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PHILIPS

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The Laser Deflection Scanner

Philips
Competence Centre
Applied Technology Glass, Aachen

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1 Introduction

1.1 Introduction - Preface

To supervise and improve product quality, methods are needed to determine the various aspects that represent this quality. High gloss of polished surfaces is now characterized by human eye. To compare high gloss from different glass screens and factories, we need an objective method for quantification of high gloss. Currently two methods to measure high gloss are investigated: 1. the laser deflection scanner and 2. the camera measurement method.

This report deals with the laser deflection scanner and its implementation. The measuring device was developed by the group Industrial Optics, Philips CFT Eindhoven. The software was developed in the Philips Competence Centre, Applied Technology Glass, Aachen. Also the tests, described in this report, were done there.

1.2 Introduction - Practical work

This project was done as practical work in accordance with the regulations[1] of the Rheinisch-Westfälische Technische Hochschule Aachen (University of Technology, Aachen).

The electrotechnical faculty of the RWTH Aachen demands an acknowledged testimony of a practical work. The testimony will be given after an approval of the institution for practical work (Praktikantenamt) of the report concerning the practical work.

Engineers are mainly educated to be employed in the practice. During the education they should get a first look in the realities of business by practical work. The industrial practice delivers knowledge and experience, leading to better understanding of the educated material, setting individual accents in the study and easing the change to a profession. The practical work is therefore an important necessity for a successful study in regard of the later profession.

The practical work should consist of engineer-like occupations in the field of electro-technics within:

- Finishing, assembling, operating, maintenance, testing, commissioning
- Research, developing, calculation, projection, construction.

1 Prof. Dr. rer. nat. G. Pietsch, “Richtlinien für die praktische Tätigkeit der Studierenden der Elektrotechnik”, Printing, Praktikantenamt der Fakultät für Elektrotechnik RWTH Aachen, 7 Jul. 1994

1.3 Introduction - Goals

The goals set for this project were:

- Adapting the hardware setup for use with the VME system, because this is the used system in the Philips Glasfabrik Aachen.
  (Chapter 3)

- Writing software to control the measuring device.
  The software should run under the ERM operating system, because this is the installed operating system of the VME system.
  (chapter 4)

- Developing a method for quantifying high gloss screens.
  (chapter 5)

- Evaluation of the laser deflection scanner.
  (chapter 6.2 and 7.1)

- A comparison between the laser deflection scanner and the camera measurement method (Surface Quality Measuring System, SQ-MS) of Philips BTG developed by Joris Kuin and extended by Peter Gerling.
  (chapter 7.2)

2 High gloss[1]

2.1 High gloss - What is gloss?

One of the most important requirements of the surface of a television or monitor screen is its appearance. It can be said that the appearance is determined by the optical properties. Three factors which effect the appearance are: opacity, the gloss of the surface and the colour. By these factors, an exterior can be assessed from the point of view of its appearance.

Gloss, sheen, lustre; these are all terms to describe the result of a visual appraisal of the surface of a material, and as such they are subjective. Defining such terms precisely is difficult and dictionaries, technical or otherwise, are rarely of any help. An alternative definition of gloss is ‘the quality of shining by superficial reflected light’. From a comprehensive study of this subject was concluded that ‘gloss’ was a gestalt[2], and that is probably the only overall description possible.

2.2 High gloss - Factors influencing gloss

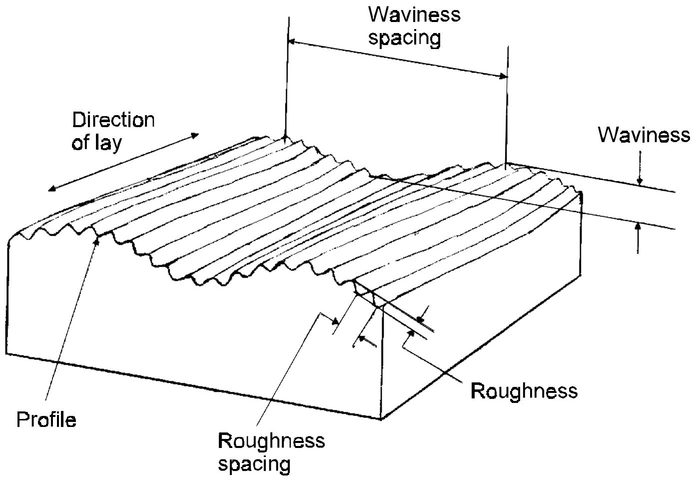


Fig. 2.2.1 *Surface characteristics*

The gloss of an exterior is a purely visible quality but is closely related to surface structure and smoothness. A surface which is nominally flat and smooth may be afflicted with waviness. In case it can never be perfectly smooth and will always have some roughness, which may vary from fine to coarse according to the finishing process used. Some surfaces may exhibit both roughness and waviness as is illustrated in figure 2.2.1. Surface structures from quite large irregularities down to features smaller than the wavelength of light may affect the gloss, and the loss of gloss may be due to the development of this surface structure. The majority of surfaces scatter the incidented light, either because one or both surfaces are irregular or because the material is inhomogeneous.

2 V.G.W. Harrison, "Definition and Measurement of Gloss: A service published literature", Printing, Packaging and Allied Trades Research Association, 1945

3 The hardware

3.1 The hardware - The measuring device[2]

All the elements are assembled on a vertical metal plate. The purpose of the mirrors 1 and 2 is to achieve a more compact device, by ‘folding up’ the laser beam.

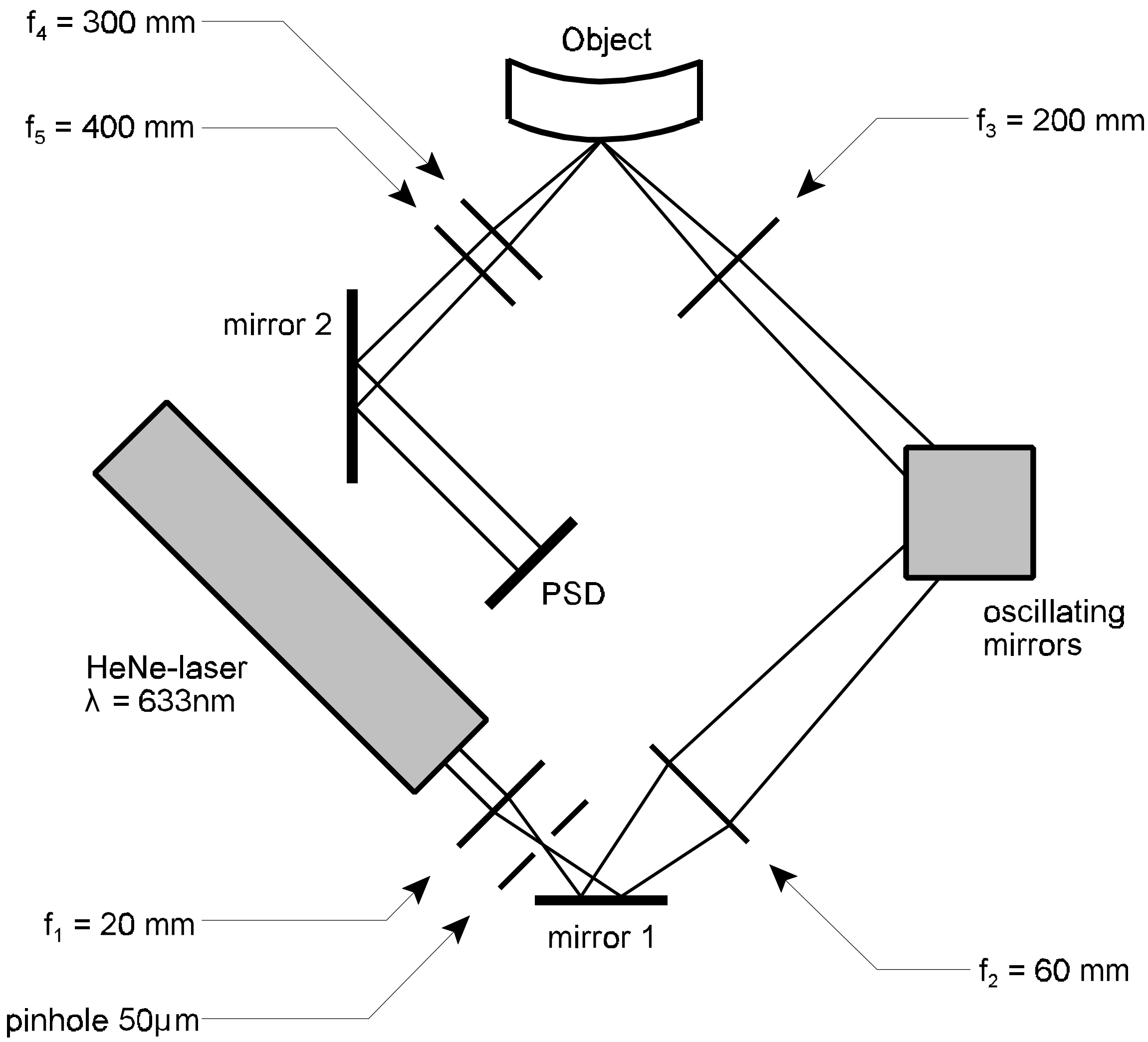


Fig. 3.1.1 *The measuring device*

The lenses 1, 2 and 3 focus the beam on the object. As a result of the arrangement of the optical elements, the laser beam has an area on the object with a diameter of 100 µm.

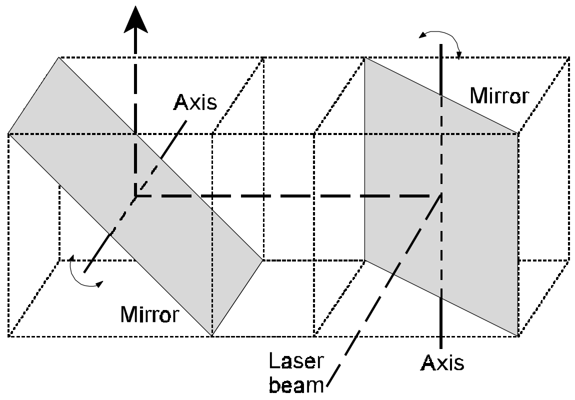


Fig. 3.1.2 *The oscillating mirrors*

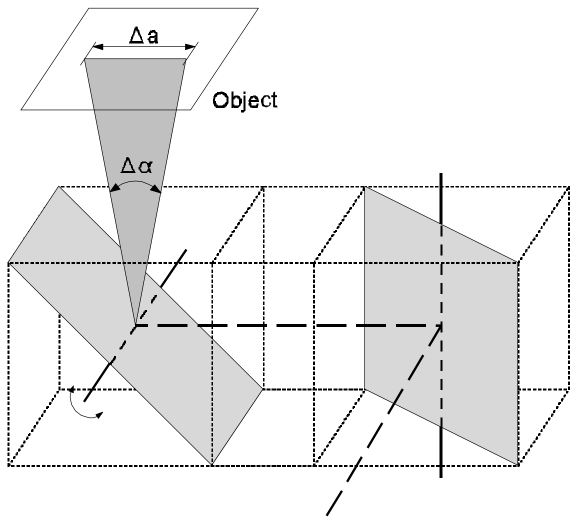


Fig 3.1.3 *Longitudinal displacement range*

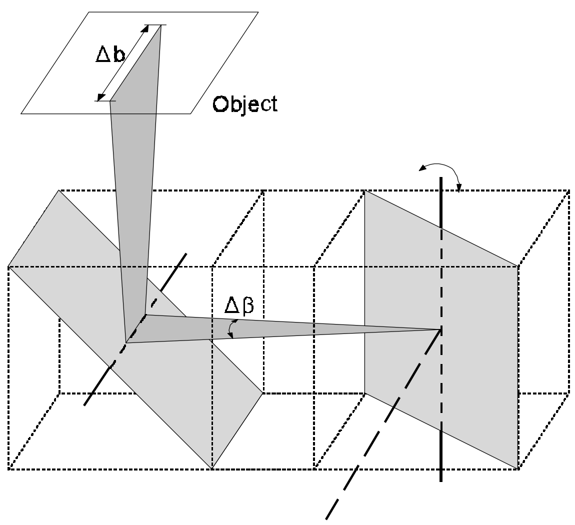


Fig 3.1.4 *Transversal displacement range*

The oscillating mirrors (figure 3.1.2) steer the position of the laser beam. The system consists of two mirrors, one for longitudinal and one for transversal displacement. Each can be separately moved. Such a movement leads to an angular displacement of the laser beam and this results in a shifting of the laser spot on the object. The distance the spot is moved depends also on the curvature of the object.

The relation between the angular displacement and the shifting of the laser spot on the object is shown in the figures 3.1.3 and 3.1.4.

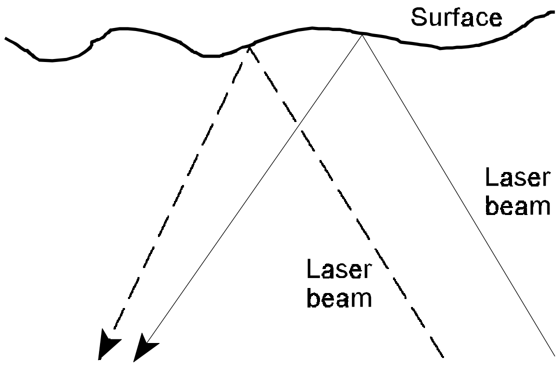


Fig. 3.1.5 *Reflection at a surface*

The laser beam is reflected by the object (the glass screen). The texture of the surface of the object determines under which angle the beam is reflected (figure 3.1.5). The lenses 4 and 5 project the laser beam on the PSD (Position Sensitive Detector). These lenses make it possible to make optimal use of the rail, on which the PSD can be shifted. With flat objects the PSD should be in a more forward position, with spherical ones the PSD should be placed in a more backward position.

The combination of the two lenses can be regarded as one:

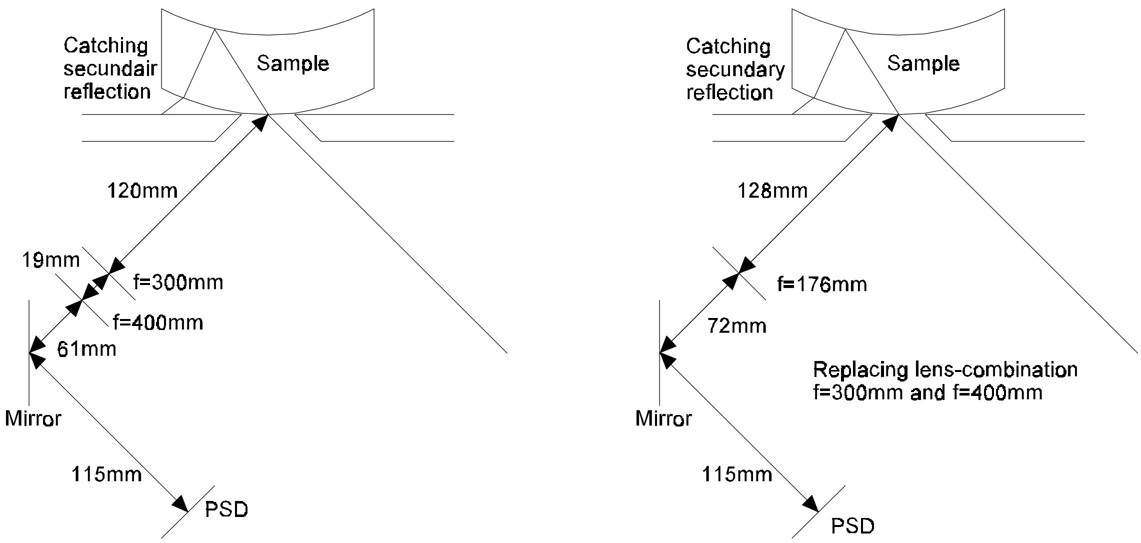


Fig. 3.1.6 *Replacing the lens-combination*

3.2 The hardware - Operating the measuring device

The sample (glass screen) should be placed on the three points on top of the measuring device. Make shure it really touches each point. Take also care that the sample does not reflect any laser beams into the room.

There are two ways of operating the measuring device:

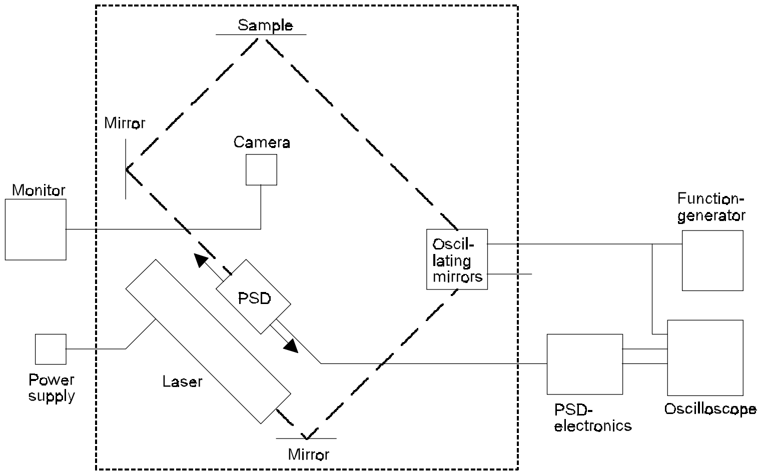


Fig. 3.2.1

1) The longitudinal oscillating mirror is connected to the function generator. The function generator should deliver a sine wave voltage of about 40 Hz. The amplitude should be so large, that the entire lens 3 is used to project the scanline. This signal is also used to trigger the oscilloscope. The PSD is connected to the entry labelled ‘PSD1’ of the PSD-electronics. The transversal PSD-signal (entry x) is connected to channel A of the oscilloscope, the longitudinal (entry y) to channel B. The scanline should be projected on the middle of the PSD. This can be achieved by changing the arrangement of mirror 2.

With flat objects the PSD should be in a more forward position, with spherical ones the PSD should be placed in a more backward position. The image on the oscilloscope is a good help in finding the best place for the PSD. A perfect smooth surface of the object would lead to a perfect sine function on the oscilloscope. A defect in the surface would be immediately visible.

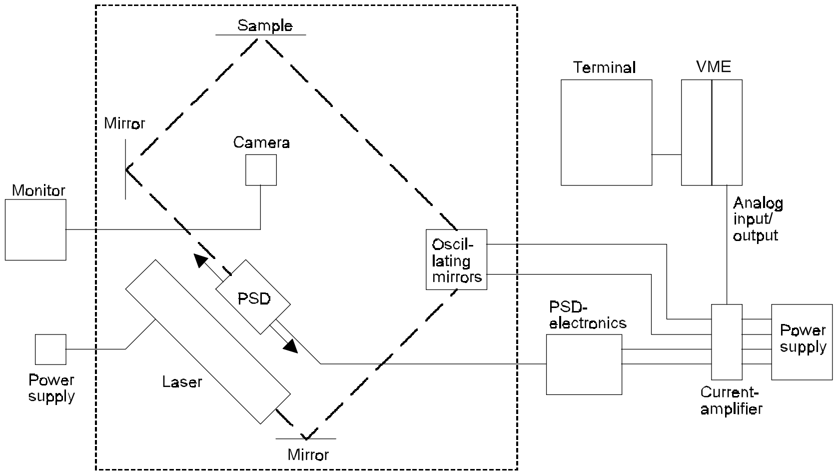


Fig. 3.2.2

2) The transversal oscillating mirror is attached to the connection labelled 'trans out' of the current amplifier, the longitudinal oscillating mirror to 'longt out'. The PSD is connected to the entry labelled 'PSD1' of the PSD-electronics. The transversal PSD-signal (entry x) is connected to 'trans in' of the current amplifier, the longitudinal (entry y) to 'longt in'. The current amplifier is attached to the analog io-card of the VME system. The current amplifier needs a power supply of +10V, 0V and -10V.

This setup measures a number of scanlines of about 10 mm on the object. Every scanline consists of a number of points. The oscillating mirror steers the laser beam to such a point, then the PSD is read out and the data is stored. After this, the oscillating mirror steers the laser beam to the next point. When all the scanlines are read out in this way, the data can be processed.

3.3 The hardware - The VME system

The VMEbus standard is the open standard in industry, designed specifically to build embedded real-time control systems[3]. Philips was one of the initiators of the VMEbus standard, and it is supported by more than a hundred manufacturers organized in VITA. When it comes to speed, processing performance, flexibility and availability, VMEbus products offer a wide range of solutions. Therefore, VME systems are being used in the glass factory in Aachen since 1989.

CPU board

The basis of the VME system is the CPU board, in this case the Philips PG2050. This board is a high performance Single Board Computer, containing all the resources to act as a full stand alone computer unit. Additionally, it is designed for use in a VMEbus system. Because of its properties, the PG2050 is highly suitable for advanced real-time processing systems. It is equipped with a Motorola MC68020 CPU (Central Processing Unit). The ERM system version 4.01 is installed on EPROMs. (See chapter 4.4)

Analog input/output

The analog input and output between the current amplifier and the VME system is done by the Pentland MPV901A (compatible to the Philips PG3651). The output voltage range is set to [-5V, +5V], the input range to [-10V, +10V].

The software demands the following settings of the Pentland MPV901A:

Switches:											
		1	2	3	4	5	6	7	8	9	0
sw1	Interrupt Request Line Selection	off	off	ON	off	off	off	off	ON	off	off
sw2	Base Address Selection (A08 - A15)	ON	off	ON	off	off	off	ON	ON		
sw3	Base Address Selection (A16 - A23)	off	off	off	off	off	off	off	off		
sw4	Interrupt Vector Selection	ON	ON	ON	ON	ON	ON	ON	off		
sw5	1,2 = Differential mode 3,4 = Complementary straight binary	off	ON	off	ON						
sw6	Analog Output Range Se-lection	ON	off	ON	off	off	ON	off	ON	off	off
Jumpers:											
Inserted are:		J2	J5	J7	J9	J20					
Out are:		J1	J3	J4	J6	J8	J10				
IC43:		all inserted									

3.4 The hardware - The current amplifier

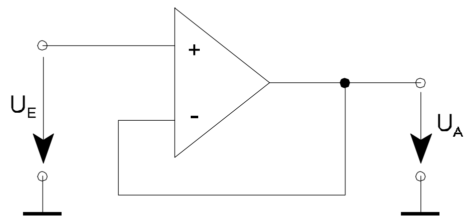


Fig. 3.4.1 *Current amplifier*

Since the analog input-output card is supposed to deliver only a voltage and not a power, it is necessary to amplify its signals. Therefore, a current amplifier was created. The current amplifier simply follows the voltage of the analog io, delivering current from an extern source. The basic circuit is shown in figure 3.4.1, but this circuit still delivers not enough power. To increase the maximal output current, the operation amplifier was replaced by the circuit[4] pictured in figure 3.4.2. In figure 3.4.3 you can find the entire circuit of the current amplifier for both the transversal and the longitudinal oscilating mirror. The mirrors them selves have a resistance of 10Ω. A resistance R_2 of 90Ω was connected in series in order to achieve a higher resolution; The oscillating mirror demands a signal between -0.5V and +0.5V. The analog io-card delivers a voltage between -5V and +5V with a resolution of (10 / 4096) volt. The resistance R_2 enables the use of the whole output range of the analog io-card.

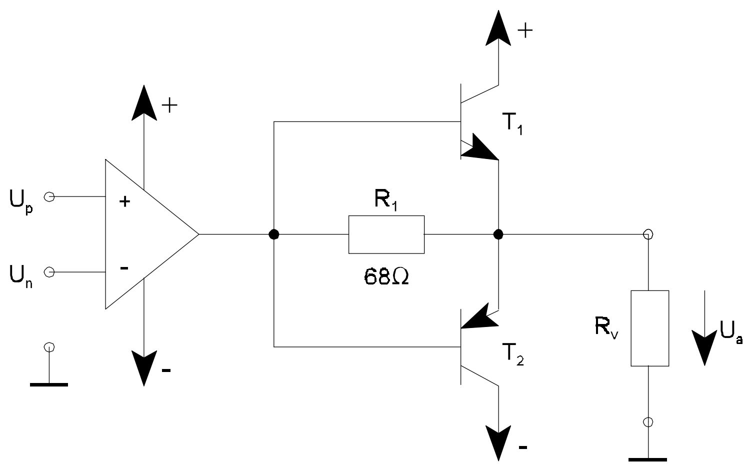


Fig. 3.4.2 *Operation amplifier with complementary emitters*

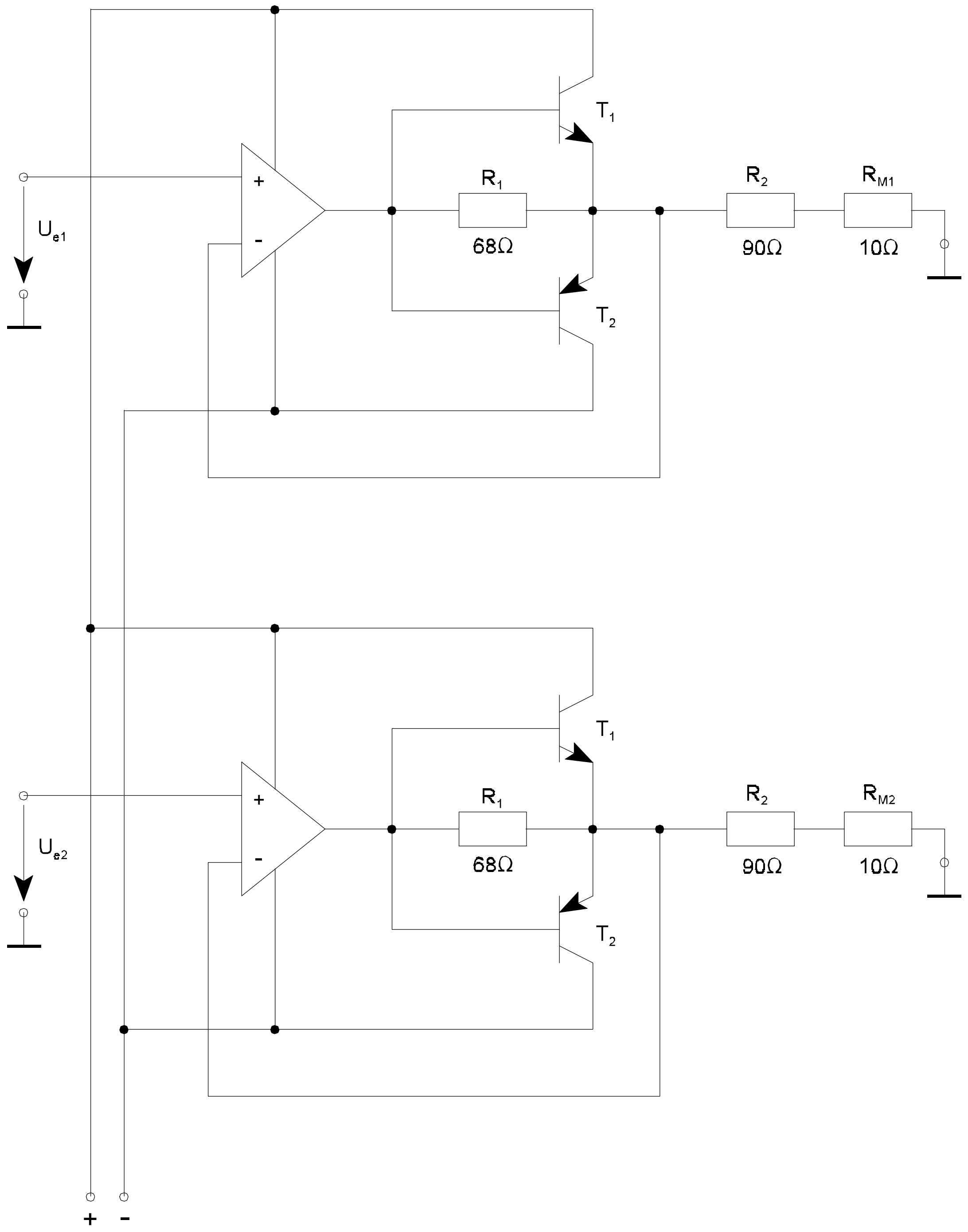


Fig. 3.4.3 *The current amplifier*

4 The software

4.1 The software - Introduction

Often software programs, especially industrial ones, are very complicate to operate. Complex menu structures, variables without default values, poorly designed screens etc. makes it that even highly educated engineers cannot handle such programs without the help of manuals, etc.

Of course this has to be prevented. Therefore this program is equipped with pull-down menus (figure 4.1.1) and fill-in forms (figure 4.1.2), like we know them from ms-windows-based programs and the ms-editor. Using the cursor-keys, you can easily walk through menus and fill-in forms. Further all variables are put in a special settings menu, all having default values.

Anybody with only little computer experience should be able to handle this program.

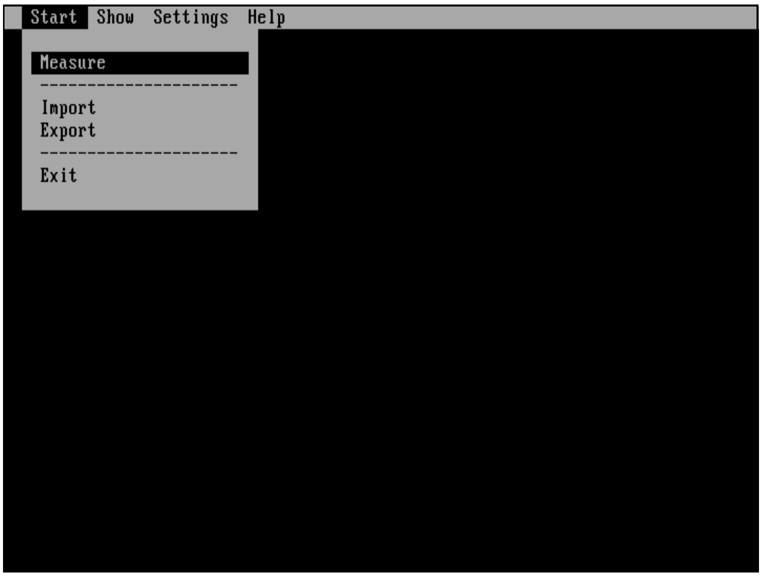


Fig. 4.1.1 *A Pull-down menu*

Fig. 4.1.2 *A Fill-in form*

4.2 The software - A manual

The menu

The menu is of the ‘pull-down’ type. This means you will have to use the menu bar to select a submenu. From such a submenu you can choose either a command or a further submenu. Use the arrow-keys to switch between menu items. The arrow-keys are also used to switch between buttons and input fields. (The Tab key is also allowed). This ‘pull-down’ type was chosen to provide a maximal user-friendly environment.

A description of the menus:

Start: This menu provides the most essential functions.

- **Measure**: this command starts the measuring process.
- **Import**: previous saved data is imported, using com1: (x4, 4800 baud, 8 data bits, no parity, 1 stopbit (8,n,1)).
- **Export**: the measured data, the number of lines, the number of points and the ratings are exported, using com1: (x4, 4800 baud, 8 data bits, no parity, 1 stopbit (8,n,1)).
- **Exit**: leave the High gloss program.

Show: This menu enables you to display data as text and as graphic.

- **Draw measured values**: The measured data is displayed in a graphic. Use the buttons to switch between the lines and between transversal (trans) and longitudinal (longt).
- **Draw FFT**: The Fourier transform of the measured data is shown in a graphic. Use the buttons to switch between the lines and between transversal (trans) and longitudinal (longt). The data can be displayed either as *real / imaginary* or as *amplitude / phase*.
- **Draw filtered**: Only the frequencies, of the measured data, set in the frequency window are displayed. This means all frequencies NOT in the frequency window are filtered out (Bandpass).
- **Print measured values**: The measured data is displayed as text on the screen.
- **Print mirror positions**: the calculated mirror positions are displayed as text on the screen. 1 corresponds with the lowest output voltage (normally -0.5 V). 4096 corresponds with the highest output voltage (normally +0.5 V).
- **Print Rating**: The ratings of the individual lines as well as the overall rating of the measured data is displayed on the screen.

Settings: In this menu the settings are handled. [*Settings*]

- **Print settings**: The current settings are displayed on the screen.
- **Change settings**: A submenu to change the settings:

    - **Highgloss**: A fill-in form in which all [*High gloss settings*] are handled.
    - **FFT**: In this fill-in form the frequency window, used to filter the Fourier transform, can be changed. [*FFT settings*]
    - **Graphics**: Here you can configure the graphic settings of your terminal. [*Graphics settings*]

- **Use default settings**: All settings are set to the default settings.

Help: The help menu, provides online help.

- **Help index**: choose this option when you need some help.
- **Info**: program info.

Settings

Settings are variables, which can be set by the user.
In this program there are three kinds of settings:

High gloss settings:

High gloss settings contain the variables of the testing procedure.

number of lines: the number of scanlines.

number of points per line: the number of points per scanline.

read out each line x times: to improve the quality of the measurement it is possible to read out each line several times. This leads to a smaller standard deviation.

read out each point x times: it is also possible to read out each point several times. Reading out the same point several times leads to a smaller influence of high frequency disturbances. It also leads to a smaller standard deviation.

moving interval: (trans, longt): moving the mirror from one point to another should be done smoothly, to maintain a better stability of the mirror. This is achieved by moving the mirror in small intervals.

moving interval waiting time x ms: This is the time (in milliseconds) which is waited between two movements, when the mirror is smoothly moved from one point to another. This is also the time which is waited between reading out the same measuring point. x must be at least 1 ms, 5 ms is advised.

measure interval waiting time x ms: This is the time (in milliseconds) which is waited before reading out a point. It is necessarily to wait this time because the mirrors oscillate a little after each movement. Before each measurement they have to reach stability. x must be at least 1 ms, 35 ms at least is advised.

calculate range in TRANS from a to b : a is the position of the most right line. b is the position of the most left line. 1 corresponds with the lowest output voltage (normally -0.5 V). 4096 corresponds with the highest output voltage (normally +0.5 V). $1 < a < b < 4096$

calculate range in LONGT from a to b : a is the position of the lowest point. b is the position of the highest point. 1 corresponds with the lowest output voltage (normally -0.5 V). 4096 corresponds with the highest output voltage (normally +0.5 V). $1 < a < b < 4096$

FFT settings:

FFT means Fast Fourier Transform. (See chapter 5)
The Fourier transform of a function is its spectral-function.

To investigate whether certain frequencies correspond to a certain glass surface quality, you may want to filter out all other frequencies. This is enabled by setting the frequency-window: All frequencies, except those in the frequency-window are filtered out. The result is visualized in the [*draw filtered*] function in the [*show*] menu.

The rating of the measured lines is also only calculated over the frequencies in the frequency-window.

FFT frequency window:

lower limit: the lowest frequency in the frequency-window.
upper limit: the highest frequency in the frequency-window.

The maximum range of the frequency window is [0, ((nr of points) / 2)].
When the frequency-window is set to this maximum range, all frequencies are included.

Graphics settings:

Some terminals (like the vt220) do not enable graphics.
The program runs also on these kind of terminals, however you are strongly advised to use a terminal that can display graphics (like the vt341) or a terminal emulation program (like smartterm240) to display the measured data, the FFT and the filtered data graphically.

[X] *Terminal enables graphics*: This box should be filled in when the terminal has a graphical display. Use SPACE to change this option.

On different terminals the resolution and colours may be different, therefore you can change all that in the graphics settings.

Graphic window:
(left, top): (x,y): coordinates of the left-top position of the window in which the graphics are drawn. ATTENTION: this should not be the very top of the screen, because there should be room for 4 lines of text.

(right, bottom): (x,y): coordinates of the right-bottom position of the window in which the graphics are drawn. ATTENTION: both on the right and on the bottom should be enough room for the coordinates.

colour grid: the colour in which the grid is drawn.
colour graphic: the colour in which the graphic itself is drawn.

4.3 The software - About the source code

The software consists of a complete program designed to control the actual measurement as well as to process the read out data. This program consists of several modules. Each module is designed to perform a separate task and contains all the necessary routines to do so.

The program was written in the ‘C’-programming language, a language commonly used in the industrial world. The ‘C’-language is a so-called mid-level language. This means it gives the programmer great control over the hardware, but it also possesses the comfort and tools of a high-level language. The program was especially designed to run under the ERM operating system to meet the goals described in chapter 1.3. However the linearity of the program would make it easy to convert it for use under an other operating system, e.g. ms-dos.

4.4 The software - ERM operating system

The Embedded Real-Time Monitor System, abbreviated as ERM system, is developed for factory and process automation applications. It supports concurrent and asynchronous processes. The kernel, file manager and device drivers are delivered in PROM. The ERM development environment contains a run-time library, target and host tools. The ERM system is a real-time multitasking operating system.

operating system
An operating system hosts all running programs and forms a bridge between these programs and the hardware. It also provides tools to access and control the various hardware-components.

real-time
This means it provides several tools to monitor time and execute time-depending procedures.

multitasking
The ERM system is able to run several routines simultaneously. To control these routines there are tools like semaphores and mailboxes.

5 Calculation ratings

5.1 Calculation ratings - Introduction

To compare screens, it is necessary to develop a method for quantifying high gloss screens. It is possible to characterize a screen either by eye or by interpreting data measured by a measuring device. The measured data can be displayed in a graphic. But it is also possible that from the measured data a rating is calculated indicating high gloss quality. If there is a distinct correlation between the calculated ratings and the high gloss quality of the screens, of course the latter method is preferable, since this method would leave no room for different interpretations.

5.2 Calculation ratings - Fast Fourier Transform[5]

The measured data can be described either in the *distance domain*, by values of some quantity *h* as a function of distance, e.g. *h(x)*, or else in the *frequency domain*, where the process is specified by giving its amplitude *H* (generally a complex number indicating phase also) as a function of frequency *f*, that is *H(f)*, with $-\infty < f < \infty$. For many purposes it is useful to think of *h(x)* and *H(f)* as being two representations of the same data. The calculations of the ratings are based on the *frequency domain* of the measured data.

One goes back and forth between these two representations by means of the *Fourier transform* equations,

$$H(f) = \int_{-\infty}^{\infty} h(x)\, e^{2\pi i f x}\, dx \qquad \textbf{(1)}$$

$$h(x) = \int_{-\infty}^{\infty} H(f)\, e^{-2\pi i f x}\, df$$

Function *h* is measured in points (distance), and *H* in 1/points (frequency). Here, in the High gloss project, function *h* is sampled (i.e. its value is recorded) at evenly spaced intervals. Let Δ denote the interval between consecutive samples, so that the sequence of sampled values is

$$h = h(n\Delta) \quad n = \ldots, -3, -2, -1, 0, 1, 2, 3, \ldots$$

The reciprocal of the interval Δ is called the *sampling rate*; if Δ is measured in seconds, for example, then the sampling rate is the number of samples recorded per second. Here Δ is measured in millimetres and the sampling rate in number of samples per millimetre.

For any sampling interval Δ, there is also a special frequency f_c, called the *Nyquist critical frequency*, given by

$$f_c \equiv \frac{1}{2\Delta} \qquad \textbf{(2)}$$

If a sine wave of the Nyquist critical frequency is sampled at its positive peak value, then the next sample will be at its negative peak value, the sample after that at the positive peak again, and so on. Expressed otherwise: Critical sampling of a sine wave is two sample points per cycle.

The Nyquist critical frequency is important for two related, but distinct, reasons. One is good news, and the other bad news. First the good news. It is the remarkable fact known as the *sampling theorem*: If a continuous function $h(t)$, sampled at an interval Δ, happens to be *bandwidth limited* to frequencies smaller in magnitude than f_c, i.e., if $H(f) = 0$ for all $|f| >= f_c$, then the function $h(t)$ is *completely determined* by its samples h_n. In fact $h(t)$ is given explicitly by the formula

$$h(t) = \Delta \sum_{n=-\infty}^{\infty} h_n \frac{\sin[2\pi f_c (t - n\Delta)]}{\pi\,(t - n\Delta)} \qquad \textbf{(3)}$$

Now the bad news. The bad news concerns the effect of sampling a continuous function that is *not* bandwidth limited to less than the Nyquist critical frequency. In that case, it turns out that all of the power spectral density that lies outside of the frequency range $-f_c < f < f_c$ is spuriously moved into that range. This phenomenon is called *aliasing*. Any frequency component outside of the frequency range $(-f_c, f_c)$ is *aliased* (falsely translated) into that range by the very act of discrete sampling. You can easily convince yourself that two waves $\exp(2\pi i f_1 t)$ and $\exp(2\pi i f_2 t)$ give the same samples at an interval Δ if and only if f_1 a nd f_2 differ by a multiple of $1/\Delta$, which is just the width in frequency of the range $(-f_c, f_c)$.

Since the amplitudes of $H(f)$ in the High gloss-project approach zero as the frequency approaches f_{max} from below, or f_{min} from above, we might assume that there is only little aliased power in this particular case.

5.3 Calculation ratings - Methods

Rating R_1

Earlier tests[2] done by Fred Couweleers showed that within a certain range the amplitudes of the frequencies correspond with a high gloss quality. Especially the lowest frequencies represent the global form of the measured data. The highest frequencies might just be higher orders of the basic frequencies of the screen surface. Rating R_1 is based on these assumptions. Therefor we will regard the Fourier transform only within a certain range, called the frequency window. The limits of the frequency window can be changed in the *FFT settings* option. (See chapter 4.2)

The area below the amplitudes in the frequency window seems to be a good criterion for the occurance of those frequencies. Therefore the first rating R_1 is based on the integral over the amplitudes within the frequency window. A higher rating corresponds with a lesser high gloss quality.

$$R_1 = \int_{f_{window}} H(f)df$$

The PSD has to be shifted for screens of different curvature. This leads to different scales in the graphics and different amplitudes by the same high gloss quality. The influence of external light may do the same. To correct this (as much as possible) the amplitudes should be regarded relative to the whole graphic *h(x),* instead of absolute. To achieve this, rating R_1 is divided by the area under the graphic *h(x)*. This area is calculated by first eliminating of the zero-frequency part of the measured data, resulting in graphic $h_0(x)$. Then $h_0(x)$ is integrated (figure 5.3.1).

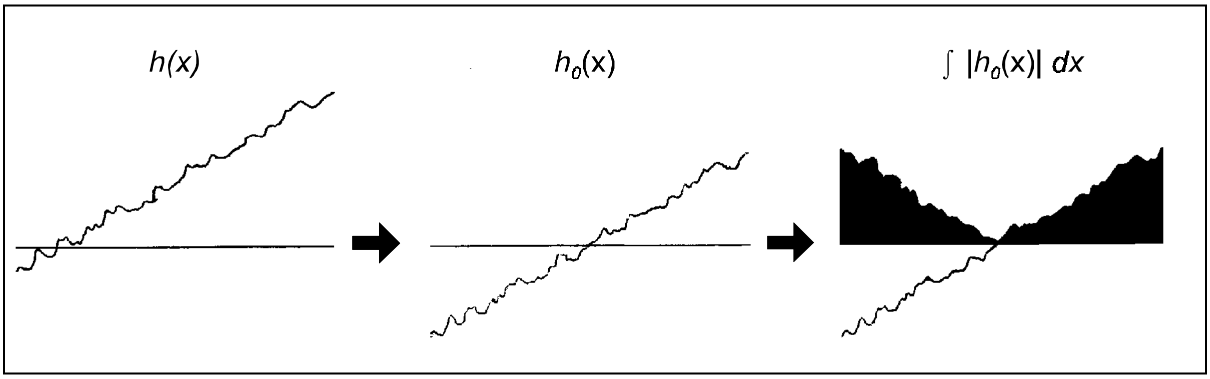


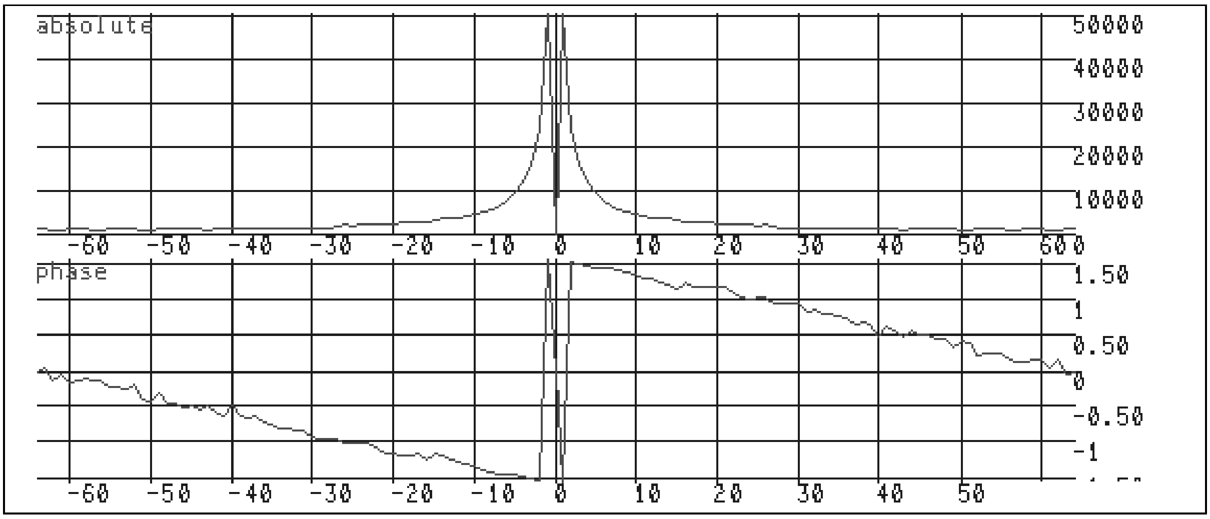
Fig. 5.3.1 *Integral over* $|h_0(x)|$

The new, standardized rating $R_{1,relative}$ can be calculated as follows:

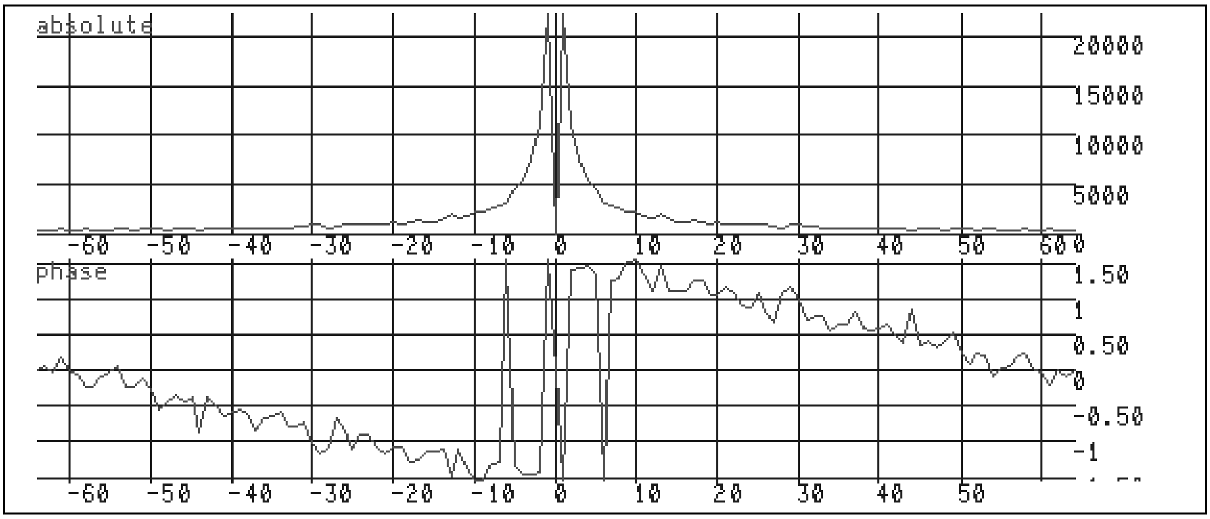
$$R_{1,relative} = \frac{R_1}{\int |h_0(x)|\,dx} = \frac{\int_{f_{window}} H(f)\,df}{\int |h_0(x)|\,dx}$$

Rating R_2

During the tests described in chapter 6 it showed that a lesser or better high gloss quality was immediately visible in the phase-frequency graphic of the Fourier transform. Because every disturbance of the surface has its characteristic form and changes the phase diagram. Therefore, I developed a second rating R_2. A perfect screen would produce as phase in the Fourier transform: $\Phi_{expected}(f) = 0.5\,\pi - (0.5\,\pi / f_{max}) * f$.



Good quality high gloss



Slightly lesser quality

Within the frequency windows, $\Phi_{expected}(f)$ is subtracted from the measured phase $\Phi_{measured}(f)$. The integral over these differences seems to be a good criterion to characterize high gloss. Again a higher rating corresponds with a lesser high gloss quality.

$$R_2 = \int_{f_{window}} |\Phi_{measured}(f) - \Phi_{expected}(f)|\, df$$

Since the phase in the Fourier transform always lies between -0.5 π and 0.5 π, and it depends only on the shape of *h(x)* and not on its amplitude, there is no need to calculate a relative rating. It already is standardized.

6 The tests

6.1 The tests - Implementation

Certain benchmarked screens have been taken to test the laser deflection scanner for its capability to distinguish different surface qualities. The benchmarking was done by A.C. v.d. Heuvel (ATG-FiT) and J. Severijnen (ATG-QA) of Philips ATG Aachen and described in internal memo VGB 685-95.0111. The collection of screens originates as well from Philips Glass factories as from competitors.

Due to the physical limitations of the measuring device the screens could only be measured in the centre. To decrease the influence of direction-depending defects, all screens were first measured at 0° and then at 45° clockwise. To decrease the influence of noise pollution each point and every scanline were red out more than once.

For every measurement the following settings were used:

number of scanlines:	3	
number of points per line:	128	
read out each line:	3 times	
read out each point:	10 times	
moving interval:	trans: 20	longt: 20
moving interval waiting time:	5 ms	
measure interval waiting time:	35 ms	
calculation range in TRANS:	from 2000	to 2800
calculation range in LONGT:	from 300	to 3800

(For terms see chapter 4.2, high gloss settings)

From the measured data the ratings $R_{1,relative}$ and R_2 were calculated for four different frequency-ranges:

$$f \in [0\ cm^{-1}, 64\ cm^{-1}]$$
$$f \in [22\ cm^{-1}, 64\ cm^{-1}]$$
$$f \in [0\ cm^{-1}, 45\ cm^{-1}]$$
$$f \in [22\ cm^{-1}, 45\ cm^{-1}]$$

6.2 The tests - Results

The graphic of the measured data is mostly climbing, sometimes falling. This is because sometimes the PSD is placed before the spatial focus, sometimes behind. But for the processing of the data this makes no difference.

In general the ranking of the benchmarked screens is pretty good recognizable in the graphics of the measured data (Appendix B). However, sometimes the graphic of a screen does not seem to fit in its place. For instance the screen 'Philips Simonstone 51FS-SC' (C7) is remarkably better rated by the laser deflection scanner than it is by human eye. It is possible that these screens are just in the middle of better quality than the other screens and on the edges worse. But maybe they are rated on different criteria by the human eye than by the laser deflection method. The differences in high gloss quality are even better visible in the phase diagram of the Fourier transform (Appendix C).

To evaluate the rating-methods $R_{1,\ relative}$ (amplitude) and R_2 (phase) the screens were rated for four different frequency ranges in the positions 0° and 45° clockwise. From those two positions an average rating was calculated for every frequency range. You can find all this data in the table in appendix D. The average ratings were put in diagrams like figure 6.2.1. The most left point corresponds with the first screen of a group, for instance the most left point of line C represents screen C1, 'Asahi 51FS-SC'. Since a lesser high gloss quality gets a higher rating the line should be climbing. But if two successing screens are of the same quality class the line should be more or less constant, like for example it is the case for screens E4a and E4b (the last two points of line E).

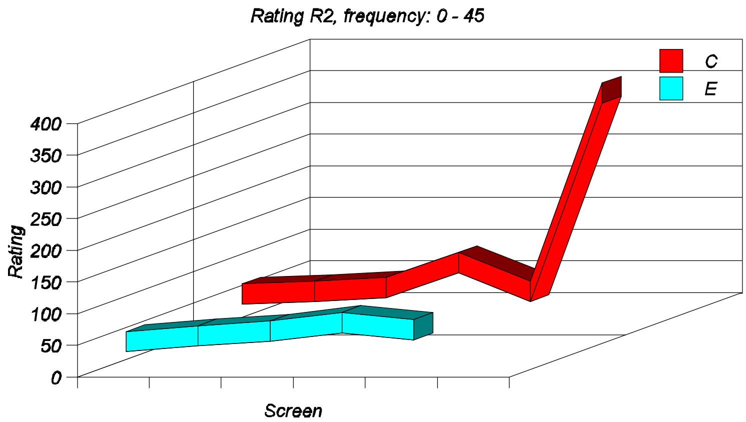


Fig. 6.2.1 *Example diagram*

From the diagrams (Appendix E) can be concluded that rating $R_{1,relative}$ is hardly useful. The diagrams of R_2 however show a distinct relation between high gloss quality and the ratings. Filtering out the highest frequencies improved that relation even. Filtering out the lowest frequencies did not make much of a difference. Dull gloss screens are generally rated lesser than high gloss screens, because of their roughness.

7 Discussion

7.1 Discussion - The laser deflection scanner

Defects are spread all over the screen, however they may appear more frequently in certain areas. Also the quality and smoothness of a screen may vary in different areas. Due to the physical limitations of the measuring device the screens could only be measured in the centre. This limits the value of the measured data, since two screens may have the same high gloss quality in the centre of the screen, but differ on the edges. For further investigations a new measuring device, that could measure all over the screen, should be developed to overcome these limitations.

During the tests the measuring device showed to be very sensitive for vibrations. It was even possible to make sound, spoken just above a tested screen, visible on the oscilloscope. Therefore, the laser deflection scanner can be only used in a room with little sound and mechanical vibrations. High frequent hardware filters and reading out the PSD repetitiously for each point may decrease the influence of high frequent noise. Repeating every scanline more than once will lessen the influence of noise of all frequencies, but increases the measuring time considerably.

The PSD has to be shifted for screens of different curvature. This leads to different scales in the graphics. It also leads to different amplitudes by the same high gloss quality and the resolution may vary a bit. Although this all is corrected as much as possible in the calculation of the ratings (see chapter 5), it is still necessary to consider this when you are comparing screens of different curvature.

7.2 Discussion - A comparison

For the project ‘high gloss measuring device’ two alternatives were studied. One of them, the laser deflection scanner, is described in this report. The other is the camera measurement method (Surface Quality Measuring System, SQ-MS), developed by Joris Kuin and extended by Peter Gerling.

The camera measurement method was tested on the same screens as the laser deflection scanner. If we look at the results[3] (Appendix F), we can find no significant differences to the achievements of the laser deflection scanner. The screen ‘Philips Simonstone 51FS-SC’ (C7) was ranked even higher by both methods than it was by human eye. However it must be considered that the laser deflection scanner has the disadvantage that it can only measure screens in the middle. Peter Gerling mentioned in his report that the camera measurement method could not always make a clear statement about the quality differences just by measuring a screen in the middle.

The camera measurement method delivers a 2-dimensional image of a measured spot, while the laser deflection scanner measures only in one direction. However because of the displacements between the scanlines and by measuring a screen at 0° and 45° it is possible to get a 2-dimensional impression of the surface. And further is it also necessary for the camera measurement method to measure at 0° and 45° to overcome problems with the rectangular form of the pixels.

The time it takes to assess a spot is equal for both systems. The laser deflection scanner consumes the most time measuring, while the camera measurement method needs the most time processing the data. Suggestions to improve this matter for the laser deflection scanner can be found in section 7.1. An evaluation of the software of camera measurement method maybe would lead to a faster program (Its menu might need some work too).

An advantage of the camera measuring method is that it directly can be used in practice, even though it is an experimental system. The laser deflection scanner in its present form can only be used for experiments.

3 Rating R2 with frequency range [22 1/cm, 45 1/cm] was compared to the ‘newer numbers’ from the table in Appendix G.

8 Conclusions

- It is possible to use the laser deflection scanner in order to assess high gloss quality of screens. The calculation of rating R_2 proofed to be a good method to quantify high gloss quality, especially when the higher frequencies were filtered out.

- For further investigations a new measuring device, that could measure all over the screen, should be developed to overcome the limitations of the present measuring device.

- There are not any significant differences between the laser deflection scanner and the camera measurement method in their ability to quantify high gloss screens.

Acknowledgement

First of all, I would like to thank my mentor William Hofman. He has been a great help in bringing this project to a successful ending. Also would I like to thank him for his suggestions during writing this report. Fred Knijnenburg and Allan Maguire are acknowledged for lending me their equipment and delivering the FFT routines. Further would I like to thank Robert Karhausen, Peter Rutjes, Jack Severijnen and Jacques Stevens for their pleasant cooperation. Last, but not least I would like to thank Philips in the person of Huub Schrans for giving me the opportunity to do this practical work.

Danny Ruijters,
Aachen, 8 November 1996

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2. Fred Couweleers, “Meting van beeldschermkwaliteit met deflectiemeter”, Philips CFT Eindhoven, CTB 596-94-3030, April 1994.

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Appendix A

Benchmarked polished screen faces - Internal memo

The tests (see chapter 6) were based on the screens described in internal memo VGB 685-95.0111 by A.C. v.d. Heuvel and J. Severijnen. Therefore, I included this memo.

FROM	:	A. C. v.d. Heuvel J. Severijnen	ATG-FiT ATG-QA	
PHONE	:	3182/3239		
TO	:	Members I.T.M. Finishing		
SUBJECT	:	Benchmarking polished screen faces in-/outside Philips		
COPY	:	Messrs.	M. Miraglia B. Taylor K.H. Tung H. Emonts H. Hagreis B. Mansfeld C. v. Otterloo	(PB) (PS) (PT)

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1. INTRODUCTION

In recent years ATG have collected many screens from all Philips Glass factories and competitors. From the various batches a representative sample was selected. All samples which were visually inspected are now exposed in the exposition room in building PS in Aachen.

The number of samples is not pretending to be complete. You are all invited to send us more screens, from your own factory or any competitor, to extend this ranking.

2. RESULTS

All screens were inspected on normal inspection criteria. The screens are ranked on total impression of the screen face.

The results are described in annex 1. We have chosen to present the results divided in dull gloss and high gloss quality and in groups tiny, medium and big screens.

RANKING SCREEN FACE QUALITY

A. 14"/20" SC DULL GLOSS

order	**type**	**supplier**	**sealing edge**	**remarks**
1.	14" SC	PH Brazil	as pressed	modular line
2.	14" SC	PH Taiwan	as pressed	wipers
3.	20" SC	PH Brazil	as pressed	philiflow

B. 14"/41FS/17" SC HIGH GLOSS

order	**type**	**supplier**	**sealing edge**	**remarks**
1.	14" SC 41 FS-SC	Asahi/PGC PH Simonstone	hg polished touch ground	
2.	17" SC	Asahi	hg polished	
3.	14" SC	PH Brazil	as pressed	modular line
4.	14" SC	NEG	as pressed	
5.	14" SC	PH Taiwan	polished	
6.	14" SC	Ekranas	ground	pg grooves
7.	14" SC	PH Brazil	as pressed	philiflow

C. 19V/20"/51FS/21" SC HIGH GLOSS

order	**type**	**supplier**	**sealing edge**	**remarks**
1.	51 FS-SC	Asahi	hg polished	
2.	51 FS-SC	PH Taiwan	polished	
3.	21" SC	NEG	as pressed	
4.	19V	Corning	polished	
5.	51 FS-SC	PH Simonstone	as pressed	modular line 1
6.	51 FS-SC	PH Simonstone	as pressed	autoline
7.	51 FS-SC	PH Simonstone	as pressed	modular line 2
8.	20" SC	Ekranas	as pressed	

D. 59 FS-SC DULL GLOSS

order	**type**	**supplier**	**sealing edge**	**remarks**
1.	59 FS-SC	Videoglass	polished	very good quality
2.	59 FS-SC	PH Aachen	as pressed	
3.	59 FS-SC	PH Taiwan	polished	

E. 59 FS/25" SFS HIGH GLOSS

order	**type**	**supplier**	**sealing edge**	**remarks**
1.	59 FS-SC	PH Simonstone	polished	
2.	59 FS-SC	Novel	polished	
3.	59 FS-SC	PH Taiwan	polished	
4.	59 FS-SC 25" SFS	PH Aachen PH Aachen	as pressed polished	

F. 66 FS-SC DULL GLOSS

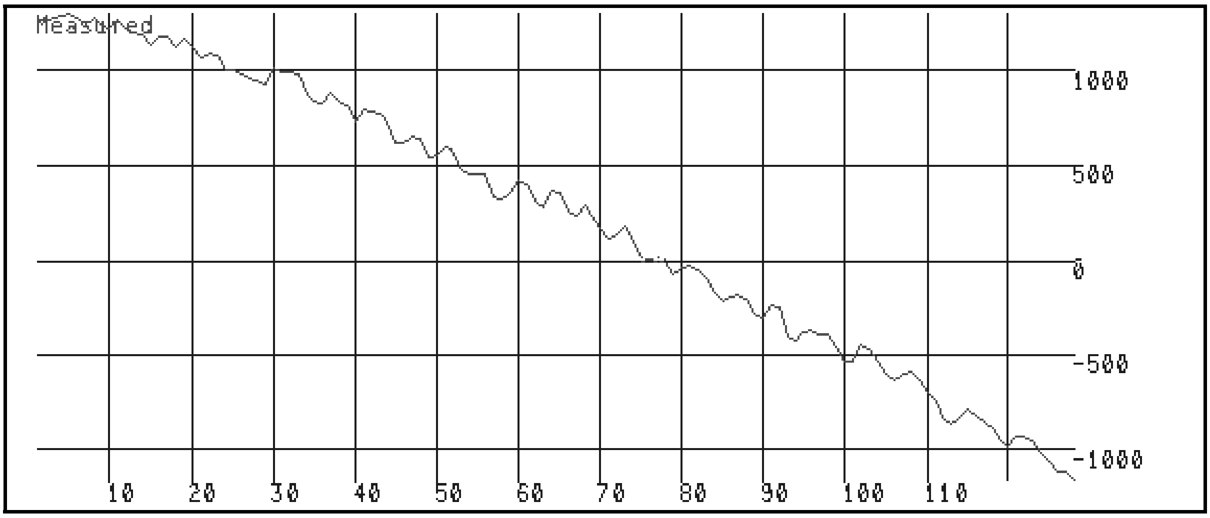
order	**type**	**supplier**	**sealing edge**	**remarks**
1.	66 FS-SC	Schott	polished	
2.	66 FS-SC	PH Aachen	as pressed	

G. 66 FS/28" WS/29" SFS HIGH GLOSS

order	**type**	**supplier**	**sealing edge**	**remarks**
1.	66 FS-SC	NEG	polished	
2.	66 FS-SC 28" WS 29" SFS	PH Aachen PH Aachen PH Aachen	polished polished polished	

Appendix B

The measured graphics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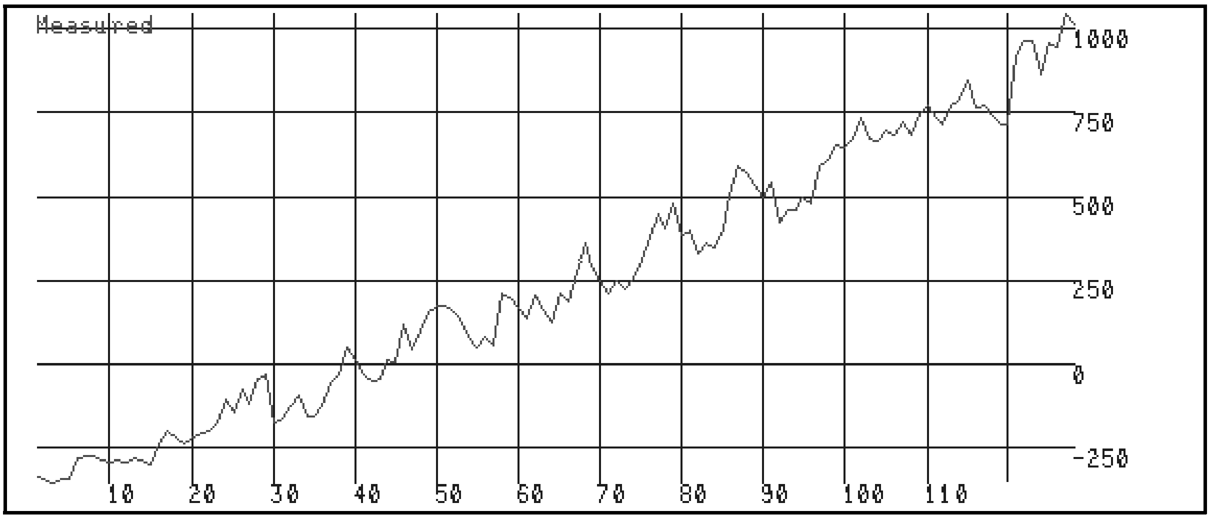
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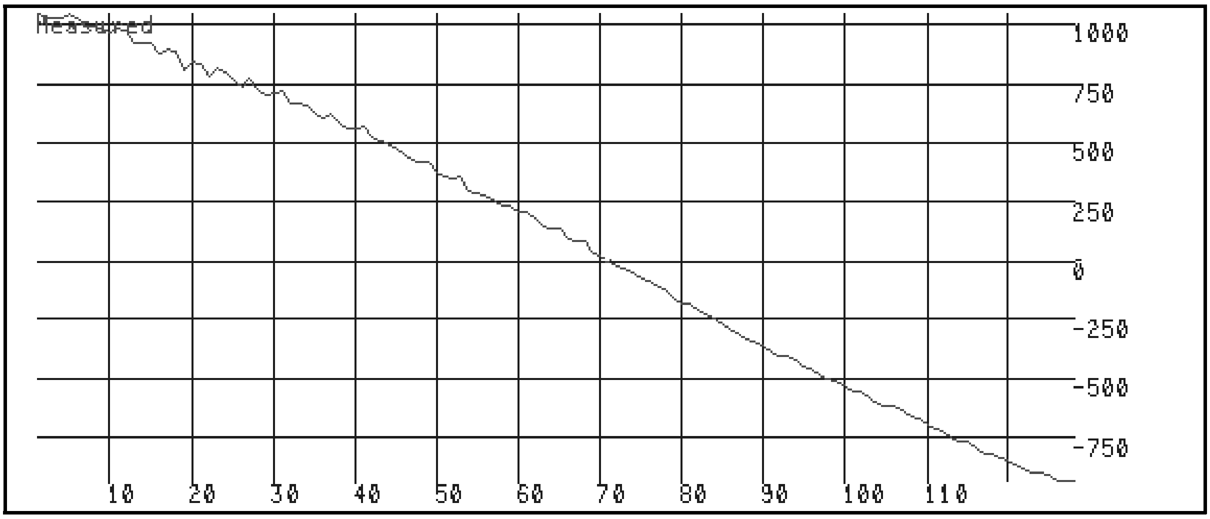
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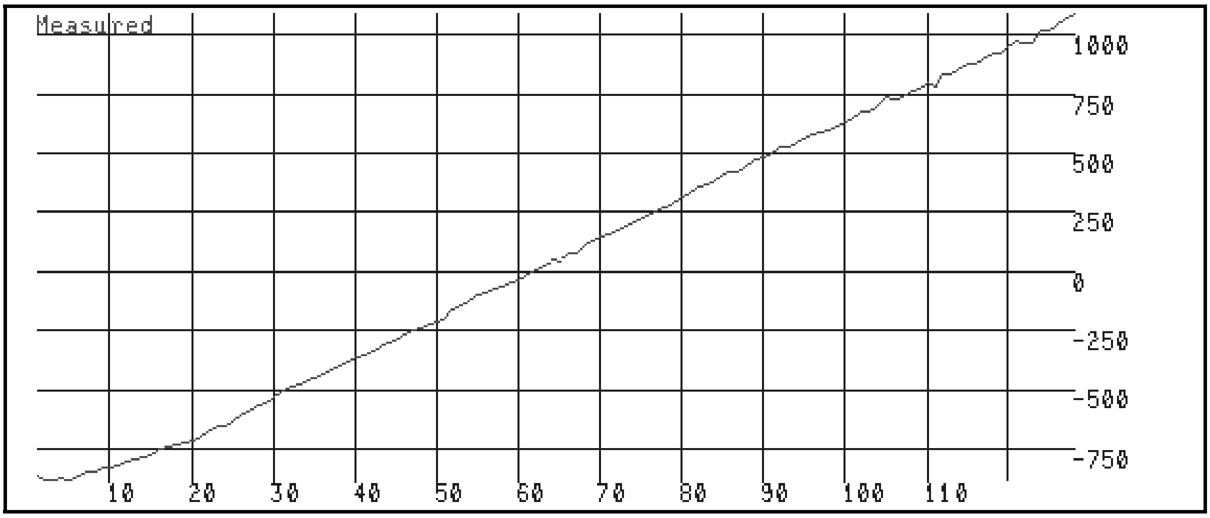
B1a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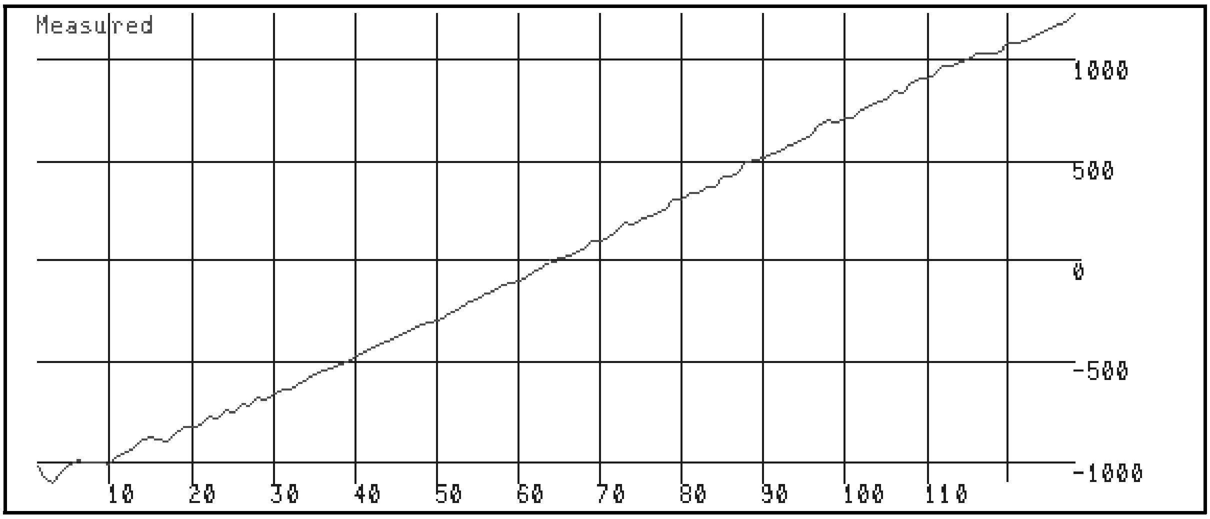
B1b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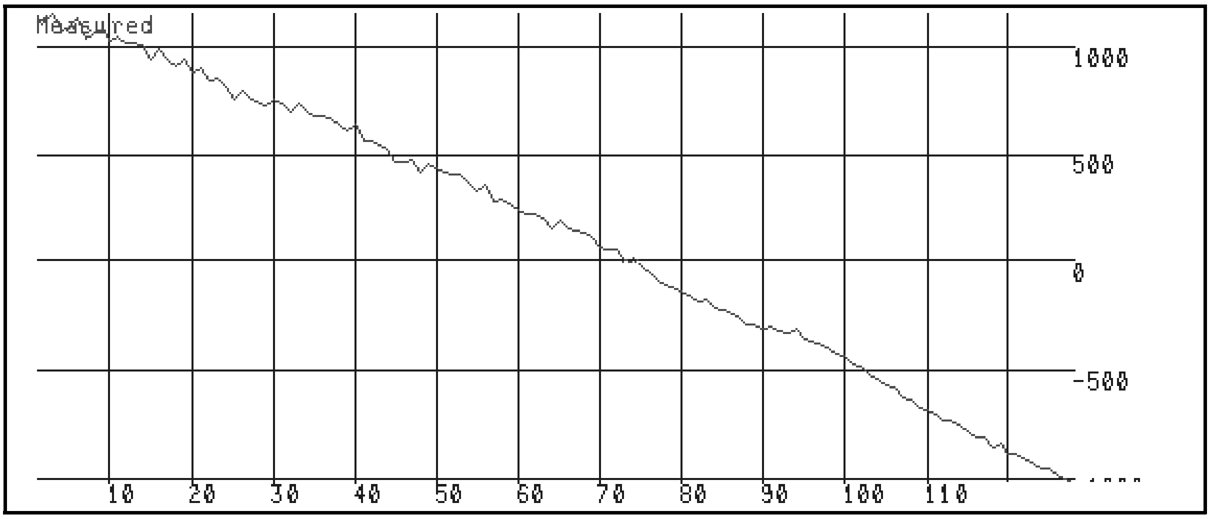
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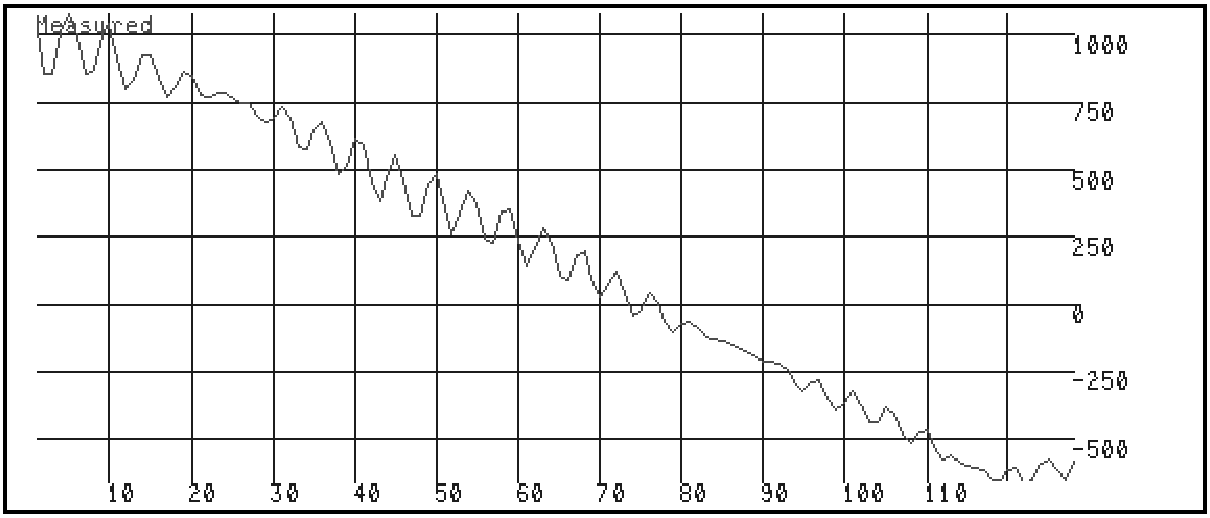
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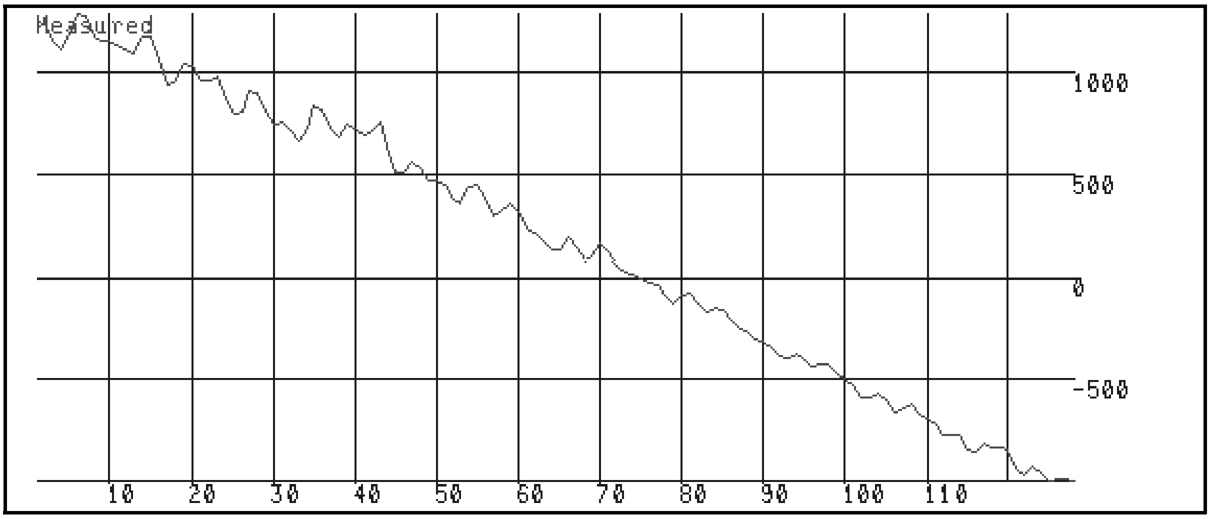
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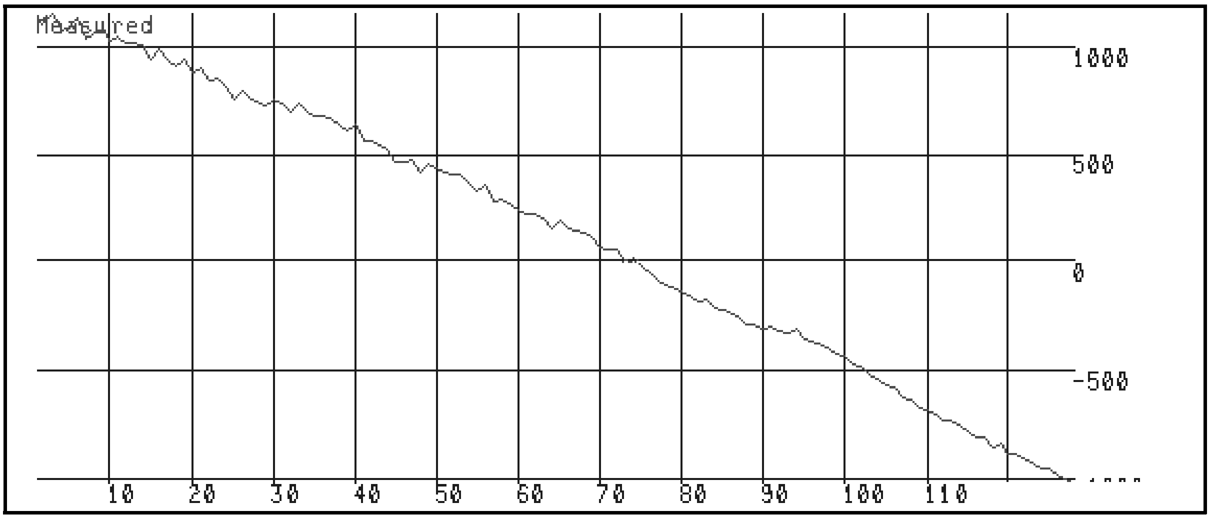
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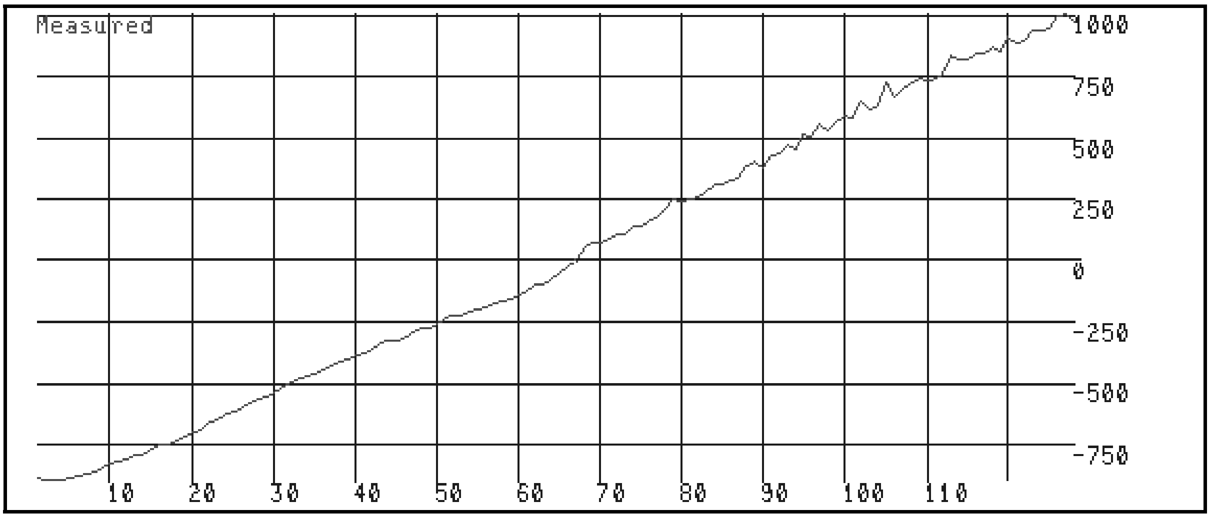
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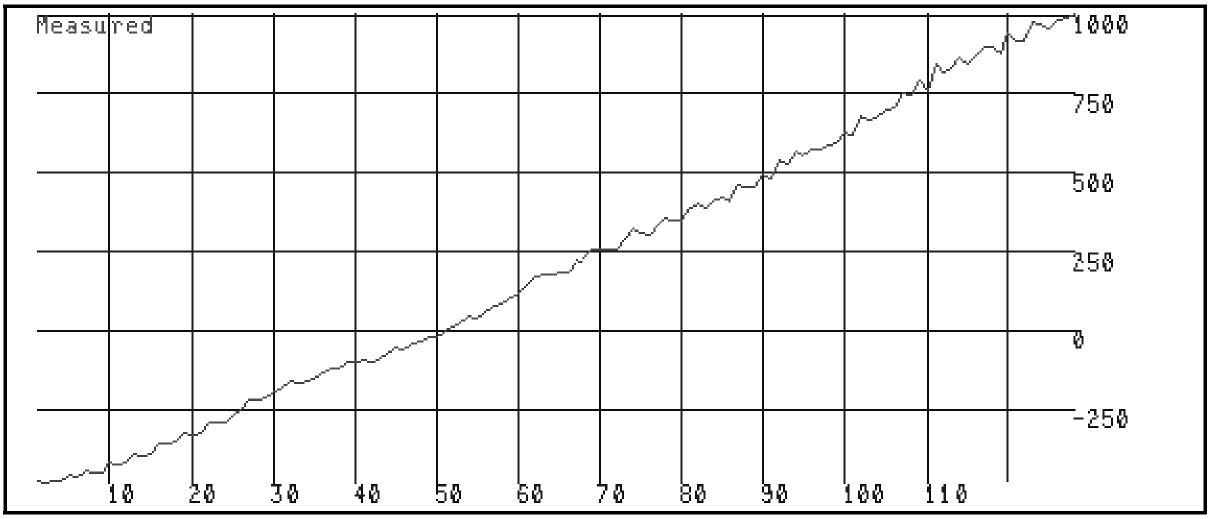
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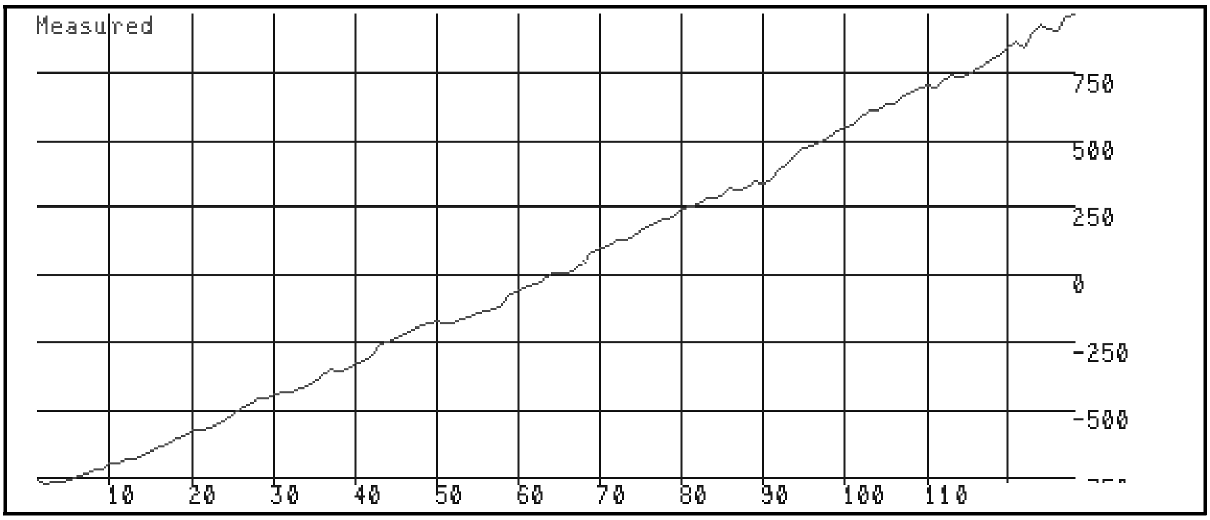
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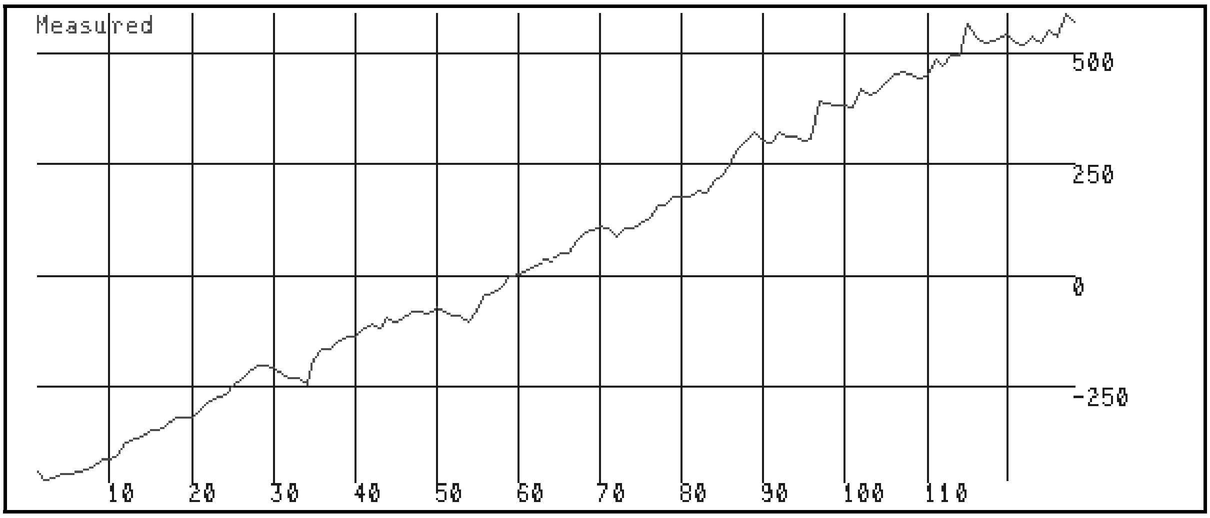

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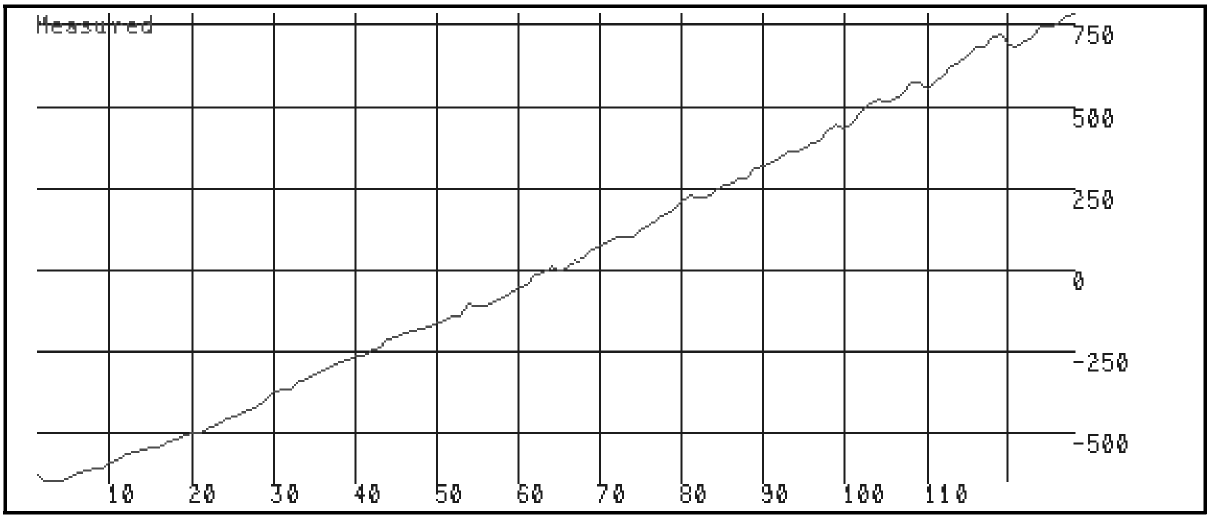

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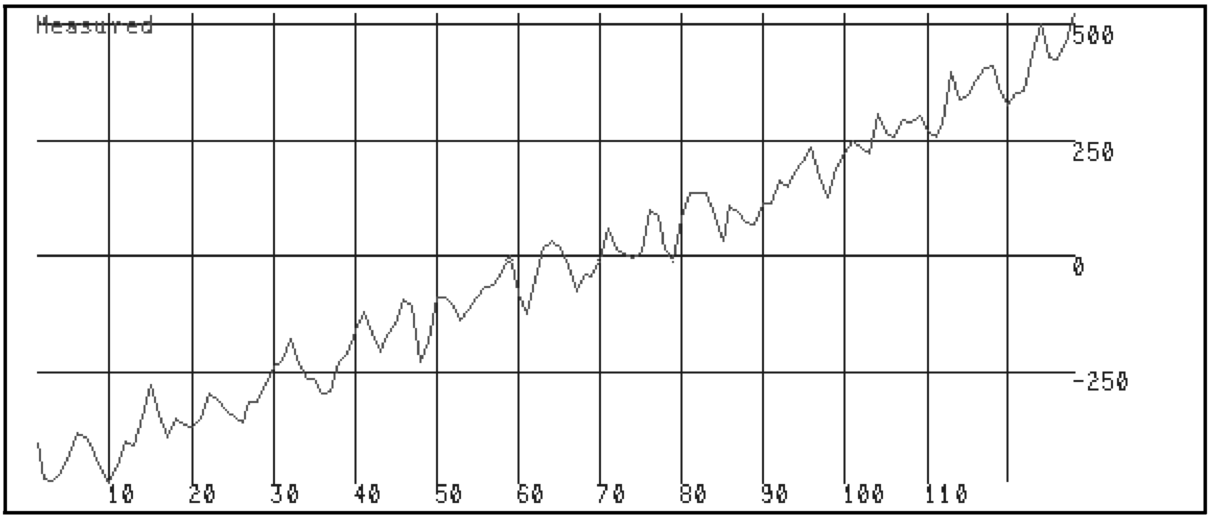

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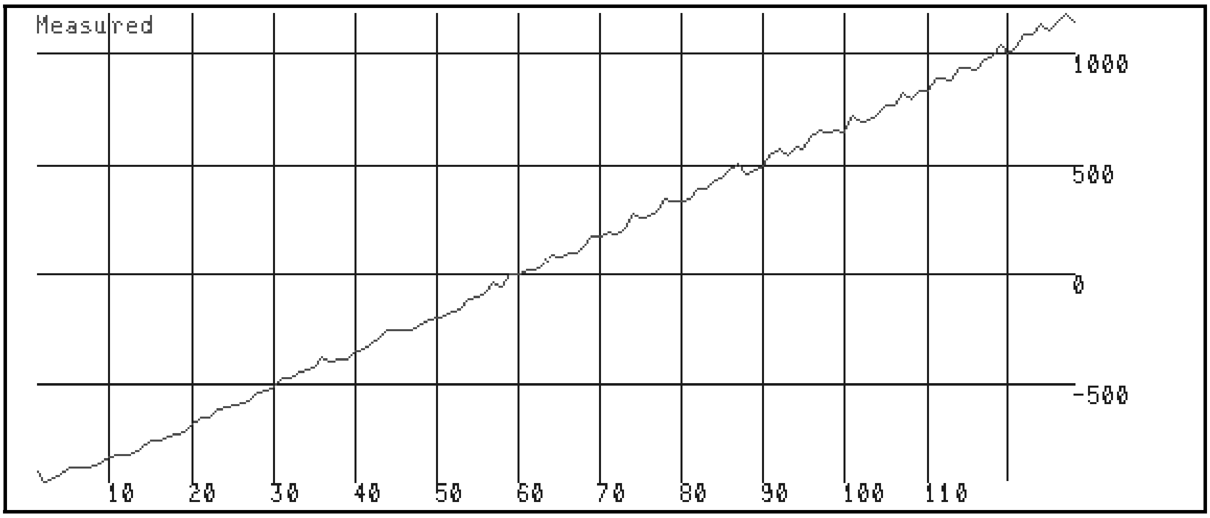
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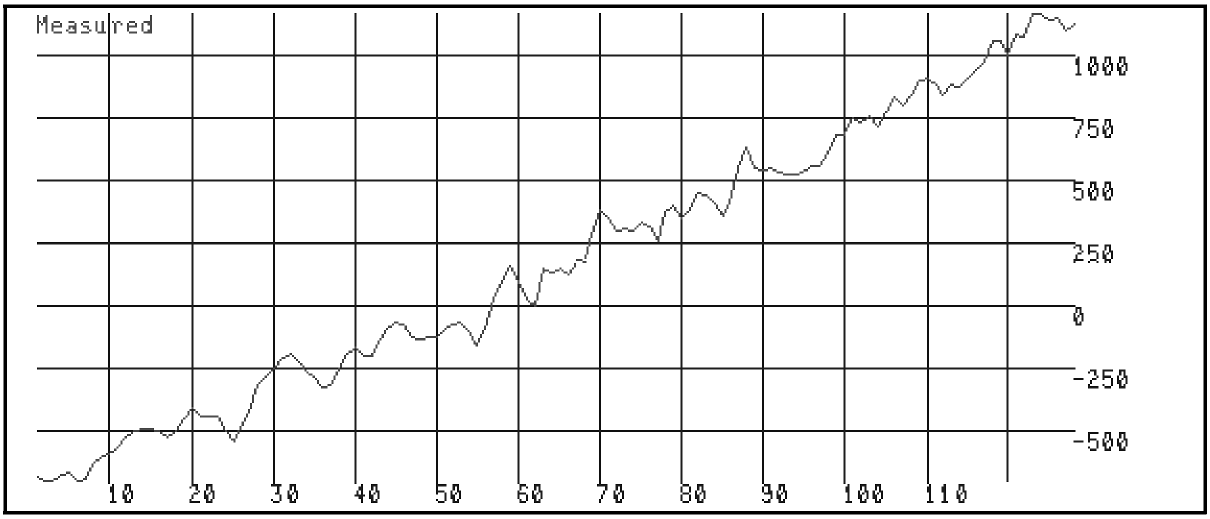
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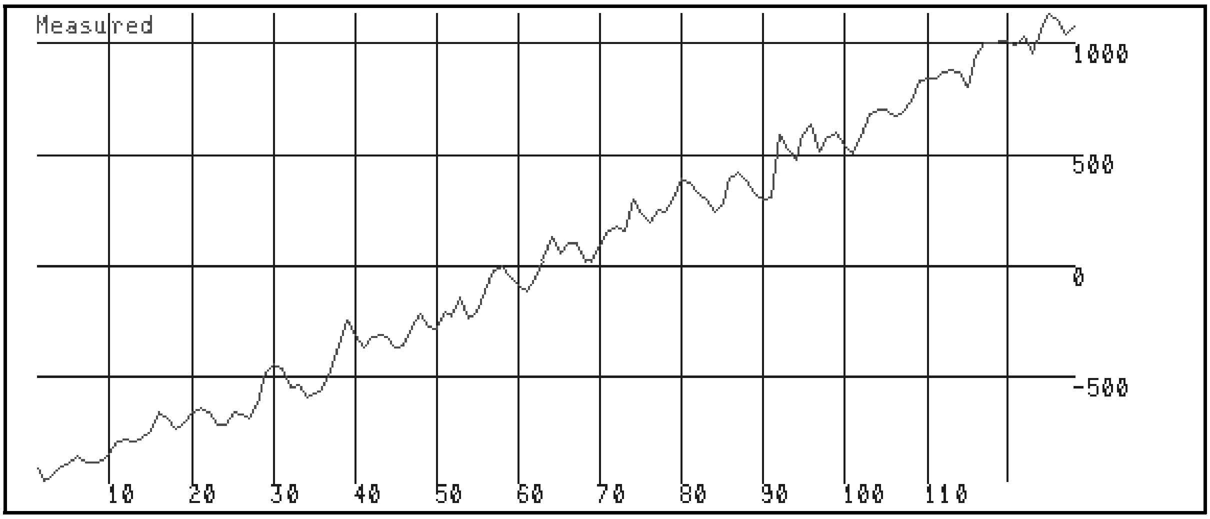
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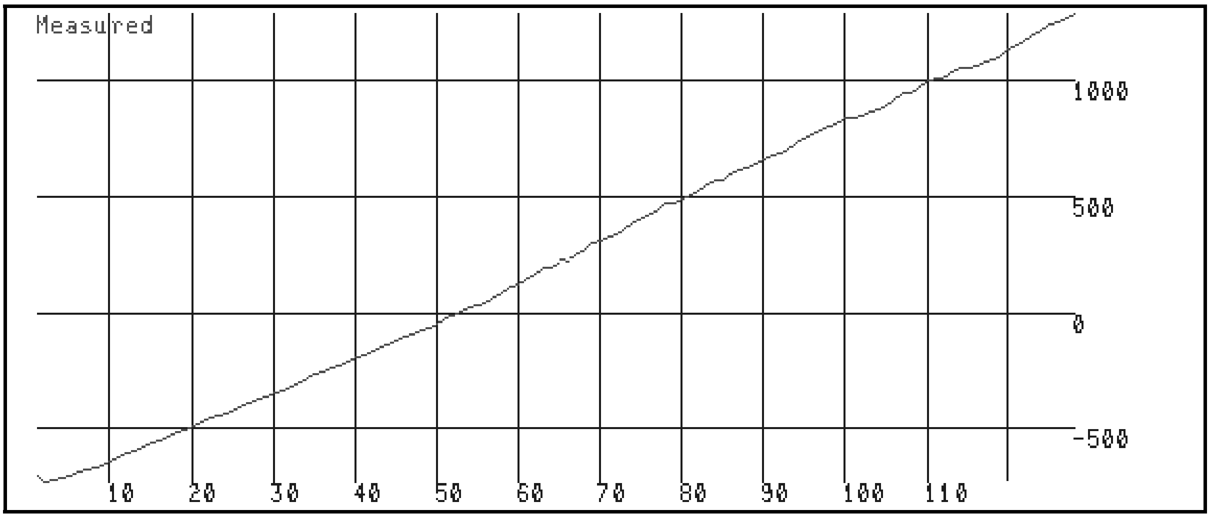
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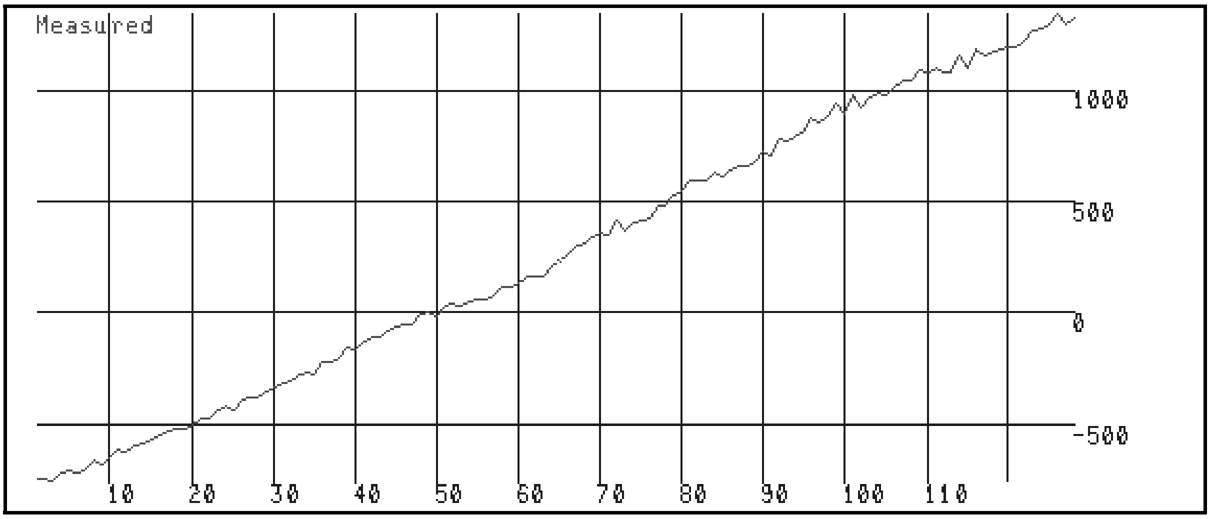
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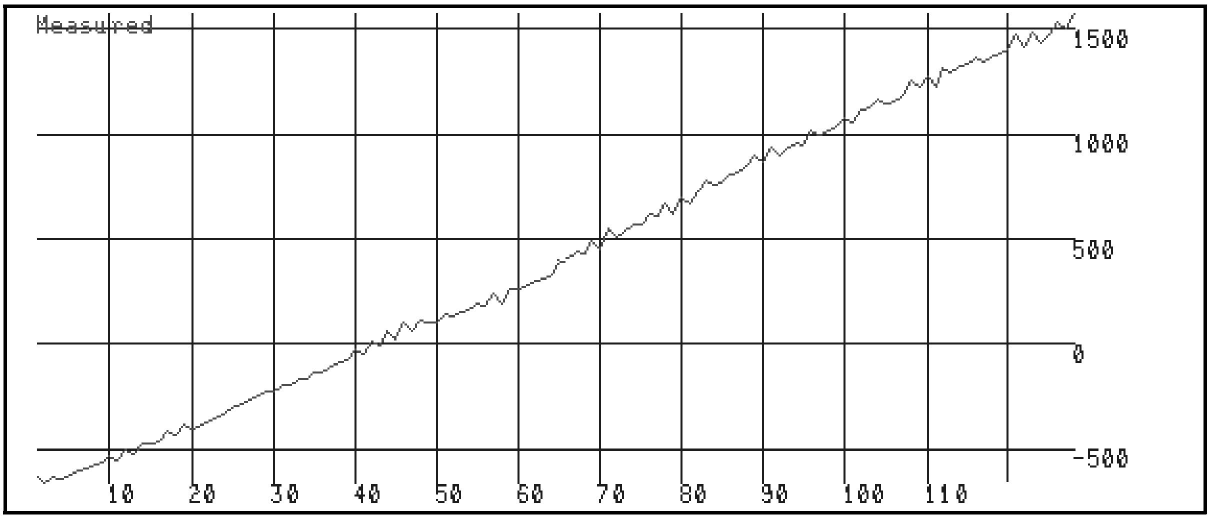
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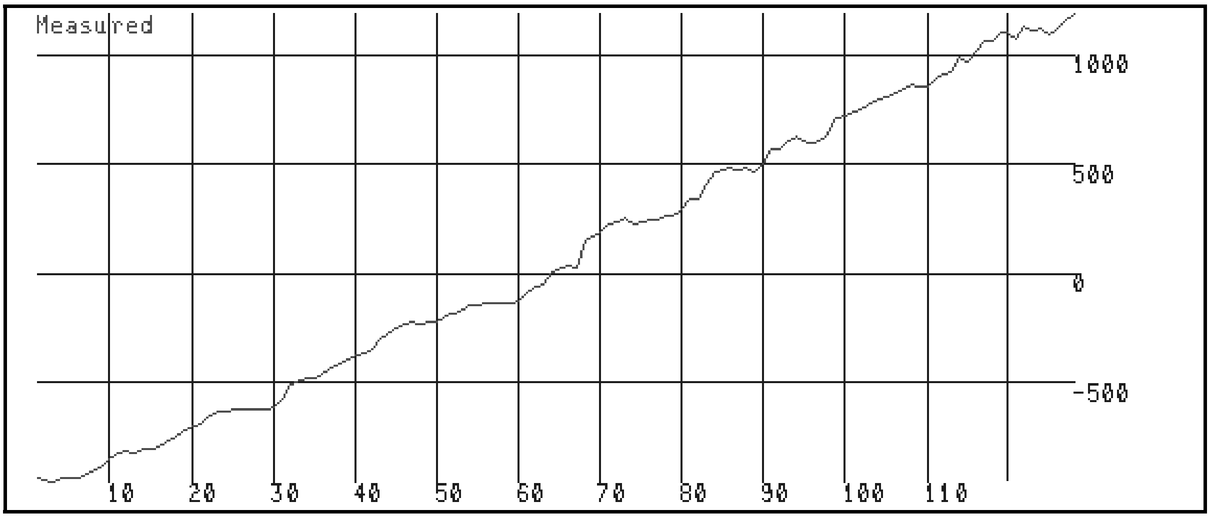
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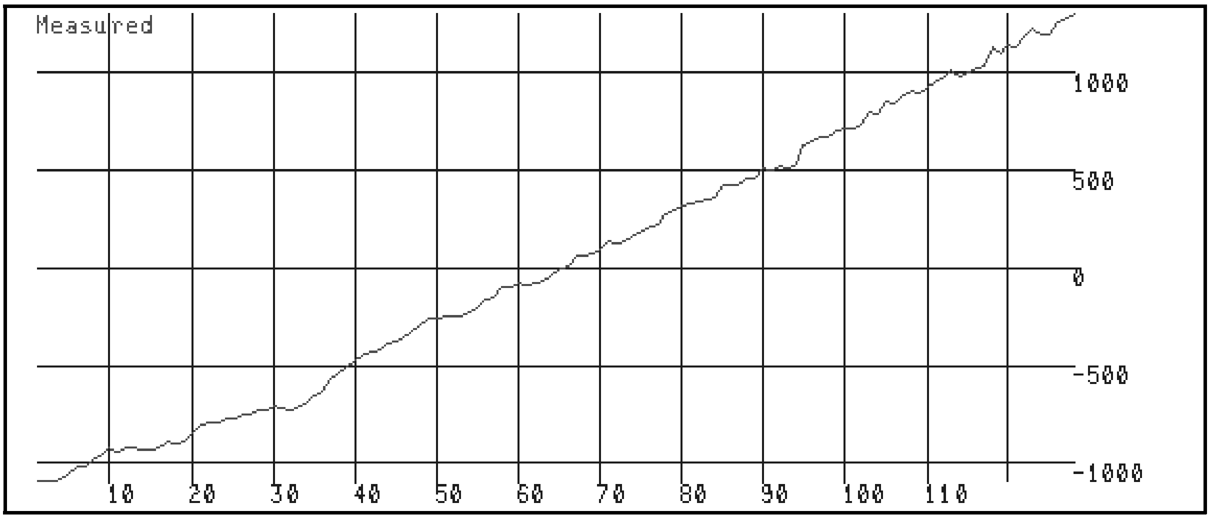
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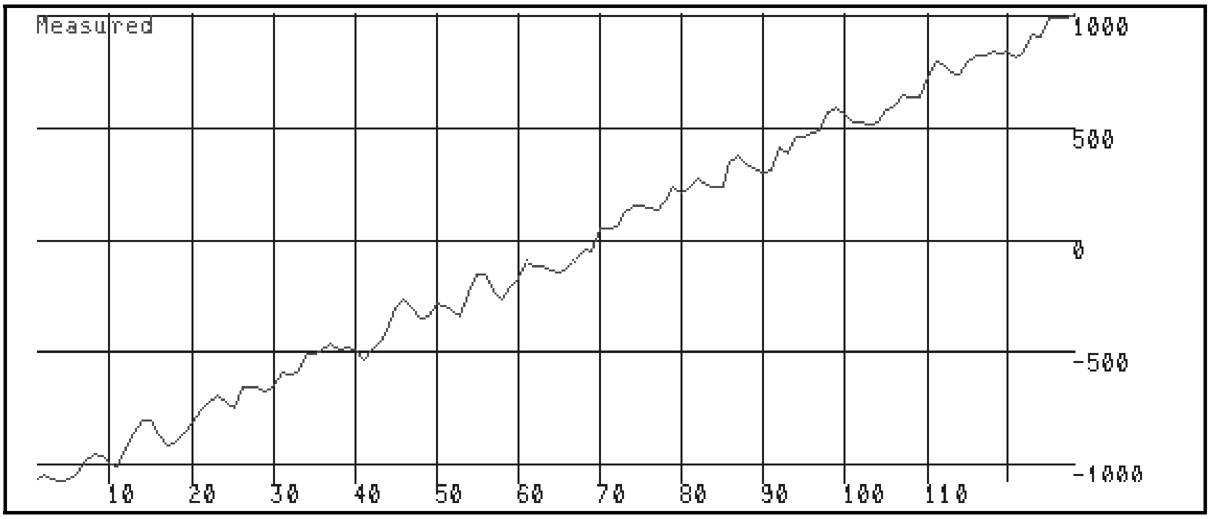
E4b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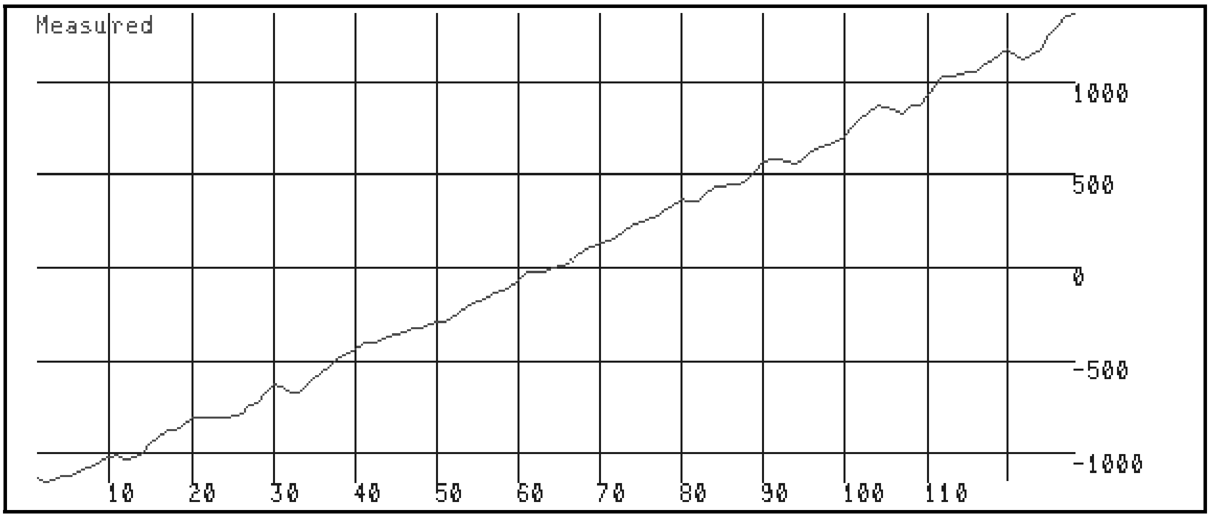
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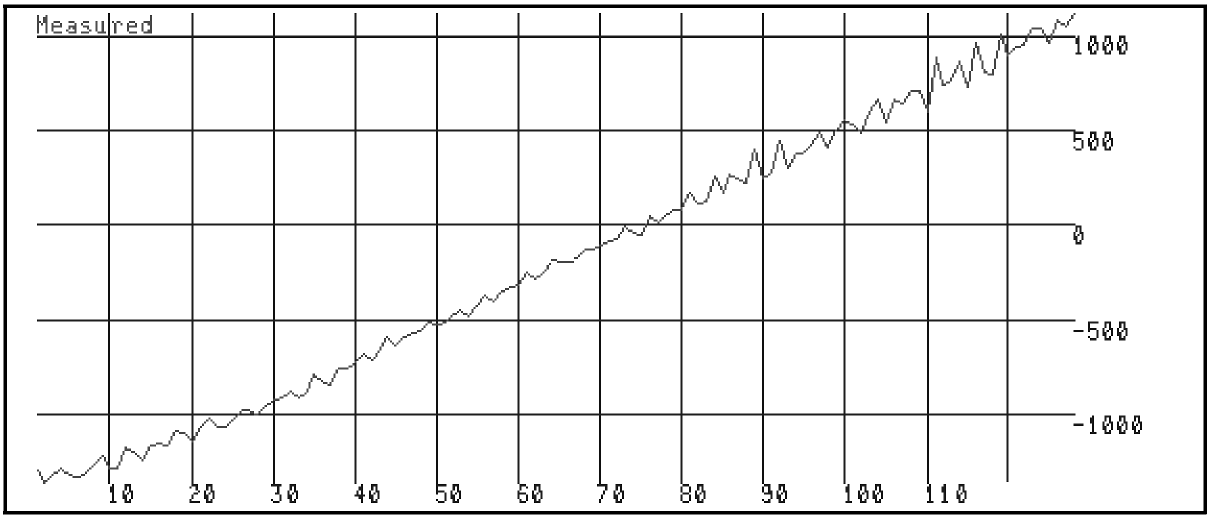
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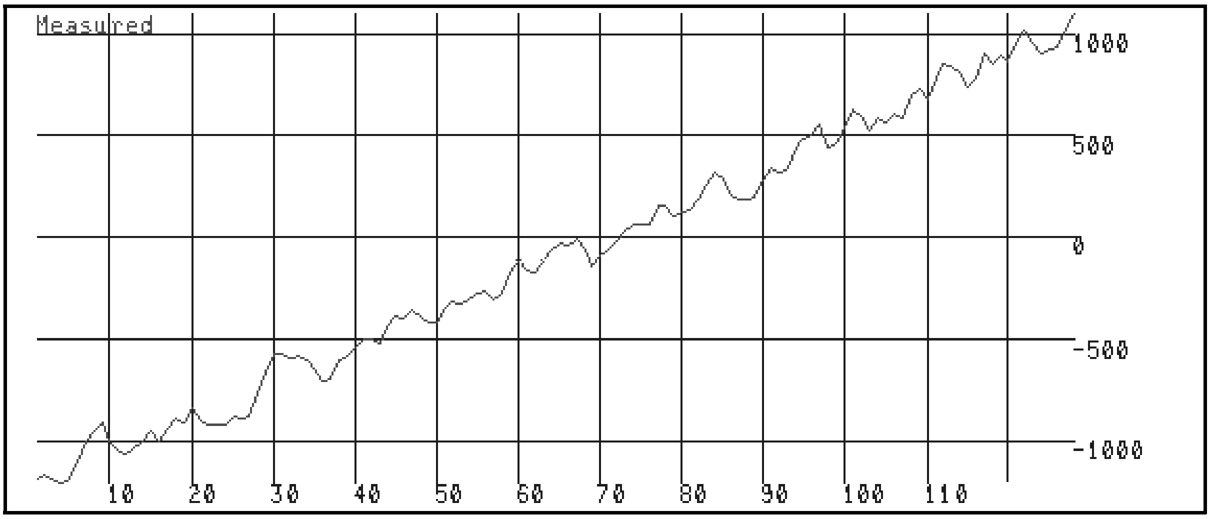
50
60
70
80
90
100
110

G1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-500
-1000
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20
30
40
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60
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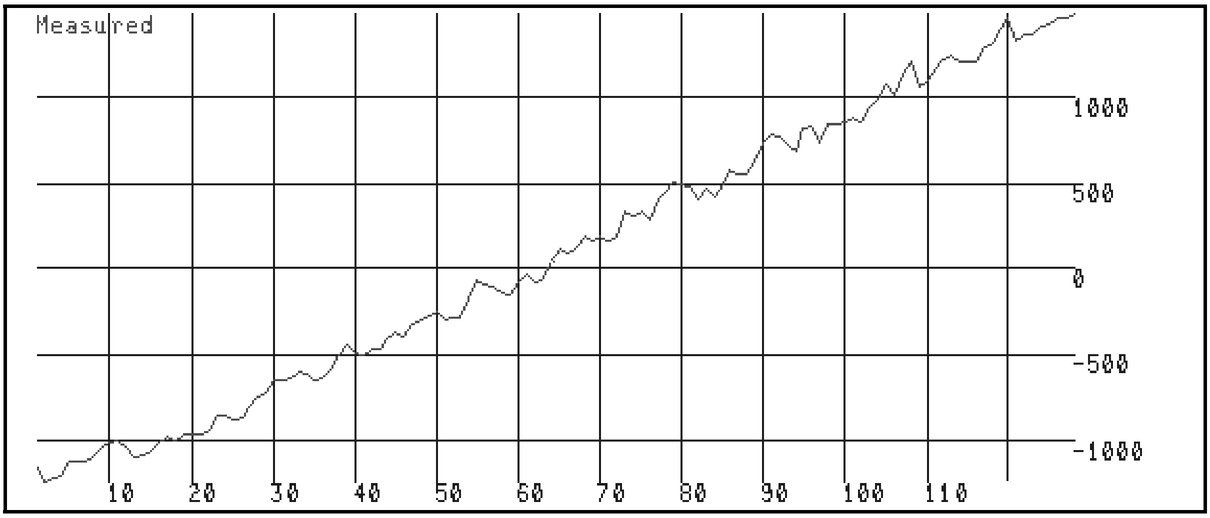
80
90
100
110

G2a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40
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60
70
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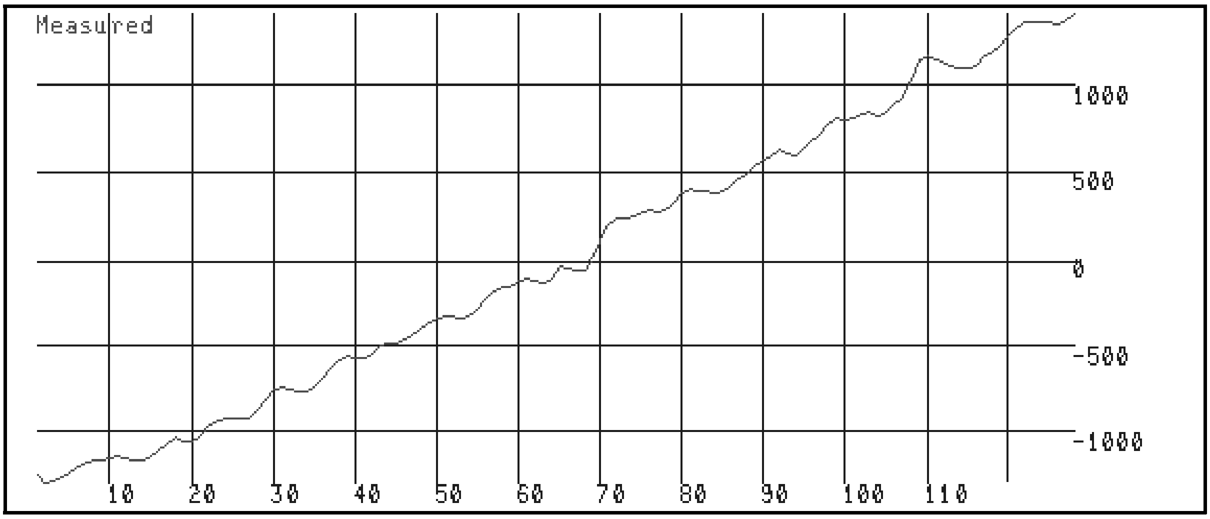
90
100
110

G2b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90
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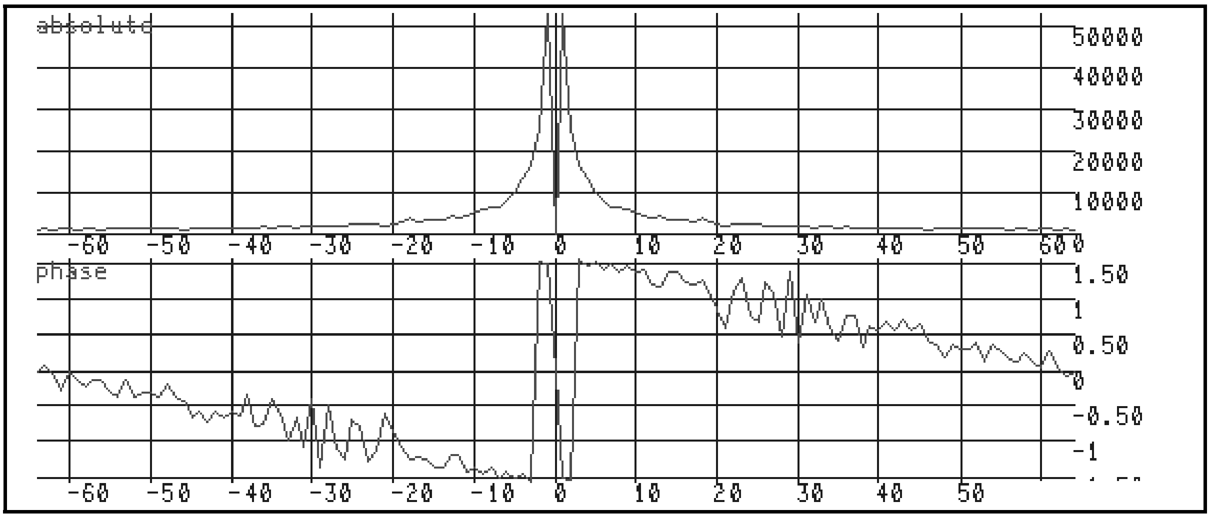
110

G2c

Appendix C

The Fourier transform graphics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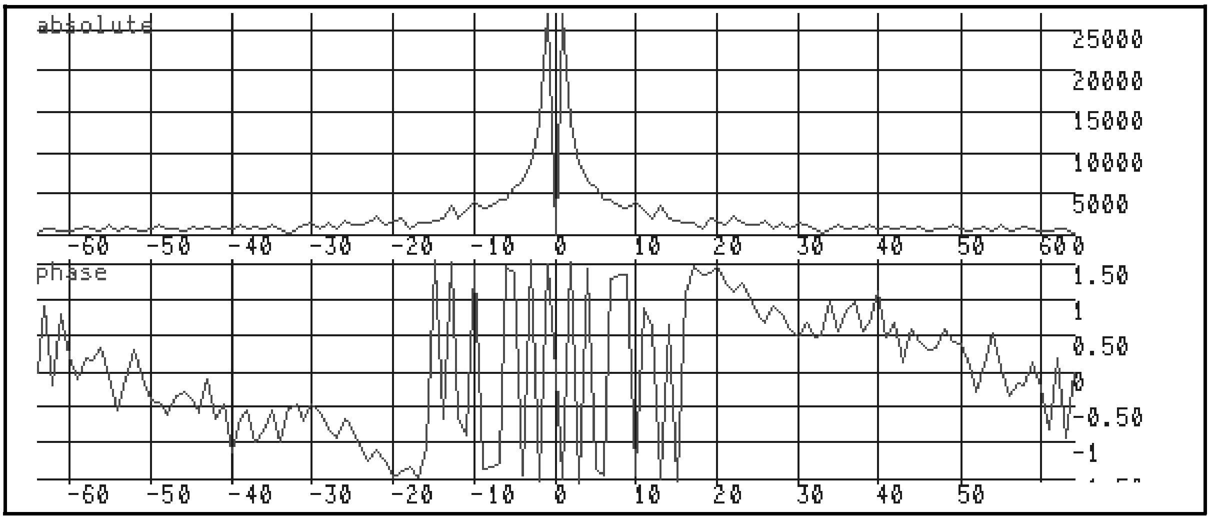
-0.50
-1
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50

A1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-1
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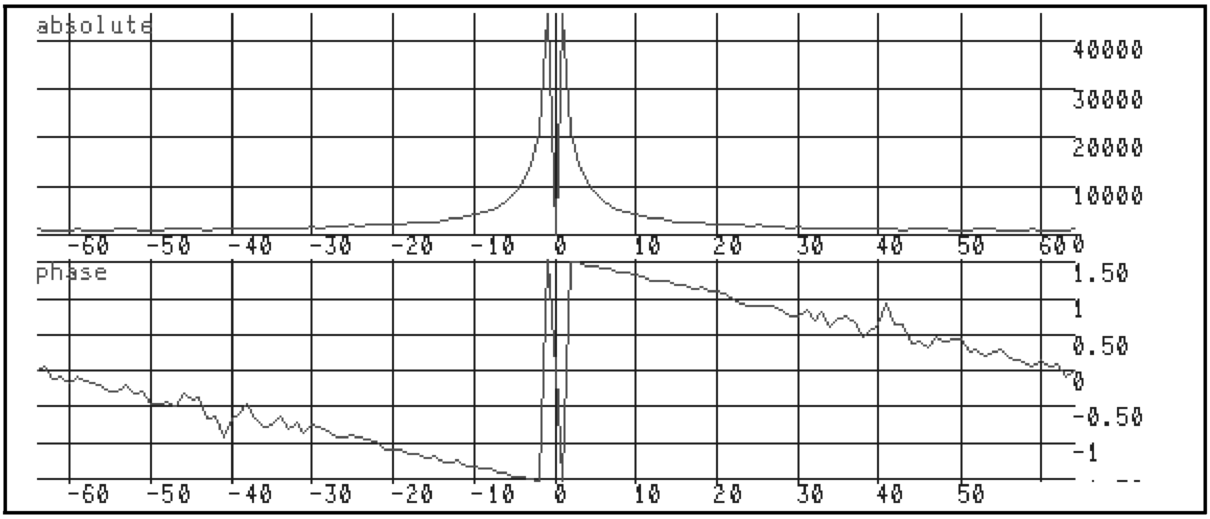
A3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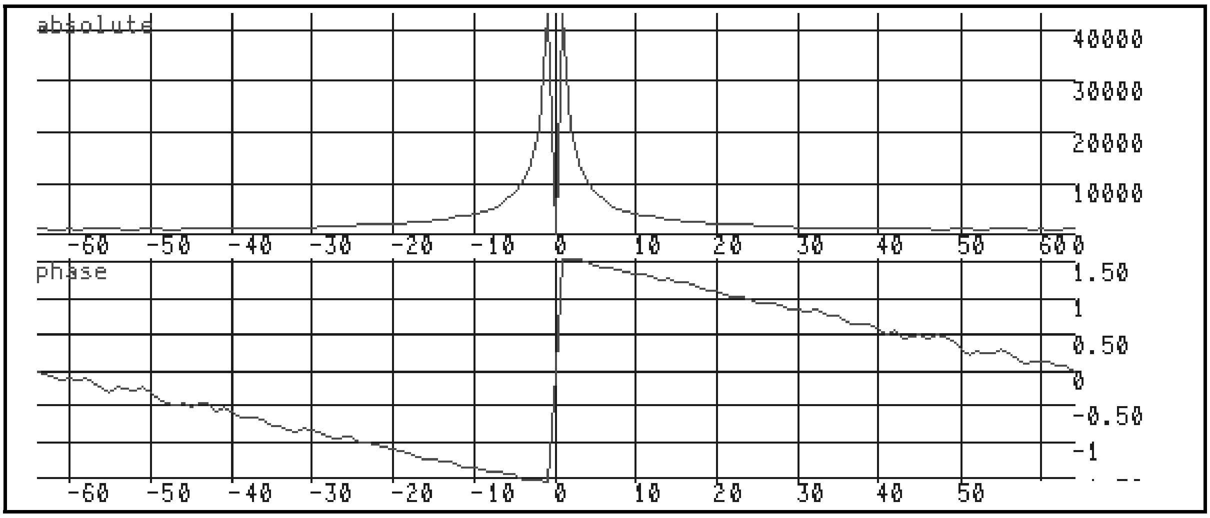
-1
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50

B1a



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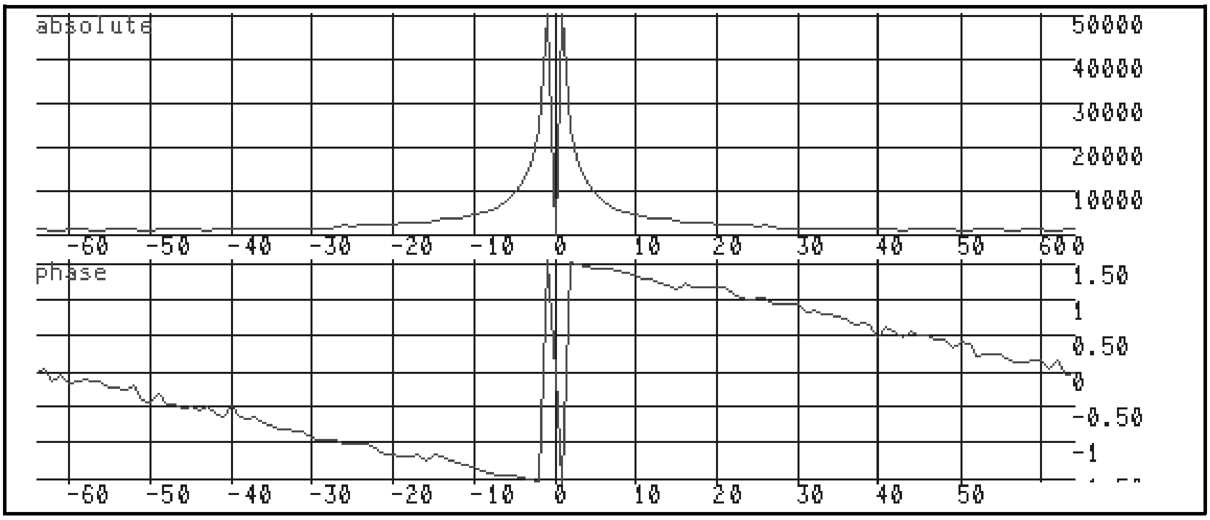
B1b



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-1
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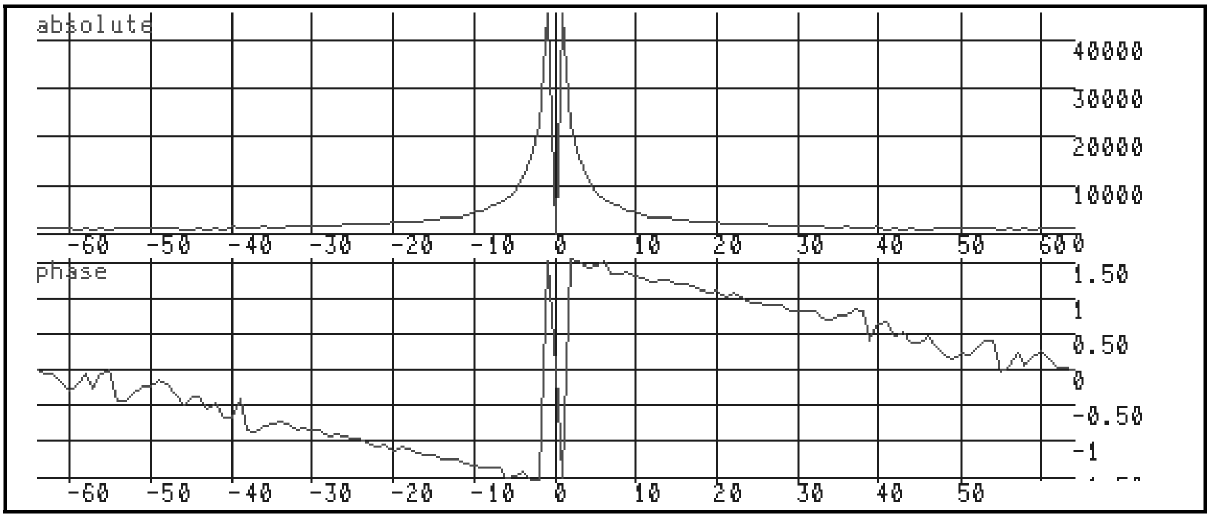
B2



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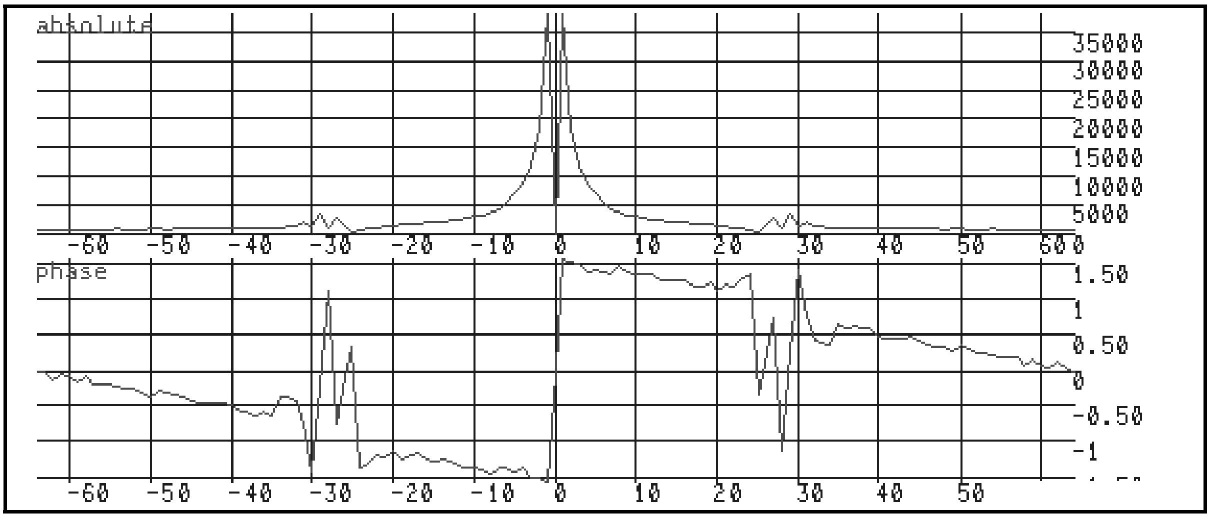
-1
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50

B3



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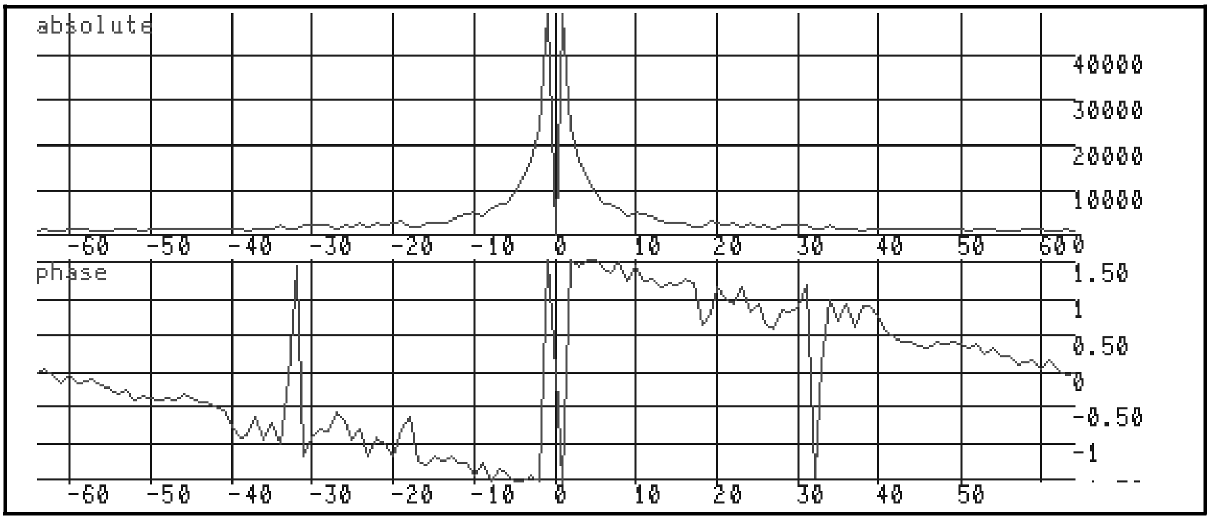
-0.50
-1
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50

B4



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0.50
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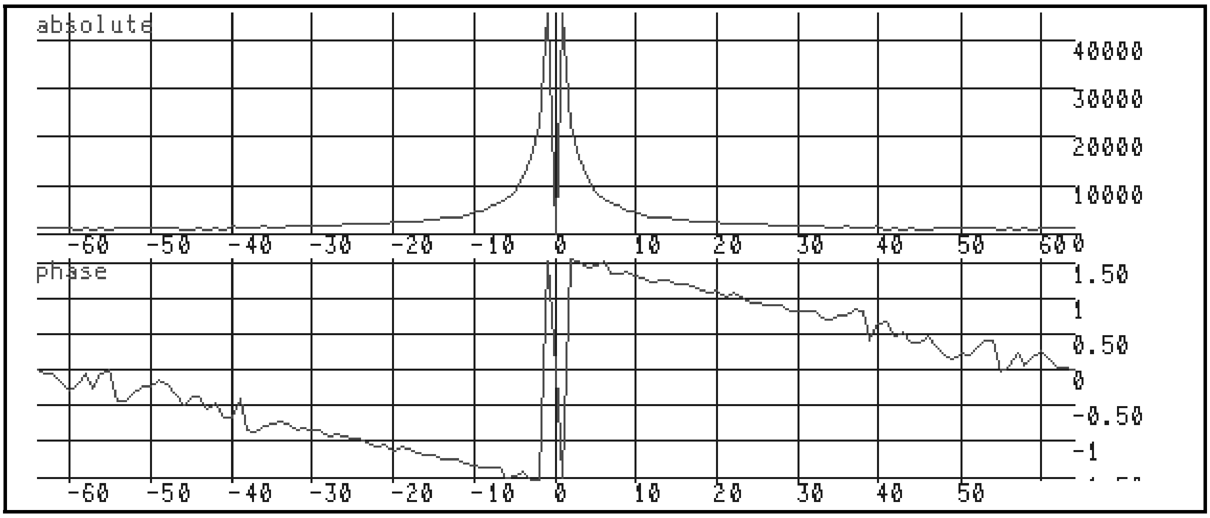
-1
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50

B5



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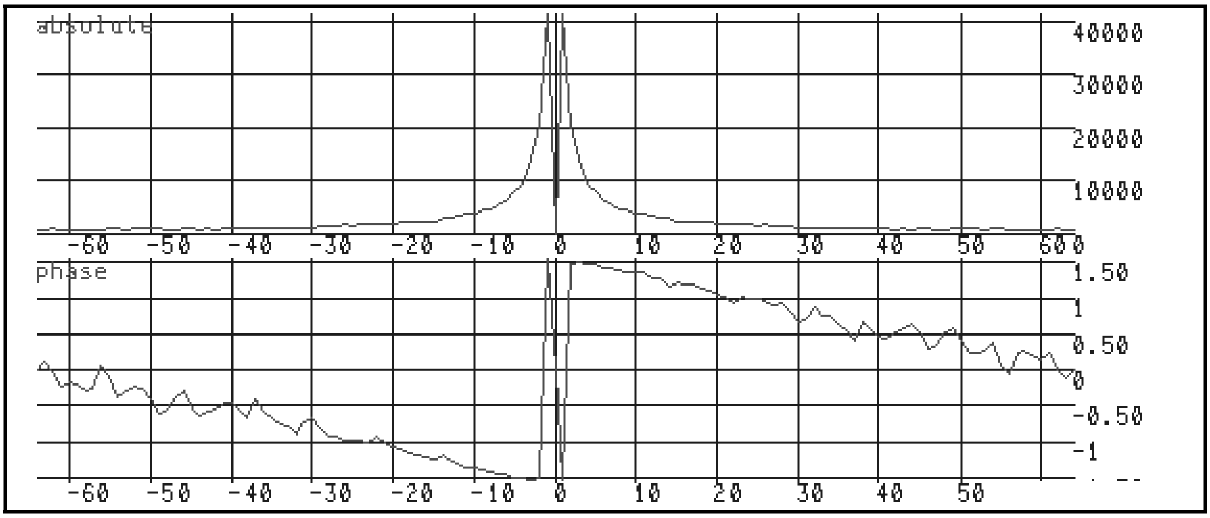
-1
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50

B7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-1
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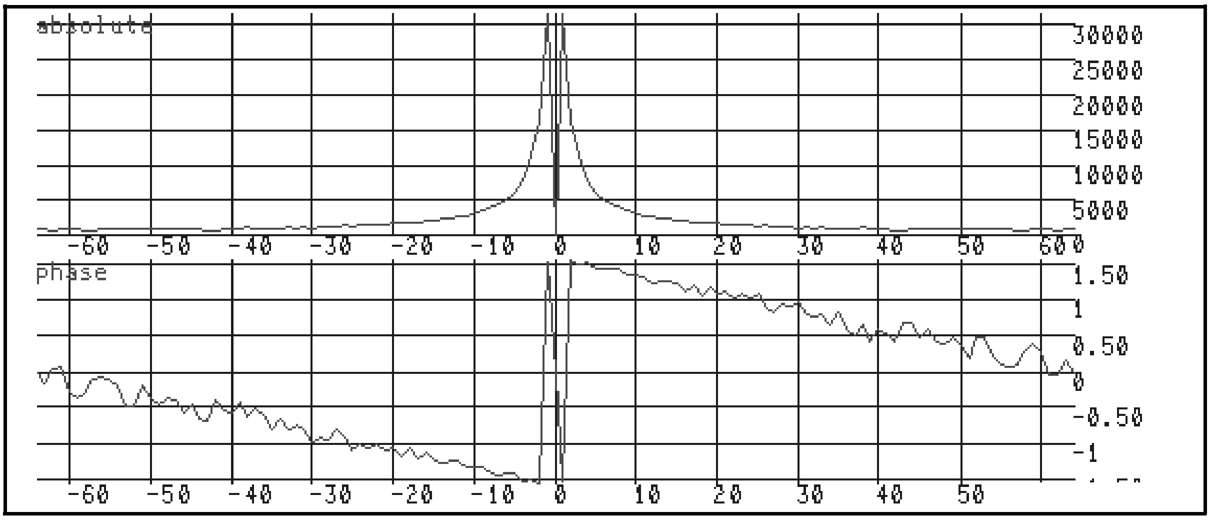
C1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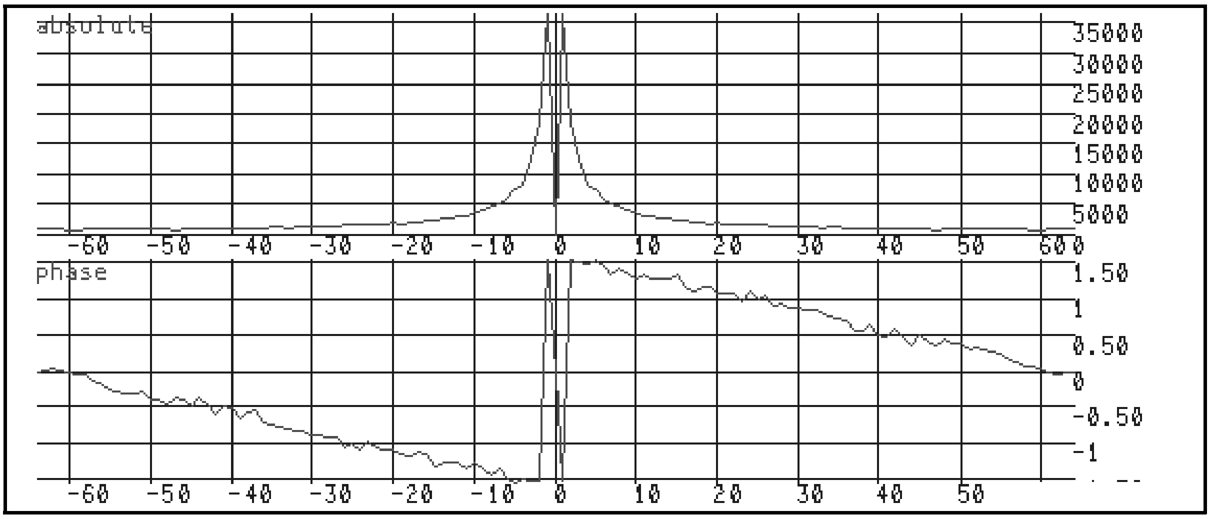
C2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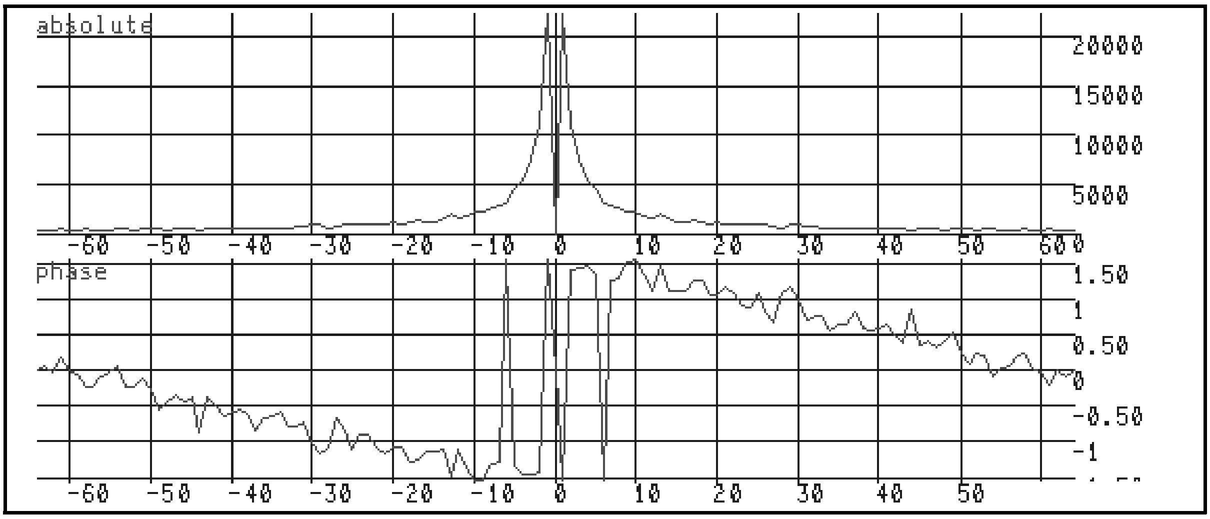
C3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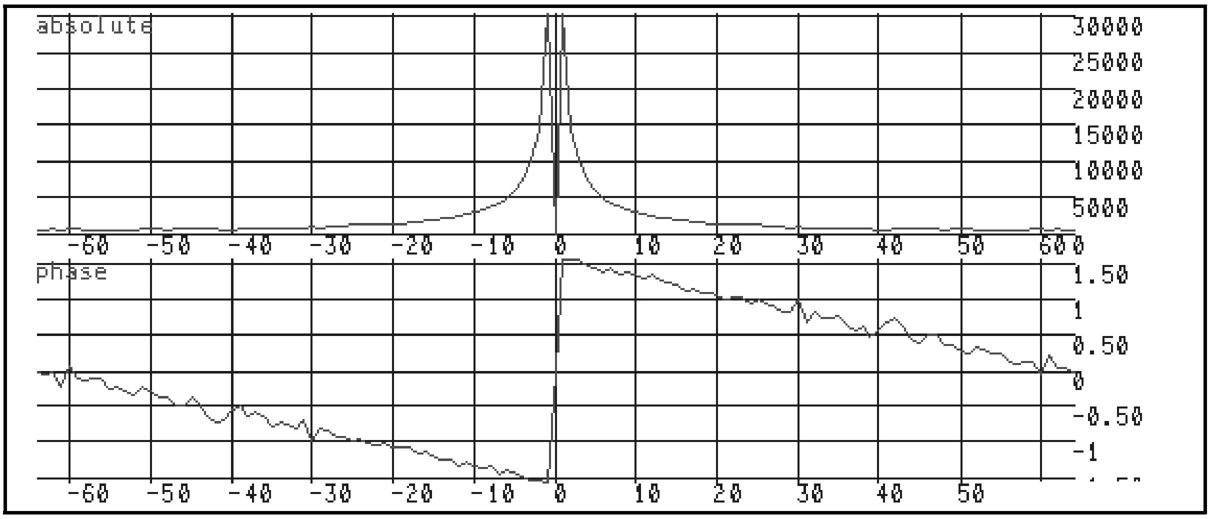
C4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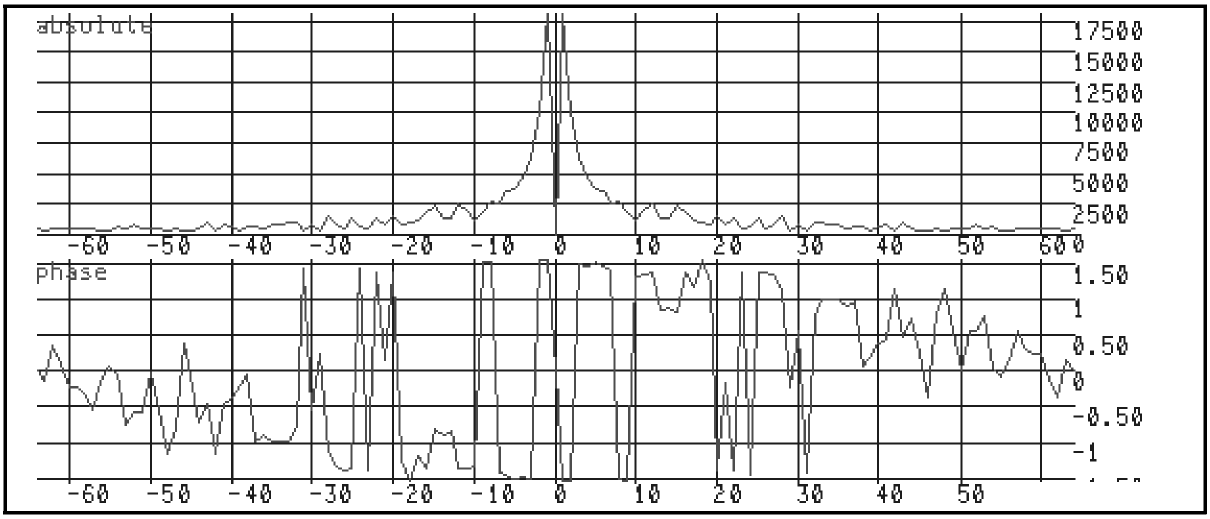
-1
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50

C7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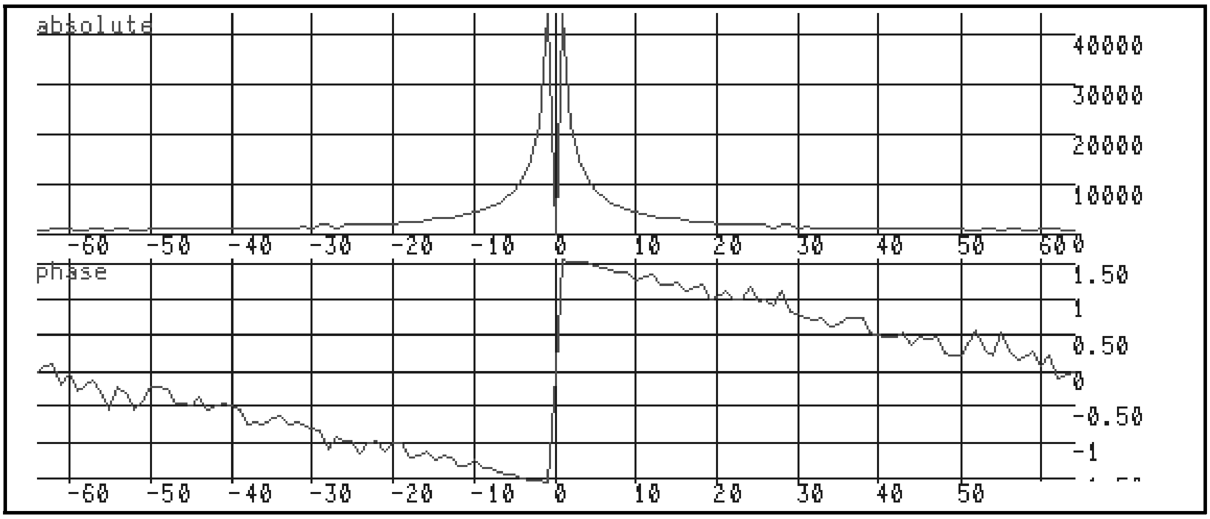
C8



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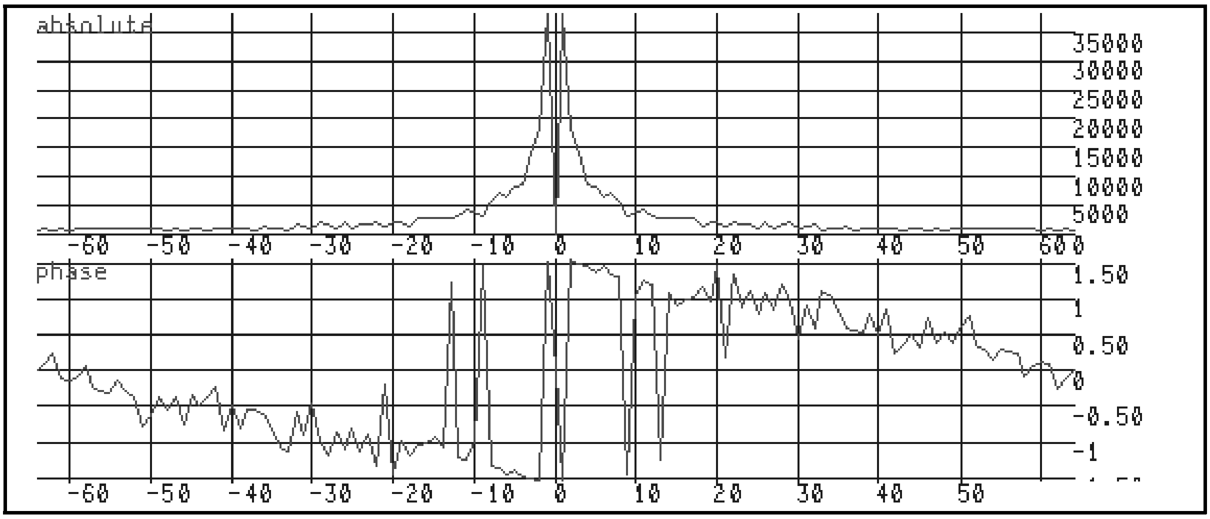
D1



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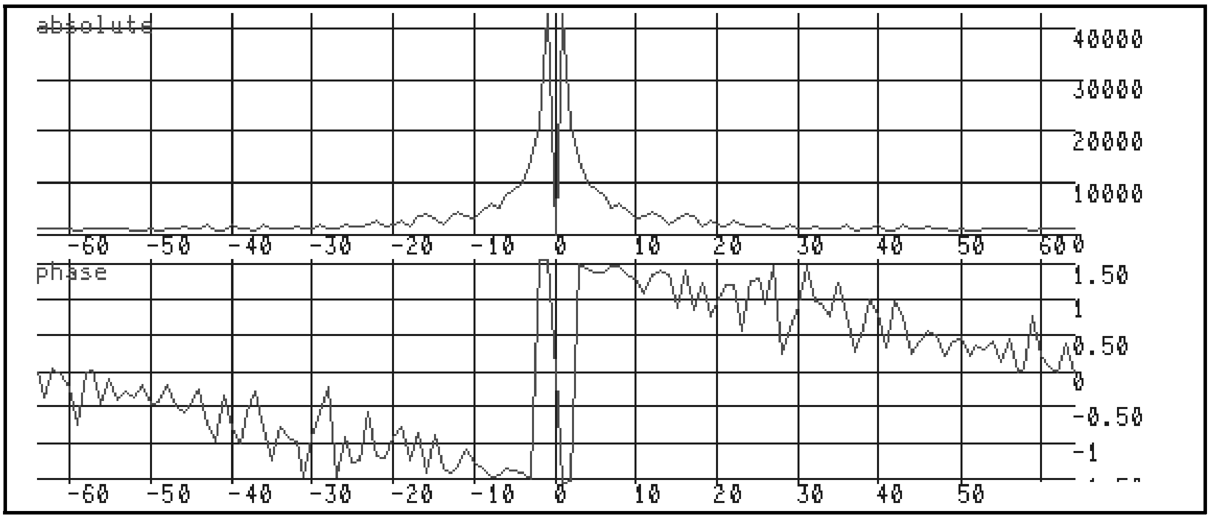

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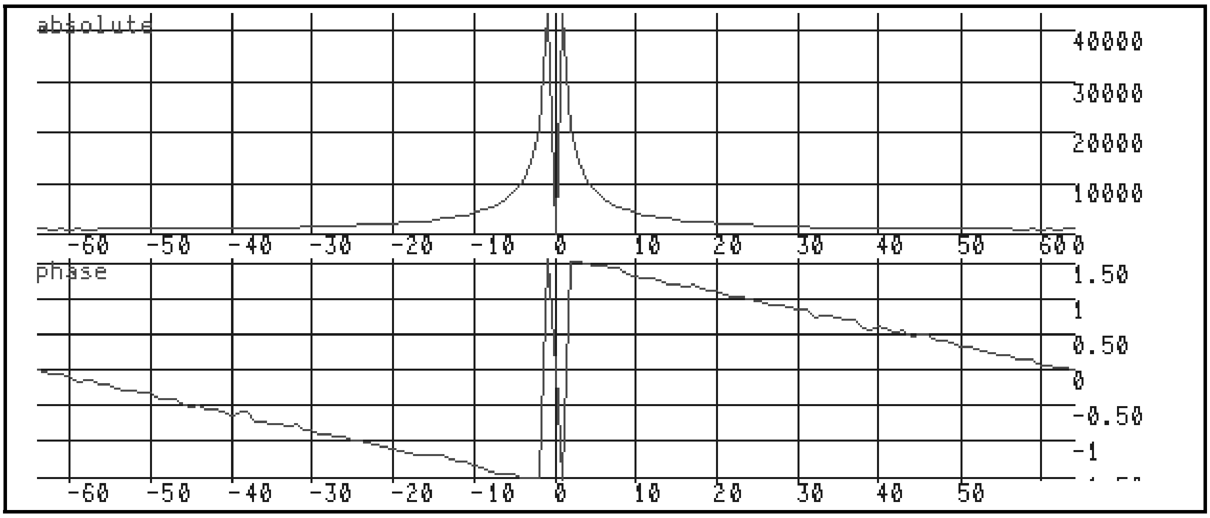
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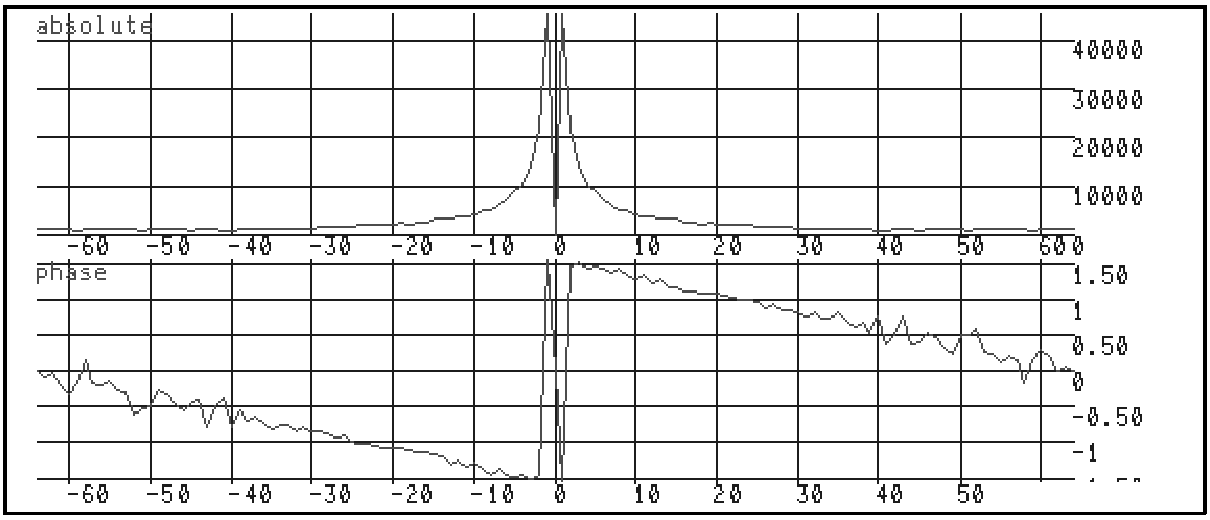
E1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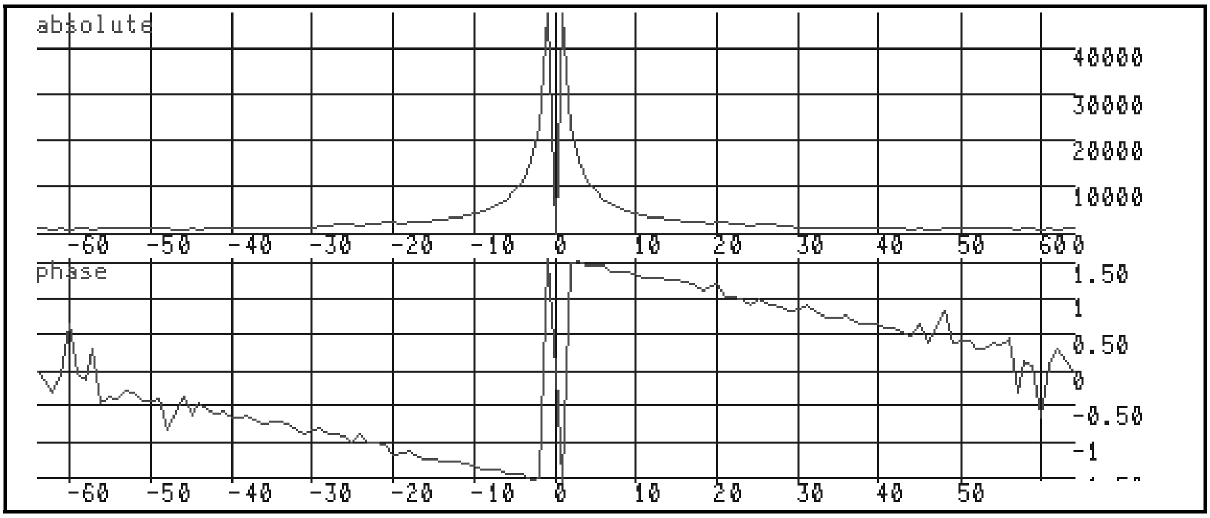
E2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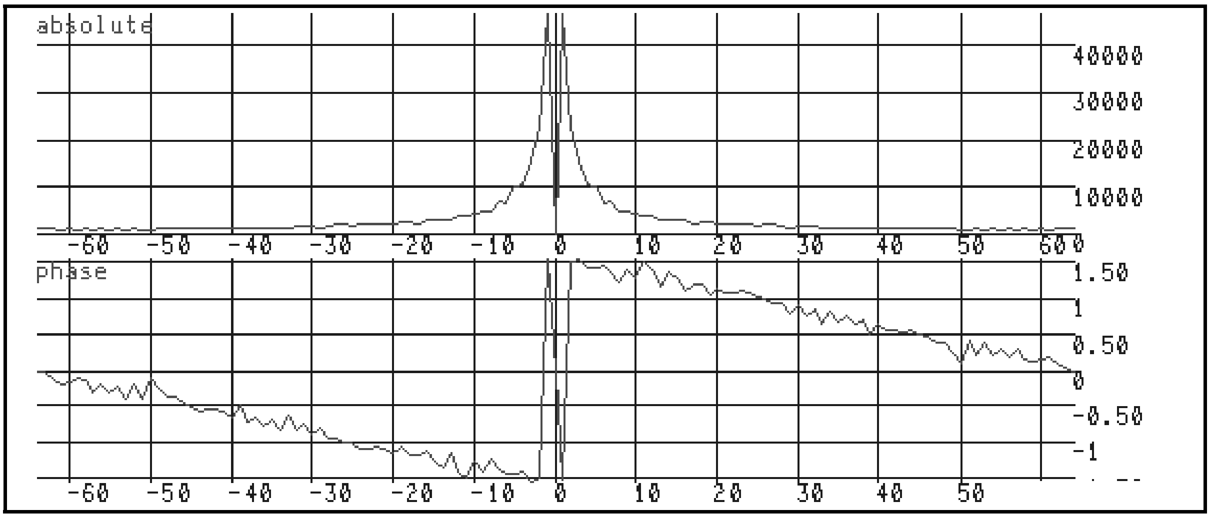
E3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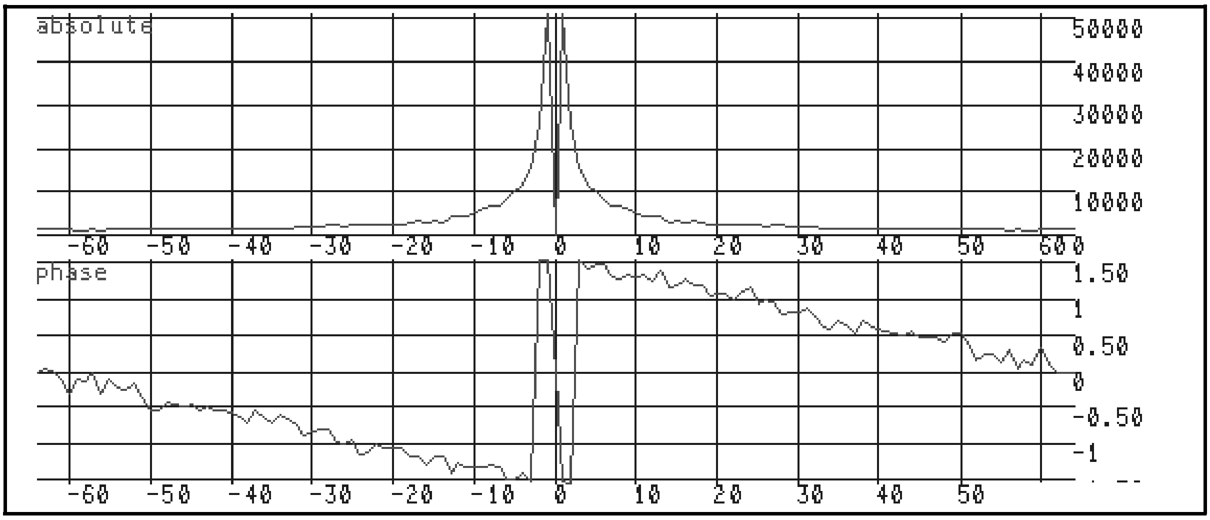
E4a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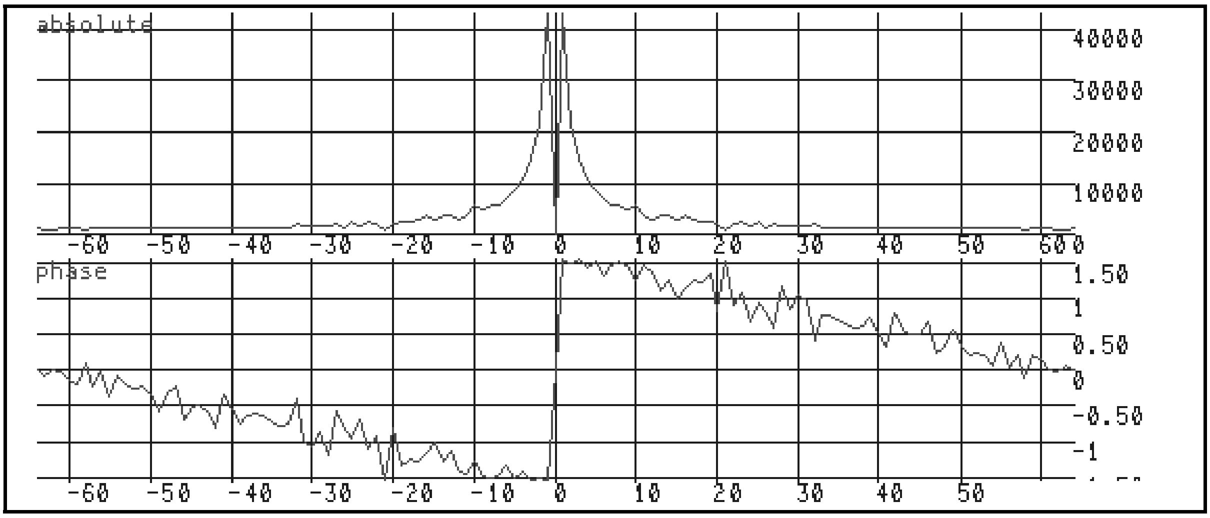
E4b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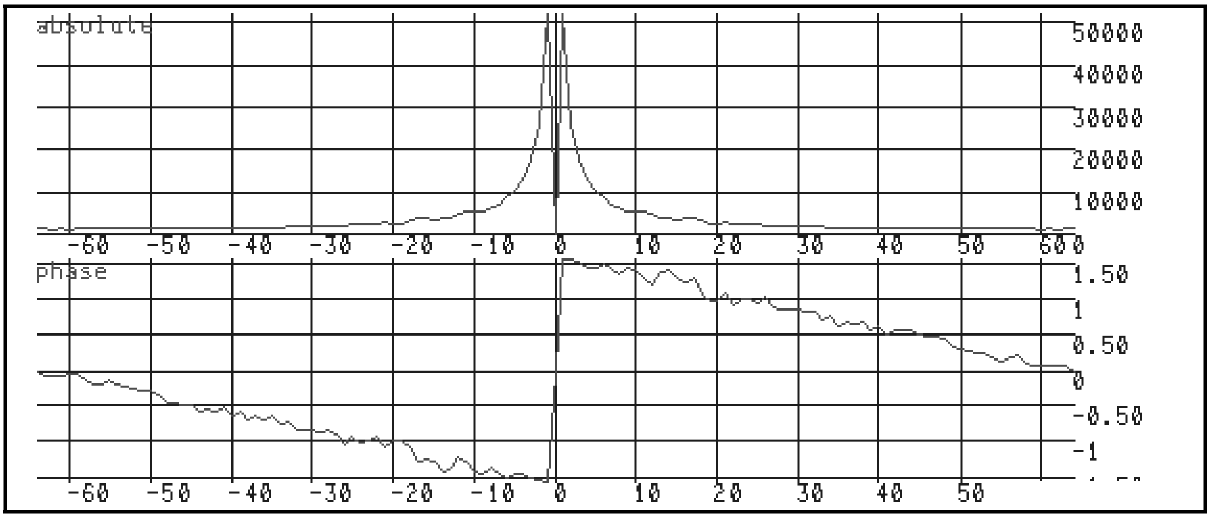
F1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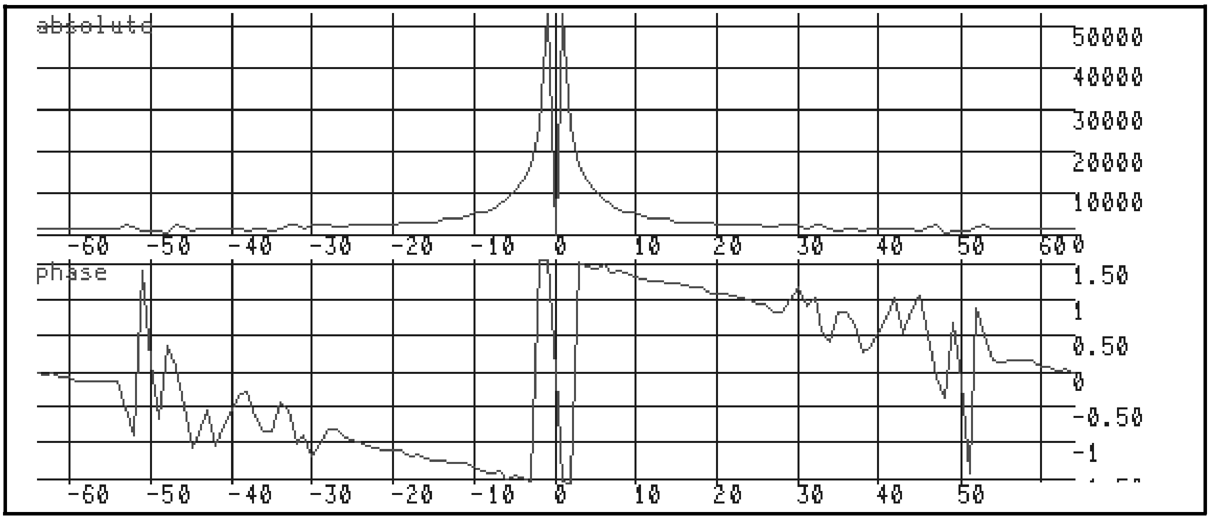
F2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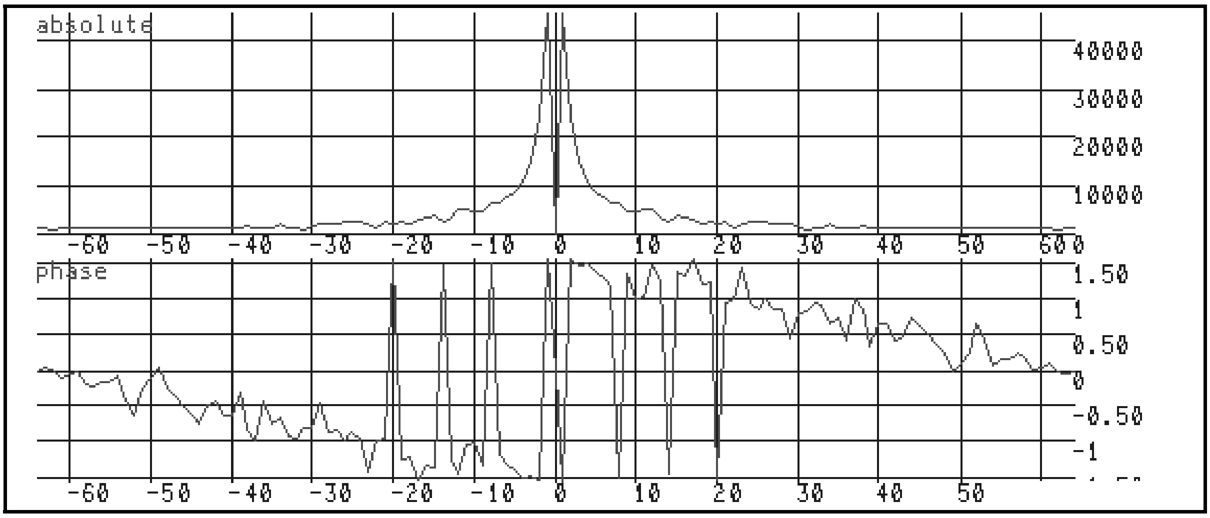
G1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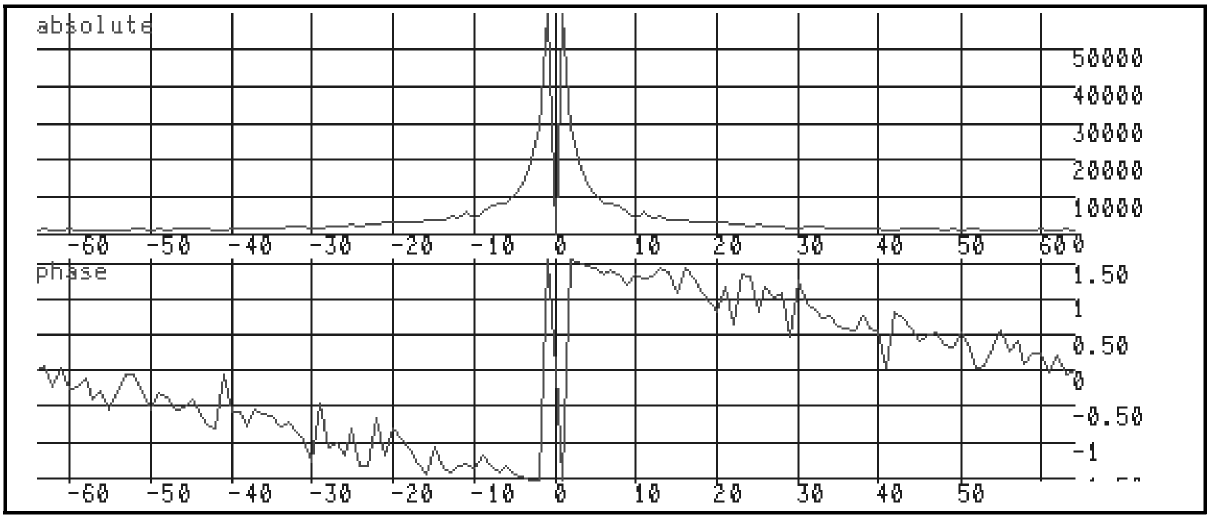
G2a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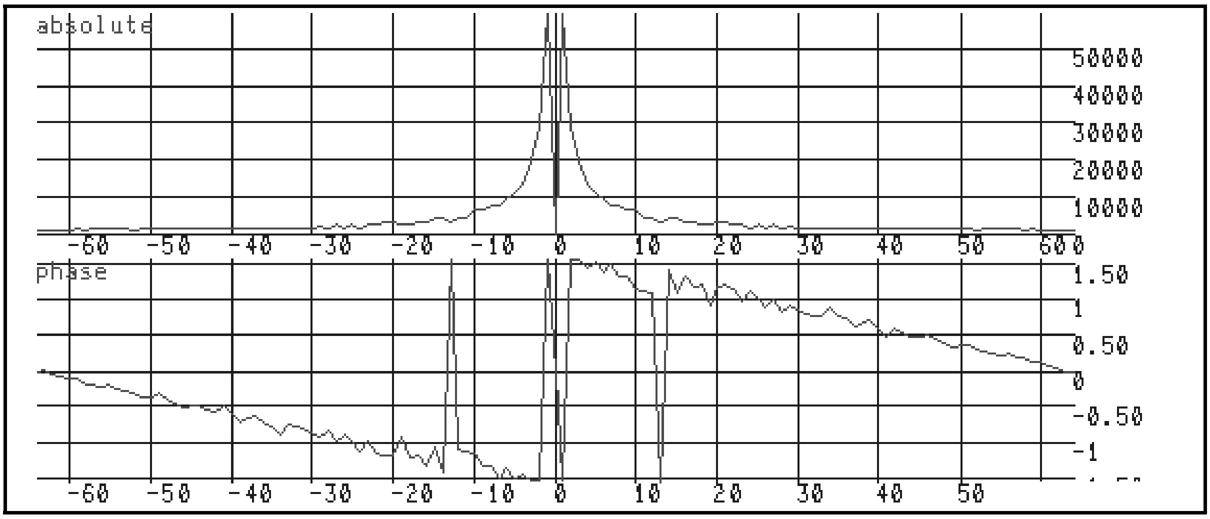
G2b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0
-0.50
-1
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50

G2c

Appendix D

Table of the Ratings

FFT-frequency-window range		**0 - 64**	**22 - 64**	**0 - 45**	**22 - 45**
Position	**Rating**	**Screen**			
		A1, Philips Brazil 14"SC modular line			
0°	Amplitude	530	186	684	212
	Phase	177	219	123	149
45°	Amplitude	476	179	613	206
	Phase	223	283	122	136
Average	Amplitude	503	182,5	648,5	209
	Phase	200	251	122,5	142,5
		A3, Philips Brazil 20"SC philiflow			
0°	Amplitude	607	209	787	239
	Phase	442	519	270	249
45°	Amplitude	580	191	701	220
	Phase	364	418	305	347
Average	Amplitude	593,5	200	744	229,5
	Phase	403	468,5	287,5	298
		B1a, Asahi/PGC 14"SC			
0°	Amplitude	482	174	622	199
	Phase	119	167	35	44
45°	Amplitude	465	163	601	192
	Phase	105	163	33	45
Average	Amplitude	473,5	168,5	611,5	195,5
	Phase	112	165	34	44,5
		B1b, Philips Simonstone 41FS-SC			
0°	Amplitude	483	185	620	211
	Phase	52	62	30	28
45°	Amplitude	489	133	629	207
	Phase	56	68	35	36
Average	Amplitude	486	159	624,5	209
	Phase	54	65	32,5	32

FFT-frequency-window range		0 - 64	22 - 64	0 - 45	22 - 45
Position	**Rating**	**Screen**			
		B2, Asahi 17"SC			
0°	Amplitude	478	182	611	204
	Phase	117	156	59	76
45°	Amplitude	476	185	609	211
	Phase	52	65	29	30
Average	Amplitude	477	183,5	610	207,5
	Phase	84,5	110,5	44	53
		B3, Philips Brazil 14"SC			
0°	Amplitude	489	177	630	199
	Phase	179	252	49	61
45°	Amplitude	508	183	655	207
	Phase	87	101	71	81
Average	Amplitude	498,5	180	642,5	203
	Phase	133	176,5	60	71
		B4, NEG 14"SC			
0°	Amplitude	505	181	653	209
	Phase	181	225	141	182
45°	Amplitude	493	194	625	211
	Phase	277	403	75	114
Average	Amplitude	499	187,5	639	210
	Phase	229	314	108	148
		B5, Philips Taiwan 14"SC			
0°	Amplitude	510	191	657	219
	Phase	255	352	163	252
45°	Amplitude	481	179	621	208
	Phase	143	190	96	135
Average	Amplitude	495,5	185	639	213,5
	Phase	199	271	129,5	193,5

FFT-frequency-window range		0 - 64	22 - 64	0 - 45	22 - 45
Position	**Rating**	**Screen**			
		B7, Philips Brazil 14"SC			
0°	Amplitude	530	212	669	229
	Phase	275	372	183	271
45°	Amplitude	513	214	655	218
	Phase	297	401	121	155
Average	Amplitude	521,5	213	662	223,5
	Phase	286	386,5	152	213
		C1, Asahi 51FS-SC			
0°	Amplitude	489	182	630	209
	Phase	128	179	36	41
45°	Amplitude	506	192	650	218
	Phase	168	238	37	42
Average	Amplitude	497,5	187	640	213,5
	Phase	148	208,5	36,5	41,5
		C2, Philips Taiwan 51FS-SC			
0°	Amplitude	558	185	725	210
	Phase	105	138	44	49
45°	Amplitude	517	192	666	220
	Phase	63	75	37	34
Average	Amplitude	537,5	188,5	695,5	215
	Phase	84	106,5	40,5	41,5
		C3, NEG 21"SC			
0°	Amplitude	491	186	631	214
	Phase	158	216	42	38
45°	Amplitude	482	171	617	212
	Phase	150	225	51	48
Average	Amplitude	486,5	178,5	624	213
	Phase	154	220,5	46,5	43

FFT-frequency-window range		**0 - 64**	**22 - 64**	**0 - 45**	**22 - 45**
Position	**Rating**	**Screen**			
		C4, Corning 19V			
0°	Amplitude	512	186	660	213
	Phase	146	176	86	84
45°	Amplitude	495	186	635	212
	Phase	255	341	86	83
Average	Amplitude	503,5	186	647,5	212,5
	Phase	200,5	258,5	86	83,5
		C7, Philips Simonstone 51FS-SC			
0°	Amplitude	495	184	637	211
	Phase	80	103	42	48
45°	Amplitude	489	182	627	205
	Phase	77	100	40	45
Average	Amplitude	492	183	632	208
	Phase	78,5	101,5	41	46,5
		C8, Ekranas 20"SC			
0°	Amplitude	532	223	677	257
	Phase	471	576	348	423
45°	Amplitude	542	195	703	229
	Phase	481	590	359	441
Average	Amplitude	537	209	690	243
	Phase	476	583	353,5	432
		D1, Videoglass 59 FS-SC			
0°	Amplitude	492	183	635	212
	Phase	142	195	56	71
45°	Amplitude	496	187	637	214
	Phase	128	171	57	68
Average	Amplitude	494	185	636	213
	Phase	135	183	56,5	69,5

FFT-frequency-window range		0 - 64	22 - 64	0 - 45	22 - 45
Position	**Rating**	**Screen**			
		D2, Philips Aachen 59 FS-SC			
0°	Amplitude	530	192	685	221
	Phase	269	320	186	201
45°	Amplitude	524	191	674	217
	Phase	311	364	235	261
Average	Amplitude	527	191,5	679,5	219
	Phase	290	342	210,5	231
		D3, Philips Taiwan 59 FS-SC			
0°	Amplitude	479	182	616	208
	Phase	222	269	171	208
45°	Amplitude	481	188	614	212
	Phase	308	398	190	241
Average	Amplitude	480	185	615	210
	Phase	265	333,5	180,5	224,5
		E1, Philips Simonstone 59 FS-SC			
0°	Amplitude	540	185	701	211
	Phase	20	20	16	12
45°	Amplitude	546	184	709	210
	Phase	113	156	40	51
Average	Amplitude	543	184,5	705	210,5
	Phase	66,5	88	28	31,5
		E2, Novel 59 FS-SC			
0°	Amplitude	546	186	707	209
	Phase	152	214	31	31
45°	Amplitude	547	183	710	209
	Phase	65	80	43	51
Average	Amplitude	546,5	184,5	708,5	209
	Phase	108,5	147	37	41

FFT-frequency-window range		**0 - 64**	**22 - 64**	**0 - 45**	**22 - 45**
Position	**Rating**	**Screen**			
		E3, Philips Taiwan 59 FS-SC			
0°	Amplitude	572	187	744	211
	Phase	137	191	36	38
45°	Amplitude	499	187	643	215
	Phase	81	107	53	72
Average	Amplitude	535,5	187	693,5	213
	Phase	109	149	44,5	55
		E4a, Philips Aachen 59 FS-SC			
0°	Amplitude	495	186	638	214
	Phase	71	72	54	39
45°	Amplitude	490	190	628	216
	Phase	74	74	62	50
Average	Amplitude	492,5	188	633	215
	Phase	72,5	73	58	44,5
		E4b, Philips Aachen 25"SFS			
0°	Amplitude	481	186	616	212
	Phase	115	152	48	54
45°	Amplitude	503	184	648	209
	Phase	83	100	46	42
Average	Amplitude	492	185	632	210,5
	Phase	99	126	47	48
		F1, Schott 66 FS-SC			
0°	Amplitude	493	196	630	224
	Phase	171	199	118	117
45°	Amplitude	474	183	609	211
	Phase	201	251	138	171
Average	Amplitude	483,5	189,5	619,5	217,5
	Phase	186	225	128	144

FFT-frequency-window range		**0 - 64**	**22 - 64**	**0 - 45**	**22 - 45**
Position	**Rating**	**Screen**			
		F2, Philips Aachen 66 FS-SC			
0°	Amplitude	492	187	631	213
	Phase	45	36	47	33
45°	Amplitude	478	184	613	211
	Phase	49	41	52	40
Average	Amplitude	485	185,5	622	212
	Phase	47	38,5	49,5	36,5
		G1, NEG 66 FS-SC			
0°	Amplitude	526	191	676	215
	Phase	247	347	89	122
45°	Amplitude	489	187	626	208
	Phase	190	264	55	63
Average	Amplitude	507,5	189	651	211,5
	Phase	218,5	305,5	72	92,5
		G2a, Philips Aachen 66 FS-SC			
0°	Amplitude	509	189	655	216
	Phase	263	323	176	205
45°	Amplitude	494	191	636	222
	Phase	286	351	226	288
Average	Amplitude	501,5	190	645,5	219
	Phase	274,5	337	201	246,5
		G2b, Philips Aachen 28"WS			
0°	Amplitude	477	174	615	199
	Phase	227	292	130	157
45°	Amplitude	489	181	629	206
	Phase	123	149	75	77
Average	Amplitude	483	177,5	622	202,5
	Phase	175	220,5	102,5	117

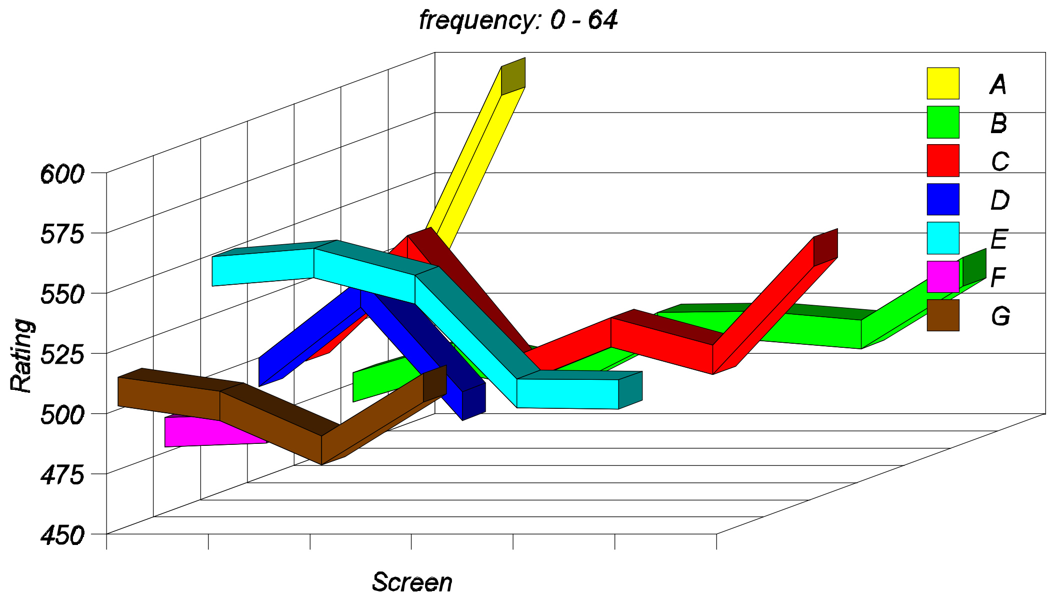
FFT-frequency-window range		**0 - 64**	**22 - 64**	**0 - 45**	**22 - 45**
Position	**Rating**	**Screen**			
		G2c, Philips Aachen 29"SFS			
0°	Amplitude	480	182	617	208
	Phase	86	91	62	51
45°	Amplitude	538	178	701	204
	Phase	113	133	72	70
Average	Amplitude	509	180	659	206
	Phase	99,5	112	67	60,5

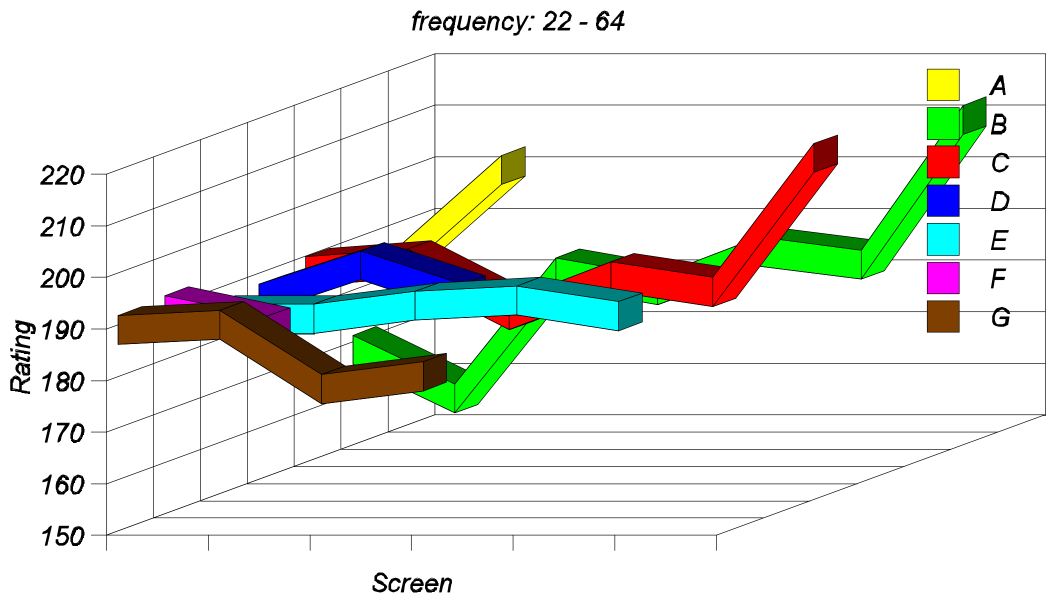
Appendix E

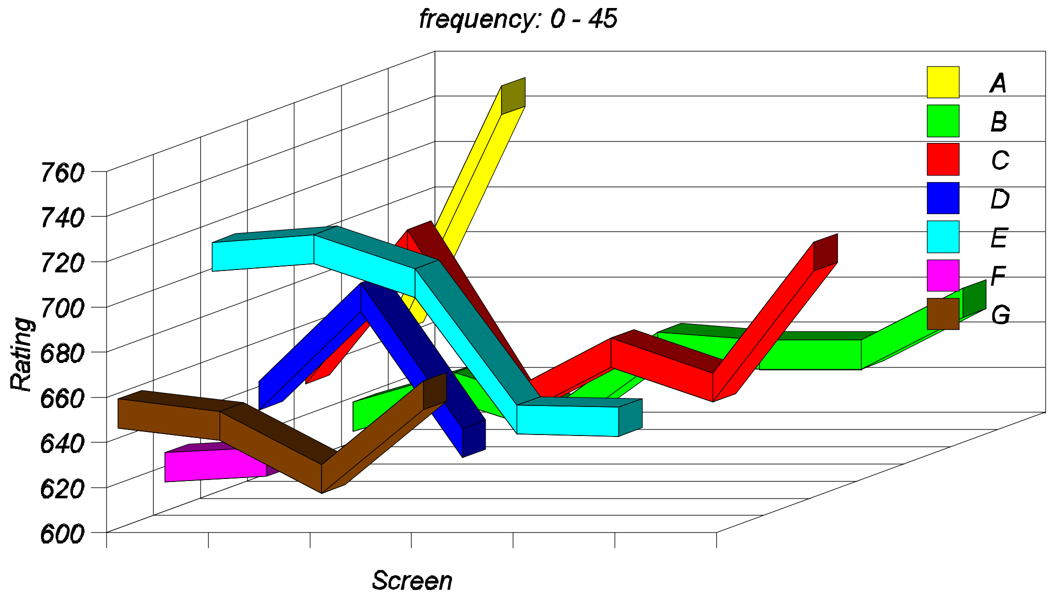
Graphics of the Ratings

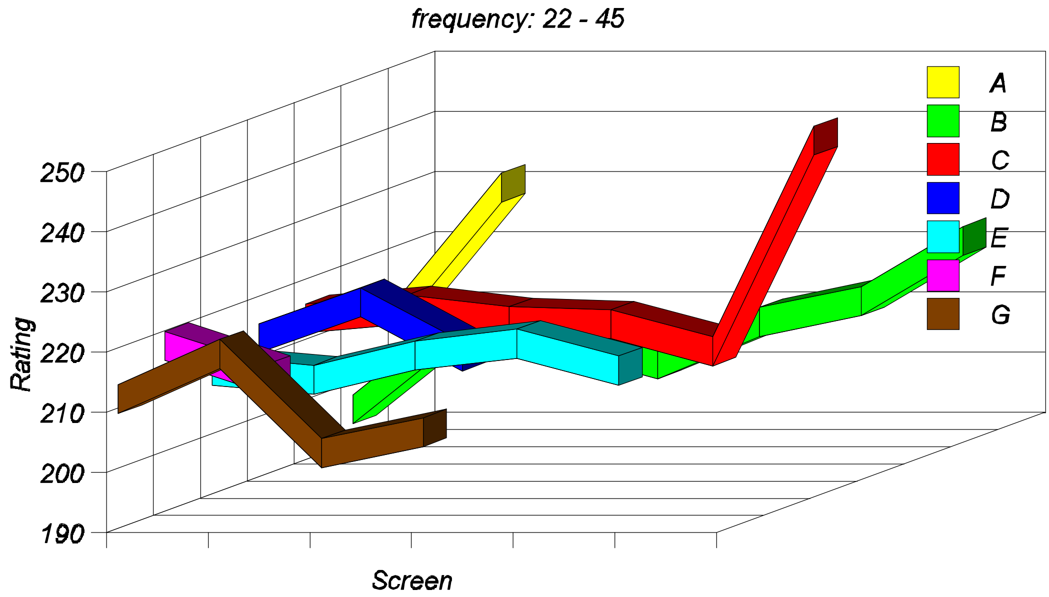
Average ratings $R_{1,relative}$

(Based on the amplitudes in the Fourier transform, see chapter 5)



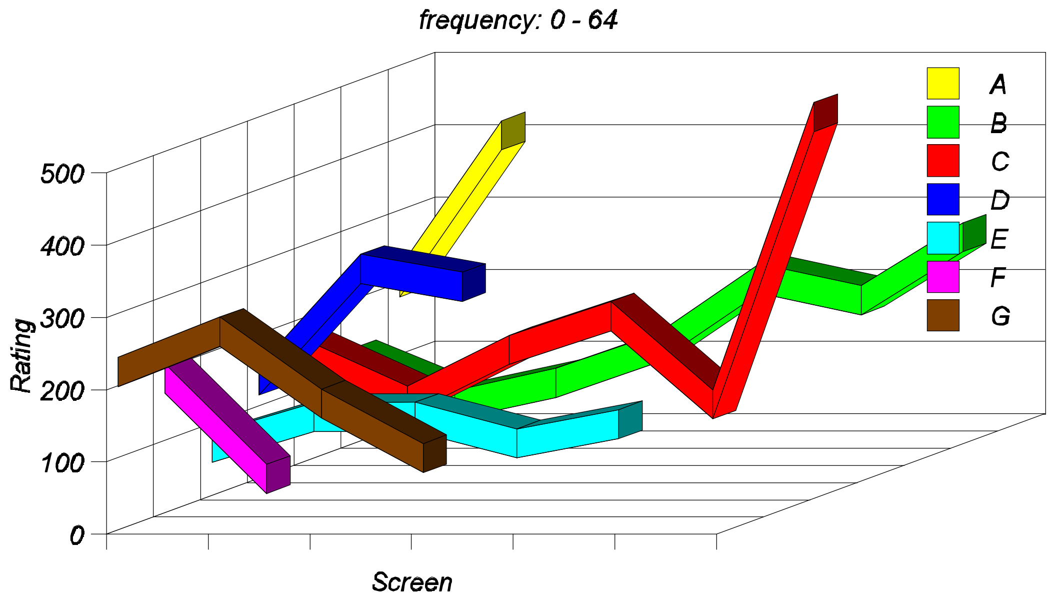


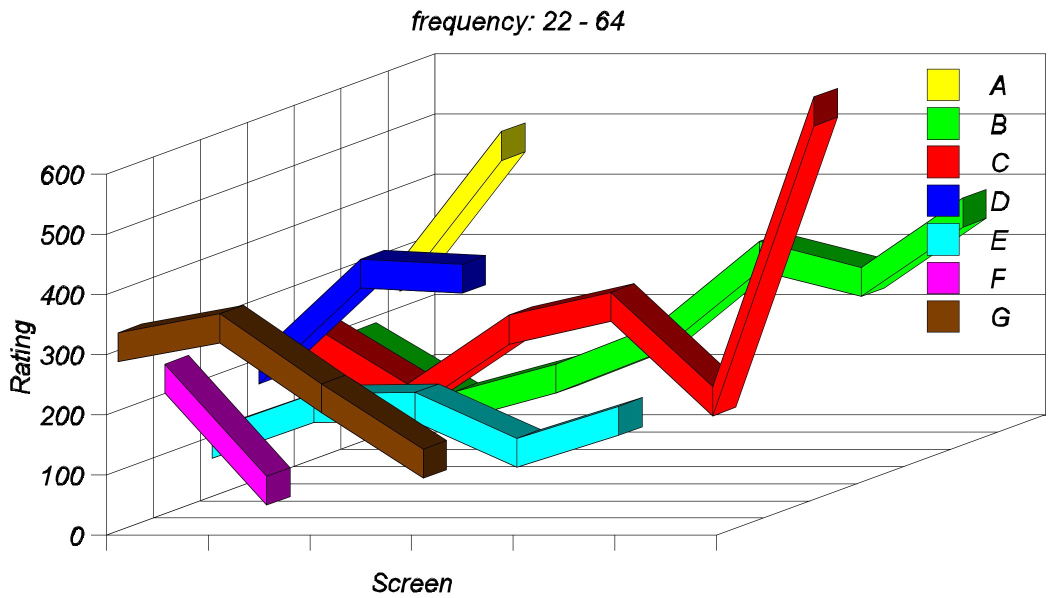

frequency: 0 - 45
760
740
720
700
680
660
640
620
600
Rating
Screen
A
B
C
D
E
F
G

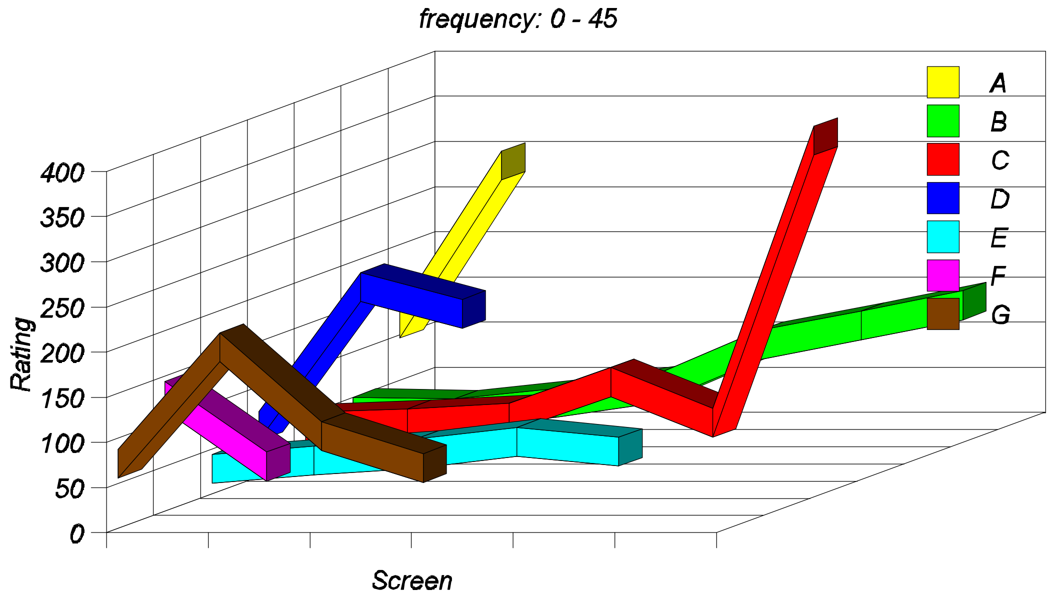

frequency: 22 - 45
250
240
230
220
210
200
190
Rating
Screen
A
B
C
D
E
F
G

Average ratings R_2

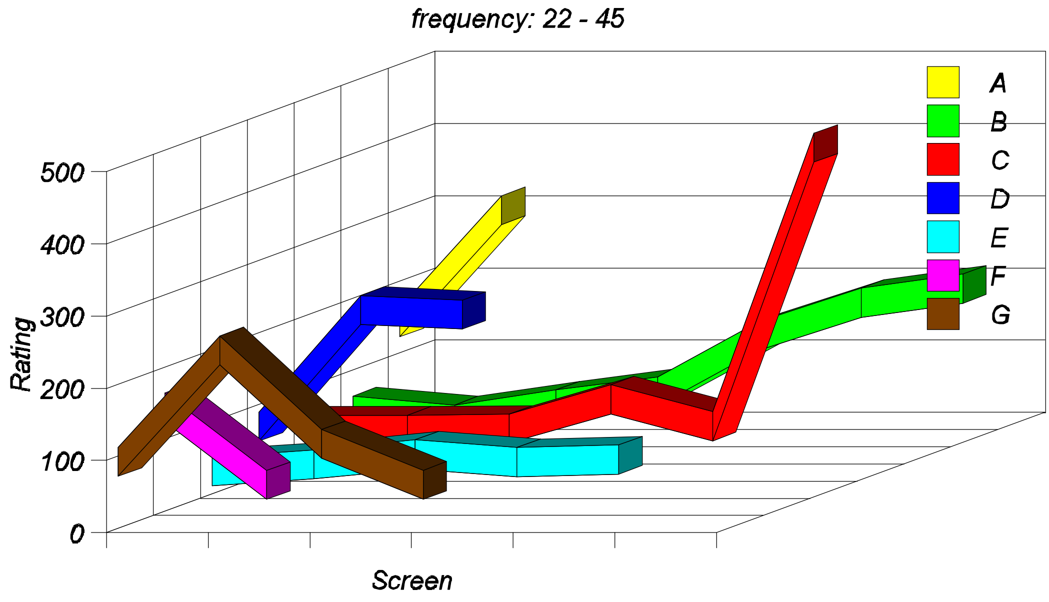
(Based on the phases in the Fourier transform, see chapter 5)







frequency: 0 - 45
400
350
300
250
200
150
100
50
0
Rating
Screen
A
B
C
D
E
F
G



frequency: 22 - 45
500
400
300
200
100
0
Rating
Screen
A
B
C
D
E
F
G

Appendix F

Best results

Rating R_2 (phase), with a frequency range of [22 cm^{-1}, 45 cm^{-1}] turned out to be the best criterion for high gloss quality of the investigated methods.

Group	Screen	Rating R_2 , frequency range: 22 cm^{-1} - 45 cm^{-1}
A1	Philips Brazil 14"SC	1425
A3	Philips Brazil 20"SC	298
B1a	Asahi/PGC 14"SC	445
B1b	Philips Simonstone 41FS-SC	32
B2	Asahi 17"SC	53
B3	Philips Brazil 14"SC	71
B4	NEG 14"SC	148
B5	Philips Taiwan 14"SC	1935
B7	Philips Brazil 14"SC	213
C1	Asahi 51FS-SC	415
C2	Philips Taiwan 51FS-SC	415
C3	NEG 21"SC	43
C4	Corning 19V	835
C7	Philips Simonstone 51FS-SC	465
C8	Ekranas 20"SC	432
D1	Videoglass 59FS-SC	695
D2	Philips Aachen 59FS-SC	231
D3	Philips Taiwan 59FS-SC	2245
E1	Philips Simonstone 59FS-SC	315
E2	Novel 59FS-SC	41
E3	Philips Taiwan 59FS-SC	55
E4a	Philips Aachen 59FS-SC	445
E4b	Philips Aachen 25"SFS	48
F1	Schott 66FS-SC	144
F2	Philips Aachen 66FS-SC	365
G1	NEG 66FS-SC	925
G2a	Philips Aachen 66FS-SC	2465
G2b	Philips Aachen 28"WS	117
G2c	Philips Aachen 29"SFS	605

Appendix G

The camera measurement system results

The **camera measurement method** was also tested by Peter Gerling on the screens described in internal memo VGB 685-95.0111. (The laser defection scanner was tested on the same screens). In the following table you can find the results of the camera measurement method. Source: Report of test-results of camera measurement method by P. Gerling.

Group	Screen	older number	newer number
A1	Philips Brazil 14"SC	866	112
A3	Philips Brazil 20"SC	1151	151
B1a	Asahi/PGC 14"SC	2505	4096
B1b	Philips Simonstone 41FS-SC	1.934	0.2907
B2	Asahi 17"SC	1.675	0.2127
B3	Philips Brazil 14"SC	2.561	
B4	NEG 14"SC	3.561	1.35
B5	Philips Taiwan 14"SC	3.059	1.06
B7	Philips Brazil 14"SC	9.3	
C1	Asahi 51FS-SC	1.905	0.317
C2	Philips Taiwan 51FS-SC	2.008	0.4075
C3	NEG 21"SC	2.93	0.9476
C4	Corning 19V		1.8745
C7	Philips Simonstone 51FS-SC	3.36	1.109
C8	Ekranas 20"SC		18.21
D1	Videoglass 59FS-SC		2.353
D2	Philips Aachen 59FS-SC	10.11	13.1 / 12.33 (2.series)
D3	Philips Taiwan 59FS-SC	10.38	13.06 / 12.66 (2.series)
E1	Philips Simonstone 59FS-SC		0.3818
E2	Novel 59FS-SC		0.4338
E3	Philips Taiwan 59FS-SC		0.4759
E4b	Philips Aachen 25"SFS		3.321
F1	Schott 66FS-SC	10.38	13.65 / 15.07 (2.series)
F2	Philips Aachen 66FS-SC	10.7	12.62 / 13.67 (2.series)
G1	NEG 66FS-SC		0.4553
G2a	Philips Aachen 66FS-SC		5.017
G2b	Philips Aachen 28"WS		4.39
G2c	Philips Aachen 29"SFS		7.552