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ACTIVE NOISE REDUCTION AS AN EXPERIMENTAL APPLICATION OF THE GENERAL SYSTEM THEORY

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INTRODUCTION

Active Noise Reduction (ANR) is a relatively new theme of research in Acoustics. The purpose of the present paper is to show how ANR has been influenced, implicity a little more than explicity, by some very general concepts belonging to or connected with a permanent trend of thought now known as the "General System Theory" (GTS). The effects of this interaction are yet in expansion and lead even now to new suggestions for future work and developments in ANR and its sister theme in mechanics : Active Vibration Damping (AVD). In another field of Acoustics, external to Noise Control, they resulted in "holophony" which is a very promising extent of stereophony.

A REMARK ON THE HISTORY OF ANR

ANR started in the years 1932-36 with Paul Lueg's patents. A good account of the early work and the present state of the art in ANR can be found in G.E. Warnaka's paper, in which he quotes 75 references on ANR. Another paper with an extensive bibliography is G. Mangiante's article in the Journal of the Acoustical Society of America, with 85 references for the period 1936-1977. But if one accounts also for any kind of publications on ANR, including articles in newspapers, reports and abstracts for technical or scientific meetings, notes or communications in less wide circulation, one may attain a number of about 300. The distribution of them as a function of time would not, however, differ substantially from that shown in Warnaka's paper. Fig. 1 gives a graph where Warnaka's statistics is completed by Mangiante's references. The main conclusion remains unchanged : a strong development of the publications is observed from 1968. This starting point can be identified with the appearance of a really new scientific approach of ANR, while the period 1932-68 would be that of an empiric or pragmatic approach without a convenient leading theory.

THE THEORETICAL BASES OF ANR

There exist many different ways for a scientific approach to ANR. The Soviet acousticians use, since at least 1970, Malyuzhinets' method, based on a new interpretation and application of the well-known Helmholz-Kirchhoff formula, which is a mathematical translation of Huygens' principle. Swinbanks' method, for ANR in a waveguide, consists of computing the radiation of two sets of sources and studying the conditions under which these two sets may cancel a given primary wave everywhere along the dowstream part of the guide, while radiating a zero wave upwards.
Malyuzhinets' method is valid only for waves obeying the Helmholtz or Dalembert equations. Swinbanks' method is valid only for guided waves. But there exists a much more general approach, whose main results are independent of the physical nature of the wave or the radiated field, i.e. independent of the precise expression for the wave or field equations, of the number of dimensions and of the shape for the domain where the field or wave is to be confined. Applied to acoustics, this method may be called the JMC method, after the names (Jessel,Mangiante, Canévet) of the first three pioneers who used and verified it in various applications. The JMC approach starts with a general theorem that may be called the "commutator lemma". Hereafter it will be shown in enlarged form, as a theorem of "modification" which indicates how, by what means, may be obtained any well specified modification of a given field or wave distribution.
In spite of the fact that the results of the JMC theory have been published without reference to any epistemological background, such a basis has been really very important in setting up this method.
In fact, an explanation of the connection between epistemology and the JMC method will also help to answer some important questions raised by G.E. Warnaka in his paper on the state of the art in ANR. This explanation will take place with the help of the general system theory.

THE GENERAL SYSTEM AND ITS MOST CHARACTERISTIC FEATURES

Systemics is now the name of the science that studies the general System Theory in its various aspects : cybernetics, information theory, theory of games, topology, theory of categories and so on ...
As for the nature of the systems that are of interest for GST, there is no restriction, but it is important to underline that GST is most helpful for open systems, and especially for those where the entropy is not increasing but decreasing, as in living systems.
Systemics tries to cope with complexity. Complexity is encoutered in biology, in sociology, but also sometimes in physics and in engineering. Traditionally one went from the simplest to more complex, but in GST one goes from the most complex, the whole universe, to the simplest. Among other noteworthy pecularities of GST, there is goal seeking by purposeful behaviour, which is an inversion of the common way of analysis and causality : instead of deducing the effects from the given

causes, one tries to discover the causes i.e. the means that can lead to a given result. This "means and end analysis" may in fact be used in an alternation with the conventional causal approach. Such an alternative procedure minimizes the number of trials needed for attaining a given goal and ought to reduce substantially the costs of research.

THE THEOREM OF "MODIFICATION"

Suppose we have a set of primary sources S' (initial or boundary conditions may also be primary sources). These S' may be taken as the input of a processing system $\mathbb{P}$ whose output will be the primary field F', according to the operational equation $\mathbb{P}\ F' = S'$

But F' (computed or measured!) is not, we suppose, the expected field: we want to obtain a field F_r (required field) different from F'. Then we define a modification operator M such that $F_r = M\ F'$.

M is easy to obtain, as we know both F' and F_r. Now we extend M in such a way that it can also operate on S' and we define $S_m = M\ S'$.

But S_m does not suffice to produce F_r, because $\mathbb{P}\ F_r \neq S_m$!

Then we introduce secondary sources S" which will enable us to obtain F_r, the required field, via the operational equation

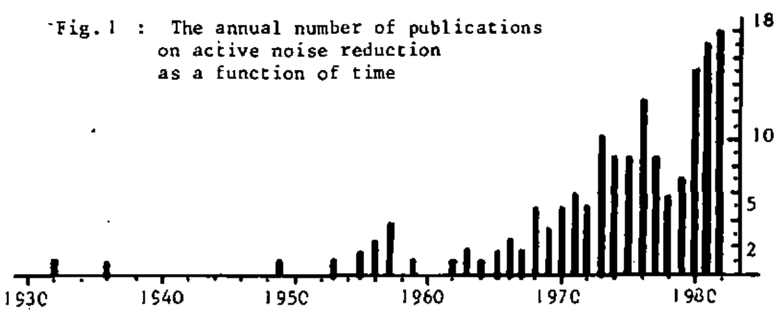
$$\mathbb{P}\ F_r = S_m + S'' \quad .$$

Therefore the S" will be given by the relation

$$S'' = (\mathbb{P} M - M\,\mathbb{P})\ F' \quad .$$

This commutator formula has many applications. ANR corresponds to the special case where M is made zero anywhere in the space to be silenced.

Fig. 1 : The annual number of publications on active noise reduction as a function of time



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