A DIGITAL MEASURING CONCEPT AS A MEANS OF TRAFFIC NOISE CONTROL

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1. INTRODUCTION

In the middle of the 1980s mounting public resistance to the ever-increasing amount of road traffic - for example the problem of the international goods transit via the Tyrol - led to the decision to promote railway traffic in general and to shift part of the volume of goods transport from road to rail. These political aims were explained in more detail in the concept "Neue Bahn" (New Rail) and in the General Traffic Concept of Austria 1991 (GVK-Ö 1991) [1]. The first three guidelines of the GVK-Ö 1991 are:

* Guideline 1: Avoidance of unnecessary traffic.
* Guideline 2: Promotion of the environmentally friendly railway traffic, of transport by ship and of non-motorized traffic.
* Guideline 3: Application of state-of the art technical facilities as early as possible to avoid negative effects of traffic.

A number of studies have already shown that as far as noise pollution is concerned, railway traffic cannot exactly be described as environmentally friendly and that measures aiming at reducing railway noise are therefore urgently required.

The "Microcensus" of March 1991 [2], a periodic survey of a representative number of households which were questioned on the environmental living conditions, has shown that the number of persons who felt disturbed by noise in general dropped from 37.2 % in 1988 [3] to 33.5 % in 1991. However, during the same period the number of persons who felt considerably or greatly disturbed by railway noise during the day or night rose from 4.5 % to 5.9 % and from 5.4 % to 10.5 % respectively. These figures clearly show that railway noise is regarded increasingly as a nuisance, which can be attributed on the one hand to a growing sensibilisation of the population to railway noise and on the other hand to an increase in railway traffic (fig. 1).

In June 1991 - after the "Microcensus" - the "Neue Austro-Takt (NAT 91)", a new Austrian logistically improved timetable, was introduced. This was the first step towards the integration of all branches of public transport in Austria into one single timetable. This led to an increase in train frequency on many routes which often gave rise to capacity problems, making it necessary to transport goods during the night. Studies of noise emissions carried out by the Federal Environmental Agency [4] in order to determine the effects of the NAT 91 have indicated an increase of up to 3.4 dB in the A-weighted equivalent sound level $L_{A,eq}$ (fig. 2).

Assuming that it will in fact be possible to shift at least a part of the volume of goods transport to the rail and that, due to capacity problems, goods will increasingly be transported during the night, it is to be feared that the population will cease to believe in the environmental friendliness of railway transport.

Until recently, in Austria railway noise was only a problem that concerned protective labour legislation. Therefore

- there was a lack of data concerning noise emitted by rolling stock,
- not much about the generation of noise was understood; consequently, it was not known how to effectively model train noise,
- there are still no limits for either emissions or immisions.

The Federal Environmental Agency is by act of law charged with environmental control. In discharging its task the Ageny launched in 1990 an extensive research programme that aims at obtaining basic data and at laying the foundations for effectively controlling railway noise.

2. MEASUREMENTS AND DATA EVALUATION

For the purpose of taking the necessary measurements and evaluating the data obtained, a new measuring concept - the first of its kind in Austria - was developed. Its axioms are:

- no real-time analysis, but multichannel storage of the noise radiated by a passing train on Digital Audio Tape (DAT).
- establishment of a clear time/position relation between sound pressure level SPL at a given time and current train position,
- evaluation of recordings only by means of analyzers equipped with a PC interface,
- further processing, i.e. calculations and the plotting of charts for all measured parameters (SPL, loudness), only digitally on PCs.

The recording of the passby train noise on Digital Audio Tape more or less preserves the noise event; the fidelity of reproduction is very high. Thus , the stored data can be evaluated in various ways without it being necessary to arrange large-scale and expensive train runs for each single measurement.

Together with the special course in data processing and microelectronics at the Höhere Technische Lehranstalt (College for Higher Technical Education) in Vienna, the Federal Environmental Agency has developped an electronic controlling device which makes possible remote control and synchronisation of up to 5 DAT Recorders and thus a 2*5-channel recording. In our measurements, three DAT Recorders were integrated in the system (fig. 3).

The remote control has two modes of operation:

- remote control as such, operating over long distances (up to 150 meters) and
- local control, operating over distances of up to 3 meters between the individual units.

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Over long distances the DAT recorders are controlled by means of optical data transmission. For each of the recorder functions "play", "record + play" and "stop" a specific bit map is created within the central control unit and then transmitted to the decoder via fiber optics. The decoder interprets the data packages it receives and activates the corresponding circuit of the remote control that is a standard-type part of the recorder.

The transmission range of the system is limited by the beam power of the optical transmitter. At the present stage of development it amounts to a little more than 150 meters. This was sufficient for our applications up to now and had the advantage that the electric charge of a 9 volt alkaline battery was powerful enough to operate the remote/decoder unit all day long. The control mechanism also functions at a distance of more than 150 meters; in these cases, however, optical transmitters with greater beam power have to be used which requires the application of a powerful external energy source, e.g. a car battery.

The local control mechanism is applied in all cases in which the points of measurement are located close together and the DAT recorders are therefore operated in the immediate vicinity of the central control unit. In these cases the data are not transmitted via fibre optics, but the standard-type remote control of the recorder is activated directly by the control unit.

When the local control mechanism is used, the operator is working near the recorder. In this situation therefore the most important thing is not to switch the recorders on and off but rather to synchronize the individual DAT recorders and to mark specific points on the DAT.

Apart from the acoustic signal as such, various subcodes can also be recorded on the DAT. One of these subcodes is the index that makes it possible to locate exactly a particular point marked on the tape. At the moment when the front of the train passes the point of measurement, a light barrier gives an impulse to the central control unit and the DAT is indexed. A list of the type of rolling stock involved and the velocity measured by means of a radar pistol are necessary to establish the time/position relation in the profiles and thus to perform a selective analysis and to locate exactly individual noise sources, such as wheel flats.

The interface between the operator and the central control unit is constituted by the keyboard and the display of a Sharp 1403 pocket calculator. A laptop could be used as well and would make the whole system more professional. However, the Sharp 1403 serves the same purpose while being considerably less expensive.

The recordings are analyzed in the laboratory on a Cortex Audio Workstation. This is an acoustic evaluation method which permits various kinds of analyses, such as third band, octave band, loudness or FFT analyses, with sampling rates of up to 2 ms in real time. The data obtained are available in standard PC form and are processed by means of specially developed software or commercial software packages.

3. APPLICATIONS AND RESULTS

In the first two series of measurements that were part of our research programme, we took only dual-channel measurements and the remote control was tested with regard to the "indexing" function. The first series of measurements dealt with the noise emission of passenger coaches. The SPL and sound-power level of passenger coaches of the newest type tolerating speeds of up to 200 km/h were compared with those of older coaches [5]. The results showed that the older coaches were about 3 to 4 dB louder at 140 km/h than the new ones at 200 km/h.

Figure 4 shows how sensitive the system is. In one of the trains that the ÖBB, the Austrian Federal Railways, made available specially for our measurements, there was a car with a wheel flat. The damaged bogie, the rise of the SPL caused by the wheel flat, and its impact can be accurately located in the chart.

The second series of measurements, in the course of which the effects of lateral skirtings on the car body were to be tested [6], demonstrated the limits of the accuracy of measurements and also revealed the extent to which slight changes in the noise profile can actually be detected. The measurements followed the prescribed standards, i. e. the individual measurements for each train velocity and for each type of car make-up (with and without skirts) were repeated twice. When evaluating the data, it was found that the deviations between the three measurements (one with and two without skirts) taken under the same conditions were of a similiar magnitude as the alleged effects of the skirts and furthermore that the octave bands showed to some extent contrary trends (fig. 5). I will deal with this aspect in greater detail later on in the conclusion.

The following tests were concerned mainly with the noise emission of goods wagons, these being considered the greater and more pressing problem. A series of measurements, performed in May 1991 and again supported by the Austrian Federal Railways, was undertaken to determine how much the noise emission levels of different types of wagons differed at speeds of up to 100 km/h.

In these tests 2*3-channel measurements were made for the first time. Four microphones were arranged in keeping with the Austrian standard, ÖNORM S 5024 [7], on an area approximating a quarter circle around the emission point *E* (fig. 6). The emission characteristics of cars of different types vary quite distinctly, not only with regard to emission levels, but also as far as source directivity is concerned (fig. 6). The highest levels were registered for bogie high sided wagons of the type "Eaos". However, there were deviations of about 1.5 dB between different wagons of the same type. Loading can reduce the emission level of hoppers of the type "Fds" by about 1.8 to 2.5 dB as compared to empty cars of a similar type (Tds). The fall-off of the emission level correlates with the angel φ , which indicates that cargo muffles the car body.

Pallet box vans with sliding doors of the type "Hbils" had the most satisfactory emission properties of all the cars that were tested. Still, their emission level is about 13 dB higher than that of modern passenger coaches! Car inspections (Gbs-neu) reduced the emission levels of the box vans that were tested at about 1 dB.

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On the whole, the results of our measurements show that the car body construction of goods wagons has a greater influence on the total emission level than is generally assumed (see ORE [8]). This is also indicated by measurements involving a noise barrier [9]. The 6 microphones integrated in the system were mounted at two distances from the track axis and in three tiers above ground level behind a 2.8 meter noise barrier (fig. 7). Another DAT recorder, mounted outside the noise barrier in order to make reference recordings of the free propagation of sound, was not integrated in the system.

The motorized inspection trolley with an overall height of about 2.5 meters registered the greatest decrease of the emission level in regard to the reference point outside the 2.8 meter noise barrier, the bogie hopper train the smallest (Table 1).

4. CONCLUSION

The concept of measurements and data evaluations presented here has not only made our work more efficient and expanded the knowledge about the mechanisms of the train noise in Austria, but has also shown us the limits of analytical methods. The digital processing of the data obtained from our measurements yields large data matrices containing lots of high-definition information. This high information density can be distinctly heard, but not visually distinguished. The two graphs of fig. 8 will illustrate this. All we see is a "muddle", we cannot perceive the substantial differences between the two noise events.

The conventional and easiest way out of this dilemma is the determination of a mean value, whether of frequency (A-weighting) or of time (L_{eq}). By using an integral method such as averaging, however, a lot of information is lost. Therefore, we will try in future to apply statistical methods that are more sophisticated in order to be able to make better use of the data obtained for the purpose of noise control. However, we have only just begun our work. I cannot yet present any results, but maybe the next time.

5. ACKNOWLEDGMENTS

The author wishes to thank many employees of the Austrian Federal Railways whose efforts helped to create the operational conditions necessary for carrying out the measurements. Special thanks is due to the author's assistants, Mr. Werner Pamperl and Mr. Oswald Seirer, for their dedication and personal involvement in the measurements and in the evaluation.

6. REFERENCES

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Fig. 1: Annoyance by Noise Source

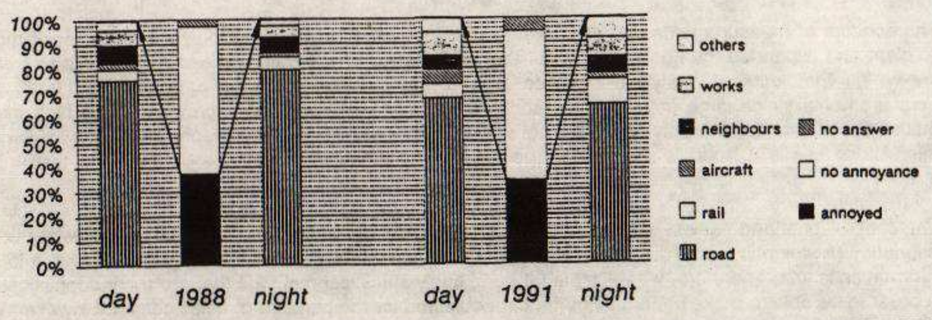

Fig. 2: Noise Emission Survey - Rail Noise

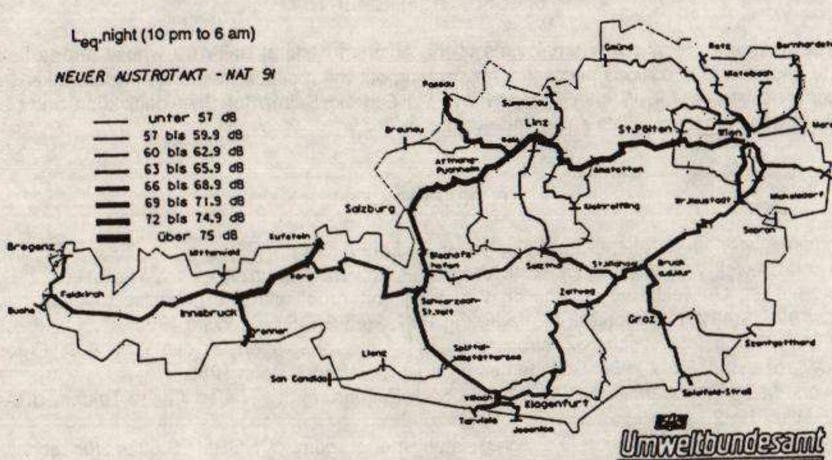

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Fig. 3: Remote control and synchronisation system

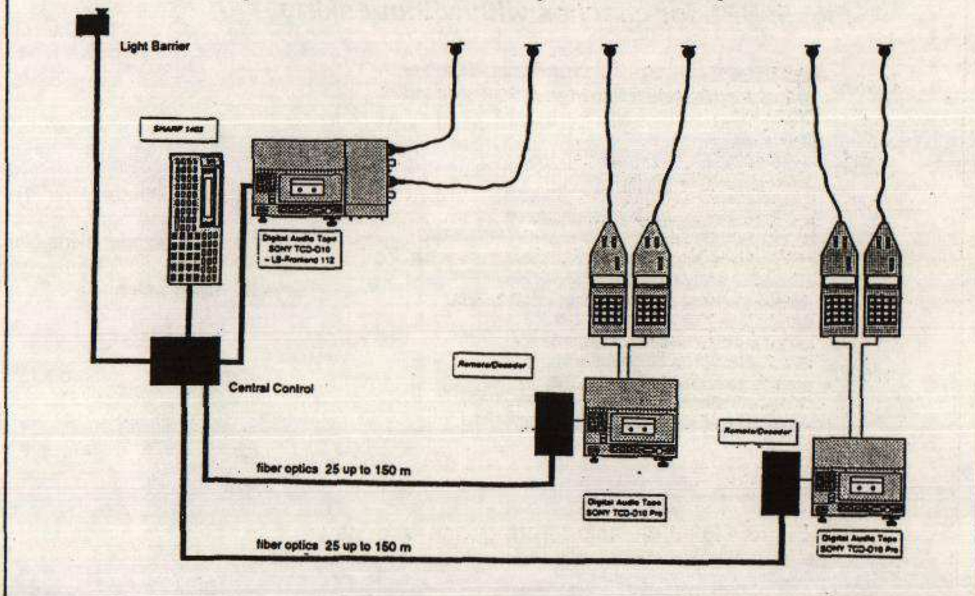

Fig.4: Wheel flat

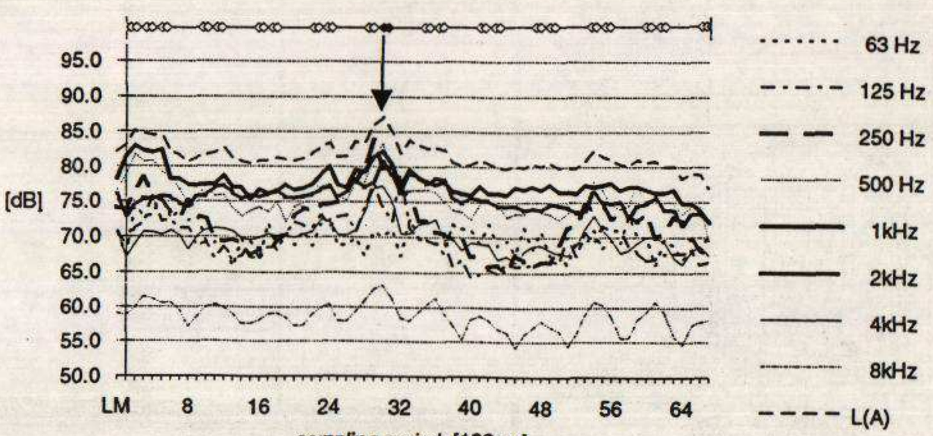

Fig. 5: SPL for coaches with/without skirts

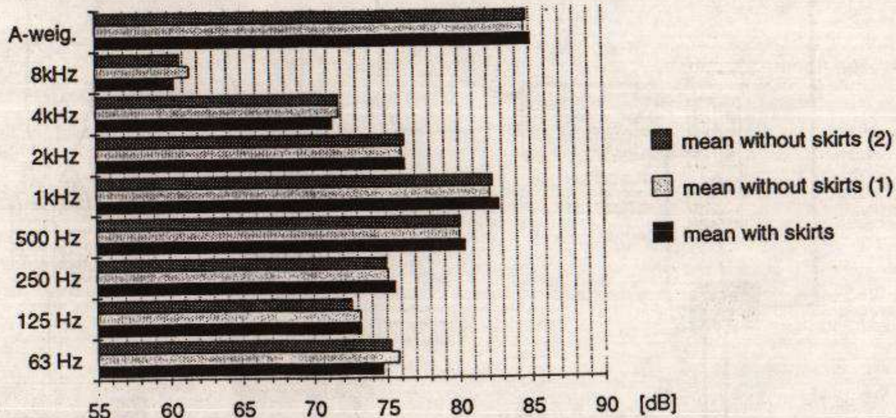

Fig. 6: Noise emission from goods wagons

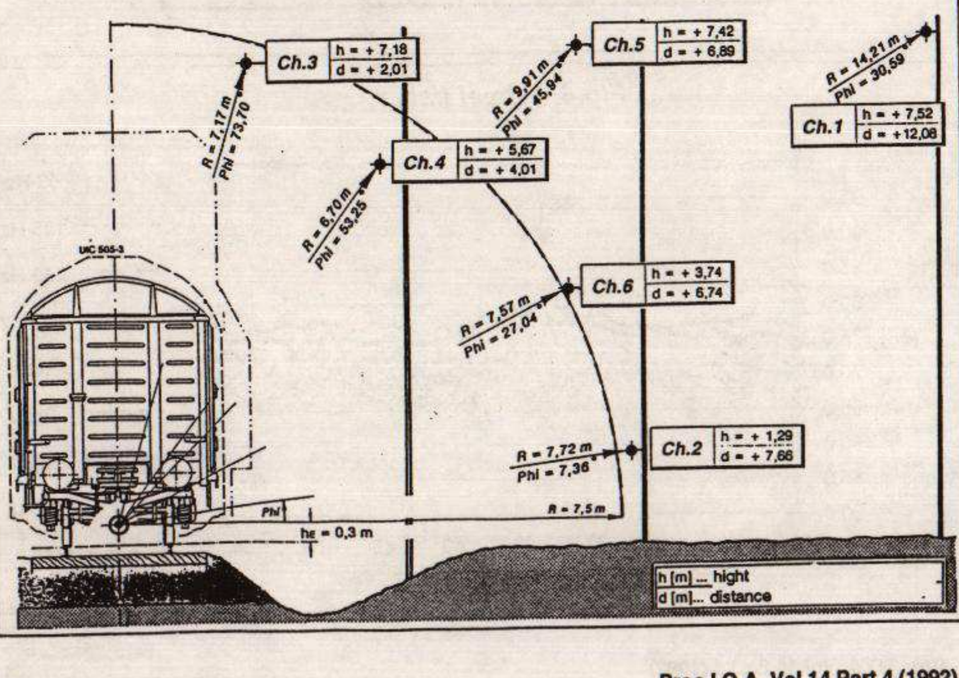

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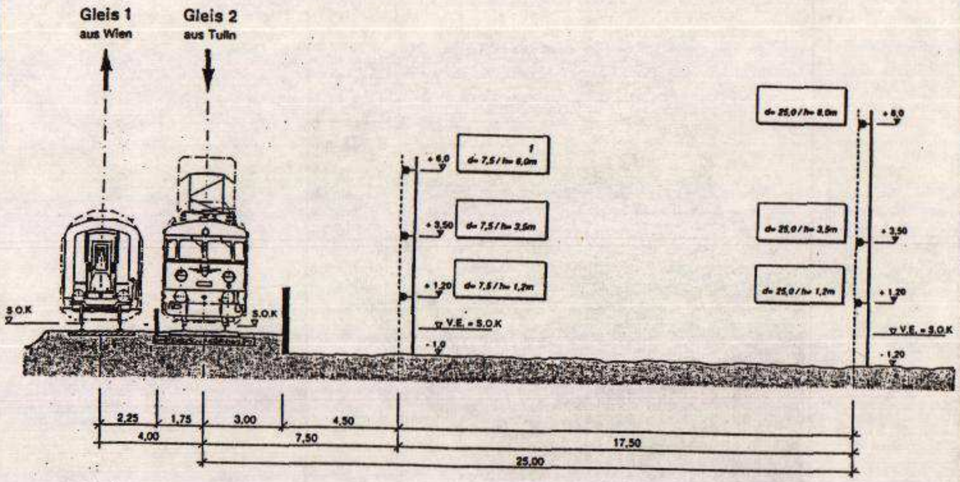
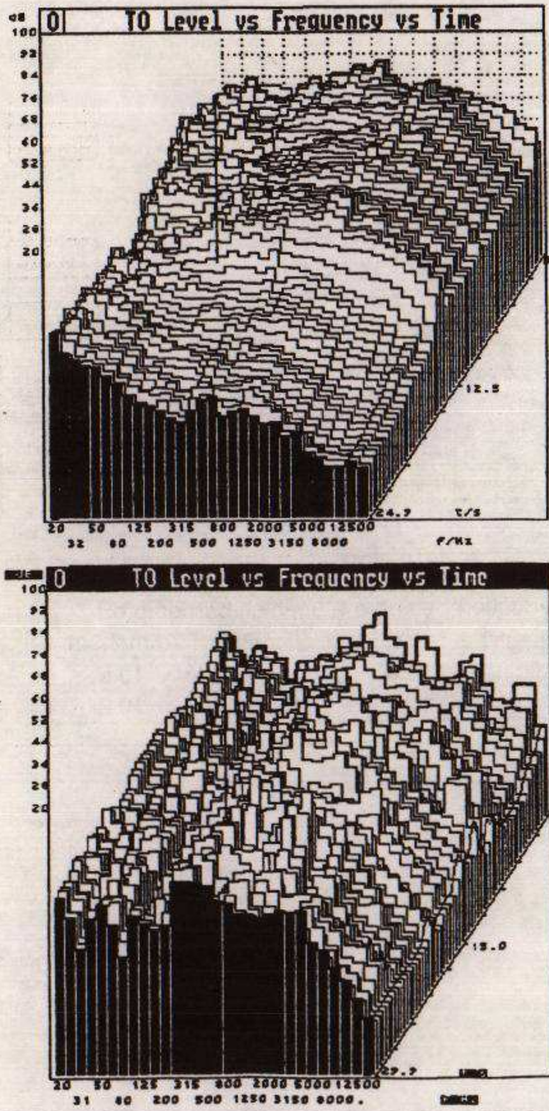
Fig. 7: Noise behind a 2.8m barrier



Tab. 1: Noise reduction behind a 2.8m high barrier in dB

distance/height	7,5m/3,5m	25m/8m	25m/3,5m
bogie hopper train	13.9	9.4	10.5
motor. trolley	14.5	13.5	19.2

Fig. 8: Rail noise (a) - music (b)



(a)

(b)