The Global Analysis of the Electromagnetic Disturbance Phenomena With Electronic Programmable Equipments Used in Computer Control Systems

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Abstract: It is well- known that best performances of Computer Control Systems can be annihilated by the effects of electromagnetic disturbances; even more , they can induce faults and accidents, unless suitable measures of identification and protection are taken.
This paper presents a method and a software technology of the sensitivity **self-testing** of computers used in Computer Control Systems, to electromagnetic disturbances **in general**, that usually applies to any electronic programmable equipment. Based on an analysis and prediction model of statistical dynamics - the **Burg-Levinson model** -, the proposed method comes to support the tests made on computers' behaviour to electromagnetic disturbances, and give them a way to the disturbances sensitive subsystems , **having important roles in saving test time, the testing devices and the costs involved here.**

Keywords: Autotesting, Electromagnetic Compatibility, Electromagnetic Disturbance, Perturbative Pollute, Time Series, Stochastic Process, Electromagnetic Interference

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1. The Problem and Its Importance

The authors have carried out a minute investigation of the electromagnetic disturbative interferences with electronic equipments and, especially, with electronic computers. The results of a ten-year investigation show that, except for some theoretical characterizations of each type of disturbative phenomenon, based on the electromagnetism laws, there exists no general theoretical background allowing an unitary and systematic approach of such phenomena as a whole.

Given such a finding, and aware of the literature[1] dedicated to the domain, the authors proceeded on considering electromagnetic disturbances in general, and their effects on the programmable equipments as typical random processes, in particular. So a proper analysis method was needed and it was statistics which provided it, i.e. the analysis and prediction method of time series. According to this the disturbative process evolution is viewed as a sequence of data to be

[1] INSR (France, 1985) conducted a study on an important number of programmable equipments(robots). It pointed out that no one of many attempts could be identified as actually simplifying the procedure for getting general information .

collected at different time intervals called time series [3], [6], [7], [8], [9].

Consequently, it has been considered that the most suitable analysis of the random disturbative effects would be the analysis method associated with time series.

This explains why the BURG-LEVINSON model of analysis and prediction has been chosen [1], [2], [4], [5].

This model analyses several time series generally reached as a result of self - testing of the sensitivity to electromagnetic disturbances (called ED) of some microcomputers manufactured in Romania (TPD, CUB-Z), based on the Z 80 microprocessor.

The ANASER software package, based on the AR BURG-LEVINSON algorithm, was used.

2. Data Acquisition

The sensitivity to electromagnetic disturbances, and respectively, the level and capacity which an electronic computer - as the main component in Computer Control Systems - and, generally, an electronic programmable equipment has for coping with the disturbances energy, make essential information on practically evaluating such equipments' performances.

The sensitivity to disturbances testing of these equipments should be reorientated.

For some two years (1987-1989) the authors could realize, through sampling a number of computing and peripheral equipments' manufactured in Romania, and through some systems based on such equipments, that the EMC(EMI)[2] problem had hardly been dealt with, the specialists' only concern being to make these equipments comply with the European Standards relative to radiation fields.

Under such circumstances, it was conceived and tested a software technique and technology for self-testing the microcomputers' susceptibility to disturbances , which, without giving up proper measurements, could bring about some very useful information on the weakpoints of such equipments.

This technique means:

1.The use of a software package specifically developed for self-testing the microcomputers' sensitivity to ED (electromagnetic disturbances) and for obtaining the characteristic time series.

2.The time series analysis by the ANASER software package (developed at the Territorial Computing Centre in Constanta in 1987), based on the BURG-LEVINSON algorithm.

3.The sensitivity to disturbances evaluation of the testing equipments, based on the information and diagrams at hand as well as on the prediction of such a behaviour.

The following will be an attentive view of each of the three points:

1.The software package has been conceived with a view at the self-testing sensitivity . It includes the following modules:

- the TRAP program for self-testing of the microcomputers' interruption system under ED condition by wire and fields;
- the UC program for self-testing of the central unit processor under perturbative conditions;
- the MEM program for self-testing of the internal memory;
- the FD program for self-testing of floppy disk units.

The programs have been written in a macroassembler language under the CP/M OS. They test the Z 80 (JUNIOR, CUB-Z, TPD) microprocessor based microcomputers. These microcomputers were manufactured by the Peripherals' Equipments Factory in Bucharest and Computer Manufacture Factory in Bucharest.

The used techniques consisted in the introduction of some traps to reveal the parasite interruptions caused by an ED by wire and radiation, which affect the under testing equipment.

Thus, an undesired ED occurs, and the IS (interruption system) alarms the CU (central unit) of the system which interrupts the running program. An automatic jump is addressed to one

[2] ElectroMagnetic Compatibility (ElectroMagnetic Interference)

of the breakoff routines, corresponding to the 8 levels of interruption (0-7) of the microcomputer.

Here the most important element is the zero level (the real time clock).

Then the IS is automatically turned down.The jump address is to be found on the INTBL Table of the OS, meant for the interruptions control.

The TRAP program will readily introduce routines' address in the INTBL table for dealing with the parasite interruptions, with the turned down operating system, and for preventing new interruptions.

When such an interruption occurs, there is addressed one of the RITN0-RITN7 processing routines included in the TRAP program.

The routines' functions are the following :

a) to save the general A, B-C, D-E, H-L registers and the indices in the stack conditions;
b) to increment the counters at each parasite interruption turned up at one level (named CIT0-CIT7 in the program);
c) to display, after the counters incrementation, a message about the level and number of parasite interruptions during a time period.

After signalling an interruption , the interruptions' routines get the IS reinforced and run it for signalling a new interruption.

The program also involves an additional routine for the data binary-decimal conversion for display purpose.

The eight levels of interruptions correspond to the following interruptions:

- the 0 level -the timer system of interruption;
- the 1-st level-the USART receiving interruption;
- the 2-nd level-the display interruption;
- the 3-rd level-non-operational;
- the 4-th level-the punched tape reader interruption;
- the 5-th level-the keyboard interruption;
- the 6-th level- non-operational;
- the 7-th level-the floppy disk unit interruption.

Separating the OS parasite interruptions from the normal ones, i.e. those for data access on terminals, is only feasible by a program looping, so that the single interruptions which come up should be parasite interruptions.

The TRAP program is correlated with a C: nnn switch, which has two working modes:

a) recording the EMI effects noticeable over a certain time period under the sample forms of "nnn" quanta;
b) displaying a protocol with the recorded data.

The **UC program** has been developed in order to test the correct operation of the machine code instruction system of the main groups:

- the 1-st group- transfer instructions on byte;
- the 2-nd group- transfer instructions on two bytes;
- the 3-rd group- arithmetical instructions;
- the 4-th group- logical instructions.

This program works in the loop ,automatically going from one instruction to another and from one instruction group to another; and then coming back to the first group.

The **MEM program** has been created with a view at testing the internal memory right functioning under ED conditions, in general . It can also work in loop and in the "write-check" regime.

Thus, the program writes in the memory some different sequences of binary configurations and next checks on the correctness of writing for all binary positions of a byte. The possible inconsistencies discovered are displayed in an "nnn" number form, as already shown.

The **FD program** writes the fixed configurations of bytes on a diskette (a sector for example), on the extreme or the middle tracks, it "reads" these configurations and compares them, also displaying their possible inconsistencies in the "nnn" number form.

Provided that some ED should turn up and affect the normal operation of a computer, the system will display, by the above described mechanism, an error message of the following type:

> << Parasite breaking of "nnn" level>>
>
> << Reading-writing inconsistency: the expected area/the found area>>
>
> << Executing error instruction, the group : "g">>.

By acting the real time clock of the microsystem, the error messages get limited and time is pointed out from 60 sec to 60 sec.

These limits have been set by the necessity for data acquisition on the tested system response to disturbances, during the considered time period.

These data are time series which are subject to statistical analysis. They represent the tested system response to the general environmental electromagnetic disturbances.

It should be mentioned that the acquired data have no physical significance with respect to a certain type of ED which could affect the microcomputer, but they indirectly express the system sensitivity by the frequency which the "victim" responses to ED with; this technique certainly is a qualitative one.

Using this technique does not necessarily mean that the current measurements and tests for estimating the system sensitivity to ED, are given up.

Under certain conditions, an evaluation of the system behaviour during the whole ED interval may be sufficient for the problem to be solved. In other cases, as shown above, both techniques can be used; this paper proposes a less expensive and simpler technique, yielding very useful information in the experts' behalf; by means of this information, measurements and tests can be directed to the most sensitive to disturbances subassemblies.

3. Data Analysis

In 1987, Territorial Computing Centre in Constanta developed the ANASER software package. It was used in carrying out an automatic analysis of time series, deduced from the sensitivity self-testing of all electromagnetic disturbances of microcomputers.

This software package has the following functions:

a) the polynomial trend testing and its removing;
b) the cyclic component testing and its removing;
c) the analysis of the random component.

This analysis consists in:

- the model parameters calculation;
- the model order calculation;
- the self-correlating function calculation;
- the spectral density function calculation;
- the white noise evaluation;
- the model entropy calculation.

Model parameters estimation was based on the Maximum Likelihood (ML), and the optimum model order was based on the Akaike Information Criterion (AIC).

By calculating the model entropy, there will be found out the model reliance. Thus, the larger the number of entropy diagrams, either null or near terms, is, the greater the reliance on the model becomes, and respectively, the greater the model relevance is. The ANASER software package includes the following modules:

- TREND-for calculating and removing the polynomial trend;
- CYCLIC-for calculating and removing the cyclic component;
- BURG-for analysing the model residuals;
- SPECTR-for calculating the spectral density function;
- FUNCTOR-for calculating the correlating function, and the self-correlating function;
- CALMED-for calculating the media value, the variance and the standard deviation of data;

- GRAPHIC-for the graphical representation of the initial time series and of the stochastic component of the series (remaining after having removed the polynomial and cyclic components), of model residuals series, as well as of some statistical data, such as trend, cyclicity, self-correlation, spectral density, etc.

The obtained information and graphics allow a statistical analysis of the data involved (the corresponding time series). Thus, very important conclusions can be drawn on the susceptibility to ED of the under test equipments, as well as of their subassemblies.

Important decision-making will be enabled such as:

- the equipment replanning, respectively, the equipment zero series remanufacturing;
- a strategy for carrying out the most precise measurements and tests.It features technical (the direction to certain subassemblies, for instance) and economic (the reduction of the measurements number, or the reduction of the measuring devices, for example) advantages;
- a prediction on the complexity and the price of cost of the protective means under disturbative conditions, with all the advantages the equipments' users might have;
- a short or average time prediction on the disturbative process evolution.

The proposed also takes into account the self-disturbance of the computing equipments because of a switching in supply sources.

4. An Application

With a view at proving the analysis technique and technology of the computer sensitivity (suscept.[illegible]ility) to ED **in general**, in an operational environment, there have been carried out some large scale experiments in seven industries in Constanta.

The sample industries have different production layers: naval mechanics, shipyards, public transport with trams and trolley-buses, milling and bakery, pulp and paper, rubbers' and plastics' processing. On testing all these industries worked at their full capacity.

The benchmark consisted of two TPD microcomputers based on Z-80 microprocessor, of 25 Mhz oscilloscopes (E0109-IEMI Bucharest), digital frequency meters (E0502-IEMI Bucharest), 10Hz-100Khz passage frequency distortion meter (E0706-IEMI Bucharest).

Two minisystems having the same type and manufacture series and version need be used for a comparative validation of data and for making sure that the data to be processed are not erroneous data produced by a breakdown in the computer system under testing .

Power supply was mainly from the power boards of the main production sector. This made it possible to record the highest level of ED which propagated through conduction. For the same reason, the galvanic connection between the grounding screw of every microcomputer and the grounding circuit of the corresponding electric board (panel) was effected.

Some important disturbances could enter the system through the grounding connection.

In order to take grasp on tops of charges, measurements were purposely carried out from 9:00 a.m. to 1:00 p.m.

Switching on and off manoeuvres of the capacitors' batteries in all the industries should be done for ameliorating the power plant, and for setting up proper conditions of the distortioning regime.

Whenever possible, some start/ stop/ switch of the direction, as well as variations in the technological quipments' charge led to obtaining important and different transient regimes.

During measurements, the distortion factor of tension was of 4 to 9 percent.

Two of industries also determined the current distortion factor , this one raising to 25 percent values in the case of the power stations redressors for trams and trolley-buses, or in the case of high power ovens with spring(1- 1.5 Mw). Loop programs presented a lot of errors when there was a transient behaviour due to driving facilities or there was a switching on/off of the capacitors' batteries for improving the power factor and filtering the harmonics.

As concerns the disturbances through radiation fields (far fields), it has been evaluated that their level of propagation is quite high at the seaside because of the great number of civil and military radio transmission stations, as well as because of their important power.

In some industries (such as Shipyards), the radio disturbances have been enhanced by portable radio-telephones, frequently used.

Tests were accomplished under the following conditions:

- a variation in the power tension frequency of 46.8 to 48.8 Hz;
- a variation in the distortion factor of tension of 4 to 9 percent, as already shown;
- air temperature was between 22^0 C and 28^0 C, being in the prescribed limits given by the computing equipments' manufacturer ($15\text{-}35^0$ C);
- air humidity was between 62 and 67.2 percent, also observing the maximum prescribed limit ;
- the level of the mechanical vibrations was below 8 Hz, thus being within the prescribed limits given by the manufacturer .

It has been found out that the interruptions observed with the computers running in loop testing programs, were due especially to ED.

The following could be noticed:

- The TPD (JUNIOR and CUB-Z also included) microcomputers' sensitivity to ED in general. Interruptions in microcomputers' operation frequently pointed to errors with random distribution in the testing programs
- The number of signalled errors significantly increased in the power tension frequency variations of above 0.5 Hz (one percent) and also in the distortion factor variation of the tension wave.In the case of disturbances by radiation fields, the number of disturbances increased as well.
- The largest number of errors was signalled by the TRAP program and the least one-by the UC program. The FD program signalled a relatively important number of interruptions.
- Generally, the TRAP program signalled errors, on both interruption system dedicated levels, and the breakoff levels, usually non operational.

The most affected levels were those with 5 (keyboard interruption) and 7 (interruption of floppy disk units) numbers.

5. The Analysis of Time Series

In the following the reported technology is applied to one of the time series, yielded by the tests done at the Milling and Bakery Factory in Constanta . The data subject to such an analysis, cover the number of minute -by -minute signalled and recorded errors in a time period of 55 minutes. One of the two microcomputers on the benchmark is used.

The data reveal that parasite interruptions mainly affect level 5 (the keyboard interruption). The data sample for this level represents the chosen time series for a statistical analysis supported by the ANASER software package.

Given the essential role of a keyboard on a process computer, it is easy to understand the process control problems when an intensive disturbative pollution is suffered by such a microcomputer.

The automatic analysis and calculation results are referred in the following.

The time series subject to analysis involved 55 values, and is presented in Figure 1. The maximum order of the autoregressive model has been chosen as being 9.

The automatic analysis consists of:

- computation of the main statistics of the original time series: mean value, variance and standard deviation;
- evaluation of the polynomial trend of time series and its removing;
- estimation of the cyclic component of the series and its removing;
- the cyclic component period resulted to be of 3 minutes;
- selective evaluation of the correlating function;
- computation of the autoregressive model coefficients from the 1-st order to the 9-th order;
- choice of the optimum model by AIC; an autoregressive model of the 3-rd order does result.

The final model form is:

- $y(t) = 0.34252y(t-1) + 0.06160y(t-2) + 0.34907y(t-3) + e(t)$.
- computation of the spectral density of the model residuals, and of its logarithm for simplifying the graphical representation, respectively;
- estimation of the model maximum entropy, for determining the interval of its reliability (the test of relevance).

The initial time series' statistical analysis points to:

- a non- important polynomial trend
- a cyclic component (of 3 min.), as seen in Figure 2. This disturbative phenomenon, as the technological process analysis shows, is due to the periodical running of some fuel burning converters (220/15000V) at bread baking ovens; stopping the converters' supply leads to this component removing. Once the cyclic component removed and the series centred, Figure 3 presents the random component of the series
- the calculus of the correlating function for the model residuals e(t) shows that this can be approximated by a white noise, so that the proposed model should be checked; this is also shown in the spectral density diagram (Figure 4 and Figure 5).

The entropy diagram certifies the fact that the chosen model is a relevant one, its air resting at near zero values for most of the series terms (about 80 percent) (Figure 6).

6. Conclusions

The analysis method is the result of global ED with microcomputers. The proposed software technology presents two major advantages:

a) it can quickly point out the susceptibility to ED of a computer, or of its sub-sets (internal memory, disks units, central unit);

b) it can orientate the measurement, which is the only investigation technique used today.

This method can ideally be coupled with the measurements' method, the latter being the only method currently used. Both methods support analysis at any desired level. In some cases, the application of the proposed method can even make measurements be given up.

Thus, before installing an electronic computer,either an individual one, or an embedded one in a supervisory and control system, , it is highly recommended that a "map" of the ED propagation in a given place, is drawn up. **The self-testing method of the sensitivity , with all its advantages, will certainly support this action**, otherwise impossible by means of measurements.

But the proposed method can also provide information about some disturbances. The example at Milling and Bakery Factory is very suggestive: identification of the disturbances' sources with a three- minute periodicity in fuel burning converters of the baking ovens.

The disturbative phenomena analysis, the analysis of the system's response to ED respectively, is also relevant.

Using some transducers and interfaces, let even non-programmable equipments benefit the intercorrelating techniques.

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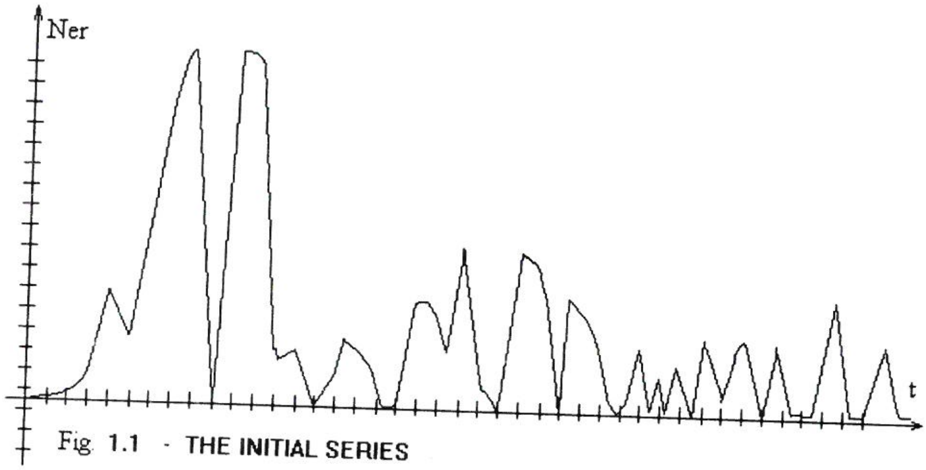

Fig. 1.1 - THE INITIAL SERIES

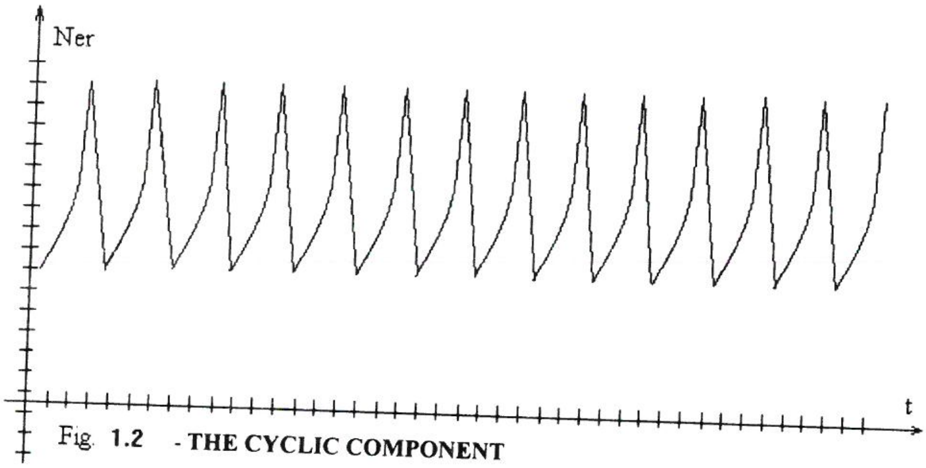

Fig. 1.2 - THE CYCLIC COMPONENT

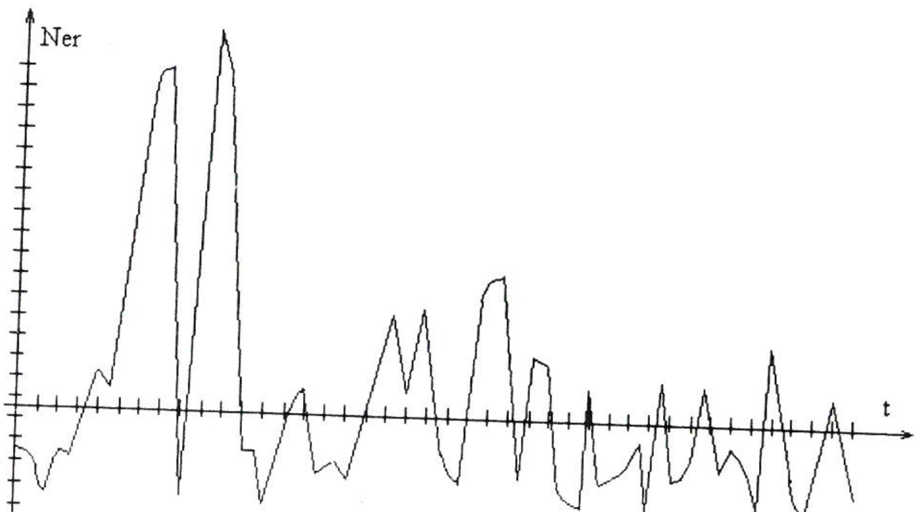

Fig. 1.3 - THE TIME SERIES SUBJECTED TO THE ANALYSIS

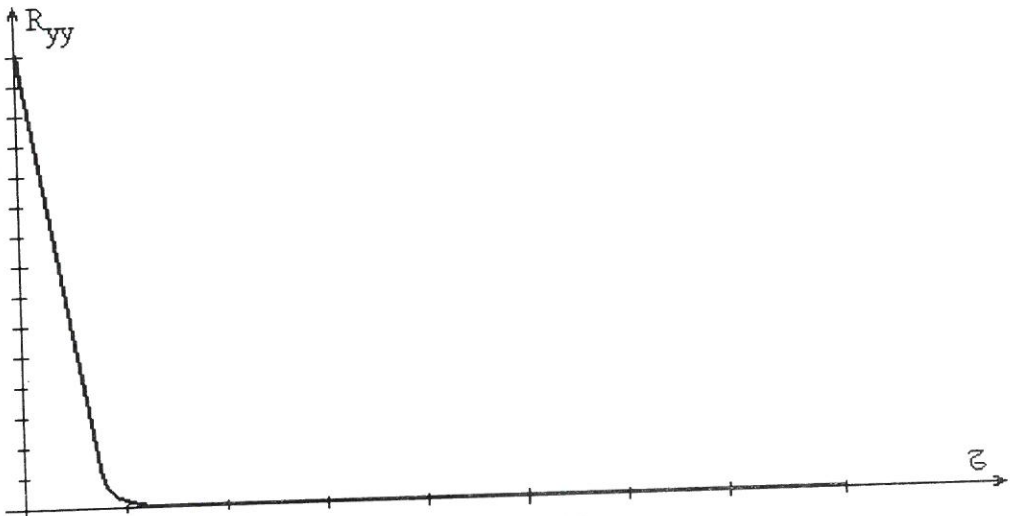

Fig. 1.4 - THE CORRELATION FUNCTION

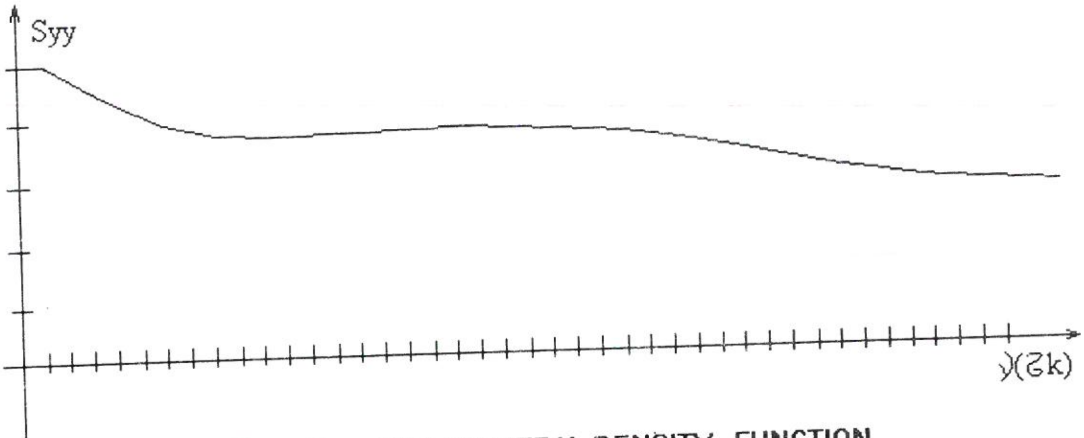

Fig. 1.5 - THE SPECTRAL DENSITY FUNCTION

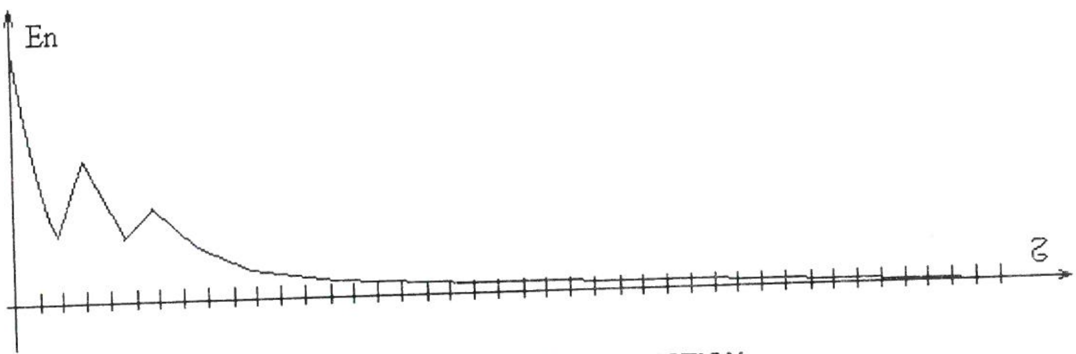

Fig. 1.6 — THE ENTROPY FUNCTION