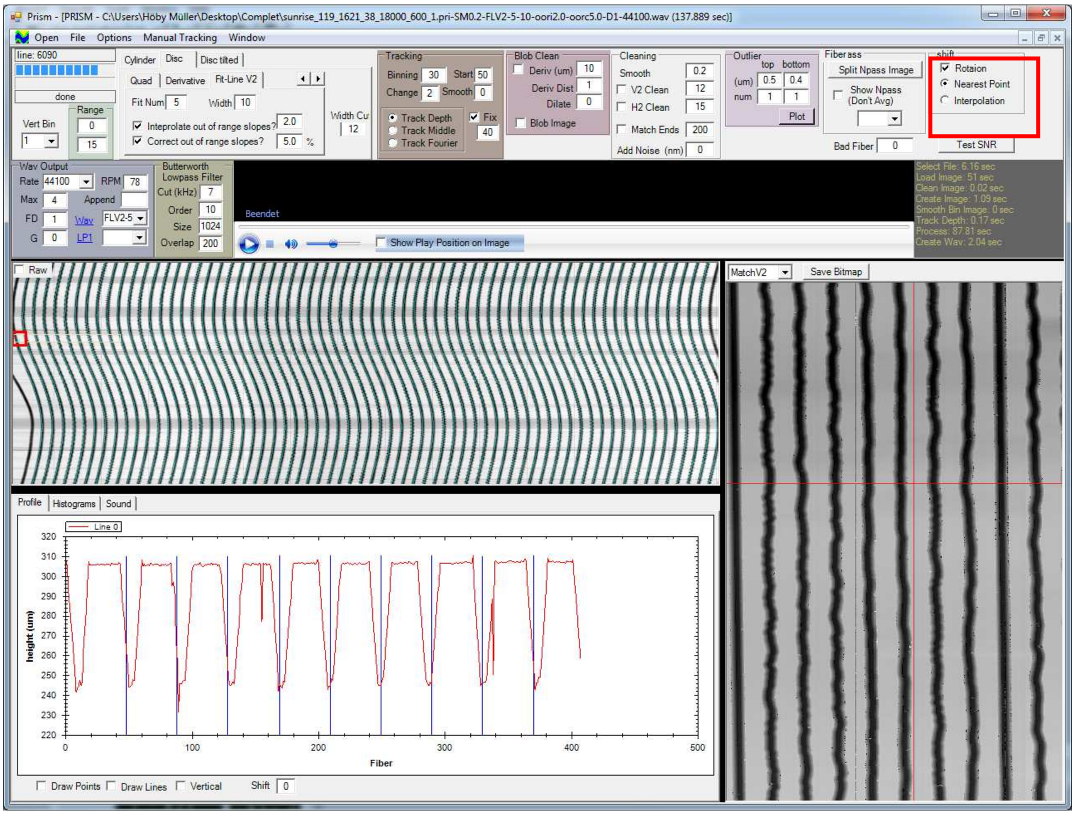


Figure 64 Changes in the program PRISM

The changes in the program are the following: if you start the program with a file .rot it makes the shift and saves the shifted data in a file .pri. The program makes the shift only with the file .pri.rot and it does not depend if the check box is selected or not. The check box is only a help to find the files pri.rot faster. It also makes the shift if the check box is not selected. Both files .pri.rot and .pri.rot.bri are shifted and saved in a file .pri and .pri.bri. After the shifting of the file, PRISM works with these two new created files. That means it works directly with the shifted files. The points to shift are calculated for every round because the shift table change depends on the radius, so the calculation of this table is new every time.

The time difference is mostly not exactly on the sampling rate. With this effect you must shift the measurement points not only for integer number, you can choose now if you only want to take one point (the nearest of the measurement) or if you want to interpolate the two nearest points of the exact time distance. The advantage of the nearest point is that a wrong measured point is only counting once in the new file, with the interpolation you use the wrong measured point two times. The advantage of the interpolation is, that for two good points the interpolation gives a result for the time place on the disc that is more precise than with the nearest point only.

8.3.3.1 Realization in PRISM

The program PRISM contains a new class for the shifting of the file. This class has the name rotation.cs and contains five methods. The main method which is called in the case you open a file with the ending .pri.rot in the class Haredware.cs is the method shift_file(). More information about the structure from the whole program and the diagram the class you find in the project of Adrien Nicolet.

8.3.3.1 Class Rotation.cs

Constructer of the class:

```
public Rotation(Hardware hardware, string name_rot, frmMain mvc)
```

The constructer of the class Rotation takes tree argement the first is the hareware object which contains all information before. The name of the file wich he must contains and the interface of the program

Methods of the class SNR.cs:

```
public void Shift_file()

private void nearest_point()

private void interpolation_points(){

private void shiftTabel(int number_round)

private void writeFloat(float write_fl)
```

The methods of the class rotaion.cs are Shift_file() which is called by the object Hardware and which make the whole process of the shift. First he call the method shiftTabel() to calculate the array to shift every point the right distance the argument of this class at which round of measurement we are to calculated the right table. The method nearest_point() and the method interpolation_points are used to shift the file it is only one of them called every time. The method writheFloat() write a float to the new data in the file .pri and .pri.bri.

8.4 Test the Realization

8.4.1 Control of the angle

To control if the angle calculation is correct, I can compare if the program always gets the same angle. And the angle must be in a range that is acceptable. For the calculation of the shift it would be nice if we have an exact value. The displacement from one ring to the next is in 1 µm possible. And the sound is normally stored from 6cm to 12cm in the radius. With an angle of 25° we can measure 1.63mm at one time. So for one whole disc we scan 36 rings. After these 36 rings it would be nice to have a maximum difference of 10µm or for one ring a difference of only 0.27µm.

This is not really possible, because the maximal error from one ring to the other is 1µm that is the minimal changes for the x axis. This 1µm is for an angle from 25° 0.075° difference.

8.4.1.1 Calculated angle

The first measurement gives us the result that the angle is 24.79°

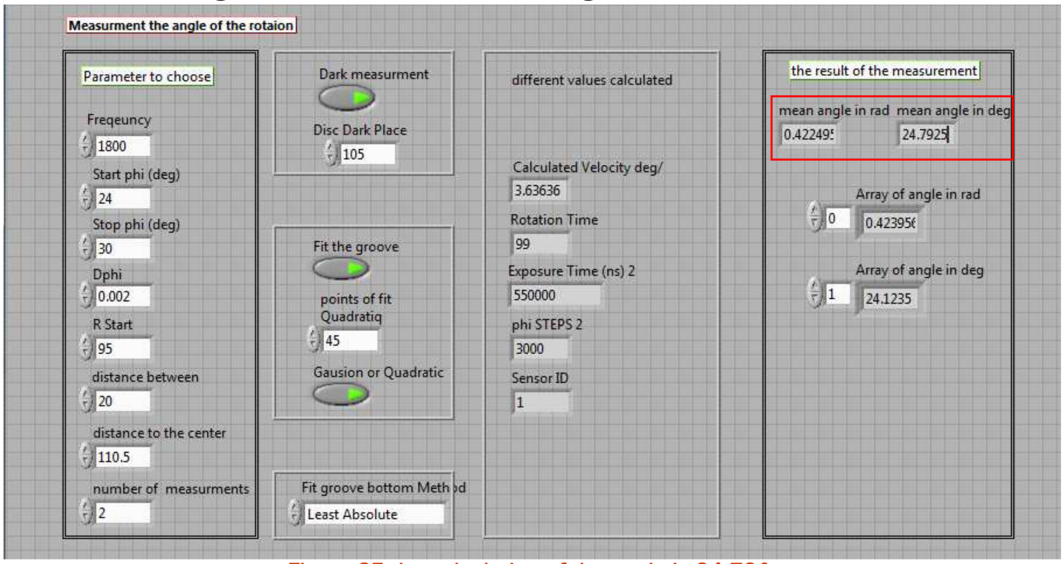


Figure 65 the calculation of the angle is 24.79°

If I change some parameters in the calculation, the angle must be almost the same. Some different measurements give us the following results for the same angle.

24.7909°	24.7812°	24.7638°	24.7699°	24.7535°
17.5972°	17.6075°	17.5821°	17.5897°	17.5809°
29.8738°	29.8511°	29.8697°	29.8616°	29.8452°

The difference between these measurements is only 0.037°. The median value is 24.7718°, so we are in a tolerance of ±0.019°. This is much smaller than the calculated maximum of 0.075°. For the 17.5914° I am in a tolerance of ±0.016°and for the 29.86° I have a tolerance of ±0.015°.

8.4.1.2 Angle test with the long part of a disc

In a long measurement of a disc we do not have a big difference. So the error at the end of the disc is not too big to get the right groove. It is only important for the part in which the changes from one ring to the next are in a slope because with the slopes we calculate the groove movement.

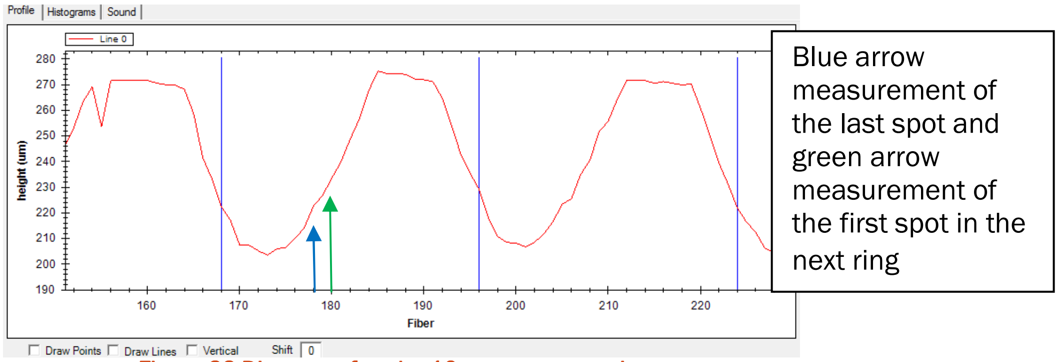


Figure 66 Distance after the 10 measurement rings

After a measurement of 10 rings I have an error that is smaller than 10µm. You cannot see any change from point 179 to point 180 which is the measurement from the new ring. The angle that we have calculated is the right one. A test has showed that after 36 rings I have a very small offset that is smaller than 15µm and it is not really important. The groove could be found very well in all the points. If the angle is not correct, the offset would be more.

8.4.2 *Shift in the program PRISM*

To make the shift in the program PRISM, I create a new class, the class rotation. This is the class that creates a new file in which the measurement data is now in the right place. This class is only applied if we get a file .rot.

8.4.2.1 Test the different shift table

In every ring we get some different shift tables that are calculated. With this table the file is not shifted. For these tables it is important that they always have the right distance. Further it must work in all cases, that means with a normal measurement and also with overlapping measurements.

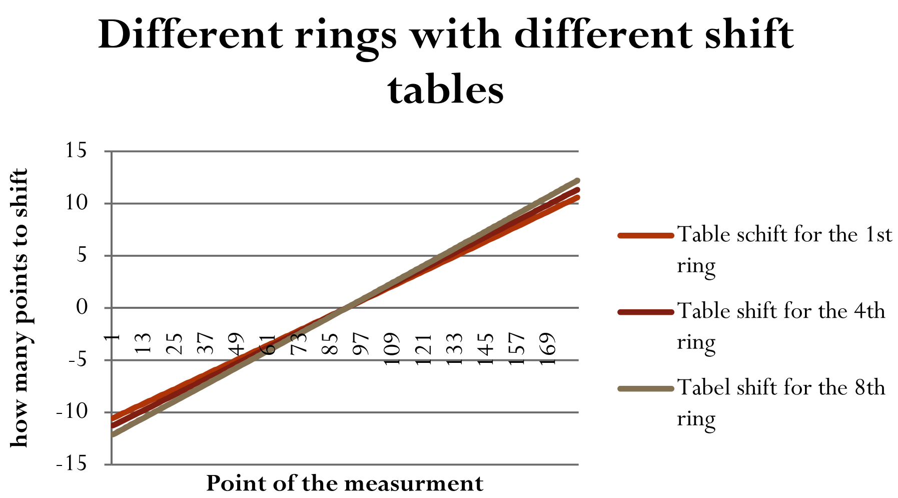


Figure 67 different rings with different shift tables

In every ring the talbe to shift is new calculated, if the measurement is near the center the shift is bigger. In the graphic above you can see some different shifts for some different rings. The lines that you see are the different tablet to shift from 4 rings. The maximal shift for the 1st ring is 10.5 points and for the 8th ring it is 12.8 points. The 8th ring is near to the center and the calculation of the Prism looks good.

8.4.2.2 Test the shift with the known angle

To control is also, if the shift of the file is correct for this test. The simplest way to do this is to measure the radial groove of the platter with the normal acquisition program. We compare the result of the shifted file with the file that is not shifted.

The first test is, to take one ring only and to shift and control if the result of the interpolation and the nearest point are horizontal after the correction. The result that we want to get is to see the radial groove of the platter horizontal through the measurement.

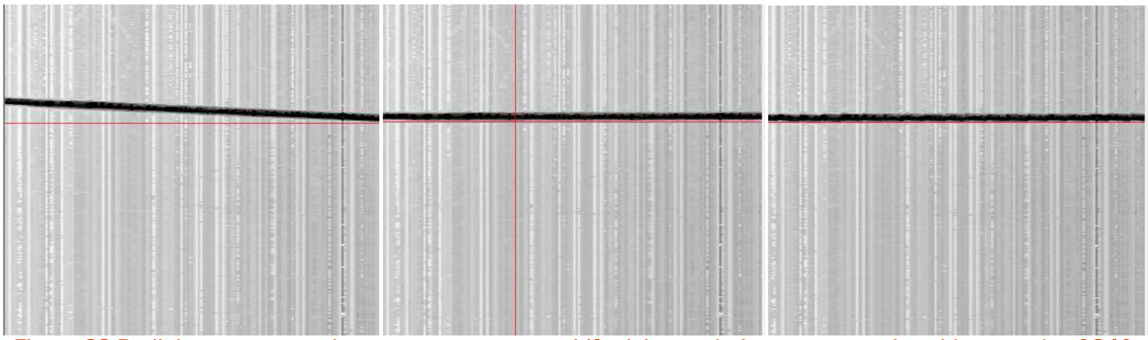


Figure 68 Radial groove correction, measurement not shifted, interpolation, nearest point with an angle of 24°

With only one measurement ring the radial groove is straight after the correction as you can see in the image for an angle of 24°. For other angles we got the same result. The interpolation of the two nearest points gives an image that is better than if we take the nearest point only. The line has not small changes in the line. Measurements at other positions also give the same images.

Another test is to make the same over more than only one ring. We control the last two rings at the same place and also horizontal. The last ring has not the same radius as the given first radius. The calculation of the shifting table is different.

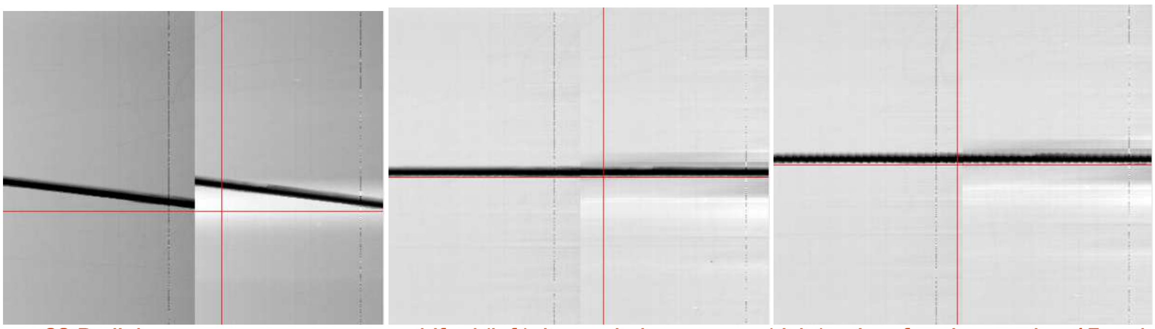


Figure 69 Radial groove measurement not shifted (left), interpolation, nearest (right) point after ring number 15 and 16

The last test for the radial groove is to test if it also works with an overlapping of more than only one measurement at the same place. The result should be one line as we have seen it in the image before. It should not be bigger, it must be the same. The only thing that changes is that the result is an average of more than one ring.

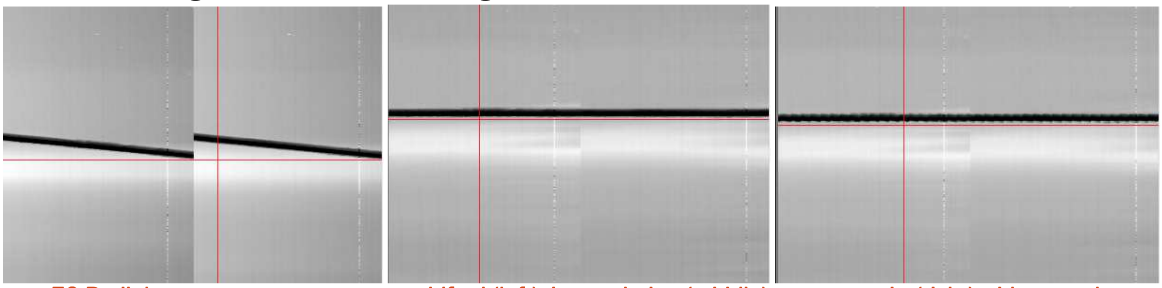


Figure 70 Radial groove measurement not shifted (left), interpolation (middle), nearest point(right) with more than one pass after the ring 6 and 7

The result you can see in the image above is achieved with a measurement of 6 rings and every ring is measured three times. The result for the radial groove is one straight line. The groove is not bigger and does not have other changes. The shifting of the file function is as it must be. For the radial groove the result of the interpolation is always better than with the nearest point only. The method with the nearest point only always has some small steps in it. For discs with a good quality the interpolation is the better method. For discs that have more points that are wrong it is possible that the method with the nearest point is better.

For the test disc, which is a good disc with a good measurement, the interpolation of the two nearest points gives us the better result. We get much less noise in the high frequencies which indicate that the groove has less small steps in it.

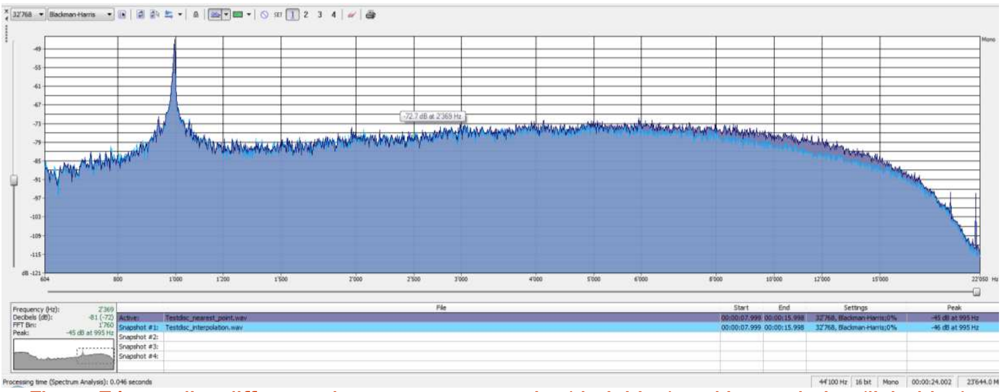


Figure 71 test disc difference between nearest point (dark blue) and interpolation (light blue)

Also the specter for the disc “Aloha” is smaller in high frequency and in low frequency the result is almost the same, but it looks like the result with the nearest point only is a little bit better.

Figure 72 Disc “Aloha” difference between nearest point (dark blue) and interpolation (light blue)

For most kinds of discs the interpolation gives a better result and is therefore normally used.

9 Analysis of the quality after rotation and shift

9.1 Spectrum with rotation and shift

For the test disc the result of the spectrum should be near the same with shift or without shift. Because the spectrum with only the rotation is already good. The spectrum should not change with the shift from the file.

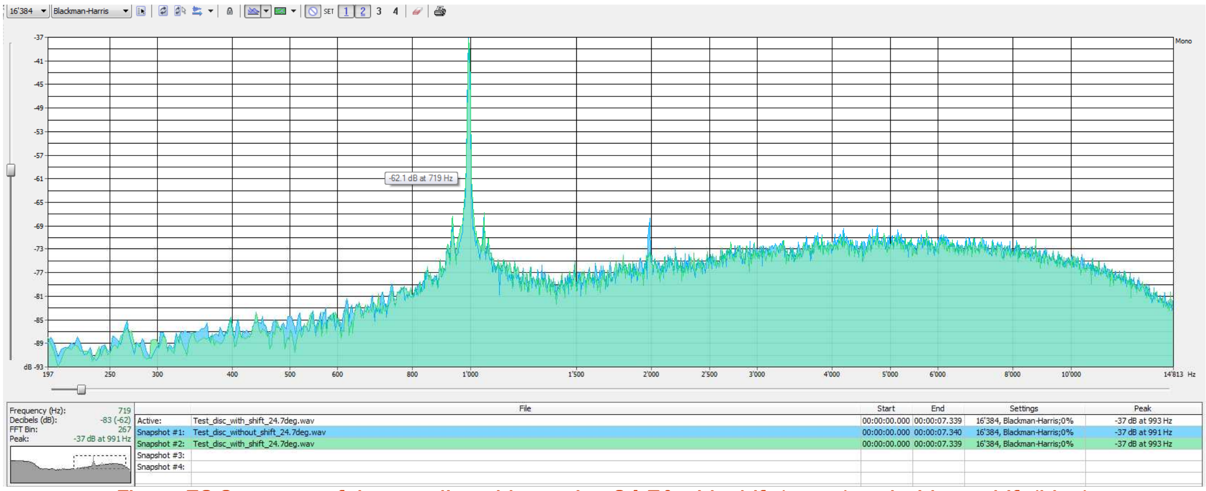


Figure 73 Spectrum of the test disc with rotation 24.7° with shift (green) and without shift (blue)

The fundamental peak is the same and also the two peaks at 60Hz around the fundamental are the same. The only thing that changes is the harmonic peak at 2 kHz. It is much less than without the shift.

For the disc “Aloha” and also for the disc “Moonlight” the spectrum looks similar. It does not have so much changes in it. The shifting of the file does not reduce the white noise of the file. So the constant noise will stay in the file and the shift does not help to get a much better spectrum.

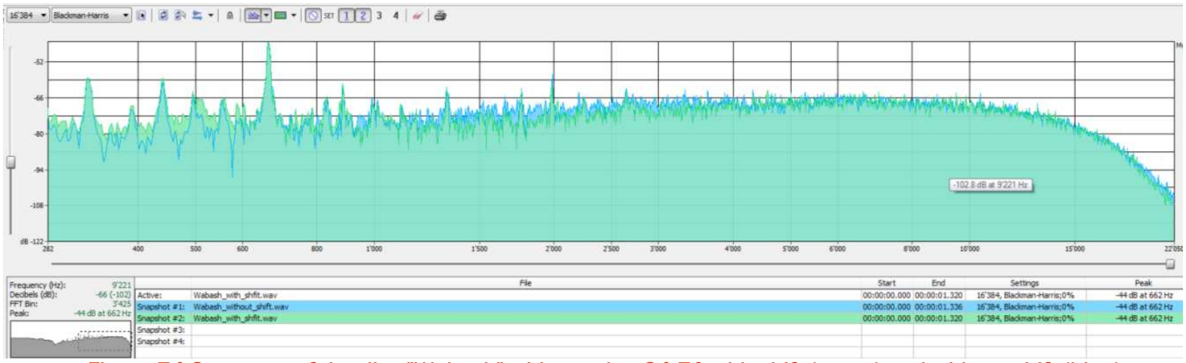


Figure 74 Spectrum of the disc "Wabash" with rotation 24.7° with shift (green) and without shift (blue)

For the disc "Wabash" the spectrum is better and there is not so much noise. There is a part at 1-4 kHz with less noise. The peaks are the same in the low frequency, but they are thinner, therefore the sound should be easier to hear.

9.2 COMPARISON OF THE SOUND

9.2.1 COMPARISON OF THE TEST DISC MEASUREMENTS

In this test we control if the result is better when we recalculate the file or if it is the same as before. This test is only working on the test disc. It gives us an answer to the question how good the rotation is. For the comparison I made new measurements, because the old measurements did not include the angle of the rotation. The result of the file without shift is almost the same as the measurement before.

9.2.1.1 Comparison of the SINAD and the THD

After the recalculation of the file .pri I can calculate the SINAD from the test disc with this new created file that gives me some new sound files. The comparison of the corrected rotated file with the rotated file is a test that is very exact because the measurement is the same and I can get exactly the same place to compare this new method.

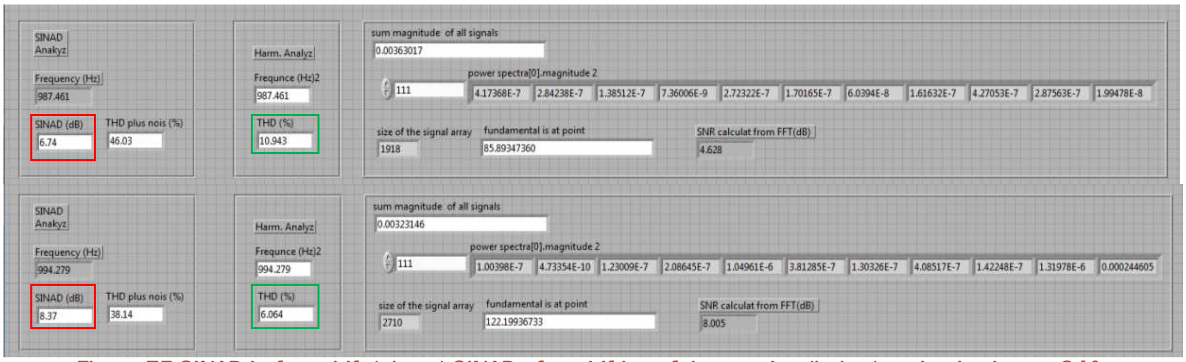


Figure 75 SINAD before shift (above) SINAD after shifting of the rotation (below) and noise image 24°

The SINAD for the test disc at 1 kHz is new 8.4 dB and the THD is 6.1%. That is 1.6 dB better than without shifting the file. Also the THD is, with 6.1%, better than before. For the calculation of the FFT I get a much better result with the shifted file than with the rotated file. The result for the shifted file is nearly the same as the calculation of the SINAD.

9.2.1.2 Comparison of the SNR

The comparison of the SNR is once more a control of the program. The difficult part here is always the same. We have to find a place of the disc that represents a good SNR. The SNR can change very fast and depends a lot on the place of the measurement.

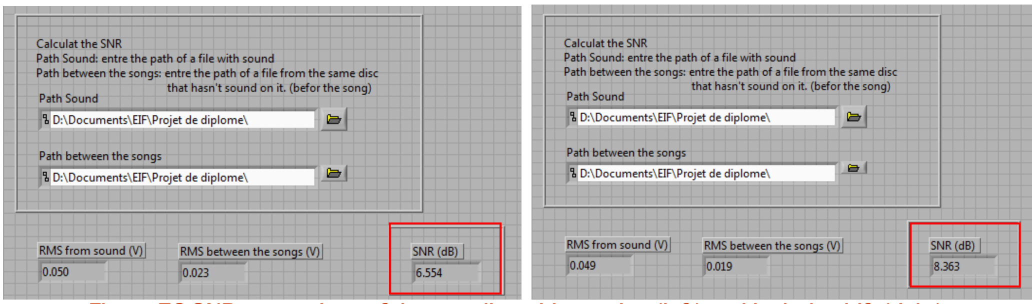


Figure 76 SNR comparison of the test disc with rotation (left) and include shift (right)

The SNR for the test disc without shift gives a SNR of 6.6dB what is the same as I had in the chapter 6. After shifting the file, the result of the SNR is 8.3dB and that is much better than before. The shifting of the file is important to get a better quality.

9.2.2 COMPARISON OF THE SOUND DISCS

We do not only have to test the test disc, but also the disc with real sound. I expect that we get a better result with the shifting of the file than with the rotation. The rotation should be nearly the same as in chapter 6.

9.2.2.1 Comparison of the SNR

The SNR of the disc “Aloha” was in the first measurement with the rotation 4.6dB.If the shifting works really well, the result for the measurement with rotation must be nearly the same and with shifting it should be better. The test below is made with the same measurement one time with deactivation of the shift and the other time with the shift. The two files are from the same moment of time on the disc.

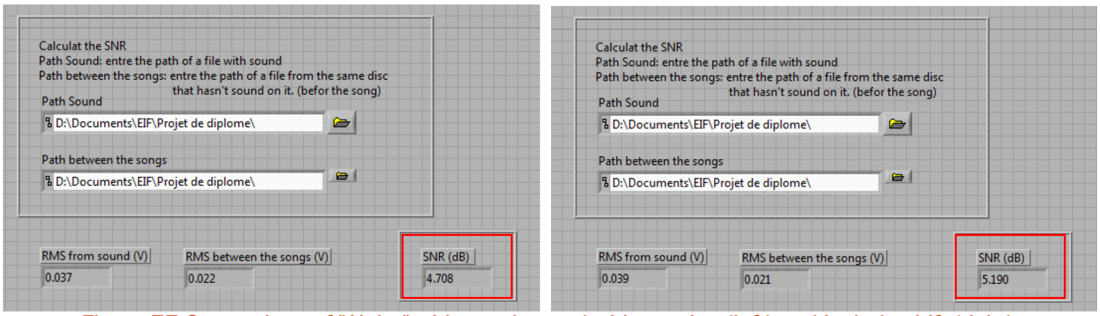


Figure 77 Comparison of "Aloha" with rotation and with rotation (left) and include shift (right)

The result for the disc “Aloha” is better with the shift. We get a SNR of 5.1dB with the shift and without shift we have a SNR of 4.7dB for the same place. This is 0.4dB better. In comparison without rotation, the SNR was only 1.3dB. So we get a much better result with rotating and shifting the file.

For the disc "Moonlight" we had a SNR of 5.2dB in the measurement in Chapter 6, what already was a good signal. Without rotation the SNR was the same, so the rotation does not help so much for the quality of this disc.

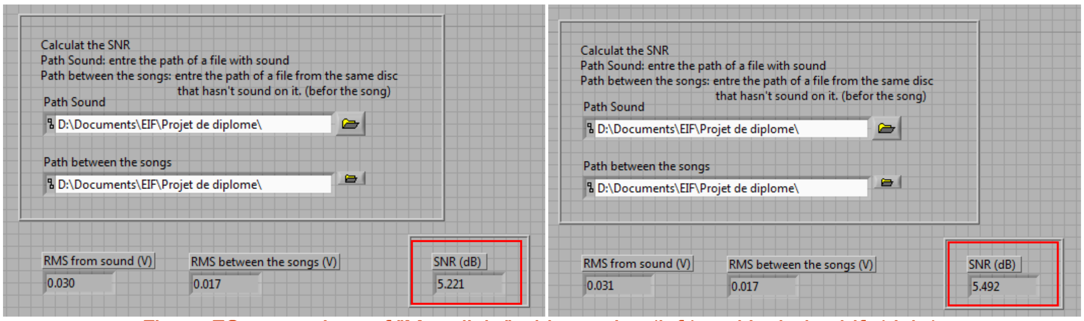


Figure 78 comparison of "Moonlight" with rotation (left) and include shift (right)

The quality of the disc “Moonlight” does not change so much after the shift of the file. The SNR is 5.5dB, what is only 0.2dB better than without rotating and shifting. For discs that are matte the rotation and the shifting do not increase the quality.

The disc "Wabash" had a very good quality before, the SNR with rotation was 6.8 and without rotation the SNR was 4.2dB.

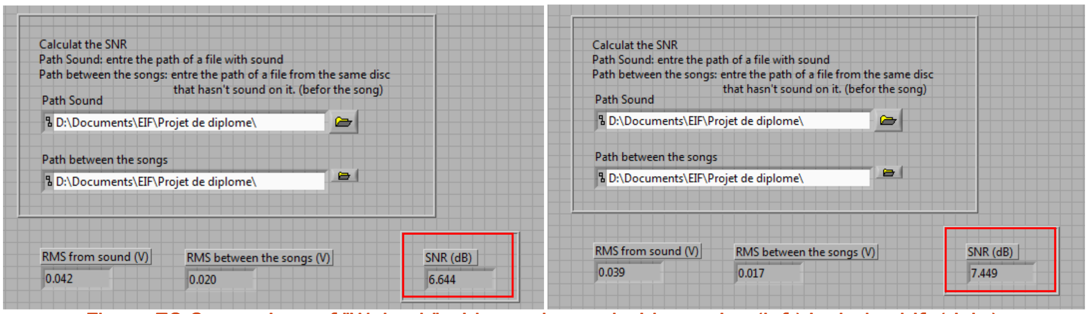


Figure 79 Comparison of "Wabash" with rotation and with rotation (left) include shift (right)

With the new method of shifting the SNR is 7.4dB, what is 0.8dB more than before. For all files the SNR is better with the shift than without. The shifting is important to have a good quality and it is useful at all places of the measurement.

Shifting the files is not useful for discs that we cannot read with rotation. The shifting only helps to increase the quality of the disc, what we could measure before.

9.2.3 COMPARISON OF THE AUDIO SOUND

To hear the difference of the shifting is not possible. The only thing that I can compare is the wave form of the newly created files. In the next images you can see if the wave from has fewer clicks and less noise.

9.2.3.1 Comparison of the sound from the test disc

It is not possible to compare the sound of the test disc. Therefore we only have a look at the wave form. The wave form for the test disc looks better. The wave form is not better in every point, but it has fewer points that contain many clicks or the clicks are less high.

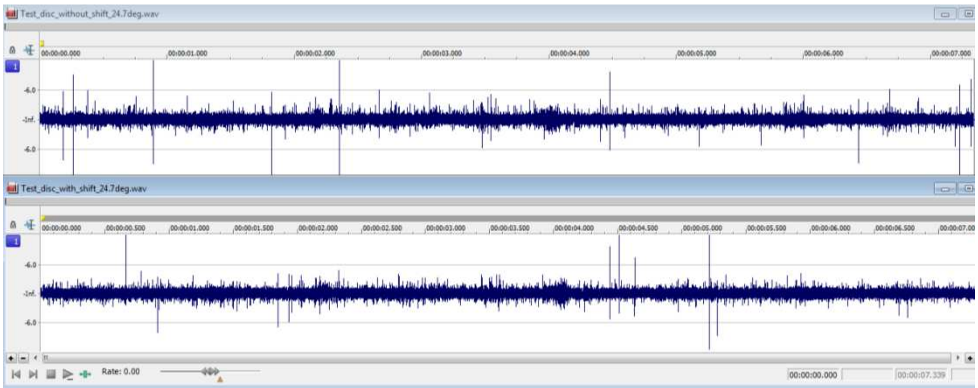


Figure 80 Sound file “test disc” with rotation above and with rotation and shift below

In the image below (with shift) the clicks are fewer. But we also get some points where we do not have any clicks. With the shifting of the file we get some new clicks. But mostly they are not as big as the one that disappeared with the shifting. The zoom into the sinus looks nearly the same. There are only some little changes.

9.2.3.2 Comparison of the sound from the disc Wabash

The sound of the disc “Wabash” looks also a bit better. It does not contain so many clicks and if it has some clicks in it the clicks are thinner. The spectrum of “Wabash” was better at some frequencies, but you cannot hear any differences between these two files.

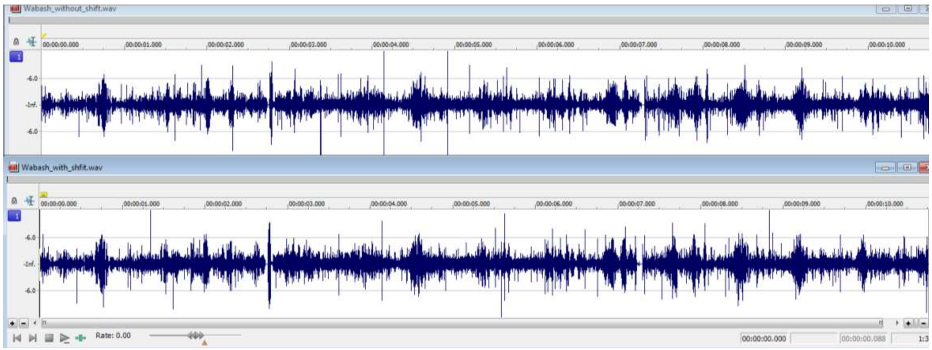


Figure 81 Sound file “Wabash” with rotation above and with rotation and shift below

The quality of both files is not so bad. I only have the problem that it contains some missing from the measurement. The sound quality is really good.

The results of the other two discs are the same with the shift. The sound quality is not really better. You do not hear any changes in the sound file. It is only the wave form that contains fewer and thinner clicks. I cannot hear the echo that must be in the wave files and so it does not change a lot to hear with the shifting.

9.3 Conclusion of the rotation

9.3.1 *Conclusion of the shifted file*

The acquisition program LabVIEW creates a new file .pri.rot and a new file pri.rot.bri. For this program it is necessary to give the angle of the rotation for the measurement. To get the angle of the probe, the new program written also in LabVIEW calculates the angle with the radial groove on the platte. The shift of the file is made in the program PRISM and it calculates a new table of shift for every distance in the file. This entire shifting works as it must work. The quality of the sound is better after the rotation and the shifting. A lot of discs can be read with a good quality. After one rotation the rotation is no longer useful, because the shifting saves the result in a file .pri and in a file pri.bri

9.3.2 *Conclusion over all measurement changes*

Until now all changes have resulted in an improvement and the SNR is always better. For all these measurements I used short sound files. This can give a good SNR for the moment, but not for the whole disc. This method is okay to compare different kinds of measurements. What are the improvements from the changes to get a measurement?

Overview over all SNR:

	Old probe	New probe	Rotation of the probe	With shift
Test disc	1.5dB	6.8dB	7.6dB	8.4dB
Moonlight	1.0dB	5.3db	5.6dB	5.5dB
Wabash		4.2dB	6.8dB	7.4dB
Aloha		1.3dB	4.8dB	5.2dB

The SNR for the test disc has an improvement of 6.9dB from the old to the new probe with rotation and shift. For the disc “Moonlight” the improvement is 4.5dB. And also the improvement for other discs is good. The quality of the sound files is much better than before.

10 ANALYSIS OF DIFFERENT ALGORITHMS

In PRISM exist at the moment a different algorithms and every algorithm has some parameters to change. At the moment it is not clear which parameters are the best for some algorithm. The best algorithm general is Fit-Line v2 flowed by Derivative and Fit-Line. The other algorithm gives until now not so a good quality. The program PRISM has a lot of parameters and if you change the parameter the program can calculate the sound with a better quality or not. To find the right algorithm and the best parameter was until now difficult and long.

10.1 ANALYSIS

In PRISM we have at the moment four algorithms to calculate the groove bottom center. The four algorithms are different in the hearing method. Every algorithm has some parameters to choose, but mostly the parameters are fixing and no one changes them. That makes it possible that some algorithm are better for a disc than others, but it is difficult to find the best possibility.

Not for every disc it is the same parameter that is the best, because the discs are made with different methods. Further they can be used more or less and this with different stylus, so that they have different erosions. Also the way they are stored, acoustically or electronically, can change the quality of a disc. It is not possible to get the same quality for every disc.

10.2 FIND THE BEST ALGORITHM

The idea is to test the sound quality of the disc with different algorithm very simple and change the parameter to get the best result. This test should be easy to make and should also make a lot of test if this is possible. The whole idea is to test the different algorithm with the different parameter automatically and give at the end the best method with the best parameters back.

10.2.1 *DIFFERENT ALGORITHMS*

Every algorithm has his own method to find the groove bottom center. This center is important to recalculate the sound on the disc. Some algorithms work better and some are not so good. With some changes of the parameter the result of the founded center can be more precise or less.[8]

10.2.1.1 Algorithm Fit

This is the easiest algorithm in term of calculation time and processing principle. The slopes on the left and the right are computed with an interpolation line. The crossing of the two lines is the center of the groove.

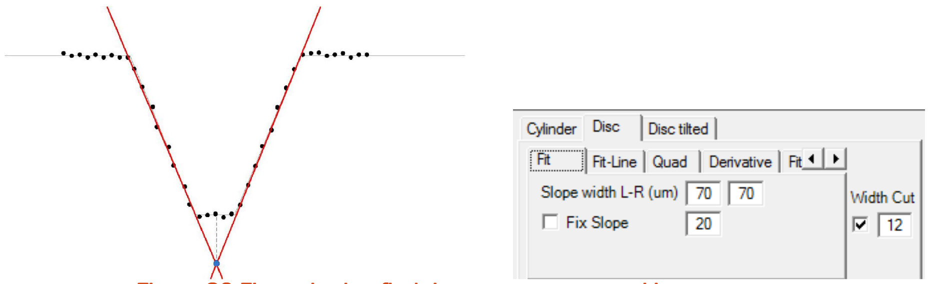


Figure 82 Fit method to find the groove center and its parameter

The parameters for this method are the length of the slopes on the left and the right side. The fix slope is to detect and we correct bad points on the slopes. The last parameter is for the tolerance distance in micros for bad points detection.

Algorithm Fit-Line

The Fit-Line method is one of the best algorithms until now. Adrien Nicolet has made a new variant of this Algorithm Fit-Line V2. The principal is the same, but in the new version there is added a correction rate and an interpolation for slopes that are out of the range.

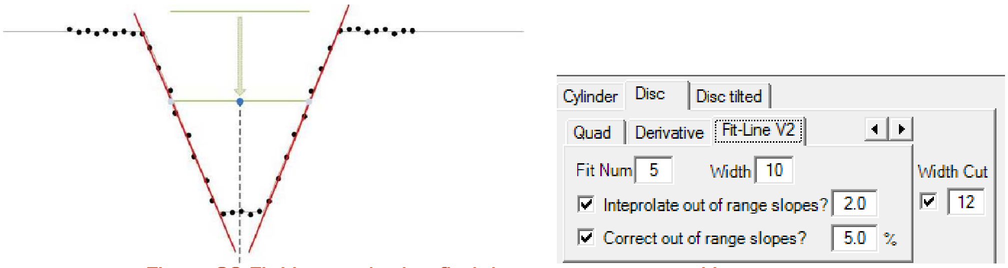


Figure 83 Fit-Line method to find the groove center and its parameters

In this method the program places a line with the given width parameter in the groove one time the place of the line is found. The program takes the points around this line. The number of points that are taken is given by the parameter Fit Num. With the number of points the method calculates two lines, one on the left and the other on the right side. after the two lines in the slop he drop the line one more time into the calculated tow lines the middle of the dropped lien is the center of the groove.

For the Fit-Line V2 we have the following parameters: The Fit Num defines the number of points around the first approximate drop the line to calculate the slope lines. The width is the length of the dropped line. The interpolation out of range gives the value of how much the slope can be away from the standard derivation (x times the standard derivation) and the center is interpolated. The parameter "correction out of range slopes" is given in % and corrects the value of slopes that are not correct. For a good disc this value should be around 0 and for a bad disc be more. If it corrects some slopes it takes less or more points to make the fit and searches the slope line near the median of all slopes.

10.2.1.2 Algorithm Quadratic

In this algorithm the program does not only calculate lines like the algorithms Fit and Fit-Line. To find the groove center, this function takes the parameter "Number of Points" and takes this value around the groove center to fit a quadratic function in these points.

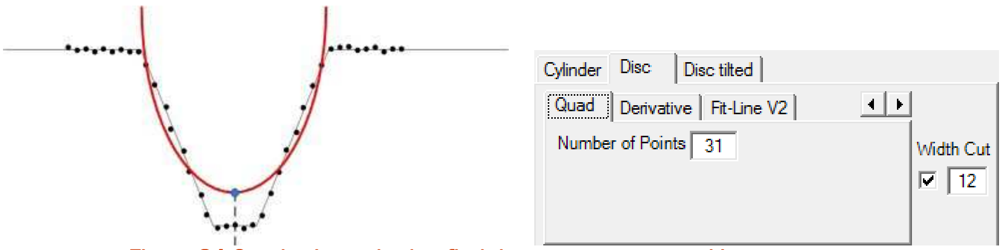


Figure 84 Quadratic method to find the groove center and its parameters

The zero-point of the quadratic function gives the center of the groove. The parameter to choose is the number of points to use for the Quadratic fit.

10.2.1.3 Algorithm Derivation

The method Derivation gives a good sound quality. It does not need any parameters and it is less sensitive to single errors. The program calculates all information itself. The idea is to use the property of the groove, which gives the horizontal movement.

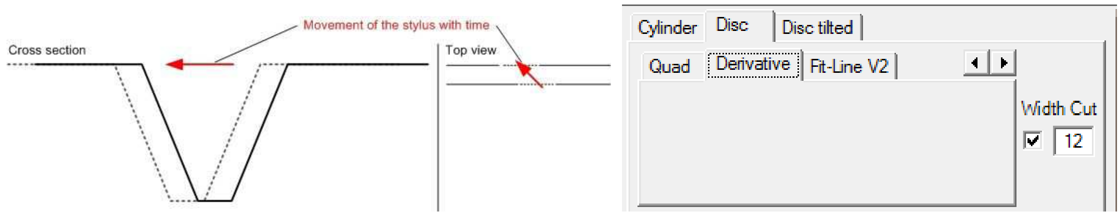


Figure 85 Derivation method to find the groove center and its parameters

This method calculates the depth difference of one measurement line to the next and with this information it finds the change of the groove center. With the intensity of the measurement the program finds then the slopes and can calculate the groove center with this information.

10.3 REALIZATION

The objective has changed during the project and some other parts of this project have become more important. So the calculation of the angle of the rotated probe was used more, as well as the test with the tilted probe. There was not enough time to make the full automatically test and also for the test of different algorithms there was not enough time left. The idea was to integrate the program LabVIEW in the program PRISM to test the SNR and to make the program LabVIEW useful in a general method, so that it does not only give us a number.

10.3.1 USE LABVIEW IN THE PROGRAM PRISM

To include the program LabVIEW in PRISM it is necessary to install also the program LabVIEW on the machine. In the program PRISM you must include the reference of the program LabVIEW. The second thing that is essential to include the LabVIEW program in PRISM is to add LAB_VIEW_REF in the Microsoft Visual Studio. You can find it under Project→Prism properties…→Build→ conditional compilation symbols add LAB_VIEW_REF.

10.3.2 Changes in PRISM

The change in the program PRISM is only a button for the "Test SNR" on the front panel. If the program LabVIEW and the reference of the program are correctly installed, this botton opens a new window which nearly looks like the normal LabVIEW program to control the SNR.

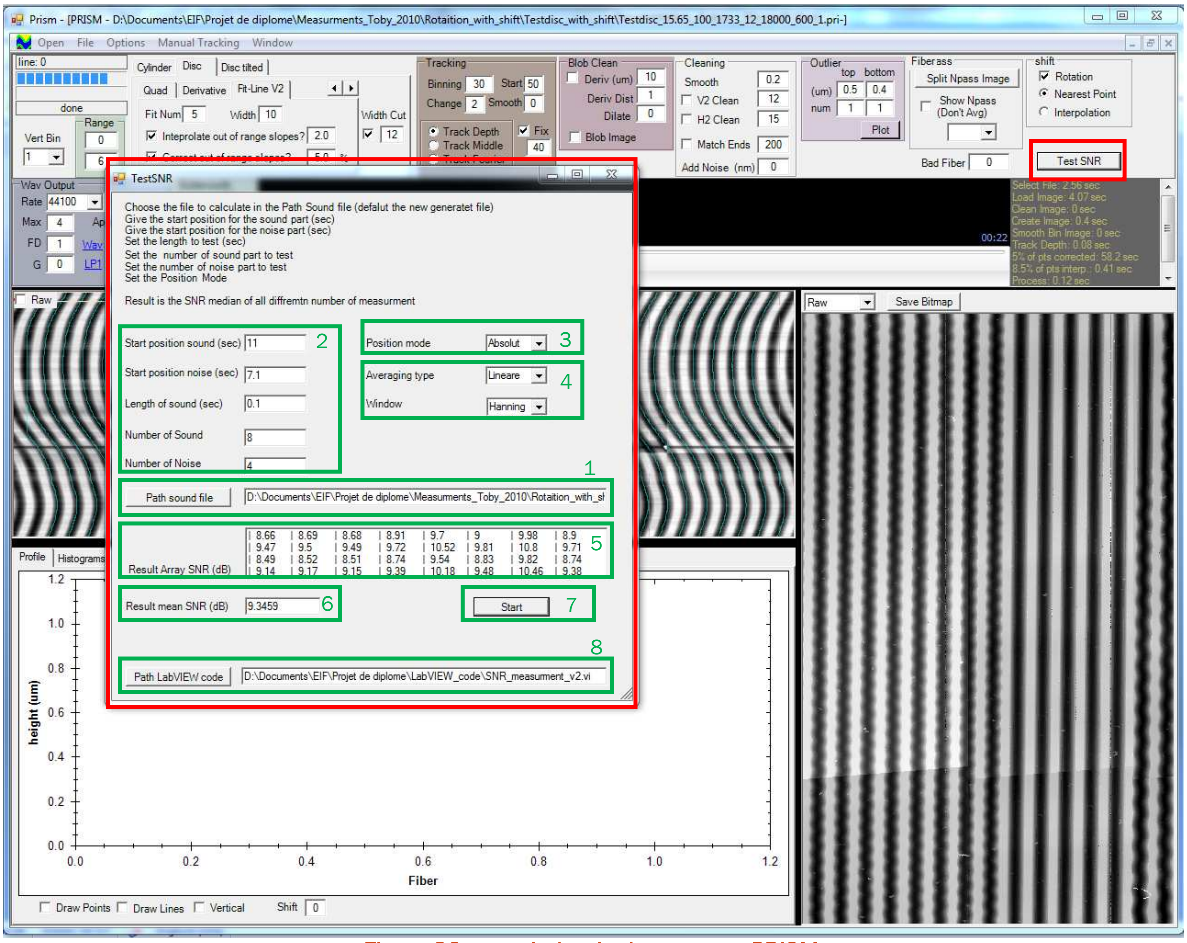


Figure 86 new window in the program PRISM

The button at the top on the right opens the new window. This takes the same parameter as the program LabVIEW.

1) -The path for the sound file is necessary if a sound file was generated before this file is chosen as default. You can change other files with the button Path sound file.
2) -Two points of the sound are necessary, the first point is the start position for the sound file and the second point is the start position for the noise part of the disc.
   -The length of both sound parts are requested they should be short (1-2sec)
   -Number of different sound measurements. It takes one or more times the sound part and compare this one with the noise part. For the first measurement it takes the start position, for the other it takes as start position the point of start plus the length of the sound.
   -Number of different noise parts as the sound part takes more than one noise part and compare all the different noise parts with all the different sound parts.
3) -The position mode absolute takes the start position from the beginning of the file. With the mode relative it takes the start position at the current location of the file mark plus the position offset. Normally the position mode is absolute.

4) Is used for the calculation of the RMS:
   -averaging type is the type of averaging used during the measurement:
      -Linear –Integration time is equal to the record length
      -Exponential- Time constant is half the record length
   -Window applied to the time record before RMS computation
      -Rectangular (no window)
      -Hanning
      -Low side lobe
5) The output array of all the different calculations of the SNR. The rows are the different parts of the noise and the colons are the different parts of the sound.
6) The mean value of all different SNR calculation (dB)
7) Starts the program
8) Path to the LabVIEW program

Start the program LabVIEW is synchronal and must wait until the program has made all the calculations. This can take some time, because the machine must open the program and calculate after. The speed to open the program LabVIEW depends of the machine.

10.3.2.1 Class SNR.cs

In the class SNR.cs it is necessary to use the reference from LabVIEW to communicate directly with this program. It is only activated if the conditional compilation symbol is set.

References to use:

```
#if (LAB_VIEW_REF)
    using LabVIEW;
#endif
```

With the reference LabVIEW the program in c# can communicate directly to a program written in LabVIEW and can set parameters, read parameters and run the program.

Constructer of the class:

```
public Snr(TestSNR frSNR)
```

Constructer of the class SNR which uses the parameter TestSNR which is the interface of the new window.

Methods of the class SNR.cs:

```
public void snr_measurment()
private bool ControlNumbers()
```

There are two methods in this class. The class snr_measurmetn which is called after using the button Test SNR, is the class that makes all the communication with the program LabVIEW. Some special commands are below and the method ControlNumber, which controlls all the entries of the interface if they are possible and return a booleon if everything is all right or not.

Special function for LabVIEW

```
_Application labVIEWApp = new ApplicationClass();
VirtualInstrument vi;
vi = labVIEWApp.GetVIReference(vi_path, "", false, 0);
vi.OpenFrontPanel(true, FPStateEnum.eVisible);
vi.SetControlValue("Start position sound (sec)", start_pos_sound);
vi.Run(false);
snr_res = (double)vi.GetControlValue("SNR (dB)");
vi.CloseFrontPanel();
```

This are the main functions to communicate with the program LabVIEW.
-Application Class();start application LabVIEW
-Virtual instrument: Makes the object LabVIEW
-GetVIReference(): Assign an object reference to vi

-OpenFrontPanel():	opens the front panel and you can see the front panel of the program LabVIEW
-SetControlValue():	the first parameter must have the same name as the control in LabVIEW and the second parameter is the number to set in this control.
-Run ():	starts the program with false synchronal or with true asynchrony
-GetConrlValue():	return the value of the indicator with the same name like the first parameter
-CloseFrontPanel():	closes the Front Panel and stops the program LabVIEW

10.4 TEST OF THE DIFFERENT ALGORITHMS

10.4.1 *HOW TO TEST*

The test on which I make my conclusion is the method to calculate the SNR. This is not an absolute value to find the best algorithm and parameter, it only gives an indication which algorithm should be the best. To test is after that also the image of the sound wave and the spectrum of the sound file. The test of the SNR is always made with the same part of the file and with more than only one measurement, so that you do not only compare the mean value of the SNR. It is possible that one method is better for one part than for the other but we want to test the quality of a long part of the disc and not only of one part of the disc. Until now the test of the SNR was only made with a small part and always with a good part of the sound file. With more than one test the result is more general.

The tests are made with the newest version of PRISM, so that also the changes from Adrien Nicolet are included. The tests are made with new measurements that means with measurements that have a rotation angle and a shift.

10.4.2 *TEST THE ALGORITHM FOR THE TEST DISC*

For the test it is difficult to say with which parameter I should begin. So I begin with the standard values and then I change the parameter, so that I can find the best values for each algorithm. All tests are made with the width cut of 12 parameters. For the test disc I used the file:

To find the best parameters the simplest way is to change one value in one direction and compare the SNR with the old measurement. After that we have to decide if the value is better or not. If the value is better, the direction is the right, if it is not better, we have to change in the other direction. After changing the first parameter we can change some other parameters and make the same. In most of the cases this method works.

In this test the SNR is smaller than in the documentation before. This has the reason that the test is made with longer parts of sound and noise. I changed the length for the test because the test with longer parts of a file is more stable and you can see in the table of the different array that the SNR does not change the value so much. In the case if you make the measurement only with small parts, the SNR changes for every part of the sound and is not really representative for the whole disc. Before it was not really important what the quality of the disc is, because the test before represented only a small part of the disc with a good quality. Now the test shows the global result.

10.4.2.1 First test

To test is the file with all standard implementation of the algorithm. I calculate the SNR of the same part of the measurement with all variants.

	Parameter	Calculated SNR
Fit	Slope width L-R(um)70,70, Fix slope 20	4.5dB
Fit-Line	Fit Num 5,Width 10	6.5dB
Quadratic	Number of Points 31	2.1dB
Derivative	-	8.8dB
Fit-Line V2	Fit Num 5, 10,Interp. 2 Corr. 5	7.4dB

10.4.2.2 Second test with optimal numbers for each algorithm

The new founded parameter and the result of some different test gives us the results below.

	Parameter	Calculated SNR
Fit	Slope width L-R(um)70,70, Fix slope 15	4.9dB
Fit-Line	Fit Num 7 ,Width 11	7.9dB
Quadratic	Num Points 15	6.8dB
Derivation	-	8.8dB
Fit-Line V2	Fit Num 7, Width 11,Int 2 Corr 2	9.2dB

To find the best parameters is not so easy. Which one gives the best solution? In the case of the test disc the best solution looks like the Fit-Line V2 method and the second would be the Derivative.

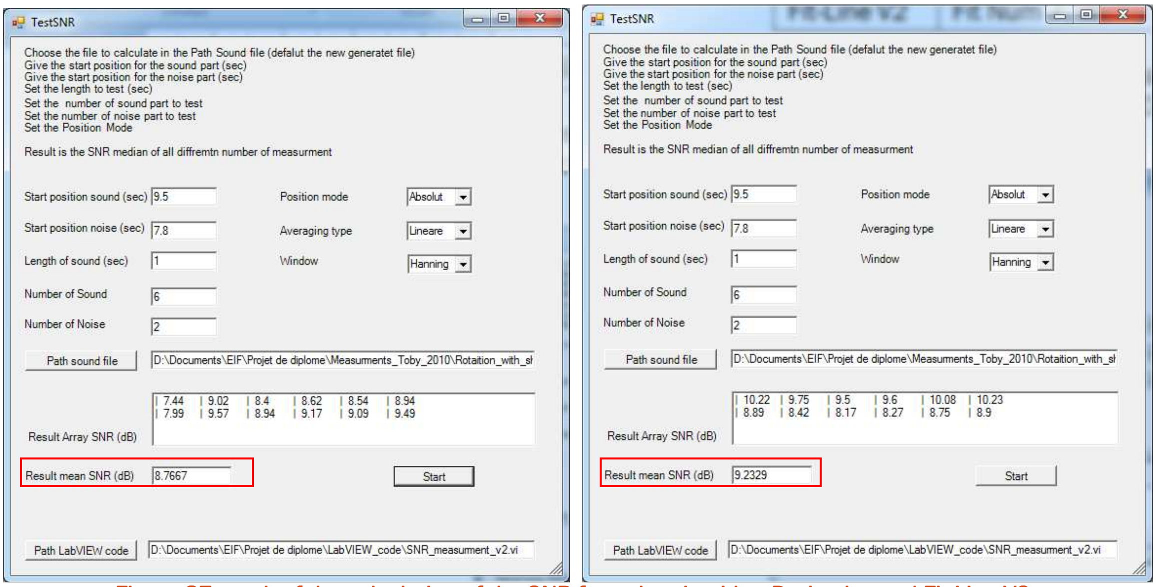


Figure 87 result of the calculation of the SNR from the algorithm Derivative and Fit-Line V2

This result is only one indication. To control is now also if the sound is really the best with this method. To ckeck is also the spectrum of the best parameter files and to have a look at the sound wave of the file. In the method Fit-Line v2 it is really important that you do not have too much interpolation, because the interpolation can make the SNR better. This has the effect of a low pass filter and you loose to much sound information.

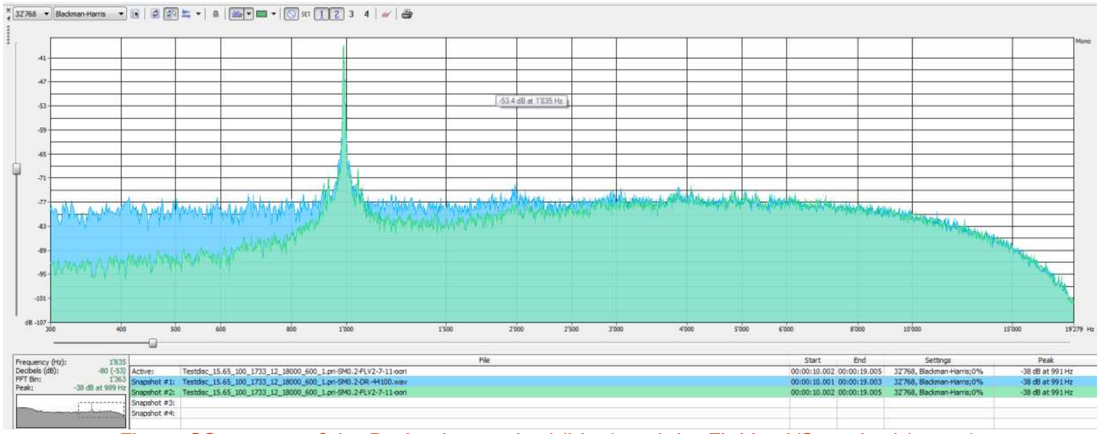


Figure 88 spectra of the Derivative method (blue) and the Fit-Line V2 method (green)

The spectrum of the Fit-Line V2 method looks much better than for the method Derivation. It has less noise around the peak and the peak is much smaller. In the high frequency the Derivation method is a bit better but not so much. The Fit-Line v2 is the better solution, also for the spectrum.

To control if the Fit-Line V2 method really is the best, I test it with the method SINAD which only uses one file with sound.

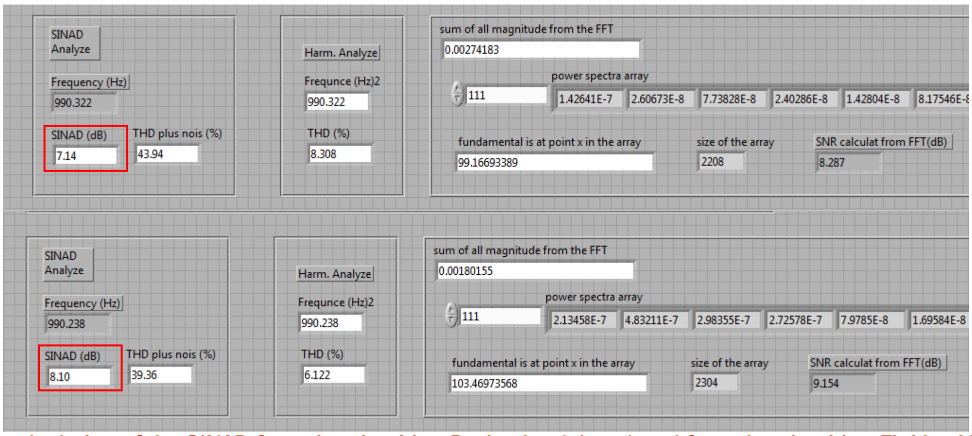


Figure 89 calculation of the SINAD from the algorithm Derivation (above) and from the algorithm Fit-Line V2 (below)

The SINAD from the method Fit-Line V2 is better in the SINAD analysis and in the calculation with the FFT function. The best method is the Fit-Line V2 method and it has a SNR of 9.2dB over a long period. The sound of this measurement is good and it has not too much interpolation in this file. The value for the SINAD is smaller or nearly the same with the calculation of the FFT.

10.4.3 TEST THE ALGORITHM FOR "ALOHA"

The disc "Aloha" is an old disc and has a lot of small cracks and wrong parts in it. For this reason the quality of the disc is not the best. It is more difficult for the program PRISM to find the groove center of this disc. It is not so easy to find the best place to get the measurement. The used file for this test is: aloha_60_1670_5_18000_600_1.pri.rot with the shift method interpolation.

10.4.3.1 First test

The first test is done with the parameter per default:

	Parameter	Calculated SNR
Fit	Slope width L-R(um)70,70, Fix slope 20	1.7dB
Fit-Line	Fit Num 5,Width 10	1.5dB
Quadratic	Number of Points 31	0.8dB
Derivation	-	0.7db
Fit-Line V2	Fit Num 5, 10,Interp. 2 Corr. 5	2.0dB

It is difficult to find the values. The problem is that the disc has a bad content and the measurement cannot read well every place. The other problem is to find a place in which all algorithms have a noise level that is acceptable. The values of the SNR can change a lot in this measurement and this is an indicator that the measurement is not good. In this case it is difficult to find the best parameters with the method SNR.

10.4.3.2 Second test with optimal numbers for each algorithm

It is difficult to find the best parameters, but I will test it. The problem in this case is, if I change some parameters, the program makes a lot of interpolation and this means that the SNR would be better, but the sound quality is worse. The reason is the interpolation that is a low pass filter which also filters the important values. I also changed the with cut value so that I do not have too much interpolation in one file.

The founded parameters for each algorithm:

	Parameter	Calculated SNR
Fit	Slope width L-R(um)50,50, Fix slope 20	2.0dB
Fit-Line	Fit Num 6,Width 8	2.3dB
Quadratic	Number of Points 11	2.1dB
Derivation	-	0.7dB
Fit-Line V2	Fit Num 6, 8,Interp. 2 Corr. 2	2.5dB

The best algorithms are Fit-Line and Fit-Line v2. The difference is not so big, but Fit-Line v2 is 0.2dB better than the Fit-Line.

The parameters for this disc are different from the test disc and the entire discs have some other parameters that give the best result. It is important that the best method will be found. If we compare with the standard parameters, the results are much better with the parameters that are optimal.

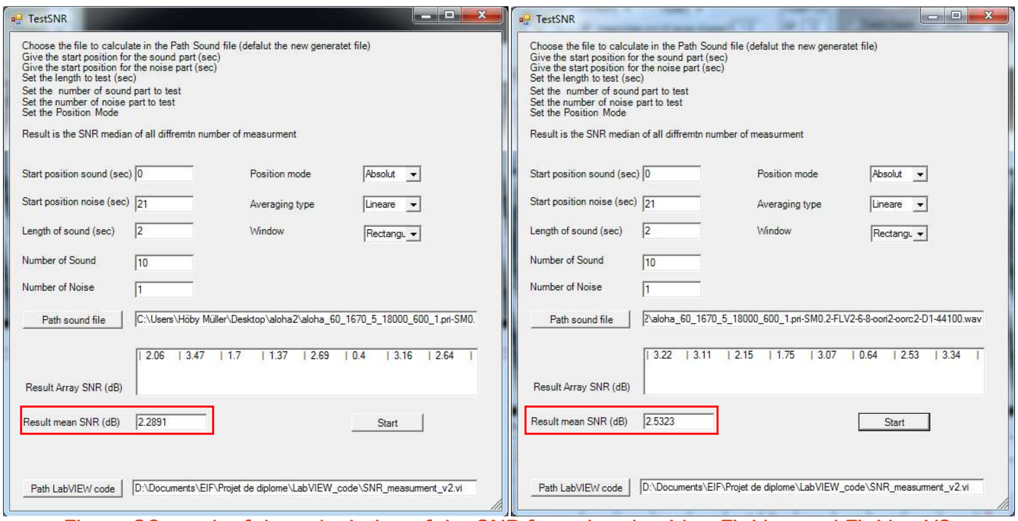


Figure 90 result of the calculation of the SNR from the algorithm Fit-Line and Fit-Line V2

The spectrum of the measurement also shows the same as the measurement SNR. The spectrum for the algorithm Fit-Line v2 has a much better result in the higher frequency than the algorithm Fit-Line.

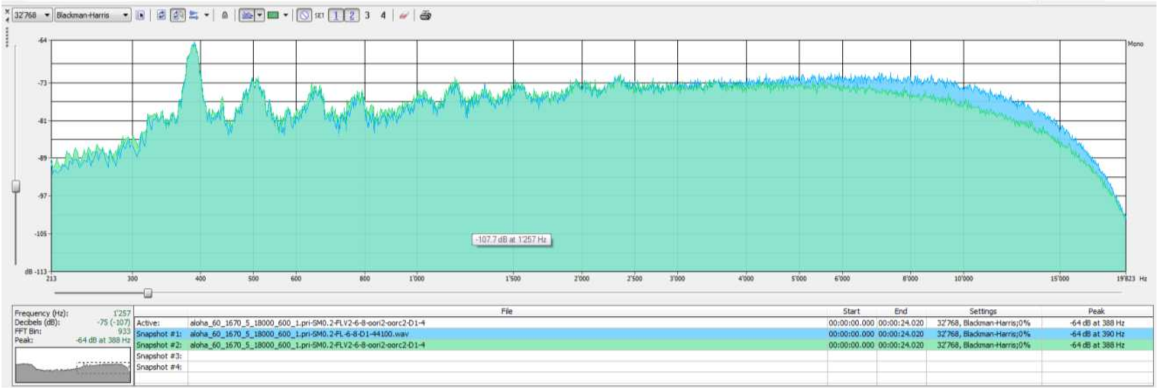


Figure 91 spectra of the Fit-Line method (blue) and the Fit-Line V2 method (green)

But also in this measurement with Fit-Line v2 the SNR changes a lot and it is not so constant. That indicates that the measurement is not so well and the sound file is not constant. It can change a lot. But on the disc there is sound and the sound power is not the same at every moment, so for sound discs the SNR changes every time. In the case of "Aloha" it is too much.

10.5 Conclusion of the Analysis of different algorithms

The calculation of the SNR in the program PRISM is something that is good because you do not have to search the file. The program chooses the file automatically and it compares the sound information in a simply way. The different algorithms always give different results. It is difficult to say which algorithm is the best after a few tests. The best method until now is Fit-Line V2. But also other methods can give a very good result of audio file. The parameters are different for every disc and therefore must be tested for every disc. The test to find the best parameters must also include the measurement of the different spectra and also the wave form of the sound is important. At the moment these two things are not made automatically in the SNR test. It would also be good, if all these different changes of the parameters were automatically, so that at the end of the program we have all the variants with the best method. The test of the SNR is a good variant to give approximately the best algorithm with the best parameters. One mistake that can occur is to interpolate too much signal. This allows us to get a better SNR but the audio file is not better.

11 COMPARISON OF THE WHOLE RESULT

The results of the sound files are not so bad. To test is what the result of the measurement at the end is. For a comparison I take some new discs, which are also tested with the program IRENE, the 2D system also produced by the Lawrence Berkeley National Laboratory. Some of the discs are also read by a normal stylus system. The new discs for this comparison are "Johnny" from Les Paul and Mary Ford, "Double check stomp" by Duke Ellington and his Orchestra and "Chattanooga Blues" by Ida Cox.

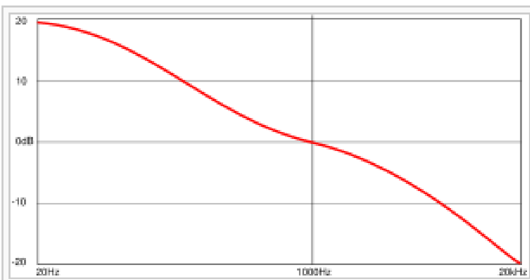
The different discs are:

Figure 92 Disc to compare with the system IRENE

Label	Title	Disc type	Disc quality	Content	Named
Bluebird	Double check stomp	Half shiny	Good quality Shiny	Song by Duck Ellington and his Orchestra	Stomp
Capitol	Johnny	Mostly matte	Good quality	Song by Les Paul and Mary Ford	Johnny
Paramount	Chattanooga Blues	Matte, Acoustic recording	Cut, bed quality	Song by Ida Cox	Chattanooga

Comparions

The file that with hey I can compare are have include some filtering and some cleaning. This makes the quality of the disc much better and you can hear the music well. I will first compare what we can make with adding the same filter on our file. In the version of IRENE they had add a filter RIAA equalization this is a specification for the correct playback of gramophone records and is established by the recording Industry Association of America. [9]



The RIAA equalization curve for playback of vinyl records.

Figure 93 RIAA equalization

Test the disc Stomp

The first test is made with the disc “Stomp” (Double check stomp), this disc is a shiny disc in a good condition. The sound from IRENE is very well and you can hear the sound really good. So we test to make the same measurement with the 3D system. For this test we only take a sampling frequency of 18000Hz and read every ring only once, that means without overlapping. To take a measurement in this condition goes fast, to take the whole disc takes approximately 15min.

For the test I take the same part of the disc, and the calculation of the SNR is made at the beginning of the disc. It is the beginning of the disc with only noise for the first 0.7 sec. For the test with the program PRISM I used the file: stomp_120_1699_11_18000_600_1.pri.rot. The best result was found with the method: Fit-Line v2 and the parameters With Cut: 12, Fit Num: 5 Width: 10 Interpolation: 2, correction: 5 and shift the file with the method interpolation.

The improvement from the RIAA filter is that the high frequencies are filtered and the low frequency are amplified. This has the effect that the noises in the high frequency are much lower and the sound quality is better.

First I check what is the improvement for the measurement in PRISM with the RIAA equalization.

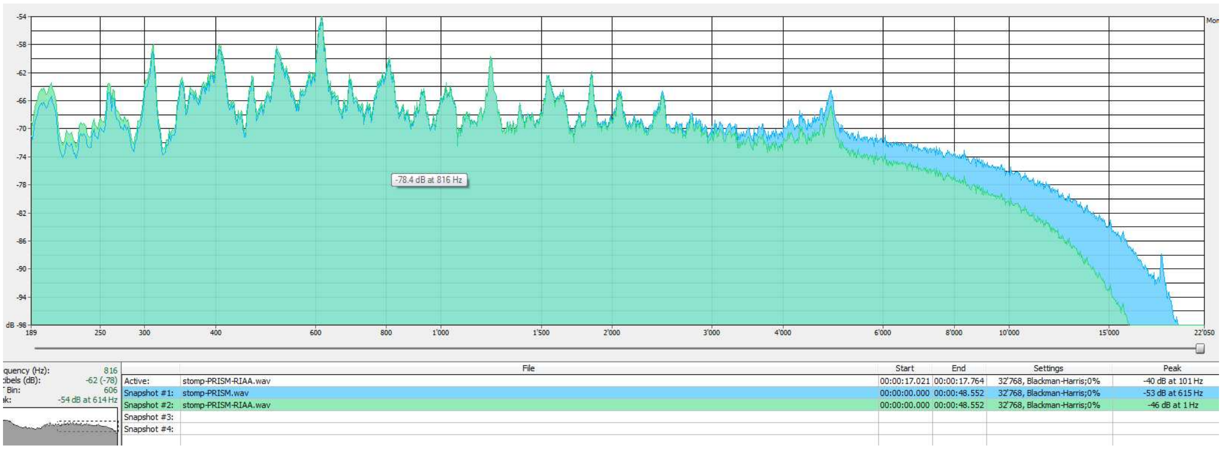


Figure 94 comparison spectrum from PRISM with RIAA (green) and without (blue)

You can see that the spectrum with the RIAA equalization has in the high frequency a much smaller spectrum and in the low frequency I much higher spectrum than for the file without RIAA equalization. The SNR calculation for the file without RIAA is 7.4dB and with the filter we get a SNR of 9.6dB, this is an improvement from 2.2dB.

The file with the RIAA equalization would be compare with the file from IRENE that has also included the same RIAA equalization.

The SNR from the measurement with IRENE and the RIAA is 11.1dB and for the measurement with PRISM and RIAA we get a SNR from 9.6dB. The program IRENE is 1.5dB better than the program PRISM.

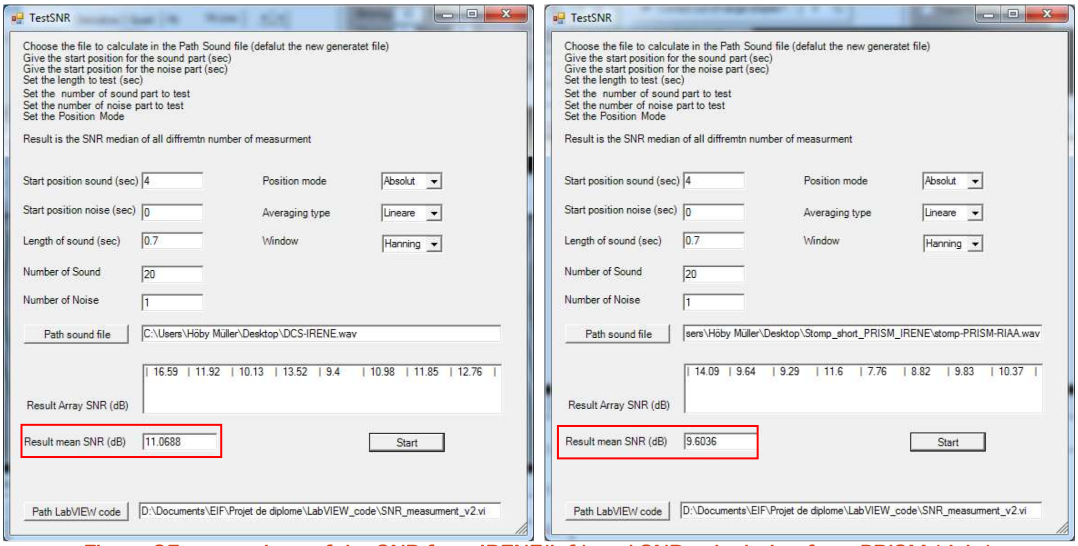


Figure 95 comparison of the SNR from IRENE(left) and SNR calculation from PRISM (right)

The SNR from the program IRENE is 11.1dB and for the program PRISM we get a SNR of 7.3dB. That means that the program IRENE gives us a SNR that is 3.8dB better than this one from the program PRISM.

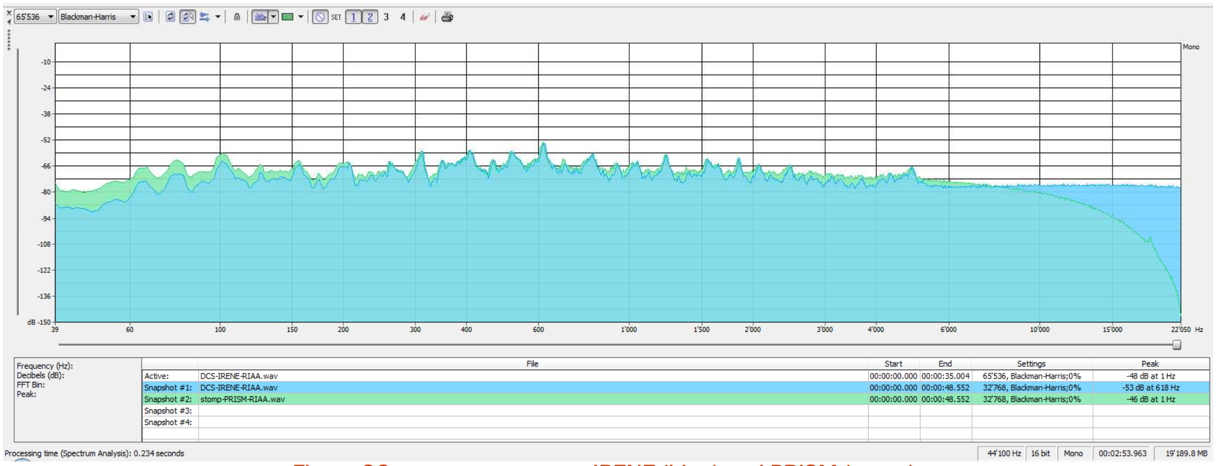


Figure 96 compare spectrum IRENE (blue) and PRISM (green)

The spectrum in the low frequency is higher but for all frequency and also for the noise in this part. In the frequency of 1 kHz to 10 kHz the spectrum of IRENE is better. After 10 kHz the spectrum of PRISM is better, but in this range we do not have any sound, and it is possible that this improvement over 10 kHz comes only from a lower sampling frequency.

Test the disc Johnny

The second test is bigger, because from the disc “Johnny” we also have some measurements with a normal stylus. For this test I use the file: johnny_120_1676_12_18000_600_2.pri.rot. The parameters with the best solution are: algorithm: Fit-Line V2, With Cut: 25, Fit Num: 6 Width: 10 Interpolation: 2.5, correction: 3 and shift the file with the method interpolation.

For the “Johnny” I get had some sound file they ware taken with a normal stylus system and after that was added a RIAA equalization. For the file in PRISM I had only a file with RIAA equalization and after the equalization he added also a declicking (DC) which means it cleans also some clicks of the file they have a too high gain.

I will compare first what happen with the measurement file from PRISM if I add also a RIAA equalization and also with the declicking.

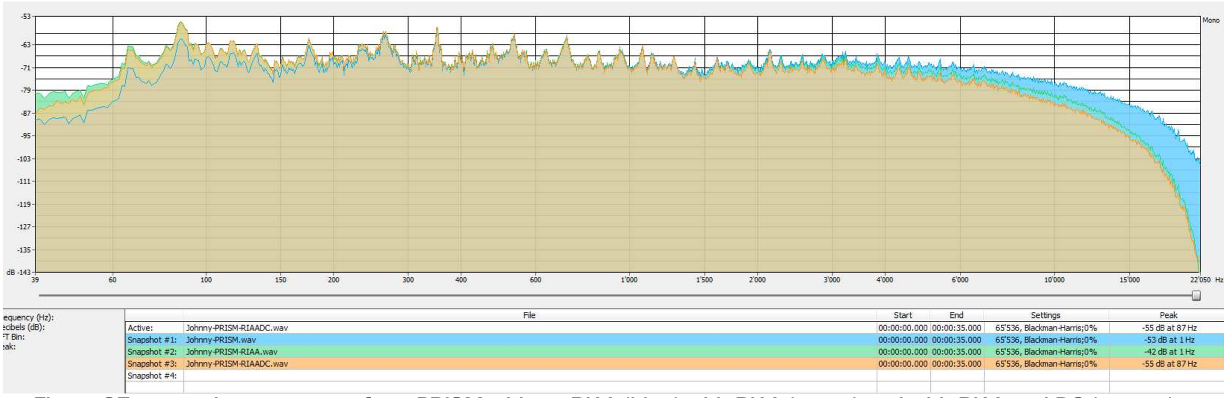


Figure 97 comparison spectrum from PRISM without RIAA (blue) with RIAA (green) and with RIAA and DC (orange)

The spectrum with the RIAA and the declicking is the best it is in the high frequency because it contains not a lot of clicks. In the low frequency it is the same as the version with only the RIAA equalization. The version without some improvement is the worst. For the version without some improvement the SNR is 7.3dB for the version with RIAA equalization the SNR is 8.9dB and for the version with RIAA and declicking the SNR is 12.6dB. The version with RIAA and declicking has u much higher SNR than the version without something.

Compare between IRENE and PRISM

To compare IRENE with PRISM I add to the measurement of PRISM a RIAA equalization and also a declicking. So that booth files have the same improvement.

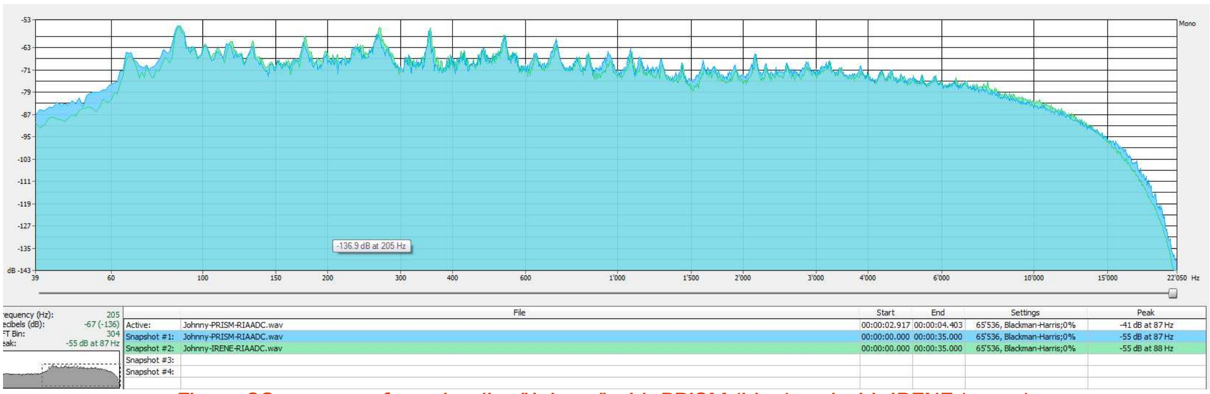


Figure 98 spectrum from the disc "Johnny" with PRISM (blue) and with IRENE (green)

The spectrum from the measurement with IRENE is in the lower frequency better it does not contains so much power between the piques and the piques are smaller. In the frequency above 200Hz the spectrum is near the same.

For the comparison with the normal stylus system I improved the measurement from PRISM only with the RIAA equalization because the measurement with the stylus is also indicat with this improvement.

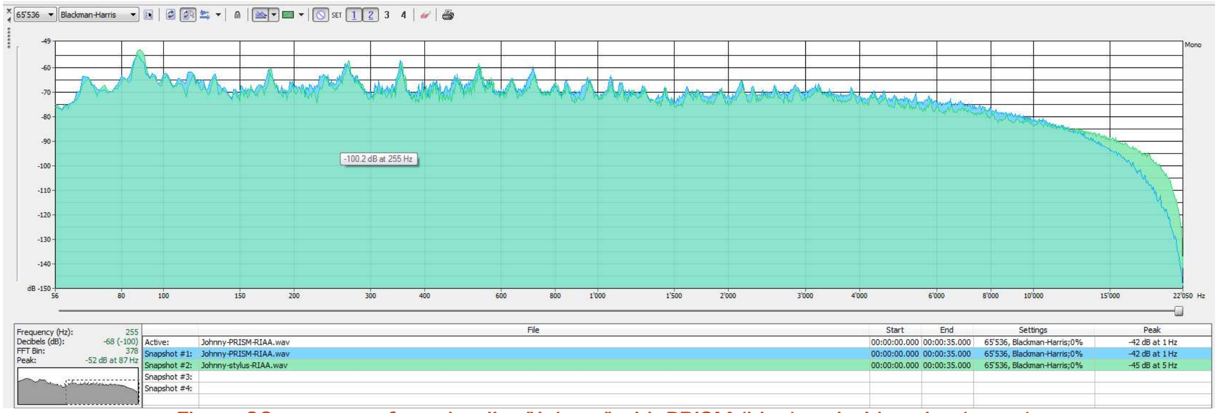


Figure 99 spectrum from the disc "Johnny" with PRISM (blue) and with stylus (green)

The spectrum of the measurement with the stylus has smaller piques and the piques are higher than in the version of PRISM that indicate that the version of PRISM contains more white noise, than the version with the stylus.

The SNR that we arrive with the method PRISM is 12.9dB this is a good quality but we want also compare it with the other methods.

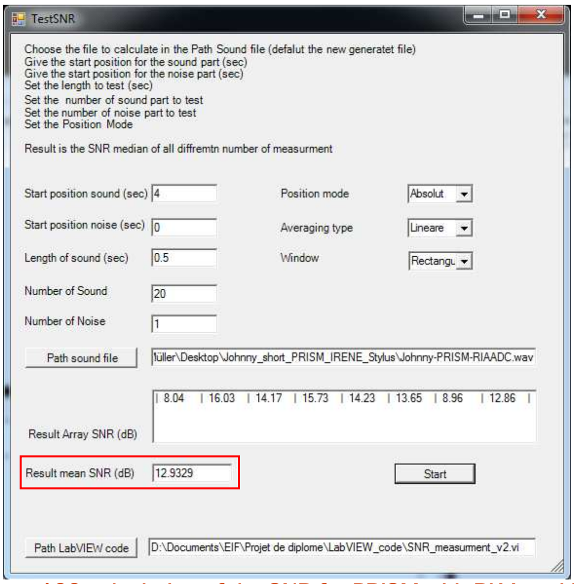


Figure 100 calculation of the SNR for PRISM with RIAA and DC

The different SNR that we get are:

Version	SNR
Stylus with RIAA	10.2dB
IRENE with RIAA and DC	13.4dB
PRISM without something	8.3dB
PRISM with RIAA	9.0dB
PRISM with RIAA and DC	12.9dB

The best version is with the method of IRENE that includes the RIAA equalization and the declicking. Also the version of the stylus is better than the version from PRISM with only the RIAA equalization.

Test the disc Chattanooga

The last test is done with the disc “Chattanooga” which has a bad quality. It is an old disc which is recorded acoustic and there is a cut in the radial. The program LabVIEW is made for big cuts. The result is not so bad. The problem with the cut is explained in the report of Adrien Nicolet. The main thing with this cut is that we cannot use together the With Cut interpolation, the method interpolation out of range and the correction out of range. For this measurement I used the file: chattanooga_119_1676_11_18000_600_1.pri.ror with the shift method interpolation and the algorithm Fit-Line. The best parameters are Fit Num: 6 Width: 10 Interpolation: 5 no correction and no Width.

For this disc we have only a sound file that was made with the program IRENE and this file contains also an improvement from a filter RIAA.

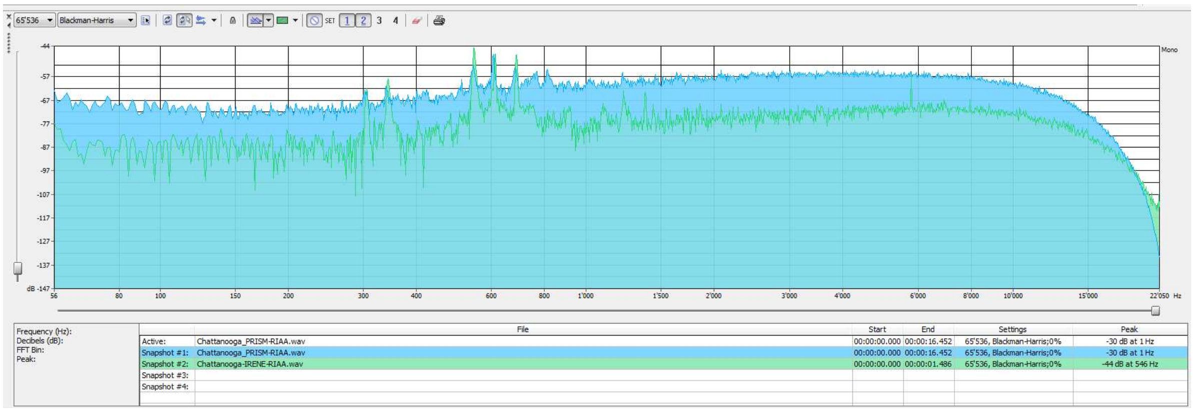


Figure 101 spectrum from the disc "Chattanooga" with PRISM (blue) and with IRENE (green)

The spectrum of the program IRENE is much better it contains much higher piques and the white noise is much lower. In this case the program IRENE is better for measurements with a cut on the disc the program PRISM is not really used for this case.

Is the program for disc with a cut so much better than the program PRISM I calculate also SNR from booth method.

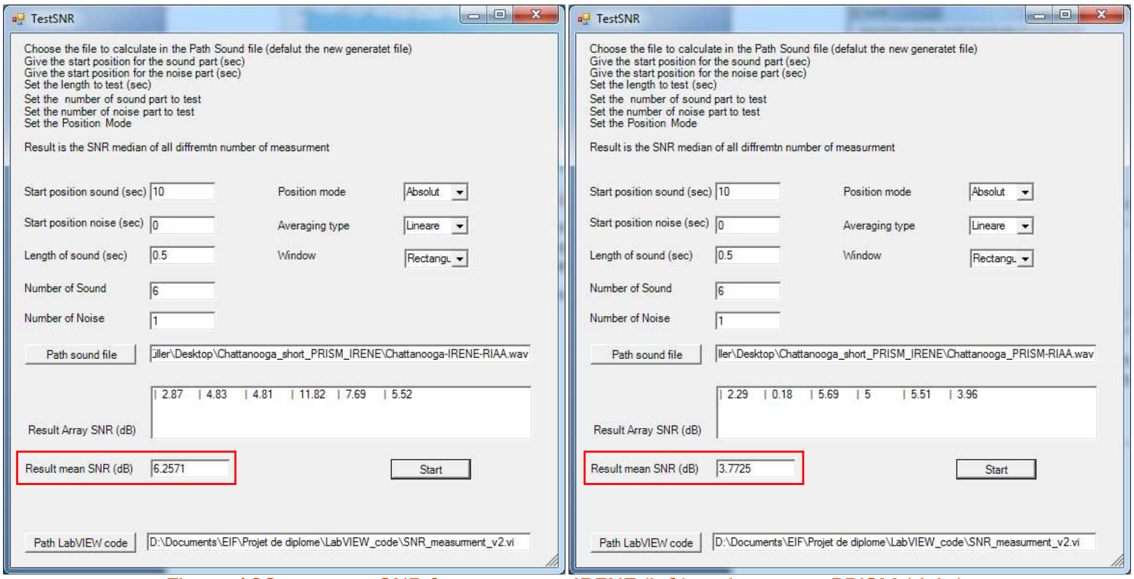


Figure 102 compare SNR from program IRENE (left) and program PRISM (right)

The SNR for the disc “Chattanooga” with the program IRENE and the RIAA equalization is 6.3dB and for the program PRISM the SNR with the 3.8dB. The SNR for the program IRENE is 2.5dB better than this one from the program PRISM it is possible that his different come from the case that we cannot use the correction and the width cut in the case of a cut on the disc.

Sound from all three disc
All this files are well and can hear the sound very well all of them contains some small noise but this is not really something that disrupt. These are all disc and you do not want a perfect sound from this disc. For this entire three disc the quality is enough to listen to them.

If we hear to the sound it gives us the solution also that the program IRENE make the better solution it contains less noise in it. The solution with the stylus has u much other kind of noise in the sound file and it is difficult to compare this method with IRENE and PRISM.

11.1 CONCLUSION COMPARISON WITH IRENE

The sound qualities of all three methods are good. The best one is the method with the system IRENE but it is also that one that uses the longest time to get the acquisition. It contains not a lot on noise and you can hear the sound really well. The system with the stylus give has also a good quality and you hear the music very well. The problem with this system is that you need a needle to get the infromation and this is not all times possible. The method 3D with the program PRISM make a faster acquisition than the program IRENE but it has at the moment more noise in the sound file.

12 CONCLUSION

After analyzing different methods I got the result that the new probe MPLS v2 is much better than the old one. The new probe reads the disc more exactly and can read more kinds of discs. The analysis of the quality was made with different aspects. The simplest way is the one with the method SNR and SINAD. The second aspect was the image of the spectrum from the calculated sound file and the last one was the image and sound of the sound file.

The changes to get the measurement, the rotation and the tilt of the probe are useful to get a better result of the measurement. But the rotated version is better than the tilted. It can read more data in one time to get a good result. With the rotation of the probe a lot of light reflection can be eliminated and the results of the measurement are much better.

The rotation of the probe has the effect that not all of the measurement points are in the same time place on the disc. The shifting for this time difference is necessary to get a better quality. The difference between the rotation calculation and the rotation with the shift is not so big, but the SNR of the sound file and also the spectrum is better. To hear is only that we got fewer clicks with the shift. For the shifting the angle of the rotated probe is important to get a measurement with all groove points in it. With the new LabVIEW code and the radial groove on the disc the angle can be calculated exactly enough to get a good measurement of a disc. The quality of the new sound files is much better and it contains less noise in the sound files.

With the improvement of Adrien the new sound files have nearly the same quality as the system IRENE or a normal stylus system. The first steps to get the right parameters for all discs are also done by including the calculation of the SNR in the program PRISM. One finding is that every disc has its own parameter to get the best sound quality and this should be tested.

The whole project was a nice experience and it gives a large horizon about signal analyzing and signal processing. I learned a lot about the programming language LabVIEW and c# and improved my programming skills in the part of a big program with a lot of classes. It was nice to work on a project that contains a lot of different parts of programming, analyzing signal processing and acquisition of measurements.

For the future of this project it is not a problem to work more on the quality to get better results and to get some measurement that are nearly perfect for all kind of discs. It was very nice working on this project in the Lawrence Berkeley National Laboratory and I had a good time.

13 FURTHER DEVELOPMENT

13.1 AUTOMATIC SYSTEM TO TEST PARAMETER

Until now the program to test which parameters are the best for which kind of disc is made by you. It would be great to have a program that tests the different algorithms with their parameters itself and checks which parameters are the best for this disc, so that at the end only one sound file is made. For this automatic system it would be nice to test not only the SNR but also the spectrum of the sound file and the numbers of interpolation in the sound file.

13.2 AUTOMATIC SYSTEM TO GET THE MEASUREMENT

Until now you must use three different programs to get a measurement and all programs must work together to get a good measurement. It has a lot of parameters in all the programs to get the measurement. One thing is to find the optimal parameters for most of the discs. The other thing is to make it possible to get the measurement in a simpler way. Until now the program has too many points that can give you a wrong measurement. And if you miss to copy some parameters from one program to the other, the measurement is wrong and not useful.

13.3 CUTS

Until now the program PRISM is not stable in the case of cuts on the disc. If the disc has a cut or a missing part, the interpolations of the bad points do not work well. And the result of the recalculation is bad. One problem is that you do not know which part of the disc is interpolated with the parameters. And if you change the range number it does not interpolate the same points as before. The quality and also the result of the SNR change if you take another range to make the sound file. This makes it difficult to find cuts and to interpolate these cuts correctly.

13.4TILT OF THE PROBE

The probe cannot read all discs until now. With some really shiny discs the probe has always problems with light reflection. One possibility is to rotate and to tilt the probe at the same time. Some measurements have shown that this solution could help to read more discs. For this part it would be necessary to change the program PRISM, so that the program only reads the measurement points that are good.

13.5DIFFERENT TYPES OF INTERPOLATION

The interpolation that is used in the program is a linear interpolation between two points. This is the easiest way to interpolate some points that are not good. But the sound movement normally is not linear. So the interpolation method between two points should be changed. If more than one point is wrong, a quadratic interpolation would be better than a linear. And also if too many points in series are wrong the sound file can be really bad.

13.6 SAVE DATA IN DATA BASE

At the moment all the data is saved in a directory and there does not exist any place that stores all the calculated files and it does neither save with which parameters the wave file was calculated. It would be great if all the information about the measurement and all the information from the recalculation would be stored in a data base .It would be easier to find the sound files with all the conditions.

14 ACKNOWLEDGEMENTS

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Berkeley, August 24 2010

Tobias Müller

15 REFERENCES

[1] Wikipedia The Free Encyclopedia, "*Gramophone record*", 2010, http://en.wikipedia.org/wiki/Gramophone_record

[2] Sven Hezel and Severin Nowak, "*Extraction of sound using 3D*", Berkeley, LBNL, October 2008, http://irene.lbl.gov/diplomaproject/REPORT.pdf

[3]Philippe Ballestraz and Raynald Seydoux,"Estimation of groove position and correction of defects" Berkeley,LBNL,Augutst 2009,

[4] Stilsa, "MPLS 180 line sensor", 2010, http://www.stilsa.com/catalog2/flash.html#/32/

[5] Carl Haber and Earl Cornell, "*Preliminary Study and Comparison of New MPLS 180 Performance*", Berkley, LBNL, 11 January 2010

[6] Dave Owen, "*All you need to know about SINAD*", April 1999, *http://www.aeroflex.com/ats/products/prodfiles/articles/530/sinad.pdf*

[7] National Instruments, "*LabVIEW help*", Austin, National Instruments, 2008

[8] Adrien Nicloet,"*New probe for depth estimation of records:software*", Berkeley ,LBNL, August 2010, http://irene.lbl.gov/bachelorthesis2010/nicolet/documentation/bachelor_thesis_2010_nicolet.pdf

[9] Wikipedia The Free Encyclopedia, "*riaa EQUALIZATION*", 2010, http://en.wikipedia.org/wiki/RIAA_equalization