Loudspeaker Testing at the Production Line

Ib Kock Rasmussen

K & K International ApS & K & K Development ApS
Glostrup, Denmark

www.kk-int.dk

November 2022

Contents

Introduction

Manufacturer of electro-acoustical transducers such as loudspeakers, headphones and complete speaker systems have to test the sound quality of the final products.

In the past the human ear has been considered to be the best way to detect defects. However a test in a mass production becomes more and more automated and the times between the test cycle becomes faster than a manual handling and listening.

In the following a description of useful test parameters and description how to handle a QC test in a production environments.

Focus has been set on different Rub & Buzz types, simulation and handle variance on production lines.

Equipment used in this document for examples is a P900 test system from K & K International / K & K Development.

Selecting test equipment

On the marked there are many different type of test and measuring equipment.
Test signals as pulses, noise, sine, stepped sine, sweep sine and dual tone have been used on different test systems.

For rub & buzz measurements signals as a pure sine, stepped sine and a sine sweep can be used with a good result.

For a fast test it is only a stepped sine or a sine sweep there is useful.
If a stepped sinus is used it is recommended not to go below 20 measuring points for each octave. If so some selective rub & buzz resonances can be lost in the measurement.

For rub & buzz detection there are on the marked used two different types for analyzes. To analyze of FFT calculations or advanced filter technologies are used.

In this document are based on systems there use measurement on sine sweep and make use of advanced filter technology used for distortion measurements.

Test parameters

On the marked there are many different systems to measuring and test of loudspeakers.

Many test systems are able to measure parameters as:
Frequency Response, Polarity, Sensitivity, Phase, Impedance, Resonance, Thiele-Small, THD, Rub & Buzz, Q, Impulse response, etc.

Not all parameters have an interest in a production line test due to speed and used signal used to test speakers.

Useful test parameters for a production line test are:

- Frequency response
- Sensitivity
- Polarity
- Impedance
- Resonance
- Rub & Buzz

One or more microphones can be used to test frequency response, sensitivity, rub & buzz and polarity. Impedance and resonance do not need a microphone. In some special case polarity can be tested without a microphone, in a Bl measurement.

Frequency response

A frequency response is most common test parameter. To make a frequency response measurement following parameters must be selected before a test can be fulfilled.
Output power sent to the speaker.
Frequency range must be selected as well the position of microphone.
For a sine sweep start and end frequency must be selected as well the sweep time.

Quite often voltage / power used to test the device are fixed due to the test specification for the device as well the frequency range.

Sensitivity

The sensitivity measurement is normally a part of the frequency response where a single test point or the whole frequency response is used as criteria for sensitivity. The reference for the sensitivity is normally a reference speaker due to test camber and microphone position is not ideal.

Polarity

A polarity test is normally done to be ensure the tested device have a correct polarity.
For speaker systems where more than one speaker unit is used, mishmash in the polarity can be seen in the frequency response.
The polarity test is a separate test done before or after the sine sweep.
For our test equipment a short square wave is used, as step response for this test.

Impedance

Impedance measurement is a pure electric measurement. Often the current to the loudspeaker is measured by a sense resistor in serial with the speaker and power amplifier.

Resonance

The resonance measurement is a part of the impedance measurement. Out of the resonance parameters as resonance frequency and the Q can be calculated. Depending of the speaker system more than one resonance can be present as a system used a woofer and a resonance port. The resonance frequency and Q for a woofer normally seen changed due to the power added on the system. This due to more power more mass on the speaker unit is activated.

Rub & Buzz

Rub & Buzz is important OC test parameter. The Rub & buzz is different from THD. Rub & buzz test values is often much less than a THD value.

Rub & buzz is the most difficult parameter to measure on a production line due environment noise. Furthermore a test cycle on a production line must be fast as possible to reduce cost. Attention must be taken so a test sequence is not to short. If so some rub & buzz component do not have time (time / energy) to be measurable.

Test of loudspeakers in a production environment

Signal to Speaker

Test on a loudspeaker or loudspeaker system for a rub & buzz have normally only tree parameters you can control.
The power added to the system, the test time and the selected frequency. The power has carefully to be selected and the test time must be so long that power / time product have so much energy to enable the rub & buzz to be detected by a microphone. Another parameter to take in account is if a stepping sweep is used that the step between frequencies is close enough to avoid missing selective resonances.

The power on a speaker to be tested is normally described in specification of the speaker. A typical pitch fall is to add so much power to the speaker that the THD begin to mask out some of the rub & buzz information.
Depending of the speaker design the THD begin to increase non-linear at a certain level and begin to generate higher harmonic signals.

Microphone types

You find on the marked many different microphone types. To measure the rub & buzz a microphone must have a prober dynamic range due to some rub & buzz levels can be lower than -50 db from fundamental signal.
For a reference measurement a microphone need to be linear in the used frequency range. For a relative measurement it is not necessary however the dynamic range is needed.
The most of all capacitor microphones fulfill this requirement.

Microphone placement

To measure a speaker frequency response normally only one microphone is used. For a speaker system the distance between speaker and microphone can be in the range 1 to 4 meters. For a speaker unit normally the distance is less.
To detect rub & buzz signals normally more than one microphone is used for a speaker system depending the distance between speaker and microphone. Normally a microphone is placed in around or near the nearfield to better detect rub & buzz. For a speaker system between one up to tree microphones can be used.

For a speaker unit the microphone is normally placed around or near the nearfield. The best distance have been find by experiment where the distance is so close as possible without losing a accepted frequency response. A hint. For a woofer try the distance between a 0.5 to 2 time the diameter of the speaker membrane.

Testing environment

To test a speaker or speaker system in production environment require some preparations to isolate environment noise. For systems it normally is necessary to test the system in a sound isolated shelter. While testing the speaker system must be placed so there not can be generated external rub & buzz signals due to vibrations.

For speaker units the speaker is normally placed on a test box where the speaker is outside and the measuring microphone is inside the box.
The speaker unit must be fixed to the test box so no external rub & buzz signals are generated due to vibrations. If the speaker unit is fixed by a fixture there press the speaker down on the back site be sure that the force to not to high so it change the parameter of the speaker due to small change in the mechanical tolerances.

Test of loudspeaker units

Many companies can recognise that test of speaker unit can be a challenge when the test is done in a production environment.

To test a speaker unit in an office can easy be done without any baffle or with mounted a baffle.

In a production environment you have lot of running machinery and other tolls there generate lot of acoustical noise and as well electronic signals, public information or locally entertainment systems.

To isolate the testing device from acoustic noise some action are needed. A simple way to solve the acoustic noise is to stop all noisy machinery while testing. This is normally not an option. Another possibility is to move the test of speakers to another room with little or no noise. This is normally not possible or inconvenient.

A test box to test the speakers is needed to isolate environment noise.

Test box

To make a test box for testing speaker unit you need to take care of some following parameters.

- The size of the test box
- Open or closed version
- Acoustical damping material inside test box
- Position of microphone
- Mounting fixture to handle different speaker types
- Tools to fixing the testing speaker to avoid vibrations

The size of the test box depends of the speaker you want to test. To test woofers the box must so big so the measuring of lowest frequency is possible.
To test midrange or tweeters the size of the test box can be much smaller than to test a woofer.

To minimize the test box for woofer tests it can sometimes be a benefit to use an open test box.
An open test box is a test box where the bottom is more or less open at the floor.

A test box needs to be isolated by some damping material. It is very important that you use so much damping material that there are no critical standing waves inside the box.

It is not possible to make a flat frequency response when using a test box. However it is not needed when testing. Normally the test is a relative against a well-known accepted speaker types. The most important is that there are no standing waves there so dominating that the frequency response is difficult to measure.

The position of the microphone is normally placed in or near the nearfield area. This is to give better signal to microphone and better isolate environment noise. The position depends of the speaker type you want to test in special if more different speaker types have to be tested on the test box. Normally it is a compromise to find the best microphone position. The position of the microphone could be changed due to the different types there have to be tested. This is not recommended. It is very difficult to get the exact same frequency response when the microphone position is moved. Note normally the speaker tests are done against some reference test levels. Find the position of the microphone where the most linear frequency responses are obtained.

To enable use different speaker types on same test box normally a mounting fixture is used. Further it is possible to use different electric connection to the speaker on test as handled by hand or by fully automatic process. When use of a mounting fixture it is important that this fixture do not generate noise due to vibrations. Use of vibration damping around the fixture is important.

A speaker unit must be fixed to the box or the mounting fixture to avoid false rub & buzz signals due to vibrations. The unit can be fixed on the speaker edge or often used by pressing the speaker down to the fixture by an arrangement back on the tested unit. If so the force must be a level so no vibration occurs however not so much that there are changes on the speakers' mechanical tolerances.

Environment around text box

Further reduction for external environment noise can be reduced by building a shelter around the test station.
A shelter can be a small house containing an automatic test station or a small house where an operator can work inside. Often some ventilation is needed inside a test shelter due to the temperature can to be too high for an operator to work inside. If so be sure the ventilation does not add an external noise.

If a conveyer system is used to move the unit's bee sure there are not transferred acoustic signals via the conveyer system. Sometimes it is necessary to make a separate conveyer system inside the shelter to avoid external transferred acoustic signals to disturb a measurement.

Do not place power cables close to microphone wires.
Some CRT systems (old displays) generate magnetic interference if a microphone wire is to close the CRTs.

Be sure if magnetizers are used in the factory that they are placed so far away that there are no interference whit those systems.

Test of Speaker cabinets

Normally when testing speaker cabinet the speaker unit have been tested before mounting the units in the cabinet.

Problems seen on testing a speaker cabinet are rub & buzz generated due to vibrations bad mounting of speaker units or the cabinet. Defective speaker filters, wrong speaker units etc.

Small or medium size speakers can be tested by using s test box where the microphone is places inside the box.

If the cabinet is too big it is recommended that the test is done in shelter or a small house or places where there are a minimum of environment noise.

To minimize external environment noise it often is necessary to make use of more than one microphone for test of big speaker cabinets. A microphone for frequency response and other microphones used to test rub & buzz on closer to speaker units.

Detect external noise

Some test systems can with benefit use a microphone to detect environment noise.
The microphone is placed outside the test box to detect interfering acoustic signals.
This microphone detect is an acoustical signal size over a pre-programmed level and indicate if test was rejected to repeat the test.

A little more advanced system look out the impedance distortion level. If you have a bad signal in the impedance the reason for a reject even there is an external noise signal.

Loudspeaker distortion measurement

Well known terms for loudspeaker measurements are THD (Total harmonic distortion) and "Rub & Buzz".

THD

The THD is more and less a design parameter for a loudspeaker. The THD depends of the speaker design and depends of how much power you add to the speaker in the range the speaker is designed to handle.
The most domination signal in a THD measurement is the 2 and 3 harmonic.

Rub & Buzz

Rub & Buzz tell you about the production quality of the speaker. Normally rub & buzz come from different manufacturing defects. The rub & buzz should be low as possible or in the level for the design of the speaker type. Normally the rub & buzz measurement is compared to an accepted speaker. A rub & buzz measurement must then be within an accepted range compared to the reference speaker. If outside this range the speaker will be marked as bad.

The rub & buzz level is lower than THD. Often the rub & buzz can recognize by human even the level is many times below the THD level. Often the rub & buzz is less than 10 times the THD or as low -50 db from fundamental signal.

A typical reason where rub & buzz are generated can come from different production defects as:

Misalignments in mechanical tolerance around the voice coil and the magnet and the voice coil hitting the magnet. The voice coil not is in the middle of the magnetic field can course an impact at high excursion level.
Particles between magnet and voice coil. Bad gluing around voice coil, spider or surrounding, dust cap etc. can generate a selective distortion. Bad lead wires. The wire can be long or to short or hitting surrounding.
Not improper gluing coursing a whistling sound due to compressed air pressure. The speaker is correct mounted in baffle witch vibration can generate distortion.

Rub & Buzz behaver

Rub & buzz can be categorized in different groups due to the behaver.

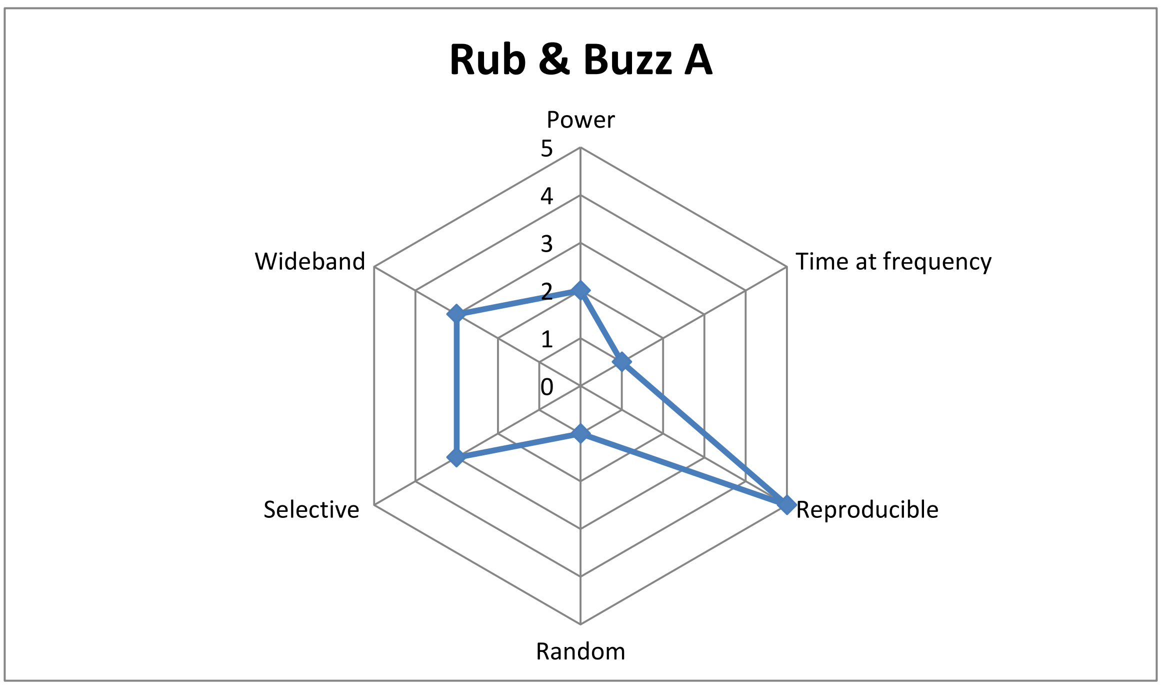
Some rub & buzz are depending of the power added to the speaker, the time the power is present at tested frequency. Some rub & buzz are generated as a predictable process however other is pure random generated. Some rub & buzz pattern are generated at selective frequency and other are over a wide frequency range.

Rub & buzz can be categorized with following behavior:

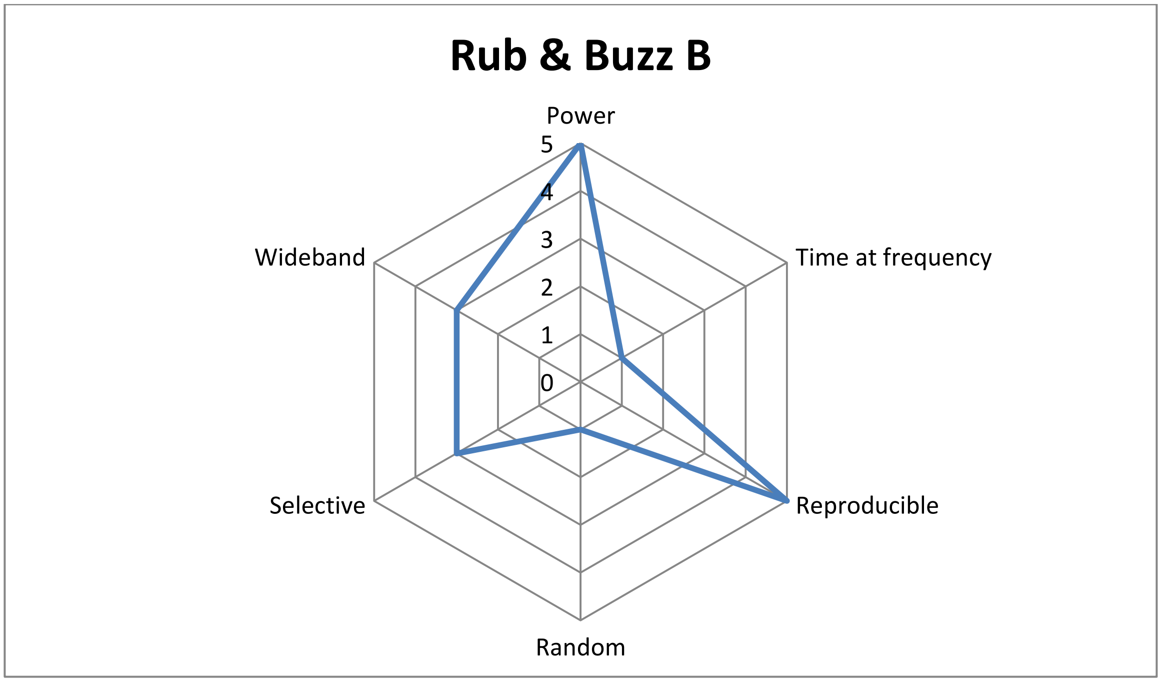
- Reproducible – not predictable (random)
- Power depended
- Frequency depended
- Power over time depended (energy)
- Selective - wideband

As examples:

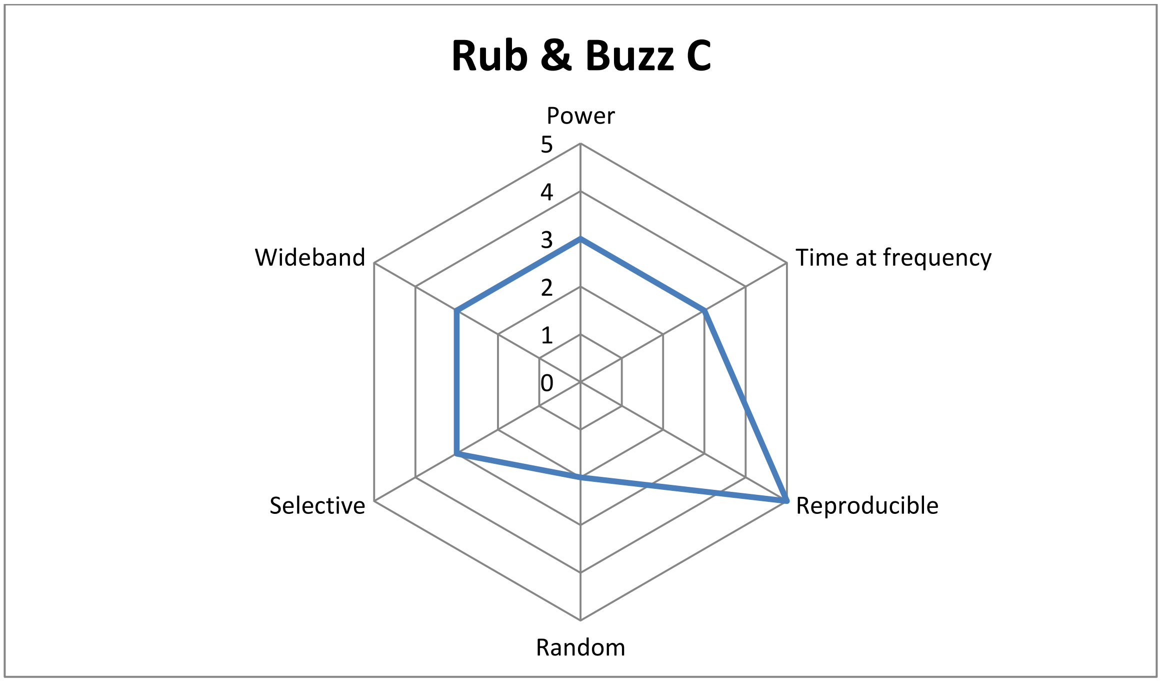
A) Signal generated due to non-linearity in magnetic field against voice coil due to mechanic out of tolerance.
   Predictable, fast test speed, some power depended. Normally this is generated around resonance frequency.



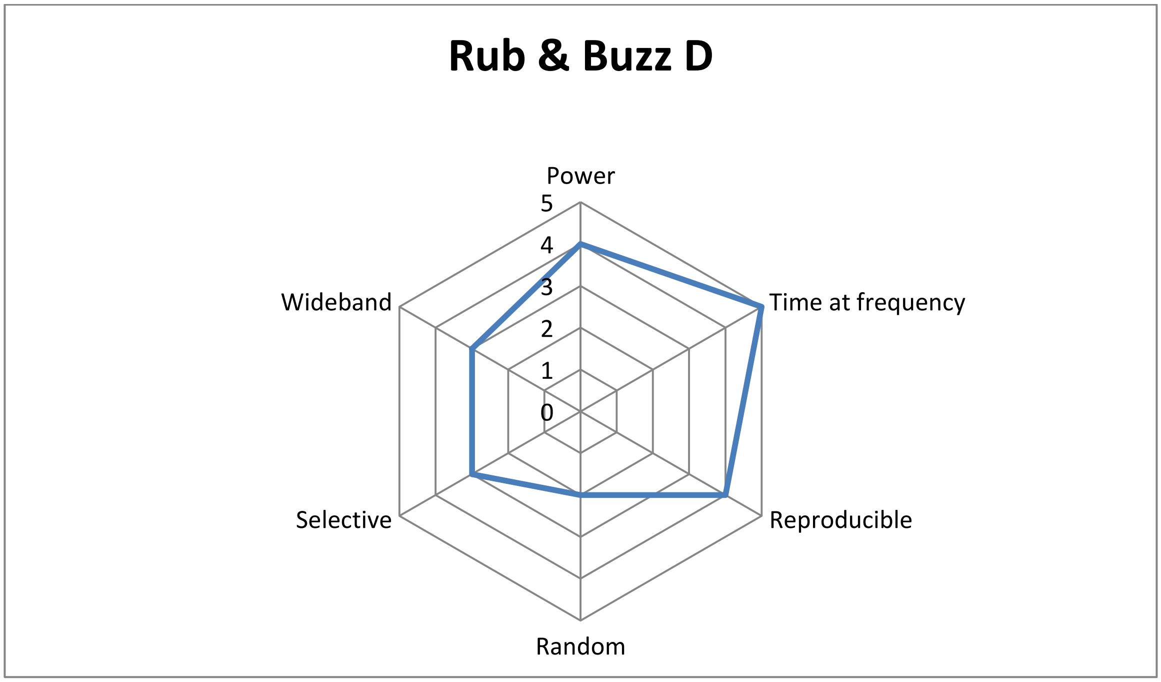
B) Signal generated due to voice coil hitting the back plate.
Predictable, fast test speed, very power depended. Normally this is generated around resonance frequency.



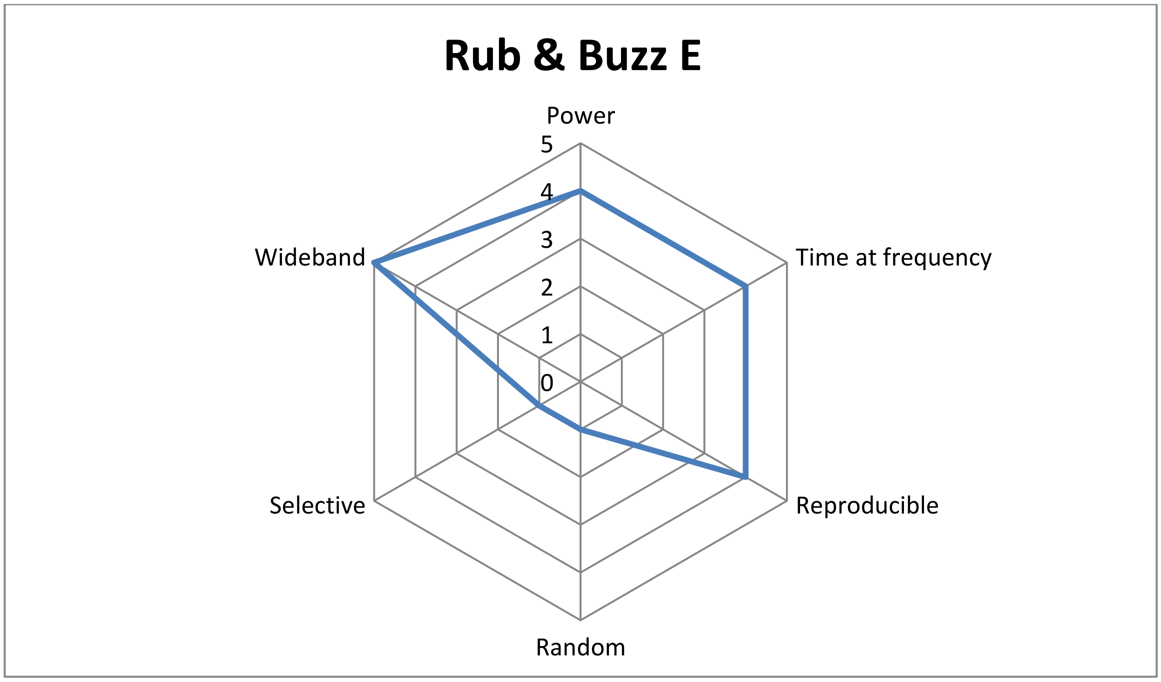
C) Signal generated due to voice coil hitting magnet.
Medium predictable, fast or medium test speed, some power depended. Can been seen over a wide frequency area.



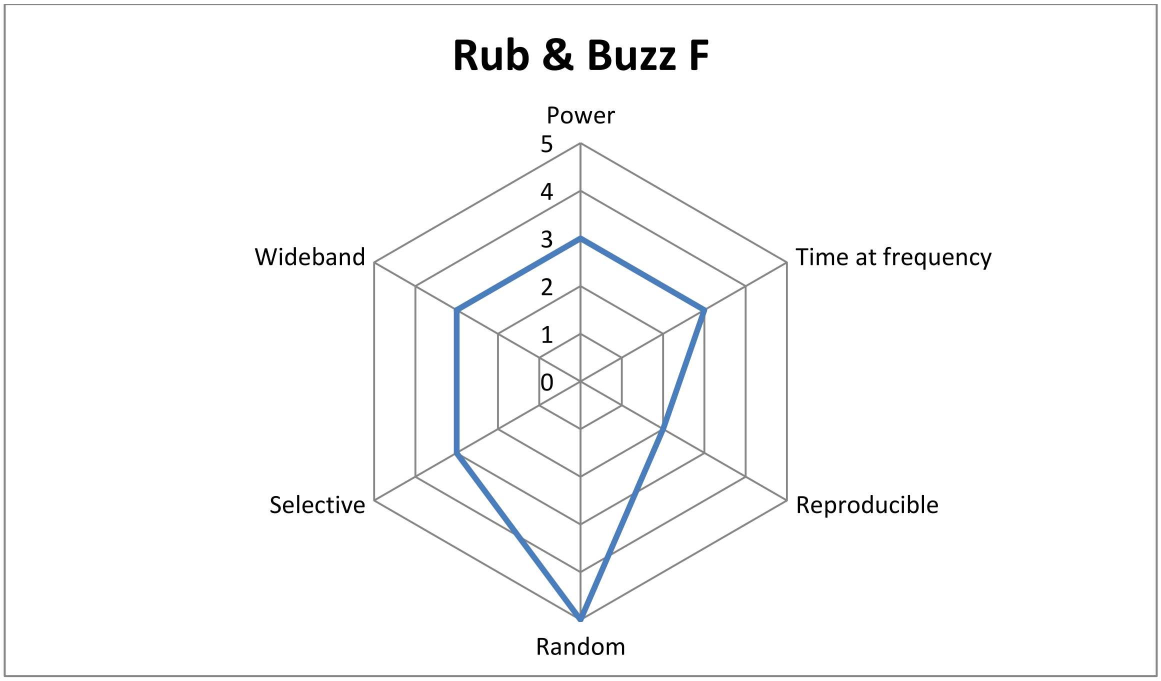
D) Buzzing signal as selective resonance generated due to some missing gluing. Medium predictable, medium or slow test speed, some power depended. The selective resonance generated due to missing glue need to be energized. So this is time and power depended. Faster test more power etc.



E) Air leakage noise generated signal.
Medium random, medium or slow test speed, power depended. Signal covers a wide band frequency range.
Normally this type of signal is generated from dust cap or missing gluing around membrane one bad mounting in a cabinet.



F) Rub & buzz generated due to loose particles.
Random generated, medium test speed, some power depended. Loose particles can be in the magnetic gab or hitting the membrane.



Variance

When testing many loudspeakers you find that there are variances between measurements. This variance in the measurements become from many sources. It is important that any variance of measurements comes from the tested devices and not the setup of the particular test system.

Variance from test setup

The variance in the measurements come from your test system must be in a value so the variance does not eat out your test limits for your speakers you want to test.

Normally the variances from the test system come from the tolerance on placing your test device on the test fixture.

Placing the microphone is very important. Any changes have a very big impact of measurements.
If a test system makes use of more than one test bench it is difficult to use same test setup / limits for each system unless the software can handle the difference.

How to check setup variance

a) Place your device to test on your test bench.
   Make serval test on monitoring the variance in measurement to be in the wanted level.
   Some test systems have tools to monitoring the variance.

b) Mount and dismount your same device on your test bench.
   Use the same procedure as above.

Normally the most changes are seen at the upper test frequency due to a shorter wavelength.

Variance from devices

To make reference limits for a particular device serval procure are possible.

The most simple way to make a reference limits is to use a well-known golden device.
However this is the simplest way to make a reference but it do not take in account of variance of different devices.

To make references with some known good units is better. Here it is possible to calculate variance of the tested units into your references.

It is better to use many tested device into the reference settings especially if more than one batch of devices are used. This gives a lot of work if those data have to be processed by hand. However some test systems have software to process this data more or less automatic.

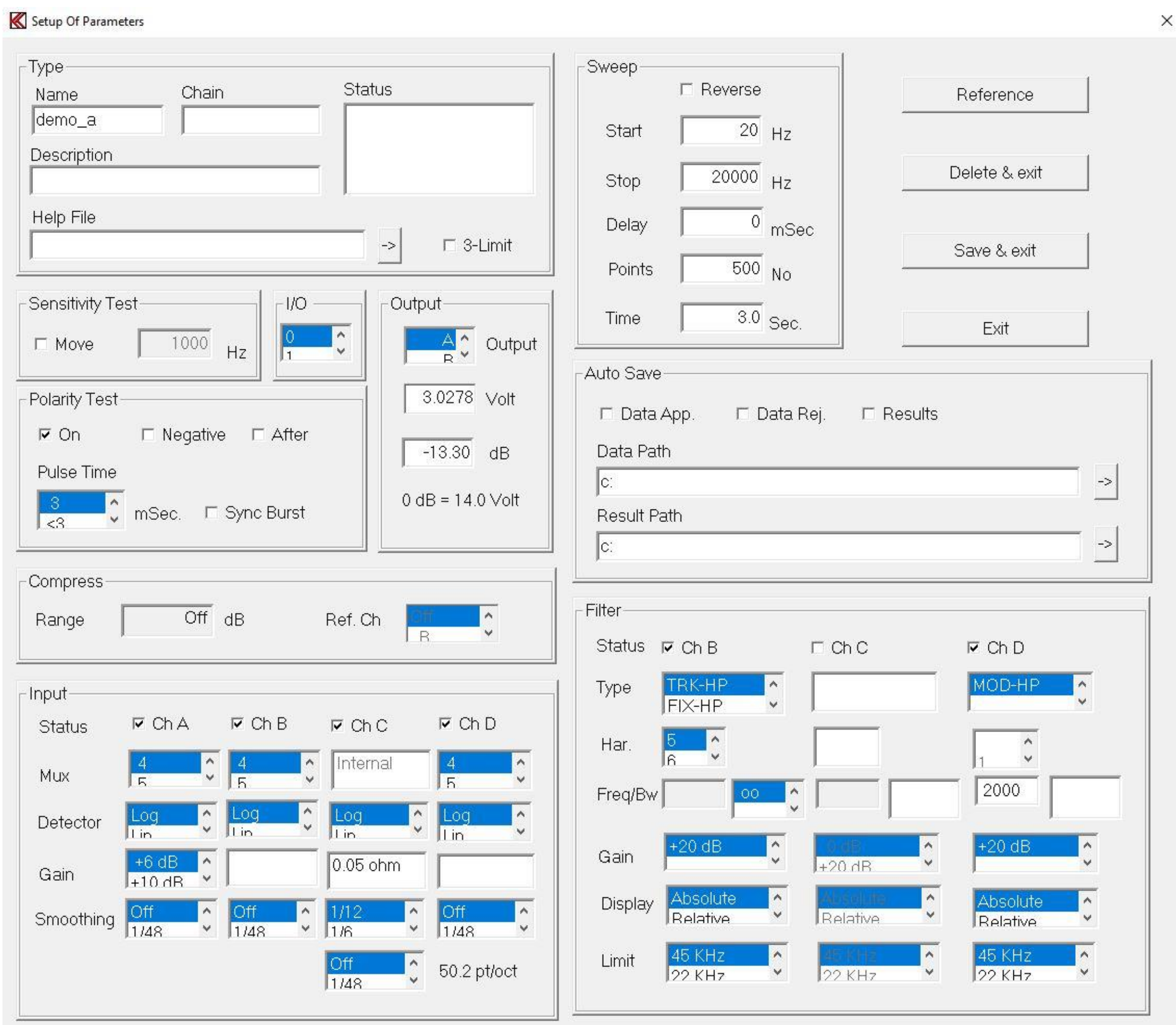
The most advanced test systems have an Ai function there can modify and calculate the reference setup on the fly. Note an Ai function need to learn how to calculate data to work properly.

Examples

Setup test parameter for P900

Following setup of test system P900 show following test parameters as Frequency Response, Sensitivity, Polarity, Impendence, Resonance and Rub & Buzz.

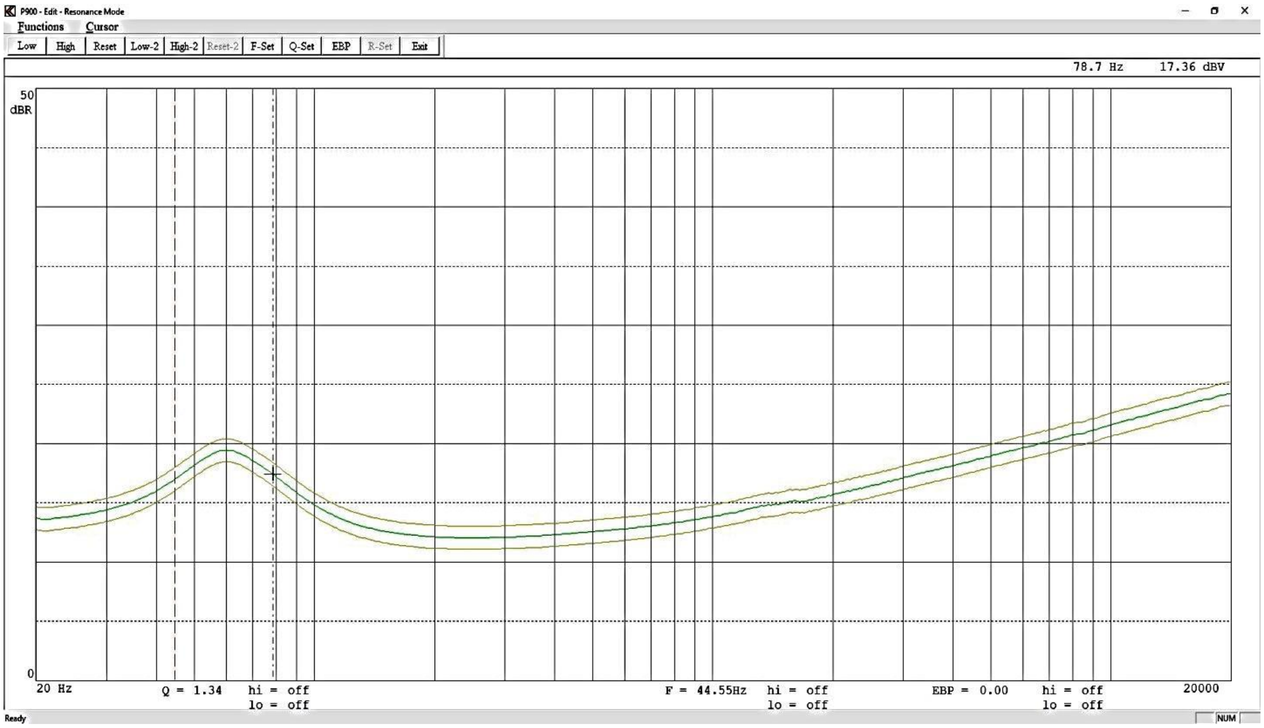
Used speaker is a speaker unit in free field. Used output voltage on speaker is selected to 3 volt and selected frequency range for sine sweep is 20 to 20000 Hz.
Sweep time is 3.0 second used. For detection of rub & buzz is to filters used. Channel B tracked high pass filter for 5 harmonic and higher (TRK-HP). Channel D a semi fixed high filter (MOD-HP). The semi high pass corner is set to 2000 Hz.



Test of resonance is set around resonance.

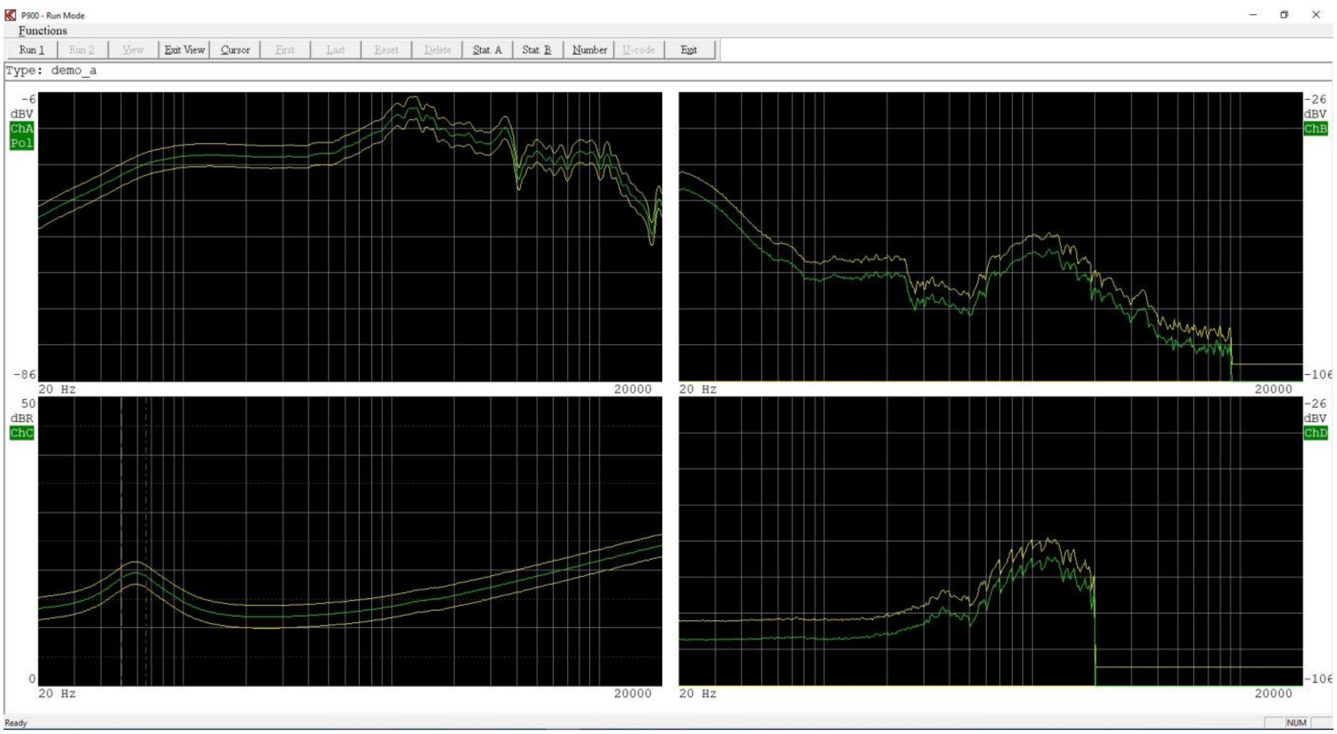
This setup is done in edit-mode.

The lower and upper limit for testing resonance is seen between the brown markers.



Test envelope for Frequency response is used +/- 3 db. In this case the sensitivity has to be within this envelope.
Test envelope for impedance is +/- 2 db.
Test of rub & buzz is set to be less than 4.5 db from reference. Note these values have to be modified from model and type of speaker and even part of the frequency spectra.

Following test result is following in run-mode:



How to generate rub & buzz

It is possible to generate some different rub & buzz types to test your measuring system.

1) To generate a reproducible rub & buzz you just use a speaker and add some power.
   a) Compare the THD and the rub & buzz with different power level. Note that at higher power level the THD begin to mask out the rub & buzz level. The rub & buzz level around and below resonance rise more than the power level there is added.
   b) Add high power to the speaker. The speaker generates normally a lot of rub & buzz. NOTE do not put too much power on the speaker. This can damage the speaker.

2) To generate a selective rub & buzz resonance to a speaker.
   Add an item with a tape to the speaker membrane. Example a piece of paper. Then a test signal is added at the resonance of the piece of the paper it begins to vibrate and make its own sound. Normally this very selective and it are very time over power depended.

3) To generate a pure random rub & buzz add some lose items on the membrane.
   When testing those items jumping up and down and generate a random rub & buzz.
   If the test is repeated the rub & buzz is repeated however on a totally different pattern.

4) To generate a wideband air sound rub & buzz.
   Open some of the dust cap or make some hole on membrane or let the air pass some other way. The air sound just become at some level of air pressure and normally need some power to be generated.

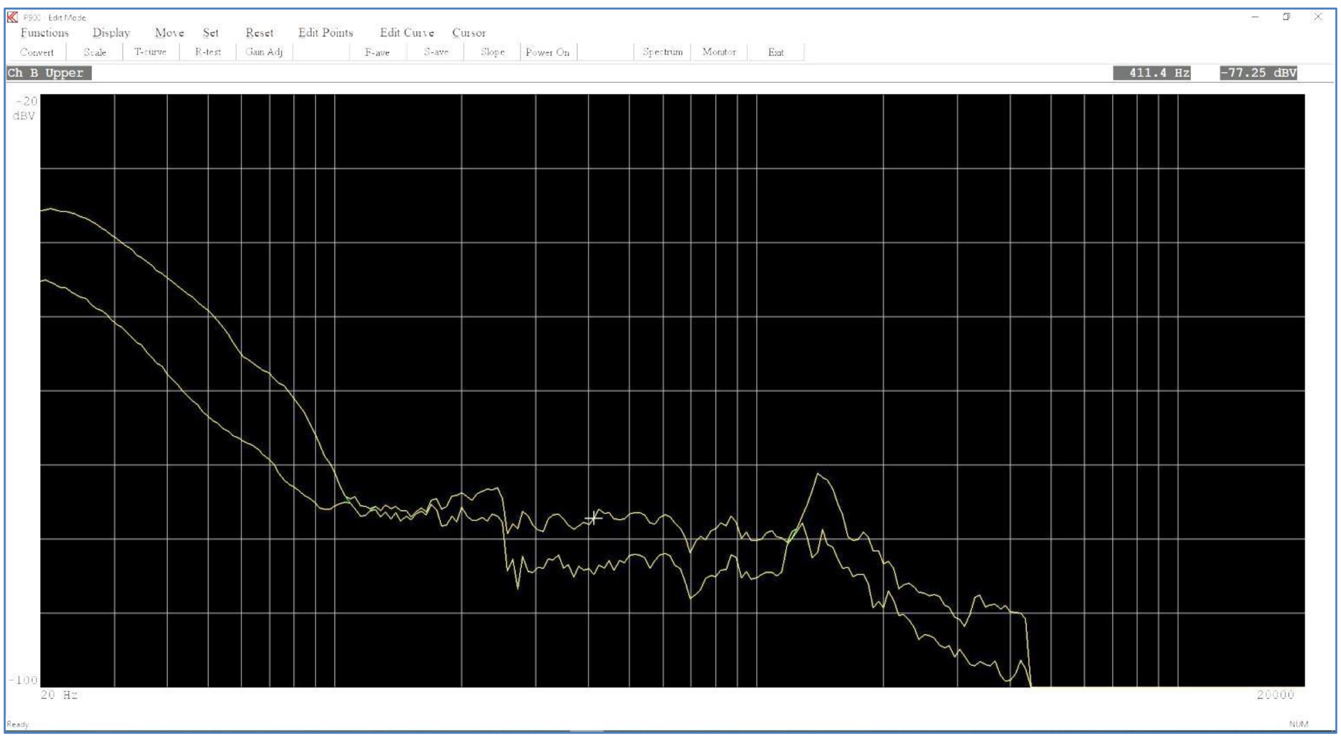
Measuring examples

In the following examples are used different advanced filter technologies to measure rub & buzz.
P900 a test system from K &K Internal / K & K Development have been used for following examples:

The P900 test system has up to 4 curve display with primary and secondary tests.
Channel A normally frequency response.
Channel B & D normally used for rub & buzz with different filter settings.
Channel C for impedance measurements.
Those 4 display channels can have than one test displayed against tolerance and reference curves.

Example 1a

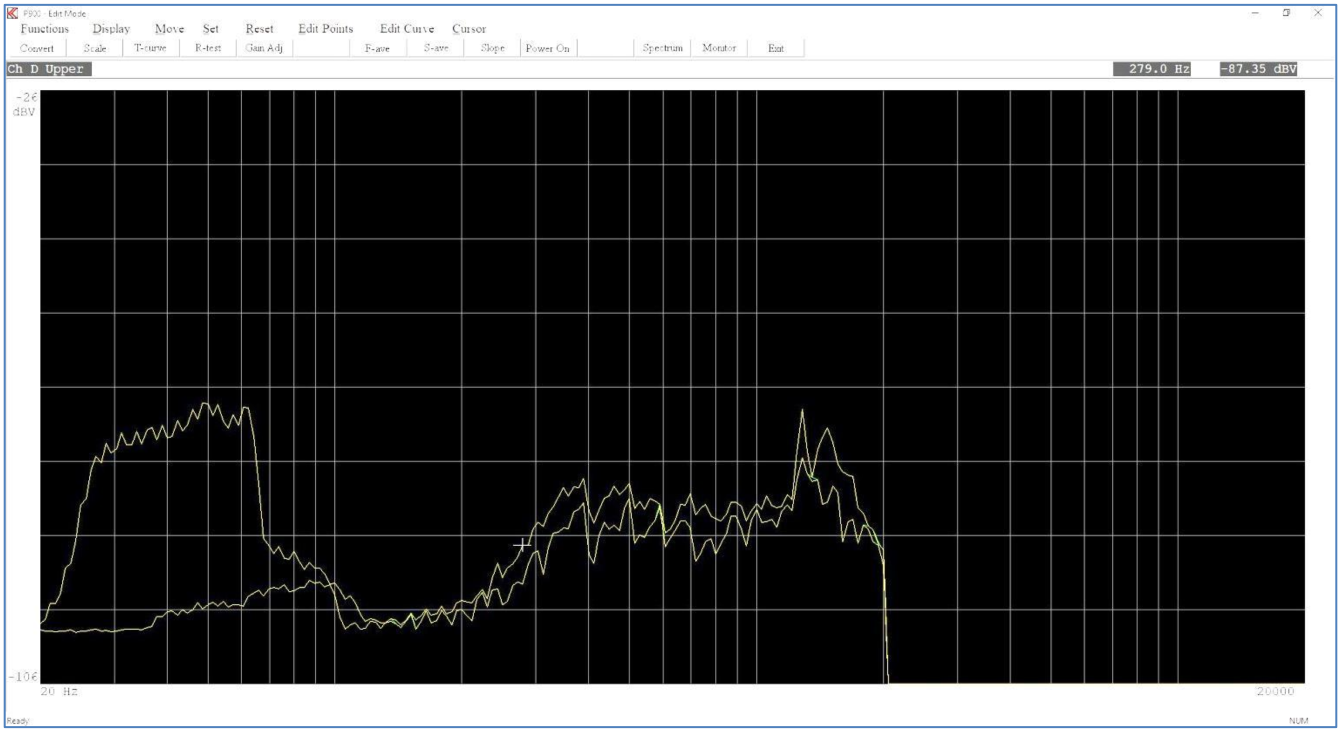
This example shows a rising in rub & buzz due to non-linearity in speaker.
The power was raised +6 db however the rub & buzz are raised more than 6 db.
These masks out other rub & buzz values.



P900 test is used with a TRK-HP filter in channel B.

Example 1b

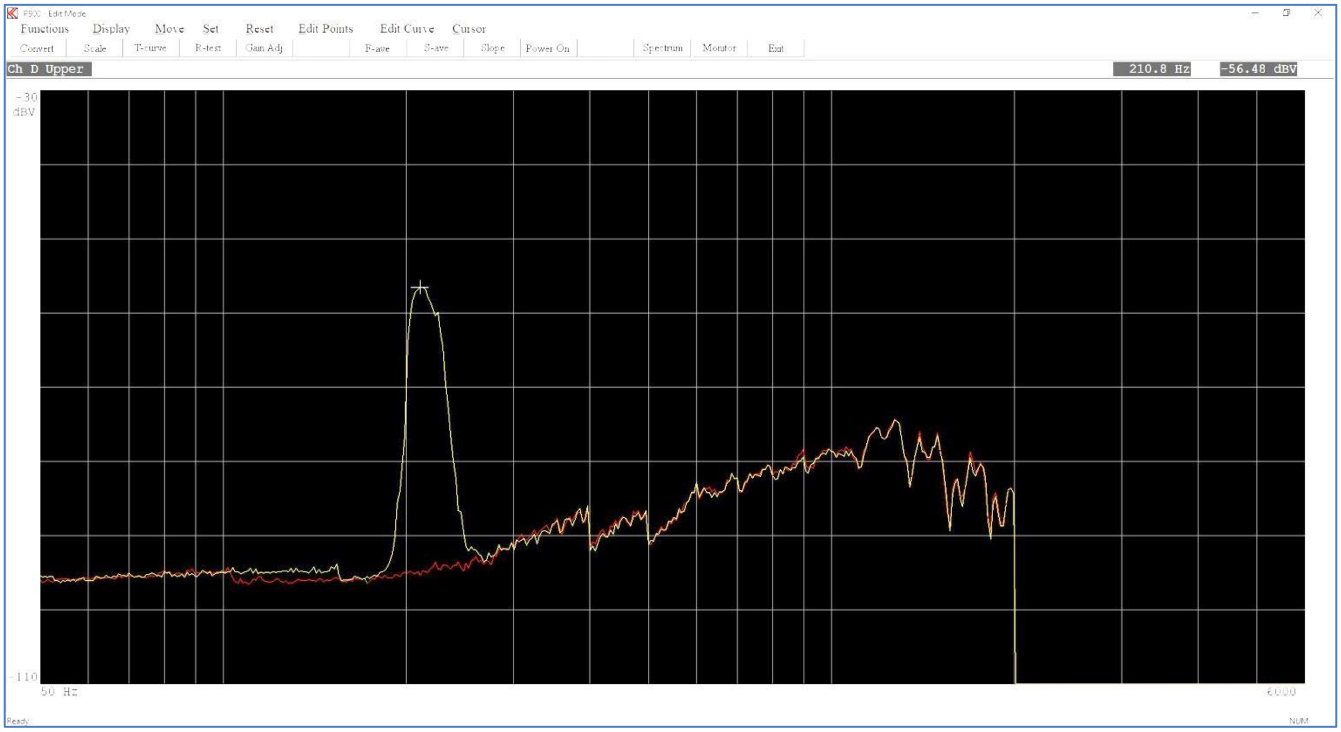
These example shows rub & buzz due to much power to speaker. Membrane hit limit around resonance in the frequency range 30 to 60 Hz.



P900 test is used with a TRK-HP filter in channel B.

Example 2

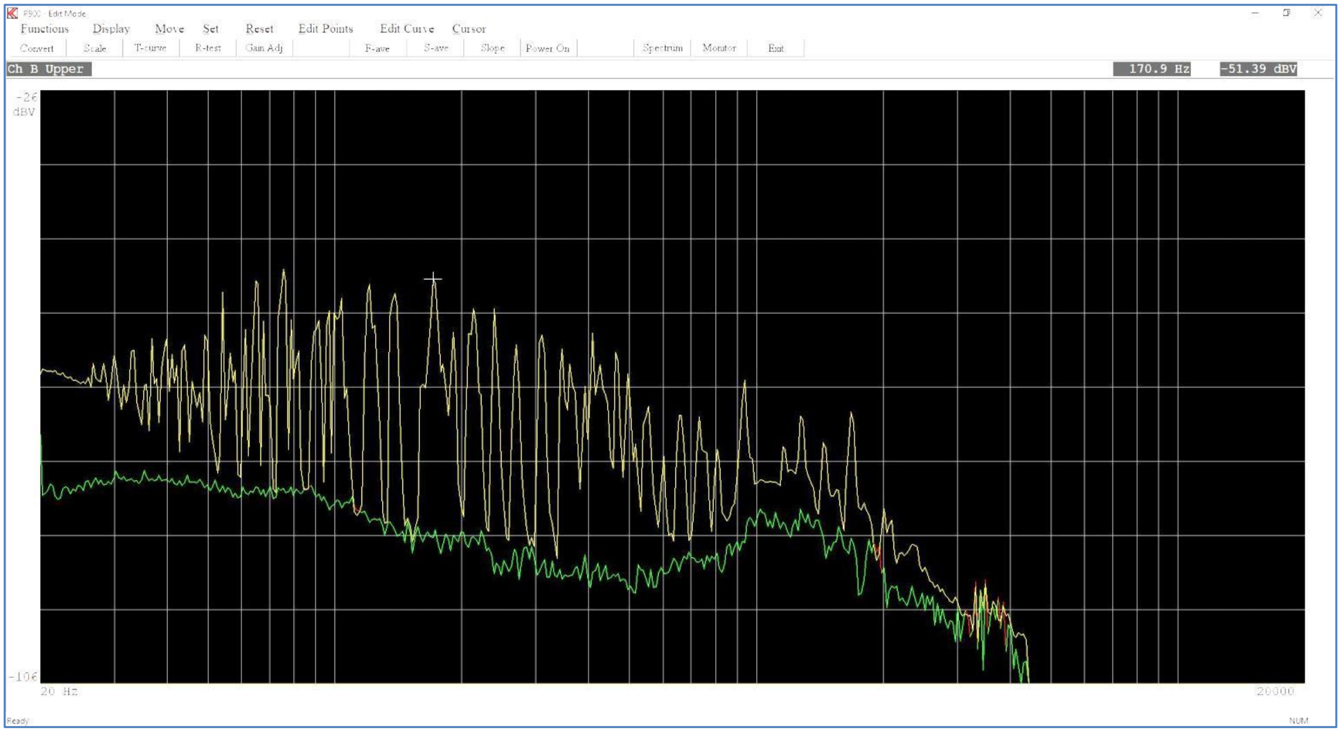
This example shows a selective rub & buzz.



P900 test is used with a FIX-MOD filter in channel D

Example 3

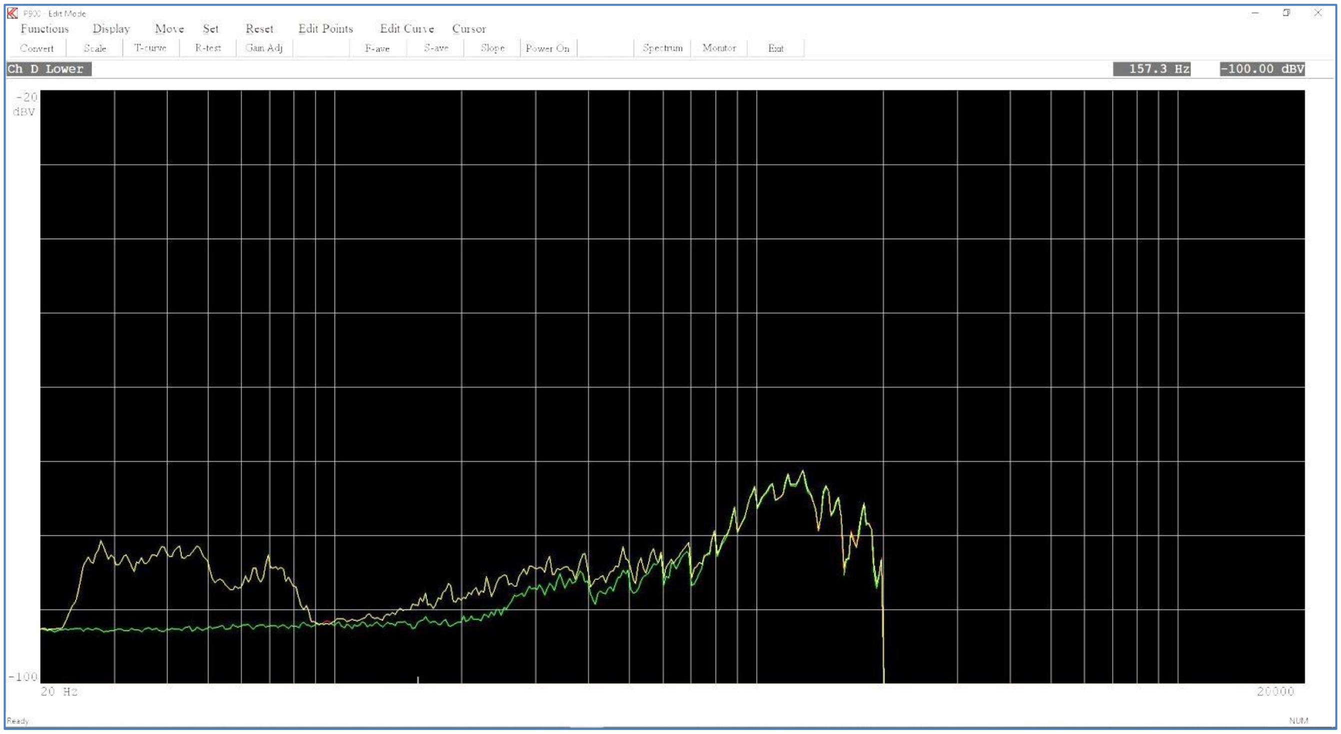
This example shows a random rub & buzz.



P900 test is used with a TRK-HP filter in channel B. The test sweep is from 20 to 20 KHZ.
If the test is repeated the behaver will be different from this example.

Example 4

This example shows an air ab noise in the range 25 to 100 Hz range.



P900 test is used with a FIX-MOD filter in channel D

Methods to make reference data.

When testing loudspeakers you need to know what you are testing against.

Normally you test against some reference parameters.

The concept used for all models produced by K & K International the references tested against is upper (maximal) and lower (minimal) limits or upper limits only.

On the following descriptions are explained how to make those limits.

a) Make references with a known golden unit.
b) Make references with some known good units.
c) Make references with many units and select manual statistical data to make limits.
d) Make references with many units and auto select statistical data to make limits.
e) Ai-mode to auto learns and modifies references on the fly in run-mode.

The following examples show the differences between the different ways to make limits and not how to setup the different tests. It is recommending look in the user manual for actual test system.

Make References with a known golden unit.

To make test limits with a well-known good speaker, a golden unit it is very easy and simple.
After the desired test parameters are selected as start and end frequency, output voltage, test time, input channels and gain and setup of filters if need a measurement is done.
Include all data and then edit the limits.

In the following example only frequency curve limits are used. The limits are moved +/-3.1db.
Normally higher tolerances are given at the lower and higher frequency due to wider deviations.

Benefit: Very simple to make.
Disadvantage: No guarantee that the golden unit is representative for a wider number of units.
Test for units: Few number of units.
References: One.

Make references with some known good units.

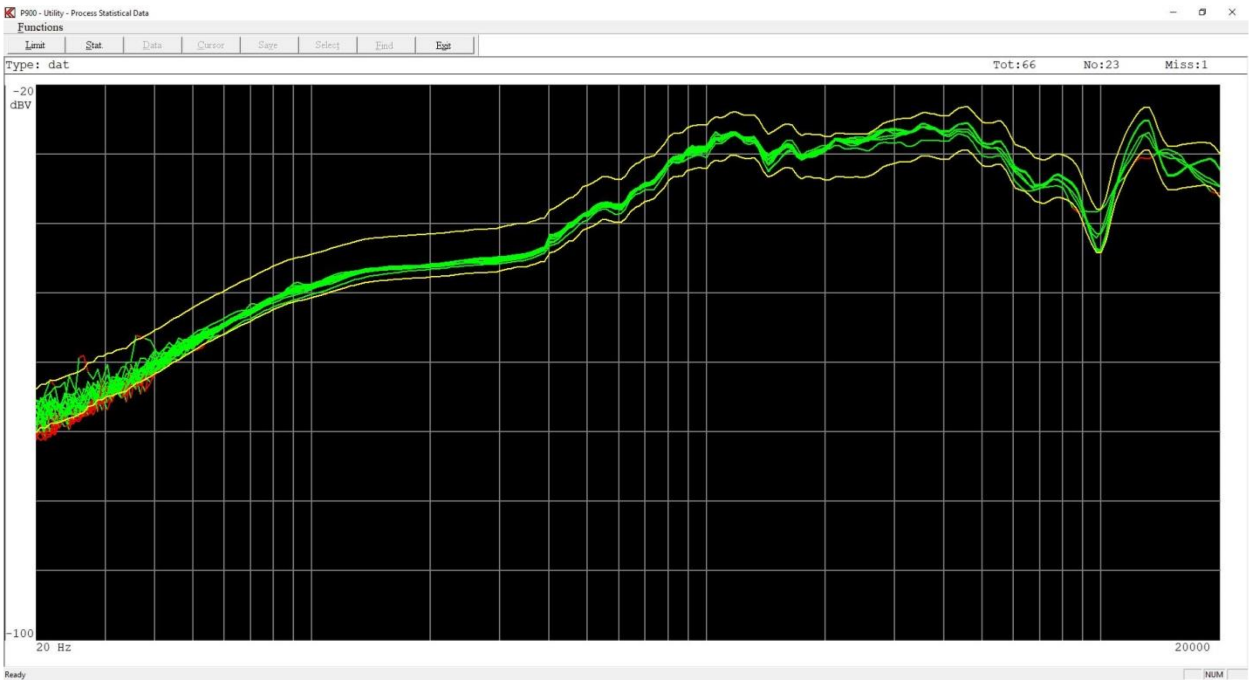
To make test limits with some well-known good speakers.
After the desired test parameters are selected as start and end frequency, output voltage, test time, input channels and gain and setup of filters if need a measurement is done.
Include all data and then edit the limits. Repeat this with a number of good units.
Every time an “include” is done the upper and lower limits are grown if the measured data are outside the present limits before an “include”. On this way the limits give a better tolerance for a wider population of number of tested units.

In the following example only frequency curve limits are used. The limits are moved +/-2 db.
Here are used 10 good units. The difference from only use 1 unit and now using 10 units see in this case at frequency higher than 4000 Hz.

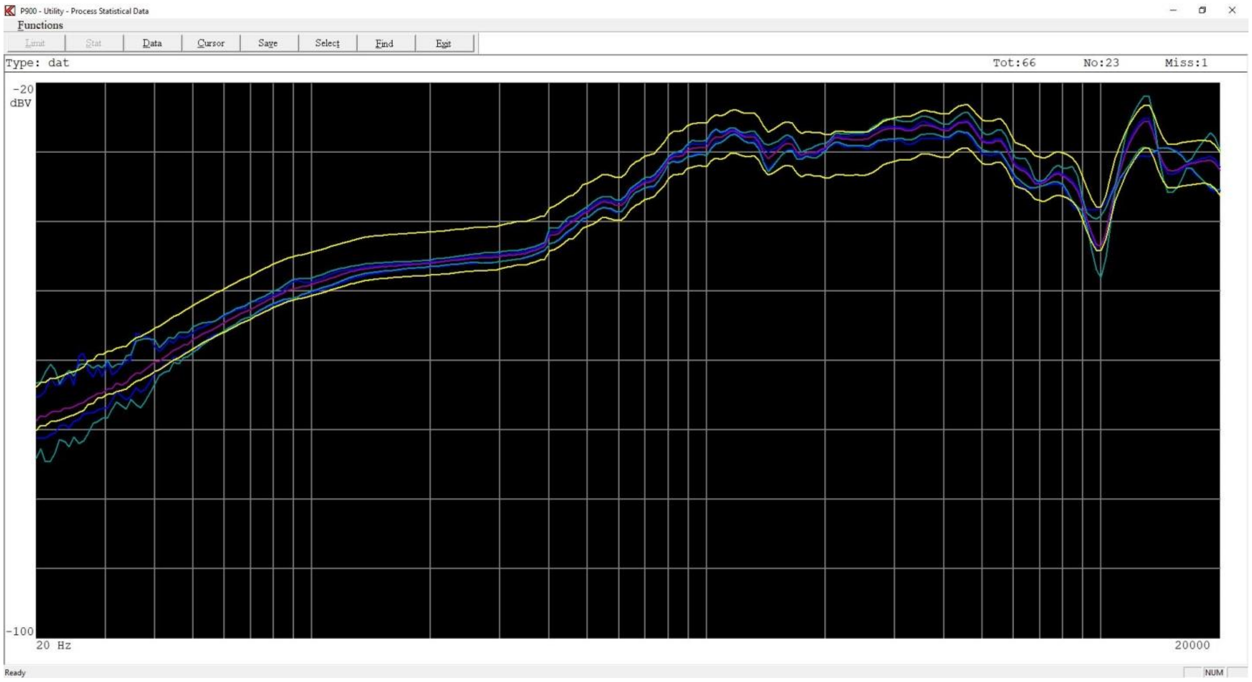
Benefit: Very simple to make. Give a better representation for a number of units.
Disadvantage: No guarantee that the good units give representation for a large number of units.
Test for units: A wider number of units.
References: Few units as 5 to 25 good units.

Make references with many units and select manual statistical data to make limits.

A better way to make test limits is to collect a number of stored measured data for analyze.
To this make a complete setup for a wanted speaker. When a setup is complete and all test parameters are done you are ready to run test in run-mode. You have made test limits as described above.
Now collect all measured data both approved and rejected to a4mstat.dat file (default name). To do this enables the function in global-setup. When serval measurements are done and data is collected and stored use the utility function "Process Statistical Data".



In this example above show only the frequency curve data processed in manual mode. Number of collected measurement is in this case 23 out of 66 measurements. This show that the current limits could be fitted better to the measured data.

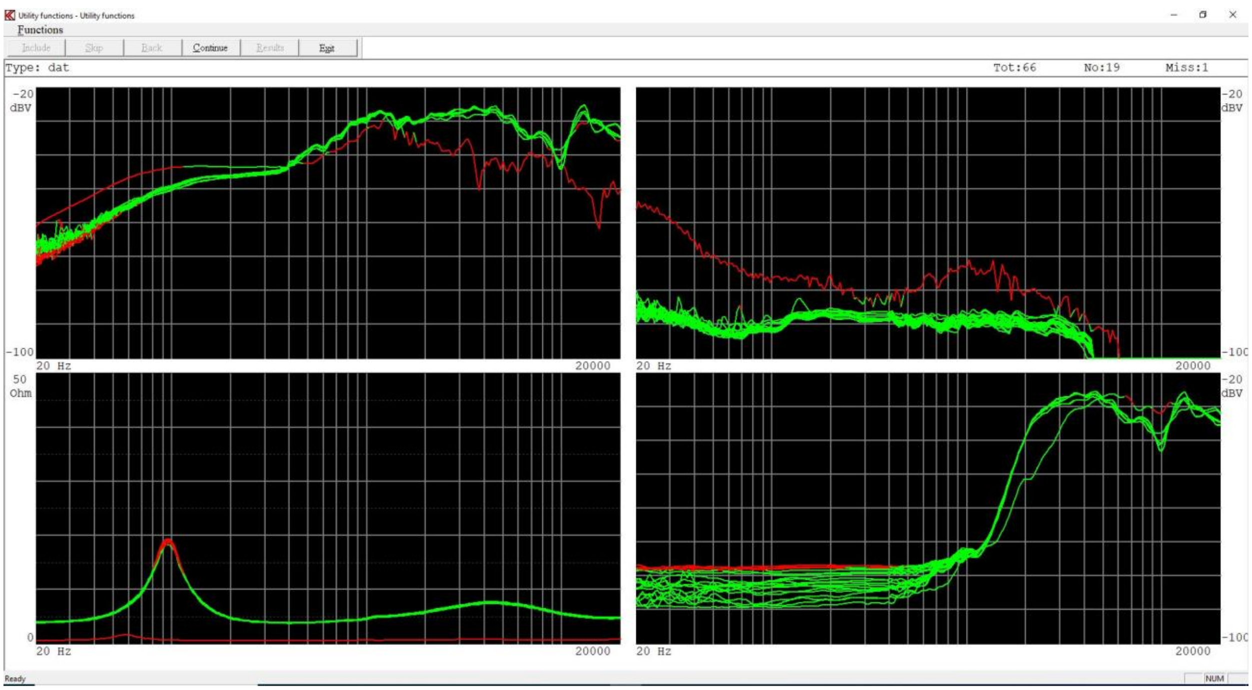


The same data is now processed. Displayed are the upper and lower limits, the average of collected and selected data and in this case +/- 3 Standard diversions (sigma). With benefit the upper and lower limits could be modified. I would use +/- 3 sigma and add a limit example +/- 1 db to this.

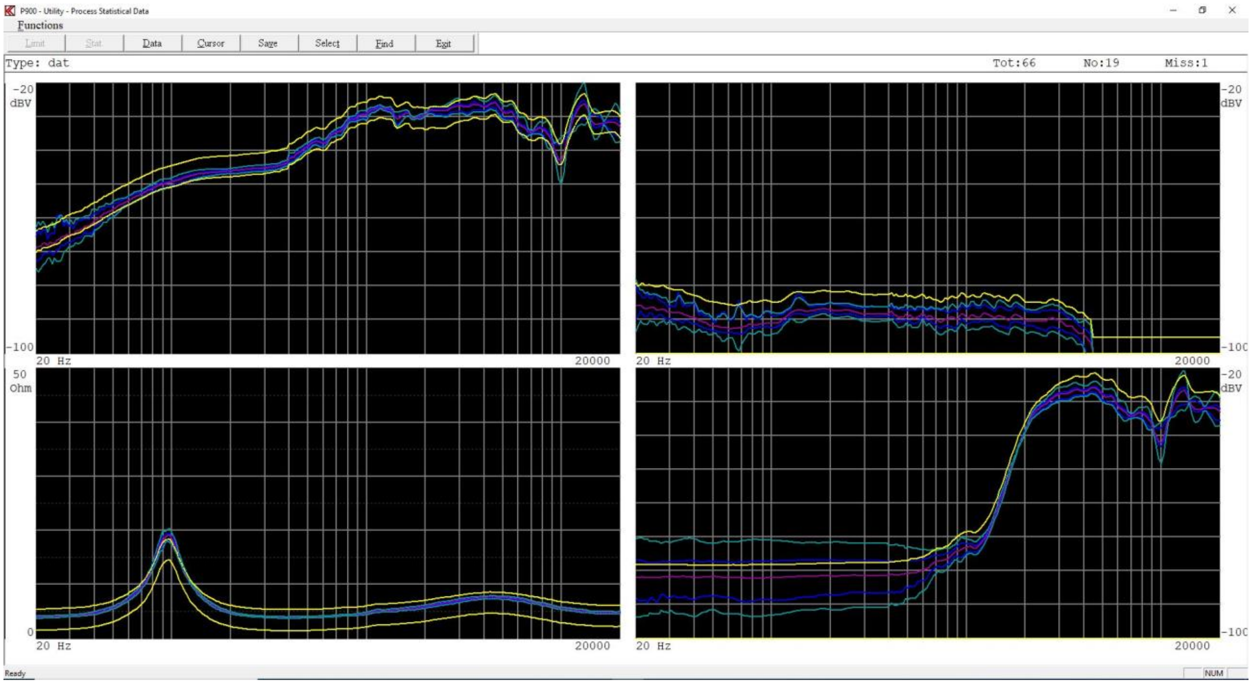
Benefit: Give a good representation for a many number of units.
Disadvantage: No guarantee that this gives representation a large number of units in different batch.
It takes time to manual process the collected data.
Test for units: A wide number of units.
References: Units as 25 to 100 of accepted good units.

Make references with many units and auto select statistical data to make limits.

As to “Process Statistical Data” in manual mode the data can be processed on auto mode. The auto mode is a “pseudo learning mode” where a large number of data can be processed. This mode a suppress function is very powerfully. To get a more correct population of data as both rejected and approved data however not direct very bad measurements this suppress function are used. Simply it take the current limits and add a new limit (the suppress values) to data before the processing are excluded in the collecting of data.



In this example a suppress function is used for all 4 channels. There are collected 19 measurements of 66 stored measurements.

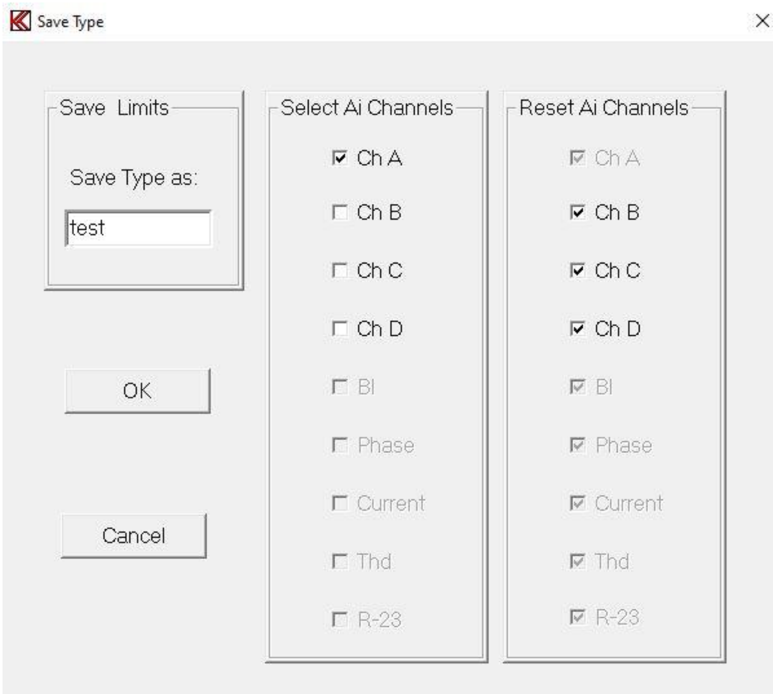


The data is now processed for all channels. Improvements of limits are recommended for all channels. The stored data used are the same used in manual and auto mode.

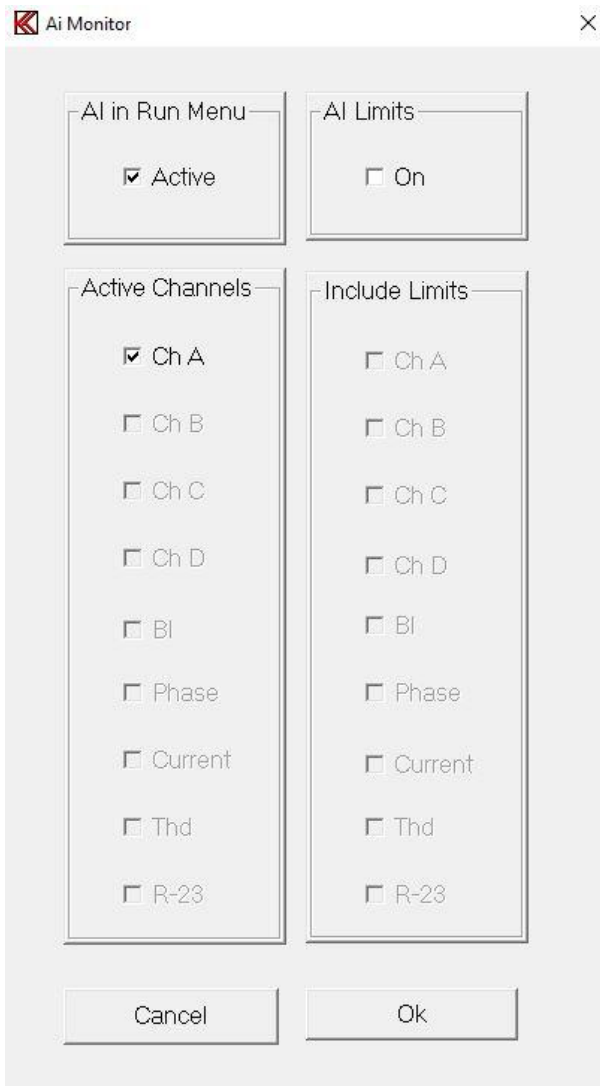
Benefit: Fast to use. Give a good representation for a large number of units.
Disadvantage: No guarantee that this gives representation a large number of units in different batch unless data are collected from different batch.
Test for units: A large number of units.
References: Units as 25 and > 10000 of accepted units.

Ai-mode to auto learns and modifies references on the fly in run-mode.

A step further can the system auto learn the entire population of measured data on the fly.
First accepted measurement higher than 50 units must be processed by the utility “Process Statistical Data”. Typical this is done in the auto-mode. In Ai-mode the system learns for every measurement in run-mode where the averages of the population have to be placed. The upper and lower limits are them auto moved under the auto learning, however not the gap between upper and lower limits. Then saving the processed limits you got following.



In this case all tests were processed, due to highlighted under Reset Ai Channels. We do only want to select Channel A. The selected Ai channels are prepared to use / select for later auto learning.
Before the auto learning can be activated the references for the selected channels must be selected as above. When this is done the channels must be selected in edit-mode the Ai-mode activated. It is allowed to select all channels as picture above and later only select one of them in edit-mode. If the channels are not selected when save data in utility the reference in Ai-mode are missing.



Now next time a measurement is made in run-mode the auto learning is done. If auto learning is not wanted click the Ai in Run mode off. It is possible to see the difference of the references in auto learning and the reference mode before learning in the edit-mode.
The save measured data set in global setup can be OFF or ON this do not interfere the learning mode.

Benefit:	Fast to use. Give a good representation for very large number of units.
Disadvantage:	The auto-learn function do move limits by machine learning. It is needed to check that the machine take over test result by mistake (run away case).
Test for units:	A very large number of units.
References:	Minimum units as 50 and up.