Title: DEVICE AND PROCESS FOR EXAMINING THE SIGNALS OF SYSTEMS RELEASING THEM DURING OPERATION OR IN RESPONSE TO EXTERNAL EXCITATION

Abstract: The object of the invention is a measuring device (1) for measuring and evaluating the signal of a system releasing a measurable signal during operation or on the effect of external excitation, which device contains a signal receiving unit (2) and an output unit (5,6). It also contains an evaluating unit (3,4) adapted for performing Fourier transform on the time dependant signal captured by the receiving unit, for calculating the power density function of the Fourier transform, for fitting a power function having an exponent on the power density function, and for transmitting the obtained exponent to the output device.
DEVICE AND PROCESS FOR EXAMINING THE SIGNALS OF SYSTEMS RELEASING THEM DURING OPERATION OR IN RESPONSE TO EXTERNAL EXCITATION

This invention refers to a device and procedure to be used in the course of planning processes, wearing tests and qualitative examination, and applicable to the noise measurement of systems producing measurable signals during operation or on the effect of external noise source.

The test of wearing and tearing is of vital importance in the respect of preventive maintenance and operation life. The problem is rather complex and complicated as we have to conclude on the properties of the given equipment from the results of type tests, and on the other hand, we have to specify the characteristic values of the type in question by using the operation data of several single devices. This problem can be practically traced back to a single root: the used systems are open, and connected to their environment through a number of elements, as well as, can not be considered as closed systems even for the duration of measurement. They form an open system from an energetic point of view (energy exchange with the environment, having the characteristic values of energy input (feeding) and energy take out (useful effect), non-deprivable substantial characteristics) because of the interactions indispensable for the operation (on which the effect of the system is directed, retroactive effects), and owing to the influences of environment (environmental loads, e.g. temperature, contamination, pressure, rain etc.), as well as on account of the user's habits and conditions (e.g. early morning usage, usual usage order, effects of usual intensity, direction etc.). Relying upon these characteristics the measured values are to be handled according to the rules of fuzzy logic, and the multitude of interactions might make impossible the parametric distribution hypotheses. (e.g. Kaplan-Meier non-(semi)-parametric lifetime evaluation.)
Dynamical effects and changes are noise-free only in the case of very simple and reversible cases (for energetically closed systems). This is practically a theoretical idealization, because in the reality the noise is always present as the fluctuation of the given signal (measured, set, used etc.) (Robinson FNH: Noise and Fluctuations, Clarendon Press, Oxford, 1974; and Freeman JJ: Principles of Noise, John Wiley & Sons, Inc. 1958).

The noise/fluctuation source is composed of many-sided interactions, the continuous energy and entropy/information exchange of open dynamical systems and the mutual dependence of the single subsystems, and the actual noise spectrum is formed in a synergetic way (Reif F: Statistical and Thermal Physics, McGraw Hill, New York, 1965). Consequently, the desired effect is accompanied in every real case by the noise/fluctuation spectrum composed of the specific features of the dynamical systems. Thus, the noise/fluctuation is a form of appearance of parameters, processes, dynamical behaviour etc. arising always, but not directly involved in the given examination.

In the course of the usual wearing tests and quality examinations, each element of the system is examined separately by using several sensors, and during this measurement one tries to eliminate or minimize the noise. Consequently, the aim at these measurement procedures is to filter the noise and create the best possible signal-to-noise ratio in order to get the most exact information possible regarding the given partial system.

There are two fundamental strategies for the elimination of noises:

- All the possible interactions are registered, the dynamics of changes are restricted as much as possible, and handled only as a static condition (filtering with fixed parameter).
- The dynamical interaction is accepted as the source of noise, however, it is separated from the „useful“ signal to be examined by using filtering mechanisms (lock-in type filtering).

In the case of open, dissipative systems (basically, every occurrence realizing not spontaneous thermodynamical changes, e.g. heat engines, biological systems, electromagnetic radiators etc.) the reduction of noise is impossible by fixing the interactions, because the open, dissipative feature assumes the definite
interaction with the environment. For this reason, at the real, irreversible dynamical systems we may consider only the second possibility, namely, we have to consider noise, and – at the most – the chosen dynamical methods may suppress the noise and bring out the „useful“ signal as far as possible.

The noise/fluctuations, however, provide information on the interactions (inside and/or outside the system) of the examined system.

The concept of the invention is based on the recognition that the whole dynamics is included in the noise/fluctuations, and practically all those dynamical variables appear therein the interactions of which have a share in the creation of the given (desired/useful) signal. Moreover, the noise/fluctuation spectrum gives account of the correlations within the system. Therefore, the examination can be carried out for the whole system, and the system operation can be analysed from its noise spectrum. All the failures arising because of wearing, tearing and fatigue processes (in general through stochastical changes) results in the continuous change of noise spectrum. Each systematic change due to wearing processes or incompatibility problems arising at a given time is effecting the evolution at a second given time, which means that it can be deduced in a recursive manner (Markov chains). This recursive behaviour is what gives rise to the systematic fluctuations making it a universal characteristic of the system. If the system characteristics at a given moment only depend on the previous moment then the system’s fluctuation behaviour can be best described with the Brown-motion parameters and the Brown-noise. However when the complexity of the system defines long distance correlations within the system, then the noise (as a system characteristic) is more similar to other coloured noises, in ideal cases to pink noise, which can be described by a 1/f function. Therefore, the assumption of noise spectrum allows the prediction of the wearing and tearing (fatigue etc.) processes. The width of the time period that can be considered as the “unit” of the recursive progress is determined by the characteristic frequencies of the given system. It is recommended but not compulsory to choose a unit frequency which is in the same order as the system’s characteristic frequency in a given examination type.
Our aim is to provide a device and procedure by means of which we may obtain information on the whole dynamics of the complex systems in order to be used for the planning processes and qualitative examinations.

According to the invention we are providing a device to be used in the course of planning processes, wearing tests and qualitative examination and applicable to the noise measurement of system producing measurable signals during operation or on the effect of external noise source. This device:

- contains a measuring unit which receives the signals and if necessary converts them into electric signal;
- contains a processing unit which carries out the Fourier transformation of the non-steady signals; and
- analyses the Fourier transform.

Moreover, the present invention relates to a procedure serving for the noise measurement of system producing measurable signals during operation or on the effect of external noise with the intention of using it for planning processes, wearing and tearing tests and qualitative examination, in the course of which:

- the continuously appearing signal is measured in time by means of measuring unit;
- then the Fourier transform is generated;
- and the values of Fourier transform is analysed as a function of frequency.

The other advantageous embodiments of the device and procedure according to the invention are described in the dependent claims.

It is to be noted that noise measurement, it is the measurement of a system's noise/fluctuations, should be understood as measuring the output signal of the system without applying noise filtering on the output signal. Thus the measured signal is made up of the useful signal (in certain cases including the characteristic frequencies) and the noise superposed thereupon. It can be easily shown that the useful signal (or the characteristic frequencies as the case may be) only appears with a minimal weight in the Fourier transform of the signal, since in an ideal case periodic signals are mapped into one single point of the Fourier
space. As it will be apparent practically only the noise part of the whole signal will be analysed during the examination, hence we refer to the method of the invention as "noise measurement".

In the context of the present invention noise measurement of a given process means measuring the time change of either electric, or mechanic, or other measurable signal. The concept of the invention is that, as opposed to the known solutions, we do not filter the noise, on the contrary, the noise itself provides the valuable part of the signal. Namely, we observed that the spectrum of the noise measurable on any physical parameter (namely, the Fourier transform of the noise signal) shows a typical collective characteristic: it depends on the frequency as a power function. We measure the exponent of the power function, which can be regarded as the invariant quantity typical to the dynamics of the system, and we use it for the observation of the system dynamics. Therefore, this measured value serves as a parameter for the properties, not for the single noises (information from the observation of individual frequencies), but for the whole system (features of the whole frequency spectrum), which as such is able to sensitively characterize the changes taking place in the dynamics of the system. Consequently, the monitoring of this parameter may replace the multi-sensor observation of complex systems by incorporating the actual status of the system into a single invariant and integral parameter. Accordingly, this parameter is technically suitable for the following:

• by using the parameter predetermined for the system of proper operation we can observe the state of system completeness,

• we are able to replace a complicated system of multi-sensor observations (at the same time, in order to the specify the place of fault we have to use local sensors, but in more integrated measurement groups, as without the use of process of the present according to invention),

• we are able to forecast the trends indicating possible faults,

• we are able to observe the trend of system wearing-out (lifetime),
• during development we are able to measure to what extent a uniform
dynamical load is assured by using the exponent,
• we are able to explore the „unusual”, suddenly occurring changes,
usage faults and unauthorized usage (e.g. a non-qualified person
intervenes and modifies the invariant quantity even if it does not result
in operation fault, e.g. manual change gearbox of cars).
• in the course of general renovation and up-grading the trend of
evolution can be measured for control and documentation purposes,
demonstrating the efficiency of the renovation or up-grade. This can
also be an efficient way of screening and warding off inherent
incompatibility problems.

Active screening can be applied to the system to be examined by which
faults and errors can be detected more accurately and specifically; the source of
the failure and the resonance points can be localised and warded off. Further
details of the invention will be apparent from the following embodiments with
reference to the accompanying drawings, in which:

Figure 1 is a block diagram of one of the embodiments of noise measuring
unit according to the invention,

Figure 2 is a block diagram of a tested radio-frequency amplifier,

Figure 3 shows the result of a noise measurement carried out on a radio-
frequency amplifier,

Figure 4 illustrates the result of a noise measurement carried out on two
radio-frequency amplifiers under different conditions,

Figure 5 is a block diagram of an examined water-cooler,

Figure 6 shows the result of a noise measurement carried out on a water-
cooler,

Figure 7 illustrates the result of noise measurements performed on the
water-cooler under different operating conditions.

Figure 1 is a block diagram of one of an embodiment of a noise measuring
device (1) according to the invention. At the input of the device (1) is a measuring
unit (2). As the most simple solution is to trace back the noise measurement to the
measurement of voltage, consequently, the measuring unit (2) usually works as a
voltage measuring unit, in a given case, supplied with a transforming unit for the transformation of non-voltage signal (e.g. mechanical vibration) to voltage signal. The measuring limit of the measuring unit (2) is determined by the operating range of the actual equipment to be examined, while the accuracy depends on the type of the actual noise. The measuring unit (2) is connected to a fast Fourier analyser (3). Under laboratory conditions oscilloscope or spectrum analysers can be used as measuring unit (2). These latter ones can have built-in FFT function, and in this case there is no need to have a built-in analyser (3) in the system.

The output of the analyser (3) is connected to a data processing equipment, preferably to a computer (4), with an installed software for the evaluation of the noise measurement results. Display unit (5) (e.g. monitor) or an actuating unit (6) can be connected to the computer (4), and the latter one reacts upon the operation of the system depending on the evaluated results, and can work as a control unit. The regulating action can be off-line (human interventions after the displayed result), however, on-line or real time actuating unit (6) can be advantageously used based on the measured parameters. Both the display unit (5) and the actuating unit (6) can be omitted, however an element that can be regarded as an output unit is necessary, otherwise it would be useless to measure the \( \alpha \) exponent. So the resulting \( \alpha \) value has to be transmitted via an appropriate output unit to an operator or a serviceman. For example the \( \alpha \) value can be displayed via the display unit (5), in other cases the output means can be a telecommunication device, e.g. an Internet port, which transmits the information to the computer of a distant user. Another option could be that the output unit performs automatic control of the examined system. For example the position of a rotary capacitor could be adjusted by means of the actuating unit (6) as shall be evident later on.

The analyser (3) and computer (4) of the measuring device (1) can be integrated in one element. For example the analyser (3) can be a software part of the computer (4), it could even be part of the software evaluating the results of the noise measurement. Instead of using a computer as the measuring device (1) it can be integrated into a "One-chip PC" having A/D converter, which could also perform the function of the analyser (3) and could be adapted to receive and
evaluate the signal transmitted by the measuring unit (2) and to calculate the $\alpha$ exponent.

The noise measuring unit (1) may have an independent power-supply unit (7), which is not compulsory, but it can be advantageous in the case of certain measurements.

In general applications we may measure a signal appearing at a certain part of the system by means of the measuring unit (2) connected to the system (in certain cases this unit transforms the system signal into voltage signal). The analyser (3) measures the time dependant $h(t)$ signal, and transforms it into the Fourier space by applying fast Fourier transform, that is, transmits $h(f)$ frequency-dependent discrete values to the computer (4). (Of course, the quick Fourier transform is not the only possible solution, however, this method is suitable for the accomplishment of real time evaluation.) The signal processing software raises the frequency-dependent $h(f)$ Fourier transformed noise values to the second power and divides it by the $\Delta f$ effective frequency band-width, which is simply the width of the frequency window, by means of which the quick Fourier transformation can be performed. Therefore we get the

$$S(f) = |h(f) \cdot h(f)^*|^2/\Delta f$$

power density function.

As we mentioned earlier, according to our observation the $S(f)$ power density depends on the frequency accordant to the $S(f) \sim f^\alpha$ power function, and the exponent is suitable for the characterization of the collective dynamical behaviour of the examined system. If the construction of the system is ideal, the correlation lengths are of infinite extent, and in this case the noise spectrum is harmonic $S(f) \sim 1/f$, that is $\alpha = -1$. Also, we found that in the case of devices operating optimally the value of $\alpha$ was constant and practically independent from the operating conditions. Accordingly, we have to examine two aspects in the course of planning processes, wearing and quality tests: how the value of $\alpha$ approximates the ideal (-1) value, and how does it change when modifying the operating conditions.
For the illustration of the operation of the device and process of according to the invention we are going to show the results of noise measurements carried out on exemplary systems.

Example 1

By using a device (1) according to the invention we measured the noise of a high-performance, controlled, radio-frequency (RF) amplifying unit (8), which can be seen on the schematic drawing of Figure 2. The amplifying unit (8) is composed of a quartz-crystal pre-amplifier (9) operating on 13.56 MHz, and a connected RF amplifier of high noise suppression (minimum 60 dB), an both of them are supplied with controlled power supply unit (11). Between the external load (12) and the RF amplifier (10) a matching device (13) of 50 Ohm is inserted. For the noise measurement, we placed the device (1) between the load (12) and the matching device (13), and carried out the measurement of the appearing signal by using a measuring unit (2) (in this case this was a voltage measuring unit).

On Figure 3 the logarithm of the above S(f) function is illustrated as a function of the logarithm of the frequency, and we fitted a straight line (linear function) on the obtained measurement points. The exponent \( \alpha \) in this case equals to -0.8208, and the accuracy of fitting is 0.5983. It should be noted that the maximum value corresponds to the 13.56 MHz primary frequency, that is, to the operation frequency of the pre-amplifier (9). The characteristic frequencies and the operating frequencies of the examined system (in this case the amplifier denoted by 8) are always present in the measurement results, however, the number of points falling into this ranges is relatively few as compared to the points forming the basis of the best-fit line, therefore the fitting a line can be considered as justified and reasonable. For the exact calculation of the exponent in question we take in every case the average of several measurements.

Example 2

In the course of this experiment we tested the exponent \( \alpha \) of the amplifying unit (8) described in the first example before and after maintenance under different operating conditions. The measurement results are summarized on Figure 4. The EG1, EG2, EG3 show the obtained results at the output powers of 50 W, 100 W, 150 W with a pure resistance load. The same \( \alpha \) values obtained for complex loads
are indicated by the captions EB1, EB2, EB3. All the points of the diagram are calculated as the average of five measurement results, and the deviation from the average is indicated by the vertical fault intervals. We adopted 1024 points per measurement, and after fitting on this set of points we got the indicated values of $\alpha$.

As we may see, the operation of amplifying unit (8) can be regarded as optimal after maintenance, as the value of $\alpha$ is constant and approximates (-1) independently from the external conditions. On the contrary, the $\alpha$ value of the amplifier (8) waiting for the servicing changes considerably depending on the extent and type of load (ohmic or complex).

The obtained diagram illustrates well that using the noise measurement according to the invention the devices and systems not working properly can be pre-filtered.

Example 3

In this example we examined a Peltier water cooler (14) illustrated schematically in Figure 5 by means of the measuring device (1) according to the invention. The water cooler (14) is equipped with a circulation water pump (15) and a heat exchanger (16) containing Peltier battery and ventilator. The object (17) to be cooled and the internal measuring unit (18) are connected in series with the water pump (15) and the heat exchanger (16) containing for example a water flow measurer. We connected the noise measuring unit (1) to the power-supply unit (19), and measured the power consumed by the water cooler (14) as the signal appearing in the system.

In the course of the measurement we deliberately put one or several components of the water cooler (14) out of order, and observed the change in the exponent $\alpha$ and the consumed power. The latter one can be followed by observing the change of a normalization factor A appearing in the S(f) function ($S(f) = A f^\alpha$). The results of the measurement are illustrated on the diagram of Figure 7, where the literal notations denote the following cases:

G: water cooler (14) with faultless operation,
NV: insufficient operation of ventilator,
NP: the operation of the Peltier battery is inadequate,
NW: insufficient operation of the water circulating pump,
+: any combination of the above cases.

In the example illustrated in Figure 6 we showed a measurement result for $\alpha$. The axes of the diagram are of log scale, consequently, the fitting is carried out on the power function. There is no characteristic frequency in this case, although we may observe several distinguished frequencies because of the controlling electronics, the circulation and other technical solutions.

In Figure 7 we showed the measured values of a water cooler (14) under different operating conditions. In the column beside the diagram we listed the numerical values of $\alpha$ and $A$ for each condition. We adopted 1024 points per measurement, and after fitting on this set of points we obtained the values of $\alpha$ and $A$. All the points of Figure 7 are calculated as the average of five measurement results, and the deviation from the average is indicated by the vertical error bars.

By observing the change of the exponent $\alpha$ we may state that by the gradual aggravation of problems relating to the operation of water cooler (14) the value of $\alpha$ moves away from the value (-1) and from the value of faultless operation (-0.537). At the same time we may observe the decrease of the value $A$, which means a decrease of the consumed power indicating that the operation of the device is less and less efficient.

The frequency of the sampling used during the FFT (fast Fourier transform) or other digital Fourier transform is not indifferent with regard to the noise measurement of the invention, meaning that the frequency of retrieving the value of the measured signal produced by the examined system in order to perform the Fourier transform cannot be left out of consideration. We have examined the frequency dependence of the $\alpha$ exponent in the case of the amplifying unit (8) shown in example 1 and operating at 13,56 MHz. The results are shown in Figure 8. The digitalizing frequency is represented on a logarithmic scale. We also indicated the graph of the correlation values. It is apparent that when the digitalising frequency is substantially smaller than 13,56 MHz then the correlation is also smaller and we obtain a very poor $\alpha$ value. The explanation is that sampling rate is too small with regard to the frequency of the amplifying unit (8), hence it is possible that all sample values originate from nearly the same
phase while the values corresponding to other phases of the measured signal have been disregarded. It can be seen that over 10 MHz both the $\alpha$ value and the correlation becomes stable. We found 10 MHz sampling rate to give satisfactory results.

Naturally, the same applies for discrete measuring units (2) but in such cases the frequency of the measuring unit (2) itself has to be taken into account too.

Figure 9 shows the $\alpha$ exponents and correlation values for amplifying units (8) of different conditions. The $\alpha$ values are indicated as bar diagrams and the calculated values can be read off from the left hand side axis. The correlation values are connected and the values corresponding to each amplifying units (8) can be read off from the right hand side axis. The FFT was performed with a 10 MHz sampling rate. The left side bar and point correspond to the $\alpha$ and correlation value of a well operating amplifying unit (8). One may observe that $\alpha$ is close to (-1) and the correlation is approximately 1. The two other bars show the noise measurement results for two different, not tuned-in amplifying units (8). No. 1 amplifying unit (8) shown in the middle has a correlation value which is only slightly smaller than that of the well operating amplifying unit (8). The correlation of No. 2 amplifying unit (8) indicated on the right has a much smaller correlation value. The $\alpha$ exponent is smaller for each out-of-tune amplifying unit (8) in comparison with the tuned-in amplifying unit (8).

One of the possible applications of the measuring device (1) according to the invention is its integration into the system to be monitored (e.g. into the above appliances). By accomplishing continuous measurement and evaluation we are able to follow up the ageing process of the system. The extent of wearing and tearing can be observed from the change of $\alpha$, and as the system ages so the value of $\alpha$ moves away from a reference value taken at an early age of the system. Experimentally, we may specify an $\alpha$ value at which the inspection and servicing of the system is advisable. By observing the change of the $\alpha$ value in time, we may determine the trends indicating the breakdowns and wearing. On the base of the $\alpha(t)$ curve the date of the required service/maintenance can be forecasted. If abrupt and significant changes can be observed in the $\alpha(t)$ curve as compared to
the trend-like change – that is, the function has a jump discontinuity – this indicates a particular failure which in general is not in connection with the usual ageing process and requires instant servicing.

We need continuous measurement also for the specification of the unauthorized or unprofessional usage and tampering. The abnormal operation of the system is visible in the abrupt change of the \( \alpha(t) \) curve, and if no permanent damage has occurred, the value of \( \alpha \) returns to its original value (or approximates it) by restoring the system's proper operation.

With the help of the above described noise measurement abrupt system changes can be perceived allowing for detection of non-appropriate usage or sudden, unpredicted changes in the operating conditions. Naturally, any evolution, which has taken place suddenly and without a history (for example due to a non-operational, abrupt impact, unexpected event, mishandling factors, etc.) cannot be traced back with the present invention. However since these sudden errors are most likely to be due to other factors than normal, prescribed operation of the system (it is, they are due to new effects which formally did not play a role in the dynamical operation of the system), hence un-authorised, non-trained, unprofessional, illegal use can be detected, or such operational errors, which are caused by the handling personal when using the system in an incompetent way or altering the operating conditions unprofessionally. This method allows for the detection of tampering (unauthorised technical examination of the system) or unauthorised re-installation if any of the dynamical parameters have changed leaving a trace in the noise spectrum. Accordingly errors accompanied by a noise spectrum with sudden changes or without an appropriate noise history generally indicate mishandling/environmental/vis-major situations. These can be filtered out by observation and continuous control of the noise spectrum (e.g. collecting noise spectrum data regularly by means of a computer).

When using the noise measuring device (1) in design-development processes, we are able to determine the extent of equilibrium in the established complex system: if any of the dynamical partial actions or structural elements participate in the operation of unit with a higher dominance than in the ideal case of a system operating at an equilibrium with only a necessary redundancy, then
the noise spectrum deviates increasingly from the harmonic $1/f$, and the same is true also for the value of $\alpha$ regarding the expected (-1). By measuring continuously or intermittently the $\alpha$ value, the process according to the invention allows for the optimisation of planning.

Apart from development the noise measurement of the invention can also help in evaluating and installing the final equipment or system. During installation or reinstallation determining the $\alpha$ parameter could be adequate for the testing of the final assembly. If $\alpha$ value is sufficiently near to (-1), or if $\alpha$ has reached a predetermined value, meaning that we have succeeded in creating a system that can be regarded as ideal, then we can be certain of the proper global function of the whole of the system without having to check the constituting elements.

In certain cases the measuring device (1) can be remote controlled and can interact with the system by means of the actuating unit (6). Generally all systems have calibration parameters, which should be reset due to changes occurring during the course of operation. For example in Example 1 the amplifying unit (8) is tuned to 50 Ohm resistance, which is achieved by adjusting the position of a rotary capacitor and/or a potentiometer. However, during use, it might be necessary to tune the amplifying unit (8) to a different load, or to have it re-tuned (e.g. due to aging). The actuating unit (6) could be suitable for adjusting the rotary capacitor or the potentiometer. By carrying out the noise measurement of the invention at different positions of the rotary capacitor and the potentiometer, one can establish the most optimal $\alpha$ value this way the amplifying unit (8) can be tuned in automatically via the actuating unit (6). This tuning method can be remote controlled or pre-programmed and the procedure can be fully automated.

A further possible application is the control of renovation, improving, upgrading activity. Instead of changing equipment of high value and/or of restricted location/building/infrastructure they are usually renovated/up-graded. Similarly upgrading is an inherent necessity of electronic and high-tech development even in the case of smaller modern devices since it would be rather expensive to change the device so as to keep up with the pace dictated by the fast development rate. However the modules/components/appliances built in during renovation or upgrade are more modern than the parts they are substituting, might have
substantially better properties, meaning that substituting parts manufactured by technologies other than the original parts have to be built in. In the case of such replacements the compatibility of the components can present a considerable risk. The new part is compatible with regard to its form and compatible with the directly connected interface, however any hidden incompatibility problems will only show during the course of operation, maybe only after substantial damage has occurred. This is a serious problem increasing with the spreading of modern electric equipment made up from interconnected modules, with the creation of remote service technique and the demand for compatible modular structure. The noise measurement of the invention allows for the control of such complex systems and proper compatibility can be assured. By measuring the $\alpha$ parameter hidden incompatibility problems can be detected and corrected straight away. This is particularly important in the case of modular equipment (e.g. computers and peripheries) where compatibility has to be checked otherwise it could completely block the use of the system.

In the case of the examples presented here we examined the internal noise of the systems, that is, passive noise measurement was carried out. However, it is possible that the intensity of passive noise measurement is not adequate (particularly for systems operating under extra high noise suppression), and in this case we may "screen" the system by using active noise source. This means that an outer noise source is connected to the system, and the changes occurring in relation to the spectrum of the added noise is monitored by the noise measuring unit (1). If the system is not complex enough but has cyclic variables, then it will act as a filter in response to white noise, and can indicate the system's adequacy or operational faults with a special sample-test response. (See P. Szendro, G. Vincze, A. Szasz: Bio-response to White Noise Excitation, Electro- and Magnetobiology, 20:215-229, 2001). Similarly to what has been said, faults or near-faulty state can be detected from the noise spectrum.

The measuring device (1) according to the invention can be used to examine practically any kind of system releasing measurable signal during operation or on the effect of external noise source. In the above Examples we were measuring a voltage signal produced by an amplifying unit (8) and a water
cooler (14); we applied a Fourier transform; calculated the power density function; fitted a power function; and determined the $\alpha$ exponent. To make it more simple, we fitted a liner function on the logarithm of the power function, and the $\alpha$ exponent was obtained as the slope.

In case of electric appliances it is practical to measure the power input or output and examine it using the method according to the invention. It is however possible that depending on the actual application other signal would be carrying more relevant information with regard to the aim of the examination.

It can be said generally that one should preferably measure the signal, which is the most descriptive for the whole of the system (e.g. power consumption for a cooling device) or the signal that can be most effected by the introduction or possible introduction of a new component (e.g. testing during development, or upgrading or component replacement).

Example

We would like to up-grade a computer from PCBs (Printed Circuit Boards) and would like to estimate whether the planned up-grading would improve or degenerate the operation of the computer.

(1) Changing to consumer electronics with bigger consumption. First we examine the power consumption with the measuring device (1) in case of the original consumer, meaning that we measure the input power as described in the water-cooler's (14) example and calculate the $\alpha$ value characteristic for the system. We then replace the original consumer with the new one and find the new $\alpha$ value via the measuring device (1). Comparing $\alpha$ values obtained for the original and the new consumer we can decide whether it is worth to change the consumer.

If the new $\alpha$ value is closer to (-1) than the formal $\alpha$, then the global function of the computer has improved, in the opposite case it is advisable to try again with a different consumer.

(2) Up-grading the computer with a new video card. Since the video card doesn't have a substantial influence on the power consumption, therefore it would be difficult to determine the effect of the video card there from. On the other hand, the clock signal could change measurably when installing the video card, it is therefore more advantageous to measure the clock signal with the device (1) of
the invention. We can compare the $\alpha$ values obtained with and without the video card and see how the operation of the computer would change.

(3) We would like to find the video card most fitted to co-operate with the already assembled parts of the computer in the design-development stage. We measure the $\alpha$ value in the above described way for different video cards and we choose to build-in the one which gave the $\alpha$ value best approximating (-1) or an experimentally pre-determined ideal value.

In the case of non-electric systems the mechanical or other kind of signal is advantageously converted into voltage signal. For example in the case of mechanical signals known types of piezo-crystal means or stroboscopic signal converters could be used, or other effects accompanying the mechanic movement could be measured (e.g. gate examination, examining creep or displacement).

For example when testing bearings (annular, cone, ball and socket, etc.) known techniques seek to determine the characteristic frequencies, that is, detect any outstanding frequencies in the spectrum, which could indicate a crack in the bearings. Opposed to the known technique, the noise measurement of the invention allows for a global insight as to the state of the bearings by calculating one single parameter, which means a significantly faster, easily automated measurement and analysis. Any know measuring means designed for testing bearings can be used as the measuring unit (2).

We will now describe further possibilities of application, which, in combination with the above said information, will be easily put in practice by a person skilled in the art.

In Example 2 we have seen that $\alpha$ parameter of the amplifying unit (8) needing service depended strongly on the external conditions (that is, on the applied load at the output), whereas after maintenance the optimally functioning amplifying unit (8) had a stable $\alpha$ value independent of the external conditions. This is not only the case for amplifying unit (8). This phenomenon can be made use of in relation with any product to which the noise measurement of the invention can be applied. For example in case of mass production faulty products can be easily filtered from good ones by measuring the stability of the $\alpha$ value.
The noise measurement and noise measuring device (1) according to the invention is also suitable for health monitoring of buildings, for example after natural disasters such as earthquakes, tornados, landslides. The health monitoring may be conducted by applying artificial shocks via known vibration machines for example, and, like in the case of known health monitoring, by measuring the vibration of the structure. As opposed to the known examinations, we do not seek to detect outstanding signals (characteristic frequencies), instead we are monitoring any change occurred in the $\alpha$ value and determine there from the extant of damage caused in the building's structure. For this purpose initial measurement results should be collected beforehand. Such reference measurements are advantageously conducted before the opening of the building.

Health monitoring can be necessary in the case of practically any kind of equipment. As an example we may mention equipments where measuring the noise of the input power could be used to predict the health condition of the equipment like in the case of the water cooler (14). Such equipment can be a hard disk drive, PC, DC fan, TMP (turbo-molecular pump), RP (rotary pump), etc.. In case of electric circuit board elements it is usually recommended to measure the noise of the current flow or the voltage signal. Such is the case for LSI testers, which cannot be evaluated by electronic tester if some contaminants are adhered to the surface of the circuits.

The noise measurement and noise measuring device (1) according to the invention can also be used for examining biological systems. The aforementioned principles about long-term correlations apply to complex biological systems (such as human or animal body) just like to electric, mechanical, or other kind of non-biological systems. Biological systems are also capable of emitting different signals (e.g. physiological signals) and the noise (that is, the fluctuation) of such signals, similarly to the above-described systems, carries global information related to the whole biological system.

We will now describe some simple examples, from which further possibilities of medical or diagnostic application of the method or device according to the invention will be apparent to a person skilled in the art.
Example

Human/veterinary health monitoring by ECG.

In this case the biological system is the human (or animal) body and the output signal is the heartbeat, which can be measured in a known way via an ECG (electrocardiograph). ECG devices draw out the measured signal or transmit them in digital form, e.g. to a computer. In all cases the measured signal is transformed into a voltage signal, which can be easily coupled out. This electric signal is led to the input of the measuring device (1) of the invention, which can be the measuring unit (2) or even the Fourier analyser (3) performing the Fourier transform. The input signal will then be Fourier transformed by the analyser (3), after which we obtain the $\alpha$ exponent by fitting a linear function on the measured points represented on a logarithmic scale. By regularly repeating the noise measurement of the invention we can determine from the changing of the $\alpha$ value whether the general health condition of a patient is improving or worsening. If the $\alpha$ value moves closer to (-1) then the health condition is improving, if $\alpha$ moves away then it's worsening. It must be emphasised that the noise measurement of the invention will supply information on the patient as an entire biological system, thus through the noise measurement performed on the ECG signal information is not only obtained on the heart action but we are also able to detect the effects of internal changes which would not yet be recognisable in other ways. For instant, if we detect a significant aggravation in the patient's $\alpha$ value, then a general health examination can be recommended even if there are no complaints as yet, since the aggravation of the $\alpha$ value could predict developing illnesses. Similarly during the course of curing chronic illnesses regular noise measurement can help in determining whether the cure is effective even before any signs of improvement would be visible.

Similarly to what has been said before, the stability of $\alpha$ could be examined instead of watching out for changes in the $\alpha$ value. ECG measurements can be performed in different conditions (ECG at rest, ECG during exercise) to see the extent of dependency of the external conditions in the $\alpha$ value. As shown in the case of the amplifying unit (8) the $\alpha$ value of a well operating system is independent of the external load or conditions, that is, nearly constant. There are
24 hours ECG monitoring devices (Holter monitoring), which is attached to the examined person during the whole of the day. In the case of known examinations it is required that the examined person note his or her activities during the day, since this is needed in order to determine whether the measured ECG could be regarded as normal for certain activities. The obtained ECG has to be analysed with regard to the person's diary, which is a time consuming and often unnecessary task. Instead the 24 hours ECG monitoring device can be incorporated in the above-mentioned one-chip PC embodiment of the noise measurement device (1) according to the invention, which can calculate the $\alpha$ value with a given regularity. The person evaluating the ECG results would then take a look at the $\alpha$ values, and if the $\alpha$ values are found to have been approximately constant, then the examined person's good health condition could be affirmed without the need of further investigation of the ECG results.

Instead of using ECG any signal produced by humans or animals can be examined. Holter monitoring devices are also directed to blood pressure measurements, but gastric acid or urine can be equally examined. There are numerous medical diagnostic devices that can be used by a person skilled in the art for measuring and converting different biological/physiological signals into voltage signals. It is possible for example, to perform noise analyse on breath or pulse rate.

A wide range of possible examinations is available. For instance, it is possible to analyse the measurement results of brain cell activity or splanchnic or other activity. For example brain cells can be illuminated by near infrared light and the measured reflected optical signals are suitable for examining the brain activity. An $\alpha$ value significantly differing from (-1) indicates sick brain activity.

However, totally different kind of "signals" can equally be measured, like comfort rate (hunger, needs, etc.) due to lack of treatment in case of elderly people can also form the basis of the noise measurement of the invention. A known measurement consists in measuring the rate or length of strides during walking, the noise of which can also provide the $\alpha$ exponent.
Example

Special applications are also possible, such as monitoring the health condition of an automobile driver during driving. A 24 hours ECG monitoring device can be used in this case too, but less disturbing measurements are also available. For example it is possible to detect the eye movements of the driver via a camera recording every movement of the iris as a noise-spectrum. Such devices are available and are easily modified by a person skilled in the art in such a way that the electric signals of the device can be evaluated according to the invention. The obtained $\alpha$ values can be used to determine if the driver is tired. With appropriate personal calibration a threshold $\alpha$ value can be determined, which when reached means that the level of alertness is not adequate anymore and that the driver should preferably stop for a break.

Weariness can also be detected from measuring the miographical signs (muscle-electric signs) of the hand/leg/body, which measurements are known to a person skilled in the art, and which can be analysed similarly. An effective way of measuring weariness can consist in stimulating the driver to react actively and examine the response. The stimulus can be artificial (constraint to act according to a given signal) or natural (order of movements when taking a road bend). The noise measurement can consist in examining the reaction.

Similar methods can be applied for determining weariness/sickness/age of moving life beings, including the method of noise measurement performed on a pre-chosen detail of a high-resolution video recording.

Similar to the case of examining the reaction to an exterior stimulus of a driver the reaction and the reaction's relaxation of humans or animals can be examined in other fields too. The measuring of this type of physiological signals and converting them into electric signals is also known from the art, thus the noise measurement of the invention can be performed on the obtained electric signals. Instead of physiological measurements pH or other chemical measurements can be suitable too, the noise of which can be examined as described above.

It can be stated generally that the possible measurements for practically any kind of systems are nowadays performed with devices having sensors registering all happenings (be it of mechanical, chemical, biological, cosmic,
electromagnetic, nuclear, etc. nature) and convert them into electric signals, the device being directed to the analyse of such electric signals. In case of parallel input information these are sorted according to certain considerations and are analysed, stored and displayed accordingly (e.g. video recording). The measuring device (1) of the invention can be best applied when an electric signal is already at hand. The specific appliance converting the measured signal into electric signal can depend on the application, and will be apparent from the present description to the person skilled in the art, he will then be able to choose an adequate appliance and make minor modifications if necessary in order to couple out the electric signal and to conduct it to the measuring device (1) of the invention. It is important that the appliance used for the measurement should have an output, that is, it should be possible to transmit the information in electrical form for further processing. A group of embodiments of the measuring device (1) according to the present invention incorporates a known measuring means which has been modified so as to transmit the electric signal of the measuring means to the analyser (3) performing the Fourier transform (which can, as seen above, be incorporated in a computer (4) or any other digital signal processing unit). In this case the modified measuring means can substitute the measuring unit (2), however in certain cases a unit for receiving the electric signal can be used to connect the measuring means with the analyser (3), or in certain cases the measuring unit (2) can perform this function.
<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>noise measuring device</td>
</tr>
<tr>
<td>2</td>
<td>measuring unit</td>
</tr>
<tr>
<td>3</td>
<td>analyser</td>
</tr>
<tr>
<td>4</td>
<td>computer</td>
</tr>
<tr>
<td>5</td>
<td>display unit</td>
</tr>
<tr>
<td>6</td>
<td>actuating unit</td>
</tr>
<tr>
<td>7</td>
<td>power supply unit</td>
</tr>
<tr>
<td>8</td>
<td>amplifying unit</td>
</tr>
<tr>
<td>9</td>
<td>pre-amplifier</td>
</tr>
<tr>
<td>10</td>
<td>RF amplifier</td>
</tr>
<tr>
<td>11</td>
<td>power supply unit</td>
</tr>
<tr>
<td>12</td>
<td>load</td>
</tr>
<tr>
<td>13</td>
<td>interface</td>
</tr>
<tr>
<td>14</td>
<td>water cooler</td>
</tr>
<tr>
<td>15</td>
<td>water pump</td>
</tr>
<tr>
<td>16</td>
<td>Peltier batteries</td>
</tr>
<tr>
<td>17</td>
<td>object</td>
</tr>
<tr>
<td>18</td>
<td>internal measuring unit</td>
</tr>
<tr>
<td>19</td>
<td>power supply unit</td>
</tr>
</tbody>
</table>
CLAIMS

1. Measuring device for measuring and evaluating the signal of a system releasing a measurable signal during operation or on the effect of external excitation, which device contains a signal receiving unit and an output unit, characterised in that it also contains an evaluating unit adapted for performing Fourier transform on the time dependant signal captured by the receiving unit, for calculating the power density function of the Fourier transform, for fitting a power function having a exponent on the power density function, and for transmitting the obtained a exponent to the output device. Measuring device according to claim 1, wherein the evaluating unit includes a fast Fourier transform analyser (3).

3. Measuring device according to claim 1 or 2, wherein the signal receiving unit is a measuring unit (2) capable of registering the system’s voltage or current signal, or converting the system’s signal into voltage or current signal.

4. Measuring device according to claim 1 or 2, wherein the signal receiving unit is a voltmeter connected to an external unit capable of converting the system’s signal into voltage signal.

5. Measuring device according to claim 1 or 2, wherein the signal receiving unit is capable of converting the system’s mechanical, optical, biological, chemical, nuclear or other physical signal into an electric signal.

6. Measuring device according to claim 3, wherein the measuring unit (2) measures the input or output power of the system.

7. Measuring device according to any of claims 1 to 6, wherein the evaluating unit is part of a PC, a one-chip PC, a microchip or a micro-controller.

8. Measuring device according to any of claims 1 to 7, wherein the output device is a unit (5) for displaying the obtained a exponent.

9. Measuring device according to any of claims 1 to 7, wherein the output device is an actuating unit (6) adapted to act upon the system in a way depending from the obtained a exponent.
10. Measuring device according to claim 8, wherein the display unit (6) is a screen capable of displaying the power function and/or exponent and/or other calculation values calculated by the evaluating unit.

11. Method for measuring and evaluating the signal of a system releasing a measurable signal during operation or on the effect of external excitation, where the system’s time dependant signal is captured by a signal receiving unit, characterised in that we perform the following steps by means of an evaluating unit: Fourier transforming the captured signal, calculating the power density function of the Fourier transformed signal, fitting a power function with a exponent on the power density function, and transmitting the obtained a exponent to an output unit.

12. Method according to claim 11, wherein the system’s signal is measured by means of the signal receiving unit and in certain cases the signal is converted to voltage or current signal.

13. Method according to claim 11 or 12, wherein the signal captured by the signal receiving unit is fast Fourier transformed by the evaluating unit.

14. Method according to any of claims 11 to 13, wherein the evaluating unit plots the power density function of the Fourier transformed signal on a logarithmic scale, fits a linear function on the plot and determines the a exponent as the slope of the linear fit.

15. Method according to any of claims 11 to 14, wherein we determine an optimal a value for the system.

16. Method according to claim 15, wherein in the course of determining an optimal a value the measuring method is conducted for different values of the system parameters, and the parameter (or set of parameters) is chosen, which corresponds to the a value best approximating the (-1) value of an ideal complex system.

17. Method according to any of claims 11 to 16, wherein certain parts of the system are changed or replaced and the a exponent is calculated for each system variation, the obtained a values are compared with an optimal a exponent predetermined for the system, or an a value measured beforehand, or with the (-1) value of an ideal complex system, and it is determined from the comparison
whether the system has improved or worsened, this information to be used for controlling maintenance work, up-grading, general renovation, design-development or installation.

18. Method according to any of claims 11 to 16, wherein the measurement is repeated with different working conditions/external conditions and change in the $\alpha$ value is examined, and an improvement or worsening of the system is determined from the stability of $\alpha$ during the course of maintenance work or wearing and quality tests, or for predicting system faults, or for controlling up-grading, general renovation, design-development or installation, or for detecting unprofessional or unauthorised use, or for general health monitoring.

19. Method according to any of claims 11 to 16, wherein measurements are carried out on the system at different times and change in the $\alpha$ value is examined comparing the obtained $\alpha$ values with each other or with an optimal $\alpha$ value predetermined for the system and an improvement or worsening of the system is determined from the result of the comparison during the course of maintenance work or wearing and quality tests, or for predicting system faults, or for controlling up-grading, general renovation, design-development or installation, or for detecting unprofessional or unauthorised use, or for general health monitoring.

20. Method according to any of claims 11 to 16, wherein mechanical, optical, biological, physiological, chemical, nuclear or other physical signal of the examined system is converted into an electric signal and measured.

21. Application of the measuring device according to any of claims 1 to 10 during the course of maintenance work or wearing and quality tests, or for predicting system faults, or for controlling up-grading, general renovation, design-development or installation, or for detecting unprofessional or unauthorised use, or for general health monitoring.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
GOIR29/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
GOIR H04L GO1M GO1N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
</table>
| X        | US 5 888 374 A (POPE ET AL)  
30 March 1999 (1999-03-30)  
figure 2A  
abstract  
column 2, line 5 - line 45  
column 4, line 8 - line 64  
column 6, line 20 - column 7, line 11  
claims 1,7,8 | 1-21 |

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents:

A: document defining the general state of the art which is not considered to be of particular relevance
E: earlier document but published on or after the international filing date
L: document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
O: document referring to an oral disclosure, use, exhibition or other means
P: document published prior to the international filing date but later than the priority date claimed

T: later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
X: document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
Y: document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

* Document member of the same patent family

Date of the actual completion of the international search: 3 February 2006
Date of mailing of the international search report: 13/02/2006

Name and mailing address of the ISA
European Patent Office, P.B. 5618 Patentboulevard 2
NL - 2280 HV Rijswijk
Tel: (+31-70) 340-3040, Tx: 31 651 apnl, FAX: (+31-70) 340-2016

Authorized officer: Höller, H
<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>WO 02/095633 A (SIMMONDS PRECISION PRODUCTS, INC) 28 November 2002 (2002-11-28) figures 1,12,18B,24B-24G abstract page 3, line 1 - line 11 page 25, line 13 - page 26, line 15 page 37, line 21 - page 42, line 10 claims 81,82,84,89,91,94,97,99</td>
<td>1-5,7, 10,21</td>
</tr>
<tr>
<td>A</td>
<td>US 5 774 379 A (GROSS ET AL) 30 June 1998 (1998-06-30) figures 4A,4B abstract column 4, line 37 - column 9, line 37</td>
<td>1,11,21</td>
</tr>
<tr>
<td>A</td>
<td>US 6 779 404 B1 (BRINCKER RUME ET AL) 24 August 2004 (2004-08-24) abstract column 2, line 56 - column 9, line 44</td>
<td>1,11,21</td>
</tr>
<tr>
<td>Patent document cited in search report</td>
<td>Publication date</td>
<td>Patent family member(s)</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>-----------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 1390739 A2</td>
</tr>
<tr>
<td>JP 2004215854</td>
<td>05-08-2004</td>
<td>NONE</td>
</tr>
<tr>
<td>US 5774379</td>
<td>30-06-1998</td>
<td>NONE</td>
</tr>
<tr>
<td>US 6779404</td>
<td>24-08-2004</td>
<td>AT 296440 T</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AU 1131201 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE 60020399 D1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WO 0133182 A1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 1250579 A1</td>
</tr>
</tbody>
</table>